**BEE 6740 - Ecohydrology**

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**Course Overview:** This course will cover introductory concepts in ecohydrology focusing on: catchment water and energy balances, hydrologic modeling (PET, snow accumulation and melt, soil moisture, plant growth, surface runoff), introduction to model sensitivity and calibration techniques (e.g. NSE, DDS), application of tracers in ecohydrology, issues in parameterized hydrologic model climate-transferability, and basic R scripting. The objective of this course is to develop proficiency in fundamental modeling principles used to describe watershed hydrology and various associated ecosystem functions.

**Text**: There is no comprehensive Ecohydrology modeling text. Over this semester we will read relevant literature, with particular emphasis on recent scientific advances. Journal article readings will directly support the in-class development of models, or introduce parallel approaches currently used in research and practice. I will provide handouts as needed to reinforce or expand on models that are unfamiliar to students.

**Topics:**

Week 1 – Intro to Ecohydrology / R

Week 2 – Flow Metrics

* Baseflow Separation, Flashiness Index, Baseflow Index

Week 3 – Watershed Actual Evapotranspiration (AET)

Week 4 – Reference Evapotranspiration (ET0, PET) Modeling

* Penmann Monteith, Priestly Taylor, PET\_from\_Temp
* Deterministic sensitivity analysis of ET0 to albedo
* Leaf area index (LAI)

Week 5 – Vegetation Scaling of ET0

* Single Crop Coefficient Model
* Dual Crop Coefficient Model

Week 6 – Snowmelt Modeling

* Energy Budget, Degree Day Method
* Monte Carlo Sensitivity of SWE to Albedo, Forest Canopy, and Wind Speed (U)

Week 7 –Watershed Modeling

* Runoff-Infiltration partitioning
* Thornthwaite-Mather AET and Soil Water Balance
* Lumped VSA Model
* Watershed Sensitivity Analysis

Week 8 –Model Calibration

* Objective Functions: Nash Sutcliffe Efficiency, Percent Bias
* Calibration Methods: Dynamically Dimensioned Search Algorithm (DDS)

Week 9– Forcing Hydrologic Models with Climate Projections

* Downscaled GCM Predictions
* Land surface-climate feedbacks (ET0, Snowpack, Annual Flow, Floods)

Week 10 – Ecohydrologic Processes and Model Transferability

* Calibration of Lumped VSA Model to multiple climate periods
* Model & Parameter Transferability under climate change

Week 11 – EcoFlows

Week 12 – Tracers in Ecohydrology

* Overview of applications of common tracers
* Two-component End Member Mixing Analysis (EMMA)

Week 13 – Application of Stable Water Isotope Tracers

* Canopy interception & throughfall, ET partitioning, Rooting Depth
* Ecohydrologic separation

**Reading Assignments:** All readings should be completed by the week indicated.

**Week 1**

No readings, but be aware of these resources as we progress through the class.

https://cran.r-project.org/doc/manuals/r-release/R-intro.pdf

https://www.youtube.com/watch?v=eDrhZb2onWY

https://stackoverflow.com/

**Week 2**

Baker, D. B., Richards, R. P., Loftus, T. T., & Kramer, J. W. (2004). A new flashiness index: characteristics and applications to Midwestern rivers and streams. *JAWRA Journal of the American Water Resources Association*, *40*(2), 503-522.

**Week 3**

Walter, M. T., Wilks, D. S., Parlange, J. Y., & Schneider, R. L. (2004). Increasing evapotranspiration from the conterminous United States. *Journal of Hydrometeorology*, *5*(3), 405-408.

Wang, K., & Dickinson, R. E. (2012). A review of global terrestrial evapotranspiration: Observation, modeling, climatology, and climatic variability. *Reviews of Geophysics*, *50*(2).

**Week 4**

Archibald, J. A., & Walter, M. T. (2014). Do Energy‐Based PET Models Require More Input Data than Temperature‐Based Models?—An Evaluation at Four Humid FluxNet Sites. *JAWRA Journal of the American Water Resources Association*, *50*(2), 497-508.

Jasechko, S., Sharp, Z. D., Gibson, J. J., Birks, S. J., Yi, Y., & Fawcett, P. J. (2013). Terrestrial water fluxes dominated by transpiration. *Nature*, 496(7445), 347-350.

**Week 5**

Allen, R. G., Pereira, L. S., Smith, M., Raes, D., & Wright, J. L. (2005). FAO-56 dual crop coefficient method for estimating evaporation from soil and application extensions. *Journal of irrigation and drainage engineering*, *131*(1), 2-13.

Kim, J., Hwang, T., Schaaf, C. L., Orwig, D. A., Boose, E., & Munger, J. W. (2017). Increased water yield due to the hemlock woolly adelgid infestation in New England. *Geophysical Research Letters*, 44(5), 2327-2335.

**Week 6**

Walter, M. T., Brooks, E. S., McCool, D. K., King, L. G., Molnau, M., & Boll, J. (2005). Process-based snowmelt modeling: does it require more input data than temperature-index modeling? *Journal of Hydrology*, *300*(1), 65-75.

Valeo, C., & Ho, C. L. I. (2004). Modelling urban snowmelt runoff. *Journal of Hydrology*, 299(3), 237-251.

**Week 7**

Archibald, J. A., Buchanan, B. P., Fuka, D. R., Georgakakos, C. B., Lyon, S. W., & Walter, M. T. (2014). A simple, regionally parameterized model for predicting nonpoint source areas in the northeastern US. *Journal of Hydrology: Regional Studies*, *1*, 74-91.

**Week 8**

Tolson, B. A., & Shoemaker, C. A. (2007). Dynamically dimensioned search algorithm for computationally efficient watershed model calibration. *Water Resources Research*, *43*(1).

**Week 9**

Taylor, K. E., Stouffer, R. J., & Meehl, G. A. (2012). An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, 93(4), 485-498.

**Week 10**

Pourmokhtarian, A., Driscoll, C. T., Campbell, J. L., Hayhoe, K., Stoner, A. M., Adams, M. B., ... & Shanley, J. B. (2017). Modeled ecohydrological responses to climate change at seven small watersheds in the northeastern United States. *Global change biology*, *23*(2), 840-856.

Broderick, C., Matthews, T., Wilby, R. L., Bastola, S., & Murphy, C. (2016). Transferability of hydrological models and ensemble averaging methods between contrasting climatic periods. *Water Resources Research*, 52(10), 8343-8373.

**Week 11**

Poff, N. L., Richter, B. D., Arthington, A. H., Bunn, S. E., Naiman, R. J., Kendy, E., ... & Henriksen, J. (2010). The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater Biology*, 55(1), 147-170.

Buchanan, B. P., Auerbach, D. A., McManamay, R. A., Taylor, J. M., Flecker, A. S., Archibald, J. A., ... & Walter, M. T. (2017). Environmental flows in the context of unconventional natural gas development in the Marcellus Shale. *Ecological Applications*, 27(1), 37-55.

**Week 12**

McMillan, H., Tetzlaff, D., Clark, M., & Soulsby, C. (2012). Do time‐variable tracers aid the evaluation of hydrological model structure? A multimodel approach. *Water Resources Research*, 48(5).

Evaristo, J., McDonnell, J. J., & Clemens, J. Plant source water apportionment using stable isotopes: A comparison of simple linear, two‐compartment mixing model approaches (revision 3). *Hydrological Processes*.

**Week 13**

Evaristo, J., Jasechko, S., & McDonnell, J. J. (2015). Global separation of plant transpiration from groundwater and streamflow. *Nature*, 525(7567), 91-94.

Sprenger, M., Tetzlaff, D., & Soulsby, C. (2017). Soil water stable isotopes reveal evaporation dynamics at the soil–plant–atmosphere interface of the critical zone. *Hydrology and Earth System Sciences*, 21(7), 3839.

**Grading**

Grading will be based 45% on submission of weekly in-class assignments, 40% on an individual project, and 15% in-class participation.

R code assignments: Each week we will work together on developing R code to simulate or estimate an ecohydrologic process. Each assignment will be scored based on the following criteria:

25% - Submission of R code and a three paragraph description of the 1) purpose 2) method and 3) and conclusions.

25% - The code is well commented (i.e. all steps and variables are explained with units)

20% - R code is free of syntax errors, or the errors are understood and well explained in the project writeup

20% - Assignment is free of conceptual errors

10% - Assignment is completed

Individual Projects: Select a topic in ecohydrology and develop an interesting research project. Take a concept further than we have in class, or attempt to apply concepts covered in class to a variety of watersheds in varied climates. If you are a graduate student you are strongly encouraged to choose an ecohydrology project that contributes to your own research.

In Class Participation: We will have three quizzes (each quiz is 3 conceptual short answer questions) to determine retention of ecohydrologic concepts.