

[My Desktop](#)  
[Prepare & Submit Proposals](#)  
[Prepare Proposals in FastLane](#)  
[New! Prepare Proposals \(Limited proposal types\)](#)  
[Proposal Status](#)  
[Awards & Reporting](#)  
[Notifications & Requests](#)  
[Project Reports](#)  
[Submit Images/Videos](#)  
[Award Functions](#)  
[Manage Financials](#)  
[Program Income Reporting](#)  
[Grantee Cash Management Section Contacts](#)  
[Administration](#)  
[Lookup NSF ID](#)

## Preview of Award 1331828 - Annual Project Report

[Cover](#) |  
[Accomplishments](#) |  
[Products](#) |  
[Participants/Organizations](#) |  
[Impacts](#) |  
[Changes/Problems](#)

### Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1331828
Project Title:	Boulder Creek CZO II: Evolution, Form, Function, and Future of the Critical Zone
PD/PI Name:	Suzanne P Anderson, Principal Investigator Robert S Anderson, Co-Principal Investigator Noah P Molotch, Co-Principal Investigator Harihar Rajaram, Co-Principal Investigator Gregory E Tucker, Co-Principal Investigator
Recipient Organization:	University of Colorado at Boulder
Project/Grant Period:	10/01/2013 - 04/30/2019
Reporting Period:	10/01/2017 - 09/30/2018
Submitting Official (if other than PD\PI):	Suzanne P Anderson Principal Investigator
Submission Date:	07/02/2018
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Suzanne P Anderson

---

### Accomplishments

#### \* What are the major goals of the project?

Boulder Creek CZO (BcCZO) was established in 2007 as a natural laboratory to study how erosion and weathering together shape the architecture of the critical zone. The aim of BcCZO is to develop a deeper understanding of the structure, functioning, and evolution of the critical zone in a mountainous landscape. The Colorado Front Range serves as a natural laboratory, in which variations in rock type, erosion history, climate, and ecosystems have produced recognizable differences in topography and critical zone architecture. We focus on addressing deep chemical and geobiological weathering processes that alter unweathered rock, on monitoring water and weathering fluxes, and on modeling the evolution and behavior of these

landscapes. Boulder Creek exemplifies landscapes in the American West inhabited by large populations and facing changing snow regimes, fires and beetle infestations.

Our goals are to: 1) Document critical zone **evolution** in the Colorado Front Range, where climate has been the chief driver since the end of the Laramide orogeny about 40 Myr ago. This entails determining rates of incision and exhumation of the range and its adjacent basin, as well as describing the structure of the critical zone throughout the range. 2) Understand how individual processes shape the critical zone (**process to form**). Weathering processes and sediment transport processes together shape hillslopes and move weathering fronts into rock. 3) Discover how critical zone architecture influences the storage and flow of water (**form to function**). The critical zone serves as a filter for water quantity and quality delivered to streams. 4) Explore critical zone functional response to **future** perturbations. As temperatures increase (especially summer), and the elevation of the rain-snow transition rises, and as fires or insect infestations change in frequency or intensity, we will require process models to explore the landscape's hydrologic, geomorphic, and biogeochemical response. Anticipated outcomes include models of processes at short timescales, and an integrated model of critical zone evolution, function and response to future climate to 2050. The team brings together expertise in geomorphology, hydrology, geobiology, ecology, and geophysics.

**\* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

Over the last year, we accomplished the following:

1. Maintained year-round monitoring in three watersheds, upgraded instrumentation on a long-term (historic) weather station (B1 of the networks established by John Marr), took over maintenance of an alpine deep ground temperature monitoring site on Niwot Ridge, supported two NADP sample collection sites established in 2017, established dust sampling sites at nine sites at elevations from 1600-3500 m (an effort supported by BcCZO, LTER, and City of Boulder).
2. Maintained and augmented an integrated database, which includes 60 datasets, 27 of which are updated monthly, and 1 (Betasso meteorology) streams in real-time.
3. Published 12 journal papers (including one in *Science* and two in *Journal of Geophysical Research*). An additional paper is in press and 6 in review.
4. Hosted a visit from a delegation of 16 scientists from the Chinese Geological Survey, Nov 6-10, 2017. Meeting included a one-day science meeting, two days of field trips, lab tours, and opportunities for discussions.
5. Graduated one PhD student (Theo Barnhart), one undergraduate senior honors thesis (Dylan Lanka).
6. Held team meetings during the academic year.
7. Ran extensive K-12 and Community College programs and teacher professional development class.
8. PI Anderson is a guest editor for a special issue of *Hydrological Processes* (with Ying Fan Reinfelder, Rutgers University, and Gordon Grant, USFS/OSU) titled "Passive-Aggressive: Water in the Critical Zone". A total of 22 manuscripts are in process, of which at least 9 have been accepted to date.
9. Goal 1, *Critical zone evolution*: Work on CZ evolution has shifted from timing to process, with work on blocky hillslopes being a prominent focus. Team members: RS Anderson, K Singha, GE Tucker, SP Anderson; post-doc Matt Rossi; grad students Abby Langston (now a researcher at Kansas), Rachel Glade, Charlie Shobe and Brittany Selander. **Three papers** (Shobe et al., in press; Glade and Anderson, 2018, Langston and Tucker, 2018) published.
10. Goal 2, *Understand how individual processes shape the critical zone* (process to form): Process work has focused on biogeomorphology, microbiology, interactions between slope and channel processes, modeling hillslopes, and work on understanding the conditions—both in state of rock weathering and hydrologic controls—that produce slope instability. Team members: H Rajaram, RS Anderson, SP Anderson, BA Ebel, N Fierer, GE Tucker; post-doc Ruth Heindel; grad students Tess Brewer, Rachel Glade, Charlie Shobe, Kelly Kochanski; undergrads Dylan Lanka. **Eight papers published** (Brantley et al., 2017; Brewer and Fierer, 2018; Delgado-Baquerizo et al., 2018; Kochanski et al., 2018; Rengers et al., 2018; Pelletier et al., 2018; Litaor et al., 2018; Dethier et al., 2018), **One paper in review** (Anderson, Rajaram and Anderson).

11. Goal 3, *Discover how critical zone architecture influences the storage and flow of water* (form to function): Work on water includes continued foci on snow and ecohydrology, as well as biogeochemistry, stream chemistry, including dissolved organic matter, wildfire effects on hydrochemistry, and colloidal transport of matter. Team members: SP Anderson, HR Barnard, M Gooseff, ES Hinckley, D McKnight, NP Molotch, SF Murphy, H Rajaram, K Singha; post-docs Adam Wlostoski, Matt Rossi; grad students Isaac Bukoski, Theo Barnhart. **Five papers published** (Rue et al., 2017; Knowles et al., 2017; Wieting et al., 2017; Zhang et al., 2018; Murphy et al., 2018). **One dissertation** completed (Barnhart, 2018).

Specific Objectives: Objectives listed in 2017 Annual Report:

**1) Maintain monitoring in existing catchments, coordinate with Niwot Ridge LTER on field monitoring in the alpine settings. Maintain sampling at the two new NADP sites (Betasso and Boulder) we established this year.**

1.1 Weekly water sample collection and snow depth measurements maintained.

1.2 Instrumentation & networking of data-loggers maintained.

1.3 National Atmospheric Data Deposition Program (NADP) collection sites at SkyWatch (in Boulder, next to SEEC building) and Betasso have now been running for a full year, in cooperation with Scott Wetherbee, USGS. BcCZO is handling weekly sample collection.

1.4 We are now seeking to link the historic B-1 site weather station to our automated networked sites.

1.5 BcCZO personnel have taken over maintenance of temperature monitoring at “Fahey site” on Niwot Ridge, site formerly maintained by Niwot LTER.

1.6 Field personnel participated in annual Green Lakes Valley snow survey.

**2) Support cross-CZO postdoc Adam Wlostowski on Hydrologic partitioning.**

2.1 Adam Wlostowski has met with team members (Suzanne Anderson, Bob Anderson, Noah Molotch, Hari Rajaram, Greg Tucker, Eve Hinckley, Ruth Heindel, Sheila Murphy) individually and in small groups

2.2 Adam invited to give Geography Department colloquium on his cross-CZO research, November 2017

2.3 Adam is mentoring grad student Kate Hale on hydrologic modeling

2.4 Adam is co-author with Suzanne Anderson on Gordon Gulch hydrology manuscript and her GSA talk.

2.5 Adam participated in BcCZO team meetings

**3) Plan and possibly host cross-CZO landscape modeling workshop, collaborating with the Community Surface Dynamics Modeling System (CSDMS) and Lejo Flores (Reynolds CZO).**

3.1 This goal still remains a goal.

**4) Complete microbial DNA analysis of soil samples from all CZOs for the cross-CZO microbial ecology project (headed by Emma Aronson).**

4.1 Grad student Tess Brewer has completed analyses and is working on a manuscript investigating microbial communities found in deeper soil horizons.

4.2 Noah Fierer and his group are working with CZO datasets to investigate broad scale biogeographic patterns in soil microbial communities and their influences on biogeochemical processes.

**5) Support the Research Experience for Community College Students in Critical Zone Science (RECCS) program**, by supporting administrative staff needed to run an REU, providing mentors and research support, participating in the skills training in the program.

5.1 BcCZO provides about 1 month of salary support for Renee Curry, who takes over day-to-day management for RECCS from Jennifer Taylor.

5.2 Suzanne Anderson led field trip to Table Mesa and Betasso for students on June 6, 2018.

5.3 Fierer lab mentored student Eryn “Lady” Grant in summer 2017 (on bacterial taxa abundance in AIPO<sub>4</sub> and free PO<sub>4</sub> conditions, and student Cora Rutledge in summer 2018.

5.4 Post-doc Ryan Webb and Niwot LTER grad student Anna Hermes mentored Kara Garcia in summer 2017 on hydraulic conductivity at sites from Niwot Ridge to Gordon Gulch.

5.5 Sheila Murphy presented on fire to RECCS students.

**6) Support K-12 education outreach programs of Science Discovery.**

6.1 Bob Anderson, Suzanne Anderson, and Rachel Glade led field trip to Niwot Ridge as part of a 3-day teacher professional development course “Mountain Research Experience”, June 27, 2018. The course is run by Science Discovery’s Eric Carpenter, and reached 12 teachers from around the state of Colorado.

6.2 Science Discovery offered 27 CZO-themed events: 19 teacher professional development STEM workshops, 2 Mountain Research Experience teacher professional development courses, and 5 school-based events (including 18 classroom presentations).

**7) Facilitate production of *Hydrologic Processes* special issue on the critical zone.**

7.1 A total of 23 manuscript submitted; 8 have been accepted and published, 1 rejected, 2 rejected with encouragement to resubmit, and 10 are in various stages of review and revision.

**8) Goal 1, *Critical zone evolution*:**

- Produce paper on hillslope evolution, incorporating water flow paths and geochemical alteration of rock (Bob Anderson, Hari Rajaram, Dan Richter (Calhoun CZO) and SP Anderson). **Outcome:** revised manuscript in re-review

(Anderson, RS, Rajaram, H, and Anderson, SP: Climate driven co-evolution of weathering profiles and hillslope topography generates dramatic differences in critical zone architecture. *Hydrological Processes*). Two presentations (Anderson RS at AGU 2017; Anderson SP at Goldschmidt 2018)

- Conduct preliminary research on rock weathering on steep slopes (SP Anderson, Brittany Selander). **Outcome:** Selander et al. poster at AGU 2017; Selander passed oral exam, spring 2018, earned drone pilot credentials, May 2018.
- Other prog:

**9) Goal 2, *Understand how individual processes shape the critical zone (process to form):***

- Complete investigation of seasonal variability in soil microbial communities across different soil types and how these correlate with shifts in nutrient dynamics (Carini, Hinckley, Rue). **Outcome:** Manuscript currently circulating among co-authors, submission planned in Fall 2018.
- Preliminary work on snow mold and N-dynamics (Hinckley, Chiara Forrester) **Outcome:** snow-mold sampling done during snowmelt.
- Continue field measurements of forces at the root-rock interface at both the Eel River and Boulder Creek CZOs (Marshall) **Outcome:** Marshall began faculty position in Arkansas in Fall 2017; she has visited, and plans re-instrumenting plots in Boulder in the coming year.
- Document shifts in ecotones from airphotos over the last 70 years in the subalpine forest zone (Doak, Anderson, Gulick). **Outcome:** Gulick graduated, and has not continued to work on this project.
- Examine controls on vertical structure of bioturbation by gophers using Cs and 210Pb, model behavior observed (Winchell, RS Anderson). **Outcome:** Chapter 2 of Winchell's 2017 dissertation "Modeling the vertical signature of gopher activity in Colorado Front Range subalpine landscapes utilizing conditional gopher digging rules, stones lines, 137Cs and 210Pbex" has been submitted to *Geomorphology*.
- Measure and model rocky landscapes (hogbacks, Flatirons, blocks in channels) (Tucker, RS Anderson, SP Anderson, Glade, Shobe, Selander, with Francis Rengers, USGS). **Outcomes:** 3 presentations at 2017 AGU meeting; 3 posters and 1 invited talk at CSDMS 2018 Annual meeting. Published Glade and Anderson (2018); Rengers et al. (2018); Shobe et al. (in press).

**10) Goal 3, *Discover how critical zone architecture influences the storage and flow of water (form to function):***

- Model and build observational data on snowmelt timing, rate and amount influence on streamflow production from point to regional scale (Barnhart, D Barnard, Molotch, SP Anderson) . **Outcome:** Barnhart dissertation, 2018.
- Submit paper on Gordon Gulch hydrology (SP Anderson). **Outcome:** manuscript titled "Runoff response in semi-arid headwater driven by catchment-scale water movement" in preparation, submission planned summer 2018.
- Submit paper on extreme precipitation event in Betasso (SP Anderson). **Outcome:** still planned.
- Write paper on groundwater dynamics elucidated from analysis of Betasso deep well (RS Anderson, H Rajaram, SP Anderson, Cowell). **Outcome:** still planned.

**Significant Results:**

**Landscape evolution:** Members of our team have been working in parallel on understanding bedrock-dominated landscapes. Brittany Selander (working with Suzanne Anderson) used LiDAR data and Digital Globe imagery to examine the distribution of bedrock and tree cover on the walls of Boulder Canyon, work that she presented at AGU in 2017. This forms the basis of her dissertation on rocky slope evolution. Grad students Charlie Shobe (working with Greg Tucker) and Rachel Glade

(working with Bob Anderson) are both focused on the role of large blocks of rock in long-term landscape evolution. Charlie has focused on how large blocks play a key role in a number of montane CZO sites, including Boulder Creek (where the name says it all!), Southern Sierra, Reynolds Creek, Jemez/Catalina, and Luquillo. They are using field observations and computational models to understand how blocks are produced and how they influence hillslope and channel evolution. Modeling of river profile evolution under the influence of blocks indicates that the blocks can exert a significant influence in making mountain streams steeper and rougher than they otherwise would be, and thereby retard the rate of long-term erosion. Recent work by Shobe and colleagues indicates that this influence can be modeled in a simple way through the use of an erosion threshold that varies with local erosion rate, as a proxy for the supply of blocks (Shobe et al., in press, *JGR Earth Surface*). Rachel focuses on how blocks generated on hillslopes affect the morphology and evolution of the slope, with an emphasis on landscapes comprised of layers of alternating hardness such as comprise hogback terrains. Her analytical model is presented in Glade and Anderson (2018, *JGR Earth Surface*). Charlie and Rachel are now finishing a manuscript in which their models are combined to show the interactions between hillslopes and channels where large blocks are generated.

**Microbial ecology:** The Fierer lab has been leading the charge on studying microbial systems and their role in critical zone function. They recently completed a study investigating the microbial communities living on exposed rock surfaces, the traits that allow them to survive in this environment, and the microbial mechanisms involved in mineral weathering. This study used tombstones as a model system and the resulting manuscript (Brewer & Fierer, *Environmental Microbiology*, 2018) was featured in the 'Editor's Choice' section of Science, April 19, 2018 issue. They have also been working with CZO datasets to investigate broad scale biogeographic patterns in soil microbial communities and their influences on biogeochemical processes, and have a manuscript in preparation on this topic. Fierer and Brewer are members of the team that recently published the first-ever atlas of soil bacteria (Delgado-Baquerizo et al., 2018, *Science*). This work cuts through the universe of taxa found in soils, and reveals that a small fraction (2%) accounts for nearly half of the soil communities around the world. Research on these dominant taxa can make significant improvements in our understanding of the function of bacteria in soils.

**Extreme events:** Extreme climate events—including wildfire, drought, and flooding—are some of the world's most deadly and expensive hazards. Such events disrupt human society, water supplies, and ecosystems, and are predicted to increase in frequency and magnitude in the future. Despite their critical importance, extreme climate events and their impacts on watersheds are challenging to study due to their unpredictability, the extensive damage they cause to infrastructure, and a lack of pre-existing data to which the response can be compared. Murphy et al. (2018, *JGR-Biogeosciences*) measured the hydrologic and water chemistry response of a stream near Boulder, Colorado to four extreme climate events: wildfire, drought, and two periods of extreme rainfall. They found that extreme climate events can alter hydrologic flow paths through the critical zone and thus stream concentrations of sediment and pollutants, in different ways. Wildfires, by altering soil conditions, led to infiltration-excess overland flow during thunderstorms and the rapid conveyance of water, sediment, and constituents present in ash and soil to streams, while bypassing subsurface flow paths. During drought, when stream discharge was <20% of average, concentrations of sediment, dissolved organic carbon, and calcium fell below typical concentrations. Extreme rainfall totals saturated the subsurface and led to prolonged elevated stream discharge; the relationships between stream discharge and bedrock-derived constituents (such as Ca), were altered, while those for dissolved organic

carbon were not. Water-quality impairment was exacerbated by previous disturbances, including historical mining. Murphy et al., (2018) is an important advance in our understanding of the hydrologic and water quality response to wildfires, floods, and droughts, and thus will improve predictions of water-quality impairment caused by extreme climate events.

Key outcomes or Other achievements:

**Nutrient deposition:** Increased nutrient deposition (particularly N, but other nutrients such as P as well) have been recognized in alpine settings for some time. Litaor et al. (2018, *Catena*), publish data from soil pits in a Green Lakes valley catena first sampled in 1982. The pits were re-opened and re-sampled by BcCZO in 2008, and have been monitored by BcCZO for temperature and volumetric water content since 2008. Using soil samples collected in 2008 and shallow samples collected in 2015, Litaor **shows the effects of 33 years of N deposition on the soils**, finding a decline in exchangeable base cations coupled with an increase in exchangeable aluminum. The work illustrates the importance of long-term sampling.

BcCZO post-doc Ruth Heindel has established an array of **nine dust deposition sampling sites** across a 2000 m elevation transect from Boulder to Niwot ridge in order to study nutrient inputs, particularly phosphorus in different settings. Preliminary data (7 monthly samples at the longest-running sites so far) reveal that dust deposition is highest in spring, and that dust chemistry is enriched in phosphorus relative to average upper continental crust (as is found globally). Two of Ruth's sites are co-located with the NADP (National Atmospheric Deposition Program) sites that BcCZO established in spring 2017 in collaboration with the USGS. The NADP sites were designed to be part of an urban network of precipitation collectors. The preliminary results from these samplers show that Betasso, at the eastern edge of the Rocky Mountain surface, looks more like urban precipitation than the long-running subalpine and alpine NADP sites in the Front Range. These data point to the importance of atmospheric transport on sediment and aerosol inputs, and that these are controlled by circulation patterns rather than by elevation per se.

**Topographic analysis and photogrammetry:** Our ability to study landscapes and landscape change is exploding. Ten years ago, obtaining aerial LiDAR was the cutting edge technology. Today, digital surface models (DSMs) can be generated from multiple overlapping photographs using a technique called structure-from-motion, a form of photogrammetry. Imagery can be taken with cameras mounted on drones or other platforms. BcCZO now has three certified drone pilots (Toby Minear, Rachel Glade and Brittany Selander), and these tools are being deployed to study landslides and cascading hazards (Minear et al., 2018, AOGS), solifluction lobes (Glade et al., 2017, GSA), and rock slopes (Selander et al., 2017, AGU).

Toby Minear is using Boulder Creek as a test site for "StreamSurf", a stereo camera system to monitor stream flow using non-contact methods. He demonstrated this system to the Chinese Geologic Survey on Cherry Creek in downtown Denver in November 2017.

#### **\* What opportunities for training and professional development has the project provided?**

##### **Post-docs**

BcCZO Post-doctoral Fellow Ruth Heindel has held regular mentoring meetings with Eve-Lyn Hinckley and Sheila Murphy, and occasionally with PI Suzanne Anderson. She has been a resource for graduate students, and has participated in outreach activities.

Cross-CZO post-doc Adam Wlostowski meets regularly with supervisor Noah Molotch, and virtually with co-supervisor Ciaran Harnan (Johns Hopkins). He has met with other team members (e.g., Suzanne Anderson, Bob Anderson, Hari Rajaram, Greg Tucker) throughout the year.

EarthLab post-doc Matt Rossi meets with “Team Erosion” (Greg Tucker, Bob Anderson, Suzanne Anderson) on alternate weeks to discuss projects and development topics.

Post-docs have attended all PI meetings held this year.

### **Graduate students**

Graduate student Katherine Hale worked with Science Discovery educator Eric Carpenter to develop an education module on snow stratigraphy for middle-school level students.

Graduate students Katherine Hale and Kelly Kochanski participated in organizing the student-run Hydrological Sciences Research Symposium at CU Boulder in April 2018.

### **Undergraduate students**

BcCZO provides about 1 month of salary support per year to the RECCS (Research Experience for Community College Students) program manager, a position that cannot be adequately funded on the 1 month allowed in REU proposals. During the program, they are introduced to the CU campus and research in week 1, complete a Communicating Science workshop (weekly meetings), weekly check-ins, and meet with CIRES and CZO staff to learn about education and career pathways. These activities are in addition to conducting a research project with a mentor, and presenting their findings in a poster and oral session. In summer 2017, 11 students participated, while in 2018, 10 students are participating.

In summer 2017, BcCZO-II faculty and students mentored 2 of the 10 students:

1) Grad student Tess Brewer and Prof. Noah Fierer mentored Eryn “Lady” Grant (Community College of Denver). Final poster: *Comparative Abundance of Bacterial Taxa Between Free Phosphate and Aluminum Phosphate Conditions*, Lady Grant, Tess Brewer, and Noah Fierer

2) Post-doc Ryan Webb and grad student Anna Hermes mentored Kara Garcia (Front Range Community College). Final poster: *Hydraulic Conductivity Among Varied Elevation Gradients within Boulder Creek CZO & Niwot Ridge LTER*, Kara Garcia, Ryan Webb & Anna Hermes

### **Undergraduates: other activities**

Our newest undergraduate field techs (Nathan Graham, Hannah Timlin, and Jordan Garrett) are all taking a CPR course tailored for workers in mountain field conditions (e.g., lightning strikes and drowning situations).

Undergraduate senior honors thesis:

Dylan Lanka, BA *summa cum laude* in Physical Geography, 2018. Senior honors thesis: *Solifluction Lobes on Niwot Ridge: Using Drones, Time-lapse Cameras, and Weather Data to Study Periglacial Features*. Supported by a von Dreden Stacey Fellowship in summer 2017.

### **K-12 Teacher Professional Development class (Science Discovery):**

Earth Systems Science Teacher Mountain Research Professional Development Workshop/ Field Course (3-Day/24 Hour), June 26-28, 2018. Enrollment: 12 teachers. This course is led by Eric Carpenter, and he is supported by exchanges with graduate students, post-docs and faculty.

**\* How have the results been disseminated to communities of interest?**

### **Field Trips**



1) *Suzanne Anderson* led two days of field trips for a delegation of 18 scientists from Chinese Geologic Survey on Nov 8 and Nov 9, 2018. The first day visited field sites in Betasso and Gordon Gulch, while the second day visited to a USGS urban stream gage on Cherry Creek in Denver with Dr. John Fulton (USGS) and Dr. Toby Minear (CIRES).

2) *Suzanne Anderson* to lead a field trip of Front Range geology for Research Experience for Community College Students (RECCS) in Critical Zone Science students, June 6 2018. 10 students.

3) *Robert Anderson* led field trip to Niwot Ridge, Boulder Creek CZO for Earth Systems Science Teacher Mountain Research Professional Development class, June 28, 2018. Bob was assisted by Suzanne Anderson, post-doc Megan Peterson, and grad student Rachel Glade. Rachel collected data with a drone for studies of a solifluction lobe and of *Silene* (cushion plants). 12 teachers.

## **Presentations at Conferences**

We gave 47 presentations at professional science meetings:

- 21 presentations at AGU Fall Meeting, New Orleans, CA, Dec 2017
- 8 presentations at GSA Annual Meeting, Seattle, WA, Oct 2017
- 4 presentations at the CU Hydrological Sciences Symposium, Boulder, CO, April 2018
- 4 presentations at the CSDMS Annual Meeting, Boulder, CO, May 2018
- 4 presentations at the AGU-SEG Hydrogeophysics Workshop, Stanford, CA, July 2017 (not reported in previous annual report)
- 2 presentations at the Western Snow Conference, Albuquerque, NM, April 2018
- 1 presentation at the Asia Oceania Geosciences Society annual meeting, June 2018
- 1 presentation at the Goldschmidt Conference, Boston, MA, Aug 2018
- 1 presentation at the Society of Exploration Geophysics Annual meeting, Anaheim, CA, Oct 2018

## **Other professional talks by team members:**

1. **Noah Fierer**, 2017. "Searching for simplicity amidst the complexity of the soil microbiome". French National Institute for Agricultural Research (INRA). Dijon, France
2. **Noah Fierer**, 2018. "Searching for simplicity amidst the complexity of the soil microbiome". College of Agriculture, Colorado State University
3. **Greg Tucker**, 2017. "Some community resources for modeling critical-zone dynamics". Webinar presented to Cross-CZO Modeling Series.
4. **Suzanne Anderson**, Sept 27, 2017, "Boulder Creek CZO-II: Activities and goals", Niwot LTER meeting, Boulder, CO.
5. **Suzanne Anderson**, Feb 26, 2018, "Glacial legacy on the critical zone: Perspective from Boulder Creek CZO", CZO PI Science Discussion webinar.
6. **Adam Wlostowski**, Nov 11, 2017, "Critical storage: Characterizing hydrologic function across the CZO network", CU Dept of Geography colloquium.
7. **Robert Anderson**, April 14, 2017, "Hills and their evolution: Involving parabolas, exponentials and hyperbolas", CU Dept of Applied Math colloquium
8. **Robert Anderson**, November 3, 2017, "From the shoulders of GK Gilbert: hillslope evolution paying attention to rocks and climate", University of Washington Earth and Space Sciences colloquium.
9. **Robert Anderson**, November 2, 2017, "From pure ice to rock-covered ice: the glacier-rock glacier continuum", University of Washington Earth and Space Sciences colloquium.
10. **Robert Anderson**, November 27, 2017, "Alpine Ice on Planet Earth: Glaciers and Their Rocky Cousins", CU Dept of Astronomy colloquium.
11. Graduate student **Rachel Glade** presented at "Nerd Nite", a free event at the Outback Saloon, on her blocky hillslope work. <http://www.dailycamera.com/events/things-to-do#!/details/NERD-NIGHT/4622983/2018-03-05T19>
12. Post-doc **Ruth Heindel** presented her BcCZO dust deposition work at a "Science Salon" event hosted by the Boulder Pod of 500WomenScientists. The audience was a crowd of ~40 people at Twisted Pine brewery in Boulder.

13. **Noah Fierer** talked about “The microbial ecology of our homes” at a free “Science on Tap” event at Gunbarrel Brewing Company, April 3, 2018.

### **Stakeholder contacts**

*Sheila Murphy*

NADP program

City of Boulder Sourcewater Protection program

City of Boulder Stormwater Program

Boulder County Public Health

*Ruth Heindel*

City of Boulder Open Space and Mountain Parks

### **Media: print and radio**

CU Press release on Delgado et al. *Science* paper: <https://www.colorado.edu/today/2018/01/18/what-lives-your-dirt>

CU Press release on Rachel Glade’s work on layered landscapes:

<https://www.colorado.edu/asmagazine/2018/02/21/whats-and-whats-going-down-hogbacks>

Science focus on Tess Brewer and Noah Fierer’s paper in *Environmental Microbiology*:

<http://science.sciencemag.org/content/360/6386/281.3>

### **Website**

Content was created and/or updated and on many of the webpages at [www.criticalzone.org/boulder](http://www.criticalzone.org/boulder). We now have content on a variety of styles of models (<http://criticalzone.org/boulder/models/conceptual-models-boulder/>).

### **Social media presence**

PI *Suzanne Anderson* tweets on CZ-related topics. [Suzanne Anderson @Suzanne44827923](https://twitter.com/Suzanne44827923)

Boulder Creek CZO has a twitter account: Boulder Creek CZO @bc\_czo

**\* What do you plan to do during the next reporting period to accomplish the goals?**

- 1) Maintain monitoring in existing catchments, coordinate with Niwot Ridge LTER on field monitoring in the alpine settings. Maintain sampling NADP and dust collection sampling sites.
- 2) Support cross-CZO postdoc Adam Wlostowski on Hydrologic partitioning.
- 3) Plan and possibly host cross-CZO landscape modeling workshop, collaborating with the Community Surface Dynamics Modeling System (CSDMS) and Lejo Flores (Reynolds CZO).
- 4) Publish on microbial DNA analysis of soil samples from all CZOs for the cross-CZO microbial ecology project (headed by Emma Aronson). Fierer is working with microbial ecologists, soil scientists, and biogeochemists from every CZO site to plan, coordinate, and implement a cross-CZO microbial ecology that spans all current CZO sites. The research focuses on exploring the structure and function of microbial communities in deeper soil horizons.
- 5) Support the Research Experience for Community College Students in Critical Zone Science (RECCS) program, by providing mentors and research support, participating in the skills training in the program.
- 6) Support K-12 education outreach programs of Science Discovery in curriculum development, and through providing domain expertise as needed.
- 7) Complete production of *Hydrologic Processes* special issue on the critical zone. The working title for the issue is: *Passive-Aggressive: Water in the Critical Zone*. The project was initiated by Ying Fan Reinfelder (Rutgers Univ), with the support of Editor-in-Chief Doerthe Tetzlaff. Ying Fan's co-guest editors are Suzanne Anderson and Gordon Grant (OSU/USFS).
- 8) Goal 1, *Critical zone evolution*:
  - Publish paper on hillslope evolution, incorporating water flow paths and geochemical alteration of rock (Bob Anderson, Hari Rajaram, and SP Anderson).
  - Development and exploration of a computational model that combines block production, motion on hillslopes, weathering delivery to channels, and in-situ erosion and/or mobilization in channels (Shobe, Glade, Tucker, Anderson, Anderson, Selander)
  - Development and exploration of computational models for snow bedform genesis (Kochanski, Tucker, RS Anderson)
  - Publish paper in *Elements* on mechanical weathering (SP Anderson)
  - Write paper on chemical weathering in Gordon Gulch for edited book on chemical weathering and soil formation, edited by Markus Egli and Allen Hunt, for AGU Centennial celebration (SP Anderson)
- 9) Goal 2, *Understand how individual processes shape the critical zone* (process to form):
  - Submit manuscript on investigation of the temporal variation in soil microbial communities across 2 plots in the Gordon Gulch watershed where we quantified, for the first time, seasonal variation in the structure of soil microbial communities and how interactions between community members vary over time (Fierer, Carini, Hinckley)
  - Submit manuscript on a cross-CZO study investigating microbial communities found in deeper soil horizons, their influence on subsurface carbon cycling, and the unique adaptations of these communities to oligotrophic conditions (Brewer and Fierer)
  - Initiate a set of new experiments determining how aluminum (Al) toxicity shapes belowground communities and the specific taxa tolerant of high soluble Al concentrations. This work is important, as Al toxicity is common in many soils and the ability to tolerate soluble Al is likely a critical control on microbial weathering of Al-containing minerals (Fierer)
  - Support field measurements of forces at the root-rock interface at both the Eel River and Boulder Creek CZOs (Marshall)
  - Submit manuscript on controls on vertical structure of bioturbation by gophers using Cs and <sup>210</sup>Pb, model behavior observed (Winchell, RS Anderson)
  - Analyze soil water samples in context of precipitation, stream water and groundwater samples to understand chemical weathering processes (Noah Hoffman and SP Anderson)
- 10) Goal 3, *Discover how critical zone architecture influences the storage and flow of water* (form to function):
  - Sample and build conceptual model of linkages between catchment structure, water sources and flowpaths during rain and snowmelt within Boulder Creek watershed (Isaac Bukoski, Barnard, Murphy)
  - Model annual snow fraction in runoff in Gordon Gulch, and simulate changes in a warming climate (Kate Hale, Molotch)
  - Submit paper on Gordon Gulch hydrology (SP Anderson)
  - Submit paper on extreme precipitation event in Betasso (SP Anderson, Matt Rossi)

## Supporting Files

Filename	Description	Uploaded By	Uploaded On
Additional reporting 2018.pdf	Additional reporting 2018	Suzanne Anderson	07/02/2018

## Products

### Books

### Book Chapters

### Inventions

### Journals or Juried Conference Papers

Barnard, DM, JF Knowles, HR Barnard, ML Goulden, J Hu, ME Litvak, NP Molotch (2017). Reevaluating growing season length controls on net ecosystem production. *Global Change Biology*. . Status = UNDER\_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Barnard, HR, BA Skeets, HR Adams, CJ Crosby, WB Ouimet (2017). Using stable isotopes of trees to examine moisture dynamics in bedrock outcrops of a Semi-Arid Catchment. *Hydrological Processes*. . Status = UNDER\_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Brantley, S.L., Eissenstat, D.M., \*\*Marshall, J.A., Godsey, S.E., Balogh-Brunstad, Z., Karwan, D.L., Papuga, S.A., Roering, J., Dawson, T.E., Evaristo, J., Chadwick, O., McDonnell, J.J., and Weathers, K.C. (2017). Reviews and syntheses: On the roles trees play in building and plumbing the critical zone. *Biogeosciences*. 14 5115. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/bg-14-5115-2017

Brantley, SL, McDowell, W, Dietrich, WE, Kumar, P, Anderson, SP, Chorover, J, Lohse, KA, Bales, R, Richter, DdeD, Grant, G, Gaillardet, J, and Derry, LA (2017). Designing a network of Critical Zone Observatories to explore the living skin of the terrestrial Earth. *Earth Surface Dynamics*. 5 841. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/esurf-5-841-2017

Brewer, T.E., N. Fierer (2018). Tales from the tomb: the microbial ecology of exposed rock surfaces. *Environmental Microbiology*. 20 (3), 958. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/1462-2920.14024

Bueno de Mesquita, C., L.S. Tillmann, C.D. Bernard, K.C. Rosemond, N.P. Molotch, K.N. Suding (2017). Topographic heterogeneity mediates vegetation response to climate change in the Rocky Mountains, USA. *Landscape Ecology*. . Status = UNDER\_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Delgado-Baquerizo, M., Oliverio, AM, Brewer, TE, Benavent-Gonzalez, A., Eldridge, DJ, Bardgett, RD, Maestre, FT, Singh, BK, and Fierer, N (2018). A global atlas of the dominant bacteria found in soil. *Science*. 359 320. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1126/science.aap9516

Dethier, DP, Ouimet, WB, Murphy, SF, Kotikian, M, Wicherski, W, and Samuels, RM (2018). Anthropocene landscape change and the legacy of nineteenth- and twentieth-century mining in the Fourmile catchment, Colorado Front Range. *Annals of the American Association of Geographers*. 108 (4), 917. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1080/24694452.2017.1406329

Driscoll, J.M., T. Meixner, P.A.T. Ferre, M.W. Williams, J.O. Sickman, N.P. Molotch (2017). An elliptical model of catchment-scale response to snowmelt and the role of dynamic and long-term storage in dampening discharge variability. *Water Resources Research*. . Status = UNDER\_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Fierer, N (2017). Embracing the unknown: disentangling the complexities of the soil microbiome. *Nature Reviews Microbiology*. 15 579. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/nrmicro.2017.87

Foster, M.A., Anderson, R.S., Gray, H.J., and Mahan, S.A. (2017). Dating of river terraces along Lefthand Creek, western High Plains, Colorado, reveals punctuated incision. *Geomorphology*. 295 176. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.geomorph.2017.04.044

Glade, R and Anderson, R.S. (2018). Quasi-steady evolution of hillslopes in layered landscapes: An analytic approach. *Journal of Geophysical Research- Earth Surface*. 123 26. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2017JF004466

Knowles, JK, Lestak, L, and Molotch, NP (2017). On the use of a snow aridity index to predict remotely sensed forest productivity in the presence of bark beetle disturbance. *Water Resources Research*. 53 4891. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016WR019887

Kochanski, K., Anderson, R.S., and Tucker, G.E. (2018). Statistical classification of self-organized snow surfaces. *Geophysical Research Letters*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1029/2018GL077616

Langston, A, and Tucker, G (2018). Developing and evaluating a theory for the lateral erosion of bedrock channels for use in landscape evolution models. *Earth Surface Dynamics*. 6 1. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/esurf-6-1-2018

Litaor, M.I., Suding, K., Anderson, S.P., Litus, G., and Caine, T.N. (2018). Alpine catena response to nitrogen deposition and its effects on the aquatic system. *Catena*. 170 108. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.catena.2018.06.004

Murphy, S.F., McCleskey, R.B., Martin, D.A., Writer, J.H., and Ebel, B.A (2018). Fire, flood, and drought—Extreme climate events alter flow paths and stream chemistry. *Journal of Geophysical Research: Biogeosciences*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1029/2017JG004349

Pelletier, J.D., Barron-Gifford, G.A., Gutierrez-Jurado, H., Hinckley, E-L. S., Istanbuluoglu, E., McGuire, L., Niu, G-Y., Poulos, M.J., Rasmussen, C., Richardson, P., Swetnam, T.L., and Tucker, G.E (2018). Which way do you lean? Using slope aspect variations to understand Critical Zone processes and feedbacks. *Earth Surface Processes and Landforms*. 43 (5), 1133. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/esp.4306

Rengers\*, F.K., McGuire, L.A., Ebel, B.A., & Tucker, G.E. (2018). The evolution of a colluvial hollow to a fluvial channel with periodic steps following two transformational disturbances: A wildfire and a historic flood. *Geomorphology*. 309 121. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.geomorph.2018.01.003

Richter, D., Billings, S., Groffman, P., Kelly, E., Lohse, K., McDowell, W., Riebe, C., Silver, W., White, T., Anderson, S., Brantley, S., Brecheisesn, Z., Chadwick, O., Hartnett, H., Hobbie, S., Kazanski, C., Markewitz, D., O'Neill, K., Schoeder, P., Thompson, A. (2017). Elevating the biogeosciences within environmental research networks. *Biogeosciences*. . Status = UNDER\_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Rue, GP, Rock, ND, Gabor, RS, Pitlick, J, Tfaily, M, and McKnight, DM (2017). Concentration-discharge relationships during an extreme event: Contrasting behavior of solutes and changes to chemical quality of dissolved organic material in the Boulder Creek Watershed during the September 2013 flood. *Water Resources Research*. 53 (7), 5276. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016WR019708

Shobe, C.M., Tucker, G.E., and Rossi, M.W. (2018). Variable-threshold behavior in rivers arising from hillslope-derived blocks. *Journal of Geophysical Research: Earth Surface*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Wicherski, W, Dethier, DP, and Ouimet, WB (2018). Erosion and channel changes due to extreme flooding in the Fourmile Creek catchment, Colorado. *Geomorphology*. 294 87. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.geomorph.2017.03.030

Wieting, C.\*, Ebel, B., and Singha, K (2017). Quantifying the effects of wildfire on changes in soil properties by surface burning of soils from the Boulder Creek Critical Zone Observatory. *Journal of Hydrology-Regional Studies*. 13 43. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ejrh.2017.07.006

Wymore, A. S., N. R. West, K. Maher, P. L. Sullivan, A. Harpold, D. Karwan, J. A. Marshall, J. Perdrial, D. M. Rempe and L. Ma (2017). Growing New Generations of Critical Zone Scientists. *Earth Surface Processes and Landforms*. 42 (41), 2498. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/esp.4196

Zhang, Q, Knowles, J, Barnes, R.T., Cowie, RM, Rock, N, and Williams, MW (2018). Surface-subsurface water contributions to streamflow from a mesoscale watershed in complex mountain terrain. *Hydrological Processes*. 32 (7), 954. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/hyp.11469

## Licenses

### Other Conference Presentations / Papers

Hinckley, E-L (2017). *A Scope for the Subsurface: How Geophysics Can Inform Hydro-biogeochemical Studies in Managed and Unmanaged Systems*. AGU-SEG Hydrogeophysics Workshop. Stanford, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Singha, K, Navarre-Stichler, A, Pommer, RE, Novitsky, CG, Holbrook WS, and Moore, J (2017). *An integrated geophysical and geochemical exploration of critical zone weathering on opposing montane hillslope (Invited)*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hinckley, E.S. (2016). *Aspect affects the fate of N deposition during major hydrologic events in the BcCZO*. Cross-CZO workshop on Slope-Aspect. Tucson, AZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hurst, A.A., Anderson, R.S., and Tucker, G.E. (2017). *Calculating the spatio-temporal variability of bedrock exposure on seasonal hydrograph timescales as a prerequisite to modeling bedrock river evolution*. American Geophysical Union fall meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Redfern, S, Livneh, B, Molotch, NP, Suding, K, Neff, JC, and Hinckley, ES (2017). *Catchment Integration of Sensor Array Observations to Understand Hydrologic Connectivity*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Webb, Ryan, Molotch, NP, and Fend, M. (2018). *Combining Ground Penetrating Radar with Terrestrial LiDAR Scanning to Observe the Spatial Distribution of Liquid Water Content in Seasonal Snowpacks*. 86th Annual Western Snow Conference. Albuquerque, NM. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Marshall, J. (2017). *Considering the role of trees as Critical Zone architects*. Critical Zone Science: Current Advances and Future Opportunities. Arlington, Virginia. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Barnhart, T.B., N.P. Molotch, and C.L. Tague (2017). *Disentangling the Importance of Snowmelt Rate, Timing, and Amount on Runoff Production*. CU Hydrologic Sciences Symposium. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hinckley, E.S. (2016). *Does rapid ecological change have consequences for the deep critical zone?*. AGU Townhall Meeting: Critical Zone Observatories: Platforms for Collaborative Science". San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Knowles, JF, Molotch, NP, Trujillo, E, and Litvak, ME (2017). *Earlier Snowmelt Changes the Ratio Between Early and Late Season Forest Productivity*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hale, Katherine E., Wlostowski, Adam N., Badger, Andrew M., Lestak, Leanne R., Anderson, Suzanne P., Molotch, Noah P. (2018). *Effects Of Precipitation Type On Streamflow Efficiency*. CU Hydrologic Sciences Research Symposium Hydrology Horizons: Innovations in Water Science. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Anderson, RS, Rajaram, H, Anderson, SP (2017). *Effects of Climate on Co-evolution of Weathering Profiles and Hillscapes*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hale, Kate (2018). *Effects of Precipitation Type on Streamflow Efficiency At Critical Zone Observatories in the Western United States*. Western Snow Conference. Albuquerque, NM. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hale, K (2017). *Effects of Precipitation Type on Streamflow Efficiency At Critical Zone Observatories in the Western United States*. American Geophysical Union Fall Meeting New Orleans, LA. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Harmon, Ryan, Szutu, DJ, Randall, J, Barnard, HR, and Singha, K (2017). *Electrical resistivity imaging to link evapotranspiration and groundwater fluxes in the critical zone*. AGU-SEG Hydrogeophysics Workshop. Stanford, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Singha, K, Harmon, R, Mares, R, and Barnard, HR (2017). *Examining diel patterns of soil and xylem moisture from the single-tree to hillslope scale*. AGU-SEG Hydrogeophysics Workshop: Imaging the Critical Zone. Stanford, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Murphy, S (2018). *Fire, Flood, And Drought: Extreme Climate Events Alter Flowpaths And Stream Chemistry*. CU Hydrologic Science Symposium Hydrology Horizons: Innovations in Water Science. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Rossi, MW, Anderson, RS, Anderson, SP, and Tucker, GE (2017). *Geomorphic implications on the orographic transition from snowmelt to rainfall triggered extremes in the Colorado Front Range*. Geological Society of America Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Richter, D deB, Austin, J, Anderson, RS, Bacon, AR, Brantley, SL, Brecheisen, Z, Schroeder, PA, Wade, A, Holbrook, WS, Marcon, V, and Thompson, A (2017). *Gilbert's soil production paradigm applied to a critical zone's fractionation of particle sizes*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Anderson, SP, Anderson, RS, and Rajaram, H (2018). *Hillslopes in wet and dry conditions: Contrasting climates produce dramatically different critical zone architectures*. Goldschmidt. Boston, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shobe\*, C.M., Tucker, G.E., and Rossi, M.W. (2017). *Hillslope-derived blocks, erosion thresholds, and topographic scaling in mountain rivers*. Joint CSDMS-COMSESnet-SEN Meeting: Modeling Coupled Earth and Human Systems. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Singha, K (2017). *How do we estimate hydrogeologic processes given maps of subsurface geologic properties?*. Geological Society of America Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wlostowski, AN, Harman, CJ, and Molotch, NP (2017). *Hydrologic Synthesis Across the Critical Zone Observatory Network: A Step Towards Understanding the Coevolution of Critical Zone Function and Structure*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Mangel, A., Bradford, JH, and Singha, K (2018). *Imaging changes in moisture within living tree trunks using ground penetrating radar*. Society of Exploration Geophysics Annual Meeting. Anaheim, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wigmore, O, and Molotch, NP (2017). *Improving Understanding of Spatial Heterogeneity in Mountain Ecohydrology with Multispectral Unmanned Aerial Systems (UAS)*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Navarre-Stichler, A (2017). *Insights into chemical weathering patterns from geophysical data*. AGU-SEG Hydrogeophysics Workshop. Stanford, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Glade, RC, Lanka, DJ, Anderson, SP, and Anderson, RS (2017). *Legions of lobes: self-organization and movement of solifluction features at Niwot Ridge*. Geological Society of America Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Aguirre, A and Derry, L (2017). *Mechanisms Generating Chemostatic Si-discharge Relationships in Granitoid Catchments of the Critical Zone Network*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Rush, M, Rajaram, H, Anderson, RS, and Anderson, SP (2017). *Modeling Aspect Controlled Formation of Seasonally Frozen Ground on Montane Hillslopes: a Case Study from Gordon Gulch, Colorado*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Glade, R and Shobe, C (2018). *Modeling the 2-D evolution of blocky landscapes: Coupled model design*. Geoprocesses, geohazards - CSDMS 2018. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shobe, C, and Glade, R (2018). *Modeling the 2-D evolution of blocky landscapes: Hillslope-channel interactions*. Geoprocesses, geohazards - CSDMS 2018. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Evans, Sarah G., Ge, S, Voss, CI, and Molotch, NP (2017). *Potential shifts in groundwater discharge as snowmelt-dominated watersheds warm*. Geological Society of America Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Anderson, SP, Rengers, FK, Foster, MA, Winchell, EW, and Anderson, RS (2017). *Rainfall influence on styles of mass movement*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Smith, L, Gold, AU, Anderson, SP, Taylor, JL, Luna, LM, and Batchelor, R (2017). *Research experience for community college students in critical zone science: Smoothing the pipeline for 2YC students into geoscience programs at 4YCs*. Geological Society of America Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Anderson, SP, Wlostowski, A, Murphy, SF, Rock, ND, and Hoffman, C (2017). *Runoff response in a semi-arid headwater driven by catchment-scale water movement*. Geological Society of America Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Kochanski, Kelly, Tucker, Gregory, Anderson, Robert S (2018). *Self-Organized Snow In The Colorado Front Range*. CU Hydrologic Sciences Research Symposium Hydrology Horizons: Innovations in Water Science. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tucker, GE (2016). *Some aspect-related process contrasts in the Boulder Creek Critical Zone Observatory*. Cross-CZO Workshop on Slope-Aspect. Tucson, AZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Jarvis, SK, Barnard, HR, Singha, K, Harmon, RE, Szutu, D (2017). *Spatial and Temporal Patterns In Ecohydrological Separation*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Kochanski, K, Tucker, G, Anderson RS (2018). *Statistical classification of self-organized snow surfaces*. Geoprocesses, geohazards - CSDMS 2018. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Glade, R, and Anderson, RS (2017). *Steady evolution of hillslopes in layered landscapes: self-organization of a numerical hogback*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Leonard, Ryan E, Heckman, Christoffer, Minear, J. Toby, Anderson, Robert S (2018). *StreamSurf: Estimation Of River Stage, Velocity And Discharge Using Computer Vision*. CU Hydrologic Science Symposium Hydrology Horizons: Innovations in Water Science. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Barnhart, TB, Vukomanovic, J, Bourgeron, P, and Molotch, NP (2017). *Streamflow response to future land-cover change at a headwaters catchment spanning the alpine-subalpine transition on the Colorado Front Range*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Selander, B, Anderson, SP, and Rossi, M (2017). *The Breakdown: Hillslope Sources of Channel Blocks in Bedrock Landscapes*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Barnhart, T.B., C.L. Tague, B. Livneh, A.A. Harpold, J.F. Knowles, D. Schneider, and N.P. Molotch (2017). *The Cross-Scale Influence of Snowmelt Rate and Timing on Runoff Production Across the Western United States*. Critical Zone Science:



Current Advances and Future Opportunities. Arlington, Virginia. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Brooks, PD, Swetnam, TL, Barnard, HR, Singha, K, Harpold, A, and Litvak, ME (2017). *The Dual Role of Vegetation as a Constraint on Mass and Energy Flux into the Critical Zone and as an Emergent Property of Geophysical Critical Zone Structure*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Miner, J Toby, Tiampo, K., Livneh, B, Willis, M, Williams, C, and Jacquemart, M. (2018). *The Interaction of Mass Movements with Natural Hazards Under Changing Hydrologic Conditions*. Asia Oceania Geosciences Society 15th Annual Meeting. Honolulu, HI. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Webb, R, Williams, MW, and Erickson, T (2017). *The Spatial and Temporal Variability of Meltwater Flowpaths: Insights from a grid of over 100 Snow Lysimeters*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Murphy, S.F., McCleskey, R.B., Martin, D.A., Writer J.W., and Ebel, B.A (2018). *The alteration of hydrological and biogeochemical behavior after wildfire, and relevance to water quality*. Fire Continuum Conference: Preparing for the Future of Wildland Fire. Missoula, MT. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hinckley, E.S. (2016). *The critical zone: A novel framework for questions in ecosystem biogeochemistry*. CZO Network Review Showcase. Arlington, VA (NSF headquarters). Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shobe, CM, Tucker, GE, and Rossi, M (2017). *The influence of hillslope-derived blocks on erosion rate-channel steepness scaling: Emergence of variable threshold behavior*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Kochanski\*, K., Tucker, G.E., and Anderson, R.S. (2017). *The self-organization of snow surfaces and the growth of sastrugi*. American Geophysical Union fall meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Fierer, N (2018). *The structure and function of soil microbial communities in arid ecosystems*. Science and Technology Center Workshop. Biosphere2, Tucson, AZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Langston, A.L., and Tucker, G.E. (2017). *Using a landscape evolution model to evaluate the role of pulses of uplift on bedrock valley width and channel mobility*. Joint CSDMS-COMSESnet-SEN Meeting: Modeling Coupled Earth and Human Systems. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shobe, CM, Tucker, GE, and Rossi, MW (2017). *Variable thresholds in mountain rivers imposed by hillslope-derived blocks*. Geological Society of America Annual Meeting. Seattle, WA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Langston, AL, and Tucker, GE (2017). *Working Towards Interpreting Strath Terraces as Records of Climate Change: Evaluating a Model of Lateral Bedrock Erosion*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

## **Other Products**

## **Other Publications**

## **Patents**

## **Technologies or Techniques**

## **Thesis/Dissertations**

Schneider, Dominik. *Estimating the Distribution of Snow with Remotely Sensed Fractional Snow Covered Area*. (2016). University of Colorado, Dept. of Geography, PhD dissertation. Acknowledgement of Federal Support = Yes

Foster, Melissa. *From the mountains to the plains: constraining the evolution of Front Range surfaces through Quaternary dating*. (2016). PhD thesis, Geological Sci, Univ of Colorado, Boulder. Acknowledgement of Federal Support = Yes

Bandler, A.. *Geophysical constraints on critical zone architecture and subsurface hydrology of opposing montane hillslopes*. (2016). MS thesis, Colorado School of Mines. Acknowledgement of Federal Support = Yes

Wieting, C. *Quantifying Soil Hydraulic Property Changes with Fire Severity by Laboratory Burning*. (2016). MS thesis, Colorado School of Mines. Acknowledgement of Federal Support = Yes

Barnhart, Theodore B.. *The response of streamflow and evapotranspiration to changes in snowmelt across the western United States*. (2018). PhD dissertation, University of Colorado. Acknowledgement of Federal Support = Yes

Winchell, Eric W.. *Understanding the geomorphic imprint of the Northern Pocket Gopher on the subalpine zone of the Colorado Front Range*. (2017). PhD thesis, Geological Sci, University of Colorado, Boulder. Acknowledgement of Federal Support = Yes

Mills, T. Joseph. *Water chemistry under a changing hydrologic regime: Investigations into the interplay between hydrology and water-quality in arid and semi-arid watersheds in Colorado, USA*. (2016). PhD thesis, Geography, University of Colorado, Boulder. Acknowledgement of Federal Support = Yes

Websites  
Supporting Files

Filename	Description	Uploaded By	Uploaded On
Science- focus on Brewer&Fierer.pdf	Science highlight on Brewer&Fierer paper	Suzanne Anderson	06/26/2018
Delgado Science 2018.pdf	Delgado Science Atlas of bacteria in soil	Suzanne Anderson	06/26/2018

Participants/Organizations

Research Experience for Undergraduates (REU) funding

Form of REU funding support: REU supplement

How many REU applications were received during this reporting period? 40

How many REU applicants were selected and agreed to participate during this reporting period? 10

REU Comments:

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Anderson, Suzanne	PD/PI	3
Anderson, Robert	Co PD/PI	1
Molotch, Noah	Co PD/PI	1
Rajaram, Harihar	Co PD/PI	1
Tucker, Gregory	Co PD/PI	1
Barnard, Holly	Co-Investigator	1

Name	Most Senior Project Role	Nearest Person Month Worked
Doak, Daniel	Co-Investigator	0
Ebel, Brian	Co-Investigator	1
Fierer, Noah	Co-Investigator	1
McKnight, Diane	Co-Investigator	0
Murphy, Sheila	Co-Investigator	1
Sheehan, Anne	Co-Investigator	0
Singha, Kamini	Co-Investigator	1
Templeton, Alexis	Co-Investigator	0
Heindel, Ruth	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Rossi, Matthew	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Carpenter, Eric	Other Professional	2
Curry, Renee	Other Professional	1
Farrell, Emma	Other Professional	1
Langston, Abigail	Other Professional	0
Nadel, Hester	Other Professional	1
Rose, Alex	Other Professional	1
Taylor, Jennifer	Other Professional	0
Jensen, Clayton	Technician	12
Parrish, Eric	Technician	12
Ragar, Dillon	Technician	12
Rock, Nathan	Technician	6
Roth, Wendy	Technician	1
Stoffel, Chad	Technician	1

Name	Most Senior Project Role	Nearest Person Month Worked
Tebbetts Fey, Jeri	Technician	6
Barnhart, Theodore	Graduate Student (research assistant)	3
Brewer, Tess	Graduate Student (research assistant)	6
Bukoski, Isaac	Graduate Student (research assistant)	6
Forrester, Chiara	Graduate Student (research assistant)	1
Foster, Melissa	Graduate Student (research assistant)	0
Glade, Rachel	Graduate Student (research assistant)	6
Harmon, Ryan	Graduate Student (research assistant)	6
Hoffman, Claire	Graduate Student (research assistant)	6
Mills, Taylor	Graduate Student (research assistant)	0
Pandey, Sachin	Graduate Student (research assistant)	0
Rey, David	Graduate Student (research assistant)	3
Rue, Garrett	Graduate Student (research assistant)	0
Rush, Michael	Graduate Student (research assistant)	3
Selander, Brittany	Graduate Student (research assistant)	3
Wilson, Sydney	Graduate Student (research assistant)	0
Winchell, Eric	Graduate Student (research assistant)	0
Cowell, Kristina	Non-Student Research Assistant	8
Glass, Jamie	Non-Student Research Assistant	2
Gulick, Emily	Non-Student Research Assistant	0
Flechsenhaar, Jon	Undergraduate Student	0
Gamora, Joey	Undergraduate Student	0
Garrett, Jordan	Undergraduate Student	2
Gill, Nagam	Undergraduate Student	4

Name	Most Senior Project Role	Nearest Person Month Worked
Graham, Nathan	Undergraduate Student	2
Gupta, Amrita	Undergraduate Student	2
Heithusen, Brett	Undergraduate Student	0
Lanka, Dylan	Undergraduate Student	1
Straight, Joshua	Undergraduate Student	0
Timlin, Hannah	Undergraduate Student	4
Barber, Jesse	Research Experience for Undergraduates (REU) Participant	0
Bean, Scott-Wesley	Research Experience for Undergraduates (REU) Participant	0
Espinoza-Martinez, Amanda	Research Experience for Undergraduates (REU) Participant	0
Fish, Thomas	Research Experience for Undergraduates (REU) Participant	0
Lindgren, Brett	Research Experience for Undergraduates (REU) Participant	0
Ross, Sean	Research Experience for Undergraduates (REU) Participant	0
Schoenfeld, Taylor	Research Experience for Undergraduates (REU) Participant	0
Thirouin, Kevin	Research Experience for Undergraduates (REU) Participant	0
VanderBurgh, Caihong	Research Experience for Undergraduates (REU) Participant	0

#### Full details of individuals who have worked on the project:

##### **Suzanne P Anderson**

**Email:** suzanne.anderson@colorado.edu

**Most Senior Project Role:** PD/PI

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Management of the project. Hiring, supervising staff. Co-managed REU program (RECCS) with Anne Gold and Lesley Smith. Represented CZO at international level, hosting Chinese Geologic Survey team, conferring with German Delta-Earth proposal. Supervised two graduate students, several undergraduates

**Funding Support:** NSF (this project) provides 1.5 months

**International Collaboration:** No  
**International Travel:** No

---

**Robert S Anderson**  
**Email:** andersrs@colorado.edu  
**Most Senior Project Role:** Co PD/PI  
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Supervised CZO grad student, and 2 more doing CZO-relevant work; co-supervised NSF postdoc Jill Marshall, and EarthLab post-doc Matt Rossi. Geochronology, geomorphology measurements and modeling

**Funding Support:** NSF (this project) \$1500

**International Collaboration:** No  
**International Travel:** No

---

**Noah P Molotch**  
**Email:** noah.molotch@colorado.edu  
**Most Senior Project Role:** Co PD/PI  
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Supervised 1 CZO supported grad student, and another doing relevant work. Co-supervised cross-CZO post-doc Adam Wlostowski with Ciaran Harman (Johns Hopkins). Supervised post-doc Ryan Webb. Snow hydrology, snow measurements, modeling.

**Funding Support:** NSF (this project) \$1500

**International Collaboration:** No  
**International Travel:** No

---

**Harihar Rajaram**  
**Email:** hari@colorado.edu  
**Most Senior Project Role:** Co PD/PI  
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Supervised CZO graduate student. Groundwater transport and modeling.

**Funding Support:** NSF (this project) \$1500.

**International Collaboration:** No  
**International Travel:** No

---

**Gregory E Tucker**  
**Email:** gtucker@cires.colorado.edu  
**Most Senior Project Role:** Co PD/PI  
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Supervised grad student doing CZO relevant work; co-supervised NSF post-doc Jill Marshall and EarthLab post-doc Matt Rossi. Landscape evolution modeling.

**Funding Support:** NSF (this project) \$1500.

**International Collaboration:** No  
**International Travel:** No

---

**Holly Barnard****Email:** holly.barnard@colorado.edu**Most Senior Project Role:** Co-Investigator**Nearest Person Month Worked:** 1**Contribution to the Project:** Research on ecohydrology, forest evapotranspiration. Co-supervising CZO grad student (with Sheila Murphy)**Funding Support:** NSF (this project) DOE**International Collaboration:** No**International Travel:** No

---

**Daniel Doak****Email:** daniel.doak@colorado.edu**Most Senior Project Role:** Co-Investigator**Nearest Person Month Worked:** 0**Contribution to the Project:** Research on ecology, biological roles in transport processes; has not been active in BcCZO in this year.**Funding Support:** NSF**International Collaboration:** No**International Travel:** No

---

**Brian Ebel****Email:** bebel@usgs.gov**Most Senior Project Role:** Co-Investigator**Nearest Person Month Worked:** 1**Contribution to the Project:** Research on hydrology and response to extreme events.**Funding Support:** USGS**International Collaboration:** No**International Travel:** No

---

**Noah Fierer****Email:** noah.fierer@colorado.edu**Most Senior Project Role:** Co-Investigator**Nearest Person Month Worked:** 1**Contribution to the Project:** Research on microbial ecology. Supervising CZO graduate student, and post-doc Paul Carini. Working with microbial ecologists, soil scientists, and biogeochemists from every CZO site to plan, coordinate, and implement a cross-CZO microbial ecology that spans all current CZO sites.**Funding Support:** NSF (this project) \$1500**International Collaboration:** No**International Travel:** No

---

**Diane McKnight****Email:** diane.mcknight@colorado.edu**Most Senior Project Role:** Co-Investigator**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research on biogeochemistry and organic matter.

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Sheila Murphy**

**Email:** sfmurphy@usgs.gov

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Research on hydrology, geochemistry and disturbance. Five years of storm sampling have yielded an unprecedented post-fire water quality dataset and has allowed us to evaluate the effects of different types of storms on post-fire water quality. Co-supervising CZO grad student with Holly Barnard.

**Funding Support:** USGS NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Anne Sheehan**

**Email:** anne.sheehan@colorado.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research on applied geophysics

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Kamini Singha**

**Email:** ksingha@mines.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Research on hydrogeology and geophysical measurements of the critical zone. Supervised 3 graduate students.

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

---

**Alexis Templeton**

**Email:** alexis.templeton@colorado.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research on geobiology and incipient weathering

**Funding Support:** NSF



**International Collaboration:** No  
**International Travel:** No

---

**Ruth Heindel**

**Email:** Ruth.Heindel@Colorado.EDU

**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Post-doctoral researcher supervised by Eve Hinckley and Mike Gooseff; working on dust and nutrient (mostly P) deposition in the Front Range, and in Arctic environments (also supported by McMurdo LTER).

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Matthew Rossi**

**Email:** matthew.rossi@colorado.edu

**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Post-doctoral researcher with EarthLab, supervised by Bob Anderson, Greg Tucker, and Suzanne Anderson, working on hydroclimatology of Front Range and landscape evolution; rock glaciers; topographic analysis.

**Funding Support:** NSF and CU's EarthLab

**International Collaboration:** No

**International Travel:** No

---

**Eric Carpenter**

**Email:** eric.carpenter@colorado.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 2

**Contribution to the Project:** Education designer- K-12 outreach and teacher professional development

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Renee Curry**

**Email:** Renee.Curry@Colorado.EDU

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Renee is the manager of the RECCS REU program.

**Funding Support:** NSF (this project), CIRES

**International Collaboration:** No

**International Travel:** No

---

**Emma Farrell**

**Email:** emma.farrell-1@colorado.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Accounting technician for PI Suzanne Anderson

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Abigail Langston**

**Email:** abigail.langston@colorado.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Left Colorado in 2015.

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Hester Nadel**

**Email:** hester.nadel@colorado.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Admin support for education outreach (Science Discovery)

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Alex Rose**

**Email:** alexandra.rose@colorado.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Manager for outreach Field science and Citizen science (5% time). Runs High School research experience in summer.

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Jennifer Taylor**

**Email:** jennifer.l.taylor@colorado.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Former administrative support for REU site (NSF Award 1461281, REU Site: Research Experience for Community College Students (RECCS) in Critical Zone Science)

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Clayton Jensen**

**Email:** clayton.jensen@colorado.edu

**Most Senior Project Role:** Technician

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Lab manager, sampling, data generation, and analysis

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Eric Parrish**

**Email:** eric.parrish@colorado.edu

**Most Senior Project Role:** Technician

**Nearest Person Month Worked:** 12

**Contribution to the Project:** GIS-graphics specialist; web support; working on children's book

**Funding Support:** NSF (this project; CZO Integrated data management) and INSTAAR

**International Collaboration:** No

**International Travel:** No

---

**Dillon Ragar**

**Email:** Dillon.Ragar@Colorado.EDU

**Most Senior Project Role:** Technician

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Manager of field program, works closely with lab manager and data manager; has taken over from N. Rock.

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Nathan Rock**

**Email:** nathan.rock@colorado.edu

**Most Senior Project Role:** Technician

**Nearest Person Month Worked:** 6

**Contribution to the Project:** Field manager, sensor network and sampling, primary data generation; Left University Feb 2018

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Wendy Roth****Email:** wendy.freeman@colorado.edu**Most Senior Project Role:** Technician**Nearest Person Month Worked:** 1**Contribution to the Project:** Sediment lab coordinator.**Funding Support:** NSF**International Collaboration:** No**International Travel:** No

---

**Chad Stoffel****Email:** chad.stoffel@colorado.edu**Most Senior Project Role:** Technician**Nearest Person Month Worked:** 1**Contribution to the Project:** IT support**Funding Support:** NSF (this project)**International Collaboration:** No**International Travel:** No

---

**Jeri Tebbetts Fey****Email:** jeri.tebbetts@colorado.edu**Most Senior Project Role:** Technician**Nearest Person Month Worked:** 6**Contribution to the Project:** Data manager; participates in cross-CZO data managers working group. Left University January, 2017.**Funding Support:** NSF (this project)**International Collaboration:** No**International Travel:** No

---

**Theodore Barnhart****Email:** theodore.barnhart@colorado.edu**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 3**Contribution to the Project:** Research on hydrologic partitioning and snowmelt; cross-CZO work with Christina (Naomi) Tague, using RHESSys. Completed PhD spring 2018.**Funding Support:** NSF (this project)**International Collaboration:** No**International Travel:** No

---

**Tess Brewer****Email:** Tess.Brewer@Colorado.EDU**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 6**Contribution to the Project:** PhD research on microbial ecology and microbial function

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Isaac Bukoski**

**Email:** ibukoski1@gmail.com

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 6

**Contribution to the Project:** Research on ecohydrology; starting July 2017

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Chiara Forrester**

**Email:** Chiara.Forrester@colorado.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Research on snow mold and N dynamics; partial support

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Melissa Foster**

**Email:** melissa.a.foster@colorado.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Completed PhD with Bob Anderson in 2016.

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Rachel Glade**

**Email:** rcglade@gmail.com

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 6

**Contribution to the Project:** Hillslope geomorphology research

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

---

**Ryan Harmon**

**Email:** ryanharmon@mymail.mines.edu

**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 6

**Contribution to the Project:** Ryan is a Colorado School of Mines student, working between Kamini Singha and Holly Barnard on ecohydrology projects on tree-water use.

**Funding Support:** Unsupported Colorado School of Mines student

**International Collaboration:** No  
**International Travel:** No

---

**Claire Hoffman**

**Email:** clho9798@colorado.edu

**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 6

**Contribution to the Project:** Research on hydrology and weathering; starting July 2017

**Funding Support:** NSF (this project)

**International Collaboration:** No  
**International Travel:** No

---

**Taylor Joseph Mills**

**Email:** taylor.mills@colorado.edu

**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 0

**Contribution to the Project:** Completed PhD with Suzanne Anderson in Fall 2016.

**Funding Support:** none

**International Collaboration:** No  
**International Travel:** No

---

**Sachin Pandey**

**Email:** sachin.pandey@colorado.edu

**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 0

**Contribution to the Project:** Completed PhD with Hari Rajaram in 2015.

**Funding Support:** none

**International Collaboration:** No  
**International Travel:** No

---

**David Rey**

**Email:** drey@mymail.mines.edu

**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 3

**Contribution to the Project:** Rey is a Colorado School of Mines graduate student, working jointly with Niwot LTER and BcCZO under the supervision of Kamini Singha and Eve Hinckley. His work is on hydrogeophysics of seasonally frozen ground.

**Funding Support:** NSF (this project), Niwot LTER, USGS

**International Collaboration:** No

**International Travel:** No

---

**Garrett Rue**

**Email:** Garrett.Rue@Colorado.EDU

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research on dissolved organic matter, especially in flood waters

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Michael Rush**

**Email:** michael.rush-1@colorado.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Research on coupled thermo-hydrologic models incorporating snowmelt and PFLOTRAN. Involved in outreach with RECCS and Science Discovery.

**Funding Support:** NSF (this project); Fulbright

**International Collaboration:** No

**International Travel:** No

---

**Brittany Selander**

**Email:** brittany.selander@Colorado.EDU

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Research on rock-dominated hillslopes; summer 2018 support

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Sydney Wilson**

**Email:** sywilson@mymail.mines.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Completed MS with Kamini Singha in 2015.

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Eric Winchell**

**Email:** eric.winchell@colorado.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Completed PhD with Bob Anderson in 2017.

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Kristina Cowell**

**Email:** Kristina.Cowell@Colorado.EDU

**Most Senior Project Role:** Non-Student Research Assistant

**Nearest Person Month Worked:** 8

**Contribution to the Project:** Undergraduate work study field assistant through Dec 2017; then Temporary aide (full time) through May 2018.

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Jamie Glass**

**Email:** ocephus@gmail.com

**Most Senior Project Role:** Non-Student Research Assistant

**Nearest Person Month Worked:** 2

**Contribution to the Project:** Undergraduate work study field assistant. Graduated in Fall 2016, continued on as a field assistant in Fall 2017.

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Emily Gulick**

**Email:** emily.gulick@colorado.edu

**Most Senior Project Role:** Non-Student Research Assistant

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Completed senior honors thesis in 2016.

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Jon Flechsenhaar**

**Email:** Jon.Flechsenhaar@Colorado.EDU

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Undergraduate field assistant; now working for Niwot LTER



**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

---

**Joey Gamora**

**Email:** joeygomora@gmail.com

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 0

**Contribution to the Project:** 2015 REU participant working on watershed hydrology with Mike Gooseff; continued work as CU undergraduate for short period.

**Funding Support:** Supplement to this grant (NSF)

**International Collaboration:** No

**International Travel:** No

---

**Jordan Garrett**

**Email:** jordan.garrett@colorado.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 2

**Contribution to the Project:** Undergraduate work-study field assistant

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Nagam Gill**

**Email:** nagam.gill@colorado.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 4

**Contribution to the Project:** Undergraduate work study field assistant.

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Nathan Graham**

**Email:** nathangraha13@gmail.com

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 2

**Contribution to the Project:** Undergraduate work-study field assistant

**Funding Support:** NSF (this project)

**International Collaboration:** No

**International Travel:** No

---

**Amrita Gupta**

**Email:** Amrita.Gupta@Colorado.EDU  
**Most Senior Project Role:** Undergraduate Student  
**Nearest Person Month Worked:** 2

**Contribution to the Project:** Undergraduate work study field assistant.

**Funding Support:** NSF (this project)

**International Collaboration:** No  
**International Travel:** No

---

**Brett Heithusen**  
**Email:** brett.Heitshusen@colorado.edu  
**Most Senior Project Role:** Undergraduate Student  
**Nearest Person Month Worked:** 0

**Contribution to the Project:** Graduated in 2016, left Colorado in spring 2016.

**Funding Support:** none

**International Collaboration:** No  
**International Travel:** No

---

**Dylan Lanka**  
**Email:** dylan.lanka@colorado.edu  
**Most Senior Project Role:** Undergraduate Student  
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Completed undergraduate honors thesis (summa cum laude) in spring 2018.

**Funding Support:** NSF (this project) and Geography Dept. Von Dreden-Stacey research fund

**International Collaboration:** No  
**International Travel:** No

---

**Joshua Straight**  
**Email:** Joshua.Straight@Colorado.EDU  
**Most Senior Project Role:** Undergraduate Student  
**Nearest Person Month Worked:** 0

**Contribution to the Project:** Former undergraduate work study field assistant.

**Funding Support:** none

**International Collaboration:** No  
**International Travel:** No

---

**Hannah Timlin**  
**Email:** hannah.timlin@colorado.edu  
**Most Senior Project Role:** Undergraduate Student  
**Nearest Person Month Worked:** 4

**Contribution to the Project:** Undergraduate work-study field assistant

**Funding Support:** NSF (this project)

**International Collaboration:** No  
**International Travel:** No

---

**Jesse Barber**

**Email:** jbanddawn@att.net

**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research in summer 2016 with Theo Barnhart on assessing trends in forest type and density in the Boulder Creek watershed.

**Funding Support:** none

**International Collaboration:** No

**International Travel:** No

**Year of schooling completed:** Sophomore

**Home Institution:** Red Rocks Community College, Lakewood, CO

**Government fiscal year(s) was this REU participant supported:** 2016

---

**Scott-Wesley Bean**

**Email:** scottwesleybean@gmail.com

**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research with Noah Fierer and Tess Brewer on the microbial ecology of the atmosphere in 2016.

**Funding Support:** NSF1461281

**International Collaboration:** No

**International Travel:** No

**Year of schooling completed:** Sophomore

**Home Institution:** Arapahoe Community College, Littleton, CO

**Government fiscal year(s) was this REU participant supported:** 2016

---

**Amanda Espinoza-Martinez**

**Email:** amanda\_espinozam@hotmail.com

**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research with Mike Gooseff on base flow hydrology in Gordon Gulch.

**Funding Support:** NSF1461281

**International Collaboration:** No

**International Travel:** No

**Year of schooling completed:** Sophomore

**Home Institution:** Community College of Denver

**Government fiscal year(s) was this REU participant supported:** 2016

---

**Thomas Fish**

**Email:** thomaswfish@yahoo.com

**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research with Theo Barnhart on assessing trends in forest type and density In the Boulder Creek watershed

**Funding Support:** NSF1461281

**International Collaboration:** No

**International Travel:** No

**Year of schooling completed:** Sophomore

**Home Institution:** Community College of Aurora, Aurora, CO

**Government fiscal year(s) was this REU participant supported:** 2016

---

**Brett Lindgren**

**Email:** BrettLindgren87@gmail.com

**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research with Dave Barnard on using laser scanning to quantify the interception of solar radiation by forest canopies

**Funding Support:** NSF1461281

**International Collaboration:** No

**International Travel:** No

**Year of schooling completed:** Sophomore

**Home Institution:** Colorado Northwest Community College: Craig, CO

**Government fiscal year(s) was this REU participant supported:** 2016

---

**Sean Ross**

**Email:** seanlross@gmail.com

**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research w/Suzanne Anderson on rock weathering.

**Funding Support:** NSF1461281

**International Collaboration:** No

**International Travel:** No

**Year of schooling completed:** Sophomore

**Home Institution:** Red Rocks Community College, Lakewood, CO

**Government fiscal year(s) was this REU participant supported:** 2016

---

**Taylor Schoenfeld**

**Email:** teschoenfeld@student.cccs.edu

**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant

**Nearest Person Month Worked:** 0

**Contribution to the Project:** Research with Greg Tucker and Charlie Shobe on how large blocks of rock are distributed in river channels.

**Funding Support:** NSF1461281

**International Collaboration:** No

**International Travel:** No

**Year of schooling completed:** Sophomore

**Home Institution:** Front Range Community College, Fort Collins, CO

**Government fiscal year(s) was this REU participant supported:** 2016

---

**Kevin Thirouin****Email:** kevin.thirouin@gmail.com**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant**Nearest Person Month Worked:** 0**Contribution to the Project:** 2015 REU researcher working with Dave Barnard and Holly Barnard, now supported by Supplement to this grant.**Funding Support:** Supplement to this grant (NSF)**International Collaboration:** No**International Travel:** No**Year of schooling completed:** Sophomore**Home Institution:** Red Rocks Community College**Government fiscal year(s) was this REU participant supported:** 2016

---

**Caihong VanderBurgh****Email:** qiucaihong67@gmail.com**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant**Nearest Person Month Worked:** 0**Contribution to the Project:** 2015 REU research with Noah Fierer, now supported by Supplement to this grant.**Funding Support:** Supplement to this grant (NSF)**International Collaboration:** No**International Travel:** No**Year of schooling completed:** Sophomore**Home Institution:** Front Range Community College-Westminster**Government fiscal year(s) was this REU participant supported:** 2016

---

**What other organizations have been involved as partners?**

Name	Type of Partner Organization	Location
CIRES	Academic Institution	University of Colorado
Colorado School of Mines	Academic Institution	Golden, CO
Niwot Ridge LTER	Other Organizations (foreign or domestic)	Boulder, CO
United States Geological Survey	Other Organizations (foreign or domestic)	Boulder, CO

---

**Full details of organizations that have been involved as partners:****CIRES****Organization Type:** Academic Institution**Organization Location:** University of Colorado**Partner's Contribution to the Project:**

Personnel Exchanges

**More Detail on Partner and Contribution:** BcCZO-II has partnered with CIRES to run RECCS (Research Experience for Community College Students) in summers 2015-2017, and will continue in summer 2018. Both groups are contributing to the considerable administrative and intellectual work required to support 10 community college students. CIRES researcher Toby Minear is spearheading a group from CIRES Earth Science and Observation Center (ESOC) that is leveraging BcCZO data in a NASA Cascading Hazards project.

---

### Colorado School of Mines

**Organization Type:** Academic Institution

**Organization Location:** Golden, CO

**Partner's Contribution to the Project:**

Collaborative Research

Personnel Exchanges

**More Detail on Partner and Contribution:** Professor Kamini Singha is a member of the team, and is spearheading work on geophysics and hydrogeology. She has several grad students and a post-doc working in BcCZO; we have requested supplemental funding to provide partial support to a Mines student who would work between BcCZO and Niwot LTER.

---

### Niwot Ridge LTER

**Organization Type:** Other Organizations (foreign or domestic)

**Organization Location:** Boulder, CO

**Partner's Contribution to the Project:**

Facilities

Personnel Exchanges

**More Detail on Partner and Contribution:** Boulder Creek CZO shares one field site- Green Lakes Valley- with the Niwot LTER. LTER personnel assist CZO personnel, and we are beginning some collaboration on hydrology and frost processes on Niwot Ridge.

---

### United States Geological Survey

**Organization Type:** Other Organizations (foreign or domestic)

**Organization Location:** Boulder, CO

**Partner's Contribution to the Project:**

Facilities

Collaborative Research

**More Detail on Partner and Contribution:** USGS scientists Sheila Murphy and Brian Ebel are members of the team, and bring expertise in fires, hydrology, and geochemistry. Murphy has spearheaded monitoring in Fourmile Canyon in the wake of the 2010 Fourmile Canyon wildfire. Ebel is a hydrologist who has worked on understanding runoff generation.

---

### What other collaborators or contacts have been involved?

Nothing to report

---

## Impacts

**What is the impact on the development of the principal discipline(s) of the project?**

BcCZO's work on microbial ecology is cutting edge within the microbial field, and connects critical zone science to the bustling world of microbiology. This field is growing at an incredible pace; costs and time required to identify microbial taxa has fallen in the years of the project. This means that it is difficult to project even the methods that will be employed in coming years. Fierer and his team have produced high profile publications that help narrow down the number of bacterial taxa that we need to target to understand major soil functions (Delgado-Baquerizo et al., 2018). This focuses attention on the important question of "who" to study amongst the soil microbial community. They have found associations of microbes by rock type and climate on rock surfaces (Brewer and Fierer, 2018), and they are now working on a similar analysis of deep soil communities. Sampling and analysis is complete for a study on seasonal changes in surface soil communities (Carini et al in prep). These contributions should take us several more steps toward understanding microbial soil functions.

We have made great strides in understanding bedrock slopes and their connections to channel incision through modeling work by Charlie Shobe and Rachel Glade (and their advisors Greg Tucker and Bob Anderson). In fact, Rachel's model of landscape evolution of a hogback (rock slopes in tilted strata with a hard rock layer overlies a softer rock layer) earned 2nd place in the 2018 Jai Syvitski Student Modeling competition at the CSDMS Annual Meeting. Rock slopes remain enigmas in the landscape evolution world, because it is extremely difficult to capture the dynamic of having some areas accumulate soil and other areas shed soil to produce the mixed soil and outcrop morphology that we see in steep terrains world wide. These are fundamental critical zone processes.

The importance of snow, rain, and vegetation on water supply can be judged from the number of researchers grappling with the problems. Understanding rain and snow contributions to streamflow is a focus for at least three researchers within BcCZO at present (SP Anderson, Kate Hale/N Molotch, Isaac Bukoski/H Barnard/S Murphy), and has been a focus in the past as well. We also have two teams working on frozen ground impacts on runoff generation, for the purposes of understanding past and future streamflow. Mickey Rush has focused on Gordon Gulch in his modeling, and David Rey/Kamini Singha/Eve Hinckley are interested in these processes in Niwot Ridge's Saddle catchment. The latter project represents a collaboration between Niwot LTER and BcCZO, drawing the best of both projects.

#### **What is the impact on other disciplines?**

Nothing to report.

#### **What is the impact on the development of human resources?**

- **4 professional staff members** are supported by BcCZO. We encourage and offers opportunities to develop skills and expand horizons
- **7 graduate students** received full or partial support from BcCZO in the last year (Brewer, Rush, Glade, Forrester, Selander, Hoffman, Bukoski)
- At least **6 additional graduate students** work in/with BcCZO sites or data, without receiving direct financial support from the CZO (Harmon, Hermes, Zhang, Kochanski, Shobe, Rue)
- **4 post-docs** have worked with BcCZO in the last year, 2 with direct financial support from BcCZO, and 2 because of the data and knowledge infrastructure resources we provide (Wlostowski, Heindel, Webb, Rossi)
- BcCZO has supported financially and intellectually the RECCS REU program, which provides a pipeline for students from community college to 4-year schools and beyond.
- BcCZO staff and students ran several stations during the annual INSTAAR Open House, which brings ~120 middle school students to visit.

#### **What is the impact on physical resources that form infrastructure?**

BcCZO supports staffing for sample collection and instrument maintenance from 2 National Atmospheric Deposition Program monitoring sites. These sites would not operate without our support.

BcCZO's instrumentation in Gordon Gulch and Betasso, including groundwater wells, weather stations, snow depth measurements, stream gages and soil volumetric water content sensors, are unique at their altitudes in the Colorado Front Range. We literally help fill in the gap between the heavily studied alpine terrain and the Plains.

#### **What is the impact on institutional resources that form infrastructure?**

Nothing to report.

#### **What is the impact on information resources that form infrastructure?**

Nothing to report.

**What is the impact on technology transfer?**

Nothing to report.

**What is the impact on society beyond science and technology?**

Eric Parrish has worked with Suzanne Anderson to create a children's book (aimed at K-3rd grade) on the critical zone. The book with working title "Discover the Critical Zone: Where Rock meets Life", follows a young girl on a hike in the mountains with her parents. She sees soil exposed by a fallen tree, which opens up the world of rock weathering, water movement, organism growth and death, and chemical cycling. Parrish and Anderson are now working with an agent to find a publisher for the book; she is confident that the content, style, artwork and science are ripe for publication in a commercial market. Parrish would like to grow this into a book series that could make significant contributions to early childhood science enrichment.

---

## Changes/Problems

**Changes in approach and reason for change**

Nothing to report.

**Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

**Changes that have a significant impact on expenditures**

Nothing to report.

**Significant changes in use or care of human subjects**

Nothing to report.

**Significant changes in use or care of vertebrate animals**

Nothing to report.

**Significant changes in use or care of biohazards**

Nothing to report.