Susquehanna Shale Hills Critical Zone Observatory

All Hands Meeting Agenda and Abstract Volume

The Pennsylvania State University

University Park, PA

May 2018

SSHCZO All Hands 2018 Agenda

Wednesday, May 9th

Arrival of out of town participants

2:45pm – Virginia Marcon will meet Dr. Reinfelder in Atherton Hotel Lobby
3:00pm – 4:00pm CZO student meeting with Dr. Reinfelder (311 Hosler Building)
4:00pm – 5:00pm Li Li meeting with Dr. Reinfelder (311 Hosler Building)
4:00pm – 5:00pm Poster Session Set-up (2217 EES Suites)
6:30pm – Dinner Ying, Lili, Dave, and Sue @ Spat's at The Grill

Thursday, May10th **ALL HANDS MEETING - 117 EES Building**

8:00am – 8:15am – Welcome and Introductions to SSHCZO. Talks are to be 10 -12 minutes followed by 5-7 minute Q/A session and 1 minute speaker switchover

8:20am – 8:40am – Synthesis Talk: CZO Research

8:45am – 9:30am – ***Opening Poster Session***

- **If a Tree Falls…Plant Regeneration and Resource Availability in a Tree Tip-Up Chronosequence (Dillner, B. & Kaye, J.)**
- **Preliminary Results of the Near-surface Geophysical Characterization of Cole Farms in the Susquehanna Shale Hills Critical Zone Observatory, Pennsylvania, USA. (Mount, G. & Hayes, J.)**
- **Identifying the critical measurements in representing the hydrologic response at the forest catchment using model-data synthesis (Xiao, D., Shi, Y., and Li, L.)**
- **Heave and throw: Aspect dependent processes drive geomorphological asymmetry at Shale Hills (West, N. & Zhang, Y.)**
- **Stratigraphic control of landscape response to base-level fall, Young Womans Creek, Pennsylvania, USA (DiBiase, R.A., Denn, A.R., Bierman, P.R., Kirby, E., West, N., and Hidy, A.J.)**
- **Investigating climate change versus land use controls on hillslope erosion and valley sedimentation at the Cole Farm study watershed, central Pennsylvania (Silverhart, P. & DiBiase, R.A.)**
- **Electrical Resistivity and Seismic Models for the Shale Hills CZO: Imaging the Interflow layer (Nyblade, A., Delisser, T., Miles, R., and West, N.)**
- **What can we learn from GroundHOG? From spatial and aspect contrast view (Marcon, V., Tang, Q., Del Vecchio, J., Hodges, C., and Szink, I.)**
- **What environmental factors affect sap flow in the trees? (He, Y., Tang, Q., Szink, I., Primka, E., and Reed, W.)**
- **Water cycle and water chemistry (Xiao, D., Wayman, C., and Hoagland, B.)**

- **Everything we know about Cole Farm (Wayman, C., Silverhart, P., Hodges, C., Tang, Q., Forgeng, M., and Carpenter, N.)**

9:55am – 10:10am – Team H1 *Geomorphic constext for the Susquehanna Shale Hills Critical Zone Observaory: implications for the "age" of the critical zone and the sensitivity to climate and land use pertubations* – DelVecchio, J., Silverhart, P., DiBiase, R.A., Bierman, P.R., and West, N.

10:10am – 10:15am – Discussion of H1

10:15am – 10:30am – Team H2 *Soil gas concentrations in the Shale Hills and Garner Run watersheds indicate different drivers of gas production and consumption* – Hodges, C., Kim, H., Brantley, S.L., and Kaye, J.

10:30am – 10:35 am – Discussion of H2

10:35am – 10:50am – Team H4 *Assessing soil water movement using co-located estimates of soil moisture and temperature* – Tang, Q., Guo, L., Xiao, D., Li, L., Eissenstat, D., and Lin, H.

10:50am – 10:55am – Discussion of H4

10:55am – 11:10am – Team H5 *Understanding the hydrologic and geochemical control of regolith formation at the hillslope scale* – Xiao, D., Li, L., and Brantley, S.L.

11:10am – 11:15am – Discussion of H5

11:20am – 12:00pm – ***Posters, Break, and Field Trip Preparations***

12:00pm – 3:00pm – Field Trip with Ying Fan Reinfelder to Lake Perez for lunch, tour of Shale Hills, and a quick stop in Garner Run – meet in EES Building parking lot – sandwiches and water provided for RSVP participants. Not all team members are required to participate; however, one from each Hypothesis team is required. ***We will emphasize depth of roots and where trees get their water.***

4:00pm – 5:00pm – Featured Seminar by Ying Fan Reinfelder, Professor of Rutgers University Department of Earth and Planetary Sciences, will present "**Three Hydrologic Depths in the Earth's Critical Zone – Linking Hillslope to Global Processes " in 114 EES Building**

6:30pm – Dinner - Pizza with students and Reinfelder (217B EES Building)

Friday, May 11th **ALL HANDS MEETING - 117 EES Building**

8:00am – 9:00am – ***Opening Poster Session***

9:05am – 9:20am – Team H6 *Sandstone ridges act as collectors for dust and overlying soil particles over 100 ka timeframes* – Marcon, V., Hoagland, B., Gu, X., Kaye, J., and Brantley, S.L.

9:20am – 9:25am – Discussion H6

9:25am – 9:40am – Team H7 *What are the most important variables controlling the land-air-ecosystem interactions of Shale Hills?* – He, Y., Davis, K., Shi, Y., Eissenstat, D., Kaye, J. and Kaye, M.

9:40am – 9:45am – Discussion H7

9:45am – 10:00am – Team H8 *Using statistical tools to understand spatial and temporal variability in Shaver's Creek watershed* – Wayman, C., Hoagland, B., Forsythe, B., Russo, T., Li, L., and Brantley, S.L.

10:00am – 10:05am – Discussion of H8

10:05am – 10:20am – Team H9 *Understanding Hydrobiogeochemical Dynamics Using an Upscaled Simple Model* – Wen, H., and Li, L.

10:20am –10:25am – Discussion of H9

10:25am – 10:40am – Team H3 *Root Processes in the Critical Zone* – Malik, R., Szink, I., Primka, E., Orr, A., Kaye, J., and Eissenstat, D.

10:40am – 10:45am – Discussion of H3

10:45am – 11:30 am – ***Break and Posters***

11:30am – 12:30pm – Review and Outcomes of January Science Retreat – Facilitated by Ken Davis

12:30pm – 12:40pm – Greg Mount, Assistant Professor IUP – GeoPATHS summer field camp

12:45pm – 2:00pm – ***Lunch and Discussions and Posters – 2217 EES Building***

2:00pm – 2:20pm – Shaver's Creek Research Collaborations (Joshua Potter, Lucy McClain, Justin Raymond, Doug Wentzel)

2:20pm – 2:30pm – Discussion of collaborations – Next steps

2:30pm – 3:30pm – ***Break and Posters***

3:30 – 4:00pm – Feedback from Reinfelder – Observations of the SSHCZO

4:00pm – 5:00pm – Science for the Future (pop-ups welcome?)

6:00pm – Happy Valley Brewing Company – for Social and Happys

The 9 original hypotheses

H1 - ***Feedbacks among frost shattering, weathering reactions, and the evolution of topography have resulted in an asymmetric distribution of fractures that in turn controls the observed differences in fluid flow in the subsurface between the sun-facing and shaded sides of catchments within Shale Hills and much of the Susquehanna River Basin.*** *(DiBiase, Kirby, Bierman, Singha, Brantley, Lin)*

H2 – ***The distribution of weathering reactions across a landscape can be described as a function of biotic and abiotic production and consumption of acids (CO2, DOC) and O2.*** *(Kaye, Brantley, Eissenstat, Li)*

H3 – ***Trees with deeper roots (oaks) are associated with less frequent tree throw, slower hillslope erosion rates, fewer vertical macropores, faster weathering at depth, and deeper regolith than trees with shallower roots (maples).*** *(Eissenstat, Davis, Kaye, Brantley)*

H4 – ***Macropores are important in controlling fluid flow and chemistry in soils derived from various lithologies, but the nature and effects of these macropores differ significantly among shale, calcareous shale, and sandstone.*** *(Lin, Duffy, Eissenstat, Davis)*

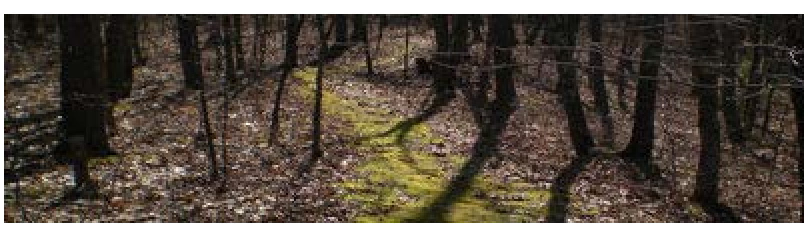
H5 – ***Greater evapotranspiration on the sunny, north side of Shale Hills means that less water recharges to the stream, explaining why Mg and other cations are less depleted in the regolith on the north compared to the south hillslopes.*** *(Li, Brantley, Kaye, Shi)*

H6 - ***Ions that are released quickly from ion exchange sites (Mg, Na, K) throughout the catchment demonstrate chemostatic behavior (~constant concentration in the stream), whereas Fe, Mn, and DOC concentrations vary with changes in watershed-stream connectivity.*** *(Russo, Brantley, Li, Kaye, Shi)*

H7 - ***Land-atmosphere fluxes of carbon (C) and water, ground-water hydrology, and ecosystem change are coupled processes at time scales of months to decades. This coupling varies with the lithology and land use and position on the hillslope***. *(Davis, Shi, Eissenstat, Duffy, Lin, Kaye)*

H8 - ***Co-located, intensive, relocatable measurements of soil moisture, tree sap flux, sapwood area, LAI, ground water depth, temperature, 18O and D/H along with a 4-component radiometer, laser precipitation monitor and landscape-level soil moisture (COSMOS) can be assimilated within a multi-scale distributed modeling framework to project physical processes from Shale Hills to Shavers Creek to YWC and Snake Creek watersheds.*** *(Shi, Duffy, Davis, Eissenstat, Lin)*

H9 - ***Increasing atmospheric CO2 in the future will cause higher temperatures and faster weathering of clays in the catchment, increasing streamwater solute loads.*** *(Brantley, Godderis, Li, Duffy, Davis)*



The Susquehanna Shale Hills Critical Zone Observatory

hosts Dr. Ying Fan Reinfelder, Professor of Rutgers University Department of Earth and Planetary Sciences, for the 2018 All Hands Meeting

Dr. Reinfelder presents ***"Three Hydrologic Depths in the Earth's Critical Zone – Linking Hillslope to Global Processes"*** in 114 EES Building @ 4:00pm on Thursday, May 10th

Abstract:

What is the depth and frequency of rainfall infiltration? How deep do plant roots penetrate into the soils? How deep is the groundwater table? Infiltration brings the acidic and thus chemically aggressive surface fluids into contact with the basic regolith and bedrocks, and by doing so it controls weathering rates. It also determines the wetted soil depth and hence influences plant rooting depths, the latter determines the depth of the Earth's crust penetrated and altered by terrestrial life. It also controls the infiltration depth and the water table depth through ET consumption, and a suite of soil microbial processes. The water table depth defines the redox boundary and hence a range of biogeochemical reactions. Its depth also determines its hydraulic connection with the rainfall infiltration depth, hence completing the flushing of weathering products into groundwater and streams. Therefore these three mutually dependent hydrologic depths shape the plumbing system of the Earth's Critical Zone and its structure, function and evolution. Observation syntheses are presented to illustrate the mechanisms and the resulting patterns, and a high-resolution dynamic inverse model is used to explore the global structure in the co-evolution of the three depths. But all starts at the hillslope scales...

Geomorphic context for the Susquehanna Shale Hills Critical Zone Observatory: implications for the “age” of the critical zone and the sensitivity to climate and land use perturbations

Joanmarie Del Vecchio[1], Perri Silverhart[1], Roman A. DiBiase[1,2], Paul R. Bierman[3], Nikki West[4]

[1]Department of Geoscience, Penn State
[2]Earth and Environmental Systems Institute, Penn State
[3]Department of Geology, University of Vermont
[4]Department of Earth and Atmospheric Sciences, Central Michigan University

At the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO), three study watersheds—Shale Hills, Garner Run and Cole Farm—reflect variations in lithology, base level, and land use. The sensitivity of the critical zone to perturbations in base level, climate, and land use thus varies from site to site. At Shale Hills (erosion rate = 20-30 m/Myr), the mobile regolith and topography are thought to reflect Holocene processes, whereas the sandstone catchment of Garner Run (erosion rate = 7 m/Myr) retains a signature of Pleistocene cold-climate conditions, resulting in contrasting chemical weathering profiles and sediment transport processes between the sites. At Cole Farm, we posit that the anthropogenic impact of farming drives spatial patterns in soil chemistry, regolith thickness and sediment transport. Ongoing work at Cole Farm using soil pits and coring will elucidate how short-term denudation related to agriculture compares to long-term landscape lowering, and the degree to which farming has mobilized and redistributed sediment. A planned coring campaign at nearby Bear Meadows will provide insight into how the biotic and abiotic features of the critical zone responded to climate change in the past, thus contextualizing modern observations. Additionally, shallow geophysical surveys provide insight into the spatial variability of subsurface architecture within each site. A key finding of geomorphic investigations at the SSHCZO is the understanding that localized conditions (lithologic, base level, and land use) result in landscapes with variable critical zone integration timescales, or “ages”. This framework is crucial for cross-site interpretations as well as contextualizing observations made at larger geographic scales.

Soil gas concentrations in the Shale Hills and Garner Run watersheds indicate different drivers of gas production and consumption

Caitlin Hodges[1], Hyojin Kim[2], Susan Brantley[2], Jason Kaye[1]
[1]Department of Ecosystem Science and Management, Pennsylvania State University
[2]Department of Geosciences, Pennsylvania State University

Patterns in soil gas concentrations are invaluable for understanding the drivers of the carbon cycle. Variations in CO_2 and O_2 concentrations help elucidate ecosystem processes because they document the integrated effects of soil diffusivity, C substrate availability, and the metabolic pathways that mineralize organic C. They also potentially highlight CO_2 dissolution that could drive increased porewater acidity and bedrock weathering. The Apparent Respiratory Quotient (ARQ), the ratio of the differences of soil CO_2 and O_2 from the atmosphere, corrected for diffusivity, can provide information on processes driving variation in O_2 and CO_2 in the soil system. If we assume that aerobic respiration and diffusion are the two dominant processes driving variation in CO2 and O2 concentrations in the soil profile we can calculate a theoretical ARQ. Deviations from this theoretical ARQ suggest preferential use of particular C substrates in C mineralization, CO_2 dissolution in porewater, or O_2 consumption in redox reactions.

To better understand the soil gas system, we measured soil pCO_2 and pO_2 along one shale and one sandstone catena at the Susquehanna Shale Hills CZO for one year. We sampled four total sites per lithology, and three depths per site. Regressions were conducted to examine the potential for deviation from the assumed (i.e. the theoretical ARQ) metabolic and diffusive conditions observed at the two lithologies. Slopes of pCO_2 vs. pO_2 for the Shale Hills (-1.21 ± 0.034 se) and Garner Run (-0.86 ± 0.031 se) sites were significantly different, and both deviated from the theoretical relationship of pCO_2 to pO_2 slope of -1.32. Slopes more shallow than -1.32 suggest oxygen consumption or abiotic CO_2 production in the soils of Garner Run.

Data were also interpolated using a kriging routine to examine CO_2, O_2, and ARQ changes with depth and time. With these kriged surfaces we have pinpointed potential hot-spots and moments of mineral weathering and C mineralization.

Root Processes in the Critical Zone

Rondy Malik, Ismaiel Szink, Edward Primka, Alexandra Orr, Jason Kaye and David Eissenstat

Roots are dynamic and play a vital role in soil structure formation and fluxes of water, carbon and other elements. Yet, our understanding is basic as to how lithology and topography may influence root distribution, rhizosphere decomposition and soil respiration. Here the aim was to unravel ways in which lithology and topography may affect root distribution and production, rhizosphere-mediated wood decomposition and soil CO_2 efflux. Across sites in Pennsylvania, root distribution was assessed with respect to soil depth at shale and sandstone sites. In addition, root effects on wood decomposition were assessed across shale and limestone sites. At shale sites, topography was used as a predictor of root production and soil respiration. Tree species distributed their roots at shale sites as would be predicted by aboveground relative abundance. In contrast, at sandstone sites, oaks contributed more deep roots than other neighboring tree species. Compared to areas were roots were recently removed, the decomposition of wood in the presence of living roots was greatest at shale sites in contrast to sites of limestone parent material. Within a shale catchment, topography strongly affected soil CO_2 efflux and fine root production. Specifically, soil CO_2 efflux was greatest and root production lowest at swale locations. Collectively, these findings reveal some of the complexities of how lithology and topography influence the way roots influence the critical zone.

Assessing soil water movement using co-located estimates of soil moisture and temperature

Qicheng Tang[1], Li Guo[1], Dacheng Xiao[2], Li Li[2], David Eissenstat[1], Henry Lin[1]

[1]Department of Ecosystem Science and Management, Pennsylvania State University, PA, USA
[2]Department of Civil and Environmental Engineering, Pennsylvania State University, PA, USA

Macropores strongly affect water movement and solute transport in soils. We contrasted the effect of macropores on soil water movement between a shale site and a sandstone site in central Pennsylvania. For each site, probes which simultaneously measured soil moisture and temperature in a 10-min interval were installed at three depths (10, 20, and 40cm) on the north mid-slope and south mid-slope. Thus, both lithology and aspect serve as potential factors governing soil water movement. Soil moisture response time difference was selected as the criterion to detect preferential flow, and the co-located soil temperature was used to determine the water source of a particular soil depth. Based on the results, lithology seemed to be a more significant control on preferential flow occurrence than slope aspect. The shale site had a higher preferential flow frequency compared with the sandstone site, which may be caused by dense shale fractures embedded in soils or steeper microtopography at the shale site south mid-slope. For the sandstone site, preferential flow occurred more often during the dry season (e.g., October) compared with the wet season (e.g., March), which indicated the seasonal dynamics of the macropore structure. By combining soil temperature data into the preferential flow analysis, two hydrological processes were further confirmed at both sites: (1) the fast and gravity-driven rainwater was mixed with the old soil capillary water and (2) water flux (with temperature fluctuations) might not necessarily cause changes in water content.

Understanding the hydrologic and geochemical control of regolith formation at the hillslope scale

Dacheng Xiao[1], Li Li[1], Susan Brantley[2]

Chemical weathering transforms rock to soil and determine soil texture, bedrock depth, and soil hydrological properties. At the Shale Hills watershed in central Pennsylvania, field evidence indicated that the regolith depth, hydrologic processes, and chemical depletion are different at the two aspects (Clarke et al., 2013; Ma et al., 2013; Shi et al., 2014). Current regolith formation models considering reactive transport processes have a limitation in coupling complex and evolving hydrodynamic conditions. We hypothesize that deeper regolith forms when more water flushes dissolved mass out of the system. The hypothesis is tested by developing a two-dimensional regolith formation model at the hillslope scale using measured mineral composition and hydrologic properties at Shale Hills using CrunchFlow.

A 2-D hillslope domain was setup to simulate hydrogeochemical processes at north and south aspects and to understand the evolution of hydrodynamics, rock properties, and extent of chemical reactions. The bedrock has the primary minerals of illite, chlorite, and pyrite; goethite, vermiculite and kaolinite precipitated as secondary minerals. The permeability, mass transfer coefficient, and groundwater table depth were constrained by field measurement (Brad Kuntz et al., 2011; Brantley et al., 2013; Brantley et al., 2017). We implemented different recharge rates on north and south aspects based on the annually averaged fluxes from a current reanalysis using a hydrologic model. The simulation started from a homogeneous bedrock composition at 10,000 years ago. After 10,000 years' weathering, the south facing aspect with small recharge rate has a shallower soil and regolith. The simulation output indicates the formation of a shallow and a deep groundwater, based on the formation of lateral flow that connects to the stream. One is at the interface between high permeability soil zone and low permeability regolith zone, forming a relatively high-velocity perched groundwater layer. The remnant water infiltrates into the deeper low permeability zone and forms the regional groundwater layer. Because of high permeability in perched layer on north facing aspect, the remnant water in regional groundwater layer leads to shallower water table depth on north facing aspect. The model will be used to understand the role of organic matters, fractures, climate, and mineral compositions in affecting regolith formation.

[1] Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, PA.
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Sandstone ridges act as collectors for dust and overlying soil particles over 100 ka timeframes

Virginia Marcon[1], Beth Hoagland[1], Xin Gu[1], Jason Kaye[2], Susan Brantley[1,3]

[1]*Department of Geosciences, Penn State;* [2]*Department of Ecosystem Science and Management, Penn State;* [3]*Earth and Environmental Systems Institute, Penn State*

In a headwater catchment completely underlain by quartz arenite, thick soils (>1m) enriched in Al, K, Fe, and Mg have developed despite the insoluble nature of the protolith. High iron concentrations, red coloration of deep groundwater, and iron-staining on quartz-rich boulders recovered from drill cores indicate transport of iron-rich particles or solutes through quartz-rich colluvium. The thick soils, $^{87}Sr/^{86}Sr$ ratios in soils and bedrock (Fig. 1), and iron particles suggest that non-silica components are largely derived from stratigraphically younger shale units that have weathered from the catchment but have been retained in the subsurface. K-feldspar grains observed in the soils developed over the sandstone are not observed in arenite or the shale and are likely brought to the catchment via atmospheric deposition. Additionally, soils on the sandstone have higher phosphorus availability for vegetation and phosphorus concentrations are higher in live foliage present at the sandstone sites as compared to shale suggesting an additional source of nutrients in sandstone soils besides the shale alone.

In contrast, other nutrients (Ca, Mg, Fe, K) are depleted in the sandstone soils relative to shale soils in a nearby watershed with faster erosion rates and little evidence of eolian deposition. Thus, it appears that atmospheric deposition of dust has contributed nutrients to the chemically resistant quartz arenite watershed. In the eastern U.S. where precipitation exceeds evapotranspiration, dust-derived nutrients might be considered to be negligible as compared to chemical weathering of in-place rock. However, in a chemically resistant catchment with slow erosion rates (~6 m/Ma) and long exposure times (100-350 ka) such as those found along topographic highs in the Valley and Ridge Province, US, dust and residua from overlying rocks apparently accumulate as an important source of nutrients within a watershed that would otherwise be nutrient-limited.

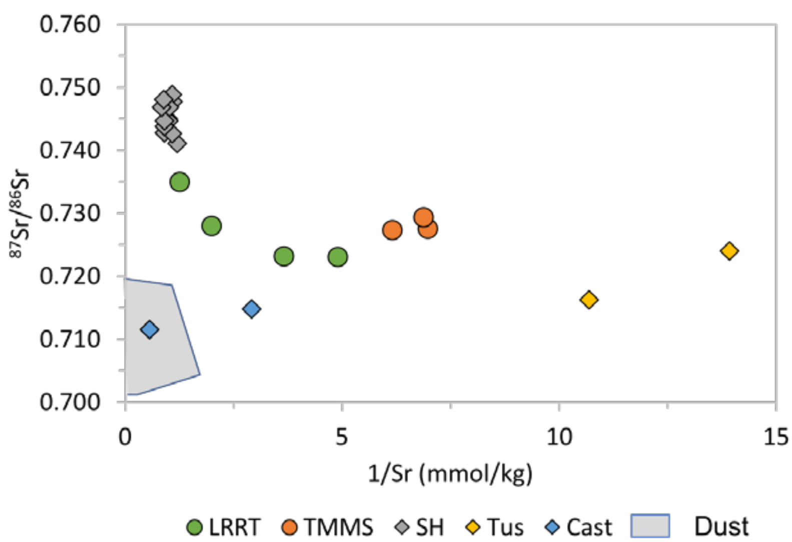

Fig. 1: Strontium isotopic ratios versus inverse strontium concentrations for soils (circles) and possible parent sources (diamonds). Soils developed over the sandstone (LLRT and TMMS) fall between the shale parent (SH) and the sandstone parent (Tus) indicative of end-member mixing. Soil $^{87}Sr/^{86}Sr$ ratios are similar between both sites, which suggests the soils are derived from similar sources. Average dust (shaded grey) is from Aarons et al. (2017).

What are the most important variables controlling the land-air-ecosystem interactions of Shale Hills?

Yuting He[1], Kenneth Davis[1], Yuning Shi[2], Dave Eissenstat[2], Jason Kaye[2], Margot Kaye[2]

1 Department of Meteorology and Atmospheric Science, The Pennsylvania State University, University Park, PA, USA
2 Department of Ecosystem Science and Management, The Pennsylvania State University, University Park, PA, USA

The interactions among land, air and ecosystem are carried by the movement (cycling) and interactions of energy, water, carbon, and nutrients in these mediums. The Shale Hills critical zone observatory has implemented comprehensive observations/field campaigns during the past decade to monitor the fluxes and/or the storages of these components (e.g. energy, water, carbon and nitrogen) in a temperate forested watershed. Shale Hills has also been a testbed for a suite of models, which synthesize different measurements to understand different aspects of the watershed. In this hypothesis, we incorporated intensive relevant observations into a biogeochemistry model, Biome-BGC, to unveil: 1) the role of topography and soil properties on carbon cycle; and 2) the most important model variables and parameters to observe. A fully coupled land surface hydrologic terrestrial biogeochemistry modeling system, Flux-PIHM-BGC, has also been developed to further elucidate the processes and parameters that are most important in shaping the watershed hydrology, carbon and nutrient cycles. Our results indicate that topography and soil properties, which are partly shaped by lithology, control the carbon distribution in complex terrain through redistributing water and nutrients. Sensitivity analysis of the model Biome-BGC further indicates that carbon dynamics are sensitive to a small number of the eco-physiological parameters (e.g. specific leaf area and C allocation ratio between stem and leaf), but the spatial distribution of carbon in complex terrain is controlled by another set of parameters that are related to soil properties (e.g. van Genuchten parameters). These results are informative to the fully coupled model as well as to the construction of observational network. The method applied in this watershed is useful to study other watersheds with different lithology and land use types, and to upscale the study site to a larger scope.

Using statistical tools to understand spatial and temporal variability in Shaver's Creek watershed

Callum R. Wayman[1], *Beth Hoagland*[1], *Brandon Forsythe*[2], *Tess Russo*[2,3], *Li Li*[2], *Susan L. Brantley*[2]

[1] Geosciences Department, Pennsylvania State University
[2] Earth and Environmental Systems Institute
[3] Mathematics Department at Pennsylvania State University

The Susquehanna Shale Hills CZO (SSHCZO) is encompassed by the Shaver's Creek watershed (163 km^2). Land use and lithology types vary spatially throughout the watershed. Long term hydrologic and geochemical data sets have been collected from three subcatchments within the watershed: Shale Hills, Garner Run, and Cole Farm. These three catchments are each underlain by shale, sandstone, and calcareous shale, respectively. Cole Farm is an agriculturally developed catchment, while the other two are primarily forested. Four main stem sites within Shaver's Creek are also continuously monitored and sampled. The amount of agricultural land drained by each site increases with distance downstream. Variations in solute concentrations at the three subcatchments and within Shaver's Creek indicate that land use and lithology changes are playing a major role in solute flux from Shaver's Creek watershed. However, controls on surface water chemistry may vary temporally. We performed two synoptic sampling campaigns in Shaver's Creek to create a summary of geochemical and hydrologic states in the watershed on a given day. One campaign was performed during a wet period and one during a dry period in the watershed. Watersheds were delineated for all tributaries and Shaver's Creek main steam sampling sites that were sampled during synoptic campaigns. Watershed boundaries were then used to estimate the percentage of various land use types and lithologies within each watershed. These watershed characteristics, combined with synoptic sampling data and long-term data sets have been used to attempt to understand the relationships and controls between land use, lithology, and stream chemistry throughout Shaver's Creek. Understanding these relationships will help to scale up from subcatchment scale models (both conceptual and numerical), to models of the large scale Shaver's Creek watershed.

Understanding Hydrobiogeochemical Dynamics Using an Upscaled Simple Model

Hang Wen, Li Li

Department of Civil and Environmental Engineering, Penn State University

Abstract: Complex process-based models have been developed to explicitly understand the regulation of hydrological processes on solute transport and mineral dissolution / weathering. However, the application of complex process-based models is still quite limited, due to the demand on a large number of model parameters and field data, and high computational and labor cost. In this work, we developed an upscaled simple model to answer two questions: 1) what are the key parameters / processes that capture hydrobiogeochemical dynamics at the watershed scale? 2) How much dynamics can we capture using the simple model? We focused on the discharge, the nonreactive chloride (Cl) and reactive magnesium (Mg) in the Susquehanna Shale Hills Critical Zone Observatory (CZO). Results show that the upscaled simple model captures the trends of discharge, and concentrations of Cl and Mg in stream. Sensitivity analysis reveal that the most dominant soil type plays a critical role in capturing hydrobiogeochemical dynamics. Considering that stream hydrology and chemistry data have become largely available, this simple model can be a potential tool for further exploring the general principles across different CZOs.

"If a Tree Falls…Plant Regeneration & Resource Availability in a SSHCZO Tree Tip-up Chronosequence"

Benjamin Dillner[1], Jason Kaye[2]

[1]Ecology M.S. student- Department of Ecosystem Science and Management, The Pennsylvania State University, University Park, PA, 16802
[2]Professor of Soil Biogeochemistry, Chair of Ecology Intercollege Graduate Degree Program- Department of Ecosystem Science and Management, The Pennsylvania State University, University Park, PA, 16802

Tree uprooting from wind (tip-up) is a major source of forest disturbance in the SSHCZO. Tip-ups affect the soils, vegetation dynamics and microtopography. An uprooted tree creates a pit and mound, which have very different characteristics than the surrounding forest floor. Through forest gap dynamic modeling, we know that a fallen canopy tree generally promotes growth of seedlings and saplings, filling the gap. However, we know little about the specific processes occurring on tip-up pit and mound microsites, especially on a shale bedrock site. My ongoing M.S. thesis project seeks to elucidate plant regeneration and soil resource availability trends on tree tip-ups of different age classes. Some key questions include: Do canopy tree seedlings preferentially colonize mounds? How do soil profiles develop on pits and mounds? Which resources underlie patterns of vegetation growth on the tip-ups?

Preliminary Results of the Near-surface Geophysical Characterization of Cole Farms in the Susquehanna Shale Hills Critical Zone Observatory, Pennsylvania, USA.

Gregory J. Mount[1], Jorden Hayes[2]

[1]Department of Geosciences, Indiana University of Pennsylvania, Indiana, PA 15705
[2]Department of Earth Sciences, Dickinson College, Carlisle, PA 17103

Geophysical techniques provide a relatively rapid and spatially extensive means to indirectly elucidate subsurface critical zone architecture. Moreover, geophysical measurements can help extrapolate discrete measurements from direct subsurface samples and help guide future research efforts. In the spring of 2018, a joint field campaign by Indiana University of Pennsylvania, Dickinson College, Penn State University, Temple University and Rutgers University was conducted to investigate the subsurface architecture of the Cole Farms site in the Susquehanna Shale Hills Critical Zone Observatory. Students enrolled in geophysics classes at their respective institutions conducted seismic refraction and electrical resistivity surveys across two 200-meter transects. Survey locations were chosen to exploit existing infrastructure and measurements at the Cole Farms (i.e., GroundHOG and auger transects). The goals of these surveys were to (1) determine the subsurface structure (e.g., depth to bedrock) and (2) identify features that may serve as a preferential flowpaths. We present preliminary results from these surveys including seismic and resistivity tomograms. Our initial results constrain depth to bedrock across the survey transects and highlight architectural features across the valley. These results provide another endmember for comparison of geophysical structure between the three bedrock lithologies (i.e., shale, meta-sandstone, and limestone) of the SSHCZO. The integrated geophysical approach presented here further supports findings of other geophysical research within the CZO that demonstrates the ability to quickly and efficiently develop critical zone structure models that can reveal the linkage between potential surface and subsurface controls on landscape evolution.

Identifying the critical measurements in representing the hydrologic response at the forest catchment using model-data synthesis

Dacheng Xiao[1], Yuning Shi[2], Li Li[1]

Intensive observations are time-, money-, and labor- expensive, making it impossible to measure everything everywhere. This work aims to answer the question: what is the critical measurement to constrain hydrological model at the watershed scale? At Shale Hills, point soil moisture and stream discharge were found to be critical. Point soil moisture however may not represent watershed scale processes well. Here the neutron thermalization was also used to represent an area-averaged soil moisture by using the Cosmic-ray Soil Moisture Observing System (COSMOS). We hypothesize that the COSMOS is a critical measurement in representing the areal integrated hydrologic response and in constraining soil parameters of the hydrologic model within an intermediate footprint. The hypothesis is tested by evaluating the ability of observation combinations in constraining the hydrologic model (Flux-PIHM). The Hornberger-Spear-Young (HSY) algorithm with the real data and the Ensemble Kalman Filter (EnKF) with the synthetic experiments were utilized respectively

Comparing the observation of Frequency Domain Reflectometry (FDR) and COSMOS at Garner Run, we found the COSMOS has smaller fluctuation and longer duration time after rainfall events compared to FDR, showing a "buffer" effect by the areal average of soil moisture. In the winter, the COSMOS is higher than FDR. This is attributed to different soil moisture pools measured by the two methods: FDR mostly measures the liquid phase water in soil, whereas the COSMOS measures the total water content including the icy soil moisture. Based on the HSY algorithm with real data at Garner Run, the combination of discharge and FDR provides the best constraints when both soil matrix and macropore properties were perturbed. From the result of Observation System Simulation Experiments (OSSEs) using the EnKF, we found that only using the COSMOS, FDR or discharge is not enough for constraining each of the sensitive parameters when they are dependent. Compared to point measurement (FDR), the averaged soil moisture is more sensitive to the water persistence and water storage of the soil matrix. Our understanding of the critical measurements in representing hydrologic response at an intermediate-scale watershed will help upscale from small catchments to the larger Shavers Creek watershed.

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Heave and throw: Aspect dependent processes drive geomorphological asymmetry at Shale Hills

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One of the characteristic geomorphologic features of the Shale Hills watershed (SSHO) is the pronounced asymmetry in hillslope gradient between north- and south-facing slopes. At SSHO, north-facing hillslopes are steeper than their south-facing counterparts by 5-10 degrees. Similarly, soil thicknesses are consistently greater on north-facing slopes than on south-facing slopes. Despite these observed asymmetries, soil fluxes measured using meteoric ^{10}Be along north- and south-facing slopes are equal and on the order of 10-30 cm^2y^{-1} from ridge top to toe slope. Placed in the context of common transport laws, this observation implies that soil transport efficiencies are twice as high on south-facing slopes than on north-facing slopes. This then begs the question, what processes are responsible for the development of the observed asymmetries in gradient and efficiency and set modern measured soil fluxes? Two hypotheses have emerged to explain these observations: 1) frost action is twice as efficient at moving material off the south-facing slope due to more frequent freeze thaw cycles, 2) tree throw activity is greater on south-facing slopes, contributing to higher soil fluxes. A combination of observational data and modeling experiments suggest that while tree throw contributes to greater soil fluxes over recent decades than frost heave (median of 75 cm^3y^{-1} vs 35 cm^3y^{-1}, respectively), hillslope gradient is more sensitive to variations in transport efficiency with respect to frost heave. Thus, we contend that aspect-related variations in frost action during previous periglacial conditions (through numerous glacial-interglacial cycles) have conspired to control watershed asymmetry over geologic time, while the Holocene transition to temperate climate may have shifted the control of downslope soil transport to tree throw.

Stratigraphic control of landscape response to base-level fall, Young Womans Creek, Pennsylvania, USA

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Landscapes are thought to respond to changes in relative base level through the upstream propagation of a boundary that delineates relict from adjusting topography. However, spatially-variable rock strength can influence the topographic expression of such transient landscapes, especially in layered rocks, where strength variations can mask topographic signals expected due to changes in climate or tectonics. Here, we analyze the landscape response to base-level fall in Young Womans Creek, a 220 km^2 catchment on the Appalachian Plateau, USA underlain by gently folded Paleozoic sedimentary rocks. We measured *in situ* ^{10}Be concentrations in stream sands from 17 nested watersheds, and used a spatially-distributed model of sediment and ^{10}Be production to constrain a threefold increase in the rate of base-level fall propagating upstream from the catchment outlet. Using lidar topography and a nearby detailed stratigraphic section, we map the extent of continuous, blocky, resistant sandstone strata that act as a caprock overlying more easily erodible sandstones and siltstones. The caprock influences landscape response in two ways. First, it serves as a boundary between slowly eroding (11.5 m Myr^{-1}), low-sloping (3-5°) areas of relict topography and lower, steeper portions of the landscape adjusting to base-level fall. Second, hillslopes supported by the overlying caprock are armored with coarse sediment and are significantly steeper (20-30°) than hillslopes where the caprock has been eroded (10°), despite having similar erosion rates (36 m Myr^{-1}) and bedrock substrate. Our results illustrate how gently dipping, layered rocks engender complicated relationships between lithology, topography and erosion rate, highlighting the importance of understanding how rock material properties influence surface processes and landscape evolution.

Investigating climate change versus land use controls on hillslope erosion and valley sedimentation at the Cole Farm study watershed, central Pennsylvania

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Over the past several hundred years, agriculture has significantly changed both the magnitude and pattern of sediment transport on a global scale. In order to make informed management decisions, it is necessary understand how landscapes respond to anthropogenic perturbations across geologic and topographic settings. In the Atlantic Piedmont, accumulations of sediment trapped behind colonial mill dams document impact of widespread land use change. However, an anthropogenic signature of valley floor sedimentation is less obvious in upland landscapes within the nearby Valley and Ridge Province, where Quaternary climate fluctuations have driven valley sedimentation via periglacial hillslope processes.

Here, we focus on the 0.66 km^2 Cole Farm study watershed, a farmed calcareous shale and limestone catchment within the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO). We aim to characterize the spatial patterns in soil thickness on hillslopes, and the geometry of a >4 m-thick colluvial valley fill. To quantify spatial patterns in decadal soil transport and erosion, we are currently sampling two soil pit catenas for ^{137}Cs. We hope to constrain longer-term sedimentation history in the valley fill through radiocarbon dating of fossil charcoal, which we expect to be present based on our observations of charcoal in toe-slope soil pits. Together, the spatial patterns of soil thickness, topography, and the timing of erosion and sedimentation will help constrain the relative influence of climate versus land use controls on hillslope erosion and valley sedimentation.

Electrical Resistivity and Seismic Models for the Shale Hills CZO: Imaging the Interflow layer

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A number of electrical resistivity and seismic refraction profiles have been collected covering the ridgetops, slopes, swales and valley bottom at the Shale Hills CZO. In this poster, models for each profile will be displayed. Both the resistivity and seismic models support the conceptual hydrologic model from Sullivan et al. (2016) showing an interflow layer sitting on top of the saprock layer.