CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Schedule for the SSHCZO Virtual Site Visit

- CZO Research: 1:15 – 1:45 Presentation (Brantley, Shi, Hoagland)
  1:45 – 2:00 Q&A (All)

  Education & Outreach 2:00 - 2:15 Presentation (Davis)
  2:15 - 2:30 Q&A

- Data Management 2:30 – 2:45 Presentation (Arthur)
  3:15 - 3:00 Q&A

  Governance & Mgmt 3:00 - 3:15 Presentation (Eissenstat)
  3:15 - 3:30 Q&A

  General Questions 3:30 – 3:45 Q&A (All)

- Closed Panel Discussion 3:45-5:00

I.A, I.B, VI. C

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Names in red are those on the web conference

# Introductions: Everyone (?) involved

- Inside Penn State

Susan L. Brantley, Chris Duffy, Dave Eissenstat, Ken Davis, Jason Kaye, Li Li, Henry Lin, Rudy Slingerland, Tim White, Tom Adams, Brian Orland, Joseph Harding, Matt Fantle, Maureen Feineman, Jennifer Williams, Colin Duffy, Andrew Neal, Brandon Forsythe, Dan Arthur, Tess Russo, Roman DiBiase, Scott Hynek, Yuning Shi, Chen Bao, Ashlee Dere, Katie Gaines, Isaac Hopkins, Lauren Smith, Burkely Twiest, Julie Weitzman, Tiffany Yesavage, Xuan Yu, Yu Zhang, Xin Gu, Margot Kaye, Elizabeth Boyer, Liidia Iavorivska, Ryan Jones, Nina Bingham, Annie Klodd, Aaron Stottlemyer, Yuting He, Reese Davis, Dave Pedersen, Craig Pezak, Andrew Neely, Daniel Snyder, Sara Macdonald, Alexander Shaub, Beth Hoagland, Lillian Hill, Dacheng Xiao, Eric Wang, Arvy Adira, Joanmarie Del Vecchio, Virginia Marcon, Neil Xu, Ismaiel Szink, Warren Reed, Doug Baldwin, Evan Thomas, Molly Cain, Tyler Betz, Brennan Holderman, Weile Chen

- Outside Penn State

Paul Bierman, Al Denn, Friedhelm von Blanckenburg, Yves Goddéris, Jérôme Gaillardet, Douglas Wentzel, Joseph Graney, Frederick Meinzer, Jonathan Nyquist, Laura Toran, Lacey Pittman, Lixin Jin, Lin Ma, Steve Peters, Frank Pazzaglia, Justin Irving, Garth T. Llewellyn, Victor Heilweil, Diana Karwan, Anne Kraipel, Lou Derry, Jed Sparks, Katherine Meek, Kamini Singha, Eric Kirby, Mike Gooseff, Elizabeth Herndon, Carleton Bern, Kristen Brubaker, Robert Long, Grit Steinhoefel, Johanna Noireaux, Elizabeth Andrews, Daniel Liptzin, Pamela Sullivan, Brian Clarke, Elizabeth Hasenmueller, Eugene Ruocchio, Yvonne Pickering, Kip Solomon, Scott Mackay, Dorothy Merritts, Morgan Minyard, Nicole West

*NSF-supported Pis (draw salary) – 11 (36% women), supported staff – 3 (33% women)*

II.E, II.F III.A, III.B

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# CZO Site Research

II.

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We try to demonstrate how we integrate research/education/outrach throughout this talk

NSF Virtual Site Review – November 9th 2015

## II. CZO Site Research

- *A) Has the CZO made progress in measuring and quantifying the significant processes of the critical zone?*
- *B) Has the CZO developed a unifying theoretical framework that integrates new knowledge of coupled hydrological, geochemical, geomorphic, sedimentary, and biological processes?*
- *C) Has the CZO developed and validated systems-level models to predict how the critical zone responds to external forces?*
- *D) Has the CZO contributed to the scientific basis for decision-making regarding health, safety, ecosystem services, and environmental function?*
- *E) Has the CZO made the site available for use of the other CZOs and the broader community?*
- *F) Is the site supporting an interdisciplinary research program using long-term observations at the CZO that takes advantage of the CZO network effort?*
- *G) Are the goals of the site aligned with the spatial and temporal scope of CZO research?*
- *H) Are the various subprojects well integrated and supportive of the site goals?*
- *I) Has the CZO site complied with the EAR Data Policy and the CZO Data Sharing Policy?*

Note that the blue triangle indicates where we answer the questions

II.

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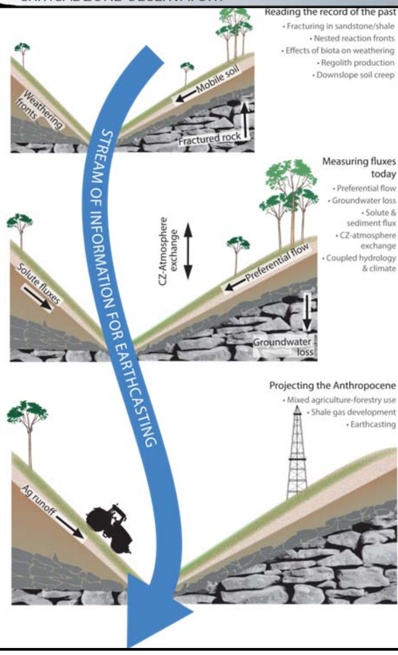


## The Susquehanna Shale Hills Critical Zone Observatory: A Virtual Site Visit

*Our hypothesis: To project CZ evolution into the future requires knowledge of geological history, observations of CZ processes today, and scenarios of human activities tomorrow.*

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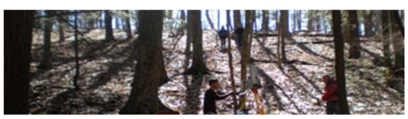
## Stated Goals of SSHCZO

- To learn to measure and model the CZ across timescales from those of the meteorologist to the geologist.
- To use our knowledge to project, or "*earthcast,*" into the future.
- To educate (at least) 8 grad students, 1 postdoc, and 8 undergrads in state-of-the-art interdisciplinary CZ research
- To teach individuals outside of the CZO about how the CZ works



II.A, II.G

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## The CZ is a system. To understand the system we need both **conceptual and numerical** models…

- Models comprise a *mechanism of developing deeper understanding* of a system through hypothesis testing
- Models are a *source of hypotheses*
- Models are the *cross-disciplinary language* we use to incorporate understanding from one discipline into other disciplines
- Models are the *numerical framework* we use to scale up or scale down over space or time
- Models are the *tool* that society needs to project the future of the complex earth surface system

II.C

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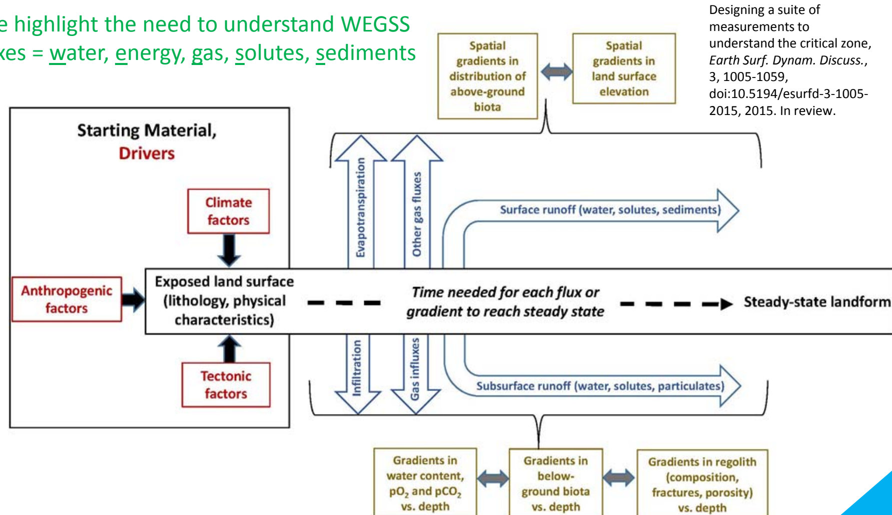
## Our schematic of a long-timescale view of how the CZ operates

Brantley, S. L., et al.: Designing a suite of measurements to understand the critical zone, *Earth Surf. Dynam. Discuss.*, 3, 1005-1059, doi:10.5194/esurfd-3-1005-2015, 2015. In review.

We highlight the need to understand WEGSS fluxes = water, energy, gas, solutes, sediments




Blue = instantaneous WEGSS fluxes    Brown = steady state gradients that emerge as characteristic of the system

II.B, II.F

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## In 2014, we published a paper articulating our answer for the question, "how do we model the CZ?"

Available online at www.sciencedirect.com
ScienceDirect
Procedia Earth and Planetary Science 10 (2014) 7 – 15
ELSEVIER
Procedia
Earth and Planetary Science
Geochemistry of the Earth's Surface meeting, GES-10

### Designing a Suite of Models to Explore Critical Zone Function

Christopher Duffy[a], Yuning Shi[b], Ken Davis[b,c], Rudy Slingerland[b,d], Li Li[e], Pamela L. Sullivan[b], Yves Goddéris[f], Susan L. Brantley[b,d*]

[a]Department of Civil and Environmental Engineering, Pennsylvania State University, Univ. Pk, PA 16802
[b] Earth and Environmental Systems Institute, Pennsylvania State University, Univ. Pk, PA 16802
[c] Department of Meteorology, Pennsylvania State University, Univ. Pk, PA 16802
[d]Dept. of Geosciences, Pennsylvania State University, Univ. Pk, PA 16802
[e] Dept of Energy and Mineral Engineering,Pennsylvania State University, Univ. Pk, PA 16802
[f] Géosciences Environnement Toulouse, CNRS-Observatoire Midi-Pyrénées, Toulouse, France

Duffy, et al., Designing a Suite of Models to Explore Critical Zone Function, *Procedia Earth and Planetary Science*, Volume 10, 2014, Pages 7-15, ISSN 1878-5220, http://dx.doi.org/10.1016/j.proeps.2014.08.003. (http://www.sciencedirect.com/science/article/pii/S1878522014000654) Keywords: Critical Zone; weathering; hydrology; ecology; watersheds

II.C, III.A

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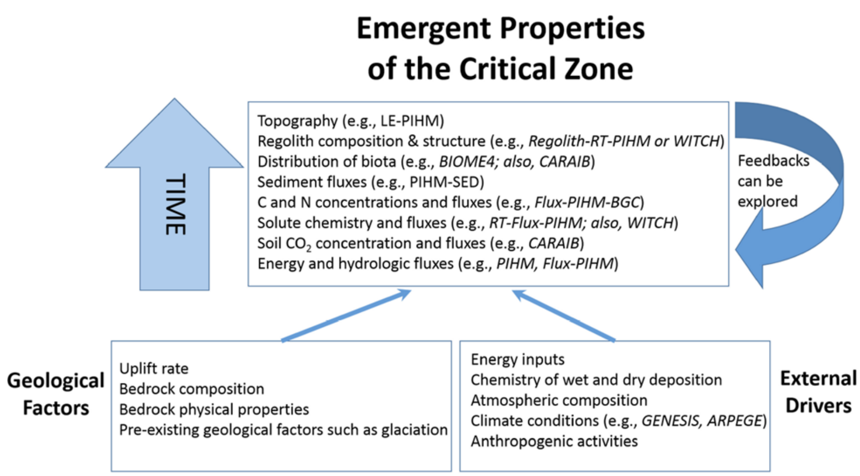
## A cascade of models is required to understand the CZ ... because of the vast differences in timescales




Duffy, et al., Designing a Suite of Models to Explore Critical Zone Function, *Procedia Earth and Planetary Science*, Volume 10, 2014, Pages 7-15, ISSN 1878-5220, http://dx.doi.org/10.1016/j.proeps.2014.08.003.

II.C, II.F

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The CZ is a system: we need dense observations with complex high fidelity numerical models that are synthesized and tested against hypotheses and measurements to understand this system.

II.C

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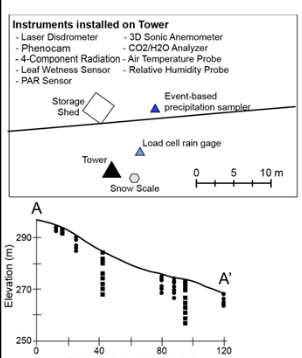
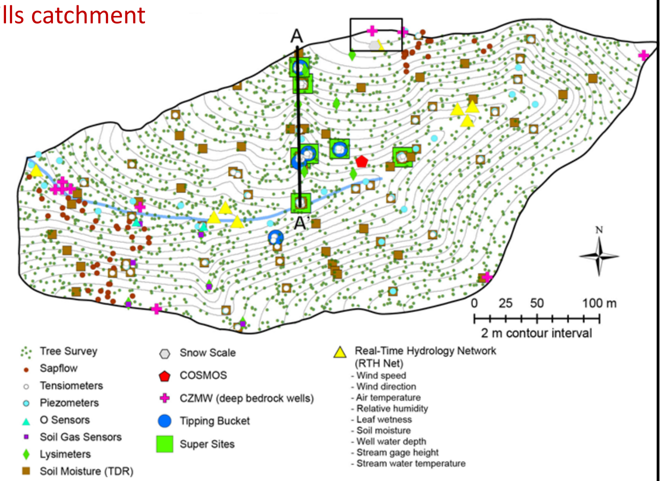
## "Measure everything everywhere"

Shale Hills catchment




Brantley, S. L., et al.: Designing a suite of measurements to understand the critical zone, *Earth Surf. Dynam. Discuss.*, 3, 1005-1059, doi:10.5194/esurfd-3-1005-2015, 2015.

The "measure everything everywhere" sampling strategy at Shale Hills. Insets show soil moisture sensors (circles) and lysimeters (squares) along the transect shown on the map. Sensor and lysimeter depths are exaggerated five times compared to the land surface elevation. Second inset shows instrumentation deployed at the meteorological station on the northern ridge. Small green dots are the surveyed and numbered trees.

II.A

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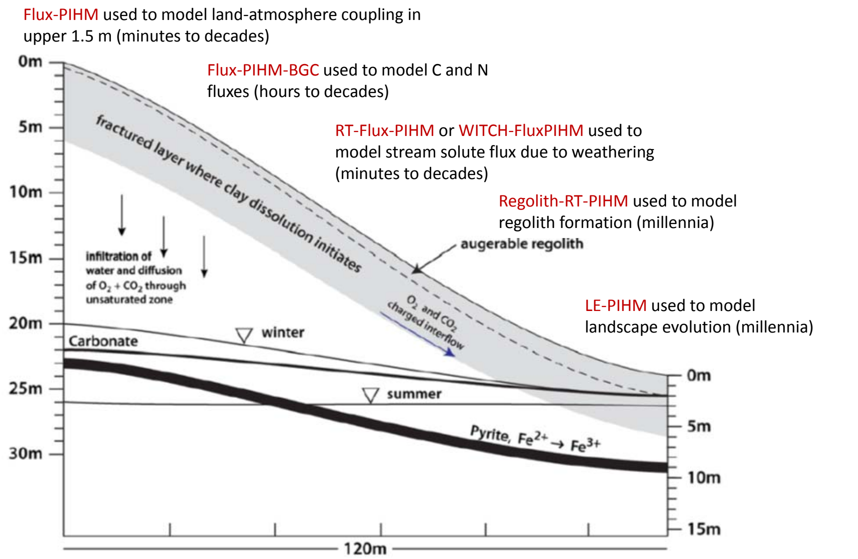
## SH conceptual model and model cascade

NSF




Brantley, S.L., Holleran, M.E., Jin, L., Bazilevskaya, E., 2013. Probing deep weathering in the Shale Hills Critical Zone Observatory, Pennsylvania (U.S.A.): the hypothesis of nested chemical reaction fronts in the subsurface. Earth Surface Processes and Landforms, doi:10.1002/esp.3415.

II.A, II.B

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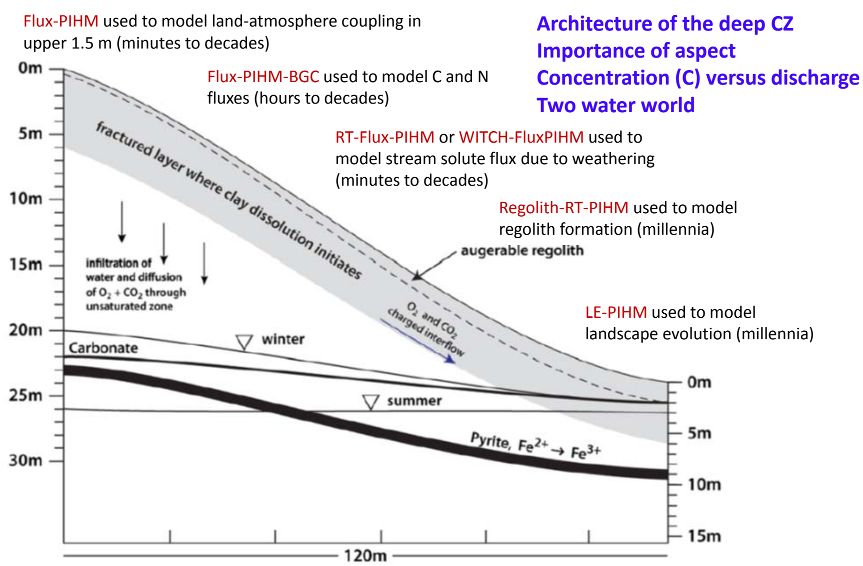
## SH conceptual model and model cascade

NSF

**Architecture of the deep CZ**
**Importance of aspect**
**Concentration (C) versus discharge (Q)**
**Two water world**

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II.A, II.B

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# Emerging understanding of Shale Hills

- Ridges are at steady state such that rate of soil production by weathering ≈ erosion by freeze/thaw. Alluvium and colluvium in the valley have accumulated over longer periods. (Nikki West's PhD)
- In the subsurface, Rose Hill shale has been imprinted with nested reaction fronts, i.e. depth intervals that record mineral reactions and that mark flow boundaries. (Molly Holleran's senior thesis)
- The reaction fronts and hydrologic flow paths are inter-related: 90% of incoming water moves out of SH as interflow in upper 5-meter fractured zone and 10% as regional groundwater flow to the first-order stream. (Pam Sullivan's postdoc)
- Trees use water only from upper tens of cms and tree water is isotopically unlike stream water (it is a "two-water world"). (Katie Gaines' PhD)
- Swales, which contain high soil organic matter and soil gas $CO_2$, largely control the flux of dissolved organic carbon and metals such as iron out of the catchment. (Danielle Andrews' PhD, Beth Herndon's PhD, Liz Hasenmueller's postdoc)
- The sunny side chemically weathers faster than shady side. (Lin Ma's postdoc)
- The Q-C relationship (stream chemistry) is buffered by connectivity, groundwater input, and ion exchange reactions. (Chen Bao's PhD)
- The stream discharge and the distribution of soil moisture is well described by Flux PIHM using rain and soil map inputs. (Y. Shi's PhD, D. Baldwin's M.S., PhD, Xuan Yu's PhD)
- Soils retain the imprint of the industrial revolution (Pb, Mn, other metals). (Beth Herndon's PhD, Megan Carter's Masters thesis)

II.A, II.B, II.C

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II.A, II.B, II.C

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The CZ is a system: we need dense observations with complex high fidelity numerical models that are synthesized and tested against hypotheses and measurements to understand this system.

But do we have to "measure everything everywhere" or can we learn from Shale Hills to "measure only what we need"?

II.A, II.B, II.C

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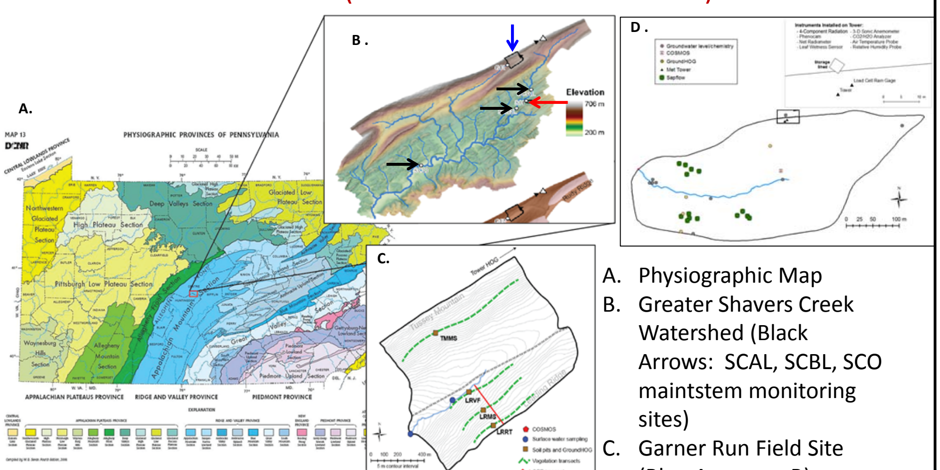
Since being renewed, we are scaling up from a 0.1 km$^2$ to a 121 km$^2$ watershed (Shale Hills to Shavers creek)




A. Physiographic Map
B. Greater Shavers Creek Watershed (Black Arrows: SCAL, SCBL, SCO maintstem monitoring sites)
C. Garner Run Field Site (Blue Arrow on B)
D. Shale Hills Field Site (Red Arrow on B)

II.A

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In scaling up, we must address the question, "*how do we measure the CZ as a system*?" We give our answer in a discussion paper, still online in review.

Earth Surf. Dynam. Discuss., 3, 1005–1059, 2015
www.earth-surf-dynam-discuss.net/3/1005/2015/
doi:10.5194/esurfd-3-1005-2015


Earth Surface Dynamics Discussions

This discussion paper is/has been under review for the journal Earth Surface Dynamics (ESurfD). Please refer to the corresponding final paper in ESurf if available.

## Designing a suite of measurements to understand the critical zone

S. L. Brantley[1], R. DiBiase[1], T. Russo[1], Y. Shi[2], H. Lin[2], K. J. Davis[3], M. Kaye[2], L. Hill[2], J. Kaye[2], A. L. Neal[4], D. Eissenstat[2], B. Hoagland[1], and A. L. Dere[1,a]

[1]Earth and Environmental Systems Institute, Department of Geosciences, Pennsylvania State University, Pennsylvania, PA, USA
[2]Department of Ecosystem Science and Management, Pennsylvania State University, Pennsylvania, PA, USA
[3]Earth and Environmental Systems Institute, Department of Meteorology, Pennsylvania State University, Pennsylvania, PA, USA
[4]Earth and Environmental Systems Institute, Pennsylvania State University, Pennsylvania, PA, USA
[a]now at: Department of Geography & Geology, University of Nebraska Omaha, Omaha, NE, USA

Received: 21 July 2015 – Accepted: 31 July 2015 – Published: 17 September 2015

Correspondence to: S. L. Brantley (sxb7@psu.edu)

Published by Copernicus Publications on behalf of the European Geosciences Union.

By publishing this, we hoped to educate and reach outside of the CZO network to stimulate thought about the CZ as a system. Please comment:

http://www.earth-surf-dynam-discuss.net/3/1005/2015/

II.A, III.A

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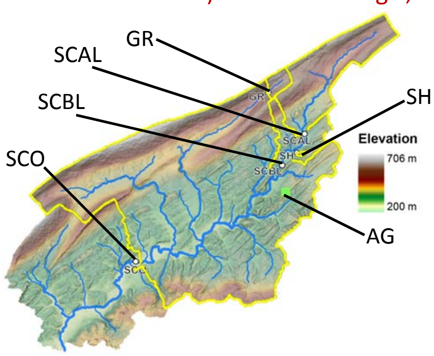
## How do we "measure only what we need?"

We must answer this question to scale from monolithologic, pristine Shale Hills (0.08 km²) to multilithologic, multi-use Shavers Creek (121 km²)




Subcatchments:
SH: Shale Hills (shale, forested)
GR: Garner Run (sandstone, forested)
AG: Agricultural Site (Location Not Final)

Mainstem stream monitoring sites:
SCAL: Shavers Creek Above Lake
SCBL: Shavers Creek Below Lake
SCO: Shavers Creek Outlet

Our scaling-up approach from Shale Hills includes:

- Intensive study using GroundHOG +TowerHOG + groundwater wells in Shale Hills (SH) and in two new first-order sub-catchments – i.e., forested, sandstone at Garner Run (GR) and agricultural calcareous shale site (AG).
- monitoring an additional three sites on Shavers creek mainstem (discharge and streamwater chemistry at sites marked SCAL, SCBL, SCO).
- geophysical observations to integrate between point measurements.
- LiDAR observations.
- geological, geophysical, and ecological observations outside the CZO footprint.
- model-observation feedbacks.

Brantley, S. L., et al.: Designing a suite of measurements to understand the critical zone, *Earth Surf. Dynam. Discuss.*, 3, 1005-1059, doi:10.5194/esurfd-3-1005-2015, 2015.

II.A

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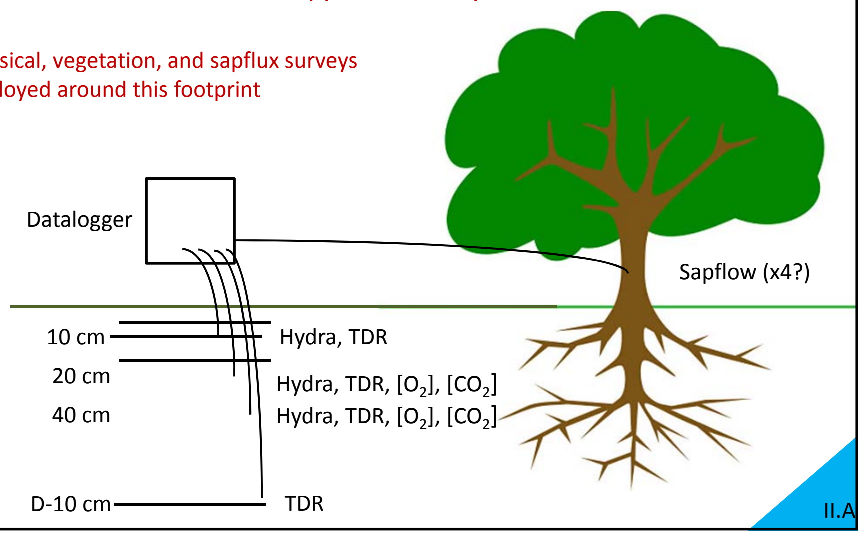
# Ground HOG

Ground-based Hydrologic Observation Gear is a sensor array (soil moisture, soil gas) deployed across 3 sites on a hillslope (i.e., a catena) + one midslope site on opposite hillslope

Geophysical, vegetation, and sapflux surveys are deployed around this footprint




II.A

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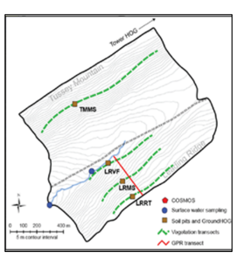
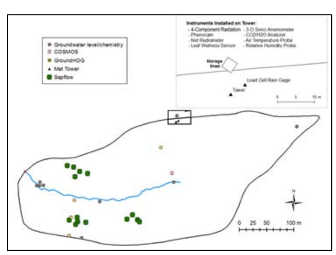
# Ground HOG

| Measurement | Manufacturer | Model | Collection freq. | Number | Depths (cm) |
|---|---|---|---|---|---|
| Soil Moisture | Stevens Water Monitoring | Hydra | 10 min | 3 | 10, 20, 40 |
| [O2] | Apogee | SO | 30 min | 2 | 20, 40 |
| [CO2] | Forerunner Research | GP | 30 min | 2 | 20, 40 |
| Soil Moisture | Eissenstat lab | TDR waveguides | Monthly? | 12 | 10, 20, 40, D-10 |
| Sapflow | Eissenstat lab | n/a | 30 min | 4? 5? | n/a |





Fully implemented in both catchments except sapflux in GR

Ground HOG comprises 4 locations in Garner Run and in Shale Hills.

II.A

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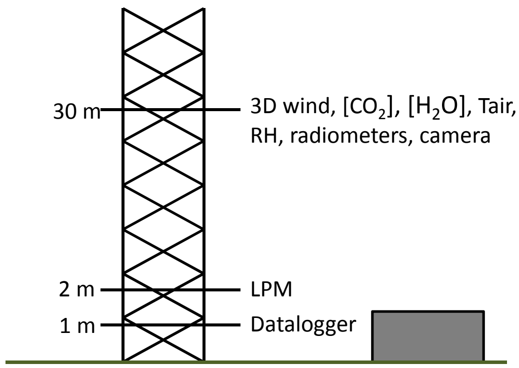
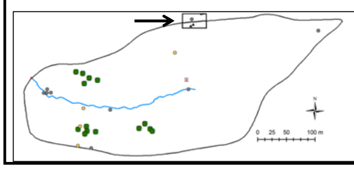
# Tower HOG

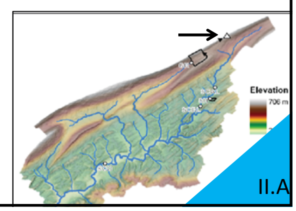
## Tower-based Hydrologic Observation Gear




Power supply (Crown Castle)

- Shale Hills: Fully implemented
- Garner Run: Will use existing commercial tower currently used by WPSU microwave relay; recently received approval from Crown Castle Inc. regarding the deployment






II.A

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# Tower HOG

| Measurement | Manufacturer | Model | Collection freq. |
|---|---|---|---|
| [CO2] | Li-cor | LI-7500A | 10Hz |
| [H2O] | Li-cor | LI-7500A | 10Hz |
| Wind velocity | Campbell Scientific | CSAT3 | 10Hz |
| Precipitation | Thies Clima | LPM | 30 min |
| Precip type | Thies Clima | LPM | 30 min |
| Tair | Vaisala | HMP60 | 30 min |
| Rel Humidity | Vaisala | HMP60 | 30 min |
| LW Radiation* | Kipp & Zonen | CGR3 | 30 min |
| SW Radiation* | Kipp & Zonen | CMP3 | 30 min |
| Snow depth† | Campbell Scientific | SR50A | 30 min |
| Digital Imagery | Campbell Scientific | CC5MPX | 24 hr |
| | | | |
| Soil moisture† | Hydroinnova | CRS-2000 (COSMOS) | 30 min |

Tower HOG system is a minimal set of sensors to support eddy covariance and micro-meteorological studies. Instrumentation is consistent with sensors currently at Shale Hills.

*--upwelling radiation at tower (paired with downwelling at Shale Hills)

†--designed as part of tower system but will be deployed at a Ground HOG location

II.A

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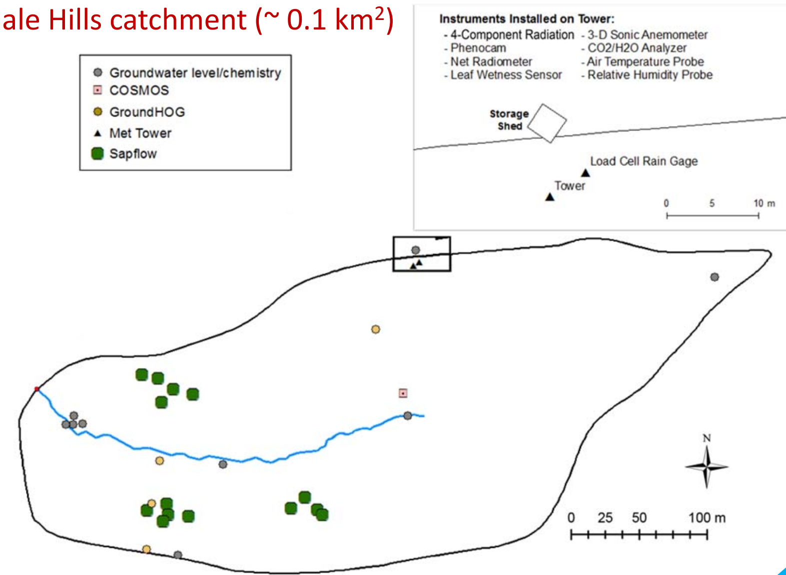
## "Measure only what is needed"

Ground HOG and Tower HOG deployment in Shale Hills catchment (~ 0.1 km$^2$)




II.A

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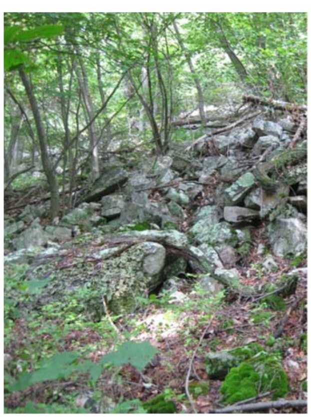
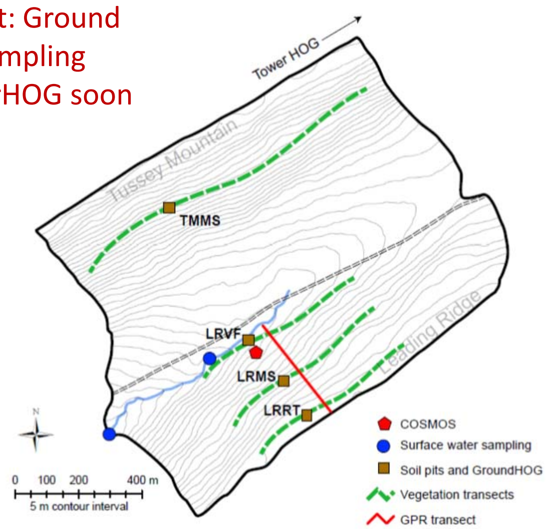
## "Measure only what is needed"

Garner Run subcatchment: Ground HOG deployed, stream sampling begun, well drilled, TowerHOG soon






II.A

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## Surface and Ground Water Measurements

*Hydracore Prospector*

*Example material recovered from 11' - 16' zone*

We could not afford to "drill the ridge" so we drilled the valley (Aug 26/27, 2015). Collaborative effort with Univ of Guelph (Beth Parker, John Cherry). We are now sampling in valley fill at 30, 20, and 7 feet bgs

Additional Details, including core photos: [https://criticalzone.org/images/national/associated-files/Shale%20Hills/HV_well_1_CZO_report.pdf](https://criticalzone.org/images/national/associated-files/Shale%20Hills/HV_well_1_CZO_report.pdf)

II.A, II.E

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CRITICAL ZONE OBSERVATORY

## Two First Year Graduate Students' Emerging Conceptual Models for Garner Run (Geosc 413W)

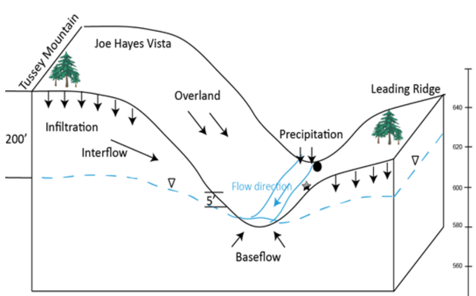
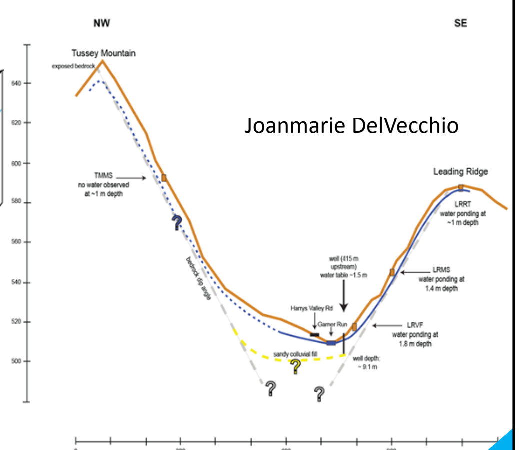



Figure 9: Model of hydrogeology in Garner Run. The well is represented by the solid circle and the spring, a star. Water level in the well sits around 5ft below the surface and the spring water is hypothesized to be sourced from the interflow.

Virginia Marcon




Joanmarie DelVecchio

II.A, II.B

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Our emerging understanding of Garner Run

- Garner Run subcatchment lies above a major knickpoint and experiences slower erosion rates than Shale Hills (below the knickpoint).
- Both sides of the catchment are dipslopes but the shady side is steeper than sunny side.
- Soils contain sandstone boulders with significant clay that must have derived from i) dust or ii) inputs from the previously overlying shale or iii) inputs from previously present shaley layers in the Tuscarora.
- Boulder colluvium and alluvium remain in the valley floor (not at steady state), documenting that erosion has not kept pace with production during glaciations.
- Trees in Garner Run are largely younger than those in Shale Hills: oaks, red maple and black birch in GR versus oaks, hickories and hemlock in SH.
- Water flows as interflow in the upper layers of the hillslope and as regional groundwater flow to the first–order stream.
- Stream chemistry looks like rainwater high in the catchment but evolves toward interflow chemistry downstream.

II.A, II.B, II.C

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

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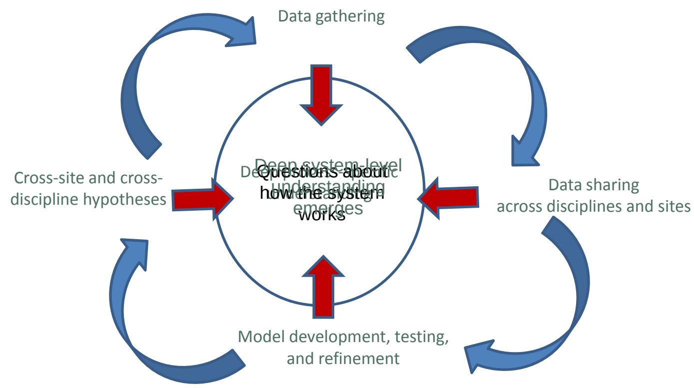
II.A, II.B, II.C

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY




## CZ Research

Research fully integrates students in all aspects of the endeavor

II.B, II.D

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Introducing…

Yuning Shi, Research Faculty working on the CZO

II.C

SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Model-Data Synthesis

- We need dense observations with complex high fidelity numerical models that are synthesized and tested against hypotheses and measurements
  - Use what we learned and collected in the field to develop numerical models, and use numerical models to interpret what we observed in the field
  - Field observations inspire model development to solve puzzles
  - Modeling results provide guideline for data collections

II.C, II.H

SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

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II.C, II.H

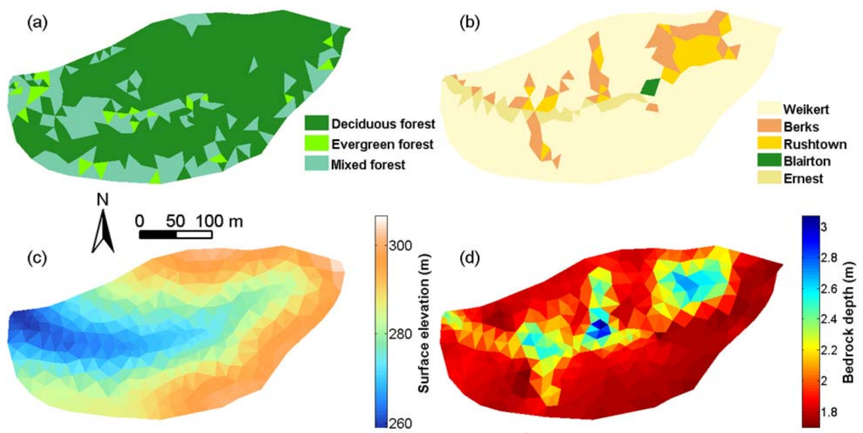
CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Integrating dense measurements into CZ models

Shi, Y., et al.: Development of a coupled land surface hydrologic model and evaluation at a critical zone observatory. *J. Hydrometeor.*, **14**, 1401—1420, doi:10.1175/JHM-D-12-0145.1, 2013

From tree survey

From soil survey




From CZO lidar measurements

From soil survey

II.C, II.H

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CRITICAL ZONE OBSERVATORY

# Integrating dense measurements into CZ models

| Parameter | Description | Source |
|---|---|---|
| $K_{\text{inf}V}$ | Vertical saturated hydraulic conductivity of infiltration layer | Lin (2006) |
| $K_V$ | Vertical saturated hydraulic conductivity | Lin (2006) |
| $K_H$ | Horizontal saturated hydraulic conductivity | Lin (2006) |
| $\Theta_S$ | Porosity | Lin (2006) |
| $\alpha$ | Van Genuchten soil parameter | Baldwin (2011) |
| $\beta$ | Van Genuchten soil parameter | Baldwin (2011) |

| Forcing Data | Source |
|---|---|
| Precipitation, 2-m air temperature, and relative humidity | CZO weather station |
| LAI | MODIS data rescaled using field LAI measurements |

II.C, II.H

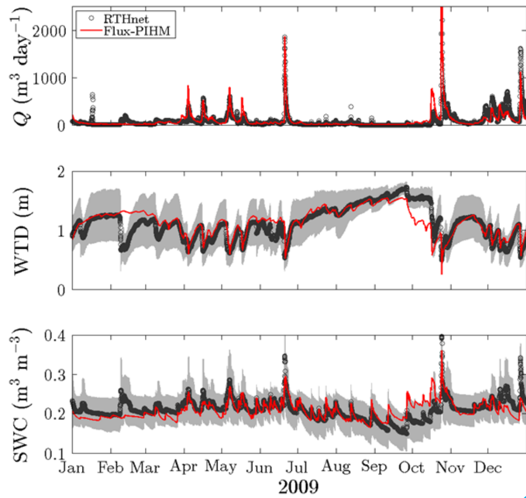
CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Using in situ measurements as input data, Flux-PIHM provides accurate predictions of discharge, water table depth, and soil water content at one location after calibration

Discharge

Water table depth at one location

Soil water content at one location




II.C, II.H

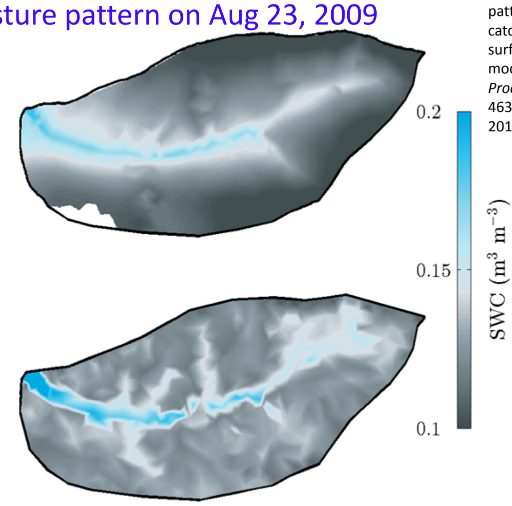
CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## When calibrated using discharge and point measurements, can Flux-PIHM predict the soil moisture pattern at Shale Hills?

10-cm soil moisture pattern on Aug 23, 2009

Measurements (interpolated)

Flux-PIHM prediction




Shi, Y., et al.: Simulating high resolution soil moisture patterns in the Shale Hills catchment using a land surface hydrologic model. *Hydrological Processes*, **29**, 4624—4637,doi:10.1002/hyp.10593, 2015

II.C, II.H

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

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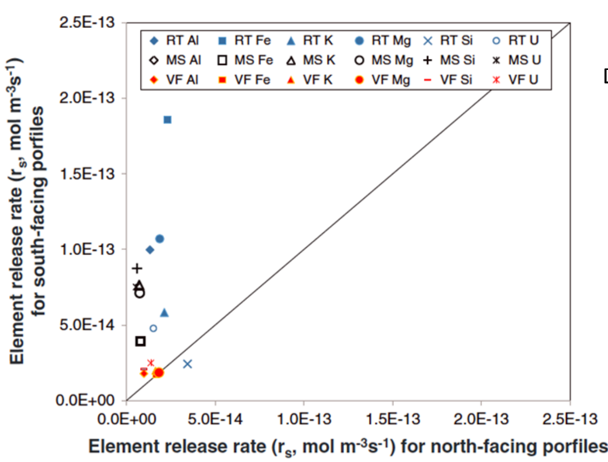
II.C, II.H

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Observation: Sun-facing hillslopes are weathering faster than shaded hillslopes

Sun-facing hillslopes




Shaded hillslopes

**Hypothesis:**

Differences in incoming *solar radiation*
↓
Differences in *evapotranspiration*
↓
Differences in *vertical water flow* (e.g., recharge)
↓
Differences in *weathering rates*

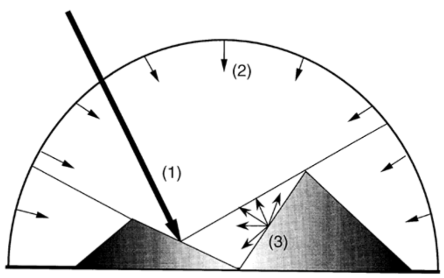
Ma, L., F. Chabaux, N. West, E. Kirby, L. Jin and S. Brantley (2013), Regolith production and transport in the Susquehanna Shale Hills Critical Zone Observatory, Part 1: Insights from U-series isotopes, J. Geophys. Res. Earth Surf., 118, 722–740.

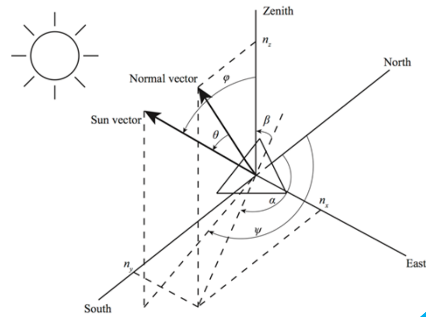
II.C, II.H

CZO | SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

## Adding topographic solar radiation module to Flux-PIHM to quantitatively investigate the difference between N. and S. facing slopes

$$S = \underbrace{S_{\mathrm{dir}} \cos\theta}_{\text{Direct radiation}} + \underbrace{V_d S_{\mathrm{dif}}}_{\text{Diffuse radiation}} + \underbrace{0.2 C_t \left(S_{\mathrm{dir}} \cos\varphi + S_{\mathrm{dif}}\right)}_{\text{Reflected radiation from nearby terrain}}$$



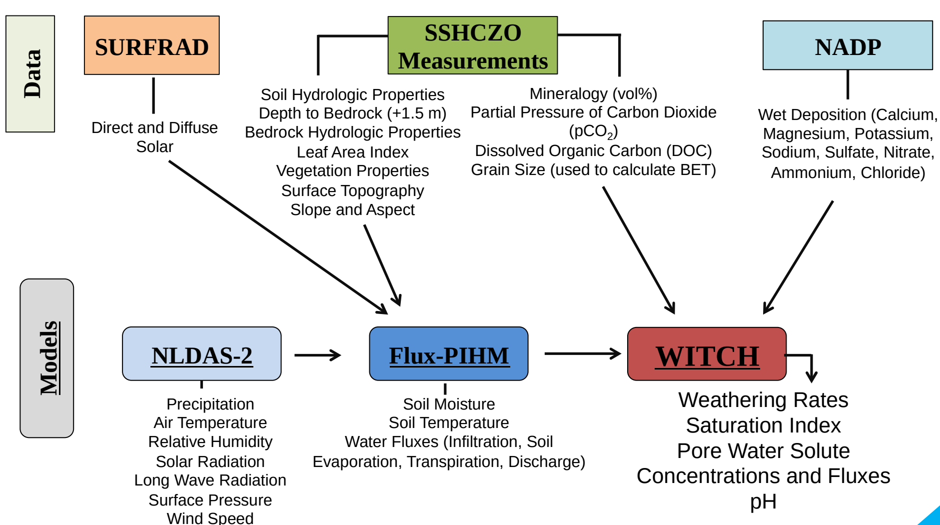

Dubayah (1994)

II.C, II.H

CZO | SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

## Linking of Flux-PIHM and WITCH

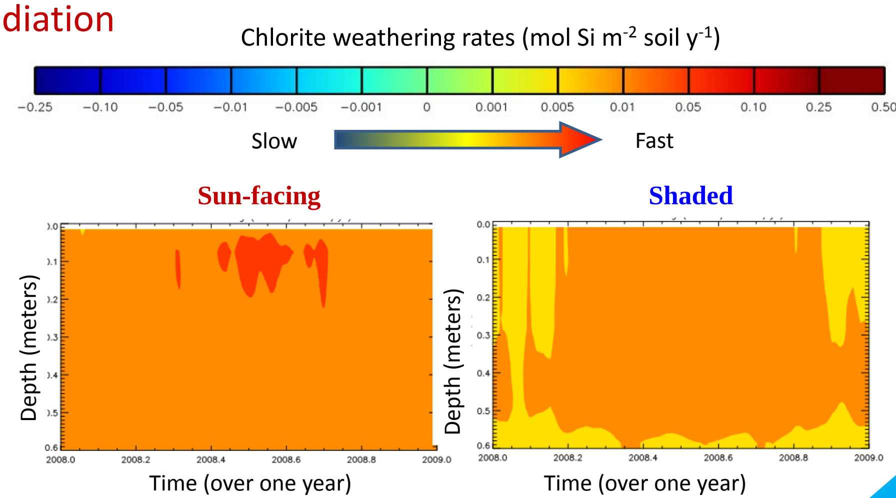
(Sullivan P. et al. in prep.)




II.C, II.H

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Flux-PIHM-WITCH model shows higher weathering rate on the Sun-facing slope after adding topographic solar radiation




II.C, II.H

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Model-Data Synthesis

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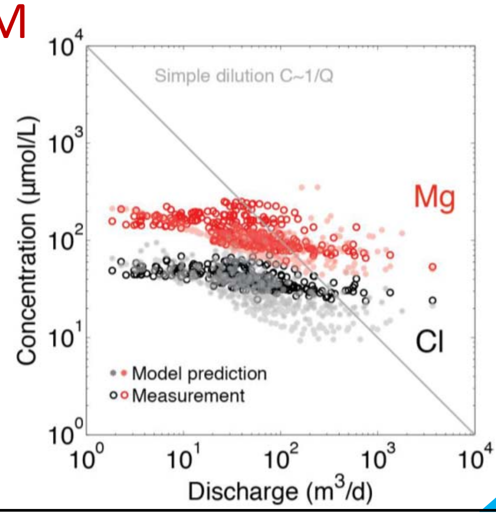
II.C, II.H

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Comparison of concentration-discharge relationship for Mg and Cl between data and RT-Flux-PIHM




Bao, C. et al.: RT-Flux-PIHM: A coupled hydrological, land surface, and reactive transport model for hydrogeochemical processes at the watershed scale. *Water Resources Research*, **submitted**.

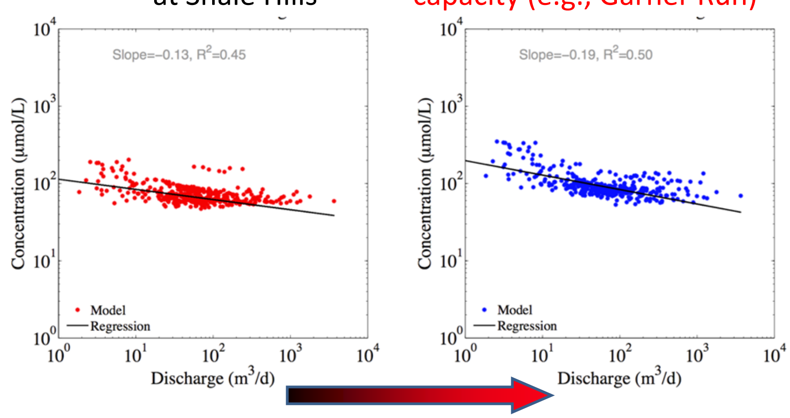
II.C, II.H

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Testing the impact of ion exchange capacity on C-Q relationship for Mg

Ion exchange capacity at Shale Hills

Lower ion exchange capacity (e.g., Garner Run)




Less chemostatic

II.C, II.H

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CRITICAL ZONE OBSERVATORY

# Introducing…

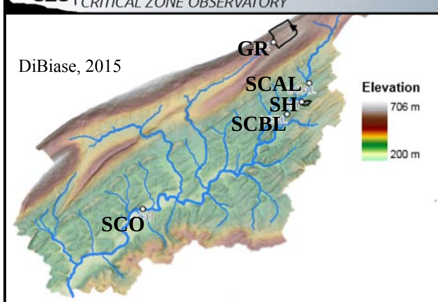
Beth Hoagland, second year graduate student in Dept. of Geosciences working on the CZO

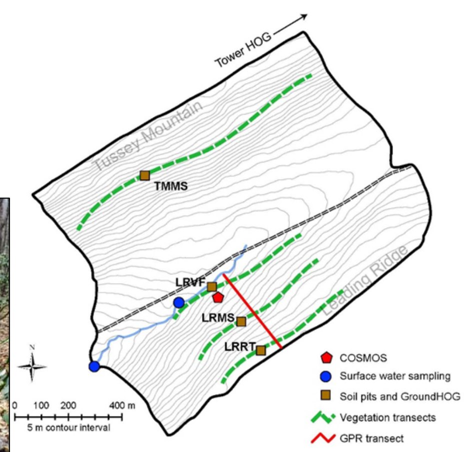
II.C, II.H

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Garner Run subcatchment: Tuscarora sandstone

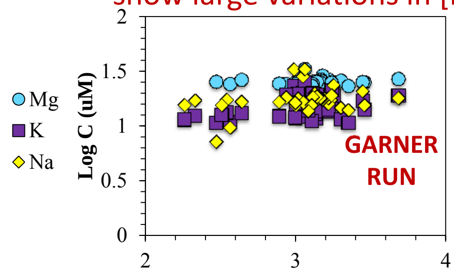
DiBiase, 2015



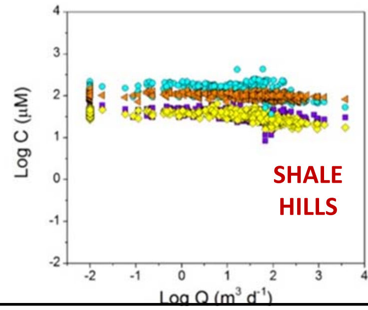




II.C, II.H

## FluxPIHM Model predicts that Garner Run catchment should show large variations in [Mg] versus discharge, but…




Hoagland, 2015




Herndon et al., 2015

**Sandstone catchment expected to have:**
(a) low cation exchange capacity (CEC)
(b ) strong hyporheic interactions (stream-groundwater interactions)

**Shale catchment characteristics:**
(a) high CEC of shale clays,
(b ) governing flowpath: swale-stream connectivity

II.C, II.H



## What is the origin of observed soil characteristics at GR?


Instrumented soil pit in the valley floor of Garner Run subcatchment

- We had thought soils on the sandstone (quartzite) in Garner Run would be clay-poor with limited cation exchange...thus very different from soils at Shale Hills
- But...Geosci 413W class discovered the soils are clay-rich
- Why are clays present in Garner Run catchment?
  - Were the clays from dust inputs?
  - Were the clays from weathering of the overlying Rose Hill shale?
  - Were the clays from shale units within the Tuscarora formation?

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CRITICAL ZONE OBSERVATORY

# Not simply fitting a model...

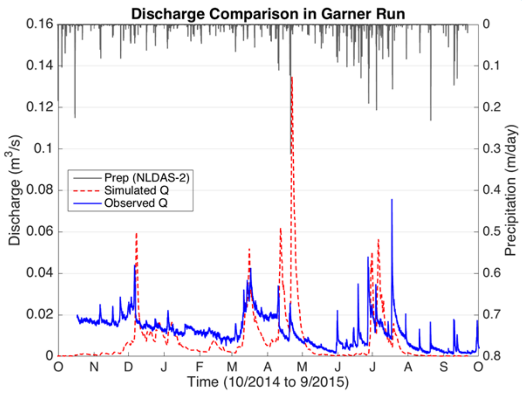
- What can our models tell us about Garner Run? Can the same fundamental modeling characteristics developed at SH apply to GR?
- So far, our Flux-PIHM model for GR was developed by Dacheng Xiao using national databases with calibration coefficients from Shale Hills

Input Data for Flux-PIHM

| Data | Source |
|---|---|
| Surface elevation | USGS NED |
| Bedrock depth | Estimating from GPR data (Lin,2015) |
| Soil map and parameters | SSURGO |
| Vegetation map | National Land Cover Database |
| Watershed boundary | NHD HUC12 |
| Forcing data | NLDAS-2 + MODIS (LAI) |

- USGS NED: United States Geological Survey, National Elevation Dataset
- SSURGO: Soil Survey Geographic database
- NHD HUC12: National Hydrography Dataset, Hydrologic unit code 12-digit

D. Xiao, 2015




II.C, II.H

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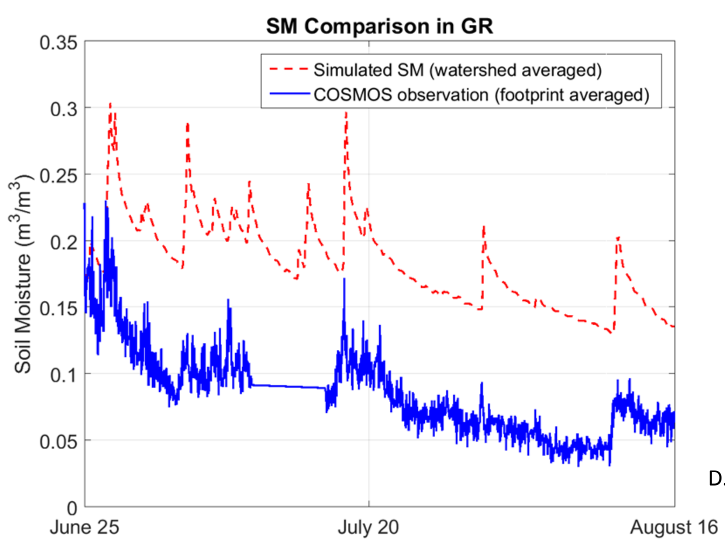
# Flux-PIHM does not yet include the unique soil characteristics of GR catchment




D. Xiao, 2015

II.C, II.H

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# Geologic pre-conditions influence CZ evolution and soil characteristics

- Periglacial conditions → boulder fields
- Are boulders the cause of differences in soil moisture modeling?

II.A, II.H

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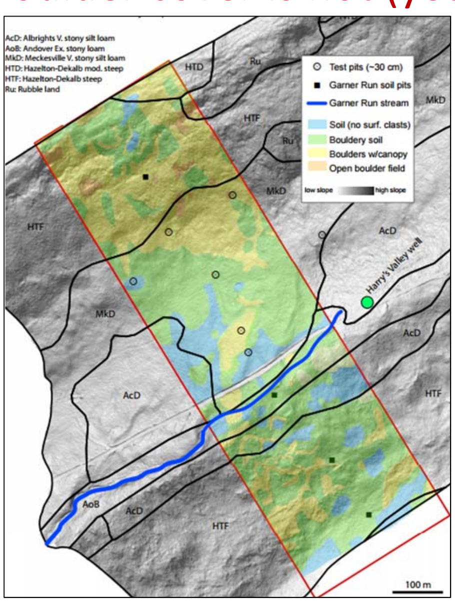
# Boulder cover is not (yet) built into Flux-PIHM




- 16 – 34% rock cover along transects

  (Margot Kaye, 2014)
- 0.05 – 0.20 $m^3$ rock size

S. Granke & J. Del Vecchio, 2015

II.C, II.H

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## Preliminary conclusions/challenges from GR

- C vs. Q relations at Garner Run and Shale Hills are the same for some solutes (Mg, Na, K)
- Geological pre-conditions need to be accounted for when applying Flux-PIHM to different catchments
- More measured data are needed to calibrate the Flux-PIHM model for Garner Run (e.g. GroundHOG measurements, etc.)

II.C, II.H

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## Summary: SSHCZO Site Research

II.

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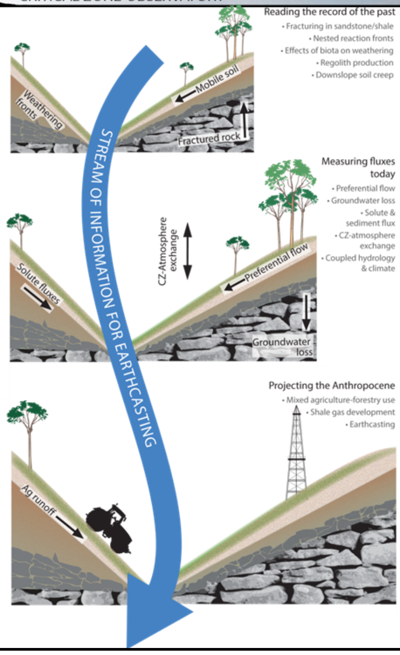
CRITICAL ZONE OBSERVATORY




## Why do we care about little catchments in central PA?

II.B, II.D

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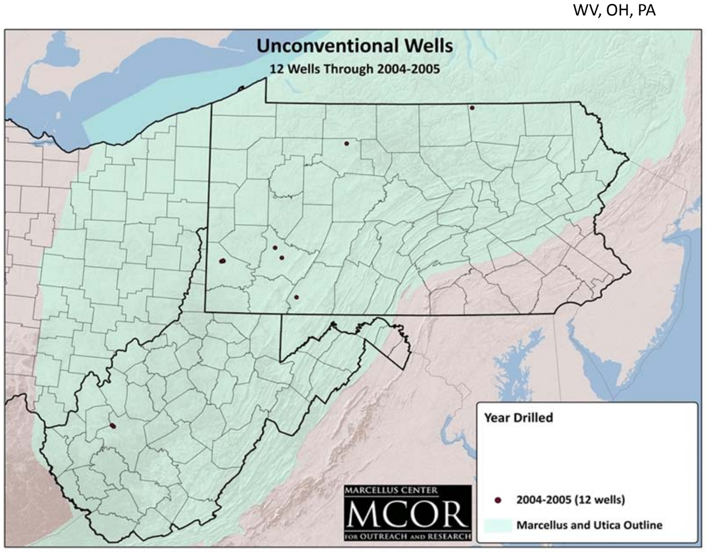
## One Example: Development of the Marcellus shale

WV, OH, PA




II.B, II.D

# Education and Outreach

III.

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

NSF Virtual Site Review – November 9th 2015

## III. Education and Outreach

- *A) Has the CZO pursued effective education and development of a diverse cohort of students engaged in critical-zone research and related issues?*
- *B) Has the CZO been actively engaged in outreach beyond the traditional academic and scientific communities?*
- *C) Has the CZO identified goals, strategies, plans, and metrics for its public outreach and education activities, including broadening participation of underrepresented groups?*

III.

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NSF

## *Overall goals, strategies, plans, and metrics for public outreach and education activities, including broadening participation of underrepresented groups*

- Goals: to teach our students about CZ science; to engage new scientists and students in CZ science; to teach non-scientists about the CZ
- Strategies: funding for students and postdocs; CZO seminar series; annual All-Hands meeting; “field crew”; student/postdoc involvement in governance; seed grants for collaborative research; Tree Workshop; CZ-tope; TeenShale Network; CZO REU/RET; CZO Data Sonification
- New Plans: Shaver’s Creek Environmental Center to feature CZO data and activities
- Metrics: students, seed grants, senior theses, REUs, RETs, under-represented groups

III.C

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CRITICAL ZONE OBSERVATORY

NSF

## Education and Outreach within the CZO

III.A

# 12 Graduate Students Supported

- Fall 2013: None (grant was awarded in Oct '13).
- Spring 2014: Yu Zhang, Yuting He, Isaac Hopkins – 33% women
- Summer 2014: Katie Gaines, Beth Hoagland, Yuting He, Julie Weitzman, Yu Zhang – 80% women
- Fall 2014: Chen Bao, Dacheng Xiao, Yu Zhang, Yuting He, Katie Gaines, Al Denn (University of Vermont) – 50% women
- Spring 2015: Katie Gaines, Chen Bao, Dacheng Xiao, Yuting He, Yu Zhang, Al Denn (University of Vermont) – 50% women
- Summer 2015: Yu Zhang, Chen Bao, Dacheng Xiao, Joanmarie Del Vecchio, Yuting He, Katie Gaines – 50% women
- Fall 2015: Joanmarie Del Vecchio, Lillian Hill, Dacheng Xiao, Chen Bao, Hua Xu – 40% women
- Total support: Undergraduates – 5 (40% women), Graduate+Postdoctoral students – 18 (61% women), PIs – 11 receive NSF salary support (36% women), staff – 3 (33% women).
- All students are part of the “field crew.”
- We have a student representative on our executive committee.

III.A



# 6 Funded Postdocs Since Renewal

- **Pamela Sullivan** – Now at University of Kansas, Asst Professor of Geography; Sullivan PL, Goddéris Y, Shi Y, Schott J, Duffy CJ, Brantley SL. *In Prep*. Using WITCH to quantify landscape and hydrologic controls on solute fluxes in the Critical Zone (Susquehanna Shale Hills Observatory, PA). Geochemica et Cosmochimica; Sullivan PL, Ma L, West N, Jin L, Karwan DL, Noireaux J, Steinhoefel G, Gaines K, Eissenstat D, Gaillardet J, Derry LA, Meek K, Hynek S, Brantley SL (In Review). CZ-tope at Susquehanna Shale Hills CZO: Testing multiple isotope proxies to elucidate Critical Zone processes across timescales. Chemical Geology ; Sullivan PL, Hynek S, Singha K, White T, Gu X, Clarke B, Duffy CJ, Brantley SL. 2015. Oxidative dissolution under the channel leads geomorphological evolution at the Shale Hills Catchment. American Journal of Science (In Revision)
- **Elizabeth Hasenmueller** – now at St. Louis University, Asst Professor of Earth & Atmospheric Sciences; Hasenmueller, E.A., Jin, L., Stinchcomb, G.E., Lin, H., Brantley, S.L., Kaye, J.P., 2015, Topographic controls on the depth distribution of soil $CO_2$ in a small temperate watershed. *Applied Geochemistry*, 63, 58-69; Hasenmueller, E.A., Xin, G., Weitzman, J.N., Adams, T.S., Stinchcomb, G.E., Eissenstat, D.M., Brantley, S.L., Kaye, J.P., The activity of deep roots in bedrock fractures at Susquehanna Shale Hills Critical Zone Observatory, USA. *Geoderma*, in prep.
- **Yuning Shi** – Penn State, Research Associate Ecosystems Science and Management; Using a spatially-distributed hydrologic biogeochemistry model to study the spatial variation of carbon processes in a Critical Zone Observatory (in prep). Shi, Y., D. C. Baldwin, K. J. Davis, X. Yu, C. J. Duffy, and H. Lin, 2015: Simulating high resolution soil moisture patterns in the Shale Hills catchment using a land surface hydrologic model. Hydrological Processes, 29, 4624—4637,doi:10.1002/hyp.10593. Shi, Y., K. J. Davis, F. Zhang and C. J. Duffy, and X. Yu, 2015: Parameter estimation of a physically-based land surface hydrologic model using an ensemble Kalman filter: A multivariate real-data experiment. Advances in Water Resources, 83, 421—427,doi:10.1016/j.advwatres.2015.06.009.
- **Brian Clarke** – University of California, Santa Barbara, Research Associate Earth Research Institute
- **Hyojin Kim** – Penn State University, Postdoctoral Scholar; Physical particle erosion occurs in the subsurface too (in prep)
- **Nicole West** – now at Georgia Institute of Technology, Postdoctoral Fellow in Earth and Atmospheric Sciences; Using ridgetop curvature to test the influence of lithology and climate on the evolution of first-order watersheds in the central Appalachians (in prep); Insights on deep critical zone evolution from seismic refraction surveys in the Susquehanna Shale Hills Critical Zone Observatory (in prep)

III.A

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

## Seminar Schedule 2014-2015

- ***September 19th***: Susan Brantley, Distinguished Professor of Geosciences and CZO PI, - "***The State of the CZO***"
- ***October 17th:*** Hyojin Kim, Postdoctoral Scholar with EESI, "***Water chemistry evolution through the critical zone revealed by parallel hydrochemistry observations***"
- ***November 7th:*** Chen Bao, PhD Candidate Energy and Mineral Engineering, "***Development of an integrated hydrogeochemical model RT-Flux-PIHM: what have we learned?***"
- ***November 14th***: Fabio Reis, Visiting Scholar, "***Stochastic models and dissolution processes***"
- ***December 5th***: Margot Kaye, Assistant Professor of Forest Ecology, will present "***Forests and the Critical Zone***" in **117 EES Building.**
- **January 16th:** Precepts for Collaboration discussion
- **February 13th:** Yu Zhang, PhD Candidate Environmental Engineering, "***A Next Generation Landscape Evolution Model with Applications to the Shale Hills CZO***"
- **March 20th:** Garner Run Updates. Multiple presenters.
- **April 10th:** Trees in the CZO. Multiple presenters.
- **May 11th– 12th**: SSHO All-Hands

Presentations may be accessed live via Adobe Connect (internal) and are archived at https://criticalzone.org/shale-hills/news/story/susquehanna-shale-hills-czo-videos/

III.A

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

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- ***October 17th:*** Hyojin Kim, Postdoctoral Scholar with EESI, "***Water chemistry evolution through the critical zone revealed by parallel hydrochemistry observations***"
- ***November 7th:*** Chen Bao, PhD Candidate Energy and Mineral Engineering, "***Development of an integrated hydrogeochemical model RT-Flux-PIHM: what have we learned?***"
- ***November 14th***: Fabio Reis, Visiting Scholar, "***Stochastic models and dissolution processes***"
- ***December 5th***: Margot Kaye, Assistant Professor of Forest Ecology, will present "***Forests and the Critical Zone***" in **117 EES Building.**
- **January 16th:** Precepts for Collaboration discussion
- **February 13th:** Yu Zhang, PhD Candidate Environmental Engineering, "***A Next Generation Landscape Evolution Model with Applications to the Shale Hills CZO***"
- **March 20th:** Garner Run Updates. Multiple presenters.
- **April 10th:** Trees in the CZO. Multiple presenters.
- **May 11th– 12th**: SSHO All-Hands

One big success during 2015 is internal publication of a document, spearheaded by CZO PI Jason Kaye, "CZO *Precepts of Collaboration*." We spent several months discussing (and signing) a group agreement about how we collaborate in CZO.

III.A

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Education and Outreach with scientists outside the CZO

III.A

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# REU/RETs and the CZO

- 2014: 2 RETs and 6 REUs, each presented poster at CUAHSI's Biennial Meeting in Shephardstown, WV, *July 28th – 30th*
  - Olivia Beaulieu (REU, University of Massachusetts Amherst
  - Jessica Fisher (REU, Brown University)
  - Quincey Johnson (REU, Hobart and William Smith Colleges)
  - Christine Kim (REU, Temple University)
  - Paul Longwell (RET, Hollidaysburg Area High School)
  - Kim Schmid (REU, The Pennsylvania State University)
  - Mieke Vrjimoet (REU, Bennington College)
  - Mark Yeckley (RET, Glendale School District)
- 2015: 2 RETs and 6 REUs, 100% female, 3 posters presented at ESA in Baltimore, MD, *Aug.10*
  - Kelsey Bicknell (REU, University of New Mexico)
  - Siobhan Donnelly (RET, Centre Learning Community Charter School, State College, Pa.)
  - Sharon Dykhoff (RET, Dominion Christian School, Oakton, VA)
  - Sarah Granke (REU, Pomona College, Claremont, CA)
  - Meaghan Redmon (REU, Hanover College, Hanover, IN)
  - Maggie Ruppel (REU, Wittenberg University, Springfield, OH)
  - Anna Schwyter (REU, Pennsylvania State University)
  - Meaghan Shaw (REU, Southern Methodist University, University Park, TX)

III.A, III.B

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Seed Grant Proposals for Collaborative Research in SSHCZO

Request for Proposals emphasizes:

- cross cutting projects between CZOs; or
- measurements that address cross cutting questions for the CZO network; or
- projects that bring in a larger diversity of scientists and especially students.

Criteria for selection:

- scientific soundness;
- novelty;
- record of productivity;
- student participation;
- correspondence to ongoing SSHO and CZO network activities; and
- significance of proposed research.

2014 – received 8 proposals, funded 2 at $10k each
2015 – received 3 proposals, funded 1 at $20k

III.A, III.C

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Seed Grants – 2012/2013 (Reported Results in Blue)

- $10k: Dr. Lixin Jin, UTEP, *Using carbon isotopes to determine the sources and mass balance of $CO_2$ during shale weathering at Susquehanna Shale Hills Critical Zone Observatory: - Student Training: Undergraduate students (Emmanuel Sosa, Sean Sahs, Isaac Martinez, Hugo Hernandez) were trained on water sample analyses including anions on ion chromatography, cations on ICP and alkalinity by Gran Titration method; - 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; - 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 $CO_2$ consumption potential during gray shale weathering: Insights from the evolution of carbon isotopes in the Susquehanna Shale Hills CZO. Geochimica Cosmochimica Acta 142, 260-280.*

- $10k: Dr. Jonathan Nyquist, Temple University, *Geophysical Prediction of Water Migration along the Soil-Bedrock Interface at the Shale Hills Critical Zone Observatory: - Matriculated Lacey Pitman, M.S. in Geophysics, Temple University; - Conference Abstracts: Nyquist, JE, Toran L, Lin, H. 2015. Ground-based LiDAR mapping of infiltration and flow paths on a bedrock slope. SAGEEP, Austin TX, March 22-26.; Nyquist, J, Toran, L, Pitman, L, and Lin, H. 2014. Dynamic time warping of time-lapse GPR data to monitor infiltration at the Shale Hills Critical Zone Observatory in a session on advances in GPR. SAGEEP, Boston, MA, March 16-20.; Nyquist, J, Pitman, L, Toran, L, and Lin, H. 2013. Geophysically-monitored dye tracer test of infiltration in the unsaturated zone at the Shale Hills CZO. Geological Society of American Annual Meeting, Denver, CO, October 27-30. Abstracts with Programs. Vol. 45, p 262.; Nyquist, J, Lichtner, D, Toran, L, Guo, L., Lin, H. 2013. Monitoring Shallow Subsurface Flow on a Hillslope using Time-lapse GPR and ERT. Symposium for the Application of Geophysics to Environmental and Engineering Problems SAGEEP. Denver, Colorado USA I March 17-2; - Publication: Nyquist, J, Toran, L, Pitman, L and Lin, H. Comparison of Time-Lapse GPR and Dye Tracer Tests for Monitoring Hillslope Flow in the Susquehanna Shale Hills CZO, Pennsylvania. (In prep.)*

Seed grants given out before renewal, publication since renewal

III.A, III.C

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Seed Grants – 2013/2014 (Reported Results in Blue)

- $10k: Dr. Margot Kaye, PSU, *Filling gaps in the aboveground carbon budget of the SSHO CZO: - Matriculated Lauren Smith, M.S. in Ecology, Penn State; - Publications: Kaye, Margot W.; Smith, Lauren; Eissenstat, David (2016): Susquehanna Shale Hills Litter and Dendroband Data. EarthChem Library. http://dx.doi.org/10.1594/IEDA/100517 ; Smith, LA, DM Eissenstat, MW Kaye, (to be submitted to Forest Ecology and Management). The role of tree species and topography in aboveground carbon dynamics of an eastern deciduous forest, USA. Forest Ecology and Management.*

- $10k: Dr. Lin Ma, UTEP, *Quantifying regolith formation rates with U-series isotopes along the shale weathering transect within the Susquehanna Shale Hills CZO: - Student Training: 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 pursues his MS degree in low temperature geochemistry at University of Tennessee; - Conference Abstracts: Invited talk at AGU: Ma, L., Chabaux, F., Dere, A., White, T., Jin, L., Brantley, S., AGU annual meeting (San Francois, CA, 2012), "Using U-series isotopes to quantify regolith formation rates and chemical weathering timescales along a shale transect within the Susquehanna Shale Hills Critical Zone Observatory," AGU, San Francois, CA, 2012. (December 6, 2012); Poster at AGU: Ma, L., Jin, L., Dere, A., White, T., Mathur, R., Brantley, S., American Geophysical Union annual meeting (San Francois, CA, 2012), "How lithology and climate affect REE mobility and fractionation along a shale weathering transect of the Susquehanna Shale Hills Critical Zone Observatory," American Geophysical Union, San Francisco, CA. (December 10, 2012); Invited talk at GSA 2015, Pardee Keynote Syposium: Lin Ma, Francois Chabaux, Nikki West, Eric Kirby, Lixin Jin, and Susan Brantley, Regolith production and transport in the Susquehanna Shale Hills Critical Zone Observatory: Insights from U-series isotopes. Annual meeting of Geological Society of America, Baltimore MD (November 1st- 4th, 2015); - Publication: Ma, L., Konter, J., Sanchez, D., Herdon, E., Jin, L., and Brantley, S. (2014). Quantifying the signature of the industrial revolution from Pb concentrations and isotopes in Pennsylvania soils. Anthropocene 7, 16-29.*

III.A, III.C

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Seed Grants – 2014/2015 (Reported Results in Blue)

- $10k: Dr. Elizabeth Herndon, Kent State, *Investigating inorganic and organic-mediated cation transport from soils to streams: GEOL 42069/52069 Hydrogeochemistry field trip of undergraduate and graduate students to the CZO; Student Training: three undergraduates were hired and trained in analytical techniques (1 fall 2014, 1 spring 2015, and 1 both terms); Conference abstracts/Publications: in preparation pending final analyses*

- $10k: Dr. Carleton Bern, USGS, *Quantification of mass balance of colloidal material across lithologies and environments*: *- Conference abstracts: planned for 2016*

III.A, III.C

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Seed Grants – 2015/2016 (just awarded)

- $20k: Dr. Kristen Brubaker, Hobart and William Smith Colleges, *Modeling fine-scale above ground carbon storage using LiDAR: A comparison across two watersheds*

III.A, III.C

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Seed Grants for the Future?

- Original plan for future: funding **1-2 awards/y up to 20k total funds available**. We expected grants would be used for activities that further science in the CZO.
- We are currently discussing whether we should do more seed grants
- Pros: seed grants bring in outsiders, bring in students from other types of institutions, allow alternate viewpoints, complements PI research
- Cons: the small amount of money involved does not allow big impact, we are short of money for our mainstream research, TeenShaleNetwork become very successful and needs funds, few publications have resulted

III.A, III.C

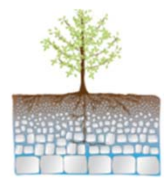
SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Tree Workshop (Sept 9-11$^{th}$, 2015)

Exploring Four Critical Puzzles about Trees, Water, and Soil: A Vision for Research

- 29 total participants (1/2 women) from across US and Canada, 6 students
- 3 international
- 15 institutions represented
- 12 oral presentations, 4 posters
- 1 field trip to the CZO
- Team is currently working on a paper: ***How trees build and plumb the CZO***
  - Nov 15: template draft to show to an editor
  - Jan 15: 1$^{st}$ draft

- Both CZO scientists and scientists new to the CZO community.
- Highly interdisciplinary group.



III.A

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Websites developed (beyond national SSHCZO page)

- PIHM modelling: private github website developed for all the PIHM modules will become public soon (MM-PIHM, i.e., multimodule PIHM)
- Locally hosted data site: http://www.czo.psu.edu/data_agreement.html
- UVM cosmogenic data site under development by graduate student Al Denn at www.uvm.edu/cosmolab/

III.B

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

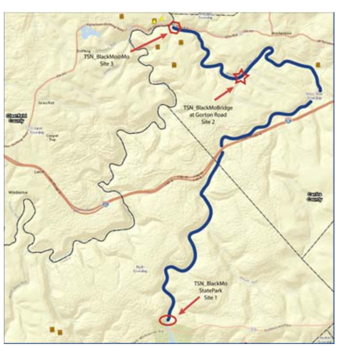
# Education and Outreach to the Public

III.B

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## OUTREACH - TeenShale Network – State College Area High School Earth Science

- 2015-2016 is 4th academic year, 2 field trips per month, 27 participants
- Water quality monitoring along Moshannon creek above and below shale gas wells
- Graduate students and some faculty are involved
- Participation of high schools students: 7 students (2012-2013), 16 students (2013-2014) and 30 students (2014-2015)





III.B

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

NSF

# CZO *Data Sonification*

- Graduate student Matthew Kenney completed his Masters of Fine Arts, Arts and Architecture, Penn State (2015), working on *Isotopic data sonification: Shale Hills Critical Zone Observatory*.
  - Presented at both the 2014 & 2015 SSHCZO All-Hands meetings at Penn State *"Data visualization and sonification"*
  - 2014 presented at State College Area High School
  - Extended abstract presented at the International Conference on Auditory Display (ICAD) 2014 at New York University.
- Original plan was to play this at the Shavers Creek Discovery Center. However Kenney's final product was not finished enough for this and we are seeking other ways to interact with the Discovery Center

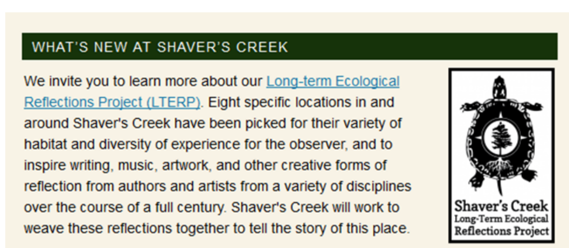
III.A,
III.B

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

NSF

# We are working to expand CZO outreach with the neighboring Shaver's Creek Environmental Center (approximately 10,000 visitors / year)

Discussions underway with Environmental Center to promote interactions between the CZO and Environmental Center. Future work might facilitate access to PhenoCAM visuals, or possibly to create a CZO "Discovery Zone" exhibit at the Discovery Center in collaboration with student teams trained at the Center




III.B

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# E & O Metrics

III.A,
III.C

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CRITICAL ZONE OBSERVATORY

# Metrics for Outreach and Education Since 10/01/13

- Seed grants awarded: 3
- Number of undergraduate senior theses: 7
- Number of grad students funded: 12; #PhDs defended: 6; #Masters defended: 3
- Number of postdocs funded: 6
- Number of REUs hosted: 12; Number of RETs hosted: 4
- Number of female PIs on project: 5 of 13
- Number of untenured PIs on project: 3 of 13
- Number of women graduate students: 10
- Number of students from under represented groups: 3
- Number of postdocs from under represented groups: 1*
- Number of high school students in Teen Shale Network: 27
- Number of papers presented at meetings: 68
- Number of scientific special sessions organized: 6
- Number of workshops funded by CZO or organized by PIs: 2
- Number of participants at our Tree Workshop: 29 (including Penn Staters)
- Number of publications in review, press, or published with student authorship: 28
- Number of publications submitted from outreach efforts: 2
- Number of publications in prep with CUAHSI and a CZO RET: 1

*postdoc was not funded by CZO but was invited to attend All Hands meeting: Brantley served on his dissertation committee at Dartmouth because of mutual interest in metal accumulation in soils; student now works as national postdoc with CZO NO

III.C

CZO SUSQUEHANNA SHALE HILLS
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# Three outreach papers in progress

III.A,
III.C

CZO SUSQUEHANNA SHALE HILLS
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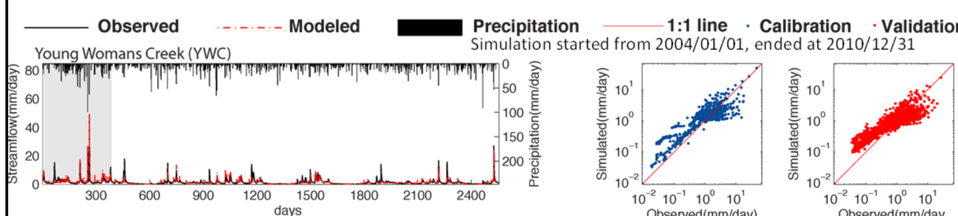
# Extending the Use of PIHM to Other Watersheds: Young Woman's Creek




Gray background means the calibration period is 2004, and white background means the validation period is 2005-2010.

Submitted paper: Yu et al., 2015 *A coupled surface-subsurface modeling framework to assess the impact of climate change on freshwater wetlands: a case study of seven watersheds of the Susquehanna River Basin,* Climate Research (in press), DOI: 10.3354/cr01348

III.A

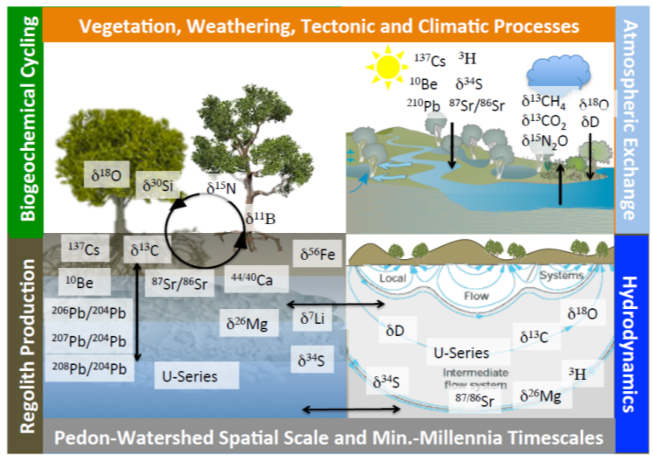
CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# CZ Tope: Using Multiple Isotopes to Investigate Critical Zone Processes in one Location

Submitted paper: Sullivan et al., 2015 *CZ-tope at Susquehanna Shale Hills CZO: Testing multiple isotope proxies to elucidate Critical Zone processes across timescales* (submitted to Chemical Geology), Oct 2015.

After presentations were made at AGU, GSA, and Goldschmidt, a cross CZO working group involving Penn State, University of Kansas, Duke, Univ of GA, Institut de Physique du Globe de Paris, University of Texas, Cornell University, and University of Minnesota has been established.

**CZ-tope: Multiple isotopes at the *same sites***




CZ-Tope is an initiative that grew out of SSHCZO to promote the use of multiple isotopes in one location

III.A

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# We are preparing a paper on data-enriched, place-based high-school science with CUAHSI and our RET (J. Geosc. Education)

Jon Pollak and Liza Brazil (both of CUAHSI) are working with 2015 CZO RET, Sharon Dykhoff (Dominion Christian School, Oakton VA), Brantley and Williams to co-author a paper featuring the novel approach of highschool stream sampling in concert with the use of data from the CUAHSI database (a la the TeenShale Network HydroClient learning experience).


*TeenShaleNetwork poster presented at All Hands meeting and online at CUAHSI education meeting*

III.A

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Data Management

II.I

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Data Management

- *II) Has the CZO site complied with the EAR Data Policy and the CZO Data Sharing Policy?*
  - *EAR Data Policy (paraphrased):*
    1. Preservation
    2. Data archives with easily accessible information (metadata)
    3. Timely sharing
    4. Submission to a national data center, publication, or through other EAR-specified repositories
    5. Openly available as soon as possible, but no later than two (2) years after collection. For continuing observations or for long-term (multi-year) projects, data are to be made public annually.
    6. Data inventories published periodically
    7. PIs may establish more stringent data submission procedures
    8. Compliance considered in Program Officer's evaluation
  - *CZO Data Sharing Policy:*
    1. Share data privately within 1 year
    2. Release data to public within 2 years
    3. Request, in writing, data privacy up to 4 years
    4. Consult with creators of private CZO datasets prior to use

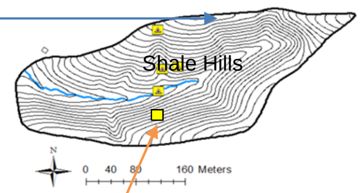
II.I

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Instrumentation Status

### Tower-HOG System

| Sensor | Parameter | Interval |
|---|---|---|
| CSAT3/LI-7500 | $CO_2$ flux | 30 min (from 10Hz) |
| | $H_2O$ flux | 30 min (from 10Hz) |
| | Sensible Heat flux | 30 min (from 10Hz) |
| Laser Precipitation | Precipitation | 30 min (from 1 min) |
| | Precip type | 30 min (from 1 min) |
| SR50 | Snow depth | 30 min |
| CMP3 | Shortwave radiation | 30 min |
| CGR3 | Longwave radiation | 30 min |
| CC5MPX | Digital imagery | 12 hour |



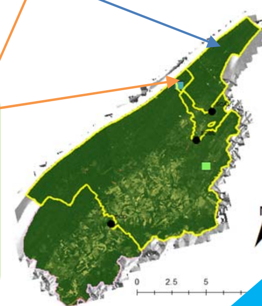

GR TowerHOG:
- Equipment has not yet been deployed due to extensive application process with Crown Castle Tower Company.
- Structural analysis review approved; waiting on final license to install.

### Ground-HOG System

| Sensor | Parameter | Interval |
|---|---|---|
| Stevens Hydra (x6) | Soil moisture | 10 min |
| | Soil temperature | 10 min |
| | Soil dielectric | 10 min |
| Forerunner GP (x3) | Soil $CO_2$ | 10 min |
| Apogee SO (x3) | Soil $O_2$ | 10 min |
| Eissenstat lab (x6) | Sapflow | 10 min |

Sensors for catena locations

| Sensor | Parameter | Interval |
|---|---|---|
| CRS-1000 (COSMOS) | Soil moisture (areal) | 1 hour |
| Hobo U-20 (x4) | Stream/groundwater level | 30 min |




II.A

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# A Data Hiatus Due to Shale Hills Weir

- Data hiatus (stream discharge) at Shale Hills because we had to replace the existing weir (left) with new flume
- New weir installed October 1, 2015; New fiber data connection installed (October 9, 2015)
- Flux-PIHM model output has been uploaded for the hiatus period

II.A

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# SSHCZO Measurement Suite

| Measurement | SH | GR | SCAL | SCBL | SCO | AG |
|---|---|---|---|---|---|---|
| 3-D Wind Velocity | KD | KD | | | | |
| 4-Component Radiation (upwelling & downwelling; SW & LW) | KD | KD | | | | |
| Air Temperature | KD | KD | | | | |
| Chemistry (DOC, TOC, DO, NO3, NH4, K, F, Cl, pH, EC, ORP) | TR | TR | TR | TR | TR | |
| Chemistry (major cations, Fe, Mn, Al, Si) | SB | SB | | | | |
| CO2 Concentration | KD | KD | | | | |
| Dendrometer-Basal Growth | DE | DE | | | | |
| Digital Imagery / PhenoCam | * | DE | | | | |
| Discharge | TR | TR | TR | TR | TR | |
| Groundwater Level | HL | HL | | | | |
| Groundwater temperature | HL | HL | | | | |
| H2O Concentration | KD | KD | | | | |
| Hyporheic zone exchange (streambed water temperature) | TR | | | | | |
| In situ 10Be concentrations in surface boulders | PB | PB | | | | |

SH - Shale Hills
GR - Garner Run
SCAL - Shavers Creek - Above Lake
SCBL - Shavers Creek - Below Lake
SCO - Shavers Creek Outlet
AG - Agricultural Site

Blue – Active Data Being Collected

KD - Ken Davis
SB - Sue Brantley
DE - Dave Eissenstat
JK - Jason Kaye
LL - Li Li

TR - Tess Russo
MK - Margot Kaye
PB - Paul Bierman
HL - Henry Lin
* - External

II.A

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# SSHCZO Measurement Suite

| Measurement | SH | GR | SCAL | SCBL | SCO | AG |
|---|---|---|---|---|---|---|
| Leaf Area Index | DE | | | | | |
| Leaf Litter | DE | DE | | | | |
| Precipitation Amount | DA | DA | | | | |
| Relative Humidity | KD | KD | | | | |
| Sap Flux | DE | DE | | | | |
| Soil CO2 | JK | JK | | | | |
| Soil Dielectric | HL | HL | | | | |
| Soil Moisture - Stevens | HL | HL | | | | |
| Soil Moisture - TDR | HL | DE | | | | |
| Soil Moisture - COSMOS | * | LL | | | | |
| Soil O2 | JK | JK | | | | |

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II.A

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# SSHCZO Measurement Suite

| Measurement | SH | GR | SCAL | SCBL | SCO | AG |
|---|---|---|---|---|---|---|
| Soil Temperature | HL | HL | | | | |
| Stage/Level | TR | TR | TR | TR | TR | |
| Suspended sediment chemistry (major cations, Fe, Mn, Al, Si) | TR | | | | | |
| Tree Survey (Height, Diameter, Species Distribution) | DE | DE | | | | |
| Turbidity | TR | | | | | |
| Virtual Temperature | KD | KD | | | | |
| Water chemistry (DOC, TOC, DO, NO3, NH4, K, F, Cl, pH, EC, ORP, major cations, Fe, Mn, Al, Si) | TR | TR | | | | |

SH - Shale Hills
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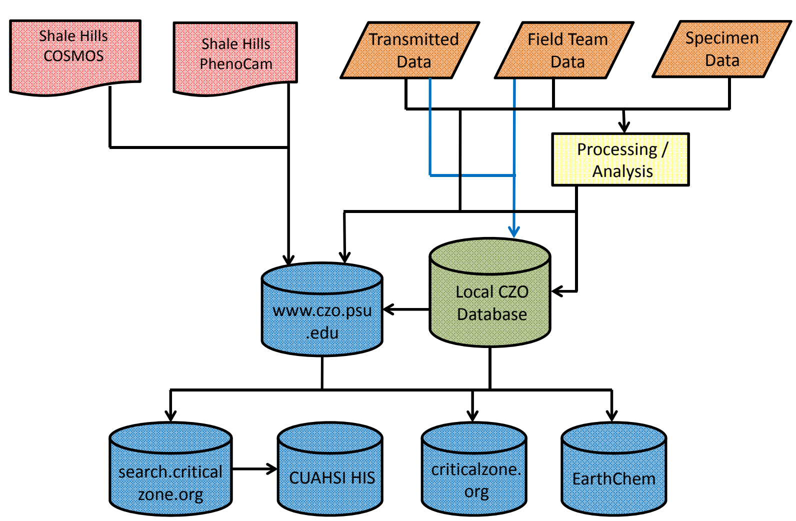
* - External

II.A

SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

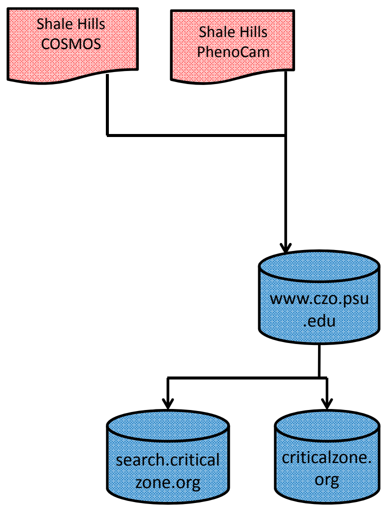
# Data Flow Process Diagram




II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Externally-Managed Sources




SH COSMOS:
- Soil Moisture Data
- Managed by University of Arizona

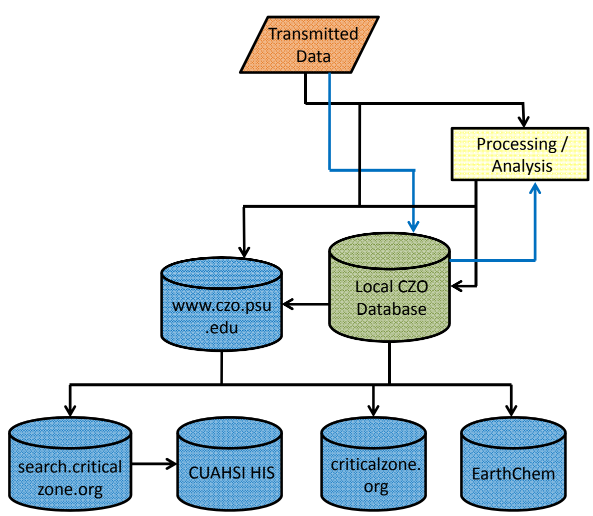
SH PhenoCam:
- Photographic Canopy Data
- Managed by Harvard University

- Links for both on www.czo.psu.edu
- Metadata pages on criticalzone.org and search.criticalzone.org

II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Transmitted Data




II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Transmitted Data

Transmitted Data

Internet Connection between Shale Hills and PSU campus

LoggerNet -> LNDB -> MS SQL Server 2008 Database ("CZO DB")

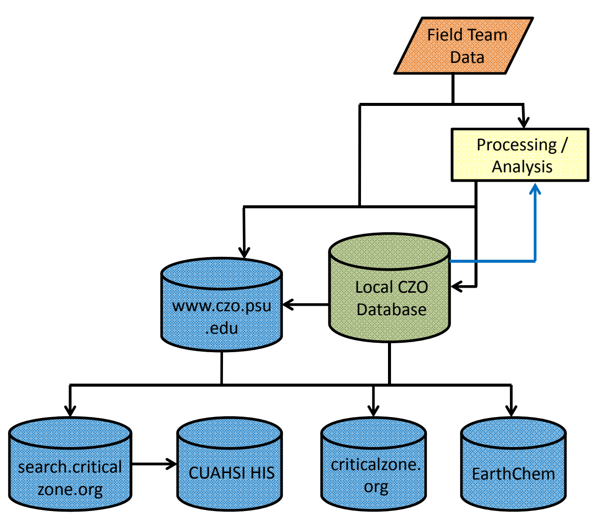
- 10 Hz Raw Eddy Covariance Data
  - Extracted from CZO DB in weekly chunks, processed by grad student (raw & processed files exchanged via box.psu.edu)
- Flux Tower Meteorology
- Precipitation (OTT Pluvio$^2$ Weighing Rain Gauge)
- Raw Stream Discharge, Turbidity (weir replacement complete, awaiting recalibration & network infrastructure upgrade completion)

**Currently Shared Live as Raw Data: OTT Precip, 4-Way Solar Radiation. Soon: Turbidity, Discharge*

II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Field Team Data




II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Field Team Data

Field Team Data

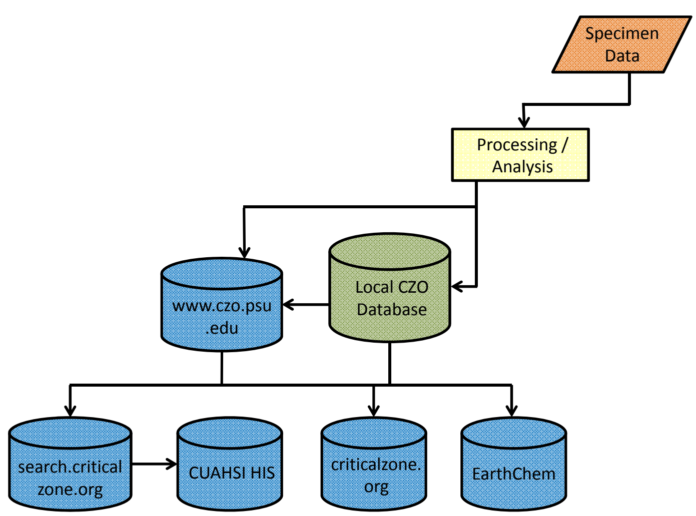
- Grad Student & Postdoc Field Team
- Collect water, gas, etc. samples as needed at Ground HOG, Tower HOG, etc.
- Download data from field dataloggers
- Upload data to internal box.psu.edu space
- Data manager looks over, notifies responsible PI/contact
- Processing completed as necessary, processed files returned to data manager
- Input into CZO DB or otherwise posted to web, external repositories

- Hydropedology:
  - Matric Potential
  - Air Temperature
  - Electrical Conductivity
  - *Dielectric*
  - Precipitation
  - *Soil Moisture (Stevens Hydra Probes & TDR)*
  - Soil Temperature
  - Water Table
- Sap Flow
- Ground HOG:
  - Soil Moisture
  - Dielectric
- Other Data Not Specifically Collected by Current Field Team, but Processed Similarly:
  - Tree Survey Updates
  - Leaf Area Index
  - Litter/Dendroband

II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Specimen Data




II.I

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

## Specimen Data

Specimen Data

Collected Specimens Cataloged (SESAR), Processed, Archived

When Released to Data Manager, Files Linked on Web (www.czo.psu.edu & criticalzone.org) &/or Imported to CZO DB

DOIs obtained via EarthChem

- Geochemistry
- Aqueous Chemistry
- Soil Gas
- Vegetative Chemistry

II.I

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

## Other Data Types

- Geophysical Data
  - Gamma Counts
  - Seismic Data
  - Ground-Penetrating Radar
- LIDAR (DEM, Density, Hillshade)
- GIS/Geospatial Data

➢ Collected from PIs when Available

➢ Usually Linked from Web, Not Suitable for CZO DB

II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

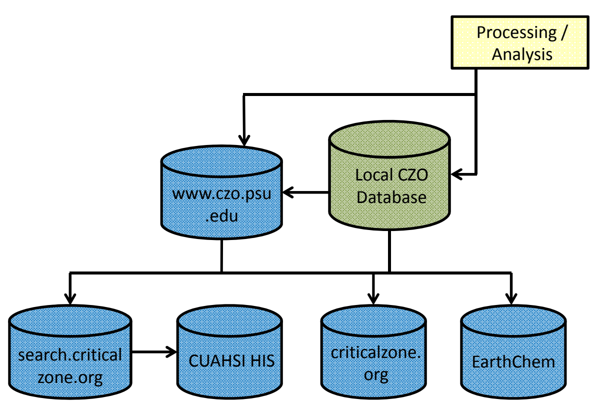
# Other Data Acquisition

- Annual “Data Call” Conducted in March
  - Reminders for Data that are
    - Not Transmitted
    - Processed by PIs/grad students/postdocs
    - From Seed Grant PIs
  - E-mail sent, including blank metadata template document with instructions, with follow-up reminders

II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Processing & Access




II.I

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

## Processing & Access

Local CZO Database

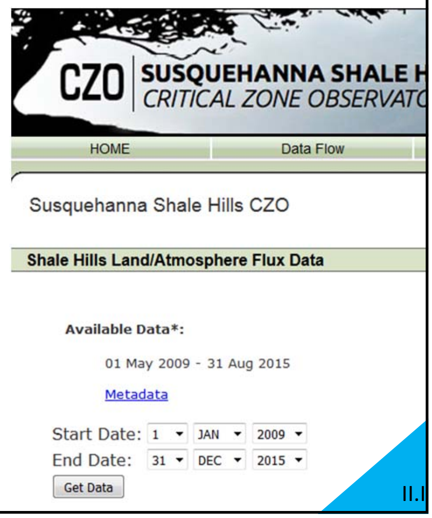
Local CZO DB

Microsoft SQL Server 2008

Administered by PSU ITS and CZO Data Manager

Structure:

- Relatively Flat with Few Table Relationships (facilitates easy access, flexible tools)
- Evaluating ODM2 implementation with CZOData assistance




II.I

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

## Processing & Access

www.czo.psu.edu

PSU CZO Web Site: HTML Pages Organized by 3 Broad Data Classifications:

- Time Series
  - Hydropedology, Land/Surface Flux, Discharge, etc.
- Geospatial
  - GIS Database, LIDAR, Tree Survey, etc.
- Geochemical/Geophysical
  - Aqueous Chemistry, Seismic Refraction, etc.

Links to:

- CSV/XLS Files
- Proprietary Files
- PHP Scripts linked to CZO DB

II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Processing & Access

criticalzone.
org

criticalzone.org/shale-hills/data

Dataset Pages Generated by Expression Engine Content Management System (CMS)

Content Maintained by Data Manager

Metadata for each dataset

Link(s) to dataset components (e.g., yearly subsets)

- Direct Links to Files on www.czo.psu.edu

or

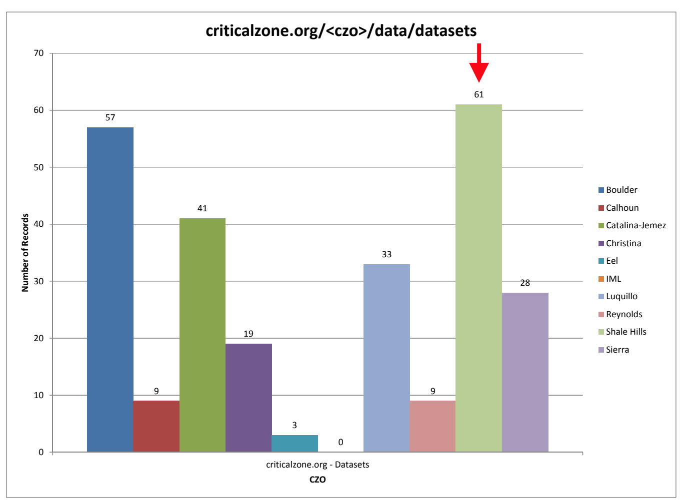
- Links to PHP scripts on www.czo.psu.edu

II.I

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Availability

criticalzone.
org




61 Datasets with 269 Components (subclassifications; e.g., year, subtype)

*Correct as of 21 Oct 2015

II.I

CZO | SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Availability

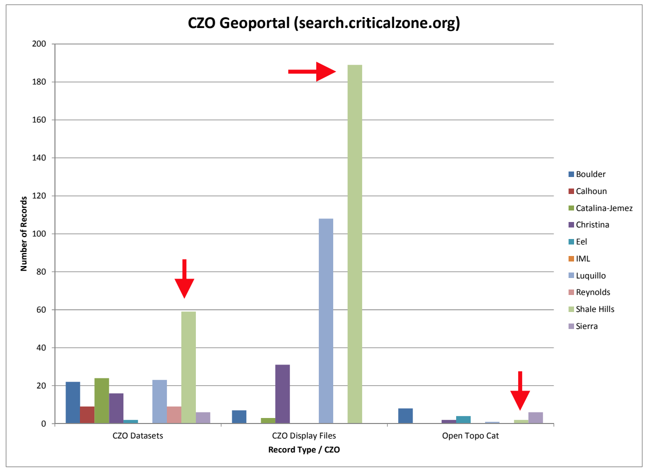
search.critical zone.org

SDSC CZO Geoportal

Data Manager Creates CZO Display Files v1 & Initiates Harvest

Data: Primarily Time Series, Some Geochemical

Converted from Source Files or CZO DB Tables




SSHCZO: 59 Datasets, 189 Display Files, 2 Open Topography LIDAR Catalog Entries

*Correct as of 21 Oct 2015

II.I

CZO | SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Availability

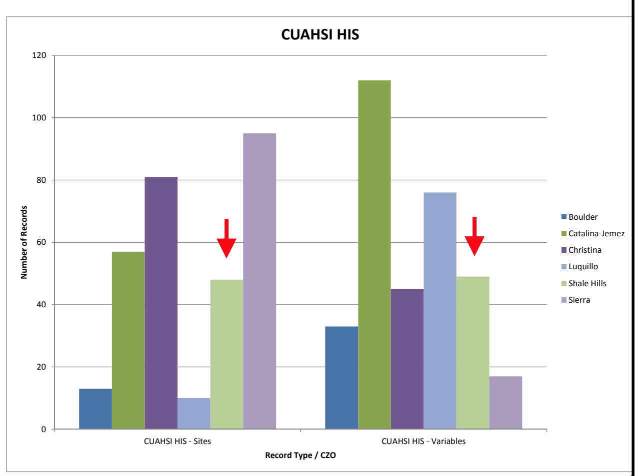
CUAHSI HIS

CUAHSI HIS

Receives metadata from SDSC Geoportal

- Time Series
- Aqueous Chemistry

Clients: HydroDesktop, Web Client




SSHCZO: 48 sites, 49 variables

*Correct as of 21 Oct 2015

II.I

CZO | SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Availability

NSF

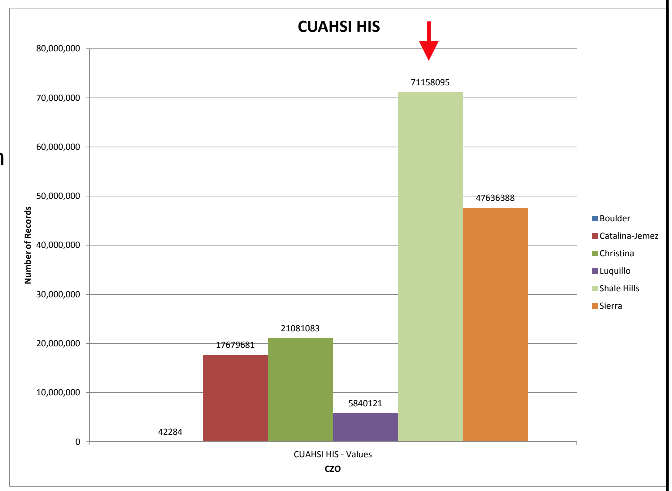
CUAHSI HIS

CUAHSI HIS

Receives metadata from SDSC Geoportal

- Time Series
- Aqueous Chemistry

Clients: HydroDesktop, Web Client




*Correct as of 21 Oct 2015

II.I

CZO | SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Availability

NSF

EarthChem

EarthChem

DOI Source – 30 for SSHCZO, including:

- Aqueous Chemistry
- Tree Survey
- Shale Transect Meteorology

II.I

# Project Management

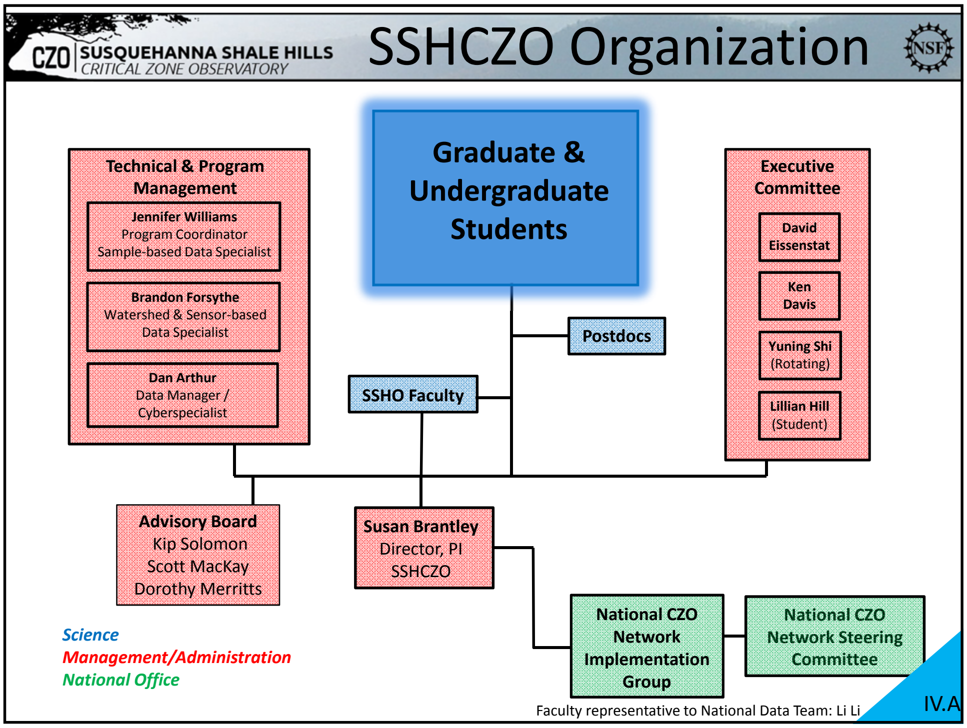
IV.



## IV. Project Management

- *A) Has the CZO Site Director implemented an efficient and effective governing structure to support all CZO project activities as specified in the Cooperative Agreement with NSF?*
- *B) Have critical elements of the governance structure met regularly and documented outcomes of their discussions?*
- *C) Does the CZO Management Plan identify sufficient milestones and metrics to monitor progress and to determine the level of continuing support? Have these milestones been met and the metrics measured? Are plans for remedial actions in place where project milestones have not been adequately met as articulated in Annual and Interim Reports?*
- *D) Does the Management Plan clearly identify roles and responsibilities for the lead and partner institutions/organizations that are part of the CZO? Have these roles and responsibilities been executed?*
- *E) Does the CZO Management Plan identify goals, strategies, and metrics for engaging other CZOs and the broader community in research activities? Have these goals been executed?*
- *F) Does the CZO Management Plan provide guidance that enables the CZO to respond to opportunities provided by scientific breakthroughs and unexpected events?*

IV.




CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

NSF

# Institutional Responsibilities and Outside Involvements in SSHCZO

**Roles and responsibilities for the institutions that are part of the CZO (13 PIs)**

- Penn State (10 PIs) — runs the field site, manages the project, coordinates research
- 
- University of Vermont (Paul Bierman) — leads cosmogenic isotope campaigns
- 
- Oregon State University (Eric Kirby) — participates in geomorphological interpretations
- Colorado School of Mines (Kamini Singha) – participates in hydrogeologic interpretations

**Pursued research with SSHCZO or visited with classes**

- Temple University
- Univ of Guelph (Canada)
- Kent State
- Univ of Pittsburgh
- Cornell University
- Univ of Minnesota
- Univ of TX El Paso
- Hobart and William Smith
- Lehigh Univ
- University of Delaware
- Beijing Normal University
- Univ of Kansas
- Institut du Physique de Globe (Paris)
- Univ of Toulouse, France
- Colgate University
- Saint Louis University
- Princeton University
- Juniata College

IV.D

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# CZO Executive Committee

- Meets monthly during academic year
  - 3 permanent PIs representing geoscience/meteorology/ecology (Brantley, Davis, Eissenstat), 1 rotating PI representing any discipline (currently Yuning Shi), and 1 student member
  - Previous rotating PIs: Henry Lin (year 1), Li Li (year 2)
  - Previous student: Nicole West (year 2)
  - Project Coordinator shares minutes with team and publishes them on Penn State content management system online

IV.B

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Program Coordinator and Sample-based Data Specialist
## Jennifer Williams

- Facilitates communications
- Coordinates research with Penn State forester
- Compiles annual reports; facilitates seed grant program; facilitates travel; organizes All Hands and CZ workshops, seminar series, executive committee and various other meetings
- Manages website
- Coordinates fieldtrips and field campaigns
- Leads TeenShale Network
- Leads geochemical data organization and publication

IV.D

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

Watershed Specialist - Brandon Forsythe
In charge of field work, watershed organization, emplacement and monitoring of sensors, moving data from the field to Penn State

---

- Plans field deployments
- Works with PA Dept of Conservation of Natural Resources on Garner Run site
- Maintains sensor infrastructure
- Helps with all field work
- Teaches students in the field
- Coordinates sensor data collection, processing and archiving (with Cyberspecialist)
- Assists with TeenShale Network

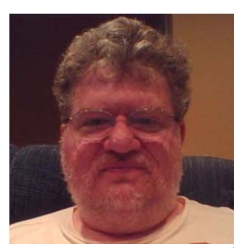
IV.D

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

Cyberspecialist - Dan Arthur
*Moves the data from the field & labs out to the community.*

SSHCZO Data Management Responsibilities:

- Data/File Management (Collection – Coordinated with Watershed Specialist & Field Team, Formatting, Conversion)
- Architecture (Database Design & Content Management)
- Retention (Backup/Archive Strategy, Coordinated w/ ITS)
- User Access, Internal (SSHCZO) & External
- Website Content Assistance/Maintenance
- GIS Support
- Visualization/Plots Assistance
- Seminar/Workshop AV Management



IV.D

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# CZO All Hands Meeting

- A 2.5 day meeting of all CZO team members held annually at the end of spring term
- Dates posted during the preceding summer; NSF program officer always invited
- Every student/postdoc team member presents research – either oral or poster
- One guest scientist is invited to participate in the meeting (including field trip to SSHCZO) and to become member of our Advisory Board
- Guest interacts with students and faculty, tours the CZO field sites, delivers seminar, provides feedback at end of meeting to entire team verbally, and then submits written feedback (stored on Penn State content management system)
- Agendas and abstract volumes available publicly at https://criticalzone.org/shale-hills/research/annual-activities-shale-hills/
  *Advisory Feedback Available on Penn State content management system*

IV.B, IV.C

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Our Growing Advisory Board

- Kip Solomon, groundwater hydrogeochemist, Univ of Utah, visited us for 2013 All Hands meeting (5/8/13-5/10/13) Talk title: ***Adding Time to Geochemical and Hydrologic Processes using Environmental Tracers***
- Scott Mackay, tree dynamics specialist, Univ of Buffalo, visited us for 2014 All Hands meeting (5/18/14-5/20/14) Talk title: ***Plant hydraulics: Integrator of coupled processes in the critical zone***
- Dorothy Merritts, geomorphologist, Franklin and Marshall College, visited us for 2015 All Hands meeting (5/10/15-5/12/15) Talk title: ***Lidar and Field Analysis of Periglacial Landforms and their Paleoclimatic Significance, Unglaciated Pennsylvania***

IV.A, IV.B

# Subcatchment Implementation Timeline

Shale Hills (measure only what is needed) – the final plan for Ground HOG and Tower HOG finalized in 2015; instrumentation finalized 2015; weir fixed in summer 2015

Sandstone field site – site selected in 2014 (Garner Run); Ground HOG set up in 2014-2015; valley well drilled Sept 2015; flux tower awaiting final approvals; sapflux instrumentation awaiting implementation

Calcareous Agricultural Shale – selection of site slated for spring 2016; instrumentation by fall 2016

IV.A

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Modelling Work Timeline : Past and Future

| | | |
|---|---|---|
| PIHM | Duffy et al. | Completed |
| Flux-PIHM | Shi et al. | Completed |
| RT-PIHM | Chen Bao and Li Li | Completed (2015) |
| Flux-PIHM-BGC | Ken Davis and Yuning Shi | In Progress |
| PIHM-WITCH | P. Sullivan and Y. Godderis | In Progress |
| PIHM-LE | R. Slingerland and Y. Zhang | In Progress |

IV.A

CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

## Cross CZO Activities Outlined in NSF Proposal

- ***Drill the Ridge*** – drill ridge, analyze geochemically, hydrologically, geophysically – Harry's Valley Well drilled in valley of Garner Run. We do not have the money to drill Tussey Ridge but we have discovered a well that was drilled in the 1970s there and are getting data for it.
- ***Workshop*** - Shale Hills ran 2.5-day CZNR Workshop on a cross disciplinary topic, "*Probing the Critical Zone – Four Tree Puzzles*", led by tree physiologist and ecologist D. Eissenstat. Workshop included 30 scientists/students from in/outside the CZO network (**September 9 - 11, 2015**). Brantley was also part of leadership team that ran the Cross CZO Deep CZ Salon in CO June 2015.
- ***Field campaign*** –We cancelled this effort with approval from NSF and used money for drilling the HV1 well.
- ***CZ-Tope:*** An international initiative to promote the use of multiple isotopes in CZ sites (postdocs Pam Sullivan and Grit Steinhofel are spearheading). Oral and poster sessions at two Goldschmidt meetings, working group within CZO formed, Special Issue in Chemical Geology is under review, and a manuscript has been submitted.
- ***Cyber-seminars*** - The CZOs were supposed to work with R. Hooper, Director of CUAHSI, to run six cyber-seminars/yr. Nothing has happened on this front.
- ***Cross-CZO modeling*** –Our effort here has been focused on attending the Q-C workshop (three Penn Staters attended) , the Tree Workshop, the Deep CZ Salon, and CSDMS meetings (Li Li and Chris Duffy)
- ***S::can*** sensors were emplaced; however, we have been having difficulties with the s::can units. We had been loaned one unit and they wanted us to pay for it, and we didn't have the money nor were we having a lot of success with it, so we sent it back. We are still working with one s::can unit in Garner Run. We are working on this in communication with Christina River CZO which is also using s::can units.

II.F, III.A

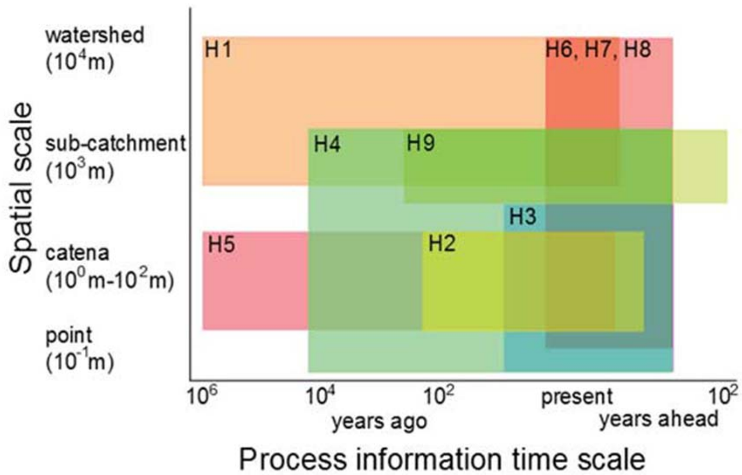
CZO | SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

Does the CZO Management Plan identify sufficient milestones and metrics to monitor progress and to determine the level of continuing support? Have these milestones been met and metrics measured? Are plans for remedial actions in place where project milestones have not been adequately met as articulated in Annual and Interim Reports?

IV.C

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

To assess achievements of our work, we are organized into hypothesis teams and we keep metrics for each hypothesis. Each team has a faculty leader, at least one student, and overall CZO data collection responsibilities. The hypotheses cross temporal and spatial scales. The teams are not restricted to work only on the stated hypothesis.




II.F, II.H

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Hypothesis teams

**H1 - The fracture hypothesis:** *Feedbacks among frost shattering, weathering reactions, and the evolution of topography have resulted in an asymmetric distribution of fractures that in turn controls the observed differences in fluid flow in the subsurface between the sun-facing and shaded sides of catchments within Shale Hills and much of the Susquehanna River Basin.* Kirby Biermann

**H2 - Imprint of biota on acid- and redox-weathering hypothesis:** *The distribution of weathering reactions across a landscape can be described as a function of biotic and abiotic production and consumption of acids (CO2, DOC) and O2. Kaye*

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

**H4 – The soil macropore hypothesis:** *Macropores are important in controlling fluid flow and chemistry in soils derived from various lithologies, but the nature and effects of these macropores differ significantly among shale, calcareous shale, and sandstone. Lin*

**H5 – The regolith-modeling hypothesis:** *Greater evapotranspiration on the sunny, north side of Shale Hills means that less water recharges to the stream, explaining why Mg and other cations are less depleted in the regolith on the north compared to the south hillslopes. Li*

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

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

**H8 – Water-data integration hypothesis**: *Co-located, intensive, measurements at a limited number of sites can be assimilated within a multi-scale distributed modeling framework to project physical processes from Shale Hills to Shavers Creek. Shi*

**H9 – Earthcasting hypothesis:** *Increasing atmospheric CO2 in the future will cause higher temperatures and faster weathering of clays in the catchment, increasing streamwater solute loads. Brantley*

II.F, II.H

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

**Metrics by Hypothesis Team – This is How We Keep Track of What We Are Doing**

**H1 Metric**: 1) Produce 2 papers describing fracture distributions in sandstone/shales in comparison to geophysical surveys; 2) train 1 postdoc
**H2 Metric**: 1) Produce 3 papers on O2, CO2, N dynamics; 2) train one grad student
**H3 Metric**: 1) Produce 3 papers on ecophysiology of deep roots in relation to topographical position and lithology, tree species, depth to bedrock, and mycorrhizas, 2) train one grad student
**H4 Metric**: 1) Produce 3 papers on soil types, macropores, and GPR in Shavers creek watershed; 2) Train one grad student **H5 metric**: 1) Develop Flux-PIHM-RT, a generic code that couples surface and subsurface hydrology with reactive transport (one paper on code development); 2) Produce one paper on chemical weathering and soil generation under relatively constant hydrological conditions using 1D modeling; 3) produce one paper on the coupling among atmospheric forcing (energy, precipitation), hydrological processes, and chemical weathering using Flux-PIHM-RT; 4) produce one paper on how heterogeneity (macropores) influence soil and stream chemistry); 5) educate one student on Flux-PIHM-RT
**H6 Metric**: 1) Produce 3 papers on solute chemistry of streams in SC; 2) Train one grad student
**H7 Metric**: 1) Produce 3 papers on using Flux-PIHM to understand C and H2O fluxes in SC; 2) Implement the mobile array concept; 3) Train one grad student
**H8 Metrics**: 1) Complete 1979-Present distributed water and energy balance for the Shaver Creek-Shale Hills site (CJD, YS, KD, LL, etc.); 2) Serve model results on-line in easy-to-use format for sharing among scientists; 3) Complete development for a coupled water, nutrient, sediment transport code in the PIHM framework (CJD, KD, JK); 4) Complete development for a coupled water, and reactive transport code in the PIHM framework (LL, CB, PS, CJD); 5) implement PIHM models for SC, YWC and Snake creek; 6) educate 1 student
**H9 Metrics**: 1) Produce one paper showing PIHM-Witch modeling; 2) Train a postdoc in using PIHM and WITCH

IV.C

CZO SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

# Some Summary Shale Hills Numbers since the Renewal

- 31 presentations by nonstudent researchers at (inter)national meetings
- 37 presentations by grad students/postdocs at (inter)national meetings
- 41 papers published, in review, or in press since the renewal was instituted
- 28 of these with graduate student or postdoctoral coauthors
- 6 dissertations defended between 2014 and 2015 (Katie Gaines, Ashlee Dere, Nicole West, Tiffany Yesavage, Xuan Yu, Chen Bao)
- 3 master theses defended (Katherine Meek, Matthew Kenney, Burkely Twiest)
- 12 REU students + 4 RETs worked with the CZO (summers 2014, 2015)
- 2 postdocs and 1 recent graduate student moved into faculty positions since 2013 (Univ. of Kansas; Saint Louis University, Univ of Nebraska Omaha) 27 high school students involved with Teen Shale Network (2015/2016)
- A huge dataset + a growing PIHM model family + deep understanding!

III.C, IV.C

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Summary: Shale Hills by the People

Thank you!

See our additional slides for updated metrics for hypothesis teams

III.A

CZO SUSQUEHANNA SHALE HILLS
CRITICAL ZONE OBSERVATORY

# Updates for each hypothesis team

IV.C

**H1 Metric**:

1) Produce two papers describing fracture distributions in sandstone/shales in comparison to geophysical surveys;

**Manuscripts in preparation:**

1. West, N., Kirby, E., Topographic fingerprints of hillslope erosion in the central Appalachians: Geomorphology (to be submitted Dec. 1)
2. West, N., Kirby, E., Nyblade, A., Clarke, B., Brantley, S.L., Periglacial preconditioning of the Critical Zone in the central Appalachians: Asymmetric rock fracturing driven by insolation during the last glacial maximum: PNAS (to be submitted Dec. 31)

(work of Denn, Bierman, Kirby, West and others):

3. Age and history of a climatically induced landform, Hickory Run Boulder Field, PA;
4. Regolith age and movement, Shavers Creek, PA;
5. A drainage basin response to base-level fall, Young Woman's Creek, PA

2) train one postdoc in fracture distribution/geophysical surveys

We have trained one postdoc (**Nicole West**, PSU) in the application of shallow geophysical data to understand fracture distributions in the Critical Zone, and training is ongoing for one M.S. student (**Alison Denn,** UVM) in the application of cosmogenic isotopes to landscapes.

IV.C



## H2 Metric (J. Kaye):

1) Produce three papers on $O_2$, $CO_2$, N dynamics;

**Field progress:**

Completed GroundHOG installation in both Shale Hills and Garner Run (L. Hill). Data collection in progress.
Sampled 5 shale and 5 sandstone sites to estimate bedrock controls on nutrient availability (L. Hill).
Continued sampling of N at Shale Hills and soon to complete N budget (J. Weitzman).

**Publications:**

Hasenmueller, E., L. Jin, G. Stinchcomb, H. Lin, S. Brantley, J.P. Kaye. 2015. Depth and topographic controls on soil $CO_2$ concentrations and effluxes in a small temperate watershed. Applied Geochemistry 63:58-69.
Jin, L., N. Ogrinc, T. Yesavage, *E. Hasenmueller*, L. Ma, P. Sullivan, J. Kaye, C. Duffy, and S. Brantley. 2014. The $CO_2$ consumption potential of 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.

**Manuscripts in Preparation**

1. Differences in soil CO2 and O2 between shale and sandstone catchments in central PA (L. Hill)
2. Differences in soil nutrient availability between shale and sandstone catchments (L. Hill).
3. Topgraphic controls on N cycling at Shale Hills (J. Weitzman).

2) Train one grad student on this topic

**Lillian Hill** (MS Student: Ecology) has installed and maintains measurements of O2, CO2, soil and soil moisture at Shale Hills and Garner Run. She is also assessing differences in soil nutrient availability (N, P, Cations) at 5 shale and 5 sandstone catchments in the area.

**Julie Weitzman** (PhD Student: Soil Science and Biogeochemistry) is measuring N availability and completing the N budget for the Shale Hills Catchment. Julie attended the cross-CZO workshop on biogeochemistry in September, 2015.

IV.C

**H3 Metric (Eissenstat, M. Kaye, J. Kaye)**:

1) Produce three papers on ecophysiology of trees and their deep roots in relation to topographical position and lithology, tree species, depth to bedrock, and mycorrhizas;

**Published:** Gaines et al., (2015) Reliance on shallow soil water in a mixed-hardwood forest in central Pennsylvania, *Tree Physiology* 00, 1–15, doi:10.1093/treephys/tpv113.
Gaines (2015) Forest ecohydrology in a central Pennsylvania catchment: a stable isotope approach, PhD Dissertation, *Pennsylvania State University*

**Submitted:** Gaines et al., (2015): Rapid tree water transport and residence times in a Pennsylvania catchment. *Ecohydrology (in review)*

**In prep (to be submitted by end of 2015)**
Gaines KP, Duffy C, Eissenstat DM The tree water isoscape of a central Pennsylvania catchment: ecohydrologic patterns and processes. (*in prep for PLOS one*)
Smith L, Eissenstat DM, Kaye MW. Variability in aboveground carbon dynamics is driven by slope aspect and curvature in an eastern deciduous forest, USA. *(In prep for Forest Ecology and Management)*
Hasenmueller, E., Gu, X., Weitzman, J.N., Adams, T.S., Stinchcomb, G., Eissenstat, D.M., Drohan, P.J., Brantley, S.L., Kaye, J.P., The activity of deep roots in bedrock fractures at Susquehanna Shale Hills Criticial Zone Observatory, USA. *(in prep for Biogeosciences).*

2) train three grad students and 1 postdoc on this topic;

**Katie Gaines** (PhD matriculated Spring 2015),
**Ismaiel Szink** (PhD student in Ecology, in progress, began August 2015),
**Warren Reed** (PhD student in Ecology, in progress, began August 2015)
**Liz Hasenmueller** (Postdoc, now Asst Prof at SLU)

Field progress: We have also mapped the vertical distribution of roots on Shale and Sandstone at Garner Run and Shale Hills as well as three additional locations on sandstone and shale at a site in south-central Pennsylvania. This work was mainly conducted by one REU student and one RET student and now is being summarized by a new PhD student in Ecology, Ismaiel Szink.

IV.C



**H4 Metric (Lin, DiBiase)**:

1)Produce three papers on soil types, macropores, and GPR;

Liu, H., and H.S. Lin. 2015. Temporal and spatial patterns of preferential flow occurrence in the Shale Hills catchment: From pedon to catchment scales. Soil Science Society of America Journal 79:362-377. doi:10.2136/sssaj2014.08.0330.

Yu, H., P. Yang, and H.S. Lin. 2015. Spatiotemporal patterns of soil matric potential in the Shale Hills Critical Zone Observatory. Vadose Zone J. doi:10.2136/vzj2014.11.0167.

2) Train one grad student on these topics

**Neil Xu** (PhD student in Soil Science, began Aug 2015). Leading work (including soil moisture monitoring, infiltration measurements, and electromagnetic induction surveys), and another graduate student **Isaac Hopkins** has also been trained to help with this work.

**Joanmarie Del Vecchio** (PhD in Geosciences) is working on mapping soils in the catchment.

IV.C

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**H5 metric (Li Li, Yuning Shi)**:
1) Develop Flux-PIHM-RT, a generic code that couples surface and subsurface hydrology with reactive transport processes (one paper on the code development);
RT-FLUX-PIHM has been developed by Energy, Mining Engineering graduate student **Chen Bao** – manuscript in revision: (We have decided to separate the manuscript into two)
Bao et al. 2015. Understanding Hydrogeochemical Processes at the Watershed scale: 1. Development of RT-Flux-PIHM. Water resources research.
Bao et al. 2015. Understanding Hydrogeochemical Processes at the Watershed scale: 2. Controls of Concentration Discharge Relationship for Chloride and Magnesium. Water resources research.

AGU abstract and poster:
Bao et al., 2015. Understanding the Concentration-Discharge Relationship of Chloride and Magnesium in Shale Hills Using RT-Flux-PIHM. AGU fall meeting

2) Produce one paper on chemical weathering and soil generation under relatively constant hydrological conditions using 1D modeling;
We have deviated from this however I think Pam Sullivan is doing something along that line?

3) produce one paper on the coupling among atmospheric forcing (energy, precipitation), hydrological processes, and chemical weathering using Flux-PIHM-RT;
The graduate student **Dacheng Xiao** is developing Regolith-Flux-PIHM, a model integrating chemical weathering and soil generation with hydrological and geomorphological processes at geological time scales. This is expected to be completed in 2018 with a paper that use this model in 2019.

4) produce one paper on how heterogeneity (macropores) influence soil and stream chemistry);
A manuscript is in development:
Bao et al., 2016. Controls of watershed connectivity on the concentration discharge relationship of the non-reactive chloride. (in prep)

IV.C

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CRITICAL ZONE OBSERVATORY

**H6 Metric (Russo)**:
1) Produce three papers on solute chemistry of streams in SC;

One manuscript in preparation to be submitted to C-Q special issue in *Water Resources Research*, Feb 2016;

2) Train one grad student on this topic;
**Graduate students.** Beth Hoagland (PhD student) has led this work,
Plan to admit another graduate student for Fall 2016 to continue this work

**Undergraduates.** Senior thesis students: **Molly Cain** (2015) and **Kenneth Weiss** (2015); REU students (2015): **Kelsey Bicknell** and **Meaghan Shaw**.

Other:
Stream discharge and chemistry data have been collected for the overall team.
Presentation: The Influence of Groundwater on C-Q Relations, Cross-CZO Concentration Discharge Relations Workshop, UNH, July 20-22, 2015.

IV.C

**H7 Metric (Davis, Shi, Kaye, Eissenstat)**:

1) Produce three papers on using Flux-PIHM to understand C and H2O fluxes in SC;

One paper is in preparation, evaluating the ability of Biome-BGC to simulate spatial variability in soil and tree biomass C pools, and ecosystem-atmosphere C fluxes at Shale Hills when the moisture, temperature and radiation conditions are imposed from observations. The Flux-PIHM-BGC coupled modeling system has been developed and is being tested as well.

2) Implement the mobile array concept;

We have implemented GroundHOG and are soon to complete implementation of TowerHOG at Garner Run

3) Train one grad student in this topic

**Yuting He** (PhD candidate in Meterology) has drafted the first paper, and recently passed her Ph.D. candidacy exam in the graduate program in Meteorology.
Ken Davis, Dave Eissenstat and Yuning Shi are her advisors.

Other

Support for Yuning Shi's contributions to this effort, and additional field data are supported by a DoE Terrestrial Ecosystem Sciences grant (Eissenstat, PI) that has substantially expanded the scope of effort that we are able to pursue.

IV.C



**H8 Metrics**:

1) Complete 1979-Present distributed water and energy balance for the Shaver Creek-Shale Hills site (CJD, YS, KD, LL, etc.);

Dacheng Xiao (PhD student, advised by Li Li and Yuning Shi) has produced a 2009--2015 water and energy balance reanalysis for Shale Hills using Flux-PIHM, driven by local meteorological forcing.

2) Serve above model results on-line in easy-to-use format for sharing among scientists;

The reanalysis results have been put online on CZO website (http://criticalzone.org/shale-hills/data/dataset/4610/)

3) Complete development for a coupled water, nutrient, sediment transport code in the PIHM framework (CJD, KD, JK);

4) Complete development for a coupled water, and reactive transport code in the PIHM framework (LL, CB, PS, CJD);

Chen Bao (PhD student, advised by Li Li) has developed a coupled water and reactive transport code (RT-Flux-PIHM), and the model development paper has been submitted to WRR.

Bao, C., L. Li, Y. Shi, P. L. Sullivan, C. J. Duffy, and S. L. Brantley: RT-Flux-PIHM: A coupled hydrological, land surface, and reactive transport model for hydrogeochemical processes at the watershed scale. Water Resources Research, submitted.

5) implement PIHM models for SC, YWC and Snake creek;

PIHM model has been implemented for YWC and Snake Creek. Simulation results have been put online on PIHM website (http://www.pihm.psu.edu/applications.html).

6) educate one student in PIHM on these topics

**Dacheng Xiao** has been trained to run PIHM and Flux-PIHM.

Others:

Dacheng Xiao installed and calibrated the COSMOS soil moisture sensor at Garner Run.
Presentation: Dacheng Xiao, Yuning Shi, Li Li. Assimilating the Cosmic-Ray Soil Moisture Observing System Measurementsfor Land Surface Hydrologic Model Parameter Estimation Using the Ensemble Kalman Filter. AGU fall meeting, 2015.

IV.C

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**H9 Metrics**:

1) Produce one paper showing PIHM-Witch modeling;

**Manuscript in preparation:**
Sullivan, P., Brantley, S.L., Shi, Y., Godderis, Y., 2016, Using Flux-PIHM as a hydrologic driver for WITCH geochemical modelling: The effect of aspect on weathering of shale. To be submitted to Geochemica Cosmochimica Acta.

Papers presented at Goldschmidt, Gordon Conference, AGU, EGU:

2) Train a postdoc in using PIHM and WITCH

**Pam Sullivan** was a postdoc at Penn State working with Chris Duffy and S. Brantley and Y. Godderis (Univ. of Toulouse, France).
She learned to use WITCH and is currently modelling soil porewater chemistry for Shale Hills soils.

IV.C