Introduction to the CZO Network Strategic Plan

Susan Brantley, PSU
William McDowell, UNH

On the behalf of all the CZO PIs
August 26, 2016

Critical Zone Observatory Network

Critical zone science spans from timescales of the meteorologist to the geologist

National CZO Program

funded by NSF

CRITICAL ZONE OBSERVATORIES

studying the zone where rock meets life

A Strategy for Advancing Critical Zone Science

February 2016

Mission – Our Core Purpose

To discover how Earth's living skin is structured, evolves, and provides critical functions that sustain life

Core Values – Our Aspirations

Interdisciplinary Collaboration

- Critical Zone science requires insights from a wide range of disciplines
- Our interdisciplinary, integrative approach drives innovation and transformative findings
- Working together in an open community, we are greater than the sum of the parts

“Deep” Science

- We encompass deep time from the instantaneous all the way to geologic time
- We embrace deep structure from the vegetative canopy down to fresh bedrock
- We explore deep linkages resulting in deep insights and impacts

Predictive Knowledge

- We believe exploration and quantitative modeling go hand in hand
- We test generalizable hypotheses to advance the field of Critical Zone science
- We generate and disseminate new knowledge that benefits humankind

Our Vision for CZ Science in 2026:
Digging deep to project the future

- Critical Zone science is recognized as an important and groundbreaking **new field of science**
- We act as a **vibrant and dynamic network** of science sites strategically arrayed along environmental gradients and optimized to advance the state of Critical Zone science
- We have **strong connections** with other important networks and partners around the globe
- We have a **growing set of conceptual models** that guide our research
- We have adopted a **set of common measurements**
- We are collecting real-time data with a system of integrated sensors – the **data are organized, available and easily accessible** on shared platforms to everyone
- We have **an ensemble of modular and integrated models and tools** that are widely used to test important hypotheses at multiple scales and timeframes across the network
- We are viewed as an **open, inclusive, collaborative community** of researchers and educators

Our 4 Major Goals:
The Focus for the Next 3 Years

Goal 1: Demonstrate the transformative nature of Critical Zone science

Goal 2: Integrate specific elements of infrastructure for the Critical Zone network by 2018

Goal 3: Increase awareness of and participation in Critical Zone science and network activities as an open and inclusive community

Goal 4: Articulate a compelling vision and structure for the future network of CZOs

Goal 1 - Desired Results

- We will articulate and widely publicize transformative ideas that form a compelling manifesto for Critical Zone science and are the direct result of the CZO network.

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- i) We will articulate and widely publicize transformative ideas that form a compelling manifesto for Critical Zone science and are the direct result of the CZO network.

The Critical Zone, Earth's living skin, has three dynamic and spatially structured co-evolving surfaces: the top of the vegetation canopy, the ground surface, and a third, deep surface below which earth's materials are unweathered.

Goal 1 - Desired Results (contd.)

By Fall 2016, we plan to work to publicize **the first three ideas** developed over the first years of the CZO network:

1) For the first time, we have obtained observations that reveal how the deep surface of the Critical Zone varies across landscapes.

2) New mechanistic models now provide quantitative predictions of the spatial structure of the deep surface relative to the ground surface topography.

3) For the first time we have obtained observations that reveal that differences in energy inputs at the Earth's surface translate into differences in water, minerals, and biotic activity at depth, and we are starting to detect how these deep properties also impact the biota and climate.

Goal 1 - Desired Results (contd.)

- ii) Publicize these and other transformative Critical Zone findings that arose from the first 8 years of the network
- iii) Create a synthesis across CZOs of the structure of physical, chemical, and biological properties
- iv) By 2018, use the growing knowledge of Critical Zone structure to explain hydrologic partitioning

Goal 1 - Key Strategies

- Engage the broader Critical Zone community to adopt / modify / finalize these findings into a short, compelling manifesto (Suzanne Anderson)
- Publicize the list of key Critical Zone findings with links to published research papers (Kitty Lohse)
- Launch an initiative to use the network's knowledge of Critical Zone structure to explain hydrological partitioning; co-fund a postdoc and two workshops to support the initiative (Noah Molotch)

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Union session

The Critical Zone: Revealing the Structure, Function, and Evolution of Earth's Living Skin

William E Dietrich, *U California Berkeley,* The critical zone: A necessary framework for understanding surface earth processes

Steven W Holbrook, *U Wyoming,* Critical zone architecture and processes: a geophysical perspective

Jennifer McIntosh, *U Arizona,* Changing energy inputs at Earth's surface translates to differences in water availability, weathering rates, and biotic activity at depth

Amilcare M Porporato, *Duke U,* Propagation of hydroclimatic variability through the critical zone

Ying Fan, *Rutgers U,* Plant rooting depth, soil hydrology, and implications to terrestrial environmental change

David J Beerling, *U Sheffield,* Harnessing the agricultural critical zone for climate change mitigation through enhanced rock weathering with croplands

EPSP session

The Architecture and Workings of Earth's Critical Zone

46 (forty-six!) contributed abstracts

Invited:

Kathleen A Lohse et al., *Idaho State U*, Taking the pulse of the skin of the Earth: Quantifying the spatial and temporal variability in soil biogeochemical cycling and stream aqueous losses

Roman DiBiase et al., *Penn State U*, Quantifying spatial variability in critical zone architecture through surface mapping and near-surface geophysics

Some additional CZ-focused sessions (not exhaustive)

Hydrology sessions

- Modeling the Critical Zone: Integrating processes and data across disciplines and scales
- Preferential flow and transport across scales in the Critical Zone
- Critical biogeochemical processes in the unsaturated zone

Biogeosciences sessions

- Microbial Geochemistry and Geomicrobiology: from DNA to Rock
- Soil carbon dynamics in the Anthropocene

Another EPSP session

- Control from Above and Below: Interactions between Climate and Lithology in Landscape Evolution

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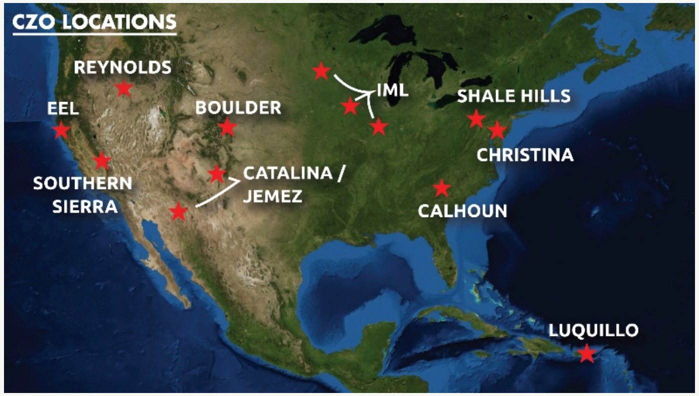
Hydrologic partitioning – Framing points

- CZOs are collecting datasets that characterize physical, chemical, and biological architecture of the subsurface, and fluxes this architecture modulates.
- Cross-CZO project will conduct intercomparisons of how CZ physical, chemical, and biological structure determines stream flow quantity and composition.
- Work will leverage datasets that have already been collected, and help drive coordinated data collection across CZOs to address broad hypotheses.



Hydrologic partitioning – Science questions and approach

1) How does critical zone structure influence hydrologic processes and functions?

2) Do hydrologic processes and critical zone structures co-evolve? We will address these questions through an inter-comparison of the landscapes represented by the CZOs.

Hydrologic partitioning – Information to be used

1) **Perceptual models** (model based on words, description, diagrams, etc.) of each CZO, capturing what is understood about their internal structure and hydrologic processes

2) **Analysis of quantitative signatures** extracted from the hydrologic dynamics that capture essential differences in the way each CZO functions.

*Aim to reconcile and synthesize these two sets of information, to understand what drives the differences between places.

Hydrologic partitioning – Current status

- Funding secured from NSF (mid Aug) as supplement to CU Boulder.
- Post doc job ad distributed to several list serves and, at last count, 30 applications had been received.
- Review of applications will begin week of Aug 29.
- Applications will 1st be reviewed by Molotch + Harman; input on short list to be solicited from CZO PIs.
- Skype interviews to be conducted in early Sept with intention for new hire to begin in Oct or Nov, if possible.

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Goal 2 - Desired Results

- Establish a defined set of common measurements in place across the Critical Zone network
- Establish a defined set of common data management protocols in place across the Critical Zone network
- Use selected models to test hypotheses at different scales and across the Critical Zone network

Goal 2 - Key Strategies

- Develop and begin using a defined set of common measurements across the network (Jen McIntosh)
- Engage with other data platforms such as CUAHSI to develop data management protocols (Sally Thompson)
- Identify / prioritize a set of models that can be applied widely across the network (Tess Russo)
- Implement an efficient, effective method to train people across the network on the defined set of models, data management protocols and measurements (Praveen Kumar)

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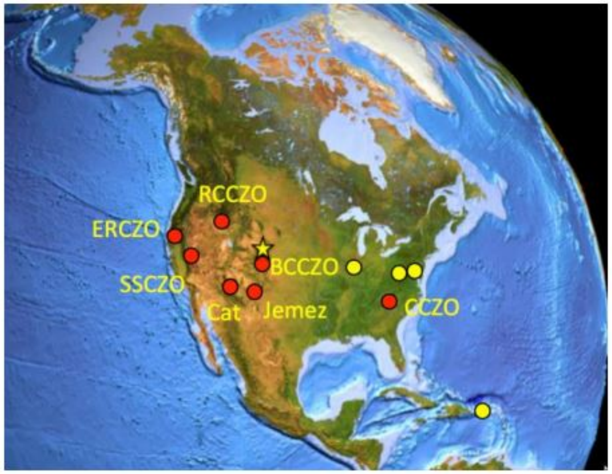
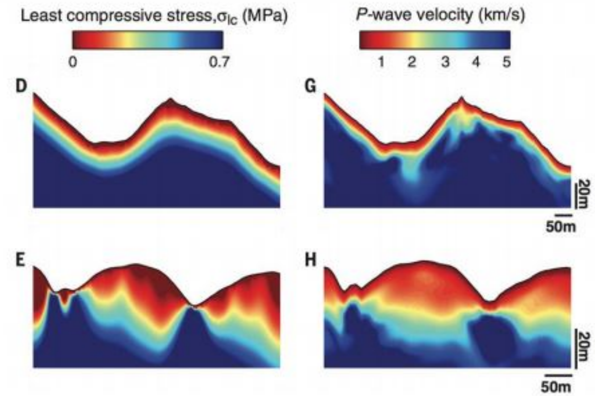
Cross-CZO Common Measurements

- **White Paper** – Jon Chorover updated this last year (available on CZO website)
- Common Measurements **Matrix** (Excel spreadsheet) – early version in White Paper and on CZO website.
  - Tim White requested updates from PIs; has received 6/9 updates and will compile in coming weeks
  - Plan to make the matrix "live" and "clickable" on the website, so users can navigate towards common data (Jon C and Tim W will oversee)
- **Research Papers** – Some of the X-CZO working groups are now putting together co-authored papers and collections of papers in special issues (e.g., C/Q relations issue in WRR, due next week) that highlight common measurements being made at multiple CZOs
- **Big Cross-CZO Common Efforts:**
  - Geophysical surveys (many CZOs working with WyCEHG)
  - Deep drilling projects to obtain cores for studying weathering processes in the deep CZ and to install GW monitoring wells
- Campaign style **Workshop** to implement a common measurements theme at multiple CZOs in 2017 – in early planning stages

WyCEHG at CZOs



Map showing locations of national CZO sites (circles). Red circles are CZOs where WyCEHG (star) has collected geophysical data.



Results of geophysical imaging (right) and stress modeling (left) from the Boulder Creek CZO (top) and Calhoun CZO (bottom). Weak compressive stress at Boulder Creek creates surface-parallel regolith, while strong compressive stress at Calhoun creates a CZ that mirrors topography [*St. Clair et al.*, 2015].

The University of Wyoming summer geophysics field team in eastern Oregon.

University of Wyoming grad students Brady Flinchum and Jordan Leone collect GPR data on fractured bedrock at the Southern Sierra CZO, California.

Comparison between scientific questions and the availability of common measurements to address them for each CZO.

	CZOs with data instrumentation	**What will be the response of CZ structure, and its stores and fluxes, to climate change?**	How will critical zone processes mediate the effects of climate change on water resources?	**What will be the response of CZ structure, and its stores and fluxes to land use change?**	What models best predict how CZ functions and outflows will respond to anticipated land use change?	**What controls CZ properties?**	How does critical zone development depend on lithology?	How does critical zone development vary with climate?	How do hydrologic and geochemical processes drive critical zone development?	How do the properties of granitic rocks influence critical zone development?	How does geologic history and landscape evolution influence critical zone structure?	How does hillslope aspect, as it influences local climate, affect critical zone evolution and structure?	How does critical zone development depend on topography (e.g. slope, relief, hillslope shape, drainage density)?	How does biota influence CZ development?	How do the properties of shale influence critical zone development?	How important is dust accretion in critical zone development?	How has past land use influenced current CZ structure?	**What controls CZ processes?**	How does vegetation influence critical zone processes?	What controls organic carbon storage in, and flux from, the critical zone?	What is the role of microbes deep in the critical zone in mediating solute evolution of runoff water and carbon processing?	What controls the chemical evolution of water through the critical zone?	How do fractures in the critical zone influence hydrologic and solute evolution processes?	How are CZ processes influenced by fire?	How do biota influence solutes and gas fluxes from the critical zone?	How does CZ structure influence hydrologic processes?	**How can improved understanding of the CZ be used to enhance ecosystem resilience and sustainability, and restore ecosystem functions?**	How do critical zone processes influence river flow and ecosystems?	How can prediction of future CZO states and functions provide useful guidance in land use management decisions?
Number of CZOs posing question:		5	5	5	5	4.8	9	6	6	5	5	5	4	4	3	3	3	4.5	10	6	6	5	5	4	0	0	4.5	5	4
Soil (vadose zone)	9.3																												
Solid- elemental composition and mineralogy	10						x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x		x			x
Solid- texture and physical characterization	10						x	x	x	x	x	x	x	x	x		x			x			x	x		x			x
Solid- organic matter content	10				x		x	x	x	x	x	x	x	x	x				x	x	x	x	x	x					
Fluid- soil moisture (sensors)	10				x			x	x			x	x	x			x		x	x		x		x	x	x		x	x
Fluid- soil temperature (sensors)	10				x			x	x			x	x	x			x		x	x	x	x	x	x	x	x		x	x
Fluid- soil solution chemistry (samplers)	9		x		x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x
Fluid - soil gas chemistry (samplers/sensors)	8				x			x	x					x			x		x	x		x		x	x				x
Solid- radiogenic isotope composition	7						x	x	x	x	x				x		x					x							
Vegetation and Microbiota	9.0																												
Structure and function above and below biomass	10		x		x			x	x			x	x	x		x	x		x	x		x		x	x	x		x	x
Microbial compostion above and below ground	9		x		x			x	x					x		x			x	x	x	x	x	x	x			x	
ET-species composition and structure relationships	8		x		x			x	x			x	x	x					x					x	x	x		x	x
Saprolite and bedrock (saturated zone)	8.7																												
Solid- petrology and mineralogy	10						x	x	x	x	x				x					x		x	x					x	x
Solid- elemental composition and organic matter content	10						x	x	x	x	x			x	x					x	x	x			x			x	x
Soild- texture and other physical and architectural traits	10						x		x	x	x	x	x		x				x			x	x			x		x	x
Fluid- potentiometric head, temperature (sensors)	10		x		x		x	x	x	x		x	x	x	x					x						x			x
Fluid- groundwater chemistry (samplers/sensors)	10		x		x		x	x	x	x		x		x	x	x	x			x	x	x			x			x	x
Geophysical Surveys- depth to bedrock	8						x	x	x	x	x	x	x		x							x	x			x			x
Fluid- saprolite/weathered bedrock gas chemistry (samplers/sensors)	3		x				x	x	x	x	x	x		x	x		x				x	x			x				
Land-Atmosphere	8.5																												
LiDAR	10						x	x	x		x	x	x	x										x		x			x
Wind speed and direction	10		x		x			x			x	x	x			x			x	x				x				x	x
Precipitation and through-fall	10		x		x			x	x		x	x	x	x		x	x		x	x	x	x	x	x	x	x		x	x
Wet and dry deposition	9		x		x			x	x		x	x	x			x	x		x	x	x	x		x	x	x		x	x
Eddy flux	7		x		x			x	x					x					x	x				x	x	x		x	x
Snowpack distribution and duration	5		x		x			x	x			x	x						x	x	x	x				x		x	x
Surface water	7.2																												
Instantaneous discharge	10		x		x			x					x				x									x		x	x
Stream water chemistry (sample/sensors)	10		x		x		x	x	x	x	x		x		x	x	x		x	x	x	x	x	x	x			x	x
Sediments (samplers/sensors)	10		x		x		x	x		x	x	x	x		x	x	x		x			x		x		x		x	x
Stable isotopes of water	7		x		x		x	x	x	x	x				x		x			x								x	
Extent of wetted channel	3						x	x	x	x	x	x	x	x	x		x									x			
Aquatic biota (invertebrates, fish, etc.)	3				x			x			x			x		x	x		x			x		x				x	
Age or rate constraints	4.0																												
Cosmogenic radionuclides	7						x	x	x		x	x	x				x												
^{14}C ages	4							x	x		x			x			x		x	x	x								
Optical Stimulated Luminescence	1						x			x	x				x														

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CUAHSI HIS hosting

› Suitable for any timeseries data (concentration, flux, etc.)

› Hosting provided

› Defined metadata

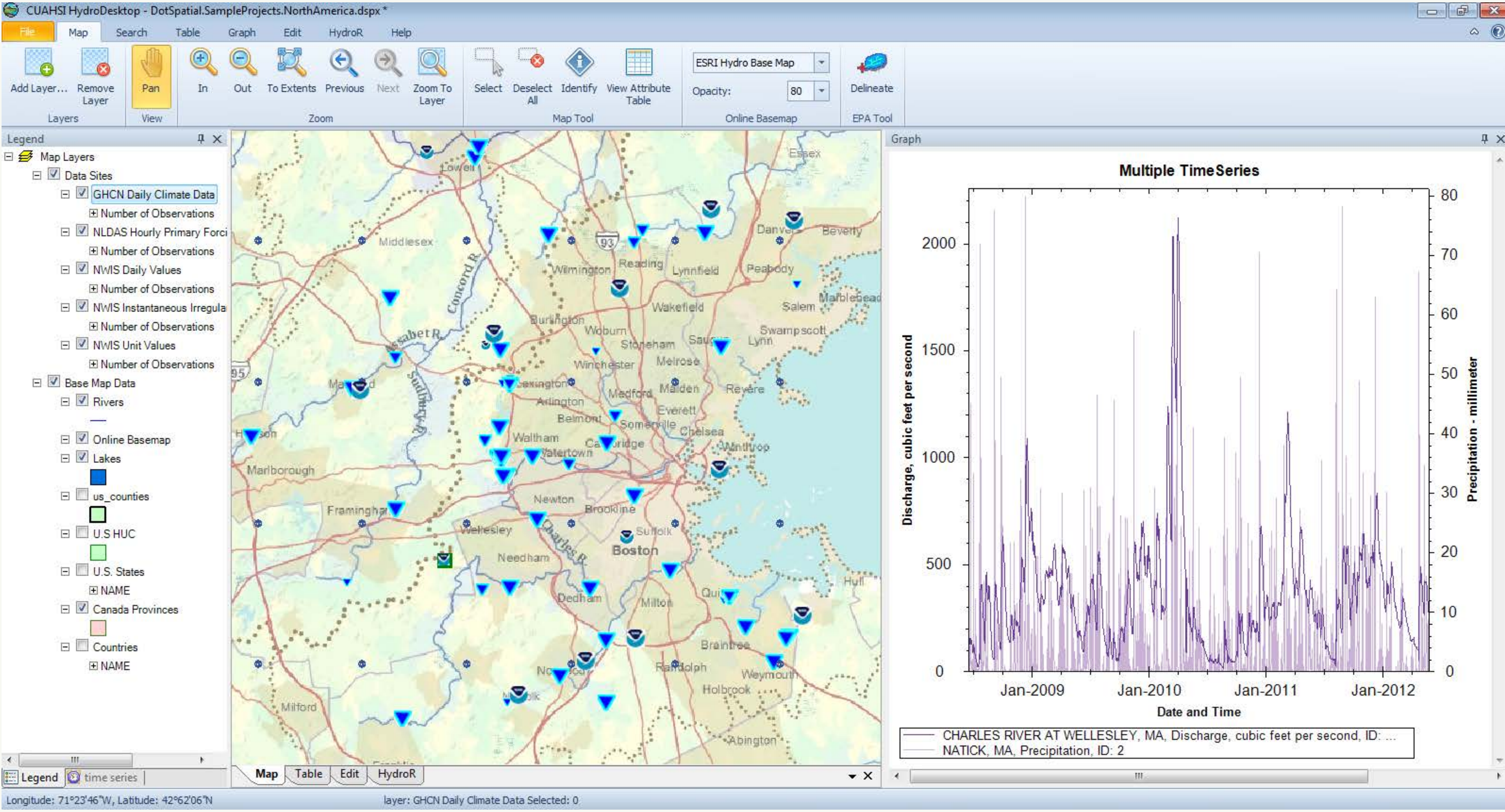
› Some CZOs using CUAHSI protocols already (ERCZO is)

› GIS referenced, map searchable

CUAHSI
UNIVERSITIES ALLIED FOR WATER RESEARCH

http://hiscentral.cuahsi.org

Hydro Desktop offers searchable interface



What we are thinking about currently with respect to data

- Individual CZO data managers work with HIS separately to use existing frameworks
- Explore reliability, user-friendliness
- Consider that other solutions are required for non-TS data

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Table 2: Conceptual models used by the CZOs.

Model name	**Systems modeled**	**Future X-CZO application**	**CZOs using model**
Bedrock to Regolith	Bedrock, fluids, soil formation	Possible	SH, LQ
Saprolite to sea	Erosion, carbon		CR
Hydrogeochem	Deposition, weathering, and transport		SH
Isotope weathering	Weathering rates		SH
10Be on hillslopes	Landscape evolution, regolith mobility		BC
Preferential flow	Fluid, solute transport	Possible	SH, CR
EEMT	Energy and mass, water and carbon		CJ
Front Range Schema	Landscape evolution		BC
Landscape linkages	Landscape evolution		BC
Dynamic Persistence	Ecosystem recovery		CL

Table 3: Numerical models used by the CZOs.

Model name	**Systems modeled**	**Future X-CZO application**	**CZOs using model**
PIHM	Hydrology	Possible	CR, SH
Flux-PIHM	Hydrology, land/atmosphere	Possible	SH
tRIBS	Hydrology		LQ, CL
hsB-SM	Hydrology		CJ
VS2D	Unsaturated hydrology		BC
Optimal sensing	Soil moisture		CL
Hydropedo Toolbox (Matlab)	Soil moisture		SH
OTIS	Streambed hydrologic exchange		SH
Alpine glaciers 1&2d	Ice motion		BC
Fluid exchange model	Estuary fluid flux		CR
PHREEQC	Aqueous geochemistry		LQ
ROMS	Ocean		EL
WRF	Weather forecasting		EL

CHILD	Erosion, sediment transport, surface evolution	Possible	BC, CL
Digital glacier bed	Elevation of glacier bed		BC
GullyErosionProfiler	Channel profile evolution		BC
Hillslope Trajectory	Erosion		BC
Range and Basin	Mountain evolution		BC
Landlab	General 2d models		BC
FEMDOC-2D	Hillslope DOC transport		CR
IDOCM_1D	Heat and DOC in soils		CR
CENTURY	Soil carbon		LQ
CN reforest dynamics	Tree/soil C and N		CL
Plant-soil feedback	Plant-soil, soil production		CL
Root deformation	Soil deformation from roots		BC
GASH	ET and throughfall		LQ
NPZD	Ecosystem		EL

PIHMSed	Hydrology, sediment transport, uplift, weathering	Possible	SH
PIHM-DOC	Hydrology, dissolved organic carbon		CR, SH
TIMS	Hydrology, microbial, geochemical, geomorph, ecology		CJ
RHESSys	Hydrology, ecology	Possible	SS
AWESOM	Atmosphere, Watershed, Ecology, Stream and Ocean Model	Possible	EL
tRIBS-ECO	Hydrology, erosion, soil C		CL

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Modeling

- IMLCZO conducted a modeling Summer Institute (4 webinars + in-person meeting Aug 16-19); SSHCZO conducted a PIHM modeling workshop
- 20 attendees; 5 CZOs represented; 2 international students
- Exposed students to ‘Dhara’ as a open-source high performance CZ modeling environment [https://hydrocomplexity.github.io/Dhara/]

Summer Institute Attendees at NCSA’s Blue Waters Supercomputing Center

Data Management

- CZO Data Managers meet regularly to discuss long-term strategy
- NCSA Led proposal under planning/development to provide longevity to CZO data
  - Involve all data managers to develop an effective strategy

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Goal 3 - Desired Results

- Establish at least one substantive, collaborative activity between the Critical Zone network and the LTER network by 2018
- Increase the number of institutions engaged in research and education at CZOs beyond the original funded partnerships
- Host an open Critical Zone science meeting that promotes collaboration with the broader scientific community
- Put a mechanism in place to facilitate sharing of education and outreach resources and expertise across the network
- Publicize the new Critical Zone network mission, values, and vision

Goal 3 - Key Strategies

- Leverage the National Office education and outreach personnel to support activities in this goal area (Tim White)
- Strengthen and engage the Network Education and Outreach Working Group to facilitate cross-network sharing of resources and expertise (Tim White)
- Enhance the National CZO web site to highlight opportunities for increasing participation by the broader community at CZOs (Lou Derry)
- Publish an overview white paper that articulates the vision for collaborative interaction among CZO / LTER / NEON (Dan Richter)
- Complete revisions on the InTeGrate course (undergraduate introduction to CZ science) and make the course publicly available at SERC website (Tim White)
- Explore new avenues to use AGU events including the townhall or special lectures to engage the greater CZ science community with CZOs (Bill McDowell)

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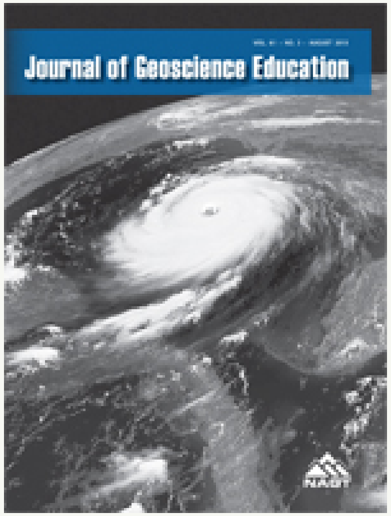
Education and Outreach – Major Achievements

- Active Working Group using BaseCamp
  - Compilation of network activities
- InTeGrate “Intro to CZ” undergrad course
  - Revisions completed this summer; “live” this fall
  - Journal of Geosciences Education manuscript on the course (in review)



- Letter of Intent submitted (last week) to NSF GP-IMPACT: Improving undergraduate education via CZ science

Education and Outreach – Ongoing Activities

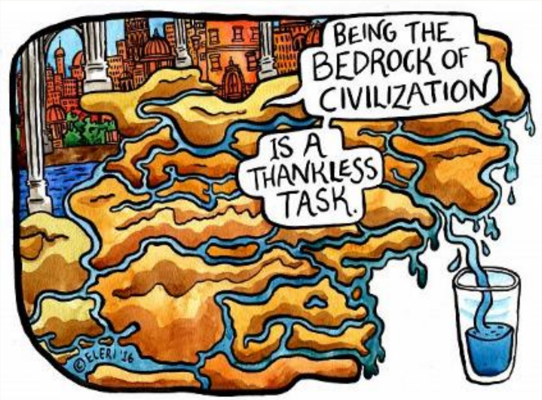
- AGI Earth Science week activity published (5th)
- Quarterly newsletter continues, most recent = July 2016 (6th); 268 receive e-version
- Twitter (last summer) and Instagram (this summer) presence established with daily posts
  - 416 Twitter followers; Instagram = 71
- Adventures in CZ blog: 1-2 posts/month
- CZO You Tube channel
- Summer 2016 teacher workshop at PSU (2nd)

2016 Teachers Workshop

CZNews

CZO Instagram

Adventures in the CZ Blog



Education and Outreach – Upcoming Outcomes

- Dec 2016 PA Science Teachers Association session
- Special issue of National Earth Science Teacher Association journal “The Earth Scientist” this fall
- Video series with WGBH (PBS, Binghamton, NY) is in planning stages for 1st video this fall

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- Strengthen and engage the Network Education and Outreach Working Group to facilitate cross-network sharing of resources and expertise (Tim White)
- Enhance the National CZO web site to highlight opportunities for increasing participation by the broader community at CZOs (Lou Derry)
- Publish an overview white paper that articulates the vision for collaborative interaction among CZO / LTER / NEON (Dan Richter)
- Complete revisions on the InTeGrate course (undergraduate introduction to CZ science) and make the course publicly available at SERC website (Tim White)
- Explore new avenues to use AGU events including the townhall or special lectures to engage the greater CZ science community with CZOs (Bill McDowell)

New avenues for use of AGU events to engage community

- Maintain AGU Town Hall but change focus to highlight discussion of CZO research and opportunities for broader engagement with CZO community…we are brainstorming, could we vote for “transformative idea of the year” and have a talk at the townhall on this idea each year?
- Organize Chapman Conference on Extreme Events that highlights CZO science and a CZO site (Luquillo)
- Develop CZ themes at AGU meetings that attract researchers from the broad CZ community, not just CZOs

International CZO Workshop, AGU 2015

Our 4 Major Goals

The Focus for the Next 3 Years

Goal 1: Demonstrate the transformative nature of Critical Zone science

Goal 2: Integrate specific elements of infrastructure for the Critical Zone network by 2018

Goal 3: Increase awareness of and participation in Critical Zone science and network activities as an open and inclusive community

Goal 4: Articulate a compelling vision and structure for the future network of CZOs

Goal 4 - Desired Results

- In 2016, submit a position paper to NSF that articulates alternative models for the future network of Critical Zone Observatories
- By the end of 2017, engage the broader community to develop a set of big hypotheses about the Critical Zone that could be tested by a future network
- By the end of 2017, engage the broader community to explore alternative models and develop a recommended optimal structure for the future network of Critical Zone Observatories

Goal 4 - Key Strategies

- Publish the existing "common questions document" as a starting point for discussion on the key hypotheses about the Critical Zone that could be tested by the network in the future (Bill Dietrich)
- Develop a proposed list of key hypotheses about the Critical Zone that could be tested by the network in the future (Bill Dietrich)
- Develop a draft set of alternative models for how to structure the future network of CZ science sites (Sue Brantley)
- Engage the broader community at a specially designed workshop in 2017 to reach agreement on the big hypotheses and the alternative models for the Critical Zone Network (Sue Brantley)
- Develop and submit a report based on the 2017 community workshop to National Science Foundation (Sue Brantley)

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We would like to develop key hypotheses about the CZ that could be tested by the network in the future (a few possibilities):

1) CZ architecture controls hydrologic and geochemical processes that drive concentration- discharge relationship in rivers. *A special volume of WRR has a submission deadline of the end of August*

2) What controls the depth to fresh bedrock: testing five hypotheses. (*See next slide for 5 mechanisms*)

3) Aspect differences can be used to reveal mechanisms linking critical zone structure, biota and hydrologic processes.

4) Deep microbial community is linked to vegetation: microbial community will be distinctly different under agriculture fields, brush, grassland, perennial forest and deciduous forest.

5) Deep Critical Zone architecture may control water availability to plants and microbial communities, which in turn will influence regional climate.

The depth to fresh bedrock is being mapped and the results suggest predictable patterns underlying hillslopes.

There are now at least five theories that emphasize different controlling mechanisms for predicting the elevation of the fresh bedrock surface under hillslopes.

a. Frost weathering
(Anderson et al. 2013, Earth Surf. Proc. Landforms)

b. Regional compressive stress on hillslopes
(St. Clair et al., 2016, Science)

c. Vertical chemical weathering front advance
(Lebedeva and Brantley., 2013,Earth Surf. Proc. Landforms)

d. Lateral flow groundwater chemical erosion
(Braun et al, in press, J. Geophys. Research)

e. Bottom up control dictated by slow drainage of groundwater through fresh bedrock.
(Rempe and Dietrich, 2014, PNAS)

It may be a combination of these processes that controls Zb.

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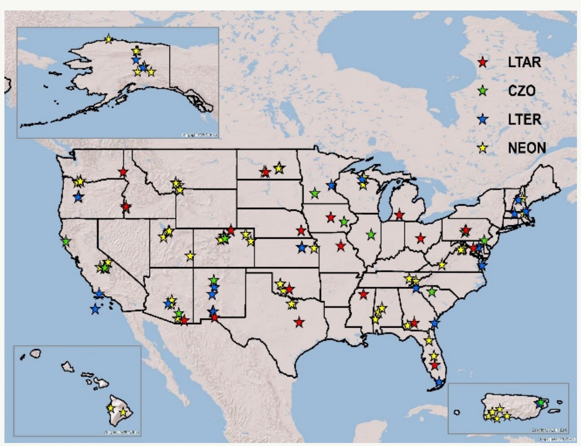
What might the future CZO network look like?

Fill-in-Gaps

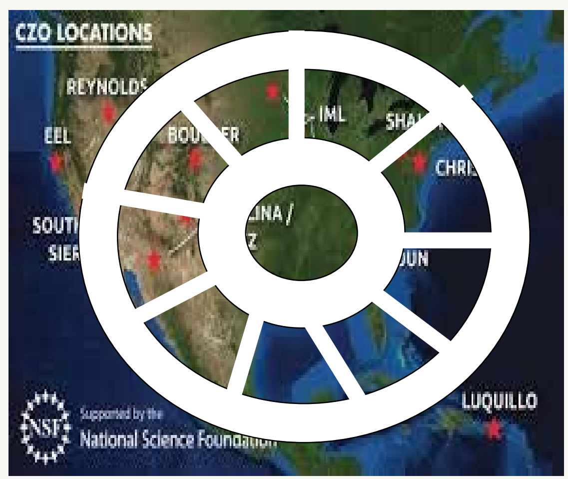
Current

Blank slate

Link networks



Hub and Spoke



Satellite sites

Goal 4 - Key Strategies

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June 2017 Meeting at the Arlington Hilton (tentative)

Wed, May 31 - Friday, June 2
Sunday June 4 - Tues, June 6
Sunday June 11 - Tues, Jun 13
Sunday June 18 - Tue, June 20
Sunday, June 21 - Tues, June 23

We are hoping for up to 200 people. This would be an All Hands and New Hands meeting. We want to be near NSF to invite NSF program officers and we hope we can attract folks from Nature Conservancy, USDA, USGS, and other entities.

We need all hands to participate!

- Ask questions or make suggestions now
- Give feedback to the PI committee directly or through your lead PI
- Participate in meetings
- Publish, engage, pursue ideas, energize, lead
- Work with others outside of CZO and abroad