Preview of Award 1239285 - Annual Project Report

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1239285
Project Title:	An Accomplishment-Based Request for Renewal of the Susquehanna-Shale Hills Critical Zone Observatory (SSHO)
PD/PI Name:	Susan L Brantley, Principal Investigator Christopher J Duffy, Co-Principal Investigator David M Eissenstat, Co-Principal Investigator Eric Kirby, Co-Principal Investigator
Recipient Organization:	Pennsylvania State Univ University Park
Project/Grant Period:	09/01/2012 - 08/31/2014
Reporting Period:	09/01/2012 - 08/31/2013
Submitting Official (if other than PD\PI):	Susan L Brantley Principal Investigator
Submission Date:	08/19/2013
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Susan L Brantley

Accomplishments

*** What are the major goals of the project?**

Hydroinformatics and Isotope Hydrology Team : 1) To complete the hydrogeologic and stable isotope experiment for 2008-2013. 2) organize all relevant and and commensurate climate and hydrologic data into a format suitable for publishing on National CZO site. 3) Complete development of PIHM flow and transport model including , stable isotope carbon, nitrogen and phosphorus for upscaling modeling results from Shale Hills to the Juniata and ultimately the Chesapeake Bay watershed. 4) Working with Dr. Kei Yoshimura, University of Tokyo, Duffy, Leonard and Thomas developed a new simulation product for and in precipitation for Shale Hills 1979-Present.

Weathering & Soils Team: to understand water chemistry in context with solid phase chemistry

Biogeochemistry Team: This research focuses on quantification of (1) soil respiration rates and the investigation of how water movement/storage and soil textured leads to variability in soil-atmosphere CO2 exchange and it importance to study the flux of soil CO2 along a gradient of topographic positions at different depths within the soil profile in order to increase our mechanistic understanding of the controls that influence gas fluxes from the soil to the atmosphere, (2) the impact of combined soil and landscape features on the flux of N2O to the atmosphere and influence of preferential flowpaths on N2O emissions in upland soils, and (3) root depth and distribution and how its impact on shale weathering dynamics.

Hydropedology Team: to reveal soil moisture spatial-temporal patterns as influenced by soil, terrain, vegetation, and season; to investigate preferential flow dynamics from the pedon to the hillslope and catchment scales

Hydrogeophysics Team: We have been mapping the orientation of fracturing within the watershed with the goal of better understanding lithologic variations and controls on fluid flow. In neighboring (drained) Lake Perez, we have been looking at stream temperature variations to explore groundwater-surface water exchange between the remnant stream and the aquifer.

Hydroclimatolgy Team: NA

Ecology Team: NA

Geomorphology Team: The overarching goal of the "geomorphology" team is to understand how lithology and bedrock fracture distributions in SSHCZO influence active critical zone processes, landscape morphology, and evolution of the critical zone through time (from the past into the future). Our efforts during the period of this 1-year, accomplishment-based renewal focused on two outstanding questions regarding the rates of regolith transport and erosion on planar hillslopes in the SSHO that arose from our initial 5-year study. In that work, we discovered that rates of downslope transport of regolith appear to be relatively uniform, despite differences in topographic gradient (West et al., 2013). This finding appears to require differences in the efficiency of regolith creep that depend on the aspect of the hillslope (Ma et al., 2013). In this year, we sought to test whether this finding was systematic in nearby watersheds of similar asymmetry, and, if so, whether the implied rates of erosion are similar.

During our initial phase of research we also learned that north- and south-facing hillslopes exhibit strong differences in the thickness of fractured and disaggregated bedrock. North-facing hillslopes retain a thick (1-2 m) mantle of fractured rock and colluvium beneath the mobile soil (Deere et al., in review), whereas this layer appears to be absent along south-facing hillslopes. We sought to characterize the depth distribution of fractures in the shallow subsurface to better understand how damage accumulates in the deep critical zone, how this damage depends on lithology, and whether topographic aspect influences rock damage through feedbacks between solar insolation and frost cracking during periglacial climates.

Infrastructure Team: The primary goal for the infrastructure team in 2012-2013 was implementation of a new wireless network system, including automated data retrieval and storage. The infrastructure team expanded in Fall 2012 with the hiring of a Watershed Specialist (Neal) to coordinate sensor systems and data management. The ongoing mission of the infrastructure team is the maintenance of existing sensor systems and data archiving.

Seed Grant Teams

Conduct U-series isotope measurements on soil samples from shale weathering transect sites: from PR, AL, and TN.

Using C isotopes to determine whether shale weathering is releasing CO2 by organic matter decomposition or consuming CO2 by mineral dissolution?

Examine water infiltration and migration in the Shale Hills CZO using ground penetrating radar (GPR) and dye tracer.

Long-term goal of the Lehigh seed-grant research is to describe soil stratigraphy and morphology for soil mantled hillslopes in three diverse CZOs – Puerto Rico, the Shale Hills, PA, and Valles Caldera, NM.

To provide foliar chemistry and tree stem growth data necessary to complete aboveground net primary productivity (ANPP) estimates for the watershed.

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

Major Activities: *Hydroinformatics and Isotope Hydrology Team:* The team drilled and installed 4 piezometers (-3m and 1 8m) around the ridge at Shale Hills. Consolidated the and stable isotope data for 2008-2013. Bhatt defended his dissertation including PIHM documentation for flow and transport and a new model for Shaver Creek watershed. Completed flow model of Young Women's Creek for the climate reanalysis period

1979-2012.

Weathering & Soils Team: measuring groundwater chemistry; colloid production at SSHO; porosity in chips at SSHO

Biogeochemistry Team: In addition to measurements of in situ gas concentrations, the Kaye group collected gas, water, and soil samples for two seasons (spring and summer: April to August of 2013).

Hydropedology Team: Real-time soil moisture monitoring and ground-penetrating radar investigations

Hydrogeophysics Team: We have drilled a series of new wells within the watershed: three 7 m holes at the ridgetop and eight 2-m deep geoprobe wells across a north-south transect in the eastern part of the watershed. In these wells, we have collected wireline logs, including gamma and optical televiewer, where possible, and have slug tested all wells for permeability. Major element analysis and XRD was conducted on collected drill cuttings.

Additionally, we analyzed a series of temperature data within Lake Perez, including distributed temperature sensing to look at discrete vs. distributed contributions to flow, and point measurements, to explore storm dynamics. We collected stream stage, temperature, and fluid electrical conductivity data collected every 15 minutes from April 2011 through October 2012. Stream data were collected at locations 200 meters apart: the upstream logger recorded stream temperature and fluid electrical conductivity, while the downstream logger recorded stream temperature and stage.

Hydroclimatolgy Team: : (1) Modeling: Improvement of Flux-PIHM model; 30-year land surface hydrologic reanalysis using Flux-PIHM and NLDAS-2 meteorological forcing; Comparison of simulated and observed soil moisture patterns; Animation of Shale Hills soil moisture patterns; Comparison of Flux-PIHM vs. conceptual hydrologic models; (2) Instrumentation: Micronetwork creation and deployment; Micronetwork data collection and maintenance (March-June); Investigation of Shale Hills surface temperature pattern and mechanisms thereof.

Ecology Team: Experiments of numerical modeling of watershed using a land surface hydrologic model, Flux-PIHM; Soil water was sampled from a variety of slope positions in 2012 up to 30 cm deep; Tree water distillation from samples collected in 2012 – both natural abundance stable isotopes and condensate collection and analysis from a deuterated water experiment in 2012; Installation of sap flow probes during July 2013 in two individuals each of Quercus prinus and Quercus rubra, and one Acer saccharum, at four sites: two on the North-facing slope and two on the South-facing slope; Tree water isotope sampling (Cornell group) and soil sampling for soil water isotopes at depth increments up to 50 cm deep in June and July 2013 at each of the four sap flow sites; Sampling canopy leaves and stream water for light and heavy isotopes and elemental C and N (Sparks and Derry Labs from Cornell) in June and July 2013; Sampling ridge top, mid-slope, and valley floor positions for root length density on south-planar and swale hillslopes.

Geomorphology Team: Our activities fall into three primary categories: 1) we collected samples of regolith for meteoric 10Be measurements in the watersheds immediately adjacent to the SSHO; 2) we conducted geophysical campaigns, using shallow seismic refraction techniques, to characterize the depth extent of rock fracture; and 3) we drilled a deep borehole along the southern ridgecrest to validate fracture density inferred from geophysics.

Infrastructure Team: Outfitted dataloggers at SSHCZO with new wireless radios

(XBEE 900MHz) to form a mesh network for data communications; Implementation of an automated data retrieval and storage system based on Campbell Scientific's Loggernet and Loggernet DB software; Planning and support for future work at SSHCZO, including development of new sites elsewhere in the Shavers Creek watershed, i.e. not associated with the Shale Hills research unit; VPN data protection including wifi at field site; Wifi maintenance of data logger at field site; Lightning protection of critical network infrastructure.

We anticipate an ongoing expansion of the wireless network at Shale Hills as new dataloggers are added to the network. Data collection at the future sites, however, will be performed manually.

Seed Grant Teams

All samples have been digested for column chemistry in May, 2013; In June 2013, samples from PR, AL have been processed for column chemistry and ready for measurements on MC-ICP-MS at UTEP. Samples from PR have been measured on MC-ICP-MS at UTEP in July 2013.

(1) Collected soil water and soil gas samples along two southern transects, streams at three locations, and nine groundwater samples along the valley; (2) Received archived soil and rock samples; (3) carried out chemical analyses: [CO2] for gas samples, major elemental chemistry, pH, alkalinity, and d13CDIC for natural waters, and d13CCaCO3 and d13COM for soils and Rose Hill bedrocks; (4) used geochemical model Solmineq.88 to calculate the saturation indexes of carbonate minerals; (5) synthesized data and submitted an abstract to a national meeting (AGU)

Conducted a tracer test of artificial infiltration and monitored hydrologic processes using ground penetrating radar. Excavated the tracer site and photographed the dye pathways. Several experiments were conducted. Soil was obtained from the proposed site and from a practice site to use in laboratory columns to test visibility of dye on soils. Laboratory tests were followed by several practice injections in the field. One was at a site on Temple's campus to evaluate timing and techniques. A second practice test was conducted in a watershed adjacent to the Shale Hills CZO to further evaluate techniques and test dye visibility in a soil similar to the CZO site. The final experiment was conducted on a well-characterized hillslope within the CZO. Funding was received in May 2013 so this report covers less than 3 months of activity.

Five soil pits were described and sampled at a 10-cm interval. Analysis of the samples will provide elemental depletion profiles to compare with the soil stratigraphy. The team plans to continue these activities in concert with other Shale Hills researchers in August, 2013 when backhoe-excavated pits are excavated in an adjacent watershed to the Shale Hills CZO.

The seed grant activities include analysis of leaf litter samples for carbon concentration (% C) and δC13 isotope ratios, and collection of tree-ring samples from 200+ trees in the watershed for estimates of annual wood growth needed for ANPP calculations.

Specific Objectives: *Hydroinformatics and Isotope Hydrology Team*: Finalize conceptual hydrogeologic model for Shale Hills hydrology.

Weathering & Soils Team: develop a model of groundwater chemistry and a model of hillslope element depth profiles and apply it to SSHO

Biogeochemistry Team: to elucidate C and N dynamics and cycling in temperate

watershed, identify spatial variability of soil gas within the watershed, and quantification of root depth and distribution and how it impacts shale weathering.

Hydropedology Team: to quantify temporal and spatial patterns of preferential flow occurrence in the Shale Hills Catchment across space and time; to develop a new protocol to reconstruct subsurface lateral flow networks with high resolution.

Hydrogeophysics Team: The rocks in the SSHO are heavily folded and fractured, and our objective is to explore the controls of fracture patterning on groundwater flow by identifying the occurrence and orientation of fractures and their relation to weathering.

In Lake Perez, our goal is to see whether there is connection between the stream and clayey lake aquifer to explore the long-term impacts of legacy sediments on groundwater-surface water exchange in remnant streams left behind from deconstructed dams.

Hydroclimatolgy Team: NA

Ecology Team: (1) Using soil moisture measurements and numerical models to identify the roles of deep root in water uptake. (2)Based on 2009 and 2011 data, trees did not appear to be using the same water that was sampled by the lysimeters. Therefore in 2012, it was a goal to characterize bulk soil water, which contains water in large and small pore spaces. (3) Natural abundance stable isotope samples were collected in 2012 in order to look at differences between depth of water use in ring-porous versus diffuse-porous tree species. Co-occuring trees of the diffuse-porous species Betula lenta, Liriodendron tulipifera, and Acer saccharum were sampled, along with the ring-porous Quercus alba and Fraxinus Americana. (4) Identifying the effect of slope aspect on tree sap flow. (5) Quantifying effect of slope aspect on depth of tree water sources. (6) Estimating range of variation in root length density at different slope positions and hillslope curvature types (planar and swale) in order to provide additional explanatory data on differences in tree physiology at these slope positions and to aid in modeling tree water uptake.

Geomorphology Team: We utilize shallow geophysical surveys, strategic drilling and borehole analyses, and detailed field investigation integrated with the rich, interdisciplinary datasets available at SSHCZO, in order to 1) characterize SSHCZO geology and critical zone architecture; 2) quantify material properties, subsurface structure, and fracture distributions within both the shallow- (<10 m) and deep-critical zone; 3) constrain the depth and intensity of weathering/fracture formation in the shallow-subsurface and better understand near-surface controls on soil/regolith production and spatial variability in the depth and transport efficiency of the mobile regolith layer; and 4) understand how variations in lithology and fractures within the deep-critical zone help modulate groundwater flow, deep weathering fronts, and the “preconditioning” of deep, parent-rock at the start of the “Critical Zone Conveyor”

Infrastructure Team: Development and maintenance of physical and technical facilities to support research at SSHCZO.

Seed Grant Teams

1) evaluate the relative contribution of “old” versus “modern” organic matter sources to soil CO2; 2) study the controls on DIC acquisition as water passes through the vadose zone to a shallow aquifer and recharges to a first-order stream; 3) Investigate the sources of dissolved SO4 at the Shale Hills watershed, and quantify the relative importance of sulfuric acid vs. carbonic acid weathering; and 4) quantify the release rates of CO2 from decomposition of fossil carbon and consumption rates of CO2 from

shale weathering, and thus evaluate the overall CO2 consumption potential of gray shale.

Improve the understanding of how GPR can be used to interpret infiltration by comparing GPR images and photographed dye pathways. Evaluate the importance of the soil-bedrock interface and saprolite fabric on infiltration pathways.

The objectives are to understand the processes recorded in soil profiles, through description of soil, colluvial, and saprolite texture and stratigraphy in the field, and quantitative measures of grain size (PSDA), major elemental analysis, weathering index analysis, and iron-oxide mineralogy. These results will add to the large, emerging data set of watershed hydrology, geochemistry, and long-term weathering in temperate soils. In addition, the hope is to help provide critical data needed to inform the geomorphic and geochemical investigation of watershed topographic asymmetry, a first-order feature observed in the instrumented watershed of several CZOs, including the Shale Hills.

To use leaf litter and tree ring data to 1) to create a spatially-explicit map of ANPP across the watershed, 2) to reconstruct ANPP through time from time series of radial growth increment, and 3) compare drought sensitivity of four tree species across diverse topographic positions in the watershed by using leaf litter δC13 values as a proxy for tree water stress.

Significant Results:

Hydroinformatics and Isotope Hydrology Team: Implemented a new distributed model code for estimating the age of water in PIHM based on a new theory for low-order moments of the transport equation (Duffy, 2010) and have begun to apply this theory to the Shale Hills CZO and other sites.

Weathering & Soils Team: Be 10 and U disequilibrium isotopes reveal that the soil production rates and erosion rates are similar

Hydropedology Team: (1) Understanding temporal and spatial patterns of preferential flow (PF) occurrence is important in revealing hillslope and catchment hydrologic and biogeochemical processes. Considerable temporal consistence was observed in both the frequency and the main controls of PF occurrence at the hillslope scale in the Shale Hills, which was attributed largely to the statistical stability of precipitation pattern over the 5.5-years monitoring period and the relatively stable subsurface preferential pathways. (2) Subsurface lateral flow (SLF) has been observed to contribute substantially to hillslope and catchment runoff. (3) Soil thickness acts as an important control for headwater hydrologic processes.

Hydrogeophysics Team: The optical televiewer data indicate significant fracturing to 7m depth at most locations within the watershed. The orientation of fracturing is striking approximately 300 degrees, dipping 40-55 degrees. Gamma data, which are a measure of clay, additionally show a lower gamma count to a depth of ~7m, highlighting weathering at shallow depths, with slightly higher gamma at the ridgetop than in the valley.

Hydroclimatolgy Team: We have synthesized field measured soil parameter data into the Flux-PIHM model for SSHCZO. Using the new set of soil parameters, the model is now able to reproduce the observed soil moisture pattern at the Shale Hills watershed at ~10 m spatial resolution. The results have been produced into animations and put on CZO website.

Ecology Team: We compared the observed soil moisture data at different sites and different vertical levels to identify the roles of deep roots in water uptake in dry periods. These results suggest that water uptake rate generally decreases with soil

depth, probably as a function of decrease in root length with depth. Those data indicate that deep roots are working less during initial water depletion when soil water contents are high.

Results indicate trees on average access water that is a combination of mobile and immobile soil water up to about 30 cm deep. This water most closely resembles summer precipitation but could be some soil water stored from earlier in the year. Based on the oxygen-18 signature, tree water is on average, originating from mobile water down to about 15 cm and closely resembles summer precipitation. Because of the topography of the hill slopes, it is likely that precipitation flows quickly down slope leaving little water to be stored in the soil profile. Any water that trees are using from this slope position would then only be available for a short period of time after each precipitation event.

For trees on the ridgetop, deuterium signatures show that tree water may be originating from immobile soil water at about 20 cm deep. Oxygen-18 results suggest that trees are using a combination of mobile and immobile water down to about 20 cm. The access to stored water on the ridgetop areas may be due to the better water-holding capacity of the ridgetop soils when compared to the mid-slope soils that allow water to be stored, and therefore fractionate, over longer timeframes.

These results have implications for modeling tree water use at different slope positions and for understanding how slope position affects risks to forests during drought.

Geomorphology Team:

1. Regolith transport: Our results demonstrate that, near the ridgetops, regolith transport rate appears to be linearly proportional to local slope. Estimates of regolith residence time and erosion rates determined from meteoric 10Be are within a factor of two of residence time and regolith production rates measured using U-series isotopes (West et al., 2013; Ma et al., 2013). Topographic analyses confirm that ridgetop curvature scales with erosion rate across similar watersheds in the Pennsylvanian Valley and Ridge Province.
2. Shallow-Critical Zone: Our velocity profiles reveal the subsurface structure of the critical zone based on depth-dependent changes in material properties (strength/density). The results show that the full regolith comprises an upper mobile layer, identified as a near-surface layer of low-velocity material (weak, low-density soils and disintegrated fragments) and a lower, immobile zone of highly fractured/weathered material, characterized by faster and progressively increasing velocities with depth (increasing strength/density). The regolith-bedrock boundary is delineated by a sharp velocity contrast that separates the slower, gradational velocities within the regolith layers from faster, uniform velocities within “fresh” bedrock below.
3. Deep-Critical Zone: Collectively, analyses of 9 boreholes throughout the watershed provide the most detailed geologic and structural analyses of SSHO to date. These results show that, although bedding orientation remains constant throughout the catchment, there appears to be substantial heterogeneity in the nature of the Rose Hill Shale (alternating mudstones, siltstones, shales).

Infrastructure Team: Testing of the wireless mesh network was successful and the network will be expanded to include more dataloggers to facilitate data collection and management. Database development was initiated and is underway in conjunction with the SSHCZO Cyberspecialist.

Seed Grant Teams

Data interpretation for PR samples is currently in progress, in conjunction with the

available REE, trace element, mineralogy data. All U-series data are expected to available by the end of Oct, 2013.

Chemical weathering in shallow soils is dominated by clay transformation, and dissolved inorganic carbon (DIC) concentrations in soil waters are low, less than 200 mmole/L. The DIC is in equilibration with soil CO2, which is as high as 40 times that of atmospheric CO2 and varies seasonally in both concentrations and C isotope compositions.

The tracer test site was photographed in detail and the images show preferential flow paths. Dye pathways were anisotropic, and strongly influenced by the saprolite fabric (oriented along strike). The patterns observed in the dye traces are being compared to the geophysical imaging. Note that the GPR does not directly image the dye, but the signals respond to changes in soil moisture and to changes in radar propagation in soil versus bedrock. The bedrock map shows a highly irregular surface at the site and shallow bedrock (generally < 0.5 m depth). The comparison between the dye trace and the GPR signals is in progress as the tracer test data were collected a week ago as of the writing of this report (July 2013). We identified root zone uptake of dye at the practice sites but not at the CZO, possibly due to drier initial conditions at the CZO.

The field excavations and sampling illustrated some key stratigraphic relationships. First, the depth to bedrock varies significantly from swale to interfluve, a result that confirms and enhances a soil depth map constructed by Lin. The relief on the soil-bedrock interface is modestly high, at least 0.5 m of relief was observed in the base of a pit 2 m long. Furthermore, all pits showed textural differences that we interpret as unsteady production and transport of parent materials under variable weathering and climate conditions in the late Pleistocene.

Leaf litter % C ranged from 43-50% for 107 samples from six tree species in the SSHO CZO.

Key outcomes or Other achievements:

Hydroinformatics and Isotope Hydrology Team: 1) Duffy was appointed chair of the Critical Zone Focus Group with CSDMS. Attended the annual meeting for CSDMS and gave the keynote talk 22-27 March, 2013. “Modeling The Isotopic “Age” of Water in Hydroecological Systems”. 2) Served on the EarthCube working group for Critical Zone Science. 3) Served on the EarthCube Working Group for Geoscience Workflows. 4) Gave an invited presentation at the EarthCube “Digital Crust” workshop 22 January 2013. 5) Completed catchment model for Lysina catchment Czech Republic CZO and SoilTrEC partner site and submitted journal paper. 5) Completed first version of the integrated hydrologic model for the White Mountains of Crete with paper in preparation.

Weathering & Soils Team: We have posted much of our water chemistry online for doi’s

Biogeochemistry Team: NA

Hydropedology Team: (1) worked closely with Evan Thomas to help him put together a publication on Spatiotemporal Patterns of Stable Isotope Compositions at the Shale Hills Critical Zone Observatory that is now published, (2) collaboration with Dave Eissenstat’s group and have two joint publications linking trees to soil moisture, (3) collaboration with Jonathan Nyquist and Laura Toran of Temple University on the use of geophysical tools (mainly GPR and ERT) to investigate subsurface hydrology.

Hydrogeophysics Team: NA

Hydroclimatolgy Team: PostDoc Shi has been working with the Biogeochemistry team to couple Flux-PIHM model with different geochemical models.

Ecology Team: NA

Geomorphology Team: In addition to the work at SSHO, Clarke is currently pursuing a complementary investigation into the influence of bedrock fractures at the Boulder Creek Critical Zone Observatory (BcCZO). To date, work in the BcCZO has been preliminary, but his efforts will be leveraged in the coming year via funding he has obtained independently through the NSF GLD program. This study thus represents one of the first, truly integrated cross-CZO research efforts, and we are excited by the opportunity to pursue the question of the controls on regolith production and the depth and transport efficiency of the mobile regolith layer.

Infrastructure Team: Long-term maintenance was performed on the eddy covariance system at Shale Hills. Several new instruments were installed, including a 2KR snow scale, s::can uv/visible spectrometer (for DOC, NO3 concentrations), Campbell Scientific turbidity sensor, and Dynamax sapflow sensors. New dataloggers were installed at long-term soil moisture monitoring sites. Spatial data associated with existing and new sensor sites were updated to reflect up-to-date infrastructure systems.

Seed Grant Teams

Our work overlapped with several other groups at the site. We exchanged information with the Lehigh soil mapping project (they mapped our trench and we visited their trenches to view contrasting sites). In addition, Elizabeth Hasenmueller, a postdoc at the CZO, described to us root zone characterization underway in the CZO and took photographs at both our test site near the CZO and on the CZO.

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

Hydroinformatics and Isotope Hydrology Team: : 1) Hosted Dr. Maria Andrianaki ETH, Zurich and Dr. Daniel Moraetis Technical University of Crete for 2 weeks in Sept 2012 to train them in using PIHM. 2) Was co-presentor with Nikos Nikolaidis, TUC, of a Critical Zone Geochemical Modeling Workshop in Chania, Crete July, 2012.

Weathering & Soils Team: Mentored Nina Bingham for her senior thesis

Biogeochemistry Team: One postdoc (Hasenmueller) and one graduate student (Weitzman) were trained in field and laboratory techniques related to the project. Hasenmueller was also involved in grant development related to the project.

Hydropedology Team: Isaac Hopkins is working on his Master thesis related to the Shale Hills CZO, Li Guo has used the Shale Hills CZO to collect GPR data to be part of his dissertation research, and the Shale Hills CZO has been used as a field laboratory for Soils 405/Geosci 405 Hydropedology class in the fall semester. A number of field trips with students have been made to this catchment.

Hydrogeophysics Team: Pallavi Chattopadhyay was a postdoc supported by this grant, who working on the wellbore analyses. Tim Gould, a BSc student in Geosciences, completed an honors thesis associated with distributed temperature sensing in neighboring Lake Perez, and Katy Kaproth-Gerecht, a PhD student, completed her MS on changes in temperature associated with storms in the Lake Perez.

Hydroclimatolgy Team: Yuning Shi, PostDoc researcher; Burkely Twiest, M.S./B.S. candidate, Meteorology, scheduled to graduate 2014; Ryan Kramer, B.S. Meteorology, Honors thesis on Shale Hills CZO research, graduated 2013.

Ecology Team: NA

Geomorphology Team: Ph.D. candidate Nicole West has continued to develop expertise in the analysis and interpretation of meteoric 10Be; in addition to sample preparation, she assisted in running the AMS at LLNL with Paul Bierman and Bob Finkel. She is also refining expertise in topographic analysis and the interpretation of landscape topography.

Postdoctoral researcher, Brian Clarke, developed his professional skills as leader of a research project in the seismic characterization of bedrock fracture density. Mentoring also occurred through direct interactions with co-PIs Kirby and Singha and through weekly meetings with other CZO postdoctoral researchers.

Under Kirby's guidance, postdoctoral researcher Brian Clarke mentored three undergraduate field assistants. Students were trained in GIS analyses, borehole data processing and analyses, cutting and characterization of rock core, making and interpreting petrologic thin sections, and field research techniques (shallow seismic, surveying, and bedrock mapping). Two of these students were supported as REU fellows (Neely, Bailey), and the other (Cannon) acted as a research assistant. Sandra Cannon will continue during her senior year at Penn State to work with outreach associated with the next phase of the CZO.

Infrastructure Team: As part of ongoing research installations at SSHCZO, undergraduate and graduate researchers are instructed in best practices for field instrumentation. Training includes sensor installation; datalogger operations, maintenance and troubleshooting; electrical systems and measurement theory; and data management methods. The Infrastructure team has worked closely with students in meteorology, hydrology and plant physiology to design and implement field research plans.

Seed Grant Teams

Diego Sanchez (UTEP undergraduate student) is trained to conduct U-series analysis at UTEP.

Training of undergraduates at UTEP for different types of chemical analyses, data analysis and geochemical modeling.

The data will be used in a master's thesis for a student at Temple University.

This seed project is providing new experiences in the field and lab for Lehigh Ph.D. candidate Johanna Blake.

One undergraduate and one graduate student were trained in sample preparation and analysis for % C and δ13C of leaf litter.

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

Hydroinformatics and Isotope Hydrology Team: 1) Attended and gave an invited presentation at the GeoBiology Conference Wujan, China, Sep 4-10, 2012 and field site visit to the Red Soils CZO in southern China.

Weathering & Soils Team: Invited talks in Lucerne, Switzerland on CZ science at SSHO; worked with scientists at Univ of Toulouse France

Biogeochemistry Team: NA

Hydropedology Team: NA

Hydrogeophysics Team: NA

Hydroclimatolgy Team: NA

Ecology Team: NA

Geomorphology Team: Results of Nicole West's research have been presented at national and international meetings, including the 2012 AGU Annual Fall Meeting and the 2013 EGU General Assembly. Initial results from Clarke's seismic surveys were presented at AGU in 2012, during a "show and tell" workshop for NSF at the BcCZO fall 2012, and at the SSHO all hands meeting in May 2013.

The more recent and complete results will be presented at the Fall 2013 GSA and AGU meeting. Clarke has been invited to give one of the keynote presentations at the NFS funded workshop on drilling and imaging the deep CZO in Denver

CO. Three manuscripts are in preparation that derives from research conducted in 2012-2013.

Infrastructure Team: Infrastructure developments in 2012-2013 will be part of larger outreach efforts to present real-time data as part of public displays at Shavers Creek Environmental Center. The Infrastructure team has shared information about sensor network development with staff from Christina River Basin CZO by email and via a one-day meeting and site visit in February 2013.

Seed Grant Teams

We will be presenting results at the Geological Society of America national meeting, at relevant CZO group meetings, and if applicable in a journal article (to be determined based on the interpretation of results).

Results from the seed grant are part of an abstract submitted by postdoctoral fellow Liz Hasenmueller for an oral presentation at the annual meeting of the American Geophysical Union.

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

Hydroinformatics and Isotope Hydrology Team: 1) The PI will complete Critical Zone science model survey for all CZO sites, Fall 2013. The idea is the first task of the CSDMS CZ Focus group that Duffy chairs and will be presented at the 2014 annual meeting. 2) Develop first HPC version of PIHM applied to Juniata River basin. 3) Complete Hydrologic models for SoilTrEC sites (Plynlimon, Damma) as part of the SoilTrEC CZO model sharing.

Weathering & Soils Team: Pam Sullivan is writing a paper on modeling weathering

Biogeochemistry Team: To accomplish the remaining goals of the project, both the Jin et al. and Hasenmueller et al. manuscripts will be submitted. Toward the understanding of nitrogen gas dynamics in the watershed, Weitzman will continue to sample for the next reporting period and then will process and analyze these for a thesis chapter and future publication. The root trenching project will commence in late August 2013. Sample and data analyses for this project will occur in the fall and winter for 2013, and will lead to the submission of a publication in 2014.

Hydropedology Team: NA

Hydrogeophysics Team: In this next year, we plan to coordinate the analysis of all wireline logs with information on the structural geology of the site and neighboring outcrops, and complete publication of this work.

Hydroclimatolgy Team: NA

Ecology Team: NA

Geomorphology Team: NA

Infrastructure Team: Work is ongoing to complete the infrastructure and database goals, with a targeted launch in Fall 2013. Remaining tasks include installation of wireless radios and implementation of the automated data archiving system. The Infrastructure team is coordinating with the Cyberspecialist and PSU Information Technology specialists to complete these tasks.

Seed Grant Teams

All U-series data are expected to available by the end of Oct, 2013. Results will be expected to submit to AGU 2013.

To finish d13CCO2 analysis for gas samples and d34SSO4 for natural waters (Sept 2013); download short-term soil respiration data from CZO website, and compare it to the long-term organic matter decomposition rate (Sept 2013); literature search for S isotopes of different end-members (pyrite vs. acid rain) and put measured d34SSO4 values at Shale Hills into a mixing model (Oct-Dec 2013); write up a manuscript and submit it to Geochimica et Cosmochimia Acta (Jan-Apr 2014).

We will continue working on data processing to refine the GPR images and make comparisons with the dye trace. We are also working on whether the surface topography reflects features in the top of bedrock mapped with the GPR. More

detailed reports (and the thesis) will be written after further data evaluation.

The team has already coordinated with other Shale Hills researchers to describe and sample a series of trenches that are planned for excavation in August, 2013. Otherwise, the research is on track to complete analysis of collected samples in the Fall, 2013.

In August of 2013 tree-ring samples will be collected and analyzed to measure annual radial growth increments of trees over the past 50-100+ years in the SSHO watershed. Annual growth increments will be used to reconstruct wood productivity through time, and time series of wood productivity will be compared to climate and competition from surrounding trees to identify where productivity is sensitive to drought stress in the watershed. Similarly, the δ13C leaf litter values from 35 points across the watershed will be compared among topographic characteristics such as aspect (N vs. S), slope position (valley bottom, hillside, ridge top), and swale vs. planar position. We hypothesize that trees growing on dryer sites such as southern aspects or ridge tops will have heavier isotopic signatures due to greater drought stress, and the data produced by the seed grant wil test this hypothesis. Data analyzed in August will be incorporated in to two manuscripts to be submitted for publication in fall 2013; one quantifying the ANPP budget of the CZO watershed and another relating above- and below-ground carbon cycling in the watershed.

Products

Books

Book Chapters

Conference Papers and Presentations

Jin, L., Ogrinc, N., Yesavage, T., Kaye, J.P., Brantley, S.L. (2012). *Drawdown of atmospheric CO2 by gray shale weathering: insights from carbon, sulphur, and oxygen isotope systematics in the Susquehanna Shale Hills Critical Zone Observatory*. 2012 Annual Meeting of the American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Singha, K., White, T., Perron, J. T., Chattopadhyay, P. B., Duffy, C. (2012). *Fracture Patterns within the Shale Hills Critical Zone Observatory (invited)*. EOS Trans. of the Fall Meeting of the American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jacob, R., Singha, K. (2012). *Micro-gravity measurements to constrain permeability in the Shale Hills Critical Zone Observatory*. SEG-AGU Workshop on Hydrogeophysics. Boise, ID. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Inventions

Nothing to report.

Journals

Banwart SA, Bernasconi S, Bloem J, Blum W, de Souza DM, Chabaux F, Duffy C, Lundin L, Kram P, Nikolaidis N, Novak M, Panagos P, Ragnarsdottir KV, Reynolds B, Robinson D, Rousseva S, de Ruiter P, van Gaans P, Weng L, White T, Zhang B (2012). Soil Processes and functions across an International Network of Critical Zone Observatories: Introduction to experimental methods and initial results. *Comptes Rendu Geosciences*. 344 758. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Brantley, S.L., Holleran, M., Jin, L., Bazilevskaya, E. (2013). Probing deep weathering in the Shale Hills Critical Zone Observatory, Pennsylvania (USA): The hypothesis of nested chemical reaction fronts in the subsurface.. *Earth Surface Processes and Landforms*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/esp.3415

Chattopadhyay, P. B., Singha, K., Gooseff, M.N. (2012). Exploring controls on saline tracer movement within the hyporheic zone using finite-element modeling and electrical resistivity. *EOS Trans. AGU Fall Meet. Suppl. (Abstract)*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Christopher Duffy, Yolanda Gil, Ewa Deelman, Suresh Marru, Marlon Pierce, Ibrahim Demir and Gerry Wiener (2012). Designing a roadmap for geoscience workflows. *EOS, Transactions American Geophysical Union*. 93 (24), 225. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1029/2012EO240002

Dere, A. L., White T. S., April R. H., Reynolds B., Miller T. E., Knapp E. P., McKay L. D. and Brantley S. L (2013). Climate dependence of feldspar weathering along a latitudinal gradient. *Geochim. Cosmochim. Acta*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Graham, C., and H.S. Lin (2012). The Hydropedograph toolbox. *Hydrol. Earth Syst. Sci. Discuss*. 9 14231. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/hessd-9-14231-2012

Guo, L., H.S. Lin, and J. Chen. (2013). Subsurface Lateral Flow Network on a Hillslope Revealed by Time-lapse Ground Penetrating Radar. *Water Resource Research*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Jin, L., Mathur, R., Rother, G., Cole, D.R., Bazilevskaya, E., Williams, J., Carone, A. and Brantley, S.L (2013). Evolution of porosity and geochemistry in Marcellus Formation black shale during weathering. *Chemical Geology*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.chemgeo.2013.07.012

Kaproth-Gerecht, K.E., Gooseff, M.N., Singha, K (2013). Anomalous stream temperature warming in response to storms in a forested headwater stream. *Environmental Research Letters*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Leonard, L. and C. Duffy (2013). HydroTerre: Cyber infrastructure for Distributed Water Resource Modeling: A National Prototype for Model-Data Web Services and Workflows. *Environmental Modeling and Software*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Liu, H., and H.S. Lin (2013). Temporal and Spatial Patterns of Preferential Flow Occurrence in the Shale Hills Catchment: From the Hillslope to the Catchment Scales. *Water Resource Research*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Liu, J., X. Chen, H.S. Lin, H. Liu, and H. Song (2013). A simple geomorphic-based analytical model for predicting the spatial distribution of soil thickness in headwater hillslopes and catchments. *Water Resource Research*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Ma, L., Chabaux, F., West, N., Kirby, E., Jin, L., and Brantley, S. (2013). Regolith production and transport in the Susquehanna Shale Hills Critical Zone Observatory, Part 1: Insights from U-series isotopes. *Journal of Geophysical Research, Earth Surface*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/jgrf.20037

Meinzer, F.C., D.R. Woodruff, D.M. Eissenstat, H.S. Lin, T. Adams, K.A. McCulloh (2013). Above- and below ground controls on water use by trees of different wood types in an eastern United States deciduous forest. *Tree Physiology*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: DOI: 10.1093/treephys/tpt012

Miller, S.R., Sak, R.B., Kirby, E., and Bierman, P.R. (2013). Neogene rejuvenation of central Appalachian topography: Evidence for differential rock uplift from stream profiles and erosion rates. *Earth and Planetary Science Letters*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.epsl.2013.04.007

Naithani K.J., Baldwin D., Gaines K., Lin H. & Eissenstat D.M. (2013). Spatial distribution of tree species governs the spatio-temporal interaction of leaf area index and soil moisture across a forested landscape. *PLoS ONE*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1371/journal.pone.0058704

Shi, Y., K. J. Davis, F. Zhang, and C. J. Duffy (2013). Development of a coupled land surface hydrologic model and

evaluation at a critical zone observatory. *Journal of Hydrometeorology*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1175/JHM-D-12-0145.1

Shi, Y., K. J. Davis, F. Zhang, and C. J. Duffy (2013). Evaluation of the parameter sensitivity of a coupled land surface hydrologic model. *Journal of Hydrometeorology*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Shi, Y., K. J. Davis, F. Zhang, C. J. Duffy, and X. Yu (2013). Parameter estimation of a physically-based land surface hydrologic model using the ensemble Kalman Filter: A real-data experiment. *Monthly Weather Review*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Shi, Y., K. J. Davis, F. Zhang, C. J. Duffy, and X. Yu (2013). Parameter estimation of a physically-based land surface hydrologic model using the ensemble Kalman Filter: A synthetic experiment. *Water Resources Research*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Shuangcai Li and Christopher J. Duffy (2012). Fully-Coupled Modeling of Shallow Water Flow and Pollutant Transport on Unstructured Grids. *Procedia Environmental Sciences*. 13 2098. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.proenv.2012.01.200

Thomas, E., Lin, H., Duffy, C., Sullivan, P., Holmes, G. H., Jin, L., and Brantley, S. L. (2013). Spatiotemporal patterns of water stable isotope compositions at the Shale Hills Critical Zone: Linkages to subsurface hydrologic processes. *Vadose Zone Journal*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

West, N., Kirby, E., Bierman, P., Slingerland, R., Ma, L., Rood, D., and Brantley, S. L. (2013). Regolith production and transport at the Susquehanna Shale Hills Critical Zone Observatory: Part 2 - Insights from meteoric 10Be. *Journal of Geophysical Research, Earth Surface*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Xianzeng Niu, Jennifer Z. Williams, Doug Miller, Kerstin Lehnert, Brian Bills, Susan L. Brantley (2013). An Ontology Driven Relational Geochemical Database for the Earth's Critical Zone: CZchemDB. *Journal of Environmental Informatics*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Xuan Yu, Anna Lamačová, Christopher Duffy, Pavel Krám, Tim White and Jakub Hruka (2013). Modeling long term water yield effects of forest management in a Norway spruce forest. *Water Research*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Yu, X., Bhatt, G., Duffy C. J., and Shi, Y. (2013). Parameterization for distributed watershed modeling using national data and evolutionary algorithm. *Computers & Geosciences*. 58 80. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.cageo.2013.04.025

Zhang, J., H.S. Lin, and J. Doolittle (2013). Soil Layering and Preferential Flow Impacts on Seasonal Changes of GPR Signals in Two Contrasting Soils. *Geoderma*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Zhao, Y., J. Yi, R. Hill, and H.S. Lin. (2013). Identifying Subsurface Preferential Flow by Multi-dimensional Modeling approach: A Case Study in the Shale Hills Catchment. *Vadose Zone Journal*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Licenses
Nothing to report.

Other Products
Databases.

Continued support of CZchemDB - A relational database, CZchemDB, which contains soil geochemical data collected at the SSHCZO as well as additional soil data, legacy and other CZO's.

Audio or Video Products.

Susquehanna Shale Hills videos showing current research in the catchment, located at https://criticalzone.org/shale-hills/news/story/susquehanna-shale-hills-czo-videos/

Audio or Video Products.

The animation (at https://criticalzone.org/shale-hills/news/story/catchment-wide-model-predictions-lead-to-animation-of-the-czo) shows the evolution of soil saturation ratio (averaged over the entire soil column) distribution at SSHCZO for the year 2009 as predicted by Flux-PIHM.

Other Publications

Patents
Nothing to report.

Technologies or Techniques
Nothing to report.

Thesis/Dissertations
Smith, L.. *Aboveground carbon distribution across a temperate watershed, pp. 72 (Master of Science Thesis)*. (2013). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Herndon, E.. *Biogeochemistry of manganese contamination in a temperate forested watershed, pp. 290. (PhD. Dissertation)*. (2012). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Bingham, N.. *C, N, and Mn in Shale Profiles along a Climate Gradient, pp 49. (Undergraduate Honors Thesis)*. (2013). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Neely, A.. *Characterizing the Recent Cenozoic Erosional History of the Appalachian Mountains through Spatial Variation in Stream Profile Metrics across the Allegheny Front, pp. 34 (Undergraduate Honors Thesis)*. (2013). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Trowbridge, P.. *Rose Hill Shale Weathering across a Climate Gradient in the Appalachian Mountains, pp 118 (Undergraduate Thesis)*. (2013). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Thomas, E.. *Spatial and Temporal Patterns of Water Stable Isotope Compositions at the Susquehanna-shale Hills Critical Zone Observatory, pp. 118 (Master of Science Thesis)*. (2013). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Gorski, I.. *The Use of Water Sensors to Examine Water Chemistry Related to Marcellus Shale Natural Gas Development, pp. 87 (Undergraduate Honors Thesis)*. (2013). The Pennsylvania State University. Acknowledgement of Federal Support = Yes

Websites
Data Site for the Shale Hills CZO
http://www.czo.psu.edu/data_agreement.html

Data overview and data flow process for the Susquehanna Shale Hills CZO.

Shale Hills Critical Zone Observatory
https://criticalzone.org/shale-hills

Part of the National CZO website. Maintained locally and updated with current news and events at the Shale Hills CZO.

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month

		Worked
Brantley, Susan	PD/PI	1
Duffy, Christopher	Co PD/PI	1
Eissenstat, David	Co PD/PI	1
Kirby, Eric	Co PD/PI	1
Davis, Kenneth	Co-Investigator	1
Kaye, Jason	Co-Investigator	1
Lin, Henry	Co-Investigator	1
Jin, Lixin	Faculty	1
Kaye, Margot	Faculty	1
Ma, Lin	Faculty	1
Nyquist, Jonathan	Faculty	1
Pazzaglia, Frank	Faculty	1
Peters, Stephen	Faculty	1
Toran, Laura	Faculty	1
Chattopadhyay, Pallavi	Postdoctoral (scholar, fellow or other postdoctoral position)	10
Clarke, Brian	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Hasenmueller, Elizabeth	Postdoctoral (scholar, fellow or other postdoctoral position)	10
Shi, Yuning	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Sullivan, Pamela	Postdoctoral (scholar, fellow or other postdoctoral position)	11
Arthur, Daniel	Other Professional	6
Duffy, Colin	Other Professional	1

Neal, Andrew	Other Professional	11
Williams, Jennifer	Other Professional	12
Adams, Thomas	Technician	1
Berger, William	Graduate Student (research assistant)	6
Bhatt, Gophal	Graduate Student (research assistant)	6
Carter, Megan	Graduate Student (research assistant)	6
Dere, Ashlee	Graduate Student (research assistant)	6
Gaines, Katie	Graduate Student (research assistant)	6
Gu, Xin	Graduate Student (research assistant)	0
Hopkins, Isaac	Graduate Student (research assistant)	6
Kaproth-Gerecht, Katy	Graduate Student (research assistant)	6
Rollinson, Christine	Graduate Student (research assistant)	1
Smith, Lauren	Graduate Student (research assistant)	6
Thomas, Evan	Graduate Student (research assistant)	6
Twiest, Burkley	Graduate Student (research assistant)	6
Weitzman, Julie	Graduate Student (research assistant)	6
West, Nicole	Graduate Student (research assistant)	6
Yesavage, Tiffany	Graduate Student (research assistant)	3
Yu, Xuan	Graduate Student (research assistant)	6
Zhang, Yu	Graduate Student (research assistant)	6
Bingham, Nina	Undergraduate Student	3
Cannon, Sandra	Undergraduate Student	2
Fedkin, Nikita	Undergraduate Student	1
Fisher, Jessica	Undergraduate Student	1
Gould, Timothy	Undergraduate Student	0

Jones, Ryan	Undergraduate Student	1
Kramer, Ryan	Undergraduate Student	0
McClure, Brianna	Undergraduate Student	1
Tapia, Everado	Undergraduate Student	1
Bailey, Gregory	Research Experience for Undergraduates (REU) Participant	2
Neely, Alexander	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: Research; mentoring of postdocs and students; overall supervision of project

Funding Support: none

International Collaboration: No
International Travel: Yes, France - 0 years, 0 months, 6 days

Christopher J Duffy
Email: cxd11@psu.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: research; mentoring of postdocs and students

Funding Support: none

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: research; mentoring of postdocs and students

Funding Support: none

International Collaboration: No
International Travel: No

Eric Kirby
Email: Eric.Kirby@geo.oregonstate.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Research; mentoring of postdocs and students

Funding Support: none

International Collaboration: No
International Travel: No

Kenneth Davis
Email: kjd10@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Research; mentoring of postdocs and students

Funding Support: none

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: Research; mentoring of postdocs and students

Funding Support: none

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: Research; mentoring of postdocs and students

Funding Support: none

International Collaboration: No
International Travel: No

Lixin Jin
Email: ljin@utep.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: received seed grant to perform research at the Shale Hills CZO

Funding Support: none

International Collaboration: No
International Travel: No

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

Contribution to the Project: received seed grant funding to conduct research at Shale Hills CZO site.

Funding Support: none

International Collaboration: No
International Travel: No

Lin Ma
Email: lma@utep.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: received seed grant to conduct research at the Shale Hills CZO site

Funding Support: none

International Collaboration: No
International Travel: No

Jonathan Nyquist
Email: nyq@temple.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: received seed grant to conduct research at the Shale Hills CZO.

Funding Support: None

International Collaboration: No
International Travel: No

Frank Pazzaglia
Email: fjp3@lehigh.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: received seed grant to conduct research at the Shale HIlls CZO

Funding Support: none

International Collaboration: No

International Travel: No

Stephen Peters
Email: scp2@lehigh.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: received seed grant to conduct research at Shale Hills CZO

Funding Support: none

International Collaboration: No
International Travel: No

Laura Toran
Email: ltoran@temple.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: received seed grant to conduct research at the Shale Hills CZO

Funding Support: None

International Collaboration: No
International Travel: No

Pallavi Chattopadhyay
Email: puc16@psu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 10

Contribution to the Project: research collaboration

Funding Support: a previous CZO NSF award

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: 12

Contribution to the Project: research collaboration

Funding Support: none

International Collaboration: No
International Travel: No

Elizabeth Hasenmueller
Email: eah262@psu.edu

Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 10

Contribution to the Project: research collaboration

Funding Support: none

International Collaboration: No
International Travel: No

Yuning Shi
Email: yshi@psu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12

Contribution to the Project: research collaboration

Funding Support: none

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: 11

Contribution to the Project: research collaboration

Funding Support: none

International Collaboration: No
International Travel: Yes, France - 0 years, 0 months, 14 days

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Daniel K. Arthur
Email: dka12@psu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 6

Contribution to the Project: cyperberspecialist, website development

Funding Support: none

International Collaboration: No
International Travel: No

Colin Duffy
Email: cmduffy@engr.psu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: technical and logistical support

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Funding Support: previous NSF CZO award

International Collaboration: No
International Travel: No

Andrew Neal
Email: aln16@psu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 11

Contribution to the Project: watershed specialist

Funding Support: none

International Collaboration: No
International Travel: No

Jennifer Williams
Email: jzw126@psu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: project and data coordinator

Funding Support: none

International Collaboration: No
International Travel: No

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

Contribution to the Project: research; field work

Funding Support: none

International Collaboration: No
International Travel: No

William E Berger
Email: web5015@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection and analysis

Funding Support: This and the previous CZO NSF award

International Collaboration: No
International Travel: No

Gophal Bhatt
Email: gxb913@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection and analysis

Funding Support: previous NSF CZO award

International Collaboration: No
International Travel: No

Megan Carter
Email: mqc5286@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection and analysis

Funding Support: other NSF awards

International Collaboration: No
International Travel: No

Ashlee Dere
Email: ald271@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection and analysis

Funding Support: CarbonEarth Fellowship

International Collaboration: No
International Travel: No

Katie Gaines
Email: kap226@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection and analysis

Funding Support: previous NSF CZO award

International Collaboration: No
International Travel: No

Xin Gu
Email: xug102@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 0

Contribution to the Project: research; data collection

Funding Support: none

International Collaboration: No
International Travel: No

Isaac Hopkins
Email: ieh105@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection

Funding Support: none

International Collaboration: No
International Travel: No

Katy Kaproth-Gerecht
Email: kgerecht@mines.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research

Funding Support: previous CZO award

International Collaboration: No
International Travel: No

Christine Rollinson
Email: crr173@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: research; data collection and analysis

Funding Support: none

International Collaboration: No
International Travel: No

Lauren Smith
Email: las586@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection

Funding Support: other federal grants

International Collaboration: No

International Travel: No

Evan Thomas
Email: emt175@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection

Funding Support: other federal grants

International Collaboration: No
International Travel: No

Burkley Twiest
Email: blt5086@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection

Funding Support: other federal grants

International Collaboration: No
International Travel: No

Julie Weitzman
Email: jnw142@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection

Funding Support: This and other federal grants

International Collaboration: No
International Travel: No

Nicole West
Email: nxw157@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection and analysis

Funding Support: NASA Fellowship

International Collaboration: No
International Travel: No

Tiffany Yesavage
Email: tay120@psu.edu

Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: research; data collection and analysis

Funding Support: NASA award

International Collaboration: No
International Travel: No

Xuan Yu
Email: xxy113@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection

Funding Support: other federal grants

International Collaboration: No
International Travel: No

Yu Zhang
Email: yzz130@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: research; data collection

Funding Support: other federal grants

International Collaboration: No
International Travel: No

Nina Bingham
Email: nlb5110@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: research; data collection and analysis for senior thesis work

Funding Support: this nsf award

International Collaboration: No
International Travel: No

Sandra Cannon
Email: sec5260@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: field work; data collection

Funding Support: this NSF award

International Collaboration: No
International Travel: No

Nikita Fedkin
Email: nmf150@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: some field and laboratory experience

Funding Support: none

International Collaboration: No
International Travel: No

Jessica Fisher
Email: jqf5226@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: some field and laboratory work

Funding Support: none

International Collaboration: No
International Travel: No

Timothy Gould
Email: twg5075@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 0

Contribution to the Project: undergraduate research

Funding Support: none

International Collaboration: No
International Travel: No

Ryan Jones
Email: rmj5093@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: lab/field assistant

Funding Support: previous CZO award

International Collaboration: No
International Travel: No

Ryan Kramer
Email: rjk5079@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 0

Contribution to the Project: undergraduate research

Funding Support: none

International Collaboration: No
International Travel: No

Brianna McClure
Email: bem5150@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: some field and laboratory work

Funding Support: none

International Collaboration: No
International Travel: No

Everado Tapia
Email: ezt5005@psu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: created an outreach video of research being done at Shale Hills

Funding Support: none

International Collaboration: No
International Travel: No

Gregory Bailey
Email: gmb5128@psu.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: field work; data collection

Funding Support: none

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: The Pennsylvania State University
Government fiscal year(s) was this REU participant supported: 2013

Alexander Neely

Email: abn5031@psu.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2

Contribution to the Project: field work; data collection

Funding Support: none

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: The Pennsylvania State University
Government fiscal year(s) was this REU participant supported: 2013

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Colorado School of Mines	Academic Institution	Golden, CO
Lehigh University	Academic Institution	Bethlehem, PA
Temple University	Academic Institution	Philadelphia, PA
University of Texas El Paso	Academic Institution	El Paso, TX

Full details of organizations that have been involved as partners:

Colorado School of Mines

Organization Type: Academic Institution
Organization Location: Golden, CO

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Kamini Singha, a former Penn State faculty member who is now with the Colorado School of Mines, is still collaborating with colleagues on CZO research.

Lehigh University

Organization Type: Academic Institution
Organization Location: Bethlehem, PA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Faculty from Lehigh received seed grant funding to conduct research at the Shale Hills CZO.

Temple University

Organization Type: Academic Institution
Organization Location: Philadelphia, PA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Faculty from Temple received seed grant funding to conduct research at the Shale Hills CZO.

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: Faculty from Texas El Paso received a seed grant to conduct research related to the Shale Hills CZO

Have other collaborators or contacts been involved? No

Impacts

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

Hydroinformatics and Isotope Hydrology Team: Duffy is working with national partners to develop strategies for sharing data and models for catchment simulation and prediction. The Penn State model has more than 50 dedicated users who are developing their own models at field sites around the world.

Weathering & Soils Team: We have been promoting the idea of earthcasting. Toward this end, we are developing ways to use PIHM with WITCH and PIHM with CrunchFlow.

Biogeochemistry Team: The results for the gas studies have established the importance of topographic position on gas dynamics.

Hydropedology Team: 1) a new GPR protocol has been developed for revealing and visualizing subsurface lateral flow, which can facilitate hillslope hydrologic and hydropedologic studies; 2) the first extensive quantification of preferential flow occurrence across the Shale Hills catchment has been conducted, which provides a means of detecting subsurface flow network at the catchment scale.

Hydrogeophysics Team: Among the most challenging and difficult problems in hydrogeology are ones involving flow in fractured rock. Here, we move toward understanding the “depth of active flow” within a watershed setting and the controls on bedrock permeability to flow by obtaining geometric information on fractures and their hydraulic connectivity. The results of our temperature data are important, as 95% of streams and 73% of total stream length in the US are headwater streams that are disproportionately responsible for temperature-sensitive ecosystem services such as nutrient uptake and transformation that impact downstream water quality. These headwaters also provide habitat for many invertebrates and fish. Furthermore, because we have observed that this stream temperature response is related to storm intensity, we expect that this phenomenon could become more frequent and widespread as high-intensity storms become more common in a changing climate, particularly in warm and humid regions.

Hydroclimatolgy Team: Wind, temperature, and net radiation data below canopy from March-June will be available for use by all disciplines.

Ecology Team: NA

Geomorphology Team:

Infrastructure Team: Work by the SSHCZO Infrastructure Team includes a mix of low-cost, open-source equipment and OEM-specific software solutions to create a hybrid wireless network. Development of the sensor network has led to important understanding in the particular problems faced by long-term, environmental sensor networks, specifically power, communications fidelity and bandwidth. Complete OEM systems are often prohibitively expensive for research purposes, but the hybrid system developed at SSHCZO reduces cost while producing a reliable network for intensively instrumented, small scale applications. We anticipate SSHCZO becoming a model for this type of research infrastructure and building a knowledge base that can be shared with other institutions.

Seed Grant Teams

The U-series isotope data from the shale weathering transect is an extension of the U-series work at Shale Hills and will provide critical information on the control of climate on shale weathering. The results will be of interests to the science community who study chemical weathering, soil formation, and Critical Zone processes.

Develop C and S isotopes as tracers to understand relative proportions of silicate versus carbonate dissolution reactions on shale terrenes and the types of weathering agents involved in Shale Hills

We expect improved use of GPR for characterization based on our dye studies.

Aboveground net primary productivity has been estimated in northeastern temperate forests with plot-level measurements that provide average values used to represent large forest areas. Spatially-explicit ANPP values calculated for the SSHO CZO show complex heterogeneity in ANPP across the watershed (Fig. 1), highlighting the potential for plot-level measurements to inadequately capture the full range of productivity in a watershed. The ANPP data produced by the seed grant can be used in multivariate spatial models to predict productivity as a function of abiotic and biotic environmental characteristics, thereby improving our ability to model ANPP as a function of topographic position and forest composition.

What is the impact on other disciplines?

Hydroinformatics and Isotope Hydrology Team: Duffy is working on several short-term EarthCube projects at present and was recently recommended for funding under the NSF INSPIRE: CREATIV program in a multi-directorate study linking models and data in collaboration with the GLEON limnology community. Title: INSPIRE Track 1: The Age of Water and Carbon in Hydroecological Systems: A New Paradigm for Science Innovation and Collaboration through Organic Team Science. This work will be an outreach effort from our work at Shale Hills Isotope Network and model development for tracing water in lake-catchment systems in the northern US.

Weathering & Soils Team: Geochemists are now working with meteorologists on C and water cycling

Biogeochemistry Team: NA

Hydropedology Team: Our work has promoted the interdisciplinary work with hydrogeophysics, plant physiology, and isotope hydrology.

Hydrogeophysics Team: NA

Hydroclimatolgy Team: NA

Ecology Team: NA

Geomorphology Team: NA

Infrastructure Team: When complete, the new automated database will be a valuable resource for SSHCZO researchers as well as external investigators interested in existing data resources. The database and web service will provide easy access to current and legacy datasets and will reduce the time and effort required to provide researchers with access to data across disciplines. By lowering disciplinary barriers, this data infrastructure, built on the sensor network, will facilitate greater interdisciplinary activity at SSHCZO.

Seed Grant Teams: NA

What is the impact on the development of human resources?

Hydroinformatics and Isotope Hydrology Team: NA;

Weathering & Soils Team: Several undergraduates worked in my lab and several grad students

Biogeochemistry Team: NA

Hydropedology Team: We have used the Shale Hills CZO as a platform to enrich the experience of two visiting scientists from China as well as the training for a Master student and a couple of undergraduate students working in the Shale Hills.

Hydrogeophysics Team: NA

Hydroclimatolgy Team: NA

Ecology Team: NA

Geomorphology Team: NA

Infrastructure Team: The infrastructure team has made their expertise available to SSHCZO researchers and students to demonstrate best practices for designing, programming, installing, and maintaining sensor systems for CZ applications. For students, this training provides valuable practical skills associated with their research.

Seed Grant Teams:

This research provided data for a Temple student's MS thesis

Formal field and lab training for Ph.D. candidate Johanna Blake.

What is the impact on physical resources that form infrastructure?

Hydroinformatics and Isotope Hydrology Team: NA

Weathering & Soils Team: We drilled several more wells at SSHO

Biogeochemistry Team: The addition of gas samplers in watershed will increase the use of the Kaye laboratories facilities.

Hydropedology Team: Our real-time soil moisture monitoring network contributes to the CZO's infrastructure.

Hydrogeophysics Team: We have drilled a series of new wells within the watershed: three 7 m holes at the ridgetop and one set of 2-m deep geoprobe wells across a north-south transect in the eastern part of the watershed.

Hydroclimatolgy Team: NA

Ecology Team: NA

Geomorphology Team: NA

Infrastructure Team: The infrastructure team manages the sensor and communications network, as well as the physical infrastructure (including electrical power and field equipment) associated with SSHCZO activities. The team works in coordination with the PSU Director of Forestlands and SSHCZO project management staff to ensure that ongoing research is sensitive to all needs at Shale Hills. As new research is proposed, the infrastructure team will continue to collaborate with PSU researchers and other partners to build the observational network and database to support continued scientific discovery.

Seed Grant Teams

More extensive use of geophysics in the CZO could greatly expand site characterization.

What is the impact on institutional resources that form infrastructure?
Nothing to report.

What is the impact on information resources that form infrastructure?
Nothing to report.

What is the impact on technology transfer?
Nothing to report.

What is the impact on society beyond science and technology?
Nothing to report.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

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.