Promoting Regional Security by Enabling Cooperative Management of the Nile River Basin through an Integrated Hydrologic Modeling Framework

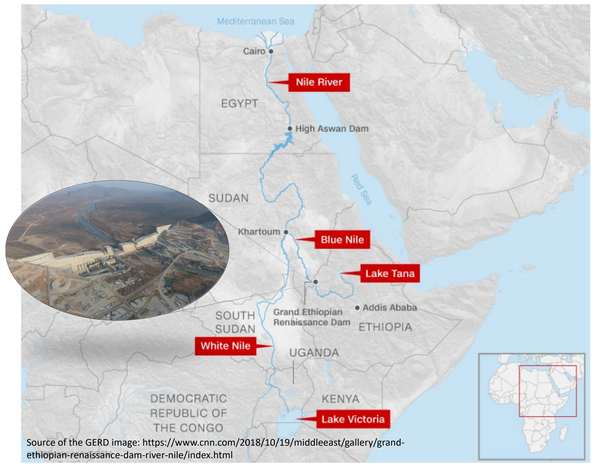
Mark W. Wahl[1, §], Ahmad A. Tavakoly[1, 2], Jane M. Smith[1], Amy L. McNally[2, 3], Christa D. Peters-Lidard[3], Augusto Getirana[3], and Martin Best[5]

[1]U.S. Army Engineer Research and Development Center, [2]University of Maryland, Earth System Science Interdisciplinary Center, [3]NASA Goddard Space Flight Center, [4]SAIC Inc., [5]U.K. Met Office

Objectives

A U.S. government Interagency Water Working Group (IWWG) Science and Applications Team (ISAT) is working to demonstrate technologies that advance understanding and decision-making related to transboundary waters by making water data transparent and facilitating information sharing. This effort aims to create a framework that links hydrologic models, e.g. the NASA Land Information System (LIS) and U.S. Army Engineer Research and Development Center Streamflow Prediction Tool (SPT), to provide real-time information. The Nile River Basin was selected for a pilot study to use the proposed framework to estimate the hydraulic loading on Grand Ethiopian Renaissance Dam (GERD) under various filling scenarios.

Nile River Basin

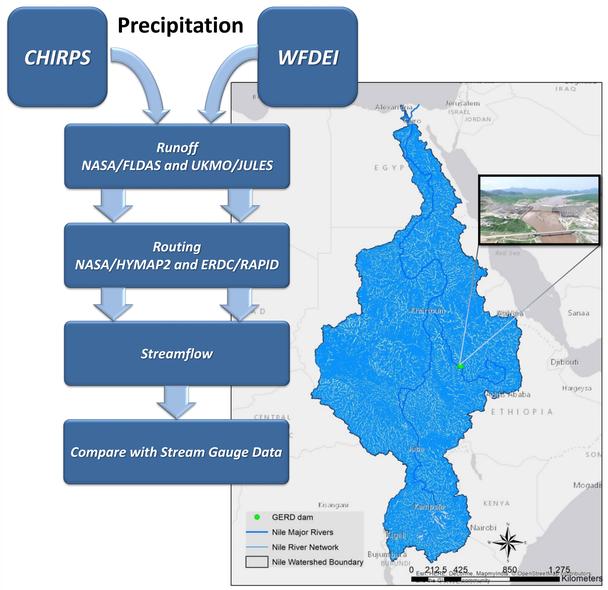


Source of the GERD image: https://www.cnn.com/2018/10/19/middleeast/gallery/grand-ethiopian-renaissance-dam-river-nile/index.html

The Grand Ethiopian Renaissance Dam (GERD)

The GERD is currently under construction on the Blue Nile River. Climate variability will likely determine the impacts downstream. Cooperative management will be key to mitigating conflict. Reliable objective forecasting is needed for trilateral cooperation. Daily runoff estimates from the Noah and Joint U.K. Land Environment Simulator (JULES) Land Surface Models in the LIS were passed to the SPT river routing component to estimate daily streamflow dynamically for the entire Nile River System. These hydrologic flows are associated with meteorological forcings from various climate reanalysis products, e.g. Climate Hazards Group Infrared Precipitation with Station data (CHIRPS)/Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) & WATCH Forcing Data methodology applied to ERA-Interim reanalysis data (WFDEI).

Hydrologic Modeling of Nile River Network



Source of the GERD image: https://www.pietrangeli.com/gerdp-hydroelectric-plant-ethiopia-africa

River network derived from HydroSHEDS 90m DEM data:

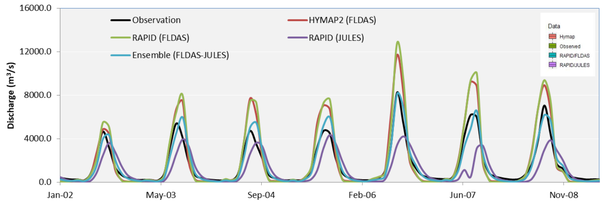
- Number of river reaches: 221,879 river reaches
- Average reach length: 4.1 km

Runoff Data:

- The daily FLDAS output: from Noah361 forcing by CHIRPS rainfall + MERRA2 meteorology for the time period of 19820101 to 20181031 (Provided by NASA-GSFC)
- The hourly JULES output: from WFDEI for the time period of 19790101 to 20161201 (Provided by UKMO)

Streamflow Simulation

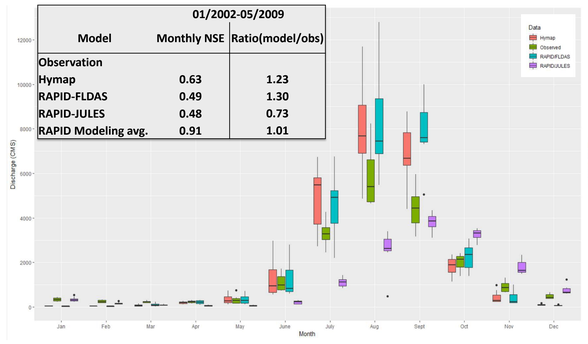
- Daily streamflow simulation using RAPID river routing model
- Monthly streamflow simulation by HYMAP (by NASA-GSFC)
- Daily observed data for the El Diem gage



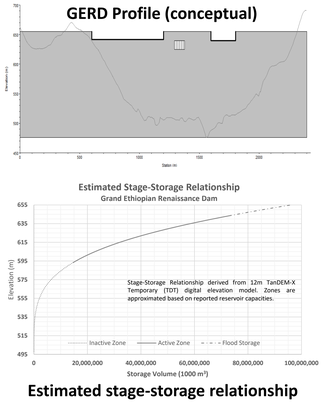
Model Intercomparison

- The streamflow estimates (ensemble mean) were well correlated with available observations (R=0.96).
- Inflow to the GERD reservoir has a strong seasonal component.
- The ensemble mean outperformed any given ensemble member.

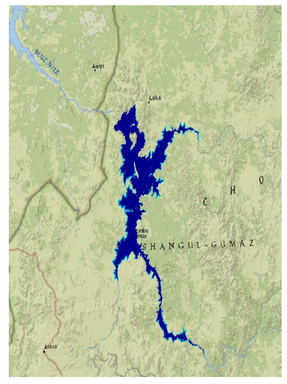
Model	01/2002-05/2009 Monthly NSE	Ratio(model/obs)
Observation		
Hymap	0.63	1.23
RAPID-FLDAS	0.49	1.30
RAPID-JULES	0.48	0.73
RAPID Modeling avg.	0.91	1.01



GERD Characteristics



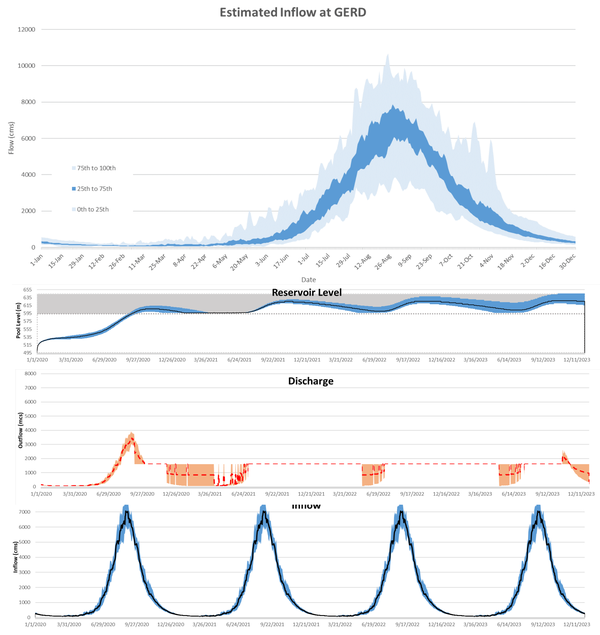
Estimated stage-storage relationship



Estimated reservoir extents

GERD Filling Scenarios

The streamflow results were then used to analyze various GERD filling scenarios based on a stage-storage relationship for the reservoir derived from a digital elevation model. Inter-annual variability presents a fair amount of uncertainty related to the volume of inflow.



Conclusion

The GERD case study demonstrates that this integrated modeling framework can address water security challenges globally and enhance understanding of the entire system, particularly in data sparse areas involving transboundary rivers.

Highlights

- A U.S. government Interagency Water Working Group (IWWG) Science and Applications Team (ISAT) is working to demonstrate technologies that advance a more sound approach for regional water resource management.
- The ensemble-based approach increases the accuracy of simulation substantially
- The timing of when filling commences and how aggressively the filling occurs will determine when hydroelectric production begins and what the downstream impacts will be.

References.

David, C. H., D. R. Maidment, G.-Y. Niu, Z.- L. Yang, F. Habets and V. Eijkhout (2011), River network routing on the NHDPlus dataset, Journal of Hydrometeorology, 12(5), 913-934. DOI: 10.1175/2011JHM1345

Getirana, A. C. V., Boone, A., Yamazaki, D., Decharme, B., Papa, F., & Mognard, N. (2012). The Hydrological Modeling and Analysis Platform (HyMAP): Evaluation in the Amazon Basin. Journal of Hydrometeorology, 13(6), 1641– 1665. DOI:10.1175/JHM-D-12-021.1

Lehner, B., Verdin, K., Jarvis, A. (2008): New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89(10): 93-94

#367878. American Meteorological Society, 100th Annual Meeting. 2020, Boston, Massachusetts

§contact information: (Mark.D.Wahl@erdc.dren.mil)