Development of a Calibrated Groundwater Model in an In-situ Data Scarce Region of the Upper Blue Nile

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AGU 100 ADVANCING EARTH AND SPACE SCIENCE | FALL MEETING Washington, D.C. | 10-14 Dec 2018

ABSTRACT #H23J-2041

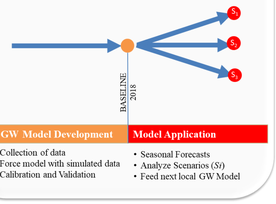
1. MOTIVATION AND OBJECTIVE

Upper Blue Nile (UBN) is a data scarce region which constrains sub-surface hydrological modelling studies

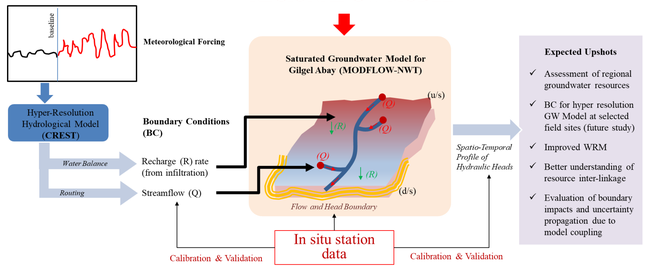
Limited knowledge on regional GW availability, seasonal fluctuation, potential to buffer climatic variabilities in the UBN region

The study area confronts irrigation challenges and associated vulnerabilities – GW use could be vital

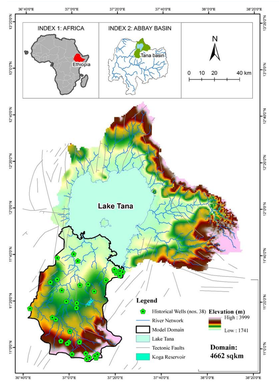
OBJECTIVE



2. RESEARCH FRAMEWORK



3. MODEL DOMAIN and SPECIFICATION

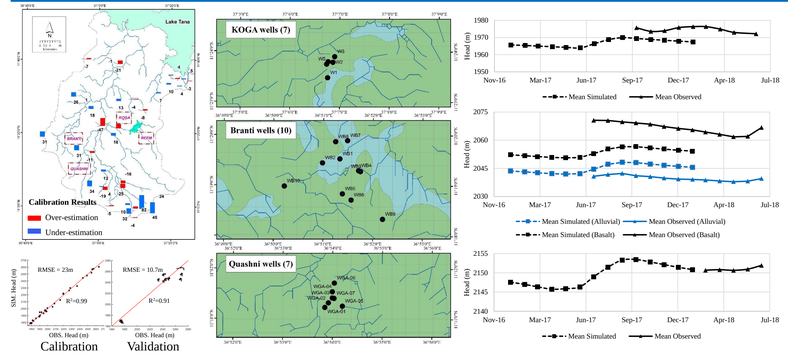


- ✓ Model domain comprises Gilgel-Abay basin
- ✓ Transient Model developed for saturated zone
- ✓ Spatial resolution: 250m*250m (horizontal); Temporal resolution: monthly (1980-2018)
- ✓ Top aquifer thickness inferred using borehole data
- ✓ Major input datasets:
  - Topography and River network (90m DEM)
  - Time-series distributed inputs (streamflow and recharge) obtained from hydrological model (CREST) simulations
- ✓ Historical lake levels (Tana) and hypothetical fluxes used as BC; steady state simulation used for IC

4. METHODOLOGY

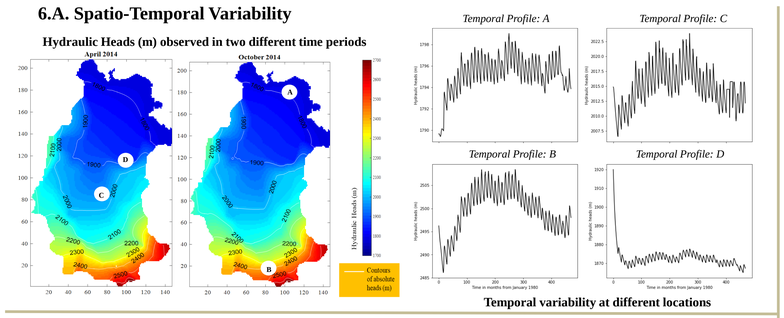
- ✓ MODFLOW-NWT (Newton-Raphson method) used for cell drying & rewetting
- ✓ Model is coupled with CREST land surface model to complement data scarcity
- ✓ CREST simulated recharge and streamflow (1980~2018) used as forcing
- ✓ Sub-basin scale geology (alluvial, basalt regions) and tectonic faults are added
- ✓ Trial-and-error calibration attempted to minimize RMSE against 38 observation wells (2013 - 2016) by adjusting:
  - *hydraulic conductivity, streambed conductance, interflow (%),* and *specific yield*
- ✓ Model is validated against bi-weekly GW depth observations at four field sites from July 2017 (Kudmi, Reem, Gaita, and and Dangishta)
- ✓ Qualitative and conceptual insight was facilitated by a *Summer-18 field visit.*

5. MODEL ASSESSMENT (Cal-Val)

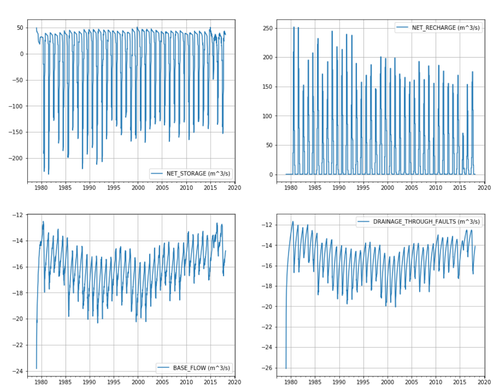


6. RESULTS and DISCUSSION

6.A. Spatio-Temporal Variability



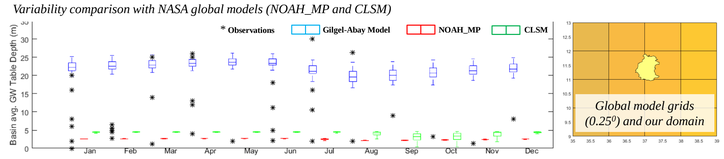
6.B. Water Budget Assessment



Some major simulated water budget components (Here, 'negative' values indicate loss of water from aquifers)

6.C. Comparison with Global Models (FAME)

Variability comparison with NASA global models (NOAH_MP and CLSM)



6.D. Discussion

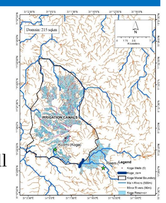
- Model is verified against observation, yielding a promising RMSE and a good R^2 fit for a large sample range with $p<0.05$
- The contribution of lateral sub-surface flow in the basin is specifically highlighted
- The model captures regional-scale spatiotemporal variability, indicating substantial under-utilized GW resources which can boost water and food security
- Global model comparisons showcase a more flexible capture of spatiotemporal dynamics
- Residual matrices could be affected by potential uncertainty propagation in model coupling

7. RESEARCH SIGNIFICANCE and SCIENTIFIC MERIT

- ✓ An effort for improved application of a one-way model coupling-based approach to develop a regional GW model in a data scarce region
- ✓ Very few attempts have showcased the sub-surface hydrological resource development in Gilgel-Abay sub-basin, which bears the highest sub-surface flow contribution in Lake Tana.
- ✓ The research goal ties with seasonal farm-scale forecasts on dry season water availability, which will help local farmers, and pivot adaptive pathways for policy and decision makers.

8. FUTURE WORK

- ✓ This research is a part of a multi-scale water-food-human nexus development initiative within the project "PIRE: Taming Water & Food Security in Ethiopia"
- ✓ This GW model is expected to serve as a B.C. for a local combined (saturated and unsaturated) GW model, which will include computationally intensive simulations.
- ✓ The local model will consider different release and abstraction scenarios and will produce soil moisture dynamics to facilitate a crop yield model (DSSAT).



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[1] Haile, G. G., & Kasa, A. K. (2015). Irrigation in Ethiopia: a review. Academia Journal of Agricultural Research, 3(10), 264-269.

[2] Shen, X., & Anagnostou, E. N. (2017). A framework to improve hyper-resolution hydrological simulation in snow-affected regions. Journal of hydrology, 552, 1-12.

[3] NOAH_MP and CLSM models developed within the The Forecasting for Africa and the Middle East (FAME) project, NASA (https://lis.gsfc.nasa.gov/projects/fame)

ACKNOWLEDGEMENT:

This material is based upon work supported by the National Science Foundation under Grant No. 1545874.

For more information, please visit: https://pire.engr.uconn.edu/