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Using a Spatially-Distributed Hydrologic Biogeochemistry Model with Nitrogen Transport to Study the Spatial Variation of Carbon Stocks and Fluxes in a Critical Zone Observatory

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Most current biogeochemical models are 1-D and represent one point in space. Therefore, they cannot resolve topographically driven land surface heterogeneity (e.g., lateral water flow, soil moisture, soil temperature, solar radiation) or the spatial pattern of nutrient availability. A spatially distributed forest biogeochemical model with nitrogen transport, Flux-PIHM-BGC, has been developed by coupling a 1-D mechanistic biogeochemical model Biome-BGC (BBGC) with a spatially distributed land surface hydrologic model, Flux-PIHM, and adding an advection dominated nitrogen transport module. Flux-PIHM is a coupled physically based model, which incorporates a land-surface scheme into the Penn State Integrated Hydrologic Model (PIHM). The land surface scheme is adapted from the Noah land surface model, and is augmented by adding a topographic solar radiation module. Flux-PIHM is able to represent the link between groundwater and the surface energy balance, as well as land surface heterogeneities caused by topography. In the coupled Flux-PIHM-BGC model, each Flux-PIHM model grid couples a 1-D BBGC model, while nitrogen is transported among model grids via surface and subsurface water flow. In each grid, Flux-PIHM provides BBGC with soil moisture, soil temperature, and solar radiation, while BBGC provides Flux-PIHM with spatially-distributed leaf area index.

The coupled Flux-PIHM-BGC model has been implemented at the Susquehanna/Shale Hills Critical Zone Observatory. The model-predicted aboveground vegetation carbon and soil carbon distributions generally agree with the macro patterns observed within the watershed. Predicted watershed average vegetation carbon and soil carbon storage also agree well with observations. The importance of abiotic variables (including soil moisture, soil temperature, solar radiation, and soil mineral nitrogen) in predicting aboveground carbon distribution is calculated using a random forest. The result suggests that the spatial pattern of aboveground carbon is controlled by the distribution of soil mineral nitrogen. A Flux-PIHM-BGC simulation without the nitrogen transport module is also executed. The model without nitrogen transport fails in predicting the spatial patterns of vegetation carbon, which indicates the importance of having a nitrogen transport module in spatially distributed ecohydrologic modeling.