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Preview of Award 1331408 - Annual Project Report

<u>Cover</u> | <u>Accomplishments</u> | <u>Products</u> | <u>Participants/Organizations</u> | <u>Impacts</u> | <u>Changes/Problems</u>

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1331408
Project Title:	Transformative Behavior of Energy, Water and Carbon in the Critical Zone II: Interactions between Long- and Short-term Processes that Control Delivery of Critical Zone Services
PD/PI Name:	Jon D Chorover, Principal Investigator David D Breshears, Co-Principal Investigator Jennifer C McIntosh, Co-Principal Investigator Jon D Pelletier, Co-Principal Investigator Craig Rasmussen, Co-Principal Investigator
Recipient Organization:	University of Arizona
Project/Grant Period:	10/01/2013 - 09/30/2019
Reporting Period:	10/01/2017 - 09/30/2018
Submitting Official (if other than PD\PI):	Jon D Chorover Principal Investigator
Submission Date:	09/18/2018
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Jon D Chorover

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)?

Major Activities:

Here we report new activities under the headings consistent with prior year reports: (1) Ecohydrology and Hydrologic Partitioning, (2) Subsurface Biogeochemistry, (3) Surface Water Dynamics, and (4) Landscape Evolution.

1. Ecohydrology and Hydrologic Partitioning

- Characterizing different CZ water stores (e.g., residence time, geochemistry, groundwater flow direction), and their connectivity to surface waters to determine how CZ structure influences its function.
- Examining the hydrologic response of groundwater and stream flow to spring snowmelt and summer monsoons, utilizing MCZOB monitoring wells and surface flows (weirs).
- Exploring the hydrologic controls on U-series and Sr isotope composition of groundwater and surface waters; then using these isotopic tracers to identify seasonal changes in source water contributions to streamflow, and differences in matrix versus fracture flow.
- Determining annual water fluxes through the deep CZ that contribute to long-term evolution of deep CZ porosity and mountain block recharge.
- Testing the role of dissolved and colloidal organic matter in the transport of metal and nutrients in the CZ.
- Understanding how fire-induced impacts on stream water quality evolved with time, and how biogeochemical processes controlled post-fire solution concentration in surface waters.
- Two recent studies on snow-climate-vegetation interactions integrated work at JRB with other CZO locations (Tenant et al 2017) and the Western US as a whole (Harpold and Brooks, 2018). Using LiDAR data from CZO sites, Tenant documented how vegetation structure and topography influence local radiative energy fluxes resulting in unique, but predictable patterns in snow water input. Working at a larger scale, Harpold and Brooks documented how spatial and temporal variability in humidity differentially influence snowpack ablation and net CZ water input.
- Integrating previous work that separately examined fluvial (e.g. Perdrial et al. 2014) gaseous (e.g. Stielstra et al 2015), and vegetation (e.g. Zapata-Rios et al. 2015) carbon sinks, Perdrial et al. (2018) developed a comprehensive carbon budget for the Jemez CZO locations that detailed the differential influences of winter vs summer precipitation on CZ carbon storage.
- Neutron probe surveys were conducted in recently installed monitoring wells in the MC ZOB to measure seasonal propagation of wetting fronts with depth.
- Failed vibrating wire piezometers in MCZOB monitoring wells were replaced with Troll pressure transducers.
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2. Subsurface Biogeochemistry

- 98 subsamples from the MCZOB boreholes were analyzed for total elemental chemistry (UA, ALEC), bulk and fine fraction mineralogy using transmission XRD technique (SSRL beamline 11-3).
- 35 subsamples from the MCZOB boreholes had clay fractions separated and chemically treated to identify clay fraction mineralogy using transmission XRD technique (SSRL beamline 11-3).
- 20 samples from the MCZOB boreholes were reacted with air equilibrated water as a function of time to quantify incongruent dissolution kinetics (aqueous solute and secondary mineral formation) in laboratory experiments as a function of depth.
- Porosity was estimated at the MCZOB borehole locations using a rock physics model and shallow surface seismic geophysical data in order to correlate changes in mineralogy with physical structure as a function of depth.
- 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).
- Monitoring wells were sampled by field staff every two to four weeks for major ions, trace metals, stable isotopes, uranium and strontium isotopes, and carbon content. Monitoring wells were sampled weekly during spring snowmelt.
- ISCO automatic samplers were installed on the shallowest monitoring well, MCZOB flume, and La Jara flume for daily sampling during the spring snowmelt.
- 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.

3. Surface Water Dynamics

- 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).
- 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
- 'Age dating' analyses (tritium and carbon-14) were completed for groundwater samples collected from the MCZOB monitoring wells.

	 Additional water samples were analyzed for U and Sr isotopic composition at the University of Texas at El Paso. Dissolved and colloidal organic matter from stream and soil pore-water were analyzed, using Fourier-transform infrared spectroscopy (FTIR), Scanning transmission X-ray microscopy and near-edge X-ray adsorption fine structure (STXM–EXAFS) macroscopy. Water chemistry data and discharge were compiled and interpreted for diurnal sampling during spring snowmelt 2017 in La Jara catchment (Fig. 1). Stream concentration-discharge relations were linked to hydrochemical dynamics in up gradient sources, by simultaneously probing soil, groundwater and stream hydrologic and hydrochemical response. Pre- and post-fire surface water solute chemistry were compared to understand fire-induced landscape chemical denudation in the JRB CZO. Springs and groundwater wells near the Marshall Gulch catchment in the SCM CZO were sampled and analyzed for solute chemistry and tritium.
	 Following on work of Shepard et al – conducted studies of alluvial fan systems in southern Arizona that link modern critical zone processes with past climate variation and cycles of erosion and deposition. Current study locations include an ancient fan terrace near the CZO B2 Desert sites (proximal to Saddlebrook, AZ and adjacent to the Biosphere2 facility) that potentially records >2 My of erosion and soil formation. Working w/ Lin Ma at UTEP to use U-series dating on pedogenic carbonates, and the UA AMS lab to perform 10Be/26AI analyses on samples to identify surface ages and erosion rates.
Specific Objectives: Significant Results:	Here we report significant results under the headings consistent with prior year reports: (1) Ecohydrology and Hydrologic Partitioning, (2) Subsurface Biogeochemistry, (3) Surface Water Dynamics, (4) Landscape Evolution, and (5) Critical Zone Services.
	1. Ecohydrology and Hydrologic Partitioning
	• Multiple separate stores of water were identified in the CZ (from the near-surface to ~50m depth) in the MCZOB. A shallow perched aquifer at well site 2 is present above clay-rich landslide deposits (unique to site 2; well 2D). Groundwater from the perched aquifer is geochemically distinct from MCZOB and La Jara stream water and deeper groundwater, and the perched aquifer does not respond to the pressure pulse associated with increasing streamflow and rising water table in the deep aquifer. This suggests that the perched aquifer does not contribute significantly to streamflow. Deep groundwater from site 2 is geochemically distinct from shallow groundwater from the site 2 perched aquifer with lower Ca2+/Mg2+ ionic ratios associated with greater dissolution of Mg2+ rich minerals at depth in contrast with dissolution of Ca2+ rich calcite in the shallow subsurface. Tritium content of shallow groundwater is more than double that

depth in contrast with dissolution of Ca2+ rich calcite in the shallow subsurface. Tritium content of shallow groundwater is more than double that of site 2 deep groundwater (4.4 ± 0.27 and 1.6 ± 0.21 , respectively) which indicates that the residence time of deep groundwater is significantly greater than that of shallow groundwater. Deep groundwater from site 1 is most chemically-representative of waters contributing to La Jara stream flow. In addition, the geologic structure (lithology, fractured bedrock, relatively long mean groundwater residence time) and function (hydrologic response, solute fluxes, and water routing) of the CZ at site 1 is most representative of the whole La Jara catchment. Further, the shape and timing of the hydrograph of site 1 deep groundwater very closely resembles that of La Jara catchment surface water due to the pressure pulse propagation resulting from higher surface water stage which indicates their hydrologic connection.

 Volumetric water content varies with depth beneath ground surface in sites 2 and 3 wells. Lenses of higher water content in the top 2 m of sites 2 and 3 and from 8 to 12 mbgs at site 3 persist across wet and dry seasons which indicates the presence of lateral subsurface flow at these depths. Evidence of vertical infiltration is also seen below 4 m at site 2 as increased water content during the wet season returns to dry conditions from 2 to 4 mbgs while water content increases beneath 4 m as water drains.

2. Subsurface Biogeochemistry

- In excavated deep CZ boreholes from the MCZOB, legacy geologic events appear to control the CZ architecture in terms of primary and secondary mineral assemblages, geologic structure (e.g. faulting and fracturing), and hydrothermal alteration and byproducts. However, modern CZ processes are also identifiable in secondary mineralogy, such as less crystalline clay accumulation, iron oxides, and redox morphology. Differences in clay and shallow water content (as identified by surface geophysics: seismic and ERT) between the western and eastern portions of the MCZOB are likely due to different legacy events. The eastern portion of the ZOB is comprised of fractured welded tuff at depth which sharply transitions to high clay and zeolite content above 15 meters below the surface. Clay and zeolite (mostly clinoptilolite) accumulation is likely due to interaction and sedimentation in an alkaline lake shortly after the primary eruption as identified by Chipera et al. 2008. The western portion of the ZOB consists of hydrothermally altered vesicular tuff overlain by volcanic collapse breccia, which is comprised of a mixture of lithologies with high clay and iron oxide content. This portion of the ZOB is characterized by a shallow perched water table likely controlled by the clay strata. Variable redox morphology is present in the volcanic collapse breccias, indicating alternating redox conditions likely the result of a fluctuating shallow water table.
- Fracture surfaces at depth appear to accumulate iron and manganese oxides. Iron oxide accumulation within the welded tuff matrix is likely due to post-eruptive interstitial water weathering of microsites forming pervasive iron oxide (mostly goethite) banding within the tuffs. Conversely, iron oxide accumulation on fracture surfaces appear as thin rinds with occasional manganese oxide precipitated onto the iron oxide surfaces (Figure 5). X-ray spectroscopy of these iron oxide/manganese oxide sequences show that manganese below the surface are a combination of Mn (II/III) with Mn (III/IV) and Mn (IV) forming manganese nodules on the iron oxide surfaces. Ongoing work is investigating whether these manganese oxides are biologically formed at depth.
- In excavated deep CZ boreholes from the ZOB, weathering does not produce monotonic elemental depletion profiles as observed at other CZOs. 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 referential flow paths and concentrated weathering around fracture surfaces.

- Subsoil *p*CO2 was quantitatively controlled by above ground plant activity (GPP ET), precipitation, and temperature.
- A significant fraction of CO2 generated by soil respiration is consumed or transported belowground (Sanchez-Canete et al. 2018).
- Larger wetting events (winter snowmelt and monsoons) draw down *p*CO2 into soil pore water and streamflow, mainly in the wetter instrumented pedons (north facing and lower convergence). Whereas smaller wetting events resulted in pulsed increase of *p*CO2
- Elevated soil *p*CO2 resulted in proton-promoted silicate weathering, and releases of Si to solution and streams.
- Silicate (albite) weathering rate, estimated *in-situ*, corresponded to previously reported values.

3. Surface Water Dynamics

- Time series data of soil, groundwater and stream hydrology and hydrochemistry provides evidence of biological weathering reactions in soil and groundwater that are propagated into stream C-Q relations.
- Cluster and principal components analysis of indices pertaining to concentration-discharge (C-Q) relations identified five groups of solutes with transport behavior governed by distinct hydrogeochemical processes.
- Colloidal metal and nutrients were co-transported with organic matter.
- An improved conceptual model was developed for Marshall Gulch catchment that honors observed long-term hydrologic behavior of CZ functioning as well as its transient geochemical responses.
- Changes in stream water geochemistry in the Marshall Gulch catchment is related to the change in CZ dynamic storage.
- Long-term deep CZ water fluxes were estimated for the Marshall Gulch catchment, which influences deep CZ development and mountain block recharge.
- Increases in nitrate and sulfate concentrations in Valles Caldera (JRB-CZO) streams after the wildfire were likely from leaching of burned biomass. The elevated NO3- and SO42- concentrations persisted for over two years and were highest during spring snowmelt.
- Base cation concentrations increased immediately, within a few weeks after the fire, likely related to leaching from combusted organic matter; and, over a period of approximately two months, base cation concentrations returned to pre-fire levels.
- Trace element behavior was also altered by fire. For example, while pre-fire aluminum concentrations in stream flow increased significantly during the wet seasons (snowmelt and monsoons), the post-fire observations do not show significant changes with increase in discharge.

Key outcomes or Other achievements:

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

- The CZO project has provided a consistent training ground for undergrduate students, graduate students and
 postdoctoral scientists who are interested in conducting research at the interface between traditionally
 segregated disciplines of hydrology, ecology, soil science, geochemistry, and geomorphology. Many of our
 previous graduate students and postdocs have gone on to faculty positions at Research 1 universities, and are
 developing independent research programs in critical zone science.
- We are training undergraduate students to deliver hands-on science education activities for the CZ Discovery program. We are working with graduate and undergraduate students to continually refine the CZD curriculum. The CZ Discovery program successfully launched in fall 2016.
- CZ Discovery students brought the critical zone demonstrations to various outreach events outside of the CZ classroom such as Hi Corbet Field for STEM night at a UA Wildcats Baseball game, Earth Day at UA Biosphere 2, and many special events hosted by Flandrau Science Center and Planetarium. These events provide the students with an opportunity to communicate the critical zone science to a much broader audience than in the classroom, further reinforcing their communication skills.
- The "Mt. Lemmon Science Tour" (MLST) app, a free smartphone audio tour about the science of Arizona's "Sky Islands" mountains, provides a science narrative for the drive from Tucson to the top of the Santa Catalina Mountains. The Tour debuted in November 2015, and has already been downloaded by over 150,000 users. The Tour focuses on integrated earth science and introduces the Critical Zone concept to the general public.

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

- Rasmussen and the UA hosted the 2018 Western Regional Cooperative Soil Survey Meetings in cooperation
 with USDA NRCS, USDA USFS and the BLM bringing together soil scientists from multiple federal agencies
 and land grant universities to set goals and priorities for regional soil survey activities. This included a field trip
 to the SCM with stops along the elevation gradient in coordination with current soil mapping activities by the
 USFS, and stops at/near the Bigelow research site in the SCM with introduction/discussion of CZO activities.
 The meeting had >40 attendees.
- PhD student Alissa White and field technician Adam Killebrew gave Cross CZO Postdoc Adam Wlostowski a tour of the JRB-CZO, including an introduction to the field site, instrumentation, and current conceptual hydrologic models.
- Chorover gave a presentation on CZO research to federal, state and country land management officers at the Southwest Public Land Management Conference in Phoenix, AZ.
- Hired and trained undergraduate and graduate students as Instructional Specialists to facilitate the Critical Zone Discovery (CZD) school field trip program that began in Fall 2016. This process engaged science students interested in outreach.
- The CZD Field Trip Program brought in 974 students from 42 schools 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).
- A new course titled *Introduction to Critical Zone Science*_was developed to teach UA undergraduates the concepts of the critical zone. The lab portion of this class will take over the role of training and supporting the classroom experience of Critical Zone discovery at the end of the funding cycle, ensuring that this valuable program will continue to be available for the local community school children moving forward.
- The "Welcome to the Critical Zone" exhibit takes 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 75,157 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 150,000 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 Effective Energy and Mass Transfer, and profiles of graduate 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.

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

Please see the supplemental proposal request for the research activities planned for this year.

In addition to the research activities described there:

- The new exhibit about Critical Zone science and research, "Welcome to the Critical Zone," will remain open to the public through 2018. We are currently working on a new "deep critical zone" component that will utilize core samples and showcase scientific insights gained from the deep drilling in the Jemez ZOB.
- In August 2018, we will train our new student Instructional Specialists to deliver the activities for the CZ Discovery program. We will continue to promote the program to regional Title 1 schools, schedule school field trips, and deliver programming starting in September 2018.
- We will continue to release and promote videos about CZO research and scientists on YouTube for the "CZO Journey" series, working with Chris Shepard. The production and release of new CZ videos will continue through 2018.

Products

Books

Book Chapters

Heckman, K, LT Strand, C Rasmussen (2017). Role of mineralogy and climate in the soil carbon cycle. *Developments in Soil Science* 35. WR Horwath and Y Kuzyakov. Elsevier. . Status = ACCEPTED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

Inventions

Journals or Juried Conference Papers

Balogh Z., Brantley S., Dawson T., Eissenstat D., Evaristo J., Godsey S.E., Marshall J.A., McDonnell J.J., Papuga S.A., Roering J., and Weathers K. (2016). On the role of trees in building and plumbing the Critical Zone.. *Frontiers in the Ecology*. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Barron-Gafford G.A., Hendryx S., Minor R.L., Colella T., Murphy P., Lee E., Scott R.L., and Kumar P. (2017). A multi-metric assessment of the impacts of hydraulic redistribution on carbon and water fluxes in a semiarid savanna.. *Global Change Biology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Barron-Gafford G.A., Sanchez-Cañete E.P., Minor R.L., Hendryx S., Lee E., Sutter L., Tran N., Parra E., Colella T., Murphy P., Hamerlynck E., Kumar P., and Scott R (2017). Photosynthetic phenological variation may promote coexistence among co-dominant tree species in a Madrean sky island mixed conifer forest. *Tree Physiology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Brantley, S.L. McDowell, W.H. Dietrich, W.E. White, T.S. Kumar, P. Anderson, S.P. Chorover, J. Lohse, K.A. Bales, R.C. Richter, D.D. Grant, G. Gaillardet, J. (2017). Designing a network of critical zone observatories to explore the living skin of the terrestrial Earth. *Earth Surface Dynamics*. 5 (4), 841. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/esurf-5-841-2017

Breshears D. D., A. K. Knapp, D. J. Law, M. D. Smith, D. Twidwell, and C. L. Wonkka (2016). Rangeland Responses to predicted increases in drought extremity. *Rangelands*. 38 (4), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1016/j.rala.2016.06.009

Burghelia, C.I. Dontsova, K. Zaharescu, D.G. Maier, R.M. Huxman, T. Amistadi, M.K. Hunt, E. Chorover, J. (2018). Trace element mobilization during incipient bioweathering of four rock types. *Geochimica et Cosmochimica Acta*. 234 98. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.gca.2018.05.011

C Rasmussen, K Heckman, WR Wieder, M Keiluweit, CR Lawrence (2018). . Beyond clay: towards an improved set of variables for predicting soil organic matter content. *Biogeochemistry*. 137 (3), 297. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

C Rasmussen, L McGuire, P Dhakal, JD Pelletier. (2017). Coevolution of soil and topography across a semiarid cinder cone chronosequence.. *Catena*. 156 338. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

C Shepard, MG Schaap, JD Pelletier, C Rasmussen (2017). A probabilistic approach to quantifying soil physical properties via time-integrated energy and mass input. *Soil*. 3 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Chang L.-L., R. Dwivedi, Y. Fang, G.-Y. Niu, G. A. Barron-Gafford et al. (2017). Controls of Lateral Subsurface Flow, Topographic Shading, and the Resulting Plant Dynamics on the Partitioning of Evapotranspiration.. *Water Resources Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Chang L.L., Fang Y.H., Dwivedi R., Knowles J.F., Niu G.Y., Pelletier J.D., Rasmussen C., Durcik M., Barron-Gafford G.A., and Meixner T. (2018). Why Do Land Surface Models for Use in Earth System Models Produce a Low Ratio of Transpiration to Evapotranspiration?. *Journal of Geophysics Research – Atmosphere*. Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Chorover, J. Derry, L. A. McDowell, W. H. (2017). Concentration-Discharge Relations in the Critical Zone: Implications for Resolving Critical Zone Structure, Function, and Evolution. *Water Resources Research*. 53 (11), 8654. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2017WR021111

Chorover, J. (2017). Biogeochemical transformation of metal(loid)s in a disturbed critical zone. *Abstracts of Papers of the American Chemical Society*. 253 (Abstract 1), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Dwivedi R., Meixner T, McIntosh J., Ferre P.A.T., Eastoe C., Castro C., Wright W.W., Niu G.-Y., Minor R., Knowles J., Barron-Gafford G.A., Abramson N., Mitra B., Stanley M., and Chorover J. (2018). Examination of fractal behavior of various water balance components and hydrologic response functions for a mountainous sub-humid

catchment.. *In preparation*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Dwivedi, R., Meixner T., McIntosh J., Ferré P.A.T., Eastoe C.J., Niu G.-Y., Minor R.L., Barron-Gafford G., and Chorover J. (). Hydrologic functioning of the deep Critical Zone and contributions to streamflow in a high elevation catchment: testing of multiple conceptual models. Hydrological Processes.. *In revision*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Elshall A.S., Ye M., Niu G-Y, and Barron-Gafford G.A. (2017). Impacts of Residual Models on Bayesian Inference and Predictive Performance of Soil Respiration Models. *Journal of Geophysical Research – Biogeosciences.*. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Fang Y., P. Broxton, G.-Y. Niu, M. Barlage et al. (2017). Effects of Topographic Shading and Scattering of Insolation on Snow Mass Distributions and River Discharge over a Mountainous Catchment.. *Water Resources Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Fang, Y. H., G.-Y. Niu, W. Zeng, X. Zhang, P. Wang, and P. Troch (2017). Terrestrial water storage change over the Upper Colorado River Basin caused by climate and land cover changes. *Water Resources Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Finley, B, P Dijkstra, C Rasmussen, E Schwartz, R Mau, X Liu, N van Gestel, and BA Hungate (2018). Soil mineral assemblage and substrate quality effects on microbial priming.. *Biogeochemistry*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Froend R.H., Breshears D.D., Law D.J., and Barron-Gafford G.A. (2017). Phreatophytes in the Anthropocene: State and Transition Models for Climate Change and Land Use Pressures. *Earth's Future*. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Harpold A.A. and P.D. Brooks (2017). Humidity will determine snowpack response to climate change.. *Nature Climate Change*.. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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Chorover, J., P. D. Brooks, R.E. Gallery, J.C. McIntosh, Y. Olshansky, C. Rasmussen (2017). *Biogeochemical control points in a water-limited critical zone*. American Geophysical Union, Fall Meeting. New Orleans, LA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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Rasmussen, C. (2017). *Using Energy and Mass Transfer to Model Pedogenic Environments and Process.*. Soil Science Society of America Annual Meetings. Phoenix, AZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Christopher Shepard. *Understanding Quaternary soil formation using a synthesis of soil chronosequences*. (2018). University of Arizona. Acknowledgement of Federal Support = Yes

White, A.. *"Examining the Impacts of Wildfire on Throughfall and Stemflow Chemistry and Flux at Plot and Catchment Scales"*. (2015). Hydrology & Water Resources, University of Arizona. Acknowledgement of Federal Support = Yes

Murphy, M. *"Interaction of wildfire and landscape position on soil microbial community nitrogen cycling"*. (2016). Soil, Water & Environmental Science, University of Arizona. Acknowledgement of Federal Support = Yes

Balocchi, F. "Soil behavior during freeze-thaw processes at a snow-dominated forest site simulated with the physically-based numerical water flow and heat transport Soil in Cold Regions Model (SCRM)". (2016). Hydrology & Water Resources University of Arizona. Acknowledgement of Federal Support = Yes

Zapata-Rios, X.. "The influence of climate and landscape on hydrological processes, vegetation dynamics, biogeochemistry and the transfer of effective energy and mass to the critical zone".. (2015). Hydrology and Water Resources, University of Arizona. Acknowledgement of Federal Support = Yes

Websites

Participants/Organizations

Name	Most Senior Project Role	Nearest Person Month Worked
Chorover, Jon	PD/PI	2
Breshears, David	Co PD/PI	1
McIntosh, Jennifer	Co PD/PI	1
Pelletier, Jon	Co PD/PI	1
Rasmussen, Craig	Co PD/PI	1
Barron-Gafford, Greg	Co-Investigator	1
Ferré, Ty P.A.	Co-Investigator	1
Meixner, Thomas	Co-Investigator	1
Niu, Guo-Yue	Co-Investigator	1
Schaap, Marcel	Co-Investigator	1
Brooks, Paul	Faculty	1
Fidel, Rivka	Faculty	1
Gallery, Rachel	Faculty	1
Litvak, Marcy	Faculty	1
Plant, Bill	Faculty	1

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Potts, Daniel	Faculty	1
Reed, Shipherd	Faculty	1
Rich, Virginia	Faculty	0
Biederman, Joel	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Field, Jason	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Harpold, Adrian	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Maurer, Gregory	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Mitra, Bhaskar	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Nesbitt, Lindsey	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Olshansky, Yaniv	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Sanchez-Canete, Enrique	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Swetnam, Tyson	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Trostle, Kyle	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Villegas, Juan	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Abramson, Nathan	Other Professional	6
Castle, Richard	Other Professional	1
Dhakal, Prakash	Other Professional	0
Evans, Michael	Other Professional	1

Name	Most Senior Project Role	Nearest Person Month Worked
Fields, Jen	Other Professional	1
Fontes, Shiloe	Other Professional	1
Kobilka, Sara	Other Professional	1
Long, Robert	Other Professional	1
Losleben, Mark	Other Professional	6
McNamee, Gergory	Other Professional	0
McSweeney, Neil	Other Professional	1
Parmenter, Robert	Other Professional	0
Ruiz, Ruben	Other Professional	1
Minor, Rebecca	Technician	2
Durcik, Matej	Staff Scientist (doctoral level)	6
Eastoe, Christopher	Staff Scientist (doctoral level)	1
Furst, Jonathan	Staff Scientist (doctoral level)	0
Hensley, Noel	Staff Scientist (doctoral level)	1
Balocchi, Francisco	Graduate Student (research assistant)	2
Barnes, Mallory	Graduate Student (research assistant)	1
Cao, Rong	Graduate Student (research assistant)	1
Chang, Liling	Graduate Student (research assistant)	1
Coe, Michelle	Graduate Student (research assistant)	1
Colella, Tony	Graduate Student (research assistant)	1
Dwivedi, Ravindra	Graduate Student (research assistant)	6
Espinosa, Noelle	Graduate Student (research assistant)	1

Name	Most Senior Project Role	Nearest Person Month Worked
Fairbanks, Dawson	Graduate Student (research assistant)	6
Fang, Yuanhao	Graduate Student (research assistant)	2
Fenerty, Brendan	Graduate Student (research assistant)	2
Howe, Amanda	Graduate Student (research assistant)	1
Kidder, Amy	Graduate Student (research assistant)	1
Kopp, Emily	Graduate Student (research assistant)	0
Logie, Cianna	Graduate Student (research assistant)	1
Lybrand, Rebecca	Graduate Student (research assistant)	0
Mann, Sarina	Graduate Student (research assistant)	1
McClure, Brianna	Graduate Student (research assistant)	0
Paras, Ben	Graduate Student (research assistant)	6
Pohlmann, Michael	Graduate Student (research assistant)	6
Sanchez, Rodrigo	Graduate Student (research assistant)	4
Shepard, Christopher	Graduate Student (research assistant)	6
Solis, Jesus	Graduate Student (research assistant)	1
White, Alissa	Graduate Student (research assistant)	6
Wilson, Zinnia	Graduate Student (research assistant)	1
Wu, Runjian	Graduate Student (research assistant)	2
Yuanhao, Fang	Graduate Student (research assistant)	2
Law, Darin	Non-Student Research Assistant	0
Aldama, Phoenix	Undergraduate Student	1
Bergeron, Hannah	Undergraduate Student	1

Name	Most Senior Project Role	Nearest Person Month Worked
Blackett, Daniel	Undergraduate Student	1
Bloodsworth, Jasper	Undergraduate Student	1
Blum, Aidan	Undergraduate Student	2
Bohlman, Melissa	Undergraduate Student	1
Bojorquez Ochoa, Mirsa	Undergraduate Student	1
Boyer, Jessica	Undergraduate Student	1
Braun, Zev	Undergraduate Student	1
Caballero-Reynolds, Marci	Undergraduate Student	1
Cagle, Curtis	Undergraduate Student	1
Callahan, Nick	Undergraduate Student	2
Canez, Tiffani	Undergraduate Student	1
Carrera, Anahi	Undergraduate Student	1
Chen, Zhao	Undergraduate Student	1
Cook, Chelsea	Undergraduate Student	1
Custer, Joy	Undergraduate Student	1
Fennie, Elizabeth	Undergraduate Student	1
Garlant, James	Undergraduate Student	1
Green, Katlyn	Undergraduate Student	1
Griffin, Nakayla	Undergraduate Student	1
Guan, Janelle	Undergraduate Student	1
Hall, Becky	Undergraduate Student	1
Hamann, Lejon	Undergraduate Student	1

Name	Most Senior Project Role	Nearest Person Month Worked
Harders, Sara	Undergraduate Student	1
Herndon, Carly	Undergraduate Student	0
Heydorn, Katherine	Undergraduate Student	1
Hoskinson, Joshua	Undergraduate Student	1
Iniguez, Isaiah	Undergraduate Student	1
Keifer, Violeta	Undergraduate Student	1
Kelly, Andrew	Undergraduate Student	1
Kong, Tianshu	Undergraduate Student	1
Lark, Callie	Undergraduate Student	1
Mello, John	Undergraduate Student	1
Perez, Angela	Undergraduate Student	1
Reynoso, Erick	Undergraduate Student	1
Riedel, Catherine	Undergraduate Student	1
Rincon, Michelle	Undergraduate Student	1
Schwartz, Dina	Undergraduate Student	1
Smith, Rebecca	Undergraduate Student	1
Snyder, Maria	Undergraduate Student	1
Sorrentino, Lexie	Undergraduate Student	1
Taylor, Bridget	Undergraduate Student	1
Thompson, Mychel	Undergraduate Student	1
Valenzuela, Allie	Undergraduate Student	1
Van Dop, Molly	Undergraduate Student	1

Name	Most Senior Project Role	Nearest Person Month Worked
Weber, Adam	Undergraduate Student	1
Weber, Nicole	Undergraduate Student	1
Wilson, Charles	Undergraduate Student	1
Wolsiffer, Sarah	Undergraduate Student	1
Yang, Julia	Undergraduate Student	1

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: 2

Contribution to the Project: Lead PI and biogeochemist

Funding Support: NSF

International Collaboration: Yes, France 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: Leading efforts related to critical zone services and tree mortality from drought.

Funding Support: NSF

International Collaboration: No International Travel: No

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

Contribution to the Project: Co-PI and lead on the surface water dynamics focal area.

Funding Support: NSF

International Collaboration: No International Travel: No

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

Contribution to the Project: Co-PI and lead on landscape evolution focal area

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: Co-PI and lead on soil science focal area

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

International Collaboration: No International Travel: No

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

International Collaboration: No International Travel: No

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

Contribution to the Project: Snow hydrology

Funding Support: DOE and this award

International Collaboration: Yes, Sweden International Travel: No

Rivka Fidel Email: rfidel@email.arizona.edu Most Senior Project Role: Faculty Nearest Person Month Worked: 1 Contribution to the Project: Instructor for a new CZ Science course in SWES

Funding Support: NSF

International Collaboration: No International Travel: No

Rachel Gallery Email: rgallery@email.arizona.edu Most Senior Project Role: Faculty Nearest Person Month Worked: 1

Contribution to the Project: Soil microbial ecologist

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: Eddy covariance measurements

Funding Support: Ameriflux Core support (160 hours), DOE TES (80 hours), NSF LTER (80 hours)

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: Education and Public Outreach Lead

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: 0

Contribution to the Project: Microbial ecologist

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: 1

Contribution to the Project: Research scientist

Funding Support: NSF & Other

International Collaboration: No International Travel: No

Jason Field Email: jpfield@email.arizona.edu Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position) Nearest Person Month Worked: 1

Contribution to the Project: postdoctoral scientist

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: 0

Contribution to the Project: postdoctoral scientist

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: 0

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 **Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position) **Nearest Person Month Worked:** 0

Contribution to the Project: postdoc

Funding Support: NSF and other

International Collaboration: No International Travel: No

Lindsey Nesbitt Email: lindseychr@gmail.com Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position) Nearest Person Month Worked: 1

Contribution to the Project: Coupled water and biogeochemical modeling

Funding Support: DOE and other NSF

International Collaboration: No International Travel: No

Yaniv Olshansky Email: yanivo@email.arizona.edu Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position) Nearest Person Month Worked: 1

Contribution to the Project: Insert

Funding Support: 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: 2

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: 2

Contribution to the Project: postdoctoral scientist LiDAR analysis

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: 0

Contribution to the Project: CZO postdoc led concentration-discharge analyses and aqueous geochemistry.

Funding Support: NSF

International Collaboration: No International Travel: No

Juan Camilo Villegas Email: villegas@email.arizona.edu **Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position) **Nearest Person Month Worked:** 1

Contribution to the Project: Research Scientist Drought Effects on Trees

Funding Support: NSF

International Collaboration: No International Travel: No

Nathan Abramson Email: nabramso@email.arizona.edu Most Senior Project Role: Other Professional Nearest Person Month Worked: 6

Contribution to the Project: Field Technician for the SCM site

Funding Support: NSF

International Collaboration: No International Travel: No

Richard Castle Email: rcastle@email.arizona.edu Most Senior Project Role: Other Professional Nearest Person Month Worked: 1

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

Funding Support: NSF

International Collaboration: No International Travel: No

Prakash Dhakal Email: dhakal@email.arizona.edu Most Senior Project Role: Other Professional Nearest Person Month Worked: 0

Contribution to the Project: Laboratory Director

Funding Support: Other funding

International Collaboration: No International Travel: No

Michael Evans Email: maevans@email.arizona.edu Most Senior Project Role: Other Professional Nearest Person Month Worked: 1 Contribution to the Project: Media technician (School of Journalism)

Funding Support: NSF

International Collaboration: No International Travel: No

Jen Fields Email: fieldsj@email.arizona.edu Most Senior Project Role: Other Professional Nearest Person Month Worked: 1

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.

Funding Support: Staff at Flandrau Science Center, no CZO funding, volunteered her time.

International Collaboration: No International Travel: No

Shiloe Fontes Email: sfontes@email.arizona.edu Most Senior Project Role: Other Professional Nearest Person Month Worked: 1

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

Funding Support: NSF

International Collaboration: No International Travel: No

Sara Kobilka Email: kobilka@email.arizona.edu Most Senior Project Role: Other Professional Nearest Person Month Worked: 1

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.

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: 1 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: 6

Contribution to the Project: Field Research Technician for JRB site

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: 0

Contribution to the Project: Science writer (Economics Dept)

Funding Support: NSF

International Collaboration: No International Travel: No

Neil McSweeney Email: mcsweene@email.arizona.edu Most Senior Project Role: Other Professional Nearest Person Month Worked: 1

Contribution to the Project: exhibit support (Flaundrau 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: 0

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: 1

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: 2

Contribution to the Project: Research Technician Eddy Covariance in SCM

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: 6

Contribution to the Project: Data manager

Funding Support: NSF

International Collaboration: No International Travel: No

Christopher J Eastoe Email: eastoe@email.arizona.edu Most Senior Project Role: Staff Scientist (doctoral level) Nearest Person Month Worked: 1

Contribution to the Project: Insert

Funding Support: NSF

International Collaboration: No International Travel: No

Jonathan Furst Email: jfurst@unm.edu Most Senior Project Role: Staff Scientist (doctoral level) Nearest Person Month Worked: 0

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

Noel Hensley Email: mnhensley@email.arizona.edu Most Senior Project Role: Staff Scientist (doctoral level) Nearest Person Month Worked: 1

Contribution to the Project: Education Program Coordinator

Funding Support: NA

International Collaboration: No International Travel: No

Francisco Balocchi Email: fbalocchi@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 2

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

Funding Support: Funded by the nation of Chile.

International Collaboration: Yes, Chile International Travel: No

Mallory Barnes Email: mallorybarnes@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 1

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Rong Cao Email: rongcao@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 1

Contribution to the Project: Graduate student - research assistant

Funding Support: NSF

International Collaboration: No International Travel: No

Liling Chang Email: lchang@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 1

Contribution to the Project: Insert

Funding Support: NSF

International Collaboration: No International Travel: No

Michelle Coe Email: macoe@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 1

Contribution to the Project: Michelle Coe has performed work towards our Broader Impacts in terms of leading in-class activities with elementary students.

Funding Support: NASA Space Grant Fellowship

International Collaboration: No International Travel: No

Tony Colella Email: tonycolella@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 1

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Ravindra Dwivedi Email: ravindradwivedi@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 6

Contribution to the Project: Has worked on understanding the origins and mechanisms for residence time distribution functions in fractured rock systems

Funding Support: This award and teaching assistantship

International Collaboration: No International Travel: No

Noelle Espinosa Email: noellee@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 1

Contribution to the Project: student researcher

Funding Support: NSF

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: 6

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.

International Collaboration: No International Travel: Yes, Italy - 0 years, 0 months, 14 days

Yuanhao Fang Email: yhfang@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 2

Contribution to the Project: Has perfromed modeling of the topgraphic 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: 2

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Amanda Howe Email: amandahowe@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 1

Contribution to the Project: Insert

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: 1

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: 0

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: 1

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: 0

Contribution to the Project: Ph.D. student, now faculty at OSU

Funding Support: NSF

International Collaboration: No International Travel: No

Sarina Mann Email: sarinanmann@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 1

Contribution to the Project: Graduate research assistant

Funding Support: NSF

International Collaboration: No International Travel: No

Brianna McClure Email: briannamcclure@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 0

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

Funding Support: teaching assistantship

International Collaboration: No International Travel: No

Ben Paras Email: bkp@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 6

Contribution to the Project: Subsurface imaging with geophysics

Funding Support: NSF

International Collaboration: No International Travel: No

Michael Pohlmann Email: mapohlmann@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 6

Contribution to the Project: Ph.D. student focused on fire effects

Funding Support: NSF and other

International Collaboration: No International Travel: No

Rodrigo Andres Sanchez Email: andressanchez@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 4

Contribution to the Project: MS student

Funding Support: Other

International Collaboration: No International Travel: No

Christopher Shepard Email: cbs9h@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 6

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

Funding Support: NSF and University Fellows program through UA graduate college

International Collaboration: No International Travel: No

Jesus Solis Email: solisleo@email.arizona.edu

Most Senior Project Role: Graduate Student (research assistant) **Nearest Person Month Worked:** 1

Contribution to the Project: Graduate research assistant

Funding Support: NSF

International Collaboration: No International Travel: No

Alissa White Email: alissawhite@email.arizona.edu Most Senior Project Role: Graduate Student (research assistant) Nearest Person Month Worked: 6

Contribution to the Project: Ph.D. student

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: 1

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: 2

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: 2 Contribution to the Project: Ph.D. student

Funding Support: NSF and other

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: 0

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

Phoenix Aldama Email: pjea121299@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

Funding Support: NSF

International Collaboration: No International Travel: No

Hannah Bergeron Email: hlberg12@gmail.com Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

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: 1

Contribution to the Project: research

Funding Support: NSF

International Collaboration: No International Travel: No

Jasper Bloodsworth Email: bloodsworth@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Insert

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: 2

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

Funding Support: NSF and TRIF

International Collaboration: No International Travel: No

Melissa Bohlman Email: mbohlman1@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: student researcher with critical zone discovery

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: 1

Contribution to the Project: Undergraduate student researcher with critical zone discovery

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: 1

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: 1

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: 1

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: 1

Contribution to the Project: research

Funding Support: NSF

International Collaboration: No International Travel: No

Nick Callahan Email: nrcallahan@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 2

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Tiffani Canez Email: tiffanicanez@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Insert

Funding Support: NSF

International Collaboration: No International Travel: No

Anahi Carrera Email: anahicarrera@email.arizona.edu Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 1

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Zhao Yang Chen Email: chenzhaoyang@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: research

Funding Support: NSF

International Collaboration: No International Travel: No

Chelsea Cook Email: cmcook@email.arizona.eu

Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Joy Custer Email: joycuster@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Insert

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: 1

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: 1

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: 1 Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Nakayla Griffin Email: nakaylagriffin@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

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: 1

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: 1

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: 1

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: 1

Contribution to the Project: student researcher

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: 0

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: 1

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: 1

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

Funding Support: NASA Space Grant

International Collaboration: No International Travel: No Isaiah Iniguez Email: isaiahininguez@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

Funding Support: NSF

International Collaboration: No International Travel: No

Violeta Keifer Email: vkeifer@bates.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Andrew Kelly Email: akelley1@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

Funding Support: NSF

International Collaboration: No International Travel: No

Tianshu Kong

Email: tianshukong@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

Funding Support: NSF

International Collaboration: No International Travel: No

Callie Lark Email: callielark@email.arizona.edu

Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

Funding Support: NSF

International Collaboration: No International Travel: No

John Mello Email: melloj@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

Funding Support: NSF

International Collaboration: No International Travel: No

Angela Perez Email: angelaiperez@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

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: 1

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: 1 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: 1

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Dina Schwartz Email: dschwartz4@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

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: 1

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: 1

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: 1

Contribution to the Project: Undergraduate student instructor

Funding Support: NSF

International Collaboration: No International Travel: No

Bridget Taylor Email: bridgettaylor@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Insert

Funding Support: NSF

International Collaboration: No International Travel: No

Mychel Thompson Email: m.thompson@student.navajotech.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Insert

Funding Support: NSF

International Collaboration: No International Travel: No

Allie Valenzuela Email: allievalenzuela@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: Undergraduate student instructor

Funding Support: NSF

International Collaboration: No International Travel: No

Molly Van Dop Email: mvandop@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: undergraduate 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: 1

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: 1

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Charles Wilson Email: cawilson@email.arizona.edu Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Sarah Wolsiffer Email: sarahwolsiffer@email.arizona.edu

Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

Julia Yang Email: juj.yang@gmail.com Most Senior Project Role: Undergraduate Student Nearest Person Month Worked: 1

Contribution to the Project: undergraduate student researcher

Funding Support: NSF

International Collaboration: No International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Arizona State University	Academic Institution	Tempe, AZ
Cornell University	Academic Institution	Ithaca, NY
USDA-Agricultural Research Services Southwest Watershed	State or Local Government	Southwest
USGS	State or Local Government	New Mexico
University of Georgia	Academic Institution	Athens, GA
University of New Mexico	Academic Institution	Albuquerque, NM
University of Texas at El Paso	Academic Institution	El Paso, Texas
University of Utah	Academic Institution	Utah
Valles Caldera National Preserve	Other Organizations (foreign or domestic)	Jemez Springs, NM
Hartwick College	Academic Institution	Hartwick, NY
Institut de Physique du Globe de Paris	Academic Institution	France

Name	Type of Partner Organization	Location
J Craig Venter Institute	Academic Institution	Rockville, MD
Kyoto Prefrecture University	Academic Institution	Kyoto, Japan
Los Alamos National Laboratory	Other Organizations (foreign or domestic)	Los Alamos, NM
Los Alamos National Laboratory	Industrial or Commercial Firms	New Mexico
State University of New York	Academic Institution	Buffalo, NY
Tucson Unified School District	School or School Systems	Tucson, AZ

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.

Institut de Physique du Globe de Paris

Organization Type: Academic Institution Organization Location: France

Partner's Contribution to the Project: Facilities Collaborative Research

More Detail on Partner and Contribution: Collaboration on the use of silicon isotopes for weathering processes in the critical zone

J Craig Venter Institute

Organization Type: Academic Institution Organization Location: Rockville, MD

Partner's Contribution to the Project: Facilities

More Detail on Partner and Contribution: Collaboration on microbial genomics analyses

Kyoto Prefrecture 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.

Los Alamos National Laboratory

Organization Type: Industrial or Commercial Firms **Organization Location:** New Mexico

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 Georgia

Organization Type: Academic Institution **Organization Location:** Athens, GA

Partner's Contribution to the Project:

Personnel Exchanges

More Detail on Partner and Contribution: Summer field course session at Jemez CZO

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 Texas at El Paso

Organization Type: Academic Institution **Organization Location:** El Paso, Texas

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

More Detail on Partner and Contribution: Collaborative research on uranium isotopes in the critical zone. Field course visit from UTEP to Jemez CZO.

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?

Miguel Leon (Luquillo CZO, University of Pennsylvania)

Dan Shapich (Shale Hills CZO, Penn State)

Will Cool (Calhoun CZO, Duke University)

Eric Parrish (Boulder Creek CZO, CU Boulder)

David Lubinski (National CZO Office, INSTAAR)

Collin Bode (Eel CZO, University of California, Berkeley)

Luigi Marini (IML CZO, University of Illinois)

Xiande Meng (Sierra CZO, UC Merced)

Impacts

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

- Providing new insights into the below ground consumption (in reactive transport) of CO2 derived from soil respiration (Sanchez-Canete et al., 2018).
- Establishing correlations among multiple characterizations geochemical/mineralogical/physical of drill cores extending through the full depth of the critical zone (Moravec et al.).
- Will provide new tools for soil microbiologists to understand the functions of dominant microbial groups in the critical zone (Carini et al.).
- Collocation of multiple sensor-samplers in instrumented pedons is enabling improved process resolution for soil dynamics affected by hydrologic events (Olshansky et al.)
- Novel approach to stream chemistry controls from multiple upgradient sources (soils, groundwater, perched aquifers) that are monitored in real time (White et al.).
- New hydrologic modeling approaches that enhance an understanding of relations between transit time and water chemistry (Dwivedi et al.)
- Establishment of relations between landscape location and microbial activities, including enzyme activities and community composition/abundance (Fairbanks et al.)

What is the impact on other disciplines?

- By engaging multiple disciplines in place-based studies of critical zone evolution, participants discovery relations of their work to those in allied disciplines. For example:
- Research is also providing key insight into the microbial role in weathering, nitrogen dynamics and trace gas utilization in oligotrophic soils (Carini, Fairbanks et al.).
- Impacts of hydrologic flow paths on solute chemistry (Olshansky et al., White et al.)
- Role of fire and subsequent hydrologic events in lithogenic solute release from catchments (Sanchez et al.)
- Role of fire in carbon burial and storage in the critical zone (Pohlmann et al.)
- Impacts of vertical variation in geochemistry and mineralogy on microbial habitats and composition (Moravec et al.)

What is the impact on the development of human resources?

• The Catalina-Jemez CZO project has trained multiple Ph.D. students and postdocs in a new field of science that focuses, deliberately, on the interfaces between existing disciplines. These individuals have now taken faculty positions across the U.S. in multiple institutions, including University of Vermont, University of Nevada, Technical University Ecuador, Oregon State University, University of Kentucky. At these institutions, they are building vibrant programs focusing on this emergent field of critical zone science.

What is the impact on physical resources that form infrastructure?

- The Catalina-Jemez CZO has developed into an instrumented natural laboratory that is drawing partners and collaborators from multiple institutions.
- Over the past nine years, this CZO has instrumented multiple field locations in the Catalina Mountains of Arizona and the Jemez Mountains of New Mexico, where the whole (i.e., the multiple sites represented) comprise an elevation (climate) and lithology gradient wherein studies can be conducted that relate critical zone structure to dynamics.

What is the impact on institutional resources that form infrastructure?

- The CZO has enabled the development of laboratory expertise and approaches that are improving precision, accuracy and throughput for complex environmental samples.
- The CZO approach enhances collaborations across institutions on research questions and scientific hypotheses that cut across disciplines.

What is the impact on information resources that form infrastructure?

- Last year were collected and processed from sensors and chemical analysis more than 30 million data values. More than 140 million data values are currently stored in the database.
- To present, 63 datasets have been published on the Catalina-Jemez website (<u>http://criticalzone.org/catalina-jemez/data/</u>), which includes:
- 2 new datasets added from 6/1/2017 to 5/31/2018: Marshall Gulch snow depth and Bigelow site streamflow and
- 7 CZO Network (National) datasets. These datasets include combined common data variables from all CZOs and were assembled by data managers from each CZO in summer 2017.
- 130 new data files were added to the CZO data website last year (for the period from 6/1/2017 to 5/31/2018) and totally 631 data files were published 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.
- 4036 samples were registered in the SESAR (the System for Earth Sample Registration, <u>http://www.geosamples.org/</u>) and assigned IGSNs (International Geo Sample Number). These samples include 2 cores, 19 core sections, 79 terrestrial sections, 190 individual samples, 11 specimens, 3653 liquid samples, 19 chemical fractions and 63 sites.
- 11 geochemistry and soil solution chemistry datasets were published and assigned DOI in the EarthChem Library (<u>http://www.earthchem.org/library</u>) which includes 5 new datasets published from 6/1/2017 to 5/31/2018.
- More than 6.2 million data values for 9 sites were uploaded to the ODM2Admin managed by CUAHSI (<u>http://odm2admin.cuahsi.org/CJCZO/mapdata.html</u>) from 6/1/2017 to present.
- Additional datasets previously published in data repositories with DOI:
- One Jemez stream water chemistry dataset was published in the HydroShare (https://www.hydroshare.org/),
- 3 Jemez River basin LiDAR datasets were published in the OpenTopography (<u>http://www.opentopography.org/</u>).
- 3 Valles Caldera (Jemez River basin) flux tower datasets were added to the AmeriFlux network (<u>http://ameriflux.lbl.gov/</u>).

 More than 12.8 million data values have been added to the CUAHSI HIS HydroClient (<u>http://data.cuahsi.org/</u>). These data are available for download via the CUAHSI HIS HydroClient or 2 Catalina-Jemez CZO registered data services (<u>http://hiscentral.cuahsi.org/pub_network.aspx?n=158</u> and <u>http://hiscentral.cuahsi.org/pub_network.aspx?n=177</u>).

Dataset Usage

1390 unique users downloaded 16984 data files from the Catalina-Jemez datasets published on the website for one year period from 6/1/2017 to 5/31/2018.

• Website Usage

The CZO website (<u>http://criticalzone.org/catalina-jemez/</u>) had 5496 opened sessions by 3859 users which includes 3353 new users for one year period from 6/1/2017 to 5/31/2018. Users viewed 16059 webpages.

Top most viewed webpages are: data and dataset listings (11.4 %), homepage (9.7 %) and field areas (3.8%).

The CZO website is accessed by users from around the world and mostly from these countries: USA (2044), China (151), India (146), UK (125), France (109) and Germany (106).

What is the impact on technology transfer?

 Techniques developed during the drilling portion of this project are being used for other non-CZO projects through collaborations with graduate students (Bryan Moravec). Techniques developed to collect high quality samples from deep core (including microbiology samples) are being communicated via standard operation procedure documentation as well as via meetings and other communication. At national meetings, techniques developed for coring and extracting high quality samples from the deep critical zone have been discussed with CZO collaborators at other CZO sites.

What is the impact on society beyond science and technology?

- The CZ Discovery program and "Welcome to the Critical Zone" exhibit introduce elementary school kids, many of them from underserved (Title 1) schools, to the concept of the Critical Zone, how cycles and systems interact in the CZ to support terrestrial life, and how the CZ provides clean air and water for people and agriculture.
- The "Mt. Lemmon Science Tour" free smartphone audio guide has introduced the general public (over 115,000 downloads and counting) to the concept of the Critical Zone, and to integrated Earth Science like the cycles, systems, layers, and time scales that are part of CZ processes and CZ services.

Changes/Problems

Changes in approach and reason for change

No major changes in approach are anticipated for the supplement year. As described in the supplement proposal, this year will focus on:

1. Maintaining CZO functions and continuing ongoing critical zone science investigations.

2. Maintaining regular measurements, sampling, analyses, and hence data streams that are central to the efforts of the CZO site.

3. Ensuring data accessibility and preservation, including continuing to make data available on the criticalzone.org website, and continuation of collaboration with other CZO sites to develop a common data management efforts.

4. Completion of current graduate students and postdoctoral scientists, including associated theses and manuscript submission for publication (see timeline in supplement proposal).

Actual or Anticipated problems or delays and actions or plans to resolve them Nothing to report.

Changes that have a significant impact on expenditures

Reduction in annual support has required a cut-back in field scale operations and personnel, with a primary focus on enabling completion of requisite ongoing data streams and graduate student projects.

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.