Reynolds Creek Critical Zone Observatory Year 3 Annual Report
September 2016

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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 completed our intense soil survey sampling in two sub-watersheds to examine 1) the local topographic controls on soil depth and soil organic carbon (SOC) storage and 2) the spatial heterogeneity of surface soil organic carbon and nitrogen pools and processes. We identified indices of vegetation biomass/cover using remote sensed and LiDAR and hyperspectral data and examined vegetative controls on SOC distribution using the broad scale landscape soil C survey. A bottom-up soil carbon model was also developed for estimating the total soil carbon reservoir based on a linear-regression kriging approach with curvature as the main variable driving the distribution of soil C. Finally, we completed our initial study of controls and distribution of soil inorganic carbon across the watershed and quantified the carbonate rock coating contribution to total carbon storage.

We completed an initial environmental characterization of elevation, aspect and vegetation controls on snow depth to understand the distribution of vegetation and likely soil carbon at Reynolds Creek. We expanded the scope of near surface geophysics with the installation of 3D time-lapse electrical resistivity arrays to evaluate soil moisture variability at the CORE sites and collected three additional transects of seismic refraction profiles in Johnson Draw to investigate variations in deep weathering depth as a function of elevation and aspect. In October 2016, we collaborated with Wyoming Center for Environmental Hydrology and Geophysics (WY CEGH) to collect airborne geophysics (EM/Mag) aimed at mapping the spatial structure of critical zone of the watershed.

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 maintain 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 a subset of data are in the process of being analyzed to determine variability in carbon balance and responses to hydroclimate. We reinstalled Granier sap flux sensors at the two tree sites (aspen, conifer) and continued 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 leaf- to ecosystem-level ecophysiological measurements to scale up plant level measurements. We deployed four forced diffusion (FD) chambers for collection of automated CO_2 flux at the CORE sites and one at Upper Sheep as well as installed CO_2 and oxygen probes with soil depth at two additional CORE sites. We manually measured CO_2 fluxes at five plots within each of the CORE sites over the growing season to quantify the spatial variability in these fluxes. We continued analysis 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. We completed a study examining rates of biological nitrogen (N) fixation associated with free-living biotic crust communities at the CORE sites to determine N inputs with elevation and possible nutrient constraints on plant productivity. Moreover, we examined the abundance and diversity of microbial community associated with these biotic crusts. We initiated a study to examine SOC-respiration responses to wildfire and collected continuous and manual CO_2 fluxes as well as soils on two aspects of two watersheds (one burned and one control) at 1, 2, 3 and 6-month post-burn intervals. We also initiated monitoring wind erosion of materials in response to fire throughout the basin (Pierce RAPID grant) and water erosion within a burned sub-watershed (Murphy Creek). We ramped up our measurement of stream export of particulate and dissolved organic and inorganic carbon during the spring and summer of 2016 and installed 4 water chemistry and colored dissolved organic matter (CDOM) automated sensors in the main stream and tributaries (Murphy (burned tributary), Tollgate (main stem), Outlet (main stem), Johnston (tributary) during the summer (when installation was safe). We initiated stream water quality sampling in burned (Murphy) and unburned catchments to understand how stream chemistry and in-stream production changes temporally and spatially with stream drying. Finally, we initiated a study to understand groundwater contributions to stream runoff and carbon export in Reynolds Mountain East subwatershed and installed three nested sets of Prenart tension lysimeters, temperature, moisture and matric potential probes within the catchment.

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 produced a model forcing data set for Reynolds Creek. This data set can be used by a variety of models and modelers to ensure spatiotemporally complete forcing benchmark data that can be used as a consistent forcing dataset across models. We carefully processed data from the meteorological and precipitation stations in the Reynolds Creek Experimental Watershed to produce temporally complete (no missing values), 31 year record (1984-2014) for the following input parameters: relative humidity, air temperature, dew point, precipitation amount, and the precipitation phase. Working collaboratively with David Garen of the NRCS, these point measurements were distributed spatially using a detrended kriging method. The result is a 10-m resolution, 31 year, hourly dataset for the 238 km^2 watershed for the above parameters. This 24 TB dataset has been published and is housed and curated at Boise State University. The data are now publicly available (see http://doi.org/10.18122/B2B59V) and are citable via a Digital Object Identifier (DOI). The data are stored in the hierarchical Network Common Data Format (NetCDF) format and available for general use.

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 and emerging coupled modeling frameworks for the modeling of vegetation dynamics and biogeochemical cycling. There are two models, in particular, that Co-PI Flores is currently parameterizing to deploy in the RC CZO. The first model, the Ecosystem Demography (ED) model (Moorcroft et al., 2001) represents the interaction of multiple plant functional types through a system of size and age-structured partial differential equations that approximate the first moment of a stochastic individual based model. ED is capable of capturing both functional and structural aspects of interactions between and among terrestrial plants (e.g., shrubs and grasses). ED is being used (supported by grants from the NASA Terrestrial Ecology Program and the Joint Fire Science Program) to simulate the response of Great Basin shrubland ecosystems to climate change and disturbances including fire and invasive species.

The second model is the Ecosys model (Grant et al., 2001) for biogeochemical cycling in the subsurface. Ecosys simulates belowground biogeochemical cycling as a reactive transport process in response to prescribed climate and ecological inputs at the land surface. In the near-term, Flores is developing point-scale simulations using Ecosys at a number of soil pits within Reynolds Creek where field sampling was performed. In particular, we are working to select a number of sites where SOC content is well-predicted by geostatistical predictors as well as a number of sites where SOC is poorly predicted through the above-mentioned geostatistical approaches. Our working hypothesis is that because Ecosys represents biogeochemical cycling through a reactive transport process, it will more accurately simulate SOC at locations where geostatistical approaches fail. In the intermediate term, Flores is investigating ways to loosely couple the output from the ED model (e.g., litterfall) with the input to Ecosys to obtain physically based, spatially distributed estimates of SOC and N. The Ecosys model is being used extensively in modeling work of a new Science Focus Area (SFA) project led by Lawrence Berkeley National Labs in the East River in Colorado. Flores has developed informal collaborations with investigators involved in the East River project and, over the next year, will seek to enhance coordination with the SFA activities with the goal of developing research questions that span both sites and developing and seeking funding for collaborative project that spans a grassland-shrubland-forested-alpine gradient of semiarid mountain ecosystems.

We have also expanded efforts to improve synthesis between models and observations. In particular, we have developed machine learning approaches to distribute observed downwelling surface solar radiation and net ecosystem exchange using a variety of geospatial predictors. We are in the process of finalizing two manuscripts summarizing these approaches.

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

Develop soil bulk density relationships for felsic and mafic materials to estimate bulk density from SOC and SOM where bulk density measurements are not available. Develop a correction term using coarse fraction materials from bulk sample to estimate fine fraction bulk density from field bulk density. Complete analysis of soil organic carbon-vegetation associations using vegetation indices from remotely sensed as well as airborne LiDAR and hyperspectral data. Map distribution of soil organic carbon based on these relationships.

Soil-Bedrock and Mobile Regolith Mapping

Quantify the relationships between total mobile regolith depths and different topographic variables in a granitic watershed and map soil depth. Evaluate generality of relationships between soil depth and curvatures across sites available from global dataset (including JRB and BC CZOs). Acquire and process seismic refraction dataset in Johnson Draw to investigate variations in deep weathering depth as a function of elevation and aspect.

1.2 Topographic controls on carbon storage

Complete quantifying the relationship between measurable local topographic features and soil depth to improve estimation of deep soil carbon across complex terrain. Develop relationships of soil depth and soil carbon at pedon scale to watershed scale. Develop a soil C map based on 30 sample pits and test for accuracy with test pits (19) and compare to other kriging approaches. Map distribution of soil organic carbon at local to watershed 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. Complete analysis of quantifying role of carbonate coating of rocks in storing deep inorganic carbon.

1.4 Snow Mapping

Complete 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 4 CORE sites. Complete analysis of subset 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, replace, and download aspen and conifer tree CORE sites sap flux sensors. Maintain tissue-heat-balance sap flux sensors (5-6 per site) at three sagebrush CORE sites. Conduct initial analyses of daily and seasonal sap flux.

2.3. Plant ecophysiology

Conduct leaf- to ecosystem-level physiological measurements of carbon and water fluxes to scale plant level water measurements to ecosystem scale

2.4 Soil Respiration

Install eight Vaisala CO_2 sensors along with soil temperature and moisture sensors (Hydra Probe) at the Low Sage and Big Mountain Sage core sites and monitor Wyoming Big sagebrush site. Estimate net CO_2 flux from the soil based on measured gas concentration gradients and porosity and to determine depths of CO_2 production in the soil. Deploy automated Forced Diffusion (FD) chambers at CORE sites to measure soil CO_2 effluxes. Initiate manual measurements of soil CO_2 effluxes at CORE sites to capture spatial heterogeneity of soil respiration.

2.5 Plant Abundance and Diversity

Refine and revise vegetation survey protocols and establish additional plots for sample vegetation for plant abundance and diversity, aboveground biomass and forage net primary productivity.

2.6 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). Measure litterfall production at tree sites and sagebrush steppe CORE and satellite sites.

2.7 Soil Carbon Dynamics and Microbial Profiling

Conduct an incubation study of soils collected along the watershed elevation gradient to understand the sensitivity of different elevations and SOC pools to decomposition in response to temperature changes

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

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

2.9 Near surface soil moisture and critical zone structure using geophysics

Initiate collection of 3D electrical resistivity tomography (ERT) data at the Nancy Gulch, Lower Sheep, and Reynolds Mountain East Core Sites to understanding spatial variability in near surface soil moisture.

2.10 Wildfire Responses

Collect dust, erosion, and water samples within burned catchment (Murphy Creek). Deploy FD chambers for 6 months following the Soda wildfire in unburned and burned hillslopes to understand the immediate post-fire respiration responses and collect soils to evaluate losses and SOC property changes.

2.11 Stream Export

Complete stream cages and install automated water chemistry and colored dissolve organic matter sensors at 2-4 locations in Reynolds over the summer. Revise stream sampling and processing protocols and continue collection and analysis of dissolved inorganic and organic carbon and other constituents manually and from autosamplers. Initiate study on spatial and temporal variability in stream chemistry and contributions of in-stream production to carbon export in intermittent streams.

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

Complete processing and QAQC of data from the meteorological and precipitation stations to produce temporally complete (no missing values), 31-year record for relative humidity, air temperature, dew point, precipitation amount, and the precipitation phase. Complete development of detrended kriging method to distribute 10-m resolution, 31 year, hourly dataset for the 238 km^2 watershed.

3.2 Integrated Modeling

Begin evaluating output of initial simulations using the Ecosystem Demography model (leveraging other funded projects) in the context of data collected in support of the CZO effort. These data include Net Ecosystem Exchange and Net Primary Productivity, soil moisture, soil temperature, net radiation, and biomass. Select a cohort of soil pit locations to begin point-scale simulations with the Ecosys model and develop initial parameterizations for the model.

c. Significant Results

Priority 1: *Landscape Soil Carbon Survey*

1.1 Soil organic matter-vegetation associations

Relationships between field bulk density and % soil organic matter (SOM) as well as soil organic carbon (SOC) were derived for felsic and mafic parent materials (Figure 1.1a for felsic materials). Robust predictions of bulk density fine fraction were derived with % coarse fraction adjustment (Figure 1.1b) (Patton et al., in review). Prediction of near surface SOC storage (0-30cm) were improved with variables derived from hyperspectral data compared to other LiDAR-derived variables and other traditional datasets (Figure 1.1c, Table 1) (Will, MS thesis).

1.2 Soil-Bedrock and Mobile Regolith Mapping

A strong inverse linear relationship was observed between mobile regolith thickness (TMR) and curvature (r^2=0.89) and a predictive map of TMR in Johnston Draw was produced (Figure 1.2a). Similar inverse TMR-curvature relationships existed across published data sets including JRB and BC CZO, although the slopes and y-intercepts varied widely (Figure 1.2b-A). The slope of the TMR-curvature function was well correlated with the variability in each catchment's curvature distribution (r^2=0.97, $p<0.0005$) and the curvature distribution of all catchments centered on values of zero m^{-1} (Figure 1.2b-B) (Patton et al. in review) (see Key outcomes). Seismic refraction lines in Johnston Draw showed greater weathering at the lower elevations and south aspects (60-80%) compared to higher elevations where higher weathering was observed on the north aspects (Figure 1.2d-e). Airborne EM/magnetic survey by WYCEHG took place during October 2016.

1.3 Topographic controls on carbon storage

Percent SOC was found to decrease with soil depth (Figure 1.3a), and varied with curvature and aspect but importantly, substantial C was found to be stored below 100 cm depth. Total profile SOC varied as a polynomial function of TMR and varied with aspect (Figure 1.3b). Soil C map based the TMR approach was found to be superior (r^2=0.96) to other kriging approaches (Figure 1.3c) (Patton et al., in review).

1.4 Geologic Controls on soil inorganic carbon (SIC)

Mean annual precipitation of 500 mm was the threshold for SIC accumulation (Figure 1.3a). The highest SIC concentrations ranged from 13 to 23 kg/m^3 (Stanbery et al., in review) (Figure 1.4a). Rock carbonate coating represented as much as 43% of total IC with an average of 13% SIC stored in the gravel fraction across sites. Pedon-scale field variability was quite high (up to 220%) compared to gravels and analytical error associated with the modified pressure calcimeter (0.001-0.014%) (Figure 1.4b) (Stanbery et al., in review).

1.5 Snow Mapping

RC CZO exhibits the greatest departure from the other CZOs and revealed the important role of vegetation in generating preferential snow storage. Vegetation height captured 54 % of the variation in snow depth in forest areas and 31% in the shrub areas. The variables, slope and eastness as an index of wind direction, also emerged as important variables. Smaller distances between freezing levels and elevations of significant storage indicate greater sensitivity at RC CZO to changes from snow to rain (Figure 1.5a).

Priority 2: Environmental Monitoring Network

2.1 Net Ecosystem Exchange (EC Towers)

Aspen and sagebrush varied markedly in gross ecosystem production (GEP), despite a similar climate. Aspen growing season GEP exceeded sagebrush by ~ 2 fold (Figure 2.1a). Growing season GEP varied weakly with annual P at both sites (Figure 2.1a). Rain that followed snowmelt explained GEP variability in sagebrush (Figure 2.1b). Snowmelt date predicted spring GEP at the aspen (Figure 2.1c). Data from one sagebrush CORE site was submitted for consideration as an Ameriflux site.

2.2 Transpiration (Sap Flux Sensors)

Tissue-heat-balance sap flux sensors on sagebrush species showed that diurnal and seasonal water fluxes were the highest high elevations and lowest at low elevations (Figure 2.2a-d). Tree sap flux showed strong linkages with trunk diameter fluctuations at daily scales in both tree species (Fig. 2.2e-h), particularly Douglas fir.

2.3. Plant ecophysiological ecology

We initiated monthly growing season leaf to ecosystem level measurements at the sagebrush CORE sites to explain differences in water and carbon flux among sites.

2.4 Soil Respiration

CO_2 profile sensors at Wyoming Big Sage core site showed the concentration gradient was almost always upward, indicating year round loss to the atmosphere, but was minimal in the winter months (Figure 2.4a). Growing season CO_2 fluxes ranged from 36-104 g CO_2-C/m^2) over the growing season and were 1.5-3x higher at Upper Sheep than other sites (Figure 2.4b).

2.5 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 continued to establish permanent plots for long-term vegetation monitoring.

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

Biomass addition estimations were 8.4+6.1 kg, 9.4+2.8 kg, and 4.8+1.3 kg in *P. tremuloides*, *P. menziesii,* and *J. occidentalis* respectively during 2014 growing season calculated using available allometric relationships.

2.7. Soil Carbon Dynamics and Microbial Profiling

Absolute cumulative C respiration and average observed temperature sensitivity (Q_{10}) was highest at the highest elevation but a greater temperature response per unit C was observed at the lowest elevation (Figure 2.7a) (Delvinne et al. in review). The highest % POM-C was found at the highest elevation, while % Clay-C was highest at the lowest elevation (Figure 2.7b-c). However, no consistent relationship was observed between %SOC pools and temperature sensitivity (Delvinne et al., in review).

2.8. Nitrogen Fixation, Dynamics and Biological Crust Bacterial Abundance and Diversity

Warmer, drier climates at lower elevations hosted greater biocrust cover and higher N_2 fixation rates compared with colder, wetter climates at higher elevations. Highest NA (0.5-29.3 µmol C_2H_4 m-^{2} h-^{1}) occurred during the early summer/spring (Figure 2.9a, Schwabedissen et al., in review). We detected dramatic shifts in the abundance of individual N_2-fixing groups (i.e., cyanobacteria, symbiotic, other) as elevation increased (Schwabedissen et al., in review). The phylum Actinobacteria represented the majority of the bacterial community (36-51%)(Blay et al, in review).

2.9 Near surface soil moisture and critical zone structure using geophysics

Data were acquired throughout the year at weekly to monthly time scales. Preliminary analysis indicates high spatial heterogeneity in water flow and distribution over the 7x8 m plot scale. However, distribution over time appears relatively stable

2.10. Wildfire Responses

Post-burn CO_2 fluxes were initially low on burned hillslope slopes (Figure 2.9a). No significant differences in soil C, N and C/N ratios were detected 2 months post-fire (Figure 2.9b).

2.11. Stream Export

DOC and DIC concentrations averaged 12.7 and 14.4 mg C/L across the stream and tributaries, and generally increased in concentration downstream and as the streams dried over the summer growing season (Figure 2.9a). Concentrations increased over the course of stream drying from April to June and shown distinct spatial and longitudinal patterns (Figure 2.9b).

Priority 3*:* **Integrated Modeling Framework***:*

3.1 Fine-Resolution Forcing Data

We completed quality control of fine-resolution, spatially explicit, forcing model input data from historic climate datasets for 239 km^2 of RCEW. A Digital object identifier (DOI) was obtained and datasets are stored at BSU.

3.2 Integrated Modeling

We initiated parameterization of the Ecosystem Demography model for the Great Basin region. We initiated informal collaborations with staff scientists at LBNL to evaluate the suitability of the Ecosys biogeochemical cycling model.

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, soil depth, and 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 3 has been the publication of a 31 yr, hourly, fine resolution (10 m raster) climate forcing data sets (24 TB) with DOI from spatially-distributed climate stations at the RC CZO using an improvement in 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, now postdoc at UC Berkeley. We used publically available LiDAR datasets from four of the CZOs (JRB, SS, RC, BC) and provide the first synthesis of LiDAR-derived snow depth datasets across the western United States, showing that elevation, vegetation, and aspect control watershed snow storage (Tennant et al., in review). Specifically, we showed that rates of snow depth increase with elevation ranged between 3.7-12cm/100m but were not statistically different among CZOs indicating site-level ablation and redistribution reduce orographic effects (Figure outcomes-1). The importance of aspect and vegetation as snowpack controls varied with incoming shortwave-to-net-radiation (SW:NetR) and wind speed. Aspect was most important at BC and JRB CZOs, where SW:NetR was highest (~0.5), and explained 17-37% of snow depth variability in forests and 32-37% in shrub areas. Vegetation height explained 40% of variability at a RC site with patchy forest and high winds, 3-6% where tall canopy intercepted snowfall and incoming SW:NetR was ~0.32 (SNV), and <3% at BC and JRB CZOs. Snowpack sensitivity to climate and vegetation change will be site-specific; however, smaller distances between freezing levels and elevations of significant storage indicate greater sensitivity at RC and SS CZOs to changes from snow to rain (Figure outcomes-2). The importance of vegetation in RC CZO snow storage suggests that changes in vegetation cover, because of drought or wildfire, could drive changes in the spatial distribution of snow storage.

Soil-Bedrock and Mobile Regolith Mapping

Soil depth is a fundamental variable in earth system sciences, yet soil depth remains difficult to predict across complex terrain. We have discovered a simple empirical model to predict soil thickness at *any* location within a catchment using high-resolution digital elevation models and a limited number of soil thickness measurements. Indeed, we show for the first time that there is a robust inverse relationship between hillslope curvature and soil depth (hereafter specified as thickness of the mobile regolith (TMR)), and that the slope of this relationship varies predictably with the standard deviations in curvature distributions for a given catchment such that high-resolution predictions of soil depth can be obtained across complex terrain. An independent test of this method with a small soil dataset shows that the model predicts TMR well (r^2=0.98 and p<0.0001) (Figure Outcomes 3) when the curvature distribution is narrow. As expected, the uncertainty in the TMR estimates increases as the catchment's curvature distribution broadens and a more diverse suite of hillslope transport processes dominates. This method of predicting soil thickness has the potential to transform the earth sciences discipline by providing key thickness parameters for weathering and landscape models, control volume estimates to predict residence time and sourcing of water and nutrients to streams, and rapid and cost efficient estimates of soil depth such that the total carbon reservoir across complex terrains can be estimated to reduce uncertainties in intermediate scale carbon cycling and land surface modeling.

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 found a strong inverse relationship between curvature –mobile regolith thickness (r^2=0.89) 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 from r^2 <0.4 to 0.96. 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 review).

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 review).

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.
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 (6-10 graduate students) and 2-3 faculty members (lead by Godsey, Reinhardt, Lohse) 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 2016 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 2015 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). This course is being revamped for May 2017 and also incorporated into Godsey's CAREER proposal.

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 discussions were extensive to evaluate post-wildlife responses. 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 3 resulted in over 180 visitor nights/yr (Jan 1 2015-August 23, 2015) were recorded and project another 50-75 visitors through November 30, 2016.

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. We have also engaged other National networks through senior personnel involvement, including UCAR, NEON, OpenTopography, LTERs, EarthCube, LTAR, and CUASHI. In yr 3, 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). Reynolds Creek is providing the ARS with critical data to parameterize BAER modeling efforts. In addition, in Yr 3, 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. Pierce received a RAPID grant to monitor 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 conducted an airborne campaign during October 2016 and are interested in collaborating in conducting more intensive measurements of Reynolds Mountain East. Holbrook and Scott Miller approached RC CZO senior personnel in December 2015 to develop a proposal linking an understanding of the subsurface using geophysics to stream runoff generation (to be submitted in May 2017). Lohse engaged ISU to fund a feasibility and cost study ($7000) in the summer of 2016 to augment the living facilities at Reynolds Creek and this study is in progress (as of Aug 2016). Senior personnel (Lohse, Seyfried, Pierson) plan to submit a proposal to augment the facility and equipment at the Reynolds Creek field station 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 (Ecohydrology in the Critical Zone), and also traveled internationally to present her research at ETH Zurich, Switzerland. Other engagement includes new collaborative proposals on cross-site studies (2 proposals for USGS Dr. Sasha Reed, Dr. Kampf at CSU, ISU Dr. Godsey) on cross-site studies including RC CZO. Completed collaborative research project with Syracuse University includes a master thesis on MS evaluating the prescribed burning impacts on soil water repellency and soil hydrological in sagebrush-steppe ecosystem (Yang Chen, Advisors, David Chandler, Chris Johnson and Mark Seyfried)

Data availability and management: We have published multiple 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 3, we generated and published 31 years 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 (24TB) (Kormos et al, 2016, Kormos et al., in review). In addition, we published a unique 10-year data set associated with the rain to snow transition and micrometeorology associated with this subcatchment (Enslin et al. in review). 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. we maintain a wiki site for the Reynolds Creek CZO for data discovery and also includes protocols, site map viewer and notes. 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: 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 repeated this module at the ISU STEM Event in March and then at the Portneuf Valley Environmental Fair in Pocetello, Idaho in April 2016, we introduced a sap flux demonstration (instrumented sagebrush) and 150 high school students participated in this exercise at the STEM Event and 150 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 repeated our an 8th grade adventure learning expedition (3rd in row) at Reynolds Creek in which the McCall Outdoor Science School (MOSS) lead adventure learning in the RCEW for 21 students and 2 chaperones for 2 overnights. Lohse and MacNeille, a new doctoral of arts student focused on science teaching, are developing informal science education modules on clays through integration with ceramics classes. On April 25, 2016, *Voices of Fire*, a documentary that presented the different perspectives of the Soda Fire, a 200,000-acre fire that swept through the RC CZO, and prior and subsequent management of Reynolds Creek, was pre-viewed in the Bengal Theater at Idaho State University. This film was produced by a Montana State University science film student (RJ Sindelar) as his 2nd yr film project and partially supported by RC CZO. It was later being modified to show on Idaho Public Television and projected to have reached 1,000,000 viewers. It also competed in the Boise Film Festival in September. Finally, videos were collected and interviews conducted this summer (June 13-25th, 2016 (20-30 participants) at RC CZO to produce a Virtual Watershed Tour (3-5 videos) on subwatershed research topics as part of a SAVI/RC CZO funded outreach/education effort. Our data manager has produced a beta version of the website that is available for all CZOs to link their videos.

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 4 revised soil carbon map created									X	X	X	
	Characterization	Conduct targeted field sampling activities						X	X	X	X			
		Complete Year 2-3 soil analysis	X	X	X	X	X						X	X
		Target Year 5 analysis	X	X	X	X	X						X	X
Strategic Priority 2: ***Environmental Monitoring Network***	**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 automated and manual soil flux measurements	X	X	X	X	X	X	X	X	X	X	X	X
	Stream and Groundwater Carbon Export	Stream, soil-water, groundwater monitoring protocols activities initiated and analyses continued	X	X	X	X	X	X	X	X	X	X	X	X
Strategic Priority 3: ***Integrated Modeling Framework***	**Create Fine Resolution Hydroclimate data**	Analyze and publish manuscript from fine resolution data		X	X	X	X	X	X	X	X	X	X	X
	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

Major Priority Area	Activity	Milestones												
		Year 3	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
	Integrated Terrestrial Biosphere Modeling	Continue initial parameterizations of ED model (leveraged from other projects)	X	X	X	X	X	X						
	Integrated Terrestrial Biosphere Modeling	Determine SOC sites at which to run Ecosys Begin developing parameterization for Ecosys model Initiate collaborative exchange with LBNL SFA staff	X	X	X	X	X	X	X	X	X	X	X	X
	Cross CZO modeling	Develop and host a Cross-CZO modeling workshop	X	X	X	X	X	X	X					

Products

Books

- ## Book Chapters

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- ## Inventions

- ## Journals or Juried Conference Papers

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- Stanbery, C., Pierce, J.L, Benner, S.G., Seyfried, M., Glenn, N. (2016). Controls on the Presence and Concentration of Soil Inorganic Carbon in a Transitional Semi-Arid Watershed.. *Geoderma*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Stielstra C.M., K.A. Lohse K.A., J. Chorover, J.C. McIntosh, G.A. Barron-Gafford, J.N. Perdrial, M. Litvak, H.R. Barnard, P.D. Brook (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. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Tennant, C.J., Crosby, B.T., Godsey, S.E., Van Kirk, R.W. and Derryberry, D.R. (2015). A simple framework for assessing the sensitivity of mountain watersheds to snowpack loss. *Geophys. Res. Lett.*. 42 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2015GL063413
- Tennant, C.J., Harpold, A.A., Lohse, K.A., Godsey, S.E., Crosby, B.T., Larsen, L.G., Brooks, P.D., and Van Kirk, R.W. (2016). Regional sensitivities of seasonal snow cover to elevation, aspect, and vegetation structure in western North America.. *Water Resources Research*. . Status = UNDER_REVIEW; 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
- Wei, L., T.E. Link, A.T. Hudak, J.D. Marshall, K.L. Kavanagh,1, J.T. Abatzoglou, H. Zhou, R.E. Pangle, and G.N. Flerchinger (2016). Simulated water budget in a forested watershed within Priest River Experimental Forest, northern Idaho, USA.. *Hydrologic Processes*. 30 2000. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: DOI: 10.1002/hyp.10769

- Williams, C.J., Pierson, F.B., Kormos, P.R., Al-Hamdan, O.Z., Hardegree, S.P., Clark, P.E. (2016). Ecohydrologic response and recovery of a semi-arid shrubland over a five year period following burning.. *Catena*. 144 163. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.catena.2016.05.006
- Zhang, Z., S. Glaser, R. Bales M. Conklin, R. Rice and D. Marks (2016). Technical report: the design and evaluation of a basin-scale wireless sensor network for mountain hydrology.. *Water Resources Research.*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

- Licenses

- Other Conference Presentations / Papers

- 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 = PUBLISHED; Acknowledgement of Federal Support = Yes
- Andrew Poley, Nancy Glenn, Aihua Li. (2016). *Above-ground Carbon Loss from the 2015 Soda Fire.*. The Sagebrush Ecosystem Conservation: All Lands, All Hands Conference. Salt Lake City, UT. Status = OTHER; Acknowledgement of Federal Support = Yes
- Andrew Poley, Nancy Glenn, Aihua Li (2016). *Above-ground Carbon Loss from the 2015 Soda Fire.*. The Sagebrush Ecosystem Conservation: All Lands, All Hands Conference. Salt Lake City, UT. Status = OTHER; Acknowledgement of Federal Support = Yes
- Andrew Poley, Nancy Glenn, Aihua Li (2016). *Above-ground Carbon Loss from the 2015 Soda Fire. The Sagebrush Ecosystem Conservation: All Lands, All Hands Conference.*. Society for Ecological Restoration Great Basin Chapter Meeting. Salt Lake City, UT. 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
- Bruk, B. and P. Youngblood (2016). *Can elevation predict soil texture?*. Undergraduate Research Presentations: Boise State University. . Status = OTHER; Acknowledgement of Federal Support = Yes
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- Hamid Dashti., Nancy Glenn., Nayani Illangakoon., Jessica J Mitchell., Shital Dakhal., Lucas Spaete (2015). *Comparison of linear and non-linear regression models to estimate leaf area index of dryland shrubs.*. AGU Fall Meeting, December 2015. 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*. Idaho State University Research Fair. Pocatello, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- Lohse, K.A. (2016). *Coupling biogeochemistry and hydrology to understand and predict ecosystem to watershed responses to anthropogenic changes.*. Invited Talk. ETH Zurich. 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
- Butt J, Schweitzer A. (2016). *Determining Carbon Sequestration in Soil: Canopy and Intercanopy Zones of the Sagebrush Steppe at Reynolds Creek*. Undergraduate Research and Scholarship Conference. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- Patton, N., K. Lohse, M. Seyfried, B. Crosby, S. Godsey (2015). *Determining Total Soil Carbon Storage in the Critical Zone Using Topography and Lithology.*. American Geophysical Union. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Delvinne H, Feris K, Flores A, Benner S, de Graaff M (2015). *Differences in the temperature sensitivity of soil organic carbon decomposition in a semi-arid ecosystem across an elevational gradient.*. American Geophysical Union. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Sharma, H., K. Reinhardt, and K. Lohse (2015). *Diurnal and seasonal variation in sap flow in sagebrush communities spanning rain- to snow- dominated elevation zones.*. Annual meeting of American Geophysical Union. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Sharma, H. and K. Reinhardt (2015). *Diurnal and seasonal variation in tree stem circumference using automated self-reporting dendrometer bands (TreeHuggers)*. Great Basin Conference. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes

- Sharma, H. and K. Reinhardt (2014). *Diurnal and seasonal variation in tree stem circumference using automated self-reporting dendrometer bands (TreeHuggers)*. All hands CZO meeting. Fish Camp, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Hamid,D., Glenn, N.F., Jessica, M., Spaete, L. (2015). *Estimation of sagebrush biochemical and biophysical paramers using hyperspectral imagery and inversion of radiative transfer models.*. 57th Idaho Academy of Science and Engineering (IASE) Annual Meeting and Symposium. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- Ilangakoon, N., Glenn,N,F. (2016). *Full waveform lidar processing of ecosystem structure in the western United States.*. NASA Airborne Snow Observatory (ASO) workshop. . Status = OTHER; Acknowledgement of Federal Support = Yes
- Nielson, T., Bradford, J., and Holbrook, S. (2015). *Geophysical investigation of differences in weathering depths between the north and south facing slopes of a small catchment in the Reynolds Creek Critical Zone Observatory.*. American Geophysical Union. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Enslin, C., Marks, D., Godsey, S., and P. Kormos (2015). *ISNOBAL: Impacts of Extreme Precipitation events in the rain-snow transition*. Summer Tri-state EPSCoR meeting. Boise, Idaho. Status = OTHER; Acknowledgement of Federal Support = Yes
- Hamid.D,. Glenn,N, Jessica, M. Spaete, L., Lejo, F. Qingtao.Z., Matt, M. (2015). *Improving Ecosystem Dynamic Models in a Semi-arid Ecosystem by Integrating Different Sources of Remotely Sensed Data.*. CSDMS Annual Meeting, May 2015. Boulder, CO. Status = OTHER; Acknowledgement of Federal Support = Yes
- Ilangakoon, N., Glenn,N,F., Hamid, D., Spaete, L. (2015). *Individual and Plot Level Shrub Characterization with Full Waveform Lidar, poster.*. NASA ARSET workshop, Idaho State University. . Status = OTHER; Acknowledgement of Federal Support = Yes
- Klos, Z., Link, T., Seyfried, M., Heinse, R., and E. Leonard (2014). *Influence of contrasting aspect, lithology, and vegetation on saprolite genesis in complex terrain: Reynolds Creek Critical Zone Observatory*. American Geophysical Union Annual Meeting December 2014. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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- Shital Dhakal, Aihua Li, Lucas Spaete, Doug Shinneman, Robert Arkle, David Pilliod, Susan Mcllroy, Charlie Baun, Nancy F. Glenn (2015). *Landsat 8 Coupled With Lidar Estimate Semi-arid Rangeland Biomass and Cover.*. American Geophysical Union. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Seyfried, M.S. and Lohse, K.A. (2015). *Long-Term Research at Reynolds Creek, Idaho: Lessons Learned*. Soil Science Society of America. Minneapolis, MN. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
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- Will, R., Glenn, N., Benner, S., Pierce, J.L., Spaete, L., Li, A. (2015). *Mapping SOC (Soil Organic Carbon) using LiDAR-derived vegetation indices in a random forest regression model.*. American Geophysical Union. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Brymer, B., Holbrook, J., Niemeyer, R., Suazo, A., Wulfhorst, J., Rachlow, J., Vielring, K., Link, T., and B. Newingham (2015). *Merging ecosystem services and social processes for a social-ecological impact assessment on U.S. public land*. International Symposium on Society and Natural Resource Management, the annual

meeting of the International Association for Society and Natural Resources. Charleston, South Carolina. Status = OTHER; Acknowledgement of Federal Support = Yes

- Watson, K., M. Masarik, and A. Flores (2015). *Modeling the hydro-climate of southwest Idaho over a range of historical conditions.*. Northwest Climate Conference.. Coeur d'Alene, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- de Graaff M (2015). *Plant root impacts on soil carbon dynamics. Critical Zone Science, Purdue University.*. Sustainability, and Services in a Changing World.. West Lafayette, Indiana. Status = OTHER; Acknowledgement of Federal Support = Yes
- Williams, C., Pierson Jr, F., and O. Al-Hamdan (2014). *Prescribed fire effects on runoff, erosion, and soil water repellency on steeply-sloped sagebrush rangeland over a five year period*. American Geophysical Union Annual Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Ilangakoon, N., Glenn,N,F., Olsoy, P. (2015). *Quantification of Sagebrush Leaf Area Index (LAI) from Terrestrial Laser Scanning, poster.*. Great Basin Consortium Conference, Boise State University. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- Delvinne H, Feris K, Flores A, Benner S, de Graaff M (2015). *Response of soil organic carbon decomposition to temperature across a semiarid elevational-climatic gradient.*. Critical Zone Science, Sustainability, and Services in a Changing World, Purdue University.. West Lafayette, Indiana. Status = OTHER; Acknowledgement of Federal Support = Yes
- Havens, S., Winstral, A., Marks, D., Kormos, P., Hedrick, A., Rothwell, E., Flores, A., Watson, K., and M. Masarik (2015). *Running a physically-based snow model for near real time operational water forecasts. Abstract H31A-07*. Joint AGU/CGU Meeting. Montreal, Canada. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Nielson, T., and J. Bradford (2015). *Sensitivity of refraction inversion to smooth and blocky velocity gradients.*. SEG 2015 Annual International Meeting and Exhibition. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Bentley, A., Holbrook, J., Niemeyer, R., Suazo, A., Wulfhorst, J., Newingham, B., Rachlow, J., Vielring, K., and T. Link (2014). *Social-ecological impacts of juniper removal in a public lands context: merging deliberative workshops and participatory GIS*. Third Annual Meeting UI-CATIE IGERT Project. Boise, ID. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Beal, L., Huber, D., Godsey, S., Kobs-Nawotniak, S. and K. Lohse (2015). *Soil Age and Geomorphology: Influence on Hydraulic Properties in Cold Desert Ecosystems*. Centennial Meeting of the Ecological Society of America. Baltimore, MA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Stanbury, C. and J. Pierce (2015). *Soil Inorganic Carbon Thresholds and Formation: What are the Controls in a Transitional, Semi-Arid Watershed?*. Great Basin

Consortium Conference. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes

- Stanbery, C., Will, R., Benner, S. Pierce, J.L. (2015). *Soil Inorganic Carbon Thresholds and Formation: What are the Controls in a Transitional, Semi-Arid Watershed?*. American Geophysical Union. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Delvinne, H., Feris, K., Flores, A., Benner, S., and M. deGraaff (2015). *Soil Organic Carbon Decomposition across an elevational gradient in a Semi-Arid Ecosystem*. Proceedings of the Great Basin Consortium Conference. Boise, Idaho. Status = OTHER; Acknowledgement of Federal Support = Yes
- Delvinne, H., Feris, K., Flores, A., Benner, S., and M. deGraaff (2014). *Soil Organic Carbon and the Temperature Sensitivity of its Decomposition along an Elevational Gradient in a Semi Arid Ecosystem*. Proceedings of the Critical Zone Observatory All Hands Meeting. Yosemite, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Walters, R., Benner, S., de Graaff, M., McNamara, J., Will, R., and A. Flores (2015). *Soil Organic Carbon in the Critical Zone: Ecohydrologic Model Sensitivity and Spin-up*. Community Surface Dynamics Modeling System Annual Meeting. Boulder, CO. Status = OTHER; Acknowledgement of Federal Support = Yes
- Aihua Li, Ryan Will, Nancy Glenn, Shawn Benner, Lucas Spaete (2016). *Spatial Pattern of Soil Organic Carbon Acquired from Hyperspectral Imagery at Reynolds Creek Critical Zone Observatory (RC-CZO).*. Whisper 2016. Los Angelas, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Aihua Li, Ryan Will, Nancy Glenn, Shawn Benner, Lucas Spaete, Nayani Ilangakoon (2015). *Spatial Patterns of Vegetation Biomass and Soil Organic Carbon Acquired from Airborne Lidar and Hyperspectral Imagery at Reynolds Creek Critical Zone Observatory.*. American Geophysical Union. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Delvinne H, Feris K, Flores A, Benner S, de Graaff M (2015). *Temperature Sensitivity of Soil Organic Carbon Decomposition across an elevational gradient in a Semi-Arid Ecosystem.*. Proceedings of the Great Basin Consortium Conference. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- Tennant, C.J., Harpold, A.A., Lohse, K.A., Crosby, B.T., Godsey, S.E., Larsen, L.G., and VanKirk, R.W. (2015). *The influence of elevation, aspect, and vegetation on seasonal snowpack: case studies from five mountain Critical Zone Observatory sites across the western U.S.*. American Geophysical Union. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Terhaar, D. (2016). *Using the chemical signature of dust to understand soil development and carbon storage in soils.*. Using the chemical signature of dust to understand soil development and carbon storage in soils. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes

- Blay, E., Schwabedissen, S., Reed, S., Sheridan, P., Magnuson, T., and K. Lohse (2015). *Variation in Biological Soil Crust Bacterial Diversity with a Changing Climate*. Idaho Conference on Undergraduate Research. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- McKinnon, J. (2016). *Variations in soil pH across climatic gradients the Reynolds Creek Watershed, Idaho.*. Variations in soil pH across climatic gradients the Reynolds Creek Watershed, Idaho. . Status = OTHER; Acknowledgement of Federal Support = Yes
- Flerchinger, G.N., A.W. Fellows, and M.S. Seyfried (2016). *Water and Carbon Fluxes Along an Elevation/Precipitation Gradient in a Sagebrush Steppe Environment.*. ASA/CSSA/SSSA Annual Meeting. . Status = OTHER; Acknowledgement of Federal Support = Yes
- Masarik, M., K. Watson, and A. Flores. (2016). *Weather Forecasting for Water Resource Management in Mountainous Terrain.*. Western Snow Conference. Seattle, WA. Status = OTHER; Acknowledgement of Federal Support = Yes

- Other Products

- *Databases.*
- Kormos, P., D. Marks, M. Seyfried, S. Havens, A. Hendrick, K. Lohse, M. Maserik and A. Flores, 2016, *Data set:* 31 Years of Spatially Distributed Air Temperature, Humidity, Precipitation Amount and Precipitation Phase From a Mountain Catchment in the Rain-snow Transition Zone, Boise State University, Reynolds Creek Critical Zone Observatory (NSF EAR #1331872), http://doi.org/10.18122/B2B59V
- *Databases.*
- Enslin, C., S. Godsey, D. Marks, P. Kormos, M. Seyfried, J. McNamara and T. Link, 2016, **Data set: Hydrological and ecological observations from the rain-to- snow transition zone: a dataset for the Johnston Draw catchment, Reynolds Creek Experimental Watershed, Idaho, USA**, Ag Data Commons, USDA Agricultural Library, http://dx.doi.org/10.15482/USDA.ADC/1258769.
- *Databases.*
- Enslin, C., S. Godsey, D. Marks, P. Kormos, M. Seyfried, J. McNamara and T. Link, 2016, Data set: Hydrological and ecological observations from the rain-to-snow transition zone: a dataset for the Johnston Draw catchment, Reynolds Creek Experimental Watershed, Idaho, USA, Ag Data Commons, USDA Agricultural Library, http://dx.doi.org/10.15482/USDA.ADC/1258769.
- *Databases.*
- Kormos, P., D. Marks, A. Boehm, S. Havens, A. Hedrick, F. Pierson, J. Williams, S. Hardegree, N. Glenn, J. Bates and A. Svejcar, 2016, **Data set: Weather, snow, and streamflow data from four western juniper-dominated experimental catchments in southwestern Idaho, USA**, Ag Data Commons, USDA Agricultural Library, http://dx.doi.org/10.15482/USDA.ADC/1254010
- *Data and Research Materials (e.g. Cell lines, DNA probes, Animal models).*

- 16S rRNA sequence datasets from RC-CZO microbiome samples deposited with NCBI.
- *Data and Research Materials (e.g. Cell lines, DNA probes, Animal models).*
- LiDAR-derived Digital Elevation Model (DEM). 1 meter. 2014.
- http://doi.org/10.18122/B26C7X

- Other Publications

- Patents

- Technologies or Techniques

- MiSeq-enabled microbial metagenome characterization.

- Thesis/Dissertations

- Schwabedissen SG.. *Climatic and Grazing Controls on Nitrogen Fixation by Biological Soil Crusts Utilizing a Climatic Gradient in a Semi-arid Ecosystem.*. (2016). Idaho State University. Acknowledgement of Federal Support = Yes
- Huber, D.. *Effects of long-term experimental manipulations of precipitation and vegetation on carbon and nitrogen dynamics in a cold desert ecosystem.*. (2016). Idaho State University. Acknowledgement of Federal Support = Yes
- Delvinne, H. *Temperature impacts on soil organic carbon decomposition across an environmental gradient in a semi-arid ecosystem*. (2016). Boise State University. Acknowledgement of Federal Support = Yes
- Tennant, C.J.. *The Sensitivity of Mountain Snowpack to Warming, PhD Dissertation, Chapter 4: The influence of elevation, aspect, and vegetation on seasonal snowpack: case studies from five mountain Critical Zone Observatory sites across the western U.S.*. (2015). Idaho State University. Acknowledgement of Federal Support = Yes
- Patton, N.R.. *Topographic Controls on Total Mobile Regolith and Total Soil Organic Carbon in Complex Terrain*. (2016). Idaho State University. Acknowledgement of Federal Support = Yes
- Enslin, C.. *Understanding the rain-to-snow transition zone: modeling snowmelt and the spatial distribution of water resources in southwestern Idaho.*. (2016). Idaho State University. Acknowledgement of Federal Support = Yes

- Websites

Participants/Organizations

Research Experience for Undergraduates (REU) funding

Form of REU funding support:

REU supplement

How many REU applications were received during this reporting period?

0

How many REU applicants were selected and agreed to participate during this reporting period?

0

REU Comments:

What individuals have worked on the project?

Participant, Roles and Months

Lohse, Kathleen	PD/PI	6
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	1
Crosby, Benjamin	Co-Investigator	1

Finney, Bruce	Co-Investigator	1
Flerchinger, Gerald	Co-Investigator	12
Garen, David	Co-Investigator	1
Godsey, Sarah	Co-Investigator	3
Marks, Danny	Co-Investigator	12
Pierce, Jennifer	Co-Investigator	2
Cadol, Daniel	Faculty	1
Chandler, David	Faculty	1
de Graaff, Marie-Anne	Faculty	1
Feris, Kevin	Faculty	1
Holbrook, W. Steven	Faculty	1
Kohn, Matthew	Faculty	1
Link, Timothy	Faculty	1
Magnuson, Timothy	Faculty	2
Pomeroy, John	Faculty	1

Reinhardt, Keith	Faculty	3
Fellows, Aaron	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Kormos, Patrick	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Masarik, Matt	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Zhou, Qingtao	Postdoctoral (scholar, fellow or other postdoctoral position)	12
McCorkle, Emma	Other Professional	12
Parsons, Susan	Other Professional	11
Reed, Sasha	Other Professional	1
VanVactor, Steven	Other Professional	12
Wilford, John	Technician	6
Clark, Patrick	Staff Scientist (doctoral level)	2
Goodrich, David	Staff Scientist (doctoral level)	1
Aguayo, Miguel	Graduate Student (research assistant)	12
Commendador, Amy	Graduate Student (research assistant)	12
Dashti, Hamid	Graduate Student (research assistant)	12

Delvinne, Hasini	Graduate Student (research assistant)	6
Enslin, Clarissa	Graduate Student (research assistant)	6
Galanter, Amy	Graduate Student (research assistant)	1
Gelb, Lucy	Graduate Student (research assistant)	12
Huber, David	Graduate Student (research assistant)	1
Ilangakoon, Nayani	Graduate Student (research assistant)	12
Klos, Peter	Graduate Student (research assistant)	6
Nielson, Travis	Graduate Student (research assistant)	12
Niemeyer, Ryan	Graduate Student (research assistant)	1
Patton, Nicholas	Graduate Student (research assistant)	12
Radke, Anna	Graduate Student (research assistant)	1
Rozin, Alexandra	Graduate Student (research assistant)	6
Schwabedissen, Stacy	Graduate Student (research assistant)	6
Sharma, Harmandeep	Graduate Student (research assistant)	12
Stanbery, Christopher	Graduate Student (research assistant)	6

Will, Ryan	Graduate Student (research assistant)	12
Spaete, Lucas	Non-Student Research Assistant	12
Watson, Katelyn	Non-Student Research Assistant	1
Blay, Erika	Undergraduate Student	6
Bruck, Benjamin	Undergraduate Student	2
Holloway, Mariah	Undergraduate Student	2
Johnson, Joel	Undergraduate Student	1
King, Remington	Undergraduate Student	4
Price, Mitchell	Undergraduate Student	1
Rangel, Ivan	Undergraduate Student	1
Refaey, Dylan	Undergraduate Student	1
Youngblood, Peter	Undergraduate Student	2
DeLucia, Evan	Consultant	1
Perdrial, Julia	Consultant	1
Clark, Martyn	Other	1

Cram, Zane	Other	12
McNamara, James	Other	1
Weppner, Kerrie	Other	1
Williams, Jason	Other	12

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 morphogenetic 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. Six MS theses, one 1PhD thesis, and one undergraduate thesis were completed in YR 3 (ISU: Schwabedissen, Patton, PhD, Huber, undergraduate Blay; BSU: Stanbery, Delvinne, Will, Gelb) with 15 papers projected to have been submitted by December 2016 as part of the RC CZO.

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 and recent road improvements are underway.

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 January 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 2016. New permanent positions proposed based on August 2015 Soda Fire are now Johnson Draw, Reynolds Creek (at Tollgate) and now at Murphy Creek and Outlet after Aug 2015 fire (Soda Fire). Murphy Creek weir and housing were restored.

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.

7. What is the impact on technology transfer?

We produced 24TB 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 are associated with these model datasets as of July 2016. These data are permanently stored at BSU.

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 STEM Event (March 2016) and then the Portneuf Valley Environmental Fair in Pocetello, Idaho on April 18, 2015. 150 high school students participated in this exercise at the STEM Event and 150 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. . On April 25, 2016, *Voices of Fire*, a documentary that presented the different perspectives of the Soda Fire, a 200,000-acre fire that swept through the RC CZO, and prior and subsequent management of Reynolds Creek, was pre-viewed in the Bengal Theater at Idaho State University. This film was produced by a Montana State University science film student (RJ Sindelar) as his 2nd yr film project and partially supported by RC CZO. It was later being modified to show on Idaho Public Television and projected to have reached 1,000,000 viewers. It also competed in the Boise Film Festival in September. Finally, videos were collected and interviews conducted this summer (June 13-25th, 2016 (20-30 participants) at RC CZO to produce a Virtual Watershed Tour (3-5 videos) on subwatershed research topics as part of a SAVI/RC CZO funded outreach/education effort. Our data manager has produced a beta version of the website that is available for all CZOs to link their videos.

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 restored the Murphy weir and are working to restore the Salmon weir though access is hampering progress.

- *Water sensors* We installed water sensors based on August 2015 Soda Fire in the following positions include Johnson Draw, Reynolds Creek (at Tollgate) and now at Murphy Creek, and the Outlet of Reynolds Creek. We also installed automated water samplers (Sigma samplers).

- *Dust collections* We installed about 12 dust collectors around the watershed consistent with the Southern Sierra CZO protocols for dust and microbial collections as part of Pierce rapid grant. 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.

- Respiration and soil responses Rozin installed FD chambers to measure soil respiration fluxes and collected soils 1, 2, 3, 6 months post fire to the Soda Fire (incorporated into Research Activities).

- *LiDAR flight* In 2016, we received the burn LiDAR layer and this layer is being use as part of the broader fire response project.

- Fire soil residues
    - 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. This thesis has been completed.

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. Wilford recently moved to a new job such that this CZO technician is being currently advertised and will be filled by the end of yr 3. We are filling this position with a temporary position.

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.

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

Special Reporting Requirements

Table A: Outcomes and Metrics

Major Priority Area	Activity	Metric	Year 3 Target	Year 3 Accomplished
Strategic Priority 1: ***Landscape Soil Carbon Survey***	**Survey**	Create Soil Map	Year 3 Map Created	Year 3 Maps Created
	Characterization	Environmental Datasets Created	100 soil pits collected & analyzed	463 soil pits collected & 4640 total samples collected and ~1150 total analyzed for SOC)
Strategic Priority 2: ***Environmental Monitoring Network***	**Core Site Creation**	# of sites created	4	4
	Net Ecosystem Exchange	Sites instrumented	3-4	4 instrumented, 1 to burned sage site (upper sheep))
	Transpiration	Sites instrumented	4	5 (3 sage, 1 conifer, 1 aspen, still waiting on juniper permissions)
	Aboveground Biomass and NPP	Sites instrumented	4	4 sites
	Soil Respiration	Sites instrumented/measure d	2	4 FD & 3 profiles at CORE Sites (soil probes)
	Stream and Groundwater Carbon Export	Samples Collected	0	500 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 (E&O, Website, Q-C, Tree, OM, BGC)
	Resource to broader community	Collaborations with X-CZO and non-CZO researchers	2	5
Strategic Priority 5: ***Public Outreach and Education Activities***	**Education**	Students and post-docs engaged	4	21 students +4 postdocs
	Public Outreach	Outreach events	1	5 (STEM, Environmental Fair, Hydrology Days, Adventure Learning, Voice of Fire (ID Public TV)
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

Major Priority Area	Activity	Metric	Year 3 Target	Year 3 Accomplished
				spreadsheets
	Data Services and Management	Cumulative unique databases uploaded and accessed (# of times)	50	>50

CZO Network Activities

Network Leadership

- Publications
    - Journal article

        Richter et al. (in review) What would Darwin and Lyell say? Fully integrating biology and geology in long-term environmental networks Bioscience

        CZO Network Strategic plan by CZO PIs (including Lohse and Seyfried)

Working groups (WG)

- Cross CZO Biogeochemistry
    - Lohse from ISU attended this 3 day meeting and outcomes were complete metrics of BGC at all CZOs
    - Lohse collected 2 full soil profiles in June for cross site microbial community analysis.
- Cross-CZO –OM
    - Graduate student Rozin from ISU and Delvinne from BSU attended
- Cross-CZO –Concentration Discharge
    - Godsey from ISU attended
- Cross CZO - Exploring Four Critical Puzzles Workshop
    - Godsey from ISU attended
    - Godsey participated in writing paper as product
- Cross-CZO Education and outreach
    - Lohse was the PI representative for CZOs and attended monthly meetings for the Education and Outreach
    - Virtual Watershed Tour
        - Videos were collected and interviews conducted this summer (June 13-25th, 2016 (20-30 participants) at RC CZO to produce a Virtual Watershed Tour (3-5 videos) on subwatershed research topics as part of a SAVI/RC CZO funded outreach/education effort.
        - Our data manager has produced a beta version of the website that is available for all CZOs to link their videos.
- Cross-CZO Website
    - Lohse was the PI representative for CZOs and attended monthly meetings for the Education and Outreach

Meetings

- *CZO PI meetings –Lohse and Seyfried attending monthly meetings*
- *CZO Strategic Planning meeting Boulder* –Lohse and Seyfried participated in 3 day strategic planning meeting in February 2016 with Cindy Zook and other CZO PIs.
- *Ecohydrology in the Critical Zone* Lohse (RC CZO and Swenam (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.

  Connectivity and runoff generation. 2016 AGU session convened by Godsey
- 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 and now postdoctoral associate at UC Berkeley, 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. Rates of increase in snow depth with elevation ranged between 3.7-12cm/100m but were not statistically different among CZOs indicating site-level ablation and redistribution reduce orographic effects (Figure 1.5a). The importance of aspect and vegetation as snowpack controls varied with incoming shortwave-to-net-radiation (SW:NetR) and wind speed. Aspect was most important at BC and JRB CZOs, where SW:NetR was highest (~0.5), and explained 17-37% of snow depth variability in forests and 32-37% in shrub areas. Vegetation height explained 40% of variability at a RC site with patchy forest and high winds, 3-6% where tall canopy intercepted snowfall and incoming SW:NetR was ~0.32 (SNV), and <3% at BC and JRB CZOs.

Nick Patton, K. Lohse, S. Godsey, B. Crosby and M Seyfried integrated published BC CZO and JRB CZO mobile regolith data into paper evaluating the generality of curvature-soil depth relationships

Lohse and Patton collected collected 2 full soil profiles in June for cross site microbial community analysis (BGC workshop).

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.

Dave Huber was awarded a SAVI grant to travel to Australia on international CZO related activities.

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, C.J., Harpold, A.A., Lohse, K.A., Godsey, S.E., Crosby, B.T., Larsen, L.G., Brooks, P.D., and Van Kirk, R.W., Regional sensitivities of seasonal snow cover to elevation, aspect, and vegetation structure in western North America, in review Water Resources Research.

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

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 revision. Climate and landscape as drivers of carbon storage in forested headwater catchments: Insights from a complete C budget" Biogeochemistry

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

RJ Sindelar, graduate student from MSU, received a SAVI grant to produce videos for a Virtual Watershed and a beta version will be available for other CZOs.

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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			Funds Requested By Proposer	Funds Granted by (If Different)
	CAL	ACA	SUMR		
1. Kathleen Lohse			0.75	$7,384	$
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			$43,709	
3. ( ) GRADUATE STUDENTS				$	
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				28495	
6. ( ) OTHER				$	
TOTAL SALARIES AND WAGES (A + B)					
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				25,378	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)					
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)				9000	
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				$8000	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				$1,500	
3. CONSULTANT SERVICES				1000	
4. COMPUTER SERVICES				$4,500	
5. SUBAWARDS				$194,173	
6. OTHER Tuition				$2520	
TOTAL OTHER DIRECT COSTS				211693	
H. TOTAL DIRECT COSTS (A THROUGH G)				325651	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 47% on salary only					
TOTAL INDIRECT COSTS (F&A)				$37406	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**$363,065**	
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)				**$363,065**	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT: $			
PI/PD TYPED NAME AND SIGNATURE* Kathleen Lohse	DATE 9/1/16	**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	ACA	SUMR	Funds Requested By Proposer	Funds Granted by (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. (0) POSTDOCTORAL ASSOCIATES	12				
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)				$55909	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				13977	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**69886**	
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				$3333	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$11000	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				$2148	
3. CONSULTANT SERVICES					
4. COMPUTER SERVICES					
5. SUBAWARDS					
6. OTHER Station fees				$10000	
TOTAL OTHER DIRECT COSTS				22148	
H. TOTAL DIRECT COSTS (A THROUGH G)				**102867**	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 11.1111 of total%					
TOTAL INDIRECT COSTS (F&A)				$11430	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				$**114297**	
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)				$**114297**	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT: $	
PI/PD TYPED NAME AND SIGNATURE* Kathleen Lohse	DATE 9/1/16	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 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	ACA	SUMR	Funds Requested By Proposer	Funds Granted by (If Different)
1 Alejandro Flores			0.25	4025	$
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. (1) GRADUATE STUDENTS				$17000	
4. () UNDERGRADUATE STUDENTS				0	
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					
6. ( ) OTHER				12200	
TOTAL SALARIES AND WAGES (A + B)				$ 33225	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				*$3349*	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**36574**	
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				$750	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				$1500	
3. CONSULTANT SERVICES				2000	
4. COMPUTER SERVICES					
5. SUBAWARDS					
6. OTHER Tuition				$11662	
TOTAL OTHER DIRECT COSTS				$18162	
H. TOTAL DIRECT COSTS (A THROUGH G)				**$60737**	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 39% MDTC on **$49074**					
TOTAL INDIRECT COSTS (F&A)				$19139	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**$79876**	
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)				**$79876**	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT: $			
PI/PD TYPED NAME AND SIGNATURE* Kathleen Lohse	DATE 9/1/16	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

NSF Form 1030 (10/99) ***Supersedes All Previous Editions*** *SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

BUDGET JUSTIFICATION IDAHO STATE UNIVERSITY (YR 4)
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 0.75 month of summer salary in yr 4.

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

Students We will pay summer salary to 4 students working on the RCC CZO in yr 4.

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 2016-2017.

EQUIPMENT

TRAVEL
Funds ($10 yr 4, total) 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 yr 4.

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 $4.5k yr 4 for Amazon Cloud Server

GRA Tuition: Graduate tuition for 1 credit ($655) for 4 students for summer tuition fees
Materials and Supplies: This category includes costs for research materials and supplies ($8k yr 4) plus service fees $1k). Funds will cover the cost of 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 4, 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 $1500 in yr 4 for publication costs.

Subawards: We request $79876 to BSU and $114297 to USDA ARS for yr 4

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 $ 4025 of summer salary in yr 4
Other Personnel:
Students. One graduate research assistant (GRA) will be supported to work with Flores on modeling. Additional salary is requested for summer salary for another graduate student. The student 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 1 graduate students, in-state graduate tuition is $ 11662 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 $750 in yr 4.
Sample/consultant fees are $2K yr 4 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 4
Indirect Costs at USDA ARS is 39% on MDTC.

USDA-ARS SUBAWARD BUDGET JUSTIFICATION
PERSONNEL
Other Personnel:
Term Research Technician (TBA). 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 4) 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 4 for participation support.
Materials and Supplies. This category includes costs for research materials and supplies at $10k in yr 4. 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, calibrants, weigh tins, soil augers, corers, plastic bags and infiltrometers.
Publications We request $2148 costs for publication fees.
Station Fees We request $10000 in station fees to cover cleaning and other maintenance fees
Indirect Costs at USDA ARS is 11.111% on total.

Additional Funding

Pierce, J., N. Glenn, E. Yager. 2015-2016, $46,724, Boise State University, RAPID: An Integrated Study of Post-fire Wind and Water Erosion in Western Rangelands

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.

Seyfried, M, $40,000 Department of Interior, Bureau of Land Management, Develop and test a user interface for the Soil Ecohydrology Model to be used for estimating forage production on semiarid rangelands.

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.

Flores, L. 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.

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 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.

Pending

Godsey, S., Idaho State University, NSF CAREER: Active Learning Across Interfaces: Controls on Flow Intermittency and Water Age in Temporary Streams

Reed, S. et al. USGS. Grazing and climate change interact to affect dryland carbon cycling via effects on plants, biological soil crusts, and soils, NASA Roses

Reed, S. et al. USGS. Grazing and climate change interact to affect dryland nitrogen cycling via effects on plants, biological soil crusts, and soils, NASA Roses

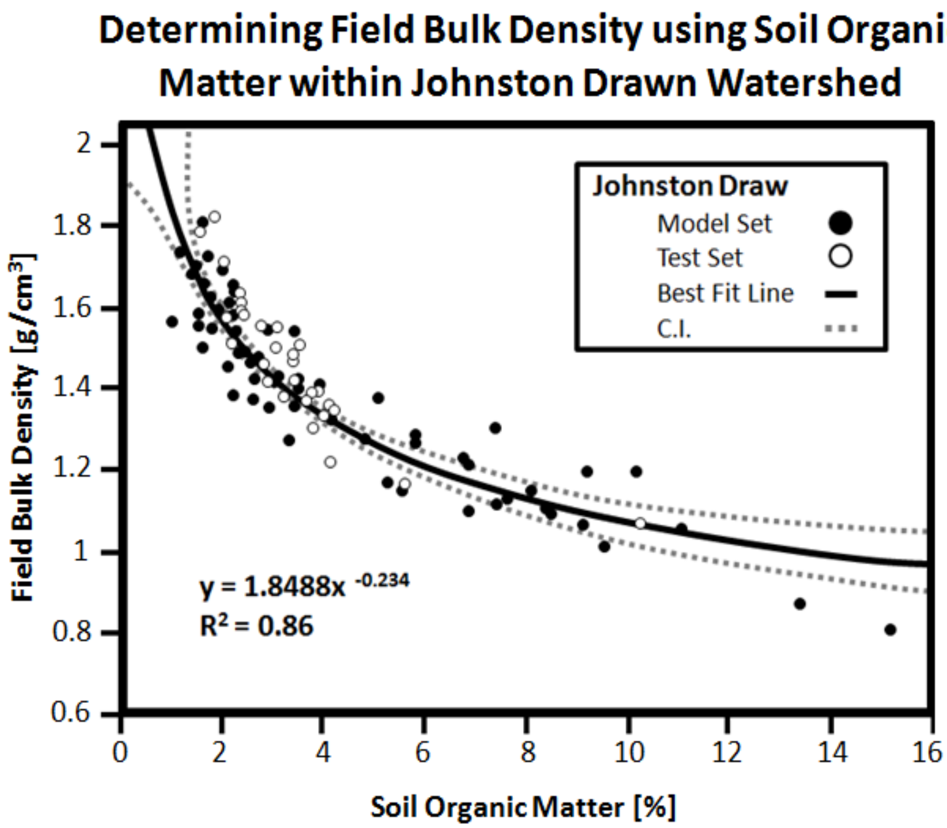


Figure 1.1a: Field bulk density using soil organic matter for felsic materials (mafic not shown)

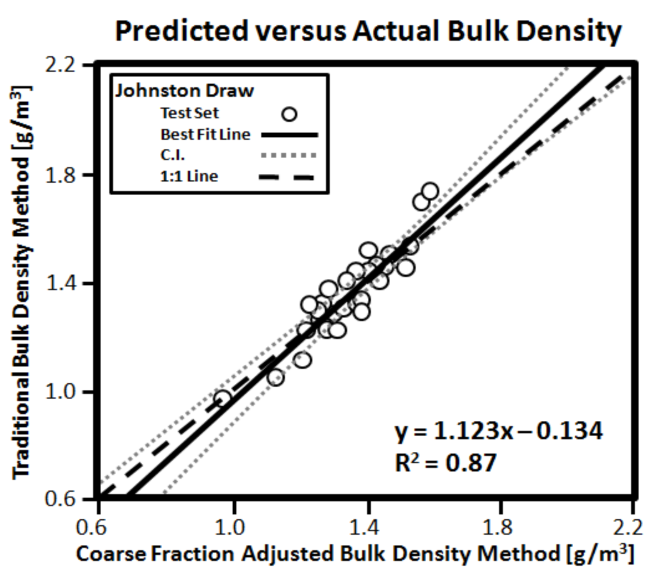


Figure 1.1b: Comparison of coarse fraction adjusted bulk density method using soil organic matter relationship to traditional fine-fraction core bulk density method.

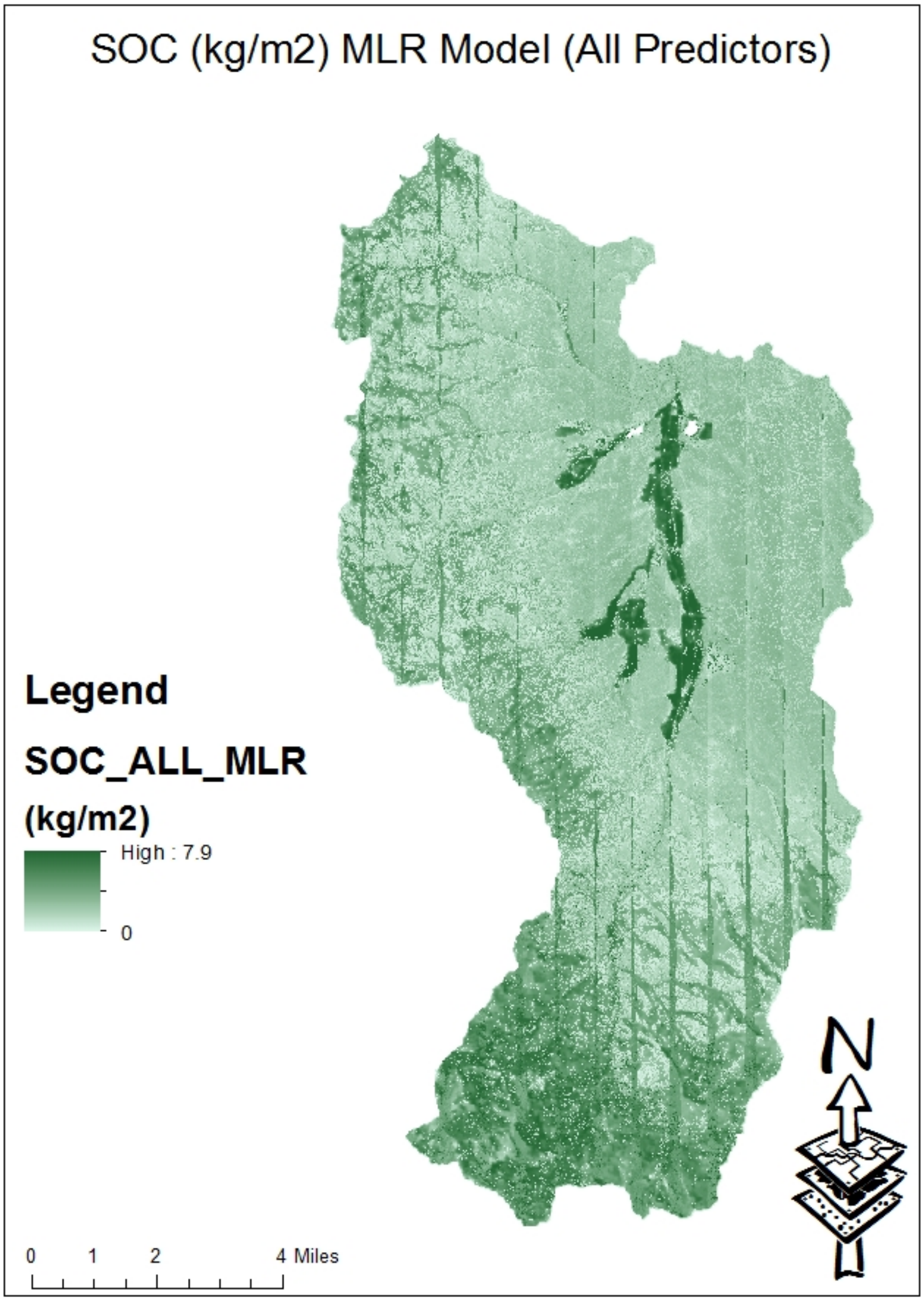


Figure 1.1c: Soil organic carbon (kg/m^2) to 30 cm depth derived from multiple linear regression (MLR) model with all predictors (see Table 1 below).

Table 1: SOC (kg/m2) Models

	Model		Field Data			
Map	R2	RMSE	R2	RMSE	Variables	Scale
Traditional (RF) (M1)	0.65	1.01	0.86	0.32	NDVI, aspect	30 m
Traditional (MLR) (M7)	0.61	1.1	0.58	0.7	NDVI	30 m
Trad/Lidar (RF) (M2)	0.57	1.12	0.77	0.56	NDVI, curvature (min) (L)	3 m
Trad/Lidar (MLR) (M7)	0.61	1.1	0.58	0.7	NDVI	3 m
All Predictors (RF) (M3)	0.75	0.63	0.86	0.55	MRENDVI (H), PRI (H), V%1_2.5m (L)	3 m
All Predictors (MLR) (M8A,M8B)	0.89	0.6	n/a	n/a	MRESR (H), NLI (H), elevation (L), V%2.5_10 (L), vegetation density (L)	3 m

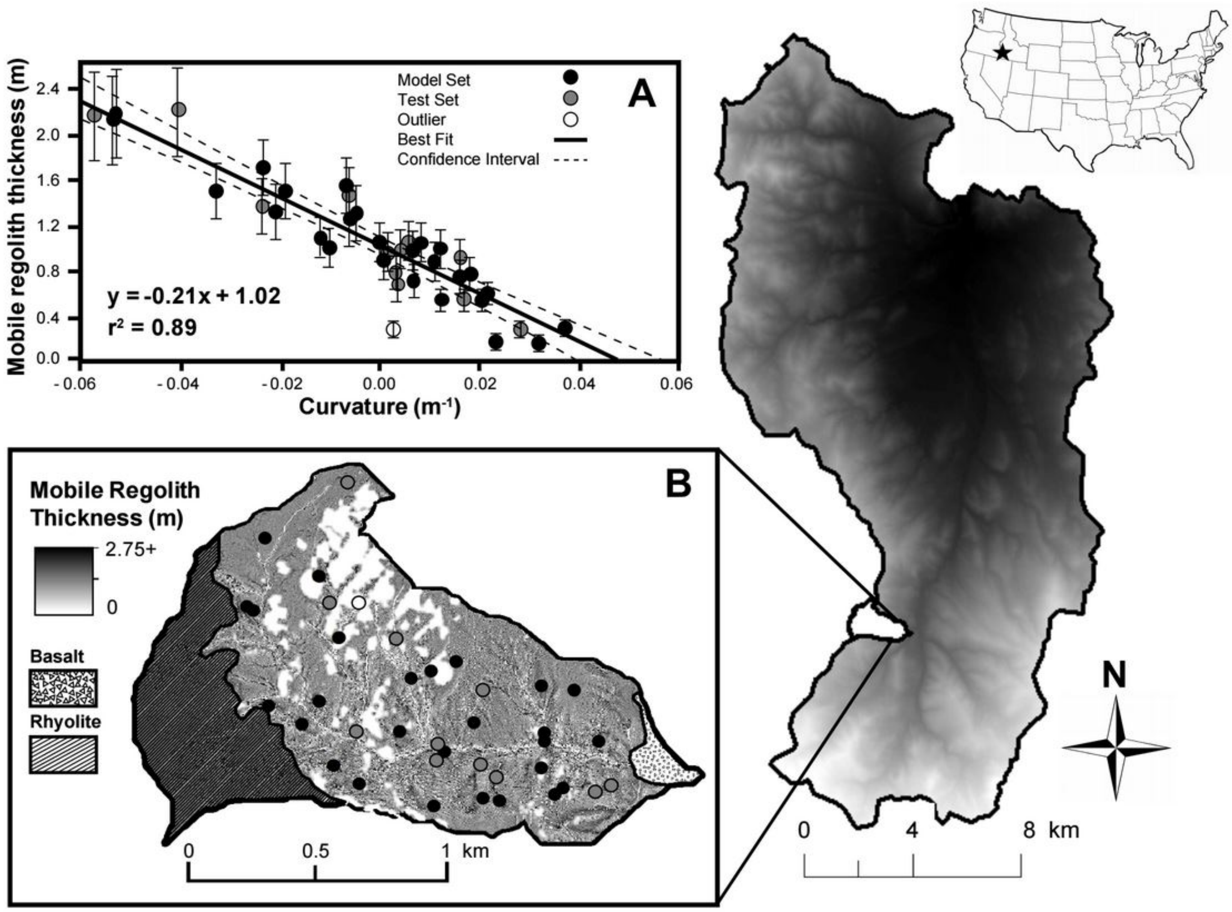


Figure 1.2a: (A) The thickness of the mobile regolith (TMR) varies as a strong inverse function of curvature in Johnston Draw. Black dots represent randomly selected build dataset (70% of sites). Gray dots represent test set to validate the model. The white dot is a location that was excluded owing to proximity to both a rock outcrop and a stream channel. (B) Predicted TMR map for Johnston Draw derived from the TMR-curvature function using a 3-m LiDAR-derived DEM. Darker shades indicate larger TMR (2.75+ m) and lighter shades indicate smaller TMR (0 m).

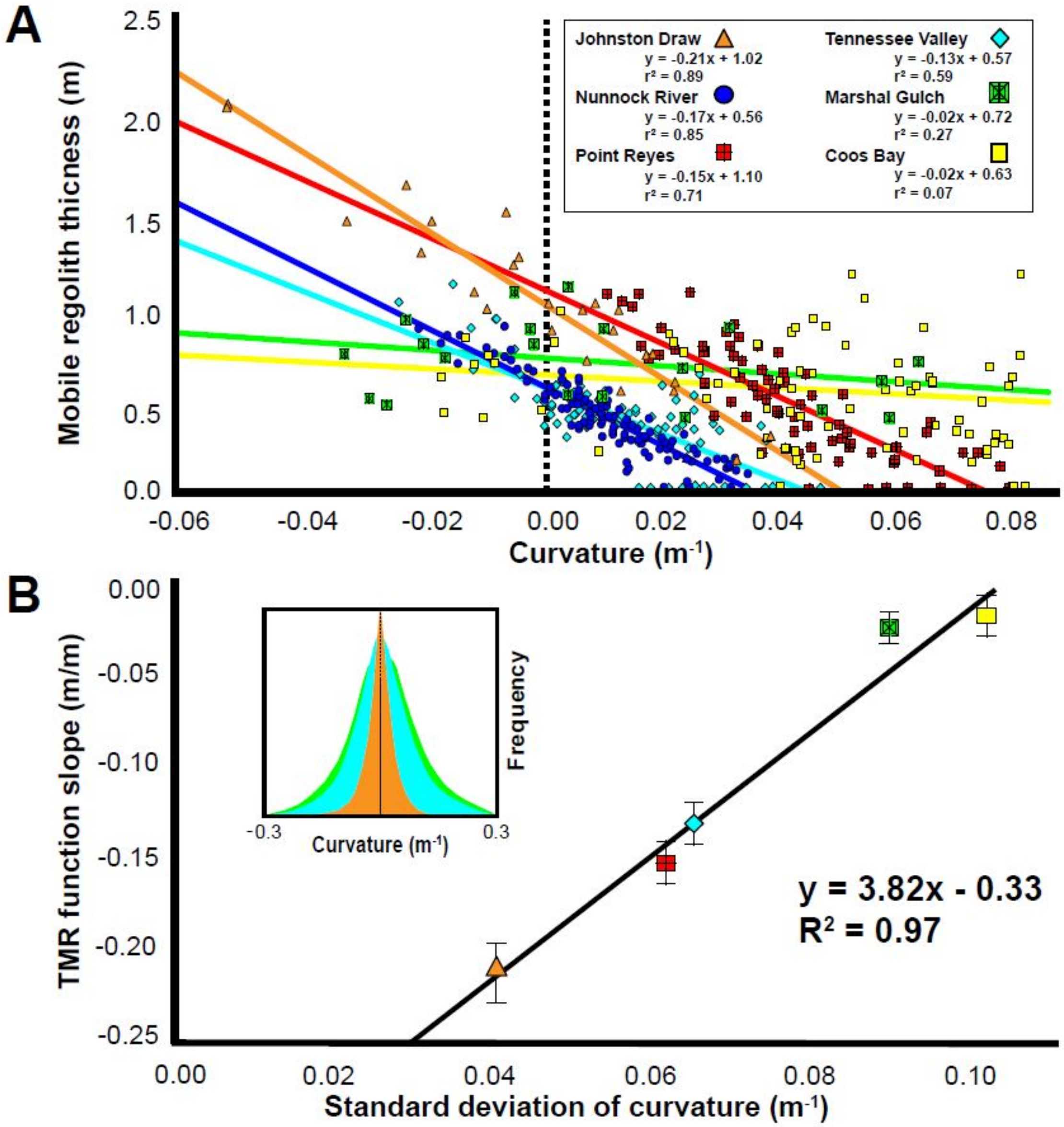


Figure 1.2b: (A) Cross-site evaluation of six catchments in which the TMR-curvature function is evaluated. (B) Cross-site comparison of the slope of the TMR-curvature function and the local roughness quantified as the standard deviation in curvature. Inset shows curvature distributions based on a 3 m DEM for Johnston Draw (orange), Tennessee Valley (blue), and Marshall Gulch (green) centered on 0 m^{-1}. Nunnock River dataset was not included in (B) due to the lack of high resolution LiDAR data; curvature estimates for Nunnock River in (A) were derived from local observations reported in Heimsath et al. (2001).

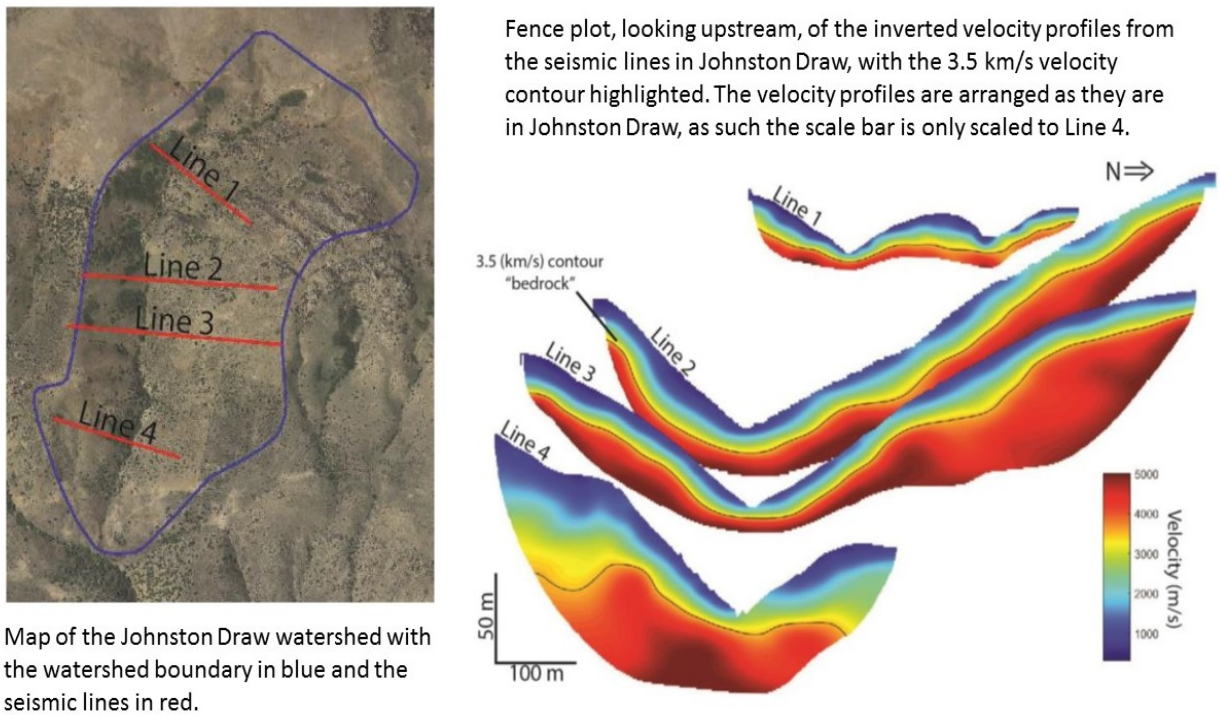


Figure 1.2d: Map of Johnston Draw and seismic refraction lines shown in red and watershed boundary in blue.

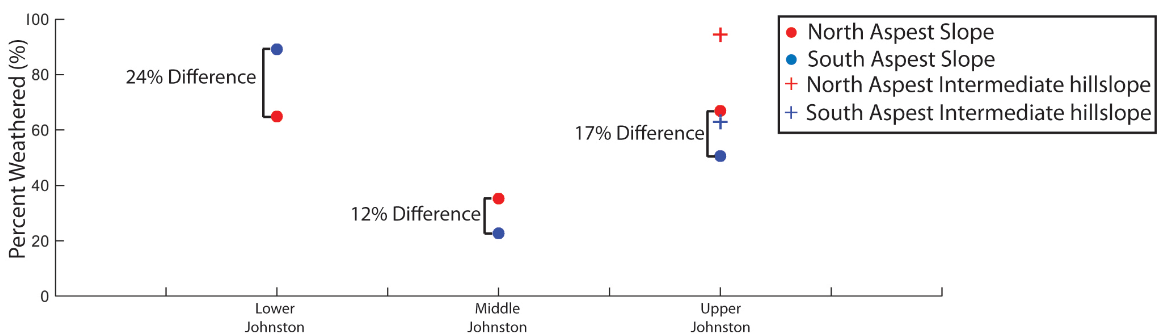


Figure 1.2d: Percent weathering calculated with the 3500 m/s contour for north and south facing aspect with expectations that north would have deeper/more weathered profiles than south facing aspect. Similar trends were observed for 2750 m contour.

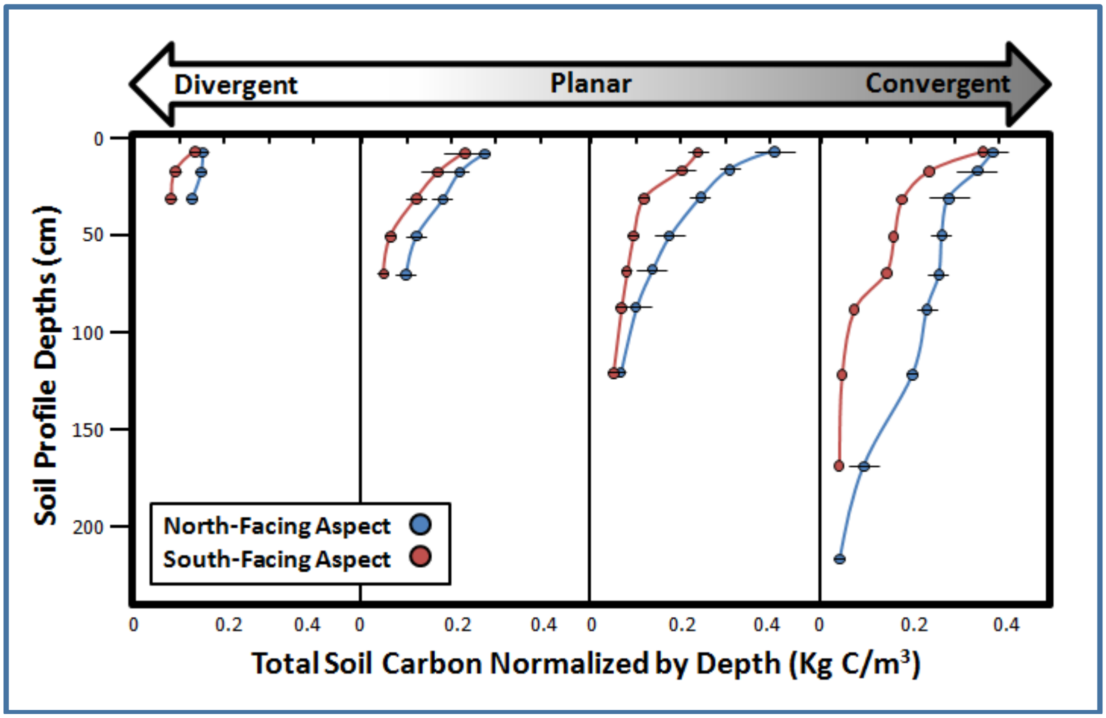


Figure 1.3a: Soil carbon decreases with depth and varies with aspect and curvature (divergent to convergent topography).

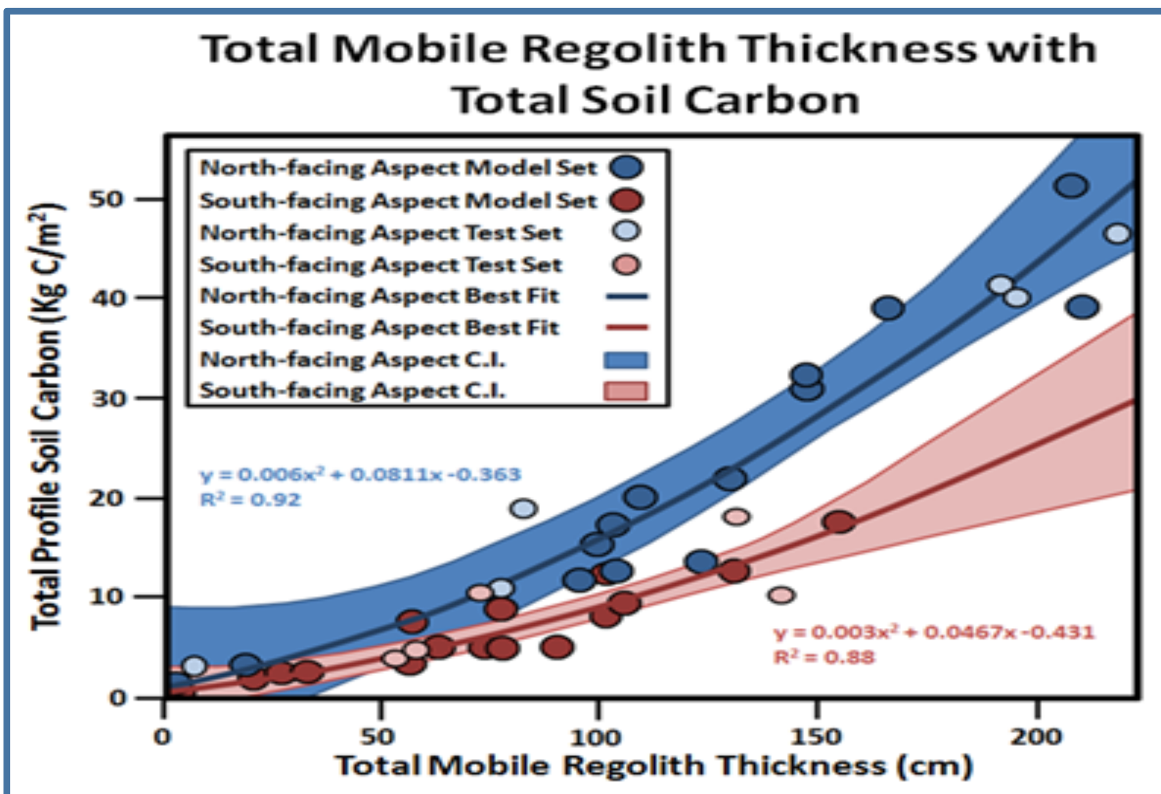


Figure 1.3b: Total profile soil carbon varies as function of mobile regolith thickness and aspect.

Method	Total Soil Carbon (Mg C)	Percent Total Soil Organic Carbon Relative to this Study					
		Total	North-Facing Aspect	South-Facing Aspect	Divergent Topography	Planar Topography	Convergent Topography
TMR Approach down to Saprolite [A]	13,338	100%	100%	100%	100%	100%	100%
TMR Approach down to 100 cm [B]	11,835	89%	66%	99%	77%	96%	46%
Kriging down to Saprolite [C]	17,346	130%	127%	133%	1167%	131%	60%
Kriging down to 100 cm [D]	15,221	114%	107%	122%	1005%	115%	52%
Kriging down to 30 cm [E]	8,043	60%	50%	72%	504%	62%	26%
Weighted Average down to Saprolite [F]	13,794	103%	71%	84%	831%	107%	43%

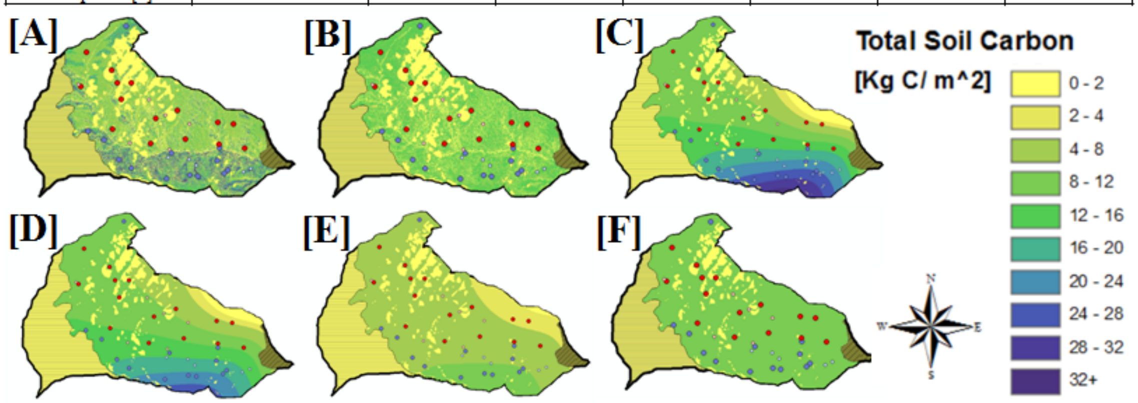


Figure 1.3c: Total soil carbon modeled using six separate methods including TMR approach. Table shows estimated total soil carbon contained within the granitic portion of the watershed. Note that methods C and D provide close estimates of total soil carbon; however, results obtained do not show true spatial distribution as method A depicts. Method F, provides evidence that utilizing the average north and south-facing aspect cites located on planar surfaces and weighing their values based on the percentage of land cover (36.6% and 63.4%, respectively), than a realistic general total soil carbon estimate can be obtained. Model fits with test sets showed that the TMR approach had superior goodness of fit (r^2=0.96) compared to other models (r^2=<0.40).

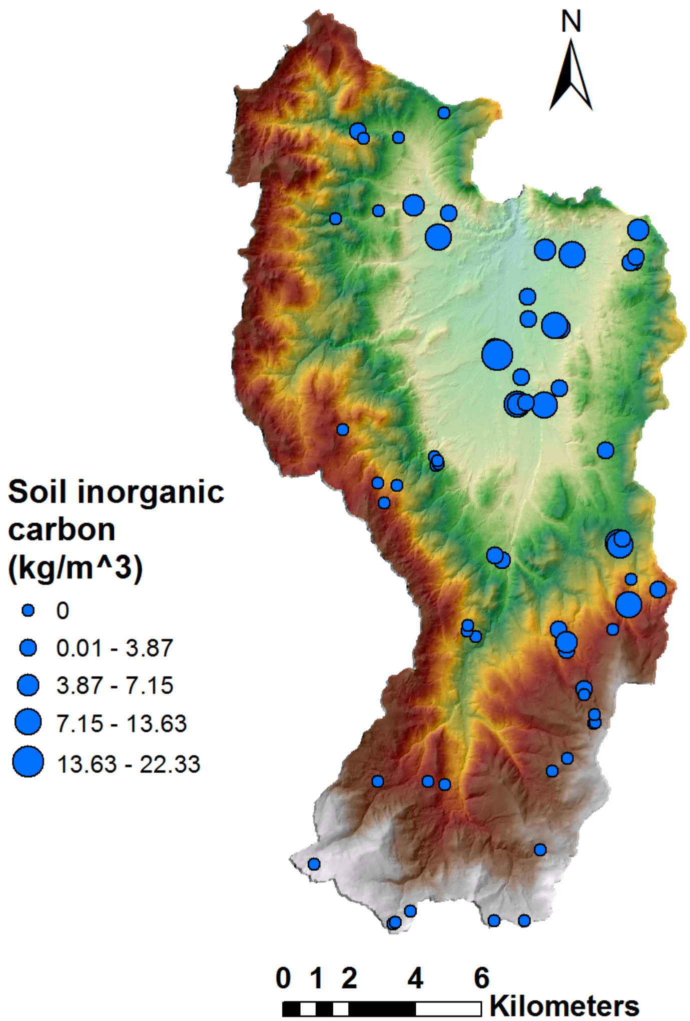


Figure 1.4a: Soil inorganic carbon on an areal basis (kg C/m2) with location of all study sites within Reynolds Creek.

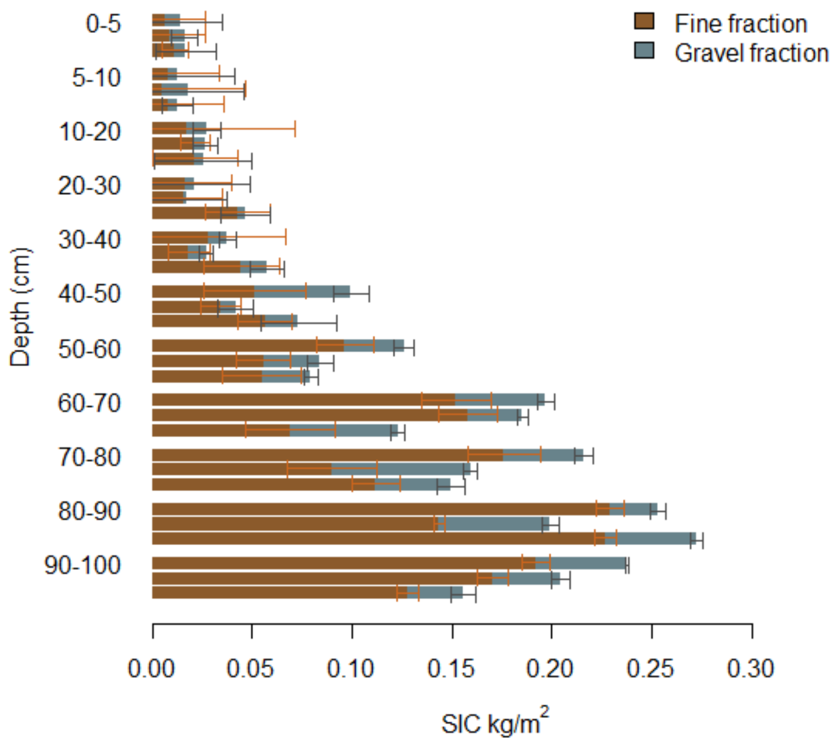


Figure 1.4b: Analysis of lab uncertainty for the measurements of both the fine and gravel fraction at the PAR1 site. The fine fractions are generally significantly different between the profiles while this is not the case for gravels.

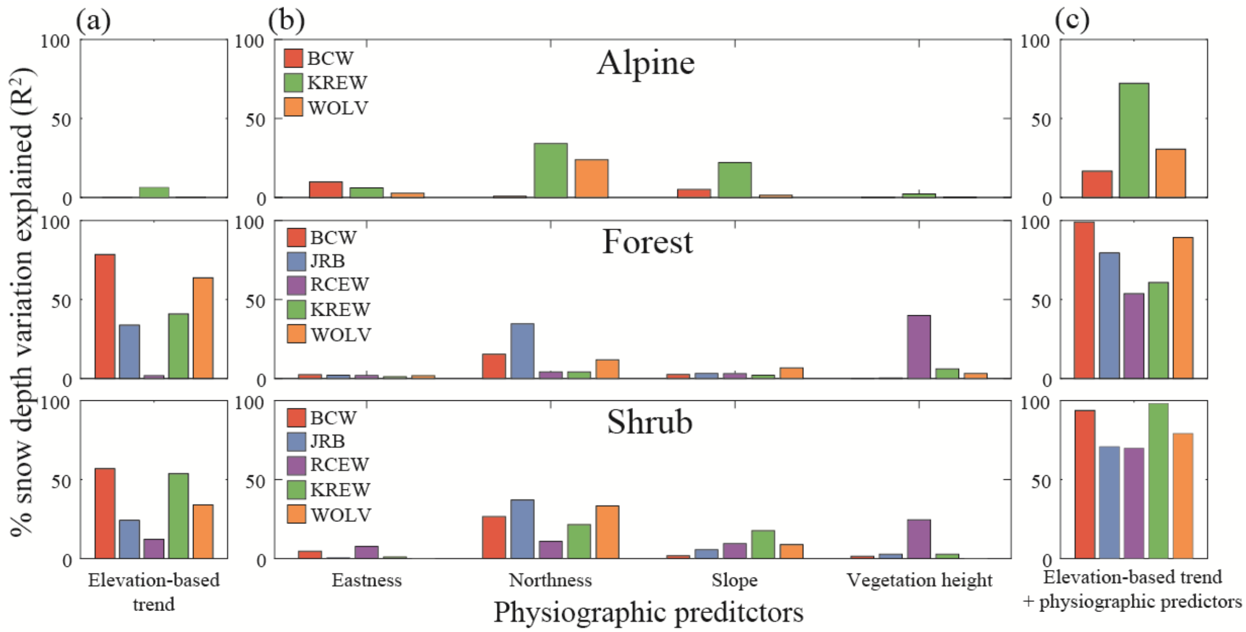


Figure 1.5a. The variation (R^2) in snow depth explained by (a) the elevation-based snow depth trends, (b) the multivariate regressions on snow depth residuals (snow depth – elevation based trend) by physiographic predictors and (c) the elevation-based trends plus the physiographic predictors for alpine (top row), forest (middle row), and shrub (bottom row) areas at the CZO sites. The elevation-based snow depth trends and northness were the most important predictors of snow depth except at RCEW where vegetation height was more important, and eastness nearly as important.

Figures: Priority 2

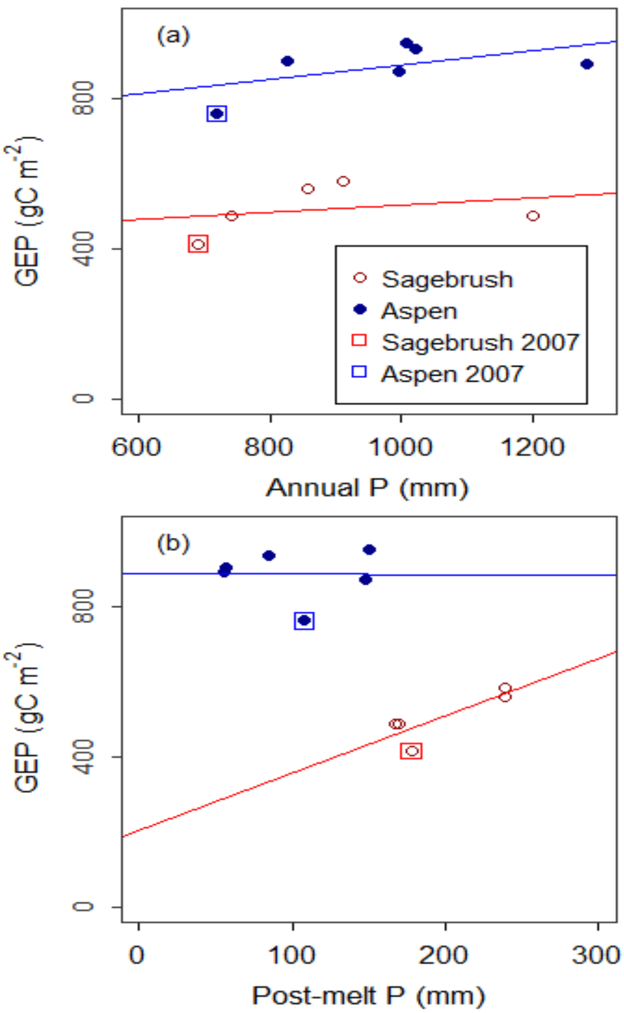


Figure 2.1a and b: Variation in growing season GEP with (a) annual precipitation (P) and (b) precipitation following snowmelt (Post-melt P).

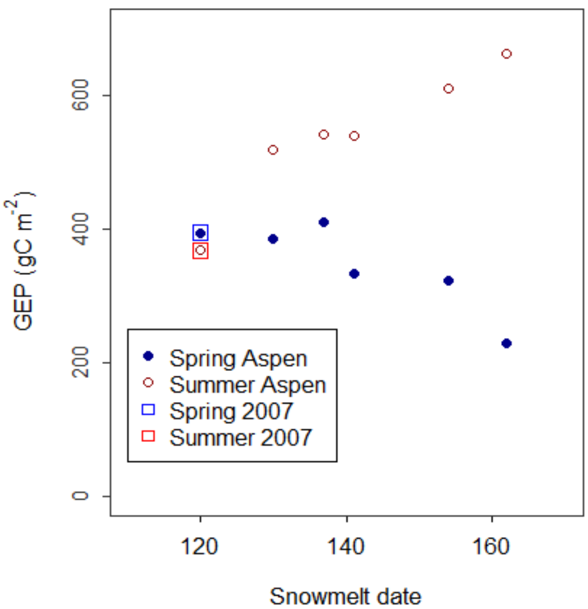


Figure 1.2c: Variation in spring (Apr.-Jun.) and summer (Jul.-Sep.) GEP with snowmelt date at the aspen

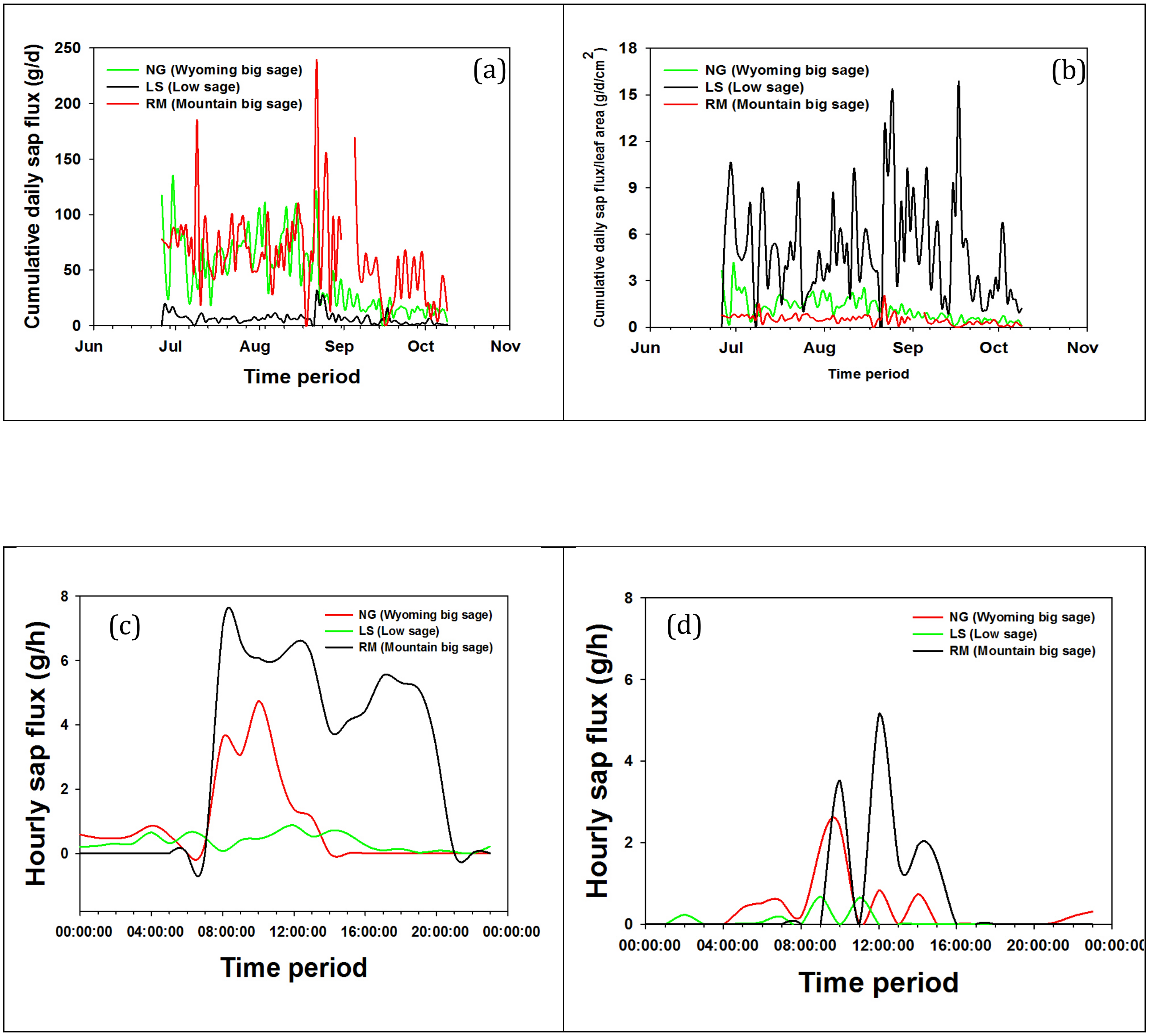
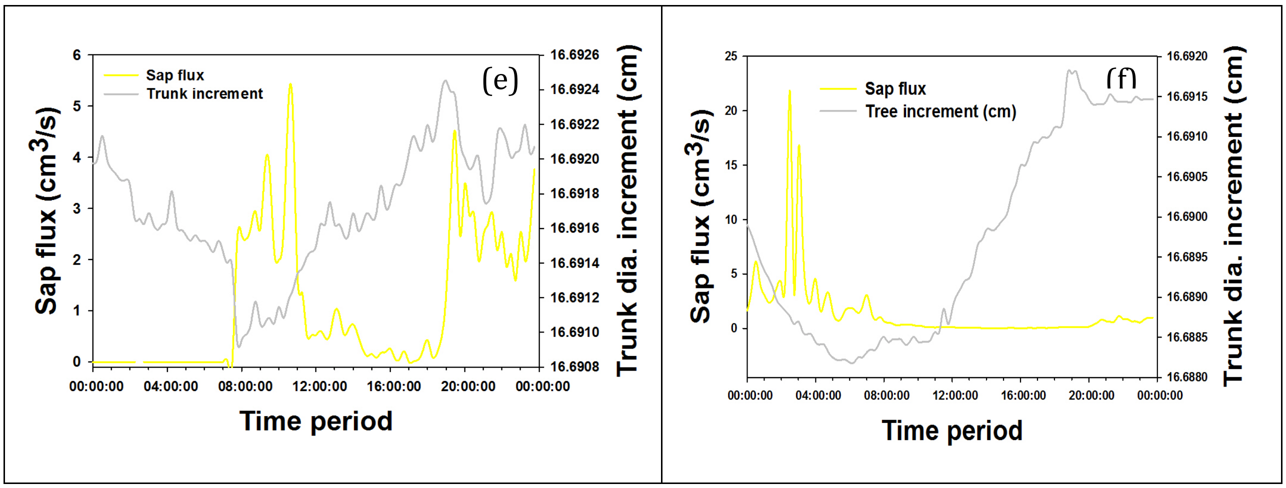


Figure 2.2a-d. Seasonal cumulative daily sap fluxes (a) and normalized seasonal cumulative sap flux based on leaf area (b) at all three sites. Early season (c) vs late season (d) diurnal sap flux values at all three sites.

Sunny **Rainy**



Sunny **Rainy**

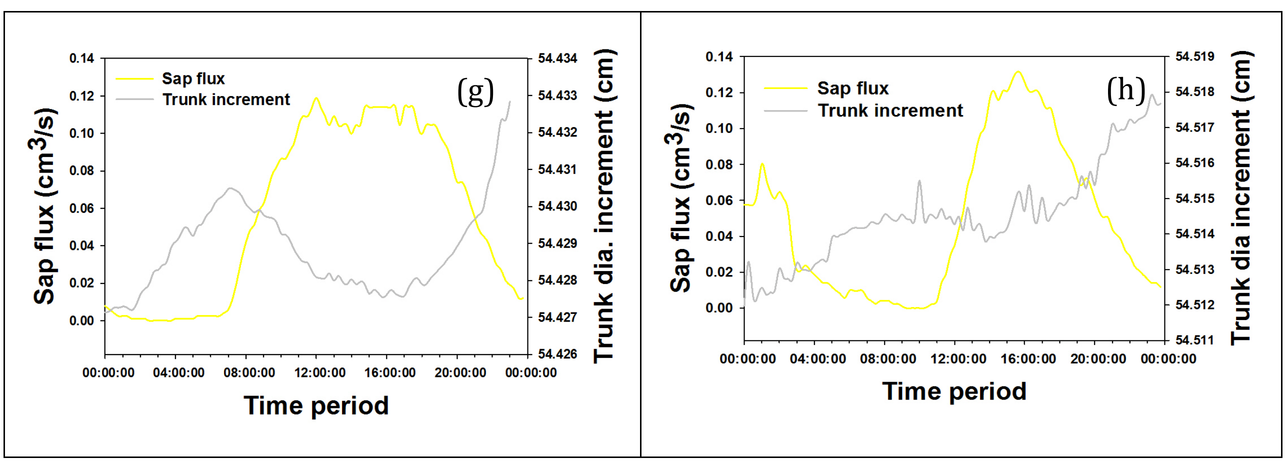


Fig. 2.2 e-h. Diurnal variation in sap flux vs. trunk diameter increment in aspen during sunny days (e) and rainy days (f). Diurnal variation in sap flux vs. trunk diameter increment in Douglas fir during sunny days (g) and rainy days (h).

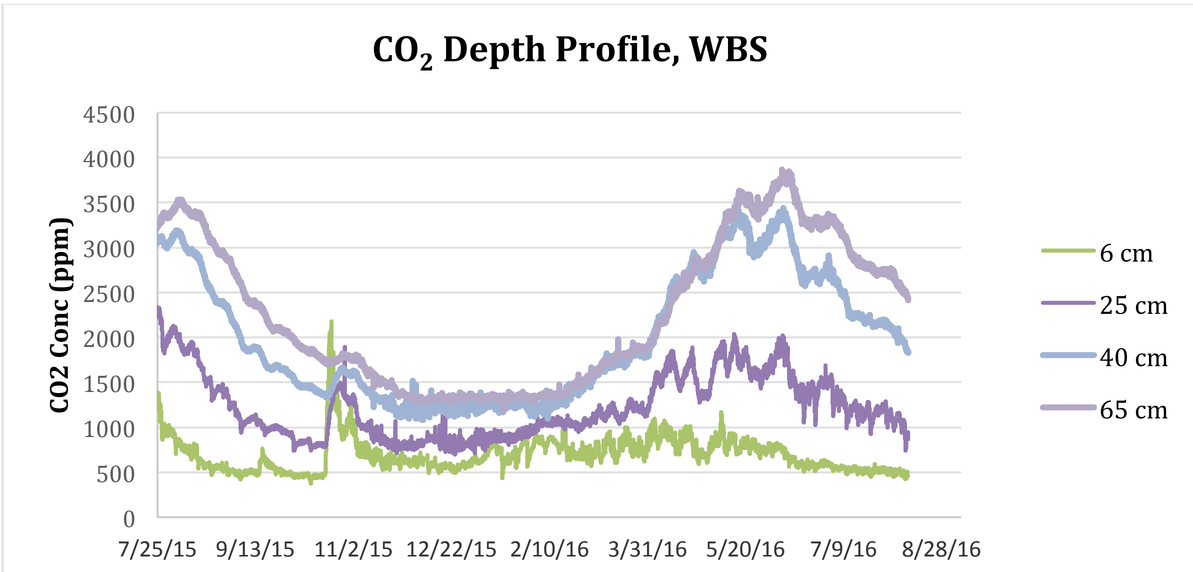


Figure 2.4a The CO_2 profile data represent averages of two sensors at each of four depths. Note the significant pulse of CO_2 on 10/18 in response to rainfall that affected concentrations as deep as 65 cm.

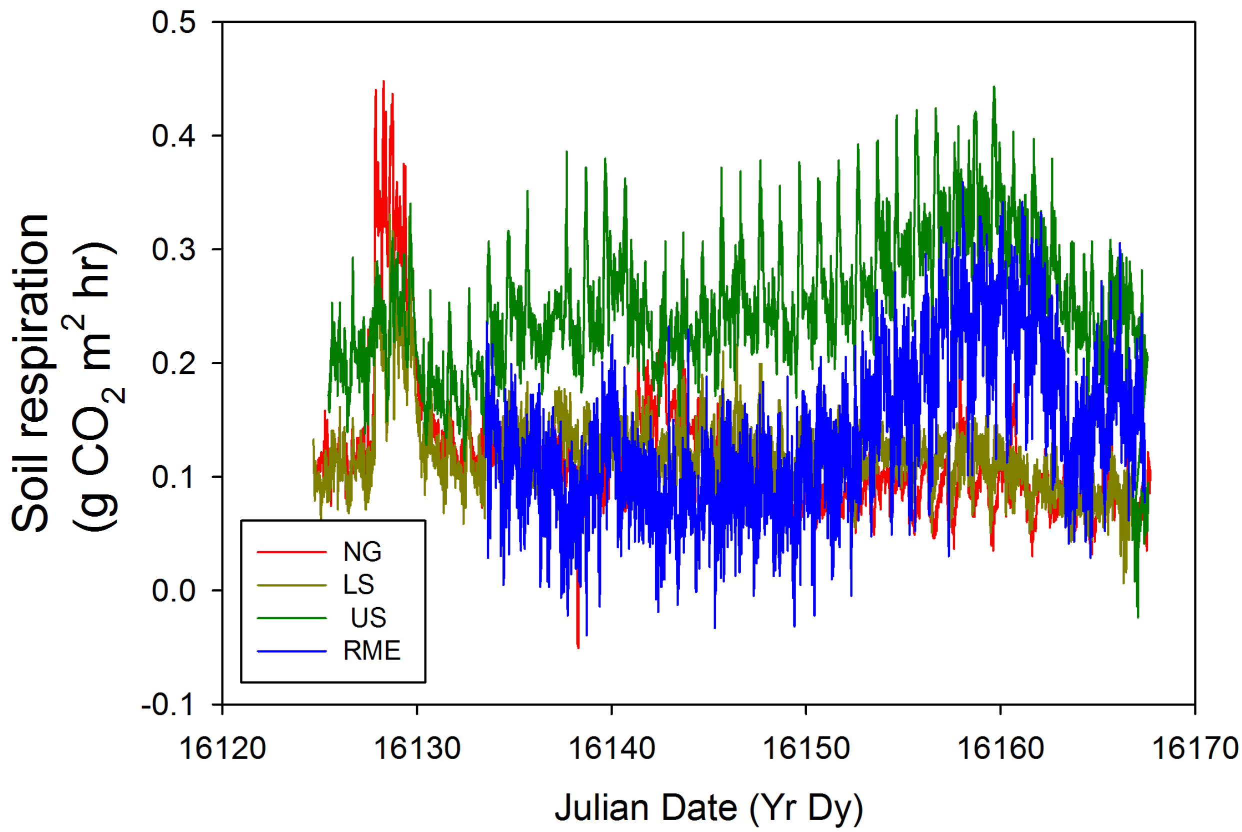


Figure 2.4b. CO_2 efflux measured from automated (every 15 minutes) forced diffusion chambers at core sites showing generally highest fluxes from Upper Sheep (US) compared to other sites likely owing to optimal moisture and temperature conditions.

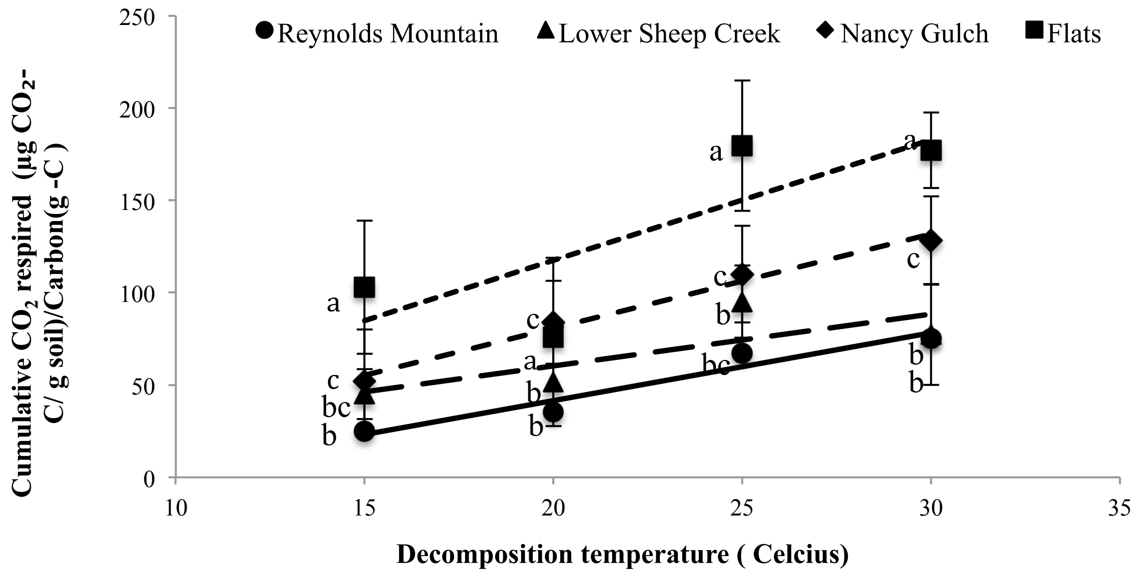


Figure 2.7a. Cumulative CO_2_respired normalized with initial C by day 365 across temperatures and elevations. Values are means ± standard errors (n=5) and letters indicate differences among elevations ($P<0.05$).

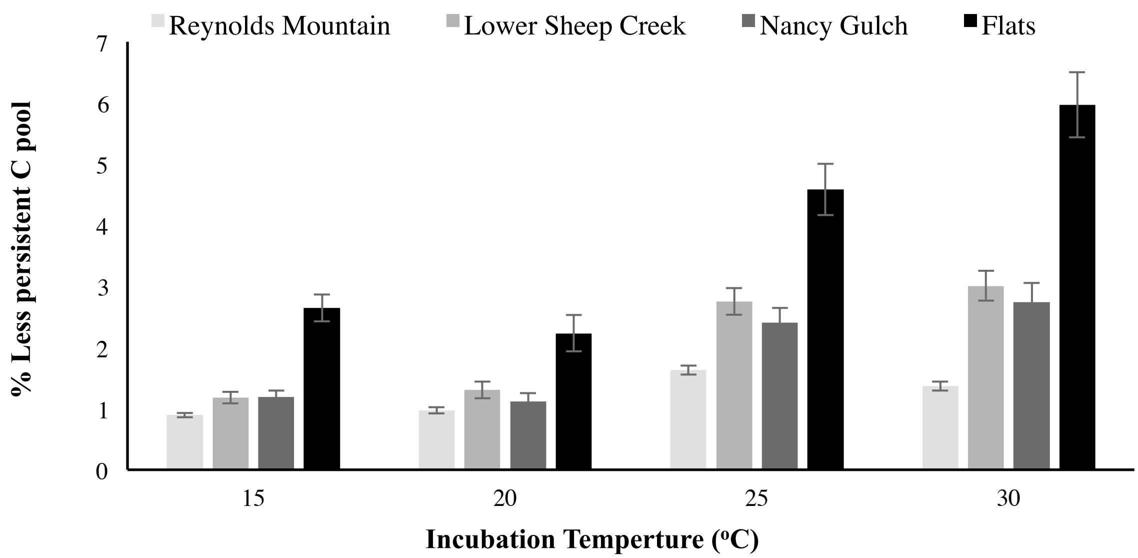


Figure 2.7b. Two pool model parameter estimates for percent less persistent pool across elevations and temperatures derived from respiration data. Error bars indicate standard errors.

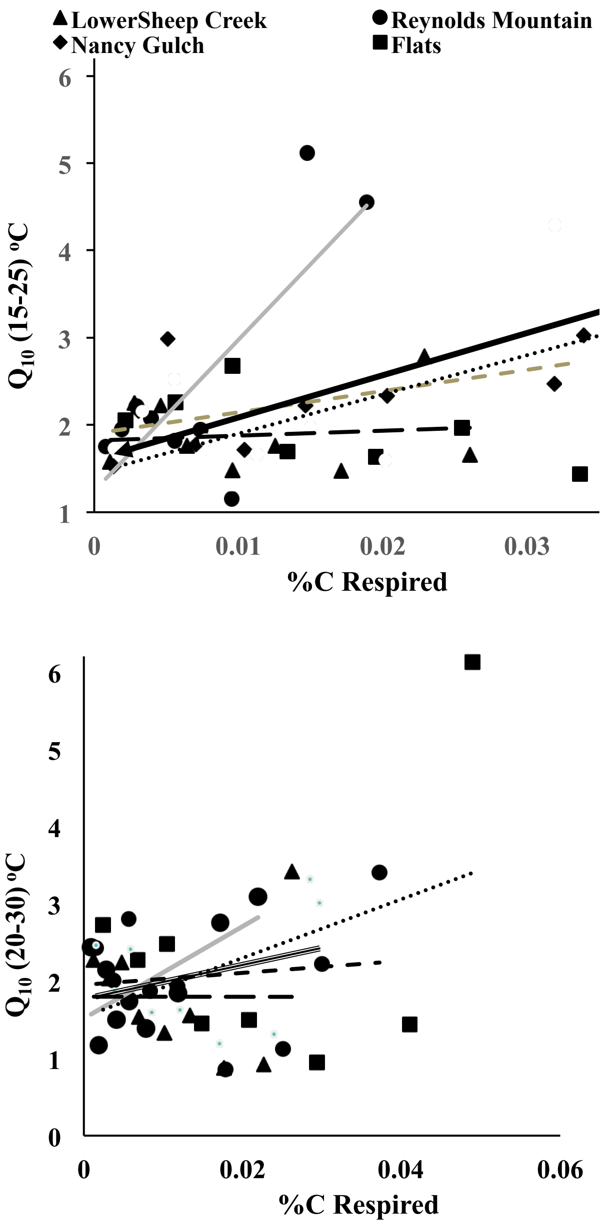


Figure 2.7c. Change in temperature sensitivity with the percent C respired from the initial C content through the incubation for (15-25) °C and (20-30) °C temperature ranges. Average linear relationship between Q_{10} and %C respired across elevations is indicated by the solid black line.

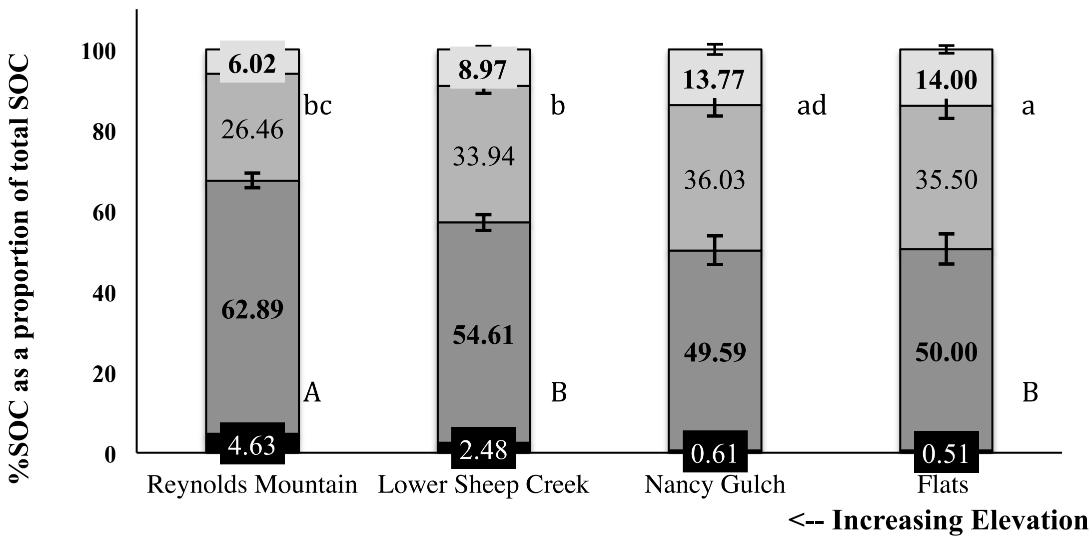


Figure 2.7d. Percent SOC content associated with each fraction across elevations. Lower and uppercase letters denote differences among fine(silt+clay) fraction associated C and uppercase letters denote differences among coarse (POM) fractions associated C.

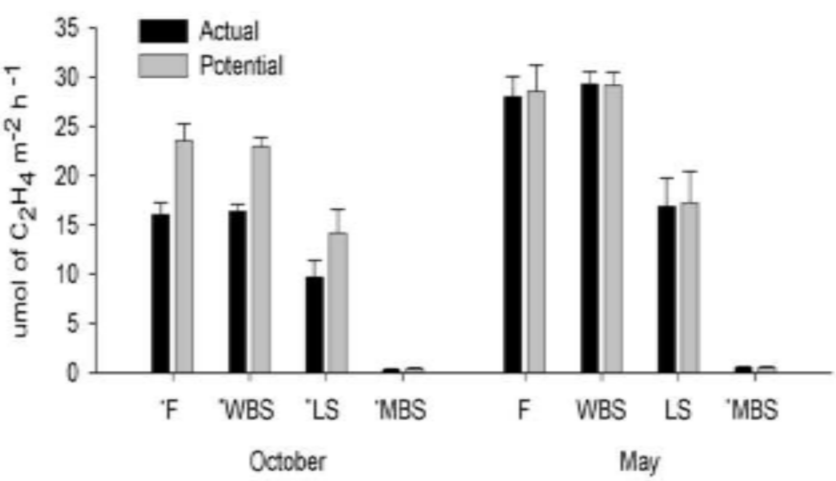


Figure 2.8a. Nitrogenase activity for samples measured at field moisture (actual) and those where water was added (potential) from October 2014 and May 2015. Values are means ± SE. An * shown near the site name on the x-axis denotes significant differences between actual and potential activity based on Wilcoxon Sign ranked test. Sites increasing in elevation are Flats (F), Wyoming Big Sage (WBS), Low Sage (LS), and Mountain Big Sage (MBS).

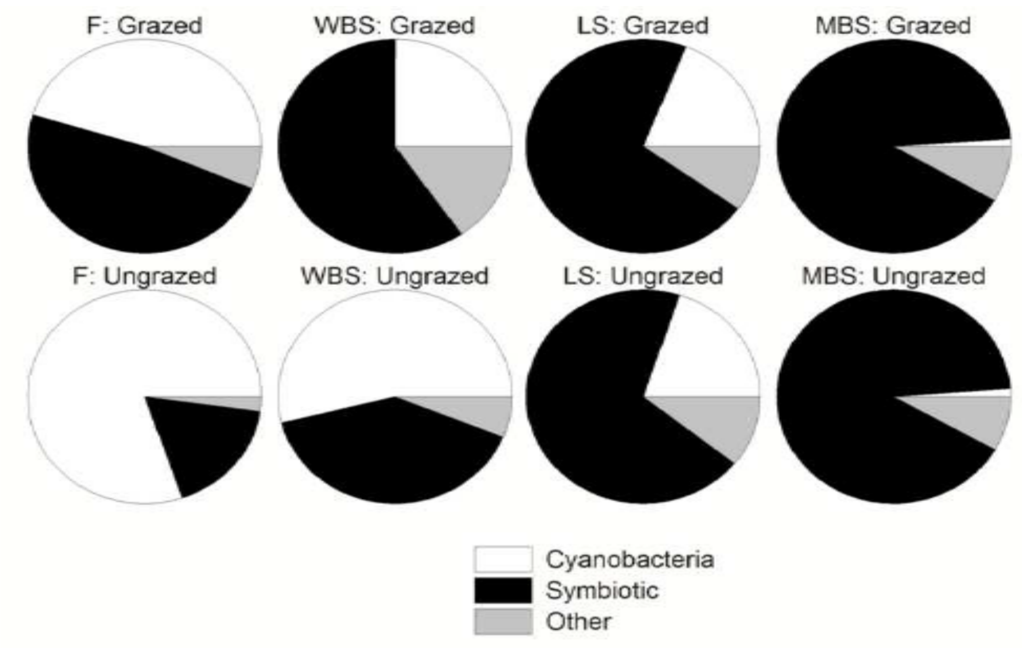


Figure 2.8b. Proportions of the genera grouped into the categories of cyanobacteria, symbiotic, and other N_2-fixing bacteria with respect to grazing and ungrazed samples.

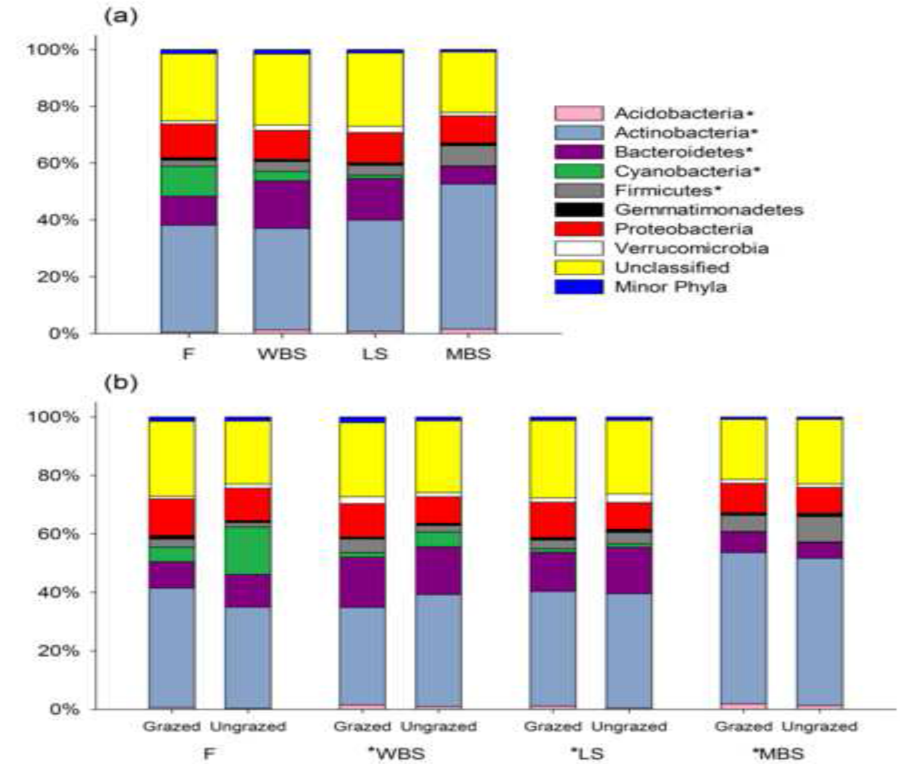


Figure 2.8c. (a) Average percent abundance of phyla at each elevation. * denotes significant differences (P < 0.05) with elevation. Minor phyla of Aquificae, Chloroflexi, Deinococcus-Thermus were also significantly different with elevation. (b) Average percent abundance of phyla by grazing disturbance at each elevation. * denotes significant differences (P < 0.05) in bacterial community between grazing and ungrazed: WBS Nitrospirae and Tenericutes; LS Acidobacteria; and MBS Lentisphaerae and Thermotogae. Site names increasing in elevation are Flats (F), Wyoming Big Sage (WBS), Low Sage (LS), and Mountain Big Sage (MBS)

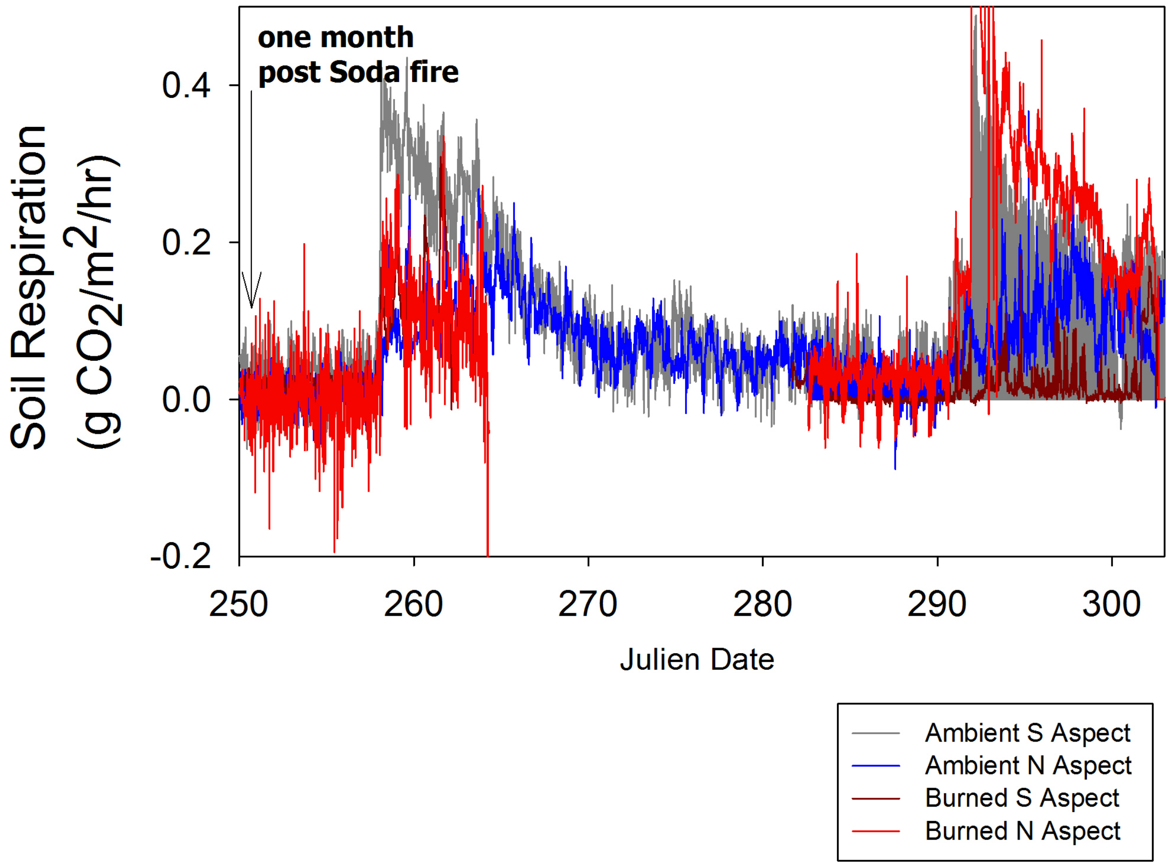


Figure 2.10a: Post-fire soil respiration responses on north and south facing granitic hillslopes showing initial lower fluxes on burn slopes and then elevated fluxes from the north facing slopes three month post-fire compared to others.

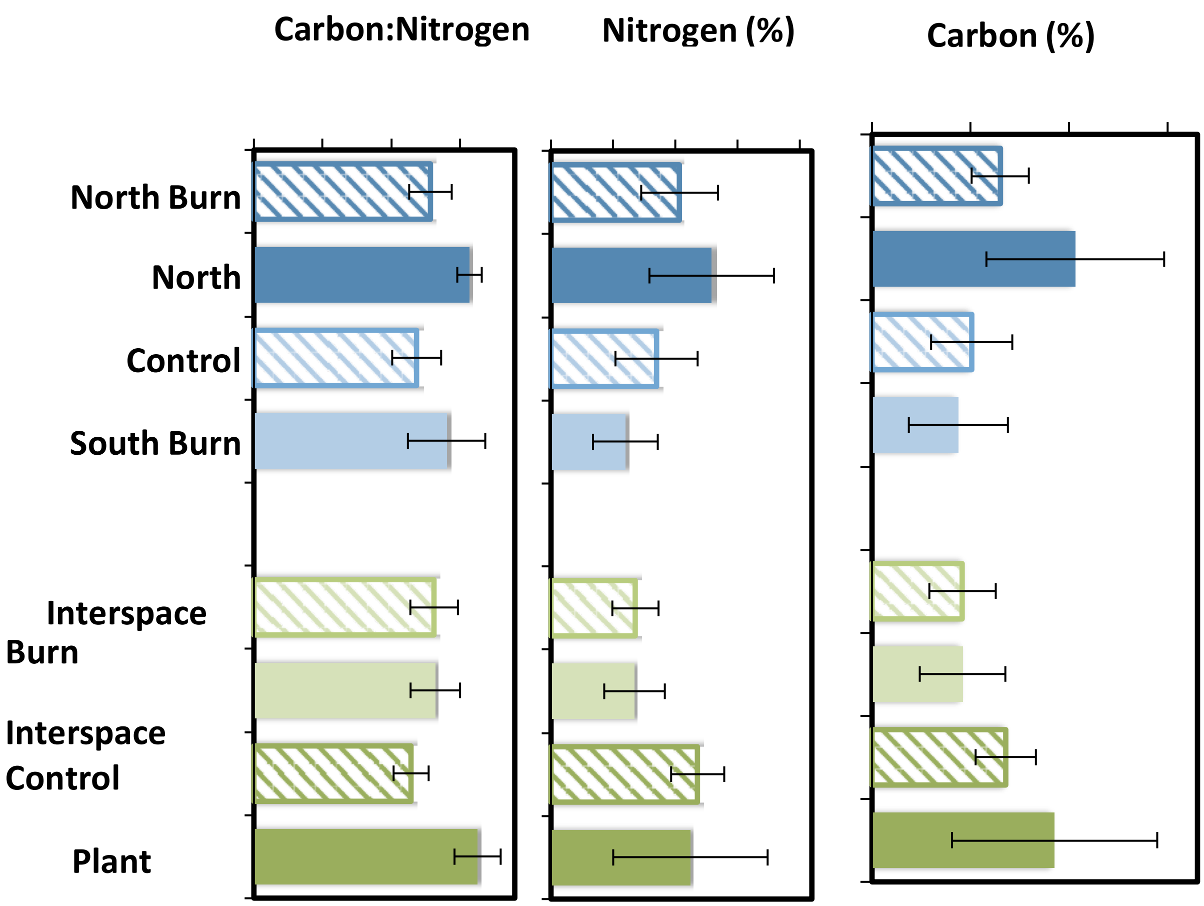


Figure 2.10b: Post-fire soil responses on north and south facing granitic hillslopes show no significant differences in soil C, N and C/N ratios 2 months post-fire.

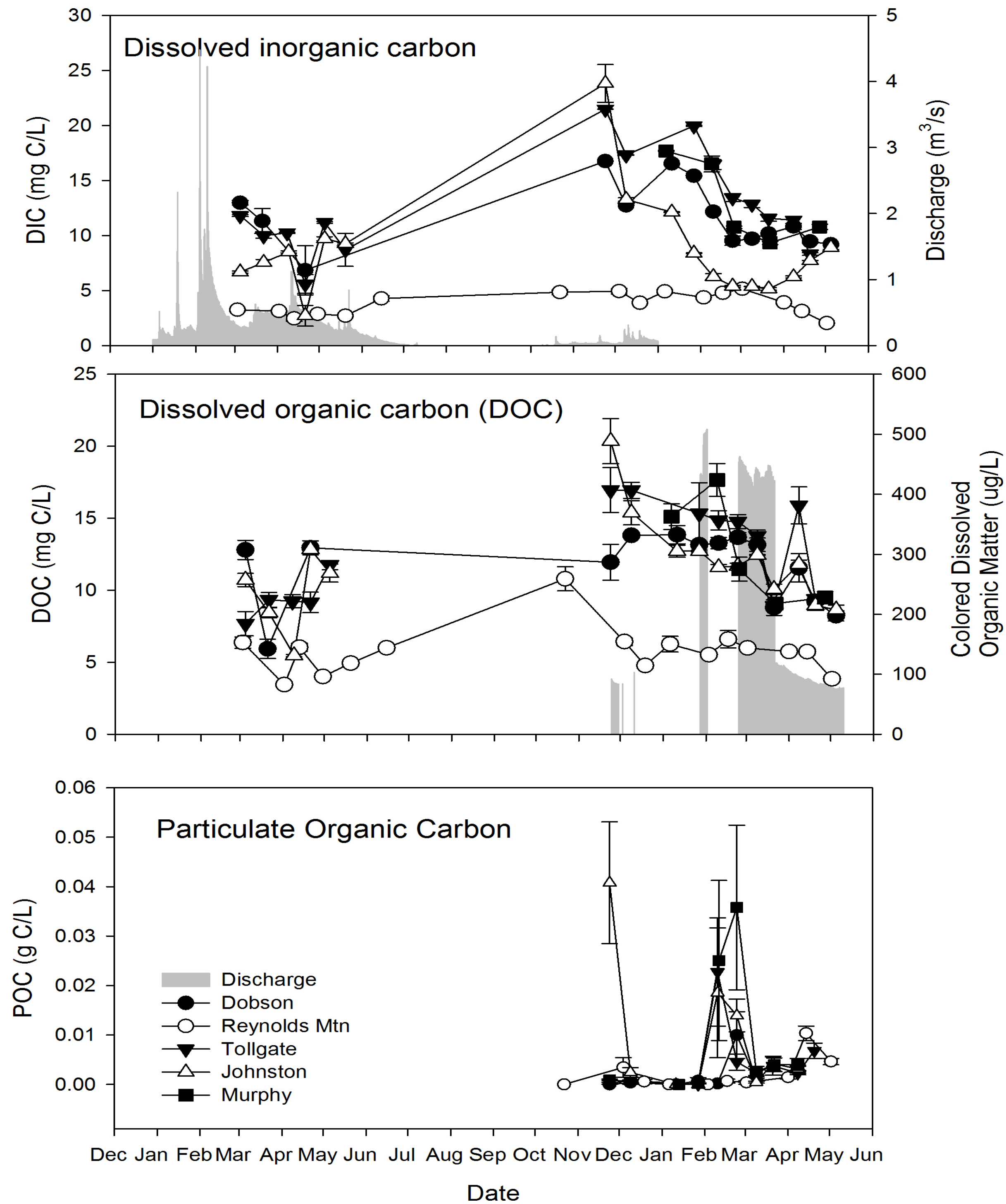


Figure 2.11a. Stream export of dissolved inorganic carbon (DIC) and organic carbon (DOC), and particulate organic carbon (POC) in main stem (Tollgate) and tributaries (Dobson, Reynolds Mountain East, Johnston, and Murphy (burned).

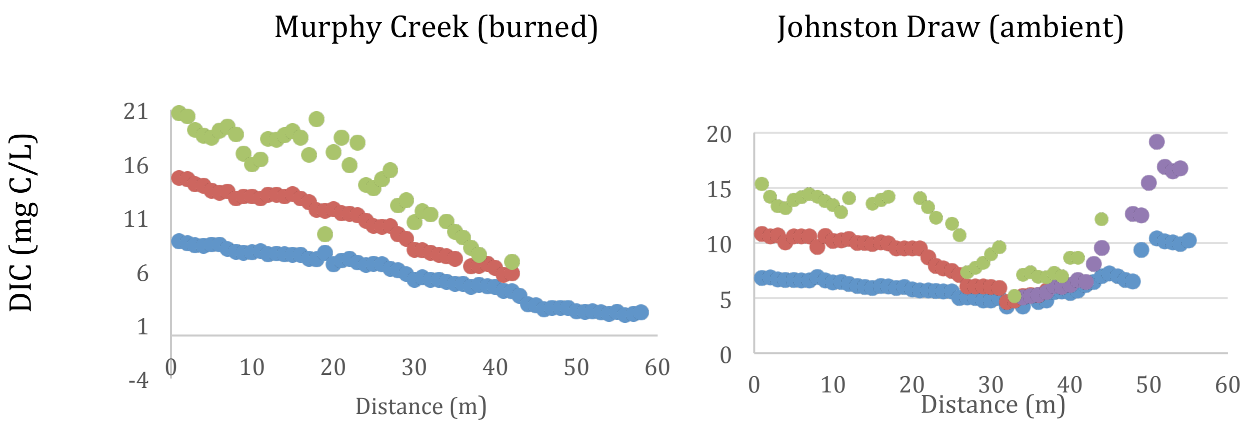


Figure 2.10b. Preliminary results of concentrations of dissolved inorganic carbon (DIC) at Murphy Creek and Johnston Draw at pools located at 50 m increment distances upstream (0 m is weir location) where blue dots indicate samples collected April 2016, red May 2016, and green June 2016. Note increasing concentration of DIC with seasonal drying of stream and opposite longitudinal trends at Murphy and Johnston Draw.

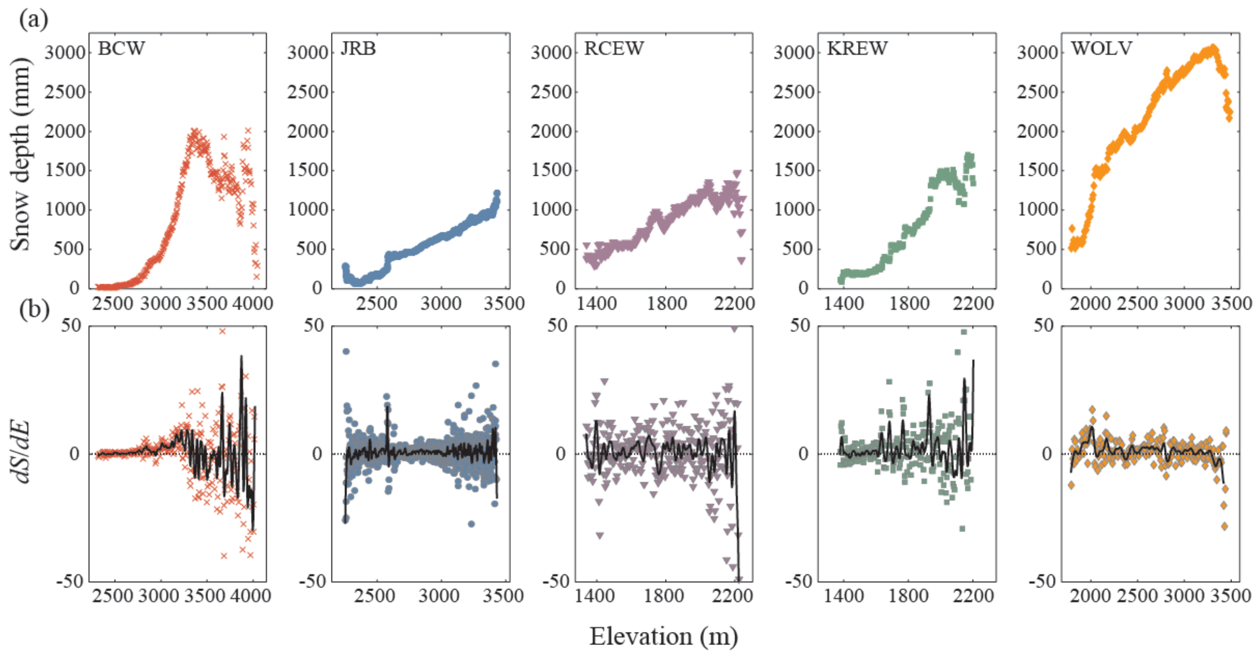


Figure Outcomes 1: Average snow depths plotted against elevation and (b) the derivative of mean snow depth and elevation (dS/dE) for the CZO sites. Snow depth derivatives (symbols in b) were computed using a fourth-order central difference; the black lines are smoothing splines fit to the derivatives to reveal their general trends. All sites experienced increases in mean snow depth with elevation (a). However, rates of snow depth change with elevation were variable and exhibited positive and negative values. The y axes are all set to the same range, the x axes are site specific to better reveal the snow depth-elevation relationships and their derivatives.

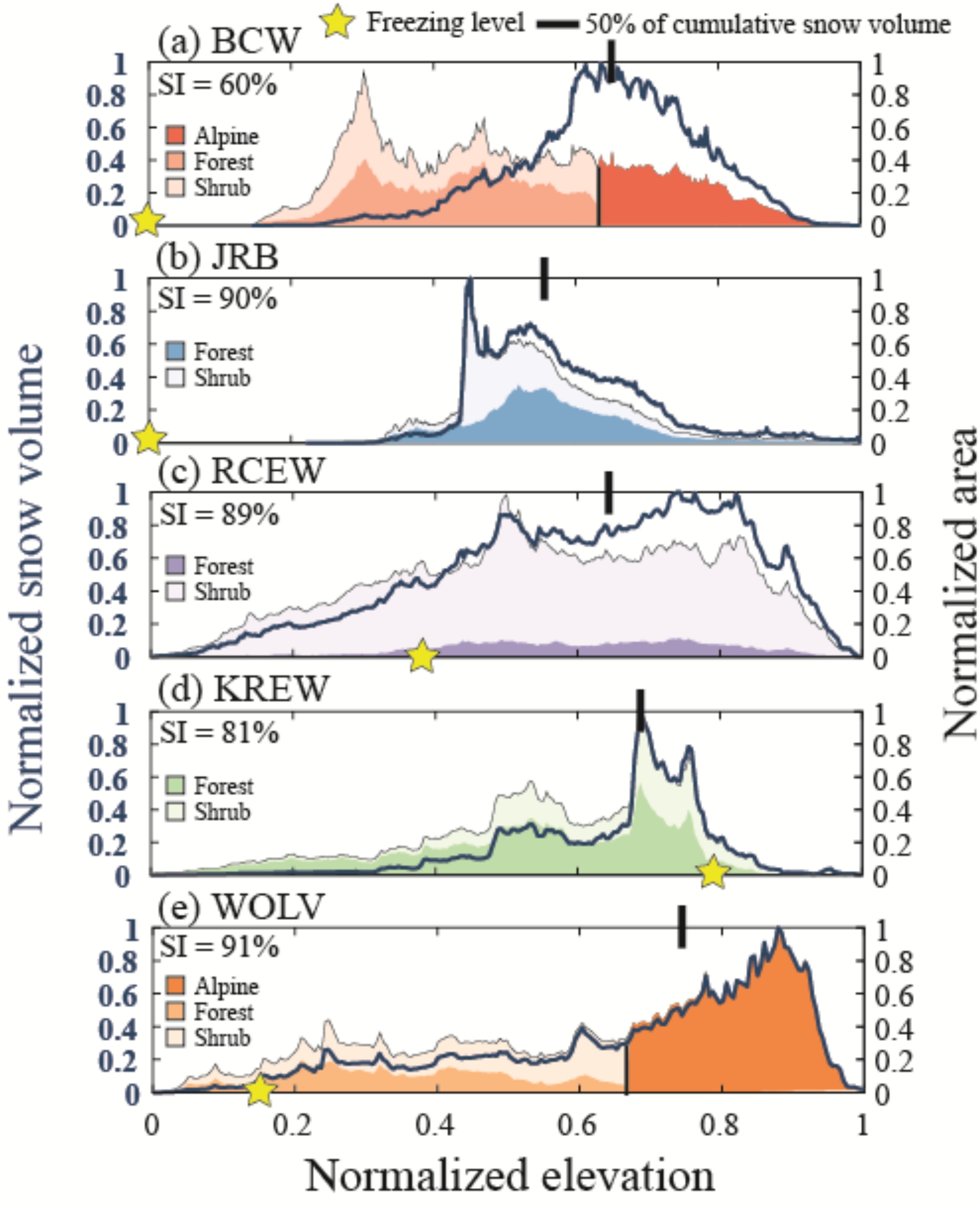


Figure Outcomes 2: Distributions of normalized snow volume, area, and vegetation cover as a function of normalized elevation for the CZO sites (a – e). The proportion of vegetation classes (inset legends), the freezing levels (star; the average elevation of 0°C between November 1 – date of snow-on flight, see Table 1 for flight dates), the elevations of the 50th percentile of cumulative snow volume (thick black vertical line), and the similarity indices (SI) are also plotted for each site. The similarity index (SI) reveals how closely a CZO's area-elevation distribution (thin black lines) matched its snow volume distribution (thick blue lines); a score of 100% would indicate identical distributions. Locations where the snow-volume and area-elevation lines depart show locations where storage was greater or less than expected. To better show the characteristics for each site, the elevation, vegetation, and snow-volume distributions were normalized by their respective elevation ranges (extended to the freezing level elevations for BCW and JRB). For unnormalized values for freezing level elevations and distances between a sites' freezing level and its elevations of 25th, 50th, and 75th percentiles of cumulative snow volume.

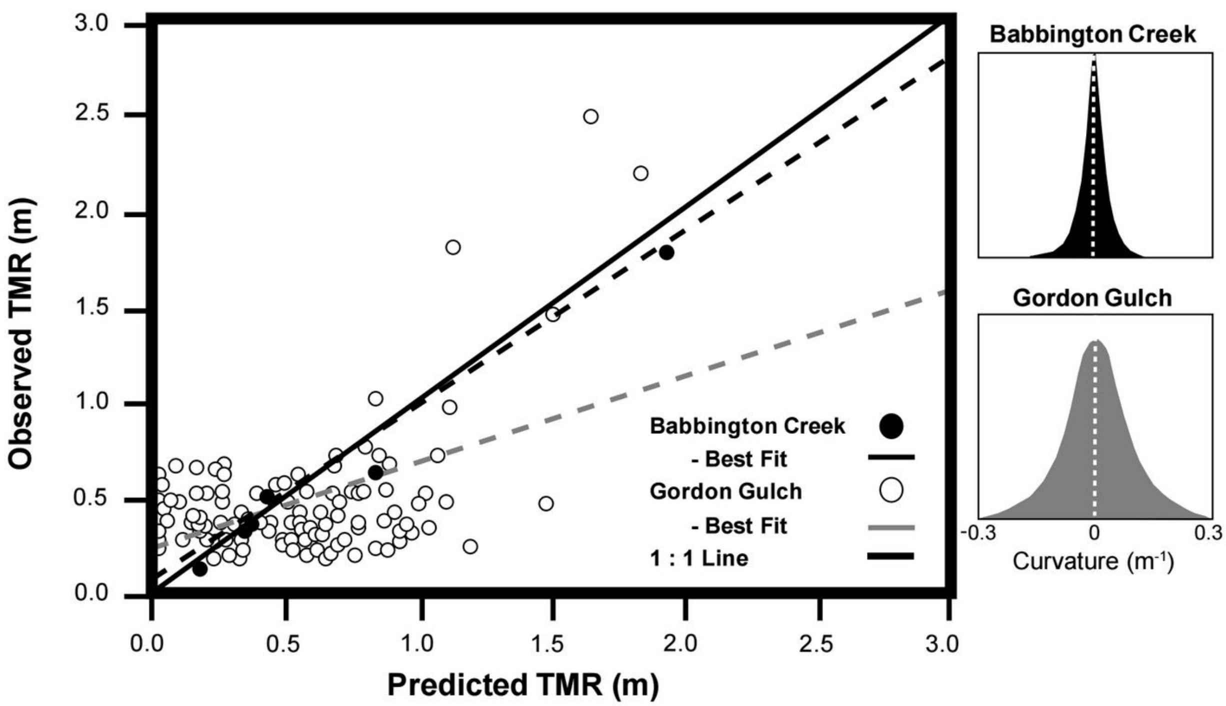


Figure Outcomes 3: Validation of the TMR-curvature approach at Babbington Creek, Idaho and Gordon Gulch, Colorado, USA (BC CZO). Dashed gray and black lines represent best-fit predicted total mobile regolith vs. observed TMR based on curvature calculated from a LiDAR-derived DEM and a single soil pit for Gordon Gulch and Babbington Creek, respectively. The best-fit slope for Babbington Creek is indistinguishable from 1 indicating an unbiased model, whereas the slope was lower than one for Gordon, indicating over-prediction with higher TMR.