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Federal Agency and Organization Element to Which Report is Submitted:	**4900**
Federal Grant or Other Identifying Number Assigned by Agency:	**1331939**
Project Title:	**Southern Sierra Critical Zone Observatory**
PD/PI Name:	**Roger C Bales, Principal Investigator** **Martha H Conklin, Co-Principal Investigator** **Michael L Goulden, Co-Principal Investigator** **Clifford S Riebe, Co-Principal Investigator** **Christina Tague, Co-Principal Investigator**
Recipient Organization:	**University of California - Merced**
Project/Grant Period:	**10/01/2013 - 09/30/2019**
Reporting Period:	**10/01/2017 - 09/30/2018**
Submitting Official (if other than PD\PI):	**Roger C Bales** **Principal Investigator**
Submission Date:	**07/27/2018**
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	**Roger C Bales**

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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. 2018), 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, inter-compare, 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. Additional, independently funded projects 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 critical-zone properties across the mountain front, ii) the processes governing critical-zone behavior, and iii) the rates that critical-zone 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

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 Critical Zone. 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 hypothesized that regolith thickness can be predicted in multiple ways, including building on direct measurements, through various estimates of utilization of water stored in the regolith, and using remote sensing coupled with terrain analysis and water balance. Regolith thickness was measured at 80 sites augered to hard bedrock or a maximum depth of 7.56 m, whichever was shallower, across the 543-ha Soaproot watershed. Patterns of regolith thickness were strongly related to covariates that proxy for stored water, water utilization, and landscape position (Figure 1). We extended our analysis of the importance of regolith water storage for ecosystems across the semi-arid western United States, with an analysis of flux-tower measurements of evapotranspiration from the CZO and other sites (Figure 2). Two related investigations focused on understanding how subsurface critical-zone structure mediates processes that occur on the surface. The first uses erosion rate, river incision rate, and geophysical data to understand how hillslopes in the Sierra Nevada have responded to changes in incision rate since the early Pleistocene. The second uses geophysical estimates of water-storage capacity to understand how differences in lithology influence subsurface water-storage capacity and how subsurface water storage ties to remotely sensed estimates of evapotranspiration and mortality.

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 water storage capacity, and plant water strategies at Soaproot, Providence and the integrating sites on P300 and Big Creek. We have used and further developed a range of models to represent hydrology. Our work on chemical processes focuses on biogeochemical budgets and transformations. We are quantifying annual sediment sources, composition and transport, and the resulting effects on water and nutrient cycling in stream and soil water. We used continuous-recording load-cell pressure sensors in four headwater streams to collect high-temporal-resolution, bedload-movement data for investigating the channel bed movement patterns within these streams for four water years (Figure 3). We also studied microbial and biogeochemical response to extreme-severity fire, which is currently not well understood. By incorporating various biochemical measurements with next-generation sequencing of microbial DNA, we are elucidating how microbial communities respond to disturbances outside the historic range of variability.

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, and fixed potassium. Synthesis of cosmogenic nuclide and U-series isotope data from stream sediment continued. We completed sampling and analysis of dust and weathering rates at the SSCZO, as part of a broader study of the importance of dust nutrient inputs to mountain ecosystems. We also analyzed soil-moisture patterns over 6 water years, and characterized repeated seasonal patterns, linked to precipitation, snow accumulation and melt.

Research Question 4, Implications of Change. A significant focus of our data analysis during the last year continues to focus on the impact of the 2012-15 drought on hydrology and forest mortality. This was extended to examine wildfire response. The CZO elevation transect also served as a study case for changing water balance with warming, focusing on snowmelt rates, and thus water availability for ecosystems and streamflow in a warming climate.

Research Question 5, Tools to Study the Critical Zone. Our catchment-scale time series measurements of snow, soil moisture, temperature, and matric potential continued, as did streamflow and met station measurements by the USFS. Additional time series data came from the flux towers. We continued monitoring of water content to 50 cm intervals in observation wells over the entire deep regolith thickness at each site using a neutron probe. We developed and applied a

observation wells over the entire deep regolith thickness at each site using a neutron probe. We developed and applied a more-robust and general algorithm for spatial sampling using wireless-sensor networks, building on our original deployment at Providence in the SSCZO (Figure 4).

Specific Objectives:

Research Question 1, Spatial Patterns. Measuring, characterizing, and understanding the spatial patterns of critical-zone properties and processes remain central objectives in the SSCZO. Key critical-zone 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 critical-zone 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. 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 soil-bedrock contact along the transect of focal sites, constrain weathering and water-storage potential at depth, and develop predictive modeling. Analysis of geophysical work over the past year has helped expand our limited measurements of subsurface regolith structure, which will help expand our process-based understanding of the critical zone. These measurements also provide information on regolith thickness that can be used in earth-system models.

Research Question 2, Physical, Chemical, and Biological Mechanisms and Interactions. Our analysis of channel-bed movement shows an annual pattern where channel bed material in the thalweg (a line connecting the lowest points of successive cross-sections along the stream) starts to build up in early fall, peaks around peak snow melt, and scours back to baseline levels during hydrograph drawdown and base flow. This pattern is punctuated by disturbance and recovery of channel-bed material associated with short-term storm events (Figure 5). 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 and carbon stocks and availability vary with climate and regolith depth.

Research Question 3, Rates of Change. Our work on regolith formation is expanding our understanding of the processes that shape subsurface critical-zone architecture over million-year timescales. 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. 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. At shorter time scales, we continue to look at changes in soil-moisture and temperature patterns due to specific local-in-time 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 examined how landscape attributes influence soil moisture storage through different seasons (Figure 6).

Research Question 4, Implications of Change. Recent wildfires, drought, and recovery have provided the opportunity to better understand how the water cycle and vegetation will respond to hotter, drier conditions. We evaluated the responses across the water-limited Kings River basin, where the SSCZO is centered, and compared with the response in the energy-limited American River basin (Figure 7). Snow and water-balance studies also focused on how snowpack water storage and snowmelt rates vary with elevation and how those gradients vary between dry, average, and wet snow seasons, as well as how historical snowpack water storage and melt rates respond to successive degrees of warming.

Research Question 5, Tools to Study the Critical Zone. One of the hallmarks of the SSCZO has been the diversity of tools we are using and developing to investigate the critical zone; these tools range from geochemical tracers to embedded networked sensor arrays to remote sensing. Our development and use of a wireless-sensor network as part of a spatially extensive catchment-scale measurement program focuses on improving methods to optimize placements of sensor clusters, and sensor nodes within the clusters. This work continues to progress on a number of fronts. The aim of our big-data, machine-learning approach to predicting sensor-network performance was to develop a much more robust and flexible approach to designing and evaluating wireless-sensor networks at multiple scales. We also partnered with JPL to assess the ability of high-resolution remotely-sensed measurements to detect soil-moisture patterns.

Significant Results:

Research Question 1, Spatial Patterns. Regolith thickness from augering averaged 4.6 m, with a range of 0-10 m (Figure 1). This work represents one of the few attempts to predict spatial trends in regolith thickness, and provides a data driven model from standardized data collected at the watershed scale. Our findings suggest that evidence from soil properties that provides clues to degree of weathering may be related to the nature of deep regolith, which could support broader modeling projects that predict regolith properties. Our assessment of regolith water storage across CZO sites showed that evapotranspiration in areas with a Mediterranean climate is significantly more dependent on subsurface storage than monsoon-dominated or Rocky Mountain sites. Locally at the SSCZO, we found that during the recent multi-year drought, trees first died in areas of deep regolith and by the end of the drought survivors were found along stream channels. The tree-ring record showed that trees exhibiting suppressed growth during drought were predominantly growing in deep

tree ring record showed that trees exhibiting suppressed growth during drought were predominantly growing in deep regolith. These findings suggest that deep regolith gave rise to an overly dense forest that was capable of withstanding short-term droughts but incapable of withstanding the most-recent multi-year drought. Our geophysical results indicate that the landscape has not adjusted to increased incision during the Pleistocene. This is likely due to intense weathering that produces fine sediment on the hillslopes that is unable to incise bedrock knickpoints. These findings may help explain the thick regolith profiles that are observed at our study site. Results from related work suggest that sites with more plant-essential nutrients like phosphorous and mafic minerals support more productive forests. However, during drought these ecosystems experience more mortality, despite having more water-storage capacity.

Research Question 2, Physical, Chemical, and Biological Mechanisms and Interactions. Our evaluation of stream sediment fluxes showed that the material in the thalweg represents a balance between sediment supply from the channel margins and sporadic, conveyor-belt-like downstream transport. This conceptual-model highlights not only the importance of production and transport rates but also that seasonal connectedness between the margins and thalweg is a key sediment control, determining the accumulation rate of sediment stores at the margins and the redistribution of sediment from margins to thalweg that feeds the conveyor belt (Figure 8). Investigations of deep soil organic matter found that stabilization by minerals was important, with organic matter having high versus low embedded energy exhibiting distinctive behavior (Figure 9). Our analysis of fire-impacted soils shows that most carbon processes do not recover by 44 years since fire, but nitrogen processes return to levels of the unburned stands by 13 years. At least for carbon biogeochemical processes, this is an extremely long recovery time for this ecosystem (twice the natural fire-return interval), longer than others have reported, and generally larger than for prescribed fire. In a separate but related investigation along a bioclimatic gradient in the Sierra, we discovered that up to 78% of carbon can be stored below the A horizon, with up to 23% of that carbon being stored in deeper regolith. Among the climatic variables investigated, deep water percolation and mean-annual temperature explain more variability in total carbon stock (soil + regolith) than mean-annual precipitation. Radiocarbon analyses show that carbon ages in regolith can range from 4,820 to 20,320 years before present, consistent with FTIR spectroscopy that shows that the old carbon in regolith is not necessarily more decomposed than carbon in the A and B horizons. These analyses indicate that carbon in various stages of decomposition is transported to the deep regolith, where it persists. A conservative global scaling of these results, based on climatic zones with the potential to form deep regolith, revealed regolith can store about 201 Pg of carbon within a thickness of 4 m. This large stock of carbon in subsoil and regolith represents a previously unexplored and potentially dynamic pool.

Research Question 3, Rates of Change. We found a pattern of relatively high modern dust supply index (DSI), defined as the ratio of dust inputs to the sum of chemical and physical outputs from erosion. This trend is driven in large part by recent changes in loss, with short-term erosion rates that are only 1% of long-term rates. Because of this large, time scale related difference in erosion rates, modern DSI values from sediment yields are 50% higher on average than values from the Last Glacial Maximum (LGM), although modern dust inputs are only 4% of LGM dust inputs to these catchments (Figure 10). Soil-moisture and water-storage patterns consistently showed repeatable behavior relative to wet up and dry down (Figure 11). Wet up coincided with fall rains, and the soil stayed wet until winter snow was largely depleted. Dry down, or recession, typically proceeded over about 3 months, followed by a dry period that lasted until fall rain returned.

Research Question 4, Implications of Change. We examined the cumulative impact of wildfires on evapotranspiration between 1990 and 2008, and we found that the lower and wetter American basin generated more than twice the evapotranspiration reduction per unit area than the higher and drier Kings basin, corresponding to greater water and energy limitations in the latter and greater fire severity in the former. A rough extrapolation of these results to the entire American River watershed suggests that evapotranspiration reductions due to forest thinning by wildfire could approach 10% of full natural flows for dry years and 5% overall (Figure 12). Snow-hydrology studies show three main implications for change in the southern Sierra. First, the sensitivity of total snowpack water storage to warming is ~10% per ^{O}C, with snowmelt rates being more sensitive to changes in the seasonal timing of precipitation than to changes in precipitation amount. Second, the middle elevations, which are dominated by forest cover and comprise a disproportionately large basin area, exhibit the greatest snowpack reductions and largest shift toward slower snowmelt. Third, increases in the frequency, intensity, and spatial extent of winter melt events occur with successive warming, impacting an area nearly twice as large in the historical period. These findings point to effects on both forest moisture conditions and flood risk, with broad implications for water supply, streamflow production, flood control, and ecosystem function in a warmer world (Figure 13-15).

Research Question 5, Tools to Study the Critical Zone. Our big-data, machine-learning, approach to network design outperforms previously reported models (Figure 16), and offers six key advantages to more-empirical, expert-decision approaches. First, it guides feature selection in a systematic way, limiting the possibility of “missing” important features. Second, it employs next-generation remote-sensing tools (e.g. LIDAR) to enable sub-meter modeling of the canopy, better representing node attributes. Third, it evaluates how much training data is required to build an accurate model, and how accuracy evolves as the size of the data set increases. Fourth, it builds a prediction-placement tool that optimizes network topologies in complex terrain, facilitating automated deployment of robust networks. Fifth, it applies the same methodology in different environments. Finally, it expands the number of machine-learning models and parameters evaluated. We also developed an algorithm to guide placement of soil-moisture measurements, using the network at Providence to determine the extent to which different attributes control wetness patterns over the year (Figure 11).

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 SSCZO.

1. Developed and applied 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 (remote sensing). Initiated cross comparison of these approaches. (Central publications include Klos et al. 2018, Bales et al. 2018, Fellows and Goulden 2016, Ferrell et al. in preparation.)

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 (Hayes et al. in review, Riebe et al. 2017, Ferrier et al. 2016, Martin and Conklin 2018).

3. Improved understanding of the implications of regolith properties for ecology, forest health, and hydrology, including partitioning precipitation into evapotranspiration versus runoff and predicting the patterns of forest die-off during drought (Bales et al. 2018, Rungee et al. in revision, Goulden and Bales in review, Ferrell et al. in preparation).

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) (Beaudette et al. 2016, Bales et al. 2018, Kim et al. 2017, Safeeq and Hunsaker 2016, Saksa et al. 2018, Rungee et al. in preparation).

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 (Aciego et al. 2017, Arvin et al. 2018).

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. Explored the effects of forest management and wildfire on hydrology/water balance and vegetation stress/mortality (Saksa et al. 2017, Roche et al. 2018).

9. Cross-disciplinary syntheses have been and continue focusing on issues including the bi-directional interactions between regolith properties, weathering, vegetation density, health and production, and hydrology (Klos et al 2018; additional syntheses are a central focus for the coming year).

It is also helpful to look beyond that past year to the full grant period. Since the start of the current NSF award in 2013, the SSCZO has met the science objectives in our proposal, and opened up new areas of inquiry for Critical Zone science and the CZO network. First, we have developed methods for measuring, characterizing, and understanding the spatial patterns of critical-zone properties across the landscape, as well as associated critical-zone processes. Second, we have determined how climate and landscape properties interact to modulate physical, chemical, and biological interactions in the critical zone. Third, we have determined rates of change for regolith properties, highlighting the interplay between lithology, vegetation, and subsurface critical-zone structure, and the influence on shorter-term critical-zone processes. Fourth, our team has used the 2011-15 drought and coincident wildfires as "natural experiments" to better understand how the critical zone will respond to climate-driven perturbations, and how management actions can modulate those responses. Fifth, we continue to develop measurement and modeling tools to better study the critical zone.

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

Students and postdoctoral researchers associated with the SSCZO 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 (M. Cooney 2017; N. Ojeda 2018). The Hart research lab employed two undergraduates this year to assist with SSCZO projects, the majority of whom identify as a gender, race/ethnicity, or socioeconomic demographic traditionally underrepresented in STEM fields. Riebe's lab at University of Wyoming has one undergraduate student working on critical zone projects as well (A. Miller). Undergraduate M Castro continues to assist with CZO outreach during the school year as well.

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 include Environmental Chemistry (M. Conklin), Environmental Monitoring (P.

students. Some examples of graduate and undergraduate courses include Environmental Chemistry (M. Conklin), Environmental Monitoring (T. Hartsough), Soils in Land Use and the Environment (A. O'Geen), Environmental Data Analysis (C. Riebe), and Fundamentals of Soil Science (A. Berhe).

Current and recent graduate students, postdoctoral researchers, and early career staff were first authors of 19 peer-reviewed journal publications that featured results or used data from SSCZO, with current statuses ranging from submitted to published. In addition, undergraduate and graduate students, postdocs, and early career staff presented more than 30 posters and talks at scientific conferences this year. Scientific conference presentations include meetings hosted by the American Geophysical Union, European Geosciences Union, Soil Science Society of America, Ecological Society of America, and SSCZO.

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 instance, students R. Callahan and M. Barnes are collaborating on critical-zone subsurface properties research. Students also successfully collaborate with non-CZO researchers to complete their research. For example, UC Merced graduate student M. Barnes has been using the Synchrotron Radiation Light Source at Stanford University in her sample analyses. Students M. Thaw and N. Dove have also conducted analyses at Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratories, respectively, this year as well.

SSCZO students attended a variety of technical workshops in the last year: the Jupyter Notebook Workshop presented by UC Merced attended by N. Dove; Introduction to python Workshop presented by Lawrence Berkeley National Lab attended by N. Dove; Science Communication Workshop presented by Lawrence Berkeley National Lab attended by N. Dove; Genomics Workshop presented by Lawrence Berkeley National Lab attended by N. Dove; Synchrotron Radiation Light Source Workshop presented by Stanford attended by M. Barnes; and ArcGIS Web Mapping workshop presented by UC Merced Engineering Service Learning attended by M. Castro and M. Gilmore.

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 undergraduate and graduate students, staff, and investigators.

Graduate students have also received several awards and fellowships to support their research, such as the UC Lab Fees Research Program In-Residence Graduate Fellowship awarded to K. Moreland this spring.

Our program is also encouraging personnel to attend safety trainings as available. E. Stacy co-led an orientation for Mountain Hydrology Research Group undergraduate students employed for summer 2018, covering lab and field safety, hazardous materials, working at heights, and practical rope skills for tower work. In June 2018, E. Stacy, M. Gilmore, and N. Ojeda attended an off-road 4x4 driving training to improve vehicle-use safety and decision-making on field site trips using automatic and manual transmission vehicles frequently driven by our program’s personnel; registration costs were covered by the University of California.

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 N. Dove, K. Moreland, and M. Thaw; undergraduate M. Castro; staff M. Gilmore and E. Stacy; faculty M. Conklin and M. Safeeq; and others have facilitated several types of events this year such as a Yosemite Forum talk, Merced City School District STEAM Center events, the Southern Sierra Headwaters Tour at Providence Creek Catchments. SSCZO personnel frequently present at professional development and advise the professional development of others. Soil profile characterization and well depth-to-groundwater measurement instruction was provided for the second year in June 2018 for the extended cross-institutional GEOPATH-EXTRA course: field based professional development for ESTEM undergraduate students. O’Geen presented workshops for three Master Gardener chapters based in the Sierra Nevada. Gilmore led two professional development workshops covering recording environmental observations and nature journaling for California teachers. Barnes has been mentoring a student throughout the year as part of the WSTEM program, helping the student build resumes, gain communication skills, and obtain employment. Lastly, UC Santa Barbara faculty C. Tague and graduate student C. Heckman advised a group of four Master’s students at the UCSB Bren School, who developed forest 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 is 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 findings with several audiences. We summarize these efforts below. Details for individual events are available in Products.

Scientific community. Dissemination to the science community includes alerting colleagues of our publications and presentations through our websites, email, and social media; attending scientific meetings and workshops; and participating in CZO network activities. In the past year, personnel and collaborators have authored over 30 peer-reviewed journal articles and book chapters related to SSCZO. Additionally, team members have given more than 60 oral and poster presentations at scientific conferences. SSCZO researchers have organized sessions and contributed presentations based on CZO research at several national and international scientific associations’ conferences. We also participated in regional scientific meetings and smaller specialty conferences. Presentations have also been given at other research-oriented venues such as departmental colloquia at several institutions. Our team contributed to CZO network activities in our outreach to the scientific community, including volunteering at the US NSF CZO Network booth at AGU and co-authoring multiple cross-CZO publications. Additionally, an interactive map of SSCZO sites will be embedded on our website in the next three months, which will highlight current and previous core instrumentation and related datasets in order to improve access to our sites and data for the broader research community.

Regional stakeholders and the public. Communication of scientific findings with stakeholders and the public includes talks around the state, briefings to

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.

Our work is informing the debate around water and ecosystem service benefits of forest management, with emphasis on climate change and runoff from the Sierra which provides about 60% of California's water supply. There is widespread interest in bringing new resources and tools to watershed and forest management, and in improving the knowledge base for predicting the effects of different management approaches.

In October 2017, our team co-hosted a stakeholder-focused tour of water cycling instrumentation and headwaters measurement in the Providence Creek Headwater Catchments alongside UC Water and USFS PSW KREW. *Southern Sierra Headwaters Tour* attendees included local landowners, Dinkey Collaborative members, legislative aides for State Assemblyman Devon Mathis and State Senator Anthony Canella, Merced County Supervisor Lloyd Pariera, and staff from multiple government and non-government affiliated groups including Sierra Resource Conservation District, Santa Rosa Rancheria, Pacific Gas & Electric, NASA JPL, CA DWR, Central Valley Regional Water Quality Control Board, Sierra Foothill Conservancy, Southern Sierra IRWM, Kings River Conservation District, USDA-NRCS, and UCANR.

In addition, four Master's students developed private landowner restoration strategies and management recommendations for the Sierra Resource Conservation District (RCD) with support from SSCZO. C. Tague, E. Stacy, and M. Gilmore co-wrote the UCSB Bren School proposal that initiated this project with Sierra RCD and USDA Forest Service. Tague and graduate student C. Heckman were advisors for the team. The team presented their findings to the Dinkey Landscape Restoration Project and submitted their final report this spring.

Our team engages with several Sierra Nevada stakeholder groups attempting to develop and implement regional solutions to the state's 21st-century water and forest management challenges. We also engage with multi-agency groups planning and financing forest restoration activities. E. Stacy continues SSCZO contributions to the Dinkey Landscape Restoration Project. M. Safeeq and R. Bart both collaborate with the Southern Sierra IRWM, and Safeeq also incorporates SSCZO research into his work with the Tulare Basin Watershed Connections group. We have collaborated to bring CZO technology to other parts of the Sierra Nevada through other funding as well. Our team continues working with water leaders to develop prototypes for a new water information system for California building on advances in wireless sensor networks developed at the SSCZO, plus parallel advances in cyberinfrastructure and in measurements by satellite and aircraft.

The SSCZO also has an active program of education and outreach to K-16 students using CZO research topics, data, and findings. Our presentations and partnership activities align with several aspects of K-12 Next Generation Science Standards and Common Core State Standards. This year we reached over 1200 K-8 students through multiple presentations at Society of American Foresters Conservation Day/Week, Southern California Edison Science Days, and presentations at Merced City School District's new STEAM Center. Center for Advanced Research and Technology (CART) students completed and publicly presented research evaluating where snowpack lasts the longest in the P301 landscape; their measurements serve a dual purpose as validations for the site's snow depth sensors. At the undergraduate level, our team hosted soil and hydrology research-based activities at P301 for ~20 undergraduate students from U San Francisco, Mt. San Antonio Coll., and Coll. of the Atlantic in June 2018; this is a continuation of the GP EXTRA-supported course that visited in June 2017. All K-16 presentations from the last year are listed in the products section.

Our educational partnerships share scientific methods and research results with educators as well. In December 2017 and March 2018, Gilmore and others from Merced Co. Office of Education (MCOE) and Green Meadows Outdoor School presented workshops on nature journaling, environmental observations, and environmental literacy to K-16 teachers at the CA STEAM Symposium and to K-8 teachers at MCOE. Gilmore also collaborated with J. Richardson and A. McGillis to produce two comics in the last year: *What is the Southern Sierra CZO?* and *A Tale of Two Dust Specks*. Both were published on criticalzone.org's blog *Adventures in the Critical Zone*. Print-friendly versions were distributed to educators from Merced City School District, MCOE, and NatureBridge. 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. Multiple screenings were held for *Beyond the Brink* by J. Thebaut. A. O'Geen's continues giving 4-hour Master Gardener short courses in Sierra Nevada communities; he discusses deep regolith and its ability supply water and buffer against drought. N. Dove also presented his CZO research at Yosemite Forum. Copies of *A Tale of Two Dust Specks* were given away at the Patterson Earth and Science Sustainability Festival. Recent publications and attention on California drought, forest mortality, and fire have also resulted in numerous media features covering research findings. For example, a recent publication by Roche et al. (2018) was covered by Science Magazine: *Forest fires keep billions of liters of water on the ground*. Videos highlighting SSCZO continue to be disseminated through UCTV. In addition, undergraduate outreach assistant M. Castro has been publishing a monthly Q&A style *Researcher Spotlight* on the criticalzone.org/sierra news section. We publicly disseminate these news, videos, articles, and other content through our website and social media. Our team uses social media (Facebook, Twitter, and Instagram) to extend our digital reach.

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

Going forward into the next year, our scientific focus will be on research questions that require interdisciplinary collaborations and syntheses, 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. During the coming year will focus on continuing the ongoing core observations (for example, the flux towers and associated water and soil moisture observations), and limited targeted measurements needed for students to complete dissertation research that is in progress. We will continue 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. The following text is drawn from our recent supplement request and details the four areas we will target for continuing integration.

Proposed Research. It is proposed to carry out synthesis activities that build on and extend the measurement, analysis, and prediction research over the past five years. This will be done through collaborative research between SSCZO investigators and other colleagues from the critical-zone community. Each synthesis activity will advance prediction of critical-zone properties, functions, and response to perturbations.

In addition to work in progress, we will focus on two types of research activities: 1) syntheses and 2) capstone analyses. This research is needed to extend and wrap up SSCZO phase 2, and will also provide foundations for possible directions for the CZO network. Syntheses will focus on issues where multiple individual lines of research within the SCZO have produced parallel datasets and findings, which need to be synthesized to produce one or more papers with broader impact. Syntheses will include very limited new observations; the focus is on distilling existing results to the key thematic findings. Capstone analyses are focused on extending the tools and approaches we have developed over the last five years, with the goal of exploring and illustrating possible themes and approaches for further CZO research. Capstone analyses will start with the tools we have developed and verified in the SSCZO at smaller scales, and apply these approaches to larger areas and questions.

Synthesis 1 - Spatial and Temporal Patterns of Biogeochemistry. The SSCZO is well poised to address several outstanding questions related to the controls on the vertical and horizontal spatial distribution of C, N, and P pools, and how these distributions are influenced by climate and disturbance (i.e., biomass removal). We will analyze existing CZO data sets to address the following questions: 1) What are the amounts and distributions of C, N, and P above- and below-ground? 2) Of the total ecosystem storage, what proportions of these nutrients are stored in long-term (low turnover rates) pools below-ground? 3) How do above-ground disturbances (e.g., fire, drought mortality) influence the cycling of these nutrients? 4) Does fire increase the proportion of these nutrients stored in long-term pools? And 5) What are the fluxes of C, N, and P laterally through erosion or vertically through the soil solution in these ecosystems, and how do these fluxes compare with other ecosystem transfers? We will use the climosequence of the SSCZO to evaluate each of these questions in the context of climate/vegetation change.

Capstone Analysis 1 - Vegetation Dynamics – Natural and Climate Driven. The SSCZO is poised to address several outstanding questions related to the effects of natural and management disturbance on vegetation dynamics and ecosystem function, including the legacy effects and rates of recovery. The overarching goal is to understand how: 1) disturbance and management affect forest processes, particularly water and carbon balances, and 2) how quickly forests recover from disturbances such as wildfire, fuel reduction and drought mortality. The applied questions focus on issues such as the immediate and legacy effects of wildfire on water balance, and the duration and canopy recovery from fuel treatments.

Synthesis 2 - Critical-Zone Perspective on Forest-Water Nexus in Managed and Naturally Disturbed Landscape – Management Implications. Under this activity we will assess vegetation post-fire recovery impacts on water use, and the impact of fuels treatment on the water cycle and on forest mortality risk. The main questions are as follows. Can we describe the observed threshold and conflicting response patterns of streamflow change caused by forest disturbance using regolith water storage? Can CZ science better inform and prioritize forest-restoration strategies and monitor hydrologic benefits?

Capstone Analysis 2 - Reactive-Transport Modeling. The next step from our conceptual modeling of regolith formation is to apply a well-developed reactive-transport model to predict both chemical composition of water draining to streams, and regolith formation. The two main questions that we will address are as follows. What is the origin of the temporal and spatial variability of water discharging from the SSCZO catchments? Why is the regolith thickness at the main SSCZO focal sites on the order of 25 m?

Supporting Files

	Filename	Description	Uploaded By	Uploaded On
(Download)	Figs_2018b_uploaded.pdf	Contains figures referenced in Accomplishments section.	Roger Bales	07/25/2018
(Download)	ADDITIONAL REPORTING 2017-2018b.pdf	Additional reporting requiements	Roger Bales	07/27/2018

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Products

Books

Book Chapters

Santos, F., Abney, R., Barnes, M., Jin, L., Moreland, K., Bogie, N., Sulman, B., Ghezzehei, T. A., Berhe, A. A. (). The role of soil physical properties for determining biogeochemical responses to soil warming. *Ecosystem Consequences of Soil Warming: Microbes, Vegetation, Fauna and Soil Biogeochemistry 1st Ed.*. Jacqueline Mohan. Academic Press. . Status = AWAITING_PUBLICATION; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

Inventions

Journals or Juried Conference Papers

Arvin, L.J.; Riebe, C.S.; Aciego, S.M.; Blakowski, M.A. (2017). Global patterns of dust and bedrock nutrient supply to montane ecosystems. *Science Advances*. 3 (12), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1126/sciadv.aao1588

Bales, R. C.; Goulden, M. L.; Hunsaker, C. T.; Conklin, M. H.; Hartsough, P. C.; O'Geen, A. T.; Hopmans, J. W.; Safeeq, M. (2018). Mechanisms controlling the impact of multi-year drought on mountain hydrology. *Hydrological Processes*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/s41598-017-19007-0

Bales, R.; Stacy, E.; Safeeq, M.; Meng, x.; Meadows, M.; Oroza, C.A.; Conklin, m.; Glaser, S.; Wagenbrenner, J. (2018). Spatially distributed water-balance and meteorological data from the rain-snow transition, southern Sierra Nevada, California. *Earth System Science Data*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Black BA, van der Sleen P, Di Lorenzo E, Griffin D, Sydeman WJ, Dunham JB, Rykaczewski RR, García-Reyes M, Safeeq M, Arismendi I, Bograd SJ (2018). Rising synchrony controls western North American ecosystems.. *Global Change Biology*. 24 (6), 2305. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1111/gcb.14128

Brantley, S.L; McDowell, W.H.; Dietrich, W.E.; White, T.S.; Kumar, P.; Anderson, S.P.; Chorover, J.; Lohse, K.A.; Bales, R.C.; Richter, D.D.; Grant, G.; Gaillardet, J. (2017). Designing a network of critical zone observatories to explore the living skin of the terrestrial Earth. *Earth Surface Dynamics*. 5 841. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: https://doi.org/10.5194/esurf-5-841-2017

Brantley, Susan L., David M. Eissenstat, Jill A. Marshall, Sarah E. Godsey, Zsuzsanna Balogh-Brunstad, Diana L. Karwan, Shirley A. Papuga, Joshua Roering, Todd E. Dawson, Jaivime Evaristo, Oliver Chadwick, Jeffrey J. McDonnell, Kathleen C. Weathers (2017). Reviews and syntheses: on the roles trees play in building and plumbing the critical zone. *Biogeosciences*. 14 (22), . Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.5194/bg-14-5115-2017

Callahan R., Ferrier K.L., Dixon J., Dosseto A., Hahm W.J., Jessup B., Miller S., Hunsaker C., Johnson D., Sklar L., Riebe C.S. (). Arrested development: Erosional equilibrium in the southern Sierra Nevada, California, maintained by feedbacks between channel incision and hillslope sediment production. *GSA Bulletin*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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

E. M. Stacy, A. A. Berhe, C. T. Hunsaker, D.W. Johnson, S. Mercer Meding, Stephen C. Hart (2018). Erosion Leads to Selective Lateral Mobilization of Distinct Soil Organic Matter Pools in Temperate Forests of the Sierra Nevada, California. *Biogeosciences*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Klos, P. Z.; Goulden, M.; Riebe, C. S.; Tague, C.; O'geen, A. T.; Flinchum, B. A.; Safeeq, M.; Conklin, M. H.; Hart, S. C.; Berhe, A. A.; Hartsough, P. C.; Holbrook, S.; Bales R. C. (2018). Subsurface plant-accessible water in mountain ecosystems with a Mediterranean climate. *WIREs WATER*. 5 (3), e1277. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/wat2.1277

Martin, S.E.; Conklin, M.H. (2018). Tracking channel bed resiliency in forested mountain catchments using high temporal resolution channel bed movement. *Geomorphology*. 301 68. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1016/j.geomorph.2017.10.026

Musselman, K.N.; Molotch, N.P.; Margulis, S.A. (2017). Snowmelt response to simulated warming across a large elevation gradient, southern Sierra Nevada, California. *The Cryosphere*. 11 2847. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.5194/tc-11-2847-2017

Oroza, C. A., R. C. Bales, E. M. Stacy, Z. Zheng, and S. D. Glaser. (2018). Long-Term Variability of Soil Moisture in the Southern Sierra: Measurement and Prediction. *Vadose Zone Journal*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.2136/vzj2017.10.0178

Oroza, C.; Zhang, Z.; Watteyne, T.; Glaser, S. (2017). A Machine-Learning-Based Connectivity Model for Complex Terrain Large-Scale Low-Power Wireless Deployments. *IEEE Transactions on Cognitive Communications and Networking*. 3 (4), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1109/TCCN.2017.2741468

O'Geen, A.T.; Safeeq, M.; Stacy, E. Hartsough, P.; Wagenbrenner, J.; Devine, S; Tain, Z.; Ferrell, R.; Bales, R. (2018). Southern Sierra Critical Zone Observatory and Kings River Experimental Watersheds: A synthesis of measurements, new insights and future directions. *Vadose Zone Journal*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

R.C. Bales, E.M. Stacy, X. Meng, M.H. Conklin, P. Kirchner, Z. Zheng (2018). Spatially distributed water-balance and meteorological data from the Wolverton catchment, Sequoia National Park, California. *Earth System Science Data*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Support = Yes ; Peer Reviewed = Yes

Rasmussen C., Heckman K., Wieder W.R., Keiluweit M., Lawrence C.R., Berhe A.A., Blankinship J.C., Crow S.E., Druhan J.L., Hicks Pries C.E., Marin-Spiotta E., Plante A.F., Schädel C., Schimel J.P., Sierra C.A., Thompson A., Wagai R. (2018). Beyond clay: towards an improved set of variables for predicting soil organic matter content. *Biogeochemistry*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Richardson J.B., Aguirre A.A., Buss H.L., O'Geen A.T., Gu X., Rempe D.M., Richter D.D., (). Mercury sourcing and sequestration in weathering profiles at six Critical Zone Observatories across North America. *Global Biogeochemical Cycles*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Roche, J.W.; Bales, R.C.; Rice, R.; Marks, D.G. (2018). Management Implications of Snowpack Sensitivity to Temperature and Atmospheric Moisture Changes in Yosemite National Park, CA. *Journal of the American Water Resources Association*. 54 (3), 724. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1111/1752-1688.12647

Roche, J.W.; Goulden, M.L.; Bales, R.C. (2018). Estimating evapotranspiration change due to forest treatment and fire at the basin scale in the Sierra Nevada, California. *Ecohydrology*. e1978. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1002/eco.1978

Rungee, J,; Bales, R.; Goulden, M. (). Evapotranspiration response to multi-year dry periods in the semi-arid western United States.. *Hydrological Processes*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = No

Safeeq, M. (2018). Precision data on snowmelt, in Downing, J.: UC groundwater research: A survey. *California Agriculture*. 72 (1), . Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.3733/ca.2018a0008

Saksa, P.C., Safeeq, M., Dymond, S. (2017). Recent patterns in climate, vegetation, and forest water use in California montane watersheds. *Forests*. . Status = PUBLISHED; 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 = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Tennant, C. J., A. A. Harpold, K. A Lohse, S. E. Godsey, B. T. Crosby, L. G. Larsen, P. D. Brooks, R. W. Van Kirk, N. F. Glenn (2017). Regional sensitivities of seasonal snowpack to elevation, aspect, and vegetation cover in western North America. *Water Resources Research*. 53 (8), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016WR019374

Tian, Z., P. Hartsough, A.T. O'Geen (). Lithologic, climatic and depth controls on critical zone transformations. *Soil Science Society of America Journal*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Uhlig, D., J. A. Schuessler, J. Bouchez, J. L. Dixon, and F. von Blanckenburg (2017). Quantifying nutrient uptake as driver of rock weathering in forest ecosystems by magnesium stable isotopes. *Biogeosciences*. 14 3111. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.5194/bg-14-3111-2017

Umaira, M., D. Kim, R. L. Ray, M. Choi (2018). Estimating land surface variables and sensitivity analysis for CLM and VIC simulations using remote sensing products. *Science of the Total Environment*. 633 470. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1016/j.scitotenv.2018.03.138

Visser, A.; Thaw, M.; Esser, B. (2018). Analysis of air mass trajectories to explain observed variability of tritium in precipitation at the Southern Sierra Critical Zone Observatory, California, USA. *Journal of Environmental Radioactivity*. 181 42. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1016/j.jenvrad.2017.10.008

White, T.; Wymore, A.; Dere, A.; Hoffman, A.; Washburne, J.; Conklin, M. (2017). Integrated Interdisciplinary Science of the Critical Zone as a Foundational Curriculum for Addressing Issues of Environmental Sustainability. *Journal of Geoscience Education*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Williams, E., A. Plante , A.A. Berhe, M. Fogel (2018). Distinct bioenergetic signatures in particulate versus mineral-associated soil organic matter. *Geoderma*. 330 107. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1016/j.geoderma.2018.05.024

Williams, E.K,; M.L. Fogel, A.A. Berhe (). Nonexchangeable δ2H of bulk soil organic matter as precipitation proxy?. *Geochimica et Cosmochimica Acta*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Zhang, Z.; Glaser, S.; Bales, R.; Conklin, M.; Rice, R.; Marks, D. (2017). Insights into mountain precipitation and snowpack from a basin-scale

wireless-sensor network. *Water Resources Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Zheng, Z.; Molotch, N.P.; Oroza, C.A.; Conklin, M.H.; Bales, R.C. (2018). Spatial snow water equivalent estimation for mountainous areas usingwireless-sensor networks and remote-sensing products. *Remote Sensing of Environment*. 215 44. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1016/j.rse.2018.05.029

Licenses

Other Conference Presentations / Papers

Ryan R. Bart, Maureen C. Kennedy, Christina (Naomi) Tague, Erin J. Hanan (2017). *A Coupled Model for Simulating Future Wildfire Regimes in the Western US. Abstract GC51A-0789.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Conklin, M. H.; Martin, S. (2017). *A Gap-Filling Procedure for Hydrologic Data Based on Kalman Filtering and Expectation Maximization: Application to Data from the Wireless Sensor Networks of the Sierra Nevada. Abstract EP53E-07*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Coogan, A.; Avanzi, R.; Conklin, M.H.; Bales, R.C.; Glaser, S. (2017). *A Gap-Filling Procedure for Hydrologic Data Based on Kalman Filtering and Expectation Maximization: Application to Data from the Wireless Sensor Networks of the Sierra Nevada. Abstract IN51E-0054*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Burke, W.; Tague, C. (2017). *Accounting for small scale heterogeneity in ecohydrologic watershed models. Abstract H13C-1382*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

E.K. Williams, M. Fogel,, A.A. Berhe, A. Plante (2017). *Activation Energy Characterization of Free and Mineral-Associated SOM*. 2017 Goldschmidt International Conference. Boston, Massachusetts. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Callahan, R., C. Riebe, M. Goulden, N. Taylor, S. Pasquet, B. Flinchum & W. S. Holbrook (2017). *Bedrock controls on mountain ecosystems evaluated using geophysics, geochemistry, and remote sensing (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Barnes, M. E., S. C. Hart, & A. A. Berhe (2017). *Climatic controls on the biogeochemical cycling of phosphorus in the critical zone (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tague, C.; Burke, W.; Ryan, B.; Turpin, E.; Wood, G. (2017). *Communicating why land surface heterogeneity matters. Abstract H51A-1249.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hart, S.C. and J. C. Blankinship (2018). *Consequences of warming and altered snowmelt timing on greenhouse gas fluxes and soil N cycling in the Sierra Nevada rain-snow transition zone*. Joint meeting of the 13th North American Forest Soils Conference and the 9th International Symposium on Forest Soils. Quebec City, Quebec, CAN. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Moreland, K. C.; Tian, Z.; Berhe, A. A.; O'geen, A. T. (2017). *Deep Soil Carbon in the Critical Zone: Amount and Nature of Carbon in Weathered Bedrock, and its Implication for Soil Carbon Inventory. Abstract B33G-03.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Moreland, K., Z. Tian, A. A. Berhe, A. T. O'Geen (2017). *Deep soil carbon in the critical zone: Climatic influences on the amount and chemical composition of carbon in weathered bedrock (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Malone, S., M. G. Tulbure, A. J. Pérez-Luque, T. Assal, L. Bremer, D. P. Drucker, V. Hillis, S. Varela, and M. Goulden (2017). *Detecting drought vulnerability across California ecosystems*. Ecological Society of America Annual Meeting. Portland Oregon. Status = PUBLISHED; Acknowledgement of Federal Support = No

Bales, R. C.; Bernacchi, L.; Conklin, M. H.; Viers, J. H.; Fogg, G. E.; Fisher, A.T.; Kiparky, M. (2017). *Developing decision-relevant data and information systems for California water through listening and collaboration. Abstract PA33D-10*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bart, R.R., Tague, C., Kennedy, M., Hanan E. (2017). *Development of a coupled model for investigating the effects of climate and forest*

management on wildfire regimes in the western U.S.. Conference on Fire Prediction Across Scales, Initiative on Extreme Weather and Climate event. Columbia University, New York NY. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bales, R. (2017). *Drought Response across Sierran Forests in a Warming Climate*. Yosemite Hydroclimate Conference. Yosemite National Park CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Riebe, C. S.; Arvin, L.; Ferrier, K.; Aciego S. (2017). *Dust and chemical erosion biases in cosmogenic nuclide studies: A factor-of-ten problem that could mask strong climatic effects on landscape evolution. Abstract EP32C-08.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Collins, C.; Maxwell, R.M. (2017). *Elucidating Critical Zone Process Interactions with an Integrated Hydrology Model in a Headwaters Research Catchment.*. American Geophysical Union. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Goulden, M.; Bales, R. (2017). *Estimating evapotranspiration change due to forest treatment and fire at the basin scale in the Sierra Nevada, California. Abstract H21B-1443.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Thaw, M., A. Visser, M. Conklin, A. Deinhart, R. Bibby, A. Everhart, M. Sharp, & J. Rungee (2017). *Evapotranspiration in the Southern Sierra critical zone: How much from where?*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Rungee, J. P.; Bales, R. (2017). *Evapotranspiration response to multi-year dry periods in the semi-arid western United States*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Rungee, J., & R. Bales (2017). *Evapotranspiration responses to multi-year dry periods in the semi-arid western United States (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wilson, A.; Jackson, R.B.; Tumber-Davila, S.J. (2017). *Examining the Relationship Between Edaphic Variables and the Rooting System of Abies concolor in the southern Sierra Nevada*. American Geophysical Union Fall Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

O'Geen, A.T.; Ferrell, R.; Tian, Z.; Goulden, M. (2017). *Exploring deep regolith*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Goulden, M. (2017). *Exploring forest mortality*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Conklin, M., P. Saksa, C. Tague, & R. Bales (2017). *Forest thinning in Sierra Nevada mixed-conifer headwater forests: Evapotranspiration, runoff and drought resiliency (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Sharkey, S. and White, T. (2017). *Fostering Collaboration Across the US Critical Zone Observatories Network.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Berhe, A.A.; Ghezzehei, T.A. (2017). *Generalized Model for the Temporal Evolution of the Carbon Sequestration Potential of Eroding Watersheds. Abstract B41E-2002*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Thaw, M.; Visser, A.; Conklin, M. H.; Everhart, A.; Deinhart, A.; Bibby, R. K. (2017). *Headwater Catchments to Mountain Range River Runoff: Utilizing Differences in Precipitation and Snowmelt Signatures to Understand Catchment Scale Links Among ET/Storage/Runoff and Major River Sources in the Sierra Nevada, Abstract #H43U-08*. American Geophysical Union Fall Meeting. New Orleans, LA. 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. Abstract H23H-1777.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Cooney, M., E. Stacy, M. Safeeq, P. Hartsough, & M. Goulden (2017). *How well do we measure precipitation? (poster)*. SSCZO Annual Meeting. Shaver Lake 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 = PUBLISHED; Acknowledgement of Federal Support = Yes

Sohrabi, M.; Safeeq, M.; Conklin, M. H. (2017). *Improving snow water equivalent simulations in an alpine basin using blended gage precipitation*

Sohrabi, M., Safeeq, M., Conklin, M. H. (2017). *Improving snow water equivalent simulations in an alpine basin using blended gage precipitation and snow pillow measurements. Abstract H43C-1658*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Visser, A.; Thaw, M.; Van Der Velde, Y. (2017). *Investigating Unsaturated Zone Travel Times with Tritium and Stable Isotopes. Abstract H23E1729.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bales, R. (2017). *Making up for lost snow: lessons from a warming Sierra Nevada. Abstract C21H-04*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bart, R. (2017). *Modeling fire regimes*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Callahan, R. P.; Riebe, C. S.; Ferrier K. (2017). *Mountain erosion over decades and millennia: New insights from sediment yields and cosmogenic nuclides. Abstract EP33C-1950*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ayers, R.; Gilmore, M.; Habecker, D. (2017). *Nature Journaling as a Cross-Subject Catalyst for Environmental Literacy*. California STEAM Symposium. San Francisco CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Visser, A.; Thaw, M.; Dinhart, A.; Bibby, R. K.; Esser, B. (2017). *New Applications of Cosmogenic Radioactive Isotopes to Study Water Travel Times. Abstract H23K-01.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dove, N.C., Arogyaswamy, K., Carey C.J., Packman, A., Hart, S.C, and Aronson E.L. (2017). *Over half of potential soil extracellular enzyme activity occurs below 20 cm*. Ecological Society of America Annual Meeting. Portland OR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dove, N. C., K. Arogyaswamy, C. J. Carey, A. I. Packman, S. C. Hart, & E. L. Aronson (2017). *Over half of potential soil extracellular enzyme activity occurs below 20 cm (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Ugwumsinachi, GN*, M. Barnes*, B. Lash, S. Hart, P. O'Day (2017). *Phosphorus speciation in atmospherically deposited air particulates from high and low elevation sites of California and Colorado (Poster)*. Stanford Synchrotron Radiation Lightsource User Meeting. Stanford CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Klos, P. Z.; Goulden, M.; Riebe, C. S.; Tague, C.; O'geen, A. T.; Flinchum, B. A.; Safeeq, M.; Conklin, M. H.; Hart, S. C.; Berhe, A. A.; Hartsough, P. C.; Holbrook, S.; Bales R. C. (2017). *Predicting Plant-Accessible Water in the Critical Zone: Mountain Ecosystems in a Mediterranean Climate. Abstract H23H-1769.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Klos, Z., M. Goulden, C. Riebe, C. Tague, A. T. O'Geen, B. Flinchum, M. Safeeq, M. Conklin, S. Hart, A. A. Berhe, P. Hartsough, W. S. Holbrook, & R. Bales (2017). *Predicting plant-accessible water in the critical zone: An overview of this and other current SSCZO projects on plant-water-subsurface interactions*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Klos, Z., M. Goulden, C. Riebe, C. Tague, A. T. O'Geen, B. Flinchum, M. Safeeq, M. Conklin, S. Hart, A. A. Berhe, P. Hartsough, W. S. Holbrook, & R. Bales (2017). *Predicting plant-accessible water in the critical zone: Mountain ecosystems in a Mediterranean climate (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Riebe, C., L. Arvin, C. Carey, S. Aciego, S. Aarons, M. Blakowski, S. Hart, E. Aronson (2017). *Reevaluating the Role of Dust in Mountain Ecosystems: Insights from Tracer Isotopes, Microbial Genomics, and Global Databases*. 2017 Goldschmidt International Conference. Boston, Massachusetts. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bales, R. Goulden, M., Conklin, M., Rungee, J., Ma, Q., Klos, Z. (2018). *Regolith controls on mountain evapotranspiration and runoff during multi-year drought*. European Geoscience Union General Assembly. Vienna, Austria. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tian, Z., A. T. O'Geen, & P. Hartsough (2017). *Regolith thickness and pedogenic processes at mid-elevations of the Southern Sierra Nevada on granitic rock (poster)*. SSCZO Annual Meeting. Shaver Lake 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.*. American Association of Geographers. Boston, Massachusetts. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tumber-Davila, S. J., & Jackson, R. (2017). *Root system plasticity of dominant southern Sierra tree species, and its implications for plant fitness*

during drought stress and climatic extremes (poster). SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wagenbrenner, J.; Safeeq, M.; Hunsaker, C. (2017). *Sediment Concentration and Its Relation to Catchment Characteristics in Forested Headwater Streams of the Sierra Nevada, California. Abstract H41C-1450.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dove, N.C., Torn, M.S., Hart, S.C., Taş, N. (2018). *Soil microbial ecology of the Sierra Nevada: Predictions for a warm and fiery future (Poster)*. Dept. of Energy Joint Genome Institute User Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stacy, E., P. Hartsough, A. T. O'Geen (2017). *Soil water wet-up and drawdown patterns during drought recovery (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Oroza, C.; Bales, R. C.; Zheng, Z.; Glaser, S. D. (2017). *Spatial Variability of Soil-Water Storage in the Southern Sierra Critical Zone Observatory: Measurement and Prediction. Abstract H41G-1539.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

M. Thaw (2017). *Surface Water-Groundwater Interactions in a Sierra Nevada Headwater Catchment using tritium and stable isotopes*. Groundwater Resources Association of California Annual Meeting. Sacramento. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bales, R. C.; Bernacchi, L.; Conklin, M. H.; Safeeq, M.; Viers, J. H.; Gilmore, M. (2017). *Sustainable California: Getting the word out through a web-based TV channel. Abstract PA42A-07*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

White, T.S., Wymore, A., Dere, A.L.D., Washburne, J.C., Hoffman, A., Conklin, M. (2017). *Teaching climate science within the transdisciplinary framework of Critical Zone science (Invited).*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Heckman, C., & C. (Naomi) Tague (2017). *The effect of plant available water storage capacity (PAWSC) on transpiration across the Critical Zone Observatories (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Riebe, C. S.; Callahan, R. P.; Goulden, M.; Pasquest, S.; Flinchum, B. A.; Taylor, N. J.;. Holbrook S. (2017). *The influence of subsurface porosity and bedrock composition on ecosystem productivity and drought resilience in the Sierra Nevada Batholith, California. Abstract EP53D-1762.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Huntington, K. W.; Klepeis, K.; Cassel, E. J.; Currie, C. A.; Dibiase, R. A.; Kirby, E.; Lang, K. A.; Pazzaglia, F.; Riebe, C. S; Zeitler, P. (2017). *Understanding the dynamic interactions between earth-surface processes and tectonics: Opportunities for progress from outcrop to global scales*. 2017 Geological Society of America Annual Meeting. Seattle, Washington. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Maurer, A.; Avanzi, F.; Oroza, C.; Malek, S.; Glaser, S.; Bales, R.; Conklin, M. (2017). *Using wireless sensor networks to improve understanding of rain-on-snow events across the Sierra Nevada.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Van Der Velde, Y.; Visser, A.; Thaw, M.; Safeeq, M. (2017). *Water Storage, Mixing and Transit Times During a Multiyear Drought. Abstract H23E-1731.*. American Geophysical Union, Fall Meeting. New Orleans, Louisiana. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Visser, A., M. Thaw, A. Deinhart, R. Bibby, Y. van der Velde, M. Conklin, & B. Esser (2017). *Water transit times at the Southern Sierra CZO derived from cosmogenic radioactive isotopes (poster)*. SSCZO Annual Meeting. Shaver Lake CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Databases.

Goulden, M. (2018) AmeriFlux US-CZ1, Sierra Critical Zone, Sierra Transect, Oak/Pine Woodland, San Joaquin Experimental Range.

Carbon flux data from SSCZO towers are now shared on AmeriFlux.

Databases.

Goulden, M. (2018) AmeriFlux US-CZ2, Sierra Critical Zone, Sierra Transect, Ponderosa Pine Forest, Soaproot Saddle.

Carbon flux data from SSCZO towers are now shared on AmeriFlux.

Databases.

Goulden, M. (2018) AmeriFlux US-CZ3, Sierra Critical Zone, Sierra Transect, Sierran Mixed Conifer, P301.

Carbon flux data from SSCZO towers are now shared on AmeriFlux.

Databases.

Goulden, M. (2018) AmeriFlux US-CZ4, Sierra Critical Zone, Sierra Transect, Subalpine Forest, Shorthair.

Carbon flux data from SSCZO towers are now shared on AmeriFlux.

Audio or Video Products.

Thebaut, J. (Director). (2017). *Beyond the Brink* [Video]. United States: Chronicles Group. https://beyondthebrinkdocumentary.org/

NSF support is acknowledged in the film's credits.

This documentary focused on water scarcity and security in California's agricultural heartland features footage from interviews with SSCZO investigators R. Bales and M. Conklin. The world premiere of the film was held in Merced CA in September 2017 and featured a post-screening discussion with M. Conklin and JPL researcher J. Famiglietti. In April 2018, another public screening was held in the state capitol, Sacramento CA. The film is now available on demand on multiple viewing platforms.

From the website: Created, directed, and produced by renowned documentarian, filmmaker and journalist, Jim Thebaut, BEYOND THE BRINK allows viewers to witness firsthand how California's evolving water crisis is a growing threat to America's national security in its capacity of providing healthy food to our nation and world. Throughout the 90-minute journey, BEYOND THE BRINK dives deep into the intricacies of the water and food nexus, while it highlights the evolving implications on a National Security threat through the lens of California's San Joaquin Valley. California is the leading provider of dairy, produce, and beef in the United States, and BEYOND THE BRINK delves into the business of the state's agriculture.

Educational aids or Curricula.

Gilmore, M. (2018) Notice and Wonder: Foundations for Scientific Inquiry in the Critical Zone. NSF U.S. CZO National Program contribution to American Geosciences Institute Earth Science Week 2018: Earth as Inspiration.

This educational material was submitted to AGI by the CZO National Office in May 2018. It will be distributed by AGI in the 2018 Earth Science Week Toolkit and available on earthsciweek.org in September or October 2018.

Educator Workshop.

Ayers, R; Gilmore, M.; Touchstone, M. *Nature Journaling Breathes Life into Environmental Literacy.* Merced County Office of Education Professional Development Workshop. Merced, CA. March 6, 2018.

Mentorship Output.

Bocanegra, M.; Gonzalez, Y.; Keungsavath, A.; Lopez, S.; O'Brien, C.; Quinonez, J.; Rodriguez, K. (2018) Sierra Snow Surveys: How Do Landscape Conditions Affect Persistence of Snowpack. 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 15, 2018.

Mentorship Output.

Moreland, K. & Gilmore, M. Ask-A-Scientist-or-Engineer Science Fair Help Night. Merced City School District S.T.E.A.M. Center. Merced, CA. Two nights in Fall 2017.

Other Presentation.

Bales, R., Avoiding California's next water crisis: lessons from a warming Sierra Nevada: a water resources & climate solutions perspective. Rae Dorough Speaker Series, Livermore CA, February 15, 2018.

Other Presentation.

Bales, R., Comments on 21st Century Water Infrastructure. Meeting of the California Water Commission, Sacramento CA, September 20, 2017.

Other Presentation.

Bales, R., Water Security in a changing climate. Water Boards Water Quality Coordinating Committee Meeting, Sacramento CA, October 25 2017.

Other Presentation.

Bart, R. Water and the Sierra Nevada: Why vegetation matters! Sierra College Science Speaker Series, Grass Valley, California. April 2018.

Other Presentation.

Berhe, AA. Soil erosion and land degradation: implications for global change and regional development. Department of Geography, University of Oregon. Eugene, OR, May 24, 2018.

Other Presentation.

Berhe, AA. Geomorphic controls on soil organic matter dynamics: role of soil erosion in soil carbon storage and stabilization University of California, Davis, Soils and Biogeochemistry Graduate Group Seminar Series. November 27, 2017.

Other Presentation.

Berhe, AA. Soil carbon dynamics in eroding landscapes. University of Illinois, Urbana-Champaign and Intensively Managed Landscapes Critical Zone Observatory webinar. February 16, 2018.

Other Presentation.

Berhe, AA. What's soil erosion got to do with carbon sequestration? Earth and Atmospheric Sciences Stout Lecture. University of Nebraska, Lincoln, April 19, 2018.

Other Presentation.

Berhe, AA. What's soil erosion got to do with carbon sequestration? Utah State University, Ecology Center sponsored Public talk. October 11, 2017.

Other Presentation.

Callahan, R. (2018) Landscape Evolution in the southern Sierra Nevada, California: A Case of Arrested Development. University of Wyoming Geology & Geophysics Brown Bag Seminar Series. Laramie, WY. March 2018.

Other Presentation.

Dove, N.C., Taş, N., Hart, S.C. (Oral – *invited*) Soil microbial ecology of the Western US: Predications for a warm and fiery future. Yosemite Forum, Yosemite National Park, April 10, 2018

Other Presentation.

Gilmore, M. & Santos, F. (2018) Fire's effects on soils and cones. Southern California Edison Science Days Part 1. Shaver Lake, CA. April 26, 2018.

Other Presentation.

Gilmore, M. (2017) What do geologists do and why is temperature important? Merced City School District S.T.E.A.M. Center 6th Grade Temperature Week. Merced, CA. October 30, 2017.

Other Presentation.

Gilmore, M. (2018) Fire's effects on soil and cones. Southern California Edison Science Days Part 2. Shaver Lake, CA. May 11, 2018.

Other Presentation.

Gilmore, M. (2018) Secret powers of Sierra Nevada Soils. Society of American Foresters High Sierra Chapter Conservation Week. Sequoia Lake CA. September 25-29, 2018.

Other Presentation.

Gilmore, M. (2018) Soils and Water. Society of American Foresters High Sierra Chapter Conservation Day. Tollhouse CA. April 24, 2018.

Other Presentation.

Gilmore, M. (2018) Using echolocation to measure snow in the Sierra Nevada. Merced City School District S.T.E.A.M. Center 4th Grade Waves Week. Merced, CA. January 30, 2018.

Other Presentation.

Heyerdahl, J., Hughes, C., Morgride, T., O'Neill, C., White, J., Motivating Public-Private Collaboration to Reduce Fire Severity in the Southern Sierra Nevada Mountains. Presentation to Dinkey Collaborative, Clovis CA, April 2018.

Other Presentation.

Moreland, K. (2018) BIOTAQ Soil Science Module. Yosemite High School, Merced, CA.

Other Presentation.

Moreland, K.; Tian, Z.; Berhe, A.A.; O'Geen, A.T. (2018) Deep Soil Carbon in the Critical Zone: Climatic influences on the amount and chemical composition of carbon in weathered bedrock. UC Merced Enviro-Lunch Seminar.

Other Presentation.

O'Geen, A.T. (2017) Soil Water Holding Capacity in Montane Gardens. Master Gardeners of Lake Tahoe Training. Lake Tahoe, CA. December 1, 2017.

Other Presentation.

O'Geen, A.T. (2018) Soil Water Holding Capacity in Montane Gardens. Master Gardeners of Eldorado County Training. Shingle Springs, CA. January 25, 2018.

Other Presentation.

O'Geen, A.T. (2018) Soil Water Holding Capacity in Montane Gardens. Master Gardeners of Tuolumne and Calaveras Training. Sonora, CA. February 22, 2018.

Other Presentation.

Safeeq, M. (2017) Kings River watershed water yield, today and tomorrow. Headwaters to Groundwater Symposium, Tulare CA, October 12, 2017.

Other Presentation.

Safeeq, M. (2018) Forests and Water: Observations from the Sierra Nevada. California Board of Forestry, Sacramento CA, April 11, 2018.

Other Presentation.

Safeeq, M. (2018) The solution: preparing for the new age of headwaters locally. ACWA Region 3 & 4 Joint Program, Auburn CA, September 8, 2017.

Other Presentation.

Tague, C., Forest responses to drought, climate warming and fire – is there a role for density reduction? RHESSys-Fire Introduction Presentation, Instituto Pirenaico de Ecología (IPE-CSIC), Huesca, Spain, September 2017

Southern Sierra Headwaters Tour.

Southern Sierra Headwaters Tour: Hydrologic monitoring in the Providence Creek Headwaters Catchments. Presented by M. Conklin, M. Safeeq, J. Wagenbrenner, M. Gilmore, L. Bernacchi. October 20, 2017.

A news article was written about this tour by M. Gilmore and L. Bernacchi. It was published on the SSCZO website and cross-posted on the UC Water website: http://criticalzone.org/sierra/news/story/southern-sierra-headwaters-tour-links-measurement-and-management-efforts/

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Arvin, Lindsay. *Quantifying the influence of dust on cosmogenic nuclide studies and soil nutrient supply in montane landscapes*. (2017). University of Wyoming. Acknowledgement of Federal Support = Yes

Heyerdahl, J., Hughes, C., Morgride, T., O'Neill, C., White, J.. *SAVING SIERRAS: Motivating Public-Private Collaboration to Reduce Fire Severity in the Southern Sierra Nevada Mountains, Final Master's Project Report, 166 pg.*. (2018). University of California, Santa Barbara. Acknowledgement

of Federal Support = No

Tian, Zhiyuan. *Soil and Weathered Bedrock Evolution along an Elevation Gradient in the Southern Sierra Nevada, California. Ph.D. Dissertation*. (2017). University of California, Davis. Acknowledgement of Federal Support = Yes

Collins, C.. *Using an integrated hydrology model to elucidate plant water use in a headwaters research catchment*. (2018). Colorado School of Mines. Acknowledgement of Federal Support = No

Websites

A Tale of Two Dust Specks
http://criticalzone.org/national/blogs/post/a-tale-of-two-dust-specks/

A Tale of Two Dust Specks: Comic by Michelle Gilmore. Illustrated by Alana McGillis. January 8, 2018

A Tale of Two Dust Specks is an educational comic based on research conducted by critical zone scientists Sarah Aciego, Emma Aronson, Lindsay Arvin, Stephen Hart, Clifford Riebe, and others. They found that dust provides important nutrients like phosphorus to Sierra Nevada ecosystems, often more nutrients than the granitic bedrock provides. Most of the dust in the Sierra Nevada comes from the Central Valley of California and the Gobi Desert in Asia. Dust particles are incorporated into soil and eventually taken up by the vegetation growing in that soil. Their results show that dust can play a major role in ecosystems across the world. As climate and land use change with time, dust will continue to impact ecosystems in the future. The researchers' findings were published in two papers in 2017 (Aciego et al. and Arvin et al.).

The comic is being shared on the Critical Zone Observatory website and within social media platforms. Since published online, the online comic has so far garnered 461 pageviews by 324 users. A printable version is also available on the site and has been distributed to local educators, the Dinkey Collaborative, and attendees of the Patterson Earth & Science Sustainability Festival.

Adventures in the Critical Zone
http://criticalzone.org/national/blogs/blog/adventures-in-the-critical-zone/

SSCZO personnel contribute to the CZO National Office blog, Adventures in the Critical Zone. Previous contributions include: *A Tale of Two Dust Specks* (2018, comic by M. Gilmore, illustrated by A. McGillis), *What is the Southern Sierra CZO?* (2017, comic by J. Richardson & M. Gilmore, illustrated by A. McGillis), *How does fire change a forest?* (2016, article by N. Dove & J. Richardson).

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 101 likes. A majority of our Facebook activity reaches our own researchers, undergraduate 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 starting in February 2013. 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 585 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, university departments, interested publics.

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.

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

SSCZO PI Roger Bales started a Twitter page in November 2014. His page is active in conversations regarding water usage, hydrologic technology and infrastructure, hydrologic research, and intersecting news. He currently has 1,252 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 related to the field of critical zone science and its researchers. Some of our researchers' accounts are listed below:
Morgan Barnes (@Morgan_E_Barnes), 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 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 205 followers.

UCTV Sustainable California
http://www.uctv.tv/sustainable-cal

UCTV Sustainable California is a public online TV channel with videos focusing on natural resource management, biological and cultural diversity, and low-impact living. SSCZO personnel, field sites, and technologies are featured in several videos on the website. The videos show how research is influential in understanding California's water supply, its impacts on ecosystems and society, and how to improve management of this precious resource. They are described in a news article on the SSCZO website: http://criticalzone.org/sierra/news/story/sustainable-california/.

What is the Southern Sierra CZO?
http://criticalzone.org/national/blogs/post/what-is-the-southern-sierra-czo/

What is the Southern Sierra CZO?: Comic by Justin Richardson and Michelle Gilmore. Illustrated by Alana McGillis. July 17, 2017

What is the Southern Sierra CZO? is an educational comic describing the research being conducted by the Southern Sierra Critical Zone Observatory's investigators.

The comic is being shared on the Critical Zone Observatory website and within social media platforms. Since published online, the comic has so far garnered XXX pageviews by XXX users. A printable version was distributed at the SSCZO Annual Meeting and to local educators.

Supporting Files

	Filename	Description	Uploaded By	Uploaded On
(Download)	Beyond the Brink Poster.pdf	Flyer for the film Beyond the Brink (listed in Products and mentioned in other sections).	Roger Bales	07/25/2018

Back to the top

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?	Nothing to Report
How many REU applicants were selected and agreed to participate during this reporting period?	Nothing to Report
REU Comments:	No REUs were administered during this reporting period.

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	1
Goulden, Michael	Co PD/PI	2
Riebe, Clifford	Co PD/PI	4
Tague, Christina	Co PD/PI	1
Berhe, Asmeret Asefaw	Co-Investigator	1
Glaser, Steven	Co-Investigator	1
Hart, Stephen	Co-Investigator	2
O'Geen, Anthony	Co-Investigator	3
Safeeq, Mohammad	Co-Investigator	3
Bart, Ryan	Postdoctoral (scholar, fellow or other postdoctoral position)	5
Klos, Peter	Postdoctoral (scholar, fellow or other postdoctoral position)	6
Oroza, Carlos	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Sohrabi, Mohammad	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Busse, Matt	Other Professional	1
Choate, Janet	Other Professional	1
Davis, Frank	Other Professional	1
Gilmore, Michelle	Other Professional	12
Hunsaker, Carolyn	Other Professional	1
McCormick, Cyril	Other Professional	1
Meng, Xiande	Other Professional	10
Stacy, Erin	Other Professional	12
Wagenbrenner, Joseph	Other Professional	1
Womble, Patrick	Other Professional	0
Hartsough, Peter	Staff Scientist (doctoral level)	1
Arvin, Lindsay	Graduate Student (research assistant)	5
Barnes, Morgan	Graduate Student (research assistant)	12
Callahan, Russell	Graduate Student (research assistant)	12
Dove, Nicholas	Graduate Student (research assistant)	9
Heckman, Christopher	Graduate Student (research assistant)	3
Moreland, Kimber	Graduate Student (research assistant)	12
Rungee, Joseph	Graduate Student (research assistant)	12
Schell, Marlie	Graduate Student (research assistant)	3
Thaw, Melissa	Graduate Student (research assistant)	12
Tian, Zhiyuan	Graduate Student (research assistant)	4
Ayala-Astorga, Maria	Non-Student Research Assistant	3
Casas, Andres	Undergraduate Student	3
Castro, Madeline	Undergraduate Student	6
Cooney, Morgan	Undergraduate Student	2
Elias, Oscar	Undergraduate Student	7
Miller, Andrew	Undergraduate Student	2
Ojeda, Nancy	Undergraduate Student	1
Serna, Blaz	Undergraduate Student	3

Full details of individuals who have worked on the project:

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: 1

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

Funding Support: SSCZO, 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: 2

Contribution to the Project: Co PI, flux towers, development of tower top remote sensing system, forest productivity and ET monitoring

Funding Support: SSCZO, 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: Yes, Australia
International Travel: No

Christina Tague
Email: ctague@bren.ucsb.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: hydro-ecologic modeling

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: 1

Contribution to the Project: Sediment transport & nutrient cycling, soil biogeochemistry

Contribution to the Project: Sediment transport & nutrient cycling, soil biogeochemistsry

Funding Support: 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: Other funding

International Collaboration: Yes, France
International Travel: No

Stephen Hart
Email: shart4@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

Anthony O'Geen
Email: atogeen@ucdavis.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3

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: 3

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: rbart3@ucmerced.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 5

Contribution to the Project: UC Merced Post-doctoral scholar with Safeeq: ecohydrologic and hydrologic modeling. Started in January 2018. Worked with Tague on ecohydrologic modeling until December 2017.

Funding Support: Other funding

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: 6

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

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

Contribution to the Project: UC Berkeley Postdoc. Developments for the wireless sensor network functionality and sensor/repeater site selection

Funding Support: SSCZO, other funding

International Collaboration: Yes, France
International Travel: No

Mohammad Sohrabi
Email: msohrabi2@ucmerced.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 1

Contribution to the Project: UC Merced Postdoc with Safeeq and Conklin, incorporating CZO data and findings into hydrologic modeling of the Kings River Watershed

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: 1

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; Computer & Network Techno II, Tague Lab Manager; ecohydrologic modeling

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: 1

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: SSCZO

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 spring 2017; USFS Pacific Southwest Research Station; Sr. Personnel; stream and watershed ecology and hydrology. Continuing to collaborate on CZO-related manuscripts

Funding Support: Other funding

International Collaboration: No
International Travel: No

Cyril McCormick
Email: mccormic@uci.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1

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

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; Core / Field manager, soil moisture, dust

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Joseph Wagenbrenner

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: 0

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

Funding Support: other funding

International Collaboration: No
International Travel: No

Peter Hartsough
Email: phartsough@ucdavis.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 1

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

Funding Support: 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: 5

Contribution to the Project: U. of Wyoming MS student; graduated December 2017. dust fluxes and nutrient content

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

Funding Support: SSCZO, other funding

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. geophysical characterization of weathered zone

Funding Support: SSCZO, U. Wyoming

International Collaboration: Yes, Australia
International Travel: No

Nicholas Dove
Email: ndove@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9

Contribution to the Project: UC Merced PhD student. microbial processes of CZ

Funding Support: SSCZO funded

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: 3

Contribution to the Project: UC Santa Barbara; PhD student, ecohydrologic modeling

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: UC Merced PhD student (Berhe lab). Researching deep soil carbon across climosequence

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Joseph 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 PhD student (Bales lab); mountain hydrology, water resources, remote sensing and spatial distribution

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Marlie Schell
Email: mschell2@uwyo.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: U. Wyoming MS student. Geochemical characterization of regolith weathering. Started in December 2017

Funding Support: SSCZO, U. Wyoming

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

Nearest Person Month Worked: 12

Contribution to the Project: UC Merced PhD student (Conklin lab); isotope hydrology and ecohydrology

Funding Support: SSCZO, Lawrence Livermore National Laboratory, other funding

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: 4

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

Funding Support: SSCZO funded

International Collaboration: No
International Travel: No

Maria Ayala-Astorga
Email: mayalaastorga@ucmerced.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 3

Contribution to the Project: Summer 2017 field assistant for Safeeq

Funding Support: other funding

International Collaboration: No
International Travel: No

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

Contribution to the Project: summer field assistant with Safeeq

Funding Support: other funding

International Collaboration: No
International Travel: No

Madeline Castro
Email: mcastro29@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 6

Contribution to the Project: outreach program assistant; website updates, outreach materials drafting and event assistance, data entry. Hart lab assistant: P biogeochemistry, root classification, litter processing.

Funding Support: SSCZO funded

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: Core / Field lab assistant, field installations; precipitation sensor evaluations

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: 7

Contribution to the Project: Hart lab assistant: P biogeochemistry, root classification, litter processing

Funding Support: SSCZO, other funding

International Collaboration: No
International Travel: No

Andrew Miller
Email: amille78@uwyo.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: U. Wyoming Riebe Lab Assistant. Geochemical characterization of regolith weathering.

Funding Support: SSCZO

International Collaboration: No
International Travel: No

Nancy Ojeda
Email: nojeda2@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: UC Merced core field and lab undergraduate assistant: Deep critical zone processes, geochemistry, geophysics, instrument maintenance and removal

Funding Support: SSCZO

International Collaboration: No
International Travel: No

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

Contribution to the Project: field assistant with M. Safeeq

Funding Support: other funding

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

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 for research and educational purposes.

Research:

T Watteyne & students [INRIA] w Glaser, Oroza

A Visser, B Esser, A Deinhart, **R Bibby**, **M Sharp** [LLNL]; **R Maxwell, C Collins** [CO Sch. Mines]; **Y van der Velde** [Vrije U. Amster.] w Conklin, Thaw

S Holbrook [VA Tech]; **K Dueker, I Keifir** [UWyo]; **S Pasquet** [IPGP], **B Flinchum** [CSIRO] w Riebe, Callahan

K Ferrier [GA Tech], **L Sklar** [SF State U], **A Dosseto** [U Wollongong]**, J Dixon** [MT State U], **S Aarons** [UC Irvine], **C Lukens** [Victoria U] w Riebe, Callahan, Schell

S Aciego [U. Wyo]; **S Aarons** [UC Irvine]; **E Aronson, M Maltz** [UC Riverside] w Riebe, Hart, Stacy, Arvin

P O'Day, G Nwosu [UC Merced]; **N Washton** [PNNL] w Barnes, Berhe, Riebe, Callahan

K McFarlane [LLNL] w Moreland, Berhe, O'Geen, Hart, et al.

J Richardson [U MA Amherst] w O'Geen *(cross-CZO)*

E Williams [UC Merced], **M Fogel** [UC Riverside] w Berhe

C Rasmussen [U AZ], **R Lybrand** [OR State U] w Berhe *(cross-CZO)*

D Johnson [UNV Reno emeritus], **S Mercer Meding** [U AZ] w Stacy, Berhe, Hart, Hunsaker

Z Zheng [UC Berkeley], **P Kirchner** [NPS] w Stacy, Bales

N Stavros et al. [NASA Cal/Val] w Bales

J Bolis & others [NEON] w Stacy, Bales

A Wlostowski [CO State U] *(cross-CZO)*

H McMillan [San Diego State U]; **F Branger, I Horner** [IRSTEA]

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

J Lauder, E Moran [UC Merced]

J Marshall [UArk] *(cross-CZO)*

E King, J Pett-Ridge [OR State U]

S Voelker [Utah State U]

E Burt, J West [U So. CA]

A Aguirre [Cornell]

P. Kumar [U Illinois] *(cross-CZO)*

S Myneni [Princeton]

Education:

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

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

R Ayers, D Habacher [Merced Co. Off. Edu.], **M Touchstone** [Green Meadows Outd. Sch.] w Gilmore

T Catchpole, D Savin-Dukoleth [Soc. Am. Forest. High Sierra] w Gilmore

S Byrd [So. Cal. Edison], **N Carroll** [Cent. Sierra Hist. Soc.], **F Santos** [UC Merced] w Gilmore

A McGillis [Self-Empl.], **J Richardson** w Gilmore

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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 supported others in using our CZO resources; over 20 research groups and 50 individuals without financial support from the current award are conducting research at SSCZO sites and with SSCZO data (see Other Participants list). Some of these research groups are closely collaborating with the core SSCZO team. Other independent researchers 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.

Scaling of evapotranspiration: Our approach to scaling of evapotranspiration, using satellite data calibrated with flux-tower measurements, is potentially transformational for estimating water balances. The high correlation between annual evapotranspiration and satellite measured greenness, typically indicated by NDVI, provides unprecedented accuracy and detail. Without calibration, satellite data provide relative values for evapotranspiration. Without satellite data for scaling, flux-tower measurements provide point data. The combination of the two provide powerful data for establishing water balances, constraining hydrologic modeling, estimating critical-zone properties, identifying areas vulnerable vs resistant to drought, and prioritizing areas for landscape restoration. All of these applications are currently proceeding, involving our team ans others.

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).

An additional evapotranspiration product in progress can be used as input into hydrologic models, to maintain an accounting of subsurface water storage drawdown and to better understand how evapotranspiration responds to climate extremes ultimately affecting runoff. This product can also be used to provide insight for observed responses and changes to the landscape, combined with soil porosity data to better understand plant rooting depth, and explain vegetation responses to climate extremes.

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. Our results suggest sensor-placement strategies must account for the relative importance of predictive features, which vary across seasons and years. Capturing the spatial variability of soil texture should be prioritized across all years. Sampling strategies focused on the wet-up period would benefit from a representative sampling of northness, and sampling strategies focused on the recession period should sample along an elevation transect. The relative importance of elevation declined in dry years, perhaps due to the decreasing differences in snowpack between the upper- and lower-elevation sites, there- fore sampling elevation gradients may be less important for dry years, except during transient snow-cover conditions. Location with respect to canopy was determined as less important in multiple studies.

Soil moisture: In semi-arid regions, the amount of subsurface water storage during drought is emerging as a key critical-zone attribute, and predicting how this modulation varies across the landscape addresses a central critical-zone-service question. Recent work has found that near-surface and below-surface soil layers become more de-coupled in drought years, which has significant implications for remote sensing (which only captures near-surface layers). During normal and wet years, tightly coupled soil layers make observations of the surface storage a good proxy for lower-level storage. In dry years, we observe greater decoupling of shallower- and deeper-soil moisture storage, particularly during the wet-up and snow-cover periods. Recent results suggest remote sensing tools may overestimate soil-water storage in the lower soil column during the wet-up period of dry years, and may underestimate soil-water storage in the lower soil column during transient snow-off conditions.

Regolith thickness: This work has generated valuable geospatial products to predict patterns in regolith thickness. Recent advances from the SSCZO have established relationships between measured ET from flux towers with modeled ET from remote-sensing products. 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 water storage. Spatial predictions of regolith thickness and water storage capacity are relevant to many disciplines including hydrology, ecology, soil science, geomorphology, geology, and geochemistry.

Bedrock geochemistry: Work from our characterization of water-storage capacity and nutrients suggests that the conversion of unaltered bedrock to saprolite and soil releases plant-available nutrients and produces water storage capacity necessary to plants. Slight changes in mineralogy affect rates of regolith formation, impacting the magnitude of nutrient availability and water storage capacity of the subsurface as well. However, during drought ecosystems with more mafic bedrock mineralogy experience more mortality, despite having more water storage capacity. This may reflect increased competition for resources during drought.

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. The role of dust in montane ecosystems may have been underestimated in the past. These findings have major implications for understanding forest and microbial ecology, biogeochemical cycles in watersheds, and landscape evolution.

Elemental cycling: Critical knowledge gaps remain on our understanding of how P dynamics are regulated by climate and depth, particularly in low-P-containing parent material. Ongoing research seeks to fill in these gaps using an integrative approach with novel techniques (XANES and NMR). This work includes studies of climate change coupled with fractionation, P pool transformations with depth, organic P speciation changes with climate, and content of P pools in temperate Mediterranean ecosystems and drylands.

Also, findings from research along a fire chronosequence will be useful in determining fire's effects on C and N cycling in the Sierra Nevada and evaluating different forest management strategies.

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.

What is the impact on other disciplines?

Three examples of impacts are described below, on forest management, electrical engineering, and isotope hydrology. Additionally, activities and findings described in previous reporting sections have potential implications in other disciplines including the fields of agricultural science, fire ecology, soil science, ecology, geology, and biogeochemistry.

Forest Management: Many forest managers do not realize that soil survey does not fully document the total amount of root accessible plant available water. This is because soil survey does not exceed a depth of 2-m. Thus, we have an incomplete inventory of water holding capacity in settings throughout the Sierra Nevada where regolith is thicker. This limitation is not realized by many geospatial scientists, and as a result, some geospatial models that predict forest response to drought are incorrect. We are working with stakeholders such as the Tree Mortality Task Force (appointed by the Governor) to realize the limitations of spatial data such as soil survey in forested terrain. We share our findings with these workgroups.

Electrical Engineering: 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.

Isotope Hydrology: 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. We also engage in public outreach to increase interest in and knowledge of the critical zone.

Public screenings and on-demand availability of *Beyond the Brink* has provided opportunities to increase public interest in and knowledge of water issues in California, and how these issues have potential impacts at national and international scales. This documentary focused on water scarcity and

issues in California, and how these issues have potential impacts at national and international scales. This documentary focused on water scarcity and security in California's agricultural heartland features footage from interviews with SSCZO investigators R. Bales and M. Conklin. The world premiere of the film was held in Merced CA in Fall 2017, and another public screening was held in Sacramento CA in Spring 2018.

Fundamental training and professional development of scholars working directly with SSCZO investigators during the reporting period include 2 M.S. students, 8 Ph.D. students, and 4 postdoctoral researchers at multiple institutions. SSCZO scholars have been awarded travel and research fellowships this year, attended research and career-related workshops, and gained experience presenting their work to a variety of audiences. Details on these students and their activities and training are found in Personnel, Products, and other sections of the report. Early-career professionals who were supported by this award as students or postdocs 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. Scholars who are utilizing SSCZO sites include MS student C. Collins at CO School of Mines and postdoc S. Tumber-Davila at Sanford.

The UCSB Bren School Master's project advised by UC Santa Barbara faculty C. Tague, graduate student C. Heckman, and others 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 and finished the project in spring 2018. They submitted a final report to UCSB and Sierra Resource Conservation District, and presented their work to the Dinkey Collaborative.

A. O'Geen's Master Gardener workshops shared CZO-based findings on deep soil and regolith water with attendees who ranged from landscaping professionals to hobbyists.

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 courses.

Several undergraduates have been employed by SSCZO researchers. At UC Merced, the project has supported two undergraduate students with the Hart research group who were employed to assist with critical-zone research, gaining skills in field and laboratory research methods (M. Castro, O. Elias). One undergraduate works with E. Stacy each summer as field assistant (M. Cooney 2017; N. Ojeda 2018). One student has also been employed during the school year since spring 2015 to assist with outreach efforts (M. Castro). M. Safeeq employed three undergraduates and recent graduates in summer 2017 as well to work in the Providence area (A. Ayala-Astorga, A. Casas, B. Serna). At the University of Wyoming, an undergraduate student is also working on CZO projects with Riebe, Callahan, and Schell (A. Miller). A majority of these students identify with one or more demographic groups (e.g., gender, race, ethnicity) traditionally underrepresented in geosciences. Most students are planning to pursue jobs related to soil science and hydrology or apply to graduate school programs upon graduating.

The University of California, Merced, where a large number of our core team is located, provides 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 2017 to 2018 undergraduate student body, 91% of students identify as non-white or international students; 53% as Hispanic. And 71% of undergraduate students enrolled are first-generation college students.

About 20 environmental studies and geology students from University of San Francisco, College of the Atlantic, and Mt. San Antonio College visited the SSCZO Providence Creek site in June 2018, an extension of the NSF-funded GP-EXTRA 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

Teacher workshops hosted in the last year reached approximately 30 educators who work across the state of California. Additionally, educators who received copies of SSCZO comics also work locally in Merced and Mariposa communities in both traditional classrooms (MCOE, MCSD) and outdoor classrooms (NatureBridge). 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. Through NatureBridge Yosemite, there is potential for SSCZO comics to reach national and international student audiences. At present we do not have data available for how many teachers have utilized workshop or comic material in their classrooms; we are following up with teachers to attempt to collect this data.

Six juniors and one senior 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, data analysis and visualization, research collaboration, and science communication. Five out of seven students identify with traditionally underrepresented groups in STEM fields: gender, race/ethnicity, or both. We are awaiting receipt of this year's post-project evaluations.

This year we reached over 1200 K-8th grade students from southern Sierra foothill and mountain communities, more than double the number of students reached last year. In September 2017 we reached approximately 800 students through M. Gilmore's participation in Society of American Foresters High Sierra Chapter Conservation Week at Sequoia Lake. She presented on the importance of soil for forests' survival. About 125 fourth and fifth graders participated in a learning station on forest soils and water at the Society of American Foresters High Sierra Chapter Conservation Day in Tollhouse (April 2018). Over 300 K-8 students visited a learning station about fire's effects on soil and cones at Southern California Edison's Science Days in Shaver Lake (May and June 2018). These K-8 presentations included CZO research findings such as soil's ability to buffer vegetation against drought and research methods such as soil pH testing. We plan to continue participating in all of these events in the next funding year.

SSCZO is also active in network-level, cross-CZO efforts to impact human resources. M. Gilmore worked with T. White and S. McGee this spring to develop a handout on behalf of the CZO Network for the American Geoscience Institute's 2018 Earth Science Week, to be released in fall 2018. Our educational resources have been added to the CZO National Office Educational Resources page (http://criticalzone.org/national/education-outreach/resources/), which is under ongoing expansion and refinement.

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, energybalance 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.

In addition, we are sharing information with water resources and forest managers and policymakers in order to identify limitations of current data, create more informed measurement and mangement decisions, and optimize best management practices.

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/realmsteam/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?

The soil moisture study (see Oroza et al. AGU presentation and VZJ paper) represents a new method of combining remote-sensing and in-situ measurements, which could be adopted as new practice for predicting spatial soil-water storage variability in addition to remote sensing.

Our wireless-sensor systems are being implemented in the Feather River headwaters and the American-Cosumnes groundwater basin. In addition, our scaling approach for estimating forest evapotranspiration has been extended 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.

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

What is the impact on society beyond science and technology?

SSCZO's work has critical links to society. We strive to communicate about our activities and findings with a variety of audiences in order to (1) improve public understanding of and attitudes toward the critical zone, forest management, ecosystem and critical-zone services, and water resources; and (2) help decisionmakers including policy makers, resource managers, and large and small landowners make more informed decisions and improve societal, economic, and ecological resilience. We focus here primarily on the latter of these impacts. Additional impacts related to society, management, and public understanding of our research and related sciences are also described in prior Impacts questions.

Our CZO has a high profile with resource-management stakeholders in California and the broader region. Ultimately our work will lead to improved forest management practices. 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. Recent intense and consecutive drought years and forest mortality 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. Practices such as controlled burning or mechanical thinning can be prioritized in sensitive areas that our research identifies.

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 water-secure future and build the knowledge base for better water-resources 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.

In addition, our work is improving the understanding of the impacts of fire suppression and resulting novel, high-severity fire on microbial communities and soil biogeochemistry, which are increasingly being recognized as critically important in forestry and agriculture industries. Understanding how microbial communities throughout the soil profile respond to global change and disturbance will increase the predictive power of earth system models, ultimately contributing to better policy decisions.

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.

Research focused on elemental nutrient stocks also has important implications for carbon budgeting and agricultural practices. Ongoing work will help us understand how carbon and phosphorus biogeochemistry is impacted by temperature, precipitation, and the response of temperate ecosystems to climate change. Ecosystem response to climate change will shift carbon fluxes; a fundamental question vital to carbon budgeting that our work relates to is, how will carbon sources and sinks change as climate changes? It is also anticipated that nitrogen limitation will be alleviated in temperate ecosystems, leading to phosphorus as the primary limiting nutrient in ecosystem development. It is estimated that phosphorus stocks in the US, which are used for agricultural fertilization, will be depleted by 2025. Current lack of understanding of phosphorus biogeochemistry often results in excess fertilizer applied to agricultural sites, leading to leaching and eutrophication of waterways, which can impair water use for industry, drinking, fisheries, and recreation.

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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 multiple years.

Panther meteorological installation will be replaced with a new model. Previous version was damaged over the 2017 winter and deemed unsafe. The new met station is planned for installation in Aug – Sept 2018.

Soaproot Saddle and SJER flux towers may be disassembled depending on decisions and direction of the new funding cycle.

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

2017-2018 NSF Annual Report: Southern Sierra Critical Zone Observatory (1331939)

Additional Reporting.

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 (1 July 2017 to 30 June 2018), 34 articles acknowledging SSCZO site use, data use, and/or funding were submitted, under review, or published in peer-reviewed journals or books. SSCZO research was also highlighted by team members in presentations at many conferences over the past year, and many more seminars and public talks. These include multiple works published and in review in leading peer-reviewed journals.

Data are housed in an online digital library that is hosted on UC Merced servers and are also accessible through the data catalog of the SSCZO website on criticalzone.org. 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. In January 2018, flux tower datasets from were also posted to the AmeriFlux data catalog (see Products).

SSCZO staff (data manager and 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. CZO data are stored in a perpetual archive and assigned DOIs.

As part of our effort to measure *outcomes*, we tracked citations of our peer-reviewed papers, use of our data, and online reach.

We use Web of Science to track citations of SSCZO-based publications. We provide two examples below. Goulden et al.'s (2012) article *Evapotranspiration along an elevation gradient in California's Sierra Nevada* has been cited 51 times since its publication, 14 of which were from papers published between July 2017 and June 2018. Hahm et al.'s (2014) article *Bedrock composition regulates mountain ecosystems and landscape evolution* has been cited 46 times since its publication, 10 of which were between July 2017 and June 2018.

We also track the number of scientists coordinating with the SSCZO. These include collaborators reported by SSCZO investigators, cooperators who contact our staff and co-PIs regarding data and field site use, and other researchers who publish research papers or conference presentations utilizing our sites and data. As listed in Other Participants in the Personnel section of the report, there were at least 57 collaborators and cooperators working on research projects at our sites or pursuing new projects with the SSCZO team in the last year. Sixteen additional collaborators have been involved for outreach purposes.

We know of at least four peer-reviewed articles published since the submission of last year's report that use SSCZO sites and do not list any SSCZO core team members as authors: Uhlig et al., June 2017 (last year's report was submitted prior to this paper's release); Tennant et al., July 2017; Musselman et al., December 2017; Umair et al., March 2018. However, it is our experience that people who use our data do not always advise us when a paper is submitted or published. In addition, at least two conference presentations used SSCZO data at the 2017 American Geophysical Union's annual meeting: Collins and Maxwell's *Elucidating Critical Zone Process Interactions with an Integrated Hydrology Model in a Headwaters Research Catchment* and Wilson et al.'s *Examining the Relationship Between Edaphic Variables and the Rooting System of Abies concolor in the southern Sierra Nevada*. Collins's 2018 MS thesis research involved modeling plant water use at the Providence Creek site using SSCZO and KREW data. These publications and presentations above are listed in Products. We are in the process of establishing Google Scholar alerts for key phrases such as "Sierra Critical Zone" and "Critical Zone Observatory" to increase the robustness of our collaborator/cooperator publication counts.

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.

The Sierra Nevada-San Joaquin Hydrologic Observatory (SNSJHO) digital library, where SSCZO datasets are stored, 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 1, 2016. Since we initiated Google Analytics, we have had more than 850 users and over 5,900 data downloads in the CZO section of SNSJHO. Between July 1, 2017 and June 7, 2018, we had 2,063 data download events, 8,820 page views, and 180 unique users (165 of which were new users). About 4% of downloads and 19% of page views during this period were made by users outside the United States.

The CZO National Office started tracking website activity on criticalzone.org with Google Analytics in September 2013. Since then, webpages in the criticalzone.org/sierra subsection have been viewed more than 100,000 times by over 21,000 users. For the lifetime of Analytics data available, 78.7% of Sierra section visitors are new and ~19% are from outside the U.S. Since July 1, 2017, more than 17,000 page views have been made in the last year by over 4,500 users. For this same period, 79.4% of site users were new visitors; ~22% of site visits have been from outside the United States. These data were obtained June 15, 2018.

Staff, students, and faculty also collaboratively maintain CZO social media accounts (in addition to personal accounts) to connect with other observatories, researchers, organizations, and members of the public interested in critical-zone science. Since the SSCZO Twitter account was launched in 2013, we have posted over 1,600 tweets and gained more than 570 followers. PI R. Bales has sent over 1,600 tweets and gained more than 1,200 followers since joining in 2014. Several other SSCZO colleagues use twitter and post tweets relevant to SSCZO, including new SSCZO presentations and publications (see Products: website category for examples). Our Facebook page has 101 likes as well. These social media metrics were obtained June 16, 2018.

We also have worked with the US NSF CZO National Office to obtain website activity for two SSCZO-focused comics published to the CZO Blog *Adventures in the Critical Zone*. Since the publication of *What*

is the Southern Sierra CZO? in July 2017, there have been 174-page views from 126 unique users (data obtained June 9, 2018). *A Tale of Two Dust Specks*, published in January 2018, has received 461 pageviews by 324 unique users (data obtained June 7, 2018). Of note, people are spending time reading through these comics. Viewers spend an average of 3 minutes and 30 seconds on the *What is the Southern Sierra CZO?* page and approximately 4 minutes on *A Tale of Two Dust Specks*.

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, mountain hydrology research personnel 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, detailed in multiple sections of the main report. 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. Of note this year, we held a stakeholder- and decisionmaker-focused tour of the Providence Creek Headwater Catchments in October 2017 (23 attendees excluding presenters and support staff).

We have employed evaluation forms to assess multiple events. Feedback from the 2016 Annual Meeting directly informed agenda structure and logistics for the August 2017 Annual Meeting. We are in the process of planning the 2018 Annual Meeting and utilizing feedback from the 2017 meeting to make improvements. We also administered an online survey about the 2017 Southern Sierra Headwaters Tour. All eight survey respondents said that they were very satisfied with the event. Six out of eight respondents said that the tour was “very relevant” for them and their organization; one person responded “somewhat relevant” (one person did not answer that question). Additionally, we have used program evaluation forms in our ongoing high school field research partnership with the Center for Advanced Research and Technology’s Environmental Research Lab. Program evaluations from the spring 2016 and 2018 cohorts suggest positive impacts on potential future STEM professionals through our mentoring partnership, based on responses to both scale-based, closed-ended, and open-ended questions covering knowledge gained and skills acquired and improved during the project. Every student who has completed an evaluation has responded “Yes” to the question, “Would you recommend the Snow Survey project to a friend?” Out of this year’s cohort of seven students, five students submitted evaluations. Selecting from a list of 24 positive, negative, and neutral descriptors, all five students circled the phrase “hands-on”; four students circled “collaborative” and “fun”; and three students circled “organized”, “informative”, “exciting”, and “outdoorsy”. When asked about the importance of measuring and monitoring snowpack, all students’ answers included a connection between snowpack and water used for societal benefits. Every student was able to adequately define the term Snow-Water Equivalent after the project. Based on the variability in responses to defining the word “watershed” and drawing a detailed model of the water cycle, we can spend more time on these subjects next year.

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.

Multiple articles published this year that highlight cross-CZO collaboration were co-authored by SSCZO researchers: White et al. (2017) *Integrated Interdisciplinary Science of the Critical Zone as a Foundational Curriculum for Addressing Issues of Environmental Sustainability* and Brantley et al. (2017) *Designing a network of critical zone observatories to explore the living skin of the terrestrial Earth*. In addition, C. Riebe participated in a workshop that directly informed Brantley et al.'s 2017 publication *Reviews and syntheses: on the roles trees play in building and plumbing the critical zone* (see manuscript's acknowledgements).

Other cross-CZO projects utilizing our sites are ongoing, such as those by J. Richardson, A. Aguirre, P. Kumar, and A. Wlostowski. A. A. Berhe is also collaborating with C. Rasmussen and R. Lybrand to investigate deep soil carbon at multiple CZOs.

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. Many students, postdocs, and faculty involved are supported by non-CZO funds. Working with the USDA Forest Service is also important, and the SSCZO is in part co-located with Forest Service research programs. UC Merced provided academic-year institutional (research) support for two graduate students last year. The U.S. Forest Service provides a budget of several hundred thousand dollars per year for the streamflow, meteorological 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 PSW and UC Merced have also jointly supported research scientists and research assistants whose work focused on the SSCZO and the co-located Kings River Experimental Watersheds program.

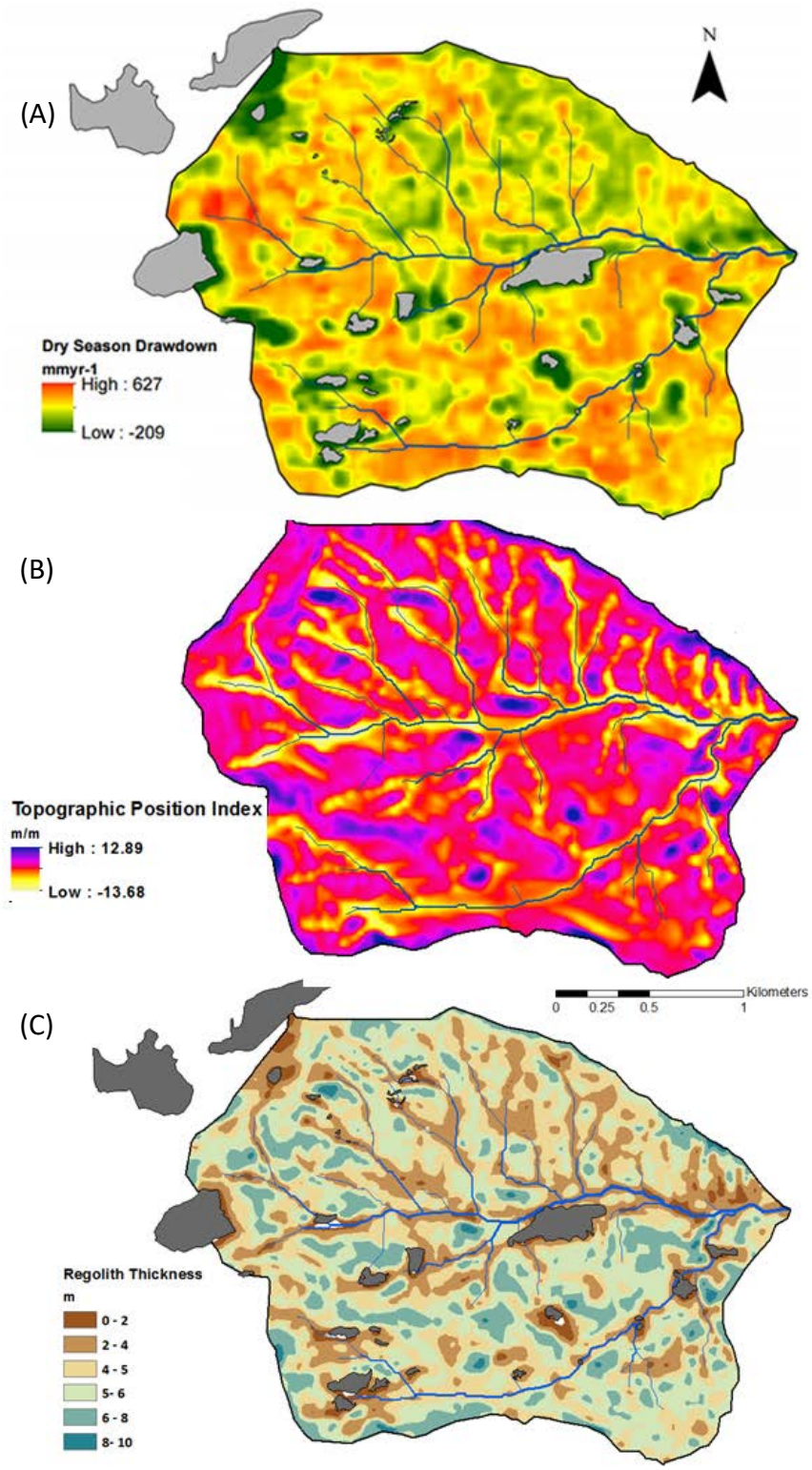


Figure 1. Maps of the Soaproot watershed showing (A) dry-season water-drawdown patterns, (B) topographic position index, and (C) modeled regolith thickness. Rock outcrops are grey and streams are dark blue lines. High topographic-position index values correspond to local topographic maximums such as convex ridges, while low values correspond to more-concave areas such as toeslopes. White areas in (C) represent negative thickness values typically corresponding to outcrop centers. Ferrell et al., in preparation.

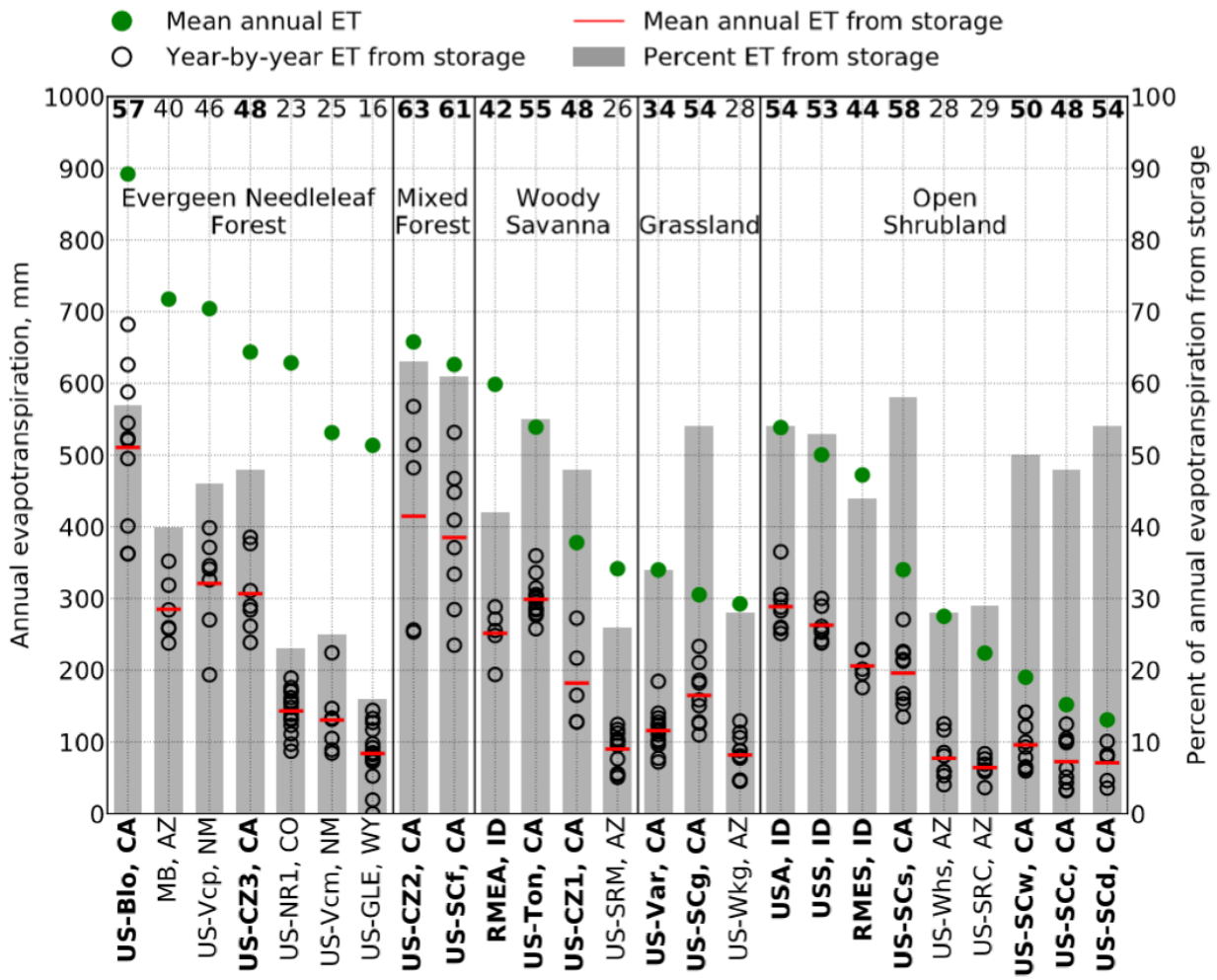


Figure 2. Amount of evapotranspiration (ET) supported by plant-accessible water storage for each water year on record by site. Site abbreviation is followed by state abbreviation. Vertical black lines separate land-cover types. Bold denotes Mediterranean climate sites. Rungee et al., under review.

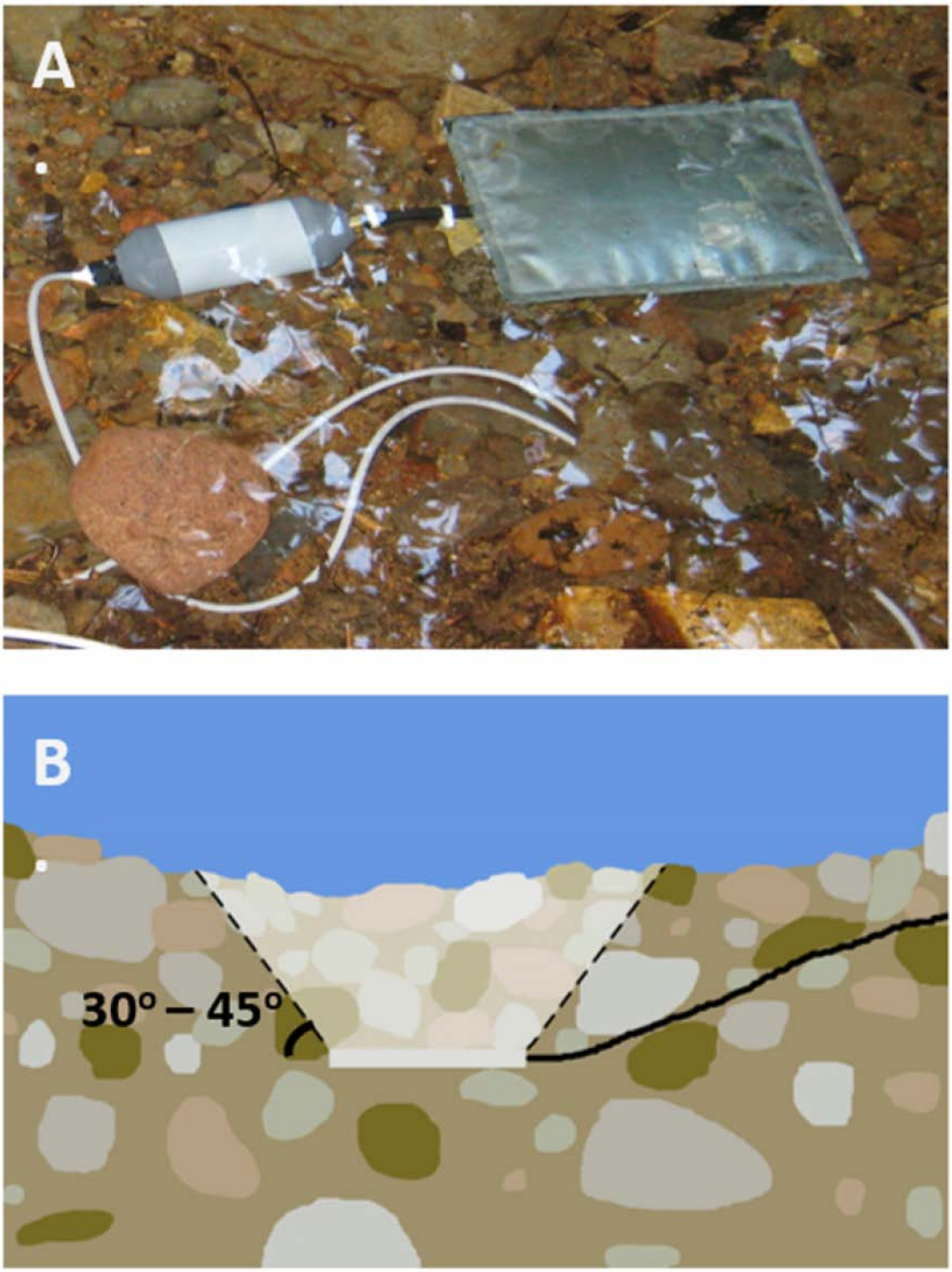
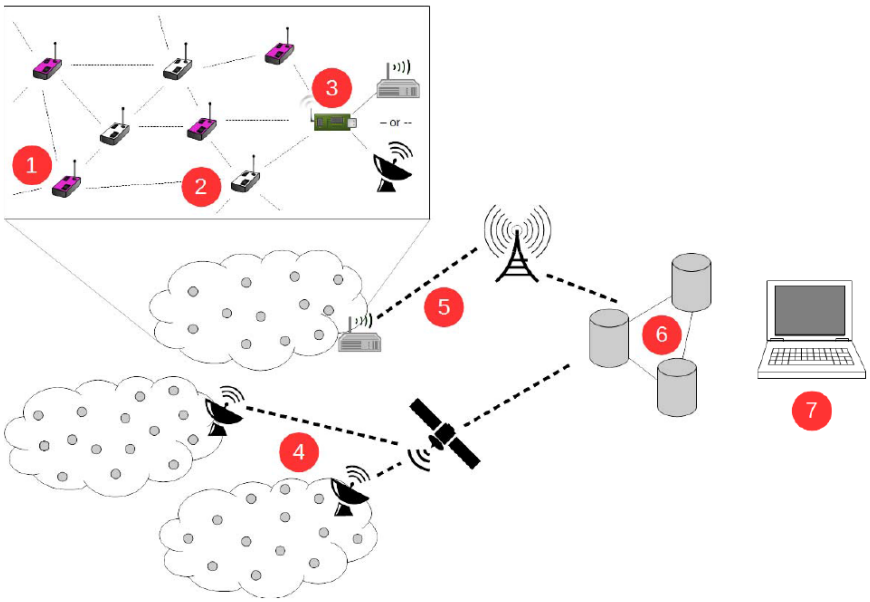


Figure 3. (A) Load-cell pressure sensor in a channel bed prior to burial. (B) Diagram of buried sensor showing the cone of influence above the sensor, based on a 30-45° angle of repose. Martin & Conklin, 2018.

(A)



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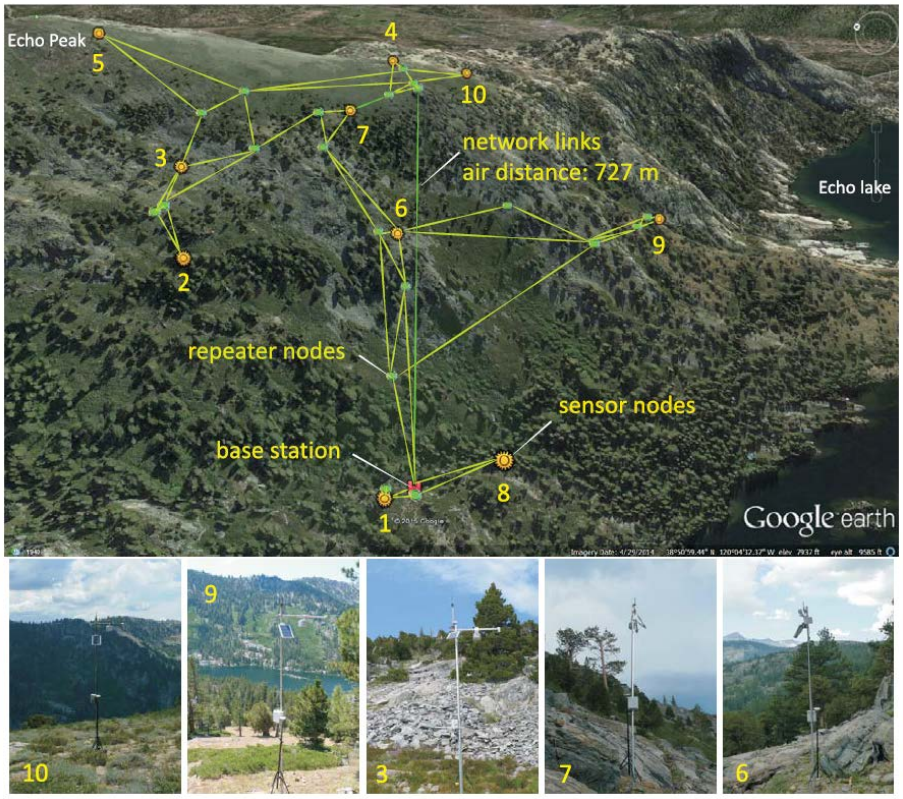

Figure 4. (A) WSN architecture. Sensor stations (1) are placed at hydrologically significant locations. Relay nodes (2) are added to ensure redundant connectivity. Sensor data is relayed to the manager (3) node, which is connected to a Linux computer. This computer connects to the Internet through a satellite (4) or a cellular link (5). Seconds after the generated data is produced in the deployment site, it appears in the database (6) and can be visualized online (7). (B) Typical WSN deployment. Sensor nodes are numbered 1-10 and located in variable terrains and vegetation coverages. Oroza et al., 2017.

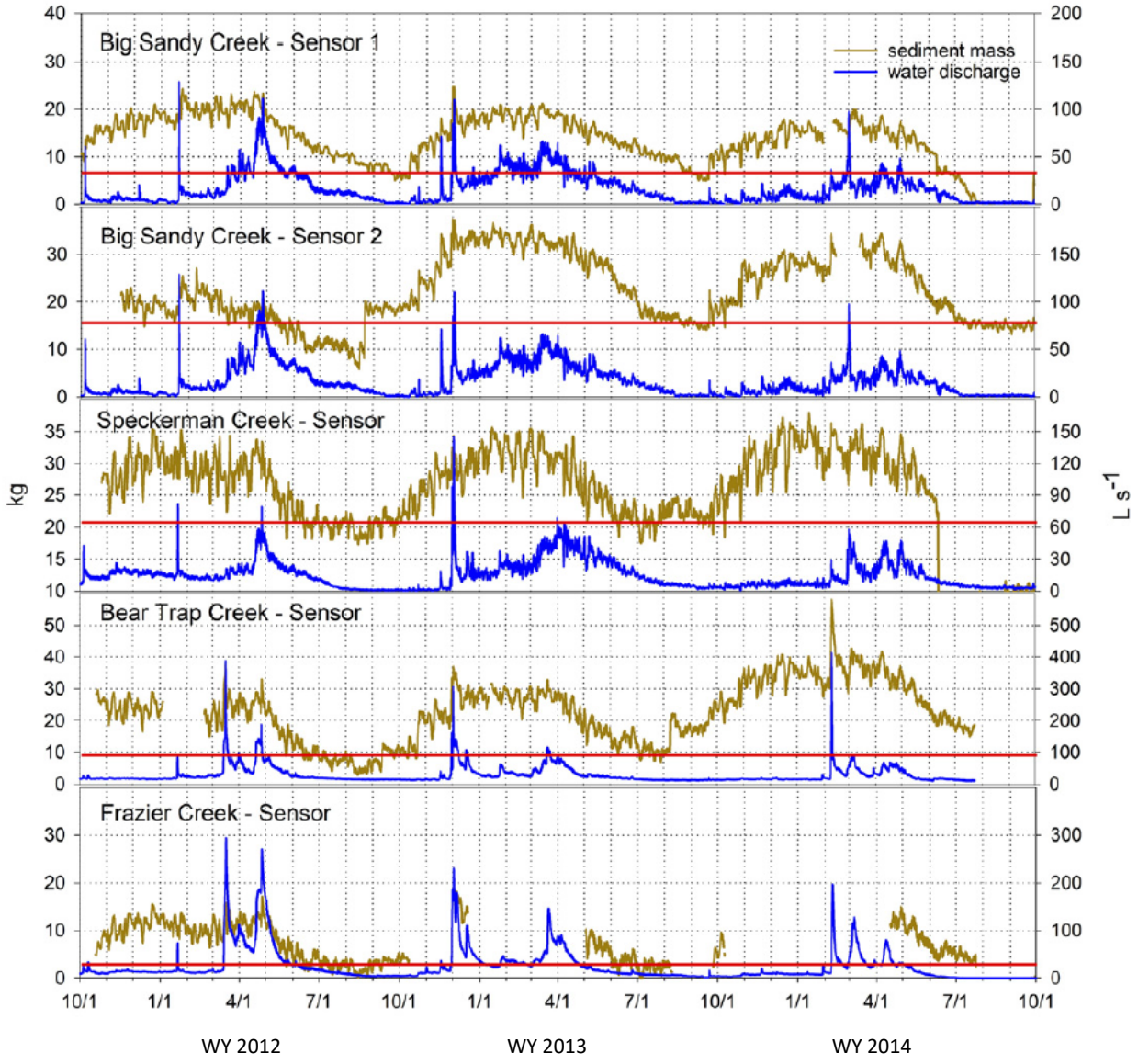

Figure 5. Load-cell pressure-sensor and water-discharge data for WY 2012–2014. Red horizontal line approximates annual stable level of channel-bed material. Drops in sediment observed at the end of WY 2014 in Big Sandy, Speckerman, and Bear Trap creeks are because of pans being unburied for calibration. Martin & Conklin, 2018.

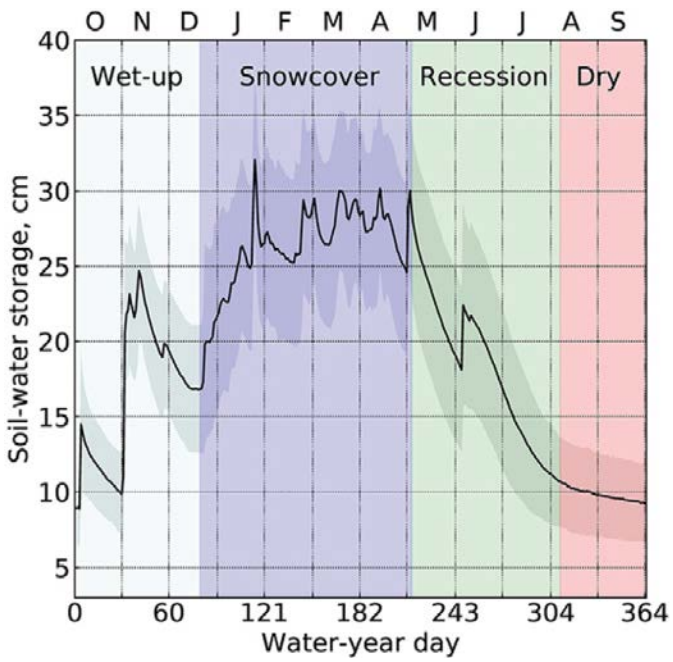

Figure 6. Mean and standard deviation of depth-integrated soil-water storage for an average-precipitation year (WY 2009) measured using WSN nodes. White, purple, green, and red sections indicate different seasons throughout the year. Oroza et al., 2018.

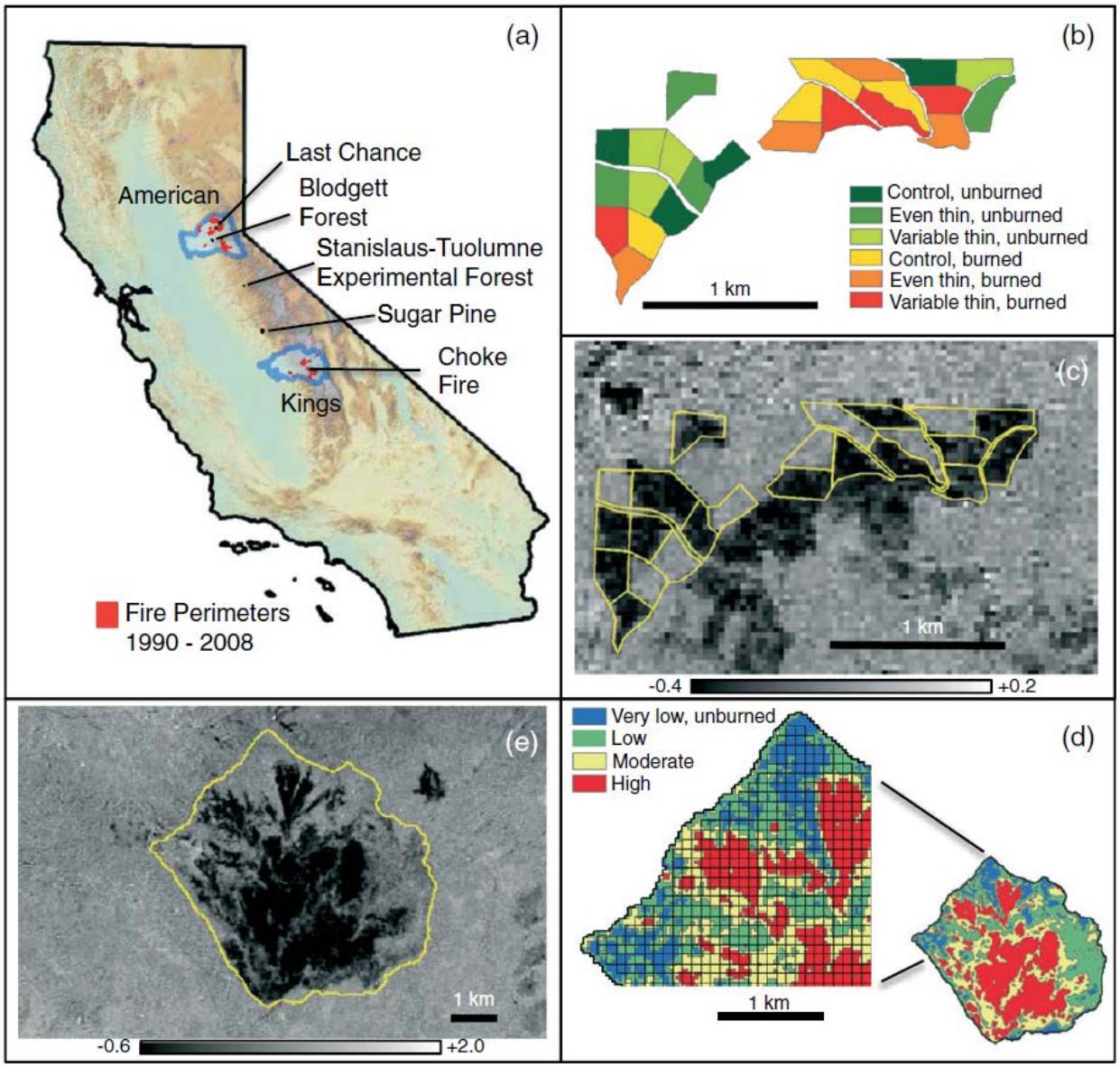

Figure 7. Location of forest fires and treatments examined in this study within California, USA, clockwise from top left: (a) overview map showing all fires in the American and Kings watersheds for the 1990–2008 period as well as selected forest treatment areas, (b) experimental forest thinning treatment design for the Stanislaus-Tuolumne Experimental Forest Variable Thinning Project (STEF), (c) NDVI change at STEF between July 22, 2010 and July 30, 2013, pretreatment and post-treatment, (d) perimeter and burn severity of the 1997 Choke Fire (lower right) and an expanded region of the fire that illustrates the 90-m polygon mesh used to sample Landsat NDVI imagery, and (e) NDVI change of Choke Fire between July 24, 1996 and July 30, 1998. Roche et al., 2018, *Ecohyology*.

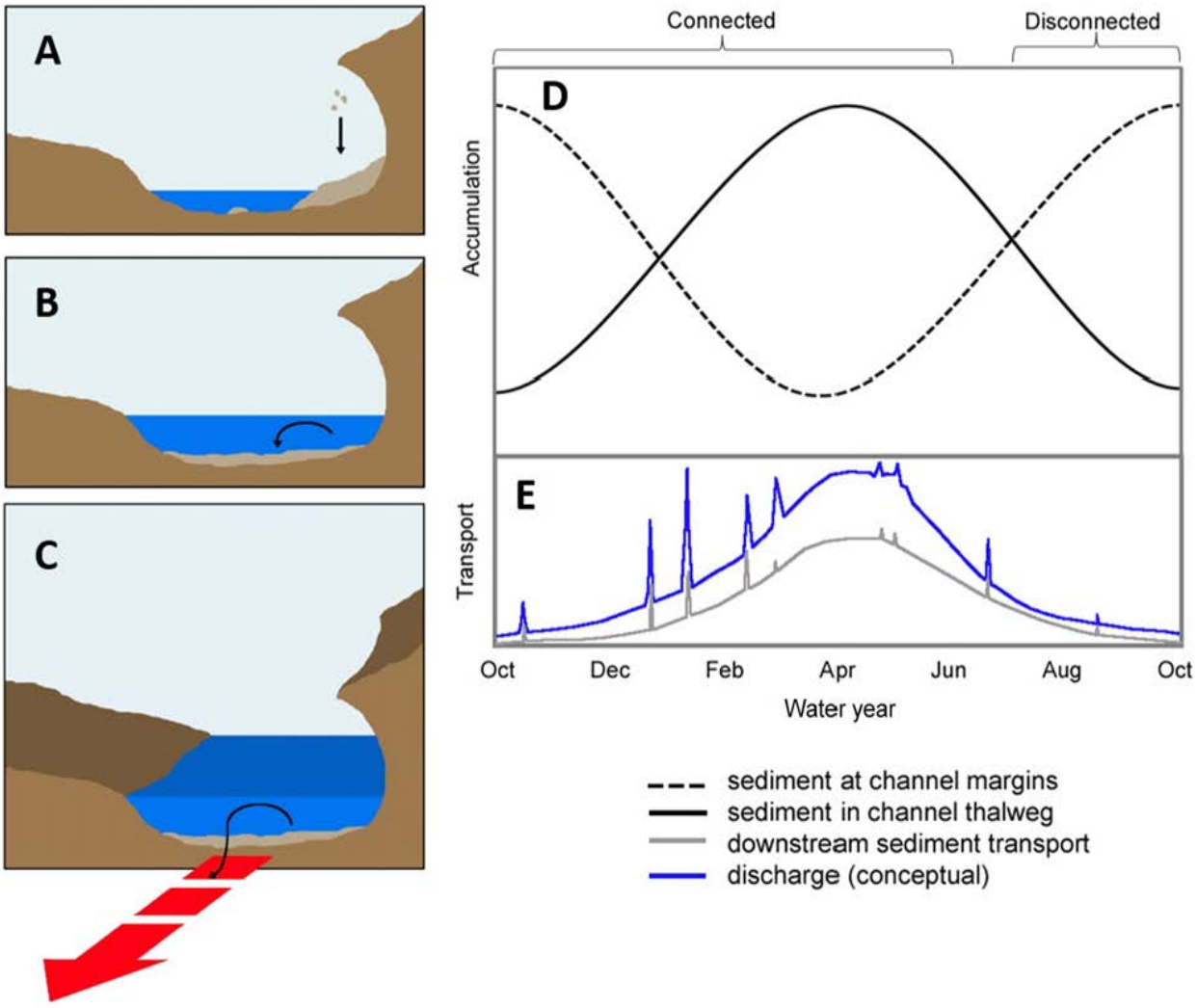

Figure 8. Conceptual model for montane streams in the Sierra Nevada. (A) shows sediment production from bank erosion at channel margins, where accumulation of sediment is highest toward the end of base flow. Material accumulates due to margin-thalweg disconnection in the dry months except for occasional scattered rain events. (B) shows a localized reworking of material within the cross section, which begins in early fall and continues through snowmelt (based on Martin et al., 2014). (C) depicts the conveyor-belt-like transport in the thalweg moving material progressively downstream with successive yet sporadic high flow events. (D) graphically represents the timing of these processes. The smoothed solid black line indicates the buildup and scour of material in the thalweg, which is measured by load cell pressure sensors (individual storm events are not depicted on this line). What the sensor sees in the thalweg is a balance of erosional processes at the margin, redistribution of material from margin to thalweg, and downstream transport of material. (E) represents a conceptual hydrograph for timing and context. Martin & Conklin, 2018.

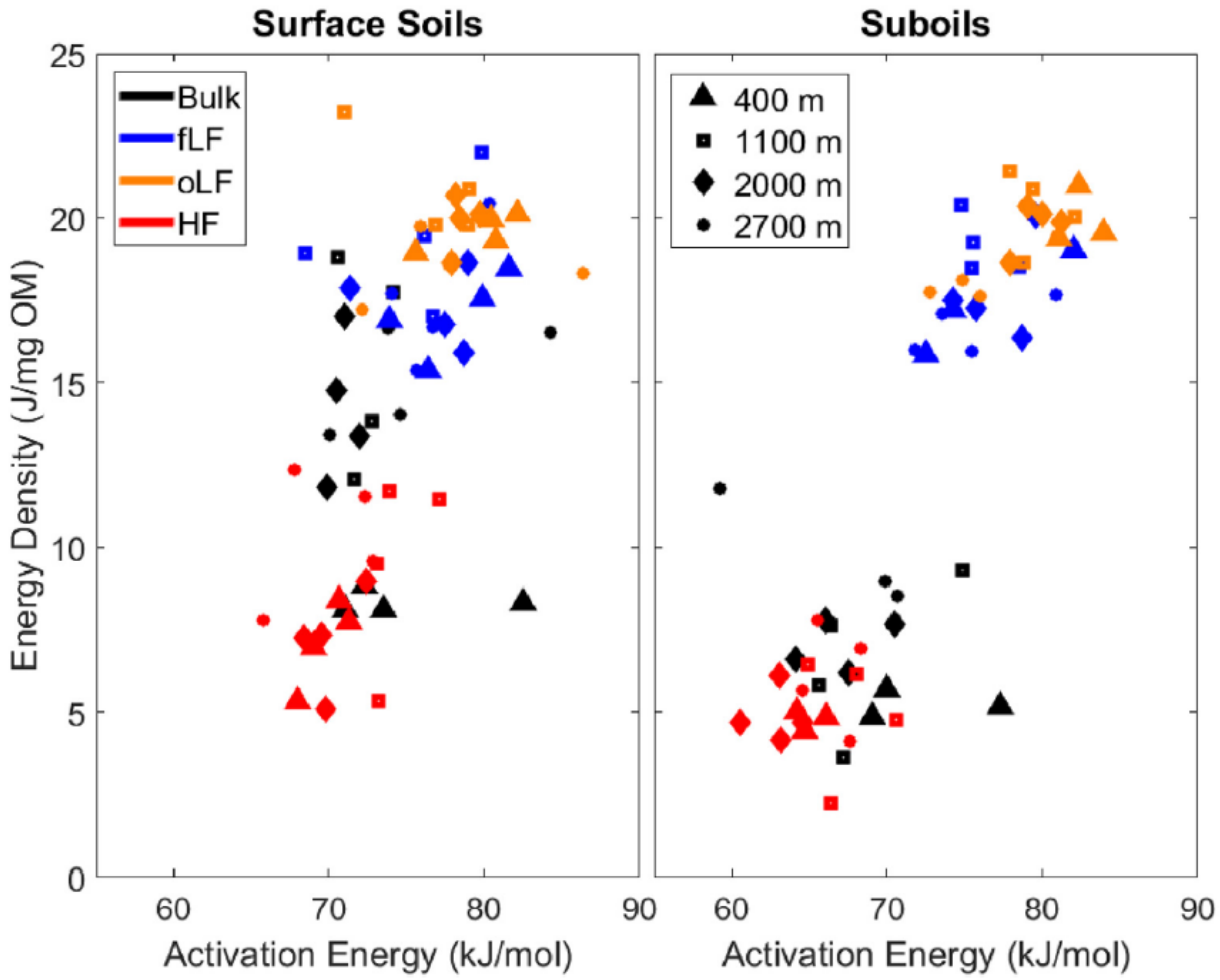

Figure 9. The relationship of energy density and activation energy for bulk soils and density fractions along the climosequence, where the differences in marker shape indicate different elevations and differences in marker color indicate different soil fractions. The bulk soils and heavy fractions are characterized by low energy density and activation energy, whereas the light fractions are characterized by high values. Williams et al., 2018.

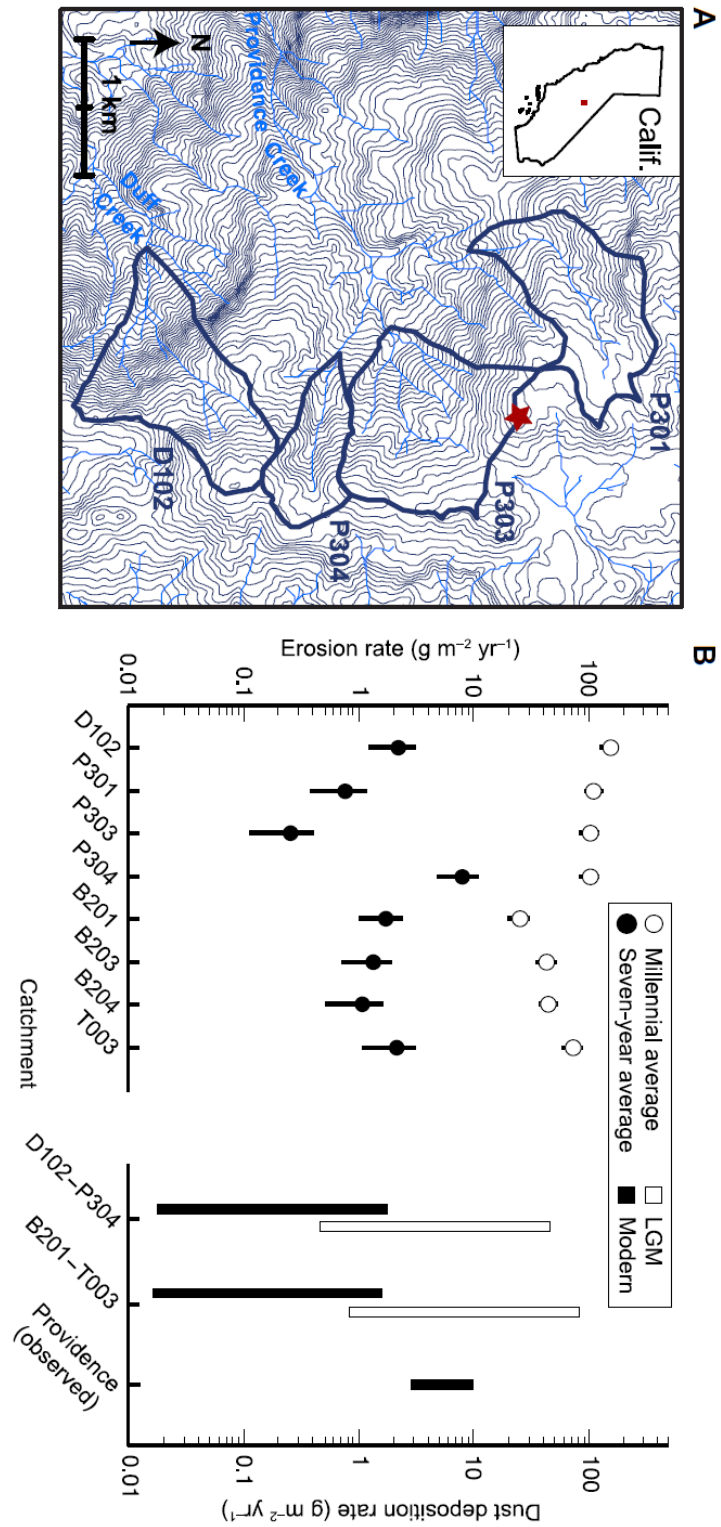

Figure 10. Erosion rates and dust fluxes in the southern Sierra Nevada, California. (A) Four southern Sierra catchments where erosion rates have been measured by both ^{10}Be and sediment yields. The star indicates the location of the Providence dust collection site from Aciego et al. (2017). (B) ^{10}Be-based erosion rates, sediment yield-based erosion rates, and modeled Last Glacial Maximum (LGM) and modern dust fluxes for eight southern Sierra Nevada catchments. Arvin et al., 2017.

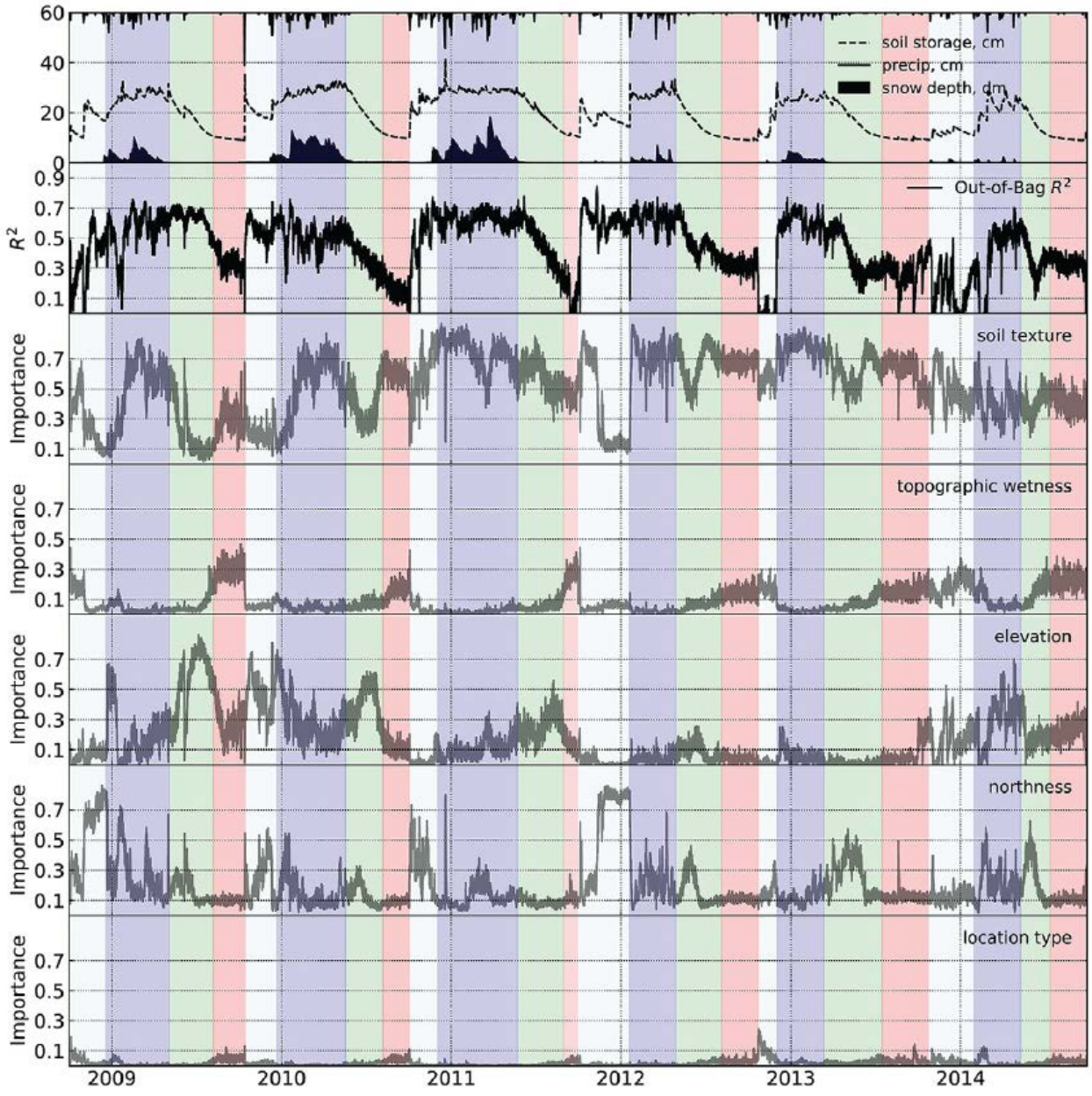

Figure 11. Regression-tree ensemble predictive accuracy and independent-variable ranking for six water years. Top panel shows daily precipitation, mean soil-moisture storage, and mean snow depth from all nodes. Second panel shows predictive accuracy (out-of-bag R^2) of the algorithm. The out-of-bag R^2 better represents accuracy on unobserved data. Lower panels show the relative importance of each predictive variable, values for which sum to 1.0. As in Figure 6 in this report, white is wet-up, purple is snow cover, green is recession, and red is dry. Oroza et al., 2018.

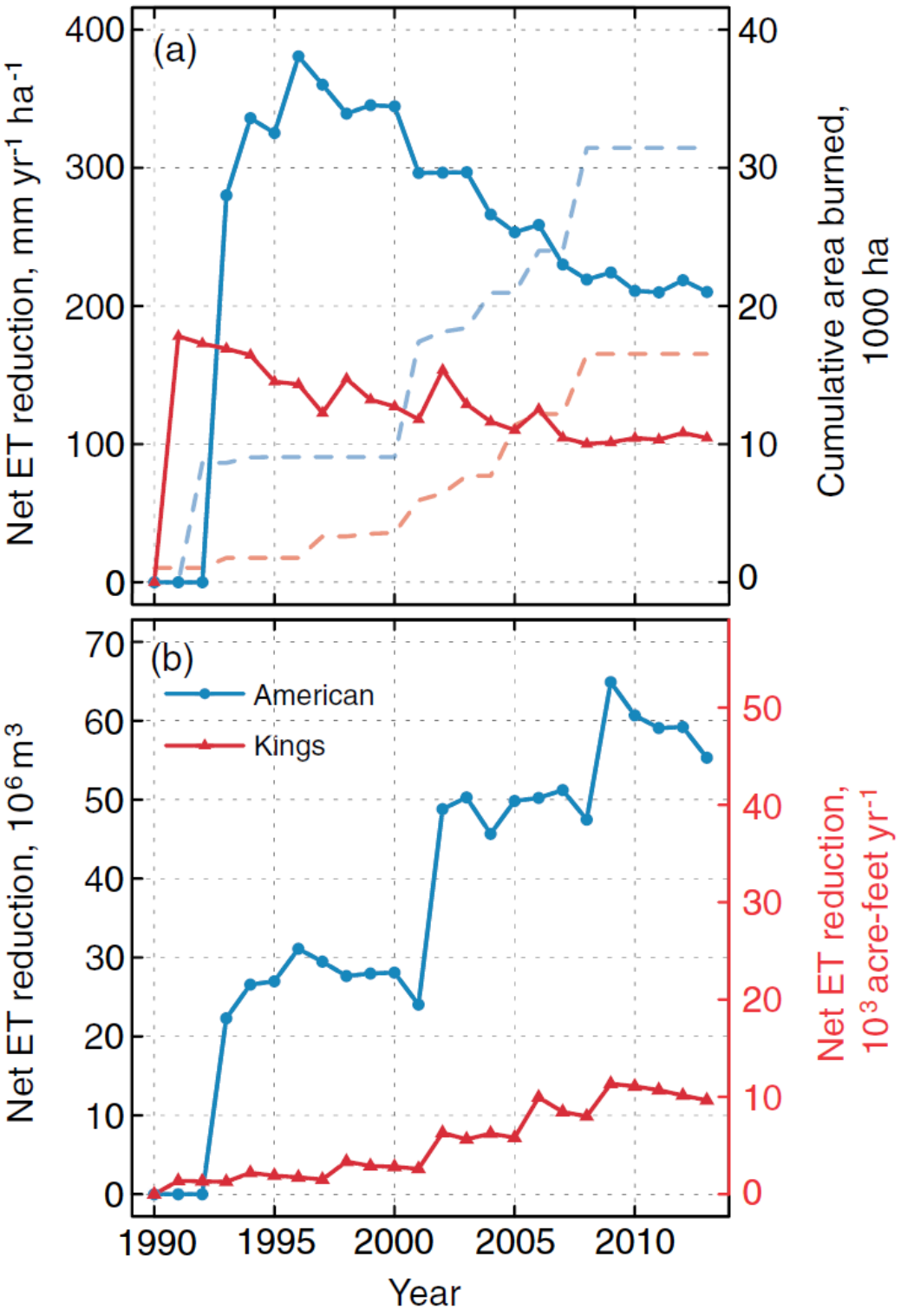

Figure 12. (a) Net annual ET reduction depth per unit area burned (bold lines) and cumulative area burned (dashed lines), and (b) net annual evapotranspiration (ET) reduction volume resulting from fires in the American and Kings River watersheds 1990–2008. Note the only fires through 2008 were included in the analysis. Roche et al., 2018, *Ecohyology*.

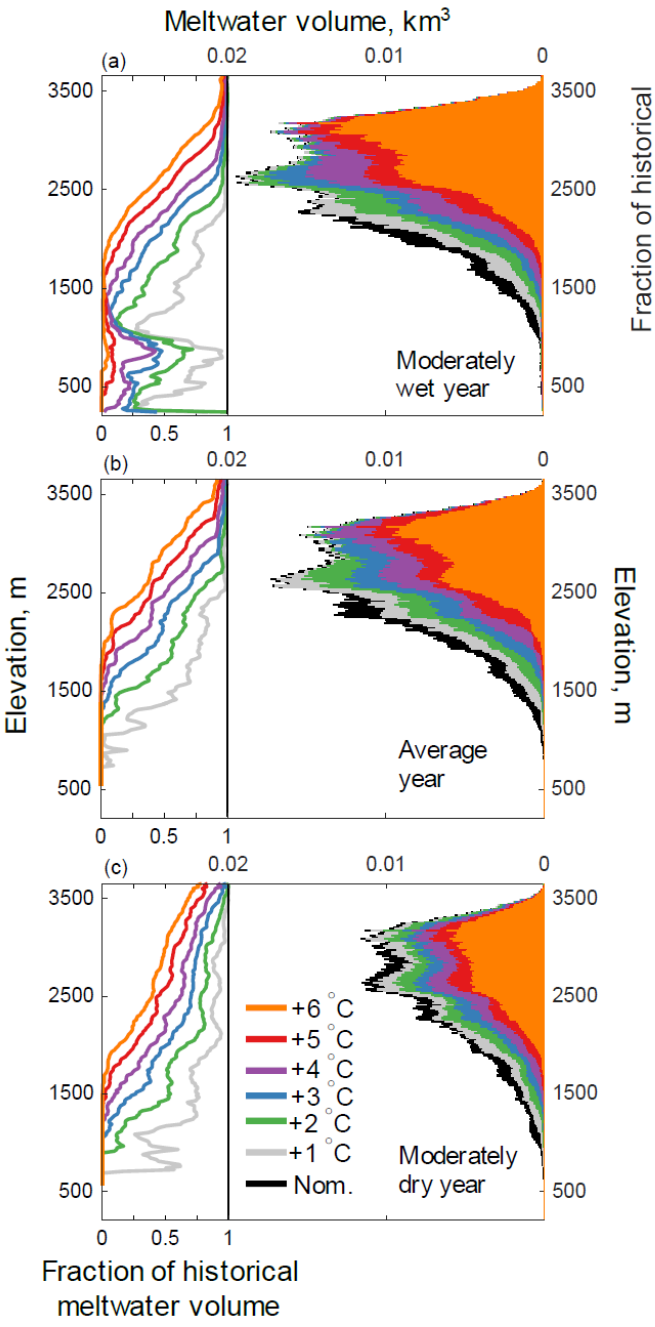

Figure 13. Elevation distribution (y axes) of simulated annual meltwater volume (bar graphs) and the fraction of that historical meltwater (line graphs) for each warmer scenario (colors; see legend) for the (a) moderately wet, (b) average, and (c) moderately dry snow seasons. The total meltwater was summed within the elevation bins. Musselman et al., 2017.

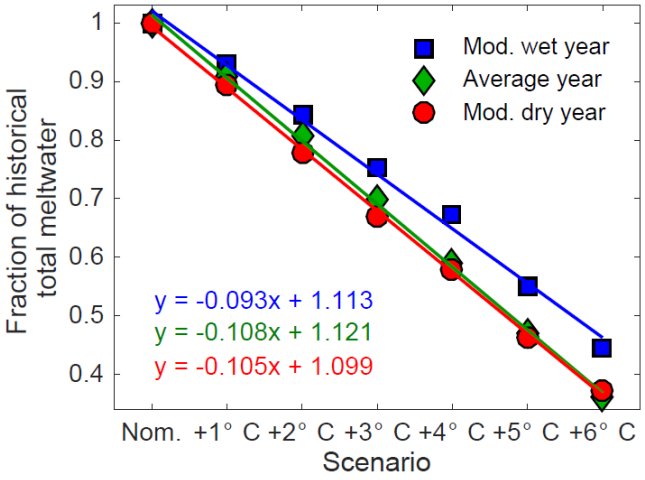

Figure 14. Fraction of simulated domain-wide historical meltwater (y axis), relative to the nominal case, for each warmer temperature scenario (x axis) for the three years (marker type and color). The colored lines and associated regression equations show linear fits to the data. For each year, the R^2 value was > 0.99 and the p value was << 1 x 10^{-6}. Musselman et al., 2017.

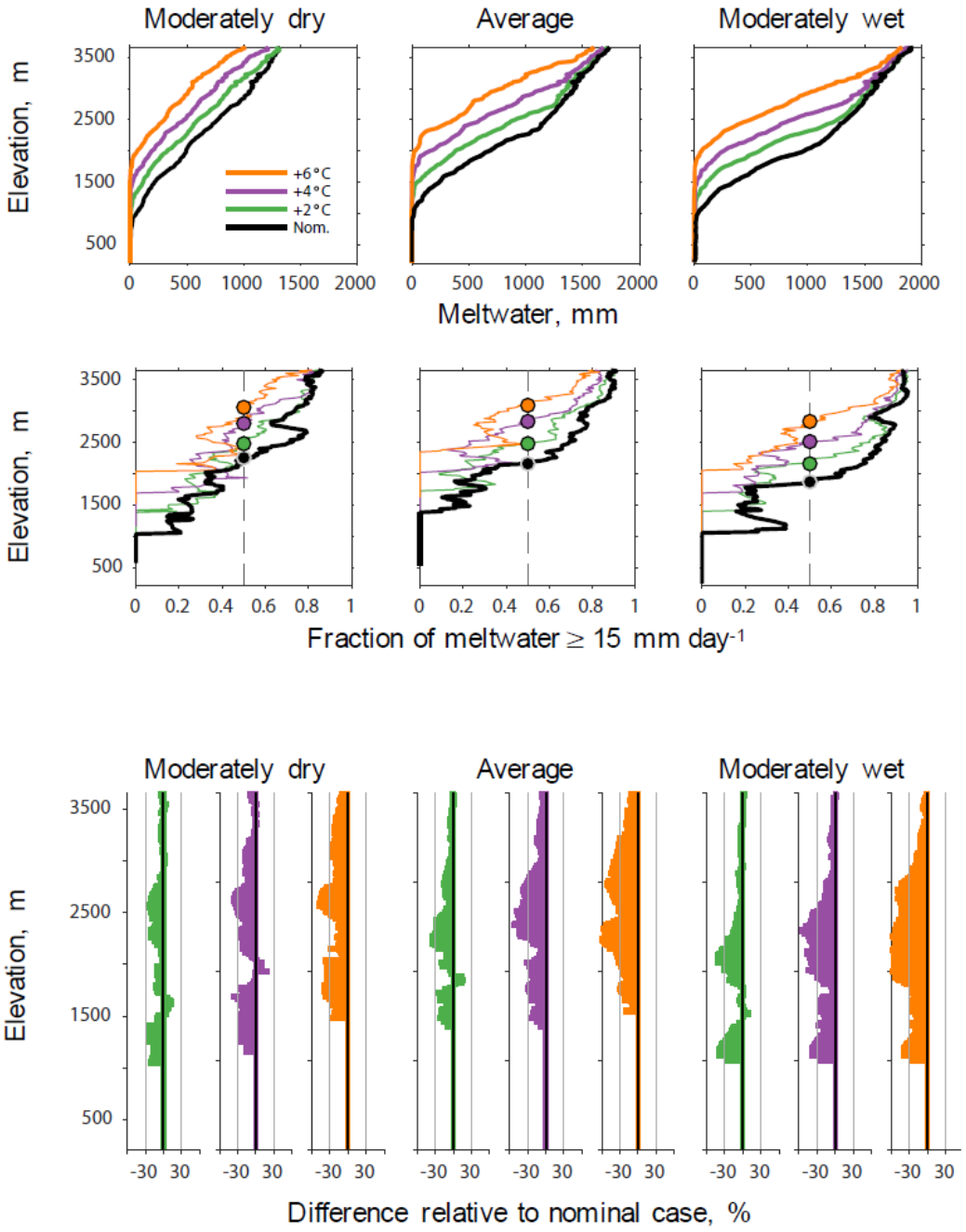

Figure 15. Top row of panels: the elevation distribution (y axes) of the average total depth of annual meltwater (x axes) simulated for the nominal case (black lines) and select perturbed temperature scenarios (colored lines). Second row of panels: the fraction of annual meltwater produced at snowmelt rates 15mm/day. The colored circles indicate elevations at which simulated melt occurs equally at rates 15mm/day and < 15mm/day. The lower panels of colored graphs show the differences from the nominal case, reported in percent of annual meltwater, produced at snowmelt rates 15mm/day for the three select scenarios. Results are shown for the moderately dry (2009; left column of plots), near-average (2008; middle column of plots), and moderately wet (2010; right column of plots) snow seasons. Musselman et al., 2017.

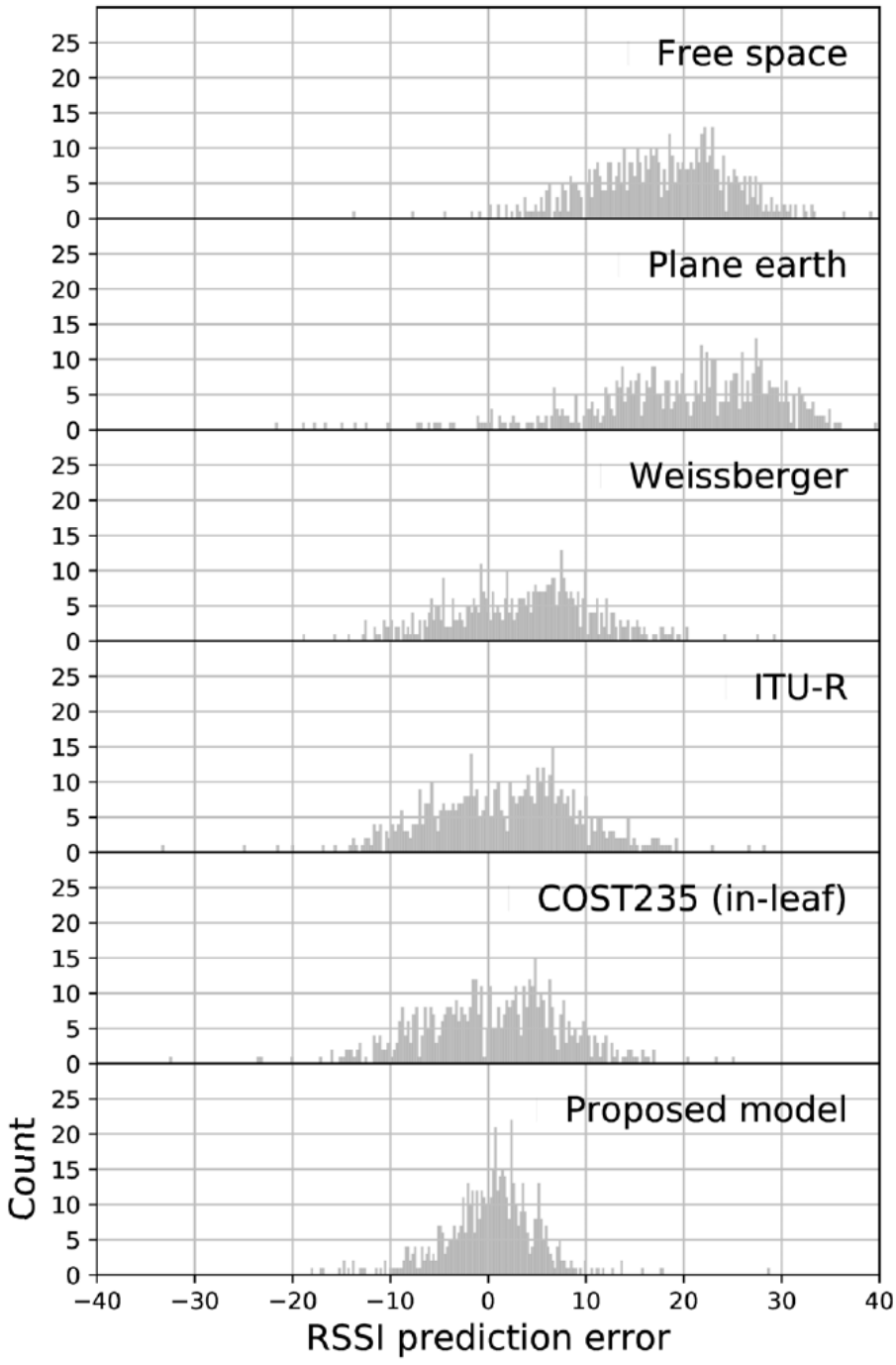

Figure 16. Distribution of errors under canonical and empirical models (top panels), compared to proposed model (bottom panel) for year-averaged RSSI data. Oroza et al., 2017.