Linking snowmelt and nitrogen cycling to vegetation community dynamics along a hillslope transect

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In recent years, decreasing snowpack and early snowmelt have been observed with increasing frequency in the mountainous west. Previous studies suggest that early snowmelt is correlated with decreased vegetation productivity, shrubification and pre-summer drought [1,2], and discontinuous snow cover is associated with reduced microbial nutrient buffer and increased nutrient leaching loss [3]. The objective of this work is to quantify the influence of variations in snowmelt timing and snowpack depth on nitrogen fluxes and plant phenology along a lower montane hillslope-to-floodplain transect in the East River catchment, Crested Butte, CO. For this purpose, a 2-D reactive transport model that can resolve lateral fluxes through the unsaturated and saturated zones of the East River lower montane hillslope has been developed using ToughReact (Figure 1). Further, to accurately capture the vegetation nitrogen demand and vertical fluxes of other nutrients in the unsaturated zone and groundwater, the ToughReact 2D numerical model has been loosely coupled with a comprehensive plant ecosystem model *ecosys* [4] through top hydrologic boundary conditions.

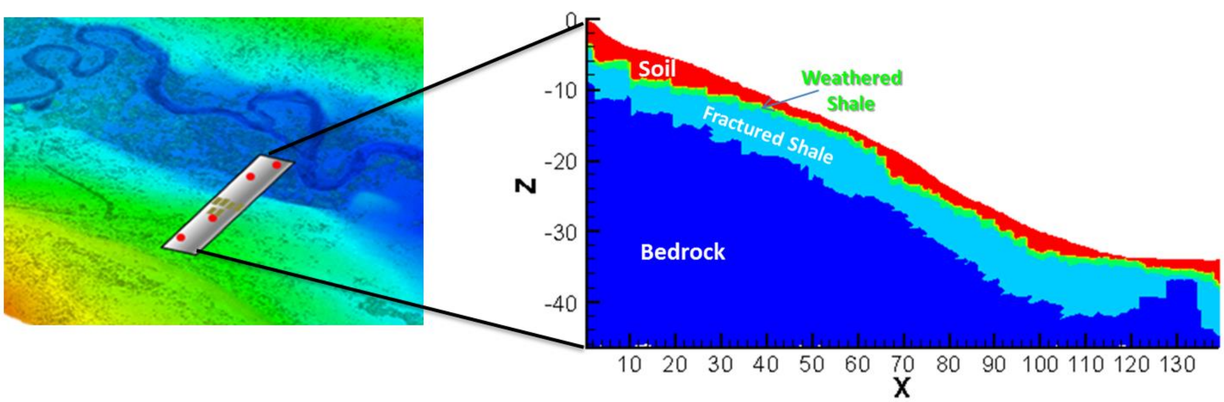

Figure 1: 2D Hillslope Transect Model of the East River Site

Model simulations show that an earlier and larger nitrate peak is obtained with advanced snowmelt in comparison to a normal snowmelt scenario. Results further indicate that differences in snowpack depths change the under-snow nutrient buffer and ammonia concentration. In both scenarios of early snowmelt and decreased snowpack, shrub dominance is observed at the site. These results clearly indicate a temporal connection between snowmelt-associated nutrient release and shrubification at the hillslope site.

Simulation results further show that distinct spatial signatures of hydrological and biogeochemical fluxes are obtained along the hillslope transect, with greater evapotranspiration rates and higher soil water storage in the floodplain as compared to upslope regions. Consistent with observations, simulated water and nitrogen fluxes are higher around the backslope region following snowmelt. Model simulations thus indicate that nitrogen runoff after snowmelt impacts vegetation community structure, resulting in islands of fertility around the backslope where veratrum are observed.

References

[1] L.L. Sloat, A.N. Henderson, C. Lamanna and B.J. Enquist. The effect of the foresummer drought on carbon exchange in subalpine meadows. *Ecosystems*, **18(3)**, 533-545, (2015).
[2] J. Harte, S.R. Saleska and C. Levy. Convergent ecosystem responses to 23-year ambient and manipulated warming link advancing snowmelt and shrub encroachment to transient and long-term climate–soil carbon feedback. *Global Change Biol.*, **21(6)**, 2349-2356, (2015).
[3] P.D. Brooks, M.W. Williams and S.K. Schmidt. Inorganic nitrogen and microbial biomass dynamics before and during spring snowmelt. *Biogeochemistry*, **43(1)**, 1-15, (1998).
[4] R.F. Grant. Nitrogen mineralization drives the response of forest productivity to soil warming: Modelling in ecosys vs. measurements from the Harvard soil heating experiment. *Ecol. Model.*, **288**, 38-46, (2014).