Award 1331939 - Annual Project Report

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

The goals of the Southern Sierra Critical Zone Observatory (SSCZO) include: i) expand process-based understanding of the CZ in a sensitive, societally crucial ecosystem; ii) provide a platform for long-term physical, biogeochemical and ecological studies; and iii) develop a framework for improving Earth System Models. In addressing these goals, the SSCZO has measurements at four main sites spanning a steep elevation gradient in the southern Sierra Nevada. This spatial climate gradient in CZ properties and processes permits predicting effects of climate change by substitution of space for time. Building on our work of the first six years, the SSCZO is focused on a cross-disciplinary approach to understanding: i) the current distribution of CZ properties across the mountain front, ii) the processes governing CZ behavior, and iii) the rates that CZ properties can evolve and change. Our scientific goals are centered on 5 research questions and 3 implications (Fig. 1). These research questions are:

1. How do regolith properties and process of formation vary over 10-m to 100-km scales?

2. How do physics, chemistry, and biology interact to influence critical-zone function over instantaneous to decadal timescales?
3. How quickly do regolith properties change in response to altered climate and biota?
4. How do regolith development and properties control, limit or modulate effects of climate change, forest management or disturbance on hydrology, biogeochemistry and ecology?
5. What measurements of the critical zone at appropriate spatial and temporal scales, using cutting-edge technology, can best advance knowledge of the critical zone?

Management implications of particular concern include the effects of forest management on: i) plant production and the cycling of carbon and nitrogen through the system, ii) streamwater quality and iii) forest evapotranspiration and streamflow. Of note, we emphasize that these are large, thematic issues; we recognize that while the SSCZO will advance knowledge on these questions, more-complete answers will emerge over the next 5 years through cooperation with sister CZOs and the broader community.

*** What was accomplished under these goals?**

Major Activities:

These research questions were addressed through a coordinated set of activities involving investigators from six institutions and the USDA Forest Service (FS), plus many more collaborators who used Southern Sierra Critical Zone Observatory (SSCZO) data and infrastructure to address the questions listed as part of our major goals, and complementary questions. Work this year focused on 11 primary activities.

1. Analysis of geochemical work at the Providence site has led to three publications. Ongoing work on regolith formation and erosion includes the expansion of geochemical regolith and rock analyses across the site transect for constraints on weathering and water storage potential at depth; cosmogenic-derived sediment tracing; and near-surface (<40 m depth) geophysical analyses. In particular, we have made significant progress in waveform tomography of our seismic refraction data.
2. Expansion of the soil-regolith relationship was achieved through sampling with a Geoprobe drilling rig at the oak woodland (400 m elev.) and pine/oak forest (1100 m elev.). Chemical and physical properties were measured on the cores and hydrologic monitoring wells and neutron-access probes were installed at each of the sites for soil-moisture monitoring. Geochemical analyses of regolith and rock samples from the CZO has expanded to include the three new sites along the altitudinal transect. Analysis of samples from the two lower sites is progressing.
3. Meteorological and eddy-covariance measurements continued at the three tower sites. Most of the maintenance effort went into processing and quality controlling the data sets. We continue to freely share these data with the SSCZO and broader communities. A replacement for the damaged subalpine tower is being installed in summer 2014, and the SSCZO is investigating potential sites for a high-elevation (above treeline) expansion of the eddy-covariance transect. Other work focused on fabrication and lab testing of a tower-top remote-sensing system.
4. In meadows, well and piezometer monitoring data were compared with historical data streams and geochemical data, and results were corroborated by end-member mixing analysis. Available information, including geophysical work, is being used to build a 2D flow model of the system. In addition, we deployed an eddy-correlation station in Long Meadow.
5. Sediment sources were evaluated through composition and stable-isotopic analysis of additional hillslope and stream-bank samples.

6. Modeling efforts continued with RHESSys and PIHM to integrate hydrologic and ecosystem biogeochemical cycling processes across the system. We developed a soil-moisture and sapflux data-collection strategy to capture spatial patterns of soil moisture and vegetation responses to inter-annual climate variability. The data are used to identify model structural errors and parameterization requirements and to suggest improvements. We use the data to test working hypotheses that model errors reflect spatial variability and errors in inputs. Results from this analysis will inform future modeling and the interpretation of estimates from RHESSys and other hydrologic models applied in this region. Ongoing simulations across the flux-tower climate gradient are being used to quantify sensitivity of ET and carbon-flux estimates to climate drivers and geologic properties.
7. The wireless sensor network is being updated with more-robust hardware and software. Recent improvements in hardware and programs for the wireless sensor network have been designed and tested in the lab. New neomote boards with embedded radios, were finalized over the past year. Tests of long-range telemetry and wireless communication with the new radios are in progress. All work is slated to be completed by September, 2014. LiDAR data will be integrated into an algorithm for site selection on future installations.
8. There were contributions by SSCZO investigators and researchers to multiple workshops and courses, including the NSF-sponsored workshop on Drilling, Sampling, and Imaging the Depths of the Critical Zone (October 2013), Watershed Science Master Class (January 2014), and the Wireless Bootcamp (August 2014).
9. The team continued serving quality-controlled data to CZO users and to the broader critical-zone community through a digital library and other community platforms. This included ongoing, spatially distributed measurements of water, energy and carbon fluxes and reservoirs, geochemical data, and spatial data on vegetation, nutrient stores, and landscape features.
10. Through K-12 partnerships, undergraduate experiences, published results, posted data, stakeholder meetings, and media projects, we leveraged education opportunities and created broader impacts. SSCZO developed an exercise for the American Geosciences Institute centered on water-resource management.
11. The SSCZO team encouraged cross-site science activities, including planning for common data products, sharing results, encouraging cross-site research, and building common infrastructure.

As part of the shift to focus on the full 2500-m elevation transect, several activities were expanded across the transect. These included hydrologic modeling and subsurface profile sampling, in addition to the ongoing eddy-covariance and meteorological work.

Specific Objectives:

A CZO spanning the rain-dominated oak savannah to the snow-dominated conifer forests of the southern Sierra Nevada is providing opportunities to develop much-needed process-based understanding of critical-zone function, evolution, and response to both rapid seasonal changes and human-induced perturbations. This understanding has applications in many areas relevant to society, including forest management, water-resources management and adaptation to climate change.

The twin threats of a changing climate and land-use practices raise fundamental questions about the sustainability of critical-zone services in the southern Sierra Nevada. The Southern Sierra CZO was developed to make progress on these questions, using an integrated, multi-disciplinary approach.

The Sierra Nevada provides water to over 10% of the U.S. population and about 40% of the runoff for California as a whole. Climate warming is shifting the elevation of the rain-snow transition, the seasonal timing of snowmelt runoff, soil-water dynamics, plant water-use and growing-season temperatures, thus dramatically altering the water cycle, weathering processes and ecosystem function. Snowmelt and streamflow timing are already occurring earlier each spring in response to warming (as much as +2ºC in recent decades). This increases the risks of springtime floods and late-summer moisture stress. Increased frequency of multi-year droughts and higher-intensity rainfall events have been predicted and may compound the hazards associated with seasonal shifts. A range of forest disturbances, including drought-related dieback, fire, disease, and background mortality, are expected to intensify with increasing drought frequency and severity. Short- to medium-term effects of climate change (floods and drought) will interact with long-term processes, including species shifts, with as yet poorly understood consequences for ecosystem function and material fluxes.

Forest-management practices are changing throughout the Western United States, with unclear consequences for critical-zone processes, including biogeochemical cycling and material fluxes. High densities of forest fuels in western mountains elevate the risk of catastrophic wildfire, and reflect fundamental changes in the structure and composition of mixed-conifer forests. Competition for resources has reduced forest resiliency, allowing pests to spread faster and with more virulence and possibly increasing vulnerability to drought. In the absence of periodic fire, standing dead and surface fuels accumulate and thus alter weathering and biogeochemical cycling. This also drastically alters fire behavior, especially when coupled with increased understory growth of shade-tolerant, “ladder-fuel” species. The implications for soil properties, water retention, nutrient movement, and erosion are largely unknown but likely significant. The Southern Sierra CZO addresses these questions in an integrated framework.

Significant Results:

Summary Since October 2013, the SSCZO had several significant findings. Hydrologic and nutrient-cycling modeling has been applied across the full transect and results are being interpreted. Geophysical techniques demonstrated that the bedrock weathering front was as deep as 30-40 m in some locations. Erosion rates on a long-term time scale (geologic scale measured through cosmogenic isotopes) are nearly 100x short-term rates based on recent measurements of sediment discharge. Differences in bedrock nutrient concentrations play a role in vegetation cover of the landscape, where exposed domes and unvegetated spaces have lower P concentrations than nearby dense forests. The combined depth of soil and regolith may relate to the water reserves accessible by vegetation. Evapotranspiration across three sites has been progressively attenuated in relation to soil depth during the past 3 years. This is one of several CZ processes that the ongoing California drought has illuminated. Another unexpected result is the continued groundwater discharge point in the studied meadows. Warmer temperatures will accelerate snowmelt, as seen in our snowmelt manipulation experiment; this impacts shallow soil moisture 2-4 months after snowmelt.

Drilling, sampling, & imaging regolith Three published papers are based on the results from the Providence site (at 2000 m elevation) that were collected over the first 6 years of the project. This includes one on factors that influence the presence/absence of soil and vegetation across the landscape. This paper reports strong evidence in support of our hypothesis that the notable bimodality in soil and vegetative cover is regulated by differences in the geochemistry of underlying bedrock (Fig. 2).

Controls on weathering & regolith formation Work focused on understanding relationships between characteristics of soils (top 1.5 m) and weathered bedrock (>1.5 m). We sampled soils and weathered bedrock to the depth of refusal using a Geoprobe across the elevational gradient at two of the four catchments [oak savannah/400 m elev., and pine-oak forest/1100 m elev.]. The 2700 m elev. site was

not sampled because it has little weathered bedrock due to glaciation. The mixed-conifer (2000 m elev.) forest site had been sampled previously. Across 3 sites, chemical and physical properties were measured from more than 170 core subsamples; analyses included saturated hydraulic conductivity, texture, bulk density, pH, total C and N, cation exchange capacity, extractable base cations, available P, and mineralogical characteristics.

Two projects are evaluating erosion controls. On a geologic time scale, cosmogenic-based sediment tracing work includes an analysis of (U-Th)/He ages in apatite from sediment in streams draining the east side of the Sierra Nevada. The goal is to use the bedrock ages to constrain the source elevations of stream sediment, which is ultimately generated from rock on slopes and thus carries a geochemical fingerprint of the source. To assess the short-term scale of sediment sources, soils from stream banks and hillslopes were analyzed for stable isotopes. Soil samples were sent off for analysis for ^{13}C and ^{15}N, and radiocarbon. Results to date suggest the majority of sediments are mostly surficial with some carving occurring in established channels (Fig. 3).

Relationship between elevation/climate & exchanges of carbon and water Our work on the eddy-covariance flux towers has led to a paper that is in revision at PNAS, as well as three chapters from A. Kelly's dissertation that should be submitted in the coming months. Mean ET projected for 2085-2100 for different scenarios (for a constant precipitation and warming) shows a marked increase at higher elevations compared to current conditions ET (Fig. 4). Other work on the flux towers involved the design, fabrication, and preliminary lab testing of a down-looking, tower-top, remote-sensing package that will be deployed at the P301 site. This system includes separate Vis/NIR and thermal IR cameras, along with a terrestrial scanning LiDAR. This will provide information on vegetation structure, health, and gas exchange; foliage and biomass temperature, to better understand the controls on winter photosynthesis and summer stress; and the 3D structure of the canopy, as well as the patterns of snow accumulation and melt.

We are investigating surface-groundwater exchange of Sierra Nevada montane meadows in the context of greater watershed processes. Monitoring wells and piezometers located in our meadows show that the meadow center continues to be a groundwater discharge point, even after two low precipitation years (Fig. 5). Results for analysis of the water for S-35, an isotope with a 90-day half-life, indicate that the water is over a year old.

The discrepancy between vertical gradients at the edge versus center of the meadow is reflected in the horizontal groundwater gradient. During snowmelt, the horizontal gradient exhibits flow more toward the center of the meadow (Fig. 6), becoming more parallel to streamflow later in the season (Fig. 7). This is indicative of shallow subsurface water discharging from the hillslope during snowmelt. As snowmelt subsides, the shallow subsurface source is diminished. Hence the vertical gradient at the meadow edge changes from groundwater discharge to recharge and the change in horizontal gradient seen in Figures 6 and 7.

Endmember-mixing analysis on streamwater chemistry is supportive, showing spring streamwater more closely resembles the snow endmember and moves toward the groundwater endmember as the season progresses. Streamwater deviates from this pattern when fall rain events occur (Fig. 8). The local meteoric water line differs slightly from the global meteoric water line (Fig. 9).

In order to tie this work together, we have started building a HYDRUS 2-D model of the upper P301 watershed using our knowledge of the meadow system, our collaborator knowledge of the adjacent forest hydrology, and the conceptual model proposed by Holbrook et al. (2014) based on geophysical work in the watershed.

Relationship between elevation/climate & nutrient cycling Completed drafts of three papers summarize baseline RHESSys model simulation (Fig. 9) and establish spatial resolution requirements (Fig. 10) and the importance of soil parameter uncertainty for ecohydrologic estimates (Fig. 11). We also extended existing RHESSys implementation to include all four flux towers at the Southern Sierra CZO. Our preliminary modeling study showed that the model captured observed ET flux at P301 flux tower, and the effects of spatial resolution of model on estimating annual ET and NPP were minor. We also found that annual ET and NPP estimates are more sensitive to root-zone, water-holding-capacity parameters than drainage parameters.

Effect of forest management on water & nutrient cycling Water and nutrient cycling are also being tracked in discharge and soil flows. Water samples from the Forest Service archives were analyzed in house for TC, TOC, TN, pH, and aromatic C from WY 2009. A small subset of the same samples were analyzed for common cations and anions to compare agreement with FS data. Investigation of nutrient hot spot and hot moments at two plots in Providence include separate horizontal grids of ion-exchange resin capsules located at multiple depths. Resin capsules are collected after first precipitation in autumn and post-snowmelt in spring. Nutrients analyzed include: Ca, Mg, Na, NH_4^+, NO_3^-, and PO_4^{3-}. Resins have been extracted and all chemical analyses completed for the last three sampling dates (from 2012 and 2013). Following previous datasets from these plots (Johnson et al. 2011 and Johnson et al. 2014), these data will help distinguish hot spots (persistence of high nutrient concentrations at a single location over multiple time periods) from hot moments (episodically high nutrient concentrations at a single location).

Key outcomes or Other achievements:

From the outset the Southern Sierra CZO was planned as a resource for the critical-zone research community, and our team has actively engaged others in using this resource. Three levels of users are represented at the Southern Sierra CZO: the core CZO team, research collaborators and cooperators. Our core team represents six universities plus the USFS. Over 20 research groups are collaborators; these groups are not formally part of the Southern Sierra CZO grant but work with the core team using largely other resources and are an important part of the SSCZO. In addition, several additional cooperators use Southern Sierra CZO data, collect samples at the Southern Sierra CZO or make use of other CZO resources in their own work.

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

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

In addition to stakeholders and decision makers, the Southern Sierra CZO has an active program of education and outreach to K-16 and the general public. Some of the most-successful education and outreach activities over the past year include building relationships with schools and local organizations. Colleagues and staff work with NatureBridge Yosemite to provide instructor trainings on hydrologic concepts and snowpack science. NatureBridge has provided award-winning, residential outdoor education programs in Yosemite National Park (YNP) for school groups since 1971. Approximately 13,000 California students cycle through this program every year. Two SSCZO researchers presented to NatureBridge teachers this past year, and SSCZO Co-PI M. Conklin remains a member of the NatureBridge Yosemite board.

Multiple other SSCZO efforts have contributed to curriculum development or teacher training. SSCZO staff E. Stacy, L. Sullivan, and M. Conklin have given interactive presentations to, among others, California Agricultural Teachers Association; TASTES, a local teacher training program; and STEM-Tracks, a two-year teacher development program covering three mountain counties. SSCZO student R. Lucas was an instructor at the California Institute for Biodiversity (CIB) Climate Change Workshop. He communicated CZO science, namely in the context of climate change, to K-12 teachers that attend the workshop. This summer, he will participate in an additional institute through CIB that will focus on bringing field investigations into K-12 classrooms in the intent to help facilitate the implementation of Next Generation Science Standards. An activity simulating water resource management decisions, developed by R. Lucas and E. Stacy, was adapted for the American Geosciences Institute for teachers, where 16,000 teachers received the free activity with additional information provided on the website.

Other K-12 partnerships include presenting each year at Southern California Edison's Science Days (4th year presenting) and the American Association of University Girls Science Camp (5^{th} year presenting). At these events CZO colleagues facilitate hands-on activities for students that focus on how Sierra Nevada hydrology impacts California's water resources. Our K-12 partnership with the Center for Advanced Research and Technology (CART) in Clovis, CA, continued, with CZO staff mentoring teams of CART students to conduct a comprehensive snow survey research project (3rd consecutive year).

At the undergraduate level, students from UC Merced and partnering universities have worked as field and lab technicians. Using supplemental funds from NSF, two REU students are working at the SSCZO this year. One is focusing on soil nutrient cycling while the other works on meadow water balance. This marks the third year for the UC Merced surface water methods, developed by M. Conklin, and the fifth successive year for the UC Davis field-methods course, developed by SSCZO researcher P. Hartsough. The SSCZO site visits with Hartsough and Conklin with the SSCZO staff allows students to learn about research and to collect data for use in class. SSCZO research provided material for other university courses as well. Currently M. Conklin and E. Stacy are part of an InTeGrate team to develop a critical zone processes course. Baseline CZO RHESSys model implementations were used to develop educational materials for two courses: ESM 237 Climate Change Impacts and Adaptation, a graduate course in the Bren School for Environmental Science and Management and ESM 495 Introduction to hydrologic modeling. RHESSys simulation results from CZO were also integrated into a new CUASHI Watershed Hydrology Master Class held at Biosphere in Tuscon Arizona. Investigator C. Tague was the hydrologic modeling instructor.

Modeling holds an important role in disseminating research results. Modifications by C. Tague to the Regional Hydro-Ecologic Simulation System (RHESSys) serve as mechanisms for encoding advances made by our field-based analyses. RHESSys is made freely available to the community and regular user training is provided.

Staff and researchers have organized two major field trips for researchers this year, and hosted workshops and sessions at the Geological Society of America meeting, the annual meeting of American

Geophysical Union, and the Mountain Research Initiative Global Fair and Workshop on Mountain Observatories. The Southern Sierra CZO is actively planning the 2014 All Hands Meeting for the CZO Network, where we will host researchers from the other 9 observatories, as well as prominent researchers from outside the network and country. The meeting will provide a venue for presenting research results; we anticipate several hard products from this researcher meeting, including outlines for journal articles, workshop ideas, and modeling approaches.

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

Several graduate students, undergraduates and recent Ph.D. graduates are involved with the CZO, and are preparing themselves for independent measurement and data analysis work in field hydrology, biogeochemistry, geophysics, and modeling. 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 both investigators and graduate students. In addition, two undergraduate students are gaining firsthand experience in field work and data analysis through the Research Experience for Undergraduates program, funded through a supplemental grant from NSF. They will present on their summer projects in August.

Other training opportunities have been organized through open workshops. In the past year, C. Riebe has actively worked as PI on a grant to organize and NSF-sponsored workshop on Drilling, Sampling, and Imaging the Depths of the Critical Zone. The workshop occurred over the period October 24–26, 2013, in Denver, CO and featured an international group of speakers and attendees (49 attendees). A report has been published online, on the criticalzone.org website. Investigators R. Bales and S. Glaser are working with CUAHSI to host a multi-day Wireless Bootcamp, August 2014 in Berkeley.

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

Our communication and sharing of scientific products with stakeholders includes frequent talks around the state, hosting of visits to our laboratories and SSCZO site, news articles in local publications, op-ed pieces in newspapers, radio interviews, television reports and web publications. A major focus has been on working with water leaders in the state to define and develop prototypes for a new water-information system for California that builds on advances in wireless-sensor networks developed at the SSCZO, plus parallel advances in cyberinfrastructure and in measurements by satellite and aircraft. We presented a snippet of our research to Congressman Jim Costa and German Ambassador Peter Ammon during their visit to UC Merced. Our presentation highlighted the use of our wireless sensor network providing real-time *in situ* measurements and our meadow eddy correlation measurements. Since the start of the current cooperative agreement in fall 2013, SSCZO PI R. Bales and Co-PI M. Conklin have briefed the California State Board of Food and Agriculture, Delta Stewardship Council, 3 Integrated Regional Water Management authorities, the National Park Service, the Sierra Water Work Group, and presented at the UC Legislative Drought Summit, and the multi-agency Fire Ecosystem Forest Management & Water Yield Symposium, California Water Policy Conference 23, Urban Water Institute's Spring Water Conference and other symposiums. C. Tague presented the current RHESSys model-based analysis of the linkages between forest hydrology and carbon cycling with climate variability at the stakeholder meeting of the California Forest Pest Council 62nd Annual Meeting.

The general public is also the audience for many of our communications, including press reports. We have given public talks in local communities, as well as presentations to civic organizations. The Southern Sierra CZO has been employing internet tools as part of its outreach program. SSCZO presences on Twitter and Facebook have gained more followers. These social media platforms are available to the public but also provide a way to disseminate information about events and activities to

CZO and non-CZO researchers and students. E. Stacy has organized a monthly Science Café for the City of Merced, drawing on SSCZO as well as other science issues of public interest. SSCZO PI R. Bales and Co-PI M. Conklin have presented to local civic groups (including Merced City Council and Rotary Club), California Partnership for the San Joaquin Valley,UC Merced trustees, and the University Friends Circle, and other public audiences. SSCZO staff E. Stacy contributed a research perspective to two region-wide meetings of watershed managers, non-profit groups, and interested parties.

The SSCZO education team is working with researchers to create new interactive activities for K-12 students using CZO data. These activities are designed to meet new common-core standards for analytical thinking and problem solving. Partnerships with NatureBridge Yosemite and the Center for Advanced Research and Technology will share research results with educators and students alike. SSCZO researchers and education staff also present to grade school students multiple times per year. New partnerships this year include curriculum development or teacher training partnerships with California Agricultural Teachers Association, TASTES, California Institute for Biodiversity (CIB) Climate Change Workshop and other CIB programs, and the STEM-Tracks grant based in Sonora, CA.

Dissemination to the research community included alerting potentially interested colleagues publications and presentations through our web pages and email, attending scientific meetings and workshops, and participating in CZO-network activities. Improvements to our digital library and engagement with CZO-network data-sharing activities were also carried out. At the 2013 American Geophysical Union Fall Meeting, the 2013 Geological Society of America and the 2014 Goldschmidt conference, SSCZO PIs, graduate students and research staff presented talks and posters (15 at AGU and several at GSA and Goldschmidt). The national CZO program was an exhibitor throughout the duration of both AGU and GSA conferences, providing information on all CZO sites, and investigators contributed to Town Hall at the 2013 AGU Fall Meeting, a student session at the 2014 Goldschmidt conference, and will host a session at the Mountain Research Initiative Global Fair and Workshop on Mountain Observatories in Reno, NV, July 2014.

Also for researchers, SSCZO staff and researchers hosted a field trip for 8 professional researchers prior to the Goldschmidt 2014 conference. Another large trip is planned following the MRI Global Fair and Workshop on Mountain Observatories; this is a collaborative effort with the U.S. Forest Service and the National Park Service that will discuss long-term monitoring in two national forests, Yosemite National Park, and at Mono Lake. Finally, a large amount of investigator and staff time has been dedicated to planning for the 2014 All-Hands Meeting, to be held September 21-24, 2014, Fishcamp, CA.

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

The next reporting period will include the balance of year 1 (through Sept 30) and extend for one year, through part of year 2. Some of the work in progress is described above, with a summary of key activities provided here. Three main types of activities are summarized. First, several graduate students have completed their research and papers based on their work are being submitted for publication. SSCZO and cross-site papers describing research being carried out by Co-PIs and postdocs are also being wrapped up and submitted. Second, field research is proceeding, with several upgrades and subsurface investigations enabled by the new cooperative agreement. New collaborators are also joining the SSCZO. Third, many of the outreach activities described for 2013-14 are continuing, with additional activities being added for the coming year.

With the new award in fall 2014 and completion of several graduate students this year, the Southern Sierra Critical Zone Observatory has recruited 10 new students, to work with SSCZO investigators at the SSCZO. Some are working this summer and others will join in the fall.

Modeling, data analysis and publication preparation activities build on the first 6 years of SSCZO research. Some of the near-term work that is maturing, in addition to the many activities described earlier in this report, follow.

- We are synthesizing the geochemical data on weathering with the cosmogenic nuclide data on erosion that we have been collecting over the years.
- Modeling of the effects of recent vegetation treatments on catchment hydrologic processes will be completed for the P301 and P303 catchments this summer, with results extended to other catchments based on detailed parameterization developed for these sites. The RHESSys model is being used for this.
- Also using the RHESSys model, we will compare ecophysiological and drainage parameter sensitivity at the P301 flux tower (rain-snow transition site) with results for towers at higher and lower elevations. These results can be used to infer how underlying geological properties influence climate responses along our CZO elevation gradient. In particular, in the next year we will focus on data assimilation of vegetation structural and physiological information into RHESSys estimates and use this improved parameterization to estimate implication of changing vegetation structure (growth, thinning, fire) and type (shrub, grass, tree species) on water use and carbon cycling. We combine existing CZO measurements with new leaf water potential measurements made by collaborator M. Moritz.
- Further papers on water balance, incorporating COSMOS and wireless-sensor-network soil moisture data, flux-tower evapotranspiration measurements, and other distributed data are in progress and should be submitted in late summer or early fall. This work explores effects of drought on water storage and fluxes, and resiliency of the forest given subsurface properties.
- Data from last summer's meadow eddy-covariance deployment are being analyzed. The station is being redeployed to pick up a second growing season's worth of data. Data from the eddy-correlation instrumentation will allow us to better measure and constrain evapotranspiration from the meadow. Additionally, this instrumentation will give us the opportunity to quantify carbon fluxes in the meadow.

The coming three months (before the close of the first year of the Cooperative Agreement), are critical to our fieldwork. Planned field activities are outlined below.

- Updates to the wireless sensor network, including installation of more resilient hardware, updated firmware, and testing long-range telemetry from the tower
- Installing and testing a tower-mounted remote sensing apparatus
- More geophysical work at multiple sites in preparation for the drilling program
- Reassigning P301 sapflow/soil moisture equipment at other Sierra CZO locations
- Deployment of the eddy correlation station in Long Meadow (SEKI NP)
- Continued data hydrologic collection (both fluxes and water chemistry, including S-35 isotopes) in P301 meadows and Long Meadow (SEKI NP).
- Installation of additional passive dust traps between June and August, so that we have a sufficient number of collectors at each of the four sites along the transect to sufficient dust for analysis.

Our outreach using public talks, briefings with decisionmakers and presentations at scientific meetings will continue along the lines initiated in past years. Some of the additional highlights planned for the next several months follow.

- A field trip is planned for July 20-22 following the MRI Global Fair and Workshop on Mountain Observatories; this is a collaborative effort with the U.S. Forest Service and the National Park Service that will discuss long-term monitoring in two national forests, Yosemite National Park, and at Mono Lake. SSCZO staff E. Stacy is the primary organizer for this trip.
- The Annual Team Meeting will be held August 4-5 in Fresno, CA. Approximately 25-30 researchers attend each year to exchange research results, plan field work, and strategize for the coming year. Local collaborators (in California) join us when schedules allow.
- The Wireless Sensing Boot Camp will be held August 11-13, 2014 in Berkeley, CA. Sponsored by CUAHSI and CZO, this workshop will cover theory to practice of radio design, network synchronization, equipment deployment, and other aspects of wireless sensor networks.
- The SSCZO Annual Team Meeting is scheduled for August 4-5, 2014. Meanwhile, the SSCZO community is planning to host the 2014 All-Hands Meeting, the first in more than three years. Five CZO network investigators (R. Bales, M. Conklin, S. Anderson, J. Chorover, and W. Silver) and SSCZO staff E. Stacy are developing the meeting agenda. Three field trips to CZ installations in the region will be a part of the program.

Supporting Files

	Filename	Description
(See end of file)	SSCZO_2014_Results_figs.pdf	The pdf file SSCZO_2014_Results_figs.pdf presents figures 1-11 with explanatory captions (includes research questions and overarching findings).

Products

Books

Book Chapters

- Granger, D. E. & Riebe, C. S. (2014). Cosmogenic Nuclides in Weathering and Erosion. *Treatise on Geochemistry: Surface and Ground Water, Weathering, and Soils* 7. J. I. Drever. Elsevier. London. 401. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Conference Papers and Presentations

- Son, K. and C. Tague. (2013). *A framework for improving the predictions of ecohydrologic responses to climate change in Sierra Critical Zone Observatory watersheds. Abstract H23F-1333*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Riebe, C.S. W.J. Hahm; and C. Lukens (2013). *Bedrock composition limits mountain ecosystem productivity and landscape evolution (Invited). Abstract B13L-02*. AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Jepsen, S.M., S. Coles, and T.C. Harmon (2013). *Catchment Scale Streamflow Response to Climate Variability in the Rain-Snow Transition Zone of California's Sierra Nevada Mountains.*

Abstract H31H-1314. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Hartsough, P.C., A.I. Malazian, M. Meadows, A.T. O'Geen, J. W. Hopmans (2013). *Characterization of Water Use Patterns in the Deep Vadose Zone through Geoprobe Drilling into Weathered Bedrock*. GSA Cordilleran Section Meeting. Fresno, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Riebe, C.S., L.S. Sklar, C.E. Lukens, and D. Shuster (2013). *Climate and Topography Control the Size and Flux of Sediment Produced on Steep Mountain Slopes*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Tague, C., K. Son, T. Brandt, and A.L. Dugger. (2013). *Climate warming and eco-hydrology of forested watersheds in the California Sierra (Invited). Abstract EP11A-07*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Rogers, H. E.; Riebe, C. S.; Granger, D. E. (2013). *Cosmogenic 10Be in quartz and magnetite: Using the same nuclide in multiple minerals to quantify differential weathering*. AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Brantley, S.L., White, T.S., Anderson, S.P., Bales, R.C., Chorover, J., McDowell, W.H. (2013). *Critical Zone Science and Observatories Town Hall: TH15D-01*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Zhang, Z., C. Oroza, S.D. Glaser, R.C. Bales and M.H. Conklin. (2013). *Developing a robust wireless sensor network structure for environmental sensing. Abstract C41B-0630*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Kirchner, P., R.C. Bales, and T.H. Painter (2013). *Estimating forest snow accumulation with LiDAR derived canopy metrics, southern Sierra Nevada, California. Abstract H13J-1507*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Lukens, C., C.S. Riebe, L.S. Sklar, and D.L. Shuster. (2013). *Evidence for climatic and topographic control of the size and flux of eroded sediment across a steep mountain catchment. Abstract EP52A-05*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Saksa, P.C., R.L. Ray, R.C. Bales, and M.H. Conklin. (2013). *Impacts of forest thinning and climate change on transpiration and runoff rates in Sierra Nevada mixed-conifer headwater catchments. Abstract GC11B-0990*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Kelly, A.E., M. Goulden, and A.W. Fellows (2013). *Interactions between cold and water limitation along a climate gradient produce sharp thresholds in ecosystem type, carbon balance, and water cycling. Abstract B23D-0585*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Berhe A.A., E.M. Stacy, E.P. McCorkle, D.W. Johnson, C.T. Hunsaker, and S.C. Hart (2013). *Mineral-organic matter associations in eroding hillslopes: findings from headwater catchments in the Southern Sierra Nevada (Invited). Abstract B21H-02*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Lucas, R.G., and M.H. Conklin (2013). *Montane meadows and hydrologic connections between forests and streams in the Sierra Nevada, California. Abstract H43K-01*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Riebe, C. S. and Chorover, J. (2014). *Report on Drilling, Sampling, and Imaging the Depths of the Critical Zone, an NSF Workshop*. Open Project Report to the Critical Zone Community. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Driscoll J.M., Meixner T., Steven J., Molotch N., Williams M.W., Sickman J.O. (2013). *Role of storage on hydrologic and chemical flux in soil-limited alpine catchments in the Southwestern USA*. AGU Chapman Conference on Soil-mediated Drivers of Coupled Biogeochemical and Hydrological Processes Across Scales. Biosphere 2, Tucson, Arizona. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hopmans, J.W. (2013). *Soil and Tree Water Status Dynamics in a Mixed-Conifer Forest of the Southern Sierra Critical Zone Observatory*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hahm, W.J., C.S. Riebe, C.E. Lukens, and S. Araki (2013). *Strong Lithologic Control on Mountain Ecosystem Productivity and Landscape Evolution*. GSA Annual Meeting. Denver, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bales R.C., Brooks P.D., Molotch N.P. (2013). *The strength of strategically placed in situ networks: The Critical Zone Observatory Program (Invited). Abstract H53L-02*. Fall Meeting, American Geophysical Union, December 2013. San Francisco, CA. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Meadows, M.W., R.C. Bales, M.H. Conklin, M. Goulden, P.C. Hartsough, J.W. Hopmans, C.T. Hunsaker, R.G. Lucas and A.I. Malazian. (2013). *Timber harvest effect on soil moisture in the southern Sierra Nevada: Is there a measurable impact? Abstract H11B-1165*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- McCorkle, E.P., A.A. Berhe, C.T. Hunsaker, M.L. Fogel, and S.C. Hart (2013). *Using stable isotopes to determine sources of eroded carbon in low-order Sierra Nevada catchments. Abstract B13G-0604*. Fall Meeting, American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Inventions

Journals

- Blankinship, J.C., Meadows, M.W., Lucas, R.G., and Hart, S.C. (2014). Snowmelt timing alters shallow but not deep soil moisture in the Sierra Nevada. *WRR*. 50 (2), 1448. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; DOI: 10.1002/2013WR014541
- Dixon, J. L., Riebe, C. S. (2014). Tracing and pacing soil across landscapes. *Elements*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes
- Goulden, M.L., R.C. Bales (). Mountain runoff vulnerability to increased evapotranspiration with vegetation expansion. *Proceedings of the National Academy of Sciences*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes
- Hahm, W.J., C.S. Riebe, C.E. Lukens, and S. Araki. (2014). Bedrock composition regulates mountain ecosystems and landscape evolution. *PNAS*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; DOI: 10.1073/pnas.1315667111

- Holbrook, W.S., C.S. Riebe, M. Elwaseif, J.L. Hayes, K. Reeder, D. Harry, A. Malazian, A. Dosseto, P.C. Hartsough, J.W. Hopmans (2014). Geophysical constraints on deep weathering and water storage potential in the Southern Sierra Critical Zone Observatory. *Earth Surface Processes and Landforms*. 39 (3), 366. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; DOI: 10.1002/esp.3502
- Johnson, D.W., C. Woodward, M.W. Meadows (2014). A Three-dimensional View of Nutrient Hotspots in a Sierra Nevada Forest Soil. *Soil Science Society of America Journal*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; DOI: 10.2136/sssaj2013.08.0348
- Kirchner1, P.B., Bales, R.C., Molotch, N.P., Flanagan, J., Guo, Q. (). LiDAR measurement of seasonal snow accumulation along an elevation gradient in the southern Sierra Nevada, California. *Hydrology and Earth System Science*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Riebe, C. S., Hahm, W. J., Brantley, S. L. (2014). Going deep to quantify limits on weathering in the Critical Zone. *Earth Surface Processes and Landforms*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes
- Riebe, C.S., Sklar, L.S., Lukens, C E.* & Shuster, D.L (). Climate and topography control the size and flux of sediment produced on steep mountain slopes. *Proceedings of the National Academy of Sciences*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes
- Shaw, G.D., M.H. Conklin, G.J. Nimz, and F. Liu. (2014). Groundwater and surface water flow to the Merced River, Yosemite Valley, California: 36Cl and Cl− evidence. *Water Resources Research*. 50 (3), 1943. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; DOI: 10.1002/2013WR014222
- Son, K. and Tague, C. (). Importance of soil parameter uncertainty in assessing climate change projections in small two Sierra Nevada watersheds. *Water Resources Research*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes
- Woodward, C., Johnson, D.W., Meadows, M.W., Miller, W.W., Hynes, M.M., and Robertson, C.M. (2013). Nutrient Hot Spots in a Sierra Nevada Forest Soil: Temporal Characteristics and Relations to Microbial Communities. *Soil Science*. 178 (11), 585. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; DOI: 10.1097/SS.0000000000000023

Licenses

Other Products

- *Educational aids or Curricula.*

For InTeGrate (Interdisciplinary Teaching about Earth for a Sustainable Future), M. Conklin and E. Stacy worked with a cross-CZO team of researchers to create curriculum for a Critical Zone university-level course. Course materials, including activities, lesson plans, and assessments, will be available through the Science Education Resource Center at Carleton College.

- *Educational aids or Curricula.*

The CZOs have cooperated for the past two years with the American Geosciences Institute (AGI) to create hands-on learning exercises using CZO data for use in secondary education classrooms. The one-page double-sided exercises were included in AGI's Earth Sciences Week packets and sent to 16,000 teachers nationwide in June 2014. The exercises are attached to this news story and are also available at the National Education and Outreach K-12 portion of criticalzone.org.

Other Publications

- Bales, R. (2014). *Can Forest Management to reduce fire risk in the high Sierra result in more stream-flow at the mountain front?*. Presentation at Sierra Nevada Research Institute 2014 Research Symposium. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Conklin, M. (2014). *Climate Change & Drought in the Sierra*. Opening Plenary, day 2 of Sierra Water Work Group Summit. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bales, R. (2014). *Current Science: Water impacts*. Presentation at Water-Forestry Forum. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bales, R.C. (2014). *Drought & the Sierra Nevada in a changing climate*. Sierra Water Work Group Annual Meeting. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bales, R. (2014). *Forest Water Management*. Presentation at How Green Is Your Valley? Your Voice, Your Future. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Stacy, E. M. (2014). *Forest Water Research Updates*. Presented to California Native Plant Society. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bales, R (2014). *Forest management and stream flows in the Sierra*. Presentation at University of California Drought Summit. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Stacy, E.M (2013). *Forest management presentation at the San Joaquin Region Road Show*. Presentation to agriculture and science teachers. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bales, R. (2014). *Forests, water, climate and disturbance in the Sierra Nevada: critical knowledge gaps*. Fire Ecosystem Forest Management & Water Yield Symposium. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Kingsbury, J., J. Branham, R.C., Bales, and M.H. Conklin (2014). *Futuristic Watershed Management- A Case Study*. Presentation at Urban Water Institute's Spring Water Conference. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Stacy, E.M., L. Sullivan, and J. Clegg (2014). *How forest water needs and forest fire behavior interact with forest density*. Activity for elementary school kids, grades 1-8. at Southern California Edison Science Days.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bales, R. (2014). *Hydrology, Forest Management and Water Security in the Sierra Nevada*. Presentation at Hydrologic Sciences Research Symposium (Water: Our Global Solvent). Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Tague, C. (2013). *Managing water in forest landscapes*. Presentation for 2013 Meeting of the CA Forest Pest Council. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Stacy, E.M., and J. Clegg (2014). *Merced River Fair*. Demonstrations with groundwater and watershed models. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bales, R. (2014). *Mountain hydrology, forest management & water security in the Sierra Nevada*. Presentation at Stanford Research Seminar. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Delgado, O., and R. Bales (2014). *Natural Capital and Ecosystem Evaluation*. Presentation at Marin Municipal Water District Annual Board Planning Retreat. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Stacy, E.M. (2014). *Overview of the Southern Sierra CZO research within the framework of climate change in the region*. NatureBridge Afternoon Seminar Series Presentation. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

- Bales, R. (2014). *Rain, Snow and Temperature*. Presentation for Sequoia & Kings Canyon National Parks, NRCA Symposium Agenda. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Meadows, M. and Stacy, E.M (2014). *Snowpack monitoring research & techniques*. Center for Advanced Research and Technology (CART): talks and student mentoring. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Meadows, M. (2014). *Southern Sierra Critical Zone Observatory*. Presentation & panel participation at Dinkey Landscape Restoration Collaborative Meeting. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Stacy, E.M. (2014). *Southern Sierra Critical Zone Observatory*. Presentation at Watershed Connections. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Stacy, E.M., C. Riebe, and J. Clegg (2014). *Southern Sierra Critical Zone Observatory field tour*. Southern Sierra Critical Zone Observatory field tour prior to Goldschmidt 2014 for 8 visiting scientists. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Sullivan, L. (2014). *TASTES teacher training*. Presentation and curriculum presentation with teachers. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Sullivan, L., and M. Conklin (2014). *University Friends Circle Yosemite SNRI Field Trip*. Field trip to Yosemite Valley for approximately 45 University Friends Circle members. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Conklin, M.H. (2014). *Water Yield changes from Forest Treatment Methods*. Presentation at Fire Ecosystem Forest Management & Water Yield Symposium. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Patents

Technologies or Techniques

- A new generation of wireless NeoMotes was developed under a spin-off company, Metronome Systems.
- Additional improvements were made to the RHESSys eco-hydrologic model for the full transect of instrumented sites, including refinements to the strategic sampling protocol, as well as evaluating the effects of DEM resolution and soil parameter uncertainty. Model adjustments will aid the models in becoming more adaptable for catchments across the region.

Thesis/Dissertations

- Hahm, William Jesse. *Bedrock composition regulates ecosystems and landscape evolution in the sierra Nevada Batholith, California*. (2013). University of Wyoming. Acknowledgement of Federal Support = Yes
- Lucas, Ryan Geoffrey. *Polymictic pool behavior in a montane meadow, Sierra Nevada, CA*. (2013). UC Merced: Environmental Systems. Acknowledgement of Federal Support = Yes
- Kirchner, Peter B.. *Snow Distribution Over An Elevation Gradient and Forest Snow Hydrology of the Southern Sierra Nevada, California*. (2013). UC Merced: Environmental Systems. Acknowledgement of Federal Support = Yes

Websites

- *SSCZO Digital Library* https://eng.ucmerced.edu/snsjho/files/MHWG/Field/Southern_Sierra_CZO_KREW

The Southern Sierra CZO continues to maintain a thorough digital library. This is the main repository for data, metadata, protocols, photos, and presentations. Raw data is freely available after upload at multiple points per year, and processed data is made available according to CZO data policies.

- *SSCZO Facebook*
  https://www.facebook.com/SouthernSierraCZO

The Southern Sierra CZO is the only known active Facebook page. This page is slowly growing, and reaches a local cross-discipline audience (broader than environmental science, hydrology, or the CZO network). The audience is more location based, centered around Merced. The page has 33 likes. Since October 2013, 72 posts have reached a total of 340 people.

- *SSCZO Twitter*
  http://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. Since beginning early in 2013, we have 86 followers, have posted a total of 178 tweets and 25 photos, and 13 re-tweets and 23 favorites. Southern Sierra CZO posts events, photos, 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.

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

This website is the home of the Southern Sierra CZO. In the 2013-2014 year, SSCZO staff expanded the research field areas, added data, posted multiple opportunities, and regularly updated field and research activities. In May 2014, staff completed a website content inventory that will direct strategic, regular, and diverse updates on news, photos and data, among other items. In the coming months, we will focus on adding further links to data, interactive maps, more photo galleries and news stories, and centralizing information for CZO presentations at upcoming conferences. Since we started tracking website activity with Google Analytics in September 2013, we have had more than 2,800 page views, 447 unique visitors, and an average site visit time of 4:22. The majority (69%) of our site views originate as organic searches.

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?
8
How many REU applicants were selected and agreed to participate during this reporting period?
2
REU Comments:

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Bales, Roger	PD/PI	2
Conklin, Martha	Co PD/PI	2
Goulden, Michael	Co PD/PI	2

Name	Most Senior Project Role	Nearest Person Month Worked
Riebe, Clifford	Co PD/PI	2
Tague, Christina	Co PD/PI	2
Berhe, Asmeret Asefaw	Co-Investigator	1
Hart, Stephen	Co-Investigator	1
O'Geen, Anthony	Co-Investigator	2
Meadows, Matt	Other Professional	8
Meng, Xiande	Other Professional	9
Stacy, Erin	Other Professional	12
Hartsough, Peter	Staff Scientist (doctoral level)	3
Hahm, Jesse	Graduate Student (research assistant)	3
Kelly, Anne	Graduate Student (research assistant)	9
Lucas, Ryan	Graduate Student (research assistant)	12
Lukens, Claire	Graduate Student (research assistant)	3
McCorkle, Emma	Graduate Student (research assistant)	9
Son, Kyongho	Graduate Student (research assistant)	12
Clegg, Joshua	Undergraduate Student	1
Dziegiel, Abby	Undergraduate Student	1
Hickman, Ariel	Undergraduate Student	1
Newman, Alexander	Research Experience for Undergraduates (REU) Participant	2
Offorjebe, Obinwanne	Research Experience for Undergraduates (REU) Participant	2

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: Core measurements, Relationship between elevation/climate & exchanges of carbon and water
Funding Support: CZO & other funds
International Collaboration: No
International Travel: No

Martha H Conklin
Email: mconklin@ucmerced.edu

Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2
Contribution to the Project: Relationship between elevation/climate & exchanges of carbon and water
Funding Support: CZO & other funds
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: Relationship between elevation/climate & exchanges of carbon and water
Funding Support: CZO & other funds
International Collaboration: No
International Travel: No

Clifford S Riebe
Email: criebe@uwyo.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2
Contribution to the Project: Drilling, sampling, & imaging regolith
Funding Support: CZO & others
International Collaboration: No
International Travel: No

Christina Tague
Email: ctague@bren.ucsb.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2
Contribution to the Project: Relationship between elevation/climate & nutrient cycling
Funding Support: CZO & other funds
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
Funding Support: CZO & other funds
International Collaboration: No
International Travel: No

Stephen Hart
Email: shart4@ucmerced.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1
Contribution to the Project: Sediment transport, nutrient cycling
Funding Support: CZO & other funds
International Collaboration: No

International Travel: No

Anthony O'Geen
Email: atogeen@ucdavis.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2
Contribution to the Project: Controls on weathering & regolith formation
Funding Support: CZO & other funds
International Collaboration: No
International Travel: No

Matt Meadows
Email: mmeadows@ucmerced.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 8
Contribution to the Project: SSCZO staff - Field Manager, ending May 23, 2014
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Xiande Meng
Email: xmeng@ucmerced.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 9
Contribution to the Project: SSCZO Staff - Data Manager
Funding Support: CZO & other funds
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 - Outreach Manager, covering field duties in absence of M. Meadows
Funding Support: CZO funds
International Collaboration: No
International Travel: No

Peter Hartsough
Email: phartsough@ucdavis.edu
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 3
Contribution to the Project: Relationships between soils and weathered bedrock
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Jesse Hahm
Email: whahm@uwyo.edu

Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3
Contribution to the Project: Regolith formation and erosion; near-surface geophysics; vegetation-landscape interactions
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Anne Kelly
Email: a.kelly@uci.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9
Contribution to the Project: 1) continued observations along the SSCZO climate gradient, 2) analysis and publication of results from the initial phase of the SSCZO, and 3) fabrication and lab testing of a tower-top remote-sensing system.
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Ryan Lucas
Email: rlucas@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Groundwater Surface Water Interactions
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Claire Lukens
Email: clukens@uwyo.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3
Contribution to the Project: Regolith formation and erosion; near-surface geophysics; vegetation-landscape interactions
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Emma McCorkle
Email: emccorkle@ucmerced.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9
Contribution to the Project: Determining sources of carbon in eroded sediments and nutrient (carbon and nitrogen) fluxes of natural waters
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Kyongho Son
Email: kson@bren.ucsb.edu

Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Core CZO measurements, data management and integration
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Joshua Clegg
Email: jclegg@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1
Contribution to the Project: Field technician
Funding Support: CZO funds
International Collaboration: No
International Travel: No

Abby Dziegiel
Email: adziegiel@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1
Contribution to the Project: 1. Determining sources of carbon in eroded sediments and nutrient (carbon and nitrogen) fluxes of natural waters 2. Assessing Nutrient Hot spot and Hot Moments in soil
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Ariel Hickman
Email: ahickman@ucmerced.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1
Contribution to the Project: Assessing Nutrient Hot spot and Hot Moments in soil
Funding Support: CZO & other
International Collaboration: No
International Travel: No

Alexander Newman
Email: anewman3@ucmerced.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2
Contribution to the Project: 1. Determining sources of carbon in eroded sediments and nutrient (carbon and nitrogen) fluxes of natural waters 2. Assessing Nutrient Hot spot and Hot Moments in soil
Funding Support: REU funds; CZO & other
International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: UC Merced
Government fiscal year(s) was this REU participant supported: 2014

Obinwanne Offorjebe
Email: oofforjebe@ucmerced.edu

Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 2
Contribution to the Project: Meadow surface-groundwater interactions, land-atmosphere transfers
Funding Support: REU funds; CZO & other
International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: UC Merced
Government fiscal year(s) was this REU participant supported: 2014

What other organizations have been involved as partners?

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

Full details of organizations that have been involved as partners:

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:

Have other collaborators or contacts been involved? Yes

Impacts
What is the impact on the development of the principal discipline(s) of the project?
The Southern Sierra Critical Zone Observatory provides a multi-disciplinary platform for research. Major scientific findings have impacted disciplines from plant physiology to geomorphology and land management. In fact, previous findings from the project contributed to the broader structure of the recent SSCZO proposal for funding. For instance, evidence that mid-elevation forests have high winter productivity contradicted long-standing understanding that the forests shut down for the winter. Because the winter productivity results in higher water needs, shifting climate will then likely lead to lower water yields overall for the state. In addition, unexpected variation in the geochemistry of different granites changes the paradigm of geomorphology in the Sierra Nevada. Hence the Southern Sierra CZO is expanding the suite of core measurements at each site in the elevational transect from 400-2700 m. Doing so will clarify the impact of bedrock and forest on regolith development and water resources.

Another impact is the development of research methods, particularly in the area of integrated field measurements using wireless sensor networks. The innovations in data collection and network design have vastly increased the frequency, distribution and accuracy of information on snowpack. Better information on snowpack distribution and water content means that water managers have more options for effective water management.

A list of the main CZO collaborators for the past year follows:

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What is the impact on other disciplines?

The cross-disciplinary understanding of critical-zone processes developed at the Southern Sierra Critical Zone Observatory (CZO) provides a foundation for further research by CZO cooperators and others in the research community. Results from studies at the Southern Sierra CZO provide a foundation for new research projects, including a test for field-based stable isotope measurements and a project estimating the potential impact of climate on vegetation communities through remote sensing and spatial modeling.

Infrastructure of the wireless sensor network, which was installed and tested first at the Southern Sierra CZO has wide applications for other disciplines. Lessons from the network can be applied to streamlining agricultural operations, monitoring recreation areas, and improving renewable power operations. In a regional context, the SSCZO is sharing information on the network structure with local utility companies, who manage land for water, hydropower and timber resources.

In addition, research at the Southern Sierra CZO provides a bilateral benefit to other complex research projects. These programs include the U.S. Forest Service Kings River Experimental Watershed and the NSF National Ecological Observatory Network (NEON). At the 2013 annual meeting, SSCZO researchers and Pacific Southwest Research Station (Forest Service) representatives discussed upcoming needs for personnel, equipment and maintenance, and how to successfully provide for those needs in a way that is efficient and mutually beneficial. With the NEON project, several of the Domain 17 sites will be co-located with SSCZO work. Biological data gathered by NEON will complement SSCZO results in geology,

hydrology, and ecosystem fluxes. Southern Sierra CZO staff work closely with the interdisciplinary Dinkey Restoration Landscape Project. That project provides a strong and stable connection to local residents and stakeholders.

What is the impact on the development of human resources?

The foundation of the Southern Sierra Critical Zone Observatory is to provide a cross-disciplinary research environment. This guiding principle is what we use to train undergraduates, graduate students, postdoctoral researchers and staff to become the next generation of researchers. Working in a team environment allows participants to combine skills to achieve wide-ranging goals. Going forward from the 2012-2013 reporting period, the Southern Sierra CZO continues to mentor graduate students and a postdoc, plus engage junior faculty. CZO staff members will also continue to develop through formal and informal training and mentoring. Training opportunities included workshops on Project Learning Tree and facilitation and collaboration, which will improve education programs and increase the efficacy and efficiency of CZO planning meetings.

Staff member E. Stacy gained additional education training and experience, as did previously untried undergraduate student employees assisting with Outreach during the summer. Work with the Southern California Edison Science Days, Auberry Conservation Days, Merced Riverfair, and American Association of University Women Science Camp exposed grade school students and the public to recent findings from the SSCZO. Activities largely focused on the health and activity of the forest, impacts of the water cycle on wildlife, and surface-groundwater interactions. An interactive display at the UC Merced library was in place for 2 months, allowing university students and staff to learn about the wireless sensor network and snow depth sensors. Additional educational material is under development for a university course on critical zone science. This course will educate students on the structure and function of the critical zone with activities that used CZO data in the classroom.

What is the impact on physical resources that form infrastructure?

The Southern Sierra Critical Zone Observatory (CZO) provides a platform to encourage and enable research in a landscape that is of vital importance to society yet poorly understood and subject to unprecedented changes as the climate warms. The Sierra Nevada is representative of seasonally snow-covered mountain regions, and the data and information developed as a result of the Southern Sierra CZO enhances the science of individuals and research groups well beyond the immediate CZO team. The Southern Sierra CZO is an important and well-used community research platform. This use is consistent with the founding vision of the CZO network and its goal of fostering broader impacts on research. Research partnerships continue to grow, extending that impact to more critical-zone disciplines, questions and scientists.

What is the impact on institutional resources that form infrastructure?

As a major component of the field research infrastructure that is accessible from campus, the Southern Sierra Critical Zone Observatory (CZO) is central to the research infrastructure of UC Merced's Sierra Nevada Research Institute (SNRI). The SNRI was established by UC specifically to use the Sierra Nevada and surrounding valleys as a natural laboratory for research, and to address knowledge gaps around management of resources in that region, and comparative regions worldwide. Many of the 30 faculty and their research groups affiliated with SNRI make use of these field resources in their research and educational programs. The Southern Sierra CZO is the best instrumented and equipped set of headwater catchments in the Sierra Nevada region, and the only elevational transect of research infrastructure dedicated to critical-zone science. Thus it is a resource for researchers well beyond SNRI and UC Merced.

What is the impact on information resources that form infrastructure?

Most of the Southern Sierra Critical Zone Observatory (CZO) data are available to the broader research community, and other data to CZO cooperators who agree to data-sharing protocols. These are significant and unique data sets that elucidate the many science questions described above. The data sets will have many secondary uses, as is already evident from the many downloads at our digital library.

As part of the national working group, staff buit a new portal on the standardized website. The new pages on the national website (criticalzone.org and criticalzone.org/sierra) offers an easily navigable portal and additional information to data already posted on the independent SSCZO digital library. Steps were taken this year to ensure more reliable and stable off-site backup.

Education efforts use Southern Sierra CZO data in classroom exercises for undergraduate and secondary students. More in-depth activities with integrated assessment procedures are being formulated as part of the InTeGrate Critical Zone course. Social media platforms act as a portal for the public, students and potential collaborators to reach the SSCZO website, where they can access in-depth information about the project.

What is the impact on technology transfer?

The Southern Sierra Critical Zone Observatory (CZO) measurement, research and outreach programs provide valuable lessons that are applicable to other multi-disciplinary earth-science observatories. Our wireless-sensor network is being scaled up to the entire American River basin (also in the Sierra Nevada) to provide a well-instrumented hydrologic observatory at the scale of interest for operational hydrology. The Southern Sierra CZO is an important testbed for new technology. Integration of this technology with our outreach helps generate strong interest in our science as well. We continue to use the CZO network, our own publications and other forums to share these lessons.

What is the impact on society beyond science and technology?

The knowledge developed at the Southern Sierra Critical Zone Observatory advances not only earth system science, but also directly informs societal decisions around management of ecosystem services. The Sierra Nevada provides ecosystem services, ranging from water to biodiversity, to a large segment of California's and the nation's population. Our growing partnerships with federal, state and local resource-management agencies show the interest that decision makers have in using research results to improve their predictive capabilities. We work with water-supply, forest and hydropower managers and the stakeholders directly affected by their decisions.

Changes/Problems

Changes in approach and reason for change

We have advanced the Wireless Boot Camp for other CZOs into year 1. This was done to accommodate the needs of the CZO program as a whole, as the other CZOs are interested in installing or upgrading wireless networks at their sites. The cost impact of this is an expenditure of up to $15,000 direct cost. We were also able to partner with CUAHSI to co-sponsor the workshop, and open it up to the broader community.

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

One planned effort for deep-subsurface drilling was postponed until additional geophysical work can be completed to inform the drilling effort; this geophysical work is planned for summer and fall 2014. Delaying this drilling until year 2 also allows better coordination with the other CZOs, based on the

outcomes and recommendations from the deep-drilling workshop. We expect that a coordinated plan for the CZO network as a whole will emerge this fall.

Changes that have a significant impact on expenditures

Following is the status of the year 1 budget and expenditures

Year 1 Project Expenditure Summary by Account

CZO-Core/Main					
Budget Element	**Budgeted**	**Current Expenditures**	**Commitments through 9/30/2018**	**Balance**	**Comments**
Participant Costs	**8,000**	**450**	**14,500**	**(6,950)**	Carry negative balance forward
Cross-Site Modeling Meetings, Seed Funding, PI Meetings					
Subcontracts*	**312,719**	**87,561**	**225,158**	**(0)**	To be expended by end of yr 1; billing can lag expenditures by several months
UC Berkeley, UC Irvine, UC Davis, UC Santa Barbara, University of Wyoming					
Other Direct Costs	**60,000**	**-**	**-**	**60,000**	Expense deferred to yr 2, pending CZO network planning
Drilling Subcontract					
Indirect Costs	**37,400**	**247**	**7,975**	**29,178**	
Account Total	**418,119**	**88,259**	**247,633**	**82,227**	

**Current Expenditures are from Invoices received.*

CZO-Project Integration and Management					
Budget Element	**Budgeted**	**Current Expenditures**	**Commitments through 9/30/2018**	**Balance**	**Comments**
Senior Personnel	**132,008**	**72,607**	**34,123**	**25,278**	Field engineer left late May; balance to be split between P. Hartsough at UCD & replacement now being recruited
Principal Investigator, Data Manager, Research Engineer, Undergraduate Asst.					
Fringe Benefits	**39,939**	**28,995**	**10,937**	**7**	
Equipment	**57,311**	**15,910**	**-**	**41,401**	To be expended summer 2014
Tower Rebuild, Equipment Replacement					
Domestic Travel	**7,648**	**-**	**2,000**	**5,648**	
Travel to Field-Site & Meetings					Vehicle charges being billed; summer travel pending
Other Direct Costs	**11,700**	**2,949**	**-**	**8,751**	
Supplies, Teleconferences, Battery Replacement, Equipment Calibration, Snowmobile Equipment Costs					Billing of charges in progress; summer expenses pending
Indirect Costs	**105,212**	**57,503**	**25,883**	**21,826**	

Account Total	**353,818**	**177,964**	**72,943**	**102,911**

CZO-Education and Outreach					
Budget Element	**Budgeted**	**Current Expenditures**	**Commitments through 9/30/2018**	**Balance**	**Comments**
Senior Personnel	**51,792**	**-**	**10,207**	**41,585**	Recruitment in progress for a 1-yr postdoc to synthesize CZO results in a water resources context -- 2 papers
Co-Investigator, Staff					
Fringe Benefits	**16,697**	**-**	**2,435**	**14,262**	
Domestic Travel	**1,600**	**-**	**-**	**1,600**	Billing of charges in progress; summer expenses pending
Travel to Field-Site & Meetings					
Other Direct Costs	**1,600**	**-**	**-**	**1,600**	Billing of charges in progress; summer expenses pending
Supplies, Teleconferences					
Indirect Costs	**39,429**	**-**	**6,953**	**32,476**	
Account Total	**111,118**	**-**	**19,595**	**91,523**	

CZO-Research					
Budget Element	**Budgeted**	**Current Expenditures**	**Commitments through 9/30/2018**	**Balance**	**Comments**
Senior Personnel	**22,639**	**-**	**18,093**	**4,546**	Rebudget to other direct costs for summer 2014
Principal Investigators					
Fringe Benefits	**2,491**	**-**	**2,171**	**320**	
Domestic Travel	**8,800**	**-**	**-**	**8,800**	Billing of charges in progress; summer expenses pending
Travel to Field-Sites & Meetings					
Other Direct Costs	**9,262**	**-**	**-**	**9,262**	Billing of charges in progress; summer expenses pending
Supplies, Teleconferences, Publication Costs					
Indirect Costs	**23,754**	**-**	**11,145**	**12,609**	
Account Total	**66,946**	**-**	**31,410**	**35,536**	

PROJECT TOTALS	**950,001**	**266,223**	**371,581**	**312,197**

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.

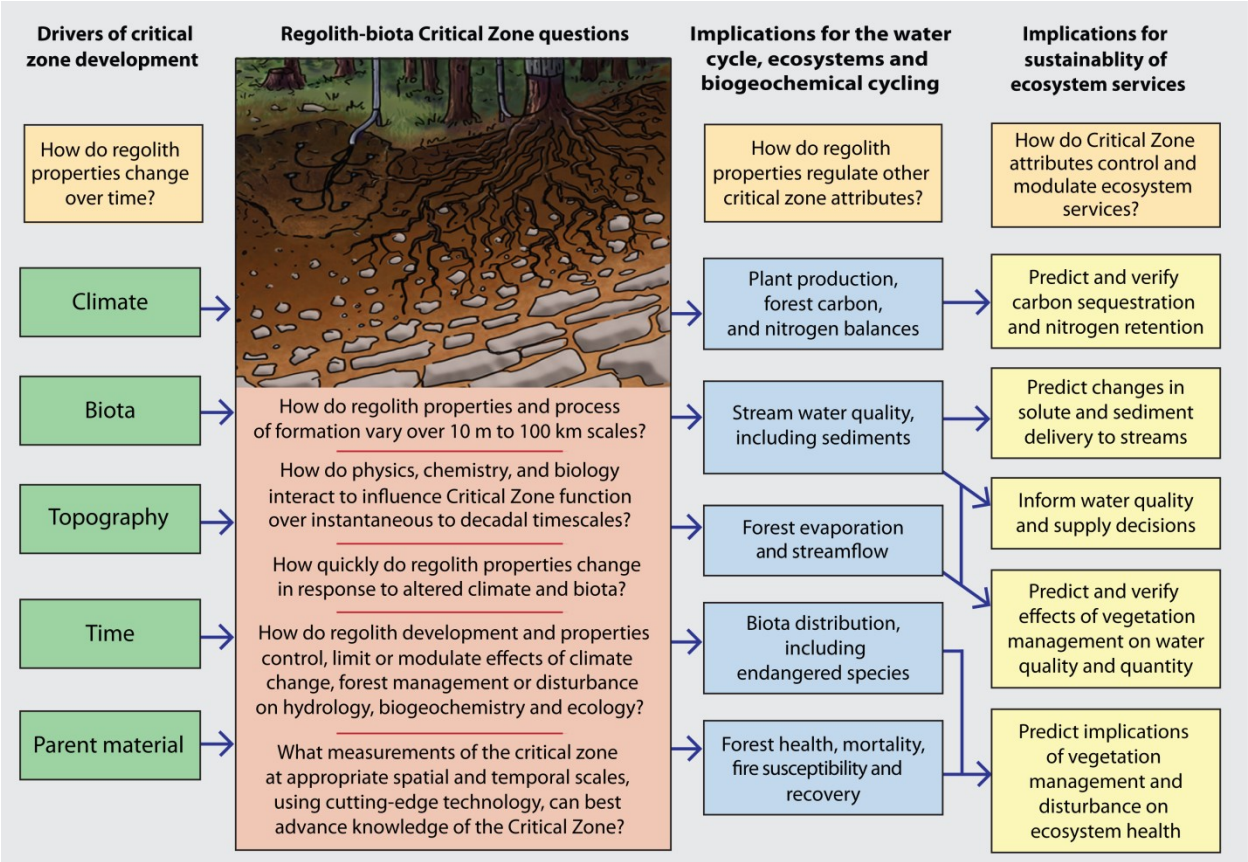

Figure 1—Science goals are organized within this schematic of relationships among drivers of critical-zone development, science questions that guide SSCZO research, implications for critical-zone attributes and implications for CZ services and sustainability.

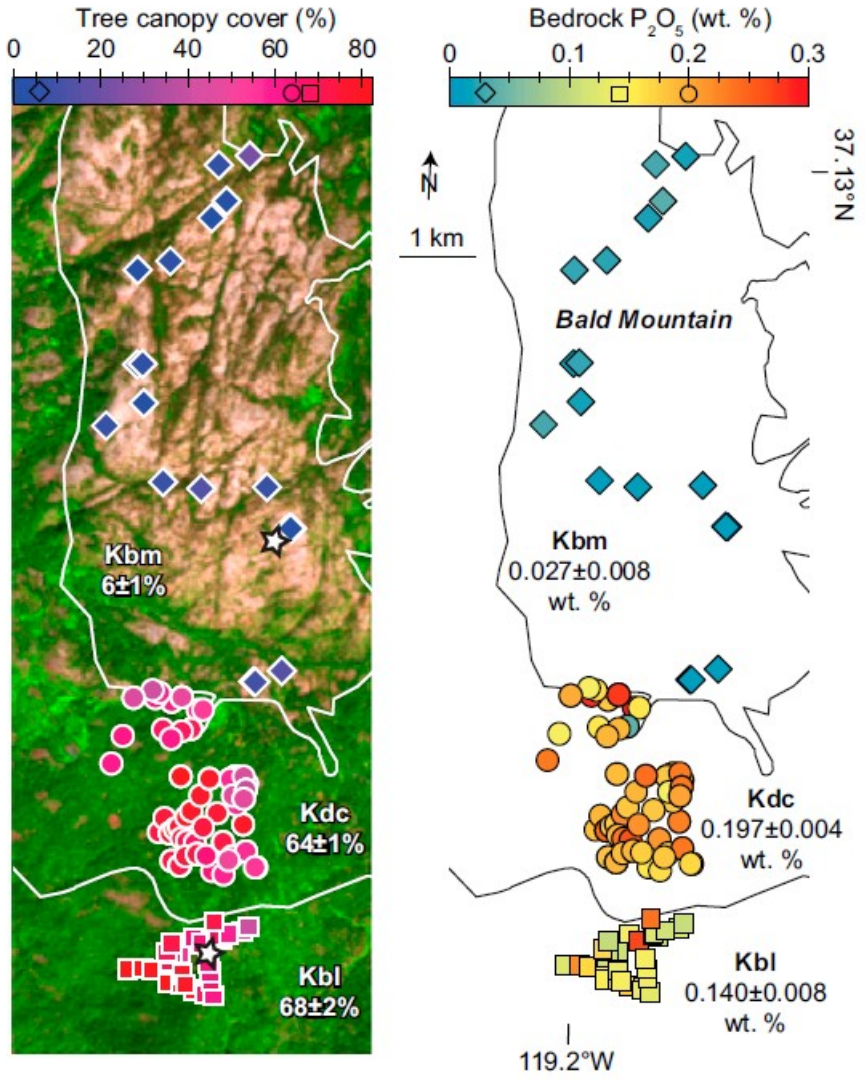

Figure 2—Distribution of vegetation across bedrock with differing phosphorus content. (Left) False-color Landsat image of CZO vicinity with georeferenced bedrock contacts from simplified geologic map shown at Right (after ref. 14). Symbol colors match colorbar scales of Landsat-derived, remotely sensed tree-canopy cover (16; Dataset S3 and SI Text) a proxy for primary productivity (Left), and bedrock P concentrations (Right). Vegetated-unvegetated ecotone coincides with boundary of Bald Mountain Granite (Kbm; diamonds) a desert in bedrock P relative to more heavily forested Dinkey Creek Granodiorite (Kdc; circles) and Bass Lake Tonalite (Kbl; squares). Labels show average (±SEM) tree-canopy cover (Left) and bedrock P concentration (Right) by rock type. Stars at Left pinpoint productivity surveys (SI Text). From *Hahm et al. 2014.*

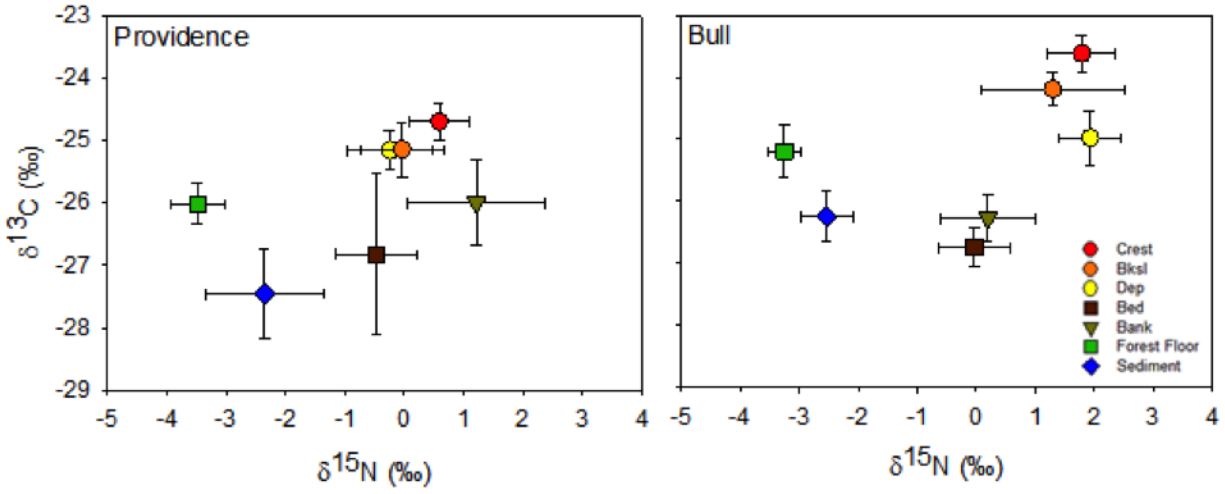

Figure 3—Results to date show that the majority of sediments collected within the two watersheds (P303 and B203) analyzed are derived from forest floor and stream bank materials. This shows that the erosion present is mostly surficial with some carving occurring in established channels.

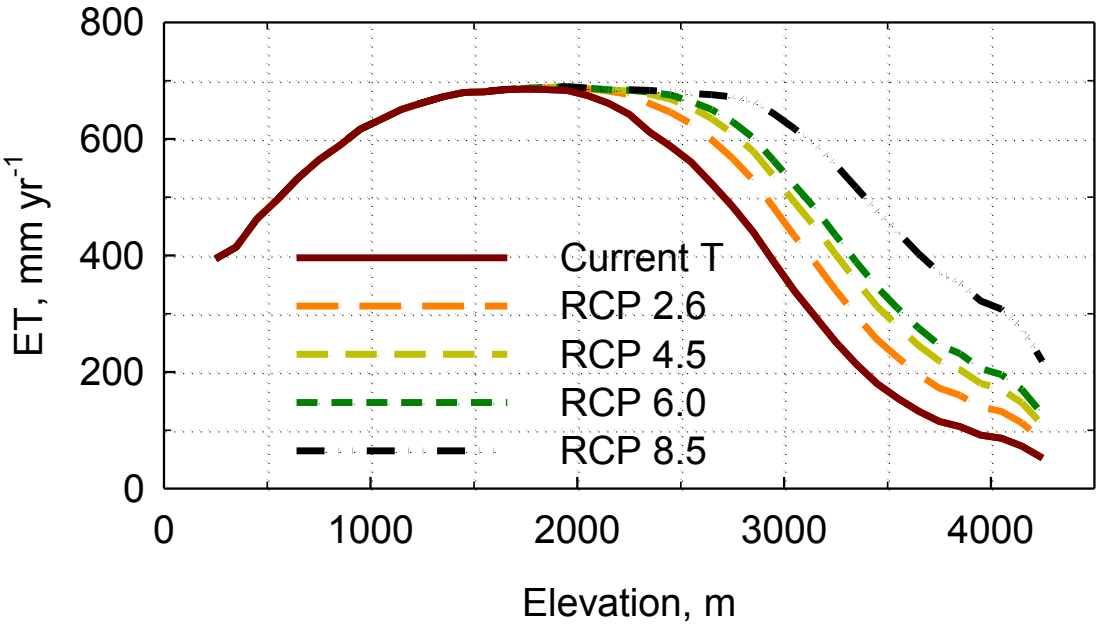

Figure 4—Relationships between elevation (m above sea level) and mean ET for a constant precipitation and warming projected for 2085-2100 with the four Representative Concentration Pathways (RCP). ET under current conditions was calculated using the climate regressions applied to the 1981 to 2010 PRISM Normals. ET under a warmer climate was calculated using the climate regressions and the elevation dependent warming predicted for each RCP. The mean 2085-2100 temperature increase in the atmosphere's lower 4 km above central California ranged from 1.3°C for RCP 2.8 to 4.1°C for RCP 8.5. From *Goulden and Bales, in review.*

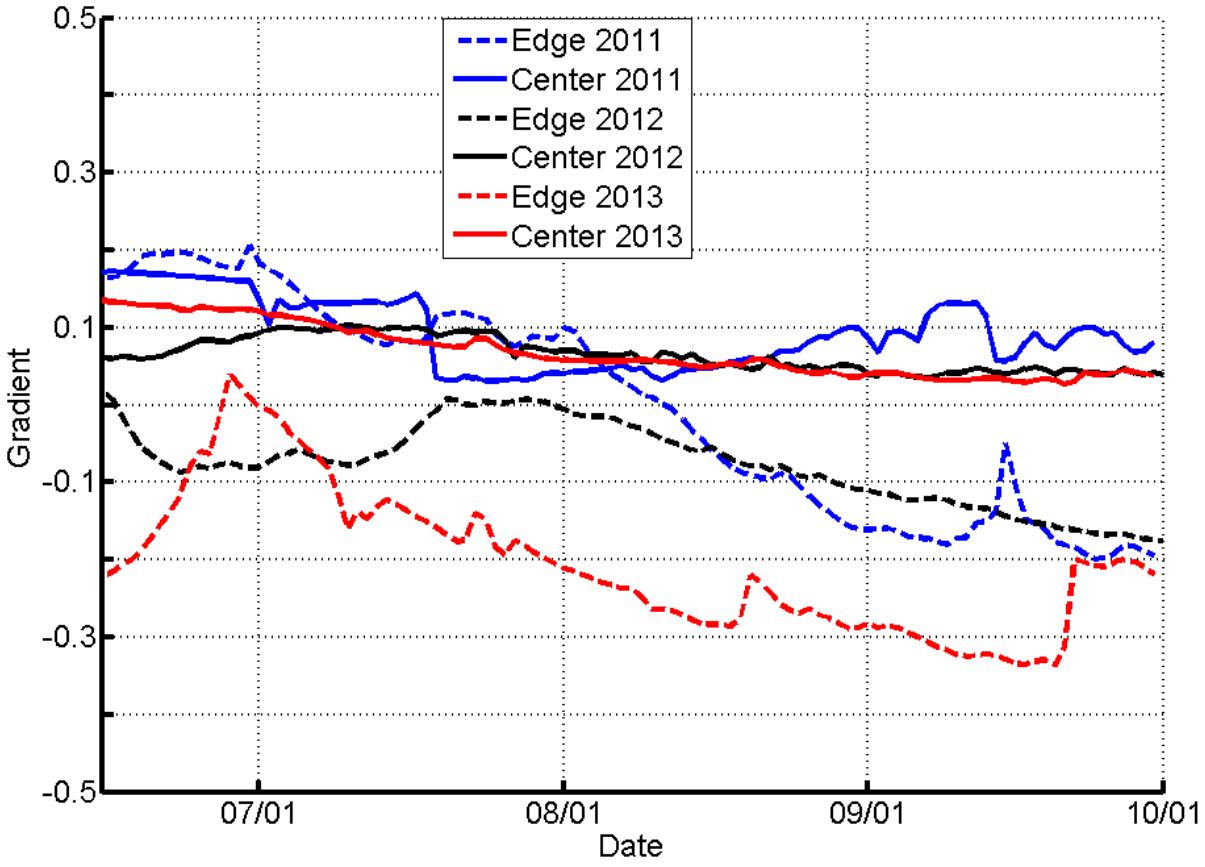

Figure 5—Vertical hydraulic gradient at the meadow edge and meadow center for the relatively wet water year (WY 2011) and two subsequent very dry years (WY2012-2013). Vertical gradient at the meadow edge is consistently negative—indicative of groundwater recharge) in the late summer and fall; while vertical gradient at the meadow center is persistently positive—indicative of groundwater discharge—even after two very dry years.

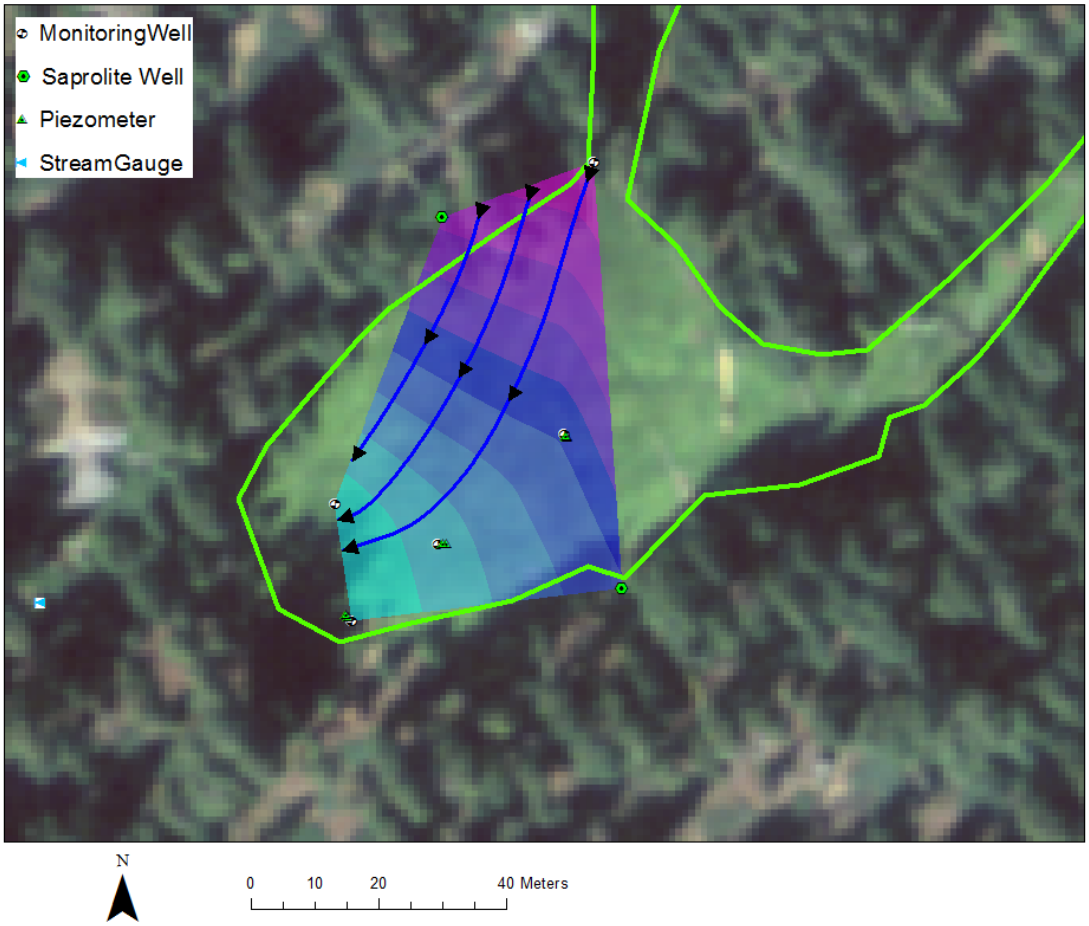

Figure 6—Groundwater elevation map generated from P301 Middle Meadow monitoring wells on for April 1, 2013. Equipotential lines reflect the horizontal groundwater gradient.

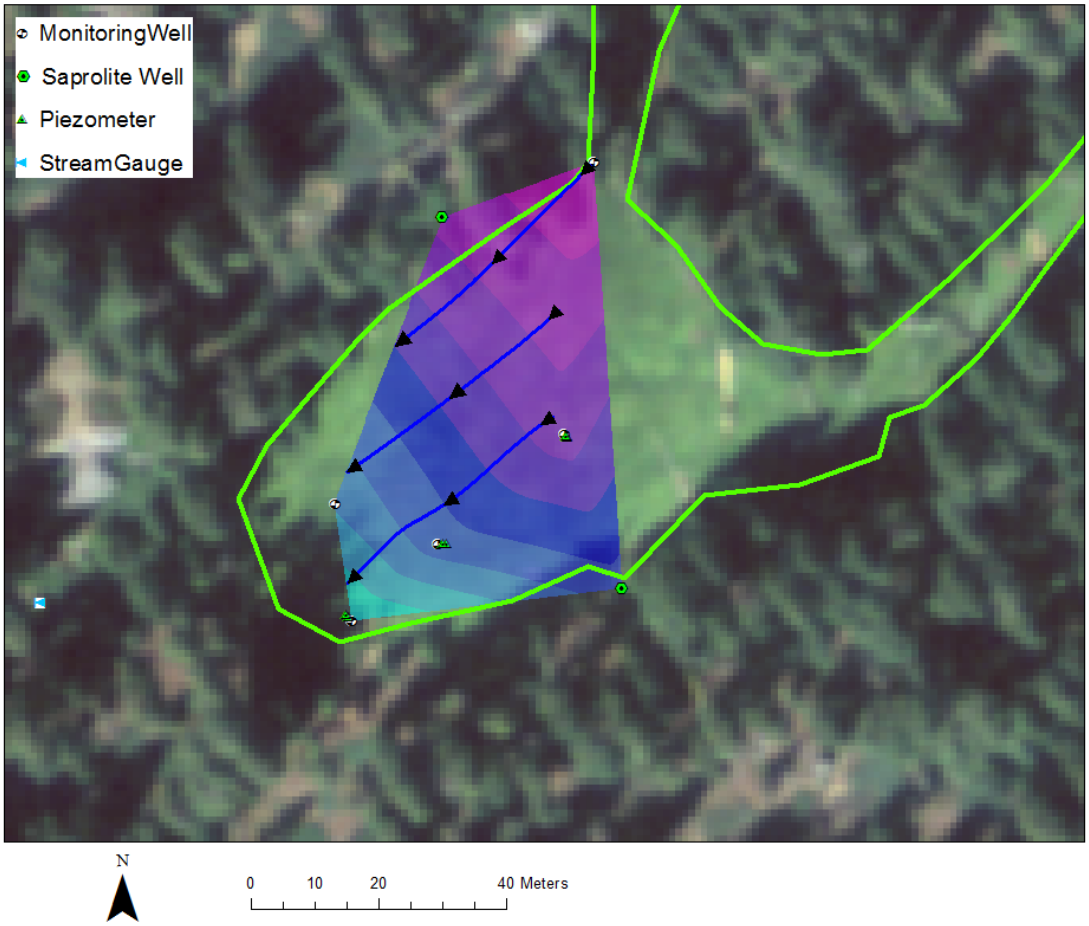

Figure 7—Groundwater elevation map generated from P301 Middle Meadow Wells for September 30, 2013. Equipotential lines represent the horizontal groundwater gradient. Horizontal gradient for this date flows much more parallel to the surface water and local stream flow than the horizontal gradient generated for April 1, 2013 (Figure 3).

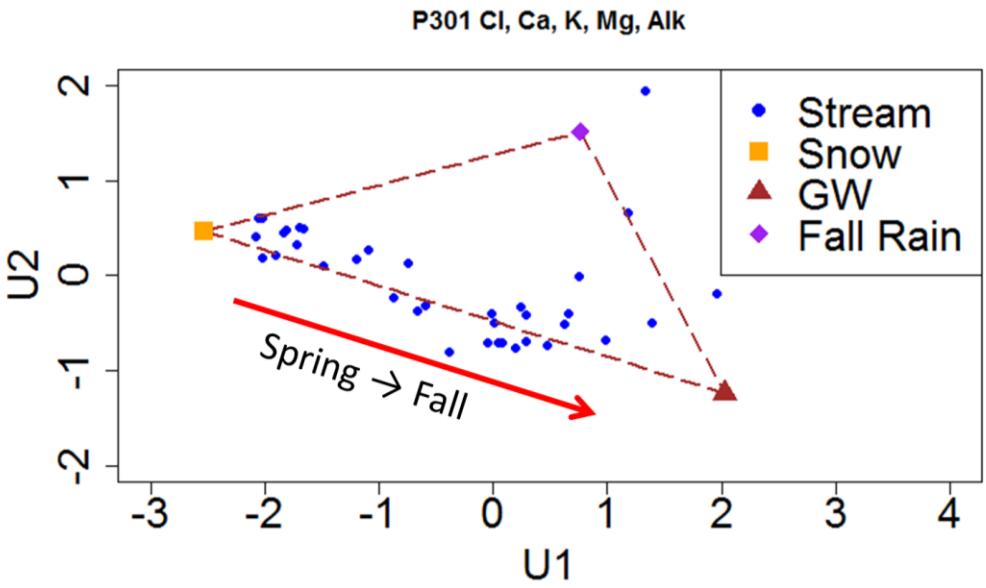

Figure 8—End Member Mixing Analysis for the P301 Meadow surface water discharge. Stream chemistry generally follows the Spring→Fall evolution moving from the Snow end member to the Groundwater end member. Stream chemistry deviates from this evolution when influenced by fall rain events.

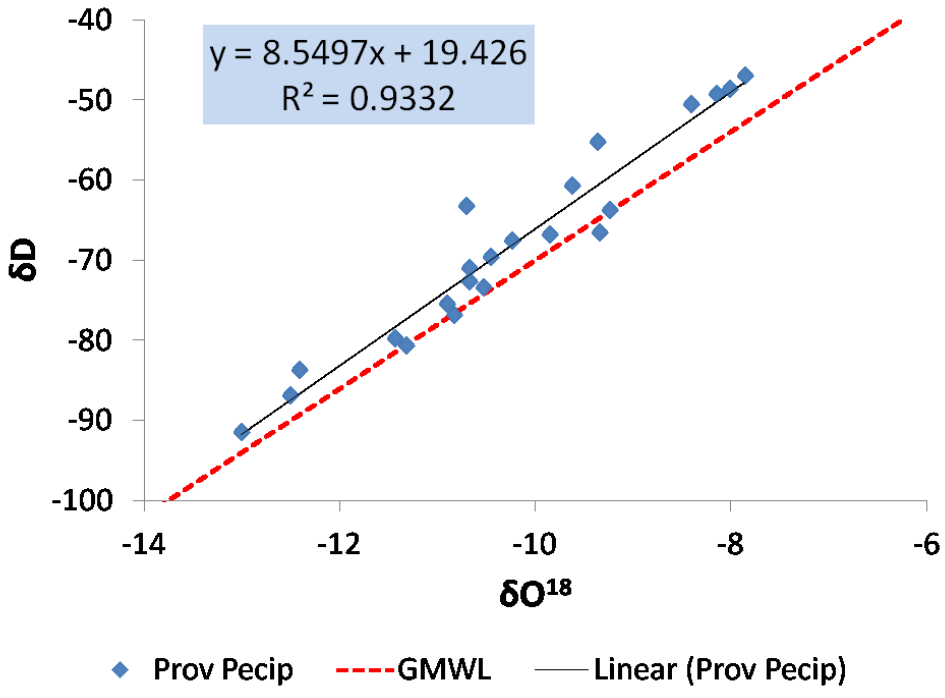

Figure 9—Providence Creek snow and precipitation samples plotted with a linear regression representing the Local Meteoric Water Line (LMWL). The LMWL has a slope of 8.5 and an intercept of 19.4; this compares to the global meteoric water line (GMWL)—dashed red line—that has a slope of 8 and an intercept of 10.

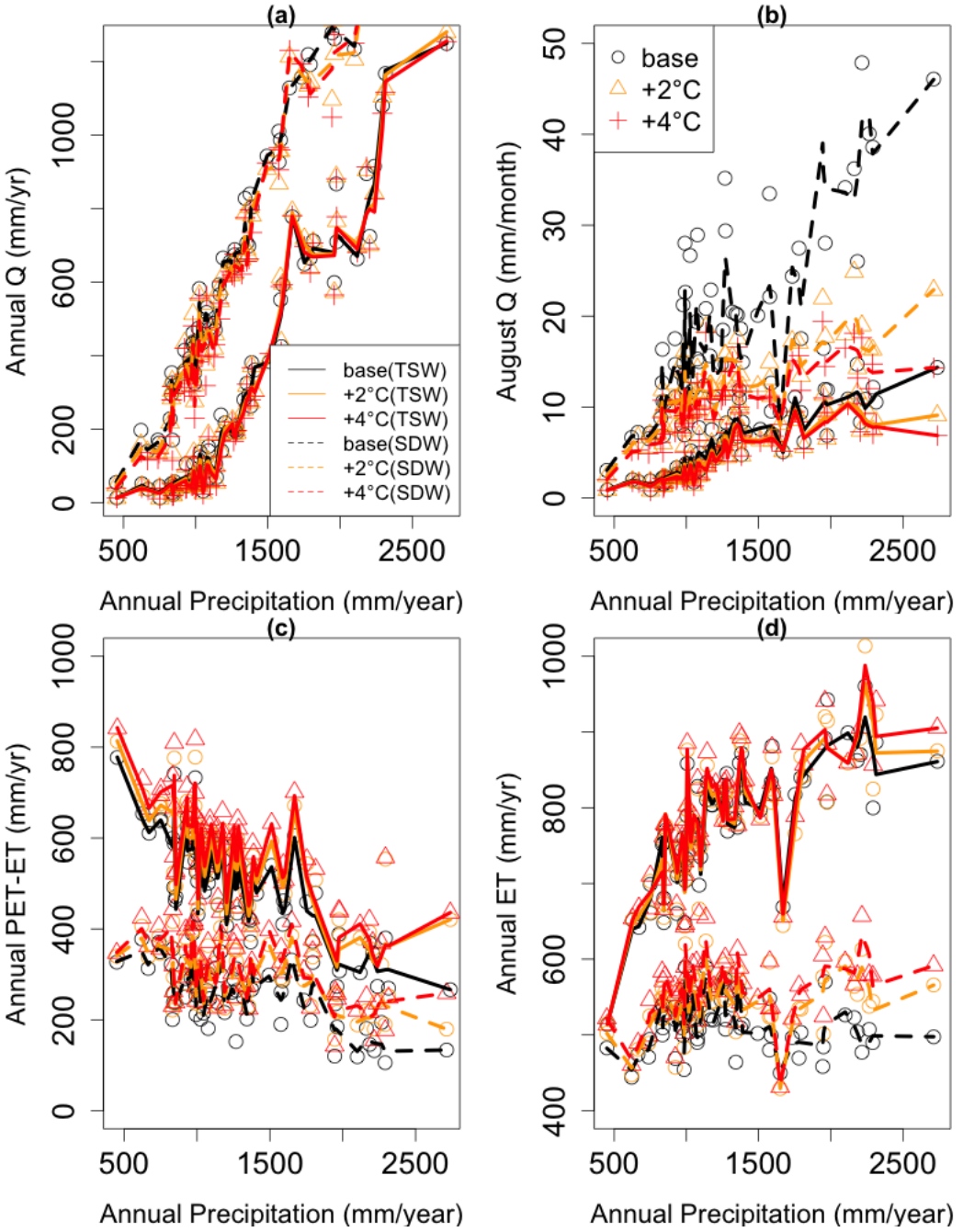

Figure 10—The relationship among annual precipitation, annual streamflow, August streamflow, annual moisture deficit (PET-ET) and annual ET of a transient snow watershed (TSW, P303) and a snow-dominated watershed (SDW, B203) during climate warming scenarios: (a) annual flow, (b) August (summer) flow, (c) annual ET, and annual moisture deficit (PET-ET) and (d) The three lines (black, orange, and red) were created by using LOESS (local polynomial regression fitting algorithm), and the interpolated line is used for only guiding visually the general pattern of model estimates and is not necessarily statistically significant.

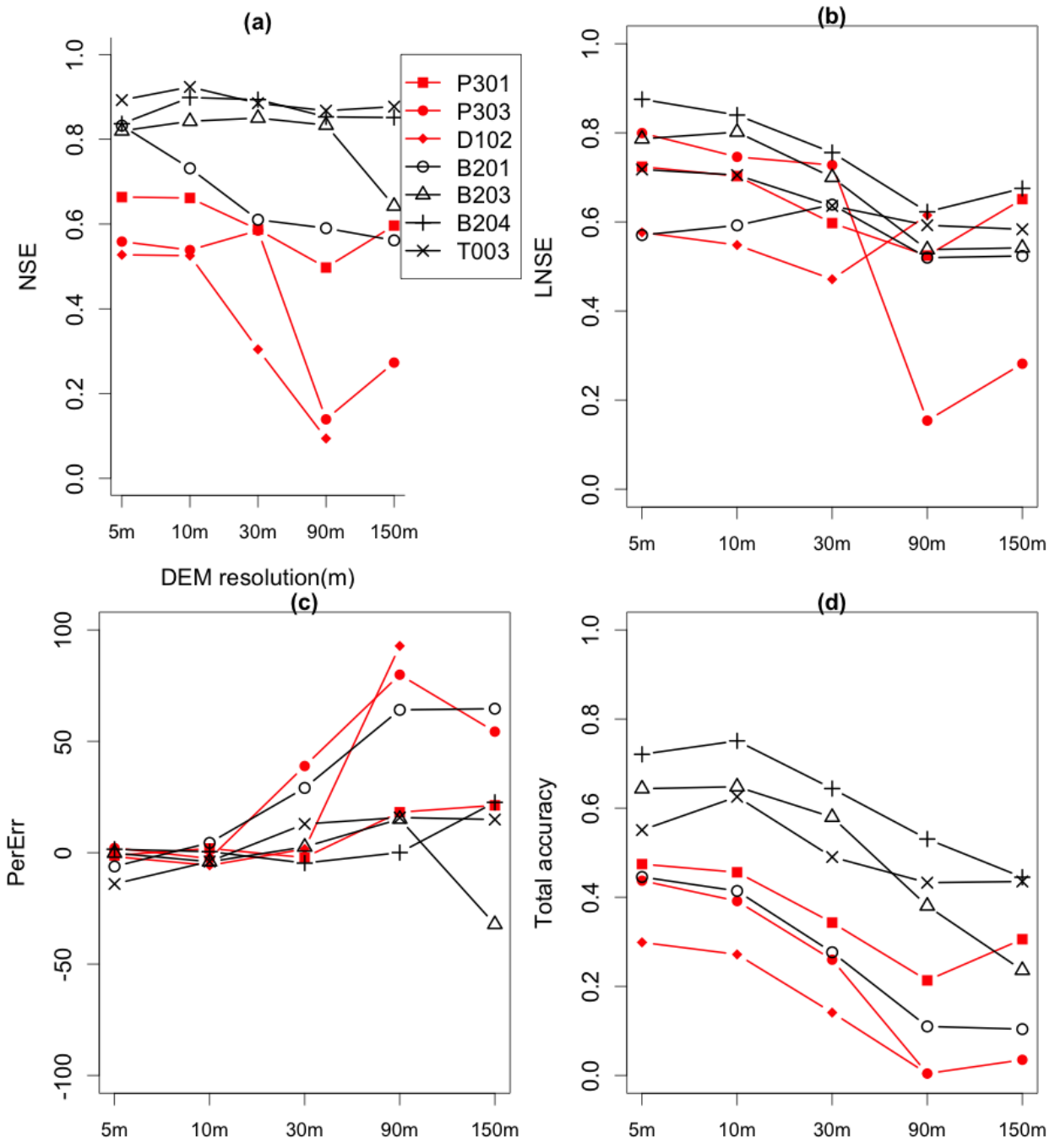

Figure 11—The model performance of streamflow prediction with different DEM resolutions: (a) NSE (Nash-Sutcliffe Efficiency of streamflows), (b) LNSE (Nash-Sutcliffe Efficiency of log-transformed streamflows), (c) PerErr (Percent Error), and (d) Total accuracy measure combing NSE, LNSE and Percent Error.

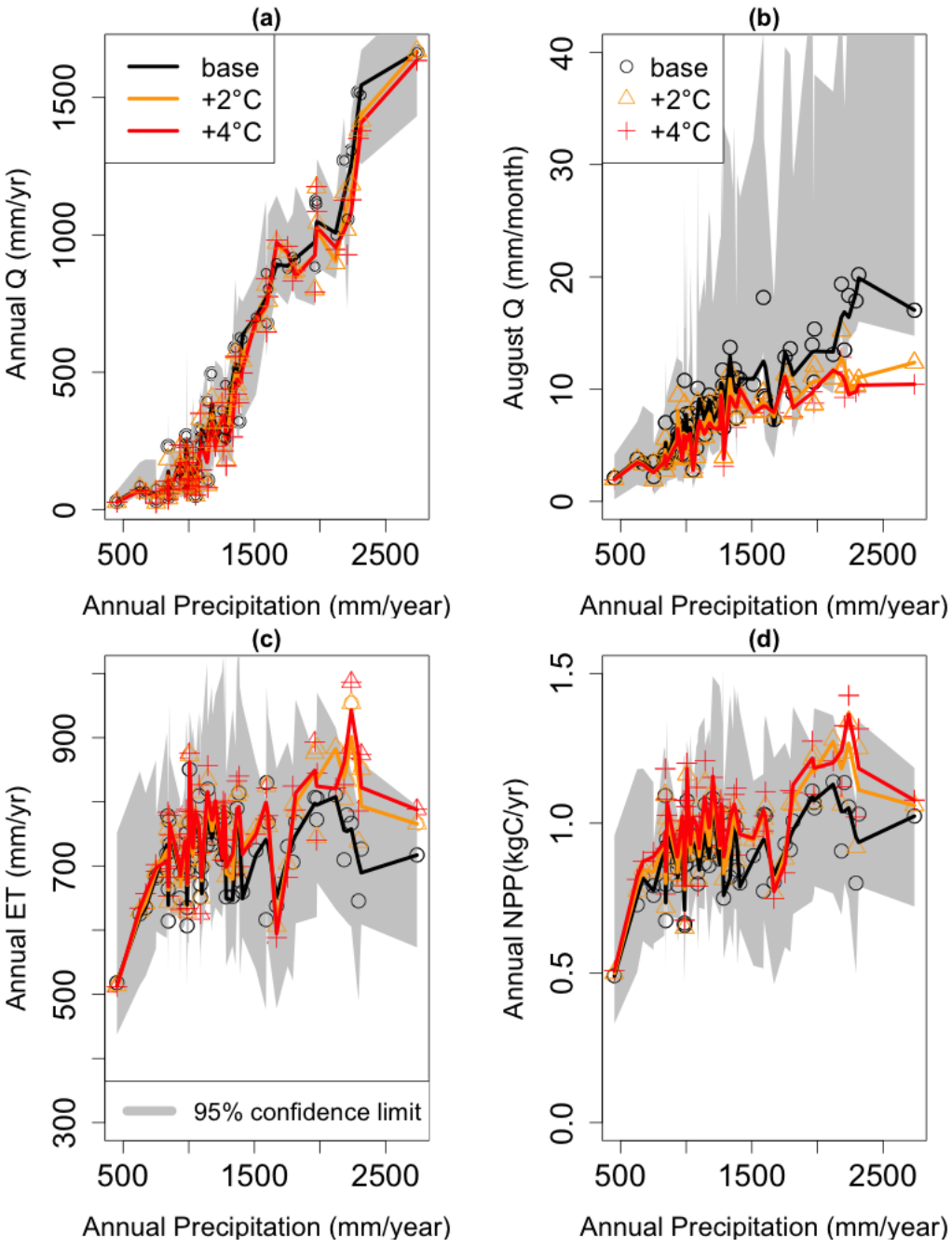

Figure 12—Comparison between climate warming and soil parameter uncertainty effects on ecohydrologic responses in TSW (P301) for: (a) annual streamflow (Q), (b) summer (August) streamflow (Q), (c) annual ET and (d) annul NPP. The three lines (black, orange, and red) were created by using LOESS (local polynomial regression fitting algorithm), and the interpolated line is used for only guiding visually the general pattern of model estimates and is not necessarily statistically significant. Gray shaded area refers to estimated model uncertainty range across behavioral soil parameters.