Regional climate and hydrological modeling in the Nile Basin

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Outline

- Nile Basin Adaptation to Climate-Change induced Water Stress
- Enhancing the Climate Resilience of Africa’s Infrastructure
- NBI Climate Change Strategy
- Enhancements to the NB DSS

Diagram:

- Observations
  - Emissions
  - Concentrations
  - Radiative Forcing
  - Global Climate Models
  - Regional Details (Downscaling)
  - Impact Models (e.g. Hydrology)
Nile Basin Adaptation to Water Stress

UNEP – DHI - UKMet
Methodology

Two set of scenarios formulated:

1) Climate projections for 2020-49 and 2070-99 from regional climate models (PRECIS) driven by anthropogenic effects (SRES A1B)

2) Projection of future water demands 2050 and 2100 driven primarily by estimates of population growth
A regional model for the whole Nile Basin is developed in MIKE HYDRO including:
- Rainfall-Runoff using NAM
- River Basin Modelling to take care of infrastructure (dams, irrigation, water supply, etc.)

The model is divided into sub-basins each calibrated against observed runoff.

Different issues are faced in different sub-basins (lakes, swamps, data shortage, etc.)
Change Indicators

1) Regional climate model consensus to reflect the climate projection variability

2) Climate Moisture Index (CMI) as an aggregate measure of potential water availability imposed solely by climate

3) Climate Moisture CV useful for identifying regions with highly variable climates as potentially vulnerable to periodic water stress and/or scarcity

4) Average monthly runoff at the key discharge stations for annual and seasonal changes in flow regimes

5) Flow duration curves to assess changes in high and low flow distributions

6) Water Demands current and future (2030-2050) for domestic, industrial and irrigation purposes
Climate Results (Sample)

Consensus plots (4 of 5 agree on the direction of change): Relative changes in precipitation estimated as the median of monthly changes for 2020-2049 (Reference period 1961-1990)

These changes are derived from the median value of the five RCM (ensemble) simulations.

Areas with no values (white) indicate that fewer than 4 out of the 5 ensemble members agree on direction of change, either increase or decrease.

- Below 1 mm/month
- - 80-90%
- - 70-80%
- - 60-70%
- - 50-60%
- - 40-50%
- - 30-40%
- - 20-30%
- - 10-20%
- - 0-10%
- + 0-10%
- + 10-20%
- + 20-30%
- + 30-40%
- + 40-50%
- + 50-60%
- + 60-70%
- + 70-80%
- + 80-90%
- + 90-100%
- > +100%

Major catchments
Countries
Lake Victoria

December
January
February
March
April
May
Hydrological Modeling (Calibration)

Lake Victoria Outflow

Lake Kyoga Levels
Hydrological Results (sample 1)
Conclusions

Equatorial Lakes

- A small but consistent decrease in the water levels and discharge for in the 2030s primarily due to decreased rainfall and increased evaporation over Lake Victoria and as well as decreased rainfall during long rains (March-May).

- The agreement becomes poor between the ensemble members in the 2080s. RCM indicates less rainfall over the lake for April to October but increase in rainfall for substantial part of the land areas especially from November to April.

Blue Nile & Atbara

- Both increases and decreases during July-August in flow but robust increase in flow from September to December with a tendency to prolonging of the rainy season during the 2030s.

- Same trend but much stronger signal in the 2080s and the increases in flow extend into the dry season for the Blue Nile.
Enhancing the Climate Resilience of Africa’s Infrastructure

WB – SEI
Methodology

Water Model (WEAP)

- Reference Climate
- Climate Futures
- PIDA and Investment Profile
- Energy Demand

Water Adaptation Optimization Tool

- Infrastructure Performances
- Prices
- Fuel Mix
- Electric Prices
- Present Value Hydro and Irrigation ($)

Energy (OSeMOSYS)

- Adaptation Investment Profiles
- Hydro Production

Economic Cost Estimation
Representative Future Climates

A Total of 122 Climate Projections up to 2050 were developed (AR4, AR5, +different downscaling)
Nile WEAP Model - datasets

- Princeton university climate dataset
  - Precipitation, temperature (Mean, Max, Min), wind speed, and humidity
  - Spanning 1948-2008
  - constructed by combining a suite of global observation-based datasets with the NCEP/NCAR reanalysis

- NBI Nile flow dataset
  - Constructed by combining data from the Nile basin encyclopedia, Ethiopian master plans, and Nile countries
  - Focus on period 1948-2008 but some stations start earlier

- Infrastructure dataset
  - All existing dams, HP plants, and irrigation schemes
  - PIDA+ Dams & HP plants that are expected before 2050
Nile WEAP Model - Components

- Water evaluation and planning (WEAP)
  - A link-node system for river basin modelling
  - 170 catchments configured for the Nile
  - SEVERAL Large Lakes and swamps (modelled as artificial dams)
  - 40 Dams (11 existing)
  - 46 Hydropower plants (18 Run-of-river)
  - 57 irrigation schemes (groupings used)
Calibration

- Maximize the benefit of available data
  - 63 gauging stations used
  - Time series for 52 stations (different periods)
  - Mean hydrograph for 9 stations (South Sudan)
- Split-sample when record length permitted
- Several calibration statistics considered (Bias, $R^2$, Log-Bias)
Potential Applications

- Assessment of climate change impacts on the flow regime, (with/without planned infrastructure), demand, hydropower generation, etc.
- Assessment of climate change adaptation options
- Are we developing the basin faster/slower than required?
- Assessment of large scale trade-offs
  - Impacts of developments in equatorial lakes basins on the sudd
  - Uni-lateral vs. coordinated operation of existing/planned reservoirs
- Identification of data gaps
Hydropower Development (1)

HP Capacity (Nile) vs. Peak Power Demand (NB Countries)

- **Power Capacity (MW)**
  - Thousands

- **Power (MW)**
  - Thousands

- **Year**: 2010 to 2050

- **HP Capacity**: Red line
- **Peak Demand**: Yellow line
Assuming the climate of 1950 – 1990 would repeat during 2010 – 2050)

HP Generation Capacity: 6,000 MW → 28,000 MW.

Major Contributors

- Ethiopian Blue Nile dams (Karadobi, Beko Abo, Mendaya, and GERD)
- SOME hydropower schemes in the Equatorial Lakes (e.g. Ayago, Murchison Falls)
- and the Baro Akobo Sobat basin (e.g. Tams)

Adverse Impacts

- The generated power from some existing schemes (e.g. HAD) is expected to reduce considerably (by around 25%).

- Power trade and inter-connection can offer a solution while system-wide saving in water might also provide incentive for coordinated operation of water storage dams.
NBI Climate Change Strategy

GIZ

Endorsed by Nile-COM in 2013

Guiding Principles

Climate Proofing of Development
Enhancing the NB DSS

DHI
DSS Front-end

Shell
- Explorers
  - Scenarios Explorer
  - Timeseries Explorer
  - Layers Explorer
- Data Views
  - Scenario View
  - Timeseries View
  - Map
  - ...

Application

Modules
- Scenario Manager
  - Ensemble Modeller
  - Model Linker
  - Optimizer
- Analysis Manager
  - MCA
  - CBA
- Timeseries Manager
- GIS Manager
- Scripting Manager
- Table Manager
- Hydro Object Manager
- System Administration
- Meta data Manager
- Report Manager
- Study Manager

Tools
- Resample
- Union
- Gap Filling
- Intersect
- Mean
- ...

Modeling Tools

DSS Database (PostgreSQL)
  - PostGIS

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Enhancements

- Climate Change data processing:
  - Automating downloads
  - Downscaling (DCF, QQ, PQ)
  - Zonal Statistics
- Web API
- Trade-off Analysis
- WEAP & SWAT Adaptors (Free Tools)
- Less Cost → More Licenses → Wider user community
Thank you

www.nilebasin.org