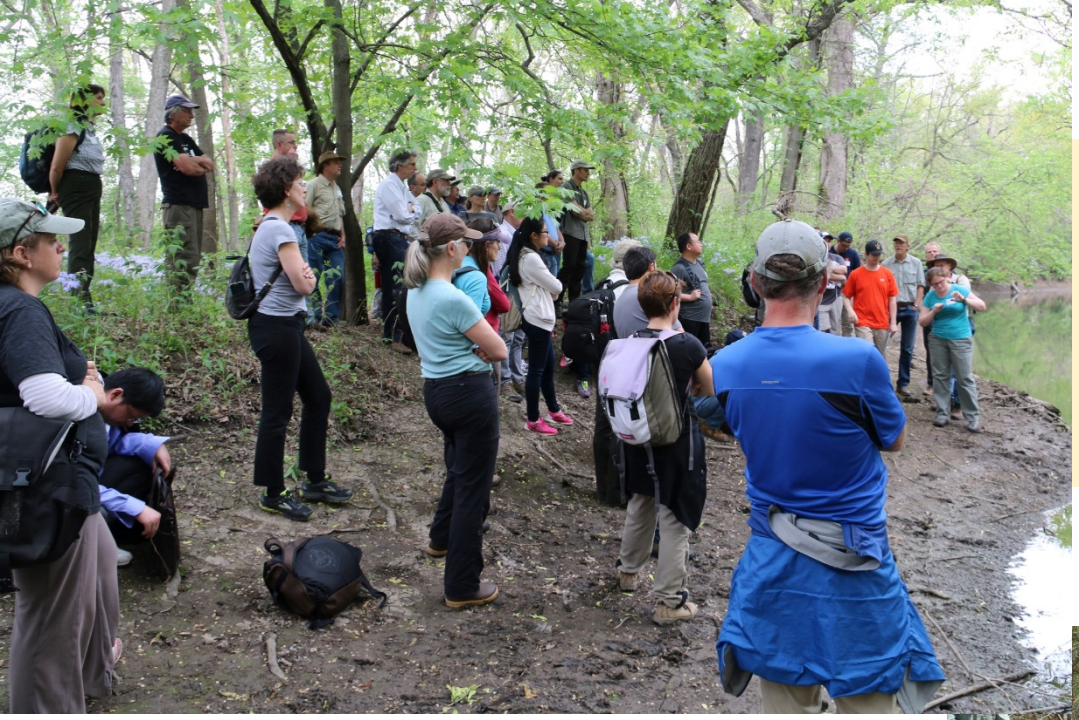
Outcomes and Impact From a Decade of the U.S. CZO Program (2007-2018)

Praveen Kumar
University of Illinois
Chair: CZO Network Executive Comm.

Bill Dietrich
Univ. of California, Berkeley
Incoming Chair: CZO Network Executive Comm.

2007-2009: 3 Observatories, 2009-2013: 6 Observatories, 2013 – present: 9 Observatories

National CZO Program
CRITICAL ZONE OBSERVATORIES
studying the zone where rock meets life
funded by NSF

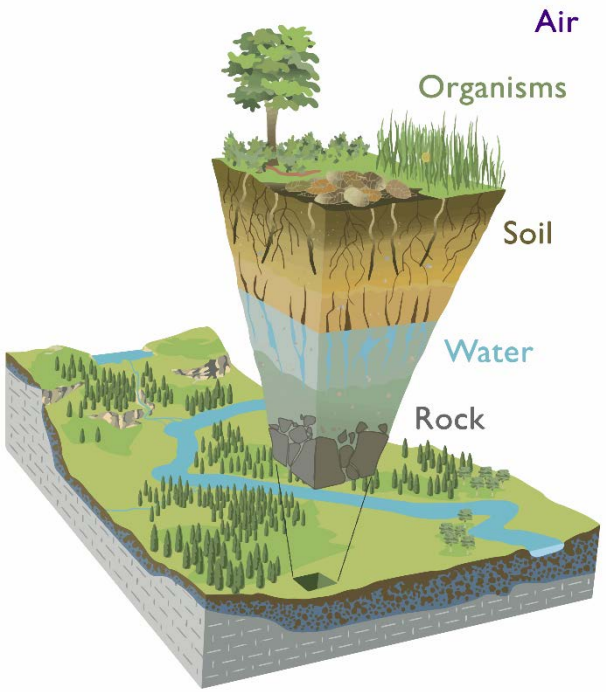


Exemplar in Convergence Research

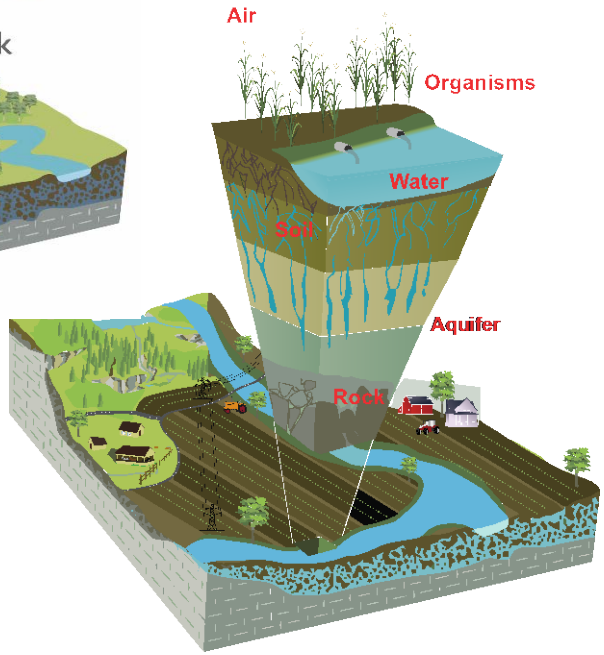
CZ Science is a New Emergent Discipline

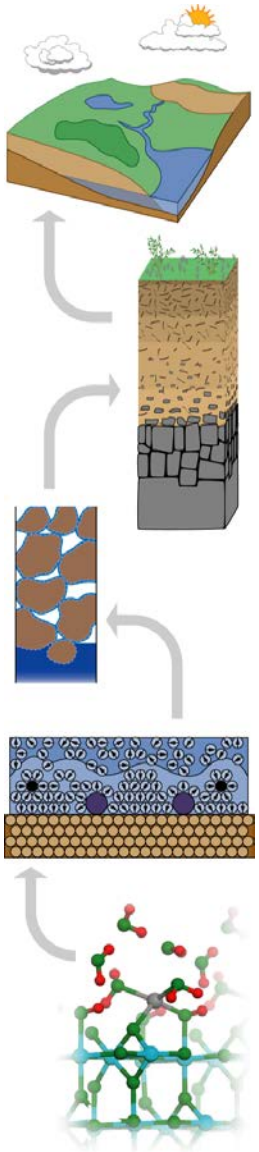
- Multidisciplinary/Interdisciplinary team investigations
- Sustained observations over long period of time
- Hypothesis driven framework: agile and iterative investigation
- Observation ← → Prediction across space-time scales

Critical Zone science aims to discover how Earth's "living skin" is structured, evolves, and provides critical functions that sustain life



Natural &
Human Modified
Environments
studies across scales





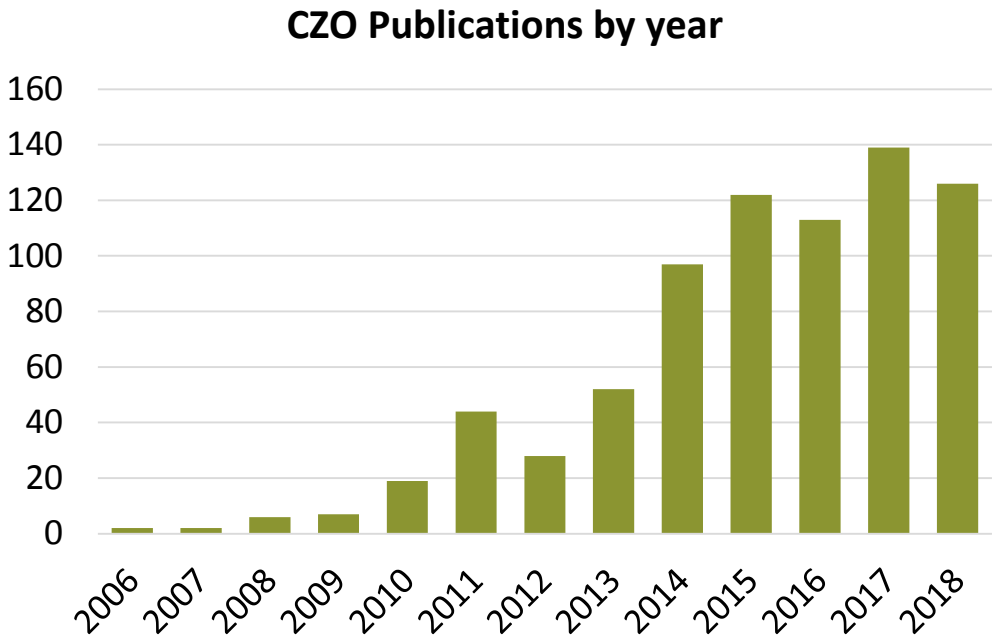
Watershed

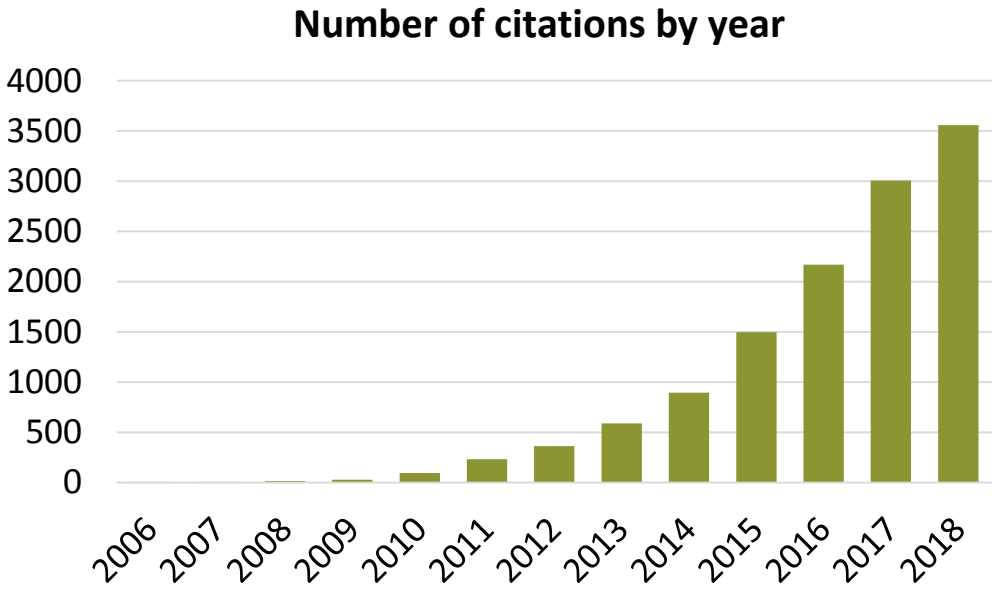
Column

Aggregates

Complexes

Molecular scale





Number of CZO Publications by Year	
2018	126
2017	139
2016	113
2015	122
2014	97
2013	52
2012	28
2011	44
2010	19
2009	7
2008	6
2007	2
2006	2

All data from Web of Science

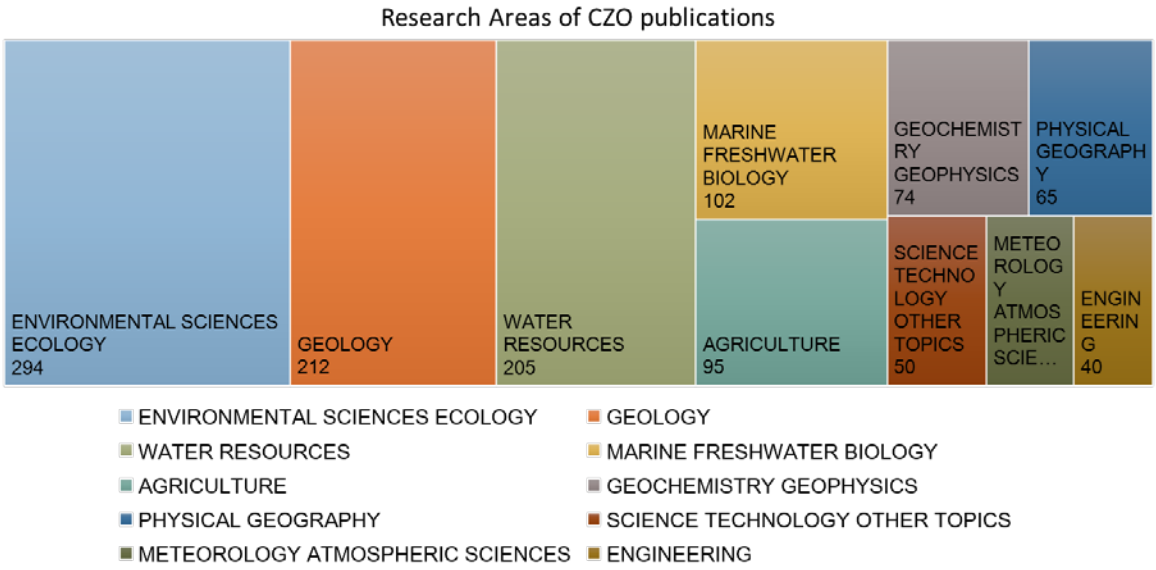
CZO network publication metrics	
Publications	794
XCZO Publications	34
Total	828
Times Cited	12,481
Average Citations	16
h-index	50

1900+ unique authors spanning
600+ organizations involved in
800+ CZ publications

Funding for CZ Science:

- National Science Foundation (NSF)
- USDA Agricultural Research Service (ARS)
- Natural Environment Research Council (NERC)
- National Natural Science Foundation Of China (NSFC)
- Department of Energy (DOE)
- Agence National de la Recherche (ANR)
- Helmholtz Association
- NOAA
- USFS
- NASA
- Foundations (i.e. Andrew Mellon Foundation, Kearney Foundation Of Soil Science)

CZ Science spans a total of 21 research areas:

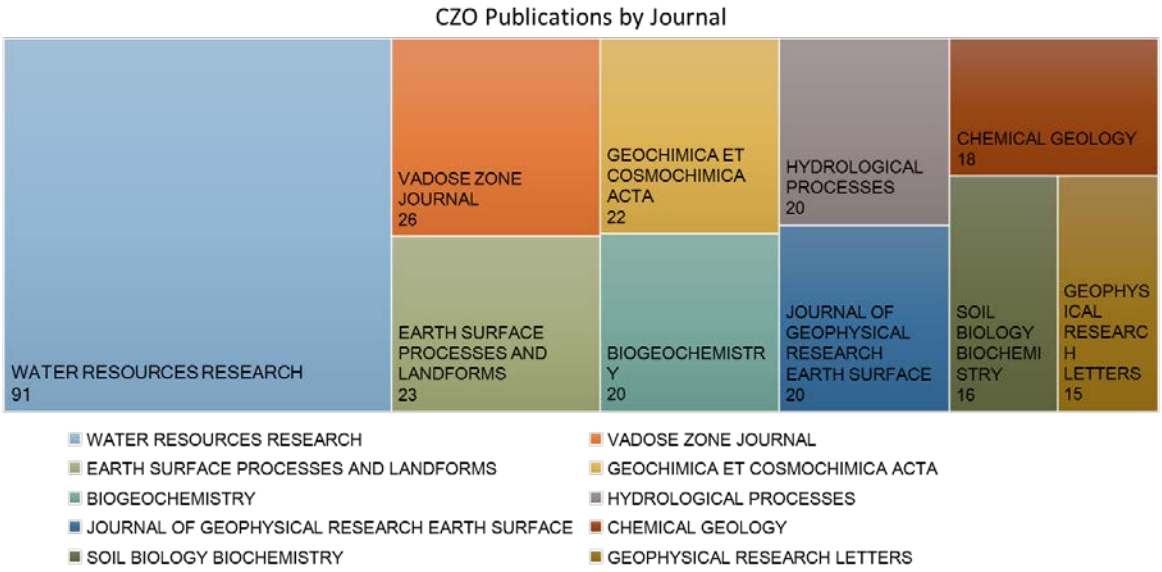


Research Areas as Defined by WOS

Major Research Areas involved:

- Environmental Sciences
- Ecology
- Geology
- Water Resources
- Marine Freshwater Biology
- Agriculture
- Geochemistry Geophysics
- Physical Geography
- Science Technology
- Meteorology/Atmospheric Sciences
- Engineering
- Forestry
- Microbiology
- Remote Sensing
- Computer Science
- Plant Sciences
- Imaging Science Photographic Technology

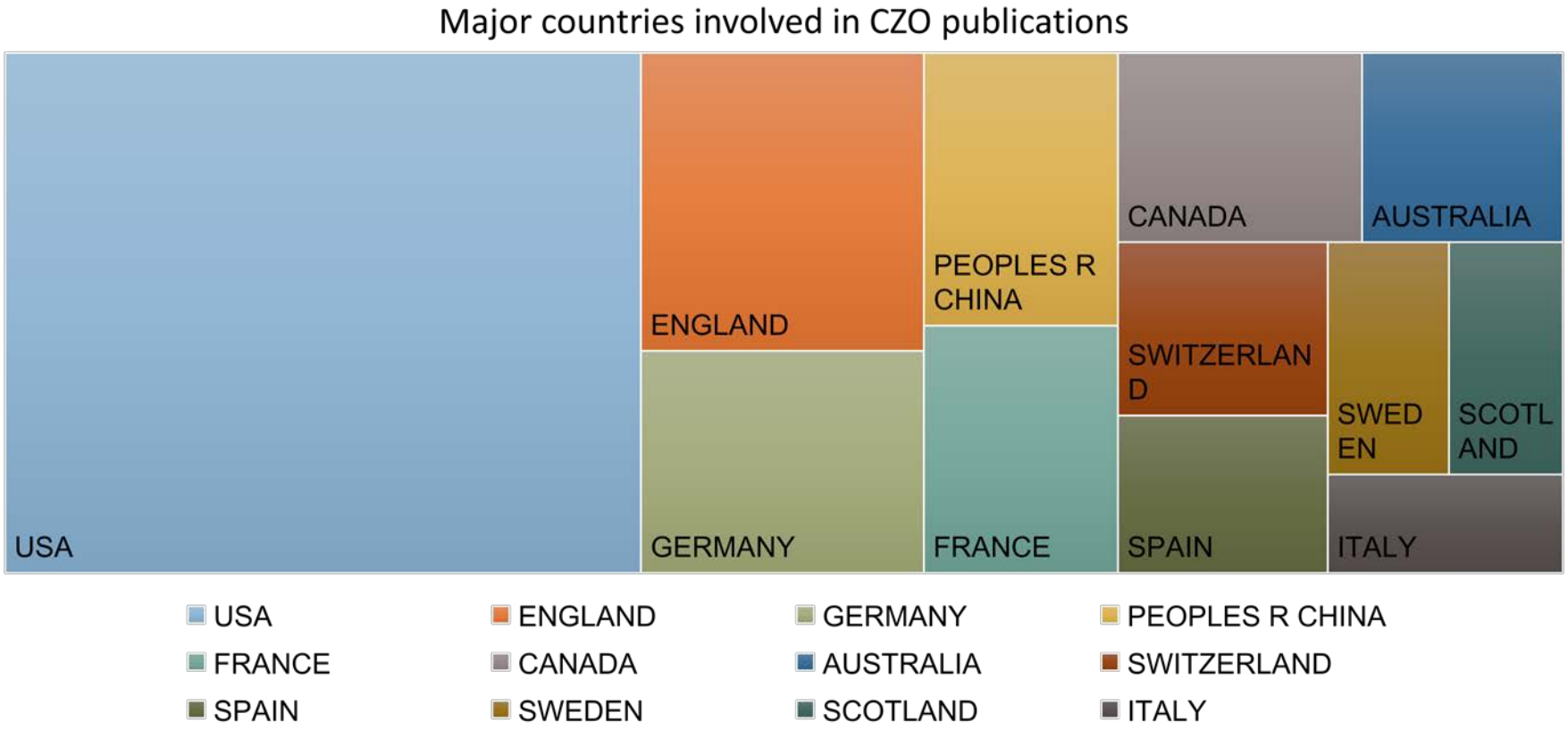
CZ Science Published Across 197 Journals:



CZ Science is published in:

- Water Resources Research
- Vadose Zone Journal
- Earth Surface Processes And Landforms
- Geochimica et Cosmochimica Acta
- Biogeochemistry
- Hydrological Processes
- JGR: Earth Surface
- Chemical Geology
- Soil Biology Biochemistry
- Geophysical Research Letters
- Geomorphology
- Proceedings Of The National Academy Of Sciences
- Biogeosciences
- Earth Surface Dynamics
- Nature Communications
- Environmental Research Letters
- Global Biogeochemical Cycles
- Cryosphere
- Earth System Science Data
- Nature Climate Change

Coauthors on CZO Publications from 54 countries



CZO Network Broader Impact

300+	Graduate students
100+	Postdoctoral scholars
90+	Ph.D. completed & 30 in progress
90+	M.S. thesis completed
420+	undergraduates
130+	REUs
1,400+	K-12 teachers engaged
16,000+	K-12 students reached
40+	Assistant professors generated
70+	CZO graduates in national labs, federal & state agencies, private companies, etc.
40+	Graduate Fellowships
1,100+	Out-of-network Collaborators
$300+M	in additional project funding
30+	international partnerships

CZO graduates work for:

- USGS
- USDA
- NOAA
- UCAR
- Army Corp of Engineers
- National Center for Atmospheric Research
- Natural Resources Conservation Service
- U.S. Navy Research
- U.S. Bureau of Reclamation
- U.S. EPA
- Cary Institute of Ecosystem Studies
- Los Alamos National Laboratory
- Argonne National Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Geologic Survey of Denmark

Federal organizations participating in CZO effort:

- Army Corp of Engineers
- Lawrence Livermore National Laboratory (LLNL)
- LTER Network
- Natural Resources Conservation Service (NRCS)
- USDA ARS
- USFS
- USGS
- U.S. Bureau of Reclamation
- U.S. National Park Service

State Agencies participating in CZO effort:

- California State Water Resources
- California Department of Forestry and Fire Protection
- Illinois State Geologic Survey
- Illinois State Water Survey
- Illinois Water Resources Center
- Pennsylvania Department of Conservation and Natural Resources
- Sierra Nevada Conservancy
- Sierra Resource Conservation District
- South Carolina State Parks

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.

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?

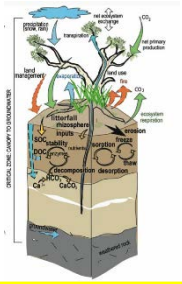
3. How can improved understanding of the critical zone be used to enhance ecosystem services?

Erosion rate

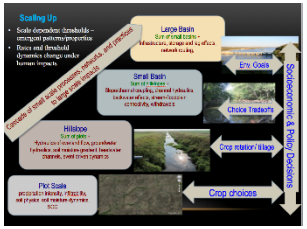
Fast

Slow

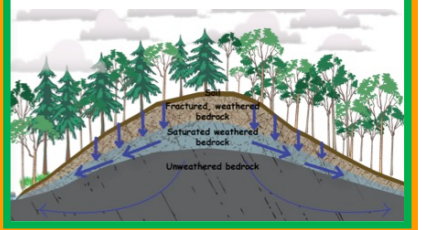
Reynolds Creek



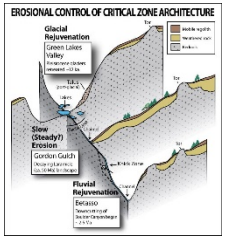
IML



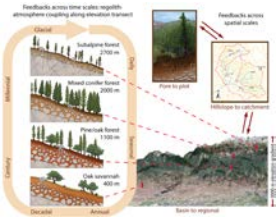
Eel River



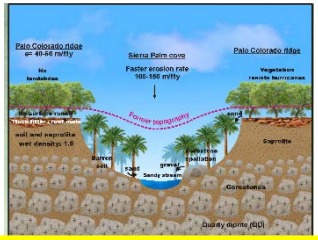
Boulder



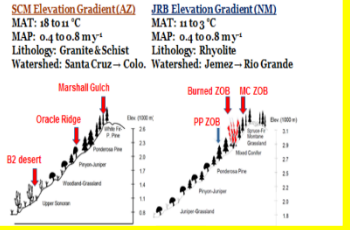
Southern Sierra



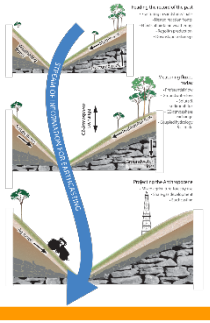
Luquillo



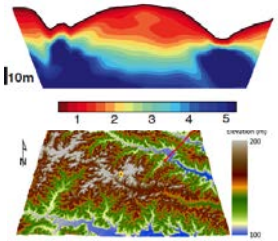
Jemez/Catalina



Shale Hills



Calhoun



Granitic (6)

Shale (2) (and sandstone)

Volcanic (3)

Glacial Dep (1)

Melange (1)

Arid

Wet

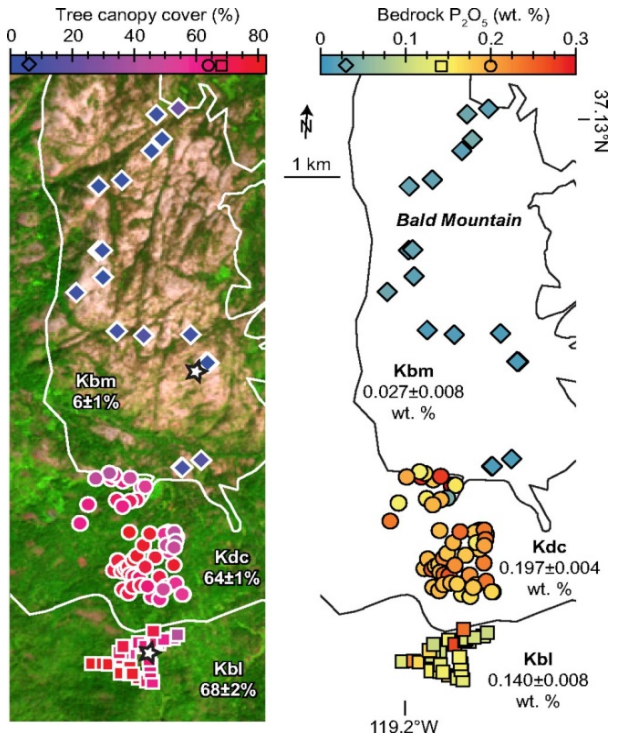
Precipitation

Three discoveries from the network of Critical Zone Observatories

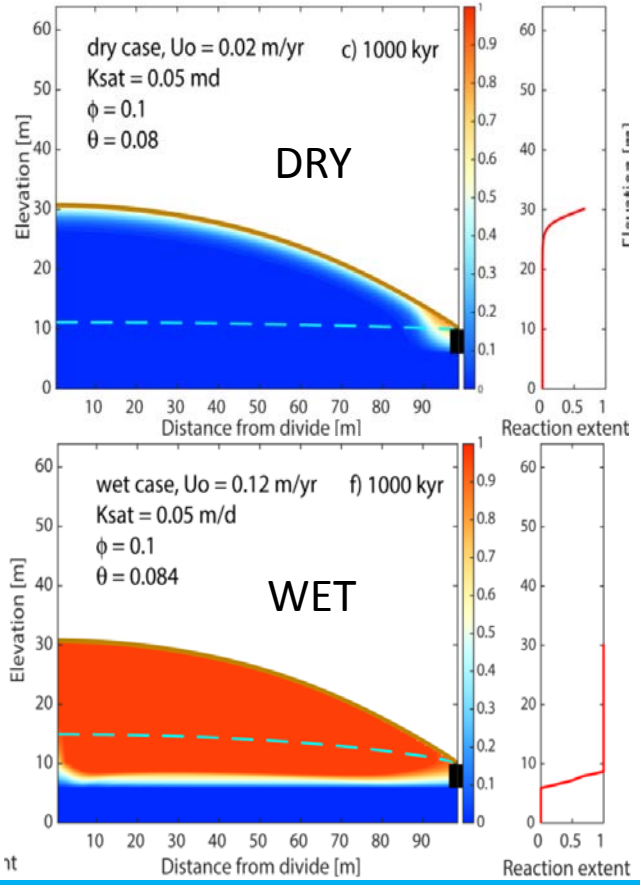
1) Observation and theory indicates that the subsurface structure of the critical zone may vary systematically, and predictably, relative to surface topography.

Deep drilling and shallow geophysics has documented structure, and six testable models, highlighting different process mechanisms have been published.

Observatories have documented the strong influence of lithology, climate, and tectonics on CZ structure.



High bedrock P → more soil & higher canopy cover



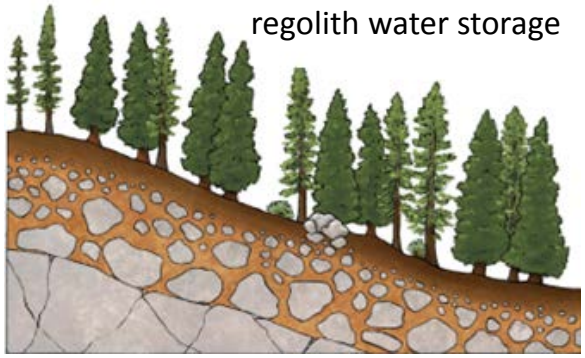
funded by NSF

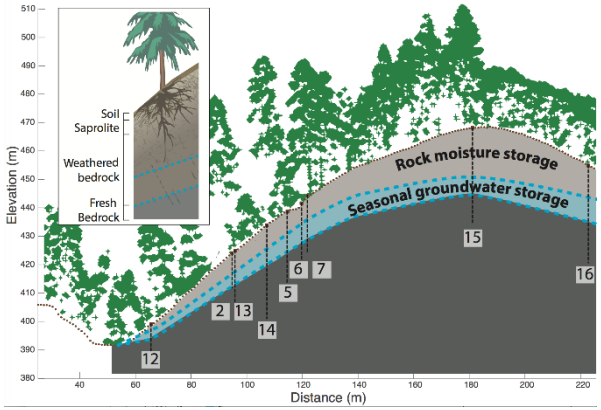
Lithology sets CZ depth structure

Climate sets CZ depth structure

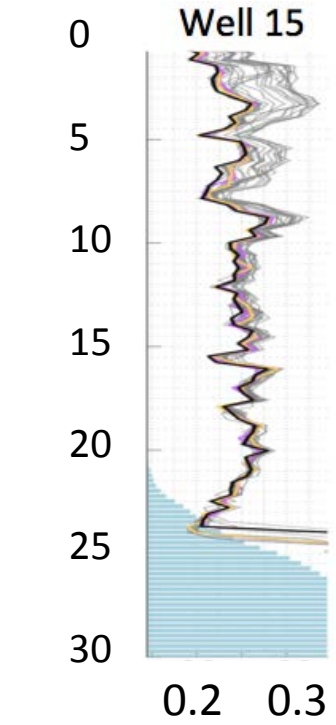
2) Beyond the soil, into the vadose zone of weathered bedrock, the CZO's have discovered significant plant available moisture storage, diverse microbial activity, chemical weathering fronts, controls on solute chemistry delivered to streams, and covariation of geochemistry and geophysical properties.

Forest vegetation copes with seasonal & multi-year dry periods through deep regolith water storage

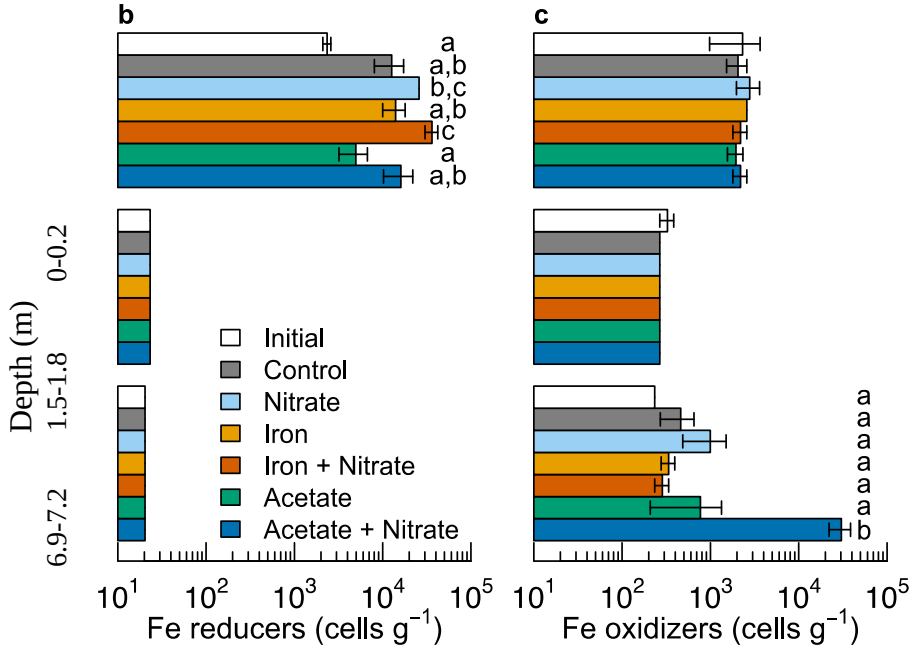




Rock Moisture: the dry West hidden water source



Volumetric water content

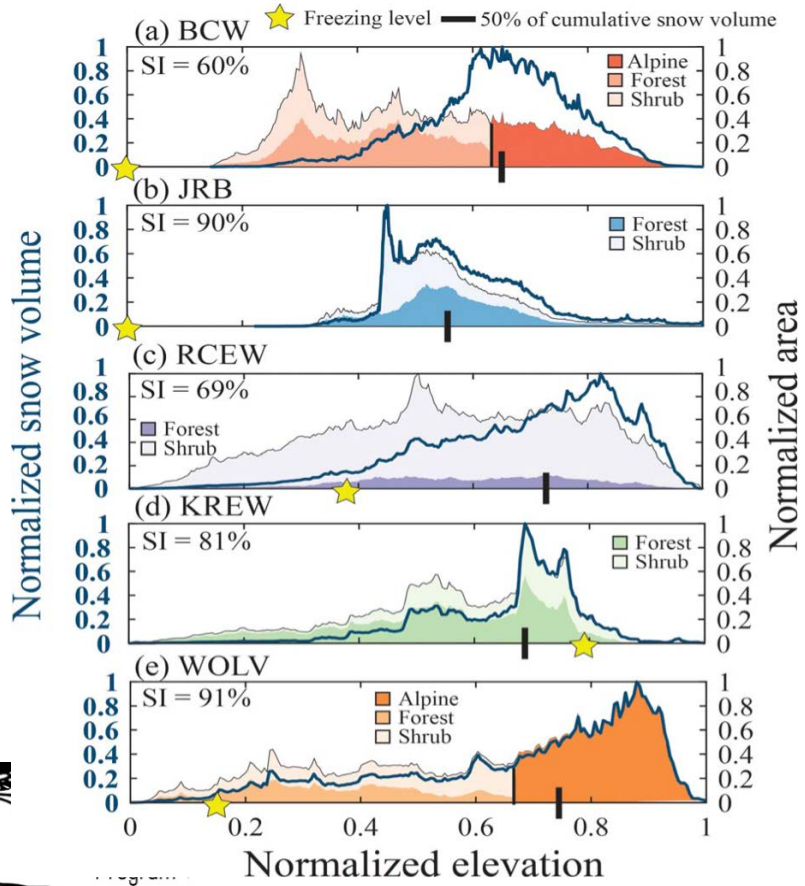


Microbes

3) Understanding critical zone structure and processes *is critical* to anticipating effects of climate change and landuse practices.

CZO research has revealed that the critical zone: stores and progressively releases deposited atmospheric pollutants, when degraded does not recover rapidly to reforestation, and can control the summer low flows discharged to channels where cyanobacteria may take hold. Intensive agriculture can transform the functions of the CZ from a primarily a transformer dominated system to one dominated by transport.

The shorter the distance between freezing elevation and the elevation below which 50% or of the snow, the more vulnerable to snow storage as the climate warms.



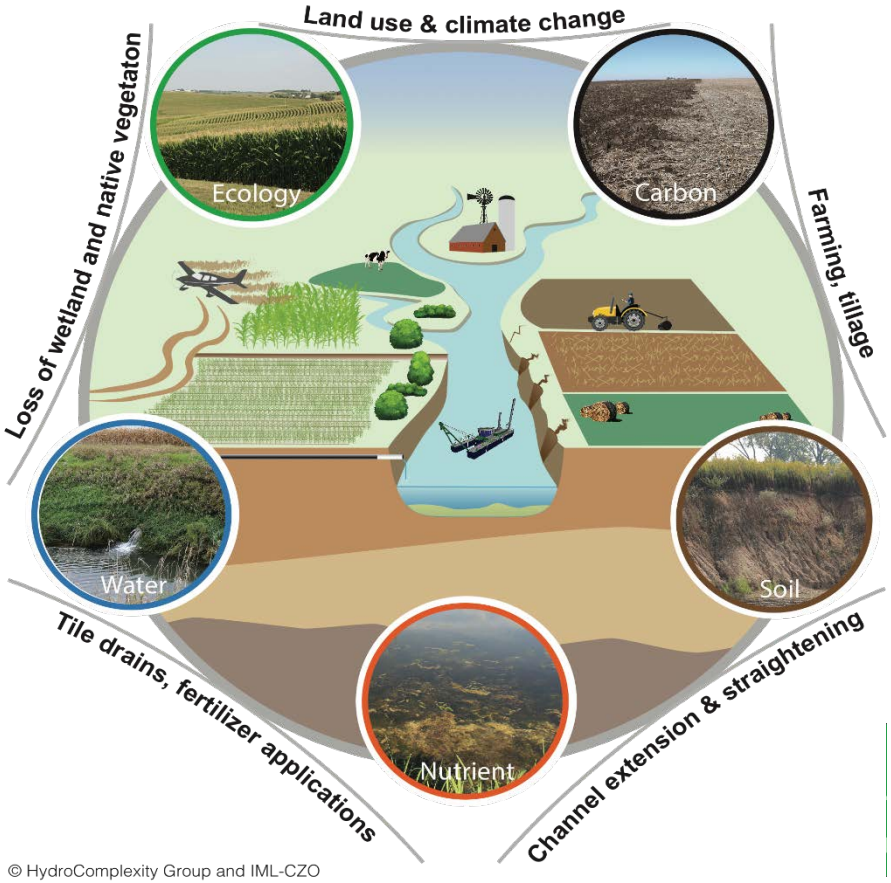
BCCZO

CJCZO

RCCZO

SSCZO

SSCZO



We have learned that the unique power of Critical Zone Observatories in advancing critical zone science derives from three attributes

1) CZOs enable the testing of hypotheses. They are not simply monitoring facilities, but rather they are instrumented and explored landscapes designed to address fundamental questions.

2) CZOs enable sustained observations over sufficient years such that drought, severe storms, fire, and management actions on critical zone processes are revealed. Long duration observations allows not only the capture of key processes, but allows the emergence and testing of new hypotheses not anticipated by our still primitive understanding of the critical zone.

3) CZOs, by attracting and supporting researchers of widely varying disciplines, have become catalysts for what could be called a new discipline of critical zone science, and students are now pioneers working widely across such fields as geology, hydrology, ecology, geophysics, geochemistry, and climate science.

Acknowledgements

- CZO National Office
  - Sarah Sharkey
  - Tim White
  - Lou Derry
  - Justin Richardson
- NSF
  - Richard Yuretich
  - Enriqueta Barrera
  - Lina Patino
  - Justin Lawrence
  - Tom Torgersen
- Gordon Grant (Chair) and Advisory Committee

Opportunities for Critical Zone Science

- Dynamics of Integrated Socio-Environmental Systems (CNH2)
- Frontier Research in Earth Sciences (FRES)
- Navigating the New Arctic (NNA)
- Mid-Scale Research Infrastructure-1 (Mid-Scale RI-1)
- NSF Earth-Science Postdoctoral Fellowships
- Other relevant programs: INFEWS, PREEVENTS
  - Proposals to core Earth Science programs: Hydrologic Sciences (HS), Geomorphology & Land-use Dynamics (GLD), Geobiology & Low-temperature Geochemistry (GLD), Sedimentary Geology & Paleobiology (SGP)
  - Future Critical-Zone Research Opportunities

CNH2 (Dynamics of Integrated Socio-Environmental Systems)

- NSF 19-528; Next deadlines: Letter of Intent (required): December 17, 2018; Full proposal: February 14, 2019
- Small (up to $750,000), large (up to $1.6 million), RCN ($500,000)
- Projects must include explicit analysis of the processes and dynamics between the environmental and human components of the system.

- Example: how changes in vegetation and soil affect land use and governance, how land use and governance determine vegetation and erosion, and the ways in which the feedbacks between the two function in an integrated fashion.

FRES (Frontier Research in Earth Sciences)

- Standing program of the Division of Earth Sciences, awards in the range of $1-$3 million
- NSF 19-531; Next deadline: Feb 20, 2019
- The FRES program will support research in Earth systems from its core through the critical zone. The project may focus on all or part of the surface, continental lithospheric, and deeper Earth systems over the entire range of temporal and spatial scales.

NNA (Navigating the New Arctic)

- NSF 19-511; Deadline: February 14, 2019
- Research grants up to $3 million and 5 years; Planning grants up to $250,000 and 2 years
- Improved understanding of Arctic change and its local and global effects that capitalize on innovative and optimized observation infrastructure, advances in understanding of fundamental processes, and new approaches to modeling interactions among the natural environment, built environment, and social systems.

Mid-Scale RI-1 (Mid-Scale Research Infrastructure -1)

- NSF 19-537; Deadlines:

  Preliminary Proposal: February 19, 2019;

  Full Proposal: May 30,2019

- Research infrastructure awards up to $20 million.
- Mid-scale RI-1 emphasizes strong scientific merit and response to an identified need of the research community. Demonstrated technical and managerial experience is required for both design and implementation projects, as are well-developed plans for student training and the involvement of a diverse workforce in all aspects of mid-scale activities.

EAR-PF (NSF Earth Sciences Postdoctoral Fellowships)

- NSF 18-565; Next deadline: September 11, 2019
- $87,000 per year for two years.
- EAR Postdoctoral Fellowship proposals must address scale dependence of processes, i.e., can the principles of interest be applied across several scales or dimensions such as local to global, lab to field, macro to micro; what is the duration or occurrence of processes over time such as deep past to present.

INFEWS (Innovations at the Nexus of Food, Energy, and Water Systems)

- New solicitation possible Spring 2019
- The FEW systems must be conceptualized broadly, incorporating physical processes, natural processes biological processes, social/behavioral processes, and cyber-components.
- Awards up to $2.5 million.

PREEVENTS (Prediction of and Resilience against Extreme Events)

- NSF 16-562. Next deadlines:
  Letter of Intent: July 26, 2019;
  Full proposal: September 17, 2019
- PREEVENTS seeks projects that will (1) enhance understanding of the fundamental processes underlying natural hazards and extreme events (2) improve our capability to model and forecast such hazards and events.
- Award size varies.

Core Programs

- Critical-zone processes are fundamental to many programs within the Division of Earth Sciences (EAR).
- Proposals are welcomed that have ties to existing CZO sites.
- Budgets should be in line with typical core-program proposals.
- EAR core programs have no deadlines; proposals received anytime.
- Indicate “CZO: Critical Zone Observatory Solic” on the cover sheet as secondary program

New Research in the Critical Zone

- Current CZO Cooperative Agreements end FY19
- Follow-up solicitation is currently undergoing administrative review (“clearance”).

Contact Information

- Richard Yuretich
- Program Director, Integrated Activities
- Division of Earth Sciences (EAR)
- ryuretic@nsf.gov
- 703-292-4744