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Reynolds Creek Carbon Critical Zone Observatory

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Accomplishments

* What are the major goals of the project?

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 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.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities:

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 focused on analyzing data and publishing products (papers, datasets) for priority 1; six manuscripts and nine datasets were published with DOIs at BSU ScholarWorks (https://scholarworks.boisestate.edu/reynoldscreek/) and linked to criticalzone.org. In particular, we completed a soil carbon model for a subcatchment within Reynolds Creek to estimate the total soil carbon reservoir based on a curvature-soil thickness relationship developed by Patton et al. (2018) and developed a rapid soil carbon method for catchment level SOC that can be determined from one to two soil profiles excavated on planar surfaces (Patton et al. in review). We are completing analyses of soils 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. At the end of yr 5, we started to compile individual studies into a comprehensive SOC dataset that will be completed in the supplement year.

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 focused on completing analyses and publication of products for the environmental monitoring network; sixteen papers and datasets were published in year 5. Three papers from the eddy covariance tower data have been published and three more papers are in review. We continued to maintain the CORE sites as part of the environmental monitoring network: eddy covariance tower measurements, sap flux measurements, tree diameter increment growth using automated dendrometer bands and manual bands, and soil carbon dioxide efflux with forced diffusion chambers and probes. We analyzed soil carbon dioxide ($CO2$) and oxygen concentrations with soil depth at the three CORE sites over the growing season to quantify the spatial variability in these fluxes. We analyzed sap flux data and completed analysis leaf- to ecosystem-level ecophysiological measurements to scale up plant level measurements and submitted two manuscripts for peer review. We continued to analyze soil samples at 1, 2, 3 and 6-month post-burn intervals on different aspects in response to the Soda Fire and incorporated this into a class project. Finally, we completed analyses examining the long-term effects of experimental manipulations of precipitation and vegetation as well as soil thickness on soil carbon and nitrogen storage dynamics in a semi-arid ecosystem.

We continued to optimize our measurement of stream export of particulate and dissolved organic and inorganic carbon samples during the spring and summer of 2018. We are completing analyses of 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. We completed analyses examining groundwater contributions to stream runoff and carbon export in Reynolds Mountain East subwatershed and submitted a manuscript on this project. In collaboration with Godsey CAREER grant, we initiated a project examining sources of spring water in the RC CZO using isotopes of water and strontium (Sr) and other dating tools.

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 completed production of model forcing data set for Reynolds Creek to include incoming solar radiation, thermal radiation above and below canopy, snow water equivalents and surface water inputs (SWI) (includes snowmelt leaving the bottom of the snowpack and rain falling directly on the soil) at 50 m resolution across the watershed and 10 m resolution for Reynolds Mountain East. We re-processed all climate forcing model data from Kormos et al. (2016) to produce data point at hourly time steps over 31 yr period for each 10 m pixel across 239 km2 to be enable parallel computing. These data are being published as new DOI for the modeling community.

We completed runs of BIOME BGC at point scales to understand the importance of heterogeneously distributed snow water to aspen communities. Preliminary run of BIOME BGC across the entire watershed is projected to be completed by end of year 5 with re-processed forcing data set. Specifically, Biome-BGC model is being used to simulate the distribution of SOC at a spatial resolution coincident with the fine-resolution forcing data. These activities were initiated in Yr 4 and Biome-BGC runs are expected to be completed at the end of Yr 5. We completed simulations using Ecosystem Demography (ED) model to develop PFTs for the watershed. Finally, we continued to develop an instance of an advanced ecohydrologic model, ParFlow, which can resolve hillslope-scale redistribution of moisture, as well as surface water-groundwater interactions and, potentially, the influence of deeper-CZ structure on land-atmosphere exchange.

Year 5 highlighted Reynolds Creek CZO as a testbed for the modeling community. Downloads of RC CZO Ameriflux eddy covariance tower data of shrubland sites by modelers exceeded 150 per site (~600 total) as of September 2018. Reynolds Creek CZO continued to work in partnership with terrestrial ecosystem modelers at the University of Montana (Renwick et al. in review), apply the reactive transport version of the Pennsylvania Integrated

Hydrologic Model (RT-PIHM) for cross-site experiments being led by Li Li (Penn State University), 4) collaborate with IML CZO scientists using EC tower data from RC CZO (Goodwell et al. 2108). We continued to engage with colleagues in the CZO, LTER, NEON, and CSDMS communities to build a community of practice organized around modeling. Two cross CZO modeling workshops were conducted and paper published on this topic (Baatz et al. 2018). Two proposals to improve computing and soil development modeling frameworks were funded.

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

Submit soil carbon and other property datasets with DOIs and prepare manuscript on analysis of soil organic carbon-vegetation associations using vegetation indices from remotely sensed as well as airborne LiDAR and hyperspectral data.

1.2 Mobile Regolith and Bedrock Mapping

Publish manuscript quantifying the relationships between total mobile regolith depths and different topographic variables in a granitic watershed and balsalt watersheds in Reynolds Creek and map soil depth. Complete evaluation of generality of relationships between soil depth and curvatures across sites available from global dataset (including JRB and BC CZOs). Complete analyses on seismic refraction dataset in Johnson Draw to investigate variations in deep weathering depth as a function of elevation and aspect and prepare this manuscript for submission.

1.3 Topographic controls on carbon storage

Submit manuscript quantifying the relationship between measurable local topographic features and soil depth to improve estimation of deep soil carbon across complex terrain. Complete revisions of manuscript on soil bulk density relationships for felsic and mafic materials to estimate bulk density from SOC and SOM where bulk density measurements are not available.

1.4 Climate and Geologic Controls on soil inorganic carbon (SIC)

Revise analyses and maps of 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.

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)

Maintain eddy covariance (EC) and heat flux sensors at 4 CORE sites and establish presence on Ameriflux Network. Complete analyses and resubmit manuscript on first 2-3 years of water and carbon fluxes along climate gradient. Submit manuscript on a subset of 2002-2010 net ecosystem exchange data associated with 4 EC towers in upper portion of catchment. Incorporate phenology routines into Dynamic Global Vegetation Models (DGVM) to examine how uncertainty in key parameters as well as the structure of existing phenology routines influence the ability of a DGVM.

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. Analyze first two years of sap flux data at three sagebrush CORE sites and publish datasets and submit manuscript.

2.3 Plant ecophysiology

Revise analysis and resubmit manuscript on leaf- to ecosystem-level physiological measurements of carbon and water fluxes to scale plant level water measurements to ecosystem scale.

2.4 Soil Respiration

Maintain and analyze eight Vaisala CO_2 sensors along with soil temperature and moisture sensors at the CORE sagebrush sites. Estimate net CO_2 flux from the soil based on measured gas concentration gradients and porosity and to determine depths of CO2 production in the soil. Maintain and analyze automated Forced Diffusion (FD) chambers at CORE sites to measure soil CO2 effluxes. Continue manual measurements of soil CO2 effluxes at CORE sites to capture spatial heterogeneity of soil respiration.

2.5 Aboveground Biomass and Net Primary Productivity

Evaluate lidar waveform features and classification performance of six major PFTs, including shrubs and trees, along with bare ground. Continue diameter increment growth measurements with Treehugger automated dendrometers and install manual dendrometer bands at tree sites.

2.6 Soil Carbon Dynamics and Microbial Profiling

Analyze soils collected 1,2, 3, 6 month following the Soda fire to evaluate losses and changes in potential mineralizable carbon and changes in texture. Complete and submit manuscript evaluating sensitivity of SOC pools to decomposition in response to temperature changes.

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

Analyze microbial communities associated with N fixation across two dates (using 16-S RNA analysis) across the watershed elevation gradient. Collaborate with cross-CZO related microbial data (Aronson et al).

2.8 Near surface soil moisture and critical zone structure using geophysics

Complete analyses 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.

2.9 Watershed Wildfire Responses

Complete analysis of dust, erosion, and water samples within burned catchment (Murphy Creek). Analyze sediment and POC exported following fire in Murphy Creek. Submit manuscript on productivity and respiration responses of montane sagebrush ecosystem to prescribed fire.

2.10 Stream Export

Complete study of water and DOC sources in montane headwater catchments. Analyze second year of data collected on fine-resolution spatial and temporal variability in stream chemistry in drying intermittent streams. Analyze sediment and particulate organic carbon (POC) export from five subcatchments in RC CZO and hindcast 25 yrs POC record from sediment and determine the response to fire. Re-analyze dissolved organic carbon and analyze anions for 2016-2018 collections.

2.11 Long-term experimental manipulations of precipitation, vegetation, and soil thickness

Complete analyses and submit manuscripts 1) evaluating the long-term (20 yrs) effects of experimental manipulations of water and vegetation type on soil inorganic and organic carbon storage in a semi-arid ecosystem and 2) evaluating the role of soil depth in controlling storage of water, carbon and nitrogen in sagebrush steppe ecosystem receiving experimentally augmented precipitation.

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

Publish data paper on 31-year record for relative humidity, air temperature, dew point, precipitation amount, and the precipitation phase and publish data paper. Complete analysis of incoming solar radiation, thermal radiation, and snow water equivalent to complete dataset for ecosystem modeling and publish dataset. Reprocess forcing data at 10 m point scale at hourly time step for 31 yrs for enable parallel computing.

3.2 Modeling the Spatial Distribution of Soil Organic Carbon

Initiate BIOME BGC runs using 31 yr forcing data set and compare predicted against observed soil carbon distribution. Apply an ecosystem dynamic model, Ecosystem Demography (ED2) to develop and parameterize a sagebrush shrubland Plant Function Type (PFT) for use in the ED2 model, which will support future studies to model estimates of GPP under different climate and management scenarios.

3.3 Integrated Hydrologic Modeling in Reynolds Creek

Continue implementation of a suite of numerical experiments that examine the role of the deeper CZ in supporting terrestrial vegetation during periods of extended drought using ParFlow.

3.4. The Reynolds Creek CZO as a Community CZ Modeling Platform

Use Reynolds Creek datasets to engage community CZ modeling.

3.5 Engaging with the Broader Integrated Modeling Community

Engage with colleagues in the CZO, LTER, NEON, and CSDMS communities to build a community of practice organized around modeling.

Significant Results:

Priority 1: Landscape Soil Carbon Survey

1.1 Soil organic matter-vegetation associations

Soil bulk density, SOC and SOM data across the Reynolds Creek CZO were published at BSU ScholarWorks (Patton et al. 2018a). Soil hydraulic properties and characteristic curves were published at BSU ScholarWorks (Murdock et al. 2018). Other soil properties across all of the RC CZO were also published at BSU ScholarWorks (Patton et al. 2018b-e).

1.2 Mobile Regolith and Bedrock Mapping

A strong positive linear relationship was observed between mobile regolith thickness (TMR) and hillslope curvature ($r2=0.89$) and a predictive map of TMR in Johnston Draw was produced (Figure 1.2a) (Patton et al., 2018) and a simple model developed to predict soil thickness at any location within a catchment with fine resolution data and a few soil measurements (see Key Outcomes). This model was used to develop a predictive map in Reynolds Mountain East (Fellows et al. 2018) (Figure 1.2b)

1.3 Topographic controls on carbon storage

Total profile soil carbon varied with aspect and strongly and linearly with hillslope curvature if the entire soil vertical dimension was determined ($r2=0.91$; Figure 1.3a, Patton et al., in review, Patton 2016). This model allowed estimation of spatial distribution soil carbon at the catchment scale at fine resolution (3m) (See Key Outcomes). 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 1.3b) and validated (Patton et al., in review).

1.4 Climate and Geologic Controls on Soil inorganic carbon (SIC)

Maps were revised (Figure 1.4) showing climate control on SIC accumulation, with the mean annual precipitation of 500 mm as the threshold (Stanbery et al., in review).

Priority 2: Environmental Monitoring Network

2.1 Net Ecosystem Exchange (EC Towers)

Annual precipitation does not explain cumulative growing season GEE at upper elevation sites. Rather, sagebrush Gross ecosystem exchange (GEE) varies with spring and summer rain and aspen GEE responds to spring snowpack conditions (Fellows et al., 2018) (Figure 2.1a). Sagebrush steppe ecosystems are carbon sinks for carbon in wetter years (WY 2016) compared to drier years where sites switch from slight sources to carbon sinks at higher elevation (WY2015) (Flerchinger et al., in review). Dry-season rainfall pulses result in increased connectivity from soil and atmospheric variables to heat and carbon fluxes (Goodwell et al. 2018) (Figure 2.1b). The largest gains in DGVM model performance were associated with the development of a new representation of phenology (Renwick et al. in review).

2.2 Transpiration (Sap Flux Sensors)

Among sagebrush sites, monthly sap flux was greater at WBS site followed by MBS and LS, except during June and July in 2016. Among years, greatest sap flux was observed in 2017 followed by 2015 and 2016 (Figure 2.2).

2.3. Plant ecophysiological ecology

Seasonal variation in NEE and ET differed among sagebrush communities, with plant-scale NEE and ET measurements greater at the highest elevation (snow-dominated) site for the growing period (Figure 2.3a) (Sharma et al., in review). Leaf water potential was significantly different between WBS and MBS in June and August (Figure 2.3b). A.t. wyomingensis at WBS has less stomatal regulations (i.e. anisohydric type behavior) in contrast to isohydric behavior shown by A.t. vaseyana at MBS (Figure 2.3c).

2.4 Soil Respiration

Whereas concentrations of carbon dioxide were observed to be high at depth as shown at WBS (Figure 2.4a), fluxes were much higher at surface than deep horizons (Figure 2.4b).

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

Small-footprint waveform features can be used to characterize the heterogeneous vegetation in RC CZO and similar semi-arid ecosystems at high spatial resolution (Figure 2.5)(Ilangakoon et al 2018).

2.6. Soil Carbon Dynamics and Microbial Profiling

Sand fraction decreased following fire (FIgure 2.6a). Potential carbon mineralized was significantly lower post-fire than unburned soils (n=64) (Figure 2.6, Lohse et al. in progress).

Sand was the best predictor of temperature sensitivity (Q10) sensitivity to SOC loss suggesting accessibility rather than recalcitrance determines sensitivity to SOC loss (Delvinne et al. in review).

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

Cross site CZO samples are being analyzed

2.8 Near surface soil moisture and critical zone structure using geophysics

Analyses indicate high spatial heterogeneity in water flow and distribution over the 7x8 m plot scale. However, distribution over time appears relatively stable (Nielsen 2017, Nielsen et al., in preparation).

2.9. Watershed Wildfire Responses

Wildfires in New Mexico had the effect of homogenizing initial pyrogenic C differences among soil horizons and watersheds within the burn perimeter (Galanter et al. 2018) (Figure 2.9a). Dust and PyC deposition from the Soda Fire in RC CZO was greatest in the fall (Roehner 2018, Roehner et al. in preparation) (Figure 2.9b). Particulate organic carbon (POC) from the burned watershed (Murphy) is 5-20 times higher than background concentrations and decline one year following fire (Figure 2.9c). GEP recovers rapidly following prescribed fires in montane sagebrush ecosystems (Fellows et al. 2018) (Figure 2.9d).

2.10. Stream Export

Multiple subsurface regions in the catchment appear to contribute differentially to streamflow as the season progresses; Sources of DOC shift from the saprolite/bedrock interface to deeper bedrock aquifers from the snowmelt period into summer (Radke et al. in review, Figure 2.10a). Particulate organic matter (POM) and suspended sediment in streams are highly correlated and vary with scale (Figure 2.10b) (Glossner et al. in progress). Semivariograms show increases variability of DIC with stream drying in both burned and unburned stream (indicated by higher sill) (Figure 2.10c) (Macneille et al., in progress).

2.11. Long-term experimental manipulations of precipitation, vegetation, and soil thickness

Sagebrush communities may become a net C source with increased dormant season rainfall rather than a C sink as previously predicted. Consideration of both organic and inorganic C pools through soil profile were critical to findings (Figure 2.11).

Priority 3: Integrated Modeling Framework:

3.1 Fine-Resolution Forcing Data

A data paper on the fine-resolution, spatially explicit, forcing model input data from historic climate datasets was published (Kormos et al., 2018). Solar radiation differs if in open, under canopy or above canopy (Figure 3.1a) and snow water equivalent and surface water inputs vary (Figure 3.1b). We re-processed all climate forcing model data from Kormos et al. (2016) to produce data point at hourly time steps over 31 yr period for each 10 m pixel.

3.2 Modeling the Spatial Distribution of Soil Organic Carbon

BIOME BGC runs are in progress and will be completed in supplemental year of funding.

3.3 Integrated Modeling in Reynolds Creek

BIOME BGC simulations at three sites within RC CZO that included wind-redistributed snow resulted in NPP values nearly 77% higher than simulations assuming uniform precipitation (Soderquist et al. 2018 (Figure 3.3a). Incorporating allometric relationships and parameter optimization methods, ED model results showed reasonable fidelity to observed values with some negative biases (Figure 3.3b). Instance of ParFlow at Reynolds Mountain East are in progress (Figure 3.3c)

3.4. The Reynolds Creek CZO as a Community CZ Modeling Platform

Reynolds Creek CZO served as a platform for at least 4 externally engaged modeling activities

3.5 Engaging with the Broader Integrated Modeling Community

Two cross CZO modeling workshops were conducted in yr 5 to build a community of practice organized around modeling (Baatz et al. 2018).

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   Unique benchmark datasets document temperature increases and shifts in the snow to rain transition with elevation at Reynolds Creek CZO over the past 30 years (Kormos et al. 2018) and a dataset in Johnston Draw, a subwatershed in Reynolds Creek, documents this in finer detail (Godsey et al. 2018). These are available to the broader modeling community through data publications and DOIs (Kormos et al., 2016, Kormos et al. 2017, Godsey et al. 2018).

Mobile Regolith and Bedrock Mapping   Soil thickness is a key but uncertain variable in the critical zone and thus hydrologic, carbon, and landscape evolution models. We showed that there is a strong positive relationship between hillslope curvature and soil thickness (r2 =0.87) in a small granite catchment in the RC CZO (Patton et al., 2018). Similar positive relationships exist across a cross-site dataset, although the slopes and intercepts vary. The slopes of these functions vary with the spread in the catchment curvature distributions as measured by the standard deviation (Key outcome Figure 1). Based on these findings, we developed 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 and validated this on three separate datasets (Patton et al., 2018). Simple methods for predicting thickness will accelerate improvements in estimates and modeling of soil carbon and other critical zone properties like plant available water (Fellows et al. 2018). This method is available to advance science (Patton et al. 2018); a US utility patent of this method was also obtained (Lohse et al. 2018).

Landscape carbon survey Much uncertainty in soil carbon budgets stems from distributing soil carbon across complex terrain where soil depth is largely unknown. We found total profile soil carbon to vary with aspect and vary strongly and linearly with hillslope curvature if the entire soil vertical dimension was determined ($r2=0.91$) (Patton et al. in review a). This model allows estimation of soil carbon at the catchment scale at a 3 m resolution (Key Outcome Figure 2). Convergent areas had 6.4 times more total SOC per area compared to divergent areas whereas north-facing aspects had 3.0 times more total SOC per area than the south-facing aspects. Soil organic carbon below 0.3 and 1 m depth was > 80 and 30 % of the total catchment SOC indicating substantial underestimation of SOC stocks if sampled at shallower specified depths. 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; Patton 2016). Models predicting soil bulk density (BD) from SOC and soil organic matter (SOM) for felsic and mafic materials across the watershed allow missing BD data to be estimated (Patton et al. in review b). Collectively, these findings support our overarching hypothesis that soil thickness and bulk density measured and modeled at the pedon to watershed scale will improve our understanding and prediction of soil carbon storage and processes governing it.

Understanding processes controlling carbon storage We linked soil thickness mapping (described above) and structure to gross ecosystem exchange (GEE) and showed that GEE is under the control of critical zone structure (depth, structure, texture) by determining plant available water storage (Fellows et al., 2018). These findings again support our overarching hypothesis that measuring and modeling soil properties such as thickness at the pedon to watershed scale will improve our understanding and prediction of the processes governing soil carbon storage.

Recent studies point to the dominance of semi-arid regions in upward trend and interannual variability in CO_2 uptake at global scale (Ahlström et al. 2015) but much uncertainty surrounds the mechanisms controlling these patterns. Because the RC CZO eddy covariance (EC) towers has sites located along a climate gradient and are some of the only available semi-arid shrubland types on Ameriflux, these data have been a magnet for modelers (>700 downloads to date) and new measurements. Using the EC towers, we show that montane sagebrush ecosystems are large carbon sinks (150 g/m2) and lower elevation carbon uptake determined by annual water storage (Flerchinger et al., in review, Sharma et al. in review, Fellows et al 2018). Collaborative modeling efforts have shown dry-season rainfall pulses increase connectivity with soil and atmospheric variables (Goodwell et al. 2018) (See Figure 2.1b). Both DGVM and ED2 models indicate representation of phenology for shrublands is critical for predicting carbon update (Renwick et al. in review, Pandit et al. in review).

Understanding whether the critical zone is a source or sink of carbon requires requires quantifying lateral export of carbon in addition to exchange with atmosphere (Perdrial et al. 2018). Export in Reynolds Creek is dominated by POC with smaller contributions as DOC and DIC. In the mixed mafic headwater catchment, the Reynolds Mountain East, we are showing that multiple subsurface regions in the catchment appear to contribute differentially to streamflow as the season progresses. Unlike most studied catchments, lateral flow of this year's soil water is not a primary source of streamflow. Instead, saprolite and groundwater act as integrators of soil water that flows vertically in this system. Our results do not support the flushing hypothesis as observed in similar systems and instead indicate that temporal variation in connectivity may cause the unexpected dilution behavior displayed by DOC in this catchment (Radke et al. in review) (See Figure 2.10a).

Experimental manipulations of temperature, precipitation, vegetation and soil depth enable understanding the roles of these factors in stabilization and destabilization of SOC. Long term (20 yr) experimental manipulations of precipitation, vegetation and soil depth showed strong interactions of these factors influencing soil inorganic carbon and organic carbon storage (Huber et al. in review). Soil depth manipulations strongly modulates the SOC and SIC responses to vegetation and precipitation treatments (Huber et al. in preparation, Huber 2017).

Controls on carbon uptake and responses to fire Finally, we document rapid recovery of carbon uptake as measured by NEE (within two years following a prescribed fire) in a montane sagebrush steppe ecosystem and associated this rapid recovery with increased herbaceous and grass productivity suggesting the prescribed fire in montane sagebrush system may be an effective management tool (Fellows et al., in 2018). Interestingly, we found a strong correlation of annual GEP to NDVImax (r2 =0.75) suggesting the possible utility in extending GEP measurement to the landscape scale. Indeed, applying this relationship to other available towers within the same vegetation type showed an average 5.6% error between observed vs predicted values indicating that GEP may be obtained remotely.

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

With a reduced budget for year 5, we were able to support research and/or salary (partial, summer, and/or full) for 4 graduates students (100% women, Radke, Sharma, Macneille, Glossner), 2 undergraduates at ISU (Facer, Durfee), and 2 postdoctoral associates (Huber at ARS and Chen at BSU). Three graduate students were trained in analytical analyses to determine water chemistry.

One undergraduate was trained in remote sensing (Facer). Four thesis (Huber, Sharma, Radke, and Roehner) were completed.

Meetings: We had weekly meetings via video conferencing with all RC CZO participants to discuss research issues and future activities and had graduate students and postdoctoral students present their research and debate findings. Weekly meeting were important to ensure interactions among the students and PIs across institutions. Presentations provided an opportunity to hone their speaking skills and sharpen their research efforts and also identify synergies/collaborations with the other students. We discussed research findings, future plans and ways to connect our research elements in the critical zone. We supported 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). In September 2018, Reynolds Creek CZO had its annual meeting at Boise State University (20 participants) to report key findings from year 5 and plan for call for proposals.

Coursework: We have continued to integrate critical zone science into our courses and developed new ones. In Fall 2017, Lohse lead an Advanced Topics in Biogeochemistry seminar and had students reviewed NSF CZ science papers and organized an review around critical zone services. This review was completed in the spring and a manuscript submitted (Lohse et al., in review). In the spring, Lohse continued to integrate research data into her winter/spring Ecosystem course. Specifically, Lohse used soils collected following the Soda Fire to teach students about different ecosystem functions. Data generated from this class are being presented at AGU (Lohse et al. 2018).

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. Postdoc Huber went to a short course to be trained on datalogging and network improvements and Chen went to a CZO modeling workshop.

* 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.

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. Visitors/year has increased from an average of 100/yr to 250 in 2015, 423 visitors in 2016, 232 in 2017, and back to ~200 in 2018. Indeed, Idaho EPSCOR recently received $20 Million RII award that will focus on genomes to phenomes in sagebrush and will specifically utilize Reynolds Creek CZO elevation gradient for measurements and also a common garden experiment. We toured lead PIs on this grant through the Reynolds Creek in the fall. Godsey received a CAREER award on stream intermittency and is focusing part of her studies at the RC CZO. Other metrics of success are publication of datasets and downloads. Nineteen large datasets including EC tower data have been published with DOIs at BSU ScholarWorks and linked to criticalzone.org; EC tower data have been downloaded (4 sites x 180 times) and other datasets have been downloaded 100 times.

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. New awards to external participants working at the RC CZO include Keleners from U WY who was awarded to evaluate hillslope structure and function using geophysics in Reynolds Creek CZO. Sullivan from U of Kansas along with Flores (co-PI) received an NSF SiTS award to develop soil development models that can be utilized by a broader community. Finally, Flores with Olschanowsky in computer sciences at BSU were also funded to develop a framework to bring together computational and domain science (hydrology) to move more quickly from tools to discoveries. We have also engaged other National networks through senior personnel involvement, including UCAR, NEON, OpenTopography, LTERs, EarthCube, LTAR, and CUASHI (Baatz et al. 2018, Richter et al. 2018).

In year 5, we continued to engage with landscape ecology modelers from University of Montana, now NASA, to examine the role of phenology in driving patterns of productivity in sagebrush steppe ecosystems using the eddy covariance data and other supporting data. Externally engaged modelers at University of Montana (Drs. Renwick and Poulter) using CORE site data found that the existing phenology types defined in the LPJ-GUESS DGVM could not adequately capture the seasonal patterns of gross primary productivity (GPP) observed at the four study sites. The model was improved substantially by a) developing a new “semi-deciduous” phenology type to represent sagebrush, and b) optimizing model parameters using site-level GPP data coupled with remotely-sensed LAI data (Renwick et al. in review). Lohse also engaged with IML researchers to utilize EC tower data and this product was published in the Proceedings of the National Academy of Sciences (Goodwell et al. 2018). In January and March 2018, Lohse organized two workshop meetings to organize an Integrate Earth Systems (IES) proposal around the critical zone and groundwater; these meetings included 9 participants from six different organizations. In particular, RC CZO engaged with College of Western Idaho, a community college in Nampa, and Dr. Melissa Schlegel who teaches there to explore possible synergies with the college and engaging her in research given her expertise in groundwater isotope geochemistry. Finally, Lohse is participating with the Department of

Geosciences in a GEOPATH proposal to evaluate current and new strategies of engaging and retaining undergraduates in Geosciences. In particular, the Department of Geosciences has worked on re-articulations for 2 year colleges to facilitate transfers and we are proposing to use field trips to field stations (including RC CZO) as vehicle for providing experiences to engage undergraduates in the earth sciences.

Data availability and management: We continue to publish multiple categories of historical datasets to present data (2018) 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 1962-2018, soil moisture and evapotranspiration for multiple stations from 1977-2018, soil temperature from multiple stations from 1971-2018, stream flow from 10 weirs from 1963-2018. We strive to make our data rapidly available to the general public and cross CZOs to increase participation ad discoverability. We are using BSU ScholarWorks to publish data and use it as a repository (https://scholarworks.boisestate.edu/reynoldscreek/). In Year 5, we published a data paper based on our 31 years of hourly, 10 m raster model outputs for many of these forcing data and others with DOI (24TB) (Kormos et al, 2016, Kormos et al., 2018). Moreover, we published a unique 10-year data set and data paper associated with the rain to snow transition and micrometeorology associated with this subcatchment (Enslin 2016; Godsey et al. 2018). Other published datasets include soil carbon, bulk density, hydrologic properties at focused sites and RCEW wide (Sharma et al. 2018, Murdock et al. 2018, Patton et al. 2018a-e) in addition to experimental data from long-term manipulations of precipitation and vegetation (Huber et al 2018a,b). Finally, we have published derived gross ecosystem productivity (GEP) and ecosystem respiration (ER) datasets to BSU ScholarWorks (Fellows et al. 2017) and also posted raw eddy covariance tower data to Ameriflux.

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). We participated in the Idaho State University STEM data outreach event (100+ students engaged directly), and the Pocatello Environmental Fair (100+ members of the public directly engaged). At RCEW, we implemented Owyhee Hydrology Camp in which 5 local high school students plus 2 chaperones came out to Reynolds for two days to learn about soils and hydrology and the science conducted at Reynolds Creek. We also repeated our an 8th grade adventure learning expedition (4rd in row) at Reynolds Creek in which the McCall Outdoor Science School (MOSS) lead adventure learning in the RCEW for 23 students and 2 chaperones for 2 overnights at Reynolds Creek.

In year 5, we focused on improving the Reynolds Creek Virtual Watershed Tour (http://reynoldscreekczo.org/wordpress/). Videos were collected and interviews conducted during the summer of 2016 at RC CZO and resulted in the production of 14, 2-4 minute videos as part of a Virtual Watershed Tour on subwatershed research topics. Sindelar incorporated animations to explain concepts discussed in the videos.

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

Main research objectives of supplement

With the supplement funds, we will complete the following:

1) We will conduct initial tests of our hypothesis that fine resolution environmental variables will improve our prediction of soil carbon. This represents the final stage of our strategic plan. We have completed simulations using BIOME BGC with our fine resolution (10 m), temporally complete 31-year fine resolution climate data (Kormos et al. 2018). This simulation required massive computational power and time (6 months) and we now need these data to be analyses and written up. We will evaluate modeled against observed soil organic carbon values to test whether fine resolution environmental variables improve our prediction of soil carbon. We expect that BIOME BGC will not distribute carbon because it does not include lateral redistribution of water.

2) We will complete surface soil water input (total snowmelt and rainfall inputs) for distributed soil moisture inputs across Reynolds Creek CZO (239 km^2, hourly) for testbed modeling.

3) We will complete instance of an advanced ecohydrologic model, ParFlow, to resolve hillslope-scale redistribution of moisture, as well as surface water-groundwater interactions and, potentially, the influence of deeper-CZ structure on land-atmosphere exchange and write up manuscript. We will produce initial instance that includes ingestion of novel CZO datasets (texture, Hydraulic properties, Murdock et al. 2018) to produce distributed belowground parameters (BSU postdoc Chao Chen).

4) We will complete analyses of soil profile carbon dioxide efflux dataset and initial modeling across the environmental gradient (postdoc: Huber).

5) We will analyze and complete interpolation of 25-year stream flow, sediment and possibly particulate organic carbon record (Gossner); we will complete DOC and DIC analyses dataset (Gossner and lab specialist), anions (time and funds permitting)

6) We will submit papers on long-term precipitation and vegetation experiment showing the importance of soil depth in controlling ecosystem responses, the role of antecedent moisture in driving responses, and importance of quantifying both forms of carbon in dryland ecosystems (Huber)

Plan for maintaining regular measurements

1) Surface Water sampling

We plan to maintain surface water collections and stream water chemistry analyses (5 locations). This will be achieved with staff (ARS CZO technician to collect and filter) and ISU CZO technician to analyze samples. Other automated sensors are also being maintained by ISU CZO technician and ARS staff. Stream discharge and climate stations are maintained by ARS staff.

2) Sap flux

We plan to maintain sap flux sensors on trees and shrub with assistance of ARS CZO technician to collect and maintain sap flux sensors (CORE sites). We are in the process of training the technician to build and replace and download data (May 2018).

3) FD and CO_2 gas flux sampling

We plan to maintain CO_2 probes and forced diffusion (FD) flux sensors at 4 sites (CORE sites). The Eddy covariance towers are being maintained currently by the ARS. We are in the process of training the technician to build and replace and download data from CO_2 probes and FD chambers (May 2018).

4) Data analysis/QAQC

CZO hydrologist and CZO ISU water chemist will assist in data QAQC and analysis as well as PI/co-PIs.

Data accessibility, preservation and collaboration with other CZOs on data management

The Reynolds Creek CZO has built an intensive sensor observatory. We have worked hard to publish these data (BSU ScholarWorks, National Agriculture Library) to obtain DOIs for the data. While our time-series data have a long-term home (ARS FTP site, and CZO website), we are concerned that the rest of the data, which is critical to our research is being placed, ad hoc, in non-permanent locations and runs the risk of being lost. In particular, we're concerned about our spatial GIS server that we have developed and are currently (with supplement) migrating our Amazon Web Services (Cloud services) to ARS server to serve spatial data to CZO network and others. We will begin the process of publicizing our dataset and sharing our datasets CUAHSI's HydroShare archive as a permanent home as appropriate. We will use ODM2 vocabulary and also engage with network related to ODM2 database management and actvities.

Graduate student and post-doctoral research timeline

Postdoc at BSU (Chen) will complete her postdoc Nov 2019 with submission of two manuscripts. Postdoc at ARS (Huber) will complete his postdoc in Nov 2019 with submission of 4 manuscripts. Graduate student Gossner will complete her MS in May 2019 and possibly continue for DA or PhD.

Supporting Files

	Filename	Description
(Download)	Figures Priority 1 2018 low res.pdf	Figures Priority 1
(Download)	Figures Priority 2 part I 2018 low res.pdf	Figures Priority 2 part I
(Download)	Figure Priority 2 part II to 3 2018.pdf	Figures Priority 2 part II and 3
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Licenses

Other Conference Presentations / Papers

- Karwan, D. L., Evaristo, J. A., Lohse, K.A. Papuga, S.A. (2017). *AGU session: Plants as Builders and Plumbers of the Critical Zone*. AGU Fall Meeting. New Orleans. Status = PUBLISHED; 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
- Lohse, K. (2017). *Challenges of quantifying short-term hydrobiogeochemical processes in the critical zone*. SEG AGU Hydrogeophysics Workshop: Imaging the Critical Zone, July 24-27. Stanford, CA. Status = PUBLISHED; 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 = ACCEPTED; Acknowledgement of Federal Support = Yes
- Lohse, K. (2017). *Critical Zone Science in Landscape Management*. Critical Zone Observatory All Hands Meeting, June 3-6th. Washington, DC.. Status = PUBLISHED; 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
- 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
- Radke, A.G., Godsey, S.E., Lohse, K.A., Seyfried, M.S., and Patton, N.R. (2017). *How Does Your Soil Carbon Flow? Hydrologic Connectivity and Carbon Dynamics Tied to Snow Drifting in Reynolds Creek Critical Zone Observatory*. Idaho State University Graduate Research Symposium. Pocatello, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- Lohse, K. (2017). *Improving prediction of soil carbon and fluxes at plot to landscape scales*. Eel River Team Meeting. UC Berkeley. Status = OTHER; Acknowledgement of Federal Support = Yes
- Lohse, K. A. (2017). *Improving prediction of soil carbon and fluxes at the plot to landscapes scale*. Invited talk at Energy and Nutrient Movement through Ecological Systems: An Ode to Odum Seminar Series. Pennsylvania State University. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Lohse, K. (2017). *Improving soil depth and carbon predictions at the plot to watershed scale in dryland ecosystems*. Department of Earth and Environmental Sciences, Stanford University, Jackson Lab. Stanford, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

- Lohse, K. (2017). *Improving soil thickness and carbon estimates: A bottom up approach at the Reynolds Creek Critical Zone Observatory*. Department of Geophysics, Stanford University. Stanford, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Watson, K., M. Masarik, and A. Flores (2016). *Investigating Precipitation and Snow Storage in Southern Idaho Via a High Resolution Regional Climate Model.*. Western Snow Conference. Seattle, WA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Lohse, K. (2017). *Lohse, K. Improving prediction of soil carbon and fluxes at plot to landscape scales,*. Department of Earth and Environmental Sciences, Stanford University, Fendorf Lab. Stanford, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Lohse, K. (2017). *Reynolds Creek Critical Zone Observatory Introduction and Research Highlights*. USGS Presentation. Menlo Park, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Lohse, K. (2016). *Reynolds Creek Critical Zone Observatory Key Research Findings.*. NSF Reverse Site Visit Meeting. Washington, DC.. Status = OTHER; Acknowledgement of Federal Support = Yes
- Radke, A.G., Godsey, S.E., Lohse, K.A., Seyfried, M.S., and Patton, N.R. (2016). *Soil Carbon Export in a Snow-Dominated Headwater Catchment*. Critical Zone Observatory Annual Meeting. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- Li, A., Will, R., Glenn, N, Benner, S., Spaete, L. (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
- Terhaar, D. (2016). *Using the chemical signature of dust to understand soil development and carbon storage in soils.*. Undergraduate Research Conference. 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
- 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.*

  Murdock, M. D., Huber, D. P., Seyfried, M. S., Patton, N. R., and Lohse, K. A. (2018). Dataset for Soil Hydraulic Parameter Estimates Along an Elevation Gradient in Dryland Soils [Data set]. BSU ScholarWorks, Boise State University, Boise, ID, https://doi.org/10.18122/reynoldscreek/10/boisestate

- *Databases.*

  Fellows, A. W., Flerchinger, G. N., Seyfried, M. S., and Lohse, K. (2017). Data for Partitioned Carbon and Energy Fluxes Within the Reynolds Creek Critical Zone Observatory[Data set]. BSU ScholarWorks, Boise State University, Boise, ID, https://doi.org/10.18122/B2TD7V

- *Databases.*

  Huber, D. P., Lohse, K. A., Commendador, A., Joy, S.. Finney, B., Aho, K., and Germino, M. (2018). Dataset for Change in Carbon Storage for Cold Desert Ecosystems Controlled by Precipitation Seasonality and Invasive Vegetation [Data set]. BSU ScholarWorks, Boise State University, Boise, ID, https://doi.org/10.18122/B2QT3J

- *Databases.*

  Patton, N. R., Lohse, K. A., Godsey, S. E., Parsons, S. B., and Seyfried, M. S. (2018). Dataset for Topographic Controls on Total Soil Organic Carbon in Semi-arid Environments [Data set], BSU ScholarWorks, Boise State University, Boise, ID, https://doi.org/10.18122/B2XT55

- *Databases.*

  Patton, N. R., Lohse, K. A., Godsey, S. E., Seyfried, M. S., and Crosby, B. T. (2017). Dataset for Predicting Soil Thickness on Soil Mantled Hillslopes [Data set]. BSU ScholarWorks, Boise State University, Boise, ID. https://doi.org/10.18122/B2PM69

- *Databases.*

  Patton, N. R., Lohse, K. A., Seyfried, M., Radke, A. and Godsey, S. (2018) Dataset for Soil Properties of Reynolds Mountain East a Subcatchment of Reynolds Creek, Idaho [Data set]. BSU ScholarWorks, Boise State University, Boise, ID, https://doi.org/10.18122/B29T3T

- *Databases.*

  Patton, N. R., Lohse, K. A., Seyfried, M.S., Will, R. M., and Benner, S. (2018) Dataset for Lithology and Coarse Fraction Adjusted Bulk Density Estimates for Determining Total Organic Carbon Stocks in Dryland Soils [Data set]. BSU ScholarWorks, Boise State University, Boise, ID, https://doi.org/10.18122/B22M6Q

- *Databases.*

  Patton, N. R., Lohse, K. A., Seyfried, M.S., and Murdock, M. D. (2018) Dataset for Soil Properties Determined at the Reynolds Creek Experimental Watershed (RCEW), Idaho [Idaho State University Collections 2010-2016] [Data set]. BSU ScholarWorks, Boise State University, Boise, ID, https://doi.org/10.18122/reynoldscreek/11/boisestate

- *Databases.*

  Sharma, H., Reinhardt, K., Lohse, K. A., Aho, K., Flerchinger, G.N., and Seyfried, M.S. (2018) Dataset for Measured and Modelled Carbon (Net Ecosystem Exchange) and Water (Evapotranspiration) Data for Three Sagebrush Core Sites at Reynolds Creek Critical Zone Observatory [Data set]. BSU ScholarWorks, Boise State University, Boise, ID, https://doi.org/10.18122/reynoldscreek/12/boisestate

- *Physical Collections.*

Terrestrial samples (n=752) have been registered in the System for Earth Sample Registration (SESAR) and have associated International Geo Sample Number (ISGN). The samples are all registered under the Field Program by the name Reynolds Creek Critical Zone Observatory (CZO) field program. We have archived samples at Idaho State University.

Other Publications

Patents

- *SOIL DEPTH MEASUREMENT SYSTEM AND METHOD*. *Patent No. 62/561,973*. UNITED STATES. Application Date = 09/22/2017. Date Issued = 09/21/2018. Status = Granted

Technologies or Techniques

Thesis/Dissertations

- Nielson, Travis. *Application of Hydrogeophysical Imaging in the Reynolds Creek Critical Zone Observatory*. (2017). Boise State University. Acknowledgement of Federal Support = Yes
- 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
- Poley, Andrew. *Deriving landscape-scale vegetation cover and above ground biomass in a semi-arid ecosystem using imaging spectroscopy*. (2017). Boise 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*. (2017). Idaho State University. Acknowledgement of Federal Support = Yes
- Roehner, C.. *Post-Fire Variation of Aeolian in the Northern Great Basin*. (2018). Boise State University. Acknowledgement of Federal Support = Yes
- Sharma, Harmandeep. *Spatial and temporal analysis of carbon and water fluxes from leaf to ecosystem scales in sagebrush steppe*. (2018). Idaho State University. Acknowledgement of Federal Support = Yes
- Radke, A. G.. *Spatiotemporal Heterogeneity of Water and Dissolved Organic Carbon Sourcing in a Snow-dominated, Headwater Catchment: A Hydrologic Investigation in Owyhee County, Idaho*. (2018). 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
- 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

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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?

Lohse, Kathleen	PD/PI
Benner, Shawn	Co PD/PI
Flores, Alejandro	Co PD/PI
Glenn, Nancy	Co PD/PI
Seyfried, Mark	Co PD/PI
Crosby, Benjamin	Co-Investigator
Finney, Bruce	Co-Investigator
Flerchinger, Gerald	Co-Investigator
Garen, David	Co-Investigator
Godsey, Sarah	Co-Investigator

Marks, Danny	Co-Investigator
Pierce, Jennifer	Co-Investigator
Aho, Ken	Faculty
Baxter, Colden	Faculty
Cadol, Daniel	Faculty
Chandler, David	Faculty
de Graaff, Marie-Anne	Faculty
Feris, Kevin	Faculty
Holbrook, W. Steven	Faculty
Kohn, Matthew	Faculty
Link, Timothy	Faculty
Magnuson, Timothy	Faculty
Pomeroy, John	Faculty
Reinhardt, Keith	Faculty
Chen, Chao	Postdoctoral (scholar, fellow or other postdoctoral position)
Fellows, Aaron	Postdoctoral (scholar, fellow or other postdoctoral position)
Huber, David	Postdoctoral (scholar, fellow or other postdoctoral position)
Kormos, Patrick	Postdoctoral (scholar, fellow or other postdoctoral position)
McCorkle, Emma	Other Professional
Parsons, Susan	Other Professional
VanVactor, Steven	Other Professional

Murray, Erin	Technician
Patton, Nicholas	Technician
Sandusky, Micah	Technician
Clark, Patrick	Staff Scientist (doctoral level)
Goodrich, David	Staff Scientist (doctoral level)
Commendador, Amy	Graduate Student (research assistant)
Dashti, Hamid	Graduate Student (research assistant)
Delvinne, Hasini	Graduate Student (research assistant)
Gossner, Kayla	Graduate Student (research assistant)
Ilangakoon, Nayani	Graduate Student (research assistant)
Macneille, Ruth	Graduate Student (research assistant)
Radke, Anna	Graduate Student (research assistant)
Roehner, Clayton	Graduate Student (research assistant)
Sharma, Harmandeep	Graduate Student (research assistant)
Vega, Samantha	Graduate Student (research assistant)
Will, Ryan	Graduate Student (research assistant)
Spaete, Lucas	Non-Student Research Assistant
Durfee, Cody	Undergraduate Student
Facer, Jeremy	Undergraduate Student
Perdrial, Julia	Consultant
Clark, Martyn	Other

Cram, Zane	Other
Galanter, Amy	Other
McNamara, James	Other
Nielson, Travis	Other
Niemeyer, Ryan	Other
Schwabedissen, Stacy	Other
Stanbery, Christopher	Other
Williams, Jason	Other

Full details of individuals who have worked on the project:

Kathleen A Lohse
Email: klohse@isu.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 6
Contribution to the Project: Lohse oversaw all aspects of the CZO. She worked with researchers on research questions to he administrative aspects, such as annual progress reports and the budget; and served as the principal contact with NSF and other the expansion of the CZO's research program to include new projects and adapt to new research directions. Dr. Lohse travelle Geophysical Union meeting, fall PI meeting, and All Hands Meeting. Lohse worked with the database manager to create web scientific community in CZO activities and external engagement for a community resource. Lohse advised 3 students and was
Funding Support: Idaho State Universtiy
International Collaboration: No
International Travel: No

Shawn Benner
Email: sbenner@boisestate.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1
Contribution to the Project: Surface soil organic carbon mapping and advised Ryan Will
Funding Support: EPSCoR
International Collaboration: No
International Travel: No

Alejandro Flores
Email: lejoflores@boisestate.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1
Contribution to the Project: Priority 3: Integrated modeling
Funding Support: NASA TE, NSF CAREER, NSF WAVE
International Collaboration: No
International Travel: No

Nancy F Glenn
Email: nancyglenn@boisestate.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1
Contribution to the Project: Remote sensing at CZO,
Funding Support: NASA TE
International Collaboration: No
International Travel: No

Mark S Seyfried
Email: mark.seyfried@ars.usda.gov
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 6
Contribution to the Project: Coordinated and facilitated field projects at RCEW as deputy director and collaborated on bulk
Funding Support: USDA ARS
International Collaboration: No
International Travel: No

Benjamin T Crosby
Email: crosby@isu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1
Contribution to the Project: Advise on LiDAR and geomorphic observations related to soil thickness model
Funding Support: Idaho State University
International Collaboration: No
International Travel: No

Bruce P Finney
Email: finney@isu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1
Contribution to the Project: I run the ISU stable isotope lab and facilitate analysis and interpretation of some of the stable is

Funding Support: ISU
International Collaboration: No
International Travel: No

Gerald N Flerchinger
Email: gerald.flerchinger@ars.usda.gov
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 6
Contribution to the Project: Selecting core sites, coordinating activities at the core sites and setting up eddy covariance syst
Funding Support: USDA-ARS and Reynolds Creek CZO grant.
International Collaboration: No
International Travel: No

David C Garen
Email: David.Garen@por.usda.gov
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1
Contribution to the Project: Assisting ARS on developing spatial meteorological forcings
Funding Support: Regular USDA-NRCS salary
International Collaboration: No
International Travel: No

Sarah E Godsey
Email: godsey@isu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3
Contribution to the Project: Recruited and supervising MS student Anna Radke's hillslope chemistry contributions to Reyn
Funding Support: NSF CAREER, NSF Tri-state EPSCoR Track II - WC-WAVE
International Collaboration: No
International Travel: No

Danny G Marks
Email: ars.danny@gmail.com
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 6
Contribution to the Project: Developing spatially continuous model forcing data for the RCCZO; working toward a 30 yr d
deposition, redistribution, melt, soil moisture, streamflow for RCCZO.
Funding Support: USDA-ARS
International Collaboration: Yes, Canada
International Travel: No

Jennifer L Pierce
Email: jenpierce@boisestate.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3
Contribution to the Project: 1) Soil Inorganic Carbon (SIC) lead: primary advisor for Chris Stanbery, who measured SIC in
following large wildfire
Funding Support: Murdock Foundation
International Collaboration: No
International Travel: No

Ken Aho
Email: kenaho1@gmail.com
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2
Contribution to the Project: Contributed to statistical analyses on numerous manuscripts
Funding Support: ISU
International Collaboration: No
International Travel: No

Colden V Baxter
Email: baxtcold@isu.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: I am a investigator and collaborator on in-stream focused ecological studies at the Reynolds Cr
Research and Education, which is a partner organization with the CZO.
Funding Support: EPSCoR
International Collaboration: No
International Travel: No

Daniel Cadol
Email: dcadol@nmt.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Collaborated on black carbon quantification at JRB and RC CZO
Funding Support: NMT, EPSCOR, WAVE
International Collaboration: No
International Travel: No

David G Chandler
Email: dgchandl@syr.edu
Most Senior Project Role: Faculty

Nearest Person Month Worked: 2
Contribution to the Project: Current investigation focuses on decadal scale impact of prescribed fire on near surface soil org
repellency and unsaturated infiltration.
Funding Support: Syracuse University
International Collaboration: No
International Travel: No

Marie-Anne de Graaff
Email: marie-annedegraaff@boisestate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Overall Objective: Understand how soil organic carbon input affects soil structure and carbon c
characters affect the response of soil organic carbon (SOC) decomposition to climate change.
Funding Support: BSU
International Collaboration: No
International Travel: No

Kevin P Feris
Email: kevinferis@boisestate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Assisted with soil collections for microbial analysis and served on committee
Funding Support: NSF, USDA, DOE, INL
International Collaboration: No
International Travel: No

W. Steven Holbrook
Email: steveh@uwyo.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: In August 2015, we acquired geophysical data (seismic refraction, electrical resistivity, ground-
induction) in several sub-watersheds of RCCZO (Reynolds Mountain, Upper Sheep Creek, Upper Johnston Draw), in collabo
Track 1 grant, and the RCCZO grant (through Dr. Lohse). We will analyze and interpret the collected data together with our F
attended workshops for IES proposal
Funding Support: NSF-EPSCoR Track 1 grant to the University of Wyoming, and the RCCZO grant (through Dr. Lohse).
International Collaboration: No
International Travel: No

Matthew J Kohn
Email: mattkohn@boisestate.edu
Most Senior Project Role: Faculty

Nearest Person Month Worked: 1
Contribution to the Project: Developing stable isotope tools for understanding interactions among hydrologic cycle, soils ar
Funding Support: Boise State University
International Collaboration: No
International Travel: No

Timothy E Link
Email: Tlink@uidaho.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Coordinating work funded by other programs with CZO goals.
Funding Support: NSF-IGERT, NSF-CBET
International Collaboration: No
International Travel: No

Timothy Magnuson
Email: magntimo@isu.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2
Contribution to the Project: I served as a Co-advisor for Ms. Stacy Schwabedissen (MS Microbiology, Idaho State Universi
University, May 2016) on her undergraduate CZO research project. I am a co-author on 3 submitted publications from these s
Funding Support: I received no direct funding from the CZO grant. I am funded by NASA (Exobiology and Astrobiology, 2
Laboratory-Pacific Northwest National Laboratory.
International Collaboration: No
International Travel: No

John Pomeroy
Email: john.pomeroy@usask.ca
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Modelling Reynolds Creek with Cold Regions Hydrological Model for snow process climate se
catchments as part of long term collaboration with USDA ARS
Funding Support: Natural Sciences and Engineering Research Council of Canada funding through Discovery Grants and the
International Collaboration: Yes, Canada, China, Germany, Spain, Switzerland, United Kingdom
International Travel: No

Keith Reinhardt
Email: reinkeit@isu.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 3
Contribution to the Project: We are in charge of installing and monitoring tree and shrub water relations. This includes sap

Funding Support: ISU
International Collaboration: No
International Travel: No

Chao Chen
Email: chaochen@boisestate.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: Modeling groundwater dynamics in PARFLOW
Funding Support: CZO, BSU
International Collaboration: No
International Travel: No

Aaron W Fellows
Email: afellowswork@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 4
Contribution to the Project: Contributing to Priority 2: Environmental monitoring network by reprocessing historic eddy co
Funding Support: USDA ARS
International Collaboration: No
International Travel: No

David P Huber
Email: hubedavi@isu.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: Analyzing data examining long-term responses to altered precipitation,vegetation and soil thick
Funding Support: USDA ARS ISU Doctor of Arts Teaching Fellowship (2 yrs) ISU CPI USGS Youth Internship Program F
International Collaboration: No
International Travel: No

Patrick R Kormos
Email: pkormos.fs@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 1
Contribution to the Project: Spatial distribution of temperature, humidity, and precipitation data over the RCZO, including
tours. Represent the RCZO at the IMLCZO summer modeling workshop.
Funding Support: ARS
International Collaboration: No
International Travel: No

Emma Paige McCorkle
Email: mccoemma@isu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 5
Contribution to the Project: Water biogeochemistry, soil biogeochemistry, field and lab manager-ish, archive master,
Funding Support: RC CZO
International Collaboration: No
International Travel: No

Susan B Parsons
Email: parssusa@isu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12
Contribution to the Project: I am a data manager, collaborating with Steven VanVactor at the USDA-ARS and Luke Spaete efforts. Additionally, I am registering data with the main CZO metadata portal, and managing content on the Reynolds Creek purpose of hosting and serving-out Reynolds Creek CZO data and research products.
Funding Support: Reynolds Creek CZO and NSF/EPSCoR Managing Idaho Landscapes for Ecosystem Services (MILES)
International Collaboration: No
International Travel: No

Steven VanVactor
Email: steven.vanvactor@ars.usda.gov
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 6
Contribution to the Project: As the database manager for the NWRC I have ongoing data collection and management respon through funding from CZO are included in our telemetered network so I will also collect and manage data from those sites. I i Creek Experimental Watershed sites that is used to support the Reynolds Creek CZO data discovery. The information window to data available from each site, and experimental graphs of data collected daily from the site to use in site performance diagn same information that was included in Google Maps. Google Earth allows a greater scale so that more sites can be visualized datasets are available now. All of these resources will be incorporated into a Reynolds Creek CZO website when a local web l
Funding Support: USDA-ARS
International Collaboration: No
International Travel: No

Erin Murray
Email: Erin.Murray@ars.usda.gov
Most Senior Project Role: Technician
Nearest Person Month Worked: 7
Contribution to the Project: As CZO hydrologist, Murray collects and maintains instruments for gas and water sampling
Funding Support: CZO, USDA ARS
International Collaboration: No

International Travel: No

Nicholas R Patton
Email: Pattnich@isu.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 5
Contribution to the Project: Determining total mobile regolith thickness and soil carbon pools on the pedon to watershed sc
Funding Support: USDA ARS ISU CERE
International Collaboration: No
International Travel: No

Micah Sandusky
Email: micah.sandusky@ars.usda.gov
Most Senior Project Role: Technician
Nearest Person Month Worked: 12
Contribution to the Project: Produced solar radiation, thermal radiation, SWE and SWI data across RCEW for 30 yr period
Funding Support: USDA ARS
International Collaboration: No
International Travel: No

Patrick E Clark
Email: pat.clark@ars.usda.gov
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 6
Contribution to the Project: Assessment of vegetation status and response to livestock grazing, fire and other landscape-sca
diversity, and production (ANPP).
Funding Support: ARS
International Collaboration: No
International Travel: No

David Goodrich
Email: dave.goodrich@ars.usda.gov
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 1
Contribution to the Project: Participation in conference calls and planning to evaluate a watershed hydrology and erosion m
CZO as a result of the 2015 Soda fire.
Funding Support: USDA-ARS base funding
International Collaboration: No
International Travel: No

Amy S Commendador

Email: commamy@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6
Contribution to the Project: As part of the CZO I will be examining processes that affect stable isotope (primarily carbon ar
gradient, holding all other state factors constant. The goal is to better understand the effect of climate on these compositions, a
of my dissertation I will be collecting soil, plant and faunal samples from across an environmental gradient for various C and
Funding Support: RC-CZO ISU for sample analyses, Idaho State University
International Collaboration: No
International Travel: No

Hamid Dashti
Email: hamiddashti@u.boisestate.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3
Contribution to the Project: Estimation of Leaf Area Index (LAI) of dryland shrubs using hyperspectral data
Funding Support: NASA, NSF
International Collaboration: No
International Travel: No

Hasini H Delvinne
Email: hasinidelvinne@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1
Contribution to the Project: Completing Assessing the temperature sensitivity of soil organic carbon pools and the impact o
Funding Support: Funded as PHD at ASU but completing outstanding products from RC CZO
International Collaboration: No
International Travel: No

Kayla Gossner
Email: gloskayl@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Analyzing particulate organic carbon and nutrients in stream water
Funding Support: RC CZO ISU GTA USDA ARS
International Collaboration: No
International Travel: No

Nayani Ilangakoon
Email: nayaniIlangakoon@u.boisestate.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Derive rangeland ecosystem variables from airborne small footprint waveform lidar attributes
Funding Support: NASA TE, BSU
International Collaboration: No
International Travel: No

Ruth Macneille
Email: macnruth@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Assessing spatial heterogeneity in streams with drying
Funding Support: ISU DA Fellowship, RC CZO
International Collaboration: No
International Travel: No

Anna G Radke
Email: radkanna@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Installation of lysimeters, soil moisture probes, soil matric potential probes, and piezometers in
transport.
Funding Support: RC CZO ISU TA
International Collaboration: No
International Travel: No

Clayton Roehner
Email: clayroehner@u.boisestate.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6
Contribution to the Project: Investigating the interplay between wind and water erosion using passive dust and sediment tra
Funding Support: NSF Rapid
International Collaboration: No
International Travel: No

Harmandeep Sharma
Email: sharharm@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: I have collected diurnal gas exchange data this summer in three sagebrush communities and sul
Funding Support: NSF CZO ISU CPI
International Collaboration: No
International Travel: No

Samantha Vega
Email: sam.vega@ars.usda.gov
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: • Installed silt fence study within Murphy Creek in order to monitor hillslope to watershed scal
Soda fire. • Collected vegetation recovery data and soil water repellency immediately after the fire, 2016, and 2017. • Collect
Funding Support: USDA ARS
International Collaboration: No
International Travel: No

Ryan M Will
Email: Rmwill139@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1
Contribution to the Project: Field sampling of soils for SOC analyses. Mapping sample sites with RTK GPS. Laboratory an
and predictor variables derived from remote sensing data.
Funding Support: CZO BSU
International Collaboration: No
International Travel: No

Lucas P Spaete
Email: lucasspaete@boisestate.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 3
Contribution to the Project: BSU data managment
Funding Support: Boise State University
International Collaboration: No
International Travel: No

Cody Durfee
Email: durfcody@isu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1
Contribution to the Project: Assisted with filtering and acid washing
Funding Support: RC CZO, ISU CPI
International Collaboration: No
International Travel: No

Jeremy Facer
Email: facejere@isu.edu
Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3
Contribution to the Project: Assist with field and lab experiments and also conducted remote sensing internship
Funding Support: ISU CPI, CZO
International Collaboration: No
International Travel: No

Julia N Perdrial
Email: Julia.Perdrial@uvm.edu
Most Senior Project Role: Consultant
Nearest Person Month Worked: 1
Contribution to the Project: Analysis of dissolved organic matter with absorbance and fluorescence spectroscopy
Funding Support: none
International Collaboration: No
International Travel: No

Martyn P Clark
Email: mclark@ucar.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Collaborating with USDA ARS on existing projects
Funding Support: NSF, Bureau of Reclamation, US Army Corps of Engineers, NOAA
International Collaboration: Yes, Austria, United Kingdom
International Travel: No

Zane K Cram
Email: zane.cram@ars.usda.gov
Most Senior Project Role: Other
Nearest Person Month Worked: 6
Contribution to the Project: I manage the Reynolds Creek Experimental Watershed and all field projects associated with the
Funding Support: USDA-ARS NWRC hard funding
International Collaboration: No
International Travel: No

Amy E Galanter
Email: agalante@nmt.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Analyzing Jemez CZO soils for black carbon concentration as part of studying impacts of wildf
Funding Support: EPSCoR, WRRI
International Collaboration: No
International Travel: No

James P McNamara
Email: jmcnamar@boisestate.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: I collaborate with Danny Marks, Mark Seyfried and others on existing projects. Our primary re
Funding Support: NSF, NASA, NOAA
International Collaboration: No
International Travel: No

Travis Nielson
Email: travisnielson@u.boisestate.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: 1) The use of time-lapse 3D electrical resistivity tomography, at the core-sites, to image change
precipitation events. 2) Seismic refraction tomography survey of Johnston Draw to map the deep critical zone architecture as
Funding Support: RC CZO
International Collaboration: No
International Travel: No

Ryan J Niemeyer
Email: niem3790@vandals.uidaho.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: -completed manuscripts
Funding Support: National Science Foundation's IGERT program (Award 0903479) - ended in January 2015, U of Idaho
International Collaboration: No
International Travel: No

Stacy G Schwabedissen
Email: kingstac@isu.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Completing analyses and manuscripts examining N fixation, which is strongly coupled to C cy
Funding Support: ISU CERE
International Collaboration: No
International Travel: No

Christopher A Stanbery
Email: chrisstanbery@u.boisestate.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 2

Contribution to the Project: Revising manuscripts for submission.
Funding Support: RC CZO, BSU
International Collaboration: No
International Travel: No

Jason C Williams
Email: jason.williams@ars.usda.gov
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Sediment yield following fire
Funding Support: USDA-ARS
International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Bureau of Land Management	Other Organizations (foreign or domestic)
NCAR	Other Organizations (foreign or domestic)
NRCS	Other Organizations (foreign or domestic)
USDA ARS	Other Organizations (foreign or domestic)
USGS	Other Organizations (foreign or domestic)
University of Idaho	Academic Institution
University of Illinois, Urbana Champagne	Academic Institution

Full details of organizations that have been involved as partners:

Bureau of Land Management
Organization Type: Other Organizations (foreign or domestic)
Organization Location: Boise, Idaho
Partner's Contribution to the Project:
Personnel Exchanges
More Detail on Partner and Contribution:

NCAR
Organization Type: Other Organizations (foreign or domestic)
Organization Location: Boulder, CO
Partner's Contribution to the Project:
Collaborative Research
More Detail on Partner and Contribution:

NRCS
Organization Type: Other Organizations (foreign or domestic)
Organization Location: Portland, Oregon
Partner's Contribution to the Project:
Collaborative Research
Personnel Exchanges
More Detail on Partner and Contribution:

USDA ARS
Organization Type: Other Organizations (foreign or domestic)
Organization Location: National
Partner's Contribution to the Project:
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges
More Detail on Partner and Contribution:

USGS
Organization Type: Other Organizations (foreign or domestic)
Organization Location: Moab, Utah
Partner's Contribution to the Project:
Collaborative Research
Personnel Exchanges
More Detail on Partner and Contribution:

University of Idaho
Organization Type: Academic Institution
Organization Location: Moscow, Idaho
Partner's Contribution to the Project:
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution:

University of Illinois, Urbana Champagne
Organization Type: Academic Institution
Organization Location: Urbana Champagne, IL
Partner's Contribution to the Project:
In-Kind Support
Collaborative Research
More Detail on Partner and Contribution:

What other collaborators or contacts have been involved?

Katherine Renwick and Ben Poulter, University of Montana, NASA Maryland

Jesse Bateman, UCLA

Kathe Todd Brown, PNNL

Julia Perdrial, UVM

Allison Goodwell, UIUC

David Chandler, Syracuse University

Steve Holbrook, UVT

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Impacts

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 (Stanbery et al. 2017). 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. Soil thickness models developed at the RC CZO (Patton et al. (2018) have the potential to transform and advance earth sciences, especially hydrologic and landscape evolution models as well as industry. 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 100-101 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.

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 100-101 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.

What is the impact on the development of human resources?

We supported research and/or salary (partial, summer, and/or full) for 4 graduates students (100% women), 2 postdoctoral associates, 2 research specialists, 2 undergraduates during year 5 of RC CZO through a combination of diversified funding sources (ISU and BSU teaching assistantships, collaborations, grant funding). Research specialist are essential for maintaining instrumentation, collection, and analyses. Postdoctoral associates and graduate students are working to complete analyses and publication of products. We continue to expand our campaign to diversify our funding sources for graduate training given that all of our graduate assistant funding ends in year 5 owing to the 50% reduction in the original budget. Four theses, 2 PhD and 2 MS thesis in YR 5 (ISU: PhD, Huber, Sharma, Radke, Roehner) with >20 papers in review and 20 published in yr 5.

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.

UTVs

ARS purchased a number of UTVs and snowcats to access the watershed. This additional infrastructure adds additional safety for participants in the field.

Road improvements

The middle (private) road of the Reynolds Creek CZO was vastly improved by the ARS personnel and this improvement has facilitated and added additional safety for participants in their field activities. The East side road of Reynolds was also improved so that access is facilitated on this side of the watershed.

Range Building at Reynolds Creek CZO

The ARS projects completed renovations on the Range Building 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 proposal to increase livng and learning opportunities at Reynolds Creek.

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.

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]

- Publication of data as DOIs (BSU ScholarWorks)
- 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.

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 transferred our server to the Research Data Center as part of Reynolds Creek CZO sustainability effort.
- Our data analyst has been hired 50% by the USDA ARS as part of sustainability plan and effort to improve geospatial services at ARS.

- 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.

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 km2 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 were reprocessed in year 5 to produce point scale (10 m cell) at hourly rates for 31 yrs across watershed. These data will also be permanently stored at BSU. Lohse obtained a US utility patent for Lohse, Patton, Godsey, Crosby associated with the thickness of mobile regolith process (Patton et al. 2018).

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. We participated in the Idaho State University STEM data outreach event (100+ students engaged directly), and the Pocatello Environmental Fair (100+ members of the public directly engaged). At RCEW, we implemented Owyhee Hydrology Camp in which 5 high school students from local schools plus 2 chaperones came out to Reynolds for two days to learn about soils and hydrology and the science conducted at Reynolds Creek. We also repeated our an 8th grade adventure learning expedition (4rd in row) at Reynolds Creek in which the McCall Outdoor Science School (MOSS) lead adventure learning in the RCEW for 23 students and 2 chaperones for 2 overnights at Reynolds Creek.

In year 5, we revamped the Reynolds Creek Virtual Watershed Tour (http://reynoldscreekczo.org/wordpress/). Videos were collected and interviews conducted during the summer of 2016 at RC CZO and resulted in the production of fourteen 2-4 minute videos as part of a Virtual Watershed Tour on subwatershed research topics. This project was as part of a SAVI/RC

CZO funded outreach/education effort. Sindelar, who produced these videos for the virtual tour, continued to revamp these videos as part of his final thesis and incorporate animations to explain concepts discussed in the videos.

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Changes/Problems

Changes in approach and reason for change

We are modeling soil carbon across the entire RC CZO using the fine resolution data published by Kormos et al (2016). In using the data for modeling, we discovered that we needed to re-process the data into a different format (one 10m cell at a time, hourly for 31 yrs, across 238 km2 area) to be able run in parallel computing. This has caused delays to modeling the entire watershed for soil carbon but this is in progress and should be completed by end of year 5 with supplemental funds to complete analyses.

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.

Federal hiring freezes

The ARS has experienced intermittent hiring freezes for the past four years as a result of federal budget negotiations and new administration. We were finally able to hire a CZO technician/hydrologist in May 2018 to assist with maintenance of instruments and collection of gas and water samples/data.

Graduate students

Boise State University is responsible for the integrated modeling component, and a graduate student leading this effort departed for a more lucrative position. We hired a postdoc at BSU who is implementing an instance of PARFLOW at Reynolds Mountain East.

Changes that have a significant impact on expenditures

Hire ARS personnel

We hired a CZO technician at ARS; at the same time, ISU lost its CZO technician running water samples. We used these funds to hire graduate students to analyze water samples as part of their summer positions.

Data manager

ISU leveraged EPSCoR funds to fund the database manager at ISU (2013-2018) and hired data analyst full time starting June 2018. We also obtained funds from ARS so that analyst can work 50% on ARS geospatial services.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.

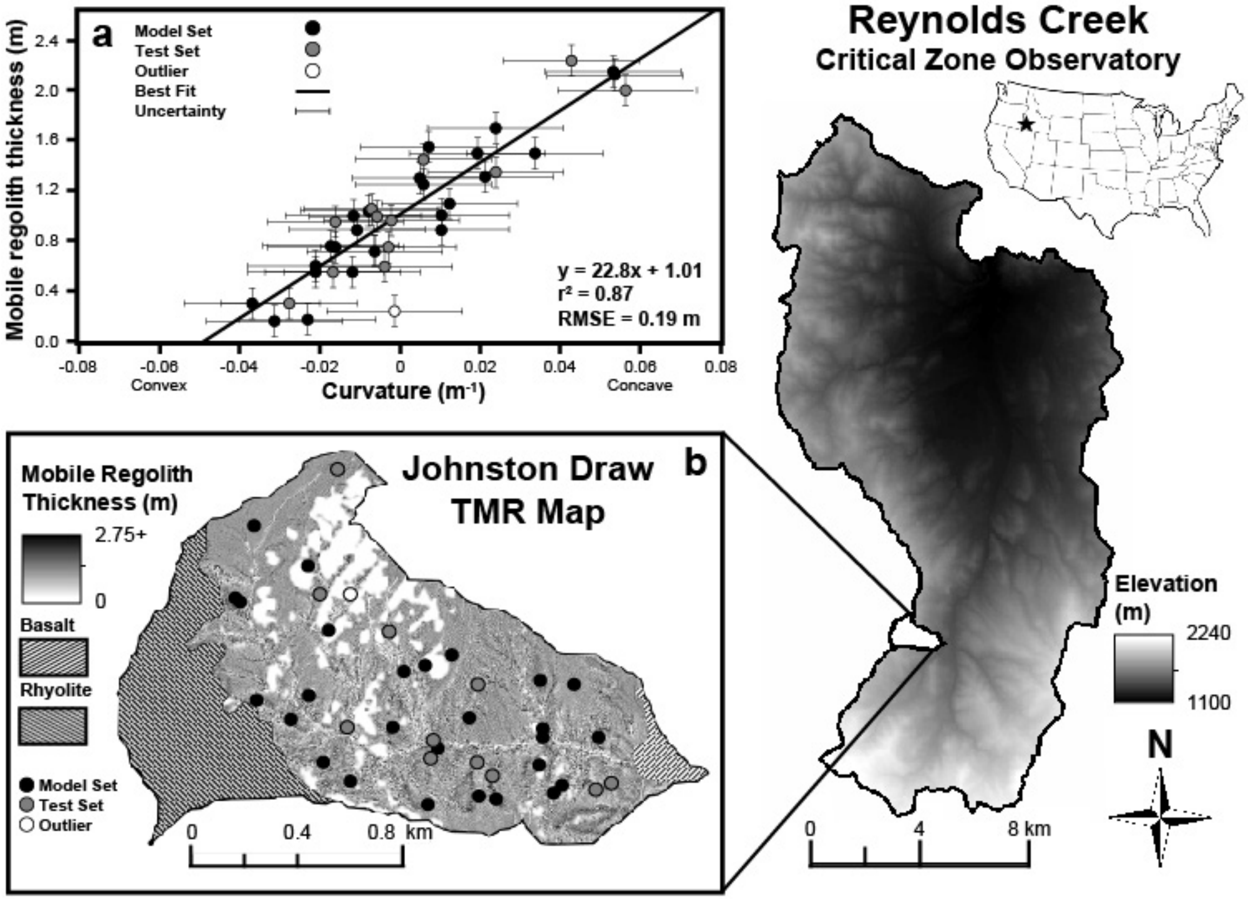


Figure 1.2a: (A) The thickness of the mobile regolith (TMR) varies as a strong inverse function of curvature in Johnston Draw. Black dots represent randomly selected build dataset (70% of sites). Gray dots represent test set to validate the model. The white dot is a location that was excluded owing to 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).

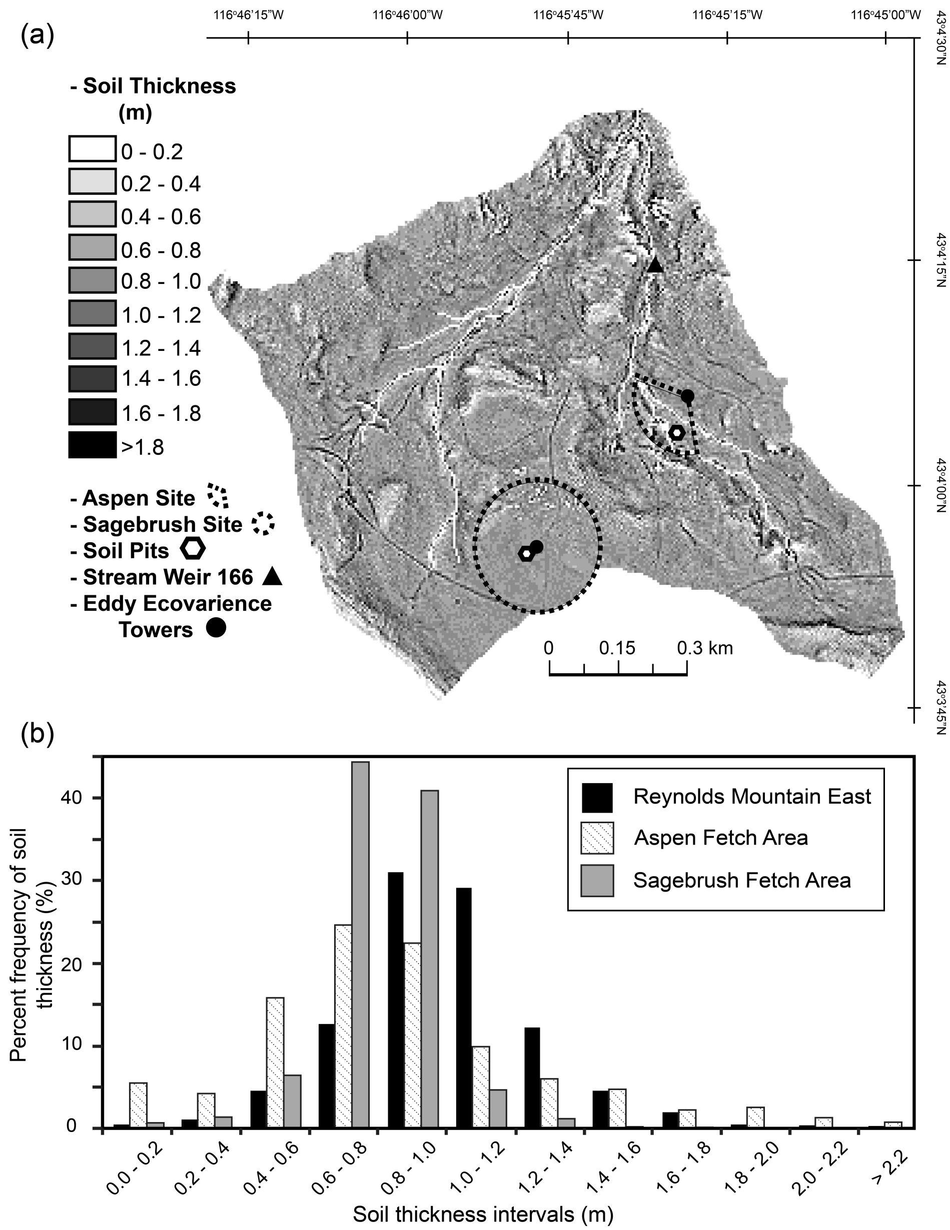


Figure 1.2.b. Reynolds Mountain East catchment with soil thickness (m) based on model from Patton et al. (2018). Figure shows location of eddy covariance tower, fetch area, and soil pits for the aspen and sagebrush sites.

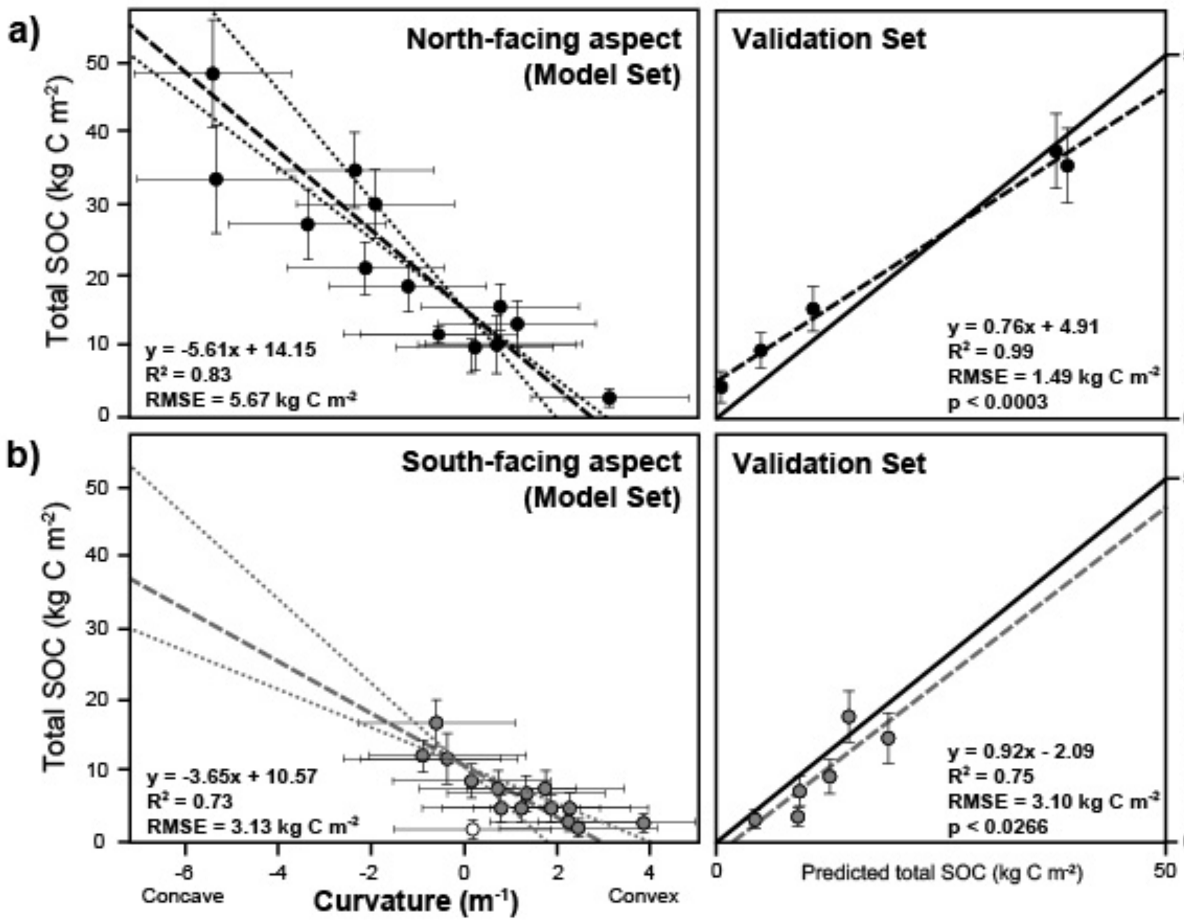


Figure 1.3a: Curvature to total soil organic carbon (curvature-SOC) functions for north- (black dots (a)) and south-facing (gray dots (b)) aspects depicting an inverse linear relationship (dashed line) bounded by 95% confidence limits (dotted line). Curvature-SOC functions were derived from a model set consisting of 70% of all sites. Note one site (white dot) was excluded from the analysis owing its proximity to the stream channel and rock outcrops. The remaining 30% of sites were utilized as a validation set and evaluated against a 1:1 line (solid line) in predicted versus measured graph (dashed line). For the north-facing function, the linear fit slightly underestimates total profile SOC while the south-facing function slightly overestimates total SOC.

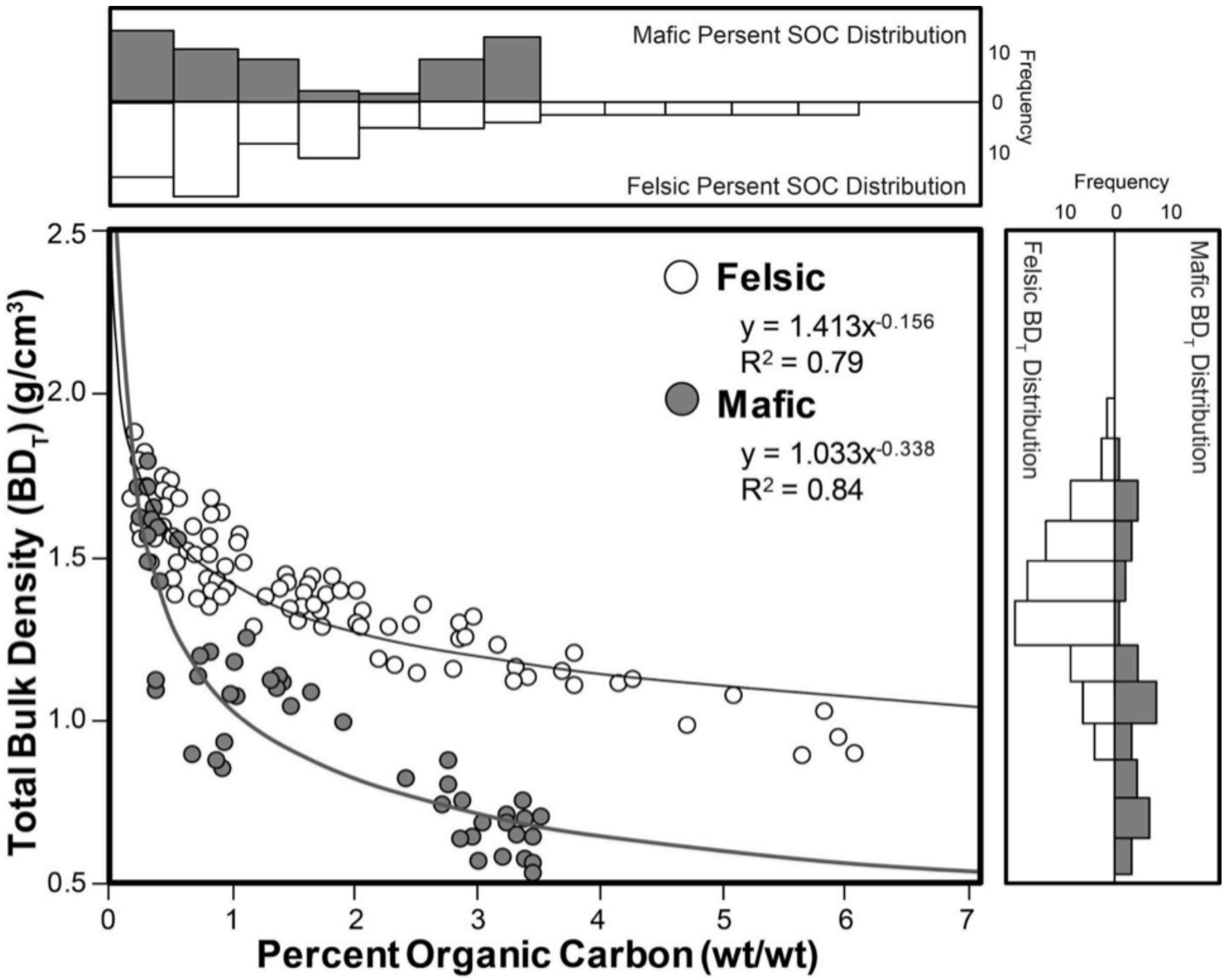


Figure 1.3b: Total bulk density using soil organic matter for felsic and mafic materials (mafic not shown) (Patton et al in review)

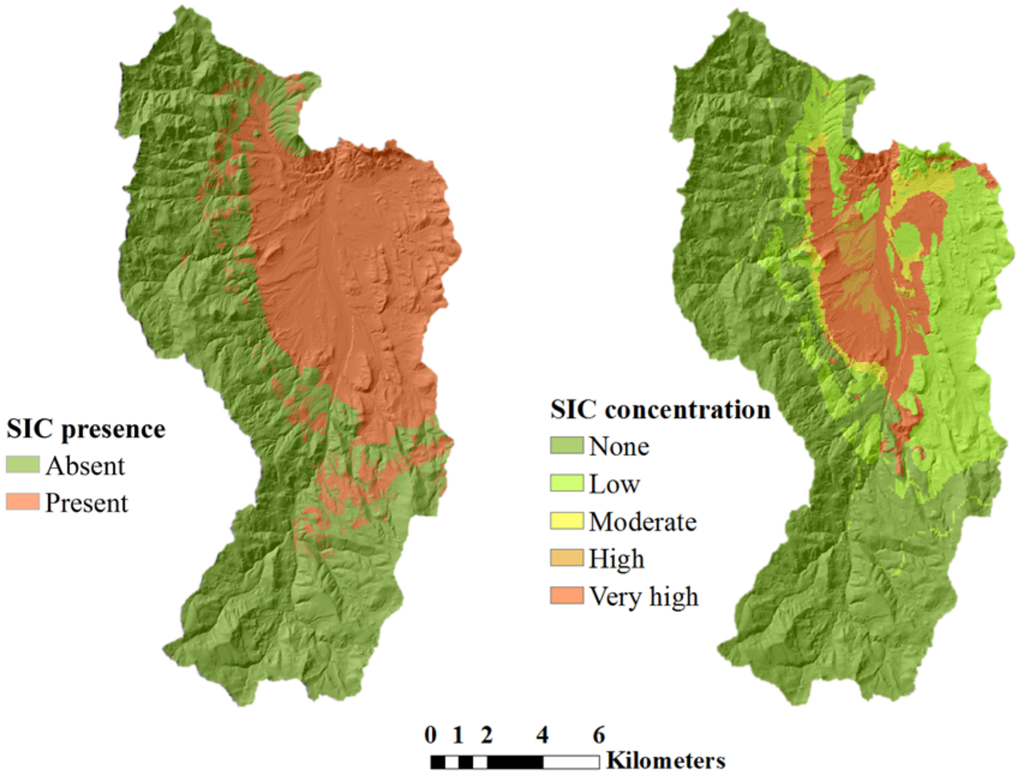


Figure 1.4a: Revised figures of soil inorganic carbon accumulation across the watershed with a) presence/absence and b) none to very high concentration of SIC

Figures: Priority 2

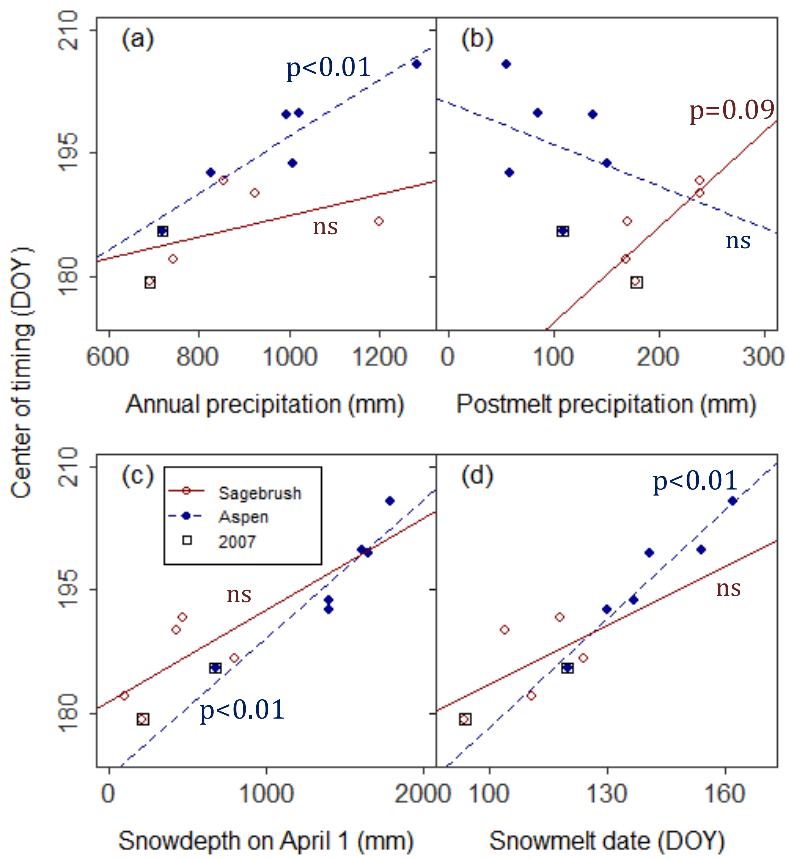


Figure 2.1a. GEE center of timing (calendar Day Of Year; DOY) with (a) annual precipitation, (b) rain that fell after the perennial snowmelt melted (postmelt precipitation), (c) April 1st snowdepth, and (d) the day that the perennial snowpack melted (Snowmelt date). Center of timing was calculated as Σ(GEE * DOY)/ ΣGEE (Fellow et al. 2018, Ecohydrology).

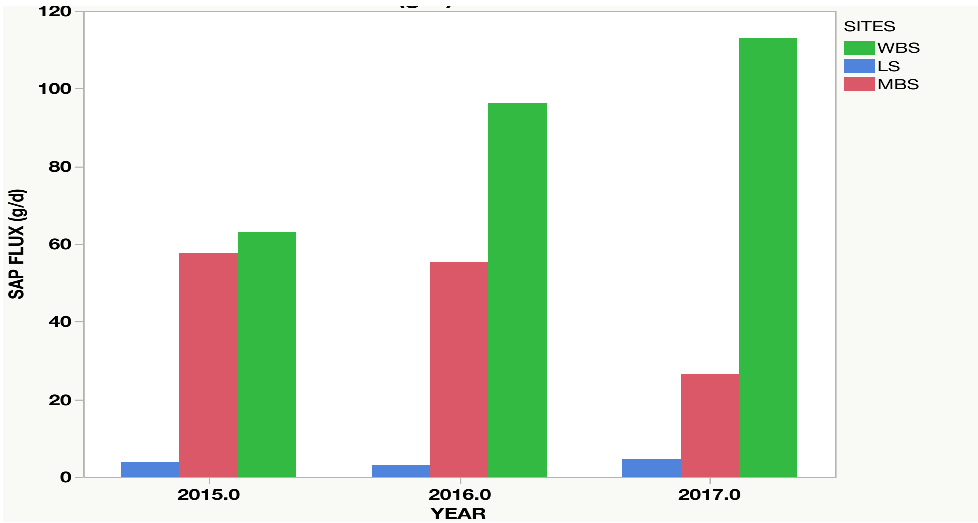


Figure 2.2. Annual sap flux at three sagebrush CORE sites for 2015-2017 (Sharma et al. in review)

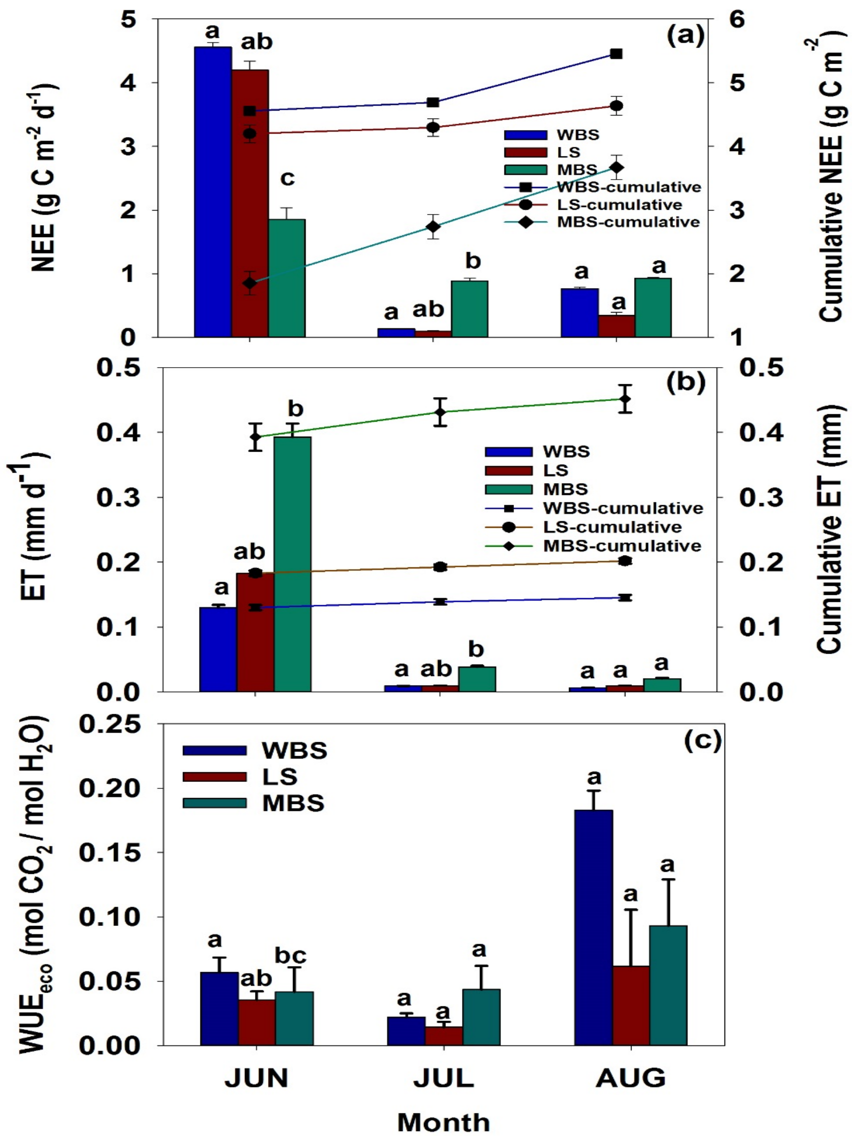


Figure 2.3a. Daily (6:00 a.m.-6:00 p.m.) and cumulative (additive across months) net ecosystem exchange (NEE) (a), evapotranspiration (ET) (b), and water use efficiency (WUE_{eco}) (c) at Wyoming Big Sage (WBS), Low Sage (LS), and Mountain Big Sage (MBS) sites June-August, 2016. Bars are means $\pm$ SE. Different letters above the bars indicate significant differences among sites ($p<0.05$) within each month (Sharma et al. in review).

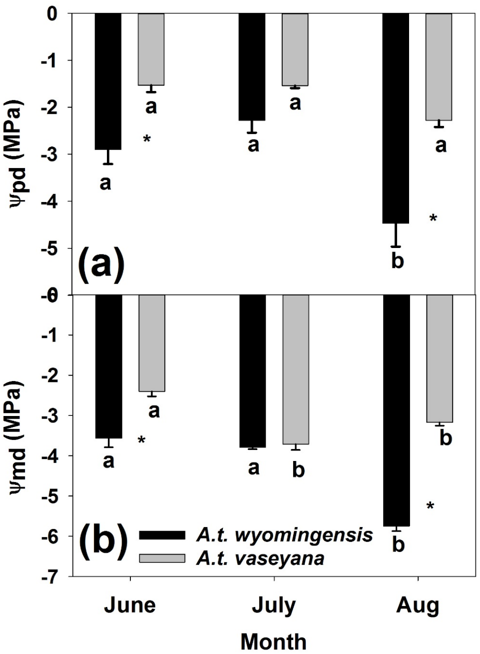


Figure 2.3b. Predawn (a) and midday (b) leaf water potential was significantly different between *A.t. wyomingensis* and *A.t. vaseyana* in June and August.
Predawn (a) and midday (b) leaf water potential reduced significantly by August in both big sagebrush sub-species (Sharma et al. in review)

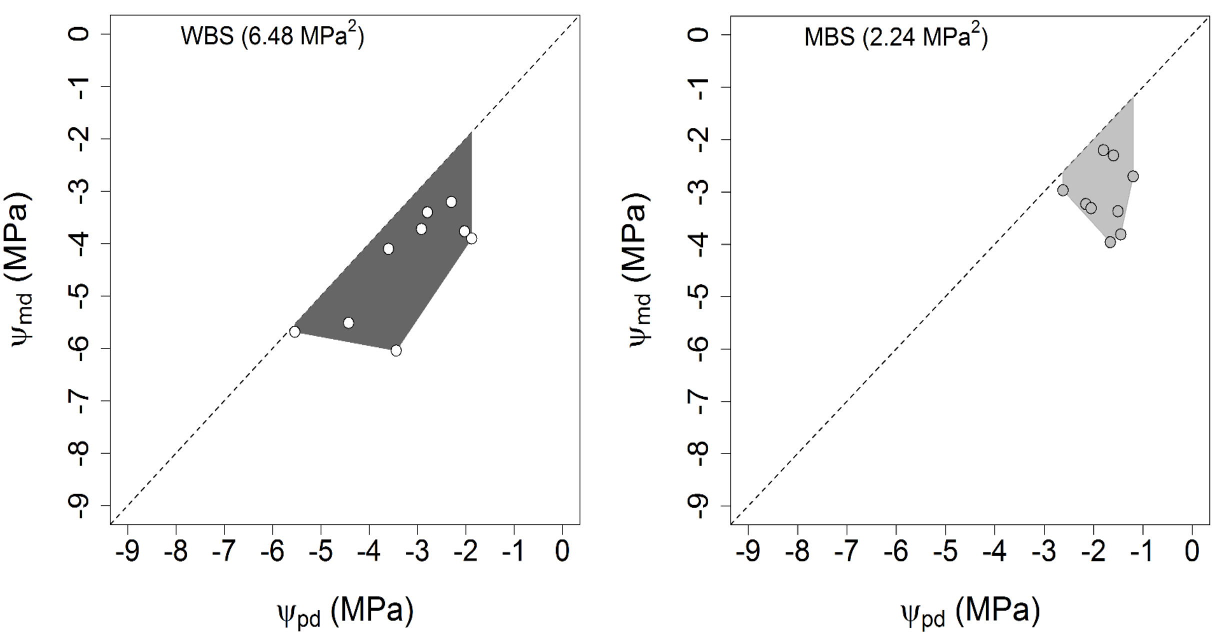


Figure 2.3c. Greater hydroscape area in *A.t. wyomingensis* indicates less stomatal regulations (i.e. anisohydric type behavior) in contrast to isohydric behavior reported in *A.t. vaseyana (Sharma et al. in review)*

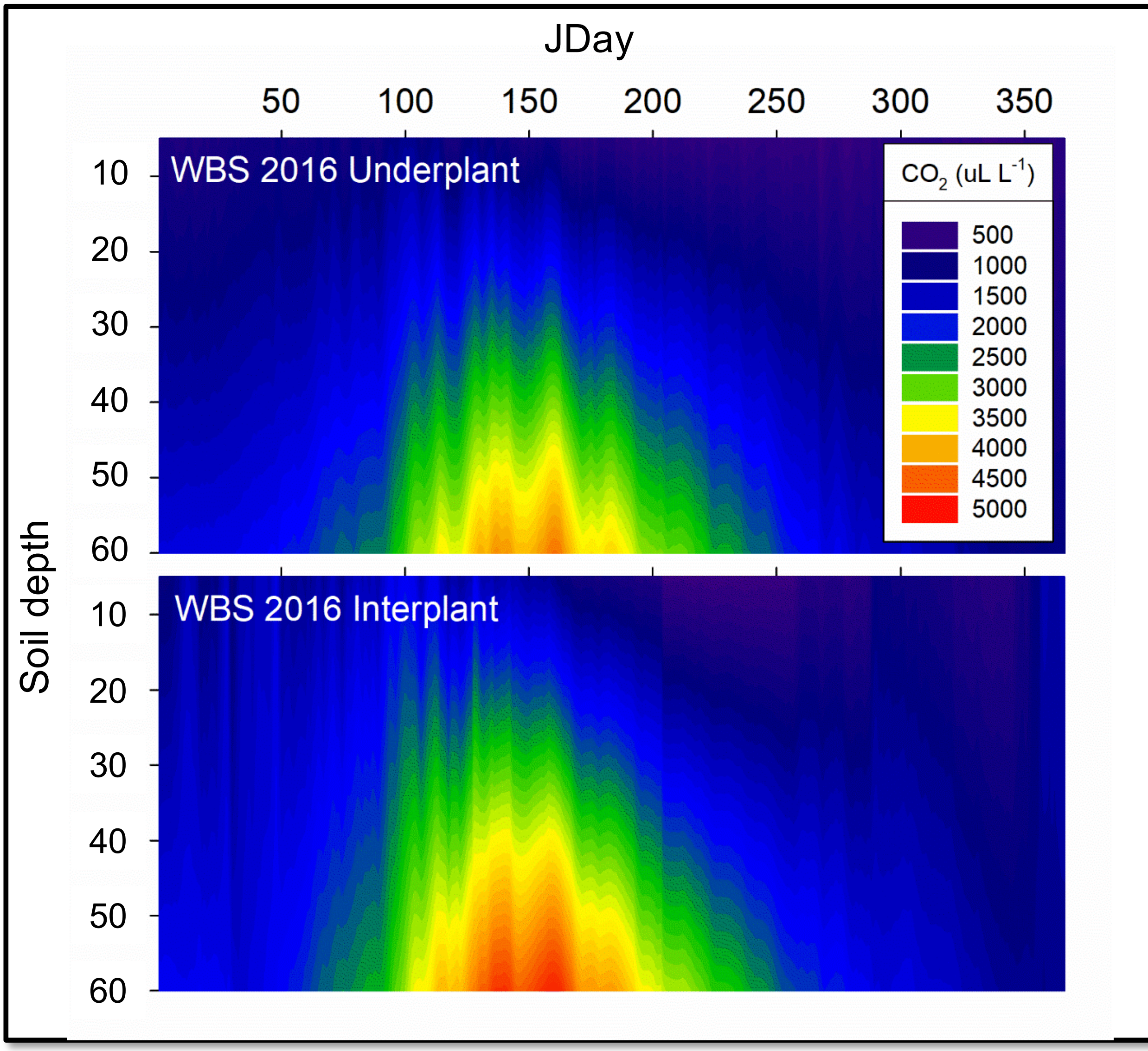


Figure 2.4a: Carbon dioxide concentrations with depth in plant and interplant space in WBS core site showing high concentrations at depth (Huber et al. in preparation)

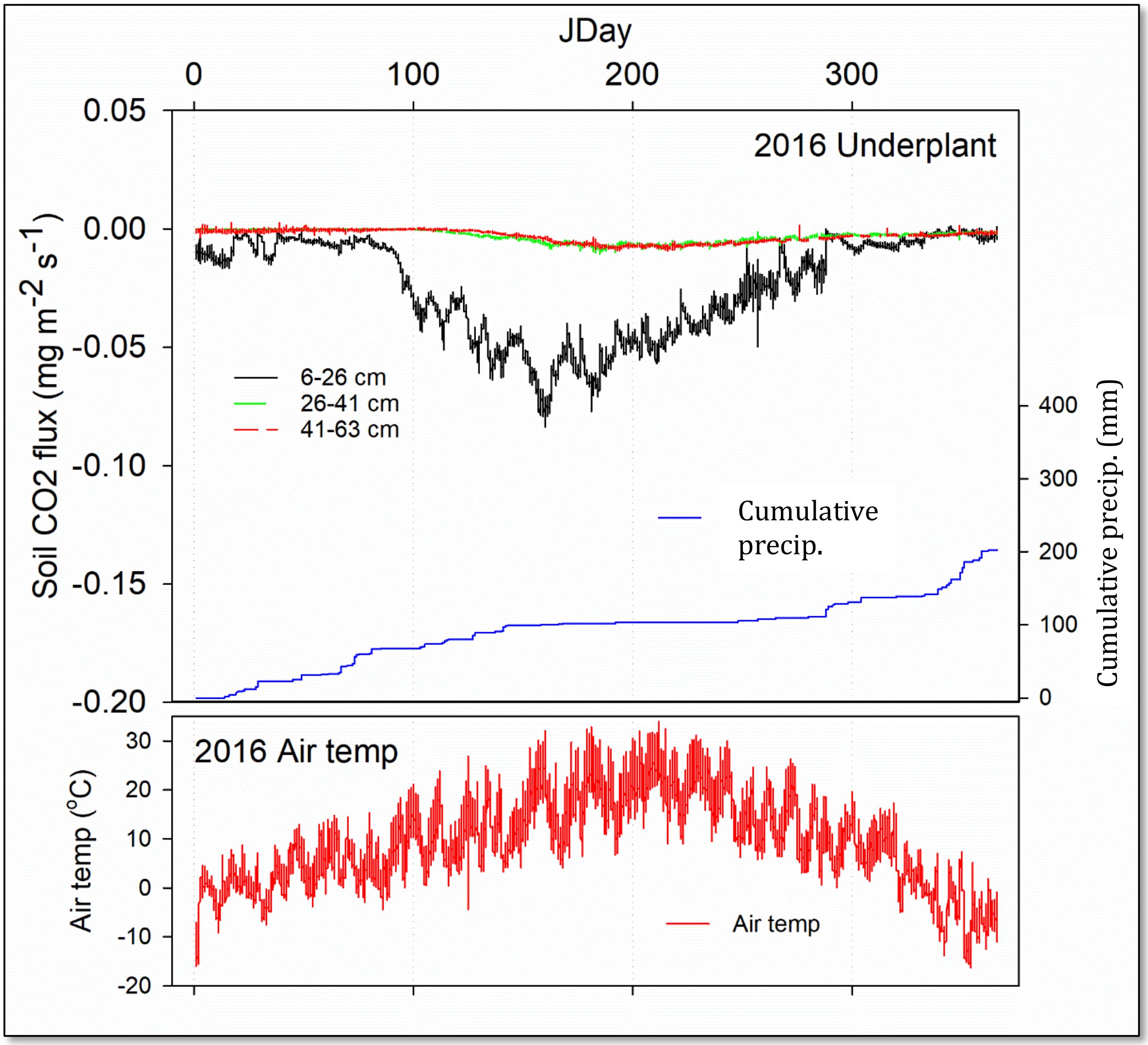
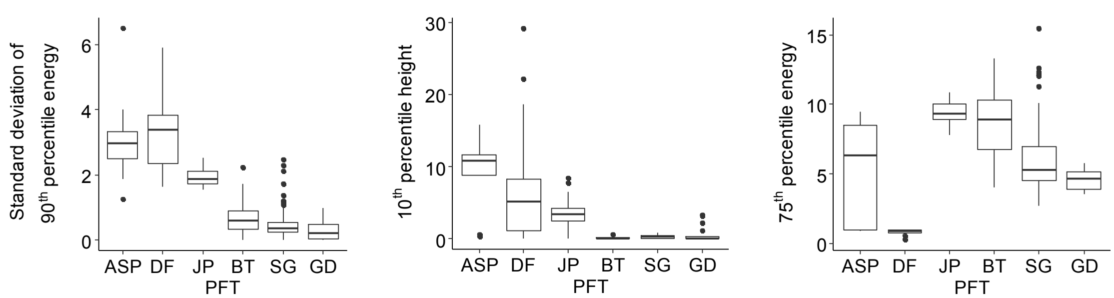


Figure 2.4b. Surface and deep soil fluxes show high fluxes at surface compared to deeper soils (Huber et al. in preparation)



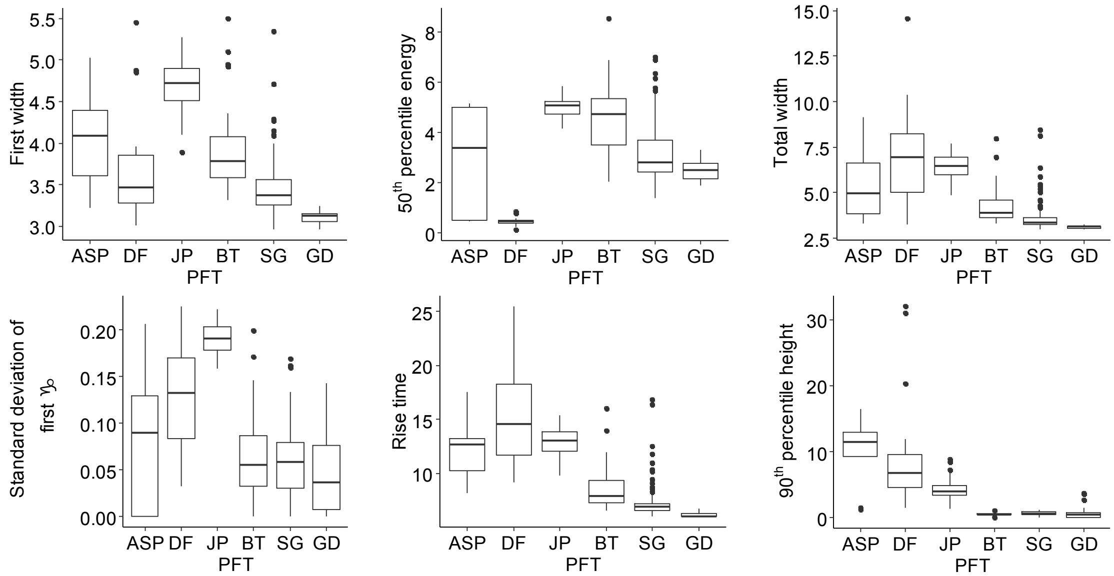


Figure 2.5: Box plots showing the variability of values of the most important waveform features at 1 m scale among PFTs. Definitions of PFTs are: ASP-aspen, DF-Douglas fir, JP-juniper, BT-bitterbrush, SG-sagebrush, GD-bare ground. From left to right, top row: variability of standard deviation of 90th percentile energy, 10th percentile height, and 75th percentile energy, respectively; middle row: variability of pulse width of first returns (first width), 50th percentile energy, and pulse widths of all returns (total width), respectively; bottom row: variability of standard deviation of backscatter coefficient of first returns (first γ), rise time, and 90th percentile energy, respectively. Note the differentiation of shrubs and bare ground with the pulse width and rise time (Ilangakoon et al. 2018, NASA TE supported research in RC CZO)

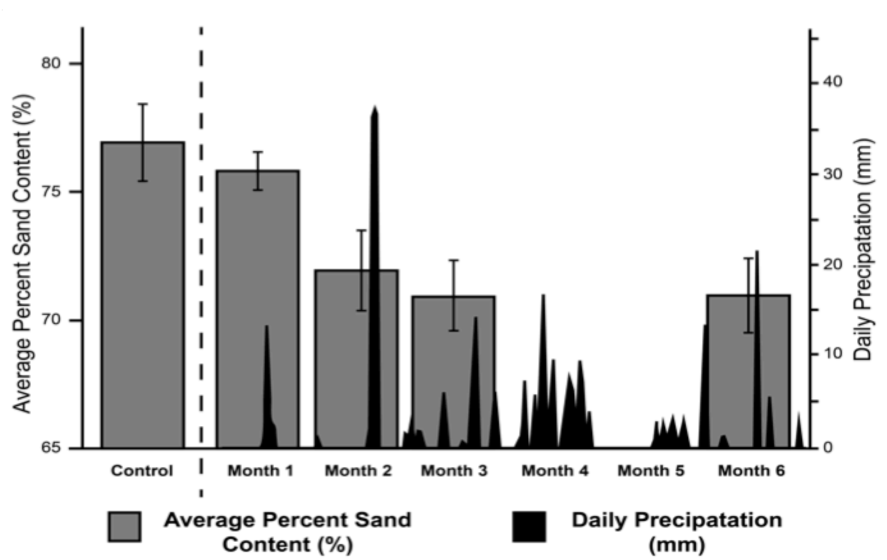


Figure 2.6a: Sand content % in burned soils decreased following fire (Lohse et al. in progress).

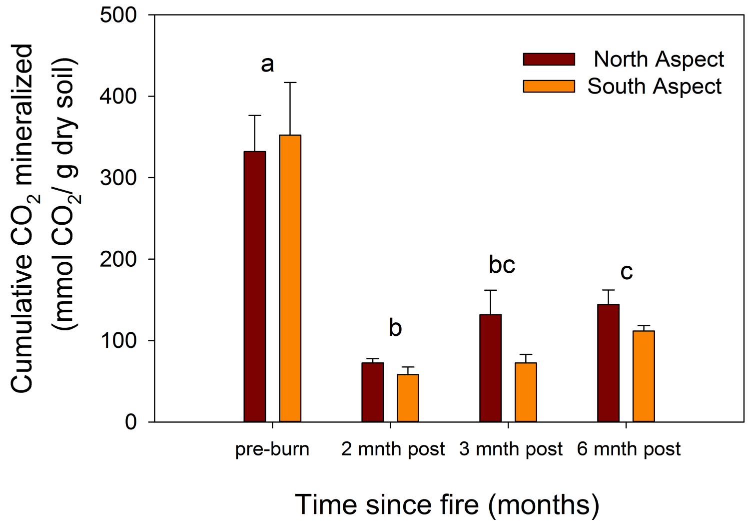


Figure 2.6a: Cumulative carbon mineralized under similar conditions (60% WHC) showed no differences in north and south recovery of mineralization following fire but relatively rapid recovery (Lohse et al. in progress)

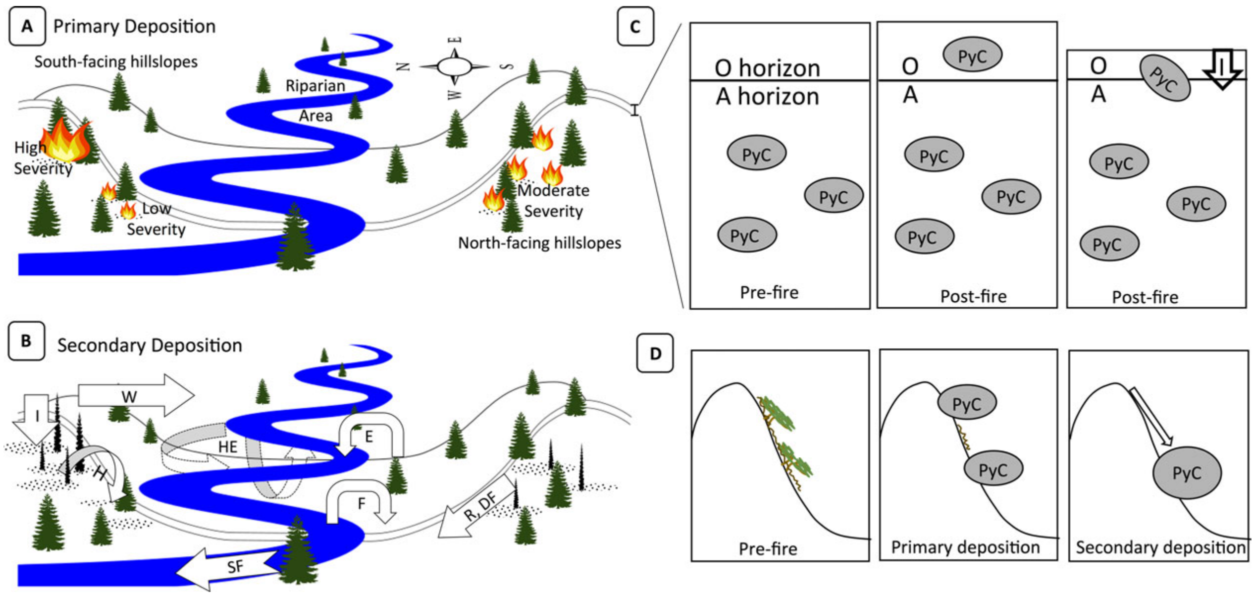


Figure 2.9a: Conceptual model of PyC transport. (A) Biomass and soil combustion generate PyC and initially distribute it through primary deposition. Variation is expected based on depositional setting (soil horizon, aspect, slope, geomorphic setting) and degree of burn severity (unburned, low, moderate, high). (B) Reworking and secondary deposition of PyC, as a particulate or as a solute, can take place via wind - labeled in figure asW, runoff - R, debris flow - DF, streamflow - SF, erosion - E, floodplain deposition - F, hillslope deposition - H, infiltration - I, and hyporheic exchange - HE. The same factors affecting primary deposition affect subsequent transport and secondary deposition. (C) Our data indicate soil horizon transport, which is influenced by O horizon erosion as well as infiltration from the O horizon to the A horizon. (D) Our data also indicate variability in secondary deposition on hillslopes, affected by changes in surface roughness and preferential flow. [Colour figure can be viewed at wileyonlinelibrary.com] (Galanter et al. 2018, ESPL)

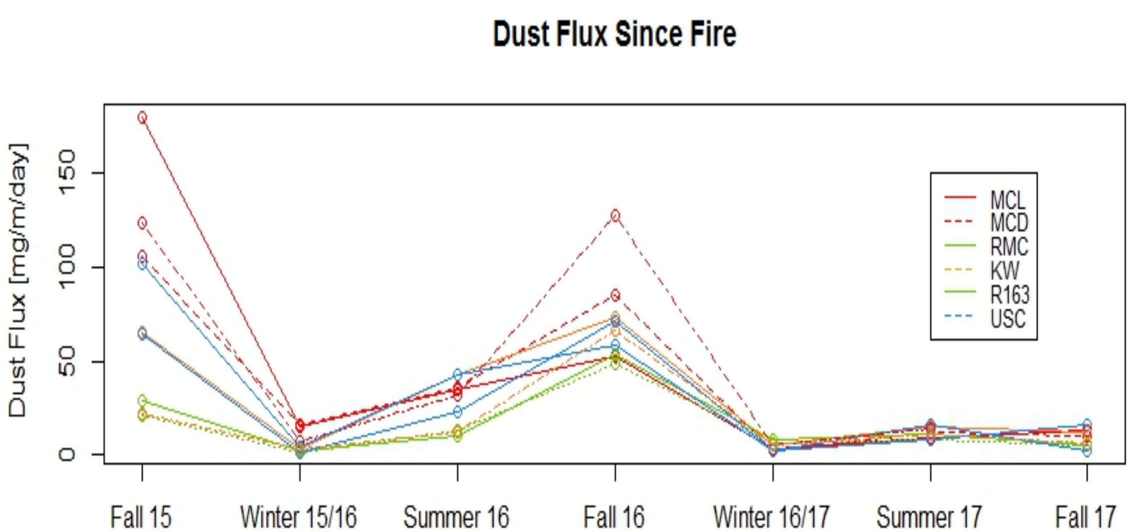


Figure 2.9b. Dust flux following the Soda Fire (Roehner 2018 thesis, Roehner et al. in preparation)

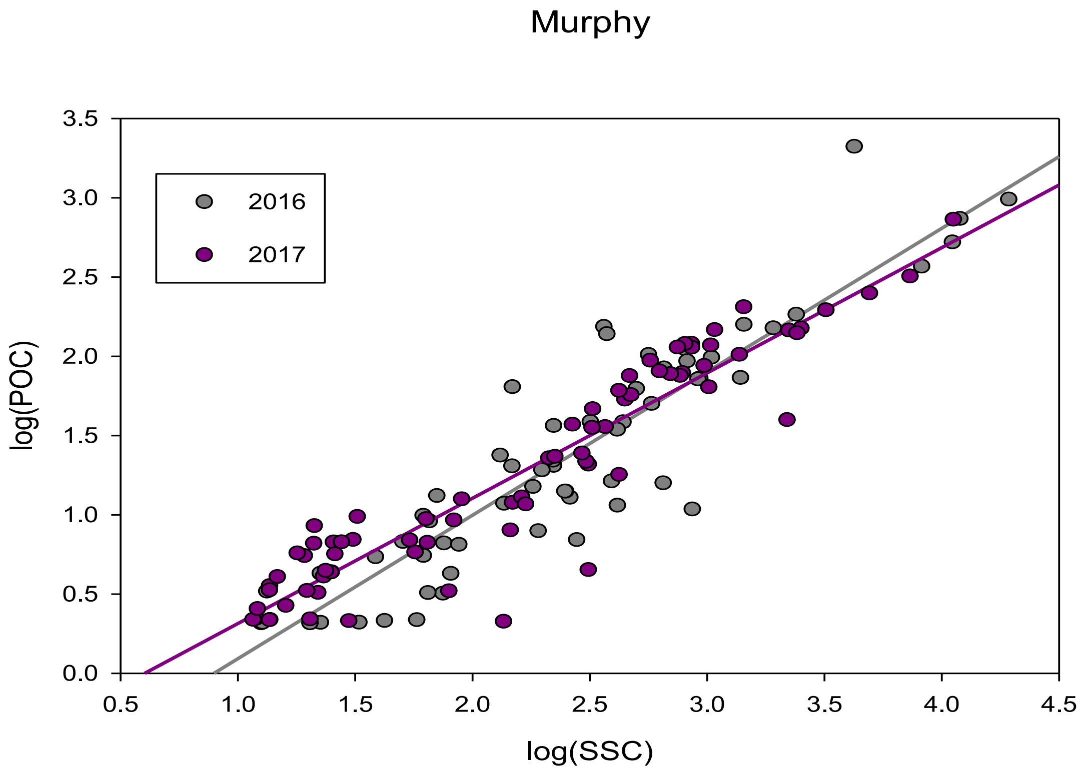


Figure 2.9c. Sediment and POC relationship in burned watershed, Murphy Creek. Sediment and POC from small drainage (1.2 km^2) as high as large drainage areas, Tollgate (54 km^2) and Outlet (238 km^2) (Glossner et al., thesis in progress).

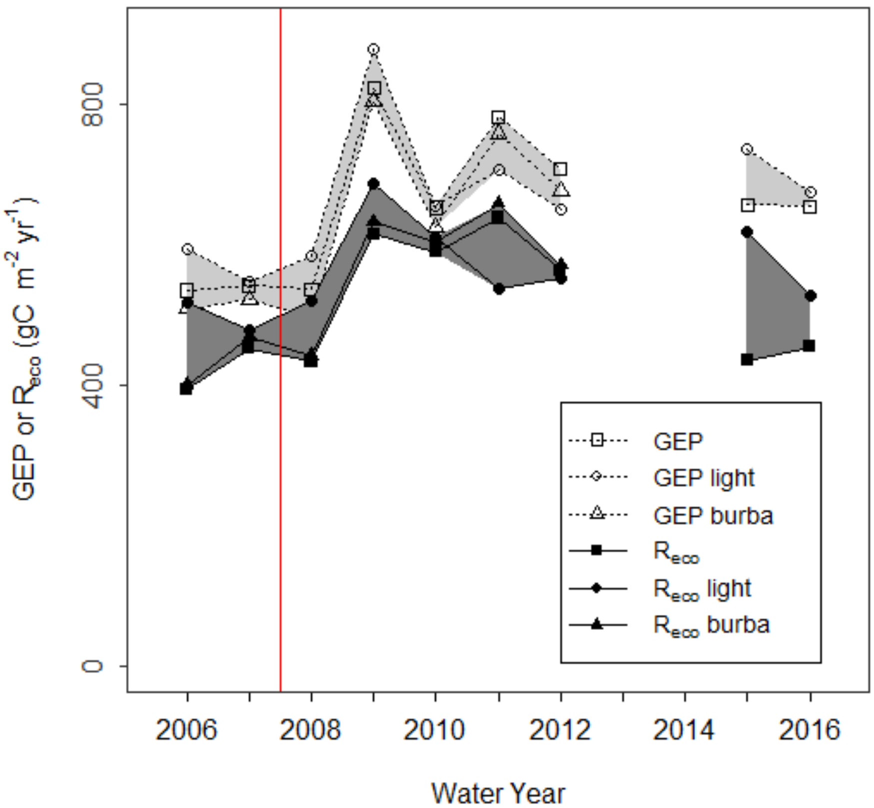


Figure. 2.9d. Pre- and post-burn Gross Ecosystem Production (GEP; gC m^{-2} yr^{-1}) and Respiration (R_{eco}; gC m^{-2} yr^{-1}). The site was burned in September 2007 (vertical red line). Annual GEP and Reco were estimated in three ways: (1) missing observations were filled with REddyProc (GEP and Reco; Reichstein et. al., 2005), (2) missing observations were filled with a light response curve (GEP light and Reco light), and (3) GEP and Reco were filled with REddyProc after adjusting the measured fluxes for sensor heating using Burba et al., (2008; GEP burba and Reco burba). Data show rapid recovery of GEP following fire (Fellows et al. 2018, Ecosystems).

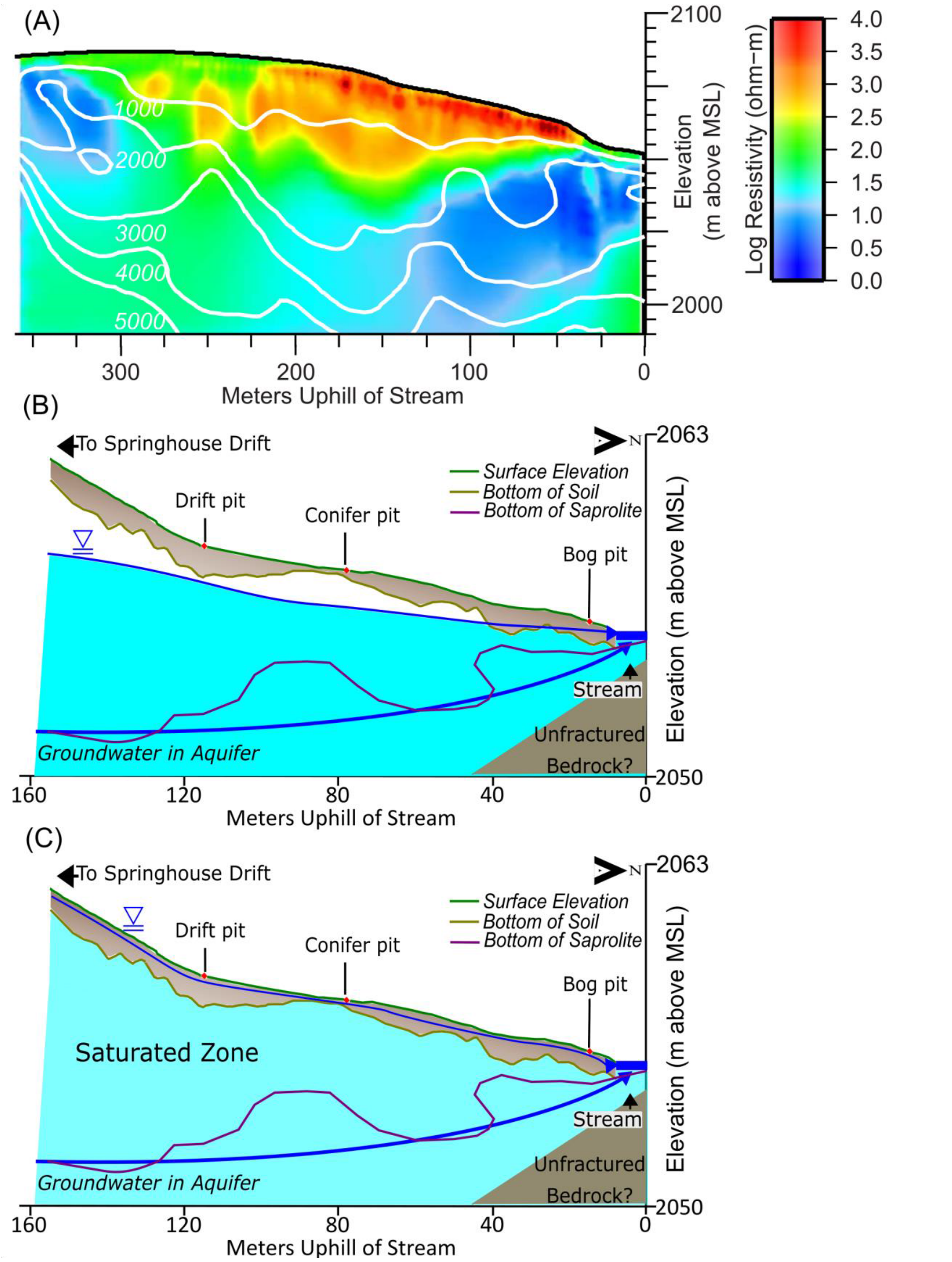
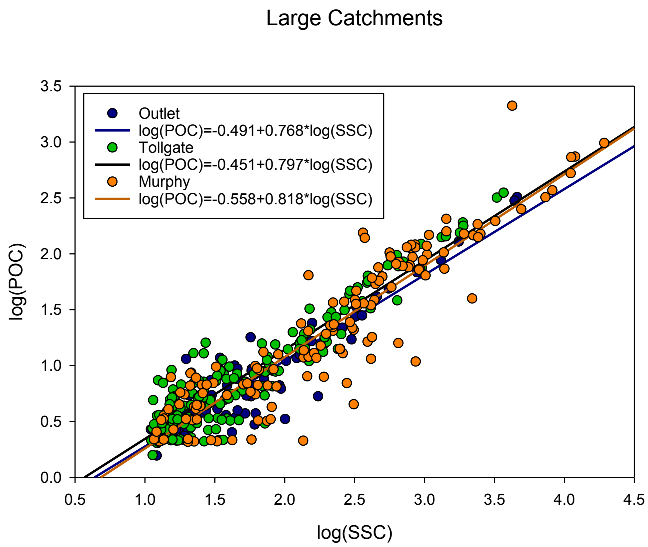


Figure 2.10.a. Geophysics results and conceptual models of RME. X-axis is distance from the main stem 828 of Reynolds Creek; the Bog pit is located at a secondary channel. (A) Color scale shows log10 829 electrical resistivity according to color bar at left. White lines show seismic velocity contours from seismic inversion (italicized numbers in m/s). (B) and (C) Water table elevation in late summer compared to during snowmelt. Summer water tables (B) are lower, leaving soil water stranded in the unsaturated zone and unable to reach the stream. With the onset of melt, the water table rises (C) and soil water is flushed to the stream. Groundwater in aquifer may be sourced from an adjacent catchment. Note that conceptual figures represent a transect passing through the soil

pits which is slightly offset from the geophysical transect, hence the difference in slope profiles; they also represent a shorter horizontal distance from the stream (Radke et al. in review)



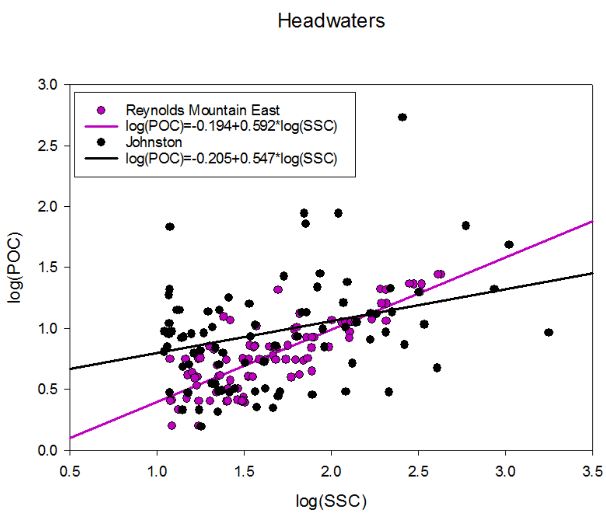


Figure 2.10b. Sediment to particulate organic carbon (POC) relationships were similar for large watersheds compared to headwater catchments (slopes were not significantly different owing to increased variability) (Glossner et al. in progress)

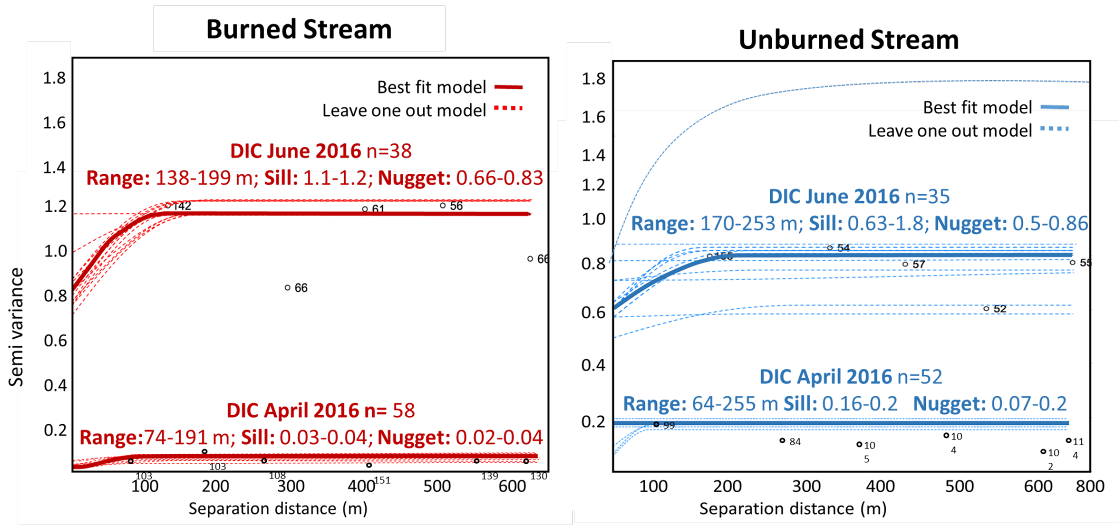


Figure 2.10c. Variability in DIC concentrations increase with stream drying indicated by increased sill (Macneille et al. in preparation)

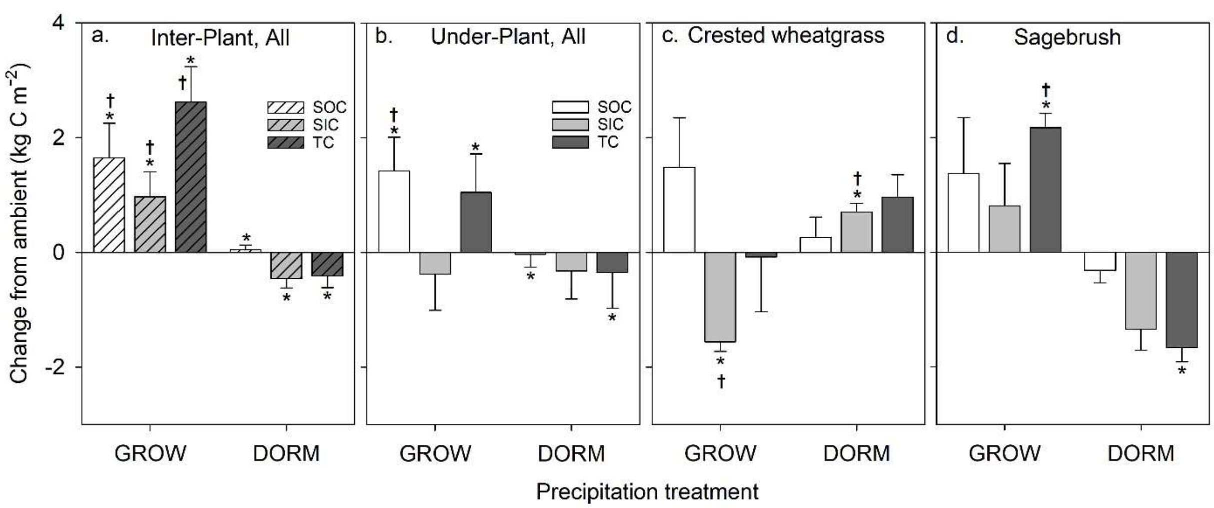


Figure 2.11: Mean difference in soil carbon to 1 m depth for supplemental rainfall treatments applied in the growing season (GROW) or dormant season (DORM). Carbon pools are presented by either a) combined interplant patches or b) combined underplant patches for combined vegetation treatments, or c) underplant only for exotic crested wheatgrass, or d) underplant only for native big sagebrush. Carbon pools include soil organic carbon (SOC), inorganic carbon (SIC), and total carbon (TC) storage. Main effects for both plant communities combined for panels a and b. * indicates statistical significance between rainfall treatments; † indicates statistical significant GROW or DORM treatment effect relative to ambient controls. All statistical analyses assessed at α = 0.05. (Huber et al. in review Ecology)

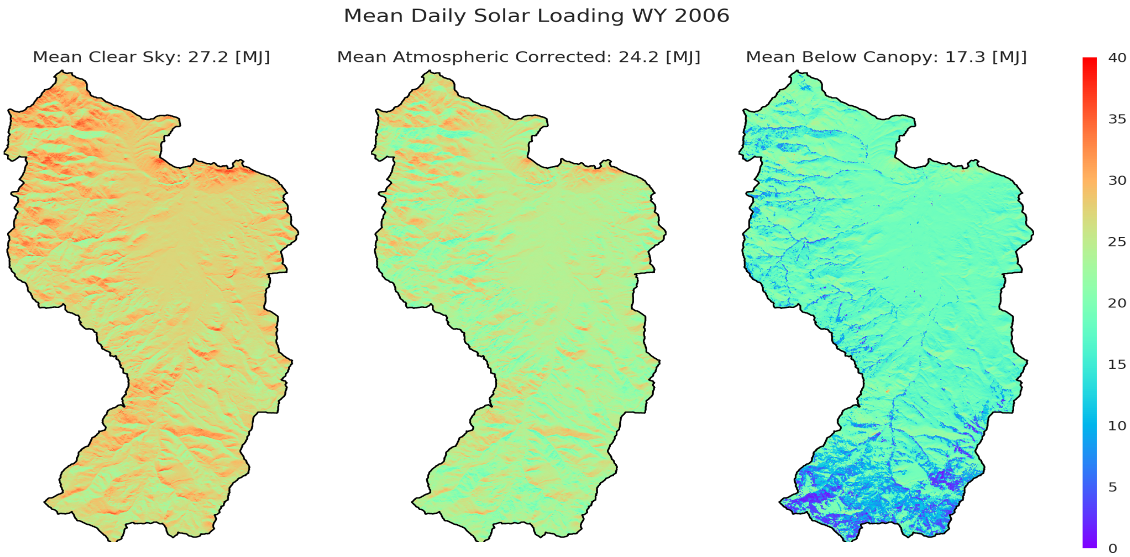


Figure 3.1a: Mean daily solar loading for water year 2006. Pictured is the comparison between terrain corrected solar radiation, solar radiation above the canopy, and solar radiation below the canopy. Spatial means are given in the figure headings (Sandusky et al. in preparation)

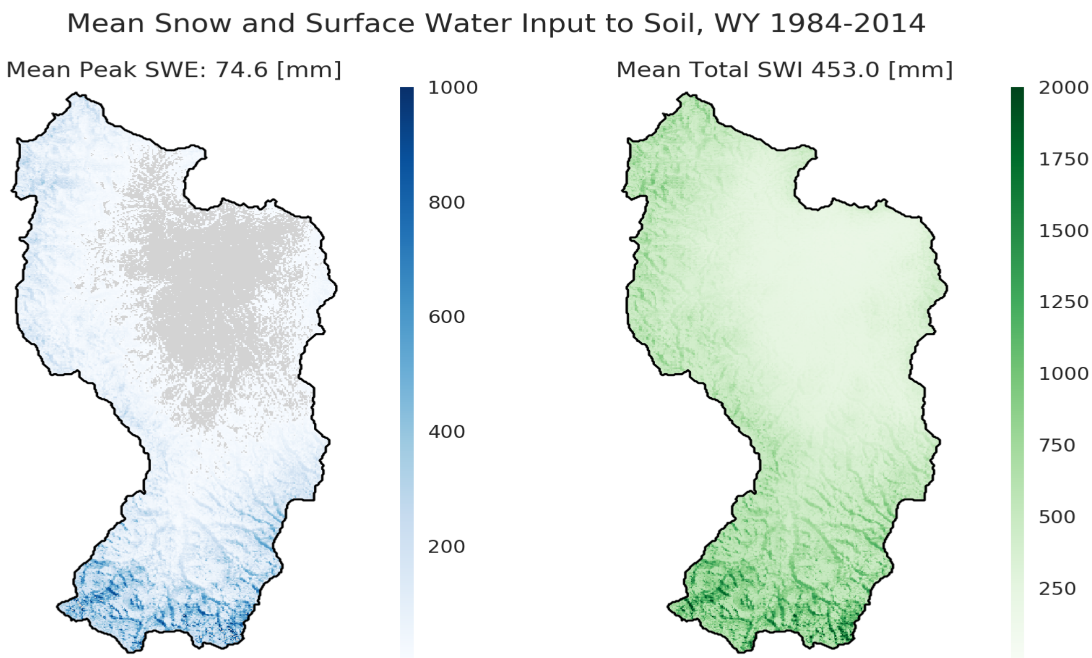


Figure 3.1b. Mean peak SWE and total SWI to the soil for the 31 year period of WY 1984-2014. SWI includes snowmelt leaving the bottom of the snowpack and rain falling directly on the soil. Values under 10mm are shown as grey. Spatial means are given in the figure headings (Sandusky et al. in preparation)

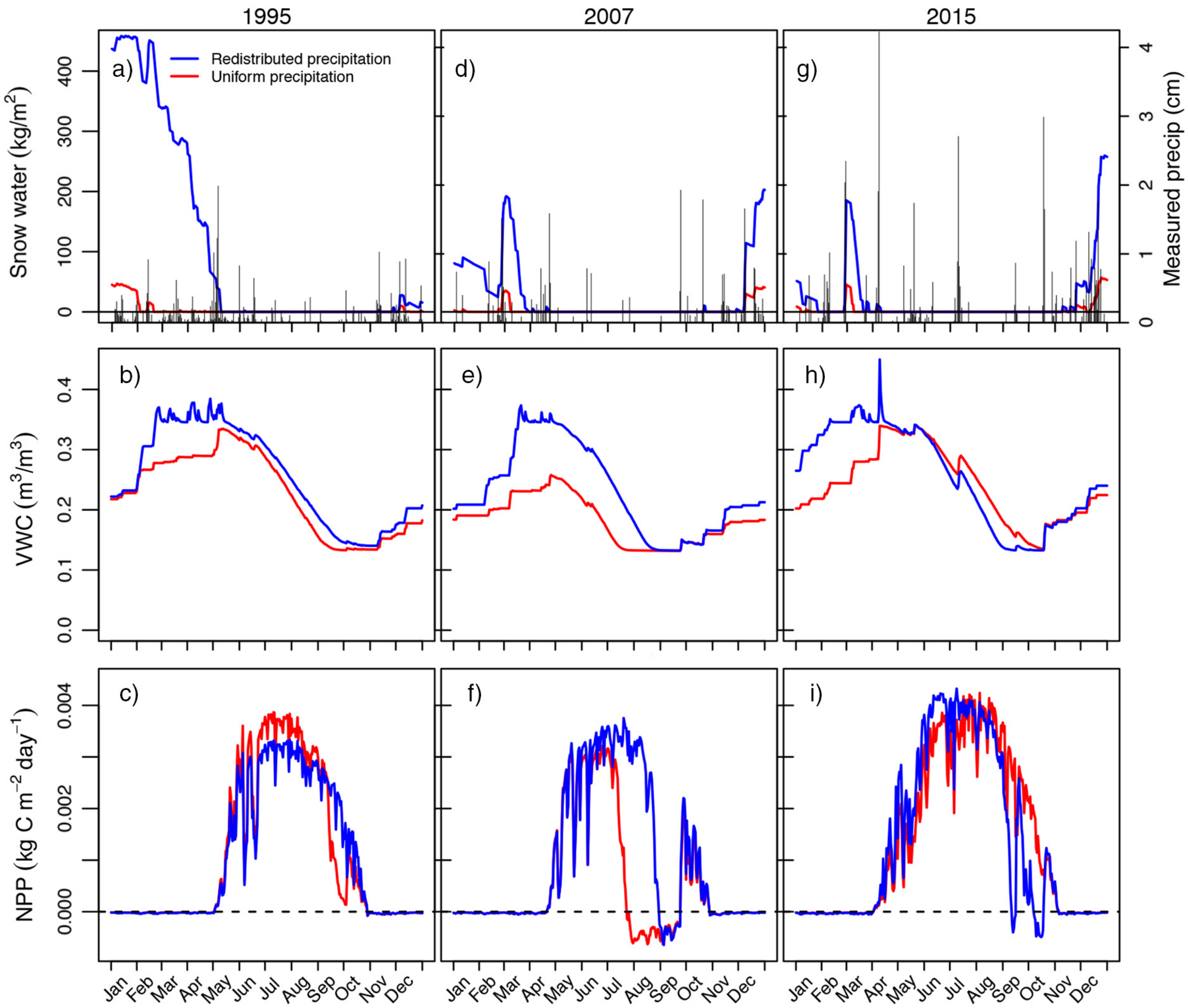


Figure 3.3a: Response of snowpack, VWC (hv), and net primary productivity (NPP) to redistributed precipitation at Sheep Creek (SC) for 1995 (a, b and c), 2007 (d, e and f), and 2015 (g, h and i). Biome-BGC simulated snow water, VWC, and NPP are shown for both uniform and redistributed precipitation treatments. Measured precipitation events are shown in gray bars (panels a, d and g). Despite large drift formation in 1995, cooler temperatures and spring rains supplemented soil moisture in the absence of a drift. Unlike 1995 and 2015, drift presence was far more important during 2007, a year with above average temperatures and increased growing season evaporative demand. After accounting for the redistribution of snow, NPP remained positive nearly 40 d longer during 2007 (Soderquist et al. 2018).

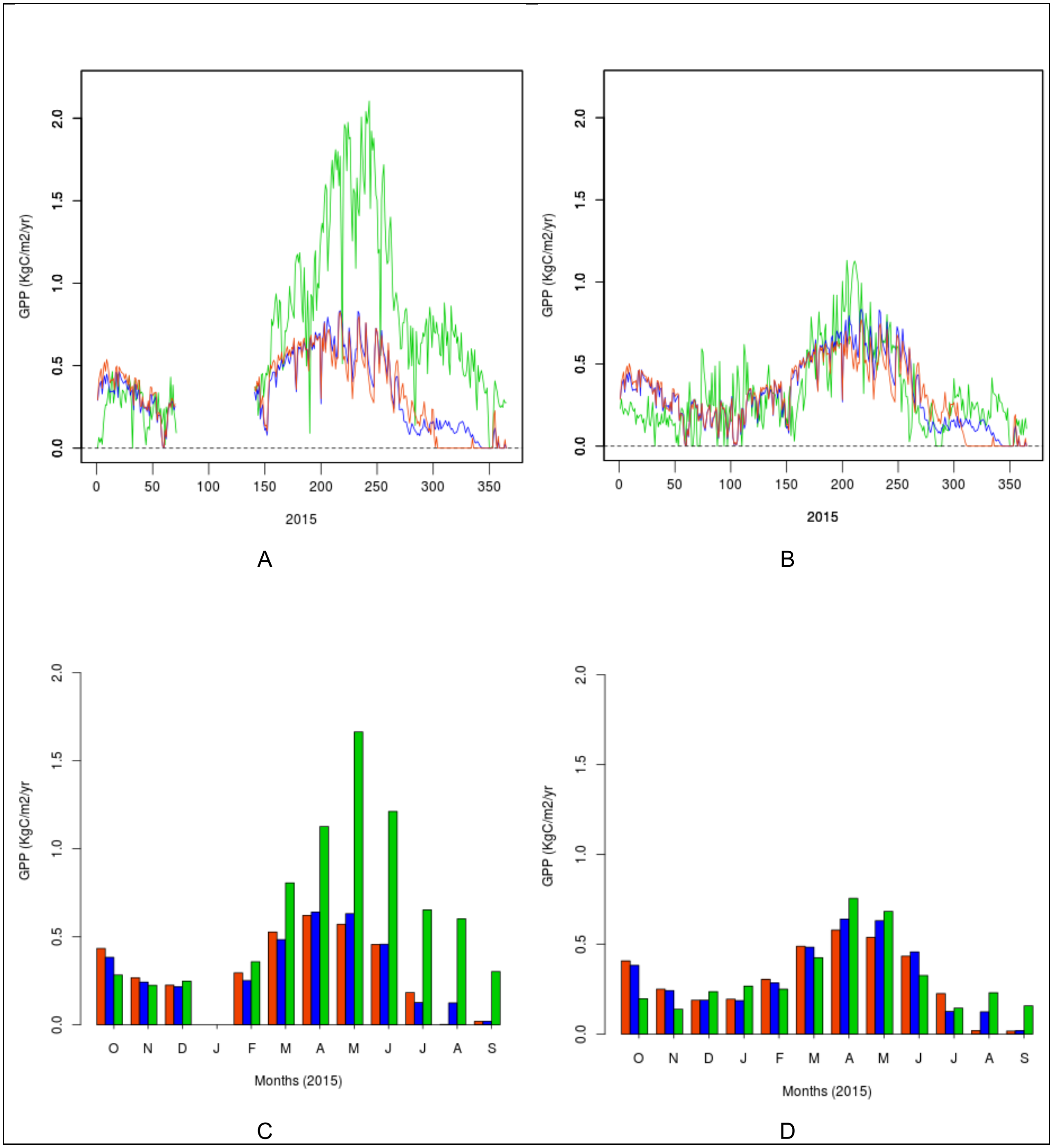


Figure 3.3b. Validation of daily and monthly GPP (KgC/m2/yr) using best case and ensemble mean against respective EC station observation data from water year 2015. a) daily GPP LS 2015, b) daily GPP WBS, c) monthly GPP LS, d) monthly GPP WBS. Blue is best case, red is ensemble mean case, and green is observed data (Pandit et al. in review).

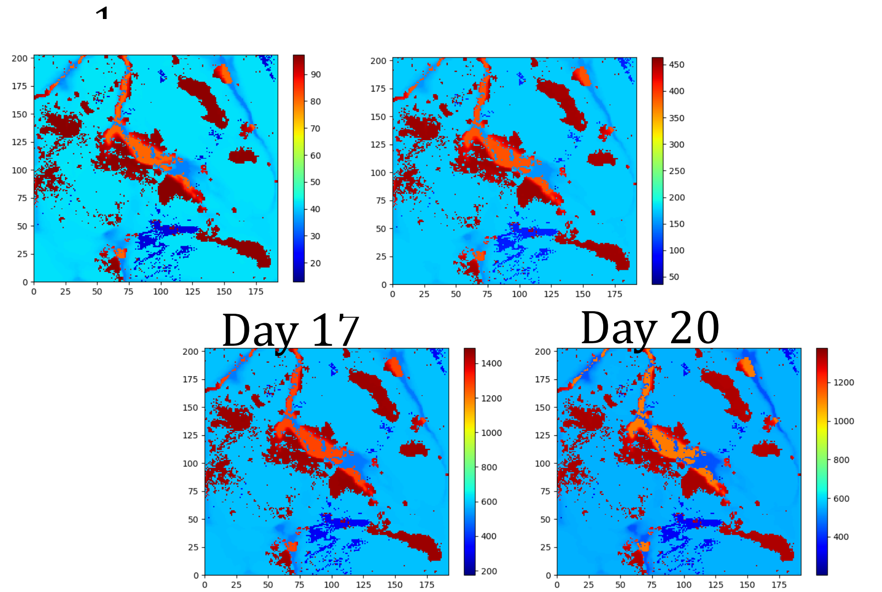
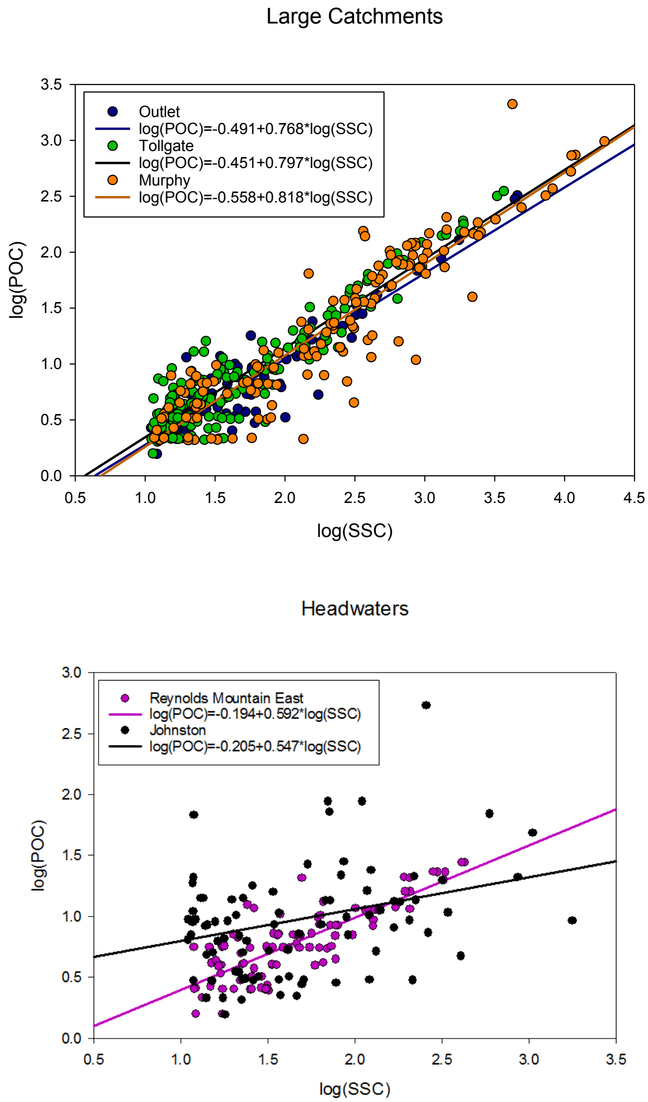


Figure 3.3b. Transient-state simulation of ParFlow-CLM (from Oct.1, 2004) at Reynolds Mountain East (Chen et al. in progress)



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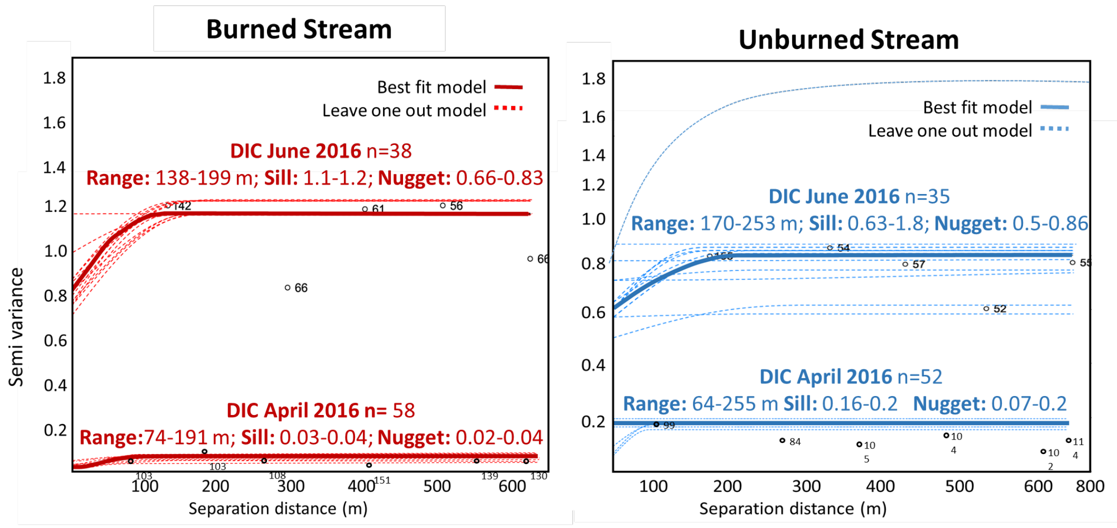

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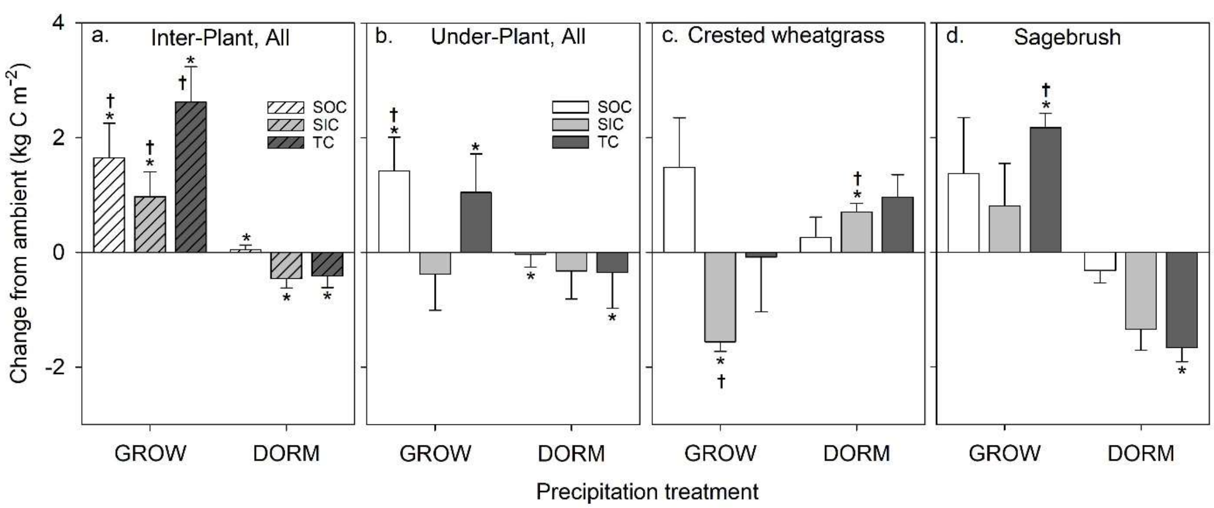

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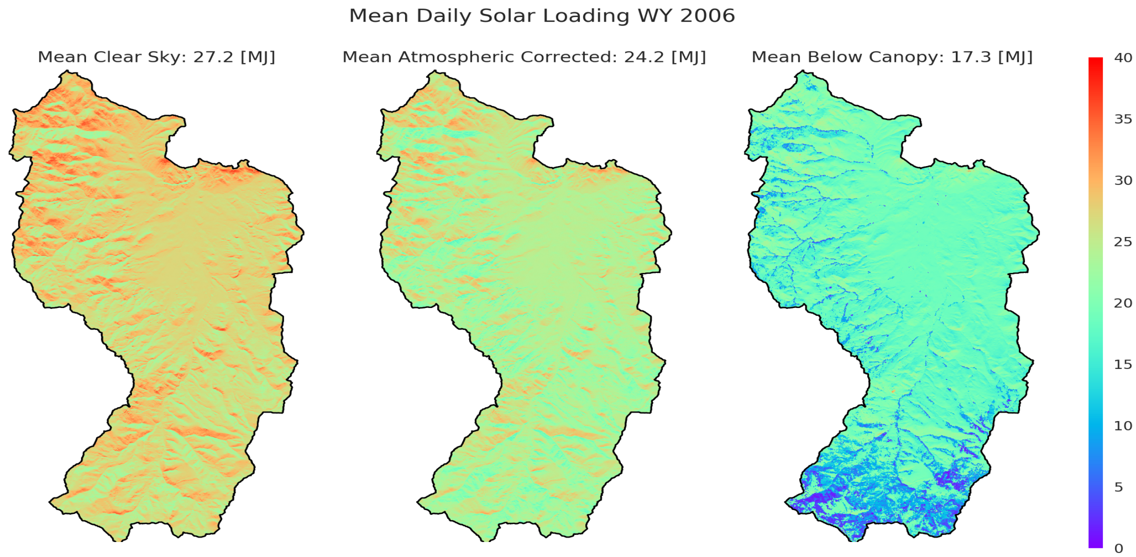

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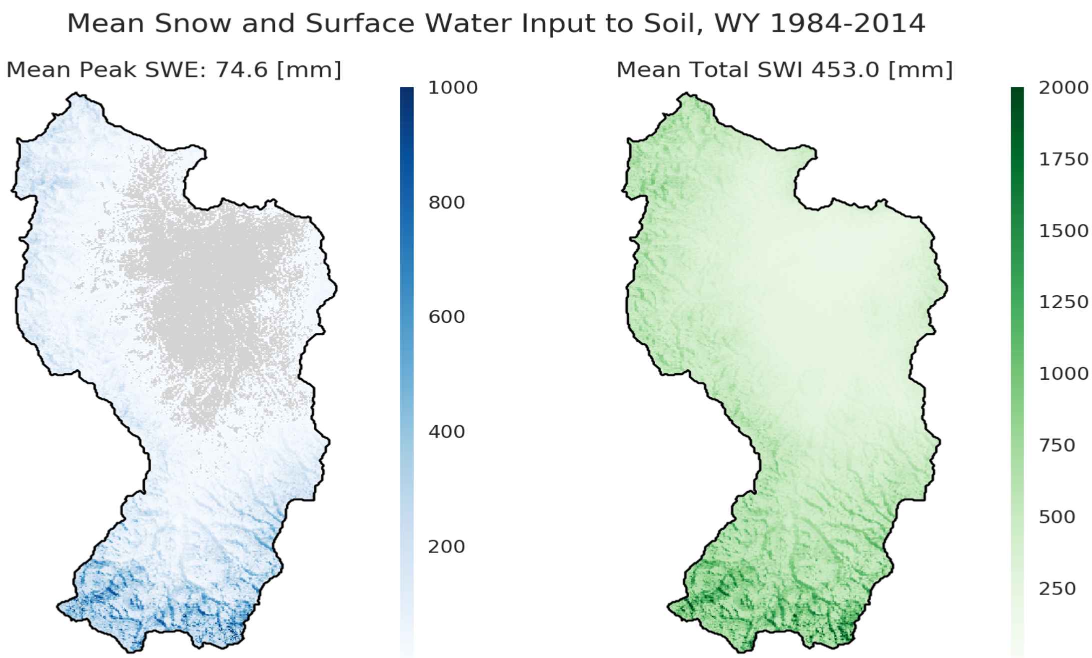

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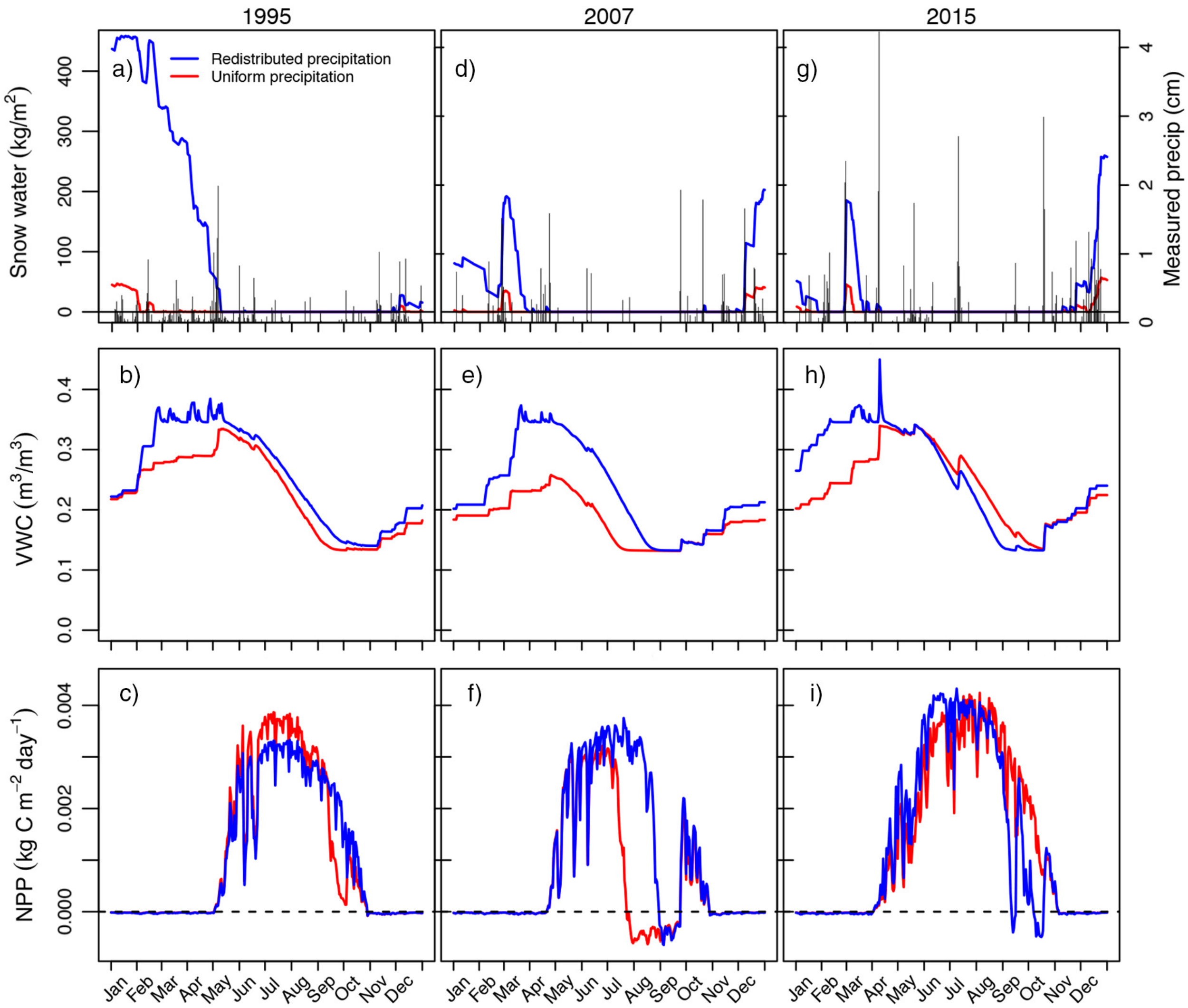

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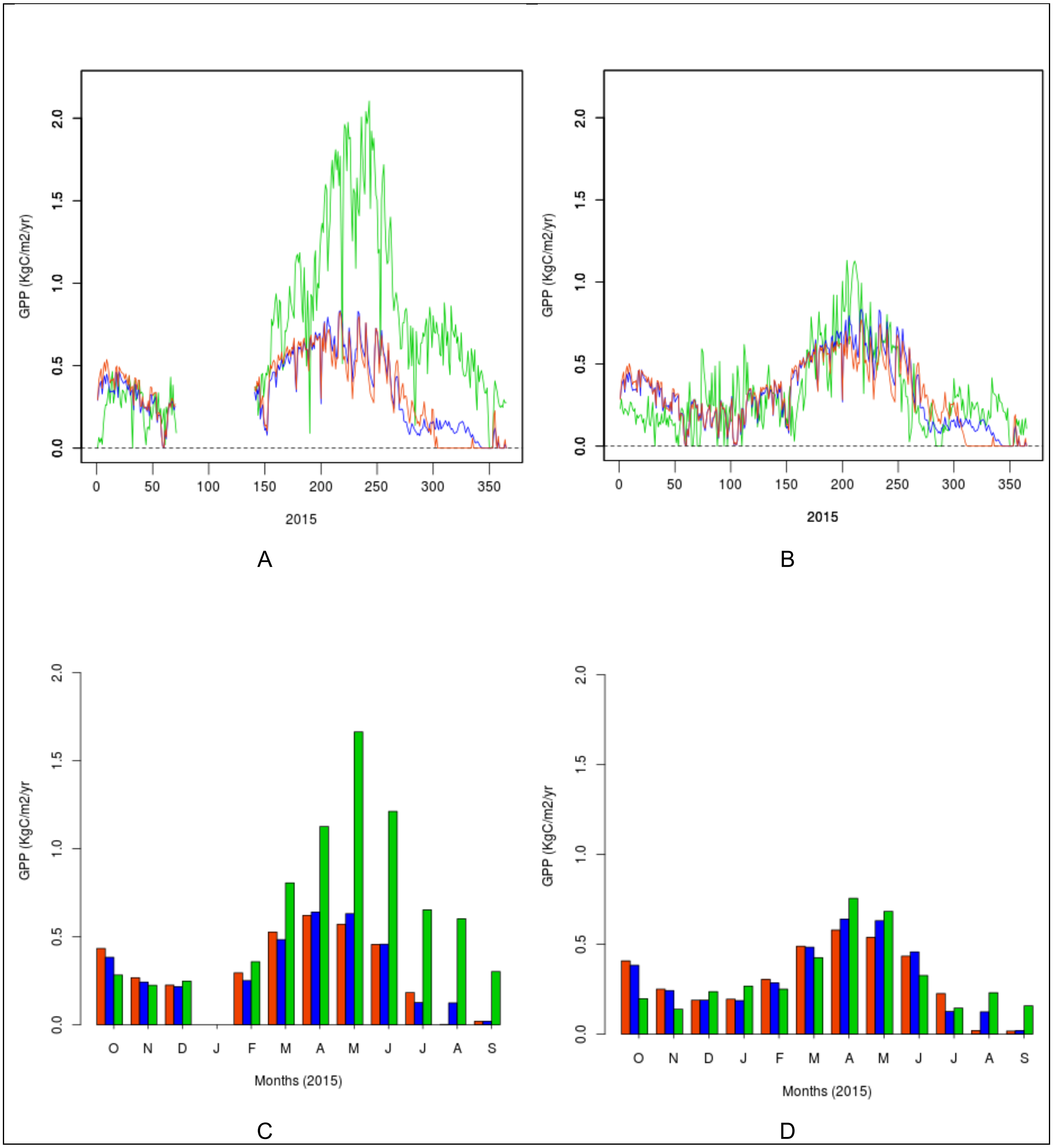

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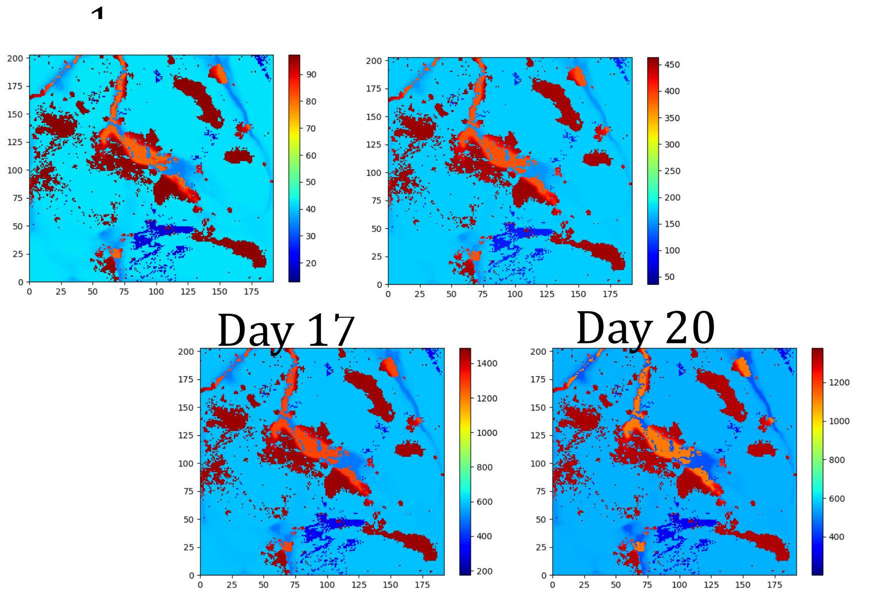

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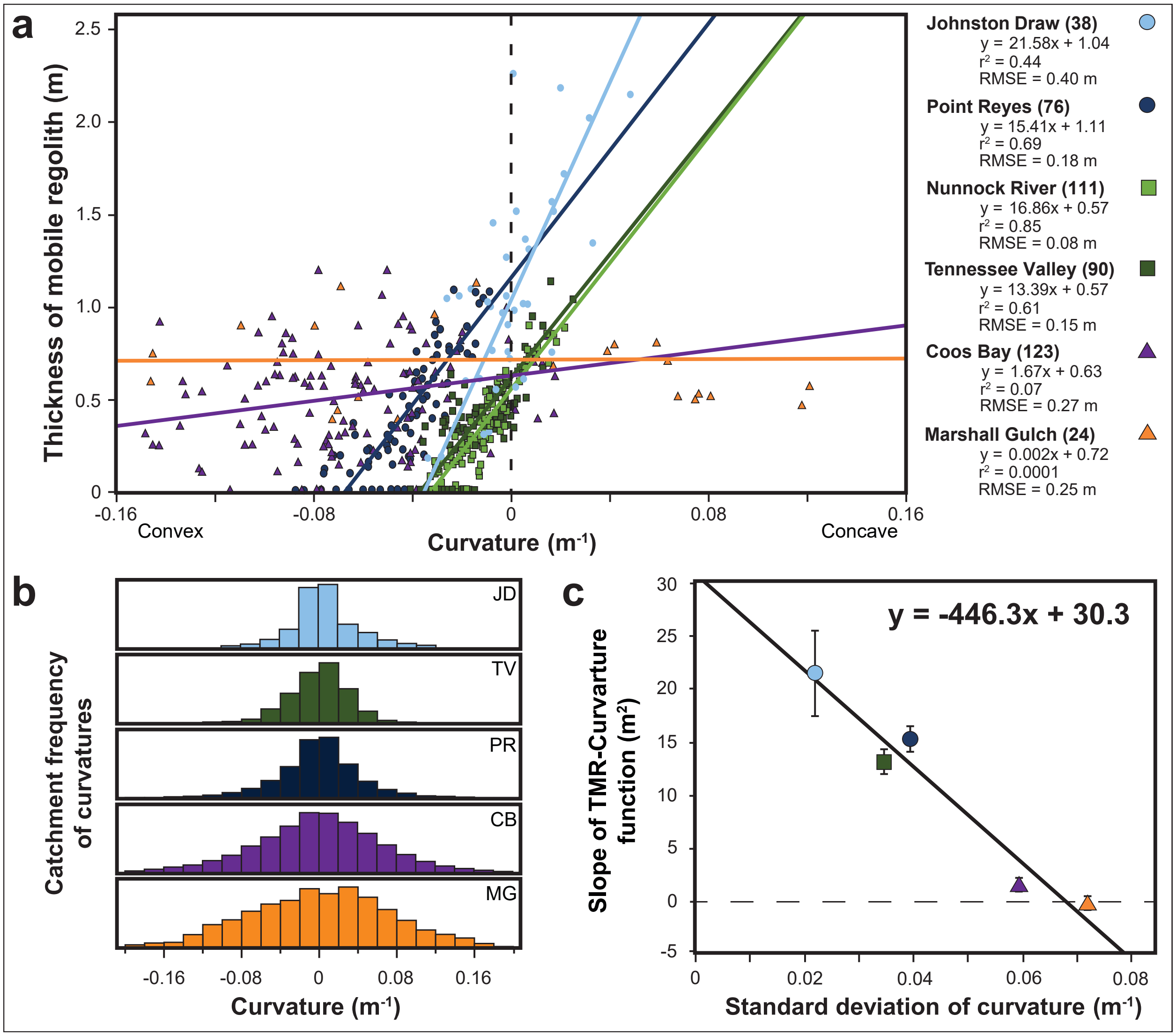
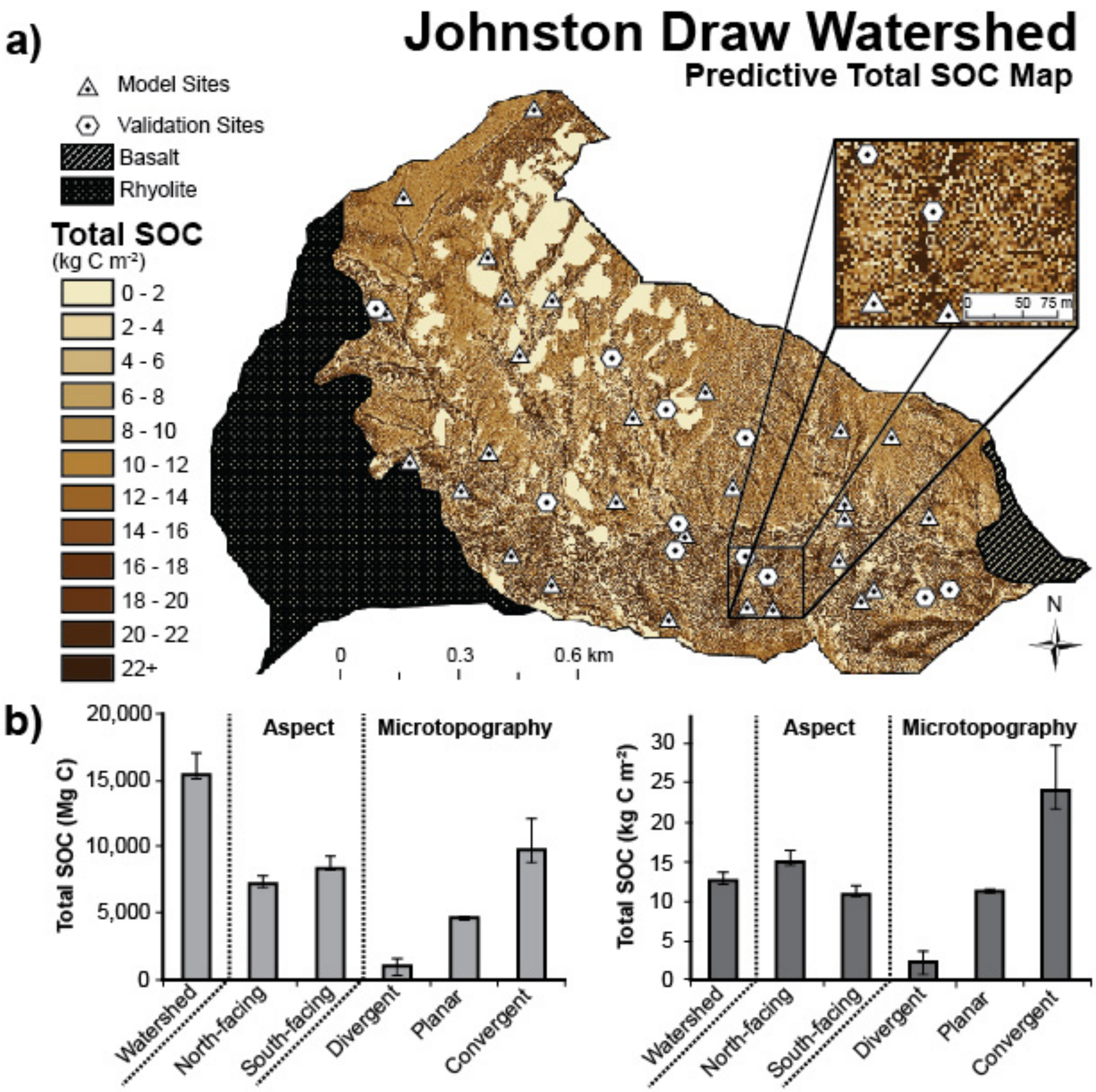


Key outcome Figure 1: Cross-site evaluation. a Cross-site evaluation of six catchments in which the thickness of the mobile regolith (TMR)-curvature (C) function is evaluated using a 5-m digital elevation model (DEM). b Depicts catchment curvature distributions based on a 5m DEM centered on 0m−1. c Cross-site comparison of the slope of the TMR-curvature function (and associated standard error) with the local standard deviation in catchment curvature (σc). Nunnock River (light green squares) dataset was not included in plots b or c due to the lack of high resolution Light Detection and Ranging (LiDAR) data; curvature estimates for Nunnock River in a were derived from reported local observations20. Note, the curvature distributions are derived from all cells within the catchment's DEM (Patton et al. 2018)



Key Outcome Figure 2: Estimates of total SOC were extrapolated across the granitic portion of Johnston Draw watershed using a 3 m DEM and the curvature-SOC functions developed from a model set (triangles), and were tested against a validation set (hexagons). The predictive map suggests visually that total SOC varies with aspect and microtopography. Total SOC concentrations are low on ridges and noses (light tans) and increase moving towards hollows and valleys (dark browns). Bars graph represents the estimated total SOC and total SOC per area for Johnston Draw with the upper 95% and lower 95% confidence limits based on relationships presented in Figure 1.3b. (Patton et al. in review)

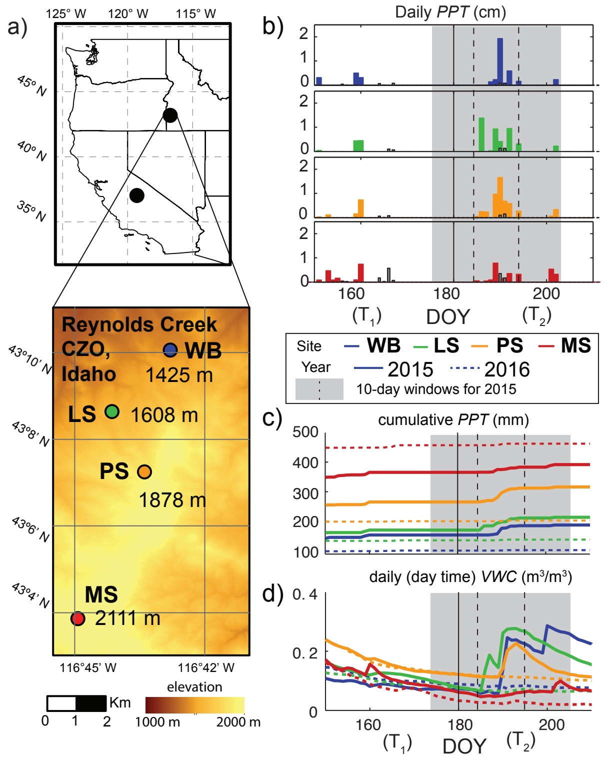


Fig. 2. One of the two flux tower transects used in this study is located at Reynolds Creek Critical Zone Observatory (RC-CZO) *(a)* in southeastern Idaho. Sites are located from south (low elevation, drier) to north (high elevation, wetter) and identified by color. *(b)* Daily precipitation (PPT) at each site for June-July for 2015 (colored bars) and 2016 (smaller gray bars). For TIPNet analysis, we denote June and July as T_1 and T_2, respectively, while the gray shading indicates 10-day periods approximately before (DOY 176-185), during (DOY 186-195), and after (DOY 195-205) the 2015 July rainfall event. *(c)* Cumulative PPT for all sites for 2015 and 2016 (solid and dotted lines, respectively). *(d)* Daily volumetric water content (VWC) shows a large increase for the lower three sites due to the July 2015 rainfall event. *(e)* Daily latent heat flux (LE) increases after the July 2015 rainfall for the lower two sites, and decreases for the higher two sites. *(f)* Cumulative evapotranspiration (ET, based on measured LE) for all sites for 2015 and 2016 (only June-July are shown). *(g-h)* Daily carbon flux (Fc) increases for all sites after the July 2015 rainfall. Positive Fc indicates an upward carbon flux, i.e. the ecosystem is a source of CO_2.

Key Outcome Figure 3 from Goodwell, Kumar, Fellows, and Flerchinger (2018) PNAS

Special Reporting Requirements

Table A: Outcomes and Metrics

Major Priority Area	Activity	Metric	Year 5 Target	Year 5 Accomplished
Strategic Priority 1: ***Landscape Soil Carbon Survey***	**Survey**	Create Soil Map	Year 5 Map Created	Year 5 Maps Created
	Characterization	Environmental Datasets Created	150 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	4	4 instrumented, 1 to burned sage site (upper sheep))
	Transpiration	Sites instrumented	4	5 (3 sage, 1 conifer, 1 aspen)
	Aboveground Biomass and NPP	Sites instrumented	4	4 sites
	Soil Respiration	Sites instrumented/measured	2	4 FD & 3 profiles at CORE Sites (soil probes)
	Stream and Groundwater Carbon Export	Samples Collected	200	500 samples collected
Strategic Priority 3: ***Integrated Modeling Framework***	**Create Fine Resolution Hydroclimate data**	Input datasets created	Completed & DOIs	Completed & DOIs
	Integrated Terrestrial Biosphere Modeling	Modeling framework Created	Biome BGC outputs	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***	**Education**	Students and post-docs engaged	4	4 students +2 postdocs
	Public Outreach	Outreach events	1	5 (STEM, Environmental Fair, Hydrology

Activities				Days, Adventure Learning, Voice of Fire (ID Public TV),
Strategic Priority 6: ***Data Management***	**Coordination and Policy Development**	Trainings	1	1 water quality
	Data Services and Management	Cumulative unique databases uploaded and accessed (# of times)	50	>600

CZO Network Activities

Network Leadership

Lohse lead a review of the last 5 years of CZ science as it relates to CZ services. This review was part of the network strategic plan.

- Graduate students in class reviewed papers on topics such as soil formation, productivity, water storage etc across the CZOs and synthesized information. Lohse compiled and wrote review and submitted to Earth's Future.
- **Lohse, K.A.**, A. S. Commendador, K. L Gossner, S.A. Stalder, C. Macek, R. MacNeille. *In review*. Critical zone science informs landscape management through quantification of slow and often elusive (episodic) constraints on ecosystem services. *Earth's Future*

Lohse participated in paper calling for strengthening biogeosciences in networks:

Richter, D. D., S. A. Billings, P. M. Groffman, E. F. Kelly, **K. A. Lohse**, W. H. McDowell, T. S. White, S. Anderson, D. D. Baldocchi, S. Banwart, S. Brantley, J. J. Braun, Z. S. Brecheisen, H. E. Hartnett, S. E. Hobbie, J. Gaillardet, E. Jobbagy, H. F. Jungkunst, C. E. Kazanski, J. Krishnaswamy, D. Markewitz, K. O'Neill, C. S. Riebe, P. Schroeder, C. Siebe, W. L. Silver, A. Thompson, A. Verhoef, and G. Zhang. 2018. Strengthening the biogeosciences within environmental research networks. *Biogeosciences,* **15**, 4815–4832, https://doi.org/10.5194/bg-2018-67

Flores and Seyfried participated in the cross CZO modeling workshop:

Outcomes include one paper and one funded SiTS proposal (co-PI Flores)

- Baatz, R., Sullivan, P. L., Li, L., Weintraub, S. R., Loescher, H. W., Mirtl, M., Groffman, P. M., Wall, D. H., Young, M., White, T., Wen, H., Zacharias, S., Kühn, I., Tang, J., Gaillardet, J., Braud, I., Flores, A. N., Kumar, P., Lin, H., Ghezzehei, T., Jones, J., Gholz, H. L., Vereecken, H., and Van Looy, K.: Steering operational synergies in terrestrial observation networks: opportunity for advancing Earth system dynamics modelling, Earth Syst. Dynam., 9, 593-609, https://doi.org/10.5194/esd-9-593-2018, 2018
- RAISE-SitS: Designing models to forecast how biogeochemical fluctuations in soil systems govern soil development, terrestrial water storage and ecosystem nutrient fluxes Award Number:1841614; Principal Investigator:Pamela Sullivan; Co-Principal Investigator:Sharon Billings, Daniel Hirmas, Li Li, Alejandro Flores; Organization:University of Kansas Center for Research Inc;NSF Organization:EAR Start Date:09/15/2018; Award Amount:$738,562.00; Relevance:35.43;

Seyfried lead a special issue on Reynolds Creek as a hydrological observatory

- Seyfried, M. S., **K. A. Lohse**, D. Marks, G. N. Flerchinger, F. Pierson. In review. Reynolds Creek Experimental Watershed and Critical Zone Observatory. Vadoze Zone Journal [*Special issue on Hydrological Observatories*].

Lohse lead two workshops funded by an ISU internal grant to develop an IES proposal using SKYTEM data collected at Reynolds and couple this with drilling and groundwater modeling to understand the role of geologic structure and paleoCZs influence groundwater flow and geochemistry (Participants:

Steve Holbrook, Sarah Godsey, Jen McIntosh, Dave Pearson, Lejo Flores, Melissa Schlegel, Mark Seyfried, Kathleen Lohse)
Lohse and Seyfried contributed to Biogeochemistry chapter as part of CZ book series

Working groups (WG)

- Cross CZO Biogeochemistry
    - Lohse collected 2 full soil profiles in June 2016 for cross site microbial community analysis and working with group to analyze data in 2018
    - Lohse contributed to manuscript on 10 big questions in Biogeochemistry in the critical zone
- Cross-CZO –Hydrology
    - Godsey submitted paper to special issue on concentration discharge relationships (Sept 2018)
    - Fellows et al. initially contribute to special issue in CZ hydrology in Hydrological Processes (2017). This manuscript was just published in Ecohydrology.
- Cross CZO - Exploring Four Critical Puzzles Workshop
    - Godsey participated in writing paper as product (see Brantley et al. 2017)

  Cross-CZO Education and outreach
    - Lohse was the PI representative for CZOs and attended monthly meetings for the Education and Outreach
- 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*
- *Lohse and Seyfried attended PI meeting at AGU in December 2017*
- *H23: Plant as Plumbers in the Critical Zone* Evaristo, Lohse (RC CZO), Shirley Kurc, Diana Karwan are convened a AGU session (AGU Fall 2017 meeting).
- *H41I: Runoff Generation Processes in Changing Environments: Integrating Observations and Processes (Godsey primary convener)*
- Community Surface Dynamics Modeling System (CSDMS) Annual Meeting
  Flores and graduate student Gelb attended the CSDMS meeting in Boulder, CO

Cross CZO Research

Graduate student, 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

- Patton, N.R., K. A. Lohse, S. E. Godsey, B. T. Crosby and M. Seyfried. 2018. Predicting soil thickness on soil mantled hillslopes. *Nature Communications* 9: 3329, DOI: 10.1038/s41467-018-05743-y

Lohse lead a review of the last 5 years of CZ science as it relates to CZ services. This review was part of the network strategic plan.

- Graduate students in class reviewed papers on topics such as soil formation, productivity, water storage etc across the CZOs and synthesized information. Lohse compiled and wrote review and submitted to Earth's Future.
- **Lohse, K.A**., A. S. Commendador, K. L Gossner, S.A. Stalder, C. Macek, R. MacNeille. *In review*. Critical zone science informs landscape management through quantification of slow and often elusive (episodic) constraints on ecosystem services. *Earth's Future*

Lohse participated in cross CZO effort strengthen biogeosciences in networks

- Richter, D. D., S. A. Billings, P. M. Groffman, E. F. Kelly, **K. A. Lohse**, W. H. McDowell, T. S. White, S. Anderson, D. D. Baldocchi, S. Banwart, S. Brantley, J. J. Braun, Z. S. Brecheisen, H. E. Hartnett, S. E. Hobbie, J. Gaillardet, E. Jobbagy, H. F. Jungkunst, C. E. Kazanski, J. Krishnaswamy, D. Markewitz, K. O'Neill, C. S. Riebe, P. Schroeder, C. Siebe, W. L. Silver, A. Thompson, A. Verhoef, and G. Zhang. 2018. Strengthening the biogeosciences within environmental research networks. *Biogeosciences,* **15**, 4815–4832, https://doi.org/10.5194/bg-2018-67

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.

Cross CZO Publications and Awards
Godsey, S.E. CAREER award, Active Learning Across Interfaces: Controls on Flow Intermittency and Water Age in Temporary Streams, July 2017-June 2022, 291,864.00

Patton, N.R., K. A. Lohse, S. E. Godsey, B. T. Crosby and M. Seyfried. 2018. Predicting soil thickness on soil mantled hillslopes. *Nature Communications* 9: 3329, DOI: 10.1038/s41467-018-05743-y

Goodwell, A. E., P. Kumar, A. W. Fellows, and G. N. Flerchinger 2018. Dynamic process connectivity explains ecohydrologic responses to rainfall pulses and drought. PNAS. https://doi.org/10.1073/pnas.1800236115

Richter, D. D., S. A. Billings, P. M. Groffman, E. F. Kelly, **K. A. Lohse**, W. H. McDowell, T. S. White, S. Anderson, D. D. Baldocchi, S. Banwart, S. Brantley, J. J. Braun, Z. S. Brecheisen, H. E. Hartnett, S. E. Hobbie, J. Gaillardet, E. Jobbagy, H. F. Jungkunst, C. E. Kazanski, J. Krishnaswamy, D. Markewitz, K. O'Neill, C. S. Riebe, P. Schroeder, C. Siebe, W. L. Silver, A. Thompson, A. Verhoef, and G. Zhang. 2018. Strengthening the biogeosciences within environmental research networks. *Biogeosciences,* **15**, 4815–4832, https://doi.org/10.5194/bg-2018-67

Brantley, S. L., Eissenstat, D. M., Marshall, J. A., Godsey, S. E., Balogh-Brunstad, Z., Karwan, D. L., Papuga, S. A., Roering, J., Dawson, T. E., Evaristo, J., Chadwick, O., McDonnell, J. J., and Weathers, K. C.: Reviews and syntheses: on the roles trees play in building and plumbing the critical zone, Biogeosciences, 14, 5115-5142, https://doi.org/10.5194/bg-14-5115-2017, 2017.

Brantley, S., W.H. McDowell, W. E. Dietrich, T.S. White, P. Kumar, S. Anderson, J. Chorover, **K. Lohse**, R. C Bales, D. deB. Richter, G. Grant, J. Gaillardet. 2017. Designing a network of critical zone observatories to explore the living skin of the terrestrial Earth *Earth Surface Dynamics* https://doi.org/10.5194/esurf-2017-36

Perdrial, J., P. Brooks, T. Swetnam, K. Lohse, C. Rasmussen, M. Litvak, A. Harpold, X. Zapata-Rios, P. Broxton, B. Mitra, T. Meixner, K. Condon, D. Huckle, C. Stielstra, A. Vazquez-Ortega, R. Lybrand, M. Holleran, C. Orem, J. Pelletier, J., Chorover. 2018. A net ecosystem carbon budget for snow dominated forested headwater catchments: linking water and carbon fluxes to critical zone carbon storage. *Biogeochemistry,* 138 (3), 225–243, 2018

Galanter, A., Cadol, D., and Lohse, K. (2018) Geomorphic influences on the distribution and accumulation of pyrogenic carbon (PyC) following a low severity wildfire in northern New Mexico. *Earth Surf. Process. Landforms*, 43: 2207–2218, doi: 10.1002/esp.4386.

Additional Funding

Lohse, K. ~$46,000 USDA ARS, ARS Geospatial Services.

- This contract supports ISU CZO data analyst 50% to expand geospatial services at ARS in Boise.

Godsey, S., $500,000, Idaho State University, NSF CAREER: Active Learning Across Interfaces: Controls on Flow Intermittency and Water Age in Temporary Streams

Nelson et al., $20 million, RII Track-1: Linking Genome to Phenome to Predict Adaptive Responses of Organisms to Changing Landscapes," NSF OIA-1757324,.

- Research Infrastructure Improvement (RII) Track-1 project from Idaho will study two keystone species (redband trout and sagebrush) in ecosystems of the American West. The project will use existing environmental legacy data to inform agent-based models (ABM) to predict adaptive capacity of these two species. The project team will determine the links between genomes and phenomes via experiments using temperature as the key variable to identify genomic responses of the adaptive capacity of these species and iteratively link them through the ABM to further inform our understanding of genetic capacity.
- Note: Activities at Reynolds Creek CZO related to setting up common garden experiment at Reynolds Creek and leveraging CORE sites for productivity and carbon measurements.

Olschanowsky and Alejandro Flores, $700,000.00, Collaborative Research: Framework: Software: NSCI : Computational and data innovation implementing a national community hydrologic modeling framework for scientific discovery, OAC 1835704

- An interdisciplinary team of computer scientists and hydrologists is developing a framework to leverage advances in computer science transforming simulation and data-driven discovery in the Hydrologic Sciences and beyond. This project is advancing the science behind these national scale hydrologic models, accelerating their capabilities and building novel interfaces for user interaction. The framework brings computational and domain science (hydrology) communities together to move more quickly from tools (models, big data, high-performance computing) to discoveries.

Keleners, T. $568,356.00. Subsurface Structure and Flow Regime for Rocky Mountain Hillslopes with Different Geologies Award Number:1818550; Principal Investigator:Thijs Keleners; Co-Principal Investigator:Andrew Parsekian; Organization:University of Wyoming;NSF Organization:EAR Start Date:07/01/2018;

- The study combines state-of-the-art geophysical and hydrological measurement and modeling techniques to examine subsurface water flow and storage in hillslopes with three different geologies. Three of the hillslopes are in Wyoming and are currently being measured by the two investigators. The other three hillslopes are proposed in Critical Zone Observatories in Idaho (2) and New Mexico (1). The six hillslopes are paired so that each of the three geologies are represented by two hillslopes. Measurements will consist of shallow seismic refraction to determine subsurface porosity structure, time-lapse electrical resistivity tomography to determine vadose zone water dynamics, and hydrological monitoring to assess water inputs and hillslope hydrologic response. Numerical models will be combined with parameter estimation algorithms to estimate subsurface hydraulic parameters.

Sullivan, Pamela Sullivan; Principle Investigator, Co-Principal Investigator:Sharon Billings, Daniel Hirmas, Li Li, Alejandro Flores, $738,562.00, RAISE-SitS: Designing models to forecast how biogeochemical fluctuations in soil systems govern soil development, terrestrial water storage and ecosystem nutrient fluxes, Award Number:1841614;

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.