Management Plan

Southern Sierra Critical Zone Observatory

February 14, 2014

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1. Introduction

The Southern Sierra Critical Zone Observatory (SSCZO) is investigating how mountain soils and weathered bedrock develop over geologic time, and interact with shorter-term climate variability and ecosystem behavior. This understanding provides the foundation for predicting how environmental change (including human disturbances, fire, pests, and changes in climate) influence water resources, material flows and forest health. The SSCZO is pioneering accurate measurement systems for snow accumulation and melt, soil moisture, climate and evapotranspiration; and the use of the measurements to drive advanced models for forecasting future conditions. Through close partnerships with regional stakeholders, SSCZO results help to assess options available to resource managers to enhance management of forests, water and other ecosystem services, given environmental change.

Since starting in 2007, the Southern Sierra CZO has invested in infrastructure and research across the rain-snow transition. This core management plan defines SSCZO milestones and metrics for measuring progress, management plans for the research program, and outlines plans to engage researchers and educators. Leadership and effective management of SSCZO is very important to achieving the program goals. The SSCZO management structure is designed to provide a responsive forum for making decisions, allocating resources and responsibilities, and monitoring and assessing progress towards meeting program objectives across partner institutions.

2. Milestones and metrics

The SSCZO research process will be tracked through the on-time completion of scheduled infrastructure updates and expansion of the research plans. Following the work plan, infrastructure and additional measurements will be made in the upcoming field season. The Geoprobe drilling & sampling was completed in Fall 2013 at the two lower-elevation sites. Major updates during the 2014 field season will include reconstruction of the flux tower at Short Hair Creek (which had been damaged by falling trees and snow) and scouting for a site at 3300 m. Additional characterizations and installations will be expanded across the transect also starting in 2014. Potential new projects, including vegetation isotope sampling, pedology characterizations, and the continuation of the dendrometer project were discussed at the SSCZO team meeting in August 2013. In support of these projects and ongoing measurements, SSCZO team members will seek additional funding opportunities to leverage the CZO and carry out research at the sites.

Meetings and collaborations are planned for within the CZO network and with external partners. The SSCZO team and staff are actively planning the 2014 All-Hands Meeting. At least biennial field trips will be offered for researchers, public, and stakeholders. Cross-CZO plans including coordinated field campaigns and modeling workshops (further detailed in Section 3 of the Management Plan) will be hosted at each of the CZOs in turn. Several other collaborations are in development. First, colleagues at other institutions have submitted grant proposals for research that would be sited at the Southern Sierra CZO. Second, the NEON investment in California is recommended to follow the elevation transect of the SSCZO research sites. In January 2014, NEON began advertising for domain staff and estimates transition to operation by February 2016 for the lowest elevation and May 2017 for the highest elevation (personal communication, K. Larson, NEON). The SSCZO has already been included in multi-site research proposals involving NEON sites, and that activity will ramp up in coming years. Third, discussions are underway about a partnerships that would expand our hydrologic modeling and ground-based sensor networks with supporting cyberinfrastructure to broader spatial coverage. Southern California Edison is (SCE) an important landowner and hydropower operator in the area, and SCE has provided a graduate fellowship for a SSCZO student for the past 3 years. Note that the San Joaquin basin from headwaters to valley is also the focus of an NSF Water Cycle and Climate grant recently awarded to T. Harmon at UCM.

Performance metrics will 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 will be tracked. Results from SSCZO research over the past six years are described in more than 36 peer-reviewed publications, plus an additional 6 that are submitted and under review, and more than a dozen in preparation. The initial funding period was in part dedicated to building research infrastructure so we expect to exceed these publication numbers over the coming five years. To house data, we have constructed an online digital library that is hosted on UC Merced servers and also accessible through the new website portals. Core measurements including water-balance instrument clusters, soil-moisture, and flux-tower data are posted in raw format promptly after retrieval from the field. Processed data, including full QA/QC procedures are posted at least annually for core measurements. Data-posting requirements for other projects are the responsibility of individual research groups. SSCZO staff (the data manager and the education/outreach coordinator) 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.

Metrics to measure *outcomes* will include tracking citations of our peer-reviewed papers and use of our data. As an online resource, the Sierra Nevada-San Joaquin Hydrologic Observatory (SNSJHO) digital library is accessed not only by SSCZO team members but also by the broader population of researchers online. An annual survey of data users on the digital library was initiated in January 2013. Of respondents, 56% use the SNSJHO to access data from the SSCZO. Nearly half (48%) access the data more than once per month. This survey will be administered annually to track access and improve ease of use for our data. We also track the adoption of our technology at other sites. For instance the wireless sensor network developed at the SSCZO has been implemented in the American River Basin project west of Lake Tahoe. Water and power utilities in the Southern Sierra Nevada also have a vested interest in snowpack distribution and water runoff. One group has expressed interest in the water-balance sensor clusters and data logging technology, and our field manager is coordinating with them. The depth and breadth of our reach will be tracked through several metrics: Google Analytics (page views, source of traffic, visit duration and other metrics for our main website), the number of followers and retweets for our account on Twitter, the number of scientists interested in coordinating with the SSCZO, and the number of publications and presentations.

Impacts include better decision making because of our research findings, and improvements to the research process. Our large-scale research endeavor in the Sierra Nevada gives us streamlined and effective ways to conduct critical zone research in a mountainous environment. In addition to learning from long-time researchers in the region, we share our experiences with others working in these extreme mountain environments, including the upcoming collaboration with the planned NEON Domain 17 site.

To achieve broader *impacts*, we have developed an extensive dissemination network. Our dissemination strategy must reach stakeholders and resource managers as well as researchers in order to be successful. 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. During the next five years we will continue to use this successful dissemination strategy, in collaboration with the communications offices at UCM and partner institutions. We will aim for monthly press reports, at least bi-annual field visits to the SSCZO by stakeholders, one film project per year (including further editing of footage already in hand), an improved web presence, at least one keynote talk annually at meetings involving water decision makers, legislative briefings, and bi-annual publications outlining the potential for use of SSCZO products in operational resource management. We will also make use of the semi-annual meetings of the Sierra Nevada Research Institute Director's Council to identify further needs and opportunities for dissemination of SSCZO products. Members of this Council include several leaders in water and other natural resource management in northern California and the San Joaquin Valley.

3. Engagement of other CZOs and the broader community

From the outset the SSCZO was planned as a resource for the CZ research community, and our team has actively engaged others in using this resource. Three levels of users are represented at the SSCZO (also see Management Plan Sections 5, 6, and 8): the core SSCZO team, research collaborators and cooperators. Our core team represents 7 universities plus the USFS. Over 20 research groups are collaborators; these groups are not formally part of the SSCZO 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 SSCZO data, collect samples at the SSCZO or make use of other SSCZO resources in their own work.

As part of the SSCZO research engagement plan, the six original CZOs proposed five activities to promote cross-site science. These activities make use of online tools, field visits, and conference opportunities to engage a broader audience in cross-CZO research. Cyberseminars offered through partners like CUAHSI and the Forest Service create a forum for interactive research discussions on CZO topics. These forums provide a cost-effective way (not requiring travel expenses) to reach a broader audience or provide follow-up for the other cross-network activities outlined here.

Cross-CZO collaborations will also be encouraged through interdisciplinary research workshops and research campaigns. These efforts will involve roughly 12 researchers (including investigators, students and postdoctoral scholars) hosted at each CZO in turn. Travel and field costs have been included in the budgets of the proposals submitted in 2013. The intent is to stimulate researchers to work together across disciplines. Each workshop will result in a proposal, synthesis paper or integrative model. CZO and other CZ data will be highlighted. Likewise, the series of cross-site visits to other CZOs will permit network-wide communication and integration of the ongoing modeling activities at each CZO. During those visits, modelers will be cross-fertilized in terms of conceptualizations and codes and will learn how to make best use of available data.

One specific campaign will improve our access to the bottom of the weathered rock, which has traditionally been difficult to access. Deep regolith is widely recognized as the CZ region we understand least. In recognition of this, the CZO network is producing a special issue in Earth Surface Processes and Landforms[*] and ran special sessions at the American Geophysical Union (AGU) and Goldschmidt conferences. Pilot coring projects at all six original CZOs will be extended in the proposed work. The idea called "Drill the Ridge" was proposed in Delaware at the 2011 workshop on Design of Global Environmental Gradient Experiments. The goal will be to reach the water table and fresh rock, typically by wireline drilling, extracting core and overburden. Holes will be logged to the extent possible (electrical, hydrophysical calipers, acoustic and optical televiewer, compensated density calipers, thermal neutrons for relative porosity, and heat pulse flowmeter). If possible, a borehole will be completed as a well, and instrumented with water-level and temperature sensors, with monthly collection of water samples using the method of choice (bailing or pump). Cross-CZO coring will provide training for students in drilling technologies. The Drill-the-Ridge campaign will provide preliminary data for future proposals to core in more locations, with accompanying geophysical surveys, pump testing, and microbiological sampling. The depth of these initial pilot holes will vary from site to

[*] Riebe et al., in review.

site depending on local conditions; we expect holes in the SSCZO to vary from 10-50 m in depth based on results from geophysical surveys[†].

Finally, the SSCZO web pages serve both internal and external communications needs. In 2012-2013, the web page was transitioned from the template that we established in 2007 to a design with many more cross-CZO features, especially around CZO-network programs and activities. The SSCZO outreach and communications person is responsible for updates to these web pages, on at least a weekly basis. The web pages also incorporate a data catalog that provides direct links to CZO data in our digital library. Internal and external users can access work plans, publications, site descriptions, information on participants and collaborators, data and metadata, and outreach activities, schedules, photos, talks, video content, press releases, working-group activities, descriptions of SSCZO models, and other items through the SSCZO web pages. It is also a portal to other CZOs in the network, CZO network activities, and related programs.

4. Public outreach and education

Like the SSCZO research plan, the education and outreach plan is designed to improve understanding of the sensitivities of the regional ecosystem and critical zone to climate change and human management. A primary focus of our work is on the interplay of forest management, water resources, and the impact of a changing climate on the activity and behavior of these systems. The results of such studies are pertinent not just to resource managers and legislators, but also to those whose livelihoods depend on the ongoing health of the forest. We share our findings about montane forests and their water supplies with resources managers, students, researchers, and stakeholders at local to international scales. A second major focus has been on working with water leaders in the state to define and develop prototypes for a new water-information system for California that builds on advances in wireless-sensor networks developed at the CZO, plus parallel advances in cyberinfrastructure and in measurements by satellite and aircraft. Our communication and sharing of scientific products with stakeholders and researchers includes frequent talks around the state and hosting visits to our laboratories and CZO site. Since the Southern Sierra CZO began, we have worked with producers on television and radio features and online educational videos , had multiple editorial pieces in San Joaquin Valley newspapers, briefed a U.S. Senator and other federal legislative staff. Other outreach efforts include public field trips, presentations to grade school students, and partnerships with local high school programs.

The SSCZO maintains a list of all education and outreach activities, including media presentations, which is updated at least on a monthly basis. To quantify outreach efforts, SSCZO staff will track audience reached - students, resource managers, stakeholders, outside researchers

[†] 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. Geophysical constraints on deep weathering and water storage potential in the Southern Sierra Critical Zone Observatory. *Earth Surface Processes and Landforms*, Accepted, doi: 10.1002/esp.3502.

- with the goal of reaching the same number or more each year. In 2013, more than 600 grade-school students were reached through partnerships with Southern California Edison Science Days and other local organizers. SSCZO researchers and staff work also with professional organizations to communicate recent findings from our work. NatureBridge Yosemite and the California Agricultural Teachers Association provide venues for educators to learn about current research efforts. New partnerships under discussion include presentations at local county fairs and at the *Forest Conservation Days*, a grade-school education event with a state-wide reach. The August 2013 public field trip to the SSCZO reached 20 participants, including stakeholders, resource managers, and policy makers.

The SSCZO outreach program is centered in Merced, Madera and Fresno counties, which have diverse populations. On the valley floor large cities are surrounded by highly rural farms. The Central Valley population has a large percentage of Spanish speakers, and the SSCZO home university, UC Merced, has been classified as a Hispanic-serving institution. Populations in the Sierra Nevada foothill and mountain communities are rural and sparsely settled. These communities are part of the mountain wildland-urban interface, face the threat of wildfire, and yet depend on the forests for fuel and power, jobs, and tourism dollars. In the same way, the Central Valley of California is one of the largest agricultural centers in a state with a $35 billion dollar agricultural industry. The public and students of both the valley and mountain regions are aware of the links to natural resources, but have little access to current research. Hence the SSCZO outreach mission focuses on these areas through presentations to students, teachers, and stakeholders, and through collaborations with local television, radio, and print publications. Finally, SSCZO maintains a representative to the Dinkey Landscape Restoration Project Collaborative, which is focused on the landscape immediately adjacent to our flagship site at Providence Creek. This Collaborative increases communication with regional stakeholders, including the Forest Service, local recreation interest groups, and tribal groups. Outreach to legislators and resource managers at the state level is conducted through partnerships in the state capitol, Sacramento, and across the university system.

Online, the website (criticalzone.org/sierra) and digital library (eng.ucmerced.edu/snsjho/files/MHWG/Field/Southern_Sierra_CZO_KREW) will continue to be the largest portals for SSCZO research and data. Through the next five years, we will update & maintain photo/data archive on website and digital library. The SSCZO Education and Outreach Coordinator is responsible for updates to these web pages, on at least a weekly basis. Data updates will be maintained through coordination between the Field Manager, the Data Manager and research staff. Google Analytics has been set up to analyze website traffic & usage on the CriticalZone.org pages. Particular metrics of interest include daily visitors, total unique visitors, average visit duration, and pages per visit. For instance, daily visitors spiked December 8-14 (245 unique visitors to website during week) as a combination of interest from the AGU Fall Meeting and a graduate research opportunity at UC Merced. Year over year, we will aim to grow the average visit duration and the number of pages per visit. Further goals for the SSCZO education and outreach program will be to double the number of education activities available for teachers to download online and explore the potential for translating these activities into Spanish or other languages.

Social media is another useful way to expand SSCZO reach both to researchers and to the general public. In 2013, the SSCZO established a presence on Twitter and Facebook. 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. During the AGU conference in Sacramento, December 2013, notices broadcast on Twitter for several SSCZO presentations were retweeted by researchers outside of the SSCZO team. Other tasks include establishing a presence on LinkedIn, and updating information on Wikipedia, both sites that can act as portals to the SSCZO main website.

The CZO education team is working with researchers to create new interactive activities for undergraduate and K-12 students using CZO data. These activities are designed to meet new - common core standards for analytical thinking and problem solving. Through partnerships with NatureBridge Yosemite and the Center for Advanced Research and Technology (CART) we provide interactive lessons for teachers and students alike. Each year, students in the CART program work with CZO staff to design and conduct a comprehensive snow-survey project.

Dissemination to the research community to share research findings 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. More than 35 articles that cite the first SSCZO grant as primary support have been published to date by Southern Sierra CZO researchers in peer-reviewed journals. Colleagues also present at other national meetings, provide seminars for universities, and give talks to stakeholders and the general public. Additional venues for outreach to researchers include field trips at Goldschmidt 2014 conference (June 2014, Sacramento) and the Mountain Research Initiative Global Workshop & Fair (July 2014, Reno).

Modeling also has been an important role in disseminating research results. Modifications 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. We also couple RHESSys with larger-scale modeling activities. Lessons on using RHESSys will be incorporated into the Watershed Science Master Class, to be held January 2014 and taught in part by Southern Sierra CZO investigator C. Tague.

5. Organization and reporting structure

The Southern Sierra CZO is a multi-institution research program involving 8 core investigators, 5 additional senior personnel, 3 full-time staff, over 20 collaborators, and several graduate and undergraduate students (see Tables 1, 2, and 3). The core team members each have leadership roles in the SSCZO and the CZO network, and form the executive committee for the SSCZO.

The core SSCZO investigators are committed to the success of the CZO network, and consider it to be a major focus of their own research. Leadership and effective management of SSCZO will be very important to achieving the program goals. The SSCZO management structure is designed to provide a responsive forum for making decisions, allocating resources and responsibilities, and monitoring and assessing progress towards meeting program objectives across partner institutions.

The lead PI (R. Bales) provides overall leadership for the SSCZO. PI Bales is responsible for leading all activities in the SSCZO including budget; research direction; collaboration with internal and external partners; integration of all SSCZO research, education and outreach activities and project management. He will ensure implementation of NSF policies and serves as chief spokesperson for SSCZO. He chairs the Executive Committee and supervises SSCZO staff except as otherwise indicated. The Executive Committee serves as the core management team and decision-making group for the SSCCZO and provides support to the PI in leading and managing the activities of the SSCZO. The Executive Committee includes Bales, Conklin, Tague, Goulden, O'Geen, Riebe, Glaser and Hart (see Section 6, Table 1). When possible, management decisions will be made by consensus of this group. If consensus cannot be reached, the PI will consult with all members of the SSCZO team and will then make final decisions on all matters. The Executive Committee will have a virtual meeting approximately monthly, and an in-person twice per year. One meeting will be in conjunction with the annual science planning and reporting meeting of the entire SSCZO team discussed below, to oversee the program administration and research, establish policies, and to plan for further development of the CZO. See Table 1 for more information about the leadership roles of the members of the EC.

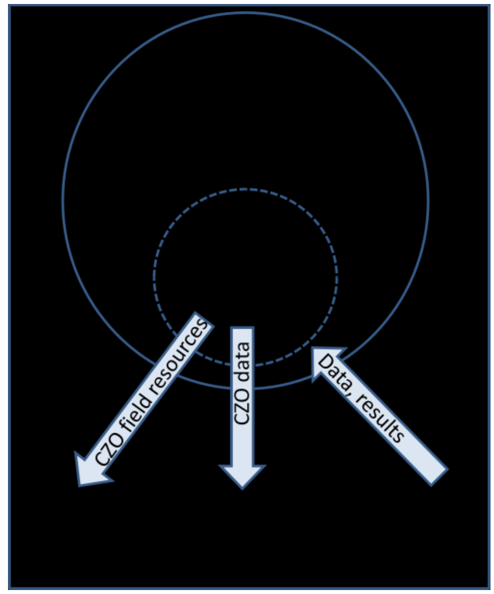

Figure 1. Levels of CZO users.

6. SSCZO team members

The current SSCZO team includes faculty from six university institutions, as well the US Forest Service Pacific Southwest Research Station. Three full-time staff, more than 20 collaborators, and several graduate and undergraduate students work on the SSCZO project. The core research team includes 8 core investigators and 5 additional senior personnel (team members and responsibilities are listed in Table 1). Three staff members interface with the core research team to ensure the successful operation of the Observatory (staff and responsibilities are listed in Table 2).

Table 1. SSCZO leadership and team

Name/Title/Institution	Role in SSCZO
Roger C. Bales, Ph.D., Lead PI Director, SNRI and Professor, School of Engineering, UC Merced	**Director, SSCZO**. Supervises SSCZO data manager, field program manager, and SNRI staff; co-lead dissemination strategy, stakeholder relations and communications with NSF and other CZOs.
Martha H. Conklin, Ph.D., Co-PI Professor, School of Engineering, UC Merced	**Member, Executive Committee**. Lead, education, outreach and communications; supervises SSCZO outreach and communications staff; co-lead dissemination strategy, stakeholder communications and communications with NSF and other CZOs. Co-lead for cross-CZO data management.
Steven D. Glaser, Ph.D., Senior Person. Professor of Civil and Environmental Engineering, UC Berkeley	**Member, Executive Committee**. Lead UCB sub-award; co-lead dissemination strategy and stakeholder communications. Has primary role for measurement technology and sensor networks within SSCZO and for planning across CZOs.
Michael L. Goulden, Ph.D., Co-PI. Professor and Chair, Department of Earth Systems Science, UC Irvine	**Member, Executive Committee**. Lead, UCI sub-award; lead for flux towers, ecosystem modeling.
Stephen C. Hart, Ph.D., Senior Person. Professor of Ecology, UC Merced	**Member, Executive Committee**. Lead, biogeochemistry and co-lead for soils. Primary science liaison with PSW. Liaison for cross-CZO biogeochemical research.
Anthony T. O'Geen, Ph.D., Senior Person. Soil Resource Specialist in cooperative Extension, Department of Land, Water and Air Resources, UC Davis	**Member, Executive Committee**. Lead, UCD sub-award. Co-lead for soils, drilling activities. Co-lead on SSCZO and liaison for cross-CZO modeling of soil formation and pedology.
Clifford S. Riebe, Ph.D., Co-PI. Assistant Professor, Geology and Geophysics, University of Wyoming	**Member, Executive Committee**. Lead, UW sub-award. Lead for geophysics and geochemistry, and liaison to Wyoming Center for Environmental Hydrology and Geophysics. Co-lead for SSCZO and cross-CZO drilling, geophysics and data management.
Christina L. Tague, Ph.D., Co-PI. Associate Professor, Environmental Science, UC Santa Barbara	**Member, Executive Committee**. Lead, UCSB sub-award. Lead for hydrologic and biogeochemical modeling and liaison for cross-CZO modeling.
Asmeret Asefaw Berhe, Ph.D., Senior Person. Assistant Professor, Soil Biogeochemistry, UC Merced	**Member SSCZO Team**. Lead on SSCZO and liaison for cross-CZO terrestrial and aquatic carbon cycling.
Marilyn L. Fogel, Ph.D., Senior Person. Professor, School of Natural Sciences, UC Merced	**Member SSCZO Team**. Lead on SSCZO and liaison for cross-CZO isotopic tools and investigations.
Jan W. Hopmans, Ph.D., Senior Person. Associate Dean, College of Agriculture and Natural Resources, and Professor, Land, Air and Water Resources, UC Davis	**Member SSCZO Team**. Lead role in soil physics and subsurface water-balance measurements and modeling.
Carolyn T. Hunsaker, D.Env., Senior Person. Research Ecologist, USDA Forest Service, Pacific Southwest Research Station (PSW)	**Member SSCZO Team**. Lead PSW scientist. Leads stream, meteorological and vegetation measurements at main CZO instrumented site.
Samuel J. Traina, Ph.D., Senior Person. Vice Chancellor for Research and Professor of Natural Sciences, UC Merced	**Member SSCZO Team**. Co-lead on SSCZO and liaison for cross-CZO modeling of soil formation and pedology.

Table 2. SSCZO staff and responsibilities

Name/Title/Institution	Role in SSCZO
Matthew Meadows, M.S. **Field-Program Manager** Sierra Nevada Research Institute, School of Engineering, UC Merced	**Staff, SSCZO**. Lead on field operations, permits, data collection, instrumentation, and site maintenance. This includes the construction and management of our environmental monitoring network, management of field operations, logistics, assisting with education outreach, and support of collaborations.
Xiande Meng, M.S., Data Manager Sierra Nevada Research Institute, School of Engineering, UC Merced	**Staff, SSCZO**. In charge of servers and digital library for archiving and computing; facilitates data access for both CZO researchers and the scientific community; processes some data from level 0 to higher levels including QA/QC, calibration and gap filling; prepares and uploads data into national CZO databases; assists researchers with data analysis and data visualizations; provides satellite/GIS data support for the group.
Erin Stacy, M.S., **Education and Outreach Manager** Sierra Nevada Research Institute, School of Engineering, UC Merced	**Staff, SSCZO**. Primary coordinator for education, outreach and communications. Responsibilities include creating and leading outreach events, updating website, managing social network feeds, preparing reports and educational handouts, coordinating with visiting researchers, journalists, and cross-CZO network teams.

7. Institutional responsibilities

The SSCZO is administered by the Sierra Nevada Research Institute (SNRI) at UC Merced. SNRI is an organized research unit reporting to the Vice Chancellor for Research, with the SNRI faculty director (2013-2014 Interim Director M. Conklin) appointed by the UC Merced Chancellor. It currently has 27 faculty affiliates representing UC Merced's three schools; its many research scientists, graduate students and undergraduate students are largely supported on research grants and fellowships. SNRI's administrative staff includes an executive director, a development director and 4 staff who provide administrative support for grants and other accounts. These staff will continue to administer the CZO award and associated grants, with appropriate support from other units on campus. SNRI also manages facilities and infrastructure supporting research, including field stations, an analytical laboratory and vehicles that are operated largely on a recharge basis. A full-time research scientist director and a caretaker staff the Yosemite Field Station. This facility is about a 45-minute drive to the lower elevation SSCZO site, and nearly 2 hours from the main SSCZO site. SNRI maintains a small satellite field station at Wolverton in Sequoia National Park, approximately a 2-hour drive from the main SSCZO site. The Wolverton catchment is instrumented, and is used by the SSCZO for higher-elevation comparisons to the main SSCZO catchments in Providence Creek. SNRI manages an Environmental Analytical Laboratory for the university, and has space for staging field work. SNRI has a fleet of eight 4WD vehicles for field research, plus four snowmobiles, three travel trailers and many smaller items of research equipment. SNRI is in the process of establishing a 6500-ac (2630 ha) Grasslands-Vernal Pool Reserve on land owned by the university adjacent to the main campus, and added a research scientist as reserve director in January 2013.

Three main SSCZO sites are located in the Sierra National Forest (SNF). The fourth is located at the San Joaquin Experimental Range, operated by US Forest Service Pacific Southwest Research Station (PSW). SSCZO researchers comply with SNF and PSW permitting regulations. SSCZO research sites overlap with the area of the Dinkey Landscape Restoration Project, a collaborative planning process under the Forest Landscape Restoration Act. The SSCZO maintains a designated representative to the Dinkey Landscape Collaborative to provide input on research findings and update SSCZO team on the planning process; the current representative is the education and outreach coordinator.

Table 3. Planned SSCZO collaborators

Sarah Aciego, University of Michigan
Emma Aronson, University of California, Irvine
Joseph Blankinship, University of California, Santa Barbara
Aniela Chamorro, Texas A&M University
Yihsu Chen, University of California, Merced
Jeff Diez, University of California, Riverside
Anthony Dosseto, University of Wollongong
Estelle Eumont, University of California, Davis
Qinghua Guo, University of California, Merced
Thomas Harmon, University of California, Merced
Jane Hayes, USFS Pacific Southwest Research Station
W. Steven Holbrook, University of Wyoming
Benjamin Houlton, University of California, Davis
Susan Hubbard, Lawrence Berkeley National Laboratory
Steve Jepsen, University of California, Merced
Dale Johnson, University of Nevada, Reno
Branko Kerkez, University of Michigan
James Kirchner, ETH Zürich
Wally Miller, University of Nevada, Reno
Noah Molotch, Jet Propulsion Laboratory
Keith Musselman, University of Saskatchewan
Bob Rice, University of California, Merced
Kristina Rylands, NatureBridge Yosemite
Shawn Serbin, NASA
F. von Blanckenburg, GFZ Potsdam
Eric Waller, University of California, Berkeley
Steve Wilson, Center for Advanced Research & Technology

The field-program manager is co-located with PSW in Fresno, about a 1-hour drive from the UC Merced campus. This provides more-convenient day-to-day access to the field sites for that person, and also facilitates cooperation with PSW field staff. The field-program manager oversees both the continuous, core-measurement program, and field visits by the CZO team and others. This person also helps organize and execute coordinated campaigns. In cooperation with PSW, he/she is also responsible for safety briefings for visitors, safety training for those doing field research and scheduling of field research. He/she maintains accurate location information on all sensors, sampling and experiments; that information is available on the SSCZO web pages.

8. Integration

Integration across the SSCZO team will be coordinated between the principal investigators and the SSCZO staff members. Research and strategic decisions will be made through consensus of the Executive Committee where possible (see Section 5). Integration planning is encouraged at the end-of-summer Annual Team Meeting, which is open to all collaborators and cooperators who can make the trip. Staff are responsible for planning the team meeting in conjunction with PIs. In the management structure, collaborators work closely with the SSCZO team, but are not funded directly by the SSCZO, while cooperators work much more loosely, using SSCZO field resources or data online (Figure 1). Further integration between SSCZO team, collaborators and cooperators occurs over email and through the website. The website has been set up to invite new researchers to make use of our data and our facilities.

Through 2013, we have established collaborations with over 20 research groups (Table 3) from outside the core team of investigators. Our plan to grow this number will involve personal contacts, presenting seminars at other institutions highlighting CZO science, invitations to visit the SSCZO and our annual science meeting, invitations to present seminars, joint proposals between SSCZO team members and collaborators, a clear web presence that provides ready, timely access to our data and descriptions of science activities, and distribution of our publications to potentially interested groups. We have budgeted a small sum ($3000 per year) to cover travel and supplies to help jump start collaborations by facilitating field visits. We will target cross-CZO research in these efforts. The cross-CZO meetings, seminars and outreach described earlier in the management plan will be part of this effort. This same approach will get the word out to cooperators and collaborators alike.

The SSCZO has worked closely with the USFS during its initial funding cycle. In particular, PSW recognizes the connection between sustainable ecosystem management and scientific knowledge and is continuing its research to contribute to predictive ability and better assessment of forest-management actions. We have been meeting with the leadership of PSW to explore ways of strengthening research cooperation between UC and PSW scientists (see letter of support on continued data and resource sharing). We are working on a formal agreement between UCM and PSW for continuation of long-term research at KREW. Our immediate plan is to jointly hire a new research scientist focused on KREW and related areas. The position is currently open and the goal is to complete the hiring by spring 2014. Our ongoing collaboration will be based on the foundation of science built over the past few years. Some insights that PSW expects in coming years include areas of research that overlap with the SSCZO aims, leading to synergistic benefits for both groups: i) effect of vegetation-management actions on ecosystem services, including water yield, timing of streamflow and C sequestration; ii) effect of climate warming and disturbance (e.g. fire, pests) on ecosystem services, and management strategies for adapting to and mitigating expected impacts; iii) interactions between soils/regolith, climate, ecosystem function and water balance, leading to a better predictive ability for water and C budget responses to perturbations and management actions; and iv) connections between forest-restoration activities and the resilience of riparian, meadow and forest ecosystems.

9. Updates to management plan

Activities are prioritized around the conceptual model and research questions (Figure 2) laid out in the most recent proposal. Strategies to coordinate activities across the SSCZO team are in part settled during the annual team meeting with ongoing updates to the plan through the Executive Committee monthly meetings. The management structure is nimble to handle changes, such as major structural damage to field installations or to accommodate new advances in technology. Finally, the SSCZO is an important part of the research of the Co-PIs and Senior Persons of the SSCZO team. Thus all have partial, leveraged research support from sources other than the main CZO award for their work at the SSCZO. These additional funds further increase the flexibility of the SSCZO research program.

10. Research, measurement and modeling activities

Over the next 5 years we will: i) improve basic understanding of how ecosystem structure and function co-evolve with regolith development, ii) improve ability to predict how the CZ changes through time in response to changes in driving variables, and iii) inform decision making for sustainable management of ecosystem services under future scenarios of climate change and land-use intensification. To address our 8 SSCZO research questions (Figure 2), we will build on our existing infrastructure and research findings to further advance mechanistic understanding of the interplay of geophysical processes, ecosystem structure and function, and material (water, C, other nutrients) fluxes across spatiotemporal scales. We will continue to combine our co-located measurements of hydro, geo, ecological and climate variables at our focus sites using process-based models of CZ evolution and coupled climate-hydrology-biogeochemical cycling. We will use the measurements to parameterize, refine and test the models; these models, along with spatial data sets such as remote sensing and digital soil modeling, permit us to generalize observations to broader scales across space and time. Characterizing the subsurface remains one of the key limitations in our understanding of how the CZ operates. Hence we will continue addressing methodological questions related to the quantification of regolith properties and CZ function.

Priorities for research activities will be guided by the SSCZO Executive Committee. Much of the conceptual plan is constructed during the semi-annual in-person meetings of the Executive Committee and the Annual Team Meeting. Work plans detailing the scope, schedule, field installations and planned publications for each project are included in Appendix C. The work plan will be reviewed and updated on a semi-annual basis when compiling progress reports.

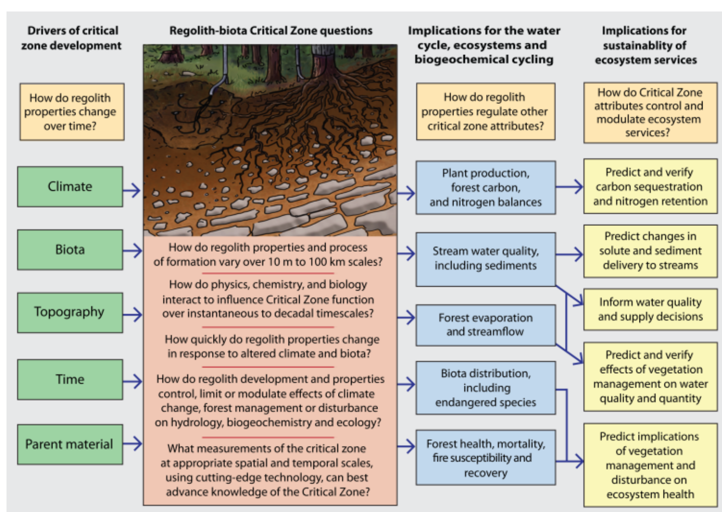

Figure 2. Regolith development and forest productivity across the elevation gradient.

11. Financial management

Funds are allocated based on a detailed budget that was prepared prior to submittal of the proposal, and agreed upon by the Executive Committee. Any changes to this allocation will be done in consultation with the Executive Committee.

SSCZO activities are administered through the Sierra Nevada Research Institute at UC Merced. Sub-grantee awards are dealt out from SNRI to the individual granting institutions, where they are managed. The SNRI accountant manages SSCZO funds; all justifications, ordering, and reimbursements are handle jointly by the accountant and administration staff in SNRI. Administrative staff at SNRI also work with SSCZO PIs to ensure that NSF guidelines are met. Significant changes to financial management plans, as with other aspects of the SSCZO research program, will be decided by the Executive Committee structure in conjunction with the Lead PI.

12. Data management

The SSCZO Data Management Plan lays out standards for data management within the SSCZO research team, as well as for common measurements and data protocols for cross-CZO projects. The internal Data Management plan covers the data types collected, data and metadata standards, policies for access, sharing and citing the data, and ultimately for preserving and archiving the data. The full Data Management plan is included in Appendix A.

The strategy for new cross-CZO research projects was streamlined by PIs across the network. Through cross-CZO organized field campaigns and modeling workshops, CZO researchers will be able to cross-fertilize terminology, conceptualizations, code. Modelers will be able to learn the best ways to make use of the available data. The Drill the Ridge Project is another cross-CZO project that will provide standardized field protocols and data collection across the network. Cross-CZO data management is standardized by lead researchers and the national data-management team (including data managers and website managers across the network). Data levels were reconsidered in 2013; the basis remains CUAHSI data level standards, though updated examples were added for CZO-specific research, and the distinctions between data levels were clarified. More in-depth information on common measurements and protocols, as well as data models and ontology is compiled in Appendix B.

13. Changes to leadership team

The organizational structure of the SSCZO lays out the Executive Committee and institutional management structure for operation (Sections 5 and 6). The larger Sierra Nevada Research Institute provides a highly stable base for SSCZO operations at UC Merced. More fully described in Section 7 of this plan, SNRI manages the day-to-day functionality of the SSCZO, including finances, hiring within UCM and coordination of larger events like the team meeting, or field trips. SNRI hosts the larger institutional responsibility for administering the CZO funds and meeting research goals. In the unforeseen event of changes to the leadership team, a new leadership chain would be established by consensus of the Executive Committee. For continuity, the first choice will likely be an established member of the CZO research team. Taking it a step further, the depth of senior investigators within SNRI would provide an alternative to presently established CZO investigators if needed.

Appendix A – Data management Plan

The CZOs are a community resource, and open data access is one of our fundamental goals. Continuing previous work, the suite of core and investigator-specific data produced by the Southern Sierra CZO (SSCZO) will be expanded and refined. Data management will be conducted in coordination with the National CZO network, and through collaboration with the Pacific Southwest Research Station (PSW) and others. As part of the SSCZO commitment to integrated, participatory research, data will be made available to CZO participants, collaborators and the broader community in a timely manner. We serve on the CZO Data Information Management Committee and maintain a close connection with the ongoing developments in NSF's CZ-EarthCube initiative.

1. Types of data collected include observational, experimental, simulation, and data that are derived or compiled. Observational data include real-time environmental records collected in the field, including but not limited to sensor readings, telemetry, images, remote sensing, seismic surveys, and on-site sampling. A recently installed COSMOS system is collecting frequent soil moisture data over a larger spatial scale. Meteorological data, streamflow, stream chemical and sediment data, and various other data are provided through cooperation with PSW. Experimental data are collected from laboratory analyses of rock, soil, and water samples. Simulation data are generated from test models, such as snow-distribution and soil-depth models. Derived or compiled data use more-complex models and data analysis, which include eco-hydrologic models (ex. RHESSys), hydrologic models (e.g., HYDRUS 2-D, PIHM), and compiled databases (ex. LiDAR-derived). Spatial expansion and temporal extension of the observational and experimental data sets provide material for analysis and validation in the conceptual and numerical models.

Data types include text, spreadsheets, binary files, spatial layers, images, model results, video files, reports, and software/programs for data collection and processing. Real-time observation data are stored in CSV files and in spreadsheets when appropriate. When appropriate datasets have a specific file type, we preserve that file format (e.g., seismic data are collected and stored as SEG2 binary files). Soil, rock, water, vegetation and other physical samples are also collected for analysis and archive records.

2. We will continue to use **data and metadata standards** based on the CZO-wide metadata format for basic site and method metadata. CZO-wide metadata standards and controlled vocabulary for some datasets were adapted from the CUAHSI Hydrologic Information System (HIS). Each dataset has one real data file and one metadata file, which are harvested into HIS. Each research site has a configure file that directs the HIS to datasets that should be harvested. The HIS checks the configure file on a specified schedule. After harvesting, the CUAHSI HydroDesktop can be used to search, download, visualize and analyze the data. We will continue to work with HIS to include the maximum variety of SSCZO data, though some datasets will need to wait for new metadata models (CZO network efforts in progress). Metadata includes location of data collection, methods, and equipment used. Additional metadata are collected and stored as needed to fully describe each dataset (e.g., individual sensor calibrations and locations at a site). Other metadata include programs for sensor acquisition, data collection, and data processing. Rock samples will go into System for Earth Sample Registration (SESAR) with an International Geo Sample Number (IGSN).

Since inception in 2007, all SSCZO data have been available through our own digital library. In it data levels have been defined, and data are archived at each level. Data-processing programs include data retrieval/collection programs (e.g., raw flux-tower data is processed into daily CSV text files) and programs for processing data from Level 0 (raw data) to higher-level, more-easily useable data files appropriate for secondary use. Each SSCZO investigator assumes responsibility for further processing on selected data streams, with the goal of making processed data available on a monthly to annual basis, depending on the measurement. For metadata we use code flags or processing notes to describe how the data have been brought to higher levels (e.g., from Level 0 to Level 2).

3. Policies for access and sharing, including a convenient, accessible and user-friendly system for data and information management, is one of our foremost priorities for a successful CZO network. Clearly defined CZO-network policies are absolutely essential for internal data management, as well as sharing data and information among investigators and with the broader scientific community. Policies in place will continue to be improved under collaborative cross-CZO efforts.

Data inventories are published for the SSCZO and updated when there is a significant change in type, location or frequency of such observations. Our posted data are used by researchers both within the CZO network and at external institutions. In a survey, nearly half of the users accessed data monthly or more frequently. Based on feedback, we are further improving the ease of access and use for the digital library. We are also working closely across the CZO network to development an integrated data/measurement framework that will document a range of critical-zone geologic and climatic settings, inform the theoretical framework that we are building for CZ evolution, constrain our modeling efforts (including coupled systems models), and test our model-generated hypotheses across the CZO network.

The SSCZO digital library is maintained at UC Merced's Sierra Nevada Research Institute, originally developed as the Sierra Nevada-San Joaquin Hydrological Observatory digital library under a WATERS testbed grant (BES-0610112). Under it, we have developed and implemented a Zope- and Plone-based digital library for convenient storage and retrieval of files on a server that has several terabytes of disk storage, which is expandable to fit our increasing storage demands. The system accepts raw data from sensors or manual measurements, provides an interface for data processing, stores multiple versions of data, and provides a public interface for convenient data retrieval. In addition to the CUAHSI HIS, data will also being made available through community portals as they develop. However, the current system assures that data will be available in common formats (flat files whenever possible), with relevant metadata, in a timely manner. Some datasets, such as geochemistry of earth materials, will also be fed into community databases (CZchem and EarthChem).

4. Policies and provisions for re-use and re-distribution. We make CZO core-measurement data available to the research community immediately upon collection (raw data) and when quality checked (processed data). Non-core data become available for re-use/re-distribution after publication or no later than two years after research is complete, whichever comes first. The original data collector/creator/ investigator retains the right to use the data before opening it up to wider use, but is still limited to the two-year time restriction. This period may be extended under exceptional circumstances, but only by agreement between the investigator and NSF. For continuing observations, processed data (e.g., cleaned, gap filled, calibrated time-series data) are made public availably annually. Non-core data include, but are not limited to, individual studies done by SSCZO investigators, collaborators, and/or students that are not intended to be part of the continuous critical-zone monitoring infrastructure. Non-core data may become available for re-use/re-distribution upon request before that time, based on contacting the Data Manager and obtaining permission from the scientist(s) who collected the data. Data are uploaded to the digital library routinely, with access initially limited to SSCZO team members. Permission for others to view/access non-public data can be obtained through our Data Manager, but must meet the requirements outlined in the CZO Data Use Agreement. This CZO-wide agreement includes provisions for appropriate acknowledgments, including acknowledgement of NSF funding, when published or cited.

5. Plans for archiving and preservation of access. All public data will continue to be deposited in our digital library, where we will support formats of the CZO or other community data systems so they can access and serve our data. Our digital library permits access to the public, provides tools for long-term data management, and permits permanent storage options. Our digital library has built-in contingencies for disaster recovery including redundancy and recovery plans, with on-site and off-site backup. We are further developing our data management to prepare datasets for long-term storage/access (20+ year access), which should allow for proper data citation including: giving the data producer appropriate credit, allowing easier access to the data for re-purposing or re-use, and enabling readers to verify scientific results. Data used for publication will be archived along with appropriate metadata citation elements, which will include: author(s), title, year of publication (the date when the dataset was published or released), publisher (the data repository), any applicable identifier (including edition or version), availability and access (URL or DOI link).

Appendix B – Common measurement and data model plan

Common measurements for the CZO network are outlined in a document drafted in 2013 (appended to management plan). It states in part that all CZOs seek to develop a common set of measurements in three areas:

1. **CZ architecture and evolution;** including structural change with time; regolith and drainage valley evolution; rates of soil production, differentiation, and erosion; 3D spatial distribution and character of bedrock, soil, vegetation, and topography.

2. **Fluxes across the CZ boundaries;** including vegetation-atmospheric; soil-atmospheric; soil-plant; bedrock-soil; terrestrial-aquatic.

    a. *Energy*: Measurements of incoming and outgoing visible and infrared radiation, plus latent and sensible heat exchange, and their distribution within a watershed.

    b. *Water*: Measurements of catchment-scale hydrologic cycles and pathways, including precipitation amount and type, evapotranspiration (ET) and its components, subsurface flows, and stream discharge.

    c. *Solutes and Sediment:* Gaseous, aqueous and solid inputs and exports of elements (carbon, metal(loid)s, nutrients) are quantified with sufficient characterization to distribute these quantities across a catchment and landscape.

3. **Fluxes and changes in storage of the major CZ reservoirs at the catchment scale**

    a. *Energy*: Changes in the thermal state of the near-surface realm.

    b. *Water*: Amounts and changes in snowpack, soil water and groundwater storage

    c. *Mass transfer:* Using known water fluxes and measured concentrations to provide solute and sediment mass fluxes and changes in the major reservoirs of the CZ. Measurements are of sufficient detail that they can describe changes as a function of depth and watershed location.

Common data models are constructed in accord with the SSCZO data-management plan and guidance of the national Information Management Committee. The CZO integrated data management system (CZOData) provides information on standardized dataset formats, metadata and other protocols. CZOData standards build upon the data levels specified by CUAHSI guidelines.

Our data manager works with other SSCZO staff, investigators and students to prepare metadata and process data for quality assurance and quality control and to meet centralized CZO standards. Data produced by the SSCZO are compiled in a central database through a collaborative effort with the other CZOs and the Spatial Information Systems Laboratory at the San Diego Supercomputer Center.

Further cross-CZO data management will be implemented as part of the workshop plan, with cross-CZO workshops for LiDAR and modelling, as well as the cross-CZO field campaigns. Communication about data efforts is facilitated through monthly web conferences, annual workshops, and on wiki-based discussion pages hosted by the Spatial Lab. SSCZO data are linked and organized through the CZO portal in order to facilitates cross-CZO data searches. Standardized CZO data are also accessible through the CUAHSI HIS HydroDesktop program, which allows searches based on geographic, topical, or temporal variables. High-resolution LiDAR data collected by the CZO team are managed by Qinghua Guo and accessible via the OpenTopography repository. Finally, soil geochemistry data collected across the network are being integrated into a database model on the EarthChem format, which is under development for online access. Data policies and public data are readily accessible on the national CZO website. While these plans are under continued development for clarity and usability, they facilitate the common standards and open-use policies of the CZO network.

The **Data Use Plan**, posted on the website (accessed January 2014, draft v.0.3.5), details the process for how secondary (those other than the producers) researchers should use and cite CZO data.

> 1. **Use our data freely**. All *CZO Data Products** except those labelled *Private*** are released to the public and may be freely copied, distributed, edited, remixed, and built upon under the condition that you give acknowledgement as described below. Non-CZO data products — like those produced by USGS or NOAA — have their own use policies, which should be followed.
>
> 2. **Give proper acknowledgement**. Publications, models and data products that make use of these datasets must include proper acknowledgement, including citing datasets in a similar way to citing a journal article (i.e. author, title, year of publication, name of CZO "publisher", edition or version, and URL or DOI access information. See http://www.datacite.org/whycitedata).
>
> 3. **Let us know how you will use the data**. The dataset creators would appreciate hearing of any plans to use the dataset. Consider consultation or collaboration with dataset creators.
>
> **CZO Data Products*. Defined as a data collected with any monetary or logistical support from a CZO.
>
> ***Private*. Most private data will be released to the public within 1-2 years, with some exceptionally challenging datasets up to 4 years. To inquire about potential earlier use, please contact us.

Similarly, the **Data Sharing Plan** is posted on the website (accessed January 2014, draft v.0.2.5) and details the public guidelines for sharing data gathered by CZO researchers .

All CZO investigators and collaborators who receive material or logistical support from a CZO agree to:

1. **Share data privately within 1 year**. CZO investigators and collaborators agree to provide *CZO Data Products** — including data files and metadata for raw, quality controlled and/or derived data — to CZO data managers within one year of collection of samples, *in situ* or experimental data. By default, data values will be held in a *Private CZO Repository***, but metadata will be made public and will provide full attribution to the *Dataset Creators*[†].

2. **Release data to public within 2 years.** CZO *Dataset Creators*[†] will be encouraged after one year to release data for public access. Dataset Creators may chose to publish or release data sooner.

3. **Request, in writing, data privacy up to 4 years.** CZO PIs will review short written applications to extend data privacy beyond 2 years and up to 4 years from time of collection. Extensions beyond 3 years should not be the norm, and will be granted only for compelling cases.

4. **Consult with creators of private CZO datasets prior to use.** In order to enable the collaborative vision of the CZO program, data in *Private CZO Repositories*** will be available to other investigators and collaborators within that CZO. Releasing or publishing any derivative of such private data without explicit consent from the *Dataset Creators*[†] will be considered a serious scientific ethics violation.

* *CZO Data Products*. Defined as data collected with any monetary or logistical support from a CZO. Logistical support includes the use of any CZO sensors, sampling infrastructure, equipment, vehicles, or labor from a supported investigator, student or staff person. CZO Data Products can acknowledge multiple additional sources of support.

***Private CZO Repository*. Defined as a password-protected directory on each CZO's data server. Files will be accessible by all investigators and collaborators within the given CZO and logins will be maintained by that local CZO's data managers. Although data values will not be accessible by the public or ingested into any central data system (i.e. CUAHSI HIS), metadata will be fully discoverable by the public. This provides the dual benefit of giving attribution and credit to dataset creators and the CZO in general, while maintaining protection of intellectual property while publications are pending.

[†] *Dataset Creators*. Defined as the people who are responsible for designing, collecting, analyzing and providing quality assurance for a dataset. The creators of a dataset are analogous to the authors of a publication, and datasets should be

cited in an analogous manner following the emerging international guidelines described at http://www.datacite.org/whycitedata.

Appendix C – Work plan

The Southern Sierra CZO draws much of its strength as an interdisciplinary research program from the diversity of research projects. These projects explore specific aspects of the research questions and may only last for part of the SSCZO duration. Meanwhile, measurements and data management for the core research are coordinated through UC Merced. Integration of research into the general conceptual model will be a joint effort between individual researchers and the greater SSCZO team. Below, vignettes cover the scope, installations, funding, schedule and manuscripts for the core measurement program as well as the individual research projects.

This work plan is a communication and reference tool for the SSCZO team. Freely available online, it also informs collaborators and interested parties of ongoing research. Updates will be made to the work plan on a bi-annual basis when progress reports are compiled. In particular, schedules will be expanded as work progresses.

Topic. Core CZO measurements, data management and integration
Investigator. Roger Bales & Martha Conklin, UCM
Students & research staff.
Matt Meadows, field hydrologist
Xiande Meng, data manager
Scope. Provide catchment-scale measurements of water and material balances in selected SSCZO catchments, and management of data and information for the SSCZO. Carry out integrated modeling of the water balance using the rich data sets in selected catchments. Share results with stakeholders in California.
Field installations & support. Core measurements made by the CZO team complement those done by the KREW team. One focus is the water-balance instrument cluster, which is anchored by an eddy-correlation flux tower but with ground measurements extending 1-2 km from the tower. The flux tower provides point measurements of water, energy and carbon exchange with the atmosphere, which are extended outward using the meteorological, snow/soil, remotely sensed and other spatial data. The instrument cluster includes three embedded sensor networks, one located in the vicinity of the tower, one at a lower elevation with cold-season precipitation a mix of rain and snow lower met station vicinity) and one at a higher snow-dominated elevation upper met station vicinity). Measurements that are part of the instrument clusters include: snow depth, air temperature, solar radiation (open and under canopy), reflected radiation, soil moisture, temperature and matric potential (multiple depths), sap flow. Across the meadow and stream sections we measure water level, temperature, and electrical conductivity in piezometers. Measurements on the tower include wind speed and direction, atmospheric water vapor flux, CO_2 flux, shortwave and longwave radiation (incoming/outgoing), precipitation, relative humidity, barometric pressure.
Data management. CZO data are archived in a digital library: https://eng.ucmerced.edu/snsjho.

Topic. Snow distribution based on LiDAR and in-situ measurements
Investigator. Roger Bales, UCM
Students & research staff.

Matt Meadows, field hydrologist
Peter Kirchner, PhD student (completed December 2013), UCM
Zeshi Zeng, MS student, UCB

Scope. Using primarily observations at the Wolverton watershed of Sequoia National Park, we are determining the influence of vegetation and other physiographic features on snow distribution and melt at multiple scales (Kirchner). We are extending that analysis to other CZO areas (Zeng).

Patterns of snowcover. It is our hypothesis that spatial variations in tree canopy cover are as important as slope and aspect for variability in snowcover. Our spatially dense measurements of snow depth are placed to capture the variability in physiographic features and vegetation across the catchments as part of our core measurement program. Radiation was quantified by using a combination of *in situ* sensors and a portable canopy imager such as the CI-110 by CID, Inc. We placed tidbit temperature loggers on grid and ordinal patterns in key locations to provide a mesoscale record of snowmelt. Scaling depends to some extent on how well distributed measurements capture the inherent variability across a catchment. The high frequency and spatially dense core measurements provide the basic data for this. Synoptic measurements conducted at mesoscales provide the ability to bridge these high-frequency data to larger scales. These findings provide a basis for linking our high frequency temporal measurements with high spatial resolution remote-sensing images.

Funding. CZO, with graduate fellowship from SCE.

Schedule, including field work. Core instrumentation in the Wolverton watershed was completed in 2007. Instrumentation calibration and maintenance are continuing in cooperation with Noah Molotch (JPL).

Manuscripts in progress & planned.

1. Snow accumulation and melt distribution in forest ecosystems. Kirchner, Bales. Uses CZO core measurement data from the Providence and Wolverton watersheds: radiation, snow depth, precipitation, and soil moisture, coupled with synoptic surveys of depth and snow water equivalent and long-term data collected at the snow courses and pillows.
2. Mesoscale representation of snow and soil moisture in forested ecosystems. Kirchner, Bales. Uses same datasets as above in addition to repeated geophysical surveys conducted at target locations throughout the Wolverton watershed. If LIDAR or hyperspectral imagery of the study areas becomes available prior to publication they will be used also.

Topic. Meadow surface-groundwater interactions and biogeochemistry
Investigator. Martha Conklin, UCM
Students & research staff. Ryan Lucas, PhD student, UCM
Scope: *Surface-groundwater interactions*
Groundwater elevation and depth-specific pressure head are monitored in 24 wells and piezometers in the P301 meadow and 31 wells and piezometers in Long Meadow. Groundwater elevations were analyzed for inter-annual and seasonal trends as well as daily evapotranspiration (ET) signals. Water samples were collected from the monitoring wells and analyzed for stable water isotope composition and major ion concentrations. Slug tests were conducted at each of the monitoring wells in both meadows in order to acquire hydraulic conductivity of the meadow substrate.
Additional salt dilution tracer tests were conducted at the two meadow stream locations in P301 meadow. The tests were used in conjunction with 15 minute interval stage measurements to improve the rating curve for each location. Water samples were collected periodically from each stream location and analyzed for stable water isotope composition and major ion concentrations. We deployed a meteorological station in P301 Meadow for the duration of the snow free season. The data from the station was used to calculate PET for the meadow and compared to ET calculated from the monitoring wells.
Field installations & support. Monitoring wells, piezometers and other infrastructure in the meadows at Providence subcatchment 301 and at Long Meadow in Sequoia National Park. Tri-pod mounted meteorological station deployed in Middle Meadow of Providence subcatchment 301. Tri-pod mounted eddy flux station deployed in Long Meadow.
Funding. Largely CZO
Schedule, including field work.

- Additional salt dilution tracer tests were conducted at the two meadow stream locations in P301 meadow. This will continue for WY 2014
- Water samples collected from the monitoring wells and streams were analyzed for stable water isotope composition and major ion concentrations. This will continue.
- We deployed a meteorological station in P301 Meadow for the duration of the snow free season. This station will be deployed again for WY 2014.
- Slug tests were conducted at each of the monitoring wells in both meadows in order to acquire hydraulic conductivity of the meadow substrate.
- Soil core samples will be collected and logs of the soil profile will be constructed at each of the monitoring well sites in P301 and Long Meadow during the WY 2014 field season.

Manuscripts in progress & planned.
In Progress:

- Polymictic pool behavior in a montane meadow, Sierra Nevada, CA
- Spatial and temporal trends in groundwater fluxes in montane meadows of the Sierra Nevada, CA. (Fall 2013)

Planned:

- Geochemical tracers to determine groundwater discharge sources in montane meadows, Sierra Nevada, CA (Spring 2014)
- Evapotranspiration in montane meadows of the Sierra Nevada, CA. (Fall 2014)

Topic. Improved measurement of snow distribution through novel wireless sensor network (WSN) technology
Investigator. Steven Glaser, UCB
Students & research staff.
Carlos Oroza PhD student, UCB
Lisa Gellerman, Senior UCB undergraduate student
Scope. The WSN, which integrates readings from over 300 sensors, provides spatially representative measurements of snow depth, solar radiation, relative humidity, soil moisture, and matric potential. We previously demonstrated that the WSN in this densely instrumented watershed captures catchment-scale snow depth and soil moisture distributions. We are now investigating how to optimize the network structure to guarantee reliability of data transmission in the event of single-element failures. In the coming year we plan to upgrade the wireless and data-logging elements of the network to take advantage of recent technological advancements. The new hardware will operate at lower power, permit the integration of more sensors at each station, and can manage up to one hundred wireless elements in each network. In the next 2-5 years we plan to connect with downstream stakeholders to understand how our data can best be utilized in the context of forest management, water resource decisions for power and agriculture, and other fields.
Field installations & support. 57-node wireless network operated and serviced by Berkeley students and professors in coordination with Southern Sierra CZO field staff.
Funding. CZO & others
Schedule, including field work.

- 1-2 years (2013-2014): We are updating wireless elements with new hardware (lower cost/power, higher reliability, can accommodate more sensors if necessary). New hardware will be subjected to a field test at the end of the November, 2013 and fully integrated by the end of summer 2014. Under development are algorithms that evaluate how robust a given spatial configuration is to the loss of an element, and can automatically configure the network for high robustness.
- 2-5 years (2014-2018): We are looking to contact downstream stakeholders to see how our data can best use for forest management, agriculture, etc. Perhaps develop models of expected runoff, etc. using our data.

Manuscripts in progress & planned:

- Bales, R., S. Glaser, M. Conklin, and Z. Zhang. Basin-Scale WSN Design: American River Basin, Sierra Nevada. *Hydrological Processes.* (In prep.)

Topic. Physical controls on water and carbon exchange and plant production
Investigator. Mike Goulden, UCI
Students & research staff. Anne Kelly (PhD student, UCI)
Background and rational
Our research focuses on the bi-directional interactions between ecosystem function and water balance. The local water balance helps control vegetation type, density, and function through the effects of drought on primary production, plant establishment, mortality, and physiology. The vegetation within an ecosystem helps control the local water balance through the effects of plant physiology and vegetation density on evapotranspiration, snow melt, and soil development. We hope to mechanistically understanding all these interactions, with the long-term goal of determining how climate change will impact montane vegetation, and how changes in vegetation will impact water balance.
Continuous micrometeorological measurements
We will repair, maintain, and expand the existing transect of eddy covariance flux towers that runs from oak savanna (410 m), through conifer forest (1160 and 2015 m), and up to subalpine forest (2700 m). The 2700-m tower must be replaced due to severe snow damage. Needed upgrades at all sites include new batteries and more solar panels. We also hope to extend the transect to a fifth, higher-elevation site above treeline (ideally ~3000-3300 m). All necessary equipment will be supplied from previous grants or UC insurance for the damaged tower; support from the SSCZO will be needed to maintain the towers and associated ground observations, and process, analyze, and publish the results.

Name	Installed	LATITUDE	LONGITUDE	Jurisdiction	Vegetation
SJER	July 10	37.10872222	-119.7315611	PSW	Oak/Pine woodland
Soaproot Saddle	Oct 09	37.03106944	-119.2564306	SNF	Ponderosa pine
P301 tower	Sept 08	37.06767222	-119.1932167	SNF	Midmontane white fir
Short Hair Creek	Oct 09	37.06659722	-118.988475	SNF	Subalpine lodgepole

Ecological measurements at tower sites
We will augment the P301 flux tower to better understand and remotely sense two key plant physiological processes identified during the SSCZO's first phase: i) a lack of dormancy and unexpectedly high rates of canopy photosynthesis during winter despite near-freezing conditions and a heavy snow pack, and ii) avoidance of stress and unexpectedly high rates of canopy photosynthesis and ET during summer despite a ~5 month dry season. We suspect both phenomena are linked to leaf temperature, and will focus on better characterizing the canopy microclimate. Our observations of leaf and canopy temperature will rely on long-term deployments of a thermal camera near the tower top. We have developed the appropriate methods with parallel support from an NSF-MacroSystems proof-of-concept grant (Goulden, Co-I, 2/13-1/15). We expect to begin installing thermal cameras at the SSCZO in summer 2014 (FLIR A325 with 12^0 FOV mounted on a D100E pan-tilt mount). The necessary equipment will be supplied from the MacroSystems grant; support from the SSCZO will be needed to maintain and analyze the camera imagery and use it to extrapolate canopy stress based on satellite imagery.

The camera-based thermal images will quantify the year-round leaf temperatures at the P301 tower site. The winter leaf temperatures will be combined with the eddy-covariance CO_2

fluxes to determine whether leaf warming with radiation loading facilitates winter photosynthesis. The summer images will be combined with the eddy-covariance energy and momentum fluxes to develop and test an energy balance approach for detecting stress based on stomatal closure and increased sensible heat flux. The energy-balance approach will then be used to estimate summer drought stress across the entire SSCZO domain as a function of elevation and climate using satellite imagery from the Landsat 8 (TIR at 100-m; 16-day repeat), MODIS (1000-m; multiple images a day), and possible future sensors such as the Hyperspectral Infrared Imager (HYSPIRI; no firm launch date; TIR at 60-m; 5-day repeat).

Field installations & support.

Three tower sites are currently in operation: San Joaquin Experimental Range, Soaproot Saddle and Providence. Continued operation and maintenance of these sites is part of our core measurements in the management plan. Further work will be done to expand the existing transect.

In addition, intermediate sites along the transect (every 400 feet a.s.l.) are instrumented with dendrometers. SSCZO researchers are in the process of transferring measurement duties to permanent staff.

Funding. CZO; UC insurance funds for damaged tower; other grants

Schedule, including field work.

- Summer 2014 - installation of replacement tower at subalpine forest (2700 m) site
- Late summer to fall 2014 - site selection and installation of a fifth, higher-elevation site above treeline (3000-3300 m)

Manuscripts in progress & planned.

Goulden, M.L., R.C. Bales. Vulnerability of montane runoff to increased evapotranspiration with upslope vegetation redistribution. (In review).

Presentations.

Kelly, A.E., M. Goulden, and A.W. Fellows. Interactions between cold and water limitation along a climate gradient produce sharp thresholds in ecosystem type, carbon balance, and water cycling. AGU Fall Meeting 2013, San Francisco December 8-13. Abstract B23D-0585.

Topic. Determining composition, sources and residence times of carbon in eroded sediments of low order catchments in the Sierra National Forest
Investigator. Stephen Hart & Asmeret Asefaw Berhe, UCM
Students & research staff.
Erin Stacy, MS student (alumnae, now staff), UCM
Emma McCorkle, MS Student, UCM
Laura Jalpa, undergraduate assistant, UCM
Nick Marlowe, undergraduate assistant, UCM
Scope. Following work on stabilization mechanisms of OM in sediment, we are analyzing differences in Sierran mixed conifer forests amongst eroded sediments and landform positions before and after prescribed burning. Present samples will be a control for pre-burn conditions and post-burn samples will be considered in a later project. This project interfaces with KREW on the burn-only watersheds P303 and B203 (KREW Study Plan, 2007). Sediment will be compared to soil from different landform positions and streambanks. The two catchments will have 6 transects each composted of three sampled points: crest, backslope, and deposition. Sediment is collected from sediment basins at the end of the water year (August/September). Samples from the sediments will be run for ^{13}C and ^{15}N along with the collected soils and litter to determine the sources of C that is transported to the stream and between the landforms with erosion, with a subset run for ^{14}C to determine residence times.

The Berhe lab will also be analyzing samples with FTIR to examine composition of the carbon compounds contained within the samples. The Hart lab will focus on the microbial and enzymatic activity of the soils. Both Berhe and Hart labs will be using various techniques to study black carbon possibly contained within the soils.
Field installations & support. There is no permanent infrastructure installed for this project. Soil sampling points are marked with digital coordinates for post-burn sampling. We coordinate with the Forest Service to quantify annual exported sediment captured in the sediment basins.
Funding. Largely CZO
Schedule, including field work. Stacy, Berhe and Hart conducted lab and data analysis on bulk composition and stabilization mechanisms in 2012. Presentations have been made at several conferences, including AGU and GSA Cordilleran Section.

McCorkle began working on the project as part of her Master's thesis in Fall 2012. Sediment removal work (for the 4th consecutive year of collaboration between the Pacific Southwest Research station and UC Merced) was conducted starting August 5th, 2013. Remainder of soil sampling in both watersheds (P303 and B203) was completed Fall 2013. The data were analyzed and findings presented in a poster at AGU December 2013. Finalized data and completion of thesis will follow in Spring 2014.
Manuscripts in progress & planned

1. Stacy, E.M. Hunsaker, C., Johnson, D., Hart, S.C., Berhe, A.A. Temporal and spatial variability of sediment export from low-order catchments in Sierra Nevada. (In prep.)
2. Stacy, E.M. Hunsaker, C., Johnson, D., Hart, S.C., Berhe, A.A. Stabilization mechanisms of organic matter in sediments eroded from first-order, granitic catchments in the Sierra Nevada. (In prep.)
3. McCorkle, E.P. Berhe, A.A., Hunsaker, C.T., Fogel, M.L., Hart, S.C. Using stable isotopes to determine sources of eroded carbon in low-order Sierra Nevada catchments (Planned).

Topic. Soil Hydrology & Pedology
Investigator. Toby O'Geen, UCD
Students & research staff, All UCD

Jan Hopmans, Faculty Researcher
Peter Hartsough, Project Scientist
Armen Malazian, Graduate Student
Maziar Kandelous, Graduate Student
Ahmad Moradi, Postdoctoral researcher
Zhiyuan Tian (Tina), Graduate Student
Stuart Dooley, Undergraduate Researcher
Emily Mecke, Undergraduate Researcher

Scope. We have continued to characterize the deep vadose zone, including drilling and characterization to the bedrock interface down to 11m. We have continued in situ measurements into the unsaturated zone beneath the active soil layer (deep instrumentation, neutron probe transects) at and near the Critical Zone Tree (CZT) sites, and complemented these with surface geophysics, and have estimated deep soil water storage and fluxes, through installation of moisture and water potential sensors. In addition, we continue to collect data to improve the depth-to-bedrock map for the experimental watershed. These point scale measurements will be scaled to the watershed to assess spatial variations of subsurface water storage and effects on water availability for forest ET and streamflow discharge.

Another area of focus has been the continued investigation of the coupling of above-ground with below-ground critical zone processes, using both data analysis and hydrodynamic modeling techniques, to further integrate data streams from the instrumented Critical Zone Trees with relevant models for hypothesis testing of coupled lower atmosphere boundary conditions (ET) and tree canopy measurements (canopy water potential, tree stem sap flow) with relevant subsurface hydrological processes (depth to bedrock, deep vadose zone, lateral flow). We have also begun to supplement existing measurement and modelling efforts with stable isotope fractionation techniques to help assess the contribution of deep vadose zone water to total tree transpiration. In this context we set out to answer two fundamental questions.

- How much water can be stored in the weathered material in the subsurface? How important is that water to the summer ET budget?
- Where are the roots of these trees and how do they access moisture? What are the mechanisms and timing of water extraction to feed transpiration demands?

These questions are being approached through four activities:

1. Ongoing monitoring at CZT-1 and 2
2. Deep Vadose Zone instrumentation and modeling
3. Subsurface investigations with the Geoprobe
4. Modeling the Soil-Tree-Atmosphere Continuum at CZT-1

We have now cored with the Geoprobe at three of the four sites. We would still like to do some characterization of the upper elevation site, though probably not with the Geoprobe. Given access limitations at the upper site, it is not feasible to get the rig to the tower installation. Deeper drilling using a rotary system is probably in the works too. We also plan to install a limited number of sensors around several "Critical Zone Trees" at the different elevation sites, probably beginning spring/summer 2014.

Field installations & support. Installation of wells, and neutron probe access tubes. Geoprobe drilling conducted. See more information under Schedule of field work.
Funding. CZO
Schedule, including field work.
Field Activities for Year 2012-2013
- September-November 2013 additional Geoprobe coring at SJER and Soaproot sites; wells installed in selected cored holes
- Spring-Summer 2014 - installation of sensors around several "Critical Zone Trees" at the different elevation sites

Manuscripts in progress & planned.
- Hartsough, P.C.**,** A. Malazian, M. Meadows, E. Rouneva, T. Kamai, and J.W. Hopmans. Monitoring of Critical Zone Processes in a Southern Sierra Nevada Ecosystem. (In prep.)
- Eumont, E., P.C. Hartsough, A. Moradi, A.M. Berry, R. Storesund, and J.W. Hopmans Analysis of a Sierra Nevada white fir root biomass using terrestrial LiDAR and image processing. (In prep.)
- Meadows, M.W., P.C. Hartsough, Roger C. Bales, Jan W. Hopmans, Armen I. Malazian. Integrating soil water measurements from plot to catchment scale in a snow-dominated, mixed-conifer forest of the southern Sierra Nevada. (In prep.)
- A.I. Malazian, Hartsough, P.C.**,** and J.W. Hopmans. Estimating Soil Water Fluxes in Proximity to a White Fir Tree in the Southern Sierra Nevada. (In prep.)
- Rings, J., T. Kamai, M. Kandelous, P. Nasta, P.C. Hartsough, J. Vrugt, J. Šimůnek and J.W. Hopmans. Optimization of hydrological parameters in a Soil-Tree-Atmosphere Continuum model of a large White Fir. (In prep.)

Topic. Hydropedologic processes in weathered bedrock
Investigator: Toby O'Geen, UCD
Students & research staff.
Robert Graham, Faculty Researcher, UCR
Jan Hopmans, Faculty Researcher, UCD
Peter Hartsough, Project Scientist, UCD
Zhiyuan Tian (Tina), Graduate Student, UCD
Jiayou Deng, Technician, UCD

Scope. Weathered bedrock plays a critical role in the hydrologic cycle and directly influences ecosystem productivity (Graham et al., 2010). Remarkably, very little is known about the spatial variability of weathered bedrock characteristics. Geophysical investigations are promising, but alone do not provide information about ecologically important characteristics such as water and nutrient availability, propensity to accommodate roots, and carbon storage. On the other hand, deep coring provides direct point observations, but of limited spatial extent and questions of representative sample collection arise. In combination with geophysical techniques and deep drilling, pedological approaches will be applied to describe deep regolith characteristics across the Southern Sierra CZO transect.

The following questions are examples of how the characteristics and spatial distribution of weathered bedrock might be addressed from a pedological perspective.

1. Do soil forming factors, (Time, Topography, Parent material, Organisms, and Climate) explain spatial variability of weathered bedrock characteristics? Are some factors more or less important?
2. To what degree do digital soil mapping techniques and their digital proxies (terrain attributes, airborne gamma ray mapping, remote sensing) explain weathered bedrock thickness and mineralogical, chemical, biological and physical characteristics?
3. To what extent does soil variability as documented by the Cooperative Soil Survey relate to spatial trends in weathered bedrock characteristics?
4. Can traditional soil analyses be applied to deep regolith to help interpret their ecosystem and hydrologic functions?
5. How does the degree of soil development influence the nature and dynamics of processes in weathered bedrock?
6. Is there a fundamental scaling relationship between the depth of regolith, canopy height, and depth of chemical alteration of bedrock?

These questions are being approached through the following activities:

1. Ongoing deep subsurface investigation with the Geoprobe and geophysical investigations
2. Deep vadose zone instrumentation and modeling
3. Chemical, physical, morphological and mineralogical characterization of weathered bedrock core samples.
4. Modeling regolith characteristics: Quantitative models that describe weathered bedrock characteristics will be investigated in order to understand critical zone processes operating at catchment and hillslope scales. Terrain-based attributes calculated from digital elevation models such as slope shape, exposure, and compound metrics describing flow (water or energy) or sediment accumulation are some of the common proxies that will be used to scale weathered bedrock characteristics. Fitting statistical models to soil and environmental

covariates (i.e. proxies for soil forming factors; geophysical investigations, vegetation characteristics), followed by prediction at un-sampled locations.

Field Installations and Support.

Would like to instrument a few representative sites within each catchment. Approximately 3-6 soil profiles per catchment to monitor soil moisture and temperature at 4-5 depths.

No additional installations needed; only observations and sampling at key landscape positions within each catena.

Funding CZO

Schedule, including field work.

- *September-November 2013:* additional Geoprobe coring at SJER and Soaproot sites; wells installed in selected cored holes primarily for the hydrology objectives.
- *Spring-Summer 2014*: field validation of soil landscape relationships; hand auger to bedrock at three upper elevation catchments. Large excavations e.g. 5 x 5 x 2 m at SJER to evaluate the nature of the soil-bedrock interface (e.g. degree of fracturing, topography of bedrock etc). It is possible that some of this work will not happen until Spring summer of 2015.
- *Summer 2013 and 2014*: Placement of small 3 x 3 inch weathering experiment containers. These PVC couplings contain a fine sand composed of a lithium feldspar. They will be placed near the flux towers of each site, underground with the top of the container at the soil surface. These containers will be collected after 5 years to explore trends in weathering.

Manuscripts in progress & planned.

Beaudette, D.E., R.A. Dahlgren and A.T. O'Geen. A quantitative Study on soil-landscape relationships of the Sierra Foothill Region. (in prep., 2014)

Tian, Z., P.C. Hartsough, A.T. O'Geen. Deep weathered bedrock development along an elevational transect in the southern Sierra Nevada. (planned, 2015)

Tian,Z., D.E. Beaudette, A.T. O'Geen. Regional patterns between soil properties and weathered bedrock characteristics in the southern Sierra Nevada. (planned, 2017)

Tian, Z., D.E. Beaudette and A.T. O'Geen. Modeling weathered bedrock characteristics in the southern Sierra Nevada. (planned, 2017)

Hartsough, P.C. Tian, Z., A.T. O'Geen. Relationships between weathered bedrock characteristics and forest productivity in the southern Sierra Nevada. (planned, 2017)

Topic. Weathering, Erosion, Regolith Development and Landscape Evolution
Investigator. Clifford Riebe, UW
Students & research staff, all UW

Claire Lukens, PhD candidate (Geology)
Jorden Hayes, PhD candidate (Geophysics)
Heather Rogers, PhD student (Geology)
Brady Flinchum, MS student (Geophysics)

Scope: The geochemical analyses of regolith and rock samples from the mid-elevation site within the CZO are now complete and data reduction has produced a number of results. A comprehensive analysis is forthcoming in a grand synthesis of our current understanding of weathering across the mid-elevation site. Two publications are now in print, two others are in press, and others are in review and in preparation. Results are shedding light on the degree of chemical weathering in saprolite and soil and how it varies across the CZO catchments. In an expansion of this work, we are pushed beyond the confines of the CZO catchments, with the goal of quantifying the roles of dust and altitudinal variations in climate in regulating the geochemistry of granitic soils in the surrounding landscape. Another aim in this expansion is to improve understanding of factors that influence the presence/absence of soil and vegetation. We now have strong evidence to support our hypothesis that the notable bimodality in soil and vegetative cover is regulated by differences in bedrock composition.. Our manuscript on. this topic has recently been accepted. Work is continuing on this question; in the next funding cycle, we will test multiple working hypotheses about the mechanisms responsible for the apparent lithologic control of vegetation and landscape evolution. One objective is to test whether vegetation is limited by nutrient concentrations in bedrock. This will require a systematic set of nutrient addition experiments.

Analyses of cosmogenic nuclides in stream sediment are nearly complete. They are providing the basis of a broad analysis of landscape evolution in the CZO and surrounding landscape. In an expansion of the cosmogenic-based sediment tracing work, we have also conducted 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 its origins in the form of U, Th, and He concentrations in apatite crystals. We have one manuscript in revision about this work.

As part of our ongoing work on erosion and weathering we will be developing methods for measuring and interpreting the cosmogenic nuclide ^{10}Be in magnetite. By measuring 10Be in two different minerals, quartz and magnetite, we should be able to infer differential weathering of magnetite, relative to the soil as a whole. The SSCZO elevation transect will permit us to evaluate differences in magnetite weathering with altitude. We have already collected many of the samples we will need for these analyses. Additional samples will be obtained from sampling at the SJER and Soaproot sites in summer 2014. We will also analyze samples collected from cores drilled into the subsurface at each of these sites in Fall 2013 by the UC Davis group.

Work is continuing on the analysis of our geophysical data from the near surface (<40 m depth) for constraints on weathering and water storage potential at depth. In particular, we have made significant progress in waveform tomography of our seismic refraction data. Although results are still preliminary, this could, if successful, provide 10 m scale resolution on flow properties in the subsurface. In standard seismic refraction analysis of first arrival travel times, a much coarser scale image of the subsurface is usually obtained.

In FY 2012, Riebe's ongoing collaborations with Leonard Sklar (San Francisco State) and Darryl Granger (Purdue University) expanded in separate but related projects to include work on weathering and erosion at the Southern Sierra CZO. The work with Granger (which will develop cosmogenic Be-10 in magnetite as a new tool in erosion and weathering studies) has been funding by NSF and includes a cross-CZO field component at the Luquillo CZO. In a separate, cross-CZO initiative, Riebe was funded with Jon Chorover (U. Arizona; Sta. Catalina-Jemez CZO PI) to organize an NSF-workshop on drilling, sampling and geophysical imaging of the deep critical zone. Riebe is also continuing to collaborate with Sue Brantley (Penn State) as guest editor of a special issue on the deep critical zone for Earth Surface Processes and Landforms (Riebe and Brantley, in prep). Meanwhile collaborations have continued with Scott Miller (Associate Professor, Terrain Analysis, U. Wyoming), Steve Holbrook (Professor, Geophysics, U. Wyoming), and Anthony Dosseto (Lecturer, Geochemistry, U. Wollongong). The collaboration with Holbrook has recently evolved into a fully funded center for environmental geophysics at the University of Wyoming. The collaboration with Holbrook on geophysics has broadly included Hopmans (SSCZO co-PI on vadose zone) and his student and post-doc as well as Riebe (erosion and weathering), thus instilling new interdisciplinary cohesion in the SSCZO team (Holbrook et al., in revision).

Field installations & support: No permanent field installations are necessary. The seismic data (etc.) is collected in the field and analyzed in the lab. Ongoing work may include the installation of dust traps, as well as fertilizer addition experiments in the Sierra National Forest and on private lands owned by Southern California Edison. Permitting for these experiments is in progress.

Funding: Largely CZO. Funding supported part-time work, both in the field and in the lab, for 3 undergraduate students throughout the fiscal year.

Schedule, including field work:

The 2013 field season included geochemical sampling at the SJER and Soaproot sites on the elevation transect. The University of Wyoming geophysics team visited the three lower sites on the transect and conducted resistivity, seismic refraction, and magnetic surveys. The sampling and geophysical surveys will be expanded into the 2014 field season and beyond. We will begin our nutrient addition experiments in the summer of 2014. Timing of the sampling, surveying and nutrient addition experiments: likely July 2014.

Manuscripts in print, accepted, in progress & planned:

In print:

- Riebe, C.S., Granger, D.E. Quantifying effects of deep and near-surface chemical erosion on cosmogenic nuclides in soils, saprolite, and sediment. *Earth Surf Proc Land* **38,** 523–533 (2013).
- Granger, D.E., Riebe, C.S. Cosmogenic Nuclides in Weathering and Erosion, in *Treatise on Geochemistry* 2nd Edition. (Drever, J. I.) **5,** (Elsevier, 2014).
- Hahm W.J., Riebe, C.S., Lukens, C.E., Araki, S. Bedrock composition regulates mountain ecosystems and landscape evolution. (*Proceedings of the National Academy of Sciences* doi/10.1073/pnas.1315667111)

Accepted or in press:

- Holbrook, W.S., Riebe, C.S., Elwasif, M., Hayes, J.L., Harry, D., Reeder, K., Malazian, A., Dosseto, A., Hartsough, P., Hopmans, J. Geophysical constraints on deep weathering and water storage potential in the Southern Sierra Critical Zone Observatory. (Earth Surface Processes and Landforms – in press) doi: 10.1002/esp.3502.

In review:

- Dixon, J.L., Riebe, C.S., Making soil. (invited contribution to *Elements*).
- Riebe C.S., Hahm, W.J., Brantley, S.L., Going deep to quantify limitations on weathering in the Critical Zone (*Earth Surface Processes and Landforms*)

In revision:

- Riebe, C.S., Sklar, L.S., Lukens, C.E., Shuster, D.L. Landscape evolution linked to climate through size of sediment produced by weathering.

In prep:

- Riebe, C.S., Hahm, W.J., Ferrier, K.L., A test for supply-limited and kinetic-limited chemical erosion.
- Riebe, C.S., Holbrook, W.S., Hayes, J.L., Araki, S., Dosseto, A., Jessup, B.S.* Depths and timescales of weathering in the Southern Sierra Critical Zone Observatory inferred from geophysics, geochemistry and cosmogenic nuclides.

Topic. Hydrologic & biogeochemical modeling to develop process understanding
Investigator. Christina Tague
Students & research staff. Khongho Son, PhD student
Scope. Coupled models of hydrologic and ecosystem biogeochemical cycling processes are key tools used to generalize results from field based analysis at the CZO to other watersheds and future climate and land management scenarios. The CZO continues to provide an excellent opportunity to assess the performance of these models and highlight strategies for improvement and/or situations where model limitations or specific parameterization approaches are likely to alter eco-hydrologic predictions. At the same time, we have used models to both guide measurements and to explore how water and carbon fluxes may change given a warmer climate. The primary focus of this research group has been the use of RHESSYs (Regional Hydro-Ecosystem Simulation System).
Three applications of RHESSys to the Southern Sierra CZO and beyond are being evaluated. First, we have applied RHESSys to data from the CZO, where we examine the influence of model implementation decisions – specifically spatial resolution of the digital elevation model and uncertainties in soil parameters on the ecologic and hydrologic estimates. Second, RHESSys results guided a field sampling campaign specifically designed to capture patterns of soil moisture and vegetation responses to climate variability. We found that model-based clusters generally followed the spatial pattern of measured soil moisture, but model failed to capture the soil moisture and sapflux dynamics in the riparian zone site, and a site where soil moisture does not follow surface topography. Third, we used RHESSys to compare the ecohydrologic response to projected climate warming between a snow-rain transition watershed (P303) and a snow-dominated watershed (B203). Model projections of streamflow changes are generally consistent with previous work in the Western US that show earlier snow melt and center-of-mass of hydrograph shifts to earlier in the year. The effect of soil parameter uncertainty was often greater than climate warming effects. Therefore, explicitly accounting for soil parameter uncertainty and its reduction in modeling are essential for reliable climate change impact analysis in this region. Our current working hypothesis is that model errors may reflect errors in climate inputs and the methods used to provide spatially distributed climate time series (precipitation, temperature and vapor pressure deficit) that drive model process computation. Collected microclimate data will be used to constrain parameters of the RHESSy, and to refine the climate inputs in order to improve the predictions of soil moisture, transpiration and streamflow in the Providence watersheds. These results inform future modeling efforts and the interpretation of estimates from RHESSys and other hydrologic models applied in this region.
Field installations & support: Microclimate stations and instrumentation at Critical-Zone Trees 3-8 were deconstructed fall 2013 in preparation for prescribed burns.
Funding. CZO
Schedule, including field work. This year has produced sensitivity analysis of the model estimates.
Papers

Tague, C., and H. Peng (2013), The sensitivity of forest water use to the timing of precipitation and snowmelt recharge in the California Sierra: Implications for a warming climate, *J. Geophys. Res. Biogeosci*., 118, doi:10.1002/jgrg.20073.

Manuscripts in progress & planned.

1. K.Son, Tague. C and , Hunsaker, C.T (in prep) Effect of spatial resolution of DEM on ecohydrologic predictions and its sensitivity to climate variability in Sierra mountain catchments, *Water Resources Research*
2. K. Son and Tague, C. (in prep) Importance of soil parameter uncertainty in assessing climate change projections in small two Sierra watersheds, *Water Resources Research*
3. K.Son, Tague, C. (in prep) Strategic sampling microclimate, soil moisture and sapflux for improving ecohydrological predictions of the Sierra Mountain watersheds., *Hydrological Processes*
4. K.Son and Tague, C. (in prep) Effect of climate warming on ecohydrologic fluxes of two Sierra mountain watersheds, *Eco-hydrology*

Topic. Kings River Experimental Watersheds: core measurements and data management
Investigator. Carolyn Hunsaker, Research Ecologist, Pacific Southwest Research Station, USDA Forest Service, Fresno
Students & research staff.
Kevin Mazzocco, hydrologic technician, Forest Service and Jason Smith, hydrologic technician through agreement with UC Merced
Students: Amber Olsson and David Bailey, California State University, Fresno
Six summer seasonals were employed
Scope. The Forest Service, Kings River Experimental Watersheds, continued to host the SSCZO. The Forest Service continued to collect all of the KREW core data as in previous years. Tree thinning was completed on four watersheds in 2012, and annual nutrient flux measurement devices were reinstalled. Data from WY2013 will be the first year of effects data from tree thinning. Dr. Hunsaker shared Forest Service data with SSCZO PIs and students that are actively collaborating with her on data analyses and publications.

In 2012-2013 the Forest Service did not receive any direct funding through the SSCZO grant. The PSW is collaborating with UCM-SNRI to establish a Joint Venture Agreement. The Agreement would encourage collaboration and enable the Forest Service to fund UC Merced staff to work on KREW tasks. A job announcement is currently posted for an open rank researcher, to work on hydrologic and ecological sciences jointly with PSW and SNRI.
Schedule, including field work. Ongoing
Manuscripts in progress & planned.
1. *Sediment budget for Providence*. This would include bedload sediment, suspended sediment, along with erosion sources from hillslopes, roads, headcuts, stream banks, etc. Hunsaker & CSU/UCM collaborators.
2. *Geochemical response across rain-snow transition: ions, pretreatment – system characterization – gradients in system*. Hunsaker and Liu. Use ion data, 2002-2006; build on first paper already published by Liu.
3. *Nutrient budget*. Hunsaker and Johnson. Atmospheric deposition, resin lysimeters at 470 locations across eight watersheds, stream and shallow soil water, etc. for five years during pre-treatment phase. Probably two papers: one on overall fluxes and one on spatial patterns.