**Accomplishments**

* What are the major goals of the project?

The Catalina-Jemez (C-J) CZO project aims to improve our understanding of the mechanisms underlying quantitative relations between climatic forcing and critical zone evolution in water-limited systems by focusing on linkages between long time-scale climate/lithology interactions and short time-scale ecological/geological feedbacks, and how both affect CZ services.

This goal motivates the proposal’s central thematic questions:

1) How do the long-term drivers of CZ structure and function (EEMT and tectonics) alter parent material to control current CZ structure and response to perturbation?
2) How is long-term CZ evolution affected by ecosystem process controls, including especially localized plant and microbial activities?

3) What is the impact of CZ structure on buffering climate- and disturbance-driven variability in water, soil and vegetation resources and how does this translate into changes in CZ services?

We postulate that the climatic forcing of subsurface CZ evolution is predicted on the basis of effective energy and mass transfer (EEMT), which combines into a single climatic term the energy transferred to the CZ as effective precipitation (precipitation in excess of evapotranspiration) and reduced carbon (i.e., net primary production).

The CZO site focus is on the water-limited (semi-arid to sub-humid) southwestern US. A broader impact of our research is, therefore, to improve societal understanding of processes that govern water resource delivery and quality in this region. Mountain block and mountain front recharge serves as the principal source of all freshwater resources to human inhabitants in this part of the world, and hence our project focuses strongly on factors affecting this aspect of the water cycle, including the partitioning of water delivered (as a result of orogenic forcing) to higher elevation catchments, and the influence of hydraulic throughput on CZ geochemical and geomorphic evolution. We are investigating how event-based partitioning of water and carbon feeds back to affect the development of hydrologic flow paths, landscape structure and (bio)geochemical heterogeneities.

Our approach involves a combination of field-based observational measurements, controlled experimentation, and conceptual/numerical modeling at each of two principal research sites in the water-limited southwestern US - Santa Catalina Mountains (SCM, AZ) and Jemez River Basin (JRB, NM). In year 4 of the CZO grant, we have initiated and completed several activities and made substantive progress in each of these areas.

Our transdisciplinary research approach interrogates CZ process dynamics and structure along four integrated lines of inquiry: (i) Ecohydrology and Hydrologic Partitioning; (ii) Subsurface Biogeochemistry; (iii) Surface Water Dynamics; and (iv) Landscape Evolution. By building bridges across these four lines of inquiry, we address linkages between short time-scale (e.g., hydrologic) events and long time-scale (e.g., geomorphic) evolution of the CZ.

In addition to the goals we have for testing hypotheses given in the proposal, the Catalina-Jemez CZO is active in pursuit of CZO network goals. Transformative, network-level science findings should result from comparably quantified structural properties and process rates at multiple sites. By doing so, we can, as a network, assess CZ coupled-process trends and test response hypotheses across the wider climate-lithology parameter space afforded by the network. For these reasons, Chorover has led cross-CZO (X-CZO) development of "common measurements" conceptual frameworks for the CZO network, along with several collaborators.

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

**1. Ecohydrology and Hydrologic Partitioning**

- Upgrade and maintain sap flux measurements associated with Bigelow Tower (SCM).
- Monitor plant physiological performance on North- versus South-facing aspect across five seasonal periods.
- Measure transpirational water loss and photosynthetic carbon uptake across seasonal periods of variable precipitation to examine interspecific differences in rates of water loss and carbon uptake efficiency.
• Extensive snow survey in the MC zob (JRB) by the spring 2017 snow hydrology class at UU in collaboration with researchers at UA and UNM. Observations were made immediately preceding melt initiation and will be used to evaluate the longer term effects of fire on snowpack accumulation.
• Existing phenocams, established by Papuga and colleagues, were incorporated into a snow ablation monitoring array providing sub-daily resolution on the timing and amount of snowmelt across the MC ZOB.
• Distributed snow samples collected immediately prior to peak accumulation and returned to UU campus for hydrochemical and isotopic analyses. These data will be used in concert with soil, groundwater, and stream samples in a multi-investigator collaboration to quantify interactions between hydrologic flowpaths and CZ structure and function.
• Swetnam et al. (2017) quantified the role of topographically driven hydrologic subsidy on biomass accrual using high resolution LiDAR data obtained as part of cross CZO research.
• Building on work from previous CZO contributions, Harpold and Brooks (in revision) evaluated the response of western snowpacks to simultaneous warming and changes in humidity.

2. Subsurface Biogeochemistry

• 98 subsamples from the MCZOB boreholes were analyzed for total elemental chemistry (UA, ALEC), bulk and fine fraction mineralogy.
• 35 drill core subsamples analyzed for uranium-series and strontium isotopic composition in the U-series Isotope Laboratory at the University of Texas at El Paso.
• Select subsamples were analyzed at SSRL to identify iron speciation in bulk samples using X-ray absorption spectroscopy (XAS) techniques (beamlines 11-2 and 4-3).
• Select thin sections mapped for elemental concentrations using uXRF and multiple energy XANES techniques at SSRL to assess redox status of iron and manganese along weathered surfaces.
• Ongoing annual post-fire analysis of pedons distributed throughout MCZOB to assess fate of bioaccumulated lithogenic solutes and black carbon.
• Drill cores were shipped to the National Lacustrine Core Facility (LacCore) at the University of Minnesota for non-destructive analysis (e.g. p-wave velocity, gamma density, magnetic susceptibility, natural gamma radiation, and electrical resistivity) by UA students who visited LacCore to split cores and describe the lithology, mineralogy, and structure with the assistance of LacCore personnel. Cores will be archived at LacCore.
• Established an international collaboration with Aqua Diva CZO and Max Planck Institute for Biogeochemistry in Jena, Germany, to train on handling, processing and extracting DNA from deep CZ core samples.
• Conducted bench scale experiments on forest floor DOM with subsoil surfaces under live soil conditions.
• Geostatistical techniques were used to integrate point-scale functional measurements of microbial activity with landscape topography to translate microbial activity to the landscape scale. Enzyme activity best corresponds to NDVI, SAGA wetness index, and total N availability, indicating important landscape controls on soil moisture, vegetation cover and microbial activity (Fairbanks et al., in prep.)

3. Surface Water Dynamics
Specific Objectives:

Slug tests conducted in October 2017 in the eight boreholes in the MCZOB in the JRB CZO to determine hydrologic parameters; however, it was discovered that the wells were silted up and required cleaning before repeating hydrologic tests. A first attempt at removing the silt from the wells was completed in October 2017 with inertial pumps.

- Each monitoring well contains a vibrating wire piezometer pressure transducer to monitor water levels at 15-minute intervals.
- Monitoring wells were sampled by field staff every two to four weeks for major ions, trace metals, stable isotopes, uranium isotopes, strontium isotopes, and carbon content.
- Increased groundwater sampling frequency (weekly) was initiated during the spring of 2017 to capture water chemistry and isotopic changes that result from the snow melt period to test hydrologic through flow at both vertical and horizontal scales. Groundwater samples are being analyzed for U-series and Sr isotopes at UTEP, in addition to the full suite of CZO analyses.
- All water samples are analyzed for field parameters (pH, Temp, EC, DO), major and minor ions, trace metals, REE, DOC, DIC, TN, and stable water isotopes).
- ISCO automatic samplers were installed on the shallowest monitoring well, MCZOB flume, and La Jara flume for diurnal sampling during the spring snowmelt.
- Bi-weekly sampling of stream waters in the MCZOB, La Jara, History Grove, Upper Jaramillo catchments for time-series hydrologic and biogeochemical data were continued throughout the year. Similar samples were collected in the SCM CZO sites (Marshall Gulch weir, Granite ZOB, Schist ZOB, Oracle Ridge, B2 Desert Sites).
- Water samples from ten springs in the JRB CZO, for which water transit time based on tritium analysis are already known, were collected during the dry seasons of 2015 and 2016 and analyzed for U-series and Sr isotopes.
- Springs, soil water, and stream water in the Marshall Gulch catchment were collected quarterly and analyzed for tritium to determine their residence time.
- Hydrochemical modeling was conducted to understand how recent forest fires in the Valles Caldera Preserve (JRB-CZO) have altered water sources and quality of streamflow.
- Expanding on the importance of topography on coupled water and biogeochemical cycles, Weintraub et al. (2016) examined N cycling in paired forest and meadow sites across a topographical gradient.

Overarching objectives of the CZO research is unchanged from prior year reports. Specific objectives pertaining to this year of CZO activities included a strong focus on:

- Developing predictive relations between EEMT and forest NPP and ET.
- Borehole drilling and groundwater well installations in locations indicated by geophysical surveys to be most beneficial to our studies.
- Core sample analyses for geochemistry and mineralogy as a function of depth.
- Elucidation of impacts of fire on surface water dynamics, including changes in chemistry and source of streamwater.
- Utilizing stable and radiogenic isotopic tracers to assess relations between water transit time and geochemical weathering.
Significant Results:

1. Ecohydrology and Hydrologic Partitioning

• We further developed the Terrestrial Integrated Modeling System (TIMS) with a scheme of topographic shading and scattering effects on insolation. We applied the model over a small sub-humid catchment (1.55 km²), the Marshall Gulch, Arizona to explore the impacts of topographic shading and scattering of insolation on energy and water partitioning as well as the impacts on snowmelt and river discharge. The topographic shading effect is dominant over the scattering effect, resulting in more river discharge by up to 40%.

• We have applied TIMS over the Marshall Gulch (1.55 km²) to investigate the impacts of rainfall redistribution through lateral subsurface flow over complex terrain on partitioning of evapotranspiration (ET) into evaporation (E) and transpiration (T). The results show that convergence of rainfall through lateral subsurface flow enhances the ratio of T to ET, suggesting that more water is used for plants in a mountainous catchment. The mountains over the Western US may provide ecosystems a great buffer to warming and drying climate.

• Building on work from previous CZO contributions, Harpold and Brooks (in revision) evaluated the response of western snowpacks to simultaneous warming and changes in humidity. They showed that the dual nature of latent energy exchange where sublimation cooling under a drier atmosphere will differentially counteract the effects of warmer temperatures while a simultaneous increase in atmospheric humidity will greatly exacerbate warming (Figure 1).

• In a cross CZO paper Swetnam et al. (2017) quantified the role of topographically driven hydrologic subsidy on biomass accrual using high resolution LiDAR data obtained as part of the cross CZO research. Surprisingly, analyses indicate that the influence of lateral water (or nutrient) distribution is greater either aspect or elevation in explaining standing forest biomass (Figure 2). Although this result has been observed before in hot/dry systems (although not this well quantified), the pattern held at cold, wet high elevation locations as well. These observations, combined with similar work at Shale Hills by colleagues there, suggest a complex interaction between below ground processes that influences above ground vegetation.

• Seasonal tritium and geochemical results in Marshall Gulch (SCM-CZO) show that older groundwater from the fractured bedrock aquifer contributes to streamflow during the spring snowmelt period, while draining of younger groundwater from shallow, perched aquifers sustains streamflow during drier periods (Figure 3A,C). Water stable isotopes and water balance calculations show that the majority of water loss to the atmospheric in Marshall Gulch catchment occurs as transpiration, rather than evaporation (Figure 3B,D).

2. Subsurface Biogeochemistry
• Wet-dry cycles affect interactions between DOM and subsurface soils by enhancing the interactions between carboxyl functional groups and soil particle surfaces. Interactions of these functionalities were dominated by Ca\(^{2+}\) bridging to soil surfaces (Figure 4). Nanoscale spatial fractionation of DOM on soil organo-mineral surfaces was diminished relative to DOM fractionation on specimen mineral phases. This is likely due to the heterogeneous composition of the weathered soil surfaces and pre-existing metal oxide and OM films coating soil particle surfaces.

• Data collected from instrumented pedons shows time variation in physical parameters associated with seasonal dependencies (Figure 5). Soil CO\(_2\)(g) followed the temperature trend, but CO\(_2\) pulses during wetting events were pronounced. These events, starting with a rapid increase in soil moisture are followed by initial decrease then increase in CO\(_2\) concentration. CO\(_2\) concentration was positively correlated with K and Si, suggesting dissolution of mica/illite or K-Feldspar.

• In excavated deep CZ boreholes from the ZOB, weathering does not produce monotonic elemental depletion profiles as observed at other CZOs (Figures 6 and 7). Heterogeneous vertical distribution of immobile element ratios (e.g. Ti/Zr) in the three boreholes suggest multiple depositional events comprise the relatively short depth interval (down to 50 m below ground surface) investigated during drilling in 2016. As a result, weathering may be confined to certain lithologies with significant primary porosity soon after deposition. However, this is confounded by tectonically induced fracturing, which may have increased preferential flow paths and concentrated weathering around fracture surfaces.

• The upper 10 meters of the eastern mid-slope borehole has significant smectite and zeolite (clinoptyilolite and mordenite) content (Figure 6). This mineral assemblage is common in other parts of the Valles Caldera and has been identified, by Chipera et al. 2008, as precipitates from an alkaline caldera lake that formed soon after caldera eruption. This constrains the age of the upper portion of this profile to 1.25 MA. The other boreholes in the ZOB do not have smectites or zeolites present in their profiles and clays in these borehole locations are likely as a result of incongruent dissolution of primary minerals (Figure 7).

• Perched groundwater appears to be controlled by the distribution of clay on the western portion of the ZOB.

• Pyrogenic C increases relative to total organic C with depth in soil profiles throughout the MC ZOB (JRB), which was burned by a wildfire in 2013.

• Data and analyses from Weintraub et al. (2016) demonstrate the interactive effects of vegetation and topography on N cycling where lateral hydrologic flowpaths transport N downslope. Their results identified a much more open soil N cycle in low topographic positions indicative of N subsidy from higher elevations (Figure 8). Only deeper rooted forest vegetation accesses this N, resulting in N rich biomass and litter, which falls and increases N in surface soils.

3. Surface Water Dynamics

• U-series (1.97 to 2.06) and Sr isotope (0.70737 to 0.70844) values of stream waters in three catchments in the JRB-CZO (La Jara, Upper Jaramillo and History Grove) vary by season in WY 2015; however, those changes are not constant between catchments suggesting that differences in the mineralogy and structure of the deep CZ likely also drive isotopic
variability. Springs and streams within the same catchment also have distinct isotopic signatures, which are likely controlled by local geology.

- Water transit times do not explain variability of U (1.60 to 3.09) and Sr isotope (0.70704 to 0.70817) values in springs throughout the JRB-CZO suggesting that 1) the relatively short length of time water interacts with rock in the JRB-CZO is not a good indicator of U isotope composition or 2) springs should be reanalyzed for tritium content because low flow (fall 2013) conditions are not representative of low flow pre-monsoon conditions when streams were analyzed for U and Sr isotope composition. Further investigation of seasonality controls on U isotopes should clarify these explanations in a summer 2017 sampling campaign.

4. Landscape Evolution

- Documented dependence of slope aspect on topography in several SW US sites, and developed a theoretical model that explains the deviation of slope-aspect asymmetry from N-S to SW-NE (Pelletier and Swetnam, 2017).
- Quantified coevolution of soil and landform development as a function of landscape age and slope aspect in volcanic landforms from Oregon to Arizona (Rasmussen et al., Catena, 2017).
- Quantified the relationships among soil production rates, topographically induced stresses, and climate in the San Gabriel Mountains (Pelletier, ESurf, accepted pending minor rev.).
- Documented and modeled global patterns of slope asymmetry in CZ variables (Pelletier et al., ESPL, 2017).

Key outcomes or discussed above.

Other achievements:

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

- We have trained undergraduate students to deliver hands-on science education activities for the CZ Discovery program. We are working with graduate and undergraduate students to continue to refine the CZD curriculum. The CZ Discovery program successfully launched in fall 2016 and has already reached hundreds of students from underserved schools, grades 3rd through 6th.
- A new interdisciplinary Hydrology and Water Resources Graduate Certificate program was developed at the University of Utah, informed by the successful cross campus CZO activities at UA. This program is open to both matriculated graduate students as well as non-matriculated professionals from the community who are seeking advanced training without needing or wanting a degree. The program is housed under the office of sustainability and incorporates coursework from six departments across four colleges providing the diverse training and exposure that defines CZ science.
- Three new courses have been developed at University of Utah that bring the diverse CZ perspective to hydrologic partitioning and landscape structure. These courses are cross listed among multiple departments.

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

- Successfully launched the CZD Field Trip Program bringing in 957 students ranging 3rd to 6th grades to engage in hands-on earth science activities and learn about the concept of the Critical Zone (See attached letters from participants).
- Successfully opened the “Welcome to the Critical Zone” exhibit in July 2016 to take visitors on a journey through the Critical Zone, exploring CZ science along the way through interpretive signage, hands-on exhibits and games, and dynamic illustrations and diagrams. Since opening the exhibit has already impacted over 36,119 visitors.
• The "Mt. Lemmon Science Tour" app, a free smartphone audio science tour for the drive/bike up the scenic Catalina Highway from Tucson to the top of the Santa Catalina Mountains, has proven increasingly popular. The Tour has been downloaded by more than 115,000 users since its debut in November 2015, and introduces listeners to the concept of the Critical Zone in addition to related earth science exposition.

• Recorded photos and video of CZO PI presentations focused on how their research ties into the overall picture of critical zone research. We hope to share several of these presentations via our Flandrau Science Center YouTube channel.

• Worked with CZO scientist, grad student, and NASA Space Grant awardee Chris Shepard to produce videos about Seismic Reflectivity research, the SCM/JRB CZO’s Scientific Drilling Project, and profiles of grad students and faculty researchers. Videos are on YouTube and have been posted on Social Media to help promote the exhibit "Welcome to the Critical Zone." Select videos are currently on display in the exhibit.

• A new Facebook page for the Santa Catalina Mountains/Jemez River Basin CZO at the University of Arizona will help disseminate CZ science and reach a broad public audience with updates on Critical Zone Science.

• Brooks continues to serve on the science advisory teams for Healthy Headwaters Initiative, Salt River Project, Salt Lake Public Utilities, Mountain Accord, and Carpe Diem West. These groups represent public utilities, natural resource managers, and NGO’s focused on improving resource management in western North America.

• Results from our forest, water, and climate work are being incorporated into forest management activities within the watersheds of the Salt River Project (SRP) and the Wasatch Front (Salt Lake Public Utilities) in partnership with local water utilities. We recently began to collaborate with western ski areas on snow management for the critically important early season (Thanksgiving to Christmas Holidays).
• Cosmogenic erosion rates have been measured for 7 drainage basins in the SCM. In the next year we will perform modeling studies aimed at interpreting the cosmogenic data and the distribution of slope angles in the SCM with climate/elevation. This work will be a fundamental contribution to our understanding of controls on soil production rates and its influence on hillslope form in semi-arid environments.

• Results from the 2017 spring snow survey will be analyzed in conjunction with observations from previous years to document the longer term effects of fire on snow accumulation and ablation.

Supporting Files

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<td>Figures file to accompany Catalina-Jemez annual report (&quot;significant results&quot; section)</td>
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Products

Books

Book Chapters


Inventions

Journals or Juried Conference Papers


Finley, B, P Dijkstra, C Rasmussen, E Schwartz, R Mau, X Liu, N van Gestel, and BA Hungate (). Soil mineral assemblage and substrate quality effects on microbial priming. *Biogeochemistry*.  Status = OTHER; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes


Harpold A.A. and P.D. Brooks (). Humidity will determine snowpack response to climate change. *Nature Climate Change*.  Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes; Peer Reviewed = Yes


Olshansky, O., R. Root, and J. Chorover (). Wet-dry cycles effects on sequential reaction of dissolved organic matter with subsurface soils. *Biogeoosciences*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes


Dynamics. (4). 471. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ;
DOI: 10.5194/esurf-4-471-2016

Perdrial, J. et al. (2017). A net ecosystem carbon budget for snow dominated forested headwater catchments:
linking water and carbon fluxes to critical zone carbon storage. Biogeochemistry. . Status = OTHER;
Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

in leaf physiological performance in a Madrean sky island mixed-conifer forest.. Tree Physiology. . Status =
ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Potts D.L., Minor R.L., Braun, Z., and Barron-Gafford G.A. (). Photosynthetic phenological variation may promote
coexistence among co-dominant tree species in a Madrean sky island mixed conifer forest.. Tree Physiology. .
Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

semiarid cinder cone chronosequence,. Catena,. (156), 338. Status = PUBLISHED; Acknowledgment of Federal
Support = Yes ; Peer Reviewed = Yes

gradient method for determining soil carbon dioxide efflux.. Journal of Geophysical Research-
Biogeosciences. 122 50. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed =
Yes

property change through time integration of energy and mass input. SOIL. . Status = PUBLISHED;
Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/soil-2016-63.

topography trumps climate in determining forest carbon reservoir size.. Ecosphere.. . Status =
AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

emitted directly to the atmosphere. Geophysical Research Letters.. . Status = UNDER_REVIEW;
Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

gradient method for determining soil carbon dioxide efflux. Journal of Geophysical Research -
Biogeosciences.. 122 50. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed =
Yes

Groundwater Subsidy Improves Prediction of Tree Mortality across the Landscape. Ecohydrology. . Status =
ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Kirk (2017). Regional sensitivities of seasonal snow cover to elevation, aspect, and vegetation structure in
western North America. Water Resources Research.. . Status = ACCEPTED; Acknowledgment of Federal
Support = Yes ; Peer Reviewed = Yes

Trostle, K. D., J. Ray Runyon, M. A. Pohlmann, S. E. Redfield, J. Pelletier, J. McIntosh, and J.
Chorover. (2016). Colloids and organic matter complexation control trace metal concentration-discharge
relationships in Marshall Gulch stream waters. Water Resources Research.. 52 7931. Status = PUBLISHED;
Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes


**Licenses**

**Other Conference Presentations / Papers**


https://reporting.research.gov/rppr-web/rppr?execution=e1s7 7/31/2017


Pohlmann, M. (2016). Fate of rapidly deposited carbon and lithogenic solutes onto surface soils within a mixed conifer catchment severely burned by wildfire.. SWESx Colloquium. Tucson, AZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes


Sanchez-Cañete EP, Scott RL, Van Haren JLM, Barron-Gafford GA (2016). *The Necessity of Determining the Gas Transfer Coefficient In-situ to Obtain More Accurate Soil Carbon Dioxide Effluxes Through the Gradient
Method. American Geophysical Union’s Annual Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes


Gallery, R.E. (2016). The ecology of soil microbes: feedbacks in semi-arid and tropical forests. (Invited) Department of Microbiology and Immunology, Montana State University. Bozeman, MT. Status = PUBLISHED; Acknowledgement of Federal Support = Yes


Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations


Websites
### Participants/Organizations

**What individuals have worked on the project?**

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Full details of individuals who have worked on the project:

**Jon D Chorover**  
*Email:* chorover@email.arizona.edu  
*Most Senior Project Role:* PD/PI  
*Nearest Person Month Worked:* 1  

**Contribution to the Project:** theme lead  
**Funding Support:** NSF  
**International Collaboration:** No  
**International Travel:** No  

---

**David D Breshears**  
*Email:* daveb@email.arizona.edu  
*Most Senior Project Role:* Co PD/PI  
*Nearest Person Month Worked:* 1  

**Contribution to the Project:** theme lead  
**Funding Support:** NSF  
**International Collaboration:** No  
**International Travel:** No  

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**Jennifer C McIntosh**  
*Email:* mcintosh@hwr.arizona.edu  
*Most Senior Project Role:* Co PD/PI  
*Nearest Person Month Worked:* 1  

**Contribution to the Project:** theme lead  
**Funding Support:** NSF  
**International Collaboration:** No  
**International Travel:** No  

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**Jon D Pelletier**  
*Email:* jdpellet@email.arizona.edu  
*Most Senior Project Role:* Co PD/PI  
*Nearest Person Month Worked:* 1  

**Contribution to the Project:** theme lead
Funding Support: NSF

International Collaboration: No
International Travel: No

Craig Rasmussen
Email: crasmuss@cals.arizona.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: theme lead

Funding Support: NSF

International Collaboration: No
International Travel: No

Greg Barron-Gafford
Email: gregbg@email.arizona.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Assistant Professor and Ecosystem Ecologist

Funding Support: NSF and other

International Collaboration: No
International Travel: No

Ty P.A. Ferré
Email: tyferre@gmail.com
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Professor and Hydrogeophysicist

Funding Support: NSF and other

International Collaboration: No
International Travel: No

Thomas Meixner
Email: tmeixner@email.arizona.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Professor and Catchment Hydrologist/Biogeochemist

Funding Support: NSF and other

International Collaboration: No
International Travel: No
Guo-Yue Niu
Email: niug@email.arizona.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Assistant Professor and Land-Atmosphere Exchange Modeler

Funding Support: NSF and other

Shirley Papuga
Email: papuga@email.arizona.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Associate Professor and Ecohydrologist

Funding Support: NSF and other

Marcel Schaap
Email: mschaap@cals.arizona.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Associate Professor and Soil Physicist

Funding Support: NSF and other

Paul Brooks
Email: paul.brooks@utah.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Performed observations, analysis, and modeling on snow cover, water balance, carbon and nutrient cycling and CA evolution.

Funding Support: DOE and this award
Rachel Gallery
Email: rgallery@email.arizona.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Theme lead
Funding Support: NSF
International Collaboration: No
International Travel: No

Roy Johnson
Email: johnson6@email.arizona.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Theme lead (Geosciences)
Funding Support: NSF
International Collaboration: No
International Travel: No

Marcy Litvak
Email: mlitvak@unm.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Has performed work in the area of keeping the flux towers running and data processed.
Funding Support: Ameriflux Core support (160 hours), DOE TES (80 hours), NSF LTER (80 hours)
International Collaboration: No
International Travel: No

Michael McKisson
Email: mckisson@email.arizona.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2

Contribution to the Project: writer
Funding Support: NA
International Collaboration: No
International Travel: No
Bill Plant
Email: wplant@email.arizona.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Education and outreach
Funding Support: NSF and other
International Collaboration: No
International Travel: No

Daniel Potts
Email: pottsdl@buffalostate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Daniel has performed work in the area of plant ecophysiology - developing an understanding of the physiological constraints of the tree community around the Mt. Bigelow eddy covariance tower site.
Funding Support: Daniel is faculty of Buffalo State College
International Collaboration: No
International Travel: No

Shipherd Reed
Email: shipherd@email.arizona.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Appointed Personnel
Funding Support: NSF and other
International Collaboration: No
International Travel: No

Virginia Rich
Email: virginia.isabel.rich@gmail.com
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Theme lead
Funding Support: NSF
International Collaboration: No
International Travel: No
Joel Biederman
Email: joel.biederman.ua@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: Graduate student/postdoc associate
Funding Support: NSF & Other
International Collaboration: No
International Travel: No

Jason Field
Email: jfield@email.arizona.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: postdoc
Funding Support: NSF
International Collaboration: No
International Travel: No

Adrian Harpold
Email: adrian.harpold@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: postdoc associate
Funding Support: NSF
International Collaboration: No
International Travel: No

Gregory Maurer
Email: gregmaurer@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: Has performed work in the area of keeping the flux towers running and data processed.
Funding Support: Ameriflux Core support
International Collaboration: No
International Travel: No

Bhaskar Mitra
Email: bhaskar.mitra6@gmail.com
Lindsey Nesbitt
Email: lindseychr@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: Coupled water and biogeochemical modeling
Funding Support: DOE and other NSF
International Collaboration: No
International Travel: No

Enrique Sanchez-Canete
Email: enripsc@ugr.es
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: staff scientist
Funding Support: NSF
International Collaboration: No
International Travel: No

Tyson Lee Swetnam
Email: tswetnam@email.arizona.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: postdoc
Funding Support: NSF
International Collaboration: No
International Travel: No

Kyle Trostle
Email: ktrostle@email.arizona.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
**Contribution to the Project:** CZO postdoc leading concentration-discharge analyses and aqueous geochemistry.

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

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**Juan Camilo Villegas**  
**Email:** villegas@email.arizona.edu  
**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)  
**Nearest Person Month Worked:** 12

**Contribution to the Project:** postdoc

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

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**Nathan Abramson**  
**Email:** nabramso@email.arizona.edu  
**Most Senior Project Role:** Other Professional  
**Nearest Person Month Worked:** 12

**Contribution to the Project:** Research Specialist

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

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**Richard Castle**  
**Email:** rcastle@email.arizona.edu  
**Most Senior Project Role:** Other Professional  
**Nearest Person Month Worked:** 12

**Contribution to the Project:** exhibit support (Flandrau Science Center and Planetarium)

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

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**Prakash Dhakal**  
**Email:** dhakal@email.arizona.edu  
**Most Senior Project Role:** Other Professional  
**Nearest Person Month Worked:** 12

**Contribution to the Project:** Laboratory Director
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<td>Michael Evans</td>
<td><a href="mailto:maevans@email.arizona.edu">maevans@email.arizona.edu</a></td>
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<td>Contribution to the Project: Media technician (School of Journalism)</td>
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<td>Jen Fields</td>
<td><a href="mailto:fieldsj@email.arizona.edu">fieldsj@email.arizona.edu</a></td>
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<td>Contribution to the Project: Giving advice as Staff, Director of Education for CZ Discovery development meetings, we provided CZ activities for some of the UA Fusion summer camps that she manages. Has performed work by providing advice and expertise on K-12 educational activities for the CZ Discovery program.</td>
<td>Staff at Flandrau Science Center, no CZO funding, volunteered her time.</td>
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<td>Shiloe Fontes</td>
<td><a href="mailto:sfontes@email.arizona.edu">sfontes@email.arizona.edu</a></td>
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<td>Contribution to the Project: graphic design/exhibit support (Flandrau Science Center and Planetarium)</td>
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<td>Sara Kobilka</td>
<td><a href="mailto:kobilka@email.arizona.edu">kobilka@email.arizona.edu</a></td>
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<td>Contribution to the Project: Provided coordination with schedule and camp counselors to pilot some of the CZ Discovery activities. She is staff, summer camp coordinator.</td>
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Funding Support: Staff at UA Fusion Camp (Flandrau summer camp), no CZO funding. Volunteers time.

International Collaboration: No
International Travel: No

Robert Long
Email: bobby@nearsightgraphite.com
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: exhibit support/illustration

Funding Support: NSF

International Collaboration: No
International Travel: No

Mark Losleben
Email: losleben@email.arizona.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Research Technician

Funding Support: NSF

International Collaboration: No
International Travel: No

Gergory McNamee
Email: gregorymcnamee@gmail.com
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Science writer (Economics Dept)

Funding Support: NSF

International Collaboration: No
International Travel: No

Neil McSweeney
Email: mcsweeney@email.arizona.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: exhibit support (Flandrau Science Center and Planetarium)

Funding Support: NSF
International Collaboration: No
International Travel: No

Robert Parmenter
Email: bparmenter@vallescaldera.gov
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Project Site coordination, presentation of results from CZO group to agencies and general public.

Funding Support: As a Federal Employee (Director, Scientific Services Division VCNP) salary is covered by the U.S. Government.

International Collaboration: No
International Travel: No

Ruben Ruiz
Email: rubelruiz@gmail.com
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: classified part-time staff - videography

Funding Support: NSF and other

International Collaboration: No
International Travel: No

Rebecca Minor
Email: rlminor@email.arizona.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 12

Contribution to the Project: Research Technician

Funding Support: NSF

International Collaboration: No
International Travel: No

Matej Durcik
Email: mdurcik@email.arizona.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 12

Contribution to the Project: Staff scientist

Funding Support: NSF
Jonathan Furst
Email: jfurst@unm.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 12

Contribution to the Project: Has performed work in the area of keeping the flux towers running and data processed.

Funding Support: Ameriflux Core support

Noel Hensley
Email: mnhensley@email.arizona.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 2

Contribution to the Project: Education Program Coordinator

Funding Support: NA

Russell Scott
Email: Russ.Scott@ARS.USDA.GOV
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 12

Contribution to the Project: Research Hydrologist

Funding Support: NSF

Francisco Balocchi
Email: fbalocchi@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Is working on understanding the hydrologic processes operating during snowmelt that induce either infiltration or runoff.

Funding Support: Funded by the nation of Chile.
<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Most Senior Project Role</th>
<th>Nearest Person Month Worked</th>
<th>Contribution to the Project</th>
<th>Funding Support</th>
<th>International Collaboration</th>
<th>International Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mallory Barnes</td>
<td><a href="mailto:mallorybarnes@email.arizona.edu">mallorybarnes@email.arizona.edu</a></td>
<td>Graduate Student (research assistant)</td>
<td>12</td>
<td>student researcher</td>
<td>NSF</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Michelle Coe</td>
<td><a href="mailto:macoe@email.arizona.edu">macoe@email.arizona.edu</a></td>
<td>Graduate Student (research assistant)</td>
<td>12</td>
<td>Michelle Coe has performed work towards our Broader Impacts in terms of leading in-class activities with elementary students.</td>
<td>NASA Space Grant Fellowship</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Tony Colella</td>
<td><a href="mailto:tonycolella@email.arizona.edu">tonycolella@email.arizona.edu</a></td>
<td>Graduate Student (research assistant)</td>
<td>12</td>
<td>student researcher</td>
<td>NSF</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ravindra Dwivedi</td>
<td><a href="mailto:ravindradwivedi@email.arizona.edu">ravindradwivedi@email.arizona.edu</a></td>
<td>Graduate Student (research assistant)</td>
<td>12</td>
<td>Has worked on understanding the origins and mechanisms for residence time distribution functions in fractured rock systems</td>
<td>This award and teaching assistantship</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
International Collaboration: No
International Travel: No

Dawson Fairbanks
Email: dawsonfairbanks@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Has contributed outreach experience and topic expertise to the development of the CZ Discovery activities, will give time to activity delivery. Also has performed work in the area of soil microbial ecology including a number of field campaigns to CZO sites to characterize and collect soils samples, laboratory assays of microbial exoenzyme activity, microbial biomass Carbon and Nitrogen quantification, DNA extractions and quality control, data analysis, and manuscript preparation.

Funding Support: She is a grad student on CZO. Sloan Indigenous Graduate Partnership Fellowship.

Yuanhao Fang
Email: yhfang@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Has performed modeling of the topographic shading effects on snow and runoff

Funding Support: Chinese National Science Foundation (CNSF) visiting scholar

International Collaboration: Yes, China
International Travel: No

Brendan Fenerty
Email: bfenerty@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Amy Kidder
Email: akidder@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Ecohydrological assessment of changes in distribution of endangered Pima Pineapple Cactus, including potential migration across Catalinas of Jemez-Catalina gradient.
Funding Support: Raytheon

International Collaboration: No
International Travel: No

Emily Kopp
Email: ekopp@optics.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: SWES graduate student

Funding Support: NSF

International Collaboration: No
International Travel: No

Cianna Logie
Email: clogie@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: M.S. student

Funding Support: NSF and other

International Collaboration: No
International Travel: No

Rebecca Lybrand
Email: rlybrand@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Ph.D. student

Funding Support: NSF

International Collaboration: No
International Travel: No

Brianna McClure
Email: briannamcculure@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Has worked on impact of fire on DOM indices and whether fire effects DOM quality and quantity.

Funding Support: This award and from teaching assistantship
Margretta Murphy
Email: mamurphy@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Has performed work in the area of soil microbial ecology including a number of field campaigns to CZO sites to characterize and collect soil samples, laboratory assays of microbial biomass Carbon and Nitrogen quantifications, DNA extractions and quality control, and troubleshooting protocols for quantitative PCR.

Funding Support: N/A

Patrick Murphy
Email: murphyp@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

Jared A. Olyphant
Email: jolyphant@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Ph.D. student

Funding Support: NSF and other

Caitlin A. Orem
Email: orem@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Ph.D. student

Funding Support: NSF
Ben Paras
Email: bkp@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Subsurface imaging with geophysics
Funding Support: NSF

Michael Pohlmann
Email: mapohlmann@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: M.S. student
Funding Support: NSF and other

Rodrigo Andres Sanchez
Email: andressanchez@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: MS student
Funding Support: Other

Andres Sanchez-Romero
Email: adressanchex@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Student researcher
Funding Support: NSF
Christopher Shepard  
Email: cbs9h@email.arizona.edu  
**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 12  
**Contribution to the Project:** Has performed work in the area of soil modeling  
**Funding Support:** University Fellows program through UA graduate college  
**International Collaboration:** No  
**International Travel:** No

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Alissa White  
Email: alissawhite@email.arizona.edu  
**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 12  
**Contribution to the Project:** M.S. student  
**Funding Support:** NSF  
**International Collaboration:** No  
**International Travel:** No

---

Zachary Williams  
Email: zwilliams@email.arizona.edu  
**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 6  
**Contribution to the Project:** research  
**Funding Support:** NSF  
**International Collaboration:** No  
**International Travel:** No

---

Zinnia Wilson  
Email: zinnia.wilson@utah.edu  
**Most Senior Project Role:** Graduate Student (research assistant)  
**Nearest Person Month Worked:** 12  
**Contribution to the Project:** student researcher  
**Funding Support:** NSF  
**International Collaboration:** No  
**International Travel:** No

---

Runjian Wu  
Email: wurunjian@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: graduate student

Funding Support: NSF and other

International Collaboration: No
International Travel: No

Fang Yuanhao
Email: yuanhao.fang@outlook.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Ph.D. student

Funding Support: NSF and other

International Collaboration: No
International Travel: No

Xavier Zapata-Rios
Email: xavierzapata@email.arizona.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Ph.D. student

Funding Support: NSF

International Collaboration: No
International Travel: No

Darin Law
Email: dlaw@email.arizona.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 12

Contribution to the Project: Co-author on critical zone services papers (Vadose Zone Journal and Eos); led installation of microclimate array at Mt. Bigelow

Funding Support: Arizona Agricultural Experiment Station

International Collaboration: No
International Travel: No

Hannah Bergeron
Email: hlberg12@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12
Contribution to the Project: undergraduate research technician

Funding Support: NSF

International Collaboration: No
International Travel: No

Daniel Blackett
Email: dblackett@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 4

Contribution to the Project: research

Funding Support: NSF

International Collaboration: No
International Travel: No

Aidan Blum
Email: aidanblum@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: Processing water samples for the CZO project. Also ran samples for water stable isotopes on the isotope analyzer.

Funding Support: TRIF and HWR

International Collaboration: No
International Travel: No

Melissa Bohlman
Email: mbohlman1@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Mirsa Bojorquez Ochoa
Email: m.holly.boom@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: Undergraduate student researcher
Funding Support: NSF
International Collaboration: No
International Travel: No

Jessica Cait Boyer
Email: jcboyer@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12
Contribution to the Project: student researcher

Funding Support: NSF
International Collaboration: No
International Travel: No

Zev Braun
Email: braunzev@grinnell.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12
Contribution to the Project: undergrad student

Funding Support: NSF
International Collaboration: No
International Travel: No

Marci Caballero-Reynolds
Email: marcicr@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 8
Contribution to the Project: Research

Funding Support: NSF
International Collaboration: No
International Travel: No

Curtis Cagle
Email: curtiscagle@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 4
Contribution to the Project: research

Funding Support: NSF
Nick Callahan
Email: nrcallahan@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12
Contribution to the Project: student researcher
Funding Support: NSF

Anahi Carrera
Email: anahicarrera@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12
Contribution to the Project: student researcher
Funding Support: NSF

Zhao Yang Chen
Email: chenzhaoyang@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 4
Contribution to the Project: research
Funding Support: NSF

Chelsea Cook
Email: cmcook@email.arizona.eu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12
Contribution to the Project: student researcher
Funding Support: NSF
Noelle Espinosa
Email: noellee@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Elizabeth Fennie
Email: efennie@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

James Garlant
Email: garlant@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: Undergraduate contributing to Ecohydrology Theme - looking at sources of plant water use in our SCM Mixed Conifer Site at Mt. Bigelow.

Funding Support: This research is supported in salary by NSF Career Award

International Collaboration: No
International Travel: No

Katlyn Green
Email: katlyngreen@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Janelle Guan
Email: jguan@email.arizona.edu
Most Senior Project Role: Undergraduate Student  
Nearest Person Month Worked: 12

Contribution to the Project: undergraduate student
Funding Support: NSF
International Collaboration: No  
International Travel: No

Becky Hall  
Email: beckyh@email.arizona.edu  
Most Senior Project Role: Undergraduate Student  
Nearest Person Month Worked: 12

Contribution to the Project: post B.S. volunteer
Funding Support: other
International Collaboration: No  
International Travel: No

Lejon Hamann  
Email: lejonhamann@email.arizona.edu  
Most Senior Project Role: Undergraduate Student  
Nearest Person Month Worked: 12

Contribution to the Project: student researcher
Funding Support: NSF
International Collaboration: No  
International Travel: No

Sara Harders  
Email: saraharders@email.arizona.edu  
Most Senior Project Role: Undergraduate Student  
Nearest Person Month Worked: 12

Contribution to the Project: student researcher
Funding Support: NSF
International Collaboration: No  
International Travel: No

Maggie Heard  
Email: maggieheard@gmail.com  
Most Senior Project Role: Undergraduate Student  
Nearest Person Month Worked: 12
Contribution to the Project: Undergraduate Student and Accelerated MS on CZO

Funding Support: NSF

International Collaboration: No
International Travel: No

Carly Herndon
Email: carlyherndon@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Katherine Heydorn
Email: kheydorn@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: undergrad student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Joshua Hoskinson
Email: jhoskinson@emai.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: Has performed work in the area of soil minerology

Funding Support: NASA Space Grant

International Collaboration: No
International Travel: No

Andrew Kelley
Email: akelley2@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF
<table>
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<tr>
<th>Name</th>
<th>Email</th>
<th>Most Senior Project Role</th>
<th>Nearest Person Month Worked</th>
<th>Contribution to the Project</th>
<th>Funding Support</th>
<th>International Collaboration</th>
<th>International Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amanda Kerr</td>
<td><a href="mailto:kerr.a@husky.neu.edu">kerr.a@husky.neu.edu</a></td>
<td>Undergraduate Student</td>
<td>4</td>
<td>research</td>
<td>NSF</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Tessa Kobida</td>
<td><a href="mailto:tkobida@email.arizona.edu">tkobida@email.arizona.edu</a></td>
<td>Undergraduate Student</td>
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<td>student researcher</td>
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<tr>
<td>Lauren Koch</td>
<td><a href="mailto:laurenkoch@email.arizona.edu">laurenkoch@email.arizona.edu</a></td>
<td>Undergraduate Student</td>
<td>12</td>
<td>student researcher</td>
<td>NSF</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Charlie Landa</td>
<td><a href="mailto:landa1@email.arizona.edu">landa1@email.arizona.edu</a></td>
<td>Undergraduate Student</td>
<td>4</td>
<td>research</td>
<td>NSF</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Katarena Matos
Email: katarenamatos@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: undergraduate student
Funding Support: NSF
International Collaboration: No
International Travel: No

Alex Moreno
Email: amoreno@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher
Funding Support: NSF
International Collaboration: No
International Travel: No

Kelly Orman
Email: kellylynnorman@yahoo.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher
Funding Support: NSF
International Collaboration: No
International Travel: No

Shawn Pedron
Email: sped398@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: undergraduate student researcher
Funding Support: NSF
International Collaboration: No
International Travel: No

Erick Reynoso
Email: edreynoso@miners.utep.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: undergraduate student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Catherine Riedel
Email: catherineridel@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Michelle Rincon
Email: michellerincon@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Rebecca Smith
Email: rkramersmith@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: Laboratory and data analyses

Funding Support: DOE and other NSF

International Collaboration: No
International Travel: No

Maria Snyder
Email: msnyder2@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 4
**Contribution to the Project:** research

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

---

**Lexie Sorrentino**

**Email:** lexiesorrentino@email.arizona.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 4

**Contribution to the Project:** research

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

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**Leland Sutter**

**Email:** lelandsutter@email.arizona.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 12

**Contribution to the Project:** undergraduate student who has performed work in the area of soil CO2 and water fluxes in the SCM CZO sites, particularly the Mt. Bigelow eddy covariance tower site. Leland also compiles datasets for analysis.

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

---

**Samantha Swartz**

**Email:** skswartz@email.arizona.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 4

**Contribution to the Project:** research

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

---

**Claire Tritz**

**Email:** ckat@email.arizona.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Worked on processing water samples for the CZO project.
Funding Support: TRIF

International Collaboration: No
International Travel: No

Molly Van Dop
Email: mvandop@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: undergraduate student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Lauren Ward
Email: laurenward@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No
International Travel: No

Adam Weber
Email: adamweber@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 4

Contribution to the Project: research

Funding Support: NSF

International Collaboration: No
International Travel: No

Nicole Weber
Email: nweber@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Funding Support: NSF
Rachel Wehr
Email: rachelwehr@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: Undergraduate contributing to Ecohydrology Theme - looking at precipitation and soil moisture trends in SCM at Marshall Gulch.

Funding Support: This research is supported in salary by NSF Career award.

Charles Wilson
Email: cawilson@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Sarah Wolsiffer
Email: sarahwolsiffer@email.arizona.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: student researcher

Julia Yang
Email: juj.yang@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 12

Contribution to the Project: undergraduate student researcher

International Collaboration: No
International Travel: No
### What other organizations have been involved as partners?

<table>
<thead>
<tr>
<th>Name</th>
<th>Type of Partner Organization</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona State University</td>
<td>Academic Institution</td>
<td>Tempe, AZ</td>
</tr>
<tr>
<td>Cornell University</td>
<td>Academic Institution</td>
<td>Ithaca, NY</td>
</tr>
<tr>
<td>University of New Mexico</td>
<td>Academic Institution</td>
<td>Albuquerque, NM</td>
</tr>
<tr>
<td>University of Utah</td>
<td>Academic Institution</td>
<td>Utah</td>
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<tr>
<td>Valles Caldera National Preserve</td>
<td>Other Organizations (foreign or domestic)</td>
<td>Jemez Springs, NM</td>
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<tr>
<td>Hartwick College</td>
<td>Academic Institution</td>
<td>Hartwick, NY</td>
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<td>Kyoto Prefecture University</td>
<td>Academic Institution</td>
<td>Kyoto, Japan</td>
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<tr>
<td>Los Alamos National Laboratory</td>
<td>Other Organizations (foreign or domestic)</td>
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<td>Los Alamos National Laboratory</td>
<td>Industrial or Commercial Firms</td>
<td>New Mexico</td>
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<tr>
<td>State University of New York</td>
<td>Academic Institution</td>
<td>Buffalo, NY</td>
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<td>Tucson Unified School District</td>
<td>School or School Systems</td>
<td>Tucson, AZ</td>
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<td>USDA-Agricultural Research Services Southwest Watershed</td>
<td>State or Local Government</td>
<td>Southwest</td>
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<td>USGS</td>
<td>State or Local Government</td>
<td>New Mexico</td>
</tr>
</tbody>
</table>

### Full details of organizations that have been involved as partners:

**Arizona State University**

**Organization Type:** Academic Institution  
**Organization Location:** Tempe, AZ  

**Partner's Contribution to the Project:**  
Collaborative Research  
Personnel Exchanges

**More Detail on Partner and Contribution:** ASU personnel including Arjun Heimsath and coworkers are conducting collaborative research in the SCM CZO.

**Cornell University**

...
Organization Type: Academic Institution
Organization Location: Ithaca, NY

Partner's Contribution to the Project: Collaborative Research

More Detail on Partner and Contribution: Through PI Louis Derry, Cornell University is conducting geochemical research at the SCM-JRB CZO.

Hartwick College

Organization Type: Academic Institution
Organization Location: Hartwick, NY

Partner's Contribution to the Project: Personnel Exchanges

More Detail on Partner and Contribution: Dr. Zsuzsanna Balogh-Brunstad, Associate Professor in Geosciences and Chemistry, is conducting her sabbatical at the University of Arizona, working in the CZO. Her research focus is on fungal mediated weathering processes.

Kyoto Prefecture University

Organization Type: Academic Institution
Organization Location: Kyoto, Japan

Partner's Contribution to the Project: Collaborative Research

More Detail on Partner and Contribution: Dr. Atsushi Nakao, professor from the Department of Geosciences at KFU is conducting his sabbatical at University of Arizona and focusing his research on the CZO. His focus is on the role of climate in mica weathering processes.

Los Alamos National Laboratory

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Los Alamos, NM

Partner's Contribution to the Project: Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Los Alamos National Laboratory loans field based equipment to the JRB-SCM CZO that is associated with our eddy covariance and ecohydrologic studies.
Partner's Contribution to the Project: Facilities

More Detail on Partner and Contribution:

State University of New York

Organization Type: Academic Institution
Organization Location: Buffalo, NY

Partner's Contribution to the Project: Collaborative Research

More Detail on Partner and Contribution:

Tucson Unified School District

Organization Type: School or School Systems
Organization Location: Tucson, AZ

Partner's Contribution to the Project: Facilities

More Detail on Partner and Contribution:

USDA-Agricultural Research Services Southwest Watershed

Organization Type: State or Local Government
Organization Location: Southwest

Partner's Contribution to the Project: Facilities

More Detail on Partner and Contribution:

USGS

Organization Type: State or Local Government
Organization Location: New Mexico

Partner's Contribution to the Project: Facilities

More Detail on Partner and Contribution:

University of New Mexico

Organization Type: Academic Institution
Organization Location: Albuquerque, NM
Partner's Contribution to the Project:
Financial support
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Professor Marcy Litvak is a subcontracted PI focusing on eddy covariance research at the JRB site.

University of Utah
Organization Type: Academic Institution
Organization Location: Utah

Partner's Contribution to the Project:
Facilities

More Detail on Partner and Contribution:

Valles Caldera National Preserve
Organization Type: Other Organizations (foreign or domestic)
Organization Location: Jemez Springs, NM

Partner's Contribution to the Project:
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Dr. Robert Parmenter of VCNP (US Forest Service) is a subcontractor on the project and assists through provision of hydrologic technician support and collaborative research.

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?

Catalina-Jemez CZO collaborators meet biweekly to present research results and integrate findings into an evolving shared framework of coupled-process understanding. We are training students who work seamlessly across disciplines (geochemistry-microbiology-geophysics-hydrology) that were previously segregated.

Several of our graduates are now faculty at institutions with programs that contain the title "critical zone" and cut across these fields of study.

We have developed two new courses in critical zone science at the University of Arizona.

What is the impact on other disciplines?
Our approach to drilling the CZ involved methodologies developed during an NSF-funded workshop that Cliff Riebe and Jon Chorover organized three years ago that highlighted the importance of informing on drilling selection on the basis of pre-assessments by geophysical methods. Geophysical methods are increasingly becoming a central component and took kit associated with CZ research.

The convergent research approach that is central to CZ science is increasingly recognized as exemplary by other interdisciplinary efforts.

CZ research is strongly impacting the ecosystem science community. By integrating ecologists into our CZO teams, we have developed an improved understanding of the impacts of deep time and deep subsurface geo-processes (e.g., soil formation and regolith depth) on sustaining ecosystem productivity (e.g., carbon fixation and organic matter stabilization).

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

The principal use of CZO funds is support for graduate and undergraduate students and postdoctoral scientists. These individuals range in the demographics of higher education training from those just entering college to those on the job market for professorial or agency/industry positions. Through this project, all of them are developing the recognition of that taking an integrated and transdisciplinary approach to Earth surface science is essential to not only understanding how the Earth functions as a system, but to sustaining the capacity of that system to provide services to society.

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

The CZO project has motivated technological developments in our laboratories, including the establishment of high throughput geochemical, mineralogical and microbiological methods, and the application of state-of-the art techniques (e.g., borehole NMR, molecular ecology, LC-MS/MS and X-ray absorption spectroscopy) to studies of the critical zone.

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

Nothing to report.

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

- More than 100 million data values are currently stored in the database.

- To present, 55 datasets have been published on the Catalina-Jemez website (http://criticalzone.org/catalina-jemez/data/). Published datasets contains 410 data files in the CZO data display format and GIS standard formats such as ArcGIS shapefile and GeoTIFF. All published datasets are periodically updated after data are processed and quality controlled.

- Eight new datasets were added from 7/1/2016 to 6/30/2017.

- 830 unique users downloaded ca. 10k data files from the Catalina-Jemez datasets published on the website for one year period from 7/1/2016 to 6/30/2017.

- To present, more than 20 million data values have been harvested to the CZO Central data and metadata depository hosted by the San Diego Supercomputer Center (SDSC). These data are available for download via the CUAHSI Water Data Center services (http://hiscentral.cuahsi.org/pub_services.aspx). These are direct links for 2 Catalina-Jemez services: http://hiscentral.cuahsi.org/pub_network.aspx?n=158 and http://hiscentral.cuahsi.org/pub_network.aspx?n=177.

**Website Usage**

https://reporting.research.gov/rppr-web/rppr?execution=e1s7
The CZO website (http://criticalzone.org/catalina-jemez/) had 6500 visits by 4200 users for one year period from 7/1/2016 to 6/30/2017. Users viewed 15,765 pages.

What is the impact on technology transfer?

• Near completion of the development of a mapping tool (hosted on OpenTopography.org) that computes solar insolation and EEMT in complex landscapes for any time range over the past 30 years, or as a long-term average. Will provide a measure of energy driving critical zone processes for any landscape at any spatial resolution. The user needs only to specify his/her area of interest.

• Developed a "smart" vadose zone pore water sampling system that can be programmed to collect pore water samples for geochemical analysis over a time series with pre-established constraints on physical conditions (e.g., soil moisture or water potential) in the unsaturated zone.

What is the impact on society beyond science and technology?

Our CZO has taken a leading role in the discussion and publication of current thinking on the concept of "critical zone services". Translation of cutting-edge research from CZ science into an improved understanding of how the critical zone provides services to society is key to impacting society beyond science and technology.

Specifically, we have articulated (e.g., Field et al., 2015, 2016) how CZ services are distinguishable from what has been described previously as "ecosystem services", and how a geosciences perspective can deepen the temporal and process-level understanding of how coupled geological and biological processes enable human societies to thrive on the Earth's surface. CZ services include, e.g., storing and purifying water, producing nutritional soils for food and fiber, and stabilizing carbon in the subsurface.

Changes/Problems

Changes in approach and reason for change

As of the time of writing this report, a wildfire is burning in the Santa Catalina Mountains (SCM) in very close proximity to our principal instrumented field site in mixed conifer forest (Bigelow Tower site). Yesterday we rescued the above ground equipment that we could. It is not yet clear what the impact of this fire will be on our operations there, but if it burns through the field site, operations will be affected.

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

None at this point.

Changes that have a significant impact on expenditures

None at this point.

Significant changes in use or care of human subjects

None at this point.

Significant changes in use or care of vertebrate animals

Not applicable.

Significant changes in use or care of biohazards

None at this point.
Fig. 1. Trends in winter and spring ablation over the last 30+ years place the snow work at Jemez and other western CZO’s in broader context (Harpold and Brooks). Trends in winter ablation (a, b) and spring melt rate (c, d) from prior to 1985 through 2015 at 462 sites. Symbol colors (a, c) represent magnitude of change and crosses denote sites with significant trends (p<0.05). Histograms (b, d) show the number of sites with trends at varying magnitudes (blue bars), red bars are significant trends (p<0.05).
Fig. 2. The role of topographically driven hydrologic subsidy on biomass accrual using high resolution LiDAR data obtained as part of the cross CZO research. Surprisingly, analyses indicate that the influence of lateral water (or nutrient) distribution is greater either aspect or elevation in explaining standing forest biomass (Swetnam et al., 2017).
Fig. 3. Flowpaths and transit times of water through the deep CZ into Marshall Gulch stream. Seasonal streamflow transit times (A), water balance (B), source water contributions to streamflow (C), and temporal pattern of isotopic composition of precipitation, soil water, and streamflow (D) (Dwivedi et al., in prep.).
Fig. 4. Carbon NEXAFS spectra of JRB subsoil following reaction with influent DOM from forest floor, under wet-dry cycling. Left, carbon NEXAFS spectra extracted from C, Ca, and Fe regions of STXM map. Spectra of unreacted soil (top) and DOM solution (bottom) are presented. Dashed vertical lines point out C species. Right, tri-colored STXM map of fine fraction from JRB soil reacted four times with DOM under wet-dry cycling; Fe (red), Ca (blue) and C (green). Image size 25 x 25μm (Olshansky et al., in review).
Fig. 5. Data collected from instrumented pedons in Bigelow ZOB show that seasonal dependence of moisture and temperature drive soil CO$_2$(g) production from subsurface respiration that, in turn, promotes associated releases of K and Si, suggesting biologically-induced dissolution of mica/illite or K-feldspar (Olshansky et al., in prep.).
Fig. 6. Elemental chemistry of core materials (site 1 borehole; eastern mid-slope of MCZOB) combined with geophysical survey. Differences in immobile elements (e.g. Ti or Zr) and mineralogy with depth suggest multiple depositional events. Smectite and zeolite (clinoptilolite and mordenite) in the upper 10 m were precipitated in an alkaline caldera lake that formed soon after caldera eruption (1.25 Ma).

Fig. 7. Elemental chemistry of core materials (site 2 borehole; western mid-slope of MCZOB) combined with geophysical survey. Results reveal non-monotonic weathering profiles, perched aquifers corresponding to clay zones (likely formed from incongruent dissolution of primary minerals), and differences in parent materials with depth in the complex volcanic terrain. There is no evidence of smectite and zeolite from the alkaline lake, as seen in Borehole 1.
Fig. 8. Soil extractable NO₃⁻ as a function of depth below the surface in spring soil samples. Downslope sites had significantly more NO₃⁻ compared to upslope sites under both forest (F₁,39 = 45.85, P < 0.001) and herbaceous (F₁,41 = 6.79, P = 0.013) vegetation. Depth was also a significant predictor of [NO₃⁻-N] under both forest (F₄,39 = 4.65, P = 0.004) and herbaceous (F₄,41 = 16.51, P < 0.001) vegetation. Letters indicate statistical groupings between depth horizons within each vegetation type according to Tukey honest significant differences.