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Accomplishments

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

The overall goals of the Southern Sierra Critical Zone Observatory (SSCZO) include: i) Expand process-based understanding of the critical zone in a sensitive, societally crucial ecosystem. ii) Provide a platform for long-term physical, biogeochemical and ecological studies. iii) Develop a framework for improving Earth System Models. The SSCZO's research emphasis during the last year has included both a growing number of within SSCZO and across CZO syntheses and analyses (these projects often involve a half dozen or more PIs and students, such as Klos et al. submitted), as well as a wide range of individual research studies by many colleagues in the critical-zone community (these projects are often driven by 1 or 2 PIs and students). The syntheses have become an increasingly important effort in the SSCZO over the last year, as we take stock of what we have learned, leverage, intercompare, homogenize and/or reconcile what our colleagues in the SSCZO and wider network of CZOs

have learned, and identify the next outstanding questions and steps in Critical Zone science. The individual research studies have been and continue to highly leverage and contribute to our core measurement program and main scientific focus.

The SSCZO's overall experimental design includes four main sites spanning a steep elevation gradient in the southern Sierra Nevada (Fig. 1,2). This gradient in critical-zone properties and processes permits analyses of the effects of climate change by substitution of space for time. The experimental design also includes satellite sites where our team and collaborators have developed comparable data. The SSCZO is focused on a cross-disciplinary approach to understanding: i) the current distribution of CZ properties across the mountain front, ii) the processes governing CZ behavior, and iii) the rates that CZ properties can evolve and change. The SSCZO team is committed to advancing both local-CZO and CZO-network science. Our overall goals extend to the broader CZO network, particularly the rapidly changing and stressed western United States. Our core CZO team is becoming increasingly engaged in network science. The team is committed to expanding our large and growing set of collaborators, both within the SSCZO and across the network.

The SSCZO is guided by five research questions:

Research Question 1, Spatial Patterns. How do critical-zone and regolith properties and processes vary over 10-m to 100-km scales?

Research Question 2, Physical, Chemical and Biological mechanisms and interactions. How do physics, chemistry, and biology interact to influence critical-zone function over instantaneous to decadal timescales?

Research Question 3, Rates of Change. How quickly do critical-zone and regolith properties vary and change in response to climate change, meteorology, forest management or disturbance?

Research Question 4, Implications of Change. How do critical-zone and regolith development and properties control, limit or modulate the effects of climate change, meteorology, forest management or disturbance on hydrology, biogeochemistry and ecology?

Research Question 5, Tools to Study the CZ. What measurements of the critical zone at appropriate spatial and temporal scales, using cutting-edge technology, can best advance knowledge of the critical zone?

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

Major Activities:

Research question 1, spatial patterns. We continued work to understand the role of lithology in controlling the spatial patterns of aboveground biomass and regolith structure by conducting additional two-dimensional (2D) shallow seismic refraction surveys across three lithologically diverse mid-elevation sites (Fig 2,3,4). These surveys were conducted in the same locations as the 3D ambient surveys in 2015 to provide a more comprehensive understanding of the site's subsurface architecture. These surveys were designed to quantify both P- and surface-wave velocity subsurface structure, allowing us to quantify the subsurface distribution of porosity, as well as subsurface water holding capacity. We also used direct excavation to complete our sampling of deep regolith at 115 sites using a geoprobe, backhoe or hand auger; with 25 of the sites reserved for chemical and physical characterization (Fig 1,2). This brings the total of regolithdepth measurements to 308.

Research question 2, physical, chemical and biological mechanisms and interactions. Our work on physical processes and properties focuses on hydrologic and meteorological processes. We are investigating residence times of water, subsurface waterstorage capacity and plantwater strategies at Soaproot and Providence (P301) and the integrating sites on P300 and Big Creek. We have used and further developed a range of models to represent hydrology. We used RHESSys to quantify how spatial variation in soilwater storage can determine whether climate warming will increase or decrease ET and how plantavailable soil water and rooting zone characteristics influence postdisturbance ecosystem recovery. We are also using RHESSys to examine how plantavailable water-storage can moderate the loss of snowpack, and influence the partitioning of ET and runoff.

Our work on chemical processes focuses on biogeochemical budgets and transformations. We are working on annual sediment sources, composition and transport continued, with water and nutrient cycling in stream and soil water. We investigated nutrient hot spots and hot moments at 3D grids of ionexchangeresin capsules. We are using Hydrus 2D to integrate data and determine the role of preferential flow paths on hotspot and hotmoment formation. We completed analysis of phosphorus and organic matter sequential fractionation, and laboratory incubation studies from soil and sediment for a range of sites). Studies assessed the potential for erosion to induce a carbon sink (as well as the fate of nitrogen in the organic matter, which is a growth-limiting nutrient in this ecosystem). We developed a Hedley fractionation protocol and began fractionating soil samples from SSCZO climosequence and White Mountain climosequence. We began collecting X-ray Absorption Near Edge Structure spectra on Hedley fractionation extracts.

Our work on biological processes and properties focuses on the role of both plants and microbes in the Critical Zone. We collected soils along a 40-year fire chronosequence and analyzed these soils for extracellular enzyme activity, nitrification potential, basal respiration, total carbon and nitrogen, net nitrogen mineralization. We extracted microbial DNA along the Southern Sierra climosequence throughout the soil profile across all sites, and analyzed soil samples collected at all 9 CZOs for extracellular enzyme activity and resin-extractable phosphorus within the upper meter. We collected dominate plant species along the SSCZO and White Mountain climosequence to understand how nutrient stoichiometry is influenced by climatic variables (temperature and precipitation). We finalized a paper that used the RHESSys ecohydrologic modeling to examine species change impacts on hydrology. We finalized a paper that used RHESSys to examine carbon allocation and hydrology.

Research question 3, rates of change. We continued to characterize chemical, mineralogical and physical properties of soils and deep regolith with the idea of understanding key ecosystem services: carbon sequestration, water storage, water infiltration, and nutrient cycling. Analyses included particle size, bulk density, water-retention curves (to assess plant available water), selective dissolution of iron, aluminum and silica (to understand pedogenic mineral transformations), clay mineralogy, cation-exchange capacity, pH, available phosphorus, phosphorus sorption capacity, exchangeable potassium, fixed potassium. Synthesis of cosmogenic nuclide and U-series isotope data from stream sediment continued, culminating in a manuscript now in preparation on landscape evolution in the region.

We collected bedrock, soil, and pine needle samples for 143Nd/144Nd isotopic analysis (εNd) from the Dinkey Creek Granodiorite and the Bass Lake Tonalite. When combined with εNd values of dust collected nearby, we can estimate the relative importance of dust and bedrock nutrient supply to the soil and vegetation. These new samples add to our 2015 samples from the Bald Mountain Granite, allowing us to assess the importance of dust nutrient supply across three different rock types with differing nutrient concentrations. We continued our global synthesis of modeled dust fluxes and measured erosion rates to estimate the relative importance of dust and bedrock nutrient supply to eroding soils (Fig 5). The results indicate that both modern and paleo dust inputs may be vital to montane ecosystems despite continuous nutrient supply from bedrock. We combined this global synthesis with our analysis of εNd in bedrock, soil, pine needles, and dust from the Bald Mountain Granite into a manuscript that is now in review.

Research question 4, implications of change. A significant focus of our data analysis during the last year has focused on the impact of the 2012-15 drought on hydrology and forest mortality. Three papers on scaling the effects of forest thinning and fire on the Sierra Nevada water balance were submitted; they describe how we used RHESSys to integrate multiyear field data and predict the effects of vegetation management. We also evaluated how shifts from conifers to shrubs at the rainsnow transition may alter water resources; and we incorporated field data to parameterize species differences in

stomatal behavior. A crossCZO modeling effort was initiated to assess how changes in the timing, rate, and amount of snowmelt influence streamflow production. We explored the sensitivity of actual evapotranspiration to plant-available water-storage capacity across the CZO network. A crossCZO research effort was initiated to use fluxtower and other data to assess the variability of the hydrologic response to multiyear dry periods across the mountain west. This includes examining streamflowsubsurfacestorage relationships and storagedeficit thresholds across multiyear dry periods.

Research question 5, tools to study the CZ. Our catchmentscale timeseries measurements of snow, soil moisture, temperature, and matric potential continued, as did streamflow and metstation measurements by the USFS. Additional timeseries data came from the flux towers. We continued monitoring of water content to 50cm intervals in observation wells over the entire deep regolith thickness at each site using a neutron probe.

Specific Objectives: Objectives are described following the structure of the five research questions.

Research question 1, spatial patterns. Measuring, characterizing and understanding the spatial patterns of CZ properties and processes remains a central objective in the SSCZO. Key CZ properties and processes of interest include regolith depth and weathering, vegetation density and growth, and water balance and flux. Our ultimate objective is to quantify and understand the spatial patterns of CZ properties, including the amount of water that is available for transpiration. We are evaluating the trends in soil and regolith thickness at spatial scales from individual study sites to entire river basins and the large altitudinal gradient of the SSCZO (Fig 1,2,6,7). Whenever possible we are using multiple techniques to characterize the CZ, and are now using three complementary approaches to determine the depth of weathered regolith and the resulting implication for water balance: i) direct excavation (Fig 1 lower right, Fig 2 upper left), ii) indirect geophysical (Fig 2 middle, Fig 3,4), and iii) inferred remote sensing (Fig 4, 7 lower right).

We are investigating the regolith by drilling and direct sampling, and also indirect seismic imaging. Our goal is to characterize vertical profiles down to the soilbedrock contact along the transect and constrain weathering and waterstorage potential at depth to: i) expand previous 2D information to 3D subsurface data and modeling; ii) explore connections between lithology and different vegetation types; and iii) investigate the role of subsurface fracturing and weathering on aboveground productivity. Our geophysical data quantify how regolith thicknesses varies across slopes at our sites and thus help us realize a major goal of the proposed work, as well as subsurface porosity structure.

Research question 2, physical, chemical and biological mechanisms and interactions. Our recent work on soil biogeochemistry emphasized organic carbon in deeper regolith. Objectives include determining: i) how climate regulates the amount, composition, stability and stabilization mechanisms of deep soil organic matter; ii) how topography regulates amount, composition and stabilization of deep organic matter; and iii) how climate and topography control stocks, stoichiometry and vertical fluxes of carbon, nitrogen and phosphorous in deep soil. Parallel research is being conducted at other CZOs, allowing us to quantify how phosphorus stock and availability vary with climate and regolith depth.

Our work on biology has emphasized both microbes and vascular vegetation. We have improved understanding of how shifts from trees to shrubs can impact water supply and how forest carbon allocation can influence streamflow. We initiated investigations of microbially mediated ecosystem consequences of prescribed fire. We hypothesize that prescribed fire will reduce soil respiration because microbial biomass will decrease due to heatinduced mortality. As a result, carbon chemistry will become more recalcitrant, and the fungal composition will change from saprotrophic to mycorrhizal. A second hypothesis is that prescribed fire will increase nitrogen leaching because microbial

assimilation will decrease due to a decrease in microbial biomass. We are also characterizing deepsoil microbial diversity, and how diversity and biogeochemical function change with depth. We expect that: i) microbial biomass and functional activity will decrease with lower organic carbon, ii) microbial diversity within a profile will be as great as between profiles, iii) microbial metabolism will change from heterotrophic to chemoautotrophic with lower organic carbon, signaled by changes in functional gene abundance, iv) across sites, similar species will appear in similar horizons rather than depth, and v) enzyme activity will also be influenced by geochemical concentrations.

Research question 3, rates of change. We are quantifying the relative importance of dust from various sources in the formation of regolith; determining the climatic and geologic factors that influence variations in tree canopy cover across the landscape; and evaluating the evolution of pedogenic processes (additions, losses, transformations, and translocations) in soils and deep regolith (Fig 5,8). This work highlights the interplay between lithology, vegetation and subsurface CZ structure; it helps clarify not only how regolith is formed over a range of scales but also helps improve understanding of the role vegetation plays in the formation of regolith. Our analyses suggest that both bedrock nutrient content and regolith water-holding capacity are key regulators of the distribution of vegetation at Earth's surface (Fig 4). We are pushing to generalize these results by compiling a dataset on the rates that CZ properties can evolve and change (Fig 5).

At shorter time scales, we continue to look at changes in soil moisture and temperature patterns due to specific localintime events. We are monitoring changes in water storage in soils and deep regolith to understand how soil properties may influence storage of water in deep regolith, and water use by vegetation. We are extending research on hot spots and moments to explain why they are occurring. Our hypothesis is that precipitation travels through the nutrientrich O horizon, collecting solutes that are transported through preferential flow paths to subsurface pockets of nutrientrich soil called hot spots (persist over time) or hot moments. Our approach uses an unsaturated-flow model (Hydrus 2D) with field data. Microbially mediated nutrients may occur as both hot spots and hot moments, while those more abiotically controlled tend to be in hot spots.

Research question 4, implications of change. The recent drought and recovery has provided the opportunity to better understand how the water cycle and vegetation will respond to hotter, drier conditions. The two mid-elevation sites experienced widespread tree mortality from the drought, with ~80% of the pines dying at the 1100 m elevation site and ~20% of the pines and firs dying at the 2000 m elevation site. This dieback was most closely associated with a year-over year drawdown of regolith moisture.

Research question 5, tools to study the CZ. One of the hallmarks of the SSCZO has been the diversity of tools we are using and developing to investigate the CZ; these tools range from geochemical tracers to embedded networked sensor arrays to remote sensing (Fig 2). Our development and use of a wirelesssensor network as part of a spatially extensive catchmentscale measurement program focuses on improving methods to optimize placements of the sensor clusters, and sensor nodes within the clusters. This work continues to progress on a number of fronts. We recently expanded the sensor-placement analysis (discussed in detail in the last report) to two 1-km2 catchments within the JPL Airborne Snow Observatory (within the Merced and Tuolumne basins) as well as the Providence catchment at the SSCZO. This permitted a long-term assessment of the algorithm (as multiple LIDAR flights are available for these regions), as well as an assessment of the transferability of the algorithm to high-elevation regions. In August 2016 we used motes from the wireless-sensor network to collect data on wireless path quality at representative locations across the P301 catchment. These data were combined with LIDAR data on path properties (terrain intersection, distance, and cumulative vegetation) to build a packet-delivery-ratio model for new wireless deployments.

Significant Results:

Research question 1, spatial patterns. We developed a remote-sensing approach to infer regolith and summer moisture availability across the landscape (Fig 6,7). This approach combines remote sensing and gridded measures of the main monthly water balance terms (precipitation, evapotranspiration, runoff) to calculate the amount of water plants transpire during the dry season. This dry-season transpiration is supported by the net withdrawal of moisture from the soil and regolith, which provides a measure of the depth and porosity of weathering.

Direct excavation showed that regolith is thinnest at 400m elevation, where precipitation is low (Fig 1,7). Spatially extrapolated regolith thickness values for the Soaproot watershed (1100 m) ranged from 0 to 10 m, averaging 4.6 m. The model for regolith thickness predicted deep (>5 m), intermediate (2-5 m) and shallow (<2 m) regolith thickness across 41, 53% and 6% respectively, of the watershed (Fig 2,7). Mean regolith thickness increased at mid elevation (1100 m) where weathering is believed to be highest due to moderately high precipitation and mild temperatures. Mean regolith thickness was lower at 2000m elevation and even lower above 3000 m, where recent glaciation evidently scoured bedrock. In non-glaciated terrain, regolith thickness increased with increasing precipitation and biotite content of the parent rock. Accounting for the insulating effects of deep regolith on temperature, we found a significant relationship between cumulative annual temperature and clay content with depth across the elevation gradient. This observation explains the very large differences in soil development across the elevation gradient where temperature variation is very large and the shared uniform characteristics of saprolite where temperature is relatively constant and low.

Research question 2, physical, chemical and biological mechanisms and interactions. Meadow ET was near potential ET rates during summer, however is only a small fraction of catchment ET due to the relatively small area of meadows. Very dry soil (during drought) led plants to retain water from spring precipitation. Additionally, the snowmelt isotopic signature was influenced by forestcanopy structure; and capturing the changing signature in hydrologic components over the year is important to characterize the plant-water strategies. Springrain tritium concentrations were higher than those in winter snow due to the “Spring Leak Phenomena”. In August, tritium concentrations in both vegetation and shallow soil were similar and elevated above the annual mean. In contrast, meadow groundwater and streams had low concentrations. The ratio between tritium in streams and snow indicates a residence time on the order of one tritium half life (12.3 years).

Dust fluxes from Asian and Central Valley sources are similar in magnitude, highlighting the importance of longdistance transport and delivery of nutrients such as phosphorus to Sierra Nevada ecosystems (Fig 5,8). Nd isotopes in pine needles and soil imply that 70-80% of the Nd in the soils and 8090% of the Nd in pine needles is dust derived. We found a significant reservoir for carbon in deep regolith. While the highest concentrations of organic carbon occur in soil, small but measureable amounts detected in deeper regolith translate into large pools at locations where regolith is thick. The integrated pool of carbon in deep regolith was therefore similar to the carbon stock of a typical rangeland soil found at 400m elevation. This finding may partly explain missing terrestrial carbon pools in global models. A complementary finding points to over 40% of total soil C being located in deeper soil layers (below A horizons).

Research question 3, rates of change. Nd isotopes in bedrock, dust, and pine needles indicate that dust supplies >99% of P to pine trees in one southern Sierra Nevada ecosystem. Further, our global synthesis of modeled dust deposition and measured erosion rates suggests that dust may provide a substantial fraction of nutrients to many other montane ecosystems (Fig 5). Together, differences in nutrient content and geophysically inferred weathering across different rock types explain ~80% of the variance in modeled evapotranspiration at our sites (Fig 4). One implication is that ecosystems with greater forest cover due to higher bedrock nutrient content and thicker weathering profiles are more vulnerable to mortality, suggesting that lower forest cover

on more felsic, nutrient-poor bedrock is better optimized for resilience during intense droughts.

Research question 4, implications of change. Analyses have shown that the forest in the SSCZO is deeply rooted, which allows trees access as much as 1500 mm of stored water (Fig 7). This moisture is critical for forest survival in the seasonally dry Mediterranean climate; the vegetation withdraws the moisture during the summer, which allows high, year-round productivity. The 2012-15 drought gradually depleted this reservoir; by the summer of 2014 the regolith at the 1100-m elevation site was nearly completely dry. This moisture depletion was not as severe at the 2000 m site, which is cooler and consequently has a lower rate of ET, and also receives more snow and total precipitation. This drawdown of regolith moisture was ultimately responsible for the forest die back.

Fluxtower results showed a significant decline in ET during the 2012-15 drought at all elevations, with the greatest reduction at the forested Soaproot site (1100 m). The Soaproot site is just above the shrubtoforest transition and is thought to be highly vulnerable to climate change, with warming expected to shift the shrubtoforest ecotone upslope. The Soaproot site experienced marked mortality in summer 2015, providing strong evidence for, and an increased mechanistic understanding of, the ecological vulnerability of lowermontane forest to climate change. On the other hand, continued measurements of ET at Soaproot during 2016 and 17 have shown only limited recovery despite average and well above average precipitation. The mortality may therefore thought of as a very rapid negative feedback mechanism, where drought causes mortality and forest thinning, which causes a lasting reduction in ET, with potentially beneficial impacts on future vegetation stress and runoff production. Complementary modeling analyses indicate that a treetoshrub conversion in the southern Sierra is likely to increase annual streamflow. This type conversion could have greater hydrologic impacts than increased temperatures; although temperature increases will have a greater impact on streamflow timing. These findings have contributed to an emerging paradigm among the SSCZO PIs: 1) shifts in vegetation distribution with climate change may have a larger impact on water balance than would be expected based on the simple, direct effects of warming on evaporative demand; 2) these shifts may occur at both lower (vegetation contraction) and upper (vegetation expansion) elevations; 3) the shifts at lower elevations may be quite rapid during warm droughts.

Research question 5, tools to study the CZ. The last year saw a concerted effort to bridge the remote sensing and in-situ work on regolith properties at a range of scales (1,2,4,6,7). A comparison of the regolith depth measured using geophysics across the three lithologically diverse mid-elevation sites showed excellent agreement with the remote sensing analysis of summer moisture access (Fig 4). Likewise, the auger and geoprobe-based measurements of regolith depth at 308 individual locations with the co-located remote sensing information at 30-m resolution yielded good agreement (Fig 2 upper right), implying that the remote sensing technique is useful for mapping the finer patterns of regolith properties.

Key outcomes or Other achievements:

Outcomes cut across the five research questions and were introduced in detail above. Some of the more significant research findings from the past year are highlighted below. Together, these give new, integrated insights into the processes determining the differences in regolith formation, weathering, forest density, forest resilience to drought and implications of climate change and management actions along the climate-ecosystem gradient covered by the Southern Sierra CZO.

1. Develop and apply tools to quantify critical zone and regolith properties at scales ranging from individual points (drilling and augering) to local transects (seismic refraction) to gridded regions by remote sensing. Initiated cross comparison of these approaches. (Fig 1,2,4,6,7, Klos et al in review, Fellows and Goulden 2016).

2. Improved understanding of the controls on regolith properties at a range of scales, from local (hill slope) to regional (climate/elevation gradient and large river basin), including rates of weathering and environmental correlates (Fig 4,8, Hayes et al in review, Riebe et al 2017, Ferrier et al 2016).

3. Improved understanding of the implications of regolith properties for ecology, forest health and hydrology, including partitioning precipitation into evapotranspiration vs runoff. (Fig 4, Bales et al in review).

4. Improved mechanistic understanding of water flows and pools; closed the water budget at a range of scales, from individual points (snow, infiltration and soil water balance at cm to m) to local (hill slope) to regional (climate/elevation gradient and large river basin). (Fig 1, Beaudette et al 2016, Bales et al in review, Kim et al 2017, Safeeq and Hunsaker 2016, Saksa et al in press).

5. Improved understanding of biogeochemical cycles and budgets, including biological and microbial controls and transformations, and stocks of organic carbon. (Carey et al 2016, Dove et al 2017, McCorkle 2016, Stacy et al 2017).

6. Found that dust is likely a more significant contributor to montane soils and ecosystems than previously thought. (Fig 5,8, Aciego et al 2017, Arvin et al in review).

7. Quantitative synthesis of findings through improved testing of the RHESSys model (Son et al 2016, Bart et al 2016, Garcia et al 2016).

8. Improved understanding of effects of severe multiyear drought (2012-15) on hydrology/water balance and vegetation stress/mortality (Malone et al 2016, Bales et al in review).

9. Began investigating effects of previous forest management and wildfire on hydrology/water balance and vegetation stress/mortality (Fig 4, Saksa et al 2017, Roche et al in prep).

10. Began cross-disciplinary syntheses focusing on issues including the bi-directional interactions between regolith properties, weathering, vegetation density, health and production and hydrology (Klos et al in review).

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

Students and postdoctoral researchers associated with the Southern Sierra Critical Zone Observatory receive fundamental training and professional development to increase scholars' scientific knowledge, research skills, and science communication experience with research and non-research audiences. Professional-development opportunities have also been made available to SSCZO staff. Personnel at all levels have also provided training and development opportunities to external audiences. Related products are described in the Products section.

At the undergraduate level, students from UC Merced and partner universities have worked as field and lab technicians. For example, the SSCZO continues to hire a full-time undergraduate field assistant to work with Field Manager E. Stacy each summer. Also, the Hart research lab employed five undergraduates this year, plus one volunteer, the majority of whom identify as a gender, race/ethnicity, or socioeconomic demographic traditionally underrepresented in STEM fields.

Several graduate and undergraduate courses related to critical-zone science are taught by SSCZO faculty-level researchers at multiple institutions. Graduate students conducting critical-zone research also serve as teaching assistants for undergraduate courses at several campuses. These courses regularly include both scientific knowledge and research techniques (field, lab, and computer-based) from the CZO; they serve both CZO and non-CZO students. Some examples of graduate and undergraduate courses taught this year include Environmental Chemistry (M. Conklin), Environmental Monitoring (P. Hartsough), Soils in Land Use and the Environment (A. O'Geen), Environmental Data Analysis (C. Riebe) and Critical Zone Science (A. Berhe). Berhe and CZO staff hosted a field trip to the Providence Creek area for the Critical Zone Science course. E. Stacy and M. Gilmore were guest in-class lecturers for the course as well.

Curriculum for the Critical Zone Science course was developed by several cross-CZO and non-CZO faculty, and became publicly available on the InTeGrate website this year. Conklin, SSCZO staff, and graduate students developed content and activities for Unit 5: Water Transfer in the Critical Zone, based on SSCZO research and its broader impacts.

Current and recent graduate students and postdoctoral researchers working with project personnel and collaborators were first authors of 23 peer-reviewed journal publications that featured results from SSCZO, with current statuses ranging from submitted to published. In addition, student and postdoctoral researchers were lead presenters of 46 scientific conference presentations, including meetings hosted by the American Geophysical Union, European Geosciences Union, Soil Science Society of America, Ecological Society of America, and the NSF U.S. Critical Zone Observatory Network.

Several M.S., Ph.D., and postdoctoral scholars are preparing themselves for independent measurement and data-analysis work in hydrology, biogeochemistry, geophysics, ecohydrologic modeling, and other disciplines. The SSCZO and national network of CZOs creates a multi-institutional team environment that is manifested through shared resources and collaborative work (e.g. shared LiDAR, sensor data, field campaigns for soil pits, analytical tools, programming, modeling). For example, as an outcome of the 2016 SSCZO Annual Meeting, UC Merced graduate student M. Barnes coordinated a trip to the University of Wyoming to (1) deliver samples for the Riebe research group to conduct XRF analysis, and (2) learn Hedley fractionation procedures for analysis of soil phosphorus from physical chemistry faculty J. Zhou.

The wireless-sensor network remains an uncommon approach to gathering remote field data. The network installed at the Southern Sierra CZO consists of 57 wireless nodes, constituting one of the largest wireless networks for this purpose. Through the work on the wireless sensor network, training and experience continues for graduate students, staff, and investigators.

Other professional-development opportunities for graduate students have included N. Dove’s attendance of the summer 2016 cross-CZO/NEON Microbial Ecology Workshop in Montreal and M. Barnes’s participation in the UC Merced WSTEM Mentoring program. Field manager E. Stacy also attended a tower and high climbing safety training in spring 2017 to improve skills for safe tower climbing and instrument access, and formulating tower field safety plans.

Training and professional development in science communication to non-research audiences continues to be strong as well. Students regularly work with faculty members to brief visitors to campuses and participate in outreach events for several audiences. UC Merced graduate students M. Barnes, N. Dove, K. Moreland, and M. Thaw; undergraduate M. Castro; Outreach Manager M. Gilmore; and Field Manager E. Stacy facilitated several K-16 presentations this year, such as Southern California Edison Science Days, Sierra Foothill Charter School Earth Day Festival, and the NSF-supported cross-institutional GEOPATH-EXTRA: field based professional development for ESTEM undergraduate students. GEOPATH-EXTRA also provided soil science and groundwater instrumentation training for attending undergraduates and faculty.

Additionally, SSCZO personnel have participated in other professional-development events as presenters and advisors for non-CZO personnel. UC Davis faculty A. O’Geen presented on regional controls on organic carbon in forest soils at workshop hosted by the California Forest Pest Council; 47 attendees included scientists, private and public forest managers, entomologists, pathologists, and others interested in the protection of forests such as USDA Forest Service and Cal Fire. And M. Gilmore continued to present at Merced County Office of Education’s TEAM-E elementary and middle school teacher trainings, co-presenting the characterization of soil and its intersections with water and ecosystems in fall 2016. Approximately 60 teachers from Merced and Mariposa counties participate in TEAM-E. Demographically the region is minority-majority, thus activities used in classrooms will reach students from backgrounds traditionally underrepresented in STEM fields. Lastly, UC Santa Barbara faculty C. Tague and graduate student C. Heckman are advising a group of four Master’s students at the UCSB Bren School, who are using environmental and socioeconomic data to develop management recommendations for private landowners in the Dinkey Landscape region served by the Sierra Resource Conservation District.

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

As described in our Management Plan, the SSCZO acts as a resource for the critical-zone research community; our team has actively engaged other scientists in using this resource. Public education and outreach are equally important. SSCZO team members share CZO knowledge and findings with several audiences. Many dissemination efforts are highlighted throughout the report and summarized below.

Scientific community. Dissemination to the science community includes alerting potentially interested colleagues of our publications and presentations through our websites, email, and social media; attending scientific meetings and workshops; and participating in CZO network activities. During this year's reporting period, personnel and collaborators have authored over 40 journal articles and given more than 80 oral and poster presentations at scientific conferences. Presentations have also been given at other venues such as departmental colloquia at several institutions. SSCZO team members have organized

sessions, given invited talks and contributed presentations based on CZO research at annual meetings of several national and international scientific associations. We also participated in regional scientific meetings and smaller specialty conferences, such as the Yosemite Hydroclimate Conference. Our team contributed to CZO network activities at these and other meetings, including the 2017 NSF Arlington Meeting for Critical Zone Science. Additionally, work is proceeding to develop a suite of online interactive maps of the SSCZO sites, which will highlight ecological, hydrologic, and geologic characteristics; datasets; and select publications in order to enhance access to our sites and results.

Regional stakeholders and the public. Communication of scientific findings with stakeholders and the public includes talks around the state, briefings to decision makers, hosting visitors to laboratories and field sites, writing op-ed pieces, and interviewing for radio features and news articles. One highlight from dissemination to stakeholders in the past year was meeting with U.S. Congressman Jim Costa and his staff.

In addition to stakeholder and decision-maker outreach, we have an active outreach program to K-16 students and educators, and the general public using CZO data and results.

Two products from SSCZO have dominated our engagement with regional stakeholders and the public. Conversations around both have heightened because of the drought, and will impact both drought preparedness and sustainability of Sierra ecosystem (critical zone) services.

First, our work is informing the debate around water benefits of forest management, with emphasis on climate change and runoff from the Sierra. Given the unsustainable forest structures in an area that provides about 60% of California's water supply, there is widespread interest in bringing new resources and tools to watershed and forest management. It is also well-recognized that the knowledge base for predicting the effects of different management approaches is insufficient.

A second major focus has been on working with water leaders in the state to define and develop prototypes for a new water information system for California that builds on advances in wireless sensor networks developed at the SSCZO, plus parallel advances in cyberinfrastructure and in measurements by satellite and aircraft.

Our team has engaged with over 10 Sierra Nevada stakeholder groups attempting to develop and implement regional solutions to the state's 21st-century water and forest management challenges. SSCZO personnel regularly attended meetings hosted by these groups. We have collaborated to bring CZO technology to other parts of the Sierra Nevada through state grants. We also engage with multi-agency groups planning and financing forest restoration activities. E. Stacy continues SSCZO contributions to the Dinkey Landscape Restoration Project; R. Bales and M. Safeeq contribute to the Tulare Basin Watershed Connections group. We are currently planning a tour of the SSCZO and KREW measurement approaches at Providence Creek watersheds for fall 2017, which will engage several stakeholder groups including policymakers and watershed management groups.

In addition, C. Tague, E. Stacy, and M. Gilmore co-wrote a UCSB Bren School Master's project proposal with the Sierra Resource Conservation District and USDA Forest Service, which was accepted this spring. Four Master's students will be utilizing environmental and socioeconomic data, including findings from SSCZO, to develop management recommendations for private landowners in the Dinkey Landscape region served by the Sierra Resource Conservation District. All organizations who submitted the proposal participate in the Dinkey Landscape Restoration Project.

The SSCZO also has an active program of education and outreach to K-16 students using CZO research topics, data and results. Our presentations and partnership activities align with several aspects of K-12 Next Generation Science Standards and Common Core State Standards. In addition to work reported in previous sections, Center for Advanced Research and Technology (CART) students completed and presented a project comparing this winter's snowpack to 2010-2011 snowpack. We describe our annual projects with CART in an article published in the educational journal *The Earth Scientist;* the Fall 2016 issue was sponsored by the NSF U.S. Critical Zone Observatory Network and highlighted educational efforts across CZOs. Other K-12 presentations this year are listed in the products section. At the undergraduate level, SSCZO graduate students and staff hosted research-based activities for nine undergraduate students and two faculty from institutions in California and Maine for three days as part of the the NSF-funded GEO-EXTRA program in June 2017. Participants characterized soil profiles at open pits and validated piezometers in P301 meadow wells. The InTeGrate Critical Zone Science course developed by several cross-CZO faculty is also now publicly available.

Our educational partnerships share research results with educators as well. In September 2016, M. Gilmore presented soil-focused work to approximately 60 K-8 teachers who are part of the ongoing Merced County Office of Education TEAM-E Science program. Gilmore is working with Merced County Office of Education to continue hosting teacher workshops on critical-zone topics as the TEAM-E program ends. M. Conklin also remains a member of the NatureBridge Yosemite board, which has provided award-winning residential outdoor education programs for school groups since 1971.

Public outreach for the SSCZO garners local to international attention.

In-person public events include A. O'Geen's 4-hour Master Gardener short courses in foothill communities each year, focused on garden soil management, understanding the variability of soils in mountainous terrain, and documenting vegetative, topographic and lithologic differences that might influence soil variability and properties. He blends SSCZO findings into the courses, in particular topics about deep regolith and its ability supply water and buffer against drought. In addition, last July, M. Gilmore and A. Ayala-Astorga presented a Junior Ranger program at Lake Alpine about the critical zone.

Recent publications and attention on the California drought have resulted in numerous media features covering research findings. For example, a recent publication by SSCZO collaborators, investigators, and graduate student highlighting the role of dust in Sierra Nevada ecosystems was covered by IFLScience, Phys.org, Seeker, and others. A. Berhe also received recognition for her research career in Sally Ride Science and VangaurdSTEM web features. Two videos highlighting SSCZO and the CZO network have been produced and disseminated online through UCTV and WSKG. We publicly disseminate these news, videos, publications, and other content through our website and social media accounts.

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

Going forward into the next year, and in subsequent years, our scientific focus will be on research questions that require interdisciplinary collaboration and measurements, and that build network understanding and predictive capability for the critical zone. This will continue to require both individual but coordinated investigations and broader synthesis. Much of our effort during the coming year will focus on continuing the ongoing, core observations (for example, the flux towers and associated water and soil moisture observations), along with additional targeted measurements (for example, detailed soil analyses along a variety of climo and chrono-sequences). At the same time, will further increase our emphasis on communicating our results to the broader community (publications); taking stock of what we've learned and building intellectual bridges; and planning for the future. We will target three areas for continuing integration; these areas map onto our original 5 questions, and involve cross-method, cross-disciplinary and cross-scale analyses, syntheses and publications.

The first area of synthesis involves understanding the spatial patterns of and implications of regolith depth. This area is especially closely related to *Research Question 1, Spatial Patterns* and *Research Question 5, Tools to study the CZ*. This work is led by Riebe et al, O'Geen et al and Goulden et al. and draws on a range of tools and perspectives as outlined above. Much of this work is nearing maturity with several papers submitted or approaching submission. Key papers expected during the next year will focus on establishing the tools to quantify regolith properties at a range of scales, analyses of the correlates between regolith properties and the environment, and analyses of the interactions between regolith properties and ecosystem function, services and resilience.

The second area of synthesis involves a mechanistic understanding of hydrology and biogeochemistry. This area maps onto *Research Question 2, Physical, Chemical and Biological mechanisms and interactions.* This work is led by Bales et al, Conklin et al, Hart et al, Riebe et al and Behre et al., and draws on a range of tools and perspectives as outlined above. Much of this work is also nearing maturity with a number of papers approaching submission. Key papers expected during the next year will focus on analyzing the effects on the 2012-15 drought on hydrology, analyses of water flows at individual field sites, and analyses of the role of deposition on biogeochemistry.

The third area of synthesis, where we plan to expand our efforts, involves issues related to sustainability, ecosystem services and land management. This area builds on *Research Question 3, Rates of Change* and *Research Question 4, Implications of Change*. This work is led by Tague et al, Safeeq et al, Bales et al, and Goulden et al. Some key foundational papers on this work will be published in 2017, with others still in draft form. Key papers expected during the next two years will focus on analyzing the effects on the 2012-15 drought on forest health and mortality, analyses of the effects of forest management on ecology and hydrology, prediction of forest resistance to drought, and continued model analysis and development of how the Sierras and the ecosystem services provided will react to climate change. We are also initiating comparative analysis with Rocky Mountain CZO and related sites.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
Figures_2017_rb2.pdf	Figures for Accomplishments section	Roger Bales	06/22/2017
Additional_2017_SSCZO.pdf	Additional reporting requirements	Roger Bales	06/24/2017

Products

Books

Book Chapters

Safeeq, M., Fares, A.In , pp. 289-326. Springer International Publishing, 2016. (2016). Groundwater and Surface Water Interactions in Relation to Natural and Anthropogenic Environmental Changes. *Emerging Issues in Groundwater Resources* Springer International Publishing. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/978-3-319-32008-3_11.

Inventions

Journals or Juried Conference Papers

A.W. Fellows, M.L. Goulden (2016). Mapping and understanding dry season soil water drawdown by California montane vegetation. *Ecohydrology*. 10 (1), e1772. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/eco.1772

Aciego, S.M.; Riebe, C.S.; Hart, S.C.; Blakowski, M.A.; Carey, C.J.; Aarons, S.M.; Dove, N.C.; Botthoff, J.K.; Sims, K.W.; Aronson, E.L. (2017). Dust outpaces bedrock in nutrient supply to montane forest ecosystems. *Nature Communications*. 14800. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/ncomms14800

Arvin, L.J., Riebe, C.S., Aciego, S.M., Blakowski, M.A. (2017). Global patterns of dust and bedrock nutrient supply to montane ecosystems. *Nature Geoscience*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Bales, R.C.; Goulden, M.L.; Hunsaker, C.T.; Conklin, M.H.; Hartsough, P.C.; Ogeen, A.T.; Hopmans, J.W.; Safeeq, M. (2017). Mechanisms that mitigate the impact of multi-year drought on mountain hydrology. *Nature Geoscience*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Bart, R. R.,Tague, C. L., Moritz, M. A. (2016). Effect of Tree-to-Shrub Type Conversion in Lower Montane Forests of the Sierra Nevada (USA) on Streamflow. *PLOS ONE*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1371/journal.pone.0161805

Beaudette, D.E. and A.T. O'Geen (2016). Topographic and geologic controls on soil variability in California's Sierra Nevada Foothill Region. *Soil Science Society of America Journal*. 80 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Black, B.A., Sleen, P., Lorenzo,E.D., Griffin, D., Sydeman, W.J., Dunham, J.D., Rykaczewski, R.R., García-Reyes, M., Safeeq, M., Arismendi, I., and Bograd, S.J. (2017). Rising synchrony controls western North American ecosystems. *Nature Climate Change*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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

Carey, C., Dove, N.C., Beman, J.M., Hart, S.C., Aronson, E.L. (2016). Meta-analysis reveals ammonia-oxidizing bacteria respond more strongly to nitrogen addition than ammonia-oxidizing archaea. *Soil Biology and Biochemistry*. 99 158. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.soilbio.2016.05.014

Carey, C.J., Dove, N.C., Beman, J.M., Hart, S.C., Aronson E.L. (2016). Meta-analysis reveals ammonia-oxidizing bacteria respond more strongly to nitrogen addition than ammonia-oxidizing archaea.. *Soil Biology and Biogeochemistry*. 99 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.soilbio.2016.05.014.

Carey, C.J., S.C. Hart, S.M. Aciego, C.S. Riebe, M.A. Blakowski, E.L. Aronson (2016). Microbial community structure of subalpine snow in the Sierra Nevada, California. *Arctic, Antarctic, and Alpine Research*. 48 (4), 685-701. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1657/AAAR0015-062

Chen, P., Taylor, N. Dueker, K., Keifer, I., Wilson, A., McGuffy, C., Novitsky, C., Spears, A., Holbrook, S (2016). pSIN: a scalable, Parallel algorithm fir Seismic INterferometry of large-N ambient- noise data.. *Computers and Geosciences*. 93 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.cageo.2016.05.003

Dove, N.C., Hart, S.C. (2017). Fire reduces fungal species richness and mycorrhizal colonization: a meta-analysis. *Fire Ecology*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Fellows, A.W. and Goulden, M.L. (2016). Mapping and understanding dry-season soil water drawdown by California montane vegetation. *Ecohydrology*. 10 (1), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/eco.1772

Ferrier, K. L., Riebe, C. S. and Hahm, W. J. (2016). Testing for supply-limited and kinetic-limited chemical erosion in field measurements of regolith production and chemical depletion. *Geochemistry, Geophysics, Geosystems*. 17 (6), 2270-2285. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016GC006273

Garcia, E.S., Tague, C.L., Choate, J.S. (2016). Uncertainty in carbon allocation strategy and ecophysiological parameterization influences on carbon and streamflow estimates for two western US forested watersheds. *Ecological Modeling*. 342 19. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ecolmodel.2016.09.021

Gilmore, M., Stacy, E., Meadows, M., Sullivan, L. (2016). Using Scientist-Teacher Partnerships to Create Student-Driven Environmental Field Research Experiences in Primary and Secondary Education Classrooms. *The Earth Scientist*. 32 (3), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Hayes, J. L., Riebe, C. S., Holbrook, W. S., Flinchum, B. & Hartsough, P. C. (2017). Porosity production in saprolite: Where volumetric strain dominates over chemical mass loss. *Science Advances*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Kim, D.; Ray, R.L.; Choi, M. (2017). Simulations of energy balance components at snow-dominated montane watershed by land surface models. *Earth Environmental Sciences*. 76 337. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s12665-017-6655-0

Klos, P.Z.; Goulden, M.L.; Riebe, C.L.; Tague, C.L.; O'Geen, A.T.; Flinchum, B.L; Safeeq, M.; Conklin, M.H.; Hart, S.C.; Berhe, A.A.; Hartsough, P.C.; Holbrook, W.S.; Bales, R.C. (). Predicting plant-accessible water in the critical zone: mountain ecosystems in a Mediterranean climate. *WIREs Water*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Lukens, C. E., Riebe, C. S., Sklar, L. S., & Shuster, D. L. (2016). Grain-size bias in cosmogenic nuclide studies of stream sediment in steep terrain.. *Journal of Geophysical Research: Earth Surface*. 121 (5), 978. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016JF003859

Lukens, C. E., Riebe, C. S., Sklar, L. S., & Shuster, D. L. (2017). Sediment size and breakdown bias in detrital thermochronometry. *Earth and Planetary Science Letters*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Ma Q., Su Y., Guo Q. (2016). Comparison of Canopy Cover Estimation from Airborne Lidar, Aerial Photo, and Satellite Imagery. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

McCorkle, E.P., Berhe, A.A., Hunsaker, C.T., Johnson, D.W., McFarlane, K.J., Fogel, M.L., Hart, S.C. (2016). Tracing the source of soil organic matter eroded from temperate forest catchments using carbon and nitrogen isotopes. *Chemical Geology*. 445 172-184. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.chemgeo.2016.04.025

Miller, Matthew P., Boyer, Elizabeth W., McKnight, Diane M., Brown, Michael G., Gabor, Rachel S., Hunsaker, Carolyn T., Iavorivska, Lidiia, Inamdar, Shreeram, Johnson, Dale W., Kaplan, Louis A., Lin, Henry, McDowell, William H., Perdrial, Julia N. (2016). Variation of organic matter quantity and quality in streams at Critical Zone Observatory watersheds. *Water Resource Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016WR018970

Oroza, C.A., Zheng, Z., Glaser, S.D., Tuia, D., Bales, R.C. (2016). Optimizing embedded sensor network design for catchment-scale snow-depth estimation using LiDAR and machine learning. *Water Resources Research*. 52 (10), 8174. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016WR018896

Richter, D., Billings, S., Groffman, P., Kelly, E., Lohse, K., Riebe, C., Silver, W., White, T., Anderson, S., Brantley, S., Brecheisen, Z., Chadwick, O., Hartnett, H., Hobbie, S., Kazanski, C., Markewitz, D., O'Neill, K., Schoeder, P. (). What would Darwin and Lyell say about integrating biology and geology across environmental science networks?. *Bioscience*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Riebe, C. S., Hahm, W. J., Brantley, S. L. (2017). Controls on deep critical zone architecture: a historical review and four testable hypotheses. *Earth Surface Processes and Landforms*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/esp.4052

S.L. Malone, M.G. Tulbure, A.J. Pérez-Luque, T.J. Assal, L.L. Bremer, D.P. Drucker, V. Hillis, S. Varela, M.L. Goulden (2016). Drought resistance across California ecosystems: evaluating changes in carbon dynamics using satellite imagery. *Ecosphere*. 7 (11), e01561. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/ecs2.1561

Safeeq, M. and Hunsaker, C. (2016). Characterizing Runoff and Water Yield for Headwater Catchments in the Southern Sierra Nevada. *JAWRA Journal of the American Water Resources Association*. 52 (6), 1327. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/1752-1688.12457

Saksa, P.C., Safeeq, M., Dymond, S. (). Recent patterns in climate, vegetation, and forest water use in California montane watersheds. *Forests*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Saksa, P.C.; Conklin, M.H.; Battles, J.J.; Tague, C.L.; Bales, R.C. (). Forest thinning impacts on the water balance of Sierra Nevada mixed-conifer headwater basins. *Water Resources Research*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Sklar, L. S., Riebe, C. S., Lukens, C. E., & Bellugi, D. G. (2016). Catchment power and the joint distribution of elevation and travel distance to the outlet.. *Earth Surface Dynamics*. 4 799. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/esurf-4-799-2016

Sklar, L. S., Riebe, C. S., Marshall, J. A., Genetti, J., Leclere, S., Lukens, C. L., Merces, V. (2017). The problem of predicting the particle size distribution of sediment supplied by hillslopes to rivers.. *Geomorphology*. 277 31. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.geomorph.2016.05.005

Son, K., Tague, C., Hunsaker, C. (2016). Effects of model spatial resolution on ecohydrologic predictions and their sensitivity to inter-annual climate variability in California's Sierra Nevada watersheds. *Water*. 8 (8), 321. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3390/w8080321

Stacy, E.M. A.A. Berhe, C.T. Hunsaker, D.W. Johnson, S.M. Meding, S.C. Hart (2017). Selective mobilization of organic matter pools by soil erosion: implications for fate of eroded soil organic matter. *Biogeochemistry*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Su, Y.; Bales, R.C.; Ma, Q.; Nydick, K.; Ray, R.L.; Li, W.; Guo, Q. (2017). Emerging stress and relative resiliency of Giant Sequoia groves experiencing multi-year dry periods in a warming climate. *Journal of Geophysical Research: Biogeosciences*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

White, T.; Wymore, A.; Dere, A.; Hoffman, A.; Washburne, J.; Conklin, M. (). Integrated Interdisciplinary Science of the Critical Zone as a Foundational Curriculum for Addressing Issues of Environmental Sustainability. *Journal of Geoscience Education*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Zhang, Z.; Glaser, S.; Bales, R.; Conklin, M.; Rice, R.; Marks, D. (). Insights into mountain precipitation and snowpack from a basin-scale wireless-sensor network. *Water Resources Research*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Zhang, Z.; Glaser, S.D.; Bales, R.C.; Conklin, M.; Rice, R.; Marks, D.G. (2017). Technical report: The design and evaluation of a basin-scale wireless sensor network for mountain hydrology. *Water Resources Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016WR019619

Zheng, Z., Kirchner, P. B., and Bales, R. C. (2016). Topographic and vegetation effects on snow accumulation in the southern Sierra Nevada: a statistical summary from lidar data.. *The Cryosphere*. 10 (1), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/tc102572016

Licenses

Other Conference Presentations / Papers

Deinhart, A., Thaw, M., Bibby, R., Egnatuk, C., Torretto, P., Visser, A., Esser, B., Wooddy, T. (2016). *A Simplified Method for the Collection and Analysis of a Cosmogenic Radioactive Age Tracer: Sodium-22*. American Geophysical Union Fall Meeting. San Francisco CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Glaser, S.D.; Bales, R.C.; Conklin, M.H. (2016). *American River Hydrologic Observatory*. 2016 American Geophysical Union Fall Meeting. San Francisco CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bart, R., Anderson, S., Moritz, M., Plantinga, A., Tague, N. (2016). *An integrated model for identifying linkages between the management of fuel treatments, fire and ecosystem services*. Southern Sierra Critical Zone Observatory Annual Meeting. Merced CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Callahan, R.; Riebe, C.; Goulden, M.; Taylor, N.; Pasquet, S.; Flinchum, B; Holbrook, S. (2017). *Bedrock controls on mountain ecosystems evaluated using geophysics, geochemistry, and remote-sensing*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Barnhart, T.B., Molotch, N.P., Tague, C. (2016). *Bidirectional Response of Runoff to Changes in Snowmelt Rate, Timing, and Amount*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Williams, E.K., Terwilliger, V.J., Nakamoto, B.J., Berhe, A.A., Fogel, M.L. (2016). *Bulk Soil Organic Matter d2H as a Precipitation Proxy.*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tian, Z., Hartsough, P.C., O'Geen, A.T. (2016). *Carbon Stocks in Soil and Deep Regolith Across the Southern Sierra Nevada*. SSCZO Annual meeting 2016. Merced, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tian, Z., Hartsough, P.C., O'Geen, A.T. (2016). *Carbon Stocks in Soil and Deep Regolith Across the Southern Sierra Nevada, California*. Soil Science Society of America International Annual meeting 11/2016. Tampa, FL. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Li, D., Wigmore, O., Vanderjagt, B.J., Durand, M.T., Molotch, N.P., Bales, R.C. (2016). *Catchment-scale snow depth monitoring with balloon photogrammetry*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Moreland, K, and AA. Berhe, Fogel, M., O'Geen, A. (2016). *Climatic Controls on Deep Soil Organic Matter in the Critical Zone*. 2016 Southern Sierra Critical Zone Observatory Annual Meeting. Merced, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Moreland, K, and AA. Berhe, Fogel, M., O'Geen, A. (2016). *Climatic Controls on Deep Soil Organic Matter in the Critical Zone*. Goldschmidt 2016. Yokohama, Japan. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Kelly, A. (2016). *Climatic Limitations on Woody Biomass and Production along a 2300 m Elevation Gradient*. 2016 Yosemite Hydroclimate Meeting. Yosemite National Park. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Barnes, M, S Hart, A Berhe (2017). *Climatic controls on the biogeochemical cycling of phosphorus in the critical zone*. Institute for the Study of Ecological and Evolutionary Climate Impacts Symposium. Santa Barbara, California. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Taylor, N.J., Riebe, C.S., Dueker, K.G., Goulden, M., Flinchum, B.A., Pasquet, S., Callahan, R.P., Hahm, W.J., Keifer, I.S., Holbrook, W.S. (2016). *Comprehensive seismic surveys suggest that subsurface water-holding capacity is secondary to bedrock nutrient content as a regulator of vegetation productivity in the Sierra Nevada Batholith, California.*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Liu, F., Miller, M.P., Williams, M.W., Conklin, M.H., Yang, J., Bales, R.C. (2016). *Concentration-Discharge Relationship and Endmember Mixing in the Intermediate and Large Watersheds of the US West*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Aguirre, A.A. (2017). *Concentration-Discharge relationships across sites in the Critical Zone Network*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hoffman, A.; White, T.; Dere, A.; Wymore, A.; Washburne, J.; Conklin, M. (2017). *Creating a Critical Zone Science Course to Address Environmental and Global Resource Challenges*. Soil Science Society of America International Annual Meeting. . Status = SUBMITTED; Acknowledgement of Federal Support = Yes

Wymore, A., White, T.S., Dere, A.L.D., Hoffman, A., Washburne, J.C., Conklin, M.H. (2016). *Critical Zone Science as a Multidisciplinary Framework for Teaching Earth Science and Sustainability.*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Berhe, A.A.; Moreland, K.; Tian, Z.; O'Geen, A. (2017). *Deep Soil Carbon in the Critical Zone: amount and nature of carbon in weathered bedrock, and its implication for soil carbon inventory*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Aronson, E.; Arogyaswamy, K.; Maltz, M.; Mayorga, E.; Packman, A. (2017). *Describing Microbial Community of the Critical Zone with CZIMEA: Critical Zone Integrative Microbial Ecology Activity*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Heckman, C. (2016). *Does transpiration increase with warming? The effect of soil water storage on plant water use in a snow dominated climate, SSCZO (Southern Sierra Critical Zone Observatory)*. Southern Sierra Critical Zone Observatory Annual Meeting. Merced CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Kennedy, M.C., Mckenzie, D., Tague, C., Bart, R.R. (2016). *Ecohydrological Projections of Fire Regimes: Balancing Uncertainty and Complexity to Integrate Cross-disciplinary Simulation Systems*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dove, N.C., Hart, S.C. (2017). *Effects of novel, high-severity fire on microbial communities and biogeochemical processes: opening the "charcoal" box*. Department of energy – Joint Genome Institute User Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Lindsay Arvin, Cliff Riebe, Sarah Aciego, Molly Blakowski (2016). *Estimating aeolian inputs to ecosystems using existing global models and Nd isotopes in vegetation*. Southern Sierra Critical Zone Observatory Annual Meeting, August 2016. Merced, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Martin, S., Conklin, M. (2016). *Evaluation of Catchment Pairs and the Seasonal Effects of Drought on Source Water in Forested Mountain Streams*. 2016 Yosemite Hydroclimate Meeting. Yosemite National Park. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Rungee, J.; Bales, R.C. (2017). *Evapotranspiration and land-cover response to multi-year dry periods in the semi-arid Western United States*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Lauder, J. (2016). *Exploring Drought Resilience in Sequoia National Park Conifers*. Sequoia National Park Centennial Science Symposium. Three Rivers, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dove, N., Hart, S. (2016). *Fire reduces fungal species richness and mycorrhizal colonization: A meta-analysis*. ESA Annual Meeting 2016. Fort Lauderdale, FL. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ma, Q. (2016). *Forest Growth Response to Competition and Environmental Conditions*. Sequoia and Kings Canyon Science Symposium. Three Rivers, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Conklin, M.; Saksa, P.; Tague, N.; Bales, R. (2017). *Forest thinning in Sierra Nevada mixed-conifer headwater forests: evapotranspiration, runoff and drought resiliency*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dove, N. (2016). *Geospatial techniques for field-based research: case studies in NW Baja California & Yosemite NP*. California Geographic Information Association Annual Geosummit. Merced, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arvin, L., Riebe, C., Aciego, S., Blakowski, M. (2016). *Global datasets and Nd isotopes in pine needles estimate dust inputs to ecosystems in eroding landscapes*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Lukens, C. E., Riebe, C. S., Shuster, D. L., and Sklar, L. S. (2016). *Grain-size bias in detrital thermochrometry: implications for interpreting sediment provenance and landscape evolution*. Geological Society of America Annual Meeting. Denver CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Heckman, C.; Tague, C. (2017). *How soil water storage moderates climate changes effects on transpiration, across the different climates of the Critical Zone Observatories*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Heckman, C., Tague, C (2016). *How soil water storage moderates climate change's effects on transpiration across the Critical Zone Observatories*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dere, A.; White, T.; Wymore, A.; Hoffman, A.; Washburne, J.; Conklin, M.; Shuster, R. (2017). *Implementing InTeGrate Critical Zone Science materials in an undergraduate geoscience curriculum*. Earth Educators' Rendezvous. . Status = SUBMITTED; Acknowledgement of Federal Support = Yes

Saksa, P.C., Safeeq, M., Dymond, S. (2016). *Implications of Increasing Forest Density and Vegetation Water Demand on Drought Impacts in California Montane Forest.*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wilson, S.G., Margenot, A.J., O'geen, A.T., Dahlgren, R.A. (2016). *Influence of Climate and Lithology on Soil Phosphorus.*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bart, R., Tague, C., Kennedy, M., McKenzie, D. (2016). *Integrating Fire Effects into an Ecohydrologic Model for Simulating Fire Regimes*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bart, R., Tague, C., Kennedy, M.C., McKenzie, D. (2016). *Integrating fire effects into an ecohydrologic model for simulating fire regimes*. 2016 Fall Meeting, AGU. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Harpold, A. (2016). *Interactions Between Hydroclimate and Soil Properties Control the Risk for Altered Hydrologic Partitioning from Changing Snowmelt in the Sierra Nevada*. 2016 Yosemite Hydroclimate Meeting. Yosemite National Park. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Thaw, M., Visser, A., Deinhart, A., Bibby, R., Everhart, A., Conklin, M. (2017). *Investigating drought vulnerability using stable water isotopes and tritium in a montane system*. European Geosciences Union General Assembly. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Visser, A. Thaw, M., Deinhart, A., Bibby, R., Esser, B. (2017). *Investigating drought vulnerability using stable water isotopes and tritium in a montane system*. European Geosciences Union General Assembly. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Weiner, J., Harpold, A.A., Safeeq, M. (2016). *Is Snow a Drought Buster? The Need to Incorporate Snow into Common Drought Indices.*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Devine, S., O'geen, A.T., Dahlke, H.E. (2016). *Is Soil Development Controlling Ecohydrologic Response to Climate Change in the Southern Cascade and Sierra Nevada Watersheds, CA, USA?*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Goodwell, A.; Kumar, P. (2017). *Local and non-local information flow along an elevation gradient*. 2017 Arlington Meeting for Critical Zone Science. A. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tague, C., Moritz, M. (2016). *Managing forests, water resources and their interaction in the face of increasing drought frequency and severity in semi-arid regions.*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tague, C (2016). *Modeling drought-related disturbance in water-limited environments*. CMWR XXI International Conference. Toronto, Canada. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Zheng, Z. (2016). *Multi-platform data fusion for more accurate forecasting of water supply from the Sierra Nevada Snow*. Western Snow Conference. Seattle, Washington. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ayers, R.; Jimenez, A.; Gilmore, M. (2017). *Nature Journaling Breathes Life into Environmental Literacy*. California STEAM Symposium. . Status = SUBMITTED; Acknowledgement of Federal Support = Yes

Arvin, L., Riebe, C., Aciego, S., Blakowski, M. (2016). *Nd Isotopes in Soils and Pine Needles Trace Aeolian Inputs to Sierra Nevada Ecosystems*. Goldschmidt 2016. Yokohama, Japan. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bales, R. (2016). *Observations From Drought in the Southern Sierra*. 2016 Yosemite Hydroclimate Meeting. Yosemite National Park. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Oroza, C., Zheng, Z., Glaser, S.D., Bales, R.C., Conklin, M.H. (2016). *Optimizing placements of ground-based snow sensors for areal snow cover estimation using a machine-learning algorithm and melt-season snow-LiDAR data*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dove, N.C.; Arogyaswamy, K.; Carey, C.J.; Packman, A.I.; Hart, S.C.; Aronson, E.L. (2017). *Over half of potential soil extracellular enzyme activity occurs below 20 cm*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Klos, Z.P.; Bales, R.C.; Berhe, A.A.; Conklin, M.H.; Goulden, M.L.; Hart, S.C.; Hartsough, P.; Holbrook, W.S.; O'Geen, A.T.; Riebe, C.S.; Safeeq, M.; Tague, C.L. (2017). *Plant accessible water in the subsurface of mountain landscapes within Mediterranean climate-types: Insights gained from the Southern Sierra Critical Zone Observatory*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ferrell, R.M.; Ferrell, D.F.; Hartsough, P.C.; O'Geen, A.T. (2016). *Predictive modeling of spatial patterns in regolith thickness and conifer productivity in the SSCZO Soaproot watershed*. Southern Sierra Critical Zone Observatory Annual Meeting 2016. Merced, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Callahan, R.P., Taylor, N.J., Pasquet, S., Dueker, K.G., Riebe, C.S., Holbrook, W.S. (2016). *Probing the critical zone using passive- and active-source estimates of subsurface shear-wave velocities*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arvin, L.; Riebe, C.; Carey, C.; Aarons, S.; Blakowski, M.; Hart, S.; Aronson, E. (2017). *Reevaluating the role of dust in mountain ecosystems using tracer isotopes, microbial genomics, and global databases*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

O'Geen, A.T. (2016). *Regional controls on organic carbon in forest soils*. California Forest Pest Council Workshop. CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Su, Y., Bales, R., Ma, Q., Nydick, K., Ray, R., Li, W., Guo, Q. (2017). *Relative resiliency of Giant Sequoia groves to multi-year dry periods in a warming climate*. 2017 AAG Annual Meeting. Boston, MA.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tague, C.L., Mortiz, M., Bart, R., Turpin, E. (2016). *Seeing the water in the trees: Challenges in estimating the impact of fuel treatments and fire on hydrology*. CUAHSI. Shepherdstown WV. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Safeeq, M., Hunsaker, C.T., Bales, R.C. (2016). *Sensitivities of dry season runoff to precipitation and temperature in southern Sierra Nevada streams*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Yoon, Y.; Conklin, M.H.; Bales, R.C.; Zhang, Z.; Zheng, Z.; Glaser, S.D. (2016). *Sierra Nevada snowpack and runoff prediction integrating basin-wide wireless-sensor network data*. 2016 American Geophysical Union Fall Meeting. San Francisco CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ferrell, R., Hartsough, P.C., O'Geen, A.T. (2016). *Spatial patterns between regolith thickness and forest productivity in the Southern Sierra Critical Zone Observatory*. Soil Science Society of America International Annual meeting 2016. Tampa, FL. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Lukens, C., Shuster, D.L., Sklar, L.S., Riebe, C.S. (2016). *Spatial variations in the size distribution of sediment supplied to channels: A synthesis of detrital thermochronometry from 11 size classes in Inyo Creek, California*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tague, C (2016). *The Ecohydrology of forest thinning in a warming Southwest climate*. ESA Annual Meeting. Fort Lauderdale, Florida. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hart, S. C., Carey, C., Glassman, S., Chung, J., Bruns, T., Aronson, E., (2016). *Towering trees have big effects on miniscule microbes: The influence of giant sequoia (Sequoiadendron giganteum) on underlying soil microbial communities*. ESA Annual Meeting 2016. Fort Lauderdale, FL. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Visser, A.; Thaw, M.; Deinhart, A.; Bibby, R.; van der Velde, Y.; Esser, B.; Conklin, M. (2017). *Tracking water through the Critical Zone: Models and isotope tracers at the Southern Sierra CZO*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Thaw, M. Visser, A., Deinhart, A., Everhart, A., Bibby, R., Conklin, M. (2016). *Tracking water through the Southern Sierra Critical Zone Observatory using radioactive and stable isotopes*. Southern Sierra Critical Zone Observatory Annual Meeting. Merced CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Thaw, M., Visser, A., Deinhart, A.L., Sharp, M., Everhart, A., Bibby, R.K., Conklin, M.H. (2016). *Tracking water through the Southern Sierra Critical Zone Observatory using radioactive and stable isotopes* .. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Callahan, R., Riebe, C., Dosseto, A. (2016). *Using Cosmogenic and U-Series Nuclides in Stream Sediment to Test Hypotheses About Mountain Landscape Evolution.*. Goldschmidt 2016. Yokohama, Japan. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Collins, C.; Maxwell, R. (2017). *Using an integrated hydrologic model to assess the ecohydrologic impacts of change on a mountain headwaters Critical Zone*. 2017 Arlington Meeting for Critical Zone Science. Arlington VA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Thaw, M. (2016). *Variability in Sierra Nevada Forest Water Sources During a Severe Drought*. 2016 Yosemite Hydroclimate Meeting. Yosemite National Park, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Su, Y. (2016). *Vulnerability of Giant Sequoia Groves to the Changing Climate and Extreme Droughts During the Last Three Decades*. Sequoia and Kings Canyon Science Symposium. Three Rivers, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

van der Velde, Y., A. Visser, M. Thaw, and M. Safeeq (2017). *Water storage and mixing in a Californian mountain catchment during a multiyear drought*. European Geosciences Union General Assembly. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tague, C., Moritz, M., Bart, R., Hanan, E. (2017). *Why subsurface features matter for managing forests, water and fire in the face of increasing drought frequency and severity*. AGU Chapman Conference on Extreme Climate Event Impacts on Aquatic Biogeochemical Cycles and Fluxes. San Juan, Puerto Rico. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Goulden, M., Bales, R.C. (2016). *Widespread tree mortality with the ongoing California drought: the roll of water balance and temperature*. 2016 AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Everhart, A. Thaw, M. (2016). *Winter field hydrology: strategies developed in the Southern Sierra Critical Zone Observatory*. Southern Sierra Critical Zone Observatory Annual Meeting. Merced CA. Status = PUBLISHED; Acknowledgement of Federal

Support = Yes

Other Products

Audio or Video Products.

(2017) Explore the Critical Zone. 6.5 minute video features footage of SSCZO personnel and collaborators M. Safeeq, E. Stacy, M. Thaw, and P. Womble conducting field work, collected by M. Gilmore. Produced by WSKG in Binghamton, NY, in collaboration with the CZO National Office. http://criticalzone.org/national/research/the-critical-zone-1national/

Audio or Video Products.

(2017) Water in the Balance. UCTV Sustainable California. 5.5 minute video features footage of SSCZO infrastructure and personnel including M. Safeeq, M. Gilmore, M. Conklin, E. Stacy, P. Womble. Produced by University of California, Merced, in collaboration with UC Water Security and Sustainability Initiative and the Sierra Nevada Research Institute. http://www.uctv.tv/sustainable-cal/search-details.aspx?showID=32342

Educational aids or Curricula.

Gilmore, M.; Rungee, J.; Conklin, M. (2017) *Water Balance in the Critical Zone: SimWater Mountains to Valley Activity.* InTeGrate Critical Zone Science, upper-level undergraduate course curriculum. http://serc.carleton.edu/integrate/teaching_materials/critical_zone/water_unit2.html

Educational aids or Curricula.

Rungee, J.; Conklin, M.; Gilmore, M. (2017) *Water Balance in the Critical Zone: Spatial Analysis and Interpolation Activity.* InTeGrate Critical Zone Science, upper-level undergraduate course curriculum. http://serc.carleton.edu/integrate/teaching_materials/critical_zone/water_unit2.html

Educational aids or Curricula.

Stacy, E.; Conklin, M. (2017) *Water Balance in the Critical Zone: Forest Water Balance Activity.* InTeGrate Critical Zone Science, upper-level undergraduate course curriculum. http://serc.carleton.edu/integrate/teaching_materials/critical_zone/water_unit1.html

Educational aids or Curricula.

Stacy, E.; Conklin, M.; Tobin, B. (2017) *Water Balance in the Critical Zone: Tree-Scale Water Budget Activity.* InTeGrate Critical Zone Science, upper-level undergraduate course curriculum. http://serc.carleton.edu/integrate/teaching_materials/critical_zone/water_unit1.html

Bren School Master's Project Proposal.

Haze, S.; Heywood, J.; Pile, L.; LaPlante, S.; Gilmore, M.; Stacy, E. (Accepted) *Developing a holistic approach to forest restoration in the southern Sierra Nevada in the face of unprecedented forest mortality*. Bren School of Environmental Science & Management 2017-2018 Master's Project.

Course Field Trip.

Berhe, A.A., Stacy, E.M., Gilmore, M.E. Soil profile characterization and moisture measurement at the Southern Sierra Critical Zone Observatory. Field trip for undergraduate Critical Zone Science course at the University of California, Merced. Shaver Lake, CA. November 5, 2016.

Course Field Trip.

Gilmore, M.E., Stacy, E.M., Barnes, M., Moreland, K., Abney, R., Cooney, M. *Soil profile characterization and piezometer validation at the Southern Sierra Critical Zone Observatory.* Field trip for NSF-funded undergraduate field course for students from College of the Atlantic, University of San Francisco, and Mt San Antonio College (PIs S. Hall, C. Schmidt, R. Walker). Shaver Lake, CA. June 11-13, 2017.

Course Guest Lecture.

Gilmore, M. Rock properties, geological processes, and their roles in landscape evolution. Guest lecturer for undergraduate Critical Zone Science course at University of California, Merced. Merced, CA. October 26, 2016.

Course Guest Lecture.

Stacy, E. Links between Land Cover and Stream Discharge. Guest lecturer for undergraduate Critical Zone Science course at University of California, Merced. Merced, CA. November 2, 2016.

Invited Presentation.

Gilmore, M. *Soil Composition and Decomposition*. Society of American Foresters High Sierra Chapter Conservation Day. Tollhouse, CA. April 20, 2017.

Invited Presentation.

Moreland, K. 2017. *Imposter Syndrome, Mental Health, Interpersonal Issues in Graduate School.* University of California, Merced, Engineering Department Professional Seminar, Merced, CA.

Invited Presentation.

Bales, R.C. (2016) *Observations from drought in the Sierra Nevada: evapotranspiration, climate & regolith weathering*, Caltech James J. Morgan Symposium. Pasadena CA. September 23, 2016

Invited Presentation.

Bales, R.C. (2016) *Water security in California in the age of drought.* University of California Berkeley Systems Engineering Presentation. Berkeley CA. November 18, 2016

Invited Presentation.

Bales, R.C. (2016) *Water, forests & climate in the Sierra Nevada*, Alpine Biomass Committee. Markleville, CA. September 6, 2016

Invited Presentation.

Bales, R.C. (2016) *Foundations for California's Water Security in a Changing Climate,* 2016 Resources Roundtable: The Water-Energy Nexus. Berkeley, CA. November 2, 2016

Invited Presentation.

Bales, R.C. (2017) *Drought Resilience & Water Security: Observations from the Sierra Nevada.* NSF U.S. Critical Zone Observatory Network Critical Zone and Society Webinar. April 11, 2017.

Invited Presentation.

Bales, R.C. (2017) *Water Security in a Changing Climate: Observations from Drought in the Sierra Nevada,* University of California Irvine Water UCI Colloquium Series. Irvine CA. February 22, 2017.

Invited Presentation.

Bales, R.C. (2017) Observations *from drought in the Sierra Nevada: evapotranspiration, climate & regolith weathering.* University of California Berkeley Environmental Engineering Seminar. Berkeley, CA. February 17, 2017.

Invited Presentation.

Bales, R.C. (2017) *Water Security in a changing climate.* The Association of Water Agencies of Ventura County 25TH Annual Water Symposium. Oxnard CA. April 20, 2017

Invited Presentation.

Gilmore, M. (2017) *Sharing Earth systems research with non-specialized audiences,* University of California Merced EnviroLunch Seminar. Merced CA. February 9, 2017.

Invited Presentation.

Gilmore, M., Ayala-Astorga, M. *Sierra Soils Extravaganza*. Stanislaus National Forest Lake Alpine Junior Ranger Program. Arnold, CA. July 20, 2016.

Invited Presentation.

Gilmore, M., Thaw, M., Castro, M. *Soil Wildlife and Decomposition*. Southern California Edison Science Days. Shaver Lake, CA. May 12 & June 2, 2017.

Invited Presentation.

Kelly, A. *How heat and drought control the growth and death of Sierra forests.* Yosemite Forum. Yosemite National Park, CA. February 14, 2017.

Invited Presentation.

Moreland, K., Dove, N., Anzules, J., Gilmore, M., Canela, S., Sooch, K. 2017. BIOTAQ Soil Science Module. Yosemite High School, Merced CA. March 16, 2017.

Invited Presentation.

Riebe, C.S. *The influence of bedrock composition on drought-induced mortality in southern Sierra Nevada forests.* Department of Earth and Climate Sciences Speaker Series, San Francisco State University, CA, November 1, 2016.

Invited Presentation.

Riebe, C.S. *Top-down and bottom-up controls on mountain ecosystems and landscape evolution.* Bren School of Environmental Science and Management, University of California, Santa Barbara, March 16, 2017.

Invited Presentation.

Tague, C. (2016) The eco-hydrology of forest density reduction. Weizmann Institute of Science, Rehovot, Israel.

Invited Presentation.

Tague, C. (Feb., 2017) Managing Forests, Water & Fire in the Face of Increasing Drought Frequency and Severity, Duke University Division of Earth and Ocean Sciences Spring Seminar Series, Durham, NC.

Invited Presentation.

Thaw, M. (2016) Southern Sierra in transition: Using isotopes in the CZO to track disappearing snow. University of California, Merced, Enviro-Lunch Seminar. Merced, CA. 20 October 2016.

Invited Presentation.

Thaw, M. (2017) Water isotopes in the Sierra Nevada: Subsurface storage and vegetation affect drought vulnerability. Yosemite Forum. Yosemite National Park, CA. June 13, 2017.

Mentorship Output.

Bradbury, K.; Guerra, J.; Robles, J. (2017) *Surveying Snow in the Sierras,* Center for Advanced Research and Technology Environmental Science and Technology Lab Spring Action Project Showcase, Mentored by M. Gilmore and E. Stacy. Clovis CA. May 16, 2017.

Mentorship Output.

Castaneda, J.; Mesple, J.; Moon, A.; Velasquez, M. (2017) *Taking Snow Surveys in the Sierra Nevada,* Center for Advanced Research and Technology Environmental Science and Technology Lab Spring Action Project Showcase, Mentored by M. Gilmore and E. Stacy. Clovis CA. May 16, 2017.

Teacher Workshop.

Gilmore, M.; Sullivan, L.; DeMers, S. *Got Soil?* Merced County Office of Education TEAM-E Year 2 Fall Teacher Workshop. Merced, CA. September 2016.

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Ferrell, R.. *Patterns and above-ground ecosystem interactions of regolith in the southern Sierra Nevada of California*. (2017). University of California, Davis. Acknowledgement of Federal Support = Yes

Websites

SSCZO Digital Library
http://eng.ucmerced.edu/snsjho/files/MHWG/Field/Southern_Sierra_CZO_KREW

Data, metadata, photos, reports, and other documents are catalogued in the SNSJHO digital library. Access to public data and files is available to anyone. Additional permissions can be obtained through registration and individual requests. Links for viewing and downloading data on criticalzone.org/sierra/data connect to
this repository. In Spring 2016 we initiated using Google Analytics for page visits and downloads on this site.

SSCZO Facebook
http://www.facebook.com/SSCZO

The Southern Sierra Critical Zone Observatory maintains a Facebook page. This page currently has 91 likes. Our Facebook activity reaches a cross-disciplinary
audience of researchers broader than environmental science, hydrology, or the CZO network; undergraduate and students from associated universities; and friends and family of SSCZO colleagues.

SSCZO Twitter
http://www.twitter.com/SSCZO

The Southern Sierra Critical Zone Observatory was the first CZO in the National CZO Program with an active Twitter account. Now that the network has expanded and other CZOs are active on Twitter, it is a space for SSCZO to connect with other observatories and researchers interested in critical zone science. SSCZO posts events, photos, videos, news items, and blog posts related to the local observatory, the CZO network, and the general scope of critical zone research.

A majority of our 428 current followers are members of the research community, including individual researchers and research programs unaffiliated with the National CZO Program. Other followers include stakeholders, students, and interested publics. In the past year we have gained over 100 new followers.

Southern Sierra Critical Zone Observatory
http://www.criticalzone.org/sierra

This website is the home of the Southern Sierra Critical Zone Observatory. Staff are updating static webpage content for improved long-term management. Publications, events, videos, and news are regularly updated. We are also currently developing interactive field site maps that are planned to launch online in Fall 2017.

Staff are also part of the network-scale Website Committee to continue improving content consistency, layout, features, and accessibility of the U.S. Critical Zone Observatory Network website.

Twitter - Roger Bales
http://www.twitter.com/rbalesuc

SCZO PI Roger Bales started a Twitter page in December 2014. His page is active in conversations regarding water usage, hydrologic technology and infrastructure, hydrologic research, and intersecting news. He currently has 1,022 followers.

Twitter - SSCZO Researchers
http://www.twitter.com

Several researchers from SSCZO - students, investigators, and collaborators - actively share SSCZO activities, publications, presentations, upcoming events; and stories and conversations generally related to the critical zone. Some of our researchers' accounts are listed below:
Lindsay Arvin (@lj_arvin), Ryan R. Bart (@ryanrbart), Asmeret Asefaw Berhe (aaberhe), Russell Callahan (@russ_buss), Nicholas Dove (@nicholascdove),
Cliff Riebe (@sedimentMatters), Mohammad Safeeq
(@safeeqkhan), Naomi Tague (@naomi_eco_hydro), Melissa Thaw (@MelissaThaw).

U.S. Critical Zone Observatory Network Instagram
http://www.instagram.com/criticalzoneorg

SSCZO contributes photos and captions to the CZO Instagram account. @CriticalZoneOrg represents all Critical Zone Observatories in the U.S. CZO network. The account became active in Spring 2016. It currently has 118 followers.

Participants/Organizations

Research Experience for Undergraduates (REU) funding

Form of REU funding support:	REU supplement
How many REU applications were received during this reporting period?	0
How many REU applicants were selected and agreed to participate during this reporting period?	0
REU Comments:	

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Bales, Roger	PD/PI	2
Conklin, Martha	Co PD/PI	2
Goulden, Michael	Co PD/PI	3
Riebe, Clifford	Co PD/PI	4
Tague, Christina	Co PD/PI	2
Berhe, Asmeret Asefaw	Co-Investigator	2
Glaser, Steven	Co-Investigator	1
Hart, Stephen	Co-Investigator	3
O'Geen, Anthony	Co-Investigator	2
Safeeq, Mohammad	Co-Investigator	1
Bart, Ryan	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Klos, Peter	Postdoctoral (scholar, fellow or other postdoctoral position)	5
Zheng, Zeshi	Postdoctoral (scholar, fellow or other postdoctoral position)	1

Name	Most Senior Project Role	Nearest Person Month Worked
Busse, Matt	Other Professional	0
Choate, Janet	Other Professional	1
Davis, Frank	Other Professional	0
Gilmore, Michelle	Other Professional	12
Hunsaker, Carolyn	Other Professional	1
McCormick, Cyril	Other Professional	2
Meng, Xiande	Other Professional	10
Son, Kyongho	Other Professional	1
Stacy, Erin	Other Professional	12
Wagenbrenner, Joseph	Other Professional	1
Womble, Patrick	Other Professional	1
Hartsough, Peter	Staff Scientist (doctoral level)	3
Arvin, Lindsay	Graduate Student (research assistant)	12
Barnes, Morgan	Graduate Student (research assistant)	12
Callahan, Russell	Graduate Student (research assistant)	12
Chen, Xaoli	Graduate Student (research assistant)	2
Dove, Nicholas	Graduate Student (research assistant)	12
Ferrell, Ryan	Graduate Student (research assistant)	9
Heckman, Christopher	Graduate Student (research assistant)	12
Lucas, Ryan	Graduate Student (research assistant)	1
Moreland, Kimber	Graduate Student (research assistant)	12
Oroza, Carlos	Graduate Student (research assistant)	10
Rungee, Joe	Graduate Student (research assistant)	12
Su, Yanjun	Graduate Student (research assistant)	1

Name	Most Senior Project Role	Nearest Person Month Worked
Taylor, Nicholas	Graduate Student (research assistant)	12
Thaw, Melissa	Graduate Student (research assistant)	12
Tian, Zhiyuan	Graduate Student (research assistant)	9
Everhart, Anthony	Non-Student Research Assistant	4
Ayala-Astorga, Maria	Undergraduate Student	2
Canela, Susana	Undergraduate Student	3
Castro, Madeline	Undergraduate Student	2
Cooney, Morgan	Undergraduate Student	2
Elias, Oscar	Undergraduate Student	3
Huang, Jennifer	Undergraduate Student	3
Lucey, Florence	Undergraduate Student	3
Ortega, Monse	Undergraduate Student	3
Vang, Mai Yee	Undergraduate Student	3

Full details of individuals who have worked on the project:

Roger C Bales
Email: rbales@ucmerced.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 2

Contribution to the Project: PI, oversight, planning, team lead, hydrologic balance

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Martha H Conklin
Email: mconklin@ucmerced.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2

Contribution to the Project: CZO co PI, InTeGrate Critical Zone course, groundwater surface water interactions, especially in meadows

Funding Support: SSCZO, UC Merced, other funding

International Collaboration: No
International Travel: No

Michael L Goulden
Email: mgoulden@uci.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 3

Contribution to the Project: Co PI, flux towers, development of tower top remote sensing system

Funding Support: UC Irvine, other funding

International Collaboration: No
International Travel: No

Clifford S Riebe
Email: criebe@uwyo.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 4

Contribution to the Project: landscape and critical zone evolution, geomorphology, geochemistry, geophysics; oversee and assist students; write papers and reports

Funding Support: SSCZO; Wyoming Center for Environmental Hydrology and Geophysics

International Collaboration: No
International Travel: No

Christina Tague
Email: ctague@bren.ucsb.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2

Contribution to the Project: modeling water and nutrient fluxes using Rhessys

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Asmeret Asefaw Berhe
Email: aaberhe@ucmerced.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Sediment transport & nutrient cycling

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Steven Glaser
Email: glaser@berkeley.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: University of California, Berkeley; Investigator; monitoring technology

Funding Support: UC Berkeley

International Collaboration: Yes, France
International Travel: No

Stephen Hart
Email: shart4@ucmerced.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3

Contribution to the Project: Sediment transport, nutrient cycling

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Anthony O'Geen
Email: atogeen@ucdavis.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Predicting regional trends in soils and deep regolith. Integrating hydrologic monitoring with processes of regolith formation.

Funding Support: other funding

International Collaboration: No
International Travel: No

Mohammad Safeeq
Email: msafeeq@ucmerced.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: hydrology, working collaboratively at UC Merced and Pacific Southwest Research Station (Forest Service)

Funding Support: other funding

International Collaboration: No
International Travel: No

Ryan Bart
Email: ryanrbart@berkeley.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 3

Contribution to the Project: Post-doctoral student working with Tague and collaborator M. Moritz on shrubs, modeling, and vegetation-water interactions

Funding Support: SSCZO, WSU, SESYNC

International Collaboration: No
International Travel: No

Peter Zion Klos
Email: zklos@ucmerced.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 5

Contribution to the Project: synthesize existing datasets, findings, and conceptual models for publication: plant-accessible water in the subsurface, metrics of seasonally and ecosystem storage dependence, and the role that deep regolith structure plays in the provisioning of water to wet meadows.

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Zeshi Zheng
Email: zeshi.z@berkeley.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 1

Contribution to the Project: Graduate student work on LiDAR ground-truthing, Wireless data at Providence

Funding Support: Other funding

International Collaboration: No
International Travel: No

Matt Busse
Email: mbusse@fs.fed.us
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 0

Contribution to the Project: USFS Pacific Southwest Research Station, advisory board

Funding Support: Other; CZO funds for travel for Advisory Board duties

International Collaboration: No
International Travel: No

Janet Choate
Email: jsc.eco@gmail.com
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: University of California, Santa Barbara; Techno II/Tague Lab Manager; RHESSys technical support staff

Funding Support: SSCZO, USGS, WSU, other NSF funding

International Collaboration: No
International Travel: No

Frank Davis

Email: fd@bren.ucsb.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 0

Contribution to the Project: Advisory Board; University of California, Santa Barbara

Funding Support: Other; CZO funds for travel for Advisory Board duties

International Collaboration: No
International Travel: No

Michelle Gilmore
Email: mgilmore2@ucmerced.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Staff, Outreach Manager

Funding Support: SCZO

International Collaboration: No
International Travel: No

Carolyn Hunsaker
Email: chunsaker@fs.fed.us
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: Retired 2017; USFS Pacific Southwest Research Station; Sr. Personnel; stream and watershed ecology and hydrology

Funding Support: USDA Forest Service

International Collaboration: No
International Travel: No

Cyril McCormick
Email: mccormic@uci.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 2

Contribution to the Project: UC Irvine project engineer; Goulden research group instrumentation

Funding Support: Other funding

International Collaboration: No
International Travel: No

Xiande Meng
Email: xmeng@ucmerced.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 10

Contribution to the Project: SSCZO Staff - Data Manager

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Kyongho Son
Email: kson@bren.ucsb.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: UC Santa Barbara PhD alumnus; core CZO measurements, data management and integration; working on publications

Funding Support: other funding

International Collaboration: No
International Travel: No

Erin Stacy
Email: estacy@ucmerced.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: SSCZO Staff, Field Manager

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Joseph Wagenbrenner
Email: jwagenbrenner@fs.fed.us
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: USFS Pacific Southwest Research Station hydrologist, Kings River Experimental Watersheds contact

Funding Support: USDA Forest Service

International Collaboration: No
International Travel: No

Patrick Womble
Email: pwomble@ucmerced.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

Contribution to the Project: University of California, Merced; occasional field assistance with SSCZO tasks

Funding Support: UCM, other funds

International Collaboration: No
International Travel: No

Peter Hartsough
Email: phartsough@ucdavis.edu

Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 3

Contribution to the Project: UC Davis project scientist. Soil and regolith hydrology

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Lindsay Arvin
Email: larvin@uwyo.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: U. of Wyoming PhD student; Conduct research on rates of dust incorporation into vegetation using geochemical techniques. Write papers.

Funding Support: SSCZO, NSF GRFP, UW Department of Geology and Geophysics travel grants

International Collaboration: No
International Travel: No

Morgan Barnes
Email: mbarnes@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: UC Merced PhD student. Climatic controls on the biogeochemical cycling of phosphorus in the critical zone. Assessing transformation of phosphorus pools and speciation along arid and Mediterranean climatic gradients to understand the role of temperature and precipitation on phosphorus biogeochemistry and ecosystem development. Researching trends in soil nutrient hot spot and hot moment formation.

Funding Support: SSCZO, Institute for the Study of Ecological and Evolutionary Climate Impacts

International Collaboration: No
International Travel: No

Russell Callahan
Email: rcallaha@uwyo.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: U. of Wyoming PhD student. Conduct research on rates of erosion and weathering using geochemical techniques. Conduct geophysical research of subsurface porosity structure. Write papers.

Funding Support: SSCZO, UW Department of Geology and Geophysics travel grants

International Collaboration: No
International Travel: No

Xaoli Chen
Email: xiaoli_chen@umail.ucsb.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: UC Santa Barbara graduate student; ecohydrologic systems modeling with RHESSys

Funding Support: SSCZO, WSU, USGS, NSF

International Collaboration: No
International Travel: No

Nicholas Dove
Email: ndove@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: UC Merced PhD student. Impacts of altered fire regimes on microbial communities and biogeochemical processes. Disturbance impacts on carbon and nitrogen cycling in the critical zone.

Funding Support: SSCZO, UCM, other funding

International Collaboration: No
International Travel: No

Ryan Ferrell
Email: rmferrell@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9

Contribution to the Project: UCD MS student. Predicting spatial trends in regolith thickness

Funding Support: SSCZO, UCD teaching assistantships

International Collaboration: No
International Travel: No

Christopher Heckman
Email: checkman@bren.ucsb.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: UC Santa Barbara; ecohydrologic modeling

Funding Support: SSCZO, USGS

International Collaboration: No
International Travel: No

Ryan Lucas
Email: rlucas@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: UC Merced PhD student; Suface-groundwater interactions

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Kimber Moreland
Email: kmoreland@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Graduate student in the Hart and Berhe labs working on nitrogen in the subsurface

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Carlos Oroza
Email: coroza@berkeley.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 10

Contribution to the Project: Graduate student on developments for the wireless sensor network and site selection

Funding Support: SSCZO, other funding

International Collaboration: Yes, France
International Travel: Yes, France - 0 years, 0 months, 14 days

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Joe Rungee
Email: jrungee@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: University of California, Merced; Ecohydrology, data modeling

Funding Support: UC Merced, other funding

International Collaboration: No
International Travel: No

Yanjun Su
Email: ysu3@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: UC Merced PhD student; remote sensing of vegetation

Funding Support: other funding

International Collaboration: No
International Travel: No

Nicholas Taylor
Email: ntaylor9@uwyo.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: U. of Wyoming Masters student. Conduct geophysical research of subsurface porosity structure. Write thesis.

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Melissa Thaw
Email: mthaw@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Graduate student in the Conklin lab; isotope hydrology, ecohydrology

Funding Support: SSCZO, Lawrence Livermore National Laboratory, UC Merced, Southern California Edison, others

International Collaboration: No
International Travel: No

Zhiyuan (Tina) Tian
Email: ztian@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9

Contribution to the Project: UC Davis PhD student. Deep regolith characterization, deep carbon, deep regolith weathering

Funding Support: SSCZO, UC ANR Strategic Initiatives, Chinese Scholarship Council

International Collaboration: No
International Travel: No

Anthony Everhart
Email: aeverhart@ucmerced.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 4

Contribution to the Project: soil, snow, precipitation, and vegetation sampling with M. Thaw

Funding Support: other funding

International Collaboration: No
International Travel: No

Maria Ayala-Astorga
Email: mayalaastorga@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Undergraduate field assistant. Vegetation, soils, infrastructure improvements, core instrumentation maintenance

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Susana Canela

Email: scanela@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: laboratory and field assistance, UC Merced Hart research group

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Madeline Castro
Email: mcastro29@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: outreach program assistant; website updates, outreach materials drafting and event assistance, data entry

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Morgan Cooney
Email: mcooney@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Undergraduate field assistant. Soils, infrastructure improvements, core instrumentation maintenance, data

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Oscar Elias
Email: oelias2@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: laboratory and field assistance, UC Merced Hart research group

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Jennifer Huang
Email: jhuang26@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: laboratory and field assistance, UC Merced Hart research group

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Florence Lucey
Email: flucey@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: laboratory and field assistance, UC Merced Hart research group

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Monse Ortega
Email: mortega24@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: UC Merced Hart research group volunteer

Funding Support: none

International Collaboration: No
International Travel: No

Mai Yee Vang
Email: mvang25@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: laboratory and field assistance, UC Merced Hart research group

Funding Support: SSCZO, other funds

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Lawrence Livermore National Laboratory	Other Organizations (foreign or domestic)	Livermore, CA
US Forest Service, Pacific Southwest Research Station	Other Organizations (foreign or domestic)	Fresno, CA

Full details of organizations that have been involved as partners:

Lawrence Livermore National Laboratory

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Livermore, CA

Partner's Contribution to the Project:
Financial support
In-Kind Support
Facilities
Collaborative Research

More Detail on Partner and Contribution: Collaboration with Co-PI M. Conklin on SSCZO meadows

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US Forest Service, Pacific Southwest Research Station

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Fresno, CA

Partner's Contribution to the Project:
In-Kind Support
Facilities
Collaborative Research

More Detail on Partner and Contribution:

What other collaborators or contacts have been involved?

Collaborators and cooperators are involved with the project for research and educational purposes.

A. Visser, B. Esser, A. Deinhart, **R. Bibby**, **M. Sharp** [LLNL]; **R. Maxwell, C. Collins** [CO School of Mines]; **Y. van der Velde** [Vrije Universiteit Amsterdam] w/ Conklin, Thaw

Y. Jin [UC Davis] w/ O'Geen

S. Hall [Coll. of the Atlantic], **C. Schmidt** [U. San Francisco], **R. Walker** [San Antonio Coll.] w/ Gilmore, Stacy

N. Stavros + others [NASA Cal/Val] w/ Bales

T. Watteyne + student [INRIA] w/ Glaser

S. Holbrook [VA Tech]; **K. Dueker, I. Keifir, S. Pasquet, B. Flinchum** [U. Wyo] w/ Riebe

K. Ferrier [GA Tech], **L. Sklar** [San Francisco State U.], **A. Dosseto** [U. Wollongong]**, J. Dixon** [Montana State U.], **S. Aarons** [UC Irvine], **C. Lukens** [formerly U. Wyo, now Victoria U.] w/ Riebe

S. Aciego [U. Wyo, U. Michigan], **S. Aarons** [UC Irvine] w/ Riebe

E. Aronson, M. Maltz [UC Riverside]; **C. Carey** [Point Blue] w/ Riebe, Hart

C. Hunsaker [USFS retired], **D. Johnson** [UNV-Reno emeritus], **S.M. Meding** [U. Arizona] w/ Stacy, Berhe, Hart

T. White [Penn State], **A. Wymore** [U. NH], **A. Dere** [U. Nebraska-Omaha], **A. Hoffman** [U. Dubuque], **J. Washburne** [U. AZ], **S. Gill** [Stroud Water Research Center] w/ Conklin

D. Li, O. Wigmore, B. Vander Jagt, M. Durand [Ohio State]; **Noah Molotch** [U. Col. Boulder] w/ Bales

S. Bynum, S. Wilson, A. Howell [Center for Adv. Research & Tech.] w/ Gilmore, Stacy

A. Jimenez, J. Rhodea, R. Ayers [Merced Co. Office of Edu.] w/ Gilmore, Conklin

T. Catchpole [Soc. American Foresters High Sierra Chapter] w/ Gilmore

S. Byrd [So. Cal. Edison] w/ Gilmore

J. Lauder, E. Moran [UC Merced]

J. Marshall [UC Berkeley]

E. King, J. Pett-Ridge [Oregon State]

S. Voelker + student [Utah State], **B. Bulaon** [USFS]

J. Richardson [Cornell]

P. Saksa [UC Water] w/ Tague, Conklin, Bales

E. Burt, J. West [U. Southern CA]

A. Aguirre [Cornell]

A. Goodwell, P. Kumar [U. Illinois]

S. Tumber-Davila, H. Lu, R. Jackson [Stanford]

S. Myneni [Princeton]

E. Williams [UC Merced], **M. Fogel** [UC Irvine] w/ Berhe

R. Ray [Prairie View A&M U.]

Impacts

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

Cross-disciplinary advances in several areas have contributed to the overall discipline of critical-zone science. In addition to those highlighted as accomplishments, these mature results are showing potential impacts.

Research community resource: From the outset, the Southern Sierra Critical Zone Observatory and the other observatories in the NSF U.S. Critical Zone Observatory Network aimed to be resources for the critical-zone research community, in order to catalyze advancement in understanding the critical zone and refining Earth system models. Our team has actively engaged others in using this resource; over 20 research groups and 70 individuals without financial support from the current award are conducting research at SSCZO sites and with existing SSCZO data (see Other Participants list). Some of these research groups are closely collaborating with the core SSCZO team, which are noted in the list of collaborators and cooperators. Other researchers are conducting independent projects and have chosen SSCZO as a natural laboratory because of the breadth and depth of research findings, sample and data archives, and infrastructure available at our sites.

Ecohydrologic modeling: Modeling holds an important role in disseminating research results. Modifications by C. Tague to the Regional HydroEcologic Simulation System (RHESSys) serve as mechanisms for encoding advances made by our field based analyses. Ongoing refinement of the RHESSys code and RHESSYs parameterization are part of the CZO, and these tools are made accessible to a broader Earth system science modeling community. RHESSys code and parameter libraries are made available through github (https://github.com/RHESSys/RHESSys).

Recent research has suggested that changes in rain/snow partitioning may affect runoff patterns in seasonally snow-covered watershed (see Berghuijs et al.) The catchment-scale mechanisms responsible for this effect are not yet well-understood. The observed changes in the Berghuijs study may be attributable to factors correlated with increased temperature rather than rain/snow partitioning specifically. Our study aims to uncover these mechanisms by analyzing streamflow response to changes in rain/snow partitioning in the P303 catchment. The model is driven by in-situ measurements of precipitation and temperature, but the rain/snow partitioning can be explicitly varied in the model. This allows us to isolate temperature effects from partitioning effects.

Sensor placement: In many observatories, the spatial distribution of snow cover must be estimated from a limited set of point measurements. Extensive field surveys are often required to identify a distribution of sensors that will be representative of

catchment independent variables. The methods proposed and tested in our sensor-placement research may enable locations to be identified based on remotely sensed data (e.g LIDAR data) rather than field surveys.

Soil moisture: Our analysis quantifies the long-term accuracy of soil-water storage estimated from in-situ sensors as well as the evolution of the relative importance of independent variables affecting the predictive accuracy. This can be used to inform future sensor-placement strategies. We also quantify the intra-annual variability of each soil state (wet-up, snowmelt, recession, and dry), which is relevant to the ecohydrological community.

Regolith thickness: Remote-sensing techniques have traditionally had limited utility in digital soil mapping, except in arid areas where vegetative cover is low. However, recent advances from the SSCZO have established relationships between measured ET from flux towers with modeled ET from remote-sensing products. This work has generated valuable geospatial products to predict patterns in regolith thickness. This finding could transform soil-survey inventories in mountainous terrane, which as of now are fairly general and limited to the upper 2 m of regolith. Findings suggest that digital models of regolith thickness could be generated to predict regolith thickness, which is essential in predicting the actual amount of plant-available storage that can extend many meters. Spatial predictions of regolith thickness and water storage capacity are relevant to many disciplines including hydrology, ecology, soil science, geomorphology, geology, geochemistry.

Bedrock geochemistry: Our finding that vegetation resilience to climate change and drought may be governed in part by bedrock lithology indicates that the response of vegetation to changing climate may be dictated, at least in part, by bedrock composition and both the depth and degree of weathering in landscapes.

Phosphorus cycling: Critical knowledge gaps remain on our understanding of how the P dynamics are regulated by climate and depth, particularly in low-P-containing parent material. This work will contribute to our understanding of how temperate ecosystems may respond to climate change with a systematic and interdisciplinary approach. Although many have investigated the conceptual model of Walker and Syers (explains how P pools evolve through time), few have coupled climate change studies with a fractionation technique, examined P pool transformations with depth, or observed organic P speciation changes with climate. In addition, only a small number of studies have examined content and P pools within temperate Mediterranean ecosystems and drylands and shifts in chemical composition of the organic pool are largely unknown. Ongoing research seeks to fill in these gaps in knowledge.

Dust biogeochemistry: Our discovery that dust plays a major role in ecosystem nutrient supply, soil microbial-community composition, and plant-uptake of nutrients in the Sierra Nevada raises the possibility that these phenomena may be more widespread. Our analysis of global datasets of erosion rates and global models of dust fluxes is consistent with this hypothesis. Thus the role of dust in montane ecosystems may have been underestimated in the past. To the extent that this is the case, it may have major implications for understanding forest and microbial ecology, biogeochemical cycles in watersheds, and landscape evolution.

Microbial ecology: By showing that over half of potential extracellular-enzyme activity occurs below 20 cm, we have demonstrated that ignoring microbial processes at depth limits our understanding of how microbial communities throughout the regolith may respond to global change.

In addition, ongoing research along a fire chronosequence is predicted to show that recent, high-severity fire may fundamentally impact microbial communities longer than low-severity or historical (pre-European settlement) fire disturbances.

What is the impact on other disciplines?

Two examples of impacts are described, on electrical engineering and on isotope hydrology. Additionally, activities and findings described in previous reporting sections have potential implications in other disciplines including the fields of silviculture, agricultural science, fire ecology, and wildlife ecology.

A central challenge of deploying wireless-sensor networks in remote regions with complex terrain involves finding a distribution of repeater nodes that will guarantee year-round connectivity. In the Electrical Engineering and Computer Science literature, many repeater placement strategies assume planar, isotropic models of node connectivity. In complex terrain, these methods don’t work. Therefore, we used wireless motes from the P301 wireless-sensor network to collect information on how terrain attributes affect wireless connectivity throughout the P301 catchment. These measurements were combined with LIDAR data in order to develop a model that uses vegetaion and terrain characteristics to predict where good links are likely to form. This model is used to evaluate the connectivity of thousands of potential placements in order to determine a distribution of repeaters that provides network redundancy. We expect that this approach will provide a better representation of link anisotropy than models in the existing literature.

The development of new hydrologic tracers and sampling methods by Lawrence Livermore National Laboratory and UC Merced researchers will impact the discipline of isotope hydrology. Sodium-22 is being used at P301 and P300 as a new isotopic tracer to complement tritium and sulfur-35 water tracing. Tritium can be used to detect relatively older water, from about 10 to 60 years old since it precipitated, while sulfur-35 can be used to detect younger water that is less than two years old. The decay rate of sodium-22 is between those of tritium and sulfur-35, which results in a higher-resolution picture of water ages older than two years and younger than ten years. Work is also being done to streamline sulfur-35 water sampling, with a proof-of-concept underway at the SSCZO Providence Creek site. Low concentration of sulfur-35 in water requires at least 20 liters of water to reach a concentration within detection limits. Thus, several hundred liters of water would typically be required to remove from the field monthly using prior sampling methods. Using ion-exchange resin columns, sulfur-35 can be concentrated in-situ as stream water is pumped through the column. This new method streamlines the chemistry procedures required in the lab and eliminates the step of researchers transporting hundreds of liters of water from the field site to the lab, and reduces ecosystem disturbance. Additionally, work is being carried out to fill the knowledge gap of quantifying the impact of air mass trajectory on atmospheric tritium variation.

What is the impact on the development of human resources?

The SSCZO has been engaged in the development of future critical-zone researchers, educators, K-16 students, and other professionals in related STEM and environmental-management fields. Details of output and outcomes are listed below.

Fundamental training and professional development of scholars working directly with SSCZO investigators during the reporting period include 2 M.S. students, 13 Ph.D. students, and 3 postdoctoral researchers. Details on these scholars and their activities and training are found Personnel, Products, and Accomplishments sections of the report. Early-career professionals who recently graduated after conducting research at SSCZO have accepted positions at universities, federal agencies, and non-governmental organizations. Research conducted at SSCZO also impacts the development of scholars and early-career research collaborators and cooperators who are not financially supported by this award, listed as other participants in the Personnel section.

The UCSB Bren School Master’s project advised by UC Santa Barbara faculty C. Tague and graduate student C. Heckman provides training and professional development for four graduate students pursuing Master’s degrees in Environmental Science and Management. Students began working on the project in spring 2017.

A. O'Geen's participation in a workshop hosted by the California Forest Pest Council reached 47 attendees at multiple career levels, including scientists from several disciplines, private and public forest managers, and others interested in the protection of forests such as USDA Forest Service and Cal Fire.

Graduate and undergraduate courses incorporating research are taught by SSCZO investigators at six institutions: five University of California campuses and the University of Wyoming. We estimate that these courses collectively share concepts related critical-zone science and findings from SSCZO and other CZOs with at least 200 students each year through 15-20 courses.

Several undergraduates have been employed by SSCZO researchers. At UC Merced, the Hart research group has employed five undergraduates, plus one volunteer, in the past year to assist with critical-zone research, gaining skills in field and laboratory research methods. One undergraduate works with E. Stacy each summer as field assistant. One student has also been employed during the school year to assist with outreach efforts. A majority of these students identify with one or more demographic groups (e.g., gender, race, ethnicity, socioeconomic) traditionally underrepresented in STEM fields. Most of these students are planning to pursue graduate school or other jobs related to soil science and hydrology upon graduating.

The University of California, Merced, is where a large number of our core team is located, and also a school providing critical opportunities to students underrepresented in STEM fields. UC Merced is a minority-majority school and the most diverse university in the UC system. In the 2016 to 2017 undergraduate student body, 89% of students identify as non-white or international students; 51% of the 2016-2017 student body identify as Hispanic. And 71% of students enrolled are first-generation college students.

Nine undergraduate environmental studies and geology students from University of San Francisco and College of the Atlantic visited the SSCZO Providence Creek site as part of the EARTH-TRACKS program by co-PIs S. Hall, C. Schmidt, and R. Walker. Students gained knowledge and skills training in critical zone science, soil science, Sierra Nevada ecology, and instrument technology. Participants included international students and other demographic groups traditionally underrepresented in STEM fields.

Sixty K-8 teachers from Merced and Mariposa counties who participate in TEAM-E collectively teach over 1000 students. Activities and content used in classrooms will reach students from backgrounds traditionally underrepresented in STEM fields; Merced County 2015 census indicates 58% of population identifies has Hispanic or Latino. At present we do not have data available for how many teachers have utilized workshop material in their classrooms; we have inquired with teachers to collect this data.

Seven juniors and seniors from the Center for Advanced Research and Technology Environmental Science and Field Research Lab participated in this year's snow survey research project mentored by M. Gilmore and E. Stacy. Students gained experience in field navigation and measurement, spreadsheet analysis, data visualization, digital mapping, group collaboration, and science communication. Six out of seven students identify with traditionally underrepresented gender, race/ethnicity, or both; data were collected via pre-project surveys. We are awaiting receipt of this year's post-project evaluations. At least one student anecdotally stated plans to pursue a career in environmental science and management at the end of the project. M. Gilmore analyzed last year's post-project evaluations during the current reporting period; six out of seven students submitted post-project evaluations. Last year's students self-reported improvements in the following skills categories, with number of students listed in parentheses: giving presentations (4), speaking in public (2), working on a team (1), sharing ideas (1), making graphs and charts (1), taking measurements (1), recording observations (1), and analyzing data (1). The majority of surveyed students (4 or more) self-selected the following words to describe the project: collaborative, exciting, fun, hands-on, important, informative, and outdoorsy. All six surveyed students completed the sentence "I never knew…" with a statement about the importance of snowpack as a water resource.

This year we reached nearly 500 TK-8th grade students at southern Sierra foothill schools. About 40 TK-8 students visited a critical-zone-focused learning station at the Sierra Foothill Charter School Earth Day Festival. Over 300 K-8 students visited a learning station covering the microscopic wildlife of soil at Southern California Edison's Science Days. Approximately 125 fourth and fifth graders participated in a learning station on soils, decomposition, and the critical zone at the Society of American Foresters High Sierra Chapter Conservation Day. These presentation stations included both scientific content and methods such as soil pH testing, as well as an arts-based component to visualize microscopic organisms in soil. M. Gilmore will be presenting similar stations in September 2017 for 1000 students at a week-long Conservation Days event hosted by the Society of American Foresters High Sierra Chapter at Sequoia Lake.

In addition, as part of a network-level, cross-CZO effort to collate educational resources on the criticalzone.org website, we have submitted our existing educational activities to the CZO National Office. Six of these resources have been added to the CZO National Office Educational Resources page (http://criticalzone.org/national/education-outreach/resources/), which will be expanded and refined by SSCZO and National Office personnel during the next reporting period.

What is the impact on physical resources that form infrastructure?

The Glaser-Bales team continues to install the new generation of wireless-sensor stations across the Sierra Nevada, using technology developed at the SSCZO. Through an NSF MRI grant, plus state and local support, that technology is being applied at the river-basin scale (American River basin) in the Sierra Nevada. The wireless-sensor network can be viewed as a platform for real-time, spatially distributed environmental monitoring. It is flexible, in that we can add different types of sensors to it, and nodes can be moved around if researchers ever want to use it for more than the current applications of snowcover, energy-balance and soil monitoring. With support from multiple state sources, the wireless-sensor stations are being extended to the Feather River basin.

What is the impact on institutional resources that form infrastructure?

The SSCZO infrastructure and data are a resource for both UC and the community. We receive frequent requests for access to both the data and site. We are making the data availability sustained over the long term through both CZO network collaboration, and archiving in the California Digital Library.

What is the impact on information resources that form infrastructure?

Data and information. Data-management policies and procedures for the SSCZO are laid out in the management plan. The SSCZO continues to maintain a current and thorough digital library. This is the main repository for data, metadata, protocols, photos and presentations. Raw data are freely available after upload at multiple points per year, and processed data are made available according to CZO data policies. The SSCZO team also participates in the CZO data-management project.

SSCZO Digital Library data catalog

https://czo.ucmerced.edu/dataCatalog_sierra.html and direct link to files:

https://eng.ucmerced.edu/snsjho/files/MHWG/Field/Southern_Sierra_CZO_KREW

The Sensor Object Library (SOL), base station software, and data preservation/visualization tools (e.g. InfluxDB and Grafana) being tested for the wireless sensor network will improve data standardization and preservation. Development on these tools is open source, meaning any researchers can benefit from and contribute to their development. See http://github.com/realms-team/sol.

Web and social media. Online efforts complement our written and oral presentations. The main SSCZO online presence is through the CZO website and the SNSJHO digital library. Facebook and Twitter accounts provide an informal counterpart where we share field activities, real time information on conference presentations, and pertinent updates on research and current events. Descriptions for each site follow.

Southern Sierra Critical Zone Observatory (www.criticalzone.org/sierra). This website is the home of the Southern Sierra CZO. During the reporting period, SSCZO staff revised the expanded the research field areas, added data, posted multiple opportunities, and regularly updated field and research activities.

SSCZO Facebook (www.facebook.com/SouthernSierraCZO). The Southern Sierra CZO is the only active CZO Facebook page that we are aware of. This page is slowly growing, and reaches a local crossdiscipline audience (broader than environmental science, hydrology, or the CZO network). The audience is more location based, centered around Merced.

SSCZO Twitter (https://twitter.com/ssczo). The Southern Sierra CZO was the first CZO in the network with an active Twitter account. Now that the network has expanded and other CZOs are active on Twitter, it is a space for the SSCZO to connect with others observatories and researchers interested in critical zone science. Southern Sierra CZO posts events, photos, news, job announcements, and links to other pertinent stories and blog posts on the Twitter page. This avenue has been useful in reaching researchers, media and other professionals, particularly in publicizing research presentations during professional conferences.

R. Bales Twitter (https://twitter.com/rbalesuc). PI R. Bales uses Twitter regularly to disseminate and comment on issues related to the SSCZO and the CZO network. Several other researchers also use twitter as a platform for discussion and dissemination of topics related to critical zone research.

What is the impact on technology transfer?

Two products from our research were more-broadly adopted over the last year. First was expansion of our wireless-sensor systems to the Feather River headwaters and the American-Cosumnes groundwater basin. Second is our scaling approach for estimating forest evapotranspiration to guide forest management. We have extended this latter scaling approach using Landsat data, which at 30-m pixel size is better suited to the scale of forest management than is our previous work with MODIS data.

The Southern Sierra CZO has a high profile with resource-management stakeholders in California and the broader region. Our research addresses fundamental knowledge gaps around management of water supplies, forests, hydropower and integrated ecosystem services. The enhanced predictive capabilities that we are developing provide much-needed tools to understand the effects of management actions, disturbance and climate warming on ecosystem services. Adapting to climate change basically involves managing ecosystem services, with water-related ecosystem services being an early if not primary focus. Having a CZO with major capability to inform and influence adaptation around water supply in California is very timely given the state's global leadership role in implementing climate solutions.

California is grappling with many challenges at the intersection of water, forests and climate. Water security is the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water related risks. Water security in semiarid regions is founded on adequate water storage. Four consecutive dry years have emphasized the significance of the problem in California. In some cases, management actions can in part offset the effects of climate warming, and can lower the risk of severe disturbance, e.g. wildfire. Both the knowledge and technology developed by the SSCZO are informing decision making around water storage and ecosystem services.

In addition to broad outreach to resource managers and stakeholders, the SSCZO attends to other audiences. The general public is the audience for many of our communications, including press reports and newspaper opinion pieces. We have given public talks in local communities, as well as presentations to civic organizations. The Southern Sierra CZO has been employing internet tools as part of its outreach program. SSCZO presences on Twitter and Facebook have gained more followers. These social-media platforms are available to the public, and also provide a way to disseminate information about

events and activities to CZO and non-CZO researchers and students. E. Stacy has organized a monthly Science Café for the City of Merced, drawing on SSCZO as well as other science issues of public interest. SSCZO PI R. Bales, Co-PI M. Conklin, collaborator M. Safeeq and others have presented to local groups in the region and across the state.

We are making make the wirelesssensor network methods under development open-source so anyone can use them, including the sensorplacement algorithm, the SOL architecture for wirelesssensor networks, and the tool to predict RSSI. See http://github.com/realmsteam/sol.

What is the impact on society beyond science and technology?

The development a viable method to quantify groundwater storage over a large-scale area (several acres) could influence water policies towards more sustainable practices. Building on the success of the SSCZO in bringing a multi-campus collaboration, three SSCZO investigators and faculty from five other UC campuses are working to address knowledge gaps that are critical to California and the Western United States through the UC Water Security and Sustainability Research Initiative (http://ucwater.org) that links headwater research under the SSCZO with complementary research on water cycling in other montane forested watersheds, valley groundwater systems, and water policy. UC Water is supported by the UC Office of the President, and aims to focus UC resources on key problems and working alongside California's water leaders to achieve a watersecure future and build the knowledge base for better waterresources management. Through integration of measurement and modeling technologies, and drawing on UC expertise across disciplines, UC Water aims to make rapid progress towards filling the gaps.

Our finding that vegetation resilience to climate change and drought may be governed in part by bedrock lithology provides new insights that may help improve prediction of ecosystem change in coming decades and thus inform better decision making in forest management.

Work from the fire chronosequence is likely to increase the public's understanding of the importance of fire in maintaining healthy forest ecosystems, and when fire is excluded for long periods of time, resulting disturbance can increase in severity.

Understanding how microbial communities throughout the soil profile respond to global change will increase the predictive power of earth system models, ultimately contributing to better policy decisions.

It is anticipated that nitrogen limitation will be alleviated in temperate ecosystems, leading to phosphorus availability being the primary limiting nutrient to ecosystem development. This work will help us understand how phosphorus biogeochemistry is impacted by temperature and precipitation to lead to a better understanding of how temperature ecosystems may respond to climate change (and contribute to the carbon budget as a net carbon source or sink). This work also has important implications within agriculture, as P stock (used for fertilizer) in the US will be depleted by 2025. A lack in understanding of phosphorus biogeochemistry often results in excess fertilizer applied to agricultural sites, leading to leaching that may lead to eutrophication of waterways (impairing water use for industry, recreation, drinking and fisheries).

Changes/Problems

Changes in approach and reason for change

The California drought has led the SSCZO to focus more directly on understanding related to the resiliency of California's critical Sierra Nevada headwaters. Essentially all aspects of the CZO research agenda, as outlined in the five areas presented in the Accomplishments section, are contributing to the focus. This is the continuation of a change that has been in progress for 2 years.

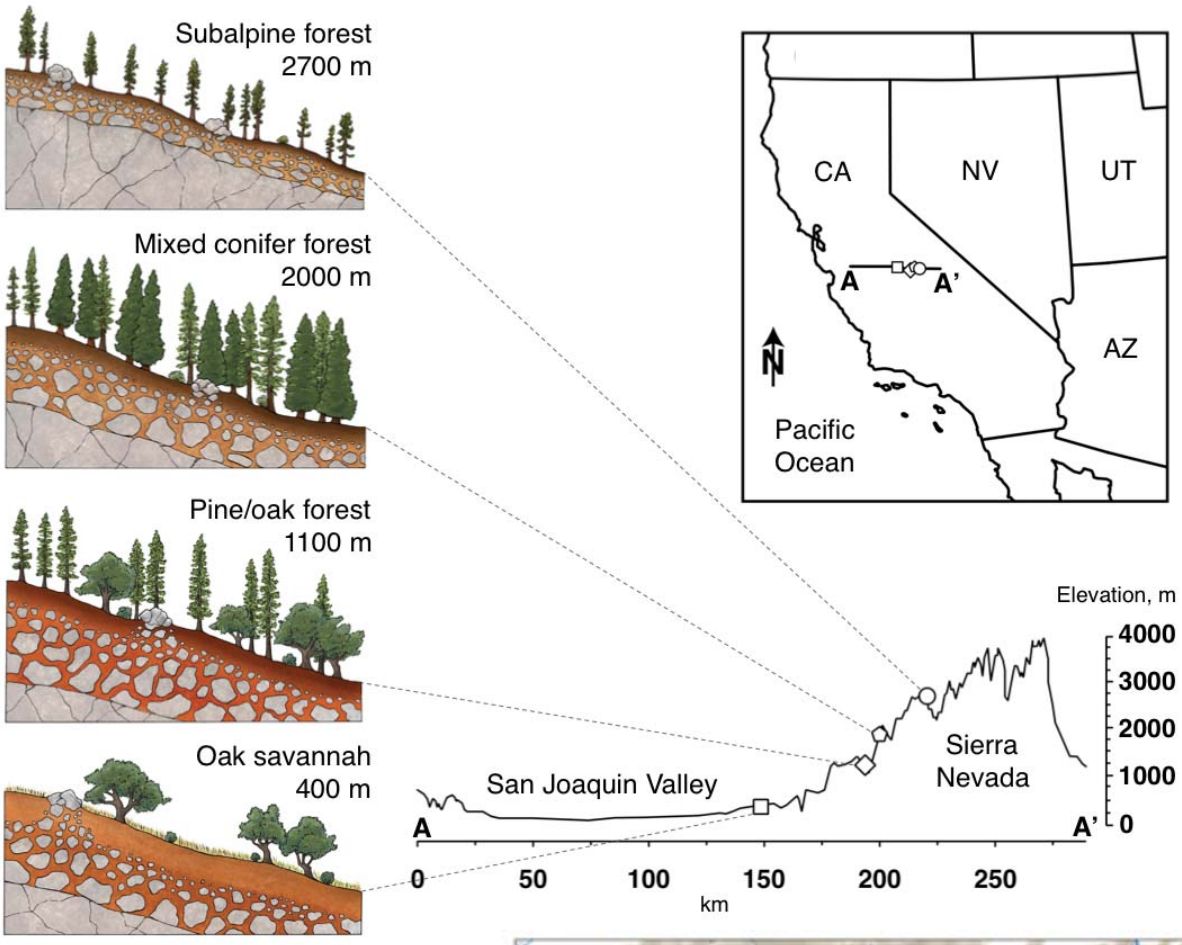
Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.



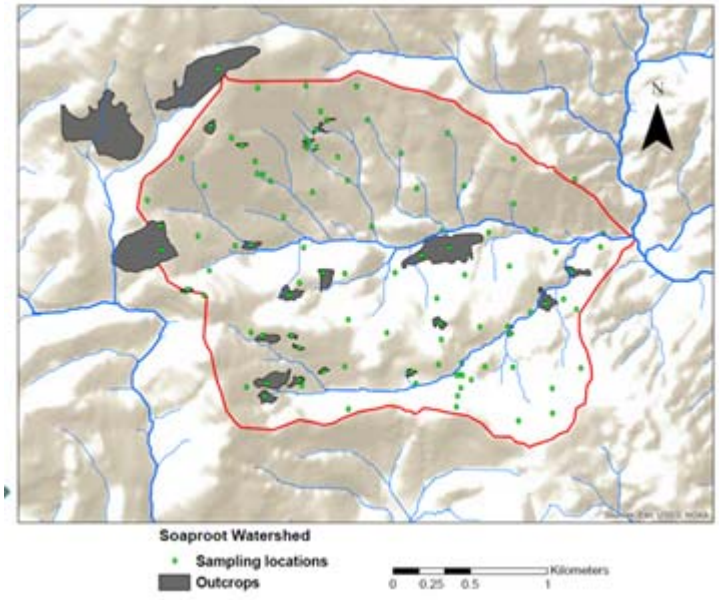


Figure 1. Overall SSCZO experimental design and location. Upper right panel shows location of elevation/climate gradient. Middle right panel shows location of four core sites along the elevation/climate gradient. Upper left panel shows characteristic critical zone structure for the four elevations. Lower right panel shows watershed at the 1100 m pine/oak forested Soaproot site, along with the location of individual augerered sampling profiles for belowground properties.

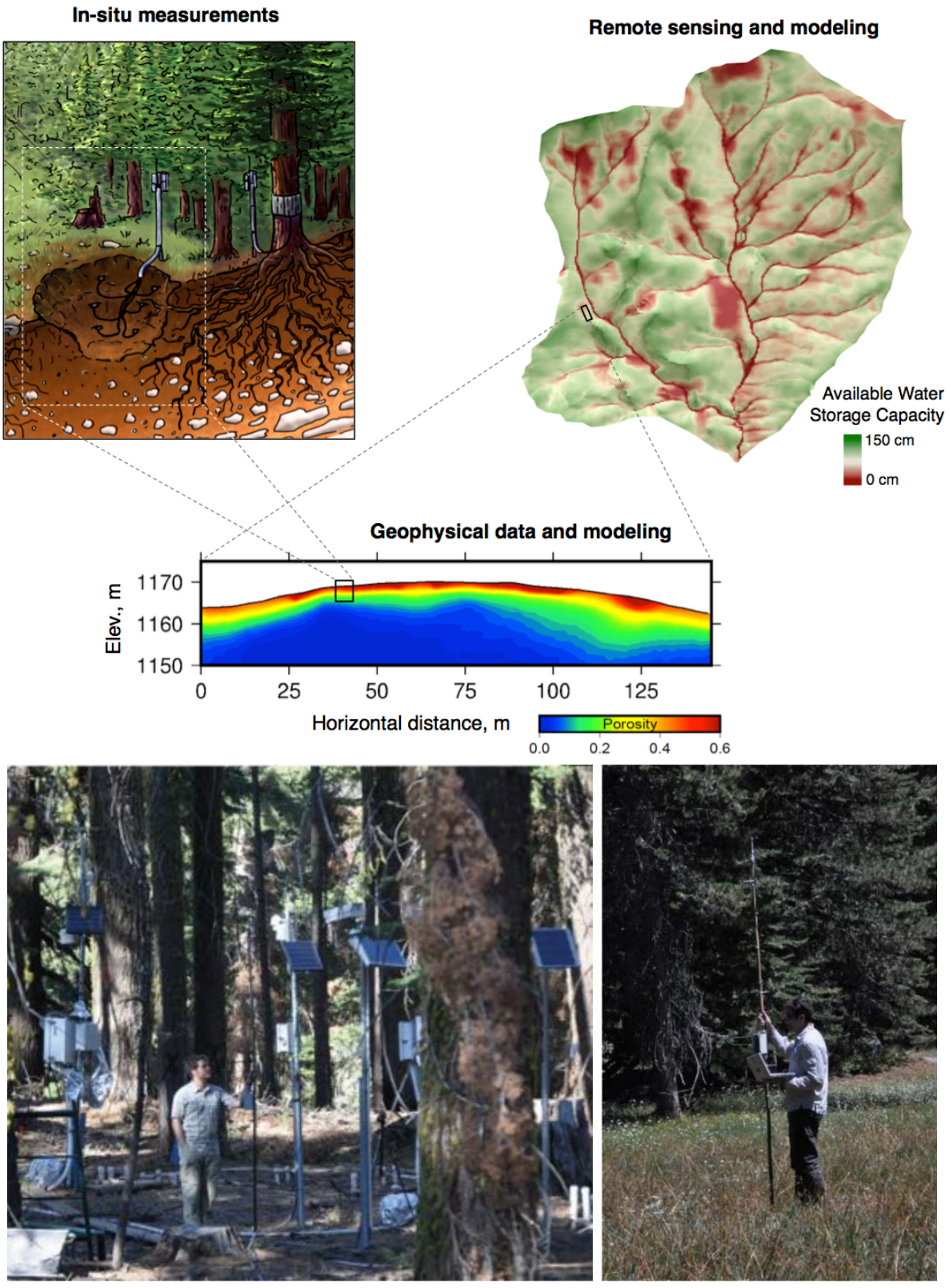


Figure 2. SSCZO multi-scale and multi-tool approach to investigating the critical zone. Upper left panel shows cartoon of typical in-situ installation and lower panel shows photos. Middle panel shows typical 150-m vertical slice of below ground porosity measured using seismic refraction and upper right shows gridded total water holding capacity to bedrock for the Soaproot watershed.

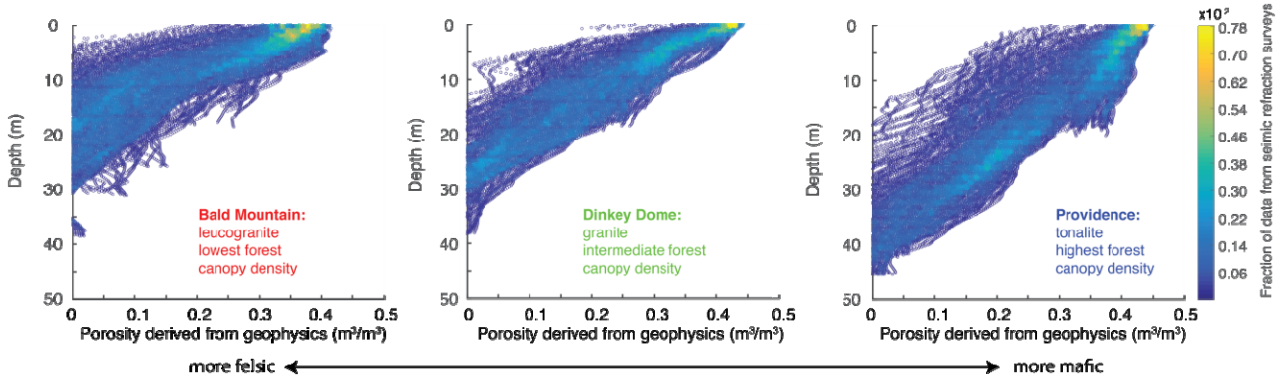


Figure 3. Differences in subsurface porosity across three sites with differing lithology. Across our three mid-elevation study areas, we observe differences in porosity and depth, reflecting differences in mineral weathering and fracturing at depth. The Providence site (right), which has the most mafic bedrock, has the deepest weathering, extending to depths of up to 45 m along some geophysical survey lines. The Bald Mountain (left) and Dinkey Dome (center) sites show broadly similar patterns in porosity with depth, but total integrated porosity (not shown) is slightly higher at the Dinkey Dome site. Interpretation: The deeper weathering at Providence may reflect higher mafic mineral abundance, consistent with our hypothesis, that vegetation contrasts are governed by differences in weathering and thus water-holding capacity.

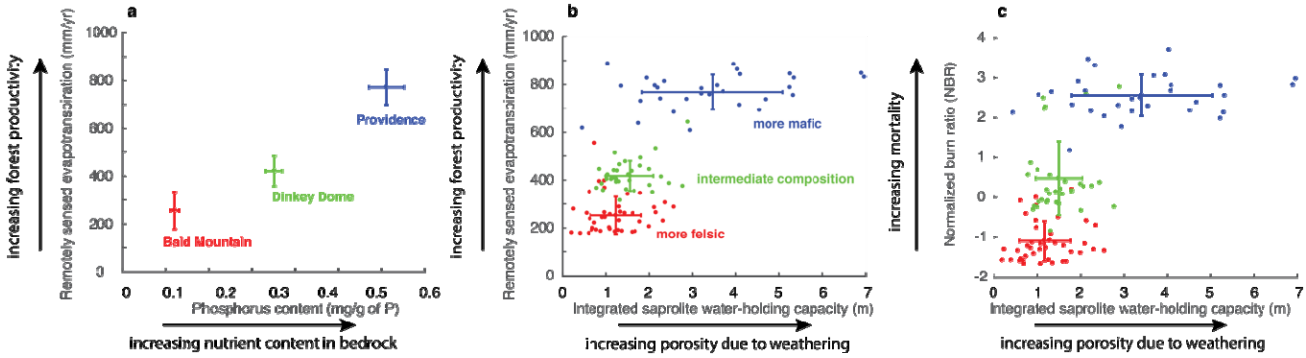


Figure 4 Coupling between lithology, water-holding capacity, and tree death. Evapotranspiration increases with increasing phosphorus content in bedrock (a), implying strong nutrient-moderated lithologic control on ecosystem productivity and also increases with near-surface water-holding capacity (b), suggesting that lithology may also control vegetation via a weathering-related mechanism. Paradoxically, drought mortality increases with increasing near-surface water-holding capacity, possibly reflecting higher vulnerability to drought at sites with higher productivity (c). Interpretation: Forest productivity appears to be strongly controlled by lithology at mid-elevation sites in the southern Sierra Nevada. Our coupled geophysical, geochemical, and remote sensing data suggests that both nutrient content and mineral weathering play significant roles in the lithologic control on forest productivity. Higher drought mortality in areas with higher productivity suggest that more densely canopied forests are more vulnerable to decreased precipitation, despite higher subsurface water-holding capacity. This suggests that lower forest cover is better optimized for resilience during intense droughts.

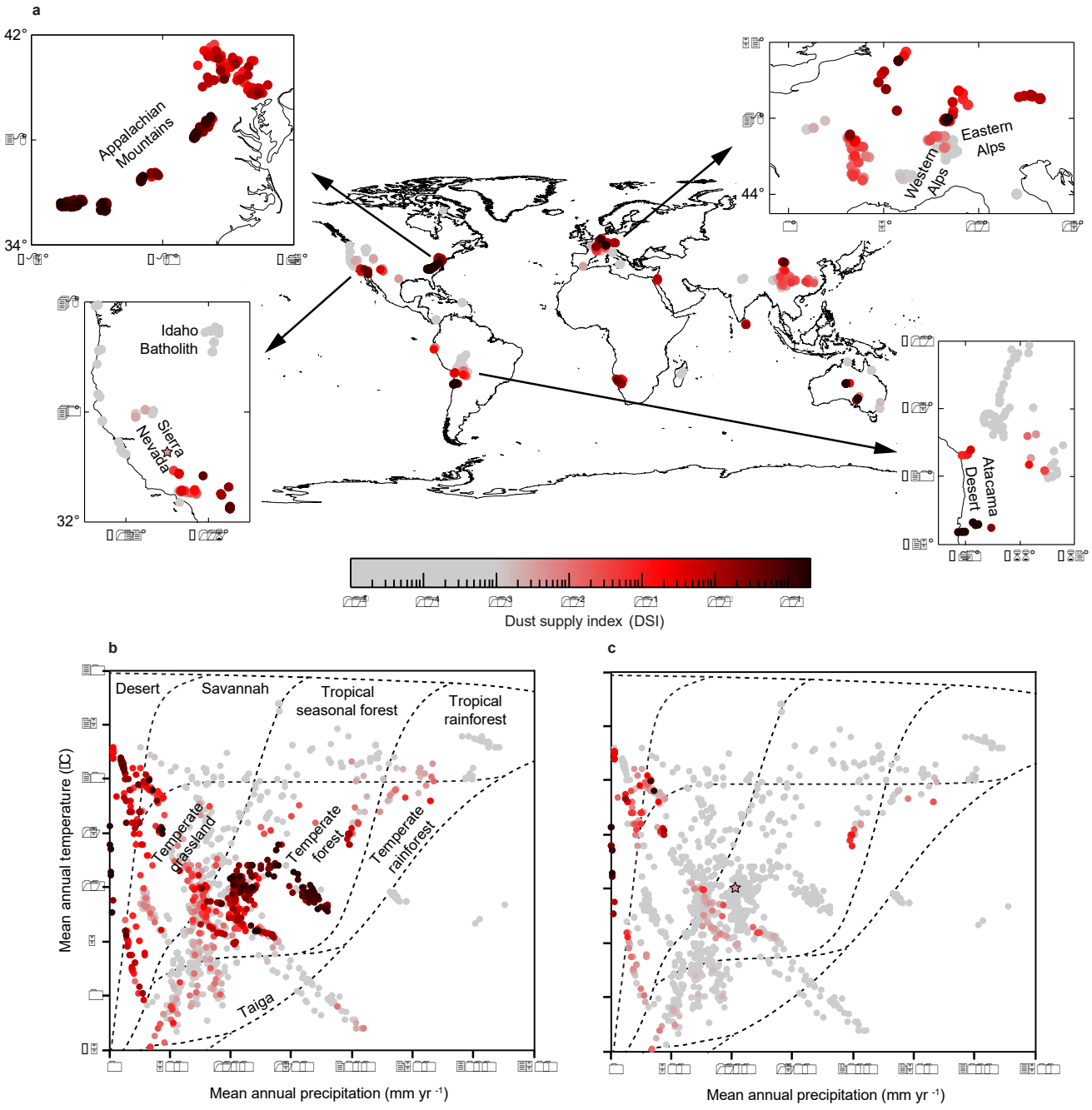


Figure 5 The dust supply index (DSI) in mountain catchments around the world. a, DSI calculated from compilation of ^{10}Be-based erosion rates and a global model of LGM dust fluxes. b, DSI from a in relation to modern mean annual precipitation (MAP) and mean annual temperature (MAT) for each sampling location, with modern biomes delineated by dashed lines. c, Same as b except DSI is inferred using modern instead of LGM dust fluxes. Star indicates DSI of 0.15 calculated from direct observations of dust fluxes and ^{10}Be-based erosion rates in the southern Sierra Nevada, California. The uncertainty in individual DSI estimates displayed here is approximately an order of magnitude.

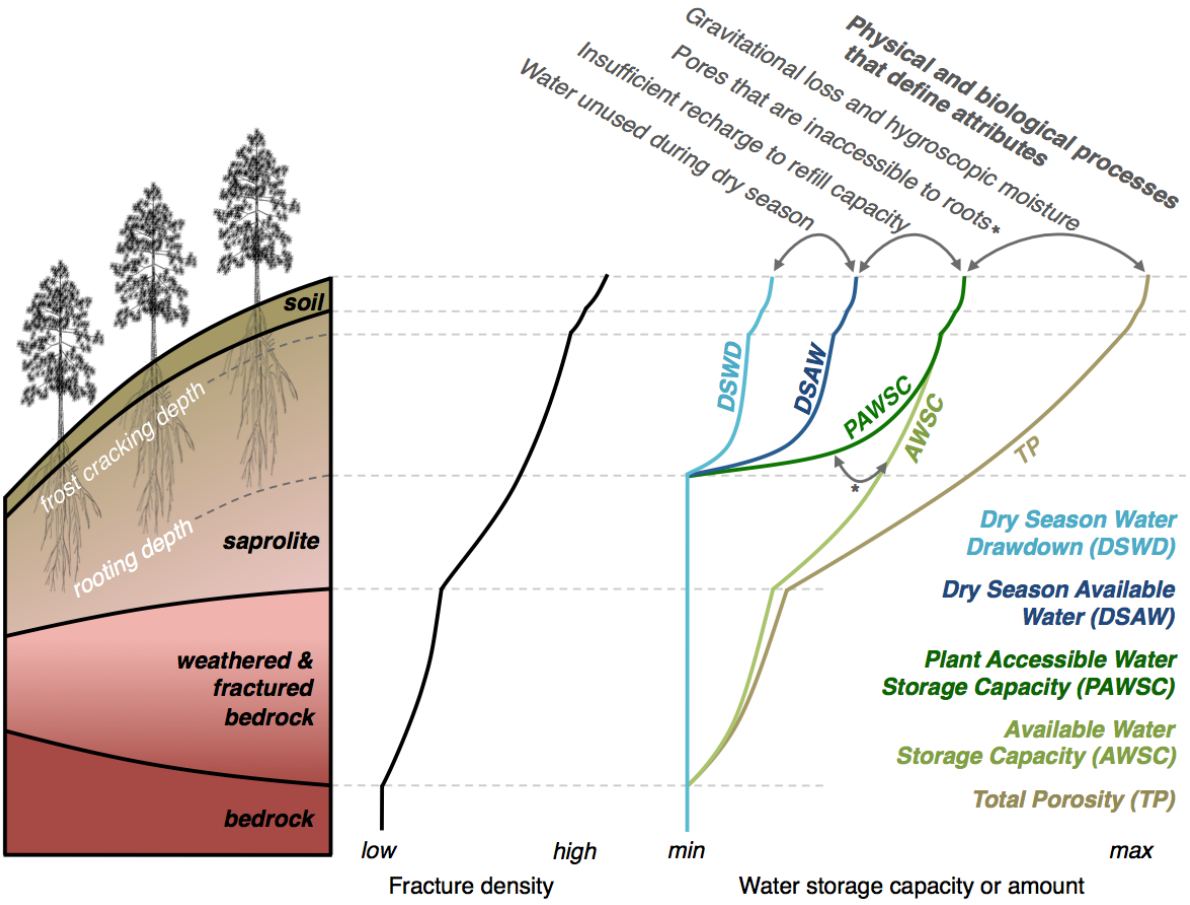


Figure 6. Five definitions of belowground water storage capacity, and hypothesized depth distribution. One of the SSCZO's main foci during the last year was to synthesize and better organize our thoughts on belowground regolith characteristics and how they relate to hydrology and ecology. One key issue we considered was the differing definitions of belowground water storage used by the range of fields represented in the SSCZO. We developed a nested set of belowground water storage terms that range from Total Porosity, (TP) which is typically measured using geophysical techniques, to a couple of water storage definitions that are emphasized by hydrologists and soil scientists (AWSC and PAWSC) to a couple of water availability and use terms that are most relevant to issues related to vegetation productivity and stress and that are measureable using remote sensing (DSAW and DSWD). This hierarchy and framework was described in Klos et al in review.

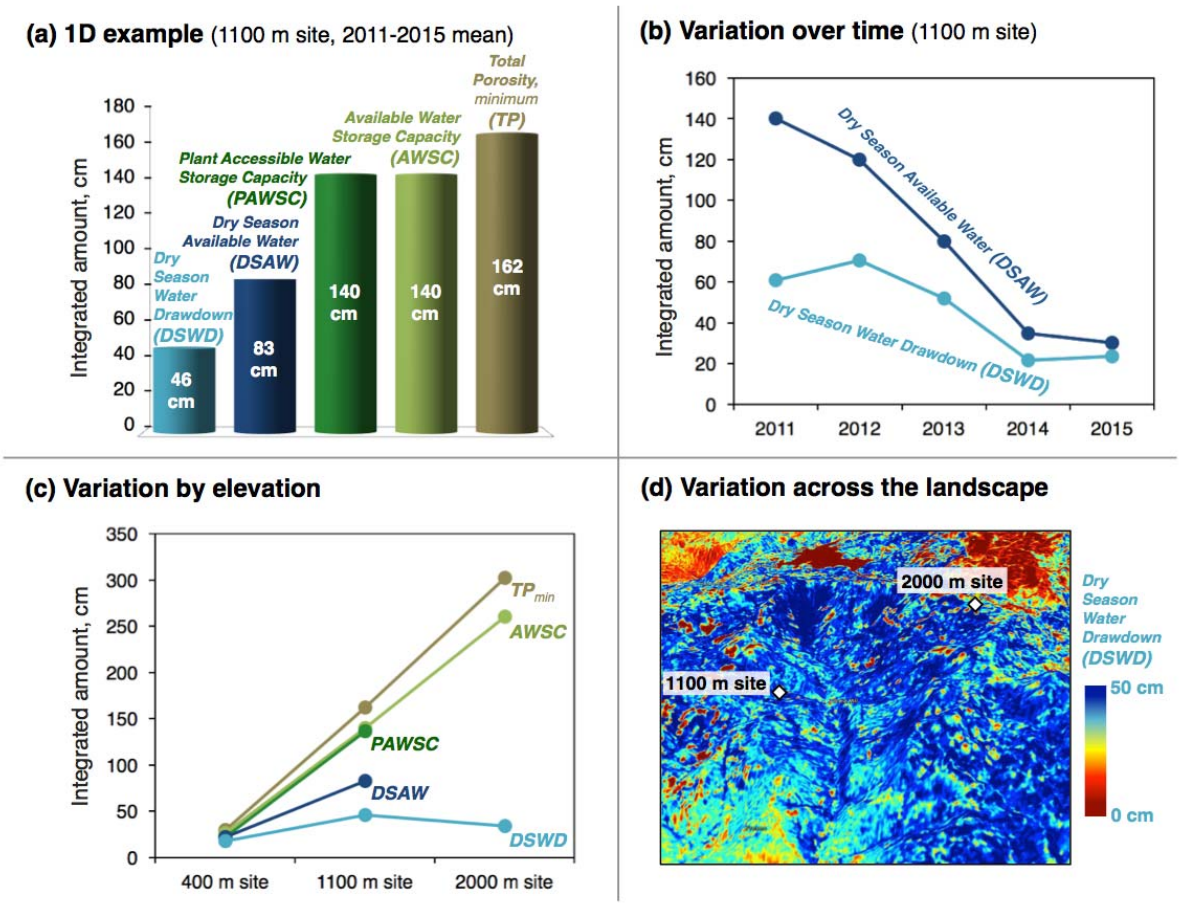


Figure 7. Five metrics of regolith water storage capacity at the Southern Sierra CZO. Upper left shows the amount of belowground water stored or used at the Soaproot site according to the five definitions in Fig 6. Upper right shows how the two definitions that vary with time changed over the 2012-15 drought. Lower left shows how the five definitions vary along the SSCZO's elevation/climate gradient. Lower right shows an oblique view of one of these definitions (Dry Season Drawdown) across the SSCZO's central elevation at 30 m resolution. All figures from Klos et al in review.

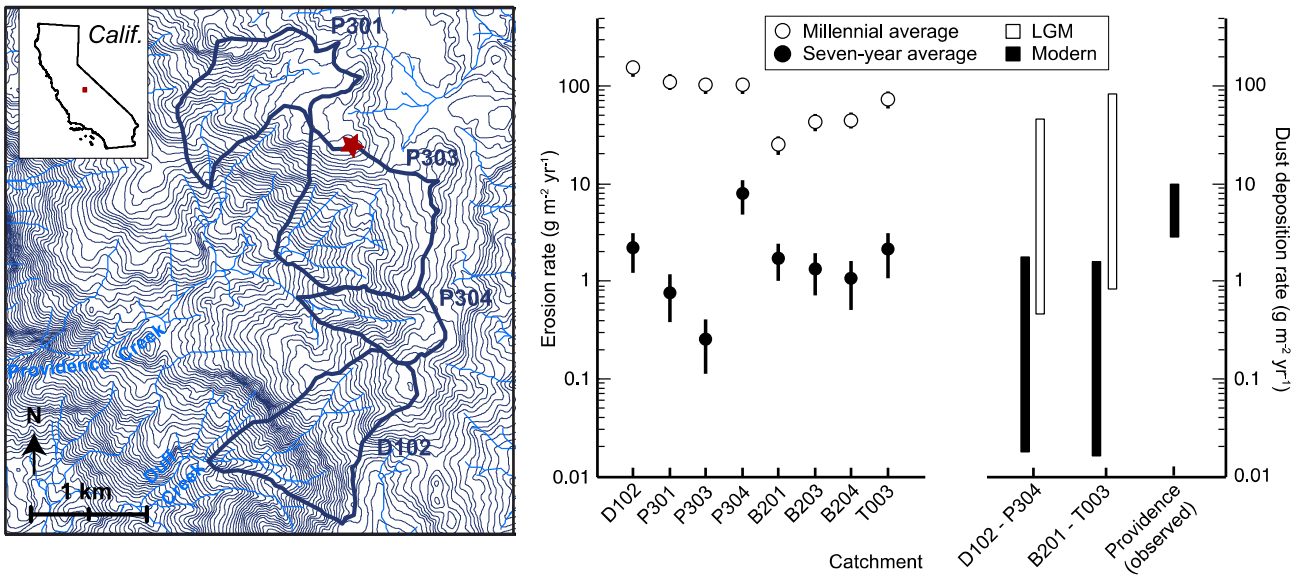


Figure 8 | Erosion rates and dust fluxes in the southern Sierra Nevada, California. a, Four southern Sierra Nevada catchments where erosion rates have been measured by both ^{10}Be and sediment yields. Star indicates location of Providence dust collection site of Aciego and others . b, ^{10}Be-based erosion rates (see Methods), sediment yield-based erosion rates, and modelled LGM and modern dust fluxes for eight southern Sierra Nevada catchments. Error bars reflect propagated analytical uncertainty in ^{10}Be-based erosion rates and standard error of the mean (s.e.m.) of seven measurements for sediment yield-based erosion rates. The range for dust fluxes represents order-of-magnitude uncertainty in modelled dust fluxes and observed range in measured dust fluxes at dust collection site.

Additional Reporting Requirements

Metrics. Performance metrics for the SSCZO fall under three categories: output metrics, outcome metrics, and impact metrics. Output metrics include the publication of data and results online in our digital library and through peer-reviewed publications. The amount of data and number of publications are tracked.

During the past year the core SSCZO team had 40 journal papers citing the SSCZO published and in review in leading peer-reviewed journals. This does not include papers by SSCZO cooperators. SSCZO research was also highlighted by team members in presentations at many conferences over the past year, and many more seminars and public talks. We are implementing tracking for publications by collaborating and cooperating investigators, but those data are not yet available. In the past year, we know of at least two peer-reviewed articles published using data and findings obtained from SSCZO, with direct mention of the Observatory within text, that do not list any SSCZO core team members as authors (Guo and Lin, 2016; Kim et al., 2017).

Data are housed in an online digital library that is hosted on UC Merced servers and are also accessible through the new website portals. Core measurements, including water-balance instrument clusters, soil-moisture and flux-tower data, are posted in raw format promptly after retrieval from the field. Processed data, including full QA/QC procedures, are posted at least annually for core measurements. SSCZO staff (the data manager and the field manager) help coordinate the compilation of data and appropriate metadata in the digital library. In accordance with the cross-CZO data-management policy, data from all projects will be posted within two years, with the possibility of restricting access for a third year if needed by the investigator for the purposes of publishing. During the last year we met these goals. Most core data underwent quality assurance and quality control and were posted within a few months after the end of the water year. We published the first five years of CZO data in a perpetual archive, and have a DOI assigned.

As part of our effort to measure *outcomes*, we tracked citations of our peer-reviewed papers, use of our data, and online reach. We also track the number of scientists interested in coordinating with the SSCZO. As listed in Other Participants in the Personnel section of the report, there are currently 70 collaborators and cooperators working on active projects at our sites or pursuing new projects with the SSCZO team.

The depth and breadth of our reach online is tracked through several metrics, including use of our data from Google Analytics for our main website, tracking activity on Twitter and Facebook, and the use of data from the digital library. As an online resource, the Sierra Nevada-San Joaquin Hydrologic Observatory (SNSJHO) digital library is accessed not only by SSCZO team members but also by the broader population of researchers online. We now have a several dozen registered users for SSCZO data on the digital library. Note that many of our data are public, and it is not necessary to register to access those data. We have been using Google Analytics with Google Tag Manager to track website activity and data downloads for main CZO data (some satellite sites not set up) on our digital library since June of 2016. Now we have had 17,267 page views by 710 unique visitors just over a year. Of these, 45% are new visitors to the digital library, and 39% of site visits have been from outside the United States. Over the year, 3682 data downloads (download events) have been made by users. About 8% of downloads was made by the users outside the United States.

Since we started tracking website activity with Google Analytics in September 2013, we have had more than 83,000 page views by 14,400 unique visitors. Over half of site use is by new visitors to our website, and 21% of site visits have been outside the United States. The Southern Sierra CZO is maintaining a Facebook page with 88 current page followers. Through Twitter, the SSCZO connects with other

observatories, researchers, organizations, and members of the public interested in critical-zone science. Since the SSCZO Twitter account was created in 2013, we have gained 437 followers and have posted more than 1,100 tweets. In the past year, we have gained 147 new followers. Since starting in Dec 2014, SSCZO PI R. Bales has sent over 1,300 tweets and has 1,033 followers. Several other SSCZO colleagues use twitter and post tweets relevant to SSCZO, including new SSCZO presentations and publications.

We also track the adoption of our technology at other sites. The wireless sensor network developed at the SSCZO has been implemented in the American River Basin project west of Lake Tahoe. Work completed in 2014 included instrumentation at 14 sites in the American River Basin project. In summer 2016 we initiated installation of 3 instrument clusters in the Feather R. basin, in collaboration with Pacific Gas & Electric. We are also working with the California Department of Water Resources to develop broader plans for soil-water, snowpack and energy-balance sensor networks. Further proposals to expand these systems are pending with state and local agencies.

Outcomes and Impacts include better decision making because of our research findings, and improvements to the research process. To achieve broader impacts, we have developed an extensive dissemination network. Our dissemination strategy reaches stakeholders and resource managers as well as researchers. To that end, we have published opinion pieces in local newspapers, produced video and radio segments through collaborations with regional television and radio stations, presented at numerous stakeholder meetings, and hosted visits to our field sites and laboratories. We have communicated with everyone from foresters and other resource managers, to legislative staff and policy makers at the state and Federal level. In aggregate, SSCZO investigators average approximately bi-weekly presentations to public audiences.

We have employed evaluation forms to assess multiple events. Among these are the 2016 Annual Meeting, and visiting researchers. Feedback from the 2016 Annual Meeting has directly informed agenda structure and logistics for the 2017 meeting. We also have used program evaluation forms in our ongoing high school field research partnership with the Center for Advanced Research and Technology. Survey feedback from the Spring 2017 project will be analyzed this summer, with two-fold potential to improve future programming and to evaluate impacts of the research project on participants. Spring 2016 students' post-project evaluations were analyzed during the current reporting period; six out of seven participants submitted evaluations. Students self-reported improvements in the following skills categories, with number of students listed in parentheses: giving presentations (4), speaking in public (2), working on a team (1), sharing ideas (1), making graphs and charts (1), taking measurements (1), recording observations (1), and analyzing data (1). The majority of surveyed students (4 or more) self-selected the following words to describe the project: collaborative, exciting, fun, hands-on, important, informative, and outdoorsy. All six surveyed students completed the sentence "I never knew…" with a statement about the importance of snowpack as a water resource. This first year of evaluation demonstrates positive impacts on potential future STEM professionals through our mentoring partnership.

CZO network activities. Cross-CZO work was used to compile and process/clean flux tower data from all CZOs and nearby sites, primarily focusing on a record of daily evapotranspiration for as many years as data were available. These data are part of our broader research on the role of root-accessible water storage in drought resistance. SSCZO team members are also participating in other cross-CZO working groups and workshops.

Researchers at a variety of career levels, from graduate student to senior faculty, gave 13 presentations activities and findings from SSCZO, as well as cross-CZO work, at the 2017 NSF Arlington Meeting on Critical Zone Science. Several presenters who are not part of our core team presented findings from work at our sites, including non-funded collaborators like A. Visser, E. Aronson, and C. Collins; as well as

scholars primarily working at other CZOs in the CZO network such as A. Aguirre, J. Richardson, and A. Goodwell.

CZO program budgets. See attached budget summary.

Additional funding. CZO investigators routinely leverage funding to support students and postdocs, install equipment, engage collaborators and initiate complementary research. All of the students listed above were supported at least in part by non-CZO funds, and most were largely supported by non-CZO funds. Leveraging with the USDA Forest Service is also important, and the SSCZO is in part co-located with Forest Service research programs. UC Merced provided institutional support for four graduate students last year. The U.S. Forest Service provides a budget of several hundred thousand dollars per year for the streamflow, met station and stream geochemical measurements and data, as well as some vegetation surveys used by the CZO team and collaborators. The U.S. Forest Service and UC Merced also jointly supported a research scientist whose main focus was on the SSCZO, and the co-located Kings River Experimental Watersheds program.

Southern Sierra CZO Carryover Report, based on encumbrances. Does not include projected expenses in budget report that are not yet encumbered.

	Cost Element	YR1 Sponsor Approved Budget	YR1 Supplemental Funds: REU & All-Hands	YR1 Expenses as of 9/30/2014	YR1 Carryforward	YR2 Sponsor Approved Budget	YR2 Budgeted + YR1 Carryforward	Y2 Expenses as of 9/30/2015	YR2 Carryforward	YR3 Sponsor Approved Budget	YR3 Budgeted + YR2 Carryforward	Y3 Expenses as of 9/30/2016	YR3 Carryforward	YR4 Sponsor Approved Budget	Year 4 Supplemental Funds: CZO Film	YR4 Budgeted + YR3 Carryforward	YR4 Expenses as of 5/31/2017	Year 4 Projections + Commitments through 9/30/2017	YR4 Projected Carryforward
Senior Personnel																			
A.1	Principal Investigator Bales	25,472	-	15,592	9,880	26,235	36,115	28,175	7,940	27,022	34,962	35,892	(929)	27,833	-	26,904	-	28,194	(1,291)
A.2	Co-Investigator Conklin	11,922	-	12,522	(600)	12,280	11,680	6,261	5,419	12,648	18,067	9,575	8,492	13,028	-	21,520	-	13,400	8,120
A.3	Co-Investigator Hart	6,489	-	6,617	(128)	6,683	6,555	6,817	(261)	6,884	6,623	6,950	(327)	7,090	-	6,763	-	5,706	1,057
A.4	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-		-
A.5	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-		-
A.6	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-		-
A.7	Total Personnel	**43,883**	-	**34,731**	**9,152**	**45,198**	**54,350**	**41,253**	**13,097**	**46,554**	**59,651**	**52,417**	**7,235**	**47,951**	-	**55,186**	-	**47,301**	**7,885**
Other Personnel																			
B.1	Post-Docs	-	-	-	-	-	-	-	-	-	-	-	-		-	-	18,869	16,772	(35,641)
B.2	Other Professionals	154,831	-	99,745	55,086	175,024	230,110	118,726	111,384	171,581	282,965	154,153	128,812	185,683	-	314,495	106,956	52,349	155,190
B.3	Graduate Students	-	-	-	-	-	-	29,687	(29,687)	26,225	(3,462)	17,228	(20,690)	26,225	-	5,535	15,329	13,110	(22,903)
B.4	Undergraduate Students	7,725	-	7,121	604	7,957	8,561	8,443	118	8,195	8,313	15,474	(7,161)	8,441	-	1,280	5,926	-	(4,646)
B.5	Clerical	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
B.6	Other	-	4,415	3,172	1,243	-	1,243	749	494	-	494	4,396	(3,902)		-	(3,902)	592	-	(4,494)
Total	**Salaries and Wages**	**206,439**	**4,415**	**144,769**	**66,085**	**228,179**	**294,264**	**198,858**	**95,407**	**252,555**	**347,962**	**243,667**	**104,294**	**268,300**	-	**372,594**	**147,671**	**129,531**	**95,392**
C.	Fringe Benefits	59,126	1,545	46,428	14,243	66,342	80,585	65,232	15,353	65,656	81,009	73,084	7,925	70,749	-	78,674	46,671	34,894	(2,891)
Total	**Salaries, Wages, and Fringe**	**265,565**	**5,960**	**191,197**	**80,328**	**294,521**	**374,849**	**264,090**	**110,760**	**318,211**	**428,971**	**316,751**	**112,219**	**339,049**	-	**451,268**	**194,342**	**164,425**	**92,501**
D.	Equipment Replacement	27,311	-	17,429	9,882	8,000	17,882	31,197	(13,314)	19,689	6,375	710	5,664	6,000	-	11,664	1,489		10,176
	Tower Rebuild	30,000	-	-	30,000	-	30,000	-	30,000	-	30,000	-	30,000		-	30,000			30,000
Total	**Equipment**	**57,311**	-	**17,429**	**39,882**	**8,000**	**47,882**	**31,197**	**16,686**	**19,689**	**36,375**	**710**	**35,664**	**6,000**	-	**41,664**	**1,489**	-	**40,176**
E.1	Domestic Travel	18,048	-	3,992	14,056	23,748	37,804	16,708	21,096	17,848	38,944	21,611	17,333	25,548	-	42,881	15,136	1,200	26,545
E.2	Foreign Travel	-	-	-	-	-	-	-	-	-	-	3,979	(3,979)		-	(3,979)			(3,979)
Total	**Travel**	**18,048**	-	**3,992**	**14,056**	**23,748**	**37,804**	**16,708**	**21,096**	**17,848**	**38,944**	**25,590**	**13,354**	**25,548**	-	**38,902**	**15,136**	**1,200**	**22,566**
F.1	PS Stipends	-	10,000	10,000	-	-	-	-	-	-	-	-	-		-	-			-
F.2	PS Travel	-	94,290	1,116	93,174	-	93,174	55,934	37,240	-	37,240	1,010	36,230		-	36,230	4,776		31,454
F.3	PS Subsistence	-	54,825	-	54,825	-	54,825	64,913	(10,088)	-	(10,088)	-	(10,088)		-	(10,088)			(10,088)
F.4	PS Other	8,000	50,949	8,990	49,959	2,000	51,959	50,425	1,533	8,500	10,033	611	9,423	2,000	-	11,423			11,423
Total	**Participant Support**	**8,000**	**210,064**	**20,106**	**197,958**	**2,000**	**199,958**	**171,272**	**28,685**	**8,500**	**37,185**	**1,621**	**35,565**	**2,000**	-	**37,565**	**4,776**	-	**32,789**
G.1	Materials and Supplies	21,362	1,027	6,653	15,736	21,020	36,756	13,830	22,926	23,404	46,330	28,302	18,028	16,823	-	34,851	19,271	1,614	13,966
G.2	Publication Costs	1,200	-	-	1,200	1,200	2,400	1,009	1,391	1,200	2,591	-	2,591	1,200	-	3,791	1,733	-	2,058
G.3	Consultant Svcs	-	-	-	-	-	-	-	-	-	-	-	-		-	-		-	-
G.4	Computer Services	-	-	-	-	-	-	-	-	-	-	-	-		-	-		-	-
G.5	Subawards	312,719	-	246,114	66,605	461,142	527,747	297,032	230,714	336,420	567,134	498,399	68,735	376,154	-	444,889	217,187	29,678	198,024
G.6	Other (Drilling Subcontract, GSR Fees)	60,000	3,040	103	62,937	-	62,937	8,220	54,718	21,685	76,403	27,065	49,338	21,685	100,000	171,023	100,793	10,000	60,230
Total	**Direct Costs**	**395,281**	**4,067**	**252,869**	**146,479**	**483,362**	**629,841**	**320,091**	**309,750**	**382,709**	**692,459**	**553,767**	**138,692**	**415,862**	**100,000**	**554,554**	**338,984**	**41,292**	**174,278**
H.	**Total Direct Costs**	**744,205**	**220,091**	**485,592**	**478,704**	**811,631**	**1,290,335**	**803,358**	**486,977**	**746,957**	**1,233,934**	**898,439**	**335,494**	**788,459**	**100,000**	**1,223,953**	**554,727**	**206,917**	**462,309**
I.	**Indirect Costs**	**205,796**	**2,607**	**114,652**	**93,751**	**188,369**	**282,120**	**162,168**	**119,952**	**203,040**	**322,992**	**215,020**	**107,972**	**211,541**	-	**319,513**	**129,246**	**91,982**	**98,286**
J.	**Total Direct & Indirect Costs**	**950,001**	**222,698**	**600,245**	**572,454**	**1,000,000**	**1,572,454**	**965,526**	**606,929**	**949,997**	**1,556,926**	**1,113,459**	**443,467**	**1,000,000**	**100,000**	**1,543,467**	**683,973**	**298,899**	**560,595**
K.	**Residual Funds**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L.	**Amount of Request**	**950,001**	**222,698**	**600,245**	**572,454**	**1,000,000**	**1,572,454**	**965,526**	**606,929**	**949,997**	**1,556,926**	**1,113,459**	**443,467**	**1,000,000**	**100,000**	**1,543,467**	**683,973**	**298,899**	**560,595**

This carryover report also includes supplemental funds not reflected in the budget report.

Project Title: Southern Sierra Critical Zone Observatory
NSF Award No.: EAR-1331939
Principal Investigator: Dr. Roger Bales
Period of Performance: October 1st, 2013 - September 30th, 2018

Cumulative Year 1, Year 2, Year 3, and Year 4

CZO-Core/Main					
Budget Element	**Budgeted**	**Current Expenditures**	**Commitments through 9/30/2017**	**Balance**	
Participant Costs	**27,630**	**18,402**	**-**	**9,228**	Annual meeting + AGU meeting
Cross-Site Modeling Meetings, Seed Funding, PI Meetings					
Subcontracts*	**1,508,551**	**1,258,733**	**29,678**	**220,140**	Billing through end of yr 4 will use this balance
UC Berkeley, UC Irvine, UC Davis, UC Santa Barbara, Univeristy of Wyoming					
Other Direct Costs	**60,000**	**22,409**	**-**	**37,591**	Drilling completed, charging/billing in progress
Drilling Subcontract					
Indirect Costs	**48,196**	**22,446**	**-**	**25,750**	
Account Total	**1,644,377**	**1,321,990**	**29,678**	**292,709**	

CZO-Project Integration and Management					
Budget Element	**Budgeted**	**Current Expenditures**	**Commitments through 9/30/2017**	**Balance**	
Senior Personnel	**560,823**	**469,662**	**78,254**	**12,907**	Use for postdoc salary in next budget year
Principal Investigator, Data Manager, Research Engineer, Undergraduate Asst.					
Fringe Benefits	**197,109**	**171,236**	**22,647**	**3,226**	
Equipment	**91,000**	**50,824**	**-**	**40,176**	Upgrade of water-balance instrumentation cluster in progress
Tower Rebuild, Equipment Replacement					
Domestic Travel	**31,592**	**28,129**	**-**	**3,463**	Balance to E&O
Travel to Field-Site & Meetings					
Other Direct Costs	**38,900**	**36,505**	**1,363**	**1,032**	Balance to E&O
Supplies, Teleconferences, Battery Replarement, Equipment Calibration, Snowmobile E					
Indirect Costs	**451,735**	**384,143**	**56,245**	**11,347**	
Account Total	**1,371,159**	**1,140,499**	**158,509**	**72,151**	

CZO-Education and Outreach					
Budget Element	**Budgeted**	**Current Expenditures**	**Commitments through 9/30/2017**	**Balance**	
Senior Personnel	**216,678**	**132,679**	**22,827**	**61,172**	Use for postdoc salary in next budget year
Co-Investigator, Staff					
Fringe Benefits	**69,853**	**51,593**	**9,338**	**8,922**	
Domestic Travel	**6,400**	**11,607**	**-**	**(5,207)**	Balance from PIM & research
Travel to Field-Site & Meetings					
Other Direct Costs	**6,300**	**8,122**	**214**	**(2,036)**	Balance from PIM & research
Supplies, Teleconferences					
Indirect Costs	**164,578**	**112,201**	**17,808**	**34,569**	
Account Total	**463,809**	**316,203**	**50,186**	**97,420**	

CZO-Research, UC Merced					
Budget Element	**Budgeted**	**Current Expenditures**	**Commitments through 9/30/2017**	**Balance**	
Senior Personnel	**159,528**	**129,249**	**28,451**	**1,829**	Additional salary pending
Principal Investigator					
Fringe Benefits	**59,072**	**30,574**	**2,909**	**25,590**	Rebudget to PI salary pending
Domestic Travel	**32,146**	**21,690**	**1,200**	**9,255**	For summer/fall 2016
Travel to Field-Site & Meetings					
Other Direct Costs	**37,755**	**25,522**	**37**	**12,195**	Publication costs & field research for summer/fall 2016
Supplies, Teleconferences, Publication Costs					
Indirect Costs	**132,152**	**100,713**	**17,928**	**13,511**	
Account Total	**420,653**	**307,748**	**50,525**	**62,380**	

PROJECT TOTALS	**3,899,998**	**3,086,439**	**288,898**	**524,661**