CZOs @ AGU:

- List of presentations: http://criticalzone.org/national/news/story/czos-at-agu/

- Exhibit Hall Booth 2521

- Town Hall:
  When: Tuesday, December 16, 12:30-1:30 PM
  Where: Room 2005, Moscone West

- Graduate Research Group social:
  When: Wednesday, December 17, 4-7 PM
  Where: Bin 55, Marriot Marquis

Using a CZO network to explore the architecture, dynamics and evolution of the Critical Zone

- Introduction
  - Dr. Enriqueta Barrera (U.S. National Science Foundation)

- CZOs: network of sites, data and people
  - Dr. Susan L. Brantley (Penn State; Shale Hills PI)

- Cross-CZO science questions
  - Dr. Bill Dietrich (UC-Berkeley; Eel River PI)

- CZO common measurements
  - Dr. Jon Chorover (U Arizona; Sta Catalina/Jemez PI)

Critical Zone Observatory Program

Enriqueta Barrera

ebarrera@nsf.gov

Program Director

Division of Earth Sciences

Webinar – Dec. 8, 2014

National CZO Program

http://criticalzone.org

The Critical Zone Observatory (CZO) program is both individual sites and a network of sites, promoting a system approach to Critical Zone Science

The CZO Program is an infrastructure for research of the CZ Community at large: <u>CZO scientists and NSF encourage community involvement</u>

Critical Zone Observatory Network

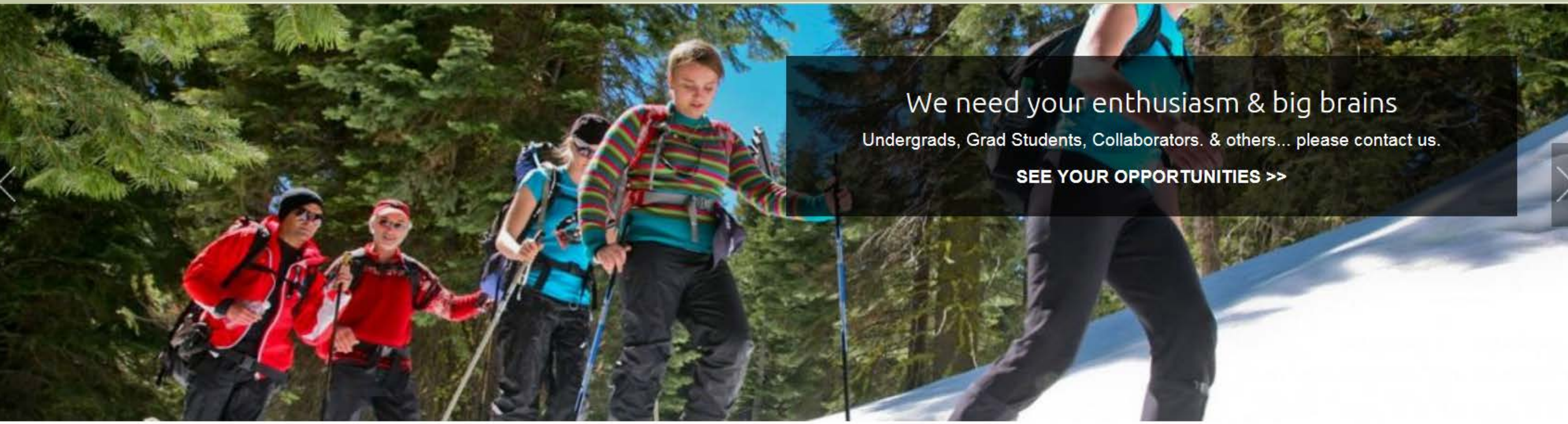
www.criticalzone.org

SWITCH OBSERVATORY ▼

CZO | **CRITICAL ZONE OBSERVATORIES**
U.S. NSF NATIONAL PROGRAM

About | News | Events | Opportunities | Contact

Research Infrastructure Data Models Publications People Education/Outreach



We need your enthusiasm & big brains

Undergrads, Grad Students, Collaborators. & others... please contact us.

SEE YOUR OPPORTUNITIES >>

Spotlight

Olga Mayol
COLLABORATOR
Luquillo CZO

Atmospheric Aerosols

Opportunities

CZOs at AGU

Postdoctoral Opportunity with the Catalina–Jemez CZO

View Opportunities >

Quick Links

What is the "Critical Zone"?

Our Ten Observatories

Future Directions for CZO Science

Common CZO Infrastructure and Measurements

Critical Zone Observatory Network

Education

At 10 CZO:

~110 graduate students at present: ~42 graduated

~ 70 undergraduate students: ~53 graduated

- **EAR Postdoctoral Fellowships (EAR-PF), July 20, 2015**
  Fellowships awarded for CZO research

- **International Scholar program**
  54 graduate students to 20 European host institutions

- **Research Experience for Undergrad/Res. Exp. Teachers (REU/RET)**
  Christina River Basin & Shale Hills joint REU/RET program

CZO National Office, CZO-NO

- ***Coordination of CZO Network Research and Educational Activities***
- ***Outreach to the Critical Zone Community at large and the public on behalf of the network***

Dr. Louis Derry - Cornell University

Dr. Timothy White - Pennsylvania State University

Dr. Robert Ross - Paleontological Research Institute

How to become involved with CZOs

- Seek a seed grant from one of the CZOs (some have them, some don't)
- Seek funding from NSF programs: EAR SEP programs and others (include letter of support from the CZO)
- Ask a CZO PI to host one of your grad students or postdocs to collect data or pursue modelling
- Use CZO data posted on the web (and notify the CZO)
- Interact with the National Program office
- Join the Graduate Research Group (contact Dr. Nikki West @ PSU: nikki.west@gmail.com)
- Attend a workshop or the all-hands meeting (hosted by SH CZO, Sept. 2016)
- Pursue cross site comparisons that leverage the CZOs

A growing international network

- US Critical Zone Observatory program
- European Commission SoilTrEC (Soil Transformations in European Catchments) http://www.soiltrec.eu/
- French RBV (Réseau des bassins versants– Network of River Basins); CRITEX (Critical Zone Program of Excellence) equipment project http://rnbv.ipgp.fr/
- TERENO (Terrestrial Environmental Observatories in Germany) http://teodoor.icg.kfa-juelich.de/overview-de
- China Critical Zone Observatory program

Using a Critical Zone Observatory Network to explore the architecture, dynamics and evolution of the Critical Zone

Susan L. Brantley, Penn State University

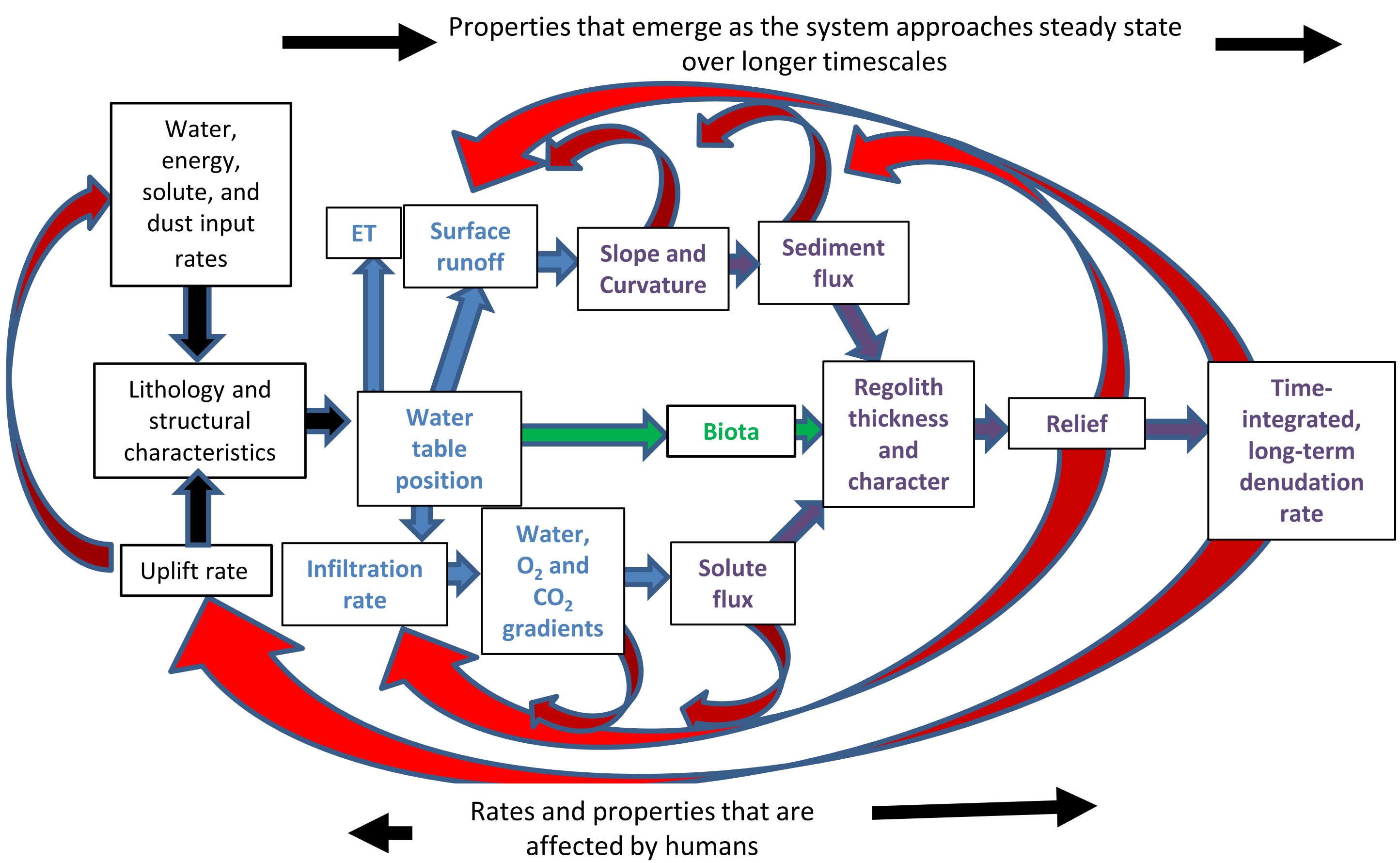
Bill Dietrich, University of California, Berkeley

Jon Chorover, University of Arizona

Outline of our presentation

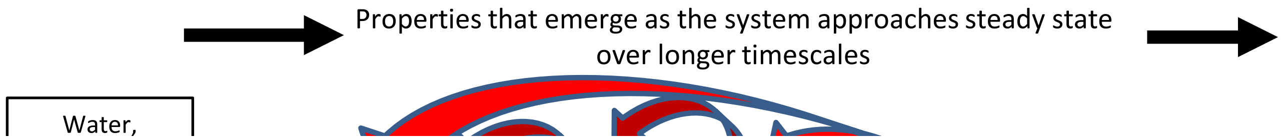
- Introduction to the CZO Network
- Cross-site questions that are emerging
- Common measurements that comprise the network

The Critical Zone is the part of the earth surface extending from outer vegetation canopy to groundwater. It is controlled by a complex network of coupled chemical-physical-biological processes that evolve over timescales from seconds to millenia:



When observed over different timeframes,
different steady states may emerge where rates balance

But everyone's picture of this diagram is different!



What we agree on:

1. The critical zone evolves a structure that influences the storage and flux of water, solutes, sediments, gases, biota and energy.

2. By mediating these stores and fluxes, the critical zone provides ecosystem services, and is thus critical to people.

When observed over different timeframes,
different steady states may emerge where rates balance

Three General Questions

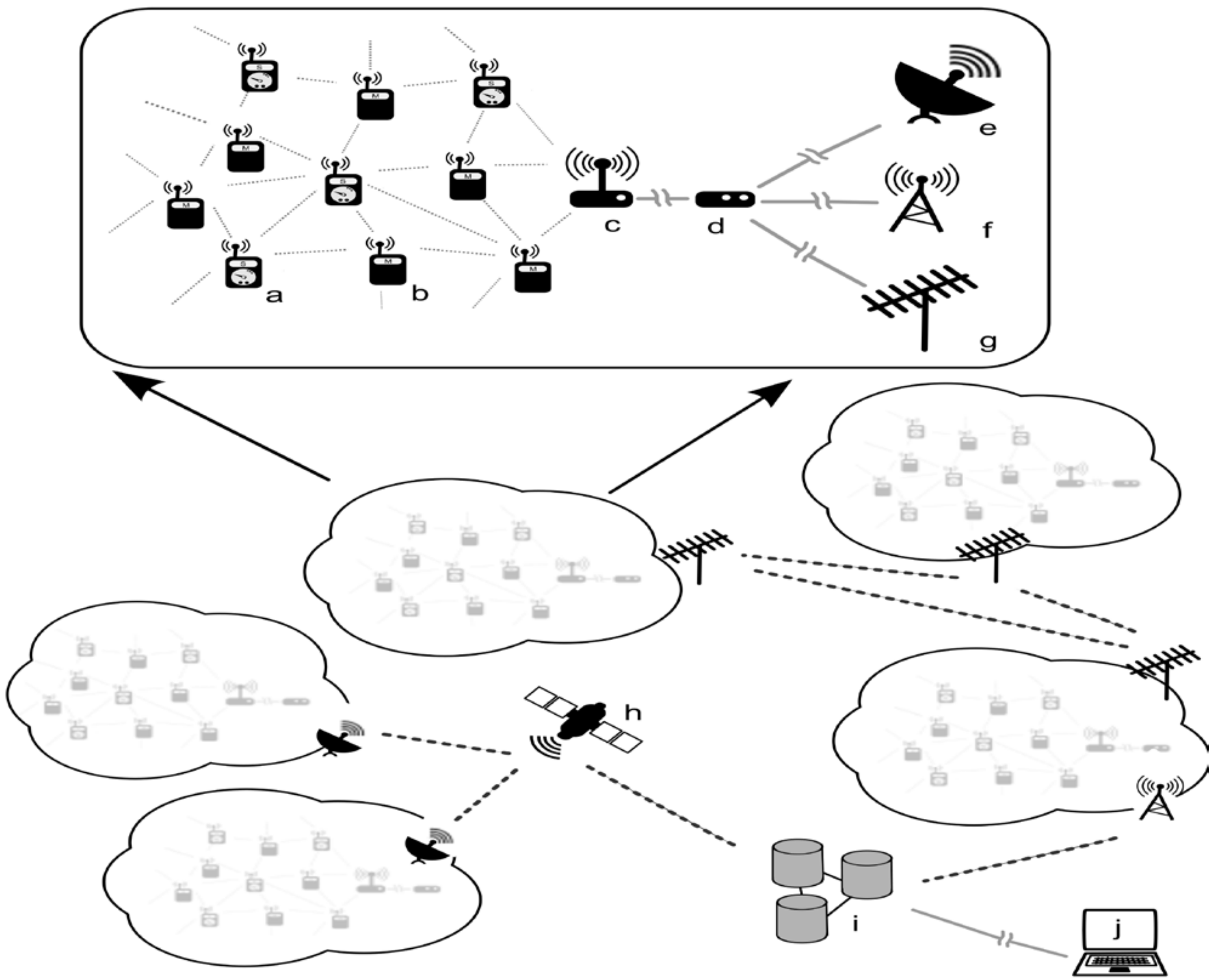
1. What controls critical zone properties and processes?

2. What will be the response of the critical zone structure, and its stores and fluxes, to climate and land use change?

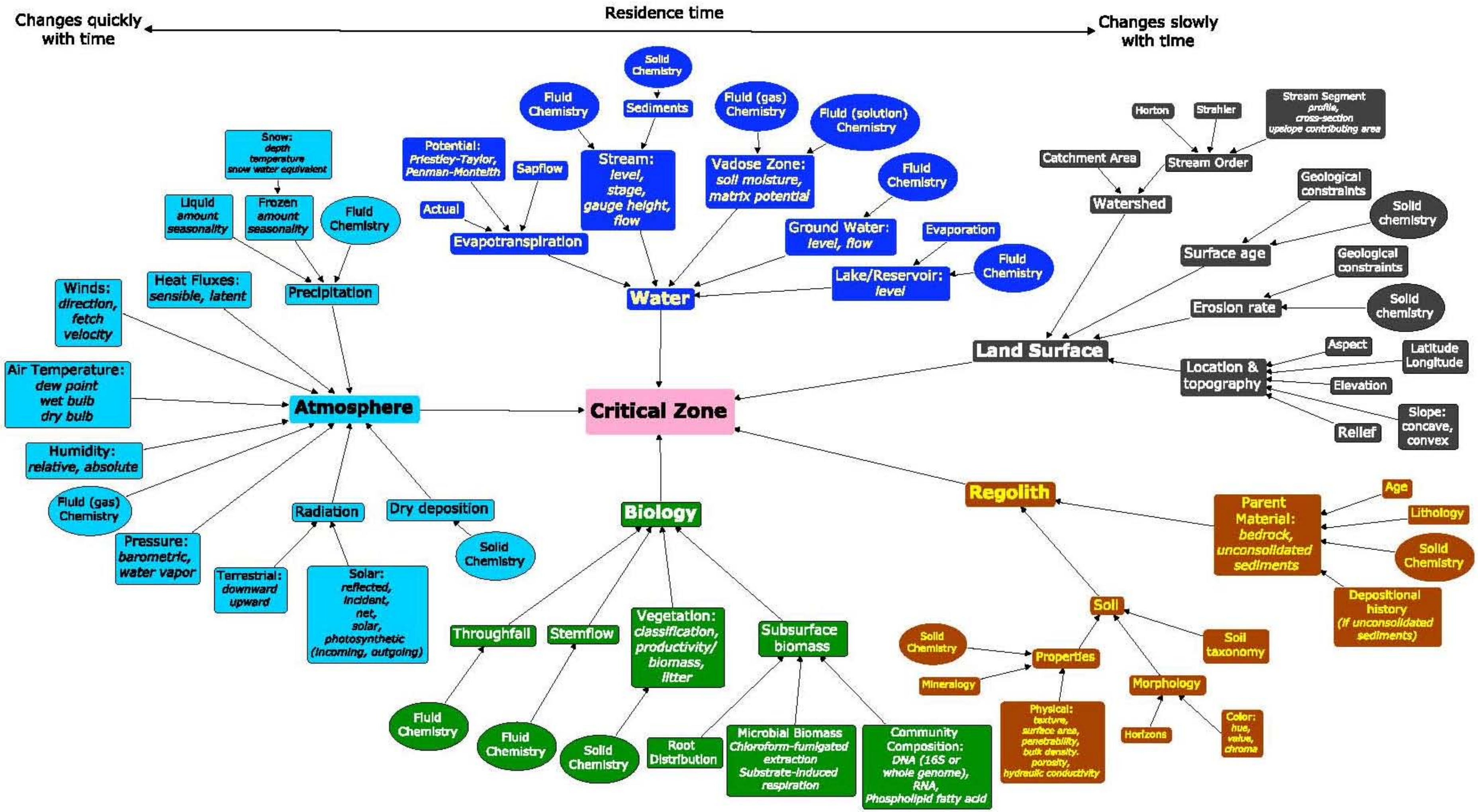
3. How can improved understanding of the critical zone be used to enhance ecosystem services?

A Critical Zone Observatory is a location chosen to develop greater understanding of the architecture, dynamics, and evolution of the CZ

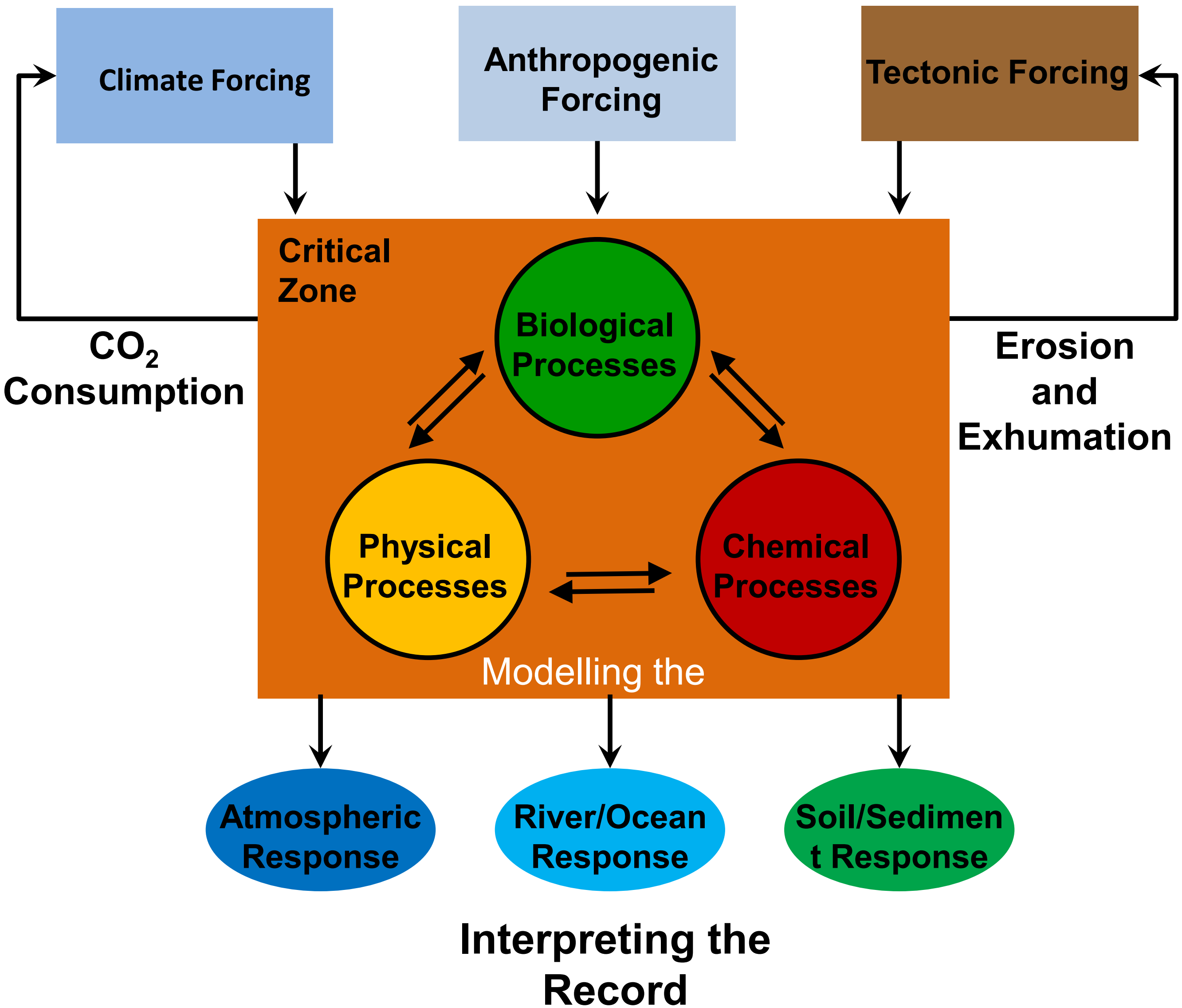
Each CZO measures landforms, surveys biota, samples and analyzes earth surface materials, makes measurements of all relevant fluxes, collects and analyzes data from sensors, measures human impacts, performs experiments…this requires measurements at all spatial scales with expertise from all earth surface disciplines

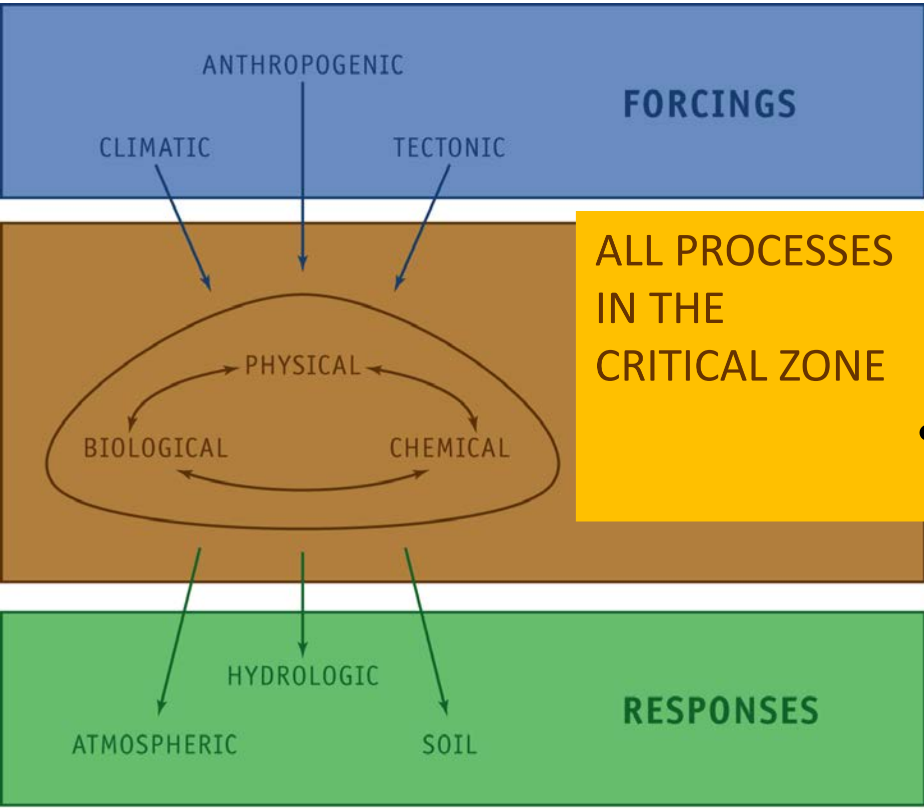


We are organizing these disparate datasets for others to use – outside of CZOs and across disciplines



CZOs are also synthesizing the data and observations and developing and testing models of earth surface processes



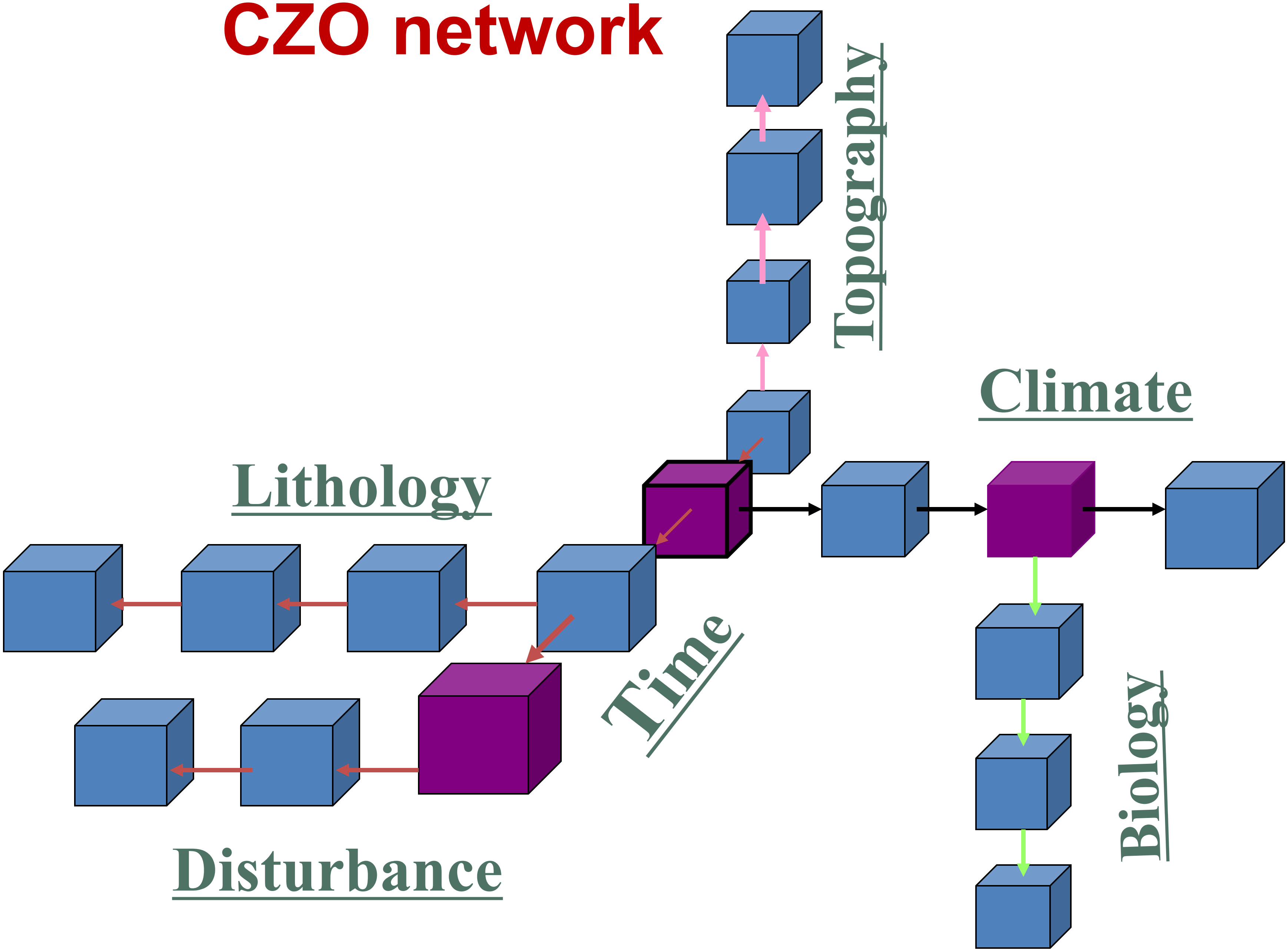


Anderson et al., 2004

Perhaps what really distinguishes CZO research is that it not only crosses spatial scales and disciplines, but also asks the question, can we relate today's fluxes to the records of those fluxes in the past?

Each CZO can only provide data for one environment: we need to understand these complex, coupled earth surface processes across all of Earth's environments

A conceptual model for the CZO network



Critical Zone Observatory Network: 2007

Critical Zone Observatory Network: 2008

Critical Zone Observatory Network: 2013

A growing international network (this is an incomplete list)

-US National Critical Zone Observatory (+CZONO) program

-European Commission SoilTrEC (Soil Transformations in European Catchments)

-French RBV (Réseau des bassins versants– Network of River Basins)

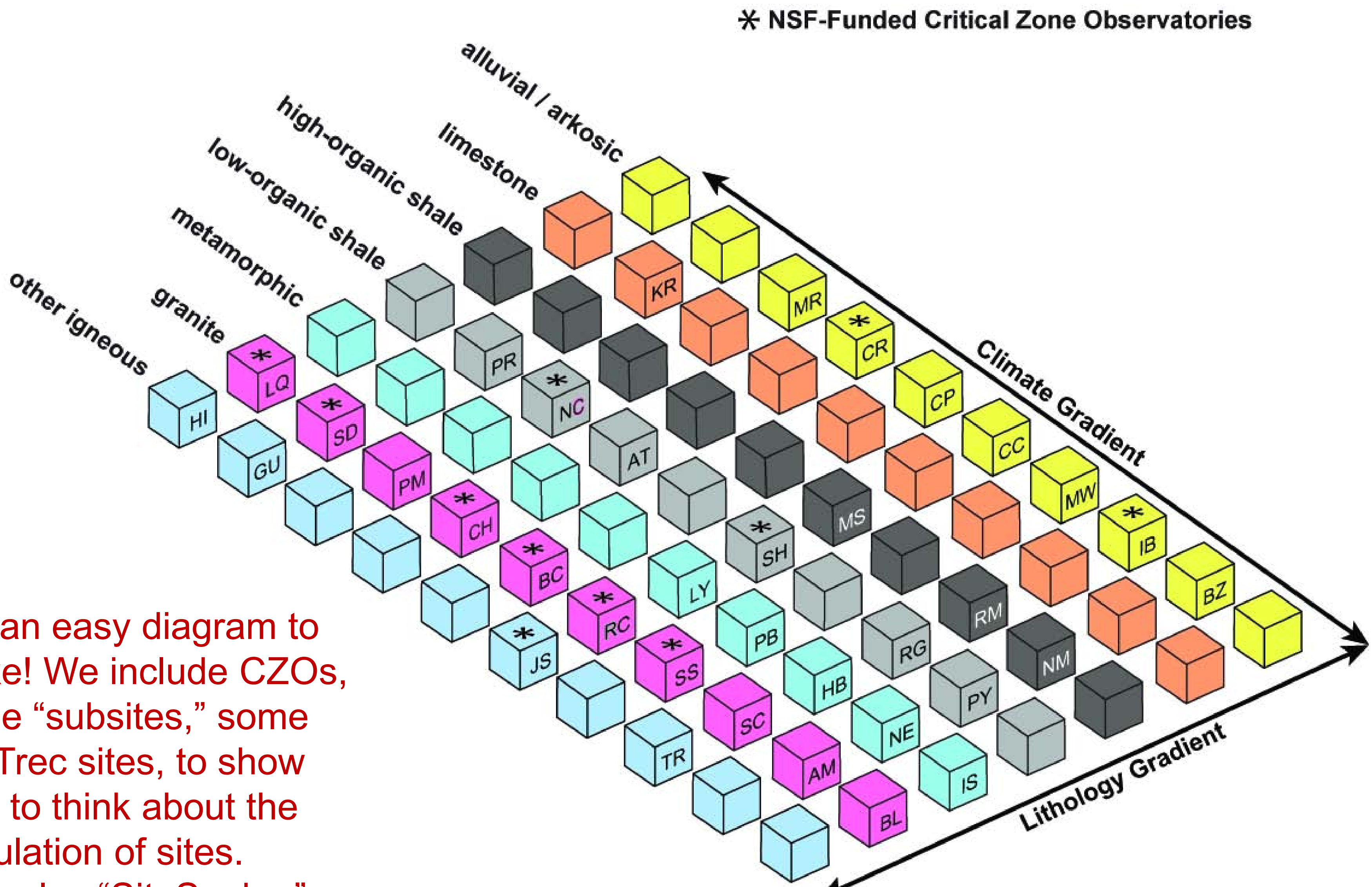
- French Critex (Critical Zone Programme of Excellence)

-Chinese Critical Zone Observatory program (announced Sept 2012)

-TERENO and AquaDiva (Germany)

- Evolving in Australia in part based on TERN Supersites

Understanding today's CZO network

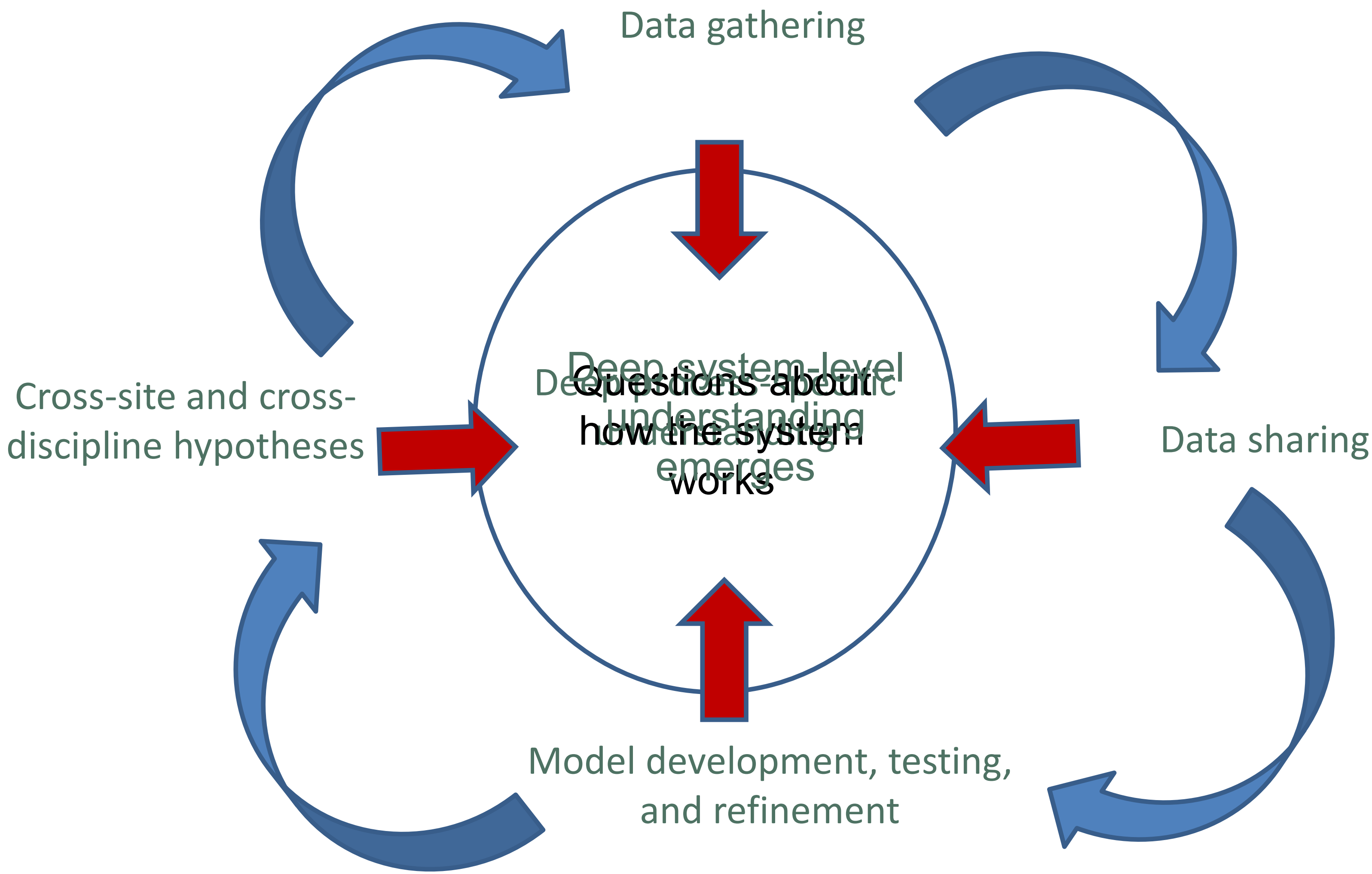


Not an easy diagram to make! We include CZOs, some "subsites," some SoilTrec sites, to show how to think about the population of sites. See, also "SiteSeeker" on czen.org

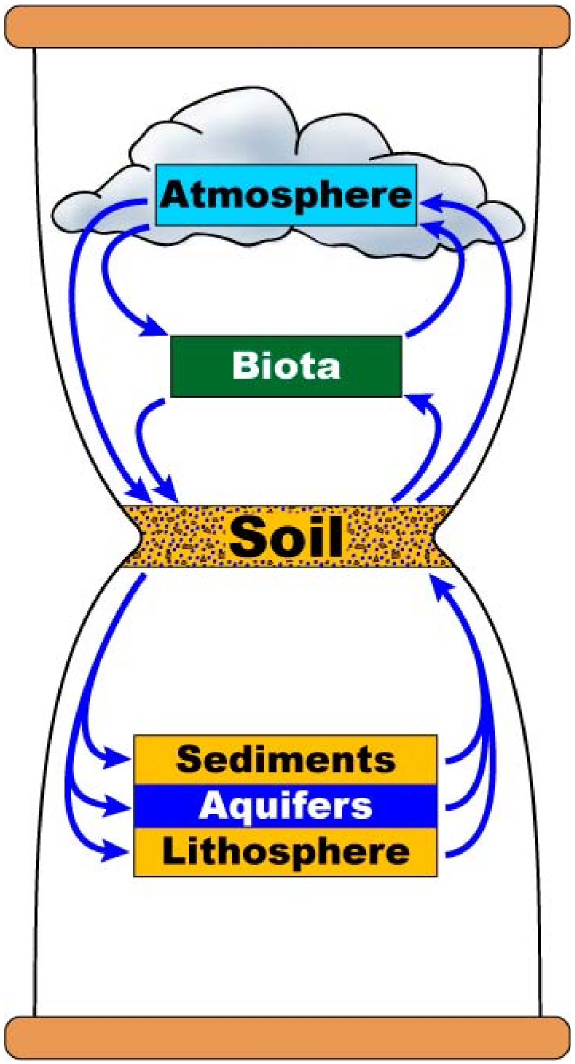
We see the CZO Network as an audacious experiment to use the CZ as a "time telescope" that looks into the present and past to drive development of "earthcasting" models to project the future

So what is the CZO network?
It is a network of people,
ideas, data, tools, and models driven by hypotheses.

- We do both science and monitoring
- We act as both individual sites and as a network
- We have cross-cutting questions but we also compete with different ideas and approaches
- We are a facility that invites new scientists for their science but we also pursue our own science

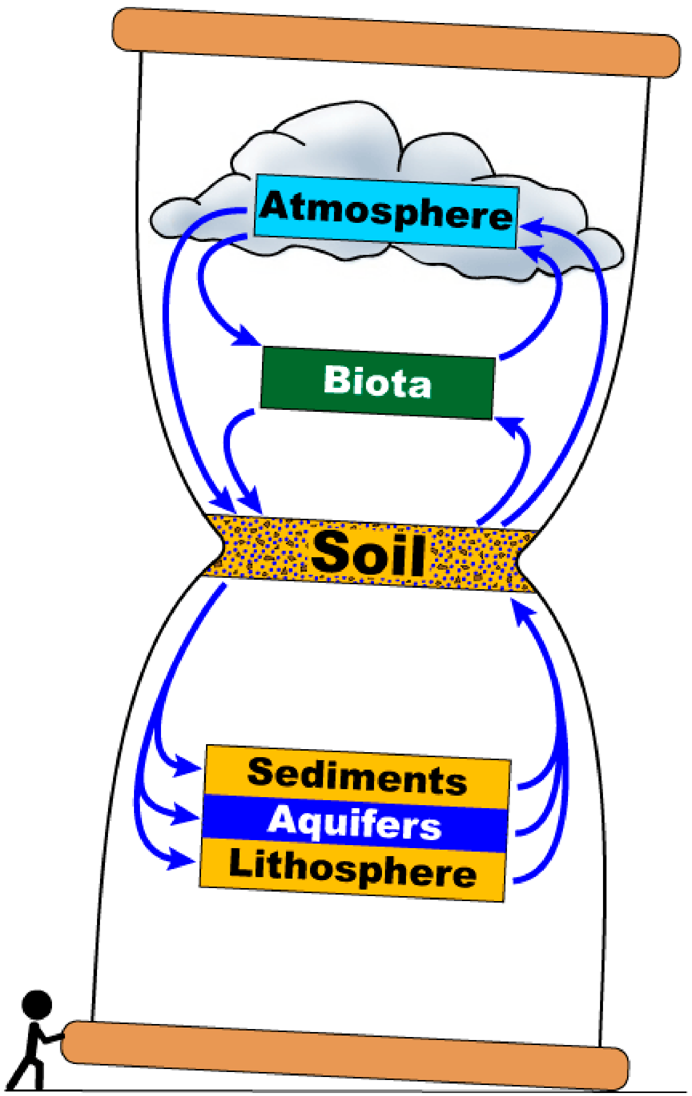


The Science of CZO Research



CZO Mission:

- Learn to measure the earth surface fluxes occurring today
- Learn to read the geological record of the cumulative effect of these fluxes over time
- Develop quantitative models of Critical Zone evolution



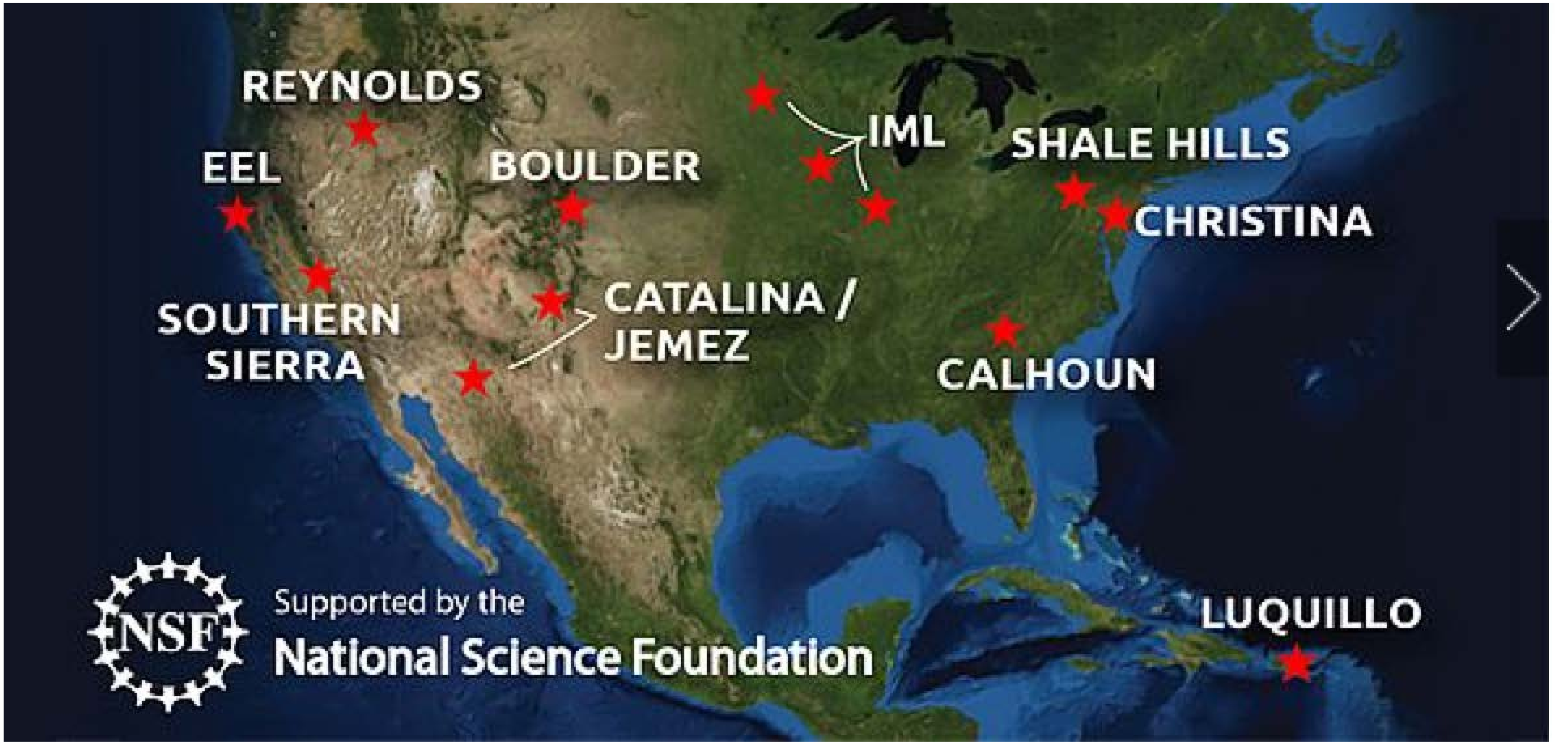
CZO Mission:

- Learn to measure the earth surface fluxes occurring today
- Learn to read the geological record of the cumulative effect of these fluxes over time
- Develop quantitative models of Critical Zone evolution

CZO Vision:

By measuring what is happening *today* and reading the record of what happened *yesterday*, we will learn to use scenarios of human behavior to project what will happen *tomorrow*

Common Questions of the Critical Zone Observatories



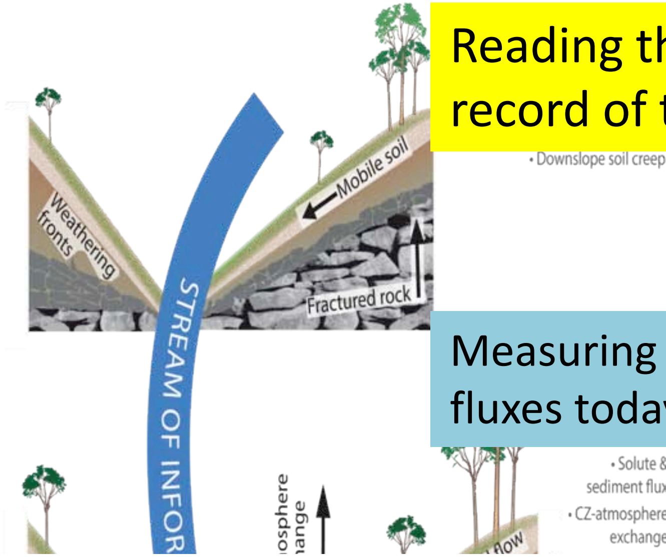
The Susquehanna Shale Hills CZO

Understanding the form, function, and evolution of the CZ developed on sedimentary rock in central Pennsylvania

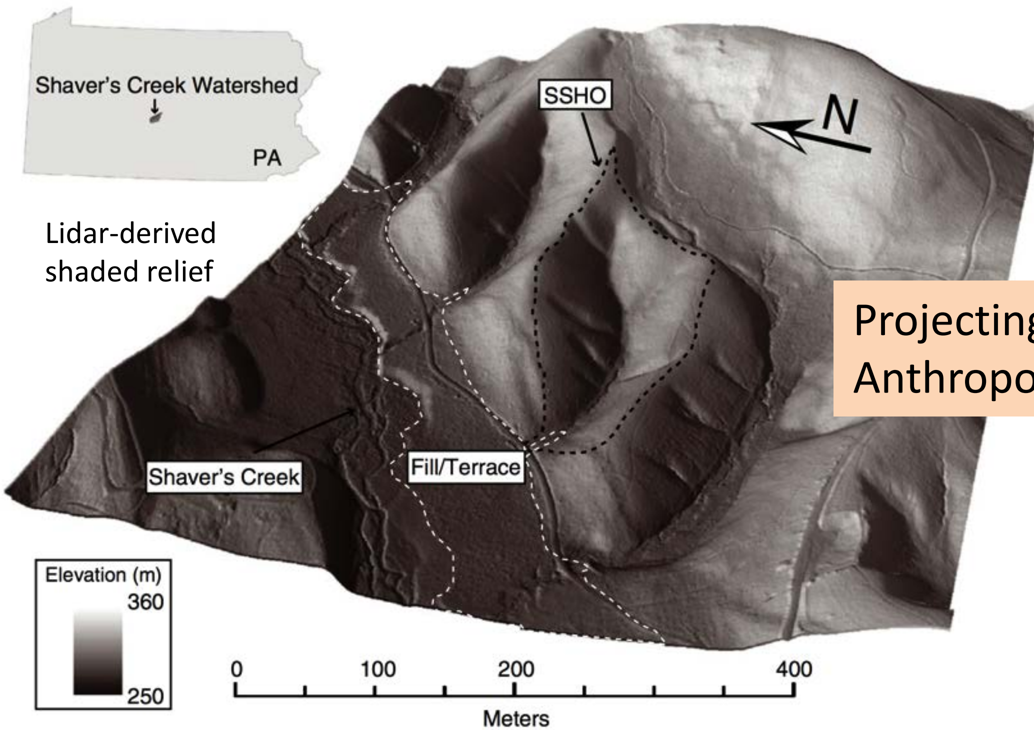
Reading the record of the past

Measuring fluxes today

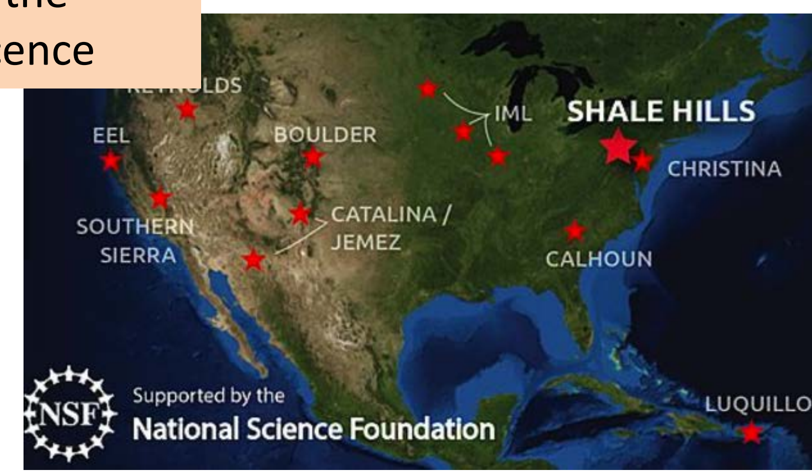
Projecting the Anthropocence



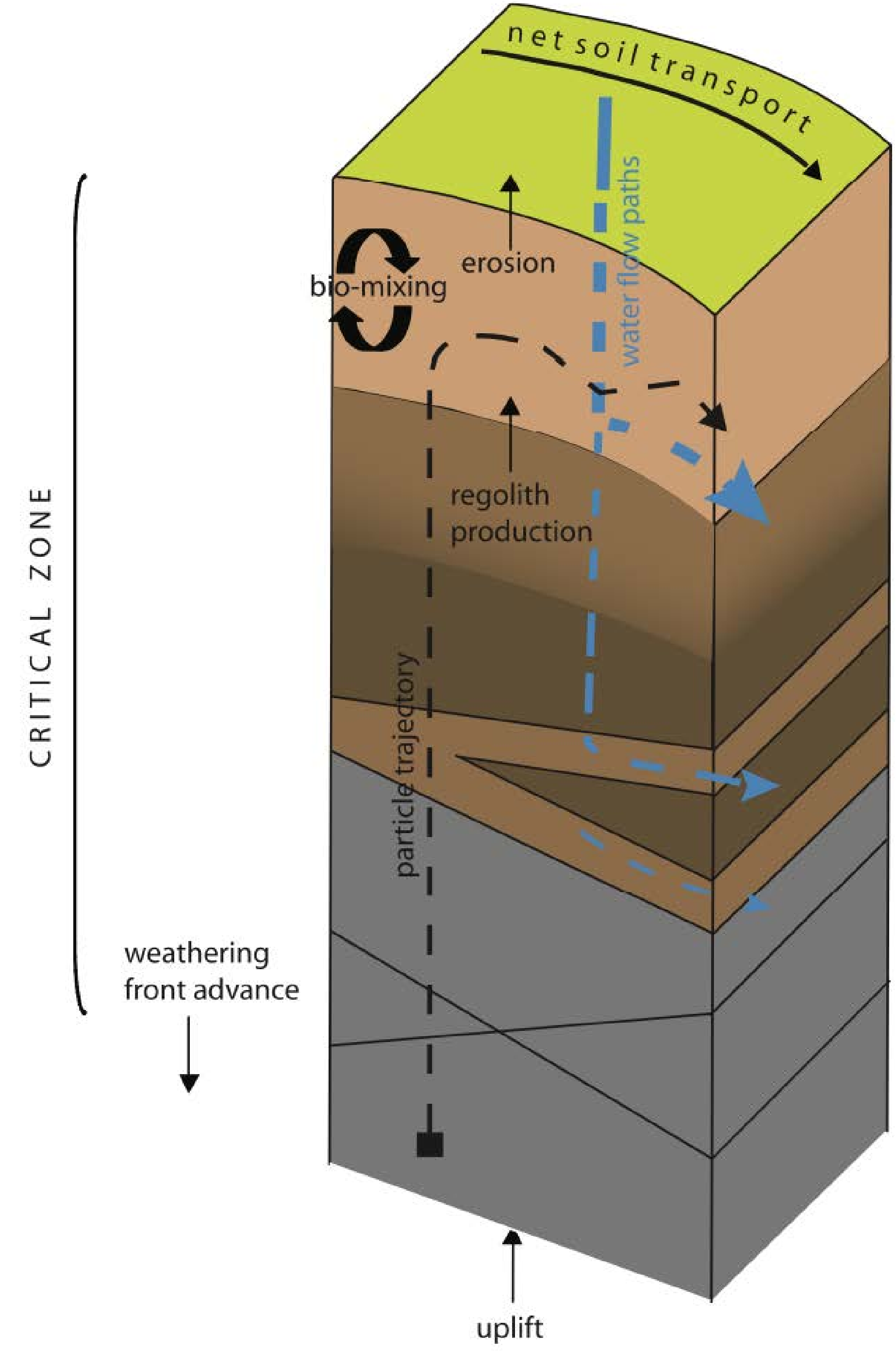
Our hypothesis: To project CZ evolution into the future requires knowledge of geological history, observations of CZ processes today, and scenarios of human activities tomorrow.



Lidar-derived shaded relief

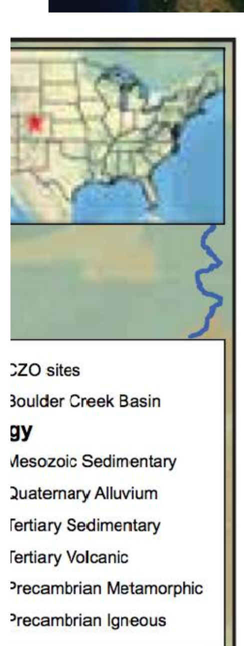


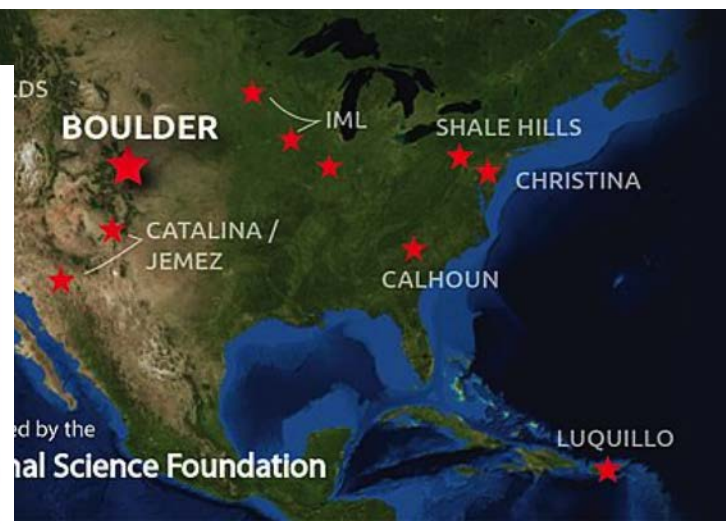
Lead PI: Sue Brantley, Penn State



The Boulder Creek CZO

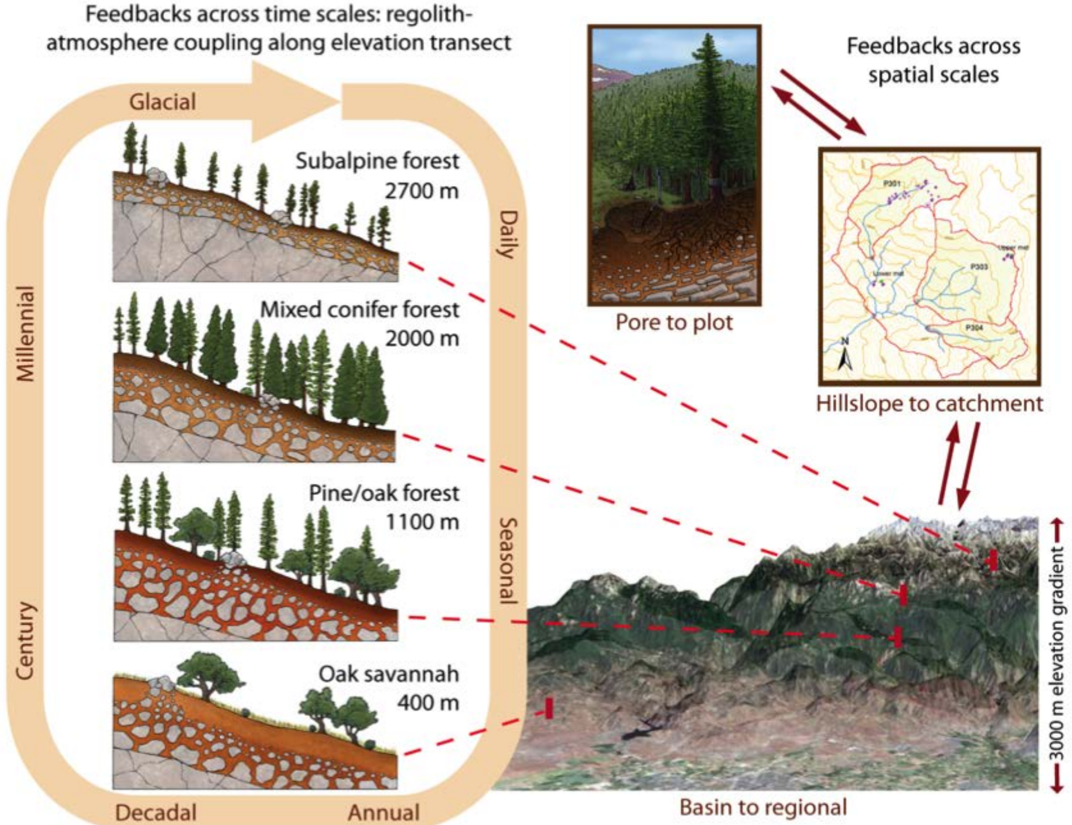
BcCZO aims to understand how CZ architecture evolves over time, how it conditions hydrologic and biogeochemical response and ecosystem structure, and how it will respond to future changes in climate. We document critical zone architecture, and study denudation processes, weathering front advance, and hydro-biogeochemical coupling.



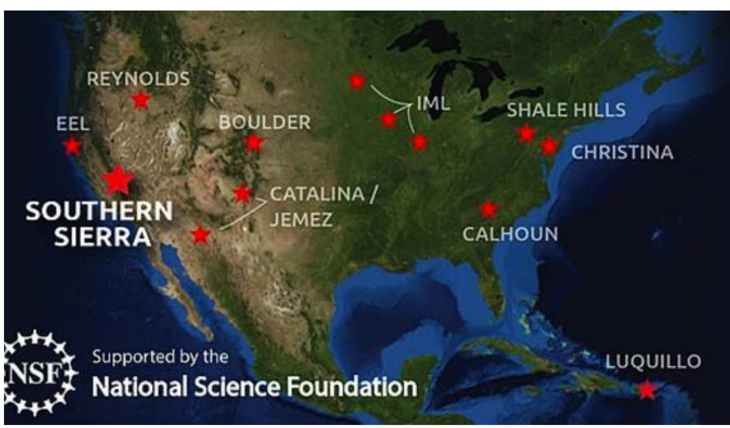


Lead PI: Suzanne Anderson,
University of Colorado

The Southern Sierra CZO

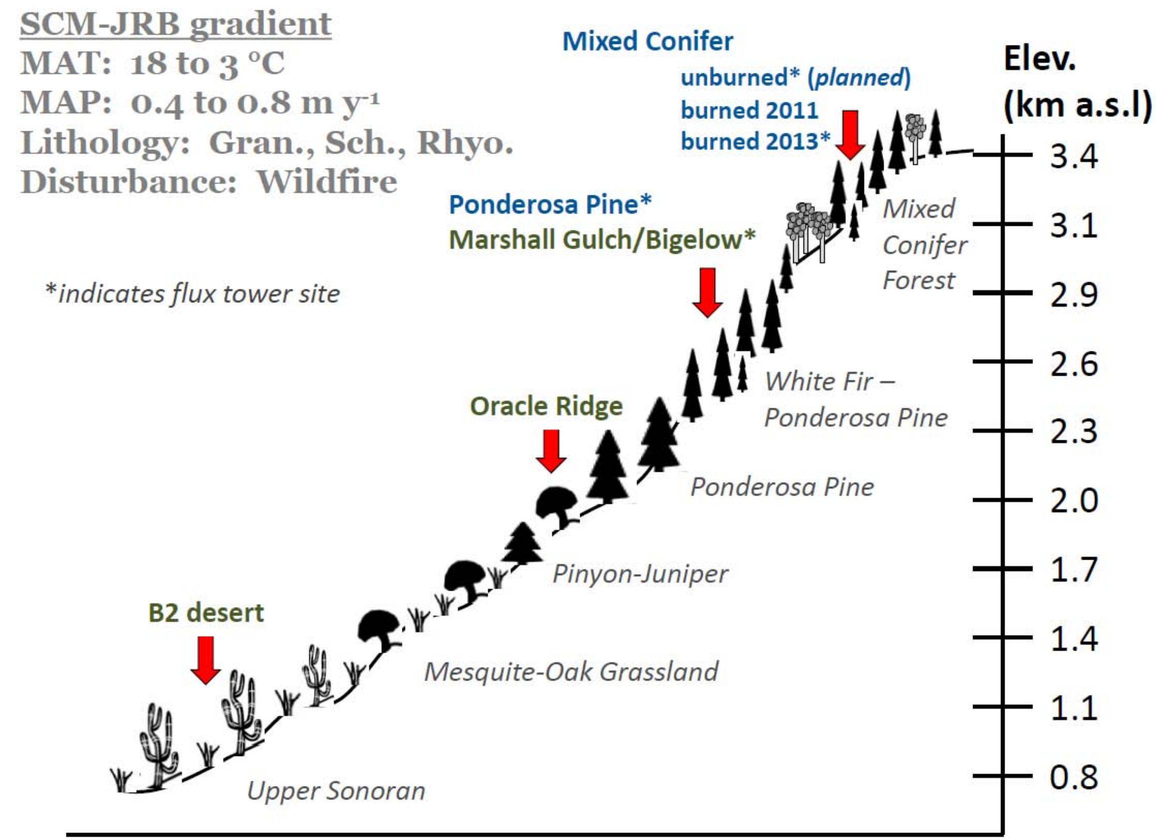


Key hypothesis: To predict how water budgets and vegetation will respond to climate warming, land management and disturbance, it is crucial to understand how vegetation, long-term climate and parent material jointly regulate the co-evolution of regolith properties and ecosystem structure and function

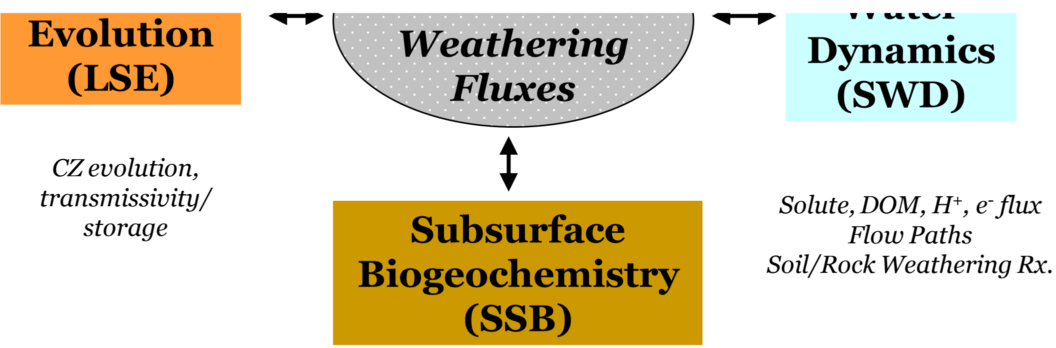


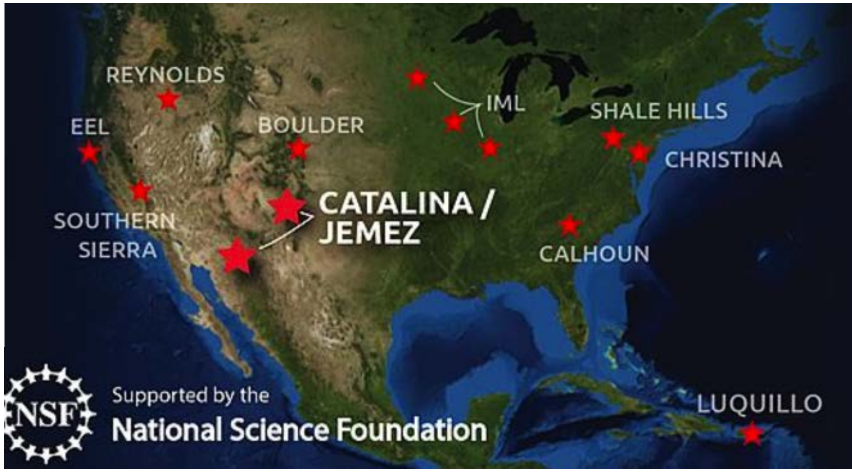
Lead PI: Roger Bales, UC Merced

The Santa Catalina Mountains and Jemez River Basin CZO



Key question: How does variability in climate, lithology and disturbance influence CZ structure and function over both short (*e.g., hydrologic event*) **and long** (e.g., *landscape evolution*) **time scales?**



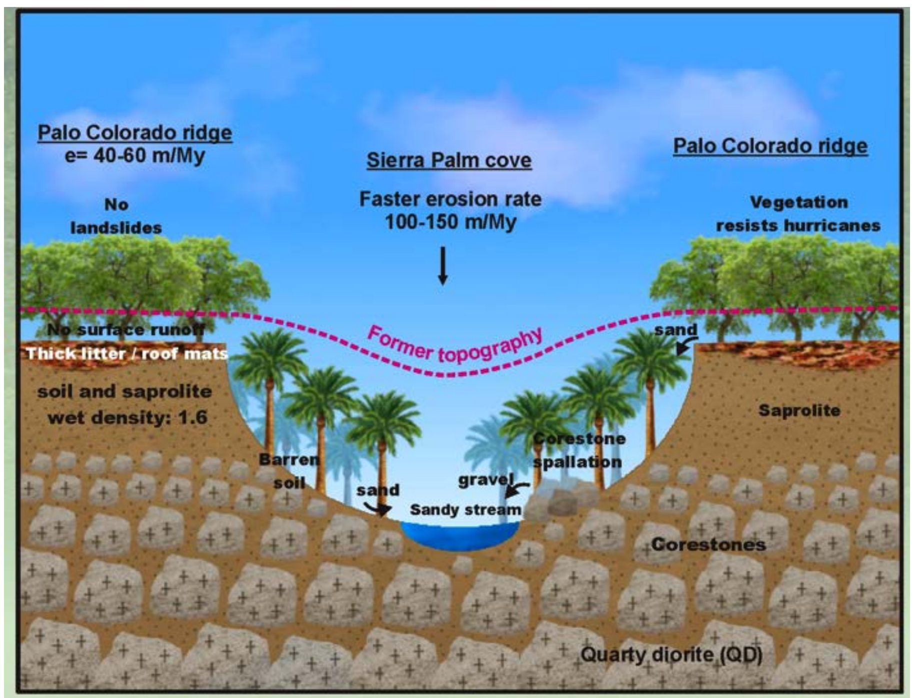


Lead PI: Jon Chorover, University of Arizona

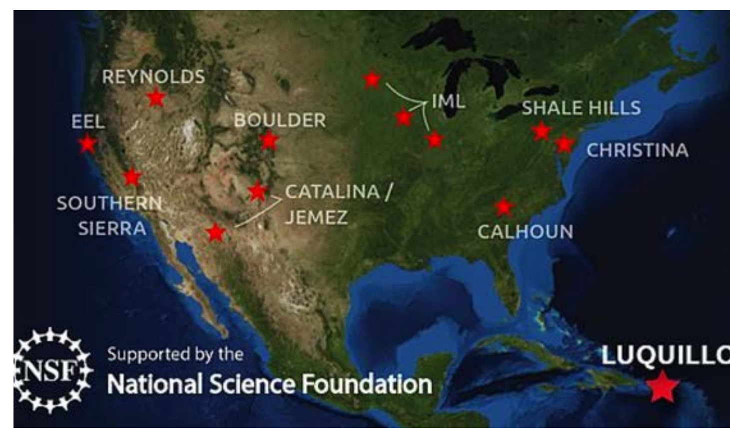
The Luquillo CZO

Key Question: Do specific locations or time periods of significant activity disproportionately impact the *weathering, biogeochemical cycling, hydrologic processes, and atmospheric inputs that drive landscape evolution and CZ function in a humid tropical forest?*

1) knickpoints and landscape position influence the weathering, soil development, and biogeochemical cycling, 2) local and intense redox fluctuations and mineral weathering influence on C and nutrient retention and loss, 3) local sediment production to streams and peak flow events influence transport of sediment, C, and nutrients, 4) scaling up and local and short-lived events in climate and hydrologic models



j. Willengbring, 2014



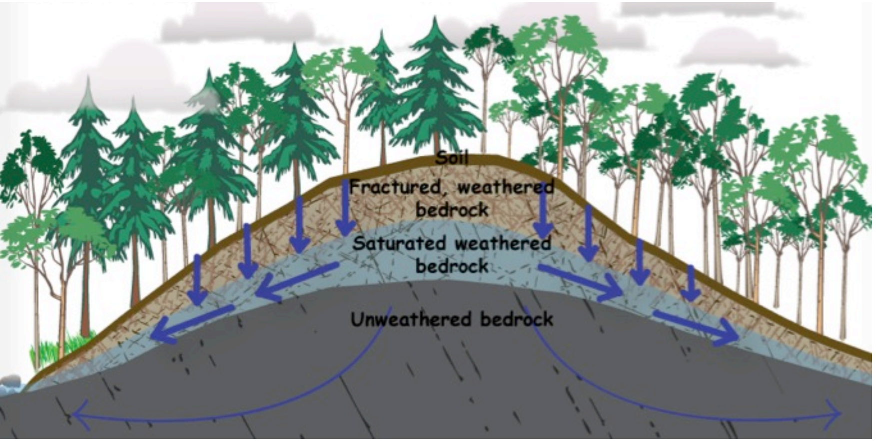
Representative PI: Whendee Silver, UC Berkeley

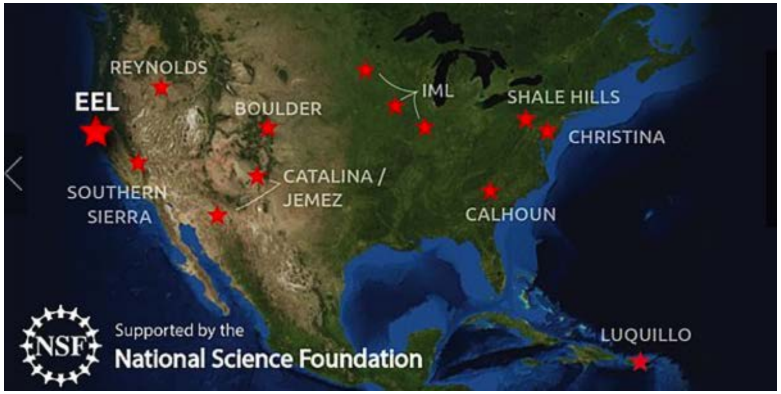
The Eel River CZO

Key Questions:

- Does lithology control rock moisture availability to plants and therefore overall resilience of vegetation to climate change in seasonally dry environments?
- How are solute and gas effluents from hillslopes influenced by biota in changing moisture regimes?
- What controls the spatial extent of wetted channels in the channel networks of seasonally dry environments?
- Will changes in critical zone currencies induced by climate or land use change lead to threshold-type switches in river and coastal ecosystems

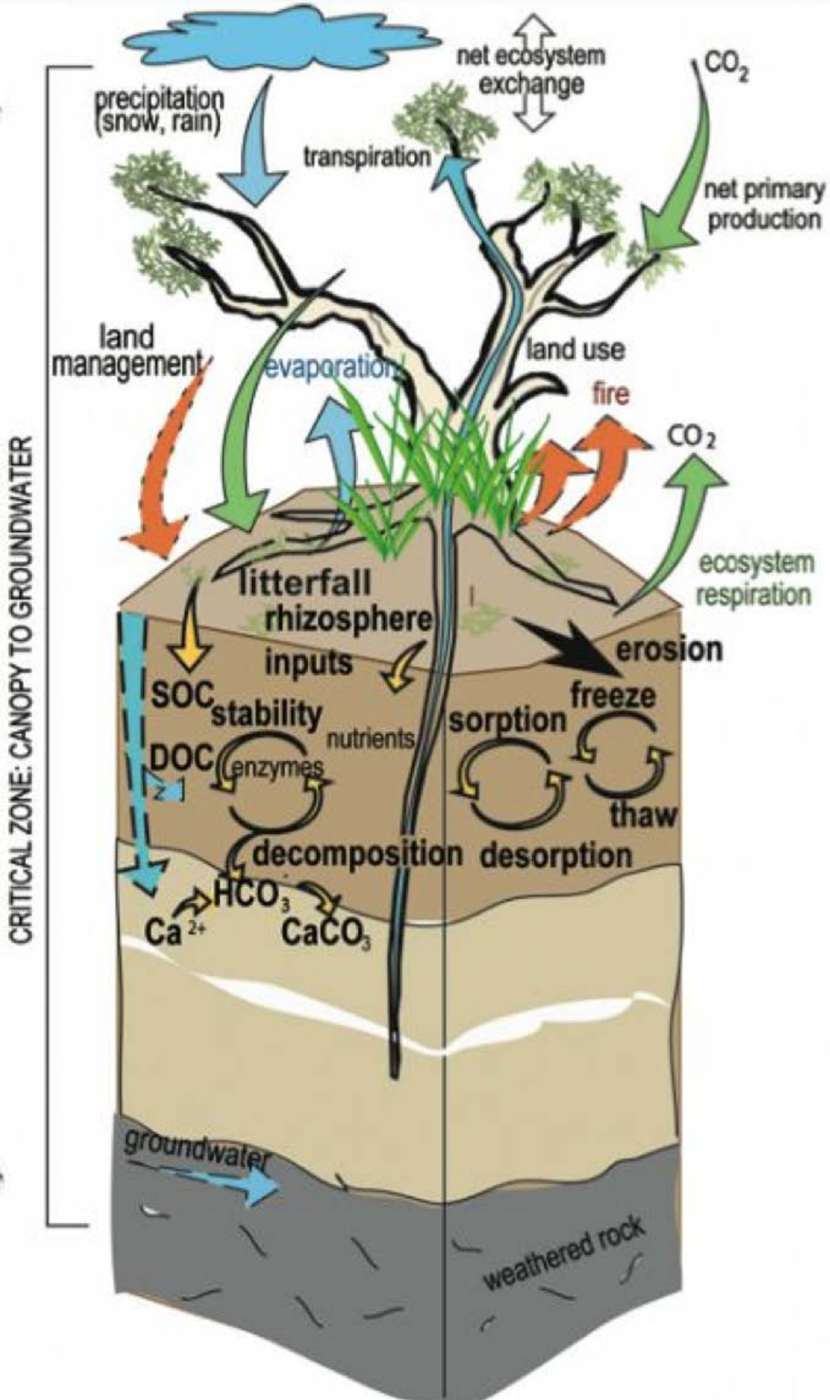
Through intensive field monitoring in the critical zone the ERCZO will follow the watershed currencies - *water, solutes, gases, sediment, biota, energy and momentum* - through a subsurface physical environment and microbial ecosystem into the terrestrial ecosystem, up into the atmosphere, and out through diverse drainage channel networks in which aquatic ecosystems interact with these currencies, mediating the delivery of nutrients to coastal ecosystems at the river mouth



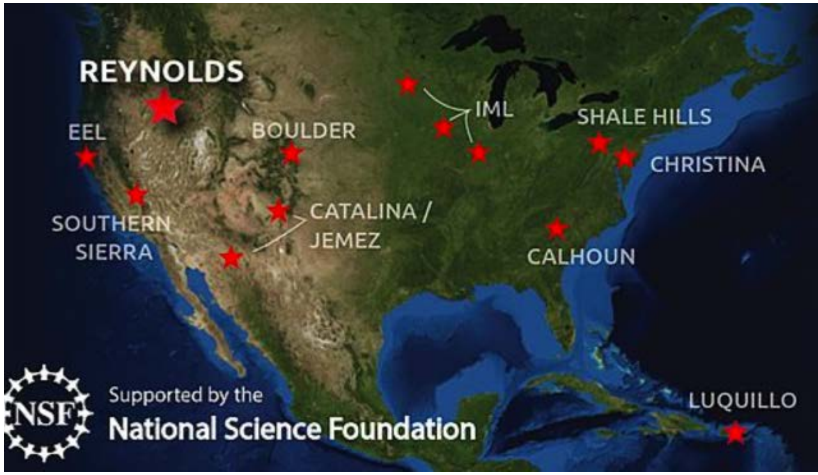


Lead PI: William E. Dietrich, UC Berkeley

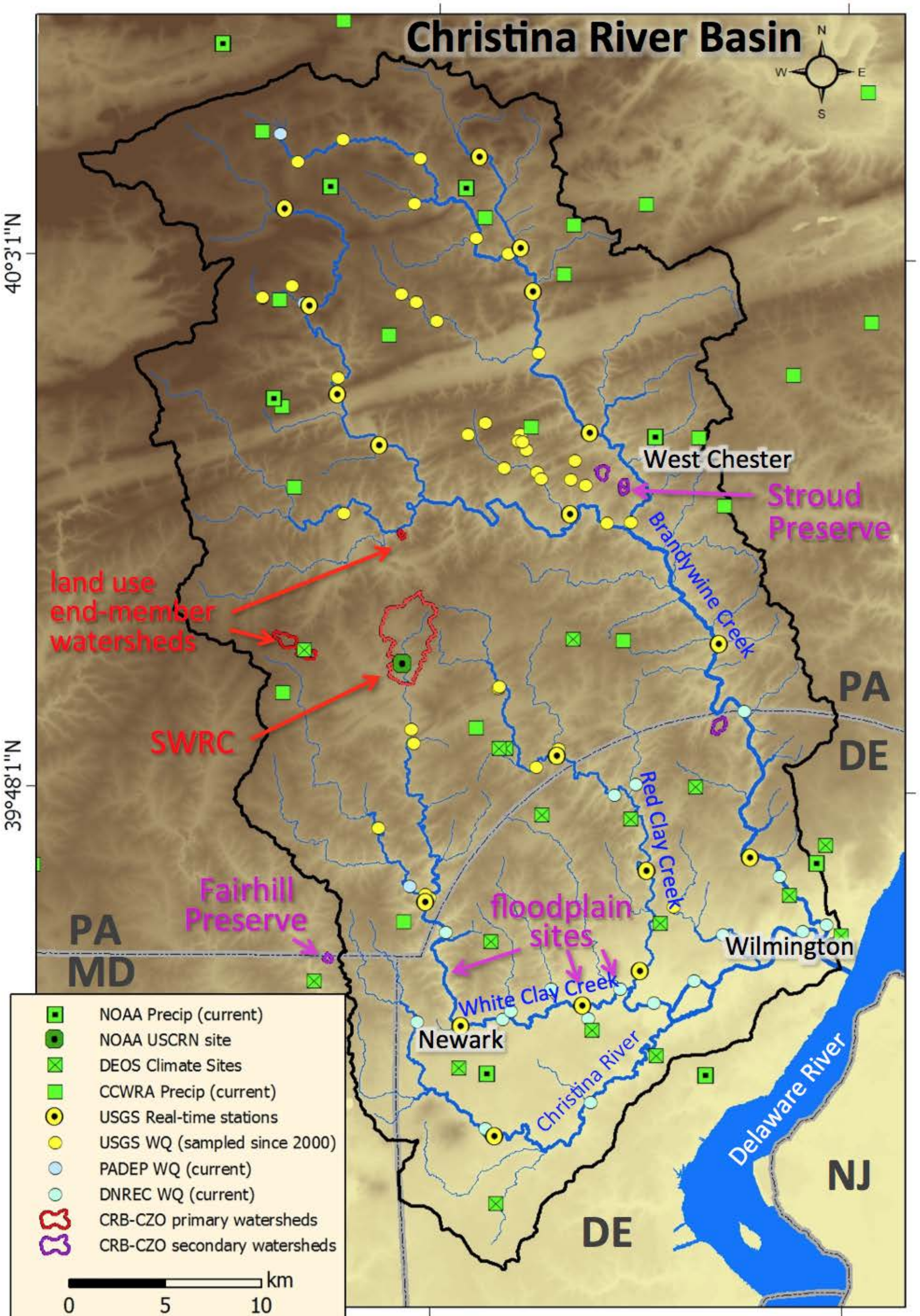
The Reynolds Creek CZO



Key hypothesis: soil environmental variables (e.g. soil water content, soil temperature, net water flux) measured and modeled at the pedon and watershed scale will improve our understanding and prediction of soil carbon storage, flux, and processes.



Lead PI: Kathleen Lohse, Idaho State

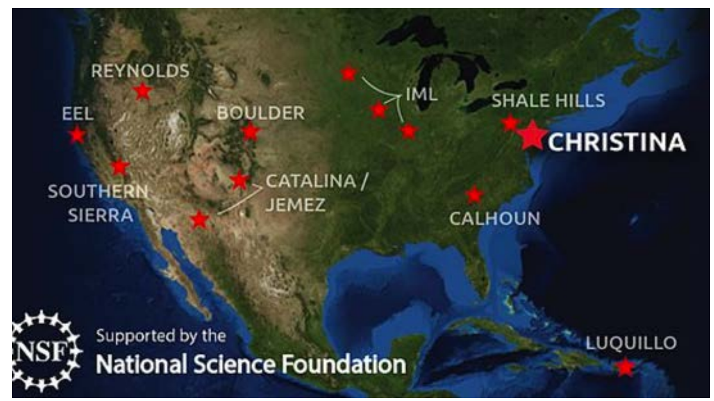


The Cristina River Basin CZO

Hypotheses:

1) Hydrological, chemical, & biological processes that produce and mix mineral surfaces and organic carbon are rate limiting to watershed-scale chemical weathering, soil production & carbon sequestration.

2) Humans accelerate rates of carbon-mineral mixing, resulting in anthropogenic carbon sequestration significant to local, regional & global budgets



Lead PI: Anthony Aufdenkampe, University of Delaware

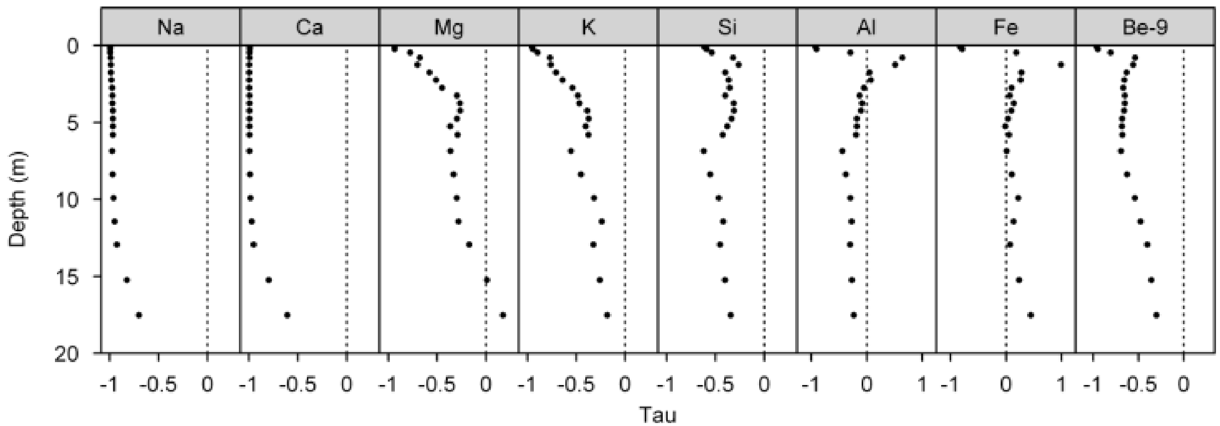
The Calhoun CZO

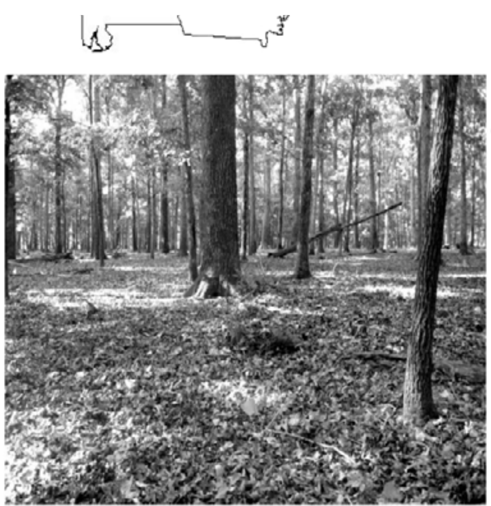
1948

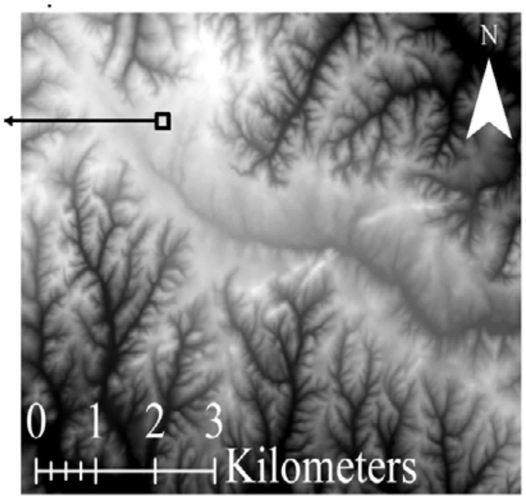
2006

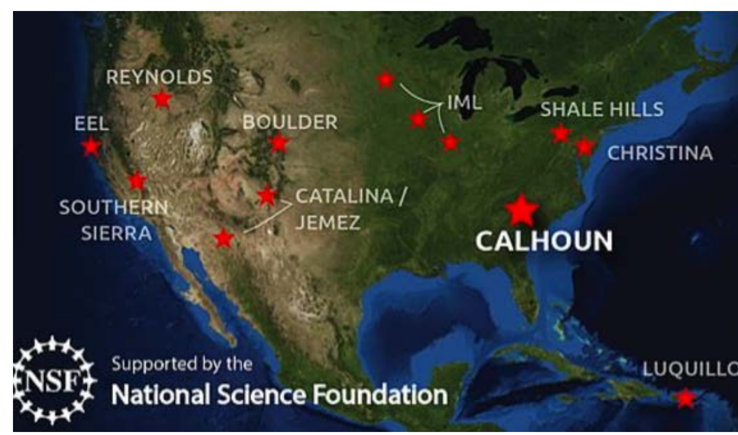
The Calhoun CZO seeks to understand how Earth's Critical Zones (CZ) respond to severe soil erosion and land degradation.

Key hypothesis: the impressive reforestation masks fundamental alterations in CZ hydrology, geomorphology, biology, and biogeochemistry and that post-disturbance CZ evolution may not so much recover as restabilize in altered states.







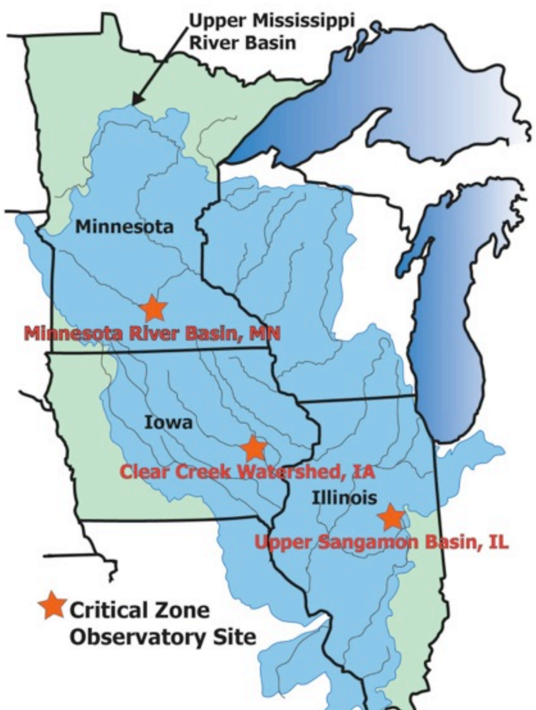


Critical Zone Observatory for Intensively Managed Landscapes (IML-CZO)

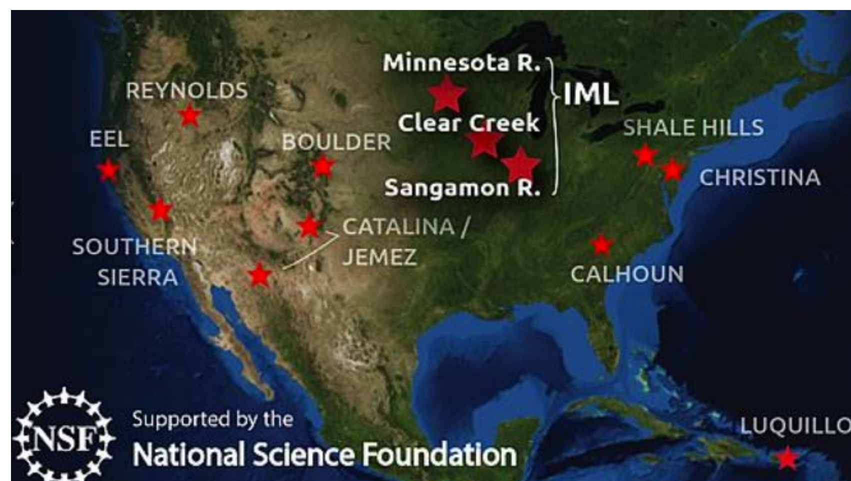
Key Hypothesis: Critical zone of IMLs has passed a tipping point resulting from human modification, and has gradually shifted from being a *transformer* with high nutrient, water, and sediment storage to being a *transporter* with low nutrient, water and sediment storage.

- System is in dis-equilibrium and maintained so due to anthropogenic activities
- Driven by event dynamics rather than seasonal/annual averages

A central research focus is the scaling up of process understanding from the plot, to the hillslope, to small basin and, ultimately, to the large watershed.



Influence of glaciation on CZ development and future states



Lead PI: Praveen Kumar, University of Illinois

Shared conceptual framework that motivates questions

1. The critical zone evolves a structure that influences the storage and flux of water, solutes, sediments, gases, biota and energy.

2. By mediating these stores and fluxes, the critical zone provides ecosystem services, and is thus critical to people.

Here "structure" generally refers to material properties of the critical zone, including vertical and lateral variation in porosity, permeability, fracture characteristics, water retention, density, composition, and texture (size distribution). The critical zone also includes the vegetation mantle. The flux through and out of the critical zone connects it to the atmosphere and to the river ecosystems which receives its drainage.

"Ecosystem services" as considered in these CZOs include carbon storage, water supply, nutrients, vegetation growth, and functional forest and river ecosystems.

Three general shared questions:

1. What controls critical zone properties and processes?

2. What will be the response of the critical zone structure, and its stores and fluxes, to climate and land use change?

3. How can improved understanding of the critical zone be used to enhance ecosystem services?

Intensive field measurements at the observatories will provide the data to guide process understanding to develop models that explain critical zone evolution, to forecast possible future states, and to guide land use decisions. All of the CZO's have modeling components, though a wide range of approaches is used.

We have identified about ~21 sub-questions being investigated at multiple CZO's!

Four example questions are:

How does the critical zone development depend on lithology?

How does hillslope aspect, as it influences local climate, affect critical zone evolution and structure?

How do biota influence solutes and gas fluxes from the critical zone?

How will critical zone processes mediate the effects of climate change on water resources?

Models under development include:

1) Mechanistic representation of fracture flow and rock moisture dynamics in hydrologic models
2) Linking vegetation species composition to critical zone properties
3) Linking the critical zone to atmospheric processes
4) Linking water runoff from the critical zone to flow in rivers
5) Reactive transport modeling and critical zone development
6) Landscape evolution modeling, including effects of critical zone development

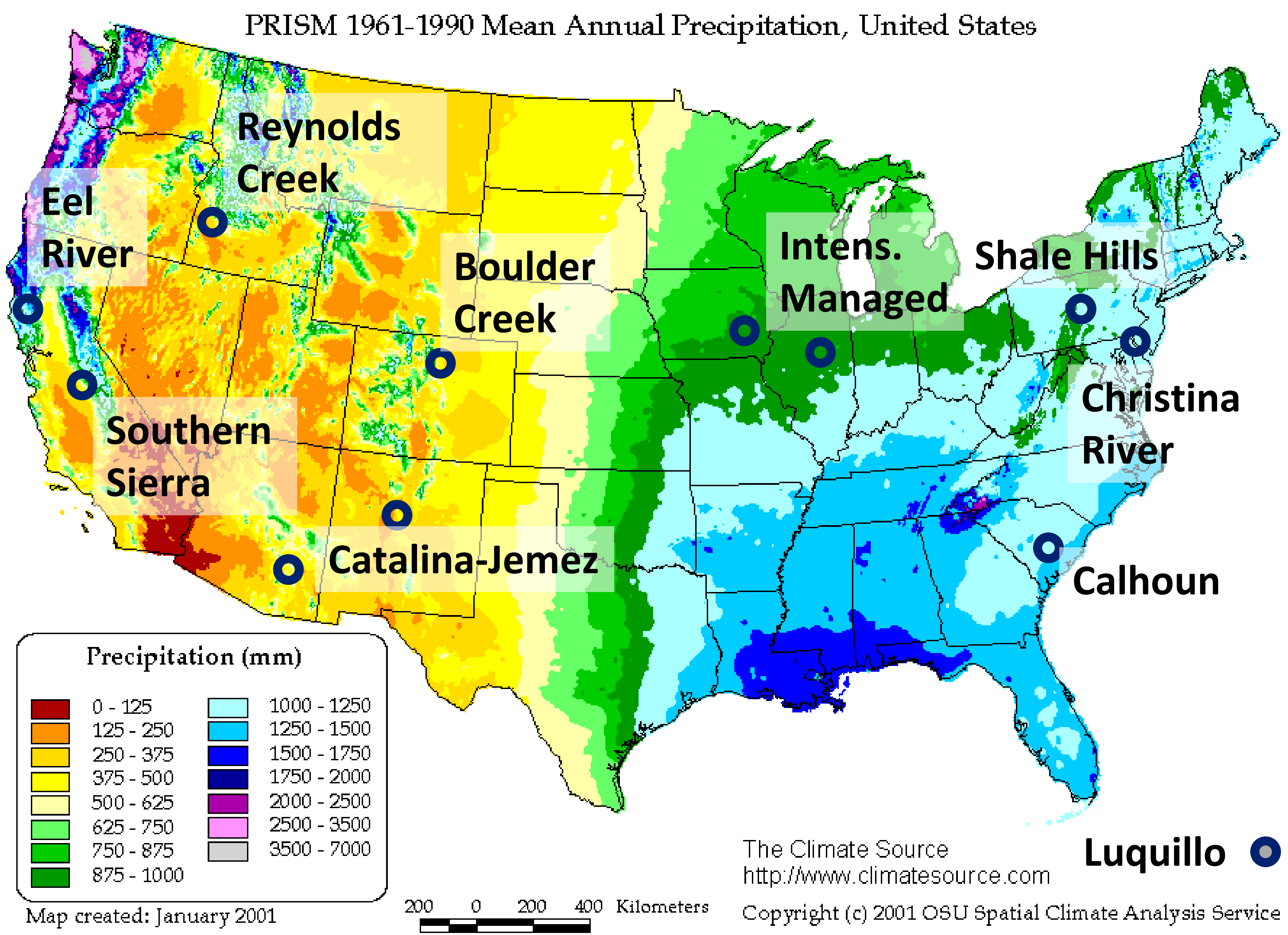
The CZO's identified emergent themes from the common questions that are leading to across CZO working groups, topics include:

a. Critical zone (CZ) properties and processes *: depth to fresh bedrock*
b. Modeling climate and fluxes in the CZ
c. CZ controls on solute concentration - river discharge relationships
d. CZ control on water available to plants
e. Organic matter in the critical zone
f. Biogeochemical processes in the CZ
g. Iron mobilization and precipitation in the CZ
h. The use of isotopes to track processes and rates in the CZ
i. Ecosystem services provided by the CZ
j. International CZOs

Context for common measurements

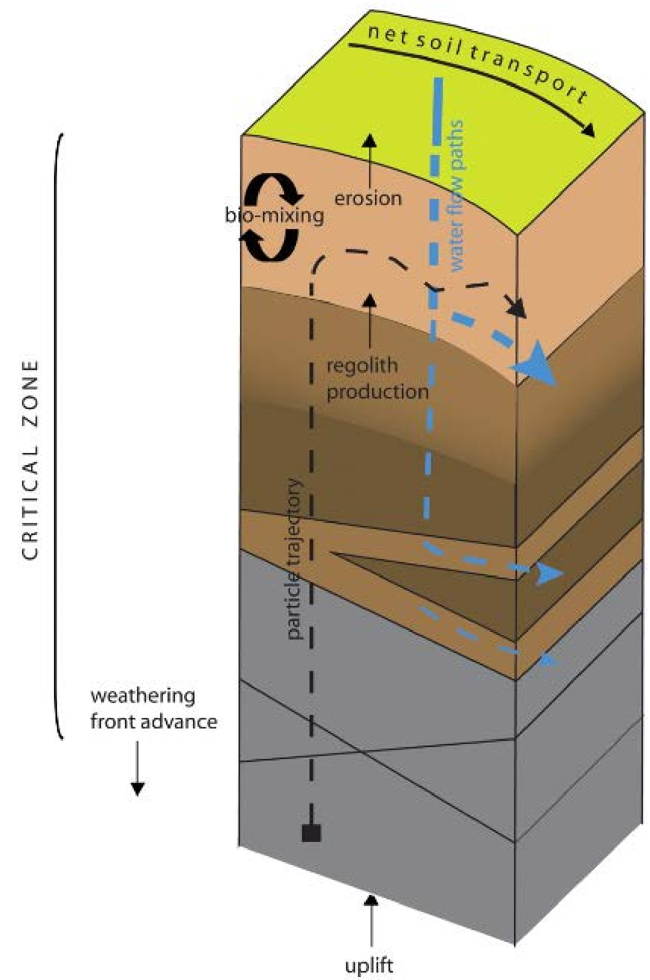
- Each CZO proposal has unique hypotheses and experimental designs.
- But an overarching goal of the CZO network is for the whole to be greater than the sum of its parts.
- Several mechanisms to achieve this including X-CZO questions, working groups, campaigns, modeling.
- Another is through a subset of “Common Measurements”

  → **Enable testing of (new) hypotheses across a wider climate, lithology, age parameter space than possible in one CZO.**


PRISM 1961-1990 Mean Annual Precipitation, United States
Reynolds Creek
Eel River
Boulder Creek
Intens. Managed
Shale Hills
Christina River
Southern Sierra
Catalina-Jemez
Calhoun
Luquillo
Precipitation (mm)
0 - 125
125 - 250
250 - 375
375 - 500
500 - 625
625 - 750
750 - 875
875 - 1000
1000 - 1250
1250 - 1500
1500 - 1750
1750 - 2000
2000 - 2500
2500 - 3500
3500 - 7000
Map created: January 2001
200 0 200 400 Kilometers
The Climate Source
http://www.climatesource.com
Copyright (c) 2001 OSU Spatial Climate Analysis Service

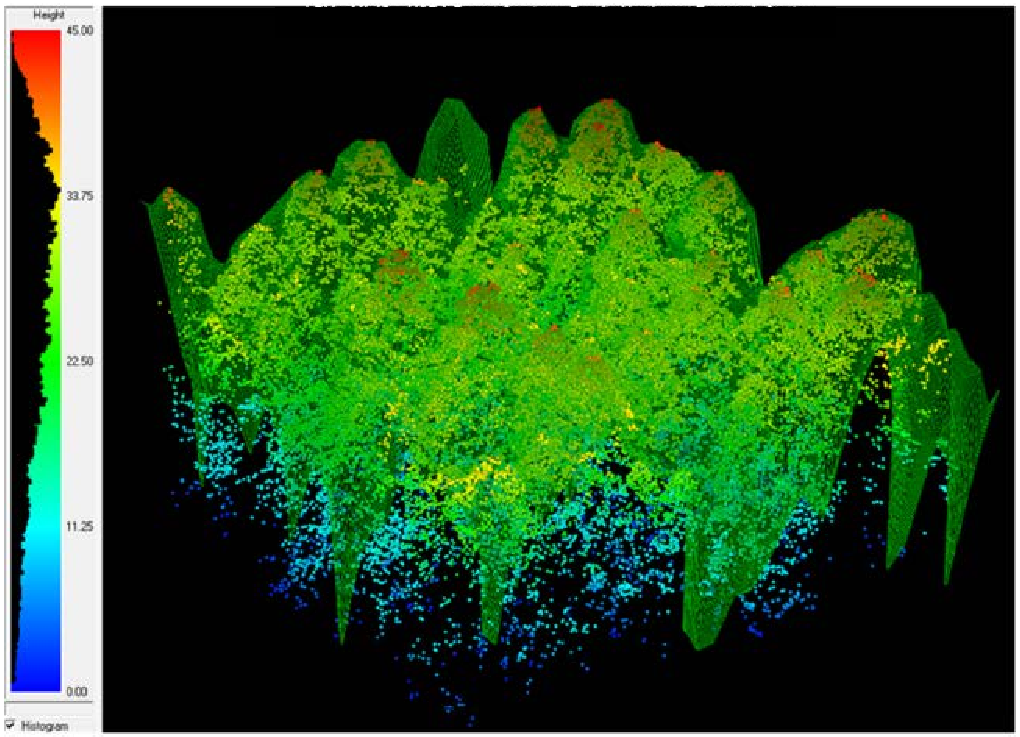
All CZOs seek to develop a common set of measurements to quantify:

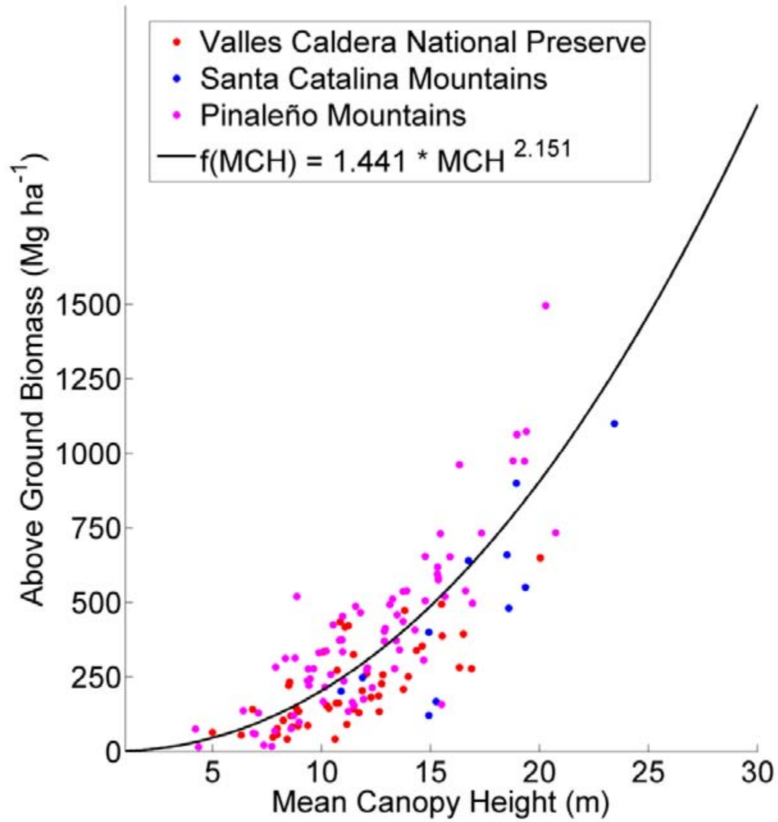
- CZ architecture
  - 3D spatial distribution of bedrock, soil, vegetation, topography
  - Chemical depletion/enrichment, microbial zonation
  - Porosity and flowpaths
- CZ dynamics
  - Event-based and continuous fluxes of energy, sediments, water, solutes, and gases across CZ interfaces
  - Changes in storage (i.e., budgets) of major reservoirs at the catchment scale
- CZ evolution
  - Regolith and drainage valley formation, bedrock fracturing, soil production, geochemical differentiation, erosion, deposition



Anderson et al. (2007)

Common approaches to surface architecture: Bare earth to canopy via LiDAR

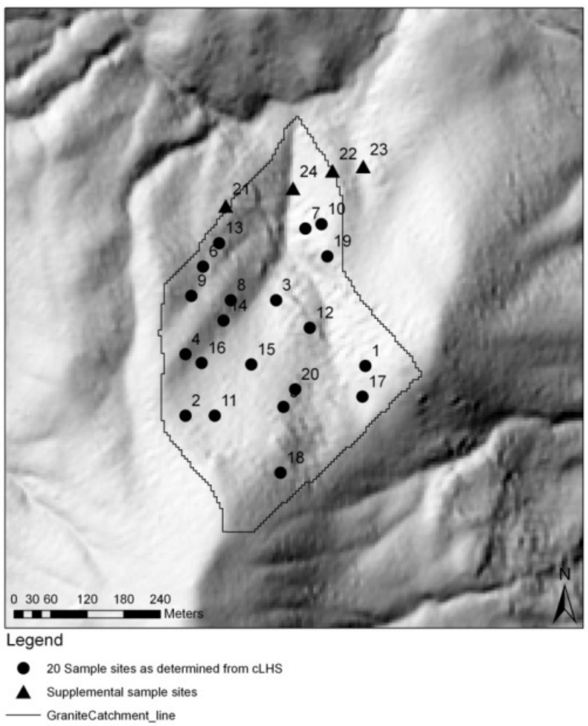


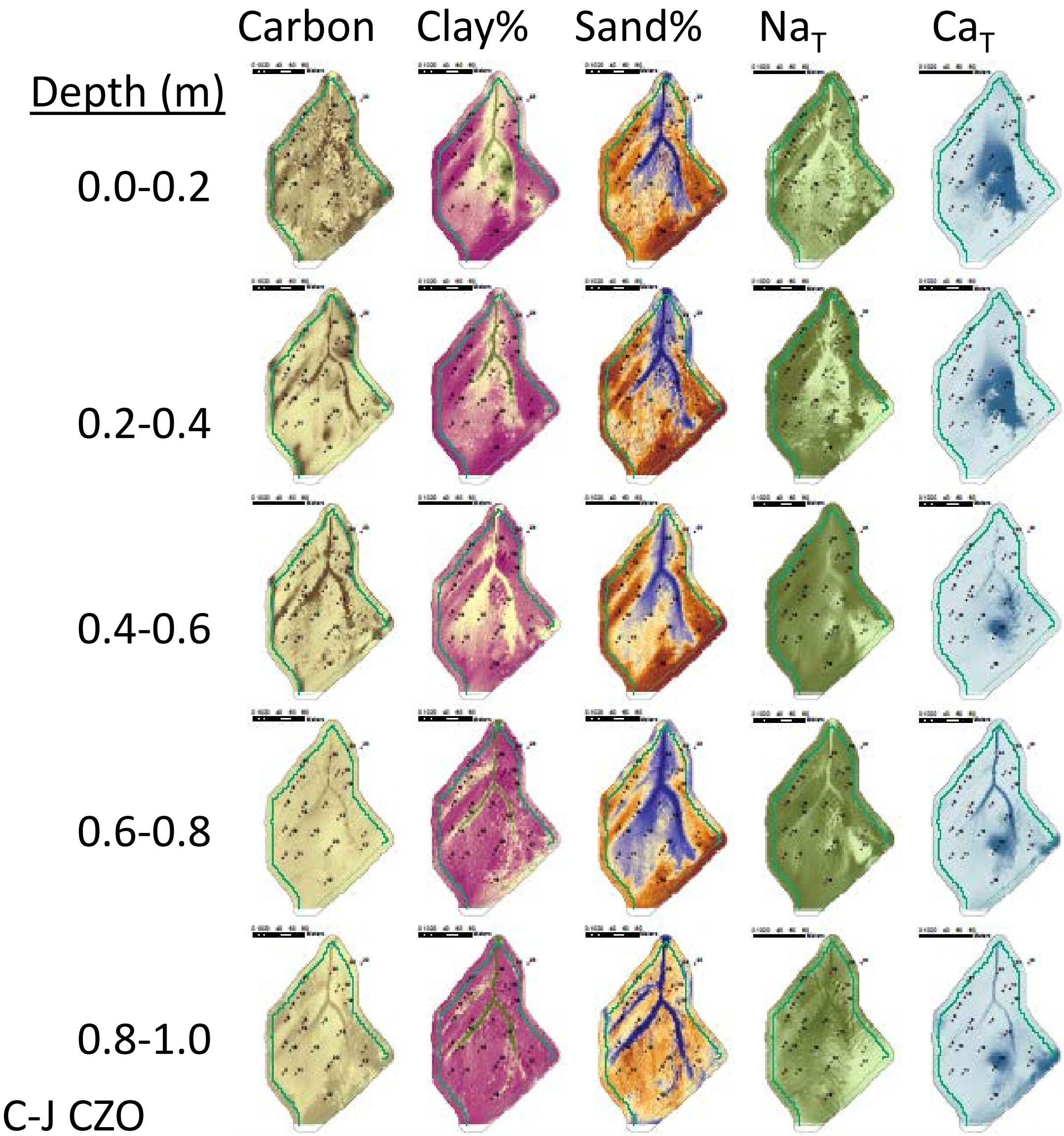


Swetnam et al., C-J CZO

Subsurface architecture: soil mapping

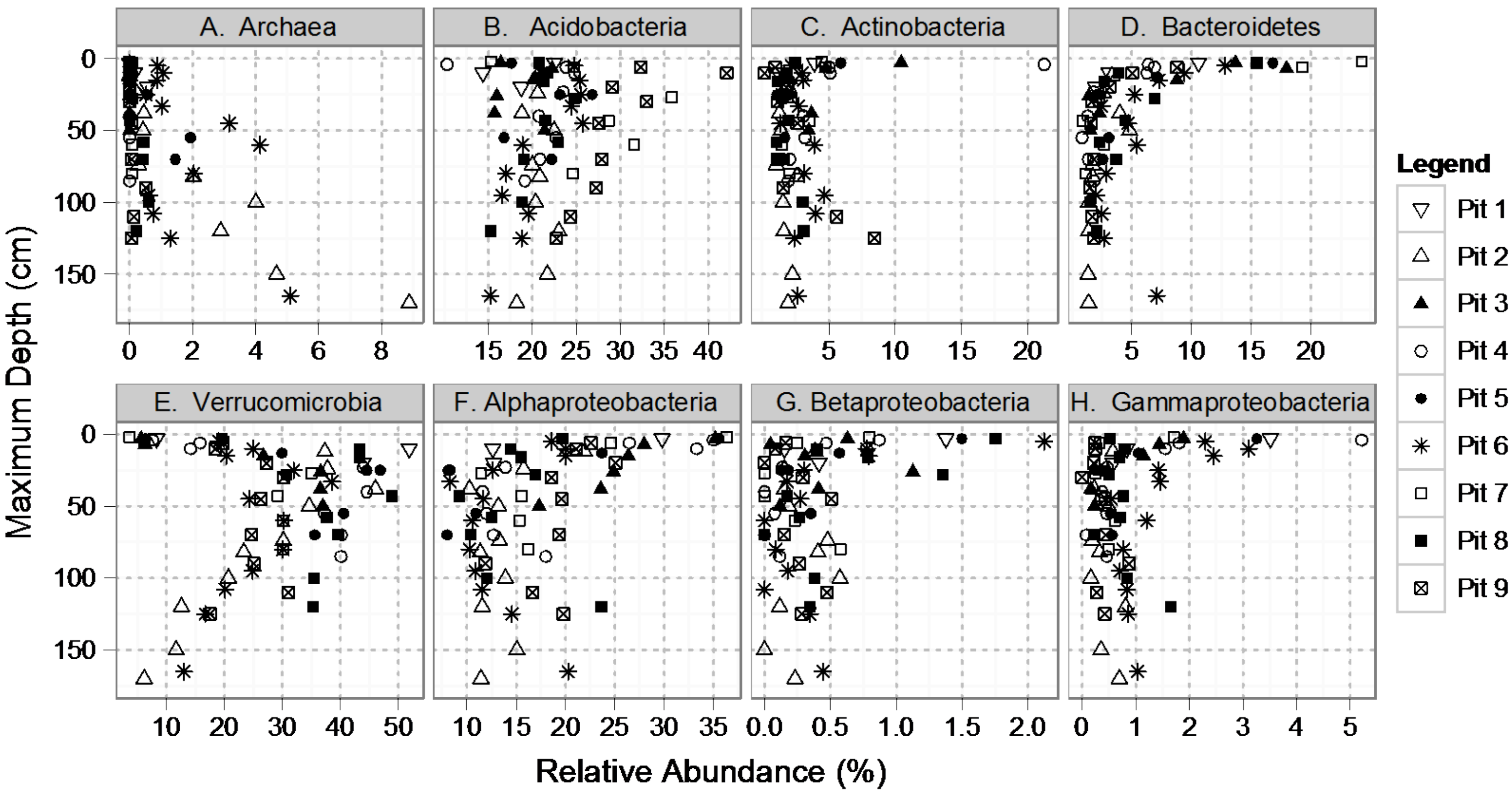
- Geospatial interpolations of solid phase characterizations





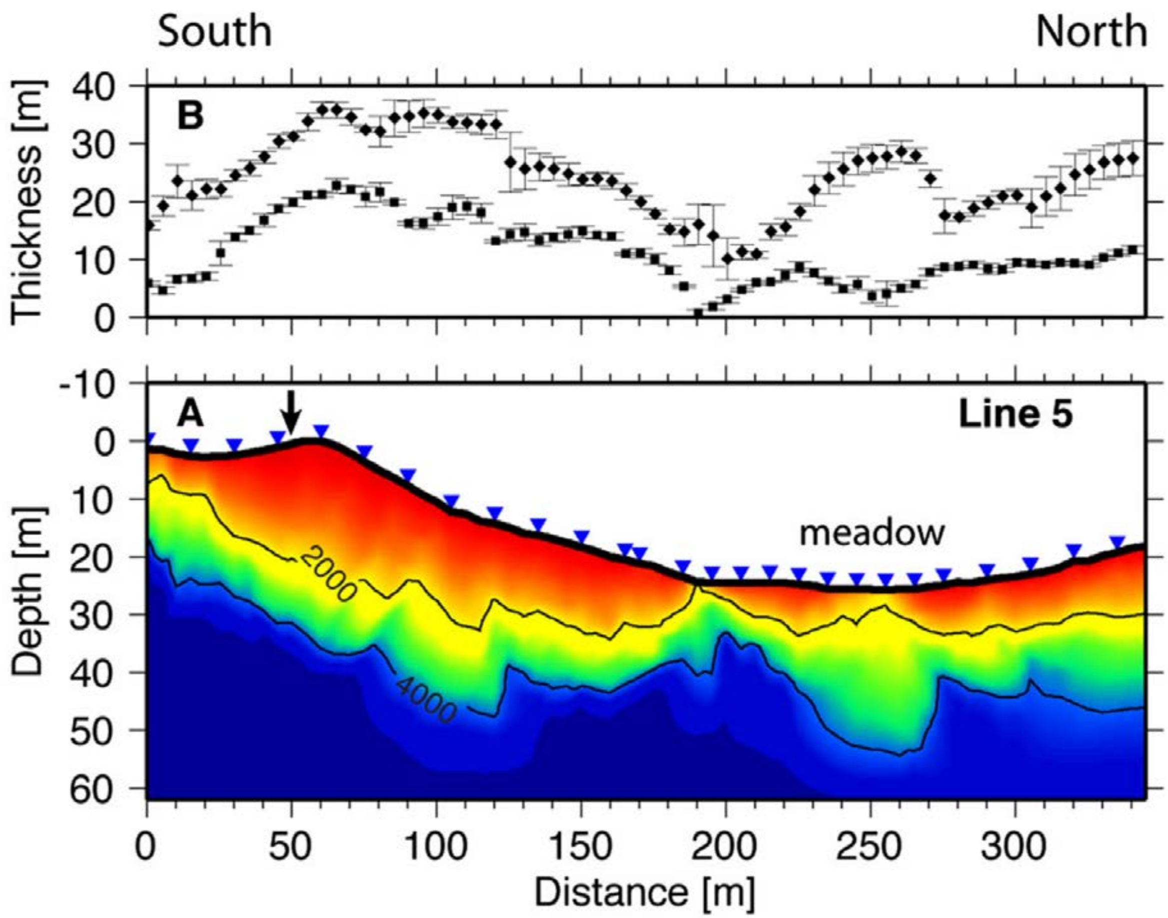
Shepard et al. C-J CZO

Subsurface architecture: Microbial diversity and abundance with depth



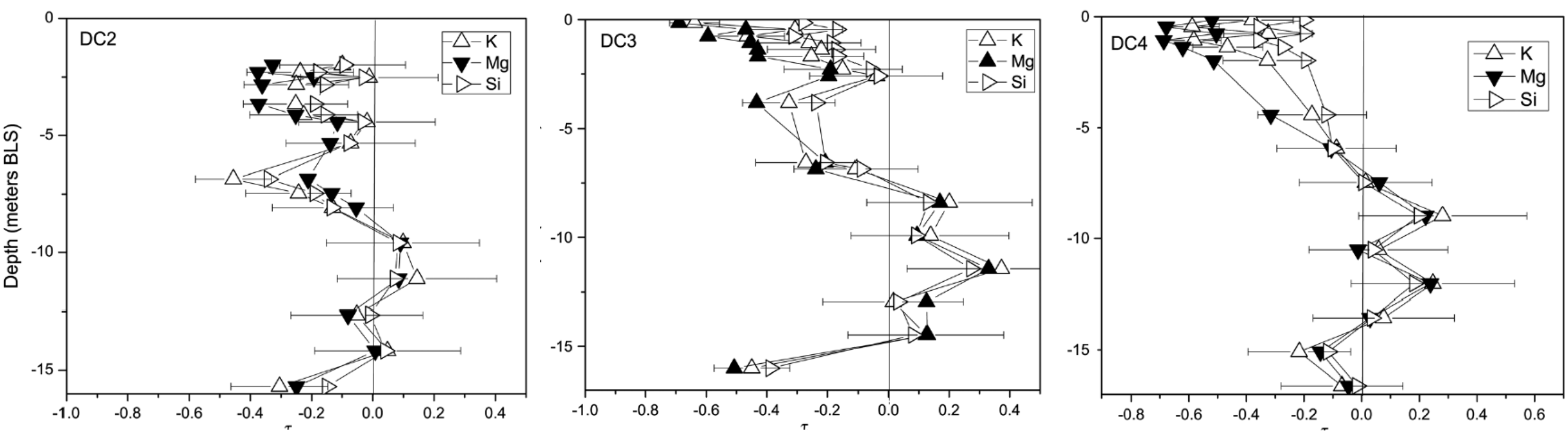
Eilers et al. BC CZO SBB 2012

Subsurface architecture
Geophysical Methods (e.g., SR, GPR, ERT)
incl. collaborations with WyCEHG



Holbrook et al. 2014 SS CZO.

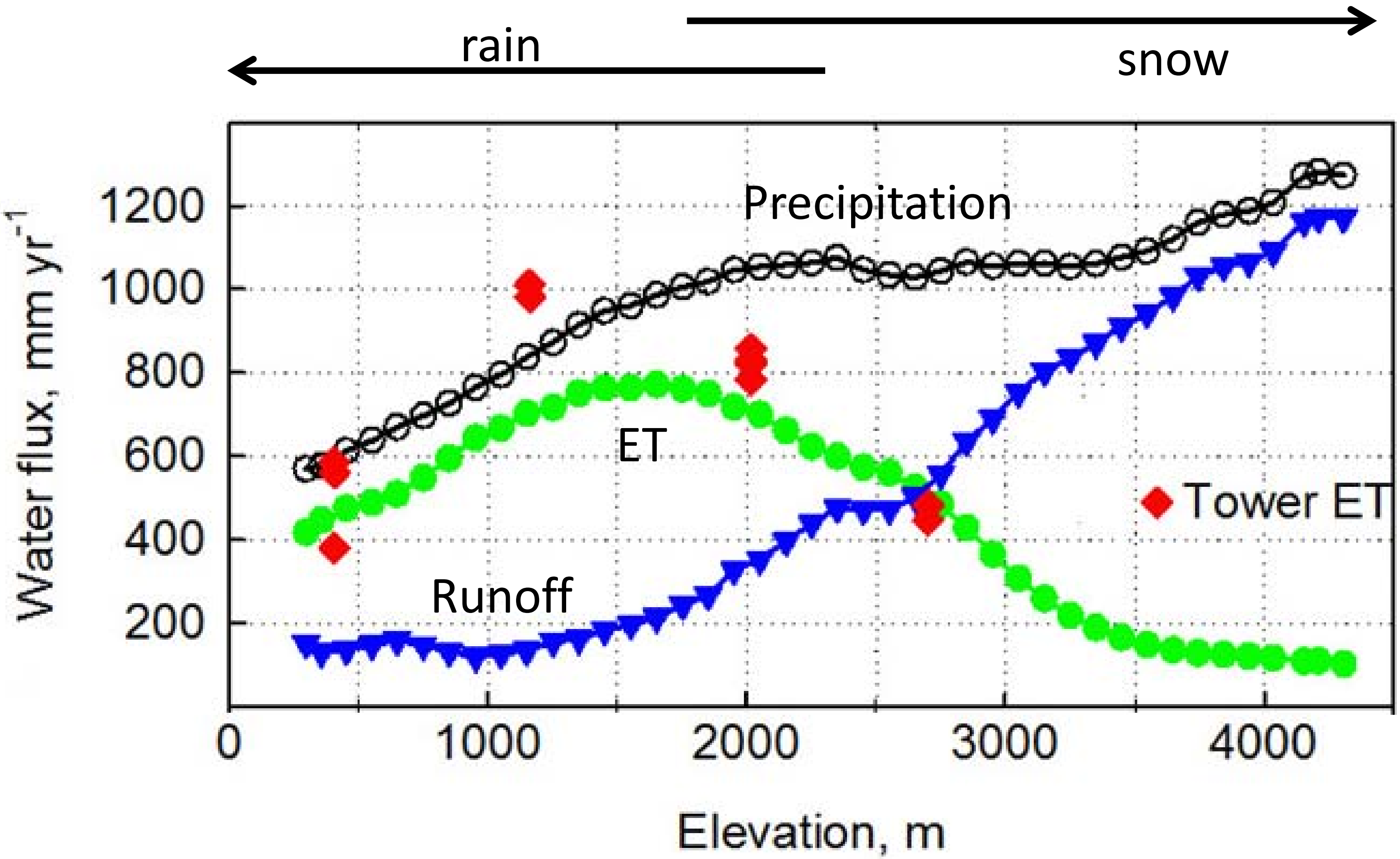
Subsurface architecture
Geochemical Methods



τ_{Zr} τ_{Zr} τ_{Zr}

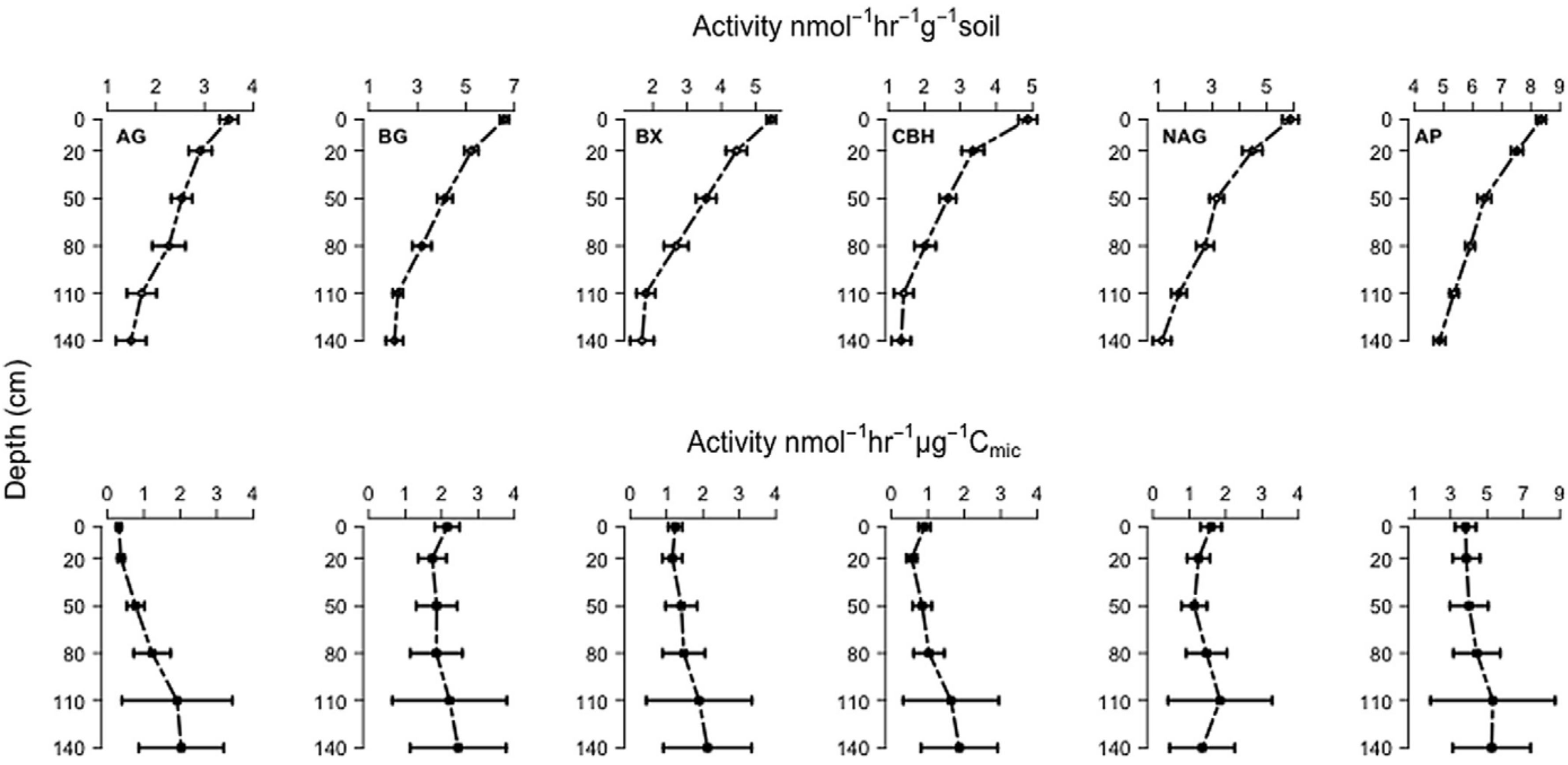
Brantley et al. 2013 EPSL, SH CZO

Dynamics: Land-Atmosphere Exchange
Water balance – Kings R. Basin



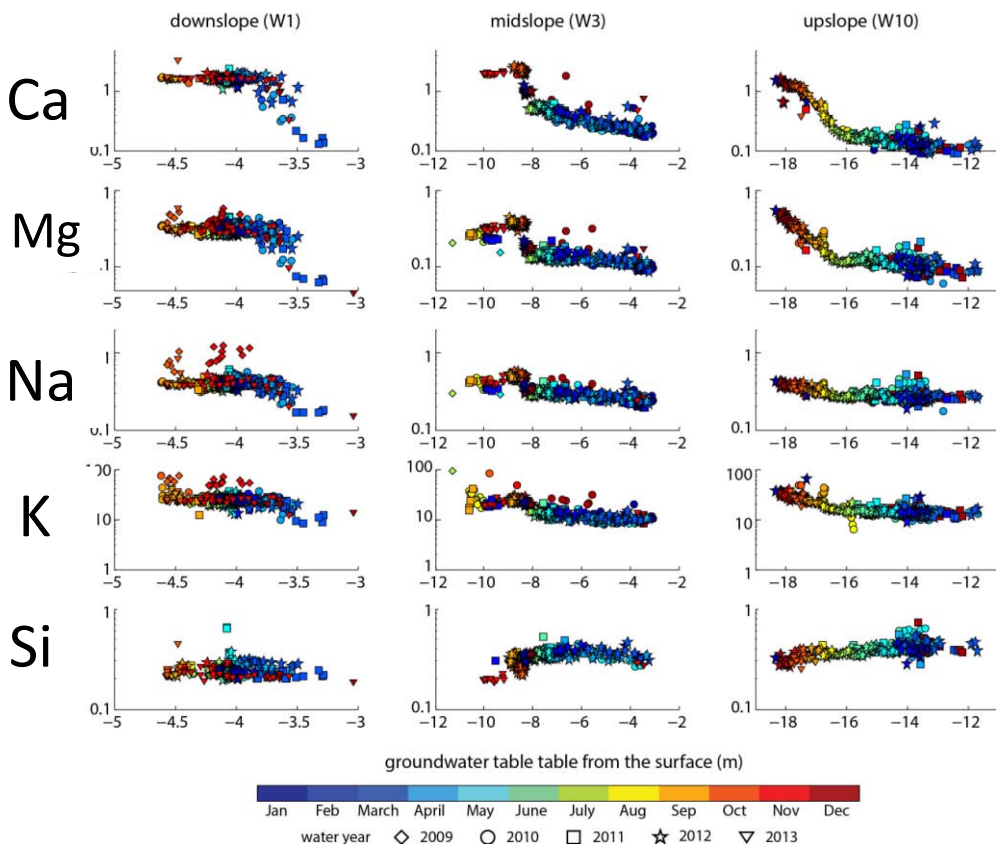
Goulden & Bales, PNAS 2014

Dynamics: Microbial activity with depth

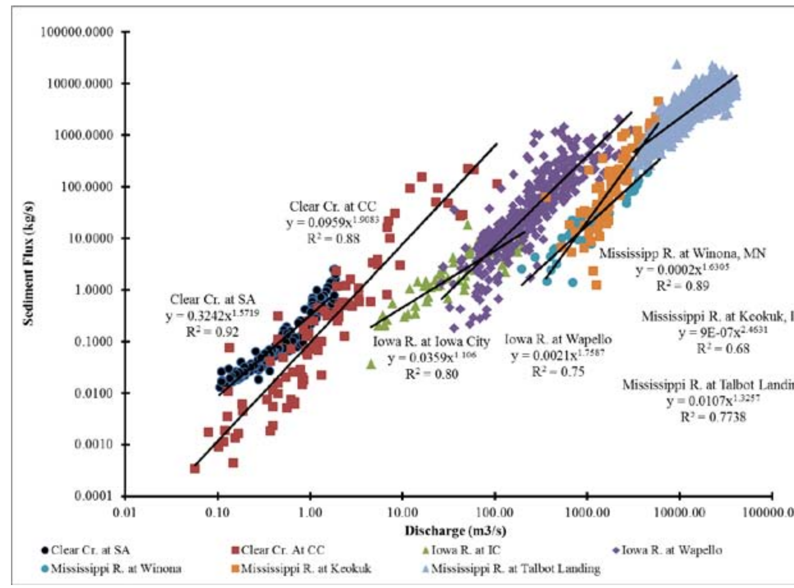


Stone et al. SBB 2014, Luquillo CZO

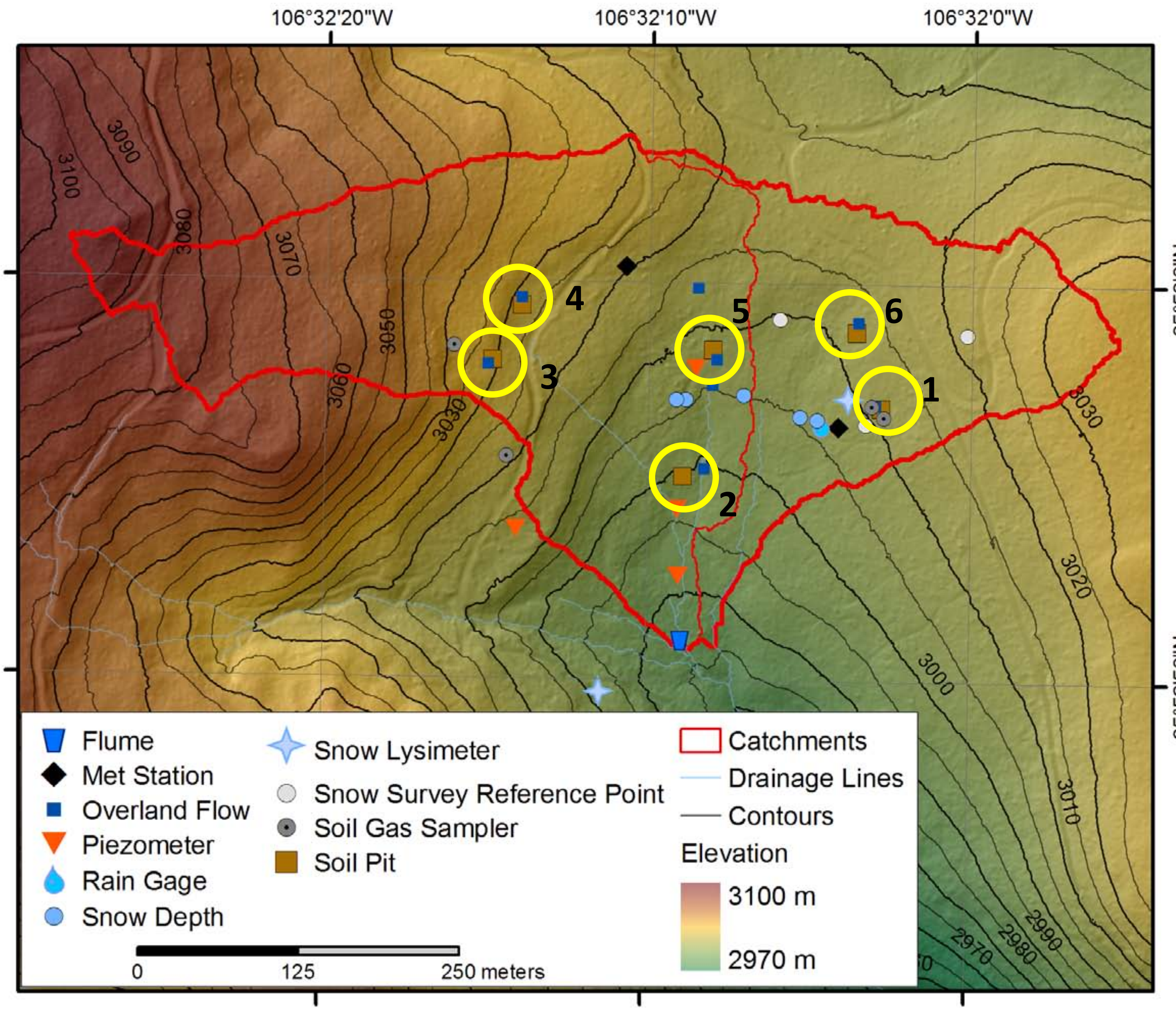
Dynamics: Aqueous Geochemistry and Sediment Transport



ER CZO



IML CZO



106°32'20"W
106°32'10"W
106°32'0"W
35°53'0"N
35°52'50"N
3100
3090
3080
3070
3060
3050
3030
3020
3010
3000
2990
2980
2970
1
2
3
4
5
6
Flume
Met Station
Overland Flow
Piezometer
Rain Gage
Snow Depth
Snow Lysimeter
Snow Survey Reference Point
Soil Gas Sampler
Soil Pit
Catchments
Drainage Lines
Contours
Elevation
3100 m
2970 m
0
125
250 meters

Further info on CZO common measurements

- Common Measurements Document available on the CZO network website
- Ongoing X-CZO collaborations on
  - LiDAR analysis
  - Geophysical methods
  - Sensor networks
  - Sample identification, handling and analysis
  - Lab exchanges and core analytical facilities for specific analyses

Common measurements of architecture and dynamics are linked through models of CZ evolution