Preview of Award 1331726 - annual Project Report

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Using the Susquehanna - Shale Hills CZO to Project from the Geological Past to the Anthropocene Future
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Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)
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Accomplishments

* What are the major goals of the project?

Overall Project: We are learning to earthcast the CZ (develop quantitative models for earth surface evolution). We focus on a 165 km2 watershed in central PA and have developed an observational model to measure important aspects of the CZ in this large watershed. Over short timescales and large spatial extents, we are developing an atmosphere-land surface model that couples meteorological and ecological processes with hydrological and biogeochemical processes in regolith using information about i) depth to bedrock; ii) permeability; iii) water uptake by roots; iv) distribution of fractures and macropores. Over long timescales and smaller spatial extents, we are developing models that predict these regolith characteristics. The models that treat these various processes are built on the Penn State Integrated Hydrologic Model (PIHM). With different modules in PIHM we plan to model changes in water, energy, sediment, and solute (WESS) fluxes at various timescales. For the sedimentary rocks underlying our CZO, we use these models to explore how the geological past has impacted the structure of regolith, and, in turn, how this structure contributes toward controlling today's fluxes.

While working on this big picture effort, we have structured our group into 9 teams, identified by 9 driving hypotheses, as described below.

H1 Team Goal: The H1 team is testing the following hypothesis while measuring fracture distributions, using measurements of cosmogenics to assess erosion rates; using boreholes, field observations, and geophysics to predict the structure of porosity and permeability in Shavers Creek watershed and surrounding relevant sites: 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.*** *(Kirby, Bierman, DiBiase, West, Denn, Brantley, Lin)* During this year, Joanmarie Del Vecchio (MS candidate, Penn State) has joined the team, working at the sandstone catchment with Roman DiBiase to characterize the influence of Pleistocene periglacial processes on landscape form, colluvial stratigraphy, and modern hillslope hydrology and surface processes.

H2 Team Goal: This team is testing the following hypothesis while developing as complete a dataset as possible that allows understanding of the distribution of soil gases, soil moisture, and organic acids and their effects on weathering of regolith in the Shavers Creek watershed: H2. ***The distribution of weathering reactions across a landscape can be described as a function of biotic and abiotic production and consumption of acids (CO_2, DOC) and O_2.*** *(Kaye, Brantley, Eissenstat, Li)*

H3 Team Goal: Team H3 is testing the following hypothesis while developing as complete a dataset as possible that allows understanding of the distribution of tree roots and their effects on water cycling, weathering, fungal distribution, macropores, erosion, and tree throw in the Shavers Creek watershed: 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 Team Goal: This team is testing the following hypothesis while developing as complete a dataset as possible that allows understanding of the distribution of regolith and macropores in regolith and their controls on fluid flow among the lithologies within the Shavers Creek watershed. 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 Team Goal: Team H5 is testing the following hypothesis while developing as complete a dataset as possible that allows understanding of the controls on regolith chemistry and mineralogy using a reactive transport model developed for simulation of regolith formation: 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, Russo)*

H6 Team Goal: Team H6 is testing the following hypothesis while developing as complete a dataset as possible that allows understanding of the controls on solute concentrations in stream waters of subcatchments within the Shavers Creek watershed, using a reactive transport modelling approach: 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, Duffy)*

H7 Team Goal: This team is testing the following hypothesis while developing as complete a dataset as possible that allows understanding of the fluxes of carbon and water in the Shavers Creek watershed using PIHM modelling: 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 Team Goal: The H8 team is testing the following hypothesis while developing as complete a dataset as possible that allows multi-scale modelling to project physical processes from Shale Hills to Shavers Creek: H8. ***Co-located, intensive, relocatable measurements of soil moisture, tree sap flux, sapwood area, LAI, ground water depth, temperature, ^{18}O 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 Young Woman's Creek and Snake Creek watersheds.*** *(Shi, Duffy, Davis, Eissenstat, Lin, Duffy)* Chris Duffy has indicated he would like to have minimal involvement with the CZO other than with respect to PIHM modelling. Instead, Yuning Shi, who has been involved in the CZO since its inception and now works part time on the project, is leading the H8 team in collaboration with Li Li.

H9 Team Goal: The H9 team is spearheading measurements to understand weathering processes in the target catchments and using models to earthcast weathering and other CZ processes into the future while testing the following: H9. ***Increasing atmospheric CO_2 in the future will cause higher temperatures and faster weathering of clays in the catchment, increasing streamwater solute loads.*** *(Brantley, Godderis, Li, Duffy, Davis, Shi)* Pam Sullivan was a

postdoctoral student working on this project and she is now an assistant professor at University of Kansas where she is writing up two papers on CZO research. Two seed grants are providing data for this team effort. A USGS Seed Grant funded Carleton Bern who is testing a protocol for extracting colloidal material from SSHCZO soils and determining the geochemical composition of colloids. He is working with the Penn State team to estimate losses of colloidal material from SSHCZO soils over the time scale of soil development via the dual-phase mass balance model. The Kent State Seed Grant was used by E. Herndon at Kent State to evaluate the spatial distribution of dissolved and colloidal elements in soils, groundwater, and surface water in the SSHCZO catchment.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities:

Overall Project: One major accomplishment of the overall project this past year was the publication of a major paper in Earth Surface Dynamics describing the design of our CZO. This paper pulled together our initial observations of the Garner Run subcatchment and helped our team articulate how the overall project works together to answer questions to integrate geochemical, geobiological, ecological, meteorological, hydrological, geophysical, and geomorphological observations. We have begun to understand the geomorphology and ecology of the new sandstone catchment (Garner Run) and we now have a conceptual model for the catchment. We have begun to compare Garner Run to Shale Hills, necessary for our understanding of the entire Shavers creek watershed. In addition, we have advanced significantly in developing new modules for use with PIHM to model landscape evolution and regolith development. Finally, two papers were submitted that integrate our understanding of hydrology and geochemistry and geomorphology: [1] Brantley SL, Lebedeva M, Balashov VN, Singha K, Sullivan PL, Stinchcomb G. Relating chemical reaction fronts to hillslope drainage. Geomorphology 2016; in review; [2] Sullivan PL, Hynek S, Gu X, Singha K, White TS, West N, Kim H, Clarke B, Kirby E, Duffy C, Brantley SL. Oxidative dissolution under the channel leads geomorphological evolution at the Shale Hills catchment. Am. J. Sci., in review.

These efforts are leading to some emerging models of watershed development. Specifically, our conceptual model of nested reaction fronts is proving to be a helpful approach toward understand CZ evolution (Brantley et al., 2013; Earth Surface Processes and Landforms); our observation that both interflow and groundwater flow occur in upland catchments seems to be a robust observation that is important in both Shale Hills and Garner Run and elsewhere; and we have discovered that hydrology in our catchment is defined by a surficial fractured layer that was probably formed during times when the catchment experienced periglacial conditions (West et al., in prep.).

In addition, the following accomplishments were reported by individual teams.

H1. The H1 team performed fieldwork in the sandstone subcatchment (Garner Run) to map soil properties and characterize the grain size distributions of hillslope and channel sediment, in order to assess aspect controls on Pleistocene periglacial processes and their influence on modern surface processes.

H2. The H2 team 1) published one paper on soil pCO2 (Hasenmueller et al. 2015) 2) contributed to team paper on sampling the critical zone (Brantley et al. 2015), 3) tested, installed, and sampled ore fluid monitoring equipment in one shale and one sandstone catchment, 4) synthesized results and completed one paper from a study of roots within rock fractures, 5) sampled foliar chemistry of trees at 5 shale and 5 sandstone catchments.

H3. The H3 team 1) began analysis of the vertical root distribution of trees as affected by shale and sandstone 2) published 2 papers, one on effective rooting depth for water uptake in trees and the other on water residence times in vegetation and (3) contributed to the broader project goals on tracking leaf phenology, litter fall, radial tree growth, and soil moisture in the Shale Hills and Garner Run catchments. This team also contributed to understanding root length density and soil respiration as influenced by topography at the Shale Hills catchment.

H4. The H4 team published 2 papers related to the Shale Hills catchment.

H5. The H5 team 1) developed the code RT-FLUX-PIHM, and 2) finished two manuscripts (one manuscript on the code development of RT-FLUX-PIHM and the other on the application of RT-Flux-PIHM to understand the concentration discharge relationship of Cl and Mg at the Shale Hills CZO). The two manuscripts have been accepted for publication in Water Resources Research.

H6. The H6 team 1) continued stream chemistry data collection at Garner Run and along the main branch of Shavers Creek, 2) installed a set of nested wells at Garner Run, and 3) conducted another tracer injection test at Garner Run, and 4) installed a new weir at Shale Hills.

H7. The H7 team 1) helped to maintain the eddy covariance flux data stream at Shale Hills, 2) assisted with plans to add a second eddy covariance flux measurement at the Garner Run watershed, 3) completed the assembly of a coupled Flux-PIHM-BiomeBGC watershed carbon-water modeling system, 4) completed a model-data assessment of the environmental factors controlling topographic variations in carbon stocks at Shale Hills, 5) began work towards a multivariate carbon-water data assimilation system that can be applied to the coupled Flux-PIHM-BiomeBGC modeling system.

H8. The H8 team 1) Installed and calibrated the COSMOS soil moisture sensor at the Garner Run watershed; 2) Performed a series of synthetic data experiments using a hydrologic land surface modeling and data assimilation system to test the effectiveness of using COSMOS areal soil moisture measurement for hydrologic and land surface state and parameter estimation at the Shale Hills watershed. Part of the results has been

presented in the 2015 AGU Fall meeting; 3) Implemented the Penn State Integrated Hydrologic Model with a land surface flux module (Flux-PIHM) at the Garner Run watershed using topography, soil map, land cover, and meteorological forcing data obtained from national database.

H9. The H9 team spearheaded a publication in Earth Surface Dynamics describing how we have designed the SSHCZO. The team also collected data on weathering characteristics in the new Garner Run subcatchment, in a program that incorporated Geosc 413W students. Pam Sullivan, former postdoc and now a prof at Univ of Kansas, is writing up a paper about the use of WITCH as a model to describe porewater chemistry due to weathering in the catchment. That paper should be submitted this coming year. This team also submitted a paper to Geomorphology describing how interflow and ground water flow patterns may be delineated in upland catchments as reaction fronts.

Specific Objectives:

The specific objectives of work accomplished this year by the hypothesis subteams are described below.

H1. In fall 2015, the team analyzed the Harrys Valley drill core from Garner Run. This core revealed at least 10 m of colluvial fill in the headwaters of Garner Run, from which we sampled 3 sandstone clasts at different depths for cosmogenic 10Be/26Al burial dating analysis.

H2. The main objectives were to 1) finalize installation and repeatedly sample a suite of pore chemistry monitoring devices along catenas, in one shale and one sandstone catchment, 2) expand sampling to other shale and sandstone catchments, 3) conduct mineralogical, elemental, and SEM analyses of samples from the root-rock interface in shale.

H3. Roots were mapped in Shale Hills and Garner Run catchments as well as in sandstone and shale sites in the Tuscarora State Forest in south central Pennsylvania.

H4. The H4 team continued soil moisture, infiltrometer, EMI and GPR data collections at the Shale Hills and the Garner Run catchments.

H5. The H5 team is now able to use their new code to simulate hydrological and geochemical processes at the watershed scale.

H6. This team has continued hydrologic monitoring at the new sandstone catchment, and is combining results from the distributed temperature sensing (DTS) experiment, streamwater, groundwater, spring water, and soil pore water to describe solute dynamics within the watershed.

H7. The team focused on testing the response of the carbon stocks and fluxes in the Biome-BGC ecosystem biogeochemistry model to environmental forcing (soil

temperature, soil moisture, light, soil hydraulic properties, nutrient availability) within the Shale Hills watershed.

H8. The team evaluated Flux-PIHM predictions of discharge and watershed average soil moisture at Garner Run using observed discharge and COSMOS soil moisture data to tested the transferability of Flux-PIHM calibration coefficients obtained from the Shale Hills at Garner Run, and produced the discharge reanalysis for 2008 to 2015 in Shale Hills using the Flux-PIHM model with North American Land Data Assimilation System phase-2 (NLDAS-2) forcing data.

H9. This team promoted a paper that has been published that described the overarching design of measurement for the CZO, and a paper that is submitted that describes the relationship between geomorphology, hydrology, and geochemistry in upland catchments. In the work promoted by the USGS Seed Grant, colloidal material was extracted from SSH soils and modeling of colloidal losses from soils was completed. In the work supported by the Kent State Seed Grant, protocols were refined to extract dissolved and colloidal material from soils, and geochemical analysis on the extracts was completed. Initial characterization of organic matter using ultraviolet-visible spectroscopy was completed for surface water, groundwater, and soil extracts.

Significant Results:

H1. The first cosmogenic data has been collected for the Garner Run subcatchment. The soils appear to be much older than expected, pre-dating the Last Glacial Maximum.

H2. Installation of porewater collectors and sensors in the catena in Garner Run was completed and we are accumulating data on porewater chemistry observation sites along catenas in one shale and one sandstone catchment. We received permits and began sampling new sites (4 on shale and 4 on sandstone) for indicators of nutrient limitation to plants and soil microorganisms.

H3. Root distributions indicated trees on sandstone are somewhat deeper rooted than those on shale. Factors positively correlated with root length density in the Shale Hills catchment included ammonium concentration and soil organic matter content. However, in general, root length density at 0-20 cm did not show strong spatial structure in relation to topography at Shale Hills. There was a general pattern of deeper rooting patterns in swales and valley floor than at ridgetop and planar midslope.

H4. The H4 team has developed a new method to detect preferential flow based on water mass balance approach using real-time soil moisture data. We also published a paper that demonstrated that combining soil and terrain attributes could help improve the stratification of a catchment into similar soil hydrologic functional units, which is valuable to distributed hydrology modeling and other applications.

H5. The team has developed the code RT-Flux-PIHM, the first of its kind to simulate hydrogeochemistry at the watershed scale. Two manuscripts are in the second round of review with WRR. A third manuscript is in development.

H6. The apparent controls on solute chemistry in the sandstone catchment are different than in the previously studied shale catchment. Preliminary results were presented at a cross-CZO C-Q workshop at the University of New Hampshire, and a manuscript is being submitted as part of a *Water Resources Research* special issue this spring.

H7. The nitrogen cycle is hypothesized to be the dominant environmental control on spatial structure in carbon stocks in the Shale Hills watershed. The spatial patterns in the nitrogen cycle are created (in the modeling system) by watershed topography and soil conditions (depth, hydraulic properties). The modeled structure in carbon stocks agrees fairly closely with observations.

H8. 1) While Flux-PIHM predictions of discharge at Garner Run have reasonable agreement with the observations, the surface soil moisture predictions show a substantial high bias, which suggests the relatively high rock volume of Garner Run must be taken into account; 2) Preliminary data assimilation results suggest that shallow soil moisture measurements obtained from COSMOS are not as effective in constraining model parameters as column integrated soil moisture measurements.

H9. Both interflow and groundwater flow are typically important in upland catchments and may be recorded in the subsurface as reaction fronts; alternately the presence of reaction fronts may cause permeability differences which explain the vertical and alteral flow patterns in the catchment. USGS Seed Grant: Substantial losses of colloidal material from SSH soils, >50 % relative to parent material mass, are indicated by the modeling. This indicates that losses of colloidal material are a significant process for soil development in this setting.

Key outcomes or Other achievements:

Three papers were submitted that integrate our understanding of hydrology and geochemistry and geomorphology: [1] [1] Brantley SL, DiBiase RA, Russo TA, Shi Y, Lin H, Davis KJ, Kaye M, Hill L, Kaye J, Eissenstat DM, Hoagland B, Dere AL, Neal AL, Brubaker KM, Arthur DK. Designing a suite of measurements to understand the critical zone. Earth Surface Dynamics 2016;4:1-25; doi:10.5194/esurf-5194-5191-2016; [2] Brantley SL, Lebedeva M, Balashov VN, Singha K, Sullivan PL, Stinchcomb G. Relating chemical reaction fronts to hillslope drainage. Geomorphology 2016; in review; [3] Sullivan PL, Hynek S, Gu X, Singha K, White TS, West N, Kim H, Clarke B, Kirby E, Duffy C, Brantley SL. Oxidative dissolution under the channel leads geomorphological evolution at the Shale Hills catchment. Am. J. Sci., in review.

We have also begun to find a site for our agricultural sub-catchment. We are working with the Penn State extension office to find a farmer willing to allow us some access to land.

Specific metrics which were promised in our Project Management Plan are summarized below along with progress:

H1 Metric: 1) Produce 2 papers describing fracture distributions in sandstone/shales in comparison to geophysical surveys (one paper in final prep.); 2) train 1 postdoc (Nikki West, starting faculty position at Central Michigan Univ this summer)

H2 Metric: 1) Produce 3 papers on O2, CO2, N dynamics (one paper published); 2) train one grad student (Lily Hill completing Masters degree)

H3 Metric: 1) Produce 3 papers on ecophysiology of deep roots in relation to topographical position and lithology, tree species, depth to bedrock, and mycorrhizas, 2) train one grad student (Ishmaiel Szink working on PhD)

H4 Metric: 1) Produce 3 papers on soil types, macropores, and GPR in Shavers creek watershed; 2) Train one grad student (new student entering in the fall)

H5 metric: 1) Develop Flux-PIHM-RT, a generic code that couples surface and subsurface hydrology with reactive transport (one paper on code development has been published); 2) Produce one paper on chemical weathering and soil generation under relatively constant hydrological conditions using 1D modeling; 3) produce one paper on the coupling among atmospheric forcing (energy, precipitation), hydrological processes, and chemical weathering using Flux-PIHM-RT (one paper in press); 4) produce one paper on how heterogeneity (macropores) influence soil and stream chemistry; 5) educate one student on Flux-PIHM-RT (Dacheng Xiao is working on PhD)

H6 Metric: 1) Produce 3 papers on solute chemistry of streams in SC (one paper published, one in final stage preparation); 2) Train one grad student (Beth Hoagland working toward PhD)

H7 Metric: 1) Produce 3 papers on using Flux-PIHM to understand C and H2O fluxes in SC; 2) Implement the mobile array concept (Tower HOG will be implemented this summer for Garner Run); 3) Train one grad student (Yuting He working toward PhD)

H8 Metrics: 1) Complete 1979-Present distributed water and energy balance for the Shaver Creek-Shale Hills site (completed); 2) Serve model results on-line in easy-to-use format for sharing among scientists; 3) Complete development for a coupled water, nutrient, sediment transport code in the PIHM framework; 4) Complete development for a coupled water, and reactive transport code in the PIHM framework (paper in press); 5) implement PIHM models for SC, YWC and Snake creek (implemented for YWC); 6) educate 1 student (Dacheng Xiao is working on PhD)

H9 Metrics: 1) Produce one paper showing PIHM-Witch modeling (paper in late stage preparation); 2) Train a postdoc in using PIHM and WITCH (Pam Sullivan was trained and is now working as a faculty member at Univ of Kansas)

* What opportunities for training and professional development has the project provided?

H1. PSU MS graduate student Joanmarie Del Vecchio (advised by R. DiBiase) was mentored in geomorphic mapping using fieldwork, GIS and lidar analysis, and in the interpretation and preparation of rock samples for cosmogenic nuclide analysis. In both summer 2015 and summer 2016, J. Del Vecchio has/will mentored an undergraduate researcher through the SSHCZO REU program. Graduate student Al Denn was mentored at Univ of Vermont by Paul Biermann.

H2. One graduate student, Lillian Hill (co-advised by J. Kaye and R. Dibiase) has been trained in datalogger programming and soil pore chemistry sampling by manual collection and automated sensors. Several other postdocs, graduate students, and undergraduates were trained to sample pore fluid chemistry.

H3. Two PhD students successfully passed their candidacy exams in Ecology (Ismaiel Szink, Warren Reed). Three students (REU, Maggie Ruppel; one RET, Siobhan Donnelly and Liza ida Brazil) were trained in root biology and developed research examining the relationships between lithology and root distribution.

H4. Two REU students and one undergraduate research assistant were trained to use infiltrometers for measuring soil water infiltration rates at the Shale Hills and Gunner Run catchments.

H5. The project has graduated a PhD student, Chen Bao, who is now working in industry. The student in the team has benefitted from monthly SSHCZO seminar and cross-disciplinary discussions.

H6. The PI (Russo) was able to attend the CZO Network strategic planning meeting in Boulder, Colorado in February 2016. An undergraduate (Lacroce) worked as a field assistant to the watershed coordinator. Two REU students hosted by Russo and Brantley in summer 2015 were trained in collecting and analyzing stream samples, and calibrating an *in situ* spectrometer (s::can) for making real-time chemistry measurements. The results were presented as posters at Penn State, and again at the AGU Fall Meeting in San Francisco. A graduate student co-advised by Russo and Brantley is completing her work on C-Q at the sandstone catchment, which will serve as one chapter of her dissertation.

H7. Doctoral student He passed her Ph.D. candidacy exam and is preparing for a dissertation proposal and comprehensive exam in the summer of 2016. Her doctoral committee includes three members of the CZO team (Davis, Eissenstat, Shi), a global climate scientist, and a watershed hydrologist.

H8. A graduate student Dacheng Xiao (co-advised by L. Li and Y. Shi) was trained to design and implement the Flux-PIHM EnKF data assimilation system. Xiao also learned how to install, operate and maintain the COSMOS instrument.

H9. The Kent State Seed Grant facilitated ongoing collaboration between early-career researchers (Herndon, Dere, Sullivan), and provided an opportunity for a student at University of Nebraska – Omaha (advised by A. Dere) to learn UV-Vis techniques. A new student, Virginia Marcon, also joined the CZO and has begun working on the Garner Run soils as part of this team. Pam Sullivan, who was a postdoc with the CZO is now working as an assistant prof at Univ of Kansas. Her work with us has resulted in 2 papers so far, with 2 more coming and has stimulated her to begin to work at a prairie site to develop it as a CZO.

* How have the results been disseminated to communities of interest?

Overall project: We published a paper in Earth Surface Dynamics describing the design of our CZO. The project team hosted the annual All Hands meeting in May. We invited Jorden Hayes (assistant professor at Dickinson College) to participate and give a talk about her work. She fully interacted with the team. The CZO also hosted Xavier Comas (Florida Atlantic Univ) and Greg Mount (Indiana Univ of Pennsylvania). The CZO also is hosting a team from Rutgers university for a Hydrogeophysics workshop June 22, 23, 24 at the CZO. This includes Kristina Keating, Lee Slater, and approximately 20 other Rutgers faculty and students, faculty from Indiana Univ of Pennsylvania (G. Mount) and from Dickinson (J. Hayes). We also ran a workshop on trees in the critical zone that included 28 participants.

H1. Preliminary geomorphic analysis of the sandstone catchment (Garner Run), and Shavers Creek as a whole, was been presented at the Fall 2015 CZO trees workshop hosted at Penn State, and the Pardee Keynote Symposium on Appalachian geomorphology at the Fall 2015 GSA Annual Meeting.

H2. The H2 team leader (J. Kaye) has been participating in the Organic Chemistry Cross CZO Working group to disseminate and learn CZO approaches. Team members gave talks on campus and at other venues. Two publications and several conference talks disseminated results to the scientific community.

H3. Work at the Shale Hills CZO was disseminated at a DOE PI meeting associated with a DOE grant at the site. Work presented included how soil respiration and root length density are affected by topography and in the coupling of Biome BGC with PHIM. Work was also disseminated in meetings with a researcher (Robert Long) of the USDA Forest Service and with forest managers of the Tuscarora State Forest (Steven Wacker).

H4. Work at the Shale Hills CZO was disseminated through 2 publications and 2 presentations.

H5. The team has been actively advocating the use of models to understand complex systems and general principles across CZOs. Specifically, i) The team, together with Russo and Hoagland (H6 team), is actively involved in a Cross-CZO C-Q relationship workshop; ii) Li has developed an online reactive transport modeling (RTM) course that can potentially be used to teach

graduate students across CZOs. The online course was taught the first time in Spring 2016. With further refinement, Li plans to make all course materials public so that anyone who is interested in using RTM can access it without the limit of time and space. To the best of the team's knowledge, this is the first RTM online course, which has the potential for teaching the next generation of scientist RTM tools for CZO work; iii) Li also led a forward-looking manuscript "Expanding the role of reactive transport models in Critical Zone Processes". This manuscript comes out of an RTM workshop (together with Kate Maher and Alexis Navarre-Sitchler) in 2014. It is current in the second round of review with Earth Science Reviews. A white paper has been submitted to NSF GG program in august 2015; iv) Li organized an AGU session "Modeling the Critical Zone: Integrating processes and data across disciplines and across scales" together with Pam Sullivan (SSHCZO), Thomas Meixner (Catalina-Jemez CZO), and Hari Rajaram (Boulder CZO) in December 2015; v) Li will also organized a session on "Novel Developments and Data-Integration in Complex Biogeochemical and Hydrological Process Models" with Christof Meile (U. Georgia) in the biennial Computational Methods in Water Resources (CMWR) conference in June 2016 in Toronto, Canada.

H6. Team members gave talks on campus and at the cross-CZO C-Q workshop at the University of New Hampshire. One REU from summer 2015 presented her research at the AGU Fall Meeting.

H7. The team has presented research results at the CZO All-Hands meeting and as contributions to the team colloquium series. A publication for peer-reviewed literature has been drafted and will be submitted shortly.

H8. Team members gave talks on campus and at other venues (e.g. 2015 AGU Fall Meeting).

H9. Team members gave talks on campus and at other venues (e.g. 2015 AGU Fall Meeting). Kent State Seed Grant: results were presented at the SSHCZO All-Hands meeting in May 2016 and are being developed into a preliminary manuscript.

* What do you plan to do during the next reporting period to accomplish the goals?

H1.Al Denn and Paul Bierman will be submitting a paper describing cosmogenic isotopes at Garner Run and the Hickory Boulder Field in Pennsylvania. Roman Dibiase and Joanmarie Del Vecchio will be preparing a paper on the geomorphology of Garner Run.

H2. Having established pore chemistry monitoring catenas, the H2 team will emphasize sampling those sites to build a two-year record of differences in pore chemistry between the shale and sandstone catchments. We will continue to analyze nutrient availability at the additional replicated shale and sandstone sites. This team will also make progress in concert with team H3 on publishing one paper describing roots within rock fractures.

H3. The team will contribute to one paper describing roots within rock fractures. The team will also begin assessing tree species composition of roots in relation to soil depth along the catenas in sandstone and shale and continue to analyze the data on root respiration and root length density in relation to topography. They will help the broader research efforts by continuing to monitor soil moisture, litter fall, LAI and tree diameter growth. New work is also planned to follow root dynamics using minirhizotrons and sap flux. There will also plans to examine the influence of lithology, tree species and soil depth on root exudation.

H4. More soil moisture and GPR/EMI data are to be collected in the field and more papers are planned for publication in the next reporting period.

H5. The team is using RT-FLUX-PIHM to explore the role of key parameters, including watershed storage capacity, soil properties, and climate conditions in controlling the C-Q relationship of the non-reactive tracer Cl. The team is also moving forward in the development of Regolith-Flux-PIHM.

H6. This team will publish a paper comparing C-Q behavior at the sandstone and shale catchments. The team will install additional observation wells along the catena and stream at Garner Run and continue to collect stream concentration-discharge data. A new student beginning in Fall 2016 will assist with instrumentation and monitoring at the new agricultural catchment, and will develop field and modeling methods for characterizing C-Q behavior in the greater Shaver's Creek watershed.

H7. Research work will be expanded to include further model-data comparison (nitrogen cycle, soil respiration, carbon stock uncertainty assessment) and, if warranted, additional field data collection to refine our understanding of the carbon-water-nutrient interactions within the Shale Hills watershed. We will also work towards a multivariate data assimilation system capable of synthesizing watershed observations with our numerical modeling system, ultimately working towards a system that could be applied to multiple watersheds including Garner Run and other CZO sites. This would result in an improved understanding of the impact of topography and soil properties on carbon-water-nutrient cycling across the earth's landscape, especially in low-order watersheds.

H8. The water, energy, sediment, and solute fluxes at Garner Run will be reproduced using the suite of PIHM models. Data assimilation experiments will be performed to optimize model performances at Garner Run.

H9. Pam Sullivan will be finishing her manuscript on modelling porewater chemistry in Shale Hills using WITCH. For the USGS Seed Grant work, a manuscript will be submitted to disseminate the results. For the Kent State Seed Grant, Herndon will continue to analyze results

for development into a manuscript and complete additional extractions and characterization as needed.

Supporting Files

	Filename	Description	Uploaded By	Uploaded On
(Download)	Figure1.pdf	Figure 1 shows a figure from Brantley et al. (2016), Earth Surface Dynamics, that explains our approach toward modelling the Critical Zone. Different modules are used with PIHM, the Penn State Integrated Hydrologic Model to simulate processes over differe	Susan Brantley	06/20/2016
(Download)	AnnualReportFigure2.pdf	Figure 2.Critical zone science investigates the architecture, character, and dynamics of the earth surface from vegetation canopy to deep ground water at all time scales. Figure reproduced from Brantley et al. (2016), Earth Surface Dynamics.	Susan Brantley	06/20/2016
(Download)	AnnualReportFigure3.pdf	Figure 3 shows a figure from the paper that is being prepared from the SSHCZO Tree workshop held in September 2016. The paper discusses carbon, energy, and water fluxes facilitated by trees in the critical zone.	Susan Brantley	06/20/2016
(Download)	AnnualReports_Figure 4_SSHCZOMeasurementsPIs-DKA20160614.pdf	Figure 4 shows a summary of the measurements being made at Susquehanna Shale Hills Critical Zone Observatory and who is	Susan Brantley	06/20/2016

Filename	Description	Uploaded By	Uploaded On
	making each measurement.		

Products

Books

Book Chapters

- White T., Brantley S., Banwart S., Chorover J., Dietrich W., Derry L., Lohse K., Anderson S., Aufdendkampe A., Bales R., Kumar P., Richter D., McDowell B. (2015). Chapter 2 – The Role of Critical Zone Observatories in Critical Zone Science.. *Principles and Dynamics of the Critical Zone 1st.* Giardino & Houser. Elsevier. 15. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/B978-0-444-63369-9.00002-1.

Inventions

Journals or Juried Conference Papers

- Ashlee L. Dere, Timothy S. White, Richard April, and Susan L. Brantley (2016). Mineralogical Transformations and Soil Development in Shale across a Latitudinal Climosequence. *Soil Science Society of America*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.2136/sssaj2015.05.0202
- Bao, Chen, Li Li, Pamela L. Sullivan, Susan Brantley, Yuning Shi, Chris Duffy (2016). Understanding Hydrogeochemical Processes at the Watershed Scale: 2 Concentration Discharge Relationship of Chloride and Magnesium at the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO).. *Water Resources Research*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Bao, Chen, Yuning Shi, Li Li, Christopher Duffy (2016). Understanding Hydrogeochemical Processes at the Watershed Scale: 1 Development of RT-Flux-PIHM.. *Water Resources Research*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Brantley Susan L., Marina Lebedeva, Victor Balashov, Kamini Singha, Pamela L. Sullivan, Gary Stinchcomb (2016). Relating chemical reaction fronts to hillslope drainage. *Geomorphology Special Issue*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Brantley, S. L., DiBiase, R. A., Russo, T. A., Shi, Y., Lin, H., Davis, K. J., Kaye, M., Hill, L., Kaye, J., Eissenstat, D. M., Hoagland, B., Dere, A. L., Neal, A. L., Brubaker, K. M., and Arthur, D. K (2016). Designing a suite of measurements to understand the

critical zone.. *Earth Surface Dynamics*. 4 211. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/esurf-4-211-2016

- Brantley, S. L., W. E. Dietrich, and S. Banwart (2015). An international initiative for science in the critical zone.. *EOS*. 96 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = No ; DOI: 10.1029/2015EO031111
- Carter, M., B.J. Gaudet, D.R. Stauffer, T.S. White, and S.L. Brantley (2015). Using soil records with atmospheric dispersion modeling to investigate the effects of clean air regulations on 60 years of manganese deposition in Marietta, Ohio (USA).. *Science of the Total Environment*. 515-516 49. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.scitotenv.2015.01.015
- Gaines KP, FC Meinzer, CJ Duffy, EM Thomas, DM Eissenstat (2016). Rapid tree water transport and residence times in a Pennsylvania catchment.. *Ecohydrology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/eco.1747
- Gaines KP, JW Stanley, FC Meinzer, KA McCulloh, DR Woodruff, W Chen, TS Adams, H Lin and DM Eissenstat (2015). Reliance on shallow soil water in a mixed-hardwood forest in central Pennsylvania. *Tree Physiology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1093/treephys/tpv113
- Harpold, A. A., Marshall, J. A., Lyon, S. W., Barnhart, T. B., Fisher, B. A., Donovan, M., Brubaker, K. M., Crosby, C. J., Glenn, N. F., Glennie, C. L., Kirchner, P. B., Lam, N., Mankoff, K. D., McCreight, J. L., Molotch, N. P., Musselman, K. N., Pelletier, J., Russo, T., Sangireddy, H., Sjöberg, Y., Swetnam, T., and West, N. (2015). Laser vision: lidar as a transformative tool to advance critical zone science.. *Hydrology and Earth System Sciences*. 19 (6), 2881. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/hess-19-2881-2015
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- Herndon E. M., A. L. Dere, P. L. Sullivan, D. Norris, B. Reynolds, and S. L. Brantley (2015). Biotic controls on solute distribution and transport in headwater catchments.. *Hydrology and Earth System Sciences Discussion.*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/hessd-12-213-2015
- Herndon Elizabeth, Lixin Jin, Danielle Andrews, David Eissenstat, Susan Brantley (2015). Importance of vegetation for manganese cycling in temperate forested watersheds. *Global Biogeochemical Cycles*. 29 (2), 160. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2014GB004858
- Herndon EM, Dere AL, Sullivan PL, Norris D, Reynolds B, and Brantley SL (2015). Landscape heterogeneity drives contrasting concentration-discharge relationships in shale headwater catchments.. *Hydrology and Earth Systems Science*. 19 3333. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/hess-19-3333-2015

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- Meek, Katherine, Louis Derry, Lawrence Cathles, and Jed Sparks (2015). 87Sr/86Sr, Ca/Sr, and Ge/Si ratios as tracers of solute sources and biogeochemical cycling at a temperate forested shale catchment, Huntingdon, Pennsylvania, USA.. *Chemical Geology*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Pollak J., Brantley S., Williams J., Dykhoff S., and Brazil L. (2015). Making Knowledge from Numbers: The Shale Network as an Honest Broker for Evaluating and Educating about the Impacts of Hydraulic Fracturing in the Marcellus Shale Region.. *ED43D-0885 Tools, Resources, and Lessons Learned for Scientists and Engineers Engaging in Education and Public Outreach II Posters, presented at 2015 Fall Meeting, AGU, San Francisco, CA, 14-18 Dec...* . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Shi, Y., B. C. Baldwin, K. J. Davis, X. Yu, C. J. Duffy, and H. Lin (2015). Simulating high resolution soil moisture patterns in the Shale Hills watershed using a land surface hydrologic model.. *Hydrological Processes*. 29 (21), 4624. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/hyp.10593
- Shi, Y., K. J. Davis, F. Zhang and C. J. Duffy, and X. Yu (2015). Parameter estimation of a physically-based land surface hydrologic model using an ensemble Kalman filter: A multivariate real-data experiment. *Advances in Water Resources*. 83 421. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.advwatres.2015.06.009
- Smith, L., Eissenstat, D., and Kaye, M. (2015). Variability in aboveground carbon dynamics driven by slope aspect and curvature in an eastern deciduous forest, USA.. *Forest Ecology and Management*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes

- Sullivan P., Ma L., West N., Jin L., Karwan D., Noireaux J., Steinhoefel G., Gaines K., Eissenstat D., Gaillardet J., Derry L., Meek K., Hynek S., and Brantley S.L. (2016). CZ-tope at Susquehanna Shale Hills CZO: Testing multiple isotope proxies to elucidate Critical Zone processes across timescales in a temperate forested landscape.. *Chemical Geology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.chemgeo.2016.05.012
- Sullivan, P.L.; Hynek, S.; Gu, X.; Singha, K.; White, T.S.; West, N.; Kim, H.; Clarke, B.; Kirby, E.; Duffy, C.; Brantley, S.L. (2015). Oxidative Dissolution under the Channel Leads Geomorphological Evolution at the Shale Hills Catchment. *American Journal of Science*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes
- Yu Xuan; Christopher J. Duffy; Alain N. Rousseau; Gopal Bhatt; Álvaro Pardo Álvarez; Dominique Charron (2016). Open science in practice: learning integrated modeling of coupled surface-subsurface flow processes from scratch.. *Earth and Space Science*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2015EA000155
- Yu, H., P. Yang, and H.S. Lin. (2015). Spatiotemporal patterns of soil matric potential in the Shale Hills Critical Zone Observatory.. *Vadose Zone J.*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.2136/vzj2014.11.0167
- Yu, Xuan, Duffy, Christopher, Gil, Yolanda, Leonard, Lorne, Bhatt, Gopal and Thomas, Evan (2015). Cyber-Innovated Watershed Research at the Shale Hills Critical Zone Observatory. *IEEE SYSTEMS JOURNAL*. . Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1109/JSYST.2015.2484219
- Yu, Xuan, Gopal Bhatt, Christopher Duffy, Denice Wardrop, Raymond Najjar, Andrew Ross, Matthew Rydzik (2015). A coupled surface-subsurface modeling framework to assess the impact of climate change on freshwater wetlands: a case study of seven watersheds of the Susquehanna River Basin.. *Climate Research*. 66 211. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3354/cr01348
- Yu, Xuan; Christopher Duffy; Yu Zhang; Gopal Bhatt; Yuning Shi (2016). Virtual experiments guide calibration strategies for a real-world watershed application of coupled surface-subsurface modeling .. *Journal of Hydrologic Engineering*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Zhang, Y., R. Slingerland, and C. Duffy (2016). Fully-Coupled Hydrologic Processes for Modeling Landscape Evolution. *Environmental Modelling & Software*. 82 89. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.envsoft.2016.04.014

Licenses

Other Conference Presentations / Papers

- Xiao, Dacheng, Yuning Shi and Li Li (2015). *Assimilating the Cosmic-Ray Soil Moisture Observing System Measurements for Land Surface Hydrologic Model Parameter Estimation Using the Ensemble Kalman Filter*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Gaillardet, Jerome, Johanna Noireaux , Pamela L Sullivan , Grit Steinhoefel , Pascale Louvat and Susan L Brantley (2015). *Boron isotopes at the Shale Hills Critical Zone Observatory*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Williams, J. Z., Forsythe B, Carroll M, Ruocchio E, Pickering Y, and Brantley S (2015). *Combining Hands-on Field Experience with Data-Driven Hydrology Education Tools*. Virtual Poster Session on Data-Driven Hydrology Education. CUAHSI, Medford, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Rousseau, Alain N, Alvaro Pardo Álvarez, Xuan Yu, Stephane Savary and Christopher Duffy (2015). *Comparison of Two Conceptually Different Physically-based Hydrological Models – Looking Beyond Streamflows*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Baldwin, Douglas C., Henry Lin and Erica Smithwick (2015). *Downscaling Satellite Data for Predicting Catchment-scale Root Zone Soil Moisture with Ground-based Sensors and an Ensemble Kalman Filter*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Herndon, Elizabeth (2015). *IMPORTANCE OF VEGETATION FOR MANGANESE CYCLING IN FORESTED WATERSHEDS*. 2015 GSA Annual Meeting. Baltimore, MD. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Denn A., Bierman P., and Kirby E. (2015). *INVESTIGATION OF A RELICT PERIGLACIAL FEATURE: HICKORY RUN BOULDER FIELD, HICKORY RUN STATE PARK, PENNSYLVANIA*. 2015 GSA Annual Meeting. Baltimore, MD. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Eissenstat, David M, Alexandra S. Orr, Thomas S Adams, Weile Chen and Katie Gaines (2015). *Influence of Topography on Root Processes in the Shale Hills Susquehanna Critical Zone Observatory (Invited)*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- West, N., Kirby, E., Brantley, S. (2015). *Invited: Microclimate controls on weathering and erosion in a temperate forest, 2015 Goldschmidt Conference*. 2015 Goldschmidt Conference. Prague, CZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- West, N., Kirby, E., (2015). *Invited: TOPOGRAPHIC FINGERPRINTS OF MICRO-CLIMATE AND LITHOLOGY IN THE CENTRAL APPALACHIANS*. Pardee Symposium, 2015 GSA National Meeting. Baltimore, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- West, N. (2015). *Isotopic tracers of asymmetric watershed evolution*. Geological Society of Washington, Meeting 1494. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Pollak, Jon, Sue Brantley, Jennifer Williams, Sharon Dykhoff and Liza Ida Brazil (2015). *Making Knowledge from Numbers : The Shale Network as an Honest Broker for Evaluating and Educating about the Impacts of Hydraulic Fracturing in the Marcellus Shale Region*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- West, Nicole, Eric Kirby, Andrew Nyblade and Susan Brantley (2015). *Microclimate controls on weathering: Insights into deep critical zone evolution from seismic refraction surveys in the Susquehanna Shale Hills Critical Zone Observatory*. AGU 2015 Fall

Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Li, L (2015). *PREDICTIVE UNDERSTANDING OF BIOGEOCHEMICAL REACTIONS IN HETEROGENEOUS POROUS MEDIA*. 2015 GSA Annual Meeting. Baltimore, MD. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Dere, Ashlee Laura Denton, Elizabeth Andrews and Timothy S White (2015). *Quantifying present-day and long-term shale weathering rates across a latitudinal climosequence*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Ma L., Chabaux F., West N., Kirby E., Jin L., and Brantley S.L. (2015). *REGOLITH PRODUCTION AND TRANSPORT IN THE SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY: INSIGHTS FROM U-SERIES ISOTOPES (Invited)*. Pardee Symposium, 2015 GSA Annual Meeting. Baltimore, MD. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Lin, H (2015): (2015). *SOIL ARCHITECTURE AND PREFERENTIAL FLOW ACROSS SCALES*. 2015 GSA Annual Meeting. Baltimore, MD. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- DiBiase, R.A., Del Vecchio, J., and Granke, S.B. (2015). *TOPOGRAPHIC AND COLLUVIAL SIGNATURES OF LITHOLOGY, BASE LEVEL, AND CLIMATE IN THE SHAVERS CREEK WATERSHED, PENNSYLVANIA*. Pardee Symposium, 2015 GSA National Meeting. Baltimore, MD. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Dykhoff, S., Williams, J., Brazil, L., Pollack, J., Brantley, S. (2016). *TeenShale Network: Combining Hands-on Field Experience with Data-Driven Hydrology Education Tools*. 2016 CUAHSI Biennial Symposium. Shepherdstown, WV. Status = SUBMITTED; Acknowledgement of Federal Support = Yes
- Weitzman, Julie N. and Jason P Kaye (2015). *The Paradox of High Subsurface [N2O] and Low Surface Flux of N2O to the Atmosphere*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Sullivan P.L., Hynek, S., Gu, X., Singha, K., White, T., West, N., Kim, H., Clarke, B., Kirby, E., Duffy, C., and Brantley, S.L (2015). *The interplay of regolith evolution and watershed hydrodynamics in a first order watershed*. 2015 Goldschmidt Conference. Prague, CZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Gaines, Katie and Kristen Marie Brubaker (2015). *The tree water isoscape of a central Pennsylvania catchment: ecohydrologic patterns and processes*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Lin, Hangsheng, Steve Banwart, Timothy Filley, Dali Guo, Daniel Richter, Susan Trumbore, Harry Vereecken and Joerg Voelkel (2015). *Towards an International Network of Critical Zone Observatories*. AGU 2015 Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Brantley, Susan L and Pamela L Sullivan (2015). *Understanding How Nested Reaction Fronts under Watersheds Impact Flow, Transport, and Geomorphological Evolution: the Shale Hills Example*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Bao, Chen, Li Li, Yuning Shi, Pamela L Sullivan, Christopher Duffy and Susan L Brantley (2015). *Understanding the Concentration-Discharge Relationship of Chloride and Magnesium in Shale Hills Using RT-Flux-PIHM*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Brantley, S.L. (2016). *Understanding the Critical Zone: from rocks to soils to water resources*. Keynote lecture for ADAPT Symposium on Advanced Assimiliation and Uncertainty Quantification in BigData Research for Weather, Climate, and Earth System Monitoring and Prediction. Toftrees Resort, State College, PA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Sullivan, Pamela L., Yves Godderis, Yuning Shi, Xin Gu, Jacques Schott, Christopher Duffy and Susan Brantley (2015). *Using WITCH to determine the factors that govern shale weathering and solute fluxes in the Critical Zone*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Sullivan, Pamela L., Yves Godderis, Yuning Shi, Xin Gu, Jacques Schott, Christopher Duffy and Susan Brantley (2015). *Using WITCH to determine the factors that govern shale weathering and solute fluxes in the Critical Zone Gordon Research Conference for Catchment Science*. Gordon Research Conference for Catchment Science. Proctor Academy, Andover, NH. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Zhang, Yu, Rudy L Slingerland, Yuning Shi, Christopher Duffy and Nicole West (2015). *Water-regolith-energy Interaction in Landscape Evolution and Its Influence on Forming Asymmetric Landscape: An Example from the Shale Hills Critical Zone Observatory of Central Pennsylvania*. AGU 2015 Fall Annual Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

- Arvy Adira. *Assessing the Subsurface Geology of Garner Run Through the Relationship Between Seismic Velocity and Layer Density (Senior Thesis, Geosciences)*. (2015). The Pennsylvania State University. Acknowledgement of Federal Support = No
- Megan Carter. *EXPLORING A 60-YEAR RECORD OF MANGANESE DEPOSITION IN MARIETTA OHIO USING SOIL CHEMISTRY AND ATMOSPHERIC DISPERSION MODELING (Master of Science, Geosciences)*. (2013). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- Molly R Cain. *Elucidating the Effects of Reservoir Filling on Watershed Hydrodynamics and Shallow Groundwater Chemistry in a Previously Impounded Lake (Senior Thesis,*

Geosciences). (2015). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

- Katie P. Gaines. *FOREST ECOHYDROLOGY IN A CENTRAL PENNSYLVANIA CATCHMENT: A STABLE ISOTOPE APPROACH (PhD Dissertation, Ecology)*. (2015). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- Matthew Kenney. *Isotopic data sonification: Shale Hills Critical Zone Observatory (Master of Fine Arts, Arts and Architecture)*. (2015). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- Yu, Xuan. *Modeling, parameter optimization, and ecohydrologic assessment of watershed systems (Ph.D. Dissertation, Civil and Environmental Engineering)*. (2014). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- Ashlee L. D. Dere. *SHALE WEATHERING ACROSS A LATITUDINAL CLIMOSEQUENCE (PhD Dissertation, Geosciences)*. (2014). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- Eric Wang. *Seismic Refraction for Subsurface Analysis of Garner Run (Senior Thesis, Geosciences)*. (2015). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- Twiest, Burkely L.. *Spatial and temporal evolution of the nocturnal surface layer in a small, steep watershed (Master of Science, Meteorology)*. (2014). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- Sara Macdonald. *Thick soil formation on Orthoquartzite since the Wisconsinan in Huntingdon County (Senior Thesis, Geosciences)*. (2015). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- West, Nicole. *Topographic Fingerprints of Hillslope Erosion in the Central Appalachians Revealed by Meteoric Beryllium-10 (PhD Dissertation, Geosciences)*. (2014). The Pennsylvania State University. Acknowledgement of Federal Support = Yes
- Bao, Chen. *UNDERSTANDING HYDROLOGICAL AND GEOCHEMICAL CONTROLS ON SOLUTE CONCENTRATIONS AT LARGE SCALE*. (2016). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Websites

Supporting Files

Filename	Description	Uploaded By	U
(Download) Annual_Report_Figure1_SSHCZO_AvailData_list&grph_20160608.pdf	Figure 1 shows the datasets that have been collected at the Susquehanna Shale Hills	Susan Brantley	0

Filename	Description	Uploaded By	U
	CZO and the time frames for which the data are available. The information is presented in pictorial and in tabulated form.		
(Download) PreceptsforCollaborationFinal.pdf	This pdf summarizes our precepts for collaboration which each member of the CZO signs and adheres to during the collaborative research.	Susan Brantley	0
(Download) Annual_Report_Figure 2_SShczo_Conceptual Model.pdf	Figure 2 shows the conceptual model we have proposed for nested reaction fronts under Shale Hills, along with the cascade of models we are developing or using to simulate CZ processes at	Susan Brantley	0

Filename	Description	Uploaded By	U
	different timescales.		
(Download) Annual Report Figure 3 DataFlowProcesses.pdf	Figure 3 shows a schematic diagram of the data flow processes that we maintain at the Susquehanna Shale Hills CZO.	Susan Brantley	0

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Brantley, Susan	PD/PI	1
Davis, Kenneth	Co PD/PI	1
Eissenstat, David	Co PD/PI	1
Li, Li	Co PD/PI	1
Russo, Tess	Co PD/PI	1
Bern, Carleton	Co-Investigator	1
Bierman, Paul	Co-Investigator	1
Brubaker, Kristen	Co-Investigator	1
Comas, Xavier	Co-Investigator	1
DiBiase, Roman	Co-Investigator	1
Gaines, Katie	Co-Investigator	1
Hayes, Jorden	Co-Investigator	1
Karwan, Diana	Co-Investigator	1
Kaye, Jason	Co-Investigator	1
Kaye, Margot	Co-Investigator	1
Keating, Kristina	Co-Investigator	1
Kirby, Eric	Co-Investigator	1
Lin, Henry	Co-Investigator	1

Name	Most Senior Project Role	Nearest Person Month Worked
Liu, Wenjing	Co-Investigator	1
Long, Robert	Co-Investigator	1
Mount, Greg	Co-Investigator	1
Nyquist, Jon	Co-Investigator	1
Perdrial, Julia	Co-Investigator	1
Pett Ridge, Julie	Co-Investigator	1
Richter, Dan	Co-Investigator	1
Singha, Kamini	Co-Investigator	0
Slater, Lee	Co-Investigator	1
Stottlemyer, Aaron	Co-Investigator	1
Donnelly, Siobhan	K-12 Teacher	2
Dykhoff, Sharon	K-12 Teacher	2
Smith, Lauren	K-12 Teacher	2
Clarke, Brian	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Guo, Li	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Hasenmueller, Elizabeth	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Sullivan, Pamela	Postdoctoral (scholar, fellow or other postdoctoral position)	0
West, Nicole	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Adams, Tom	Technician	1
Neal, Andrew	Staff Scientist (doctoral level)	0
Shi, Yuning	Staff Scientist (doctoral level)	1
Bao, Chen	Graduate Student (research assistant)	3
Chen, Weile	Graduate Student (research assistant)	1
Del Vecchio, Joanmarie	Graduate Student (research assistant)	12
Denn, Alison	Graduate Student (research assistant)	12
Dere, Ashlee	Graduate Student (research assistant)	0
Douglas, Baldwin	Graduate Student (research assistant)	1
Gu, Xin	Graduate Student (research assistant)	1
He, Yuting	Graduate Student (research assistant)	12
Hill, Lillian	Graduate Student (research assistant)	6
Hoagland, Beth	Graduate Student (research assistant)	12

Name	Most Senior Project Role	Nearest Person Month Worked
Hopkins, Isaac	Graduate Student (research assistant)	0
Iavorivska, Lidiia	Graduate Student (research assistant)	1
Jiang, Fei	Graduate Student (research assistant)	1
King, Elizabeth	Graduate Student (research assistant)	1
Orr, Alexandra	Graduate Student (research assistant)	1
Osterman, Gordon	Graduate Student (research assistant)	1
Reed, Warren	Graduate Student (research assistant)	12
Szink, Ismaiel	Graduate Student (research assistant)	12
Weitzman, Julie	Graduate Student (research assistant)	12
Wu, Yuan	Graduate Student (research assistant)	2
Xiao, Dacheng	Graduate Student (research assistant)	12
Xu, Neil	Graduate Student (research assistant)	5
Zhang, Yu	Graduate Student (research assistant)	0
Arthur, Dan	Non-Student Research Assistant	12
Brazil, Liza	Non-Student Research Assistant	2
Forsythe, Brandon	Non-Student Research Assistant	12
Williams, Jennifer	Non-Student Research Assistant	12
Duggan, Patrick	Undergraduate Student	2
Guarnieri, Marcus	Undergraduate Student	1
Pecce, Julian	Undergraduate Student	2
Seidel, Aaron	Undergraduate Student	1
Potter, Joshua	Consultant	1
Bicknell, Kelsey	Research Experience for Undergraduates (REU) Participant	2
Blackman, Taylor	Research Experience for Undergraduates (REU) Participant	2
Christhilf, Jennifer	Research Experience for Undergraduates (REU) Participant	2
Grankee, Sarah	Research Experience for Undergraduates (REU) Participant	2
Heyer, Bryan	Research Experience for Undergraduates (REU) Participant	2
Lad, Uma	Research Experience for Undergraduates (REU) Participant	2
Martin, Conner	Research Experience for Undergraduates (REU) Participant	2
Redmon, Meagan	Research Experience for Undergraduates (REU) Participant	2

Name	Most Senior Project Role	Nearest Person Month Worked
Ruppel, Margaret	Research Experience for Undergraduates (REU) Participant	2
Ryan, Sophie	Research Experience for Undergraduates (REU) Participant	2
Schwyter, Anna	Research Experience for Undergraduates (REU) Participant	2
Shaw, Meaghan	Research Experience for Undergraduates (REU) Participant	2
Silverhart, Perri	Research Experience for Undergraduates (REU) Participant	2
Wahab, Leila	Research Experience for Undergraduates (REU) Participant	2

Full details of individuals who have worked on the project:

Susan L Brantley
Email: brantley@essc.psu.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: PI, Exec Committee Chair

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Kenneth J Davis
Email: kjd10@psu.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Co-I, Exec Committee member, Coordinator of Mobile Array

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

David M Eissenstat
Email: dme9@psu.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Co-I, Exec Committee member, Coordinator of Sensor Network

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Li Li
Email: lili@eme.psu.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Co-I and Coordinator of Reactive Transport Modelling

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Tess A Russo
Email: russo@psu.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Co-I and Coordinator of Seed Grant Program

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Carleton Bern
Email: cbern@usgs.gov
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Advancing the understanding of colloidal transport

Funding Support: USGS

International Collaboration: No
International Travel: No

Paul Bierman
Email: pbierman@uvm.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Geomorphologist/Geochemist - works on Hypothesis 1

Funding Support: University of Vermont and NSF

International Collaboration: No
International Travel: No

Kristen Brubaker
Email: brubaker@hws.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Contributes to H3

Funding Support: Hobart & William Smith Colleges

International Collaboration: No
International Travel: No

Xavier Comas
Email: xcomas@fau.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Hydrogeophysics Specialist

Funding Support: NSF

International Collaboration: No
International Travel: No

Roman DiBiase
Email: rad22@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Coordinator of geomorphological soils analysis

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Katie Gaines
Email: kpgaines@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: works on tree physiology

Funding Support: CZO

International Collaboration: No
International Travel: No

Jorden Hayes
Email: hayesjo@dickinson.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: New member of advisory board, hydrogeophysics specialist

Funding Support: Dickinson College

International Collaboration: No
International Travel: No

Diana Karwan
Email: dlkarwan@umn.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Cross-CZO Investigator

Funding Support: NSF

International Collaboration: No
International Travel: No

Jason Kaye
Email: jpk12@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Soil Biogeochemist - works on Hypotheses 2, 3, 5, and 6

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Margot Kaye
Email: mwk12@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Contributes to H3

Funding Support: Penn State

International Collaboration: No
International Travel: No

Kristina Keating
Email: kmkeat@andromeda.rutgers.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Contributing collaborator

Funding Support: Rutgers

International Collaboration: No
International Travel: No

Eric Kirby
Email: eric.kirby@geo.oregonstate.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Geomorphologist - works on Hypothesis 1

Funding Support: unknown

International Collaboration: No
International Travel: No

Henry Lin
Email: hul3@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Hydorpedologist - works on Hypotheses 1, 4, 7, and 8

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Wenjing Liu
Email: wul26@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: collaborative investigator

Funding Support: unknown

International Collaboration: No
International Travel: No

Robert Long
Email: rlong@fs.fed.us
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: collaborating investigator

Funding Support: US Forest Service

International Collaboration: No
International Travel: No

Greg Mount
Email: Gregory.Mount@iup.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Hydrogeophysical specialist, collaborator

Funding Support: IUP

International Collaboration: No
International Travel: No

Jon Nyquist
Email: nyq@temple.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: collaborating investigator

Funding Support: Temple

International Collaboration: No
International Travel: No

Julia Perdrial
Email: Julia.Perdrial@uvm.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: contributing collaborator

Funding Support: University of Vermont

International Collaboration: No
International Travel: No

Julie Pett Ridge
Email: julie.pett-ridge@oregonstate.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Contributing collaborator

Funding Support: Oregon State

International Collaboration: No
International Travel: No

Dan Richter
Email: drichter@duke.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: contributing collaborator

Funding Support: Duke

International Collaboration: No
International Travel: No

Kamini Singha
Email: ksingha@mines.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 0

Contribution to the Project: Hydrogeologist - works on Hypothesis 1

Funding Support: unknown

International Collaboration: No
International Travel: No

Lee Slater
Email: lslater@andromeda.rutgers.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Collaborative investigator

Funding Support: Rutgers University

International Collaboration: No
International Travel: No

Aaron Stottlemyer
Email: ads175@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: collaborative investigations

Funding Support: Penn State

International Collaboration: No
International Travel: No

Siobhan Donnelly
Email: siobhan@clccharter.org
Most Senior Project Role: K-12 Teacher
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H3

Funding Support: NSF and CLC Charter School

International Collaboration: No
International Travel: No

Sharon Dykhoff
Email: srd224@psu.edu
Most Senior Project Role: K-12 Teacher
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H9

Funding Support: NSF and Dominion Christian School

International Collaboration: No
International Travel: No

Lauren Smith
Email: smith.lauren1030@gmail.com
Most Senior Project Role: K-12 Teacher
Nearest Person Month Worked: 2

Contribution to the Project: CZO National Office

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No

Brian Clarke
Email: bac43@psu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 0

Contribution to the Project: Geomorphologist - worked on Hypothesis 1

Funding Support: unknown

International Collaboration: No
International Travel: No

Li Guo
Email: lug163@psu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 2

Contribution to the Project: Contributes to H4

Funding Support: NSF

International Collaboration: No
International Travel: No

Elizabeth Hasenmueller
Email: hasenmuellerea@slu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 1

Contribution to the Project: Hydrochemist - works on Hypothesis 2

Funding Support: Washington University at St. Louis

International Collaboration: No
International Travel: No

Pamela Sullivan
Email: pls21@psu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 0

Contribution to the Project: Hydrochemist - works on Hypotheses 6 and 9

Funding Support: Kansas University

International Collaboration: No
International Travel: No

Nicole West
Email: nxw157@psu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 0

Contribution to the Project: geomorphologist - works on Hypothesis 1

Funding Support: CZO

International Collaboration: No
International Travel: No

Tom Adams
Email: tsa3@psu.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 1

Contribution to the Project: Contributes to H3

Funding Support: Penn State and DOE

International Collaboration: No
International Travel: No

Andrew Neal
Email: aln16@psu.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 0

Contribution to the Project: Watershed Specialist

Funding Support: CZO

International Collaboration: No
International Travel: No

Yuning Shi
Email: yshi@psu.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 1

Contribution to the Project: Hydrologist - works on Hypothesis 7 and 8

Funding Support: CZO

International Collaboration: No
International Travel: No

Chen Bao
Email: cub200@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: works on Hypothesis 5

Funding Support: CZO

International Collaboration: No
International Travel: No

Weile Chen
Email: wuc139@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: collaborative research

Funding Support: DOE

International Collaboration: No
International Travel: No

Joanmarie Del Vecchio
Email: jzd5570@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: MS student in geomorphology working on H1

Funding Support: this award

International Collaboration: No
International Travel: No

Alison Denn
Email: adenn@uvm.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: contributing to H1

Funding Support: CZO

International Collaboration: No
International Travel: No

Ashlee Dere
Email: ald271@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 0

Contribution to the Project: shale weathering along transect sites

Funding Support: University of Nebraska

International Collaboration: No
International Travel: No

Baldwin Douglas
Email: dcb5006@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: collaborative investigations

Funding Support: Penn State

International Collaboration: No
International Travel: No

Xin Gu
Email: xug102@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: collaborative research

Funding Support: Penn State

International Collaboration: No
International Travel: No

Yuting He
Email: yzh120@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: works on PIHM and Biome-BGC

Funding Support: CZO

International Collaboration: No
International Travel: No

Lillian Hill
Email: lzh157@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: contributing to H2

Funding Support: NSF

International Collaboration: No
International Travel: No

Beth Hoagland
Email: neh137@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: contributing to H6

Funding Support: CZO

International Collaboration: No
International Travel: No

Isaac Hopkins
Email: ieh105@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 0

Contribution to the Project: works on Hypothesis 4

Funding Support: unknown

International Collaboration: No
International Travel: No

Lidiia Iavorivska
Email: lui100@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: collaborative research

Funding Support: Penn State

International Collaboration: No
International Travel: No

Fei Jiang
Email: ffj5012@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: collaborative research

Funding Support: Penn State

International Collaboration: No
International Travel: No

Elizabeth King
Email: eking@coas.oregonstate.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Contributing collaborator

Funding Support: Oregon State

International Collaboration: No
International Travel: No

Alexandra Orr
Email: aso124@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: collaborative investigations

Funding Support: Penn State

International Collaboration: No
International Travel: No

Gordon Osterman
Email: gko4@rutgers.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: groundwater geophysics

Funding Support: Rutgers

International Collaboration: No
International Travel: No

Warren Reed
Email: wpr5005@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Contributes to H3

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Ismaiel Szink
Email: ips5062@PSU.EDU
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Contributes to H3

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Julie Weitzman
Email: jnw142@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: works on Hypothesis 2

Funding Support: CZO and NSF

International Collaboration: No
International Travel: No

Yuan Wu
Email: yxw5312@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Contributes to H4

Funding Support: Penn State and NSF

International Collaboration: No
International Travel: No

Dacheng Xiao
Email: dzx102@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: contributing to H8

Funding Support: CZO

International Collaboration: No
International Travel: No

Neil Xu
Email: hxx5055@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 5

Contribution to the Project: Contributes to H4

Funding Support: NSF and Penn State

International Collaboration: No
International Travel: No

Yu Zhang
Email: yzz130@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 0

Contribution to the Project: works on PIHM-sed

Funding Support: CZO

International Collaboration: No
International Travel: No

Dan Arthur
Email: dka12@psu.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 12

Contribution to the Project: Data Manager / Cyberspecialist

Funding Support: CZO

International Collaboration: No
International Travel: No

Liza I Brazil
Email: lib5105@psu.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H3

Funding Support: NSF

International Collaboration: No
International Travel: No

Brandon Forsythe
Email: brf11@psu.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 12

Contribution to the Project: watershed coordinator

Funding Support: CZO

International Collaboration: No
International Travel: No

Jennifer Williams
Email: jzw126@psu.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 12

Contribution to the Project: Program, Outreach, and Sample Coordinator

Funding Support: CZO

International Collaboration: No
International Travel: No

Patrick Duggan
Email: pcd5063@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Contribute to H6

Funding Support: Unknown

International Collaboration: No
International Travel: No

Marcus Guarnieri
Email: mjg5795@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: undergraduate student assistant

Funding Support: CZO

International Collaboration: No
International Travel: No

Julian Pecce
Email: jzp5336@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Contributes to H4

Funding Support: NSF and Penn State

International Collaboration: No
International Travel: No

Aaron Seidel
Email: A.D.Seidel@iup.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: collaborating contributor

Funding Support: Indiana University of Pennsylvania

International Collaboration: No
International Travel: No

Joshua Potter
Email: jep189@psu.edu
Most Senior Project Role: Consultant
Nearest Person Month Worked: 1

Contribution to the Project: collaborative outreach

Funding Support: Penn State

International Collaboration: No
International Travel: No

Kelsey Bicknell
Email: kbicknell@unm.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H6

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Sophomore
Home Institution: University of New Mexico
Government fiscal year(s) was this REU participant supported: 2015

Taylor Blackman
Email: tnb5149@psu.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: worked with Tim White

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: Penn State University
Government fiscal year(s) was this REU participant supported: 2016

Jennifer Christhilf
Email: jc18@umbc.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: working on H3

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No

Year of schooling completed: Sophomore
Home Institution: University of Maryland, Baltimore County
Government fiscal year(s) was this REU participant supported: 2016

Sarah Grankee
Email: sbg12013@mymail.pomona.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H1

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Sophomore
Home Institution: Pomona College
Government fiscal year(s) was this REU participant supported: 2015

Bryan Heyer
Email: bheyer@usciences.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: working on H6

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Sophomore
Home Institution: University of the Sciences in Philadelphia
Government fiscal year(s) was this REU participant supported: 2016

Uma Lad
Email: ulad@smu.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: working on H9

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: Southern Methodist University
Government fiscal year(s) was this REU participant supported: 2016

Conner Martin
Email: conmart95@gmail.com
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: worked on H1

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: University of Pittsburgh
Government fiscal year(s) was this REU participant supported: 2016

Meagan Redmon
Email: redmonm16@hanover.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H4

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: Hanover College
Government fiscal year(s) was this REU participant supported: 2015

Margaret E. Ruppel
Email: ruppelm@wittenberg.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H3

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: Wittenberg University
Government fiscal year(s) was this REU participant supported: 2015

Sophie Ryan
Email: sophie.ryan@uvm.edu

Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: worked on H6

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Sophomore
Home Institution: University of Vermont
Government fiscal year(s) was this REU participant supported: 2016

Anna Schwyter
Email: axs5408@psu.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H4

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: Penn State University
Government fiscal year(s) was this REU participant supported: 2015

Meaghan Shaw
Email: meshaw@smu.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: Contributed to H6

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: Southern Methodist University
Government fiscal year(s) was this REU participant supported: 2015

Perri Silverhart
Email: psilverhart@middlebury.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: worked on H1

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: Middlebury College
Government fiscal year(s) was this REU participant supported: 2016

Leila Wahab
Email: lmw8@rice.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: worked on H6

Funding Support: REU/RET for CZO from NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Sophomore
Home Institution: Rice University
Government fiscal year(s) was this REU participant supported: 2016

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Beijing Normal University	Academic Institution	Beijing, China
Brown University	Academic Institution	Providence, RI
Ninxia University	Academic Institution	Ningxia, China
Oregon State University	Academic Institution	Corvallis, Oregon
Princeton University	Academic Institution	Princeton, NJ
Rutgers University	Academic Institution	New Brunswick, New Jersey
Saint Louis University	Academic Institution	Saint Louis, MO
State College Area School District	School or School Systems	State College, PA
Technical Univ. of Munich	Academic Institution	Munich, Germany
Temple University	Academic Institution	Philadelphia, PA
UMass-Amherst	Academic Institution	Amherst, MA
USDA Forest Service	State or Local Government	Corvallis, OR.
CTEMPS	Academic Institution	University of Nevada, Reno

Name	Type of Partner Organization	Location
USDA-NRCS-NSSC	State or Local Government	Newtown Square, PA
Univ of Kansas	Academic Institution	Lawrence, Kansas
University of Guelph, Canada	Academic Institution	Guelph, ON, Canada
University of Nebraska Omaha	Academic Institution	Omaha, NE
University of Texas @ El Paso	Academic Institution	El Paso, TX
University of Toulouse, France	Academic Institution	Toulouse, France
Chinese Academy of Sciences	Academic Institution	Beijing, China
Colgate University	Academic Institution	Hamilton, NY
Dickinson College	Academic Institution	Carlisle, Pennsylvania
Hollidaysburg Area High School	School or School Systems	Hollidaysburg, PA
Horbart & William Smith Colleges	Academic Institution	Geneva, New York
Indiana University of Pennsylvania	Academic Institution	Indiana, Pennsylvania
Kent State University	Academic Institution	Kent, Ohio

Full details of organizations that have been involved as partners:

Beijing Normal University

Organization Type: Academic Institution
Organization Location: Beijing, China

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Brown University

Organization Type: Academic Institution
Organization Location: Providence, RI

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

CTEMPS

Organization Type: Academic Institution
Organization Location: University of Nevada, Reno

Partner's Contribution to the Project:
Facilities
Collaborative Research

More Detail on Partner and Contribution:

Chinese Academy of Sciences

Organization Type: Academic Institution
Organization Location: Beijing, China

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Colgate University

Organization Type: Academic Institution
Organization Location: Hamilton, NY

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Dickinson College

Organization Type: Academic Institution
Organization Location: Carlisle, Pennsylvania

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Hollidaysburg Area High School

Organization Type: School or School Systems
Organization Location: Hollidaysburg, PA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Horbart & William Smith Colleges

Organization Type: Academic Institution
Organization Location: Geneva, New York

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Indiana University of Pennsylvania

Organization Type: Academic Institution
Organization Location: Indiana, Pennsylvania

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Kent State University

Organization Type: Academic Institution
Organization Location: Kent, Ohio

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Ninxia University

Organization Type: Academic Institution
Organization Location: Ningxia, China

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Oregon State University

Organization Type: Academic Institution
Organization Location: Corvallis, Oregon

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Princeton University

Organization Type: Academic Institution
Organization Location: Princeton, NJ

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Rutgers University

Organization Type: Academic Institution
Organization Location: New Brunswick, New Jersey

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Saint Louis University

Organization Type: Academic Institution
Organization Location: Saint Louis, MO

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

State College Area School District

Organization Type: School or School Systems
Organization Location: State College, PA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Technical Univ. of Munich

Organization Type: Academic Institution
Organization Location: Munich, Germany

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Temple University

Organization Type: Academic Institution
Organization Location: Philadelphia, PA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

UMass-Amherst

Organization Type: Academic Institution
Organization Location: Amherst, MA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

USDA Forest Service

Organization Type: State or Local Government
Organization Location: Corvallis, OR.

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

USDA-NRCS-NSSC

Organization Type: State or Local Government
Organization Location: Newtown Square, PA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

Univ of Kansas

Organization Type: Academic Institution
Organization Location: Lawrence, Kansas

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

University of Guelph, Canada

Organization Type: Academic Institution
Organization Location: Guelph, ON, Canada

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

University of Nebraska Omaha

Organization Type: Academic Institution
Organization Location: Omaha, NE

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

University of Texas @ El Paso

Organization Type: Academic Institution
Organization Location: El Paso, TX

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

University of Toulouse, France

Organization Type: Academic Institution
Organization Location: Toulouse, France

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution:

What other collaborators or contacts have been involved?

Nothing to report

Impacts

What is the impact on the development of the principal discipline(s) of the project?

Overall: Our published paper in Earth Surface Processes and Landforms is the first such publication that describes the thought process behind designing a critical zone observatory. In this paper we have published a first order answer to the question, what must we measure to be able to quantitatively model the CZ? In addition, our ideas about nested reaction fronts, interflow versus groundwater flow, and the importance of aspect on controlling rates of weathering and erosion are starting to permeate into the community. We have pushed the importance of oxidation as one of the first reactions (if not the first) at depth in the CZ, and this idea is being picked up in many threads around the community (riverine cycling, global models, chemical-physical coupling, etc.). We have created one of the 3 most popular models for regolith formation, i.e., the chemical weathering reactive transport model of regolith formation.

Impacts for each hypothesis:

H1. By determining the age of a thick colluvial deposit at Garner Run, we will help constrain the relative efficiency of periglacial versus temperate hillslope erosion and sediment transport, and evaluate the timescales of sediment storage in upland valleys important for assessing models of Appalachian landscape evolution.

H2. Testing a simple and robust pore chemistry monitoring approach, emphasizing comparisons among catenas, could lead to a widely applied strategy to compare pore chemistry across the CZ.

H3. Coordinating with H2 and H9, the team analyzed vegetation in the sandstone site and compared it to the shale site, and examined root length density at the shale site for understanding water uptake and other biotic interactions in regolith.

H4. We have developed a new method that will allow the detection of preferential flow in soils using a new mass balance approach. This is a significant contribution to hydropedology and soil hydrology.

H5. RT-Flux-PIHM is the first numerical model capable of modeling hydrological, land surface interactions, and multi-component reactive transport all together. This provides a powerful tool to explore complex process coupling not only for SSHCZO, but also for other CZOs.

H6. This team has collected stream chemistry and discharge data, and has integrated physical and chemical measurements to locate and characterize groundwater – streamwater interactions.

H7. The watershed-resolving coupled carbon-water-nitrogen studies will enable more sophisticated simulation and understanding of the interactions of complex topography and soil lithology with the terrestrial carbon and water cycles.

H8. Team H8 will provide insight into hydrologic model upscaling and parameter transferability, and provide guidance of watershed observational system design.

H9. By publishing a paper (next year) on the use of WITCH to understand porewater chemistry, we will demonstrate how aspect can control weathering in temperate climates. This paper will have significant impact on our understanding of the rates of weathering.

What is the impact on other disciplines?

Overall: We have a good track record and organizational plan for development of our CZ model and this will be used in many ancillary disciplines:

PIHM Duffy et al. Completed

Flux-PIHM Shi et al. Completed

RT-PIHM Chen Bao and Li Li Completed (2015)

Flux-PIHM-BGC Ken Davis and Yuning Shi In Progress

PIHM-WITCH P. Sullivan and Y. Godderis In Progress

PIHM-LE R. Slingerland and Y. Zhang Paper submitted

Impacts described per each hypothesis:

H1. We have begun developing the use of GPR for geomorphology and this use of this geophysical technique in this way will be useful for soil science.

H2. Ecological experimental designs could be impacted if the team's catena monitoring approach proves successful in illuminating key drivers of ecosystem dynamics from a few carefully located sampling points. (same as last year)

H3. Work for H3 helped bring aspects of Critical Zone science to the ecological and forest management communities.

H4. We have demonstrated that combining soil and terrain attributes could help improve the stratification of a catchment into similar soil hydrologic functional units, which is valuable to distributed hydrology modeling and hillslope/catchment hydrology.

H5. The RT-FLUX-PIHM model is cross-disciplinary in its capability of integrating processes important for different disciplines (hydrology and geochemistry).

The regolith-Flux-PIHM will be integrating hydrology, geochemistry, and geomorphology.

H7. The hypothesis is inherently interdisciplinary. The multivariate model-data comparison and evaluation brings together hydrology, terrestrial ecology, soil science and micrometeorology. A primary impact is to bring scientists from these disciplines together to integrate their understanding into this work within our CZO. A second impact will result from the publication and presentation of our findings to the broader research community. The integrated carbon-water-nutrient, watershed-resolving modeling system provides additional venues for interdisciplinary collaboration. Interdisciplinary work with this modeling framework has propagated rapidly across our CZO.

H8. The land surface hydrologic observation system design method developed for H8 can be expanded to other fields (e.g., biochemistry, geochemistry).

What is the impact on the development of human resources?

During this reporting period, the CZO has hosted five undergraduate classes (FOR 475, Geosc 483, Geosc 202, Geosc 413W, and FOR 471) to demonstrate overall hydrology at the site, effects of planar slope vs swales on soil moisture, nutrient transformations, carbon landscape evolution, watershed management, geochemistry, and apply geophysical techniques in the field. Ten faculty from 5 departments worked with 6 funded graduate students, 1 postdoc, and 2 undergraduate students in the CZO. In addition, 17 papers were published and 1 PhD defended.

The Department of Conservation and Natural Resources led their environmental educators through a tour of the CZO to demonstrate active research on public land and members of the PA Geologic Survey toured the CZO and selected Shale Hills CZO for the short list of 2017 Fall field conference locations.

One seed grant was awarded to Dr. K. Brubaker, Hobart & William Smith Colleges, for ***Modeling fine-scale above ground carbon storage using LiDAR: A comparison across two watersheds***. This collaboration has trained two undergraduates, Brubaker gave a presentation in the seminar series, participated in the All-Hands, and the Shaver's Creek poster session.

A three-day CZNR Workshop, *Exploring Four Critical Puzzles about Trees, Water, and Soil: A Vision for Research*, brought 29 scientists from 15 institutions together to discuss emerging topics, producing the manuscript in progress ***How trees build and plumb the CZO***.

Xavier Comas, LCZO Co-Investigator, brought his instrumentation to the CZO, May 2016, to foster collaborations through applied geophysical techniques. The visit trained several CZO team members, as well as graduate and undergraduate students in Environmental Geophysics (Geosc 483). A direct result of this collaboration was the two-day Hydrogeophysical Workshop, June 23-24, with participants from Rutgers, SUNY Buffalo, Temple, Indiana Univeristy of PA,

Dickinson College, and Penn State, training more than twenty students in GPR, resistivity, seismic, and downhole well logging techniques. McNair scholar Aaron Seidel and his mentor Greg Mount, both of IUP, are working on geophysical questions in the CZO and Seidel will be presenting some work at the 22nd Annual University at Buffalo Undergraduate Research Conference July 21-23, 2016.

The TeenShale water quality outreach project trained 28 high school participants in authentic field research in collaboration with Penn State experts. Participants use scientific instruments to measure stream depth and velocity and water quality indicators such as stream temperature, pH, dissolved oxygen, and electrical conductivity. As an inquiry-based project, all aspects from the evolution from ideas and data gathering, to data analysis, comparisons with big data, and science communication are addressed. The academic year concluded with student analyses of water samples lead by a collaborator from University of Pittsburgh, an oral presentation at the Annual Student Symposia hosted by Allegheny College, a poster presentation at the Shale Network Workshop, and a student byline article (http://bit.ly/1UgiTdB). A manuscript is under development on the combination of hands-on field experience with data-driven hydrology education tools in place-based education projects in conjuction with a 2015 CZO RET participant, Sharon Dykhoff.

Ashlee Dere, Assistant Professor of Geology at University of Nebraska-Omaha, set up a year-long erosion experiment along four the Shale Transect sites (PA, VA, TN, and AL) during summer 2015, training four UNO undergraduates (Chadd Cuprit, Morgan Okeson, Jessica Edwards, Joe Darragh) in CZ field techniques. The team installed erosion experiments, dismantled weather stations, exhume buried shale, collect addition ridgetop and slope cores and sampled organic horizons. In August 2016, four additional UNO undergraduate students (Sara Parcher, Samuel Nath, David Johnson, and Joseph Warth) will be trained in CZ field techniques and collect the sediment traps with Dere. Dere will also exhume buried shale from the transect site in Wales late July.

Yuning Shi, co-investigator, hosted a Penn State Integrated Hydrologic Model System (PIHM) developers workshop over two days teaching fourteen participants the physics and computer code of PIHM and the additional modules, a model coupling technique, and code management. All got hands-on experience running the model and sharing code.

The team is working with educators to create an educational display for the Shaver's Creek Educational Center. Initial plans have been discussed. As part of this, our partners, Shaver's Creek Environmental Center Center, hosted a "What is the Critical Zone Observatory?" poster session, providing the public direct interaction with CZO students and their research. Topics of critical zone science are displayed in poster format and are available for viewing for the duration of the 2016 summer (http://www.shaverscreek.org/event/what-is-the-critical-zone-observatory/).

The CZO seminar series this year included the following presentations:

September 18th: Susan Brantley, Distinguished Professor of Geosciences and CZO PI, will present "***The State of the CZO"***; October 23rd**:** Preparation/Discussions of Science Presentation for the NSF Virtual Site Visit. Group presentation on "***What we measure vs. What we need***"

with respect to soil parameters and their use in the suite of PIHM models; November 13th: Kristen Brubaker, Professor of Environmental Studies, Hobart and William Smith Colleges, will present "***Understanding the influence of bedrock on patterns of vegetation and fine scale above-ground carbon storage***"; December 11th: Dissertation Defense, Douglas Baldwin will present ***"Improving Estimates of Root Zone Soil Moisture to Understand Ecosystem Drought Sensitivity"***; January 22nd: Robert Long, Forest Pathologist USFS, and Aaron Stottlemyer, Professor of Forest Ecology, Penn State DuBios, will present "***Oak Regeneration: Investigating Potential Interactions with* Lithology"**; February 26th: Dr. Tess Russo, Professor of Geosciences, and Dr. Hyojin Kim, Postdoctoral Scholar, will present "***Streambed surface water - groundwater interactions at Shale Hills Creek***"; March 18th: Ismaiel Szink, PhD student in Ecology, Alexandra Orr, MS student in Ecology, and Weile Chen, PhD Candidate in Ecology, will present their research on "***Root and Fungal Ecology at the SSHCZO***"; April 15th: Beth Hoagland, PhD Candidate Geosciences, and Lillian Hill, MS Candidate Ecology, and Yuting He, PhD Candidate Meteorology, will present "***Nutrient dynamics across catchments: from the field to the model***"; May 16th– 17th: SSHCZO All-Hands – AGU style mini-symposium, May 16th included a CZO field trip with Jorden Hayes, 5 faculty, and 25 students/postdocs and concluded with featured seminar by Jorden Hayes @ 4:00pm in 114 EES Building; May 17th included 10 student/postdoc oral presentations, 15 poster presentations, and networking. The program planner is available http://criticalzone.org/shale-hills/research/annual-activities-shale-hills/.

The 2015 CZO REU/RET summer program trained 6 REUs and 2 RETs in both field and laboratory techniques of interdiscplinary topics in critical zone science, with three presenting posters at a special session at the 100th anniversary of the Ecological Society of America's conference in Baltimore, Maryland, August 9-14, 2015. The 2016 CZO REU/RET summer program includes the training of 8 REUs (63% female) and 1 RET (female), each presenting a poster at the CUAHSI Biennial Meeting in Shephardstown, WV, July 24-27, 2016. One female student from the Math REU is also working with Tess Russo and has been incorporated into the REU activities on campus and will travel to the CUAHSI meeting. The Math REU student also presented a module incorporating fossils into the summer camp at the Shavers Creek Discovery Center for all age group children to learn about fossils in the Keefer sandstone in the CZO.

What is the impact on physical resources that form infrastructure?

Overall: The team chose the site for the agricultural subcatchment. We will start to work on that site by the end of summer 2016.

H3. In one shale and one sandstone catchment, soil moisture sensors were installed at multiple depths in pits at ridgetop, midslope, and valley floor positions. These will allow continuous monitoring of soil moisture. Dendrobands and sap flux sensor were placed on trees around one pit at Shale Hills and Garner Run.

H6. This team helped install a set of nested wells at the sandstone catchment, and installed a weir at the shale catchment.

H7. The team continues to assist with the establishment of an additional covariance measurement system at the Garner Run watershed.

H8. A COSMOS soil moisture sensor has been added to the observation array at Garner Run.

What is the impact on institutional resources that form infrastructure?

H3. The CZO research was leveraged to acquire a DOE grant (Eissenstat, Kaye, Shi, Davis, Lin, & Duffy) aimed at assessing the influence of topography on belowground carbon fluxes, and modeling these processes in the Shale Hills CZO with a coupled Earth system and hydrological model. The Shale Hills observatory was also used to assess species variation in mycorrhizal root foraging by a Ph.D. student (Weile Chen) working in the Eissenstat lab and funded by NSF BIO Directorate, IOS program.

H6. This team hosted Gregory Mount, a geophysicist from Indiana University, to visit the site and train students from his university on geophysical techniques. He is returning to the CZO to conduct additional field experiments later in 2016.

What is the impact on information resources that form infrastructure?

A “Precepts for Collaboration” guide to best practices for collaborative science at the SSHCZO was adopted by the CZO team and remains a living document for the team and collaborators. The Precepts have been uploaded in the Products section.

A user manual is being developed for RT-FLUX-PIHM and will be available for the public.

What is the impact on technology transfer?

Nothing to report.

What is the impact on society beyond science and technology?

At least two huge societal problems are related to ongoing work at our CZO. Specifically, many members of the public are worried about hydraulic fracturing and whether the injection of fracking fluids could enter groundwater resources. Will fracking harm groundwater? This can be rephrased as, what is the depth of the critical zone? We are actively working to understand how to model and predict the dept of flow of water in the subsurface.

In a second example, the US is seeking a geologic site to safely dispose radioactive waste. This disposal site must sequester the waste from groundwater, must not be eroded or weathered away, must not be easily fractured to allow inlet of new groundwater, and must be safe from human intrusion. All of these societally relevant questions are essentially CZ questions. Will a geologic repository be eroded before the radwaste decays adequately? This can be rephrased as, what is the rate of weathering and erosion in this locality? All of the work we do at the Susquehanna Shale Hills CZO is aimed at understanding these types of questions, although our target area is one watershed in central PA.

Changes/Problems

Changes in approach and reason for change

Chris Duffy no longer participates to any great extent in the CZO other than his helpful expertise in using and modifying PIHM. We had planned to use PIHM to make watershed models of Young Woman's Creek and the Snake River watershed, both in northern PA. The former has been accomplished, but we will not be able to do the latter without Chris' participation.

We had originally planned to study 4 subcatchments in Shavers creek watershed (a pristine subcatchment on shale, a pristine subcatchment on sandstone, a pristine catchment on mixed lithology, and a farmed catchment on mixed lithology). Because of the workload, we needed to limit this to 3 subcatchments, so we eliminated the pristine catchment on mixed lithology. We are moving forward a little bit slowly on completing the 3 subcatchments but we anticipate our first measurements on the farmed subcatchment by the end of the summer, and we have advanced very rapidly on the Garner run sandstone subcatchment.

Actual or Anticipated problems or delays and actions or plans to resolve them

H2. Delays in collecting sensor data occurred due to the high battery power consumption of new CO2 and O2 sensors. We purchased propane generators but they never functioned properly, so we later purchased solar panels. Hopefully these will limit power outages. Also, several sensors have failed and need to be replaced, which will result in gaps in the dataset.

H3. The student recruited for this project, Ismaiel Szink, did not join us until last year. We are therefore a little behind on this part of the project, namely learning how to incorporate trees and tree root effects into the quantitative model of the CZ for Shavers creek.

H4. The graduate student working on this hypothesis (Neil Xu) did not live up to the expectation of this project’s tasks. Thus, a new Ph.D. student has been recruited to start in Fall 2016 who will be responsible for this hypothesis.

H5. The student working on part of this project, Chen Bao, completed his PhD and left Penn State. We had anticipated that he would finish more of the reactive transport modelling. His work is now being continued by Dacheng Xiao, who is also working on other aspects of H6.

H6. The H6 team continues to progress under the new leadership of Russo with only a few issues. The H6 team has been working with the H2 team, and coordinators from the Penn State College of Agriculture to choose a new subcatchment on calcareous shale that contains working farms. Several discussions with farmers have been pursued: a subcatchment has now been identified and it is hoped we will begin some work in the catchment by the end of the summer. Finally, drilling with the help of colleagues at U. of Guelph or private companies has turned out to be too expensive to use for additional wells. A portable drill was purchased and is now being used to drill smaller monitoring wells in the sandstone valley floor and along the catena. We have also found a very deep well in the ridgeline above Garner Run that was drilled long ago.

Instead of drilling a new well for $20k or so, we will pay approximately 3k to get the old well drilled out, cleaned, and re-cased for use.

H7. Installation of the tower-based measurement system (TowerHOG – includes eddy covariance flux measurements) has been delayed at Garner Run due to the challenges of gaining access to a communications tower. This appears to be resolved at this time, and measurements should begin shortly (spring 2016).

H8. Pam Sullivan, assistant prof at Univ of Kansas wrote an unexpected paper over the last year (a paper describing many isotope measurements at Shale Hills). Because of this, she still has not finished her paper on groundwater flow in Shale Hills, nor on the use of WITCH to model porewater flow in soils in the catchment. We anticipate the first will be submitted this month and the second will be submitted by the end of the summer.

Changes that have a significant impact on expenditures

Overall: We gave 8k back to NSF to help us fund the CZO network postdoc. This can be adequately handled because we lost our watershed field coordinator, Andy Neal, and hired a new coordinator, Brandon Forsythe, and the salary savings can provide the 8k.

H2. The failure of 2 O2 sensors was unexpected and will further impact our already over-budget sensor expenditures.

H4. We found that what we paid Guelph to drill our valley floor well has depleted our resources for drilling. We therefore have no money to drill a ridgetop borehole at Garner Run. We have found an old well we can clean out and use and we plan to do this.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.