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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 - 11/30/2020
Reporting Period:	10/01/2018 - 09/30/2019
Submitting Official (if other than PD\PI):	Suzanne P Anderson Principal Investigator
Submission Date:	10/05/2019
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), including maintenance of an alpine deep ground temperature monitoring site on Niwot Ridge, supported two NADP sample collection sites established in 2017, completed a full year of dust sampling 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 8 journal papers (in top-tier journals such as *Water Resources Research*, *Science of the Total Environment*, and *PNAS*). An additional paper is in press.
4. Hosted a visit from Julia Franzen, a student from ETH seeking additional field sites for her dissertation.
5. Participated in DOE's WHONDERS Worldwide Hydrobiogeochemistry sampling campaign, August 2019.
6. Graduated three PhD students (Tess Brewer, Molecular, Cellular and Developmental Biology; Rachel Glade, Geological Sciences; Charlie Shobe, Geological Sciences), two Masters students (Isaac Bukowski and Noah Hoffman, Geography), and one undergraduate senior thesis (Kevin Knopp, Geography).
7. Held team meetings during the academic year.
8. Received CU Outreach Award funding to build an exhibit on "Past, Present, Future: Exploring Boulder's Natural Environment" for the Museum of Boulder. Collaboration between BcCZO, Niwot LTER, and the Center for Water, Earth Science and Technology.
9. PI Anderson wrapped up guest editing special issue of *Hydrological Processes* (with Ying Fan Reinfelder, Rutgers University, and Gordon Grant, USFS/OSU) titled "Water in the Critical Zone".
10. 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; researcher Matt Rossi; grad students Rachel Glade, Charlie Shobe and Brittany Selander. **Two papers** (Glade et al., 2019, Anderson RS et al., 2019) published. **Two dissertations** completed (Glade, 2019; Shobe, 2019).
11. Goal 2, *Understand how individual processes shape the critical zone* (process to form): Process work has focused on atmospheric deposition, 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, Noah Hoffman. **Three papers published** (Wetherbee et al., 2019; Anderson SP, 2019; Delgado-Baquerizo et al., 2019). **One master's thesis** completed (Hoffman, 2019), **one dissertation** completed (Brewer, 2019).
12. 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, Mickey Rush. **Two papers published** (Barnard et al., 2018; Webb et al., 2018). **One master's thesis** completed (Bukoski, 2019).

Specific Objectives:

1) Maintain monitoring in existing catchments, coordinate with Niwot Ridge LTER on field monitoring in the alpine settings. Maintain sampling at the two NADP sites (Betasso and Boulder) we established in 2017.

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, and pays for analyses.

1.4 Field personnel participated in Niwot LTER annual Green Lakes Valley snow survey.

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

2.1 Wlostowski produced a manuscript with 15 co-authors from all 9 CZOs for Water Resources Research. The manuscript is in its 3rd round of revision as of September 2019, and we hope will be submitted within a few weeks.

2.2 Wlostowski presented work at 2018 AGU Fall meeting, and in 3 job talks (U Wisconsin, Penn State, North Carolina State).

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 has not been accomplished.

4) Publish on 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 completed analyses and submitted a manuscript to PNAS in January 2019 on microbial communities found in deeper soil horizons. The manuscript was rejected, and has been resubmitted.

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

5.1 All manuscripts are now accepted, and the Introduction is being finalized.

6) 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). **Outcome:** Paper published in January 2019 (Anderson RS et al., 2019, *Hydrological Processes*, *Climate driven co-evolution of weathering profiles and hillslope topography generates dramatic differences in critical zone architecture*).
- 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) **Outcomes:** 4 presentations at 2018 AGU meeting. Published Glade et al., 2019, *Geology*, *Canyon shape and erosion dynamics governed by channel-hillslope feedbacks*. Glade dissertation, 2019; Shobe dissertation, 2019.
- Development and exploration of computational models for snow bedform genesis (Kochanski, Tucker, RS Anderson) **Outcomes:** 1 presentation at 2018 AGU meeting. Published Kochanski et al., 2019, *Cryosphere*, *The evolution of snow bedforms in the Colorado Front Range and the processes that shape them*.
- Publish paper in *Elements* (SP Anderson). **Outcome:** Published Anderson, SP, 2019, *Elements*, *Breaking it down: Mechanical processes in the weathering engine*
- 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). **Outcome:** Paper was accepted in September 2019, and is now in press: Anderson SP, et al. *"Is this steady state? Weathering and critical zone architecture in Gordon Gulch, Colorado Front Range"*

7) **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 (Carini, Fierer, Hinckley) **Outcome:** Since Carini started a faculty position at U Arizona more than a year ago, progress on this manuscript has come to a stand-still.
- 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). **Outcome:** Manuscript (Brewer and 24 others, *Ecological and genomic attributes of novel bacterial taxa that thrive in subsurface soil horizons.*) was submitted to PNAS and rejected; it has now been revised and resubmitted.
- Support field measurements of forces at the root-rock interface at both the Eel River and Boulder Creek CZOs (Marshall). **Outcome:** Marshall removed force sensors from Betasso in May 2019, as several were failing. Marshall and field manager Ragar are working to synch clocks on force sensors and an anemometer in Gordon Gulch so that high frequency (5-12 Hz) data can be analyzed to examine wind stress and tree response. Marshall is also coordinating her work with a new pilot project by Ethan Gutman (NCAR) and Holly Barnard on wind and trees in Betasso.
- Submit manuscript on controls on vertical structure of bioturbation by gophers using Cs and 210Pb, model behavior observed (Winchell, RS Anderson). **Outcome:** This goal was not reached.
- Analyze soil water samples in context of precipitation, stream water and groundwater samples to understand chemical weathering processes (Noah Hoffman and SP Anderson). **Outcome:** Hoffman completed their MA thesis "*Lithogenic mixing model approach identifies saprolite as the source of inorganic colloids in a granitoid catchment*", and is now working on a manuscript for publication.

8) **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). **Outcome:** Bukoski completed his MA thesis "*Hydrologic flowpaths in foothill catchments of the Colorado Front Range*", worked at USGS via NSF INTERN funding, and is working on a manuscript for publication.
- Model annual snow fraction in runoff in Gordon Gulch, and simulate changes in a warming climate (Kate Hale, Molotch). **Outcome:** Hale completed her MA thesis "*Streamflow sensitivity to climate warming and a shift from snowfall to rainfall*", and is now working on a PhD on related topics.
- Submit paper on Gordon Gulch hydrology (SP Anderson). **Outcome:** Manuscript is still in preparation, and submission is planned within the next 6 months.
- Submit paper on extreme precipitation event in Betasso (SP Anderson, Matt Rossi) **Outcome:** Manuscript by Rossi et al. is in revision.

Significant Results:

Landscape evolution: Members of our team have been working in parallel on understanding bedrock-dominated landscapes. Rachel Glade and Charlie Shobe have worked from hillslope and channel perspectives, respectively, on the influence of large rock blocks on landscape evolution. They show that the presence of large blocks affects channel incision, and this has feedbacks on hillslope evolution. In parallel with this work, Brittany Selander and Matt Rossi have worked on identifying locations of bedrock in landscapes from topographic analysis. Selander uses a slope and curvature-based algorithm, while Rossi is using a slope algorithm. Rossi argues in a manuscript in review (Rossi et al., GRL) that distribution of bedrock is a key component of critical zone architecture that affects the hydrologic response to precipitation and runoff.

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 global analysis of belowground microbial biodiversity in a series of soil chronosequences published in PNAS (Delgado-Baquerizo et al., 2019). This study showed that changes in belowground biodiversity were not correlated with changes in plant diversity. In low nutrient ecosystems, these changes were

correlated, but in wetter, more productive ecosystems, soil acidification led to a reduction in belowground biodiversity that contrasted with changes in plant biodiversity.

Atmospheric deposition: Boulder Creek CZO has collaborated with Greg Wetherbee (USGS) to support development of an urban-rural transect of monitoring sites to measure reactive inorganic nitrogen deposition at fine geographic resolution. BcCZO supported two new NADP monitoring stations (Skylab in Boulder, and Betasso), which fill the gap between stations in the Denver urban area and long-running sites in the alpine. The first analysis of >1 year of collection reveals that N wet deposition varies with land surface elevation and population density, and demonstrates that the urban influence cannot be accurately characterized with sparse data. The work was published (Wetherbee et al., 2019). The urban-rural monitoring network made headlines for a USGS open-file report published in 2019 documenting atmospheric deposition of microplastics in the Colorado Front Range, including in Rocky Mountain National Park (Wetherbee et al., 2019, *It is raining plastic*, US Geological Survey Open File Report 2019-1048, 1 sheet, available at <https://doi.org/10.31.33/ofr20191048>.) Although BcCZO is not a co-author or cited in the open-file report, the two BcCZO supported sites (CO84 and CO85) are in the network of sites in which these findings were made, and our Betasso monitoring site is called out as an “urban” site, despite its location some 10 km west of the city of Boulder.

Key outcomes or Other achievements:

Rachel Glade and Charlie Shobe finished their dissertations on rocky hillslopes and blocks in channels, respectively. Before they went off to new post-doctoral positions (Glade at Los Alamos, Shobe at GFZ), they built a model of the coevolution of rocky hillslopes and channels together. This was published in Glade et al. (2019). Brittany Selander (working with Suzanne Anderson) has been refining her analysis of bedrock and tree cover on the walls of Boulder Canyon. She is beginning to measure the effects of trees on fractures with instrumentation purchased with a GSA student grant.

Tess Brewer completed her dissertation on ecology of soil bacteria and archaea in May. She worked briefly as a post-doc on cross-CZO microbial data over the summer, before heading to a post-doc in Switzerland. Her rejected PNAS manuscript titled “Ecological and genomic attributes of novel bacterial taxa that thrive in subsurface soil horizons” included in the 25 co-authors a representative from every CZO as well as several people not associated with a CZO. Brewer revised and resubmitted the manuscript speedily.

PhD student Michael (Mickey) Rush was a Fulbright Scholar and CZO-SAVI International Scholar in 2018. He spent 8 months at the Centro de Investigacion en Ecosistemas de la Patagonia (CIEP) in Chile working on hydrology of the snow dominated headwaters of the Rio Coyhaique. He built a field monitoring system, and built a simple hydrologic model of the system. Most important, he gained confidence as a researcher and scientist. See <https://www.colorado.edu/ceae/2019/02/12/interview-phd-student-mickey-rush-hydrology-research-patagonia>

The experiences of the two significant cross-CZO manuscripts spearheaded by post-docs located at the University of Colorado illustrate the challenges of this kind of network science. Adam Wlostowski ran into numerous delays with the cross-CZO water balance/hydrological manuscript he is lead author of because of issues raised by co-authors. Dr. Wlostowski has been more than accommodating in waiting for and responding to co-author input, but doing so has made the process incredibly slow. He has been trying to submit the manuscript for more than 6 months. Tess Brewer was able to submit the cross-CZO microbial analysis manuscript without significant delay, but was rejected in the first submittal to PNAS due to lack of cohesion.

*** 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 met regularly with supervisor Noah Molotch, and virtually with co-supervisor Ciaran Harnan (Johns Hopkins). He traveled to all CZOs, and worked diligently to produce a truly cross-CZO analysis of water storage and runoff; the manuscript is in final final revisions before submission. Wlostowski is now in geotechnical consulting in the Boulder area.

EarthLab post-doc Matt Rossi has transitioned to a Research Associate position, and still meets with “Team Erosion” (Greg Tucker, Bob Anderson, Suzanne Anderson) on alternate weeks to discuss projects and development topics. He has a manuscript in revision with

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

Graduate students

Graduate student Mickey Rush is working with Eric Parrish and others on exhibits for the joint LTER-CWEST-BcCZO outreach award to build a Museum of Boulder exhibit on the Boulder Creek watershed.

Graduate students Katherine Hale and Mickey Rush were on the steering committee responsible for organizing the student-run Hydrological Sciences Research Symposium at CU Boulder in April 2019.

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 2018, 10 students participated. BcCZO did not provide this support in the summer of 2019, although Greg Tucker did mentor a student (who has now transferred from community college to CU and is comfortably embedded in the geomorphology-hydrology graduate student milieu).

Undergraduates: other activities

Undergraduate senior thesis: Kevin Knopp, BA Physical Geography, 2019. Senior thesis: *Mass balance of the Arikaree Glacier*. Supervised by Suzanne Anderson.

Undergraduate field assistants are hired through the work-study program to maintain our field instrumentation and sampling program. We look for students who can stay with us for a number of years. They learn about dataloggers, data quality control, water sampling, sample handling and reporting protocols, and numerous other skills. The best become mentors for new workers. One of our current undergraduate workers (Nagam Gill) is now poised to begin working for us full time upon graduation in December, and manage our lab operations. Alumni have gone to positions in state agencies (e.g., Montana Groundwater Protection Program, City of Brighton Water), geotechnical consulting (coupled with engineering degree), and graduate programs on the strength of their training.

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

How have the results been disseminated to communities of interest?

Field Trips

1) *Sheila Murphy and Ruth Heindel will lead field trip on for the National Atmospheric Deposition Program (NADP) Annual Meeting, November 7, 2019.*

Presentations at Conferences

We gave 31 presentations at professional science meetings:

- 20 presentations at AGU Fall Meeting, Washington, DC, Dec 2018
- 1 presentations at GSA Annual Meeting, Indianapolis, IN, Oct 2018
- 1 presentation at GSA Annual Meeting, Phoenix, AZ, Sep 2019
- 5 presentations at the CU Hydrological Sciences Symposium, Boulder, CO, April 2019
- 2 presentations at the CSDMS Annual Meeting, Boulder, CO, May 2019
- 2 presentations at the Western Snow Conference, Reno, NV, April 2019

Stakeholder contacts

Sheila Murphy

NADP program

City of Boulder Sourcewater Protection program

City of Boulder Stormwater Program

Boulder County Public Health

Website

Content was created and/or updated and on many of the webpages at 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

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?

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) Post-doc Ruth Heindel and Sheila Murphy are coordinating a field trip to visit the BcCZO supported NADP site at Betasso during the NADP Annual Meeting, November 7, 2019.
- 3) Publish on microbial DNA analysis of soil samples from all CZOs for the cross-CZO microbial ecology project (headed by Emma Aronson).
- 4) 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.
- 5) Complete production of *Hydrologic Processes* special issue on the critical zone titled: *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).
- 6) Goal 1, *Critical zone evolution*:
 - Submit and publish manuscript on topographic analysis of bedrock distribution in landscapes (Selander, Rossi, SP Anderson)
 - Submit manuscript on rates of landscape evolution in the Front Range (RS Anderson, former student MA Foster, SP Anderson)
- 7) 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 (Carini, Hinckley, Fierer,)
 - Publish 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)
 - Support field measurements of forces at the root-rock interface at both the Boulder Creek CZOs (Marshall)
 - Submit manuscript for publication on precipitation, stream water and groundwater samples to understand chemical weathering processes (Noah Hoffman and SP Anderson)
 - Measure fracture apertures in field setting to explore role of trees in rock wall evolution (Selander, SP Anderson)
 - Submit manuscript on dust deposition and its role in Front Range (Heindel, Murphy)
- 8) Goal 3, *Discover how critical zone architecture influences the storage and flow of water* (form to function):
 - Submit manuscript for publication on linkages between catchment structure, water sources and flowpaths during rain and snowmelt within Boulder Creek watershed (Isaac Bukoski, Barnard, Murphy)
 - Submit paper on Gordon Gulch hydrology (SP Anderson)
 - Publish paper on orographic influences on precipitation statistics and critical zone architecture influence on runoff (Rossi, Anderson RS, Anderson SP, Tucker)
 - Submit cross-CZO water balance manuscript (Wlostowski, Molotch, Harnan, Murphy, Anderson SP)

Products

Books

Book Chapters

Anderson, SP, Kelly, PJ, Hoffman, N, Barnhart, K, Befus, K, and Ouimet, W (2019). Is this steady state? Weathering and critical zone architecture in Gordon Gulch, Colorado Front Range. *Chemical Weathering and Soil Formation* A.G. Hunt and M. Egli. AGU Water Resources Monograph. Washington, DC. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Inventions

Journals or Juried Conference Papers

Anderson, RS, Rajaram, H, and Anderson, SP (2019). Climate driven co-evolution of weathering profiles and hillslope topography generates dramatic differences in critical zone architecture. *Hydrological Processes*. 33 (1), 4. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.1002/hyp.13307

Anderson, SP (2019). Breaking it down: Mechanical processes in the weathering engine. *Elements*. 15 247. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.2138/gselements.15.4.247

Barnard, DM, JF Knowles, HR Barnard, ML Goulden, J Hu, ME Litvak, NP Molotch (2018). Reevaluating growing season length controls on net ecosystem production in evergreen conifer forests. *Nature Science Reports*. 8 17973. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.1038.s41598-36065-0.

Delgado-Baquerizo, M, Bardgett, RD, Vitousek, PM, Maestre, FT, Williams, MA, Eldridge, DJ, Lambers, H, Neuhauser, S, Gallardo, A, Garcia-Velazquez, L, Sala, OE, Abades, SR, Alfaro, FD, Berhe, AA, Bowker, MA, Currier, CM, Cutler, NA, Hart, SC, Hayes, PE, Hseu, Z-Y, Kirchmair, M, Pena-Ramirez, VM, Perez, CA, Reed, SC, Santos, F, Siebe, C, Sullivan, BW, Weber-Grullon, LW, and Fierer, N (2019). Changes in belowground biodiversity during ecosystem development. *Proceedings of the National Academy of Sciences*. 116 (14), 6891. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.1073/pnas.1818400116

Glade, RC, Shobe, CM, Anderson, RS and Tucker, GE (2019). Canyon shape and erosion dynamics governed by channel-hillslope feedbacks. *Geology*. 47 (7), 650. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.1130/G46219.1

Kochanski, K, Anderson, RS, and Tucker, GE (2019). The evolution of snow bedforms in the Colorado Front Range and the processes that shape them. *Cryosphere*. 13 (4), 1267. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.5194/tc-13-1267-2019

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). Ideas and perspectives: Strengthening the biogeosciences in environmental research networks. *Biogeosciences*. 15 4815. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.5194/bg-15-4815-2018

Rossi, M.W., R.S. Anderson, S.P. Anderson, and G.E. Tucker (2019). Orographic controls on sub-daily rainfall statistics and flood frequency in the Colorado Front Range, USA. *Geophysical Research Letters*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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*. 123 (8), 1931. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi:10.1029/2017JF004575

Webb, RW, Jennings, KS, Fend, M, and Molotch, NP (2018). Combining ground-penetrating radar with terrestrial LiDAR scanning to estimate the spatial distribution of liquid water content in seasonal snowpacks. *Water Resources Research*. 54 (12), 10339. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.1029/2018WR022680

Wetherbee, GA, Benedict, KB, Murphy, SF, and Elliott, EM (2019).): Inorganic nitrogen deposition gradients in the Denver-Boulder metropolitan area and Colorado Front Range – Preliminary implications for Rocky Mountain National Park and interpolated deposition maps. *Science of the Total Environment*. 691 1027. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi: 10.1016/j.scitotenv.2019.06.528

Licenses

Other Conference Presentations / Papers

Anderson, SP, Hinckley, ES, Ragar, D, Gill, N, and Parrish, EG (2019). *A catchment in the transitional snow zone: Gordon Gulch, Boulder Creek Critical Zone Observatory*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = SUBMITTED; Acknowledgement of Federal Support = Yes

TUCKER, GE, MCCOY, SW, and HOBLEY, DEJ (2018). *A stochastic cellular model of hillslope morphology and evolution*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shobe, C.M., R.C. Glade, G.E. Tucker, and R.S. Anderson (2018). *Chaotic chasms: canyon evolution governed by autogenic channel-hillslope feedbacks*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Heindel, RC, Putman, AL, Hinckley, E-L S, Murphy, SF, Repert, DA, and Anderson, SP (2019). *Dry deposition delivers nutrients and heavy metals to the Colorado Front Range*. National Atmospheric Deposition Program Scientific Symposium and Fall Meeting. Boulder, CO. Status = AWAITING_PUBLICATION; Acknowledgement of Federal Support = Yes

JENNINGS KS, and MOLOTCH, NP (2018). *Energy balance changes drive differential response to simulated warming in an alpine and subalpine snowpack*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

SINGHA, K, HARMON, RE, VOYTEK, E, and BARNARD HR (2018). *Examining diel patterns of soil and sap flow from the single-tree to hillslope scale*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Marshall, JA (2018). *From ice to trees, surprising insights into past and present processes that sculpt our Earth*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

GLADE, R, and ANDERSON, RS (2018). *From scallops to flatirons: Planview patterns in layered landscapes*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Glade, R.C. and Anderson, R.S (2018). *Glade, R.C. and Anderson, R.S*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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

JENKINS, EE, and GOOSEFF, MN (2018). *How much does stream-groundwater exchange influence whole-stream metabolism in a small mountain stream?*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hoffman, N, Anderson, SP, and Wing, BA (2019). *Hydrologic mixing model approach identifies saprolite as the source of inorganic colloids in a granitoid catchment*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = SUBMITTED; Acknowledgement of Federal Support = Yes

WLOSTOWSKI, AN, HARMAN, CJ, and MOLOTCH, NP (2018). *Hydrologic storage and partitioning across the CZO network*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Rossi, MW, Anderson, RS, Anderson, SP and Tucker, GE (2019). *Interactions among hydrologic and geomorphic thresholds in fluvial landscape evolution*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = SUBMITTED; Acknowledgement of Federal Support = Yes

BUKOSKI, I, BARNARD, HR, and MURPHY, SF (2018). *Linking hydrologic flowpaths and catchment structure in the foothills/montane regions of the Colorado Front Range*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

JENNINGS, KS, and MOLOTCH, NP (2018). *Marked spatial variability in the sensitivity of simulated snow cover evolution to precipitation phase method selection*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Glade, R.C. and C. Shobe (2018). *Modeling the 2-D evolution of blocky landscapes: Coupled model design*. Community Surface Dynamics Modeling System Annual meeting. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Shobe, C. and R.C. Glade (2018). *Modeling the 2-D evolution of blocky landscapes: Hillslope-channel interactions*. Community Surface Dynamics Modeling System Annual meeting. Boulder, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

BROOKS, PD, BARNARD, HR, BIEDERMAN, JA, HARPOLD, A, SINGHA, K, SWETNAM, TL, and TAI, X (2018). *Multi-disciplinary insights in to the effects of vegetation change on hydrologic partitioning*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

WEBB, R, FEND, M, JENNINGS, KS, WIGMORE, O, ERICKSON, T, WILLIAMS, MW, and MOLOTCH, NP (2018). *New approaches to address scaling issues of water flow through snow*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Heindel, RC, Hinckley, ES, Murphy, SF, Repert, DA, and Anderson, SP (2018). *Quantifying atmospheric dust deposition to the Colorado Front Range*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Anderson, RS (2018). *Reflections on the Legacy of Grove Karl Gilbert, 1843-1918: Harnessing the natural experiments of the American West in the service of science*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Gold, A, Curry, R, Briggs, J, Smith, L, McNeal, KS, Atkins, RM, Batchelor, R, Luna, LM, and Anderson, SP (2018). *Research experience for community college students: Expanding the pipeline for 2YC students into geoscience programs at 4YCs*. Geological Society of America Annual Meeting. Indianapolis, IN. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

HURST, AA, and ANDERSON, RS (2018). *River channel lowering by upstream migration of bedrock steps*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Rossi, M., Tucker, G., Anderson, R.S. and Anderson, S.P (2018). *Runoff and erosion thresholds dictated by the balance between stochastic rainfall statistics and Critical Zone architecture*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Anderson, SP, Kelly, PJ, Hoffman, N, Barnhart, KR, Befus, KM, and Ouimet, WB (2019). *Steady state and slow denudation does not imply well-developed soils*. Geological Society of America Annual Meeting. Phoenix, AZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

KOCHANSKI, K, TUCKER, GE, and ANDERSON, RS (2018). *The growth of Aeolian snow features*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hale, K, Wlostowski, AN, Badger, A, Anderson, SP, Godsey, S, and Molotch, NP (2018). *Unpacking the influence of warming on hydrological partitioning in rain-snow transition zones of the western United States*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

HALE, K, WLOSTOWSKI, AN, BADGER, A, ANDERSON, SP, GODSEY, S, and MOLOTCH, NP (2018). *Unpacking the influence of warming on hydrological partitioning in rain-snow transition zones of the western United States*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

MURPHY, SF, MCCLESKEY, RB, MARTIN, DA, WRITER, JH, and EBEL, BA (2018). *Using a concentration-discharge framework to improve post-wildfire water quality interpretation and prediction*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

SHOBE, CM, TUCKER, GE, and ROSSI, M (2018). *Variable thresholds in rivers: Causes and effects*. American Geophysical Union Fall Meeting. Washington, DC. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Anderson, RS (2018). *Reflections on the legacy of Grove Karl Gilbert, 1843–1918*. Eos, 99, <https://doi.org/10.1029/2018EO112771>. Status = PUBLISHED; Acknowledgement of Federal Support = No

Patents

Technologies or Techniques

Thesis/Dissertations

Brewer, Tess. *Ecological strategies of soil bacteria and archaea*. (2019). University of Colorado, Boulder. Acknowledgement of Federal Support = Yes

Glade, Rachel C.. *Hillslope evolution in block-controlled landscapes*. (2019). University of Colorado, Boulder. Acknowledgement of Federal Support = Yes

Bukoski, Isaac. *Hydrologic flowpaths in foothill catchments of the Colorado Front Range*. (2019). University of Colorado, Boulder. Acknowledgement of Federal Support = Yes

Hoffman, Noah. *Lithogenic mixing model approach identifies saprolite as the source of inorganic colloids in a granitoid catchment*. (2019). University of Colorado, Boulder. Acknowledgement of Federal Support = Yes

Shobe, Charles M.. *River erosion in block-controlled landscapes*. (2019). University of Colorado. Acknowledgement of Federal Support = Yes

Hale, Katherine. *Streamflow sensitivity to climate warming and a shift from snowfall to rainfall*. (2018). University of Colorado, Boulder. 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

Websites

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? 0

How many REU applicants were selected and agreed to participate during this reporting period? 0

REU Comments:

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Anderson, Suzanne	PD/PI	2
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
Doak, Daniel	Co-Investigator	0
Ebel, Brian	Co-Investigator	0
Fierer, Noah	Co-Investigator	1
McKnight, Diane	Co-Investigator	1
Murphy, Sheila	Co-Investigator	1
Sheehan, Anne	Co-Investigator	0
Singha, Kamini	Co-Investigator	1

Name	Most Senior Project Role	Nearest Person Month Worked
Templeton, Alexis	Co-Investigator	0
Heindel, Ruth	Postdoctoral (scholar, fellow or other postdoctoral position)	8
Rossi, Matthew	Postdoctoral (scholar, fellow or other postdoctoral position)	4
Carpenter, Eric	Other Professional	1
Curry, Renee	Other Professional	1
Farrell, Emma	Other Professional	1
Langston, Abigail	Other Professional	0
Nadel, Hester	Other Professional	0
Rose, Alex	Other Professional	0
Taylor, Jennifer	Other Professional	0
Jensen, Clayton	Technician	8
Parrish, Eric	Technician	11
Ragar, Dillon	Technician	12
Rock, Nathan	Technician	0
Roth, Wendy	Technician	1
Stoffel, Chad	Technician	1
Tebbetts Fey, Jeri	Technician	0
Barnhart, Theodore	Graduate Student (research assistant)	0
Brewer, Tess	Graduate Student (research assistant)	6
Bukoski, Isaac	Graduate Student (research assistant)	9
Forrester, Chiara	Graduate Student (research assistant)	0
Foster, Melissa	Graduate Student (research assistant)	0
Glade, Rachel	Graduate Student (research assistant)	1
Harmon, Ryan	Graduate Student (research assistant)	4
Hoffman, Claire	Graduate Student (research assistant)	6
Mills, Taylor	Graduate Student (research assistant)	0

Name	Most Senior Project Role	Nearest Person Month Worked
Pandey, Sachin	Graduate Student (research assistant)	0
Rey, David	Graduate Student (research assistant)	4
Rue, Garrett	Graduate Student (research assistant)	0
Rush, Michael	Graduate Student (research assistant)	5
Salberg, Lauren	Graduate Student (research assistant)	1
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	0
Glass, Jamie	Non-Student Research Assistant	0
Gulick, Emily	Non-Student Research Assistant	0
Chapmin, Benjamin	Undergraduate Student	3
Elliott, Brian	Undergraduate Student	2
Flechtsenhaar, Jon	Undergraduate Student	0
Flynn, Matthew	Undergraduate Student	3
Gamora, Joey	Undergraduate Student	0
Graham, Nathan	Undergraduate Student	0
Gupta, Amrita	Undergraduate Student	0
Heithusen, Brett	Undergraduate Student	0
Lanka, Dylan	Undergraduate Student	0
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

Name	Most Senior Project Role	Nearest Person Month Worked
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: 2

Contribution to the Project: Project leader

Funding Support: NSF1331828, 1929517, 1822062, 1840758

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 graduate students, pariticipated in meetings, wrote papers

Funding Support: NSF1840758

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 grad students, attended meetings, wrote papers

Funding Support: this project

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 grad students, attended meetings, wrote papers

Funding Support: this project

International Collaboration: No
International Travel: No

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

Contribution to the Project: Supervised grad students, attended meetings, wrote papers
Funding Support: This project, NSF1822062

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: 0

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. 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: 1

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: 8

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: 4

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: NSF1822062 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: 1

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: 0

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: 0

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: 8

Contribution to the Project: Lab manager, sampling, data generation, and analysis; left the University in April 2019

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: 11

Contribution to the Project: GIS-graphics specialist; web support; data-management 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

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: 0

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: 0

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: 0

Contribution to the Project: Research on hydrologic partitioning and snowmelt; cross-CZO work with Christina (Naomi) Tague, using RHESys. Completed PhD spring 2018. Now works for USGS in Montana.

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. Completed PhD May 2019; worked as CZO postdoc for 4 months. Now on Chateaubriand post-doc in France.

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: 9

Contribution to the Project: Research on ecohydrology; started July 2017. Completed MA thesis Fall 2019; worked on USGS-NSF Intern fellowship over summer 2019.

Funding Support: NSF (this project) NSF1928430

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: 0

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. Now works at Bureau of Reclamation, Golden, CO
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: 1

Contribution to the Project: Hillslope geomorphology research; completed PhD spring 2019; now Post-doc at Los Alamos, and starting faculty position at Univ. Rochester Fall 2021
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: 4

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; completed MA in summer 2019

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. Now staff at NOAA.

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: 4

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. Completed PhD in spring 2019.

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: 5

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

Lauren Salberg
Email: Lauren.Salberg@colorado.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Research on groundwater-surface water interactions.

Funding Support: This project.

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;

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: 0

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

Funding Support: NSF (this project)

International Collaboration: No
International Travel: No

Jamie Glass
Email: ocepheus@gmail.com
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 0

Contribution to the Project: Undergraduate work study field assistant. Graduated in Fall 2016, continued on as a field assistant in Fall 2017. Now graduate student on unrelated project.

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

Benjamin Chapmin
Email: Benjamin.Chapman-1@colorado.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Undergraduate work-study field assistant

Funding Support: NSF (this project)

International Collaboration: No
International Travel: No

Brian Elliott
Email: Brian.P.Elliott@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

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

Matthew Flynn
Email: Matthew.C.Flynn@colorado.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Undergraduate work-study field assistant

Funding Support: NSF (this project)

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

Nathan Graham
Email: nathangraha13@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 0

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: 0

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: 0

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:

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:

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:

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:

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:

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:

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:

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:

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:

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 very high profile in the arena of microbial field, and connects critical zone science to the bustling world of microbiology. Researchers in Noah Fierer's lab published a global "atlas" of dominant soil bacteria in *Science* (Delgado-Baquerizo et al, 2018), and followed this up with an analysis of changes in soil microbial communities in chronosequences, published in *PNAS* (Delgado-Baquerizo et al., 2019). This type of approach is behind the still in-review cross-CZO soil microbial ecology manuscript (Brewer et al., in review). The deep and comprehensive analysis of communities in well-characterized CZO sites is motivating a proposal to the new CZ-net call for proposals.

BcCZO has maintained the strongest program in geomorphology of the critical zone, with projects that have addressed glacial processes, climate-driven landscape evolution, rates of denudation, channel incision and terracing on the Plains, erosion of bedrock-dominated landscapes, connections between CZ architecture, hydrologic behaviors and erosion, and biogeomorphology. In each of these endeavors, we articulate particular processes, e.g. frost cracking, as much as possible, we back up models with field measurements, and we have used geochronological techniques (cosmogenic radionuclides, luminescence) techniques to quantify rates.

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?

- **3 professional staff members** are supported by BcCZO. We encourage and offers opportunities to develop skills and expand horizons
- **6 graduate students** received full or partial support from BcCZO in the last year (Brewer, Rush, Glade, Selander, Hoffman, Bukoski)
- At least **5 additional graduate students** work in/with BcCZO sites or data, without receiving direct financial support from the CZO (Ryan Harmon, Anna Hermes, Kelly Kochanski, Charlie Shobe, Liz Andrews)
- **5 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 (Adam Wlostowski, Ruth Heindel, Ryan Webb, Matt Rossi, Adam Mangel)
- 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 fill in the gap between the heavily studied alpine terrain and the Plains. We installed and maintain the only groundwater monitoring wells in the area. We have reestablished one of John Marr's climate stations (B-1) in his array originally established in 1951.

What is the impact on institutional resources that form infrastructure?

Nothing to report.

What is the impact on information resources that form infrastructure?

BcCZO has built a relational database with our time-series and sample-based data, and is working with the cross-CZO data management team to port these into the CUASHI based HydroShare system. We have established a new mechanism to access our large and extensive time-lapse imagery database using Google Drive, accessible through criticalzone.org/boulder/data.

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; we are still seeking a publisher. 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

Because the coming year is our last year of funding, and we do not know what, if any, proposals will be funded to follow up or continue Boulder Creek CZO infrastructure, we are shifting our focus from maintaining to completion and possible shutdown. Depending on the proposals being written in Fall 2019 for the CZ network call, we will make decisions on what field systems to maintain and what to terminate. At this time, it appears that much of the field-monitoring network we have worked so hard to build will not continue. We will do our best to leave complete and well-documented datasets, and we will do our best to place these data in locations that will have as long a life as possible. We have already begun removing some field "debris" that has been left by prior BcCZO field projects, and anticipate that this activity will increase over the year.

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.