Exploring the Influence of Topography on Belowground C Processes Using a Coupled Hydrologic-Biogeochemical Model

Yuning Shi[1], David Eissenstat[1], Kenneth Davis[2], Jason Kaye[1], Yuting He[2], Xuan Yu[3], Christopher Duffy[4]

[1] Department of Ecosystem Science & Management, The Pennsylvania State University
[2] Department of Meteorology, The Pennsylvania State University
[3] Department of Geological Sciences, University of Delaware
[4] Department of Civil & Environmental Engineering, The Pennsylvania State University

H34G-1032

Introduction

Belowground carbon processes are affected by soil moisture and soil temperature, but current biogeochemical models are 1-D and cannot resolve topographically driven hill-slope soil moisture patterns, and cannot simulate the nonlinear effects of soil moisture on carbon processes. Coupling spatially-distributed physically-based hydrologic models with biogeochemical models may yield significant improvements in the representation of topographic influence on belowground C processes. This project aims to answer the following questions:

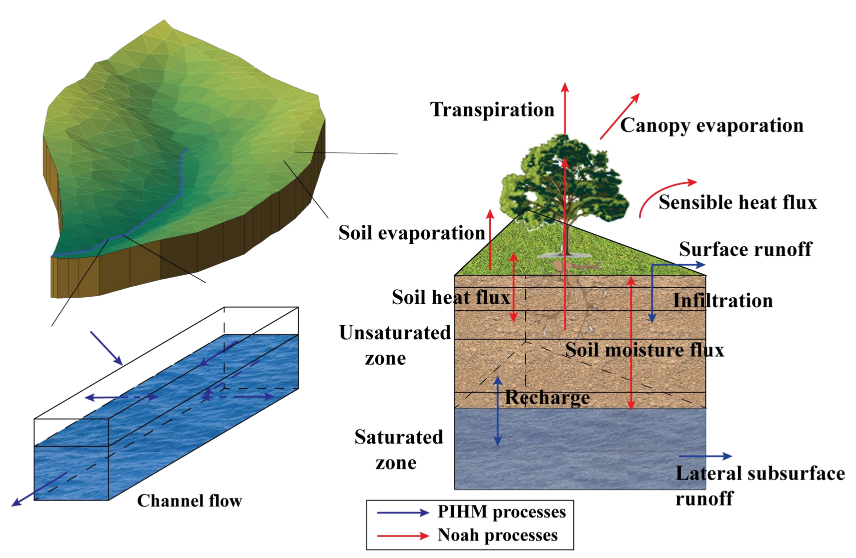
(1) What is the influence of topography on below ground C processes?

(2) Can we predict the high-resolution spatial distribution of C fluxes and stocks using a numerical model that couples hydrologic, land surface, and biogeochemical processes?

Model and Data

Flux-PIHM

Coupled land surface hydrologic model, that integrates the Noah LSM into the Penn State Integrated Hydrologic model (PIHM) (Shi et al. 2013).



Flux-PIHM-BBGC

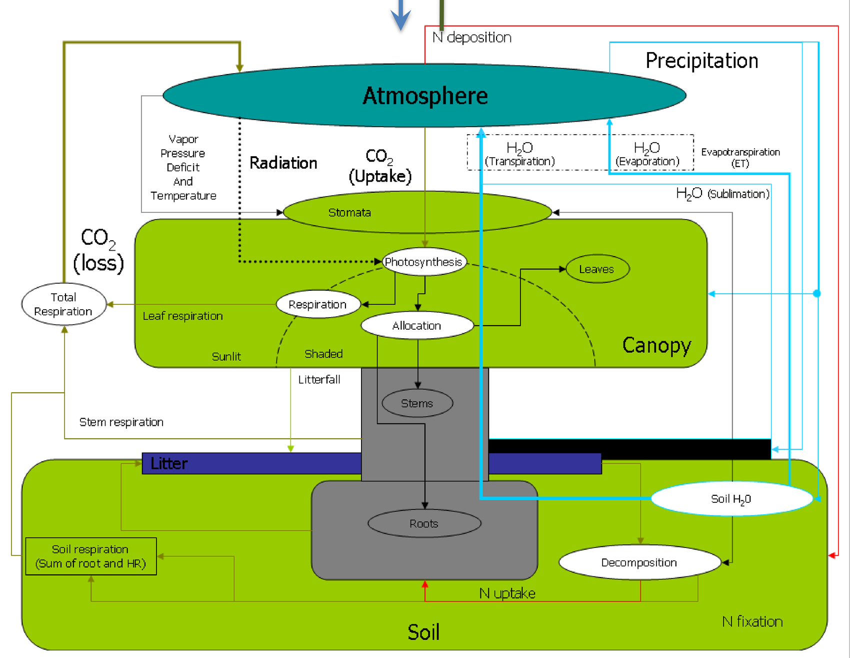
BBGC is coupled to every Flux-PIHM grid by exchanging variables on daily time step.

Soil moisture
Soil temperature
Aerodynamic resistance*

Canopy resistance*
Leaf area index*

Biome-BGC

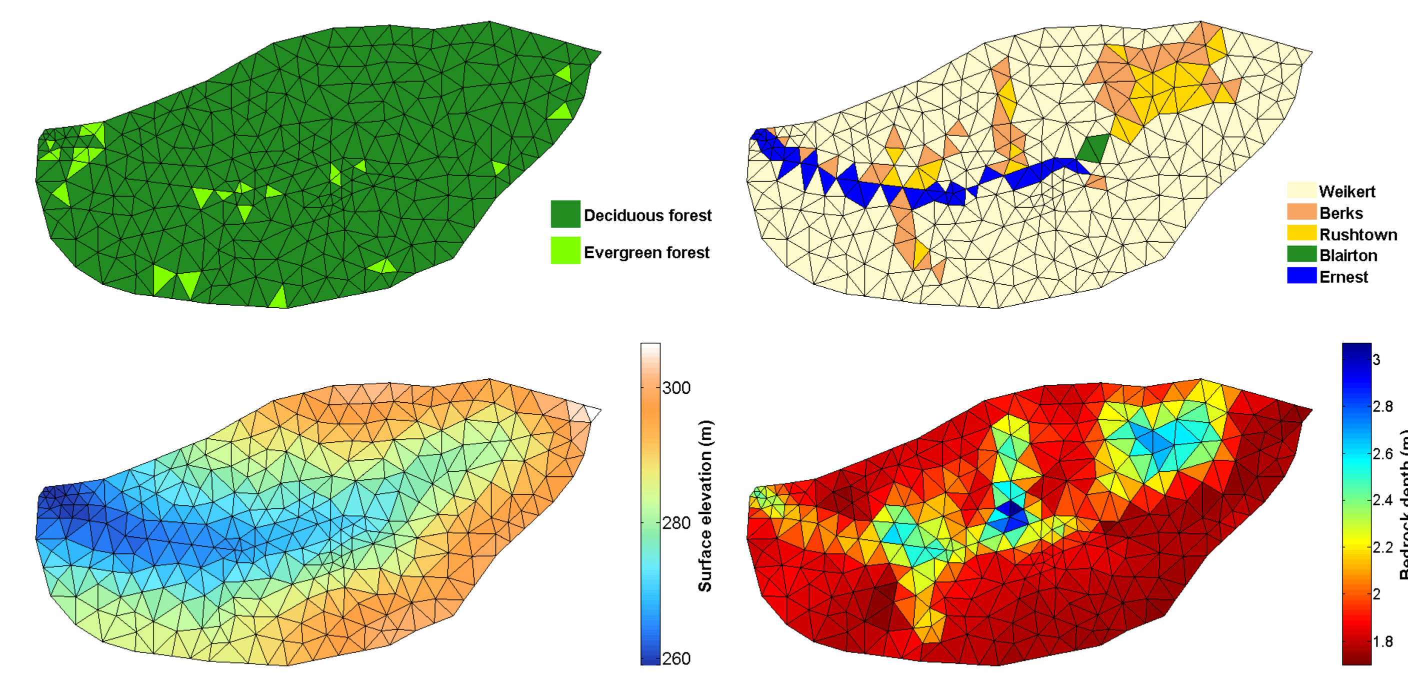
1-D mechanistic biogeochemistry model that simulates the carbon and nitrogen cycles (Thornton et al. 2002) (Biome-BGC flow figure: courtesy of http://www.ntsg.umt.edu/project/biome-bgc).



Study site: Susquehanna Shale Hills Critical Zone Observatory

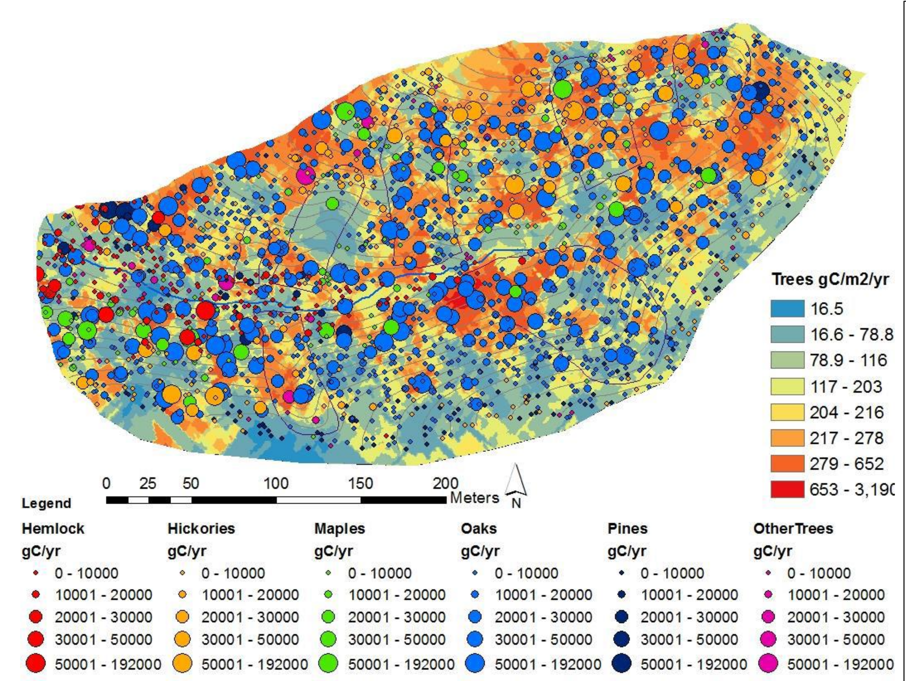
- The Shale Hills watershed is a 0.08km^2 watershed located in the valley and ridge physiographic province of central Pennsylvania.
- The slopes and ridge tops are covered by oak, maple, hickory and pine trees. The valley bottom includes many eastern hemlock.

Model and Data (continued)

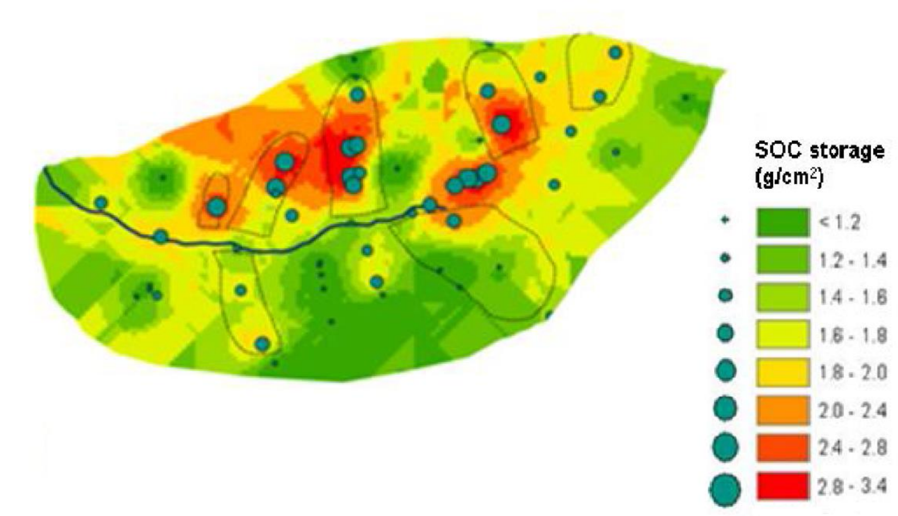


Observation array

- **Spatially distributed data (static and time series)**
  Landscape. High resolution soil depth, soil texture, bedrock depth (ground survey), surface topography (LiDAR).
  Hydrologic and energy. Soil moisture and soil temperature, sap flux, water table depth.
  Carbon cycle. Leaf area index, tree diameter growth, litter fall, soil organic carbon, canopy height, soil CO_2 efflux, root distribution and turnover rate, map of all canopy trees of greater than 20 cm DBH.
- **Watershed integrative observations (all continuous)**
  Eddy covariance, four component radiation, stream discharge, precipitation, cosmic-ray soil moisture observing system (COSMOS).

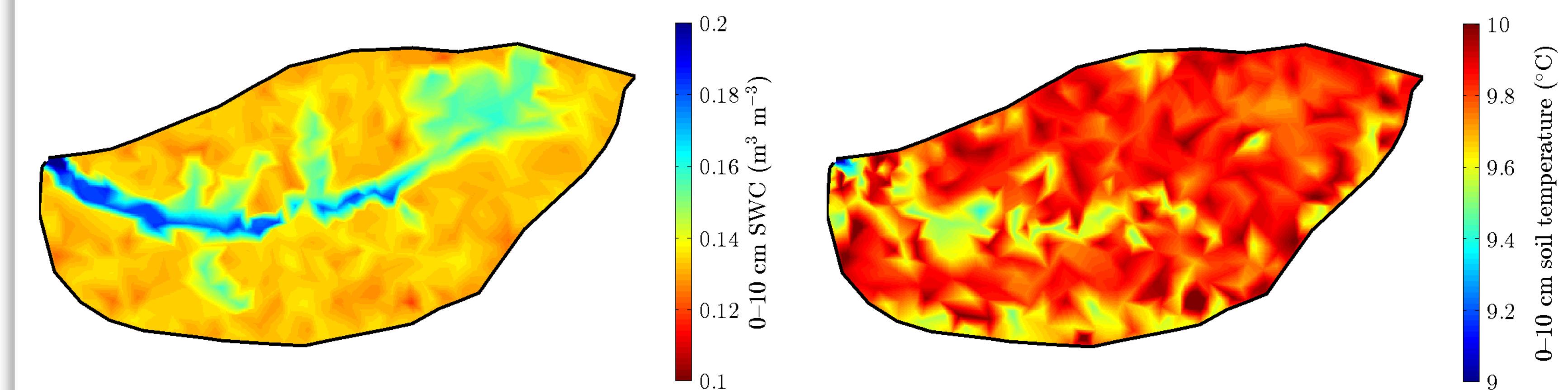


Aboveground C stored annually in tree biomass with each data point representing annual biomass accumulation (gC yr^{-1}) of a tree from 2008 to 2012. The bottom layer is an interpolated map of aboveground C stored annually in wood gC m^{-2} from each tree from 2008 to 2012. All of the 2078 trees from the tree survey had DBH greater that 20 cm. (Smith 2013)

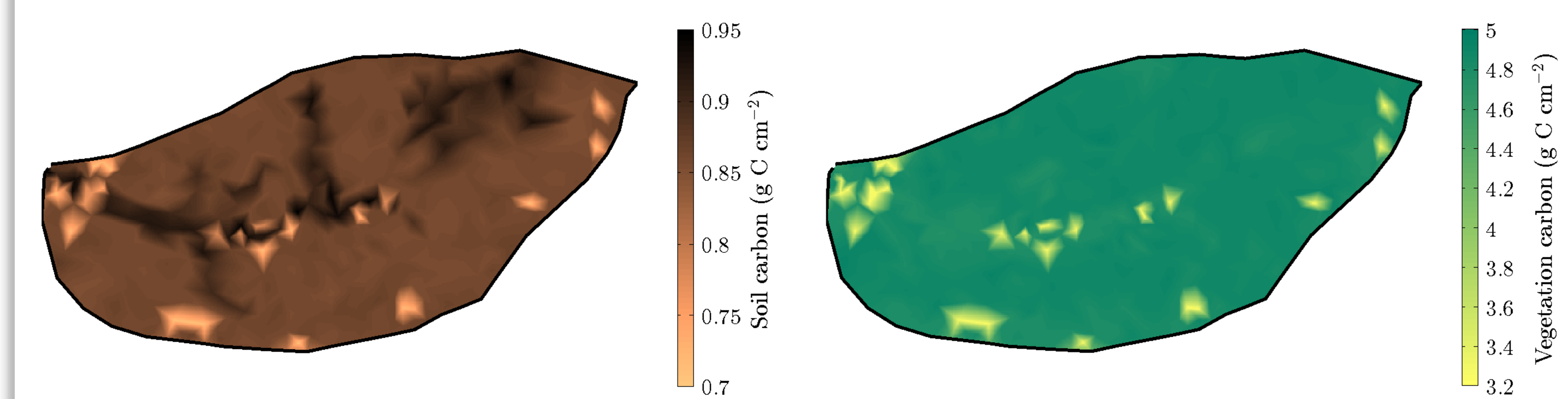


Interpolated maps of soil organic carbon (SOC) storage (g cm^{-2}) within ≤ 1.1-m soil colum based on 56 sampling sites shown on each map. (Andrews 2011)

Modeling Results



Flux-PIHM simulated 2009 average soil water content and soil temperature of the top 10 cm layer of soil, which are used to drive Flux-PIHM-BBGC spin-up.



Flux-PIHM-BBGC simulated soil carbon and vegetation carbon pools after 6000 years of model spin-up using default BBGC ecophysiological parameters. The spin-up is performed by repeating the meteorological forcing of 2009, and driven by Flux-PIHM simulated spatially-distributed soil moisture and soil temperature time series. Note that BBGC is not coupled with Flux-PIHM during the spin-up, but only driven by Flux-PIHM simulated soil moisture and soil temperature.

- The simulated soil and vegetation carbon pools are mainly affected by vegetation type.
- The simulated soil carbon pool clearly shows influences from soil moisture distribution, that are not evident for the vegetation pool.
- The simulated carbon pools do not show systematic difference between north- and south-facing slopes as in the observations. A topographic solar radiation module may be needed to properly simulate the differences in carbon pools between north and south.

Acknowledgments

This material is based upon work supported by the U.S. Department of Energy Office of Science, Office of Basic Energy Sciences Energy Frontier Research Centers program under Award Number DE-SC0012003, and the National Science Foundation Shale Hills-Susquehanna Critical Zone Observatory project through Grant EAR 0725019.

Contact

Yuning Shi (yshi@psu.edu)