Linking Hydrology and Biogeochemistry at Multiple Spatial and Temporal Scales

Universiteit Utrecht

Karin T. Rebel (k.rebel@geo.uu.nl), Kevin J. McGuire#, Ed B. Rastetter^, Marc Stieglitz§, Bob B. McKane¶
Copernicus Institute for Sustainable Development and Innovation, Environmental Sciences, Faculty of Geosciences, Utrecht University
Virginia Water Resources Research Center ^Marine Biological Laboratory, Ecosystems Center § Georgia Institute of Technology
¶ Environmental Protection Agency, Corvallis, OR

Introduction

Until recently, it has been challenging to couple hydrologic and biogeochemical processes at the watershed scale. We have coupled two well-known models, TOPMODEL and MEL, applicable to multiple spatial and temporal scales. **The goal of this project is to simulate lateral water and nutrient fluxes and their influence on ecosystem functioning.** Nutrients moving down the slope are repeatedly taken up, cycled through vegetation and soils, and released back into the soil solution.

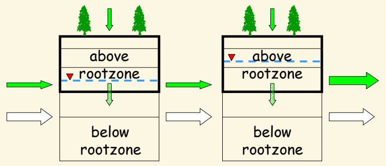


Figure 1: the connection between water flow and nutrient transport

TOPMODEL

TOPMODEL is a conceptual rainfall-runoff modeling framework at the catchment-scale. It represents lateral subsurface water redistribution, based on the hydrological similarities of points in a catchment (i.e. topographic index, dependent on contributing area and the local slope). Our hydrologic model is based in the TOPMODEL concepts, and additionally includes a layers soil water scheme.

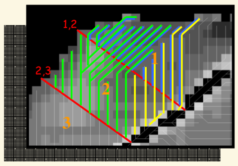


Figure 2: Local drain direction map WS10, HJA

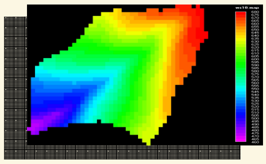


Figure 3: digital elevation map WS10, HJA

$$Q_b = \frac{K_0}{f} \exp^{-\lambda} \exp^{-f\bar{z}} \qquad q_i = \frac{K_0}{f} \exp^{-f z_i} \tan\beta \qquad z_i = \bar{z} - \frac{1}{f}\left(\ln\frac{a}{\tan\beta} - \lambda\right)$$

Q_b= base flow, K_0 hydraulic conductivity at soil surface, **f**= hydraulic conductuvity decline parameter, **λ**= average ln (a/tan ß) catchment, **z_bar** = average water table catchment, **z_i**= local water table, **a**= contributing area, **ß**= local slope soil surface, **q_i**= local water flux

TOPMODEL: Spatially explicit

up_2 is water flowing from area 1 to area 2 (blue in Fig. 2)

$$up_2 = \int_{1,2} q_i\, dl\left(line_{1,2}\right)$$

low_2 is water flowing from area 2 to area 3 (green in Fig. 2)

$$up_2 = A_{(1,2)} \frac{K_0}{f} \exp^{-\lambda up_2} \exp^{-f\,\overline{z_{up2}}}$$

$$low_2 = A_{(2,3)} \frac{K_0}{f} \exp^{-\lambda low_2} \exp^{-f\,\overline{z_{low2}}}$$

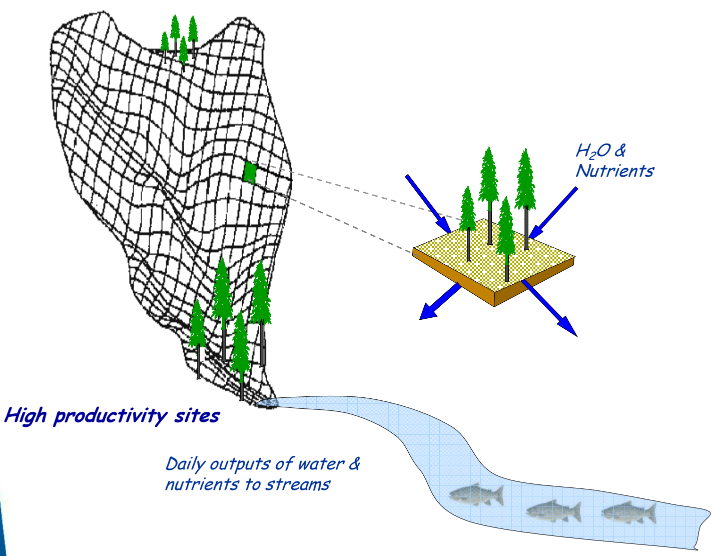


Figure 4: Linkage of a surface hydrology model to a biogeochemistry model

Using the TOPMODEL approach, water and nutrient fluxes are constrained to saturated lateral flow, which develops from the impermeable layer upward. Although computationally efficient, it might not capture the nutrient dynamics, which generally occur in more shallow parts of the soil. Current research includes the comparison of results obtained from the TOPMODEL approach with results obtained from a spatially explicit water balance approach (WTB, figure 5 and 6). WTB allows for the simulation of shallow subsurface lateral flow, which develops periodically after rain-events. We will evaluate these models using a long-term data set on biogeochemical and hydrological fluxes as well as plant productivity data in different parts of the catchment area.

WTB

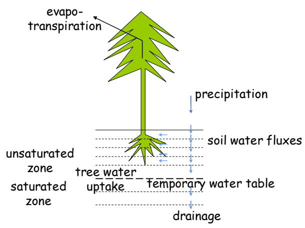


Figure 5: Soil-plant-atmosphere interaction

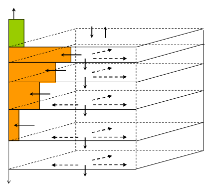


Figure 6: 3-D water balance model

Water can move vertically as well as laterally based on the tipping bucket approach. When the volumetric water content is above field capacity, water can move vertically. Lateral movements is based on the slope of either surface topography or subsurface topography. Using this approach, water tables and water fluxes can be simulated directly, assuming no steady state.

MEL

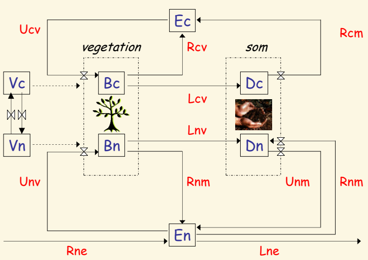
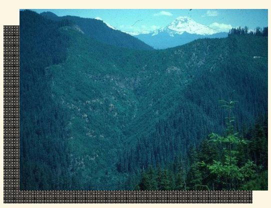


Figure 7: Scheme MEL model

Bc = C in plant biomass (gCm-2)
Bn = N in plant biomass (gNm-2)
Dc = C in soil detritus (gCm-2)
Dn = N in soil detritus (gNm-2)
Ec = CO2 concentration (ml m-3)
En = inorganic N (gN m-2)
Vc = plant C uptake effort
Vn = plant N uptake effort
Ucv = gross phytosynthesis
Unv = plant N uptake
Unm = microbial N uptake
Rcv = plant respiration
Rnm = N mineralization
Rne = externbal N supply
Lne = inorganic N leaching
Lcv = inorganic C loss
Lnv = litter N loss
Rcm = microbial respiration
Rnm = N mineralization

The Multiple Element Limitation (MEL) model is an ecosystem model, developed to simulate changes in vegetation acclimating to changes in the availability of two resources (C and N). MEL also incorporates the recycling of resources through the soil.



USFS PNW-OSU Forest Science Data Bank
Photographed by Al Levno, 1990

USFS PNW-OSU Forest Science Data Bank
Photographed by Fred Swanson, 1990

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