Reynolds Creek Critical Zone Observatory Year 2 Annual Report

September 2015

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A. Accomplishments.

1. What are the major goals of the project?
The three main goals of the Reynolds Creek CZO identified in our proposal and then refined as research priorities in our management plan are the following:

Priority 1: ***Landscape Soil Carbon Survey****: Create a landscape-distributed soil carbon (C) and environmental dataset that can inform our understanding of the processes controlling soil carbon fate from the plot to the watershed scale.*
We will create a world-class landscape-scale soil carbon and environmental dataset that will provide a foundation for investigating intermediate scale processes that dictate soil carbon fate and elucidate the complex relationships between climate, landscape, and ecology. We will conduct a landscape soil carbon survey and produce an intermediate scale soil C map.

Priority 2: ***Environmental Monitoring Network****: Develop an integrated, watershed scale, instrumentation and monitoring network focused on soil carbon dynamics that is of value across hydrologic, ecologic, and geologic disciplines.*
We will develop an integrated, watershed scale, instrumentation and monitoring network focused on soil carbon dynamics but of value across the hydrologic, ecologic, and geologic disciplines. We will focus on intensive measurements of soil carbon and aboveground and belowground processes within the vicinity of the 5 eddy covariance towers (to be redeployed as part of this research, and referred to the CORE sites hereafter) as well as collection of limited groundwater and stream samples.

The process measurements at the CORE sites will include: a) eddy covariance upgrade and deployment to determine net ecosystem exchange (NEE), b) canopy transpiration and stand water use, c) aboveground biomass and limited aboveground net primary productivity (ANPP), d) Litter and soil organic carbon dynamics, e) manual soil CO_2 gas and soil respiration measurements, f) stream particulate organic carbon, dissolved organic carbon and inorganic carbon and groundwater.

Priority 3: ***Integrated Modeling Framework****: Develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated interactions with climate, ecology, and landscape that can inform up-scaling mechanistic understanding to climate models.*
We will develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated interactions with climate, ecology, and landscape to promote up-scaling of mechanistic understanding to climate models. The expected impact of modeling activities carried out by the RC CZO team is to develop and maintain an area of excellence in ecohydrology and biogeochemical modeling. We will achieve this impact both through modeling efforts by the RC CZO team, as well as by establishing collaborations and producing benchmark datasets that will be of broad interest to the Earth system modeling community. Throughout the cooperative agreement we will leverage these datasets to attract and develop a network of collaborators to expand support for complementary modeling activities in the RC CZO. Some of the complementary current projects where we will develop immediate collaborations include the NSF EPSCoR Track 2 Western Consortium for Watershed Analysis,

Visualization, and Evaluation (WC-WAVE) award, Idaho's NSF EPSCoR Track 1 Managing Idaho's Landscapes for Ecosystems Services (MILES) agreement, a NSF CAREER grant to Co-PI Flores, and a NASA Terrestrial Ecology grant to Co-PIs Glenn and Flores.

2. What was accomplished under these goals?

a. Major Activities (currently 6000 characters, up to 8000)

Priority 1: ***Landscape Soil Carbon Survey****: Create a landscape-distributed soil carbon and environmental dataset that can inform our understanding of the processes controlling soil carbon fate from the plot to the watershed scale.*

We continued to conduct a broad soil survey across the entire watershed for soil inorganic and organic carbon and associated environmental properties to determine the ranges of values and the density of change in those values across the landscape. We intensified our soil survey in a sub-watershed to examine local topographic controls on soil depth and soil carbon storage. We refined the broad scale landscape soil survey to examine vegetative controls on soil organic carbon storage, initially using remote sensed data (normalized difference vegetation index) for indices of vegetation biomass/cover and now exploring use of LiDAR and hyperspectral products, which became available at the end of year 1 (through collaborations). Finally, we expanded the scope of inorganic carbon analysis to include the role of carbonate rock coating in contributing to carbon storage.

We expanded our scope of environmental characterization to examine elevation, aspect and vegetation controls on snow depth to understand the distribution of vegetation and soil carbon. We also expanded our scope of mapping near surface geophysics and the spatial structure of the critical zone (through collaborations and CZO efforts). In July 2015, we collaborated with Wyoming Center for Environmental Hydrology and Geophysics in another intensive week campaign involving 2 faculty members, 15 undergraduates, 2 graduate students, and 2 technicians aimed at mapping the spatial structure of critical zone at multiple sites. We continued on soil characterization from Yr 1 collections and partially completed analyses of 4640 samples from 179 soil profiles (125 to saprolite or refusal). Yr 2 soil collection included another 184 soil pits (50 soil pits to saprolite, or1327 samples total). Seven hundred eighty samples have been analyzed for texture, 1475 for SIC, and 1195 for SOC and TN. A subset of samples (76) on 10 soil profiles have been completed for soil water retention characteristics.

Priority 2: ***Environmental Monitoring Network****: Develop an integrated, watershed scale, instrumentation and monitoring network focused on soil carbon dynamics that is of value across hydrologic, ecologic, and geologic disciplines*

We continued to establish and instrument the CORE sites as part of the environmental monitoring network and also commenced analyses of historic and new data sets. Ten years of net ecosystem exchange data from five eddy covariance towers collected from the upper catchments were reprocessed, gap filled, and are in the process of being analyzed to determine variability in carbon balance and responses to hydroclimate. We continued measurement of the two tree sites (aspen, conifer) using Granier sap flux sensors and installed tissue heat balance sap flux sensors at 3 sagebrush CORE sites. We continued measurement of tree diameter increment growth for

NPP estimates using automated dendrometer bands and added additional manual bands and litterfall collectors. We initiated measurement of vegetation aboveground biomass and foliar tissue nitrogen with collection of LiDAR and hyperspectral data in the fall of 2014 (through collaborations with the NASA TE project), and coincident leaf and plot-level field data.

To examine the processes controlling soil carbon storage, we conducted a laboratory warming experiment where we incubated soils collected along a climate gradient at different temperatures and quantified the relative changes in soil organic carbon pool fractions. To determine the temperature sensitivity of SOC decomposition, we used controlled aerobic laboratory incubations. We exposed these samples to varied temperatures (15, 20, 25, 30) ^{o}C and measured CO_2 on days 1, 3, 5, 17, 30, 60, 120 using the LiCor H2O/ CO_2 analyzer. We also initiated a study to examine the vegetation-soil organic carbon-respiration responses to a prescribed wildfire slated for mid September 2015 and collected 129 shallow soil pits prior to burn in two watersheds (one slated for burn and one control) and will revisit these sites after the burn and examine the immediate soil respiration responses to burn (though see Changes with August 2015 Soda Fire). We continued to monitor soil nutrient cycling rates and inputs of N into the system via biological N fixation rates associated with free-living biotic crust communities to determine possible constrains on inputs of carbon to the watershed. We also initiated a study to examine the abundance and diversity of microbial communities and specifically nitrogen fixing bacteria associated with these biotic crusts. Finally, we initiated measurement of stream export of particulate and dissolved organic and inorganic carbon during the spring of 2015 in three tributaries of Reynolds Creek as obtain pre-burn chemistry data and installed three water chemistry and colored dissolved organic matter (CDOM) automated sensors in these streams this summer (also see Changes).

Priority 3: ***Integrated Modeling Framework****: Develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated interactions with climate, ecology, and landscape that can inform up-scaling mechanistic understanding to climate models*

To facilitate the Reynolds Creek CZO as a testbed for the development and testing of Earth system models and leveraging the rich historical datasets collected by RCEW, we have devoted significant effort toward developing a unique spatiotemporally distributed dataset of environmental forcings. Through collaboration with Dr. David Garen (NRCS), we modified and updated the detrended kriging (DK) utility to generate a 31-water year (1984 – 2014) database with a temporal resolution of 1 hour and spatial resolution of 10 m. The dataset includes precipitation amount and phase, temperature, and humidity. We are developing a manuscript summarizing the technique and dataset, and are in the process of developing a plan to document, curate, and share the associated ~45 TB database.

At the same time, and in conjunction with other funded research projects, we have initiated a suite of land modeling activities to evaluate existing and test new frameworks for the modeling of vegetation dynamics and biogeochemical cycling. Using the MTCLIM and BIOME-BGC modeling frameworks we conducted a long-term spin-up of the distribution of soil organic carbon in RCEW. This simulation, which simulates the soil organic carbon in equilibrium with current climate and vegetation patterns, was distributed at 120-m spatial resolution. Model outputs show reasonable agreement with regard to soil organic carbon observations at lower levels observed in sagebrush ecosystems and underestimations for higher SOC observations. These preliminary findings have led to a number of interesting and potentially fruitful research questions to pursue. In particular, we are interested in better understanding the drivers of model-predicted variation and error in soil organic carbon.

We have also initiated efforts to improve synthesis between models and observations. In particular, we are pursuing data fusion strategies to combine observations with model predictions of NEE in an effort to better understand to what extent plant functional type parameters can be observed or inferred from observations, and if these parameterizations are appropriate for dryland ecosystems that have very long timescales of vegetation response. Through a series of data denial experiments, we hope to identify which model parameters are sensitive to which observations in an effort to develop better parameterizations for dryland vegetation.

Specific objectives

Priority 1: ***Landscape Soil Carbon Survey****: Creation of a landscape-distributed soil carbon and environmental dataset that can inform our understanding of the processes controlling soil carbon fate from the plot to the watershed scale.*

1.1 Soil organic matter-vegetation associations

Quantify soil organic carbon-vegetation associations at broad watershed scale using vegetation indices (NDVI) and other remotely sensed products from satellite and airborne LiDAR and hyperspectral data. Continue to collect soil samples across broad scales and quantify relationships. Map distribution of soil organic carbon at broad landscape scale.

1.2 Topographic controls on carbon storage

Quantify the relationship between measurable local topographic features and soil depth to improve estimation of deep soil carbon across complex terrain. Quantify total mobile regolith depths associated with differences topographic variables in a granitic watershed and map soil depth estimates. Evaluate generality of relationships across sites available from the literature. Develop relationships of soil depth and soil carbon at pedon scale. Map distribution of soil organic carbon at local topographic scale.

1.3 Geologic Controls on soil inorganic carbon (SIC)

Measure and describe soil inorganic carbon at pedon scale across the watershed to determine the importance and role of different state factors in controlling soil inorganic carbon presence and amount. Initiate investigation to quantify role of carbonate coating of rocks in storing deep inorganic carbon

1.4 Soil-Bedrock Mapping

Map depth to bedrock and water-rock associations using shallow geophysics (through collaborations and new investigations)

1.5 Snow Mapping

Initiate analysis of snow-elevation distribution using LiDAR and association with vegetation and aspect (through CZO and SAVI grant)

Priority 2: Environmental Monitoring Network: *Develop an integrated, watershed scale, instrumentation and monitoring network focused on soil carbon dynamics that is of value across hydrologic, ecologic, and geologic disciplines*

2.1 Net Ecosystem Exchange (Eddy Covariance Towers)

Complete selection and installation eddy covariance and heat flux sensors at 3 CORE sites

Initiate analysis of 2002-2010 net ecosystem exchange (carbon flux) data associated with 4-5 eddy covariance towers in upper portion of catchment.

2.2 Transpiration (Sap Flux Sensors)

Maintain and download aspen and conifer tree CORE sites sap flux sensors. Test and evaluate tissue-heat-balance sap flux sensors on sagebrush. Install tissue-heat-balance sap flux sensors (5-6 per site) at three sagebrush CORE sites.

2.3 Soil Respiration

Install automated soil carbon dioxide (CO_2) probes at depth at select CORE sites (collaboration with LTAR). Test automated soil respiration chambers by Forced Diffusion (FD) under artificial and lab controlled snowpack (through collaborations). Deploy FD chambers prior to prescribed wildfire. Initiate manual measurements at CORE sites to capture spatial heterogeneity of soil respiration.

2.4 Plant Abundance and Diversity

Establish vegetation survey protocols and sample vegetation for plant abundance and diversity, aboveground biomass and forage net primary productivity

2.5 Aboveground Biomass and Net Primary Productivity

Continue diameter increment growth measurements with Treehugger automated dendrometers and install manual dendrometer bands at tree sites. Initiate estimation of NPP on shrub using multiple methods (TLS, branch increment growth). Initiate establishment of additional permanent grazing exclosures. Conduct ongoing ground truthing for LiDAR and hyperspectral with fine resolution above plot photos and terrestrial laser scanning (collaboration with NASA TE project). Measure litterfall production at tree sites and sagebrush steppe CORE and satellite sites.

2.6 Soil Carbon Dynamics and Microbial Profiling

Conduct study to understand how soil organic carbon inputs affect soil structure and carbon quality along an elevation gradient; evaluate response of soil organic carbon (SOC) decomposition to climate change.

2.7 Nitrogen Fixation, Dynamics and Biological Crust Bacterial Abundance and Diversity

Continued biological crust sampling focused on quantifying biological N fixation rates and nutrient dynamics and initiate characterization of associated microbial communities (using 16-S RNA analysis) across the watershed elevation gradient.

2.8 Fire Responses Baseline Data Collection

Collect soil and water samples both within the proposed burn area and associated control watershed to provide baseline data.

2.9 Stream Export

Purchase and install automated water chemistry and colored dissolve organic matter sensors at 3 locations in Reynolds [see Changes as of Aug 2015]. Establish stream sampling and processing protocols and publish on wiki and initiate collection and analysis of dissolved inorganic and organic carbon and other constituents.

2.10 LiDAR-based Assessment of Biomass and N Foliar Content

Through collaboration with leveraged projects, a watershed scale of aboveground biomass and N foliear content was initiated using a combination LiDAR and hyperspectral flights and ground campaigns.

Priority 3*: Integrated Modeling Framework:* *Develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated* *interactions with climate, ecology, and landscape that can inform up-scaling mechanistic understanding to climate models*

3.1 Fine-Resolution Forcing Data

Develop an hourly dataset for precipitation, temperature, humidity and phase

3.2 Integrated Modeling

Initiate development of a 31-water year (1984 – 2014), hourly database (10m resolution) of precipitation, phase, temperature and humidity. Initiate land surface (e.g. Community Land Model, Biome BGC) modeling activities.

c. Significant Results

Priority 1: ***Landscape Soil Carbon Survey****: Creation of a landscape-distributed soil C and environmental dataset that can inform our understanding of the processes controlling soil C fate from the plot to the watershed scale.*

1.1 Soil organic matter-vegetation associations

A watershed scale map of shrub aboveground biomass (AGB) was published using field, terrestrial laser scanning (TLS) and airborne LiDAR data (Li et al., 2015) (through NASA TE). In 2015, 25 field plots were collected for vegetation structure, LAI, and foliar chemistry, 10 for TLS, in coincidence with a repeat AVIRIS-ng (hyperspectral flight). We have documented high correlations between SOC and elevation and associated precipitation gradient. Random forest regression modeling showed that SOC was modestly correlated to NDVI and current analysis has been expanded to include LiDAR and hyperspectral data estimates of ABG. A preliminary soil C map has been created (Figure 1.1).

1.2 Topographic controls on carbon storage

We demonstrated a strong topographic control on soil C storage. Soil depth and total SOC is strongly correlated to tangential curvature in a granite-dominated subcatchment (Figure 1.2a) and a predictive soil depth map was constructed (Figure 1.2b). The generality of this relationship was found to extend to other sites (Figure 1.2c). However, slopes varied with the largest difference associated with RC CZO; the variation in slope may be controlled by hollow and nose stability along with drainage density (Figure 1.2d). Average total SOC is 3-4 times greater on the north-facing than south-facing slopes (Figure 1.2e), and %C was found to decrease with soil depth (Figure 1.2f) but importantly, substantial C is stored below 100 cm depth. A soil C map based on topography has been created (Figure 1.2g).

1.3 Geologic Controls on SIC

Broad scale climate gradients were a large determinant of SIC presence and absence (Figure 1.3a), although parent material often trumped climate as the main predictor of SIC presence, with alluvium containing 3 times more SIC than basalt and 5 times more than granite materials. Rock carbonate coating represented as much as 43% of total IC (Figure 1.3b).

1.4 Soil-Bedrock Mapping

Mapping depth to bedrock and water-rock associations using shallow geophysics show good agreement between resistivity and velocity models (through collaborations) (Figure 1.4).

1.5 Snow Mapping

Elevation-area distributions were relatively accurate indicators of snow storage at Reynolds and other CZOs indicating hypsometry provides a useful measure of a watershed's sensitivity to warming-driven snowpack loss (Figure 1.5a). Mean snow depths in forested areas were up to seven times greater than in open areas (Figure 1. 5b) (also see X-CZO work later).

Priority 2: Environmental Monitoring Network: *Develop an integrated, watershed scale, instrumentation and monitoring network focused on soil C dynamics that is of value across hydrologic, ecologic, and geologic disciplines*

2.1 Net Ecosystem Exchange (EC Towers)

We completed installation of EC towers at three sagebrush CORE sites and updated instrumentation to process data onsite. Historic (2007-2013) and current data streams are functional producing preliminary results including strong seasonality in Gross Ecosystem Exchange (GEE), dramatic differences in carbon uptake and timing between sites/vegetation types (Figure 2.1a-b).

2.2 Transpiration (Sap Flux Sensors)

Tissue-heat-balance sap flux sensors (6 per CORE site, 18 total) were installed at three sagebrush CORE sites (Figure 2.2), and providing functional datastreams of sap flux.

2.3 Soil Respiration

ARS CZO installed 2 sets of automated soil carbon dioxide (CO_2) sensors in soil profiles at one CORE site (collaboration LTAR). We initiated testing of automated soil respiration chambers by forced diffusion (FD) and deployed 4 in a granite subcatchment (Johnson Draw) for measurements prior to prescribed wildfire.

2.4 Plant Abundance and Diversity

We adopted and modified the USDA ARS vegetation monitoring protocols for the CORE sites and posted these protocols to the wiki. We established permanent plots for long-term vegetation monitoring.

2.5 Aboveground Biomass (AGB) and Net Primary Productivity (NPP)

We continued to collect diameter increment growth measurements with Treehuggers automated dendrometers, redeployed/reinstalled new ones (Figure 2.5), and installed manual bands. Litterfall traps were installed at 2 tree (aspen, conifer) and 3 sagebrush steppe CORE sites and litterfall production is being monitored bimonthly.

2.6 Soil Carbon Dynamics and Microbial Profiling

Cumulative CO_2 respired increases with increasing temperature and elevation (Figure 2.6a). In contrast, cumulative CO_2 respired normalized by unit carbon, increases with decreasing elevation (Figure 2.6b). The lowest site (Flats) showing significantly greater temperature sensitivity to SOC decomposition than other sites.

2.7. **Nitrogen Fixation, Dynamics and Biological Crust Bacterial Abundance and Diversity**

Biological nitrogen (N_2) fixation rates associated with biological crusts vary with elevation and season (range 0-3 kg N/ha/yr) (Figure 2.7a) with highest rates at one of the mid-elevation sites and lowest at the highest elevation site. Initial analysis of the 16S small subunit rRNA paired-end sequencing also shows elevation differences in Cyanobacteria fraction (Figure 2.7b).

2.8 Fire Responses

We established 16 permanent transects in a control and prescribed burn catchment prior to the burn to examine vegetation-soil organic carbon-respiration responses. A total of 129 shallow soil pits were collected prior to burn (see Changes due to Soda Fire).

2.9 Stream Export

Three automated stream water chemistry sensors and colored dissolved organic matter were installed in three tributaries of Reynolds Creek (See Changes). We developed and published protocols on the wiki, and initiated collection and analysis. Preliminary DIC and DOC data shows increases downstream (Table 2.9).

2.10 LiDAR-based Assessment of Biomass and N Foliar Content

A watershed scale analysis of AGB and N foliar content is in progress using a combination LiDAR and hyperspectral flights and ground campaigns (collaboration with NASA TE).

Priority 3: **Integrated Modeling Framework**: *Develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated interactions with climate, ecology, and landscape that can inform up-scaling mechanistic understanding to climate models*

3.1 Fine-Resolution Forcing Data

We completed generating fine-resolution, spatially explicit, forcing model input data (hourly, 10 m resolution rasterized data, 30 yr record of radiation, temperature, precipitation) from historic climate datasets for 239 km^2 of Reynolds Creek Experimental Watershed using detrended kriging methodology developed by D. Garens (participant). Digital object identifier (DOI)s are being obtained and datasets are stored at ARS and mirrored to ISU to serve.

3.2 Integrated Modeling

We performed a long-term spin-up simulation of the spatial distribution of SOC using the BIOME-BGC and MTCLIM modeling frameworks (in equilibrium with local climate, soils, and vegetation at a spatial resolution of 120 m). Model outputs show reasonable agreement with lower levels of SOC observed in sagebrush ecosystems and underestimations for higher SOC observations (Figure 3.2).

Model-data fusion techniques were initiated to interrogate models for uncertainty and parameter estimation with Community Land Model 4.5 being used for simulations including new vertically resolved soil structure option.

d. Key Outcomes or Other Achievements

The Reynolds Creek CZO seeks to understand the role of soil environmental variables that vary across complex terrain in governing soil carbon storage and turnover in a semi-arid environment. Our overarching hypothesis is that *soil environmental variables (e.g. soil water content, soil temperature, net water flux) measured and modeled at the pedon and watershed scale will improve our understanding and prediction of SC storage, flux, and processes.*

Environmental forcing data A key outcome in year 2 has been the generation of 30 yr, hourly, fine resolution (10 m raster) climate forcing data sets (45 TB) from spatially-distributed climate stations at the RC CZO through the improvement a detrending kriging utility. These datasets can used to test the above hypothesis and used by the broader climate and soil carbon modeling community. As part of our environmental characterization, we also examined elevation, vegetation and aspect controls on snow depth distributions –a key driver of soil moisture and stream flow in snow dominated watersheds in a cross-CZO study lead by a Ph.D. graduate student, Chris Tennant, at Idaho State University. We used publically available LiDAR datasets from four of the CZOs (JRB, SS, RC, BC) and key findings are that the RC CZO deviates from the rest of CZOs in terms of storing most of it snow in forested areas that make up less than 11% of LiDAR study path whereas other CZOs store more snow in open/low stature areas (Tennant et al, in review). Other CZOs showed stronger snow depth -elevation relationship than Reynolds, also highlighting the need for Reynolds in the CZO network to understand sensitivities to warming and snow loss. Funding from CZO and National Office SAVI grant enabled this research and one PhD thesis, one conference abstract, and two manuscripts are in reviews.

Landscape carbon survey Much uncertainty in soil carbon budgets stems from distributing soil carbon across complex terrain where soil depth is largely unknown. To date, soil carbon models in complex terrain have used local controls such as vegetation cover, slope, elevation, hillslope position and soil properties to distribute soil carbon. Other possible local controls such as curvature, microtopography, and lithology have received less attention and may be important variables in local carbon budget models. At the RC CZO, we are finding a strong inverse relationship between tangential curvature -soil regolith depth relationship (r^2=0.86) in a granite-dominated subcatchment that allows us to improve our prediction of soil depth across these complex granitic terrains. We also found that average total soil carbon was 3-4 times greater on the north-facing in compared to south-facing slopes and that a polynomial function was the best fit between mobile regolith depth and total soil profile carbon for both north and south-facing aspects, with r^2 values of 0.89 and 0.87, respectively. Coupling these functions, we improve our prediction of total soil carbon storage across the landscape. If soil samples were collected to 1 m depth, like most other agency or study efforts, total soil carbon would be underestimated by ~4.68 times. Our findings indicate that a significant amount of carbon is stored deep in critical zone and that some agency and large-scale research efforts that sample between 30 and 100 cm depth vastly underestimate total soil carbon stores on complex terrain (Patton et al., in preparation).

Another example of where Reynolds Creek CZO is contributing to a gap in the carbon cycle is through the quantification of inorganic carbon associated with rocks. Soil inorganic carbon stores are significant in arid and semi-arid regions, and pedogenic carbonate often follows a mophogenetic development sequence where carbonates coat rocks, form masses and nodules and eventually may become engulfed and cemented (NRCS manual). The inorganic carbon associated with these carbonate coatings associated with rocks and masses are not typically quantified by soil scientists because they are greater than 2 mm in size, the operational definition of soil and they are difficult to measure owing to the heterogeneity and scale. Consequently, soil inorganic carbon may be underestimated in arid and semi-arid regions. As part of the RC CZO, rocks with carbonate coatings are being pulverized to quantify bulk inorganic carbon. Our analyses are showing that in some cases, rock carbonate coating can represent as much as 43% of total inorganic carbon in soil profiles. Studies that only examine the fine fraction of soils (<2 mm) are overlooking a significant stores of carbon in gravely parent materials (Stanbery et al. in preparation).

Watershed-scale aboveground shrub biomass data are key to understanding inputs of carbon to the soil and these estimates are particularly challenging in shrublands. A key outcome (through collaborations) are watershed-scale aboveground shrub biomass estimates from LiDAR (Li et al., 2015); this work demonstrates the ability to scale from individual shrub-level to watershed-scale with remote sensing, along with uncertainty values. This is one of the first results in estimating low-height shrubland biomass with a multiscale approach.

Environmental network for understanding processes controlling carbon storage
Temperature sensitivity studies of soil organic carbon decomposition show the rate of SOC decomposition increased with increasing temperature across all the elevations. Overall, the results indicate that semi-arid ecosystems will release a significant amount of CO_2 from its labile fraction to the atmosphere, in the face of climate related temperature rise (Delvinne et al, in preparation).

3. What opportunities for training and professional development has the project provided?
We supported research and/or salary (partial, summer, and/or full) for 16 graduates students (50% women), 2 postdoctoral associates, 9 undergraduates, 5 high school students, 1 high school teacher during Year 2 of RC CZO through a combination of diversified funding sources (ISU and BSU teaching assistantships, collaborations, grant funding). Another set of graduate students (5 at BSU) and postdocs (2 at BSU, 1 ISU part-time) are aligned with the Reynolds Creek CZO (salary not funded by CZO but enabled by investments in CZO). A total of 21 graduate students, 4 postdocs are involved in the RC CZO. Most post-docs, graduate students and undergraduates work with several of the Reynolds Creek CZO PIs whose expertise range across geoscience, soil science, plant sciences, microbiology, hydrology, plant physiological ecology, stream ecology and geomorphology. Students freely interact across departments and universities and agencies (Idaho State University, Boise State University, and USDA ARS), and this training promotes the development of a critical mass of critical zone scientists. We continue to expand our campaign to diversify our funding sources for graduate training given that most of our graduate assistant funding ends in Year 3 owing to the 50% reduction in the original budget.
Meetings: We have weekly meetings via video conferencing with all RC CZO participants to discuss research issues and future activities and have graduate students and postdoctoral students present their research and debate findings. Weekly meeting are important to ensure interactions among the students and PIs across institutions. Presentations provide an opportunity to hone their speaking skills and sharpen their research efforts and also identify synergies/collaborations with the other students. We discuss research findings, future plans and ways to connect our research elements in the critical zone. We support graduate students to attend regional and national

meetings and work closely with them to prepare them for presentations and to advise them on manuscript preparation (See Products). Some of PIs (Lohse, Seyfried, Glenn) spend considerable time in the field with graduate students, training them in field methods and developing measurement procedures, and then others in the lab to teach analytical and modeling methods (Flores, Benner, Lohse).
Critical Zone Reading Groups: The CZO graduate students and other interested students (10-15 graduate students) and 4-5 faculty members (lead by Godsey, Reinhardt, Lohse, Crosby) have formed a critical zone reading group at Idaho State University, composed of stream biologists, plant physiological ecologist, biogeochemists, geomorphologists, that meets weekly to discuss papers on cross cutting hydro-biogeo-geomorphological topics and develop *critical* thinking skills.

Coursework: We have also continued to integrate critical zone science into our courses and developed new ones. During the spring 2015 semester, for example, Jen Pierce taught a soil geomorphology course at Boise State University and took students to Reynolds Creek to describe soils and discussion critical zone topics. In addition, at Idaho State University, we developed curriculum for an environmental methods course (2 week, intensive summer field (4 credits) focusing on water and carbon in the critical zone in the spring and implemented it for the first time from May 18-May 30, 2015 with the participation and expertise of 4 CZO investigators, Lohse (soil scientist), Crosby (geomorphology, lead on course), Godsey (hydrologist), and Reinhardt (plant physiological ecologist). We developed a website for this course, advertised it nationally via websites (criticalzone.org, ISU website), meetings (AGU), listservs (czen, ecolog), and social media (twitter). Handouts and several computer labs were developed that utilized CZO data sets. A typical day consisted of 2 hours of instruction and then the remainder of the day in the field and/or lab demonstrating the method(s), and then some form of conceptual mapping or analysis was conducted to analyze data collected from the field or synthesize concepts learned over the course of the day. For example, one day focused on lateral export of carbon in stream flow so that the morning was focused on learning about collection of samples and field methods, considerations, and limitations, and then the afternoon was spent on demonstration of collection of water samples in the field, filtering them in the lab and demonstration of analyses, and then a computer lab using CZO data to learn approaches in estimating loads of particulate, dissolved inorganic carbon, and organic carbon. Six undergraduates and one graduate student (two of them from other universities and women) took this first time course. As their final projects, the students had to develop proposals (oral and written) on a low- and high cost instrumentation design for establishing a water (week 1) and then carbon budget (week 2).

Mentoring: RC CZO disseminated guidelines for mentoring postdoctoral and graduate students. Senior participants use these guidelines in concert with their experience to mentor junior participants: faculty mentor postdocs, graduate students, and undergraduate students; postdocs mentor graduate and undergraduate students; graduate students mentor undergraduate students.

4. How have the results been disseminated to communities of interest?
Stakeholder engagement: USDA ARS has continued to organize semi- to annual meetings with the stakeholders (ranchers and private landowners (20+), Bureau of Land Management) to communicate and discuss activities and identify new areas of research activities that might affect

different stakeholders. In particular, meetings and discussion were extensive to conduct an Environmental Impact Statement (EIS) and obtain clearance for a prescribed wildlife in Johnson Draw and surrounding watershed (~12,000 acres) as well as associated contingency plan area. RC CZO has continued to use the ARS as the "gatekeeper" to coordinate and communicate with private landowners and BLM including obtaining permissions and schedule sampling/flights and other activities on different sites across the RCEW.

Memorandums of Understanding: Idaho State University and Boise State University established a memorandum of understandings with the USDA ARS (completed March 2015) to facilitate sharing and use of facilities.

RC CZO as growing magnet for an interdisciplinary scientific community: RCEW continues to be a focus of hydrologic field research, instrument development and process-oriented modeling averaging use of 100 visitor nights/year. RC CZO has increased levels of activity from the ecology and biogeochemistry communities, resulting in exciting "cross-fertilization" that results in productive science. Year 2 resulted in over 598 visitor nights/yr (Jan 1 2015-August 23, 2015) were recorded and project another 50-75 visitors through November 30, 2015.

Engage broader scientific community: We continue to engage different networks in the RC CZO and CZO network science. We continue to engage Idaho NSF EPSCoR (quarterly newsletter serves over 500 scientists and educators within and outside Idaho) and the NSF EPSCoR Western Tri-State Consortium (ID, NV, NM) and capitalize on products (e.g. downscaled climate scenarios, modeling, visualization) that can be applied to the RC CZO. For example, the NSF EPSCoR Western Tri-State Consortium WAVE team (~15 international and national scientists) visited Reynolds Creek in early June and Seyfried, Lohse and students introduced that science being conducted as part of the CZO research. Graduate students on the WAVE team are capitalizing on the RC CZO and network activities such as using data from the RC CZO for modeling and visualization purposes and participating in All Hands Meeting (through support from RC CZO), weekly and annual meetings. We have also engaged other National networks through senior personnel involvement, including UCAR, NEON, OpenTopography, LTERs, EarthCube, LTAR, and CUASHI. In yr 2, we engaged with the Long-term Agricultural Research (LTAR) Network with the advent of Reynolds Creek Experimental Watershed also being selected as a new LTAR site. This selection has resulted in major infrastructure investments in refurbishment of 5 eddy covariance instruments and new investments in soil carbon dioxide probes, invited talks at LTAR sessions (Lohse at AGU 2015), cross fertilization with other LTAR sites, particularly the SWRC in Tucson. Indeed, with the Soda Fire that burned over 1100 km2, and 68 km2 of Reynolds Creek during the week of Aug 10, 2015 resulted in a mobilization of ARS scientists (remote sensing and interest in post-burn instrumentation). In addition, in Yr 2, USGS Forest and Rangeland Ecosystem Science Center Snake River Field Station scientists approached the RC CZO/USDA ARS to instrument the burn for post-burn dust/saltation response. In Yr 1, we engaged USGS scientist (Sasha Reed) from the Southwest Biological Station in Moab in a collaborative study to quantify biological nitrogen fixation in cold desert shrubland along a climate gradient and continue in Yr 2 to work on analyses and manuscripts (see products). We have continued to engage WY CEGH in research at the RC CZO and are developing collaborations. Indeed, Steven Holbrook and team (~15-17 undergraduates and staff) conducted another campaign during the week of July 6-12, 2015 to do more intensive

measurements of Reynolds Mountain East and other parts of the catchment as part of a graduate student's UWY thesis. Holbrook and Scott Miller approached RC CZO senior personnel in December 2014 to develop a proposal linking an understanding of the subsurface using geophysics to stream runoff generation (to be submitted in December 2015). Senior personnel (Lohse, Seyfried, Pierson) have also submitted a proposal to augment the facility and equipment at the Reynolds Creek field station (FSML) to enhance engagement and research of a broader community and outreach facilities. Finally, Lohse has convened sessions at national meetings to engage ecologists to the Critical Zone science (Ecology in the Critical Zone, Ecological Society of America (ESA), and Ecohydrology in the Critical Zone), and also traveled internationally to get the CZOs on the international radar at the European Geophysical Union (April 2015) (see products).
Data availability and management: We have published 9 categories of historical datasets to present data (2014) from Reynolds Creek Experimental Watershed on the criticalzone.org website. These datasets encompass baseline monitoring data sets including precipitation data from 24 rain gages from 1962-2014, soil moisture and evapotranspiration for multiple stations from 1977-2011, soil temperature from multiple stations from 1971-2014, stream flow from 10 weirs from 1963-2014. We strive to make our data rapidly available to the general public and cross CZOs to increase participation ad discoverability. In Year 2, we have also generated 30 year of hourly, 10 m raster model outputs for many of these forcing data and others (see significant results above) and published these data with DOIs (45TB). We have also posted historical geospatial data for geology, soils, and vegetation to the criticalzone.org website and made a GIS server (http://gis.reynoldscreekczo.org/arcgis/rest/services) that is available to the public upon request. Finally, we have developed a wiki site for the Reynolds Creek CZO for data discovery and also includes protocols, site map viewer and notes (http://info.reynoldscreekczo.org/dokuwiki/doku.php?id=database:recw_map).
Finally, we are utilizing the RC CZO External Advisory Board (EAB) to help engage scientists at their institutions and within their research and education networks. Current EAB are the following: Mark Walbridge (USDA ARS, National Office), Ron Amundson (UC Berkeley), Steven Running (U of Montana), and Dave Schimel (JPL, start 2016).

Public Outreach
We have worked to continue to engage the public in Critical Zone science and importance of soils as the foundation of terrestrial biomes and in providing many ecosystems and critical zone services (See Impacts on society). In particular, we developed a learning module/demonstration on soils titled "Where is Sandy Loam the Gnome?: Forensics with Soils". Graduate students developed a video with a crime scene where Sandy Loam the Gnome (aka a gnome lawn ornament) was stolen and a footprint was left in the soil. Suspects were rounded up and soil characteristics (texture, pH, and color) were used to link the suspect to the scene of the crime. This module, including a video, has been posted to the criticalzone.org website and available for others to use. We implemented this module at the ISU Communiversity Event in March and then the Portneuf Valley Environmental Fair in Pocetello, Idaho in April 2015 and fifty-six children and young adults (age 7-18) plus parents participated in this exercise at the Communiversity Event and 57 plus parents at the Fair. At the RC CZO, we implemented Owyhee Hydrology Camp in which 10 students plus 2 chaperones came out to Reynolds to learn about soils and hydrology and the science conducted at Reynolds Creek. We also used Reynolds Creek as part of an 8th grade adventure learning expedition where the McCall Outdoor Science School (MOSS)

lead adventure learning in the RCEW for 21 students and 2 chaperones for 2 overnights. Finally, CZO graduate student, David, Huber was interviewed and recorded on Idaho Public Television (IDPTV) on the topic of soils and the video is posted on Idaho Public TV but also YouTube (http://video.idahoptv.org/video/2365493230). These videos can high viewership (~1,000,000) according to IDPTV.

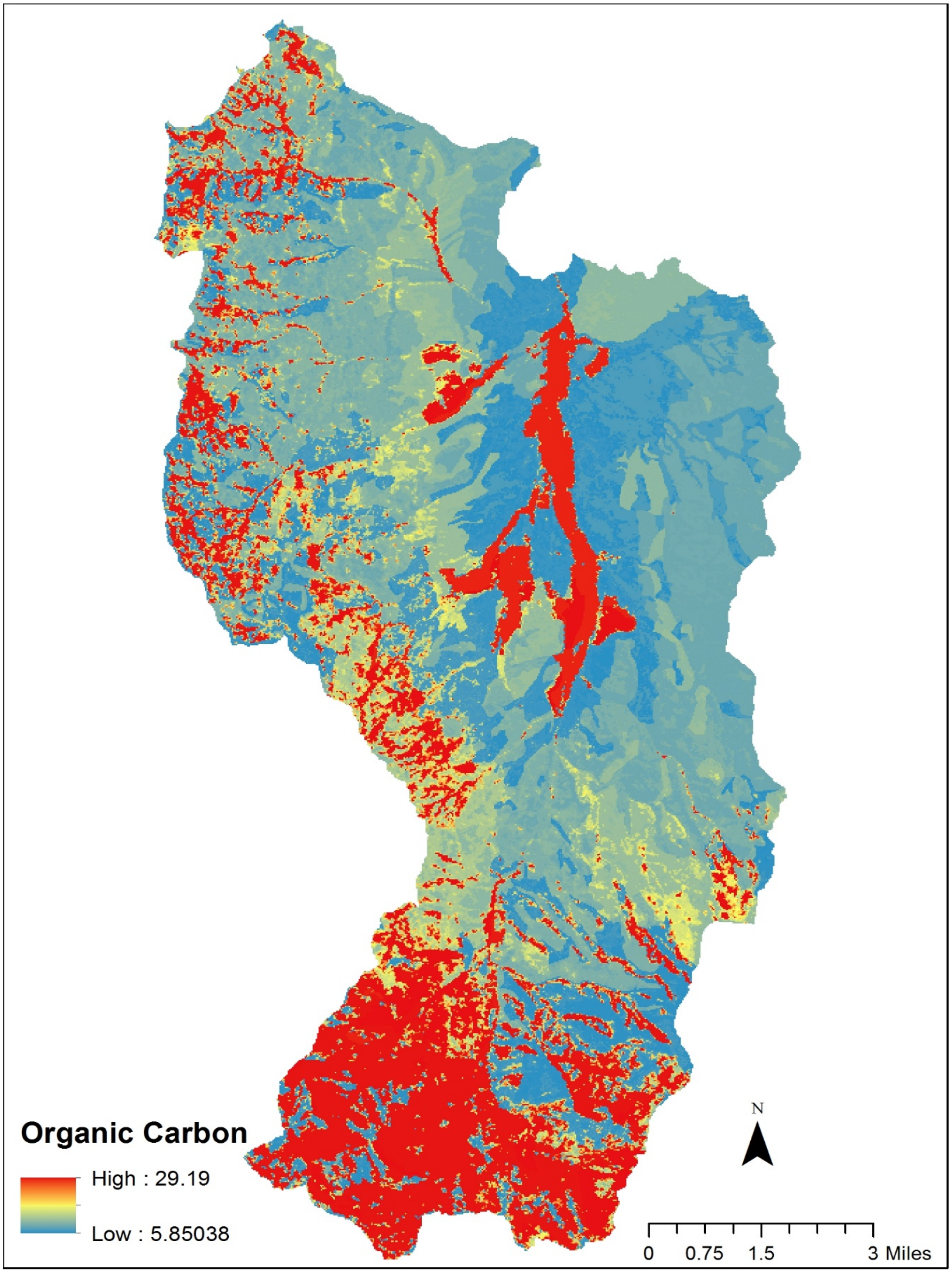

Figure 1.1: Broad-scale soil organic carbon (SOC) map based on climate and proximity to vegetation (plant or inter-plant) as proximal and distal controls on these SOC patterns (Ryan et al, in preparation).

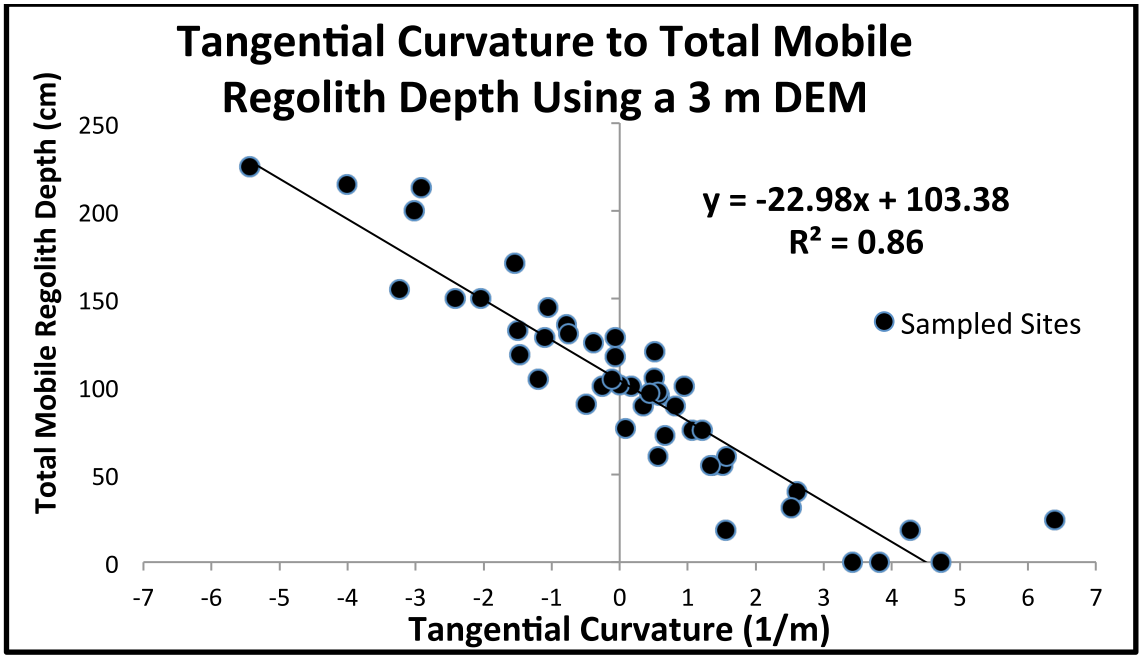

Figure 1.2a: Total mobile regolith depth varied strongly and inversely as a linear function of tangential curvature (r^2 value of 0.86) in a granite-dominated subcatchment (45 soil pits) (Patton et al. in preparation)

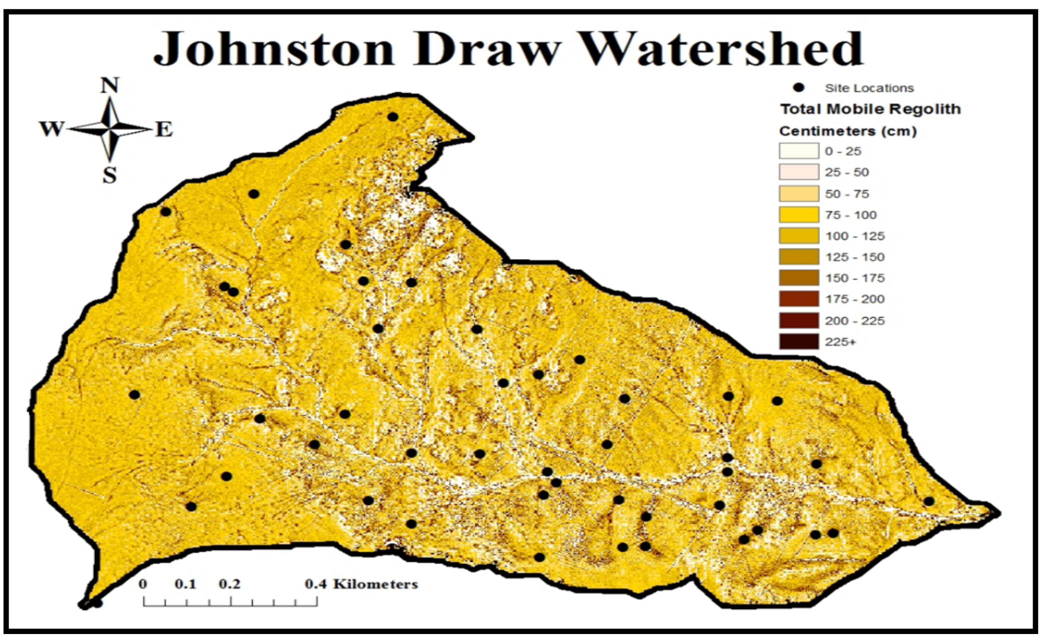

Figure 1.2b: Predictive total mobile regolith map of Johnston Draw Watershed where shallow mobile regolith depths (light colors) are found on noses and ridges while deep mobile regolith (dark colors) are found in hollows and valleys. Black dots are sample points sampled to refusal or regolith. Artifacts of Lidar flight are being corrected in final map (Patton et al. in preparation)

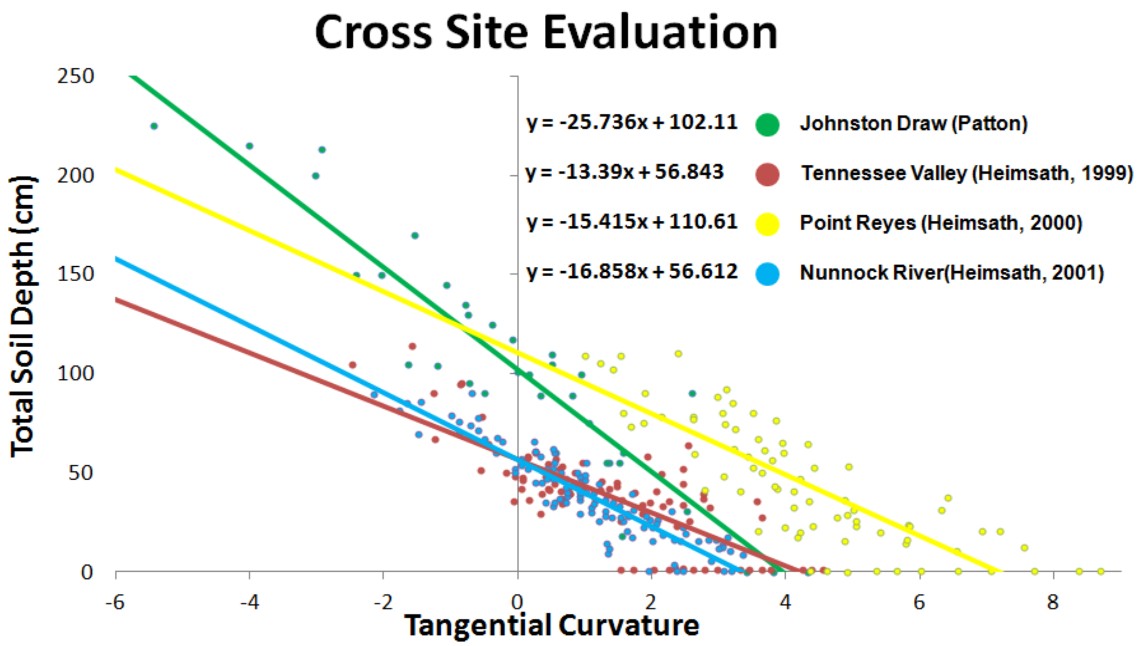

Figure 1.2c: A cross-site evaluation of tangential curvature-soil depth relationship in four watersheds: Reynolds Creek CZO (Patton et al.), Tennessee Valley (Heimsath et al. 1999), Point Reyes (Heimsath et al. 2000), and Nunnock River (Heimsath et al. 2001).

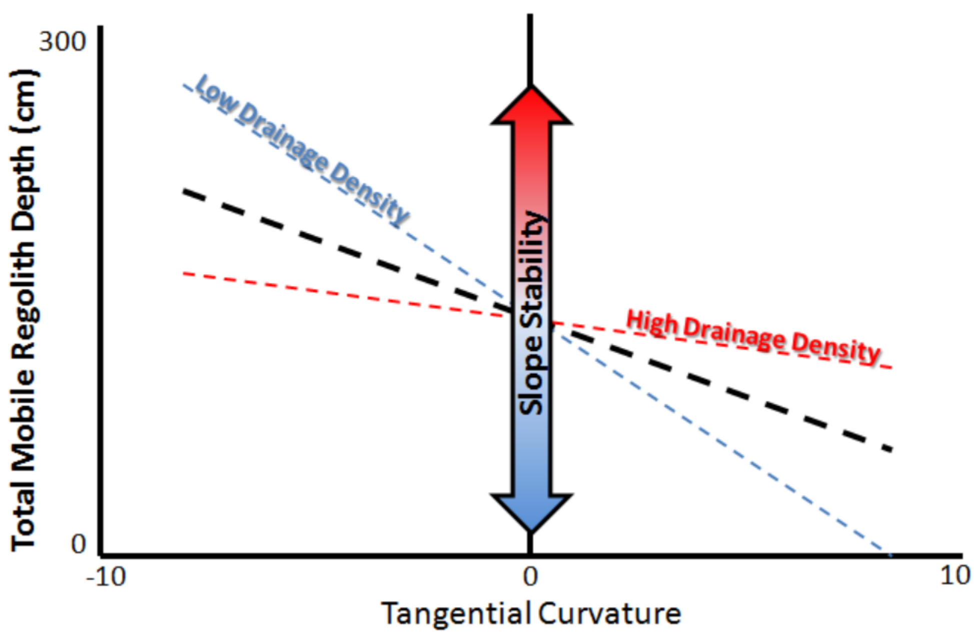

Figure 1.2d: A conceptual model that hypothesizes how the tangential curvature- total mobile regolith depth function is influenced by slope stability and drainage density.

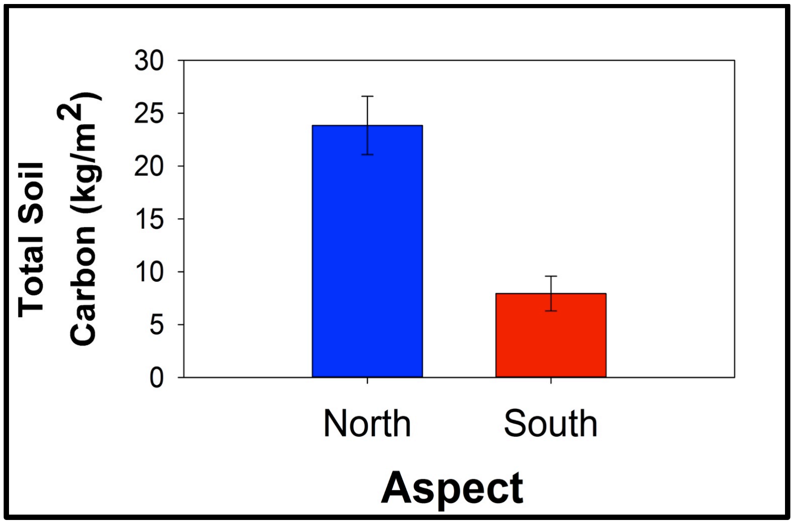

Figure 1.2e: Comparison of total soil carbon profiles for both the north and south-facing aspect, showing three to four times the amount of total soil carbon residing on the north-facing slope.

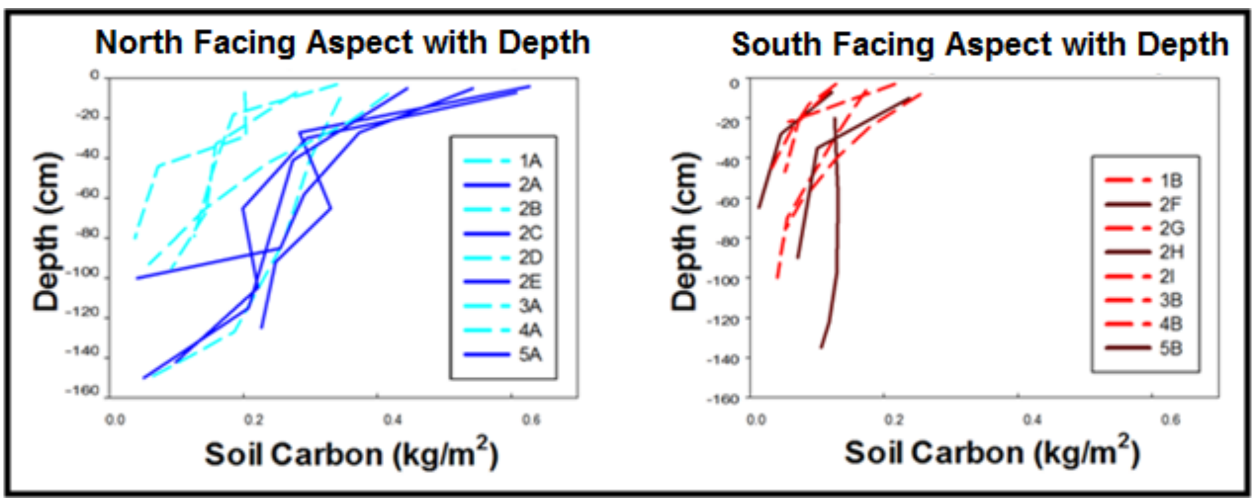

Figure 1.2f: Differences in total soil carbon with depth on north and south facing aspects where dashed lines represent convex compared to solid lines that indicate concave topography.

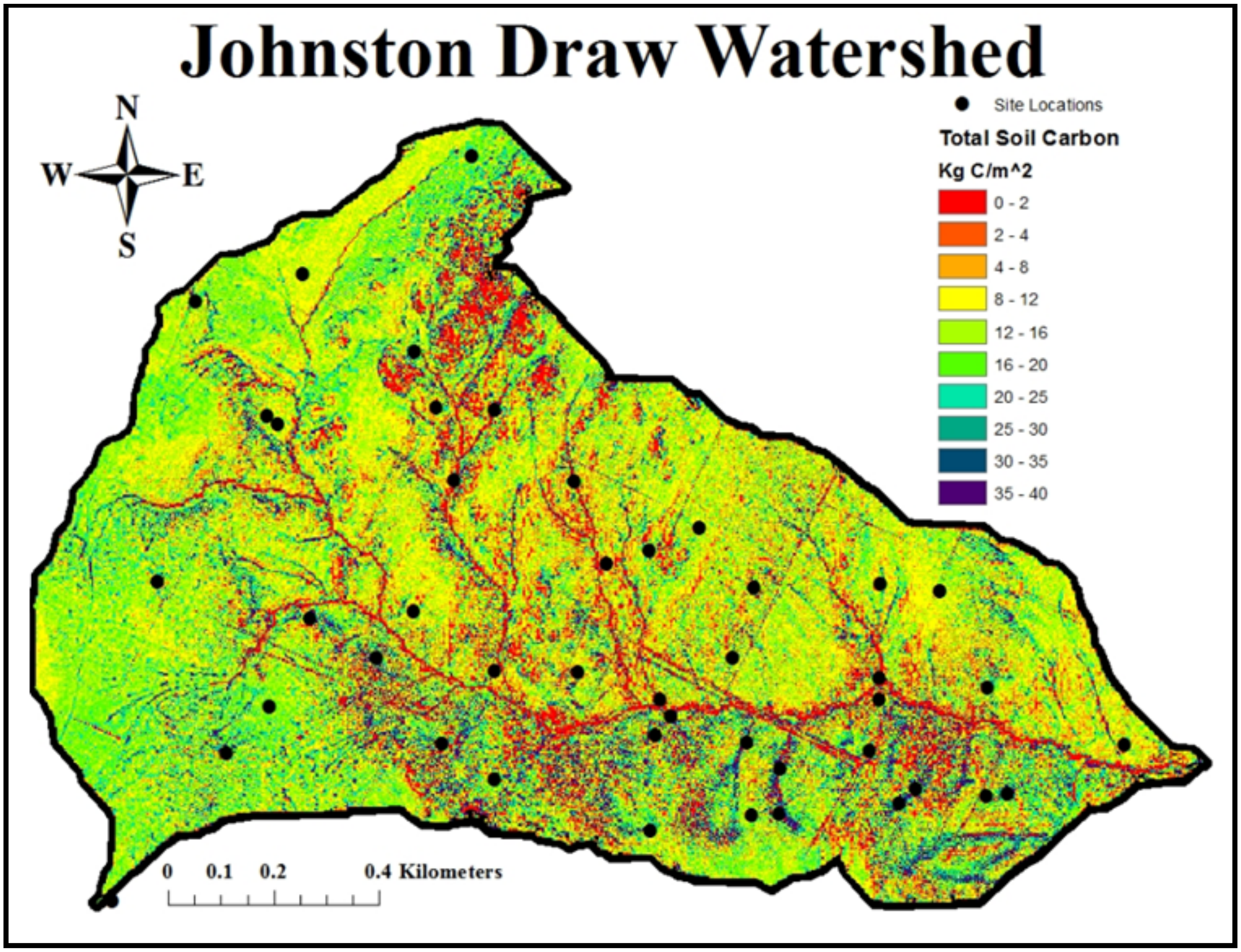

Figure 1.2g: Predictive total soil carbon map of Johnston Draw Watershed where low total soil carbon (warm colors) are found on noses and ridges while high total soil carbon (cool colors) are found in hollows and valleys (Patton et al. in prep). Artifacts of Lidar flight are being removed from final version.

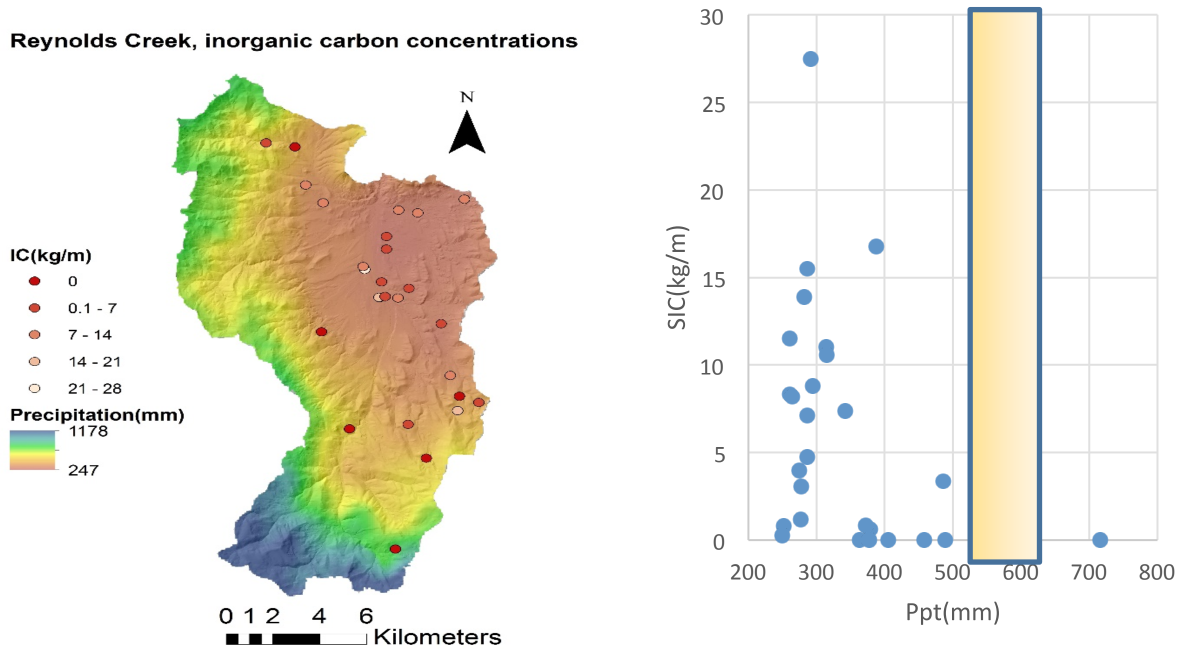

Figure 1.3a: Distribution of measured SIC concentrations throughout Reynolds Creek Experimental Watershed. The correlation between SIC concentration and precipitation is weak, but sites with no SIC become more common as rainfall reaches 500mm.

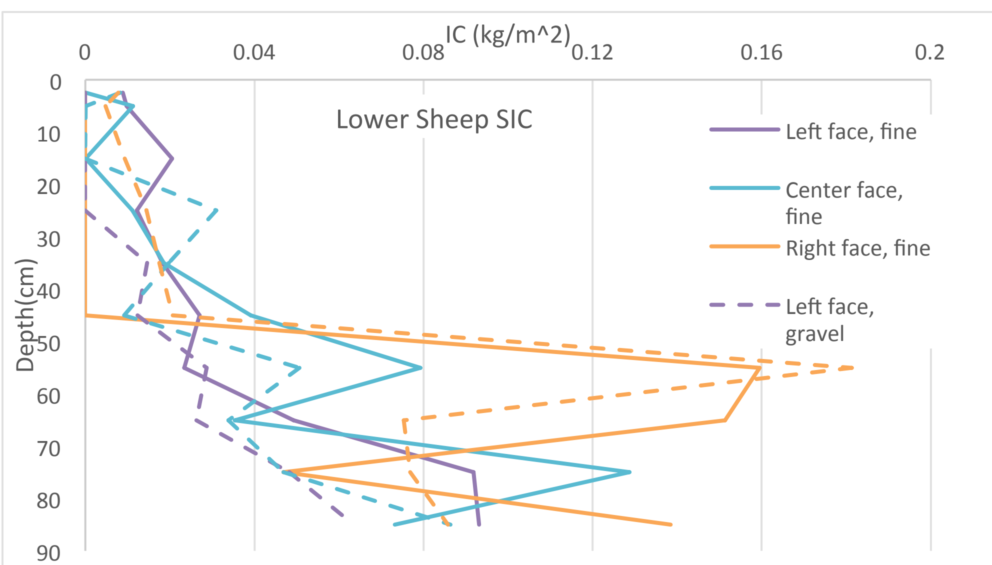

Figure 1.3b: *Substantial portions of SIC are stored in clast coatings on gravels at several sites.* Lower Sheep had almost 43% of SIC in the first meter stored in the gravel fraction

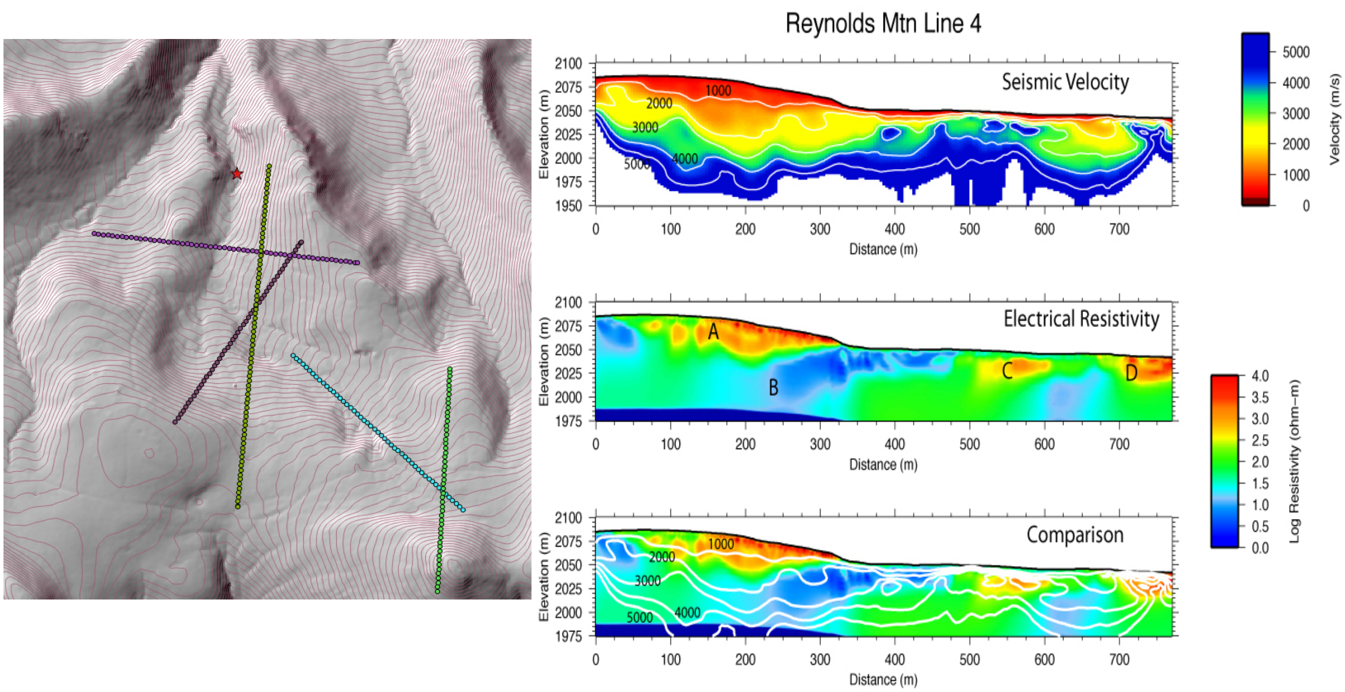

Figure 1.4: Transect is the north-south line of dark green dots in the center (a) and comparison of the resistivity and velocity models (b). Map depth to bedrock and water-rock associations using shallow geophysics show good agreement between resistivity and velocity models (activity through collaborations) The low-resistivity zone marked "B" (Figure 1.6) indicates that this is likely a basalt aquifer feeding base flow and emerging at the channel/aspen grove. We hypothesize that this aquifer consists of fractured basalt (not highly weathered basalt), which corresponds well to velocities of 2-3 km/s, which is consistent with fractured rock. The overlying zone (marked "A") is likely a highly weathered and fractured zone that is so permeable that it doesn't hold water – the high resistivities imply it is dry. Thus snowmelt passes quickly through this zone and accumulates in the fractured basalt aquifer.

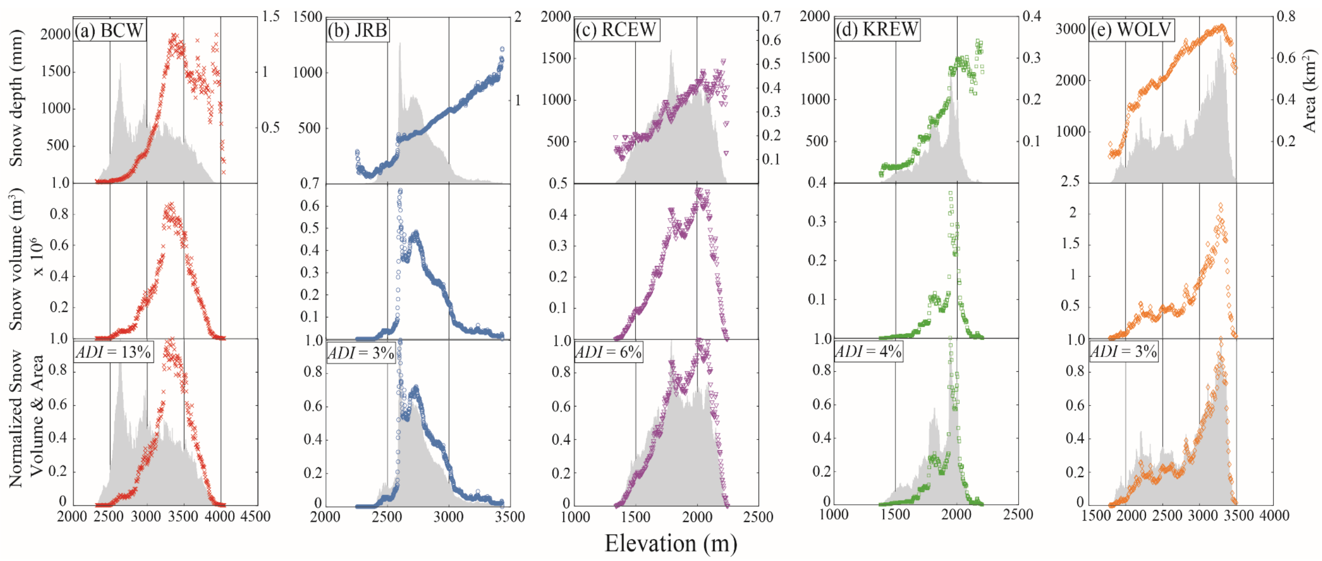

Figure 1.5a. Top row is snow depth (colored symbols) and area (gray shading), middle row is snow volume, and bottom row is normalized snow volume (colored symbols) and area (gray shading) plotted against elevation for sites at (a) Boulder (BCW), (b) Jemez (JRB), (c) Reynolds (RCEW), (d) King's (KREW) and (e) Wolverton (WOLV). The elevation and snow volume distributions generally match with exceptions at BCW and RCEW. The Agresti Dissimilarity Index (*ADI*) is the smallest percentage of the CZO snow volume distribution that needs to be reallocated to match the elevation distribution; a score of 0% indicates a perfect match between distributions. All sites exhibit increases in snow depth with elevation; however, the relationship between snow depth and elevation is not monotonic and rates of increase vary from site to site. The elevation distributions of the CZOs generally predict snow volume distributions with high accuracy, implying that hypsometry provides a useful measure of a watershed's sensitivity to warming-driven snowpack loss. At sites where elevation less reliably predicts snow storage, wind transport and aspect-dependent snow storage were important.

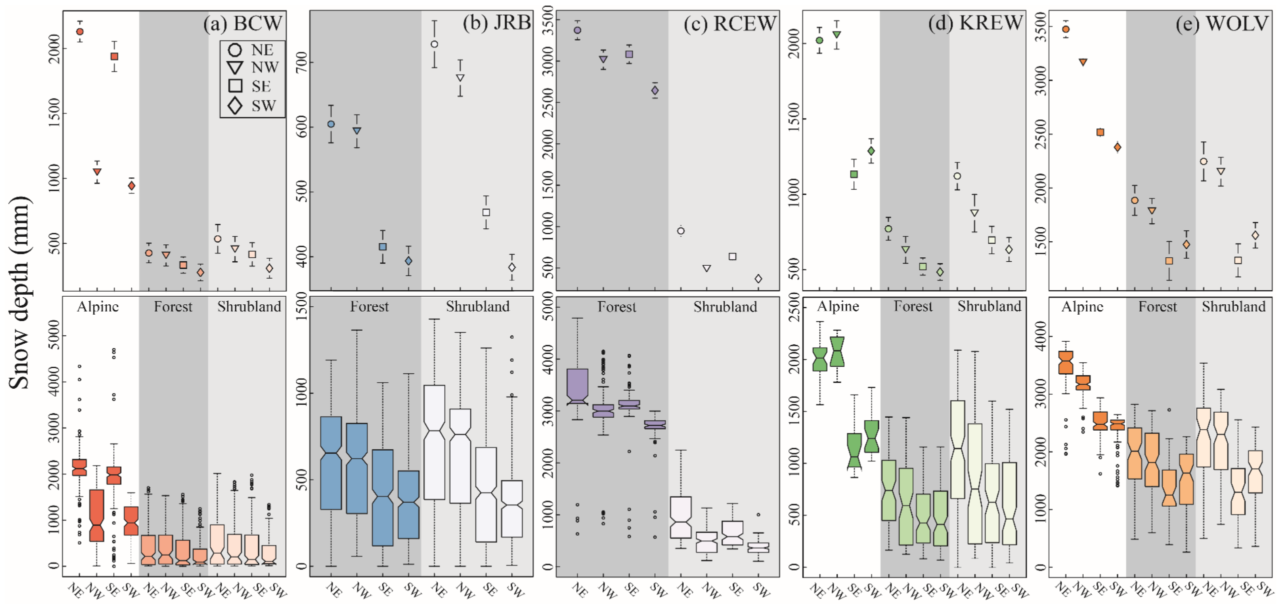

Figure 1.5b. Comparison of aspect-dependent snow depths in alpine (white background), forested (dark gray shading), and shrubland (light gray shading) areas for (a) Boulder (BCW), (b) Jemez (JRB), (c) Reynolds (RCEW), (d) King's (KREW) and (e) Wolverton (WOLV) sites. The top row shows mean snow depths (symbols) and 95% confidence intervals (vertical lines) based on the results of a Tukey's HSD test. If the confidence intervals between two means do not overlap the groups' means are significantly different. The bottom row shows boxplots of group snow depths. The notches on the boxplots extend to ± 1.58(inter-quartile range/square root(n)), and provide an additional, non-parametric test for significant differences in central tendencies of the groups. If the notches do not overlap the medians can be considered significantly different [*Chambers et al.*, 1983]. RCEW displays the most striking departure in vegetation height-dependent snow depths; snow depths across all aspects in forested areas have much greater means than in shrubland areas (Figure 5c). Differences in the means between forested and shrubland snow depths range from more than two and a half times greater (northeast shrubland vs. southwest forested) up to seven times greater (southwest shrubland vs. northeast forested; Figure 5c). While the strongest differences in mean snow depth are related to vegetation height, RCEW also exhibits aspect-dependent controls. Mean snow depths on northeast- and southeast-facing aspects are generally higher than on northwest- or southwest-facing slopes (Figure 5c). Winds in RCEW are routinely out of the west to southwest and cause preferential deposition of wind transported snow in sheltered, NE- and SE-facing aspects.

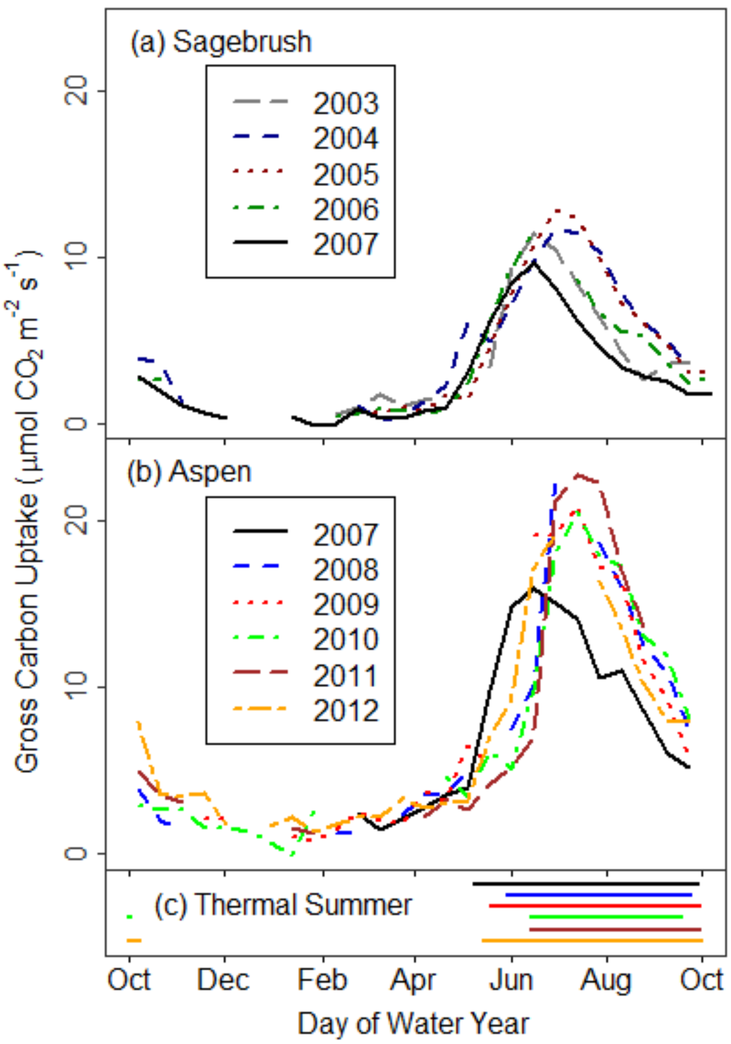

Figure 2.1a: Preliminary results show strong seasonality in GEE, characterized by near 0 GEE in winter in a) Sagebrush and a small to moderate GEE during winter in b) Aspen. Phenology is timed with warming – thermal summer – particularly at the Aspen site. Peak carbon uptake in Aspen is nearly double the peak carbon uptake in Sagebrush. There is considerable variability in when and the amount of GEE peaks at both sites – which is tied to precipitation amounts. In dry years (2007) peak carbon uptake can be ~75% of carbon uptake – and it is shifted earlier in the year where GEE declines earlier in the fall.

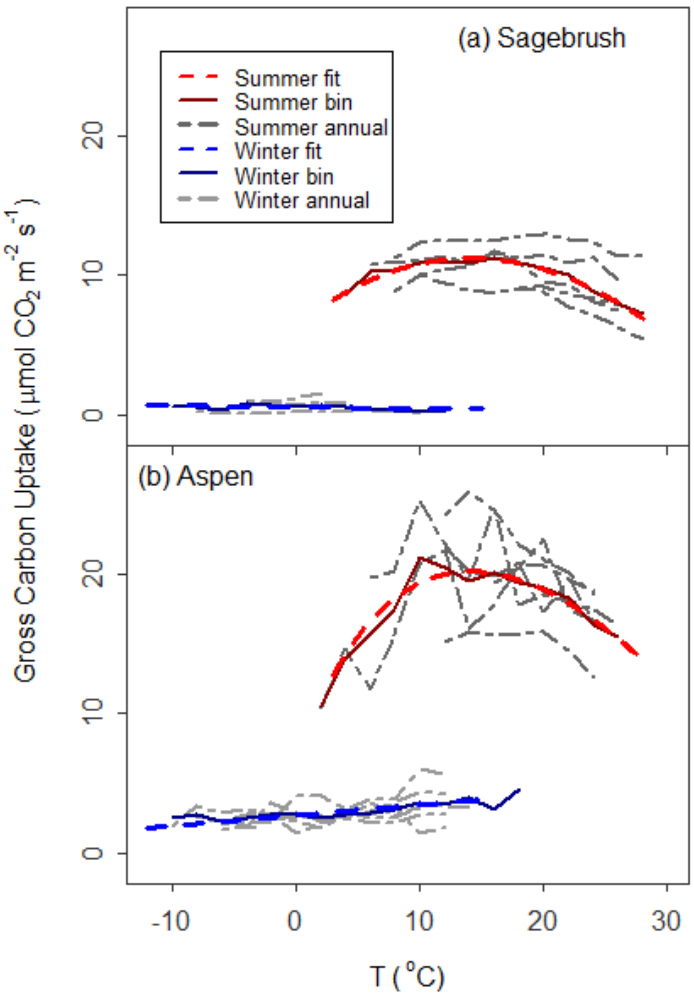

Figure 2.1b: Gross Carbon uptake –Temperature response. Dormancy is a key control of GEE. Optimum temperature for GEE is ~12-15 deg C with sharp reduction in GEE below 10 deg C. These findings provide a temperature scalar for LUE model.

Figure 2.2: Photo showing tissue heat balance on sagebrush

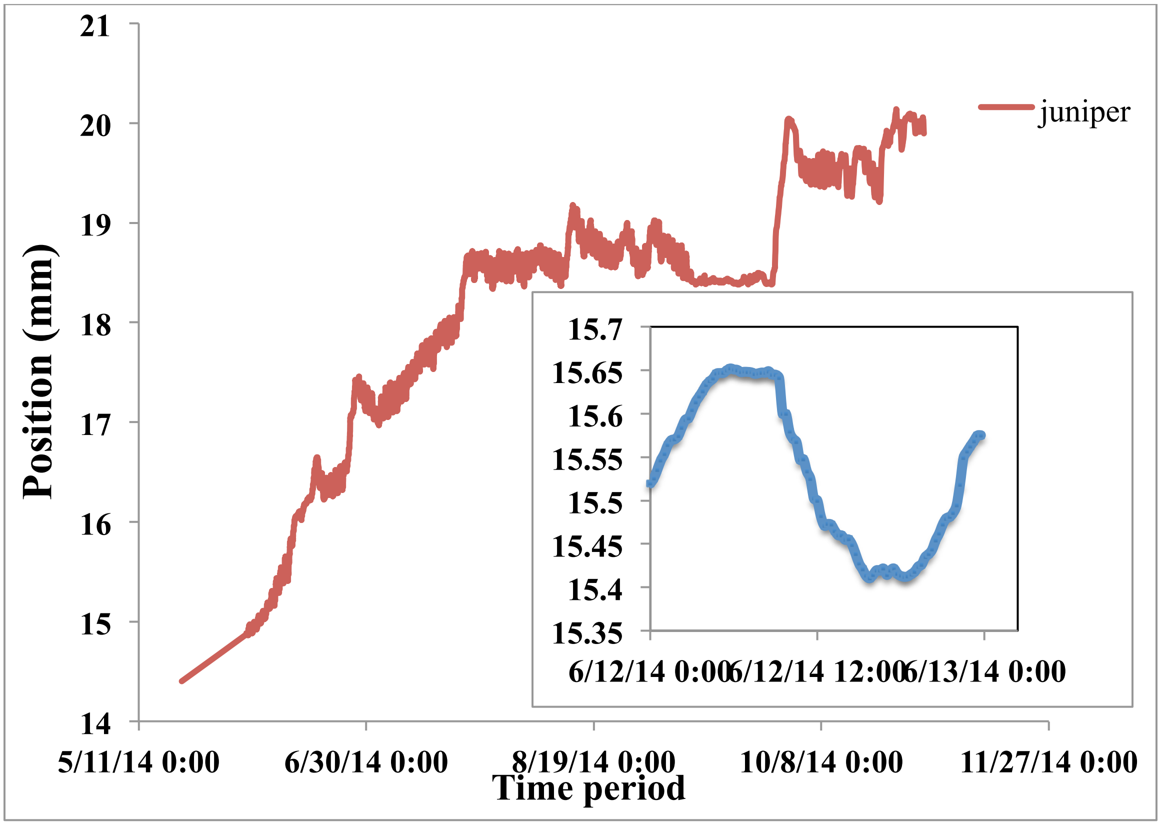

Figure 2.3: Example of (a) Seasonal and (b) diurnal variation in diameter increment growth from automated dendrometers in juniper (*J. occidentalis*) May 19 to Oct. 30, 2014. Automated dendrometers show differences in diurnal variation in tree circumference averaged about 0.17±0.06 mm, 0.67± 0.51mm, and 2.61± 1.70 mm for *J. occidentalis, P. menziesii* and *P. tremuloides*, respectively. Biomass addition to *P. tremuloides*, *P. menziesii,* and *J. occidentalis,* respectively, were 8.4±6.1 kg, 9.4±2.8 kg, and 4.8±1.3 kg during 2014 growing season based on available allometric relationships.

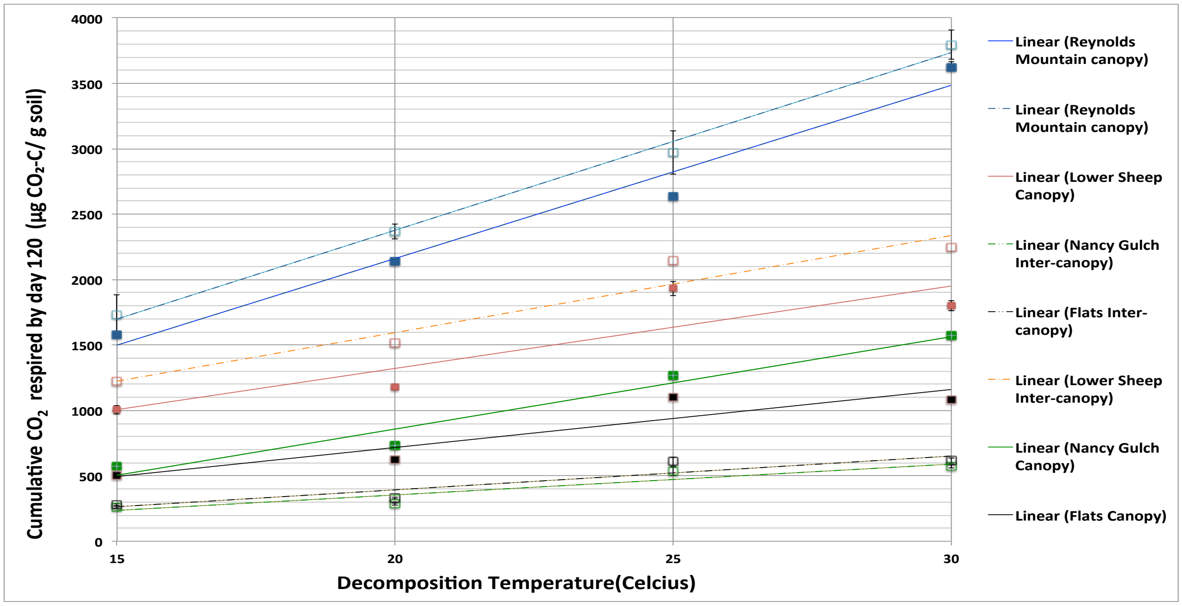

Figure 2.6a. Preliminary figure of cumulative CO_2 respired for canopy and inter-canopy areas across elevations at different temperatures. Reynolds Mountain is highest elevation site followed by Lower Sheep, Nancy Gulch and then Flats (lowest elevation).

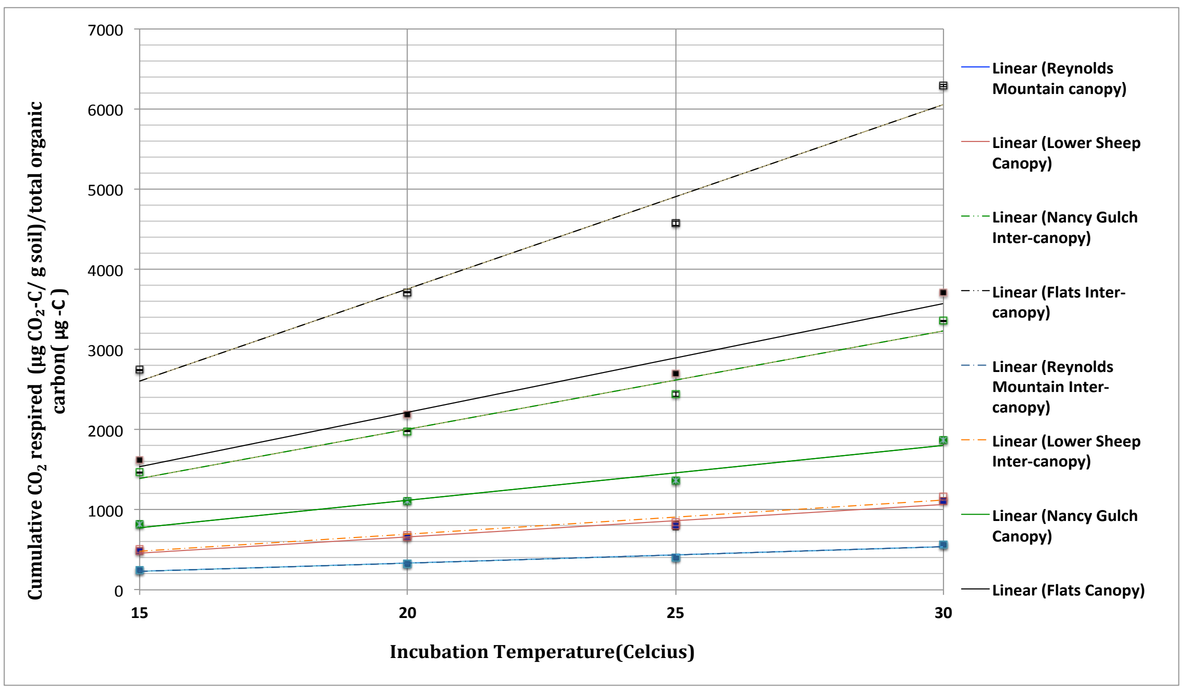

Figure 2.6b. Preliminary figure of cumulative CO_2 respired for canopy and inter-canopy areas across elevations at different temperatures normalized by total carbon. Temperature has a significant influence on decomposition. Cumulative CO_2 respired increase with increasing temperature and elevation (Figure 2.6a). In contrast, cumulative CO_2 respired normalized by unit carbon, increases with decreasing elevation (Figure 2.6b). One-Way ANOVA ($p<0.05$) established that SOC decomposition varies significantly among elevations and Tukey HSD test (95% CI) support that SOC at the lowest site (Flats) is significantly greater in its temperature

sensitivity to decomposition.

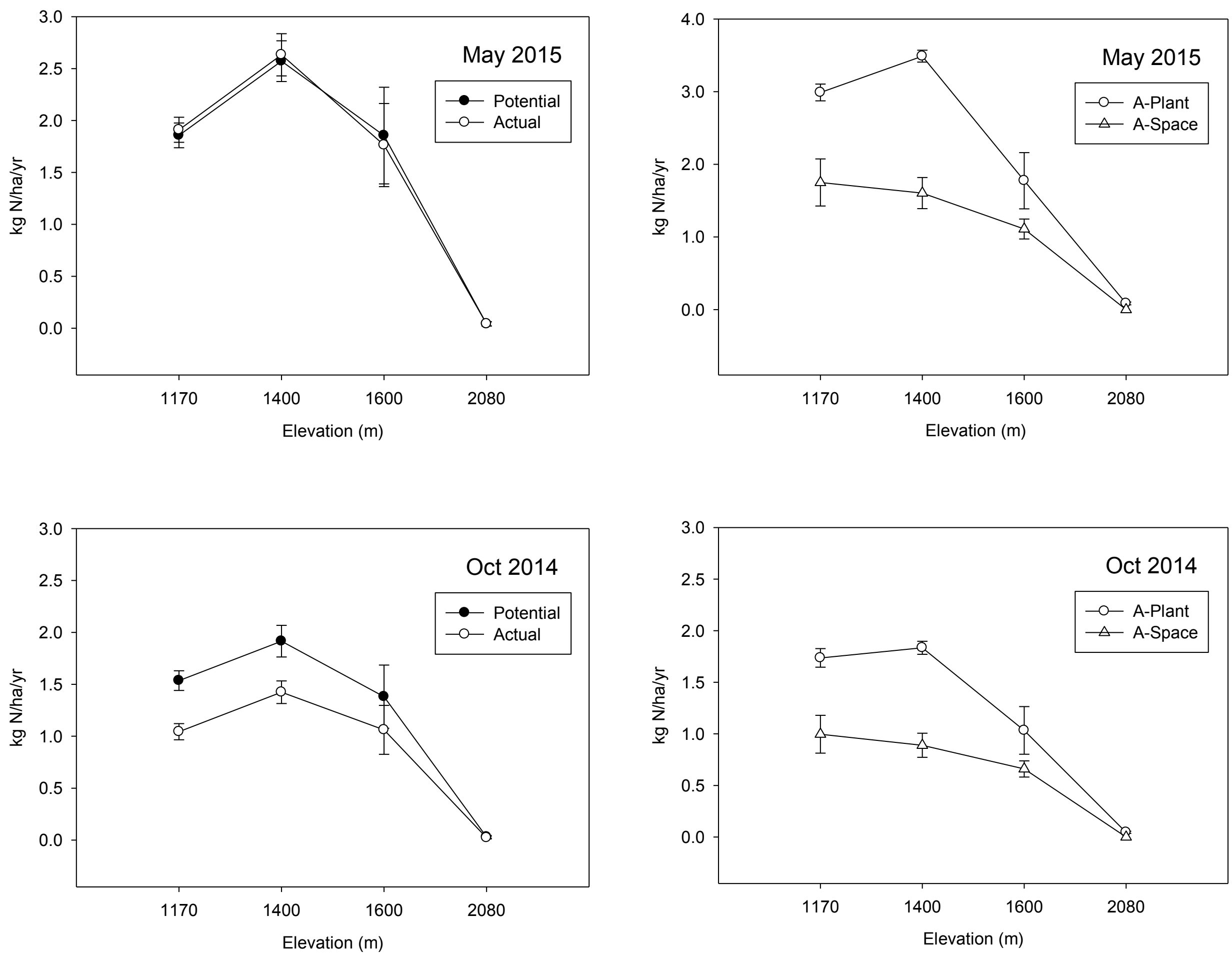

Figure 2.7a. Actual and potential (water primed) rates of nitrogen fixation measured by acetylene reduction with elevation and plant-interplant space (Schwabedissen, Reed, Magnuson, Sheridan, Lohse, collaboration with USGS S Reed). Biological nitrogen (N_2) fixation rates associated with biological crusts in this cold desert ecosystem was generally low (range 0-3 kg N/ha/yr) compared to dry desert ecosystems were consistently highest at one of the mid-elevation sites and lowest at the highest elevation site. Rates from October 2014 collection showed significant differences between potentials (water primed) and actuals (unprimed). In contrast, rates from the May 2015 collection showed little difference between potentials (water primed) and actuals (unprimed) indicating that moisture is not a limiting control during this time period.

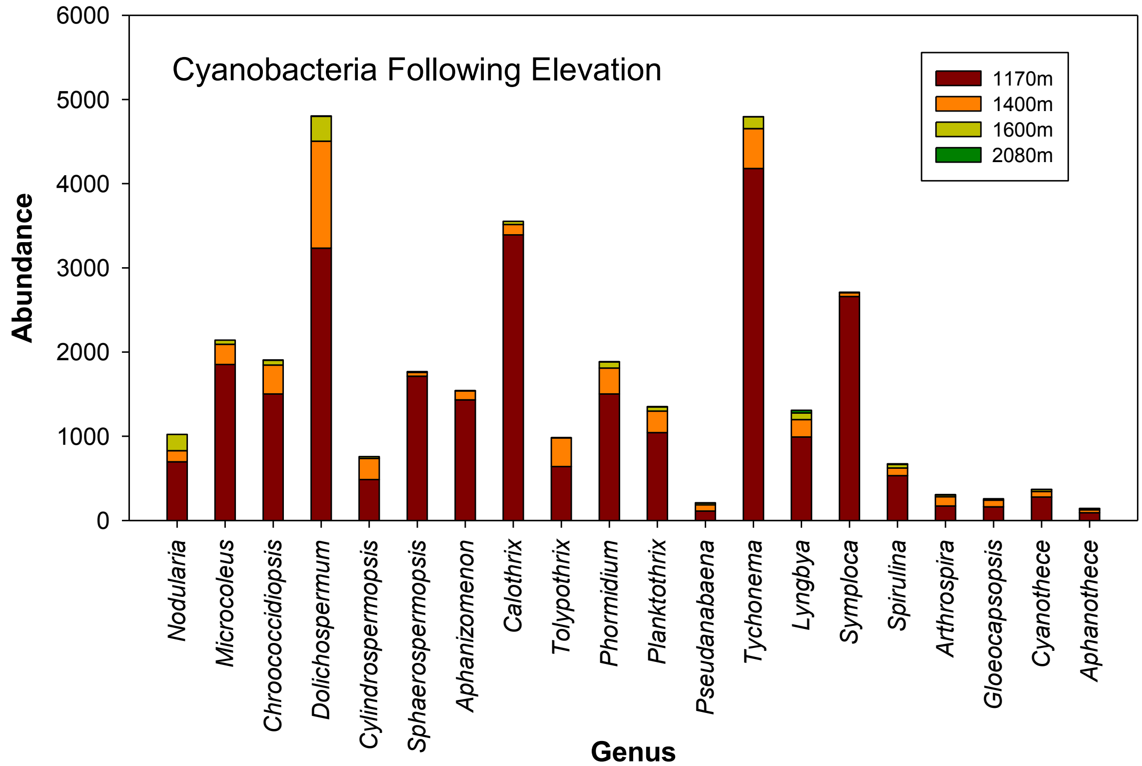

Figure 2.7b: Analysis of the 16S small subunit rRNA paired-end sequencing runs show the lowest elevation 1170m with the greatest amount of Cyanobacteria (main component of biological soil crusts), with over 73% of them following elevation. The remainder percentage is dominated in the 1400m elevation, suggesting that Cyanobacteria are more abundant in the lower elevations. The two genera within Cyanobacteria with the highest abundance were *Nostoc* and *Oscillatoria*) (Schwabedissen, Magnuson, Aho, Sheridan, Lohse)

Table 2.9: Preliminary results of average ± standard error of dissolved organic carbon (DOC as C), dissolved inorganic carbon (DIC as C), total nitrogen (TN), Fluorescence index, and nitrate-N concentrations in mg/L.

Sites	**Observations**	**DOC-C**	**DIC-C**	**TN**	**FI**	**NO_3-N**
Reynolds Mtn.	77	5.24 ±0.14	3.16±0.11	0.09±0.009	1.46	0.033±0.01
Johnston	51	9.69±0.37	7.43±0.37	0.14±0.004	1.50	0.008±0.001
Dobson	12	11.61±0.93	10.45±1.25	0.11±0.01	1.52	0.07±0.02
Tollgate	125	9.61±0.28	9.61±0.26	0.09±0.01	1.55	0.028±0.003
Outlet	8	24.3±2.06	34.26±5.52	0.43±0.151		0.003±0.002

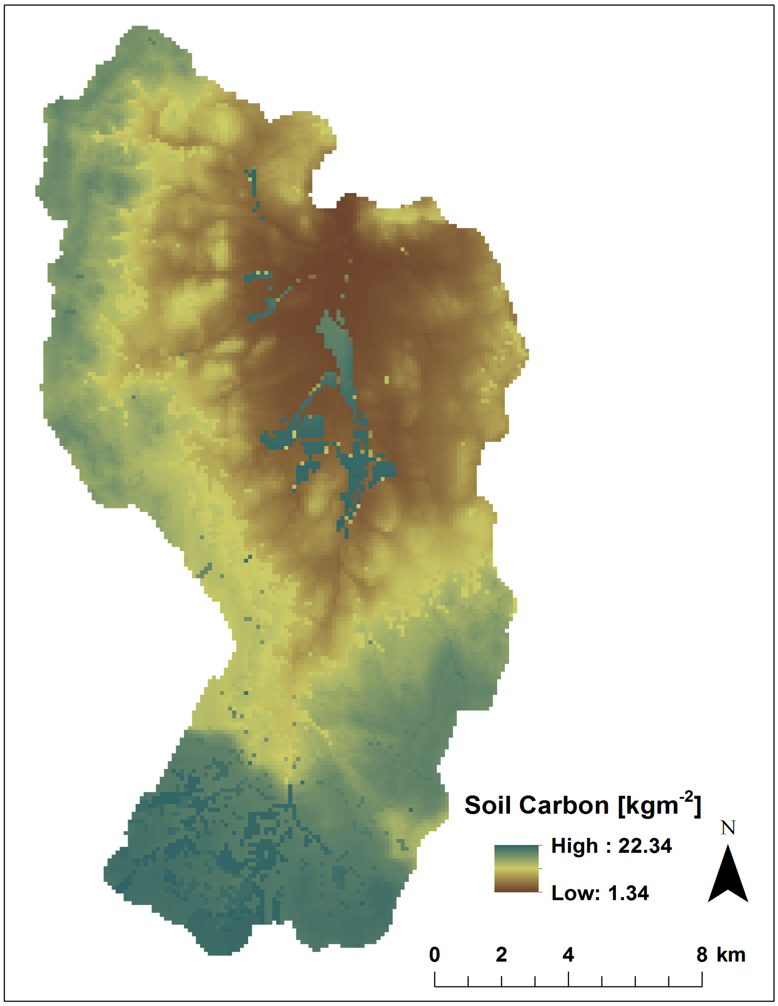

Figure 3.2: Soil carbon stocks predicted by Biome-BGC after a spin-up simulation across RCEW at 120 m spatial resolution. The model spin-up recycled through 26 years (1982-2007) of distributed meteorology data requiring between 700 and 3,000 years to reach relative equilibrium (Walters and Flores)

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

Major Priority Area	**Activity**	**Milestones**												
		Year 3	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Strategic Priority 1: ***Landscape Soil Carbon Survey***	**Survey**	Year 3 revised soil carbon map created									X	X	X	
	Characterization	Conduct targeted field sampling activities						X	X	X	X			
		Complete Year 2 soil analysis	X	X	X	X	X							
		Targets identified for Year 4 sampling and analysis											X	X
		Utilize LiDAR dataset to leverage non-CZO funded activities	X											
Strategic Priority 2: ***Environmental Monitoring Networ***k	**Core Site Creation**	Complete installation and monitoring at 5 of 5 sites.						X	X	X	X			
	Net Ecosystem Exchange	Maintain sites and monitoring continued Analyses continued on historic data	X	X	X	X	X	X	X	X	X	X	X	X
	Transpiration	All sap flux sites maintained, monitored	X	X	X	X	X	X	X	X	X	X	X	X
	Aboveground Biomass and Net primary productivity (NPP)	Continue productivity and litterfall data collection						X	X	X	X	X		
	Soil Respiration	Continue manual soil flux measurements	X	X	X	X	X	X	X	X	X	X	X	X
	Stream and Groundwater Carbon Export	Stream and groundwater monitoring and sampling protocols developed, activities initiated	X	X	X	X	X	X	X	X	X	X	X	X
Strategic Priority 3: ***Integrated Modeling Framework***	**Create Fine Resolution Hydroclimate data**	Continue to maintain site to serve data and develop bundle to interface with HydroShare		X	X	X	X	X	X	X	X	X	X	X

Major Priority Area	Activity	Milestones											
		Year 3	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
	Integrated Terrestrial Biosphere Modeling	Continue land surface modeling activities Completed integration of fine-resolution climate data with soil carbon and other environmental variables	X	X	X	X	X	X	X	X	X	X	X	X

B. Products

Book Chapters

White T., Brantley S., Banwart S., Chorover J., Dietrich W., Derry L., Lohse K., Anderson S., Aufdendkampe A., Bales R., Kumar P., Richter D., and B. McDowell (2015). Chapter 2 – The Role of Critical Zone Observatories in Critical Zone Science. *Developments in Earth Surface Processes* 19. 15. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

Conference Papers and Presentations

Enslin, C., Marks, D., Godsey, S., Kormos, P., Seyfried, M., and T. Link (2015). *A hydrometeorological dataset across the rain-to-snow transition at Reynolds Creek Critical Zone Observatory, Idaho*. American Geophysical Union (AGU) Fall Meeting. Status = OTHER; Acknowledgement of Federal Support = Yes

Schwabedissen, S., Reed, S., Magnuson, T., and K. Lohse (2014). *Biological Soil Crust Nitrogen Fixation in Semi-arid Ecosystems: Climatic and Grazing Controls*. Biological Soil Crust Nitrogen Fixation in Semi-arid Ecosystems: Climatic and Grazing Controls. Fish Camp, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Huber, D., Lohse, K., and M. Germino (2015). *Climate Change in Changing Landscapes: Controls on Soil Moisture and Nutrient Cycling*. Centennial Meeting of the Ecological Society of America (ESA). Baltimore, MA. Status = OTHER; Acknowledgement of Federal Support = Yes

Schwabedissen, S., Reed, S., Magnuson, T., and K. Lohse. (2014). *Climatic and Grazing Controls on Biological Soil Crust Nitrogen Fixation in Semi-arid Ecosystems*. AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Schwabedissen, S., Reed, S., Sheridan, P., Magnuson, T., and K. Lohse (2014). *Climatic and grazing controls on biological soil crust nitrogen fixation in semi-arid ecosystems*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Patton, N., Seyfried, M., Link, T., and K. Lohse (2014). *Controls of Parent Material and Topography on Soil Carbon Storage in the Critical Zone*. AGU Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Patton, N., Lohse, K., and M. Seyfried (2014). *Controls of Parent Material and Topography on Soil Carbon Storage in the Critical Zone*. All Hands Critical Zone Observatory Network. Fish Camp, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Patton, N., Lohse, K., Seyfried, M., and T. Link (2014). *Controls of Parent Material and Topography on Soil Carbon Storage in the Critical Zone*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Patton, N., Lohse, K., Seyfried, M., and T. Link (2014). *Controls of Parent Material and Topography on Soil Carbon Storage in the Critical Zone*. Idaho State Research Fair. Pocatello, ID. Status = OTHER; Acknowledgement of Federal Support = Yes

Zhou, Q., Flores, A., Flerchinger, G., and N. Glenn (2015). *Deriving spatiotemporally distributed net ecosystem exchange esitmates combing eddy flux and remote sensing data*. 4th Annual Great Basin Consortium Conference. Boise, Idaho. Status = OTHER; Acknowledgement of Federal Support = Yes

Galanter, A., Cadol, D., and K. Lohse (2014). *Distribution, Transport, and Accumulation of Pyrogenic Black Carbon in Post-Wildfire Watersheds*. AGU Fall Meeting. San Francisco. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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Harpold, A., Brooks, P., Perdrial, J., Lohse, K., McIntosh, J., Meixner, T., Zapata-Rios, X., Vazquez-Ortega, A., and J. Chorover (2015). Variable Groundwater Contributions Influence Nutrient Cycling in Montane Headwater Catchments. *Water Resources Research*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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Perdrial, J., Brooks, P., Swetnam, T., Lohse, K., Rasmussen, C., Litvak, M., Harpold, A., Broxton, P., Mitra, B., Meixner, T., Condon, K., Huckle, D., Stielstra, C., Vazquez-Ortega, A., Lybrand, R., Holleran, M., Orem, C., and J. Chorover (2015). Carbon budgets of seasonally snow-covered montane ecosystems reveal systematic imbalances across time and space. *Biogeochemistry*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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Seyfried, M., Finzel, J., Weltz, M., and K. Launchbaugh (2015). Simulation of long-term soil water dynamics at Reynolds Creek, Idaho: Implications for rangeland productivity. *Ecohydrology*. . Status = ACCEPTED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1002/eco.1666

Seyfried, M., Link., T., and D. Marks (2015). Soil temperature variability in complex terrain measured using distributed fiber-optic temperature sensing. *Vadose Zone Journal*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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Tennant, C., Harpold, A., Crosby, B., Godsey, S., and K. Lohse (2015). LiDAR illuminates the influence of elevation, aspect, and vegetation on seasonal snowpack: case studies from four western Critical Zone Observatories. *Water Resources Research*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Wang, C., Glenn, N., Hardegree, S., and A. Boehm (2015). Foliage biomass estimation of Douglas-fir stands using airborne LiDAR data. *International Journal of Remote Sensing*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Other Products

- *Protocols.*

Protocols to connect to GIS Services in ArcMap are provided as a protocol product to Reynolds Creek CZO participants

- *Protocols.*

Standardized protocols are available on the Reynolds Creek Wiki for samples taken from Reynolds Creek. PDFs are available of each of the protocols using the link at the top of the page. Protocol data sheets are tailored to their respective protocols and should make data acquisition easier.

Templates are also available for data and metadata to be used for submission to the data archive. Please contact Sue Parsons with any issues or questions.

If there is a protocol you need that isn't listed or if you have any issues please contact Emma McCorkle for assistance.

Protocols

- Field Methods
- Soil Processing
- Soil Physical Characteristics
- Soil Biogeochemistry
- Water Sampling
- Soil Biology

Templates

- ODM2 Compatible Templates

- Field Data Collection
- Protocol Data Sheets

http://info.reynoldscreekczo.org/dokuwiki/doku.php?id=protocols

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

- Tennant, C. J.. *The sensitivity of mountain snowpack to warming*. (2015). Idaho State University. Acknowledgement of Federal Support = Yes

Websites

- *Metadata Submission for Reynolds Creek Critical Zone Observatory Datasets*
  http://www.lohselab.com/rcew-czo-metadata.html
  These are the variables that should be collected with samples in the field. This is a template, actual data submission will be at RC CZO Metadata Submission. Please submit a document for each site where samples are collected. If multiple samples are collected at an individual site they can be included together on one document. Please contact Emma McCorkle with any questions.

Variable	Answer Criteria
Dataset Creators	Student and Advisor
Affiliation	University or Government Agency
Topic	Brief outline
Types of Samples Collected	Soil, plant, water, etc.
Field Instruments	Equipment used or installations
Date Collected	When collected from field
Study Location (Watershed)	Popular name (i.e., Flats)
GPS & Accuracy	Coordinates **must** be in NAD83 Zone 11 UTM in meters
Elevation	Meters above sea level

Variable	Answer Criteria
Distinguishing Features	Roads, geologic formations, etc.
Vegetation	Dominant type and cover
Any other notes	Other notable information
Where data is stored	Name of repository
State of data	Published, in review, being collected

- *RC CZO GIS Server*
  http://gis.reynoldscreekczo.org/arcgis/rest/services

  This URL provides a link to Reynolds Creek CZO GIS server and associated spatial data that is associated with cloud server.

  Services include the following:

  - ELEV10mDEM (MapServer)
  - GrazingExclosures (FeatureServer)
  - GrazingExclosures (MapServer)
  - Precipitation (MapServer)
  - PrelimJohnstonDrawBurn (FeatureServer)
  - PrelimJohnstonDrawBurn (MapServer)
  - RCEW_Boundaries_Regions (FeatureServer)
  - RCEW_Boundaries_Regions (MapServer)
  - RCEW_Geology (FeatureServer)
  - RCEW_Geology (MapServer)
  - RCEW_Sites_Instrumentation (FeatureServer)
  - RCEW_Sites_Instrumentation (MapServer)
  - RCEW_Soil (FeatureServer)
  - RCEW_Soil (MapServer)
  - RCEW_SSURGO (FeatureServer)
  - RCEW_SSURGO (MapServer)
  - RCEW_Vegetation (FeatureServer)
  - RCEW_Vegetation (MapServer)
  - RCEWroadsLANDstewardship (FeatureServer)
  - RCEWroadsLANDstewardship (MapServer)
- *Reynolds Creek Critical Zone Observatory Wiki*
  http://info.reynoldscreekczo.org/dokuwiki/doku.php?id=start

  Research within Reynolds Creek CZO is focused on answering questions about the carbon cycle. Our researchers are studying the Reynolds Creek watershed in Southwestern Idaho to better understand soil carbon dynamics. We are able to utilize decades of data and existing infrastructure from a mutually beneficial partnership with the USDA ARS.

This wiki is home to references for collaborators working in the Reynolds Creek watershed. If you would like more information on any ongoing projects, collaborators, or data please visit our affiliated sites listed below. If you would like information on protocols, instrument specifications, site maps, and site lists, please see side tabs.

- *Reynolds Creek Critical Zone Observatory Wiki: ODM2 Compatible Templates* http://info.reynoldscreekczo.org/dokuwiki/doku.php?id=odm2_compatible_templates

ODM2 Compatible Templates

Data and metadata should be put into these templates for future compatability with CZO data repository ODM2. Contact Sue Parsons before using these templates and if you have any issues.

- Specimen
- Time-Series

C. Participants

Lohse, Kathleen	PD/PI	3
Benner, Shawn	Co PD/PI	1
Flores, Alejandro	Co PD/PI	2
Glenn, Nancy	Co PD/PI	1
Seyfried, Mark	Co PD/PI	12
Baxter, Colden	Co-Investigator	0
Crosby, Benjamin	Co-Investigator	1
Finney, Bruce	Co-Investigator	12
Flerchinger, Gerald	Co-Investigator	1
Garen, David	Co-Investigator	1
Godsey, Sarah	Co-Investigator	2
Marks, Danny	Co-Investigator	3
Pierce, Jennifer	Co-Investigator	2
Cadol, Daniel	Faculty	0
Chandler, David	Faculty	2
Chorover, John	Faculty	0
de Graaff, Marie-Anne	Faculty	1
Feris, Kevin	Faculty	0
Holbrook, W. Steven	Faculty	1

Kohn, Matthew	Faculty	0
Link, Timothy	Faculty	0
Magnuson, Timothy	Faculty	1
Pomeroy, John	Faculty	1
Reinhardt, Keith	Faculty	2
Eberlin, DJ	K-12 Teacher	1
Fellows, Aaron	Postdoctoral (scholar, fellow or other postdoctoral position)	7
Kormos, Patrick	Postdoctoral (scholar, fellow or other postdoctoral position)	10
Masarik, Matt	Postdoctoral (scholar, fellow or other postdoctoral position)	1
Moyes, Andrew	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Zhou, Qingtao	Postdoctoral (scholar, fellow or other postdoctoral position)	12
McCorkle, Emma	Other Professional	12
Parsons, Susan	Other Professional	9
Reed, Sasha	Other Professional	1
Smith, Amy	Other Professional	12
VanVactor, Steven	Other Professional	12
Price, Mitchell	Technician	3
Aguayo, Miguel	Graduate Student (research assistant)	1

Commendador, Amy	Graduate Student (research assistant)	6
Couch, Amanda	Graduate Student (research assistant)	1
Dashti, Hamid	Graduate Student (research assistant)	1
DELVINNE, HASINI	Graduate Student (research assistant)	12
Enslin, Clarissa	Graduate Student (research assistant)	7
Farrell, Tiffany	Graduate Student (research assistant)	5
Galanter, Amy	Graduate Student (research assistant)	3
Gelb, Lucy	Graduate Student (research assistant)	1
Huber, David	Graduate Student (research assistant)	4
Ilangakoon, Nayani	Graduate Student (research assistant)	1
Klos, Peter	Graduate Student (research assistant)	6
Nielson, Travis	Graduate Student (research assistant)	1
Niemeyer, Ryan	Graduate Student (research assistant)	1
Patton, Nicholas	Graduate Student (research assistant)	12
Rozin, Alexandra	Graduate Student (research assistant)	12
Schwabedissen, Stacy	Graduate Student (research assistant)	12
Sharma, Harmandeep	Graduate Student (research assistant)	12
Stanbery, Christopher	Graduate Student (research assistant)	12

Walters, Reggie	Graduate Student (research assistant)	3
Watson, Katelyn	Graduate Student (research assistant)	12
Will, Ryan	Graduate Student (research assistant)	12
Spaete, Lucas	Non-Student Research Assistant	1
Good, Allison	Undergraduate Student	1
Good, Alison	Undergraduate Student	1
Guilinger, James	Undergraduate Student	1
Lundquist, Peter	Undergraduate Student	1
Phero, Timothy	Undergraduate Student	0
Bruck, Ben	High School Student	1
Cook, Mady	High School Student	1
DeMoss, Thomas	High School Student	1
Huq, Omar	High School Student	1
Lewis, Hayden	High School Student	1
McCormick, Maeve	High School Student	1
McKinnon, Jason	High School Student	1
Thornton, Chris	High School Student	1
Wallace, Sierra	High School Student	1
DeLucia, Evan	Consultant	1
Perdrial, Julia	Consultant	1

Black, Cody	Research Experience for Undergraduates (REU) Participant	1
Brooks, Paul	Other	0
Clark, Martyn	Other	2
Cram, Zane	Other	12
Harman, Ciarnan	Other	0
Kavanagh, Kathleen	Other	1
McNamara, James	Other	0
Rasmussen, Craig	Other	1
Stielstra, Clare	Other	3
Weppner, Kerrie	Other	1
Williams, Jason	Other	1
Winstral, Adam	Other	0

D. Impact

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

Critical Zone Science The Reynolds Creek CZO seeks to foster the development of Critical Zone Science as discipline that integrates across disciplines and fields to understand the critical zone, the surface skin of the earth that extends from the top of the tree canopy to the lower limits of the groundwater. CZOs provide a platform to conduct interdisciplinary to transdisciplinary science by integrating across geological, soil, hydrologic, ecological, and social sciences to understand the critical zone. The emergence of the CZO observatories and Network brings the ability to test hypotheses and ask questions across broad environmental conditions and gradients that could not be achieved with single principle-investigator funding efforts.

Critical Zone Science as a discipline is motivated and adds value to earth system science by addressing research gaps that occur at the interface between disciplines, across space and deep time scales, and multiple dimensions. For example, the Reynolds Creek CZO seeks to understand the role of soil environmental variables such as soil moisture and depth that vary across complex terrain in governing soil carbon storage and turnover in a semi-arid environment. For this reason, soil samples are being collected to depth of bedrock or refusal. Other networks and agencies quantifying soil carbon such as the NCAP, NEON and NRCS are measuring soil carbon to 30 cm depth in the case of NEON and 1 m depth in the case of NRCS and NCAP. These efforts may capture the variability in soil surface carbon, which is likely to be the most sensitive to land use and climate change, but may also likely overlook and vastly underestimate the total stores of carbon on the landscape. Another example of where Reynolds Creek CZO is contributing to a gap in the carbon cycle is through the quantification of inorganic carbon associated with rocks. Soil inorganic carbon stores are significant in arid and semi-arid regions, and pedogenic carbonate often follows a mophogenetic development sequence where carbonates coat rocks, form masses and nodules and eventually may become engulfted and cemented (NRCS manual). The inorganic carbon associated with these carbonate coatings associated with rocks and masses are not typically quantified by soil scientists because they are greater than 2 mm in size, the operational definition of soil and they are difficult to measure owing to the heterogeneity and scale. Consequently, soil inorganic carbon may be vastly underestimated in arid and semi-arid regions. As part of the RC CZO, rocks with carbonate coatings are being pulverized to quantify bulk inorganic carbon. Our analyses are showing that in some cases, rock carbonate coating can represent as much as 43% of total inorganic carbon in soil profiles.

Soil carbon and land surface modeling Recent studies have identified major gaps in model-data agreement with present-day soil carbon stocks and indicated that improving empirical data sets, model driving variables, and model parameterization could substantially increase model–data agreement. We are bridging the gap between empirical field studies that are conducted at plot scales and models attempted at regional and global soil scales to make advancements in soil C research and modeling efforts and producing an extensive intermediate-scale or landscape scale dataset of soil carbon (C) and associated environmental variables as a part of the RC CZO. These datasets will be used initially to evaluate predictions of soil carbon based on the initial calibration of the land surface-vegetation model used as part of RC CZO. However, we anticipate these sites will be used in combination with our landscape soil dataset by other carbon and global climate modelers to test model prediction. Our monitoring network efforts will produce the minimum set of process measurements that will be critical for landscape level model calibration. The modeling activities from the RC CZO science will yield benchmark datasets that will have broad impact and importance to the ecohydrologic and biogeochemical modeling community. These include a highly spatiotemporally resolved (order 10^0-10^1 m in space, hourly in time) environmental forcing dataset can be used as input to a wide array of ecohydrologic and biogeochemical models. This dataset will serve as an important vehicle to build collaborations with researchers from other CZOs and the broader community. This will allow us to contribute to continued advances in biophysical and biogeochemical modeling.

2. What is the impact on other disciplines?

Historical datasets of rainfall, stream flow, evaporation, and soil moisture (30 years, 10-24 sites depending on datastream) available on criticalzone.org can be used by hydrologist, landscape evolution, atmospheric scientists and other disciplines. The highly spatiotemporally resolved (order 10^0-10^1 m in space, hourly in time) environmental forcing modeled datasets are also being made available via criticalzone.org website and other avenues to land surface modelers, and regional to global climate modelers to be used as input to a wide array of land surface, regional and global climate models. These, the landscape soil dataset, and environmental network, datasets will provide improved empirical data sets, model driving variables and parameterization to increase model-data agreement.

3. What is the impact on the development of human resources?

We supported research and/or salary (partial, summer, and/or full) for 16 graduates students (50% women), 2 postdoctoral associates, 9 undergraduates, 5 high school students, 1 high school teacher during year 2 of RC CZO through a combination of diversified funding sources (ISU and BSU teaching assistantships, collaborations, grant funding). Another set of graduate students (5 at BSU) and postdocs (2 at BSU, 1 ISU part-time) are aligned with the Reynolds Creek CZO (salary not funded by CZO but enabled by investments in CZO) (total 21 graduate students, 4 postdocs). Most post-docs, graduate students and undergraduates work with several of the Reynolds Creek CZO PIs whose expertise range across geoscience, soil science, plant sciences, microbiology, hydrology, plant physiological ecology, stream ecology and geomorphology. Students freely interact across departments and universities and agencies (Idaho State University, Boise State University, and USDA ARS), and this training promotes the development of a critical mass of critical zone scientists. We continue to expand our campaign to diversify our funding sources for graduate training given that most of our graduate assistant funding ends in year 3 owing to the 50% reduction in the original budget.

In yr 2 (by August), one graduate student has attained a professional position related to their work at the RC CZO. Specifically, Chris Tennant is working at UC Berkeley as postdoctoral associate in the Department of Earth and Planetary Science. Another PhD graduate student and four master students at ISU and BSU are working towards completion of their degrees by December 2015 to May 2016.

4. What is the impact on physical resources that form infrastructure?

Vehicles

The terrain and road conditions at the RC CZO are such that four-wheel drive vehicles or ATV's are required for access to most of the research sites. These are generally supplied, free of charge, to CZO participants by the ARS. The annual wear and tear is considerable, resulting in about a $10,000 dollar cost to the ARS.

Base Station

Glenn (co-PI) and Seyfried worked with Bonneville Blueprint to facilitate installation of GPS base station located at the RCEW headquarters (Quonset) (Bonneville Blueprint provided all labor and equipment). This base station will improve collection of GPS and RTK GPS data. Through collaboration with NASA TE, one radio was purchased to be a roving radio to broadcast signal across watershed to receive RTK GPS data. Another radio is being purchased on the BSU CZO subcontract to broadcast signal across the watershed. Rather than spending 2-3 hours at each site positioning the RTK for collection, data can be collected immediately and then on-the-fly RTK GPS positions can be determined in the field.

Radios

ARS purchased an additional 5 radios for communicating in the watershed. This additional infrastructure adds additional safety for participants in the field.

Road improvements

The middle (private) road of the Reynolds Creek CZO has been vastly improved by the ARS personnel over the past year of the CZO project and this improvement has facilitated and added additional safety for participants in their field activities. The East side road of Reynolds remains problematic and experienced a gully washer in July that resulted in the degradation of the road even further. Conversations with the BLM have been initiated to promote improvement of these roads.

Range Building at Reynolds Creek CZO

The ARS projects to complete minor renovations on the Range Building by December to improve the kitchen and shower facilities for overnight visitors. In particular, these renovations include adding an additional shower and bathroom to the range building as well as adding a kitchen area with sink and stovetop burners (electric or other safe models). Lohse, Seyfried, and Pierson are writing a NSF proposal due December for improvement of the facilities to include more and better dorm space for visitors and outreach education center.

Automated water chemistry sensors

Early in 2015, ARS experienced a loss in personnel due to sickness and the funding for this person (~$50k) came back to the ARS in terms of salary. ARS moved the current CZO research technician line to this ARS line (also see changes). In lieu of this salary savings on CZO budget, PIs and EC agreed that purchase of a nested set of equipment for automated sensors for surface water chemistry to quantify stream material export and capture the fire response following a prescribed burn would be the most beneficial use of these funds. In June, we obtained 3 Hach OTT automated water sensors with temperature, pH, oxygen, conductivity, and two anion select electrodes (chloride and nitrate) in addition to three Turner Design C3 sensors for turbidity, temperature, colored dissolved organic matter (CDOM), and rhodamine dye tests. At the end of June, these sensors were all deployed temporarily in three positions within Reynolds Creek: Johnson Draw, Dobson Creek, and Reynolds Creek (at Tollgate). Permanent, long-term infrastructure (rock cages for Tollgate) are projected to be completed by October and also data telemetried to Boise on a daily basis (using existing power and radios at weirs). New permanent positions proposed based on August 2015 Soda Fire are now Johnson Draw, Reynolds Creek (at Tollgate) and now at Salmon Creek after Aug 2015 fire (Soda Fire). Salmon Creek weir and housing are being restored and in the case of housing rebuilt. Additional funding for sensors for Murphy weir (as small burned catchment) and for the Main Outlet of Reynolds Creek are now being explored.

Reynolds Creek Experimental Watershed

During the week of August 10th of 2015, the Soda Fire swept through Reynolds Creek Experimental Watershed and burn approximately 68 km^2 of the 239 km^2 watershed. The burn area of the Soda Fire totaled > 1100 km 2 in Idaho and Oregon. This resulted in loss of infrastructure (1-2 climate stations, housing for Salmon Creek weir) and fall 2015 (September – December) activities include replacing and restoring these instruments.

Permitting

Pierson and ARS continue discussions with the BLM and Shoshone-Paiute Tribe with regards to permitting the juniper selected site as a CORE site and getting permission to install the eddy covariance systems and other instruments as part of the CORE site at this location. This location has historical and cultural importance to the Shoshone-Paiute Tribe in this region.

5. What is the impact on institutional resources that form infrastructure?

Memorandum of Understanding (ARS and ISU and ARS and BSU)

Lohse (ISU), Flores (BSU), Seyfried and Pierson with the ARS established a MOU between ISU and ARS and also BSU and ARS as part of the understood CZO partnership. Signed March 2015.

Data policy agreement between ISU, ARS, and BSU

- ISU, ARS, and BSU established a data policy document for the Reynolds Creek CZO
- This document has been posted to the Reynolds Creek wiki site.

Vertically integrated data management (from cradle [field collection] to grave [archive or BORG like ODM2]

- Vertically Integrated Templates have been developed and posted to Reynolds Creek wiki such that raw data can be collected in excel spreadsheet spreadsheets that are YODA and ultimately ODM2 compatible and compliant. These resources can be used by investigators so that they do not have to transfer data from one spreadsheet to another and metadata is conserved.

6. What is the impact on information resources that form infrastructure?

Coordination and policy development activities:

- Coordination activities included working with the USDA ARS, national CZO data management group, and RC-CZO participants and students. We worked with the USDA ARS to establish a Memorandum of Understanding (MOU) and policy standards to accomplish the RC-CZO data management needs while also leveraging the long-term ongoing data management at ARS (March 2015). We attended the face-to-face IMG CZO data meeting and coordinated with the national CZO data management team to adhere and contribute to national CZO data management.
- We developed protocols and provided training to coordinate the RCCZO participants to ensure data are properly managed (including archival), as well as provided training opportunities to students for data management. We established a Wiki to be transparent in our protocols and share cross CZOs.

- Policy development activities included developing a data sharing policy and standards for data formats and metadata. A data sharing policy was developed by the EC, based on successful research data policies used by the EC on other research projects. The data sharing policy outlines the agreement to share data by investigators and collaborators who receive material or logistical support. The policy outlines the timeline for sharing data, along with proper acknowledgement. Data created by the project are being stored in a combination of formats that are appropriate for near-term use and long-term archival storage and metadata standards (such as ISO 19115-2) were agreed upon by the EC and set as a standard for all data ingested into data storage.

Data service and management activities:

- Data services activities included developing data access and sharing mechanisms, and archiving and preserving data. The RC CZO is managing its data locally through our data management staff and scientists, in collaboration with USDA ARS, but make the data broadly available through the national CZO and other regional and national portals. A data management strategy and schematic is being developed to demonstrate how the data will be posted for public consumption on a website with geospatial services. Data management to provide single location file storage, redundant file archiving, and web service maintenance are being addressed. The data is following the national CZO data format such that it can be harvested and made available on the national central CZO data portal or other available network agreed upon by the national CZO.
    - We established a cloud server as part of Reynolds Creek CZO
    - We established a website for easy posting of metadata for RC CZO data
        - http://www.lohselab.com/rcew-czo-metadata.html
    - We established an internal Wiki to post protocols and then are working to establish a mechanism to post protocols across CZOs.
    - We established and posted specimen and time series, vertically-integrated templates as EXCEL spreadsheets that can be used collect and organize field data and meta data that can then be easily converted to YODA files to be digested by ODM2
    - We established GIS web services as part (http://gis.reynoldscreekczo.org/arcgis/rest/services)
- Cyber-infrastructure research activities include extending our datasets and services to collaborating computer scientists and others interested in Big Data methodologies. As part of the NEC, Lohse is serving on the CZO data interactions to publish DOIs, store, and serve large datasets (45TB) and in discussions with Rick Hooper at CUASHI and Waters Network.

7. What is the impact on technology transfer?

We produced 45TB of data as part of the fine-resolution forcing model output data. These data include hourly, 10 m resolution rasterized data, 30 yr record of radiation, temperature, precipitation generated from historic climate datasets for 239 km^2 of Reynolds Creek Experimental Watershed (45 TB of data) using detrended kriging methodology developed by Garens (1997). DOIs will be associated with these model datasets by December 2015. We are going to permanently store these data at the ARS and mirror to ISU. Given the size of these data, we project by Dec 2015 to publish a bundle of raw data including DOI, a tool with DOI to general rasters, papers associated with this data output, and links to software downloads and open source tool to generate rates to CUASHI Hydroshare.

8. What is the impact on society beyond science and technology?

Public Outreach

We have worked to continue to engage the public in Critical Zone science and importance of soils as the foundation of terrestrial biomes and in providing many ecosystems and critical zone services. In particular, we developed a learning module/demonstration on soils titled "Where Sandy Loam the Gnome?: Forensics with Soils". Graduate students developed a video with a crime scene where Sandy Loam the Gnome (aka a gnome lawn ornament) was stolen and a footprint was left in the soil. Suspects were rounded up and soil characteristics --texture, pH, and color from the scene of the crime were used to link the suspect to the scene of the crime. This module including video has been posted to the criticalzone.org website and available for others to use. We implemented this module at the ISU Communiversity Event (March 17) and then the Portneuf Valley Environmental Fair in Pocetello, Idaho on April 18, 2015. Fifty-six children and young adults (age 7-18) plus parents (~120 total) participated in this exercise at the Communiversity Event and 57 plus parents (~114 total) at the Fair. At the RCEW, we implemented Owyhee Hydrology Camp in which 10 students plus 2 chaperones came out to Reynolds Creek Experimental Watershed to learn about soils, hydrology and the science conducted at Reynolds Creek. We also used Reynolds Creek as part of an 8th grade adventure learning expedition where the McCall Outdoor Science School (MOSS) lead adventure learning in the RCEW for 21 students and 2 chaperones for 2 overnights. Finally, CZO graduate student, David, Huber was interviewed on Idaho Public Television on the topic of soils in the Science Trek series, and the video is posted on Idaho Public TV website but also YouTube (http://video.idahoptv.org/video/2365493230). These videos can get a lot of viewership (~1,000,000) over time according to IDPTV.

E. Changes/Problems

1. Changes in approach and reasons for change

Prescribed Fire Processes operate at larger spatial and temporal scales such as fire that may ultimately determine the impact of soil carbon on the global budget. Increasing burn frequency or area, a trend in much of the Western United States (US), may return carbon to the atmosphere faster than it can accumulate. In our 2014 management plan with reduced $2.5M budget, we cut out our graduate student assistantship lines for monitoring fire responses and establishing fire chronosequences. However, the BLM and stakeholders started to explore a prescribed burn in Johnston Draw (small granitic catchment) in year 1 and assembling information for an environmental impact statement (EIS). In yr 1, Lohse initiated characterization of deep soil carbon stores in the watershed leveraging a CZO TA at ISU (Nick Patton thesis). In Yr 2 (February), it became apparent the EIS was going to be approved and burn boundary was going to be expanded to 23 km^2 of the watershed. The burn was slated for mid September 2015. In April and May of Yr 2, Lohse and graduate student, Alexandra Rozin, initiated a pre and post burn study of Johnson Draw (JD) and Whiskey Hill (WH) and established 16 permanent transects in the prescribed burn catchment (JD) and no-burn catchment (WH) prior to the burn. We quantified the abundance and diversity of plants and plant biomass and associated soil organic matter under plants and in neighboring inter-plant spaces to examine vegetation-soil organic carbon-respiration responses to a prescribed wildfire (129 shallow soil pits (0-20 cm at 0-2.5 cm, 2.5-5cm, 5-10cm, and 10-20cm increments, (516 samples) prior to burn in two watersheds (one slated for burn and one control) and planned to revisit these sites after the burn and examine the immediate soil respiration responses to burn.

Soda Fire (week of August 10, 2015)
The Soda Fire occurred on the week of August 10th, 2015 and burned ~68 km^2 of 239 km^2 RCEW. The total area of the fire was >1100 km2—one of the largest fire in the United States. This resulted in loss of infrastructure including a climate station and weir housing at Salmon Creek.

- *Weirs* In response to this fire, the ARS is working to restore the Salmon Creek weir and possibly the Murphy weir.

- *Water sensors moving and need for more sensors* New permanent positions are proposed for the water sensors based on August 2015 Soda Fire. These include Johnson Draw, Reynolds Creek (at Tollgate) and now at Salmon Creek. Additional funding for sensors for Murphy weir (as small burned catchment) and for the Main Outlet of Reynolds Creek are being explored.

- *Dust collections* We are currently installing about 12 dust collectors around the watershed consistent with the Southern Sierra CZO protocols for dust and microbial collections. The USGS (through collaborations) is distributing dust collectors (3-6) in closer proximity to fire to examine saltation following fire. These activities will allow us to quantify Aeolian inputs into the watershed from fire and other sources.

- *LiDAR flight* In 2014, NSF approved a request for a snow-on and snow off flight for Reynolds Creek CZO in 2014. However, the fall 2014 flight was delayed to test new laser instrumentation at NCALM that was put in place in August that would allow for better shrub detection (<20 cm). The Snow-off flight was moved to Feb 2016 owing to NCALM being in Antarctica and timing of return was questionable. In yr 2 after IML meeting when no budget was available for flight, we revised the plan to reduce the snow-off flight to the prescribed burn area based on acquisition of LiDAR through collaborations (NASA TE). After the Soda Fire, we have further revised our plans to fly part of the Soda Fire in early Oct 2015.

- Fire soil residues (new collaborators)
  - Dan Cadol and Amy Galanter (UNMT) This collaboration was sparked by conversations at an EPSCoR meeting and utilizes previously collected and archived soils from the JRB CZO (pre-fire) to evaluate the post-fire effects on carbon and fire residues and comparing one method to another fire residue method in collaboration with JRB CZO (Rasmussen). Cadol visited in June 2015 with an EPSCoR tour of the RCEW and is interested in running samples after the prescribed fire (now Soda Fire).
  - Dave Chandler and Chris Johnson (faculty at Syracuse University) and graduate student Yan Chen This collaborations was sparked by a visit in July to RCEW and collection of soil samples to be analyzed for fire effects of soil carbon following a 2007 prescribed fire.
  - Alain Plante (Luquillo CZO) has agreed for a student to run 600 samples (200 from CORE sites and 400 for pre and post-burn soils) on his thermal instrument at U of Penn (pending approval of the MRI, also Cross CZO activity)

Remotely sensed instrumentation in collaboration with USDOT and U of Arkansas
We are exploring collaboration with Richard Coffman at U of Arkansas to use the following equipment on the fire response 1) a Gamma Remote Sensing Portable Radar Interferometer (GPRI-II) for which development is completed, 2) a topographic differential absorption LIDAR (TDiAL) for which development is ongoing, and 3) a directional gamma ray spectrometer (DiGS) for which development is completed. These instruments have the potential to measure soil properties such as: normalized difference vegetation index , normalized burn ratio , differenced normalized burn ratio , volumetric water content , saturation , unit weight , line of sight displacement , matric potential , temperature , topography, mineral type, radionuclide concentration, and clay content

Other ongoing collaborations (External participants)
Treehugger (Evan DeLucia and Tim Mies)

This collaboration was sparked by Lohse contacting DeLucia to find out more information about their advertised Treehuggers –inexpensive, high resolution, automated dendrometer bands that can run \$1500/band. DeLucia and Mies came out to Reynolds on May 18-21st and installed and trained RC CZO team on installation and troubleshooting of Treehuggers. ISU use participant support to support this travel.

WY CEGH and Steve Holbrook and team

This collaboration was sparked by Godsey attending the Drill the Ridge workshop and interactions with Holbrook from U of WY EPSCoR. Lohse spoke with Scott Miller and Holbrook at AGU 2013 and then in the spring established a date for a week long campaign (Aug 14-20th). Lohse used participant support to support per diem and travel to RC CZO. WY CEGH conducted surveys again in Yr 2 during the week of July 6-12th.

Sasha Reed, USGS

This collaboration was sparked by Lohse when her graduate student, Stacy King, expressed interest in determining nitrogen fixation and the microbial community associated with it. Lohse's lab does not have facilities to determine ethylene so that she contacted Sasha Reed, a known leader in this field on this topic, and a collaboration was commenced in May.

Julia Perdrial, Univ. of Vermont

Lohse engaged Perdrial (young investigator and previous CZO postdoc with JRB) to analyze RC CZO stream water samples for fluorescence index (FI) and Specific UV Absorbance (SUVA)

2. Actual or anticipated problems or delays and actions or plans to resolve them

Permitting

Pierson and ARS continue discussions with the BLM and Shoshone-Paiute Tribe with regards to permitting the juniper selected site as a CORE site and getting permission to install the eddy covariance systems and other instruments as part of the CORE site at this location. This location has historical and cultural importance to the Shoshone-Paiute Tribe in this region.

3. Changes that have significant impact on expenditures

Loss of ARS personnel Early in Yr 2 (February 2015), ARS experienced a loss in personnel due to sickness, and funding for this person (~$50k) came back to the ARS in terms of salary. ARS moved the current CZO research technician (Wilford) to this ARS line to carry out ARS and CZO duties associated with electrical wiring, dataloggers, radio telemetry, solar power, and instrumentation. Wilford has worked with CZO to link new instrumentation such as sap flow sensors and Forced Diffusion (FD) CO_2 chambers into existing ARS solar power and dataloggers if possible.

Water Sensors In lieu of this salary savings on CZO budget, PIs and EC agreed that a purchase of a nested set of automated sensors for surface water chemistry and dissolved organic carbon export to quantify stream material export and capture the fire response following a prescribed burn proposed for September 2015 would be the most beneficial use of these funds. In June, we obtained 3 Hach OTT automated water sensors with temperature, pH, oxygen, conductivity, and two anion select electrodes (chloride and nitrate) in addition to three Turner Design C3 sensors for turbidity, temperature, colored dissolved organic matter (CDOM), and rhodamine dye tests. By the end of June, these sensors were all deployed temporarily in three positions within Reynolds Creek: Johnson Draw, Dobson Creek, and Reynolds Creek (at Tollgate). Permanent, long-term infrastructure (rock cages for Tollgate) are projected to be completed by October and also data telemetried to Boise on a daily basis (using existing power and radios at weirs).

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

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

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

Metrics

Table A: Outcomes and Metrics

Major Priority Area	Activity	Metric	Year 2 Target	Year 2 Accomplished
Strategic Priority 1: ***Landscape Soil Carbon Survey***	**Survey**	Create Soil Map	Year 2 Map Created	Year 2 Maps Created
	Characterization	Environmental Datasets Created	50 soil pits collected & analyzed	363 soil pits collected & 4640 total samples collected and ~1150 total analyzed for SOCC)
Strategic Priority 2: ***Environmental Monitoring Network***	**Core Site Creation**	# of sites created	4	4
	Net Ecosystem Exchange	Sites instrumented	3-4	5 instrumented, 2 in aspen- will redeploy 1 to new aspen site and 1 to juniper site)
	Transpiration	Sites instrumented	4	5 (3 sage, 1 conifer, 1 aspen, waiting on juniper permissions)
	Aboveground Biomass and NPP	Sites instrumented	4	4 sites
	Soil Respiration	Sites instrumented/measure d	2	4 FD & 2 profiles (soil probes)
	Stream and Groundwater Carbon Export	Samples Collected	0	250 samples collected
Strategic Priority 3: ***Integrated Modeling Framework***	**Create Fine Resolution Hydroclimate data**	Input datasets created	Initiated & completed in Year 2	Completed & DOIs
	Integrated Terrestrial Biosphere Modeling	Modeling framework Created	Initiated	Biome BGC outputs
Strategic Priority 4: ***Engagement***	**Stakeholder Engagement**	MOUs established	2	2 (ISU, BSU)
	Active CZO Engagement	CZO working group participation	2	4 (Q-C, Tree, OM, BGC, PAW)
	Resource to broader community	Collaborations with X-CZO and non-CZO researchers	2	5
	Education	Students and post-docs engaged	4	21 students +4 postdocs

Major Priority Area	**Activity**	**Metric**	**Year 2 Target**	**Year 2 Accomplished**
Strategic Priority 5: ***Public Outreach and Education Activities***	**Public Outreach**	Outreach events	1	5 (Communiversity, Environmental Fair, Hydrology Days, Adventure Learning)
Strategic Priority 6: ***Data Management***	**Coordination and Policy Development**	Trainings	1	5 (surface water, fine root sieving, SIC, texture, metadata and spreadsheets) Creation of wiki and YODA/ODM2 compatible spreadsheets
	Data Services and Management	Cumulative unique databases uploaded and accessed (# of times)	50	>50

CZO Network Activities

Network Leadership

- Publications

  Cross-CZO questions white paper

  Dietrich (primary) and Lohse (secondary) lead effort to compile questions posed across all CZO and identify overlapping questions.

  Book chapter White T., Brantley S., Banwart S., Chorover J., Dietrich W., Derry L., Lohse K., Anderson S., Aufdendkampe A., Bales R., Kumar P., Richter D., McDowell B.Chapter 2 – The Role of Critical Zone Observatories in Critical Zone Science (2015) Developments in Earth Surface Processes 19: 15–78
- National Executive Committee (NEC)
  - Lohse serves as the deputy chairperson for the PI representatives as part of the National Office and will serve as Chair for 2016.

Working groups (WG)

- Cross-CZO –OM (graduate student Rozin from ISU and Faculty member DeGraff from BSU are attending)
- Cross-CZO –Concentration Discharge (Godsey from ISU attended)
- Cross CZO - Exploring Four Critical Puzzles Workshop (Godsey from ISU attended)
- Cross-CZO- Modeling lead by Jon Pelletier. As part of this working group Flores has developed an online survey to assess modeling activities being conducted across CZOs (both those activities being directly supported by CZO CAs and those supported through other mechanisms but leveraging CZO infrastructure). The purpose of this survey, to be conducted in Fall 2014, is to identify cross-CZO and cross-cutting modeling science questions.

Cross CZO Plant Available Water (PAW) –Lohse and Seyfried have been leading this effort and forming collaborations across CZOs to investigate PAW using multiple techniques.

Meetings

- *CZO PI meetings –Lohse and Seyfried attending monthly meetings*
- *NEC meeting –Lohse is deputy director of NEC and attends monthly meetings*
- *CZO PI meeting at IML CZO –Lohse and Seyfried attended May 3-6, 2015*
- *Ecohydrology in the Critical Zone* Lohse (RC CZO and Papuga (JRB CZO) convened a AGU session in Ecohydrology in the Critical Zone (AGU Fall 2014 meeting). This session was used to catalyze cross-CZO discussion on ecohydrology in the critical zone and engage new participants. Flerchinger (RC CZO), Goulden (SS CZO), Barnart (Boulder CZO), and Vargas (U of Maryland) are invited speakers and 28 abstracts were submitted to this session. Lohse and Papuga are convening a session in 2015 and received 27 abstracts.
- *Ecology in the Critical Zone*

  Lohse (Chair) and W. Silver (LUQ CZO) convened an organized session at the Ecological Society of America on Ecology in the Critical Zone. It received receive press release http://www.esa.org/esa/ecology-from-treetop-to-bedrock-human-influence-in-earths-critical-zone/)
- Community Surface Dynamics Modeling System (CSDMS) Annual Meeting

  Flores and graduate student Gelb attended the CSDMS meeting in Boulder, CO in May. Both participated in a session on modeling in support of CZ science and attended the Landlab training session, organized by Greg Tucker (BC). Gelb will be using Landlab to address the role of climate, climate change, and disturbance in soil formation and landform development.

- Weather Research and Forecasting (WRF) Data Assimilation (DA) and Regional Climate Modeling tutorial
    - Flores and graduate student Watson attended the WRFDA and Regional Climate tutorial in Boulder, CO in July. Watson will be using WRFDA to identify science requirements for retrievals of falling snow rate from satellites. Flores' CAREER grant uses WRF as a regional climate modeling tool.

Cross CZO Research

Chris Tennant, graduate student at ISU, evaluated the influence of elevation, aspect, and forest cover on the spatial distribution of seasonal snow accumulation using snow-on, snow-off Light Detection and Ranging (LiDAR) data from five Critical Zone Observatory (CZO) sites across the western U.S. A SAVI grant from the NO also facilitated this research and collaborations with A Harpold (U of Nevada, Reno). This cross-site comparison allowed for the first time empirical evaluation of the generality of the snow-elevation relationships and role of hypsometry in controlling snow storage. Results showed that all sites exhibit increases in snow depth with elevation; however, the relationship between snow depth and elevation is not monotonic and rates of increase vary from site to site (Fig. The elevation distributions of the CZOs generally predict snow volume distributions with high accuracy, implying that hypsometry provides a useful measure of a watershed's sensitivity to warming-driven snowpack loss. At sites where elevation less reliably predicts snow storage, wind transport and aspect-dependent snow storage were important. The dependence of snow depth on aspect and vegetation varied with site. At four of the sites, northern aspects in alpine or non-forested areas have mean snow depths that were two to five times greater than snow depths in forested areas. At Reynolds Creek, a watershed characterized by low amounts of forest-cover (11% of total area), this trend reversed with mean snow depths in forested areas up to seven times greater than in open areas. Results from this study emphasize that the though the relation between elevation and snow depth is robust at coarser scales, the regional-scale mass and energy fluxes and site specific topographic and vegetation characteristics produce a wide range of local patterns in snow accumulation.

Danny Marks, ARS is leading real-time simulation of snow deposition, melt, snow density distribution, over a large region in the Sierra Nevada, integrated with time-series LiDAR measurement of snow depth to improve water supply forecasting during the extreme drought in California.

Reggie Walters, graduate student at BSU, was awarded SAVI grant to travel to University of Queensland in Australia to collaborate with investigators in a new international CZO at the Main Range National Park (end of Sept 2015).

Cross CZO Publications and Awards

Harpold, A. A., J. A. Marshall, S. W. Lyon, T. B. Barnhart, B. A. Fisher, M. Donovan, K. M. Brubaker, et al. 2015. "Laser Vision: Lidar as a Transformative Tool to Advance Critical Zone Science." Hydrol. Earth Syst. Sci. 19 (6): 2881–97. doi:10.5194/hess-19-2881-2015.

Tennant et al. 2015. The sensitivity of Rocky Mountain ecoregions to snowpack loss
Tennant. The sensitivity of mountain snowpack to warming. ISU PhD dissertation

Tennant. CZO SAVI award: Understanding vegetation-snow interactions and critical zone sensitivity to climate change

Tennant et al. (abstract AGU) LiDAR illuminates the influence of elevation, aspect, and vegetation on seasonal snowpack: case studies from four western Critical Zone Observatories -- Abstract title for AGU 2015 submission

Tennant et al. (in review) LiDAR illuminates the influence of elevation, aspect, and vegetation on seasonal snowpack: case studies from four western Critical Zone Observatories. WRR

Harpold, A., P.D. Brooks, J. Perdrial, K. Lohse, J.C. McIntosh , T. Meixner, X. Zapata-Rios, A. Vazquez-Ortega, and J. Chorover, *In review*. Variable Groundwater Contributions Influence Nutrient Cycling in Montane Headwater Catchments, *Water Resources Research*

Stielstra, C., K.A. Lohse, J.C. McIntosh, and J. Chorover, J. Perdrial, G. Barron Gafford, M Litvak, P.D. Brooks. 2015. Climatic and Landscape Influences on Soil Moisture are Primary Determinants of Soil Carbon Fluxes in Seasonally Snow-covered Forest Ecosystems. *Biogeochemistry*. 123 (3): 447-465

Perdrial, Julia; Brooks, Paul; Swetnam, Tyson; Lohse, Kathleen; Rasmussen, Craig; Litvak, Marcy; Harpold, Adrian; Zapata-Rios, Xavier; Broxton, Patrick; Mitra, Bhaskar; Meixner, Thomas; Condon, Katherine; Huckle, David; Stielstra, Clare; Vazquez-Ortega, Angelica; Lybrand, Rebecca; Holleran, Molly; Orem, Caitlyn; Pelletier, Jon; Chorover, Jon. In review. Climate and landscape as drivers of carbon storage in forested headwater catchments: Insights from a complete C budget" Global Change Biology

David Huber, graduate student at ISU, received National Office CZO support to participate in International CZO soil two-week course in Australia.

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SUMMARY PROPOSAL BUDGET

FOR NSF USE ONLY

ORGANIZATION Idaho State University				PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Kathleen Lohse				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	NSF-Funded Person-months CAL	ACAD	SUMR		Funds Requested By Proposer	Funds Granted by NSF (If Different)
1. Kathleen Lohse			0.75		$7,169	$
2.						
3.						
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. ( ) TOTAL SENIOR PERSONNEL (1-6)						
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. ( ) POSTDOCTORAL ASSOCIATES						
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12				$42,436	
3. (2) GRADUATE STUDENTS					$44,135	
4. ( ) UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A + B)					$93,741	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					25,356	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)					**119,097**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT						
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)					12,000	
2. FOREIGN						
F. PARTICIPANT SUPPORT 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER						
TOTAL NUMBER OF PARTICIPANTS (2) TOTAL PARTICIPANT COSTS					$4,000	
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES					$14,000	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION					$1,226	
3. CONSULTANT SERVICES						
4. COMPUTER SERVICES					$4,500	
5. SUBAWARDS					**$378,093**	
6. OTHER Tuition					$23,438	
TOTAL OTHER DIRECT COSTS					$437,257.28	
H. TOTAL DIRECT COSTS (A THROUGH G)					**$556,354**	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 47% on salary only						
TOTAL INDIRECT COSTS (F&A)					$44,058	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					$**600,412**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)						
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)					$**600,412**	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT: $	
PI/PD TYPED NAME AND SIGNATURE* Kathleen Lohse	DATE 9/1/15	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date of Rate Sheet / Initials-ORG

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SUMMARY PROPOSAL BUDGET

ORGANIZATION USDA ARS (SUBAWARD)	FOR NSF USE ONLY PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR MarkSeyfried/ Kathleen Lohse	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	NSF-Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted by NSF (If Different)
1					$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. ( ) TOTAL SENIOR PERSONNEL (1-6)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POSTDOCTORAL ASSOCIATES	12			71813	
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12			$55909	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A + B)				$127722	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				31931	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**159653**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				6500	
2. FOREIGN					
F. PARTICIPANT SUPPORT 1. STIPENDS $ ________ 2. TRAVEL ________ 3. SUBSISTENCE ________ 4. OTHER					
TOTAL NUMBER OF PARTICIPANTS ( ) TOTAL PARTICIPANT COSTS				$2333	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$11000	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				$2480	
3. CONSULTANT SERVICES					
4. COMPUTER SERVICES					
5. SUBAWARDS					
6. OTHER Station fees				$7000	
TOTAL OTHER DIRECT COSTS				20480	
H. TOTAL DIRECT COSTS (A THROUGH G)				**188966**	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 11.1111 of total%					
TOTAL INDIRECT COSTS (F&A)				$20996	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				$**209962**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$**209962**	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT: $	
PI/PD TYPED NAME AND SIGNATURE* Kathleen Lohse	DATE 9/1/15	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date of Rate Sheet / Initials-ORG

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

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SUMMARY PROPOSAL BUDGET

ORGANIZATION Boise State University (SUBAWARD)	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (MONTHS) Proposed / Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Lejo Flores/ Kathleen Lohse	AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	NSF-Funded Person-months CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted by NSF (If Different)
1 Alejandro Flores			0.25	3870	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. ( ) TOTAL SENIOR PERSONNEL (1-6)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POSTDOCTORAL ASSOCIATES					
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				$	
3. (3) GRADUATE STUDENTS				$69,300	
4. (1) UNDERGRADUATE STUDENTS				5000	
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A + B)				$ 78170	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				*$5,763*	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**83934**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				6000	
2. FOREIGN					
F. PARTICIPANT SUPPORT 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER					
TOTAL NUMBER OF PARTICIPANTS (2) TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$6000	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				$1500	
3. CONSULTANT SERVICES					
4. COMPUTER SERVICES					
5. SUBAWARDS					
6. OTHER Tuition				$32,698	
TOTAL OTHER DIRECT COSTS				$46,198	
H. TOTAL DIRECT COSTS (A THROUGH G)				**$130,132**	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 39% MDTC on **$97,434**					
TOTAL INDIRECT COSTS (F&A)				$37,999	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**$168,131**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**$168,131**	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT: $			
PI/PD TYPED NAME AND SIGNATURE* Kathleen Lohse	DATE 9/1/15	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

BUDGET JUSTIFICATION
PERSONNEL
PI. Associate Professor Kathleen Lohse is the Director of the Reynolds Creek CZO and responsible for coordination of the research, communications with NSF and oversee management. Lohse co-leads with Seyfried at ARS as deputy director to ensure quality of field data collections and coordination of data. Lohse is supervising PhD student graduate student at ISU on soil carbon-vegetation-fire responses. Lohse requests 0.075 month of summer salary in yr 3.

Research specialist (Emma McCorkle) is working 100% time to manage research field and data collected by CZO.

Students 2 PhD graduate research assistants (GRA) (Rozin, Harman) will work on the RCC CZO in yr 3. Summer salary is provided.

FRINGE
21% of salaries and wages for all full-time employees (Lohse and other personnel with 3% increase each year). 8.9% of salaries and wages for all part-time employees (less than 50% time). Students are considered part-time employees. Insurance is applied for non-faculty, non-student individuals, based on percentage of effort and a 10% increase for preceding years for projected inflation, $ 9100 for year 2013-2014.

EQUIPMENT

TRAVEL
Funds ($10 yr 3) are requested to support for interstate travel and truck rental to field sites at Reynolds Creek, ID, and lodging near site and meetings. In addition, travel will support national conference travel and lodging fees for 2 students and/or faculty. Funds are also requested for the required CZO meeting, $2000 in yr3.

PARTICIPANT SUPPORT
This category ($4k yr 3), includes participant support for seminar speakers, travel and lodging for external participants. Participant support may include lodging and travel for ISU environmental methods field course as part of the engagement plan are included.

OTHER DIRECT COSTS
Computer fees: Funds $4k yr 3 for Amazon Cloud Server

GRA Tuition: In-state graduate tuition for 2 PhD graduate students in yr 3 ($23,438)

Materials and Supplies: This category includes costs for research materials and supplies ($14k yr 3). Funds will cover the cost of field soil characterization equipment (5-10 AMS professional (sturdier) augers, slide hammers (~$1500/each), shovels, picks), 100 manual ($40/unit). Other field and lab supplies include: gloves, specimen cups, weigh tins, soil corers, plastic bags, infiltrometers, filters and collection bottles, vials, coolers, ice, dry ice, standards, pipettors, pipette tips, glass and plastic ware, filters, and reagents. In yr 3, materials and supplies will also cover material and supplies for litter quality characterization, calibration of TLS and spectrometer, litterfall trap, litter bag construction, soil protein characterization, soil enzyme assays, well plates, soil organic matter pool characterization, assays and soil organic matter mineralization, plastic bags, gas, needles, syringes, vials, septa, standards, glassware, tubing, and valves to construct incubation flasks. Sample fees include >2000 C and N mass and isotopic analysis of soil and litter ($5/sample, CAMAS, ISU, nutrient analysis ($6/sample, Lohse ISU), cations ($10/sample), basic physio-chemical characterizations, exchangeable cations ($20/sample (supplies and analysis), anions ($17/sample, Lohse ISU), TOC/TN analysis ($10/sample, Lohse ISU), tissue analyses on Elemental analyzer ($2.5/sample)

Publications: We request $1126 in yr 3 for publication costs.

Subawards: We request $168,131 to BSU and $209,962 to USDA ARS for yr 3

Indirect Costs: ISU charges 47% on wages and salaries only and no additional indirects on subawards

BOISE STATE UNIVERSITY SUBAWARD BUDGET JUSTIFICATION

PERSONNEL

PI Subaward. Assistant Professor Lejo Flores is an ecohydrologist and modeler and will be responsible for the model testing and integration. Flores will supervise a PhD graduate student with Dr. Benner at BSU. Flores will oversee subaward and be responsible for coordination of the research with ISU. Flores requests $ 3870 of summer salary in yr 3

Other Personnel:

Students. Three graduate research assistants (GRA) will be supported to work with Flores, deGraaf, and Pierce to evaluate patterns of soil inorganic carbon and the processes controlling these patterns in the RC CZO, soil respiration, and modeling. All students will be recruited to be active intellectual and physical contributors to this project, while at the same time, our expectation is that they will explore new directions through developing their own research projects in conjunction with the overall program.

FRINGE

36% of salaries and wages for all full-time employees with 3% increase each year. 4% of salaries and wages for all part-time employees (less than 50% time). Students are considered part-time employees.

OTHER DIRECT COSTS

Participant support.

GRA Tuition: For 3 graduate students, in-state graduate tuition is $ $32,698 with a 7% increase each yr.

Travel. Funds ($6k yr) are requested to support for interstate and out of state travel and truck rental to field sites at RC CZO and lodging near site and meetings.

Materials and Supplies. This category includes costs for research materials and supplies at $3K yr. 3. Other field and lab supplies include: gloves, weigh tins, soil corers, plastic bags, infiltrometers, filters and collection bottles, vials, coolers, ice, dry ice, standards, resin bag construction and resins, glass and plastic ware, filters, and reagents. Materials and supplies will also cover material and supplies for litter quality characterization, litter bag construction, soil organic matter pool characterization, soil inorganic matter xplastic bags, gas, needles, syringes, vials, septa, standards, glassware, tubing, and valves to construct incubation flasks.

Sample fees are $3K yr 3 and include C and N mass and isotopic analysis of soil and litter and inorganic carbon analysis

Publications We request $1500 for publication fees in yr 3

Indirect Costs at USDA ARS is 39% on MDTC.

USDA-ARS SUBAWARD BUDGET JUSTIFICATION

PERSONNEL

Other Personnel:

Postdoctoral associate. One postdoctoral associate (Aaron Fellows) is supervised and mentored by Gerald Flerchinger, also at the USDA-ARS. This individual is tasked with incorporating carbon flux in to the ongoing eddy flux data collection program administered by the ARS and provide scientific oversight for other support field instrumentation. In additional task is to quantitatively link carbon fluxes to other soil processes. One postdoctoral associate (Kormos) is supported on yr 1 carryover funds at half time.

Term Research Technician (Wilford). A research technician will be hired during of the project and not longer. (Term employees are hired only for a specified time allotment with no assurance of future employment). The primary tasks of the technician will be to assist with instrument installation and field sample collection, maintain/replace CZO field equipment, collect field data and perform routine field sample processing.

FRINGE

Employee fringe rate is 21%.

OTHER DIRECT COSTS

Equipment

None.

Travel. Funds ($4500 in yr 3) are requested to support for interstate and out of state travel for the postdoctoral associates and mentors to attend national conferences and CZO meetings. An additional $2000 per year is requested for the Co-lead PI and RCEW site leader to attend CZO meetings and national conferences.

Participant Support

We are requesting $2333 in yr 3 for participation support.

Materials and Supplies. This category includes costs for research materials and supplies at $11k in yr 3. This includes funds for soil CO_2 probes ($300/probe), Stephens soil temperature and moisture probes ($350/unit), heat flux plates, radios (for telemetry), solar panels and batteries. Field and lab supplies include: gloves, weigh tins, soil augers, corers, plastic bags and infiltrometers.

Publications We request $2480 costs for publication fees.

Station Fees We request $7000 in station fees to cover cleaning and other maintenance fees

Indirect Costs at USDA ARS is 11.111% on total.

Additional Funding

ISU Graduate School, ISU funded 20 semester hours of Graduate Teaching Assistantships to Lohse (through negotiation) as part of her CZO award to offset the $2.5 M reduction in CZO budget. This has funded 2 graduate students during the academic year at ISU to conduct research at Reynolds Creek CZO. Summer salaries have been covered by CZO.

USDA ARS Headquarter, 2013-2014, $80,000. The ARS National Program Staff awarded the NWRC $80,000 to direct towards purchase of scientific equipment for the RC CZO. Almost all of the equipment purchased is in use at this point in time.

USDA ARS Northwest Watershed Research Center (NWRC), $414,700. The ARS NWRC has contributed $224, 200 in Scientific Personnel, $150,500 in Support Personnel, $35,000 to Range building improvement (projected), and $5000 to road improvements.

Long Term Agroecosystem Research Network (LTAR) funds, $50,000. The NWRC became part of the USDA sponsored Long Term Agricultural Ecosystem (LTAR) network in 2014. There is considerable overlap in the type of research undertaken by the two networks. Approximately $20,000 of scientific equipment was purchased that will serve both projects out of a total of about $50,000 that will go towards research that is complimentary to the goals and objectives of the RC CZO.

NASA SMAP funds, $10,000. The NWRC is a participant in the NASA Soil Moisture Active Passive project that has provided $10,000 towards travel and instrumentation.

Glenn, N. and A.N. Flores, $748,000 NASA Terrestrial Ecology grant, start date January 2014, *Scalable vegetation structure for ecosystem modeling in the western US.* Glenn and Flores were awarded a 3-year that focuses on developing new methods for quantifying ecosystem structure and function with LiDAR and hyperspectral remote sensing. This information will be used to parameterize a shrubland ecosystem input for the Ecosystem Demography model. Reynolds Creek is one of 5 study sites in the Great Basin covering Idaho and California. In August 2014, NASA JPL's Airborne Snow Observatory (ASO) collected LiDAR with a Riegl Q1560 instrument. NASA JPL's AVIRIS-ng hyperspectral system is expected to collect imagery in September 2014 at all study sites, including Reynolds. The RC CZO ecosystem studies will benefit from these imagery and field data collections in a number of ways. For example, Glenn and Flores have a student (Ilangakoon) working on biomass and canopy cover of different vegetation communities at the study sites using LiDAR and hyperspectral data. In addition, Glenn and Flores have a student who will be testing appropriate scale and derivatives of remote sensing products for parameterizing a shrubland component in Ecosystem Demography.

Flores and Glenn, along with HP Marshall and Jim McNamara, were awarded a 3-year, $750,000 NASA EPSCoR grant *Monitoring Earth's Hydrosphere Integrating Remote Sensing, Modeling, and Verification*. The project aims to improve spatiotemporal predictions of precipitation, soil moisture, snow water storage, and runoff using remote sensing inputs for the Weather Research and Forecasting (WRF) model. The project will be mutually beneficial to the RC CZO. First, the RC CZO represents an important study site where independent verification of estimated hydrometeorologic variables (e.g., precipitation amount and phase, wind speed, radiant fluxes, temperature, etc.). Furthermore, the development of these data assimilation techniques will lead to hydrometeorologic forcing datasets that are constrained to available remote sensing data and are spatiotemporally complete during periods for which boundary condition data required as input to WRF are available.

Flores received a 5-year, $457,205 NSF CAREER Award *Citizens, Conservation, and Climate: Research and Education for Climate Literacy in Managed Landscapes*. This project investigates the role of land management policies and activities in meeting multiple and potentially competing objectives. Modeling tools include models that explicitly simulate land management activities undertaken by land management agencies under alternative hypothetical scenarios, and regional climate models (WRF) to assess the feedbacks of those management activities to regional hydroclimate. Importantly, it also includes an education program consisting on developing a k-12 teacher education program to support climate literacy in Idaho. The program uses open source electronics (e.g., Arduino, Raspberry Pi, etc.) and sensors to learn about climate, computer science, and electrical engineering. Rangelands are specifically mentioned in the grant as a target region, where grazing, fire, climate change, and invasive species interact to "replumb" the hydrologic cycle. The RC-CZO represents an important study site because of the history of investigating the influence of land management on ecohydrology.

Flores along with, H.P. Marshall, Kelly Elder (US Forest Service) were awarded a 3-year $300,000 grant *Multiple frequency active microwave remote sensing for snow water equivalent retrieval from space: a data assimilation approach* via the NASA Terrestrial Hydrology Program. This project will develop improved retrievals of snow water equivalent using a combination of modeling and remote sensing resources. Specifically, the effort targets the use of active microwave (i.e., radar) observations at several different wavelengths in an effort to characterize snowpacks. The information is assimilated into land surface models that simultaneously estimate water storages and fluxes in the landscape. RC CZO is explicitly included as a study area in the proposal due to the available infrastructure. Core sites, in particular, will be invaluable for validating estimates of sublimation from snowpacks derived from the model. The efforts will lead to improved snow water equivalent estimates that will benefit hydrologic modeling and analyses in the RC-CZO.

Flores and Godsey are engaged with Idaho's ongoing participation in the EPSCoR Track II program. Specifically, as part of the Western Consortium for Watershed Analysis, Visualization and Exploration the team is developing suites of data management and visualization tools to enable rapid prototyping of watershed models, using existing constitutive models. Specifically, Flores and graduate students are developing scripts to enable the use of output from the Weather Research and Forecasting (WRF) model to be packaged and used as input to finer-scale watershed models, specifically focusing on the ParFlow model. Godsey, Prof. Shannon Kobs-Nawotniak are developing a CSDMS wrapper for the iSNOBAL model, to enable it to more readily interface with other component models. Observational infrastructure at RC CZO will support validation and verification of model estimates. Moreover, the data management and visualization infrastructure will more broadly benefit modeling at RC CZO and across CZOs by providing and using software infrastructure to quickly develop models of critical zone processes to address cross-CZO science questions.

Lohse, Moyes, Godsey, and Reinhardt. Development of continuous soil respiration measurements in snow dominated systems for a spatially and temporally extensive network at the Reynolds Creek CZO, $49,679, Idaho State University Developing Collaborative Partners Seed Grant. This seed grant is for method development of forced diffusion (FD) chambers for measurement of soil respiration under snowpack, development of X-CZO proposal to examine snow dynamics under winter conditions as well as submitting a infrastructure grant proposal to deploy sensor network of FD chambers with proof of concept.