Incorporating a simple two-layer reservoir into a coupled land surface and river routing model to improve river temperature simulations in the Tennessee River Basin

Ryan Niemeyer, Yifan Cheng, Yixin Mao, John Yearsley, Bart Nijssen

Department of Civil and Environmental Engineering, University of Washington

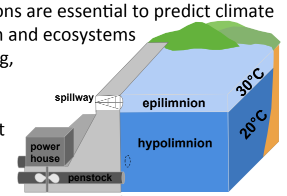
Corresponding Author: Ryan Niemeyer – rniemeyr@uw.edu. Prepared for the 2016 American Geophysical Conference Fall Meeting, San Francisco, CA, Dec. 12-16, 2016

H33B-1530

UW HYDRO | COMPUTATIONAL HYDROLOGY

Introduction and objective

- Accurate river temperature simulations are essential to predict climate change impacts on power generation and ecosystems
- Distributed land-surface, river routing, and river temperature models are powerful tools for such simulations
- Most large rivers have reservoirs, but most distributed river temperature models do not include thermal stratification in reservoirs
- **Objective**: develop a two-layer reservoir model with thermal stratification and integrate with a distributed river temperature model

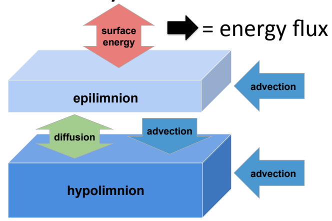


thermal stratification in a reservoir

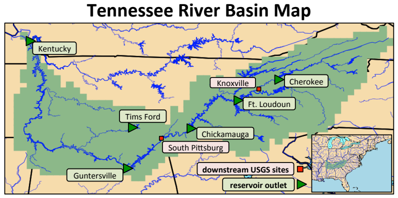
Model and data

- We developed a simple two-layer reservoir model, after Chapra (1997), to simulate reservoir temperatures
- The Variable Infiltration Capacity (**VIC**) model (Liang et al. 1994) is implemented across the Tennessee River Basin at 1/8° (~12 km) resolution

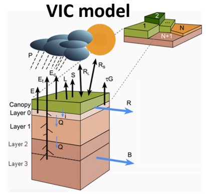
two-layer reservoir model



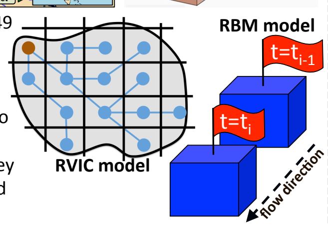
Tennessee River Basin Map



VIC model



- Meteorological forcings over 1949 to 2010 (Maurer et al. 2002)
- RVIC (Hamman et al. *in revis.*) simulates river routing
- Post-RVIC reservoir flow model to simulate regulated flow
- River Basin Model (RBM) (Yearsley 2009, 2012) simulates distributed river temperature
- Two-layer reservoir model integrates into RBM model to improve simulated temperature downstream of reservoirs



References

Chapra, S.C., 1997. Surface water-quality modeling. Waveland press.

Hamman, J., Nijssen B., Roberts A., Craig, A., Maslowski, W., Osinski, R., 2016. The Coastal Streamflow Flux in the Regional Arctic System Model. Journal of Geophysical Research: Oceans, in revision.

Liang, X., Lettenmaier, D.P., Wood, E.F., Burges, S.J., 1994. A simple hydrologically based model of land surface water and energy fluxes for general circulation models. J. Geophys. Res. Atmospheres 99.

Maurer, E. P., Wood, A. W., Adam, J. C., Lettenmaier, D. P., & Nijssen, B., 2002. A long-term hydrologically based dataset of land surface fluxes and states for the conterminous United States. J of Climate 15.

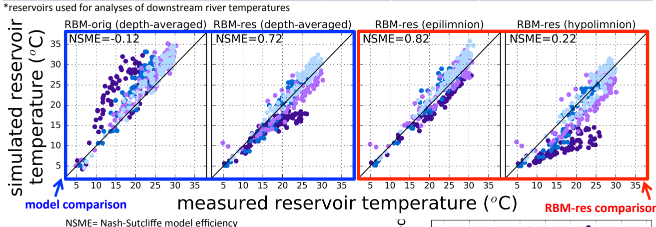
Yearsley, J.R., 2009. A semi-Lagrangian water temperature model for advection-dominated river systems. Water Resour. Res. 45.

Yearsley, J.R., 2012. A grid-based approach for simulating stream temperature. Water Resour. Res. 48.

Reservoir temperature and turnover

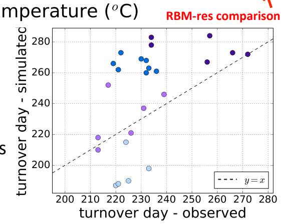
upstream reservoir	drainage area (10^3 km^2)	annual inflow (m^3 sec^{-1})	volume (10^8 m^3)	mean depth (m)	reservoir residence time (days)
Tims Ford*	1.4	27	6.5	13.5	240
Cherokee*	8.9	127	19	14.9	92
Kentucky	104	1,754	35	5.4	19
Guntersville	63	1,172	13	4.6	12
Fort Loudoun	25	463	4.5	7.6	9
Chickamauga*	54	962	9.1	5.4	8

*reservoirs used for analyses of downstream river temperatures

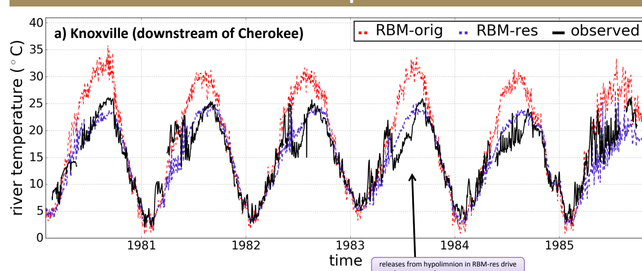


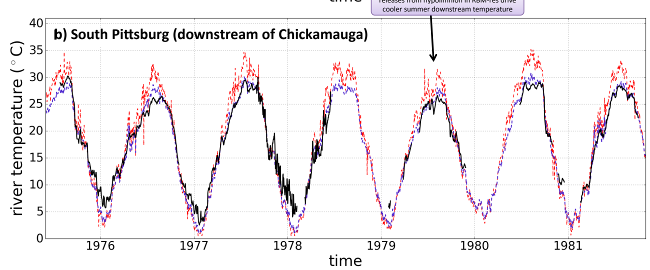
NSME= Nash-Sutcliffe model efficiency

- For RBM without the two-layer reservoir (**RBM-orig**), model performance was poorest at Cherokee (longest residence time)
- RBM model performance improved with the two-layer reservoir (**RBM-res**) at all reservoirs
- Reservoir turnover occurs in fall when water column temperature equilibrates

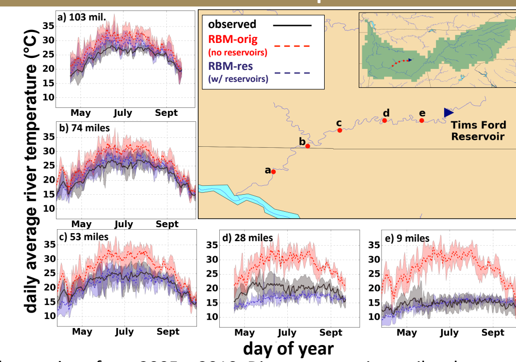


Downstream river temperature





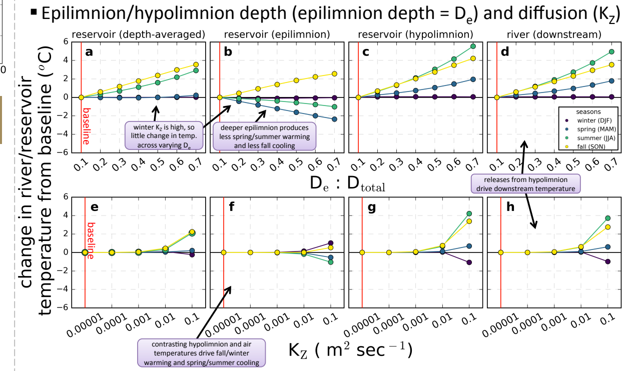
Downstream river temperature



Observations from 2005 – 2010. Distances are river miles downstream of reservoir. Only days w/ >3 yrs of observations included. Shaded area upper/lower bounds are max/min temperature of day of year.

Sensitivity analysis

- Sensitivity analysis done on/downstream of Cherokee Reservoir
- Epilimnion/hypolimnion depth (epilimnion depth = D_e) and diffusion (K_z)



Conclusion

- RBM-res improves model performance and simulates the reduced influence of reservoirs on temperature further downstream
- Improvement in model performance is greatest in/downstream of reservoirs with longer residence times
- RBM-res is sensitive to simulated epilimnion depth and K_z

Acknowledgements

This project was funded in part by NOAA grant NA14OAR4310250 and NSF grant EFRI-1440852 to the University of Washington. We also wish to thank the Tennessee Valley Authority for providing data.