

## Research Spending & Results

### Award Detail

Awardee:	PENNSYLVANIA STATE UNIVERSITY, THE
Doing Business As Name:	Pennsylvania State Univ University Park
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Co-PD(s)/co-PI(s):	Christopher Duffy David Eissenstat Eric Kirby
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### Awardee Location

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### Abstract at Time of Award

An Accomplishment-Based Request for Renewal of the Susquehanna - Shale Hills Critical Zone Observatory (SSHO)

With funding from the NSF Critical Zone Observatory (CZO) program, CZO workers led by PI Susan Brantley and coInvestigator Chris Duffy (Pennsylvania State University) will focus on cross-disciplinary synthesis, data sharing, and outreach at the Susquehanna Shale Hills CZO. Established originally in the 1970s as a site to study water flow in forested catchments, the 8-hectare Shale Hills watershed was expanded in 2007 as a CZO to understand broader questions targeting the interplay of water, energy, atmospheric gases, biota, soils, and the land surface. In addition to the small Shale Hills catchment, the CZO includes a suite of satellite sites that overly the same bedrock type (shale) but which are situated in different climate regimes. One additional satellite site is located on organic-rich Marcellus shale. These satellites allow researchers to understand how climate and organic content control water flow and soil formation while working with minority-and undergrad-serving institutions. CZO researchers are investigating i) new methodologies to model the age and chemistry of water as it moves from the atmosphere to groundwater; ii) new techniques to synthesize measurements of soil moisture for incorporation into land-atmosphere models; iii) observations that constrain water, energy, and solute fluxes related to trees; iv) models that quantify how soil grows on shale; v) new uses of isotopes to measure soil formation; and vi) observations concerning how variables describing characteristics at depth such as the fracture distribution in bedrock combine with features at Earth's surface such as the sunniness of hillslopes to control the evolution of soils and hillslopes over time. Datasets of isotopes, chemistry, soil moisture, CO2 and energy flux, LiDAR, sapflux, and other observables collected at high spatial and temporal resolution are published online.

Outreach activities include community education about natural gas development on shale and K-12 educational opportunities.

## Publications Produced as a Result of this Research

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- Zhang, J., H.S. Lin, and J. Doolittle "Soil Layering and Preferential Flow Impacts on Seasonal Changes of GPR Signals in Two Contrasting Soils" *GEODERMA*, v.213, 2014, p.560
- Jin, L., Ogrinc, N., Yesavage T., Hasenmueller, E.A., Ma, L., Sullivan, P.L., Kaye, J., Duffy, C., and Brantley, S.L. "The CO<sub>2</sub> 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*, v.142, 2014, p.260
- Shi, Y., K. J. Davis, F. Zhang, and C. J. Duffy "Evaluation of the parameter sensitivity of a coupled land surface hydrologic model" *JOURNAL OF HYDROMETEOROLOGY*, v.15, 2014, p.279
- West, N., Kirby, E., Bierman, P., Clarke, B. "Aspect-dependent variations in regolith creep revealed by meteoric <sup>10</sup>Be" *GEOLOGY*, v.42, 2014, p.507
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- Duffy, C., Shi, Y., Davis, K., Slingerland, R., Li, L., Sullivan, P.L. Goddérís, Y., Brantley, S.L. "Designing a Suite of Models to Explore Critical Zone Function." *PROCEDIA EARTH AND PLANETARY SCIENCES*, v. , 2014, p.
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- Shi, Y., K. J. Davis, F. Zhang, C. J. Duffy, and X. Yu "Parameter estimation of a physically-based land surface hydrologic model using the ensemble Kalman Filter: A synthetic experiment" *WATER RESOURCES RESEARCH*, v.50, 2013, p.706
- Leonard, L. and C. Duffy "HydroTerre: Cyber infrastructure for Distributed Water Resource Modeling: A National Prototype for Model-Data Web Services and Workflows" *ENVIRONMENTAL MODELING AND SOFTWARE*, v.50, 2013, p.85
- Yu, X., Bhatt, G., Duffy C. J., and Shi, Y. "Parameterization for distributed watershed modeling using national data and evolutionary algorithm" *COMPUTERS & GEOSCIENCES*, v.58, 2013, p.80
- Liu, J., X. Chen, H.S. Lin, H. Liu, and H. Song "A simple geomorphic-based analytical model for predicting the spatial distribution of soil thickness in headwater hillslopes and catchments" *WATER RESOURCE RESEARCH*, v.49, 2013, p.7733
- Dere, A. L., White T. S., April R. H., Reynolds B., Miller T. E., Knapp E. P., McKay L. D. and Brantley S. L. "Climate dependence of feldspar weathering along a latitudinal gradient" *GEOCHIM. COSMOCHIM. ACTA*, v.122, 2013, p.101
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- West, N., Kirby, E., Bierman, P., Slingerland, R., Ma, L., Rood, D., and Brantley, S. L. "Regolith production and transport at the Susquehanna Shale Hills Critical Zone Observatory: Part 2 - Insights from meteoric <sup>10</sup>Be" *JOURNAL OF GEOPHYSICAL RESEARCH, EARTH SURFACE*, v.118, 2013, p.1
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- Graham, C., and H.S. Lin "The Hydropedograph toolbox" *HYDROL. EARTH SYST. SCI. DISCUSS*, v.9, 2012, p.14231
- Christopher Duffy, Yolanda Gil, Ewa Deelman, Suresh Marru, Marlon Pierce, Ibrahim Demir and Gerry Wiener "Designing a roadmap for geoscience workflows" *EOS, TRANSACTIONS AMERICAN GEOPHYSICAL UNION*, v.93, 2012, p.225
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## Project Outcomes Report

### Disclaimer

This Project Outcomes Report for the General Public is displayed verbatim as submitted by the Principal Investigator (PI) for this award. Any opinions, findings, and conclusions or recommendations expressed in this Report are those of the PI and do not necessarily reflect the views of the National Science Foundation; NSF has not approved or endorsed its content.

The Susquehanna Shale Hills Critical Zone Observatory (CZO) accomplishment-based renewal utilized stable isotope, water and soil chemistry, soil moisture, eddy flux, LiDAR, groundwater, seismic, sapflux and other data to prepare models describing how earth surface processes function. Students tested how trees influence watershed transpiration, how fractures and macropores affect water flow, how

Image



rooting density drives soil thickening and carbon fluxes, how fracture distribution controls landscape evolution, and how temperature and rainfall influence erosion rates.

Preliminary results indicate that trees in the Shale Hills catchment generally access shallow soil water year round and that patterns of preferential flow and subsurface lateral flow differ on the north and south sides of the catchment. In addition, the north side of the catchment experiences less recharge than the south side, but has a higher erosional efficiency. Some of our observations are contradictory to observations made at other CZOs in drier climates and we are developing models to explore these differences.

Five research groups outside of the CZO were funded through a competitive seed grant proposal program to complete complementary projects within the CZO. Key results from these projects include 1) new observations showing how the subsurface structure influences water infiltration (Fig 1), 2) the variation in chemistry of groundwater along flowpaths, and 3) evidence found in swales that document multiple episodes of downslope movement. The Susquehanna Shale Hills team also continued to reach out to non-scientists in the Pennsylvania commonwealth to teach and learn about water quality issues related to shale gas development in the northern and western parts of the state.

As part of this outreach, we engendered a collaboration between the Earth and Environmental Systems Institute at Penn State and State College Area High School Learning Enrichment Science students. Students have been introduced to HydroDesktop, a geochemical repository for water quality data, and have participated in water quality measurements. This effort has developed into TeenShale Network (TSN). During the 2013-2014 academic year, TSN freshmen installed a water quality sensor at a local stream, collected water samples for chemical analyses, measured stream discharge, and ended the year with a student-byline article in the Centre Daily Times ([http://www.centredaily.com/2014/05/02/4162016\\_teen-shale-network-studies-effects.html?rh=1](http://www.centredaily.com/2014/05/02/4162016_teen-shale-network-studies-effects.html?rh=1)) and a poster presentation at the Annual Shale Network Conference in May 2014 (<https://criticalzone.org/shale-hills/news/story/poster-presentation-capstone-for-state-college-teenshalenetwork-spring-2014/>).

Last Modified: 11/19/2014

Modified by: Susan L Brantley

For specific questions or comments about this information including the NSF Project Outcomes Report, [contact us](#).

