Using multi-year reanalysis-derived recharge rates to drive a groundwater model for the Lake Tana region of Blue Nile Basin, Ethiopia

Abstract ID: 287378

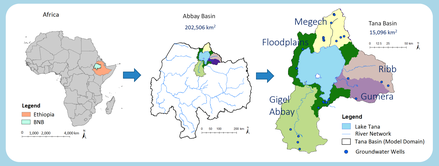
Zoi Dokou, Mohsen Kheirabadi, Efthymios I. Nikolopoulos, Semu Moges, Amvrossios C. Bagtzoglou, Emmanouil N. Anagnostou

Department of Civil and Environmental Engineering, University of Connecticut, Storrs, CT, USA

NSF PIRE:
Water and Food Security Project

Background

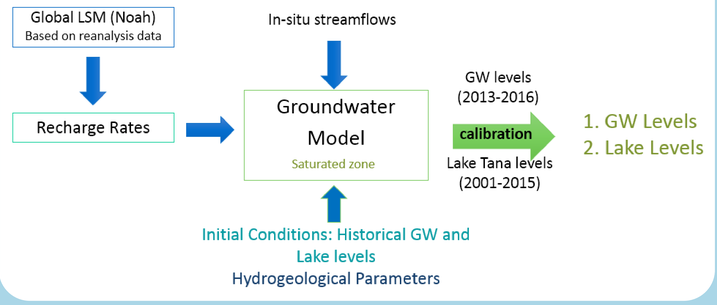
Ethiopia's high inter-annual variability in local precipitation has resulted in droughts and floods that stress local communities and lead to economic and food insecurity. Better predictions of water availability can supply farmers and water management authorities with critical guidance, enabling informed water resource allocation and management decisions that will in turn ensure food and water security in the region.



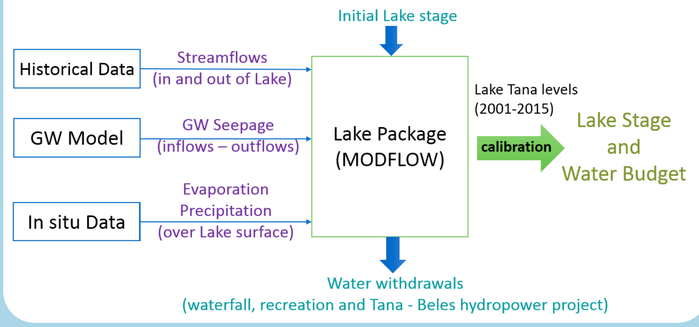
The work presented here focuses on the development and calibration of a groundwater model of the Lake Tana region, one of the most important sub-basins of the Blue Nile River Basin. Groundwater recharge estimates (subsurface runoff) are taken from a Land Surface model (FLDAS Noah), provided at a monthly time scale and 0.1˚ x 0.1˚ spatial resolution. The reanalysis derived recharge rates are incorporated into the groundwater model MODFLOW, which in combination with a Lake module that simulates the Lake water budget, offers a unique capability of improving the predictability of groundwater and lake levels in the Lake Tana basin. Model simulations are compared against in-situ observations of groundwater and lake levels.

Modeling Framework

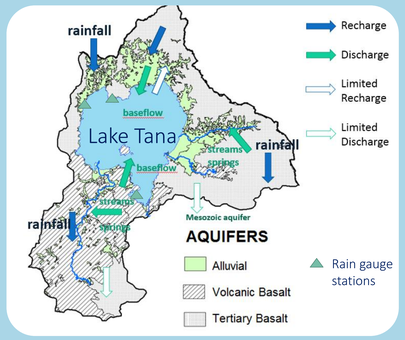
GW – Lake Model Calibration



Lake Water Budget



Conceptual Model and Input Parameters



- Transient model: 2001-2016
- Spatial resolution: 1 km x 1 km
- Initial groundwater levels (interpolated from historical data)
- Hydraulic conductivity (from literature and pumping test information)
- Recharge estimates (subsurface runoff) are taken from a Land Surface model (FLDAS Noah), provided at a monthly time scale and 0.1˚ x 0.1˚ spatial resolution.

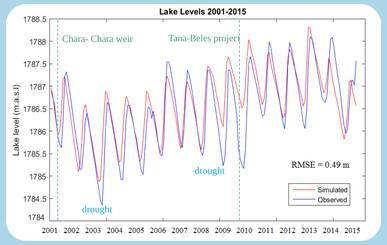
Lake package (LAK)

- Min (1784 m), max (1788 m) and initial Lake stage (1787.18 m)
- Precipitation (average of three rain gauge stations)
- Evaporation over the lake (Wale, 2008)
- Withdrawals (waterfall 0.9 BCM annually, Tana –Beles project, 2.9 BCM annually)
- Lake conductance (calibration)

Streamflow routing package (SFR)

- Four main rivers (Megech, Ribb, Gumera, Gigel Abbay)
- Channel geometry (rectangular)
- Channel Roughness (0.03, to be calibrated)
- Streamflows (in-situ data)
- Streambed hydraulic conductivity, thickness, elevation, width, depth (calibration)

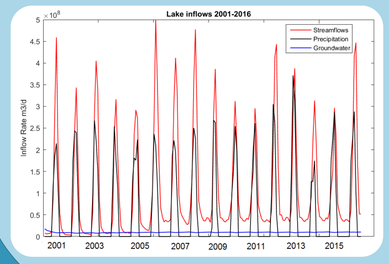
Results: Lake Level and Water Budget

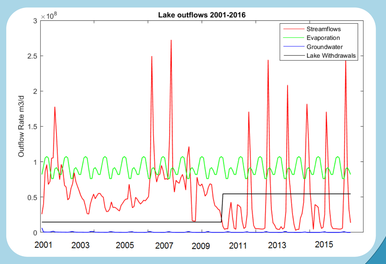


Lake Water Budget - Comparison with the literature

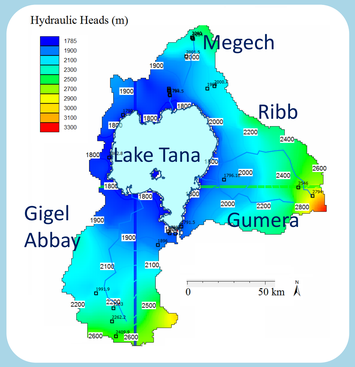
Average Inflows	GW	SW (gauged)	SW (ungauged)	PREC
m3/yr	5.81E+08	3.83E+09	2.62E+09	3.51E+09
Average Outflows	GW	SW	Withdrawals	EVAP
m3/yr	2.96E+07	3.23E+09	1.88E+09	5.44E+09

% of inflow	GW	SW (gauged)	SW (ungauged)	PREC
model	5.51%	36.34%	24.84%	33.31%
Wale (2008)	7%	38%	26%	36%
% of outflow	GW	SW	Withdrawals	EVAP
model	0.28%	30.65%	17.78%	51.50%
Wale (2008)	0	57% (SW +withdrawals)		52%

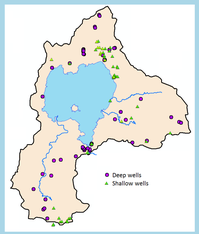




Results: Groundwater Levels



Groundwater Level Measurements



Available for years 2013 – 2016 at 44 deep and 28 shallow wells.

Conclusions

The model results show that the FLDAS Noah derived recharge rates can be successfully used to drive a groundwater – lake model in the Tana basin, in Ethiopia. Based on the model, the contribution of groundwater to the lake budget is relatively small (5.5 % on average for the period 2001-2016), a fact confirmed by the literature (Kebede, 2009; Wale, 2008) and mostly attributed to a 80 m thick clay layer below the lake. Based on the lake levels, there are three instances where the lake has dropped below normal levels (2003, 2009 and 2010). These years are associated with the construction of the Chara-Chara weir in 2001, and the operation of the Tana-Beles hydropower project that was initiated in May 2010. In addition, the years 2003 and 2009 have been characterized as drought years, a fact that is reflected in the lake levels.

This modeling effort can be further used to explore climate variability effects on groundwater and lake levels and provide guidance to governments and development agencies for more efficient management of the water resources of this important region.

Parallel and Future Work

- Parallel work: combination with GRACE data to assess the Lake variability, identify drought conditions and the role of human management in the (Abstract #263588).
- Improve groundwater model calibration
- Run for 35 yr period (1979-2014) using recharge from Noah model
- Estimate groundwater recharge using a reanalysis precipitation dataset (MSWEP) together with evapotranspiration and surface run-off estimates using water budget equations.
- Add more detailed river network
- Increase spatial resolution to 500 m x 500 m

References

Kebede S, Travi Y, Alemayehu T, Ayenew T. 2005. Groundwater recharge, circulation and geochemical evolution in the source region of the Blue Nile River, Ethiopia. Applied Geochemistry 20(9): 1658–1676.

Wale A. 2008. Hydrological balance of Lake Tana. M.Sc Thesis. International Institute for Geo-Information Science and Earth Observation (ITC), The Netherlands.

Acknowledgment

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