Preview of Award 1239285 - Final Project Report

Cover

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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: This team is analyzing the distribution of soils in the Shavers creek watershed.

Biogeochemistry Team: Our overall goal was to quantify the role of biota in controlling the distribution of acids and oxygen that promote weathering in shale. Our specific goals were to conduct a trenching experiment that allowed us to examine the chemistry of the root-rock interface and to monitor the depth distribution of soil gases along topographic gradients.

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.

Hydroclimatology Team: Evaluate the importance of topography, watershed lithology and land use on the interaction between the carbon and water cycles.

Expand on what we have learned at the Shale Hills watershed to the Shavers Creek watershed, and combine the strength of a high-fidelity model, i.e., Flux-PIHM, and a “minimum” observing system, i.e., a re-locatable multi-sensor measurement array, to provide realistic land surface and hydrologic reanalysis and projections of the Shavers Creek watershed.

Ecology Team: Our overall goal was to work with the *Biogeochemistry Team* to assess the role of biota in controlling the distribution of acids and oxygen that promote weathering in shale. Our specific goals were to assess root function with soil depth along topographic gradients using trenches.

Geomorphology Team: The geomorphology team had two primary goals: 1) to test the dependence of the efficiency of regolith transport on hillslope aspect, and 2) 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 the 2013-2014 period was deployment of a wireless network system, including automated data retrieval and storage. Data from several sites are already being collected wirelessly with more sites expected to come on line in the coming months. The ongoing focus of the infrastructure team is the maintenance of existing sensor systems at Shale Hills and data archiving.

Seed Grant Teams

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

UTEP, Jin: Using C and S isotopes and elemental mass balance to determine the CO2 consumption potential of gray shales during weathering

PSU, M. Kaye: To provide foliar chemistry and tree stem growth data necessary to estimate aboveground net primary productivity (ANPP) for the watershed.

UTEP, L. Ma: The major goal of the U-series team at UTEP is to investigate regolith formation rates with U-series isotopes along a shale weathering transect, developed mainly on Fe-rich, organic-poor Silurian shale units along a latitudinal climate gradient in eastern United States and Wales.

Lehigh: The major goals of the Lehigh seed grant project are to understand geomorphological, geochemical, and hydrological processes in the context of detailed hillslope stratigraphy and pedology.

*** 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: High frequency sampling of water stable isotopes were employed to improve the understanding of the spatial and temporal drivers of subsurface hydrologic processes at the SSHCZO . Hillslope orientation, slope location, landform type, and soil depth were examined with respect to soil water isotope signatures to determine water flowpaths associated with specific soil or landscape features.

Weathering & Soils Team: The team pursued models of soil formation and porewater chemical evolution.

Biogeochemistry Team: We monitored soil CO2, O2 and N2O concentrations at multiple depths throughout the soil profile at ridgetop, mid slope, and valley floor positions along two catenas; one planar catena and one swale catena. We used a backhoe and jackhammer to excavate pits through soil and fractured shale into shale bedrock. We quantified the distribution of roots into the rock and collected samples to analyze the chemistry of the root rock interface.

Hydropedology Team:

- Real-time soil moisture monitoring
- Ground-penetrating radar investigations

Hydrogeophysics Team: To determine the controls on the spatial variation in the subsurface porosity, lithology, density, saturation and weathering, two seismic surveys were collected along the north and south ridgetops at SSHCZO using two Geometric Geode seismographs with a laptop controller and 34 Sercel L-28 high-frequency geophones spaced equidistant along the survey line. Optical televiewer (OTV) logs were at all newly installed ridgetop boreholes (CZMW5-8) to characterize fracture patterns, lithology and weathered zones at depth within each well.

Hydroclimatology Team: The hydroclimatology compared Flux-PIHM and Biome-BGC predictions of discharge, soil water content, soil temperature, and evapotranspiration with observations at Shale Hills. Biome-BGC carbon flux and LAI predictions have been evaluated.

A solar position algorithm (SPA) has been added to Flux-PIHM, adding the ability to calculate solar radiation taking into account slope, aspect, shading of nearby terrain, and the ratio between incoming direct and diffuse solar radiation.

PIHM has been implemented in the new CZO site, the Garner Run watershed.

Ecology Team: We monitored root distribution by coring and profile wall mapping throughout the soil profiles at ridgetop, mid slope and valley floor positions along two catenas: one planar and one swale. Respiration and morphology of roots were also assessed in relationship to depth and topographical position.

Geomorphology Team: Our activities fall into three primary categories: 1) we analyzed samples of regolith for meteoric 10Be concentrations 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 logged fracture density and geotechnical properties in a deep borehole along the southern ridgecrest to validate fracture density inferred from geophysics.

Infrastructure Team: Major tasks for the infrastructure team included, installation and testing of wireless radios (XBEE 900MHz); implementation of an automated data

retrieval and storage system; with Cyberspecialist, development of a SQL Server database to store data collected from the sensor network.

Data Management Team: Created CZO Display files for 160 of 176 data files, with corresponding metadata header files, and submitted them for ingest into CZO Geoportal and further cataloging by CUAHSI HIS. Set up Microsoft SQL Server database for CZO data, including automated batch download of sensor data. Created Google MapsTM-based GIS instrument and sampling site map of Shale Hills field site, located at http://www.czo.psu.edu/data_overview.html.

Seed Grant Teams

Temple: Conducted a tracer test of artificial infiltration and monitored hydrologic processes using ground penetrating radar.

UTEP, Jin: Field - at Susquehanna Shale Hills Critical Zone Observatory: (1) Collected soil water along the southern planar transect, streams at three locations, and nine groundwater samples along the valley, in early Spring and late Fall; (2) Collected soil soil gas samples along two southern transects in early Spring and late Fall; and (3) Received archived soil and rock samples.

PSU, M. Kaye: Radial growth of trees in the watershed was measured with two approaches: 1) 2013 growth was measured with dendrobands installed on 100 stems in the CZO and 2) measuring annual growth for 100+ years in 153 trees (7% of trees) from 11 dominant tree species in the forest.

UTEP, L. Ma: U-series team: about 30 soil samples from Puerto Rico, Alabama, and Tennessee ridge top sites were analyzed for U and Th concentrations and isotopic compositions at the U-series isotope laboratory in University of Texas at El Paso.

Lehigh: The Lehigh seed grant team engaged in three primary activities: (1) excavation to bedrock and field description of soil pits in the Shale Hills and Missed Grouse watersheds, (2) collection of samples at 10-20 cm intervals in these pits, and (3) characterization of the samples.

Specific Objectives:

Hydroinformatics and Isotope Hydrology Team: To elucidate near surface hydrologic processes using water isotopes.

Weathering & Soils Team: To gain a further understanding of the existence, development and prevalence of nested chemical weathering reaction fronts and to create a model of soil formation and porewater chemistry using WITCH, in collaboration with Yves Godderis of Univ of Toulouse.

Biogeochemistry Team: To elucidate C and N dynamics and cycling in temperate watershed developing on shale and specifically, to identify spatial variability of soil gas within the watershed, and quantify 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 To determine the role of lithology on the evolution of protolith to regolith and its influence on the hydrologic patterns (i.e., groundwater residence

time, groundwater-surface water interactions and flow paths).

Hydroclimatology Team: Compare Flux-PIHM and Biome-BGC predictions with field observations to study the strength and weaknesses of both models.

Couple Flux-PIHM and Biome-BGC to produce a high-resolution carbon-hydrology modeling system for the study of water-carbon interaction.

Ecology Team: To elucidate C and N dynamics and cycling in temperate watershed developing on shale and specifically, to identify spatial variability of soil gas within the watershed, and quantify root depth and distribution as well as root function and how it impacts shale weathering.

Geomorphology Team: Shallow geophysical surveys, borehole analyses, and detailed field investigation allow 1) characterization of SSHCZO geology and critical zone architecture; and 2) quantification of material properties and fracture distributions within the shallow (<10 m) critical zone.

Infrastructure Team: The primary objective for the infrastructure team were the deployment of the wireless sensor network. Deployment at the initial set of sites was successful. Deployment at the second set of sites has required more investment than initially planned due to compatibility issues between the wireless network and the data loggers previously deployed.

Seed Grant Teams

Temple: 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.

UTEP, Jin: 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.

PSU, M. Kaye: To quantify spatial and temporal trends in radial growth of trees in the watershed to inform estimates of forest aboveground net primary productivity.

UTEP, L. Ma: U-series team: The work is to investigate behaviors of U-series isotopes during chemical weathering and quantify regolith formation rates, to understand the control of climates on soil chemistry and development.

Lehigh: An important specific objective of the Lehigh seed grant team was to find and record the presence of buried soils of late to middle Pleistocene age with the understanding that such paleosols might be associated with very different past weathering regimes, that should be preserved in deposit geochemistry.

Significant Results:

Hydroinformatics and Isotope Hydrology Team: Comprehensive investigations of the spatiotemporal patterns of soil water isotope at Shale Hill resulted in the following findings: 1) Seasonal precipitation significantly influenced shallow soil water, 2) Seasonal variation of water isotopes attenuated within depth, approaching nearly constant value within 1-2 m depth, 3) Preferential flow was evidenced by the large variations in the winter soil water isotope values at different depths at most sites, 4) Precipitation and input transpiration drive the summer the summer soil water isotope composition at the SSHCZO.

Weathering & Soils Team: The team was successful in modelling the controls on porewater chemistry for the midslope soils on both the north and south sides. The team discovered that the higher temperature on the north hillslope caused higher ET which in turn resulted in less depletion of cations from the soils on the north side. However, the actual rates of dissolution are faster on the north side than on the south side.

Biogeochemistry Team: Soil CO2 and N2O accumulate synchronously in deep soil layers at the midslope of swales and in valley floor positions of in the watershed. These are wet landscape positions, so water, through its effects on both diffusion and biological activity, appears to be driving the pattern. Oxygen concentrations are consistently inversely correlated with CO2 implicating biological control.

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. We have explored the application of time-lapse surface-based ground penetrating radar (GPR) and artificial infiltration experiment to shed light on the nature of SLF and its dynamics on a hillslope in the Shale Hills CZO.

Hydrogeophysics Team: Observed stratigraphic variations controlled the water table in parts of the watershed, indicating the position of the water table is dictated by unweathered bedrock properties alone, and not by weathering reactions.

Hydroclimatology Team: Yu (2014) showed that the using Biome-BGC simulated LAI improved PIHM prediction of discharge, compared with the model run that used default NLCD climatological LAI. When Biome- BGC is driven by PIHM simulated soil moisture pattern, the simulated soil carbon showed clear impacts from topography.

Ecology Team: Roots are common at the bottom of the pits between the shale fragments. Trenching revealed much deeper rooting than soil coring, especially in the ridge and midslope positions. We did not find a trend of reduced root respiration with soil depth as previously been reported in other studies.

Geomorphology Team: Regolith transport: Our expanded data demonstrate that, although regolith transport rate appears to be linearly proportional to local slope near ridgecrests, where regolith is shallow (West et al., 2013), a depth-dependent transport rule best explains data on regolith flux (West et al., 2014). Moreover, the efficiency of transport appears to vary with hillslope aspect, likely reflecting the influence of insolation on transport events (West et al., 2014)

Shallow-Critical Zone: Seismic surveys 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).

Deep-Critical Zone: 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).

Seed Grant Teams

Temple: Dye pathways were anisotropic strongly influenced by the saprolite fabric (oriented along strike). At the two sites studied, downslope transport was only half a meter, and significant vertical infiltration occurred.

UTEP, Jin: In this catchment, chemical weathering in shallow soils is dominated by clay transformation as no carbonates are present, and soil pore waters are characterized by low DIC and pH. The chemistry of groundwater varies along different flowpaths as soil pore water recharges to the water table and then dissolves ankerite or secondary calcite under the valley floor.

PSU, M. Kaye: Carbon isotope ratios of leaf litter of six dominant tree species ranged from -29.58 to -26.88 (VPDB) and C concentration from 43.03% to 50.23%. Many of the oldest trees sampled in the watershed established in the 1830s, with one stem dating back to the 1780s, making forest of the Shale Hills watershed older than most in the region.

UTEP, L. Ma: U-series work: Thick soil profiles (>4 meters) revealed different mobility behaviors of U-series isotopes: depletion of 234U and accumulation of 230Th in shallow soils and accumulation of 234U and 238U in deep parts. Current work is focused on quantifying the regolith formation rates, considering the different U-series behaviors of the two systems.

Lehigh: (1) excellent alignment between field pedologic, hillslope stratigraphic, Fe-chemistry, and weathering profiles for described pits. This indicates a strong influence of hillslope parent material texture, thickness, and stratigraphy in determining the weathering process and rates. (2) Little evidence for thick buried soils on hillslopes in the CZO. There is the indication that there are multiple packages of greze-litee like shale chip deposits that have accumulated in the major swales of the CZO landscape.

Key outcomes or Other achievements:

Hydroinformatics and Isotope Hydrology Team:

Thomas, E., Duffy, C.J., Lin, H.S., Sullivan, P.L., Holmes, G., Brantley, S.L., Jin, L., 2013. Spatiotemporal patterns of water stable isotope compositions at the Shale Hills Critical Zone Observatory: Linkages to subsurface hydrologic processes. *Vadose Zone*. doi: 0.2136/vzj2013.01.0029

Duffy, C., Shi, Y., Davis, K., Slingerland, R., Li,l., Sullivan, P.L. Goddéris, Y., Brantley, S.L., 2014. Designing a Suite of Models to Explore Critical Zone Function. *Procedia Earth and Planetary Sciences.* doi: 10.1016/j.proeps.2014.08.003

Weathering & Soils Team: A key outcome of this team was the creation of a model that can calculate porewater chemistry in the soils.

Biogeochemistry Team: We completed a major trenching experiment that will provide a rare view of the root-rock interface. We published one paper on the role of soil gas in shale weathering and submitted a second paper. Using her preliminary data from the CZO, Julie Weitzman received a USDA NIFA Predoctoral Fellowship to continue work on the N cycle at Shale Hills.

Hydropedology Team:

- 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.
- Two joint publications linking trees to soil moisture.

Hydrogeophysics Team:

Sullivan, P.L., Goddéris, Y., Shi, Y., Schott, J., Singha, K., Duffy, C.J., Brantley, S.L., 2014. Shale to Regolith Evolution: The Controls on Catchment Solute Fluxes. European Geophysical Union (EGU) Annual Meeting; Vienna, Austria.

Hydroclimatology Team: Publications:

Shi, Y., B. C. Baldwin, K. J. Davis, X. Yu, C. J. Duffy, and H. Lin, 2014: Simulating high resolution soil moisture patterns in the Shale Hills catchment using a land surface hydrologic model. Hydrological Processes, submitted.

Shi, Y., K. J. Davis, F. Zhang and C. J. Duffy, and X. Yu, 2014: Parameter estimation of a physically-based land surface hydrologic model using an ensemble Kalman filter: A multivariate real-data experiment. Environmental Research Letters, submitted.

Yu, X., C. J. Duffy, J. Kaye, W. T. Crow, G. Bhatt, and Y. Shi, 2014: Watershed reanalysis of water and carbon cycle models at a Critical Zone Observatory, in Remote Sensing of the Terrestrial Water Cycle (eds. Venkat Lakshmi), American Geophysical Union, Washington, D. C., in press.

Ecology Team: We completed a major trenching experiment that will provide a rare view of the root-rock interface.

Geomorphology Team: See results

Infrastructure Team: Long-term maintenance was performed on the eddy covariance system at Shale Hills, which began operation in April 2014. The system had been down since 2010. The weir at Shale Hills was replaced and the weir box excavated. During excavation leaks in the weir box were detected and renovations are planned for this Fall.

Seed Grant Teams

Temple: This work contributed to the hydrogeophysical characterization and hydropedology characterization, in particular for understanding infiltration. We exchanged information with other groups. The Lehigh soil mapping project mapped our trench and we visited their trenches to view the soil-saprock interface. In addition, we exchanged root zone information with Elizabeth Hasenmueller, a postdoc at the CZO.

UTEP, Jin: Nothing to report

PSU, M. Kaye: Nothing to report

UTEP, L. Ma: U-series work has been presented at annual meetings of AGU and CZO all hands meeting.

Lehigh: None to report yet.

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

Hydroinformatics and Isotope Hydrology Team: MS engineering (Thomas E). Mentorship of postdoctoral scholar (Sullivan P).

Weathering & Soils Team: Postdoctoral associate Pam Sullivan learned to use the model, WITCH, in collaboration with an international team of researchers.

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. Mentoring and results from this project helped Hasenmueller secure a tenure track faculty position at Saint Louis University. Bret Turner initiated work for his undergraduate honors thesis.

Hydropedology Team:

- Li Guo and Isaac Hopkins working on thesis related to the Shale Hills CZO.
- 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: Mentorship of postdoctoral scholars (Sullivan P, Clarke B, Chattopadhyay P)

Hydroclimatolgy Team:

Yuting He, Ph.D student.

Yuning Shi, Research Associate.

Burkely Twiest, M.S., Graduated May 2014.

Dacheng Xiao, Ph.D student.

Xuan Yu, PhD, Graduated May 2014.

Ecology Team: The postdoc (Hasenmueller) also was trained in ecological techniques.

Geomorphology Team: Nicole West (Ph.D. candidate and postdoc); Brian Clarke (postdoc); 3 undergraduate research assistants (Bailey, Cannon, Neely)

Infrastructure Team: The infrastructure team continues to work closely with graduate and undergraduate students from all research teams to train students on the operation, maintenance and measurement theory of sensor systems.

Seed Grant Teams

Temple: The data has been used in a master's thesis for a student at Temple University.

UTEP, Jin: training of graduate students at Penn State and undergraduates at UTEP for different types of sample collection, chemical analyses, data analysis and geochemical modeling.

PSU, M. Kaye: Two undergraduate and two graduate students were trained in dendrochronological methods to collect and analyze tree ring samples and process leaf litter samples for element and isotope analyses.

UTEP, L. Ma: An undergraduate student (Diego Sanchez) was trained to conduct U-series isotope analysis at UTEP. Sanchez obtained his BS in Geological Sciences at UTEP and now pursue his MS degree in low temperature geochemistry at University of Tennessee.

Lehigh: The grant provided training for two female early career geoscientists co-mentored by co-P.I.s Peters and Pazzaglia. Ph.D. student Johanna Blake participated in the field and lab work components of the study. She also played a mentorship role in overseeing the lab data collection of undergraduate student Jordan Dykman. Ms. Blake earned her Ph.D in the spring, 2014 and is currently a post-doc at the University of New Mexico.

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

Hydroinformatics and Isotope Hydrology Team: 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: Talks about the WITCH modelling have been given at AGU and in Europe.

Biogeochemistry Team: We provided a tour of the site to a Penn State forest soils class. We gave two presentations at the fall AGU meeting and presented our work at the CZO National All Hands meeting. We published one peer reviewed

paper and submitted a second.

Hydropedology Team: Nothing to report

Hydroclimatolgy Team: A Flux-PIHM wiki web page has been added (http://cataract.cee.psu.edu/PIHM/index.php/Land_Surface_Scheme:_Flux-PIHM). The Flux-PIHM code now is also available for download at a GitHub page (https://github.com/shiyuning/PIHM-MF) for the community to use.

The Flux-PIHM EnKF system code now is available for download at a GitHub page (https://github.com/shiyuning/Flux-PIHM-EnKF-2.0) for the community to use.

Ecology Team: We provided two presentations at the fall AGU meeting and presented our work at the CZO ALL Hands Meeting.

Geomorphology Team:

Manuscripts in refereed journals:

West, N., Kirby, E., Bierman, P., Clarke, B., 2014, Aspect-dependent variations in regolith creep revealed by meteoric 10Be, *Geology*, doi:10.1130/G35357.1.

West, N., Kirby, E., Bierman, P., Slingerland, R., Ma, L., Brantley, S., Rood, D., 2013, Regolith production and transport in the Susquehanna Shale Hills Critical Zone Observatory: Part 2 - insights from meteoric 10Be, *Journal of Geophysical Research – Earth Surface*, 118(3), 1877 – 1896. doi:10.1002/jgrf.20121.

Conference proceedings:

West, N., Kirby, E., Bierman, P., Hillslope response to differences in aspect-related microclimate, 2014 Fall Meeting, AGU, San Francisco, Calif., 15-19 Dec.

West, N., Kirby, E., Bierman, P., Aspect-related regolith flux revealed by meteoric 10Be**,** 2014 GSA National Meeting, Vancouver, BC, 19-22 Oct.

West, N., Kirby, E., Bierman, P., Brantley, S.L., Keynote Speaker, CZO Research in the Mid-Atlantic, 2014 Annual Amtrak Club Meeting, Lehigh University, Bethlehem, PA, May 16-17.

West, N., Kirby, E., Ma, L., Bierman, P., Going Steady: Testing the steady-state assumption using multiple isotopic systems at the Susquehanna Shale Hills Critical Zone Observatory, 2013 Fall Meeting, AGU, San Francisco, Calif., 7-12 Dec.

West, N., Kirby, E., Aspect-dependent regolith flux revealed by meteoric 10Be, Abstract # 248027, 2014 Geological Society of America National Meeting, Vancouver, BC, 19-22, Oct.

West N., Kirby E., Bierman, P., Aspect-related topographic asymmetry at the Susquehanna Shale Hills Crtical Zone Observatory, National Presented at the NSF National Critical Zone Observatory Program All Hands Meeting, , Yosemite, CA, 21-24 Sept., 2014.

Harpold, A., Marshall, J., Pelletier, J., Swetnam, T., Wenell, B., **West, N.**, Glenn, N., Molotch, N., Barnhart, T., et al., Laser Vision: LiDAR as a transformative tool to advance critical zone science. Presented at the NSF National Critical Zone Observatory Program All Hands Meeting, Yosemite, CA, 21-24 Sept., 2014.

Steinhoefel, G., Sullivan, P., Noireaux, J., **West, N.**, Hynek, S., Gaillardet, J., Jin, L., Ma, L., Derry, L.A., Meek, K., Karwan, D.L., Yesavage, T., Fantle, M.S., Brantley, S.L., CZ-tope: A multiple isotope approach to quantify critical zone processes – the Susquehanna Shale Hills Critical Zone Observatory as an example, Presented at the NSF National Critical Zone Observatory Program All Hands Meeting, Yosemite, CA, 21-24 Sept., 2014.

West, N., Asymmetric topography reflects variable transport efficiency on soil-mantled hillslopes in the central Appalachians, Abstract # 236666, 2014 Geological Society of America Northeastern Section Meeting, Lancaster, PA, March 22-25.

Clarke, B.A., Kirby, E., Burbank, D.W., **West, N.**, Cross-CZO contrasts: Aspect controls and critical zone architecture, 2013 Fall Meeting, AGU, San Francisco, Calif., 7-12 Dec.

West, N., Kirby, E., Clarke, B., Bierman, P., 2013, Quantifying aspect control on transport efficiency and mobile regolith flux at the Susquehanna Shale Hills Critical Zone Observatory, presented at 2013 National Meeting, Geological Society of America, Denver, CO, 27-30 Oct.

West, N., Kirby, E., 2013, Topographic fingerprints of hillslope erosion in the Appalachian Mountains of North America, EGU2013-11281, presented at 2013 General Assembly, European Geophysical Union, Vienna, Austria, 8-12 April.

Seed Grant Teams

Temple: We presented results at the Geological Society of America national meeting, at the regional Geological Society of America meeting, at the Symposium on the Application of Geophysics to Engineering and Environmental Problems (*SAGEEP*) national meeting, and at CZO group meeting.

UTEP, Jin: Journal Publication:

Jin, L., Ogrinc, N., Yesavage T., Hasenmueller, E.A., Ma, L., Sullivan, P.L., Kaye, J., Duffy, C., and Brantley, S.L. (2014) The CO2 consumption potential during gray shale weathering: Insights from the evolution of carbon isotopes in the Susquehanna Shale Hills critical zone observatory. *Geochimica et Cosmochimica Acta* 142, 260-280.

Conference abstract:

Jin, L., Ogrinc, N., Yesavage, T., Hasenmueller, E., Ma, L., Kaye, J. and Brantley, S.L. (2013) Using C and S isotopes to elucidate carbonic versus sulfuric acid reaction pathways during shale weathering in the Susquehanna Shale Hills Critical Zone Observatory. American Geophysical Union annual conference, San Francisco, CA.

Invited talks:

July-2014: Controls on atmospheric CO2 consumption during shale weathering. Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China.

Oct-2013: Physical, chemical and hydrological changes in shales during weathering: a case study at a critical zone observatory in central Pennsylvania. Van Tuyl lecture, Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO.

PSU, M. Kaye: Leaf litter isotope data were shared with collaborators at the Shale Hills CZO. Results of above-ground net primary productivity are being prepared in a manuscript to be submitted in 2014.

UTEP, L. Ma: Nothing to report

Lehigh: The Lehigh seed grant team has presented its preliminary findings: (1) GSA National meeting, Denver, CO, fall, 2013 – Steve Peters presenting; (2) AGU National Meeting, San Francisco, CA, winter, 2013 – Steve Peters presenting; GSA regional meeting, Lancaster, PA, spring, 2014 – J. Dykman presenting.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
SSHCZO_AvailData20141107.pdf	Susquehanna Shale Hills CZO datasets currently available via criticalzone.org/data	Susan Brantley	11/18/2014

Products

Books

Book Chapters

Yu, X., C. J. Duffy, J. Kaye, W. T. Crow, G. Bhatt, and Y. Shi (2014). Watershed Reanalysis of Water and Carbon Cycle Models at a Critical Zone Observatory. *Watershed reanalysis of water and carbon cycle models at a Critical Zone Observatory, in Remote Sensing of the Terrestrial Water Cycle* Venkat Lakshmi. American Geophysical Union. Washington, D. C.. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/9781118872086.ch31.

Conference Papers and Presentations

Zhang, Y., Slingerland, R.L., Duffy, C. (2013). *A New Hydrologic-Morphodynamic Model for Regolith Formation and Landscape Evolution. Abstract # EP33A-0858*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

DYKMAN, Jordan Nicole, PAZZAGLIA, Frank J., PETERS, Stephen C., and BLAKE, Johanna M.T (2014). *ALIGNMENT AND DIVERGENCE OF PEDOLOGIC, GEOMORPHIC, AND GEOCHEMICAL DATA FOR HILLSLOPE SOILS IN CENTRAL PA.*. GSA Northeastern Section 49th Annual Meeting. Lancaster, PA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

West, N., Kirby, E (2014). *Aspect-dependent regolith flux revealed by meteoric 10Be, Abstract # 248027*. 2014 Geological Society of America National Meeting. Vancouver, BC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

West N., Kirby E., Bierman, P. (2014). *Aspect-related topographic asymmetry at the Susquehanna Shale Hills Crtical Zone Observatory*. NSF National Critical Zone Observatory Program All Hands Meeting. Yosemite, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

West, N. (2014). *Asymmetric topography reflects variable transport efficiency on soil-mantled hillslopes in the central Appalachians, Abstract # 236666*. 2014 Geological Society of America Northeastern Section Meeting. Lancaster, PA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Noireaux, J., Sullivan, P.L., Louvat, P., Gaillardet, J., Brantley, S.L. (2013). *Boron isotopes at the Shale Hills Critical Zone Observatory. Abstract # H51B-1190*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

PETERS, Stephen C., PAZZAGLIA, Frank J., BLAKE, Johanna M.T., and DYKMAN, Jordan Nicole (2014). *CHEMICAL WEATHERING AND SOIL FORMATION FROM MULTIPLE PARENT MATERIALS IN CENTRAL PENNSYLVANIA*. GSA Northeastern Section 49th Annual Meeting. Lancaster, PA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Steinhoefel, G., Sullivan, P., Noireaux, J., West, N., Hynek, S., Gaillardet, J., Jin, L., Ma, L., Derry, L.A., Meek, K., Karwan, D.L., Yesavage, T., Fantle, M.S., Brantley, S.L. (2014). *CZ-tope: A multiple isotope approach to quantify critical zone processes – the Susquehanna Shale Hills Critical Zone Observatory as an example*. NSF National Critical Zone Observatory Program All Hands Meeting. Yosemite, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

PETERS, Stephen C., PAZZAGLIA, Frank J., and BLAKE, Johanna (2013). *Chemical Weathering and Soil Formation from Multiple Parent Materials in a Complex Regolith, Shale Hills Pennsylvania*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jin, L. (2014). *Controls on atmospheric CO2 consumption during shale weathering (Invited)*. Guangzhou Institute of Geochemistry, Chinese Academy of Sciences. Guangzhou, China. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Clarke, B.A., Kirby, E., Burbank, D.W., West, N. (2013). *Cross-CZO Contrasts: Aspect Controls and Critical Zone Architecture. Abstract # H43L-07*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hasenmueller, E.A., Jin, L., Smith, L.A., Kaye, M.W., Lin, H., Brantley, S.L., Kaye, J.P. (2013). *Depth and Topographic*

Controls on Soil Gas Concentrations and Fluxes in a Small Temperate Watershed. Abstract # EP13C-0876. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Sullivan, P.L., Godderis, Y., Shi, Y., Schott, J., Duffy, C., Brantley, S.L. (2013). *Developing approaches to hindcast and earthcast climate controls on solute fluxes during shale weathering in the Critical Zone . Abstract # EP11A-04*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Singha, K., Clarke, B.A., Sullivan, P.L., Chattopadhyay, P.B., Brantley, S.L. (2013). *Geologic controls on fracture distributions within the Shale Hills Critical Zone Observatory. Abstract # H43L-08*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

West, N., Kirby, E., Ma, L., Bierman, P. (2013). *Going Steady: Testing the steady-state assumption using multiple isotopic systems at the Susquehanna Shale Hills Critical Zone Observatory*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

West, N., Kirby, E., Bierman, P (2014). *Hillslope response to differences in aspect-related microclimate*. 2014 Fall Meeting, AGU. San Francisco, Calif. Status = ACCEPTED; Acknowledgement of Federal Support = Yes

West, N., Kirby, E., Bierman, P., Brantley, S.L. (2014). *Keynote Speaker, CZO Research in the Mid-Atlantic*. 2014 Annual Amtrak Club Meeting. Lehigh University, Bethlehem, PA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Harpold, A., Marshall, J., Pelletier, J., Swetnam, T., Wenell, B., West, N., Glenn, N., Molotch, N., Barnhart, T., et al., (2014). *Laser Vision: LiDAR as a transformative tool to advance critical zone science.*. NSF National Critical Zone Observatory Program All Hands Meeting. Yosemite, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Katie P Gaines, David Eissenstat, and Henry Lin (2013). *Patterns in tree water extraction depth at the Susquehanna Shale Hills Critical Zone Observatory in central Pennsylvania*. ESA Annual Meeting. Minneapolis, Minnesota. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jin, L. (2014). *Physical, chemical and hydrological changes in shales during weathering: a case study at a critical zone observatory in central Pennsylvania.*. Van Tuyl lecture, Department of Geology and Geological Engineering, Colorado School of Mines. Golden, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

West, N., Kirby, E., Clarke, B., Bierman, P. (2013). *Quantifying aspect control on transport efficiency and mobile regolith flux at the Susquehanna Shale Hills Critical Zone Observatory*. 2013 National Meeting, Geological Society of America. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ma, L., Herndon, E., Jin, L., Sanchez, D., Brantley, S.L. (2013). *Quantifying the signature of the industrial revolution from Pb and Cd isotopes in the Susquehanna Shale Hills Critical Zone Observatory, Abstract # H51B-1186*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shi, Y., Baldwin, D.C., Davis, K.J., Yu, X., Duffy, C., Lin, H. (2013). *Resolving the High Resolution Soil Moisture Pattern at the Shale Hills Watershed Using a Land Surface Hydrologic Model. Abstract # H23F-1332*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Sullivan, P.L., Goddéris, Y., Shi, Y., Schott, J., Singha, K., Duffy, C.J., Brantley, S.L. (2014). *Shale to Regolith Evolution: The Controls on Catchment Solute Fluxes.*. European Geophysical Union (EGU) Annual Meeting. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Liu, H. and Lin, H. (2013). *Temporal and Spatial Patterns of Preferential Flow Occurrence in the Shale Hills Catchment: From the Hillslope to the Catchment Scales . Abstract # H23F-1330*. 2013 Fall Meeting, AGU. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

HYNEK, Scott A., ORLANDO, Joseph J., SULLIVAN, Pamela, and BRANTLEY, Susan L. (2013). *The Architecture of Deep Weathering at Two CZOs: Groundwater, Regolith, and Solutes at Susquehanna Shale Hills and Luquillo Experimental Forest*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support =

Yes

West, N., Kirby, E. (2013). *Topographic fingerprints of hillslope erosion in the Appalachian Mountains of North America, EGU2013-11281*. 2013 General Assembly, European Geophysical Union. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jin, L., Ogrinc, N., Yesavage, T., Hasenmueller, E., Ma, L., Kaye, J. and Brantley, S.L. (2013). *Using C and S isotopes to elucidate carbonic versus sulfuric acid reaction pathways during shale weathering in the Susquehanna Shale Hills Critical Zone Observatory*. American Geophysical Union Annual Fall Meeting. San Francisco, Calif. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Pamela L. Sullivan, Yves Godderis, Yuning Shi, Jacques Schott, Christopher J. Duffy, Susan L. Brantley (2013). *Using WITCH to quantify landscape and hydrologic controls on solute fluxes in the Critical Zone (Susquehanna Shale Hills Observatory, PA)*. Goldschmidt 2013. Florence, Italy. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Neal, A., Mendoza, A., Simon, C., Abad, J., Vidic, R., Yoxtheimer, D., and Brantley, S. (2013). *Using the NSF-funded Shale Network Database and Critical Zone Observatories to Assess Water Quality Concerns in Areas of Shale-Gas Development.*. AGU Science Policy Conference. Washington, D.C.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Inventions

Journals

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 = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/esp.3415

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*. 122 101. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.gca.2013.08.001

Duffy, C., Shi, Y., Davis, K., Slingerland, R., Li,l., Sullivan, P.L. Goddéris, Y., Brantley, S.L. (2014). Designing a Suite of Models to Explore Critical Zone Function.. *Procedia Earth and Planetary Sciences*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.proeps.2014.08.003

Godderis, Y. and Brantley, S.L. (2014). Earthcasting the future Critical Zone. *Elementa*. 1 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.12952/journal.elementa.000019

Guo, L., Chen, J., and Lin, H.S. (2013). Subsurface lateral preferential flow network revealed by time-lapse ground-penetrating radar in a hillslope. *Water Resource Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2013WR014603

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 = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.chemgeo.2013.07.012

Jin, L., Ogrinc, N., Yesavage T., Hasenmueller, E.A., Ma, L., Sullivan, P.L., Kaye, J., Duffy, C., and Brantley, S.L. (2014). The CO2 consumption potential during gray shale weathering: Insights from the evolution of carbon isotopes in the Susquehanna Shale Hills critical zone observatory. *Geochimica et Cosmochimica Acta*. 142 260. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Kaproth-Gerecht, K.E., Gooseff, M.N., Singha, K (2014). 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*. 50 85. Status =

PUBLISHED; 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 = SUBMITTED; 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*. 49 (11), 7733. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2013WR013834

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*. 118 (2), 722. Status = PUBLISHED; 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 = PUBLISHED; 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*. 369-370 1. Status = PUBLISHED; 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 = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1371/journal.pone.0058704

Riebe, C., Hahm, J. and Brantley, S.L. (). Going deep to quantify limits on weathering in the Critical Zone. *Earth Surface Processes and Landforms*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Shi, Y., D. C. Baldwin, K. J. Davis, X. Yu, C. J. Duffy, and H. Lin (2014). Simulating high resolution soil moisture patterns in the Shale Hills catchment using a land surface hydrologic model. *Hydrological Processes*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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 = PUBLISHED; 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 (2014). Evaluation of the parameter sensitivity of a coupled land surface hydrologic model. *Journal of Hydrometeorology*. 15 279. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1175/JHM-D-12-0177.1

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*. 50 (1), 706. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2013WR014070

Shi, Y., K. J. Davis, F. Zhang, C. J. Duffy, and X. Yu (2014). Parameter estimation of a physically-based land surface hydrologic model using the ensemble Kalman Filter: A multivariate real-data experiment.. *Environmental Research Letters*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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 = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

West, N., Kirby, E., Bierman, P., Clarke, B. (2014). Aspect-dependent variations in regolith creep revealed by meteoric

10Be. *Geology*. 42 (6), 507. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1130/G35357.1.

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*. 118 1. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/jgrf.20121

Xianzeng Niu, Jennifer Z. Williams, Doug Miller, Kerstin Lehnert, Brian Bills, Susan L. Brantley (2014). An Ontology Driven Relational Geochemical Database for the Earth's Critical Zone: CZchemDB. *Journal of Environmental Informatics*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Xuan Yu, Anna Lamačová, Christopher Duffy, Pavel Krám, Jakub Hruška, Tim White & Gopal Bhatt (2014). Modeling long term water yield effects of forest management in a Norway spruce forest. *Hydrological Sciences Journal*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1080/02626667.2014.897406

Zhang, J., H.S. Lin, and J. Doolittle (2014). Soil Layering and Preferential Flow Impacts on Seasonal Changes of GPR Signals in Two Contrasting Soils. *Geoderma*. 213 560. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.geoderma.2013.08.035

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 = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Licenses

Other Products

Flux-PIHM wiki web page.

Land Surface Scheme: Flux-PIHM: Flux-PIHM [1] is a coupled land surface hydrologic model, developed by incorporating a land surface scheme into the Penn State Integrated Hydrologic Model (PIHM). The land surface scheme is adapted from the Noah land surface model. Because PIHM is capable of simulating lateral water flow and deep groundwater at spatial resolutions sufficient to resolve upland stream networks, Flux-PIHM is able to represent heterogeneities due to topography and soils at high resolution, including spatial structure in the link between groundwater and the surface energy balance (SEB).

PIHM code.

The Flux-PIHM code now is also available for download at a GitHub page (https://github.com/shiyuning/PIHM-MF) for the community to use.

The Flux-PIHM EnKF system code now is available for download at a GitHub page (https://github.com/shiyuning/Flux-PIHM-EnKF-2.0) for the community to use.

Other Publications

Patents

Technologies or Techniques

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

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

Name	Most Senior Project Role	Nearest Person Month Worked
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, Dan	Other Professional	12
Duffy, Colin	Other Professional	1
Neal, Andrew	Other Professional	12
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

Name	Most Senior Project Role	Nearest Person Month Worked
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

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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

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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: No

Dan K. Arthur
Email: dka12@psu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

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

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: 12

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 are developing a technique of modelling that will enable earthcasting of weathering rates into the future.

Biogeochemistry Team: The results from the gas studies have established the importance of topographic position on gas dynamics; this had never been documented before and provides a new way to view the distribution of CO2-based weathering reactions.

Hydropedology Team: Two main impacts are: 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.

Hydroclimatology Team: With the incorporation of topographic radiation and the improvement of root water uptake, Flux-PIHM enables the quantitative investigation of the effects of aspect on land surface processes.

The development of the coupled Flux-PIHM-BBGC model will add carbon-nitrogen modeling to CZO research, and yield a high-resolution carbon-hydrology modeling system. The modeling system can be used for the study of hydrology-ecosystem-atmosphere interactions, and the study of climate change impacts.

Ecology Team: The results from the trenching experiment showed that roots are exploring fractured shale, and to a greater extent at ridge top locations. This should lead the discipline toward new studies of the role of roots in weathering and the role of fractured rocks in plant growth.

Geomorphology Team: Our results represent some of the first quantitative measurements of variations in soil transport efficiency that depend on insolation. As such, our results lend support to long-held propositions that invoke such variations to explain asymmetric topography, but provide a quantitative basis from which to derive mechanistic rate laws (West et al., 2014). Moreover, our study provides a template for future study in other sites (subject to variations in climate, vegetation, etc.).

Infrastructure Team: Wireless sensor network at Shale Hills will be a model for networks in similar forest systems for other researchers.

Data Management Team: Using Google MapsTM for the web-based instrument and sampling site map platform allows for creation and maintenance of geolocation data at no additional cost.

Seed Grant Teams

Temple: We expect improved use of GPR for characterization based on our dye studies and infiltration study using LiDAR.

UTEP, Jin: 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.

PSU, M. Kaye: Ecosystem science often relies on the assumption that forest productivity is constant within a given ecotype or region. Empirical data from the Shale Hills CZO will be used to test the temporal and spatial consistency of forest productivity, and inform regional estimates of forest carbon dynamics with higher resolutions estimates of

productivity.

UTEP, L. Ma: Nothing to report

Lehigh: The Lehigh seed grant project directly impacts the thinking and science goals of primarily the geomorphology group, and secondarily the geochemistry/weathering group. Our results are not transformative, but align well with what we have already learned about hillslope processes in the CZO.

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: WITCH modelling will be useful for geochemistry, soil science, and hydrology.

Biogeochemistry Team: The research on subsurface gases will provide a new view of controls on spatial variability in soil-atmosphere gas exchange that have been the subject of numerous ecological studies. Tours of the site will impact the training for forestry students and provide a more holistic understanding of links between forestry and the CZ.

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

Hydrogeophysics Team: NA

Hydroclimatology Team: The ability of Flux-PIHM to resolve hill-slope patterns and the incorporation of topographic solar radiation make the model a good platform for coupling biogeochemistry models at low order watersheds, which represent a large areal fraction of many landscapes.

The model sensitivity analysis and data assimilation experiment will provide important guidance for observational system design. The data assimilation system can be used by other disciplines for the assimilation of different observations. The model reanalysis and predictions can be used for the study of bio/geochemical processes.

Ecology Team: This work will lead to better understanding of deep rooting and limitations of various methodologies in diverse fields of ecology, hydrology and geology.

Geomorphology Team: None, to date

Infrastructure Team: The infrastructure team provides the logistical support for other research teams in SSHCZO and ensures that high quality data remain available throughout the project. This includes: power supply, sensor maintenance, network infrastructure.

Data Management Team: By providing SSHCZO data via large data repositories such as the SDSC Geoportal and CUAHSI HIS, they are discoverable by a broader range of disciplines, enhancing and encouraging interdisciplinary research.

Seed Grant Teams

Temple: See above under Other Achievements for overlap with soil mapping and root zone characterization.

UTEP, Jin: Nothing to report

PSU, M. Kaye: Higher-resolution estimates of forest productivity can inform models of forest ecophysiology, geophysical models of soil development, and hydrological models operating at the watershed or landscape scale.

UTEP, L. Ma: Nothing to report

Lehigh: Our field work in describing the soils enjoyed considerable interest by the Ecology team that was interested in documenting root density and carbon dioxide fluxes in CZO soils.

What is the impact on the development of human resources?

Hydroinformatics and Isotope Hydrology Team: NA

Weathering & Soils Team: The team educated one postdoctoral associate, Pam Sullivan. Dr Sullivan is now a faculty member at Univ of KS.

Biogeochemistry Team: Mentoring and results from this project helped a postdoc (Hasenmueller) secure a tenure track faculty position at Saint Louis University. Using her preliminary data from the CZO, Julie Weitzman received a USDA NIFA Predoctoral Fellowship to continue work on the N cycle at Shale Hills.

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

Hydroclimatology Team: Nothing to report

Ecology Team: Mentoring and results from this project helped a postdoc (Hasenmueller) secure a tenure track faculty position at Saint Louis University

Geomorphology Team: Our work trained a rising female scientist, Nicole West.

Infrastructure Team: Infrastructure team has facilitated training of students on sensor systems.

Data Management Team: None

Seed Grant Teams

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

UTEP, Jin: Nothing to report

PSU, M. Kaye: Research for the seed grant provided training for students in field data collection, sample analysis, data analysis, and data presentation.

UTEP, L. Ma: Nothing to report

Lehigh: The Lehigh seed grant project provided support for two female early career researchers: (1) a (now graduated) Ph.D. student and (2) now graduated B.S. Earth and Environmental Science student.

What is the impact on physical resources that form infrastructure?

Hydroinformatics and Isotope Hydrology Team: None

Weathering & Soils Team: None

Biogeochemistry Team: New gas sampling tubes on a north slope transect were installed and are available for long-term monitoring.

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

Hydrogeophysics Team: None

Hydroclimatology Team: Nothing to report

Ecology Team: none to report.

Geomorphology Team: None, to date

Infrastructure Team: Infrastructure team is responsible for maintaining physical infrastructure at Shale Hills.

Data Management Team: Access to existing university resources for web site, database, and data storage hardware has minimized costs of physical computing resources for the SSHCZO.

Seed Grant Teams

Temple: More extensive use of geophysics and LiDAR in the CZO could greatly enhance site characterization.

UTEP, Jin: Nothing to report

PSU, M. Kaye: Nothing to report

UTEP, L. Ma: Nothing to report

Lehigh: Nothing significant to report

What is the impact on institutional resources that form infrastructure?

Hydroinformatics and Isotope Hydrology Team: None

Weathering & Soils Team: None

Biogeochemistry Team: None

Hydropedology Team: Nothing to report

Hydrogeophysics Team: None

Hydroclimatology Team: Nothing to report

Ecology Team: None to report

Geomorphology Team: None, to date

Infrastructure Team: None.

Data Management Team: Existing university resources for web site, database, and data hosting, maintenance, and support have been made available to the SSHCZO with little to no impact on other needs/uses for these resources.

Seed Grant Teams

Temple: nothing to report

UTEP, Jin: Nothing to report

PSU, M. Kaye: Nothing to report

UTEP, L. Ma: Nothing to report

Lehigh: Nothing significant to report.

What is the impact on information resources that form infrastructure?

Hydroinformatics and Isotope Hydrology Team: None

Weathering & Soils Team: The team published one paper describing the data model for soil chemistry.

Biogeochemistry Team: None

Hydropedology Team: Nothing to report

Hydrogeophysics Team: None

Hydroclimatology Team: Nothing to report

Ecology Team: None to report

Geomorphology Team: None, to date

Infrastructure Team: The infrastructure team, in collaboration with the Cyberspecialist and PSU Information Technology staff, has implemented an SQL Server database to serve as the repository for sensor-based data. Database development included a web server which is set to launch this Fall. Database structure follows existing standards for data sharing with National CZO data initiatives.

Data Management Team: Minimal support demands have been made on university resources for assistance in creation of CZO Display files for Geoportal ingest and for the new instrument and sampling site web map. Minor support demands have been made on university information resources for support of SQL Server database during its creation and initial development, and several terabytes of data storage already in place has been made available for continued development and use.

Seed Grant Teams

Temple: nothing to report

UTEP, Jin: Nothing to report

PSU, M. Kaye: Nothing to report

UTEP, L. Ma: Nothing to report

Lehigh: Nothing significant to report.

What is the impact on technology transfer?

Hydroinformatics and Isotope Hydrology Team: None

Weathering & Soils Team: None

Biogeochemistry Team: None

Hydropedology Team: Nothing to report

Hydrogeophysics Team: None

Hydroclimatology Team: Nothing to report

Ecology Team: None to report

Geomorphology Team: None, to date

Infrastructure Team: None.

Data Management Team: None

Seed Grant Teams

Temple: nothing to report

UTEP, Jin: Nothing to report

PSU, M. Kaye: Nothing to report

UTEP, L. Ma: Nothing to report

Lehigh: Nothing significant to report.

What is the impact on society beyond science and technology?

Hydroinformatics and Isotope Hydrology Team: Nothing to report

Weathering & Soils Team: The team is developing quantitative skills for understanding the evolution of soils.

Biogeochemistry Team: Education was enhanced by field tours with college classes.

Hydropedology Team: Nothing to report

Hydrogeophysics Team: Nothing to report

Hydroclimatology Team: Nothing to report

Ecology Team: Education was enhanced by field tours with college classes.

Geomorphology Team: None, to date

Infrastructure Team: The infrastructure team has provided logistical support to outreach projects, specifically the Teen Shale Network. Infrastructure provided materiel support and technical expertise in water quality and hydrologic methods as part of the outreach project with high school earth sciences students.

Data Management Team: Nothing to report

Seed Grant Teams

Temple: nothing to report

UTEP, Jin: Nothing to report

PSU, M. Kaye: Nothing to report

UTEP, L. Ma: Nothing to report

Lehigh: Ultimately, the Lehigh seed grant team aims to better understand the terrestrial landscape response to future global climate change. The project sought to do this by building a model of past environmental changes preserved in hillslope stratigraphy and soil development.

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

Hydroinformatics and Isotope Hydrology Team: None

Weathering & Soils Team: The team has not yet submitted a paper on the WITCH modelling. The postdoc did not finish the paper before starting a faculty position.

Biogeochemistry Team: None

Hydropedology Team: Nothing to report

Hydrogeophysics Team: None

Hydroclimatology Team: Nothing to report

Ecology Team: None

Geomorphology Team: Brian Clarke, a postdoctoral researcher working on shallow seismic characterization in the CZO, struggled to produce a manuscript. Nicole West has taken over the analysis and interpretation of the seismic data, and we expect only minor delays in the product.

Infrastructure Team: The major drawback for implementation of the wireless sensor network has been non-compatibility between older data loggers and the wireless radios. Various work-around approaches were tested with no success. Replacing these loggers represents a small but substantial cost, which is not currently included in the project budget. Current plans will replace the loggers from maintenance funds over several years.

Seed Grant Teams

Temple: nothing to report

UTEP, Jin: Nothing to report

PSU, M. Kaye: Nothing to report

UTEP, L. Ma: Nothing to report

Lehigh: Nothing significant 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.