Optimizing Reservoir Operations for Hydropower Production in Africa through the Use of Remote Sensing Data and Seasonal Climate Forecasts

Mekonnen Gebremichael (UCLA)
William Yeh (UCLA)
Thomas Hopson (NCAR)
Joshua Hacker (NCAR)
G. Robert Brakenridge (U. Colorado, Boulder)
Dan Collins (NOAA)
Andre Kamga Foamouhoue (ACMAD)
Diriba Korecha (NMA)

End Users: Ethiopian Electric Power
Tanzania Electricity Company
African Centre of Meteorological Applications for Development
National Meteorological Agency of Ethiopia

Outlook of Power in Africa

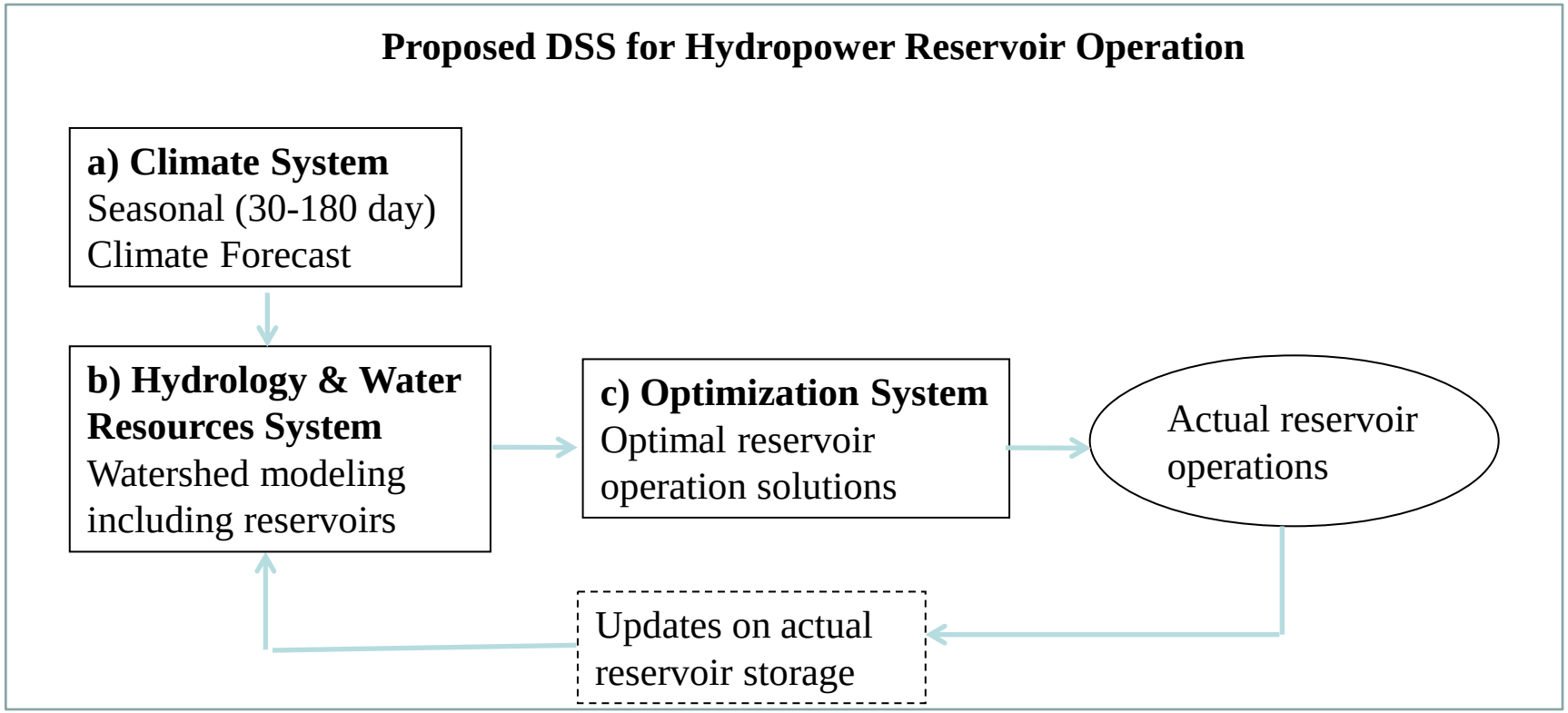
- More than 30 African countries experience power shortages and regular interruptions in service, leading many to rely on very costly leased generating plants as an emergency stopgap.
- Majority of energy comes from hydropower, yet existing hydropower systems in Africa perform far below their optimal potential, in some cases as low as 30% of design capacity.
- New hydropower dam developments are proliferating.
- East Africa Power Pool (EAPP) recently established to enhance the interconnected hydropower system operation and coordination capabilities.
- President Obama's Power Africa Initiative will provide funding and technical support amounting to $26B over the next 10 years adding extra 30GW to the total generated power capacity to the continent.

Objectives

- To optimize reservoir operation for maximum hydropower production in Africa through the utilization of remote sensing data and seasonal climate forecasts in a DSS.

- Key Features of the DSS:
  - Improved seasonal (30 – 180 day) climate and hydrologic forecasts
  - Employment of reservoir operation optimization tools and methods
  - Fully automated software with GUI

Main Components of DSS



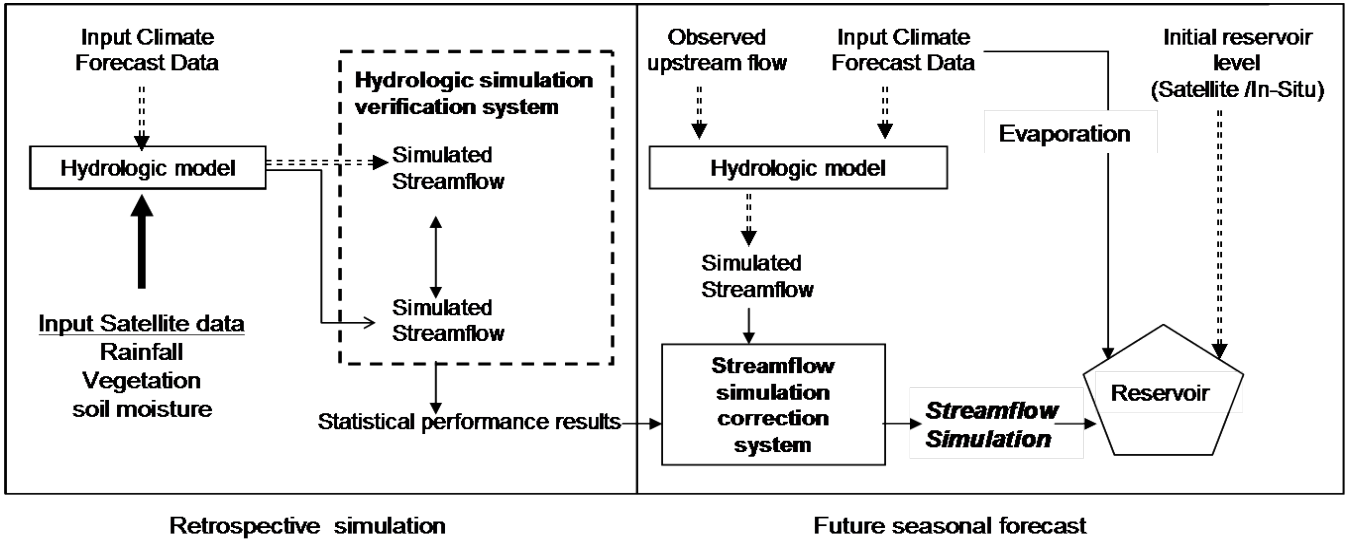
Approach

Area 1: Climate System

- Statistical and dynamical forecasts to improve Seasonal climate forecasting
- Tailoring of seasonal climate forecasts for seasonal river flow applications

Area 2: Hydrology and Water Resource System

- Aimed at using the available satellite remote sensing observations (rainfall, soil moisture, evapotranspiration, vegetation index and Leaf Area Index) in conjunction with the seasonal climate forecasts to simulate seasonal streamflow flowing into the reservoir.



Approach

Area 3: Optimization System

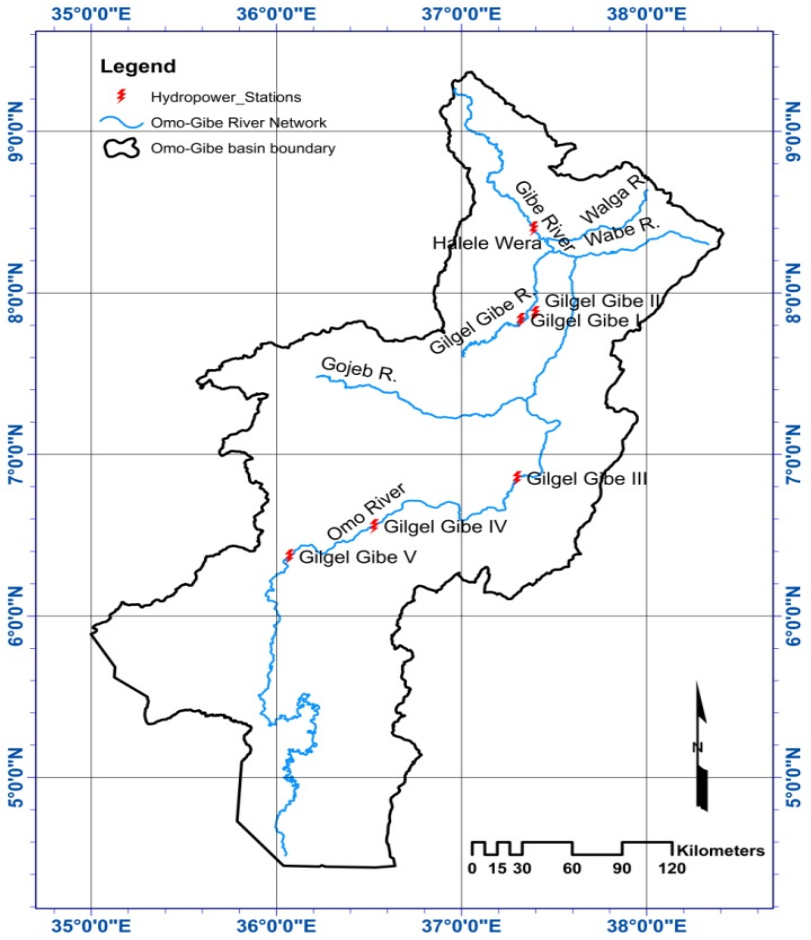
- Nonlinear programming formulation for hydropower production
- Objective function is minimizing loss of the stored potential energy. The constraint set includes energy demand, turbine capacity, flow continuity, maximum storage variation, minimum and maximum storages, minimum and maximum power releases, and bounds on non-power release.

Area 4: DSS Software

- DSS software that :
    - automates the entire process (i.e. downloads data from the ftp sites, runs the models, applies statistical models) to produce results
    - provides options to simulate the system with special operation rules defined by the user
    - has a very powerful visualization tool
    - a Graphical User Interface (GUI) to manipulate the input data, run outputs, and generate maps, graphs and tables.

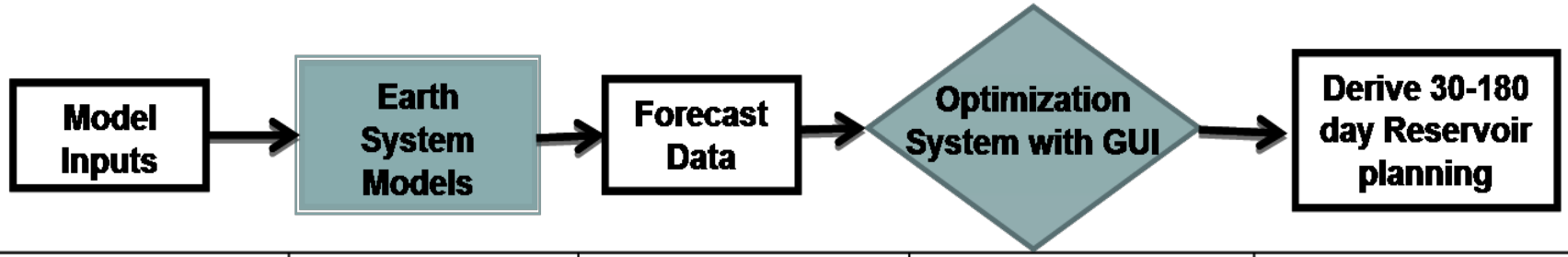
Domain

Gibe Basin (Ethiopia):
Gibe I, II, III, IV, V



Pangani Basin (Tanzania):
Nyumba ya Mungu

Anticipated Results



Earth observations	**Models**	**Model outputs**	**Decision tool**	**Values & Benefits to Society**
- Satellite precip. (*TMPA, CMORPH*) - Satellite soil moist. (ASCAT, AMSR2) - Sat. Evaporation & VI (*MODIS*) - Sat. Reservoir level (*ENVISAT*) - In-situ obs. (reservoir levels, upstream flow)	- Hydrologic system *MIKE BASIN* - Climate system *MERRA*, *CFS*, *NMME*	- Seasonal precip. & other weather variables - Seasonal Streamflow - Seasonal reservoir water storage	**Analyses** - Hydropower generation as a function of water storage and release - Optimum solutions **Decisions/Actions** - Optimum reservoir operation planning	- Increased efficiency in energy generation - Increased confidence in operation decision making - Reliable seasonal energy availability information to stakeholders - Satellite data use in applications

Performance Measures

Forecast Accuracy and DSS Performance

- Improvement in seasonal climate forecast accuracy
- Improvement in seasonal hydrologic forecast accuracy
- Improvement in seasonal reservoir storage forecast accuracy
- Improvement in updating reservoir operation rules
- Improvement in hydropower production
- Improvement in flood control

User acceptance and organizational assimilation

- User perspectives on forecast usefulness and usage
- Compatibility with real-time operations
- Climate forecast user operability
- DSS display operability

Research and team management productivity

- Journal articles and conference presentation
- Meetings
- Outreach efforts

Conclusions

- Change in Hydropower Energy Generation is coming to Africa!

- Improving reservoir operation is critical to maximizing hydropower production

- The proposed DSS will contribute towards implementation of interconnected hydropower system operation

Acknowledgement

NASA ROSES Applied Sciences Program – Water Resources Application.