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AGU-FM12

December 03 - 07, 2012

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Monday, December 03, 2012

Time	Session Info
8:00 AM-12:20 PM, Hall A-C (Moscone South), **H11B. Environmental Vadose Zone Hydrology Posters**	
8:00-8:00 AM	**H11B-1176. Soil Moisture Dynamics in Deep Southern Sierra Nevada Soils** A.I. Malazian; P.C. Hartsough; J.W. Hopmans
1:40 PM-6:00 PM, Hall A-C (Moscone South), **H13D. Groundwater-Surface Water Interactions: Quantifying Their Functional Relevance With Measurements and Models of Water and Solute Dynamics II Posters**	
1:40-1:40 PM	**H13D-1381. Groundwater-surface water interactions in montane meadows of the Sierra Nevada, California.** R.G. Lucas; M.H. Conklin
4:00 PM-6:00 PM, 3007 (Moscone West), **C14B. Snow Cover–Vegetation Interactions I**	
5:00-5:15 PM	**C14B-05. Integration of airborne LiDAR data and voxel-based ray tracing to determine high-resolution solar radiation dynamics at the forest floor: implications for improving stand-scale distributed snowmelt models** K.N. Musselman; N.P. Molotch; S.A. Margulis
5:45-6:00 PM	**C14B-08. Under-canopy snow accumulation and ablation measured with airborne scanning LiDAR altimetry and in-situ instrumental measurements, southern Sierra Nevada, California** P.B. Kirchner; R.C. Bales; K.N. Musselman ; N.P. Molotch

Tuesday, December 04, 2012

Time	Session Info
8:00 AM-12:20 PM, Hall A-C (Moscone South), **H21B. Advanced Watershed Characterization Using Remote Sensing Posters**	
8:00-8:00 AM	**H21B-1179. Elevation-dependent controls on snowmelt partitioning and vegetation response inferred from satellite observations** ***(Invited)*** N.P. Molotch; B. Guan; E. Trujillo
8:00 AM-10:00 AM, 2003 (Moscone West), **B21I. When Winter Changes: Hydrological, Ecological, and Biogeochemical Responses I**	
9:30-9:45 AM	**B21I-07. Consequences of warming and altered snowmelt timing on soil CO_2, CH_4, and N_2O fluxes in the Sierra Nevada rain-snow transition zone** J.C. Blankinship; E.P. McCorkle; M.W. Meadows; R.G. Lucas; S.C. Hart

Wednesday, December 05, 2012

Time	Session Info
8:00 AM-12:20 PM, Hall A-C (Moscone South), **H31G. Using Field Measurements and Experiments to Advance Science II Posters**	
8:00-8:00 AM	**H31G-1198. Integrating soil water measurements from plot to catchment scale in a snow-dominated, mixed-conifer forest of the southern Sierra Nevada.** M.W. Meadows; P.C. Hartsough; R.C. Bales; J.W. Hopmans; A.I. Malazian
8:00-8:00 AM	**H31G-1208. Strategic sampling of microclimate, soil moisture and sapflux for improving ecohydrological model estimates in the California Sierra** K. Son; C. Tague
8:00-8:00 AM	**H31G-1211. Paired tree and soil instrumentation: what can we learn from two instrumented sites across various gradients in a forested catchment** P.C. Hartsough; E. Roudneva; A.I. Malazian; M.W. Meadows; R.C. Bales; J.W. Hopmans
10:20 AM-12:20 PM, 3007 (Moscone West), **C32B. Diagnosing Modeling Deficiencies and the Recent Advances in Monitoring, Measuring, and Modeling Snow Processes I**	
11:05-11:20 AM	**C32B-04. Seasonal and inter-annual snowmelt patterns in the southern Sierra Nevada, California** ***(Invited)*** K.N. Musselman; N.P. Molotch; S.A. Margulis
11:50-12:05 PM	**C32B-07. Connecting the snowpack to the internet of things: an IPv6 architecture for providing real-time measurements of hydrologic systems** ***(Invited)*** B. Kerkez; Z. Zhang; C. Oroza; S.D. Glaser; R.C. Bales
1:40 PM-6:00 PM, Hall A-C (Moscone South), **C33C. Quantifying Spatial Variability of Snow and Snow Processes II Posters**	
1:40-1:40 PM	**C33C-0683. Sampling design and optimal sensor placement strategies for basin-scale SWE estimation** B. Kerkez; S.C. Welch; R.C. Bales; S.D. Glaser; K.E. Rittger; R. Rice
1:40 PM-6:00 PM, Hall A-C (Moscone South), **C33D. Snow Cover–Vegetation Interactions II Posters**	
1:40-1:40 PM	**C33D-0684. Effects of forest structure on snow accumulation and melt derived from ecohydrological instrument clusters across the Western US** ***(Invited)*** N.P. Molotch; K.N. Musselman; P.B. Kirchner; R.C. Bales; P.D. Brooks
4:00 PM-6:00 PM, 2004 (Moscone West), **B34C. Linking the Terrestrial and Aquatic Carbon Cycles I**	

5:30-5:45 PM	**B34C-07. Lateral redistribution of dissolved vs. complexed organic matter with soil erosion** E. Stacy; S.M. Meding; C.T. Hunsaker; D.W. Johnson; S.C. Hart; A.A. Berhe
5:45-6:00 PM	**B34C-08. Erosion of bulk and pyrogenic C from upland forested Sierra Nevada ecosystems *(Invited)*** A.A. Berhe; E. Stacy; M. McClintock; A. Newman; S.C. Hart; C.T. Hunsaker; D.W. Johnson

Thursday, December 06, 2012

Time	Session Info
8:00 AM-12:20 PM, Hall A-C (Moscone South), **EP41C. Natural and Controlled Experiments in Landscape Evolution I Posters**	
8:00-8:00 AM	**EP41C-0812. Combining natural experiments in source lithology with laboratory tumbling to quantify sediment resistance to comminution and its role in downstream fining** J.D. Beyeler; L.S. Sklar; C.S. Riebe
8:00 AM-12:20 PM, Hall A-C (Moscone South), **EP41D. Rock to Sediment: Biotic, Lithologic, and Climatic Controls on Regolith Production, Mixing, and Transport I Posters**	
8:00-8:00 AM	**EP41D-0821. Effects of bedrock nutrient density on vegetation and topography in the Sierra Nevada Batholith, California** W. Hahm; C.S. Riebe; S. Araki
8:00-8:00 AM	**EP41D-0822. Moving Beyond the Average in Cosmogenic Nuclide Studies of Erosion and Weathering** C. Lukens; C.S. Riebe; L.S. Sklar; D.L. Shuster
8:00 AM-10:00 AM, 2008 (Moscone West), **EP41I. The Deep Critical Zone and the Inception of Surface Processes I**	
8:30-8:45 AM	**EP41I-03. Geophysics in the Critical Zone: Constraints on Deep Weathering and Water Storage Potential in the Southern Sierra CZO** W. Holbrook; C.S. Riebe; J.L. Hayes; K. Reeder; D.L. Harry; A.I. Malazian; A. Dosseto; P.C. Hartsough; J.W. Hopmans
1:40 PM-6:00 PM, Hall A-C (Moscone South), **B43F. The Bioatmospheric N Cycle: N Emissions, Transformations, Deposition, and Terrestrial and Aquatic Ecosystem Impacts III Posters**	
1:40-1:40 PM	**B43F-0468. A Three Dimensional View of Nutrient Hotspots in a Sierra Nevada Forest Soil** D.W. Johnson; M.W. Meadows; C. Woodward
1:40 PM-6:00 PM, Hall A-C (Moscone South), **EP43B. The Deep Critical Zone and the Inception of Surface Processes II Posters**	
1:40-1:40 PM	**EP43B-0871. Fractures in the Critical Zone: Insights from GPR and seismic refraction surveys** J.T. St. Clair; W. Holbrook; C.S. Riebe

1:40 PM-3:40 PM, 2008 (Moscone West), **EP43E. Rock to Sediment: Biotic, Lithologic, and Climatic Controls on Regolith Production, Mixing, and Transport II**	
3:10-3:25 PM	**EP43E-07. Altitudinal increase in size of sediment shed from slopes revealed by tracer thermochronometry** C.S. Riebe; L.S. Sklar; C.E. Lukens; D.L. Shuster

Friday, December 07, 2012

Time	Session Info
8:00 AM-12:20 PM, Hall A-C (Moscone South), **B51C. Climatic Controls on Net Ecosystem Exchange (NEE) I Posters**	
8:00-8:00 AM	**B51C-0559. Water and energy gradients produce resilience and thresholds in ecosystem function in the western Sierra Nevada Mountains** A.E. Kelly; M. Goulden; R.C. Bales; M.W. Meadows; G. Winston
8:00 AM-10:00 AM, 3001 (Moscone West), **GC51F. Forest Hydrology Within the Context of Global Change and Forest Health**	
8:15-8:30 AM	**GC51F-02. The geography of forest drought vulnerability: Integrating modeling and measurements** ***(Invited)*** C. Tague
9:00-9:15 AM	**GC51F-05. Forest management effects on snow, runoff and evapotranspiration in Sierra Nevada mixed-conifer headwater catchments** R.L. Ray; P.C. Saksa; R.C. Bales; M.H. Conklin
10:20 AM-12:20 PM, 3003 (Moscone West), **H52E. Understanding Process Dynamics in the Critical Zone at Different Scales I**	
10:20-10:35 AM	**H52E-01. Modeling of Soil and Tree Water Status Dynamics in a Mixed-Conifer Forest of the Southern Sierra Critical Zone Observatory** ***(Invited)*** J.W. Hopmans; J. Rings; T. Kamai; M. Mollaei Kandelous; P.C. Hartsough; J.A. Vrugt
4:00 PM-6:00 PM, 3003 (Moscone West), **GC54A. Spatiotemporal Change Detection and the Data Infrastructure of Environmental Observatories IV**	
5:00-5:15 PM	**GC54A-05. Critical Zone Observatories (CZOs): Integrating measurements and models of Earth surface processes to improve prediction of landscape structure, function and evolution** ***(Invited)*** J. Chorover; S.P. Anderson; R.C. Bales; C. Duffy; F.N. Scatena; D.L. Sparks; T. White

Final ID: H11B-1176

Soil Moisture Dynamics in Deep Southern Sierra Nevada Soils

A. I. Malazian; [1]; *P. C. Hartsough;* [1]; *J. W. Hopmans;* [1];
1. Land, Air, and Water Resources, University of California, Davis, CA, United States.

Body: As part of the Southern Sierra Critical Zone Observatory, the soil surrounding a white fir tree has been instrumented with volumetric water content (VWC), temperature, and soil matric potential sensors. The VWC (5-TM (Decagon Devices, Inc.) and neutron probe) and temperature (5-TM) associated with the deep vadose zone monitoring are being measured by 5-TM sensors. The soil matric potential is measured using tensiometers and MPS-1 sensors (Decagon Devices, Inc.). This instrumentation has been installed at depths of 150, 200, and 250 cm, so as to quantify subsurface soil moisture dynamics. The soil is quite sandy to varying depths after which a saprolyte layer exists moving into a more coarse textured subsurface. As snowmelt and rainfall infiltrate the soil at the surface it wets the soil profile to field capacity with the excess water replenishing deep water resources. The deep water resources are utilized as the shallower subsurface moisture is depleted leading to a more negative soil matric suction causing an upward movement of water for the latter part of the summer. This upward movement of water is assumed to occur via total soil water potential gradients. The tensiometers can only yield data for soil matric suctions less than 600 cm of water, where the MPS-1 sensors can reach suctions up 500 kPa. Thus, since the deep vadose zone instrument installation in summer 2011, it was seen that water started moving upward in late July to early August depending on the profile and winter precipitation.

Final ID: H13D-1381

Groundwater-surface water interactions in montane meadows of the Sierra Nevada, California.

R. G. Lucas; [1]; *M. H. Conklin;* [1];
1. SNRI, UC Merced, Merced, CA, United States.

Body: Meadows often lie in low gradient, groundwater fed terrain of the Sierra Nevada.   These settings result in near saturated conditions for much of the year, shallow groundwater tables, and groundwater discharge to surface flow. Our hypothesis is that groundwater fluctuations integrate watershed processes rather than meadow specific processes. Meadow characteristics are in contrast to the adjacent forested landscapes, where soils go dry in the summer, groundwater tables are much deeper, and some fraction of soil water is lost to deeper percolation. We utilize a series water column data from monitoring wells and piezometers in two meadows, soil moisture and snow depth data from nodes in the associated catchment, located within the Southern Sierra Critical Zone Observatory, from water years 2008-2012. Water samples from wells and associated streams were analyzed for major ions and stable water isotopes. Results from the monitoring wells and piezometers show groundwater tables and pressure heads that are highest during snowmelt and decrease over the summer growing season; inter-annual variation is correlated to total accumulated precipitation for the given water year. Groundwater elevations exhibit diurnal fluctuations influenced by snowmelt and evapotranspiration (ET) processes in the spring, transitioning to an ET dominated signal during the summer growing season. These fluctuations are of greatest magnitude near the meadow-forest boundary and least near the center of the meadow. ET signals continue after the meadow vegetation senesces, suggesting influences from the adjacent forested landscape. Deep piezometers (>2.5 m depth) do not exhibit fluctuation at the daily time scale while shallower piezometers (<1 m depth) tend to show some fluctuation at this time interval. Further analysis of the piezometer data shows seasonal variation in the direction and magnitude of groundwater flux. Both near the meadow edge and meadow center, groundwater discharge is strongest during snow melt with a decrease as the summer growing season progresses. The near edge pressure head data show that the direction of groundwater flux changes to indicate groundwater recharge by fall. The near center data indicate groundwater discharge for the entirety of the summer growing season—long after the adjacent forest soils have dried out. Analysis of the geochemical data show that major ion concentrations vary little within the individual wells but vary from the edge of the meadow to the center. Stream water samples show surface flow is dominated by snow melt in the spring and is influenced more by subsurface flow as the growing season progresses. Groundwater discharges into the center of the meadows, long after the soils the adjacent Forests have dried out. This is consistent with the results from our geochemical analysis that suggests the surface water leaving the meadow systems is more influenced by subsurface flow later in the summer. Consistent groundwater discharge, with little variation in the geochemical profile of the groundwater, suggests a shallow groundwater source that is not being fully utilized by the adjacent forest landscape. These montane meadow systems provide a window for investigating groundwater surface water interactions in the catchments of the Southern Sierra Critical Zone Observatory.

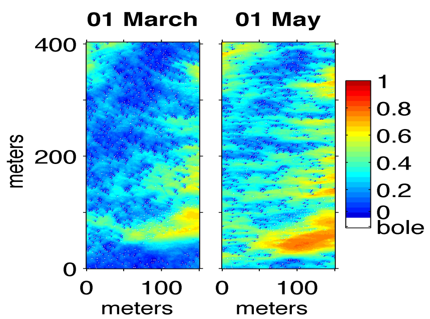
Final ID: C14B-05

Integration of airborne LiDAR data and voxel-based ray tracing to determine high-resolution solar radiation dynamics at the forest floor: implications for improving stand-scale distributed snowmelt models

K. N. Musselman; [1, 2]; *N. P. Molotch;* [3, 4]; *S. A. Margulis;* [2];

1. Centre for Hydrology, Coldwater Field Station, University of Saskatchewan, Kananaskis Valley, AB, Canada.
2. Civil and Environmental Engineering, UCLA, Los Angeles, CA, United States.
3. Geography and INSTAAR, University of Colorado Boulder, Boulder, CO, United States.
4. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States.

Body: Forest architecture dictates sub-canopy solar irradiance and the resulting patterns can vary seasonally and over short spatial distances. These radiation dynamics are thought to have significant implications on snowmelt processes, regional hydrology, and remote sensing signatures. The variability calls into question many assumptions inherent in traditional canopy models (e.g. Beer's Law) when applied at high resolution (i.e. 1 m). We present a method of estimating solar canopy transmissivity using airborne LiDAR data. The canopy structure is represented in 3-D voxel space (i.e. a cubic discretization of a 3-D domain analogous to a pixel representation of a 2-D space). The solar direct beam canopy transmissivity (DBT) is estimated with a ray-tracing algorithm and the diffuse component is estimated from LiDAR-derived effective LAI. Results from one year at five-minute temporal and 1 m spatial resolutions are presented from Sequoia National Park. Compared to estimates from 28 hemispherical photos, the ray-tracing model estimated daily mean DBT with a 10% average error, while the errors from a Beer's-type DBT estimate exceeded 20%. Compared to the ray-tracing estimates, the Beer's-type transmissivity method was unable to resolve complex spatial patterns resulting from canopy gaps, individual tree canopies and boles, and steep variable terrain. The snowmelt model SNOWPACK was applied at locations of ultrasonic snow depth sensors. Two scenarios were tested; 1) a nominal case where canopy model parameters were obtained from hemispherical photographs, and 2) an explicit scenario where the model was modified to accept LiDAR-derived time-variant DBT. The bulk canopy treatment was generally unable to simulate the sub-canopy snowmelt dynamics observed at the depth sensor locations. The explicit treatment reduced error in the snow disappearance date by one week and both positive and negative melt-season SWE biases were reduced. The results highlight the utility of LiDAR canopy measurements and physically based snowmelt models to simulate spatially distributed stand- and slope-scale snowmelt dynamics at resolutions necessary to capture the inherent underlying variability.



LiDAR-derived solar direct beam canopy transmissivity computed as the daily average for March 1st and May 1st.

Final ID: C14B-08

Under-canopy snow accumulation and ablation measured with airborne scanning LiDAR altimetry and in-situ instrumental measurements, southern Sierra Nevada, California

P. B. Kirchner; [1]; *R. C. Bales;* [1]; *K. N. Musselman ;* [2]; *N. P. Molotch;* [3, 4];
1. Sierra Nevada Research Institute , University of California, Merced, CA, United States.
2. Department of Civil and Environmental Engineering, University of California, Los Angeles, CA, United States.
3. Department of Geography, Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO, United States.
4. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States.

Body: We investigated the influence of canopy on snow accumulation and melt in a mountain forest using paired snow on and snow off scanning LiDAR altimetry, synoptic measurement campaigns and in-situ time series data of snow depth, SWE, and radiation collected from the Kaweah River watershed, Sierra Nevada, California. Our analysis of forest cover classified by dominant species and 1 m^2 grided mean under canopy snow accumulation calculated from airborne scanning LiDAR, demonstrate distinct relationships between forest class and under-canopy snow depth. The five forest types were selected from carefully prepared 1 m vegetation classifications and named for their dominant tree species, Giant Sequoia, Jeffrey Pine, White Fir, Red Fir, Sierra Lodgepole, Western White Pine, and Foxtail Pine. Sufficient LiDAR returns for calculating mean snow depth per m^2 were available for 31 - 44% of the canopy covered area and demonstrate a reduction in snow depth of 12 - 24% from adjacent open areas. The coefficient of variation in snow depth under canopies ranged from 0.2 – 0.42 and generally decreased as elevation increased. Our analysis of snow density snows no statistical significance between snow under canopies and in the open at higher elevations with a weak significance for snow under canopies at lower elevations. Incident radiation measurements made at 15 minute intervals under forest canopies show an input of up to 150 w/m^2 of thermal radiation from vegetation to the snow surface on forest plots.
Snow accumulated on the mid to high elevation forested slopes of the Sierra Nevada represents the majority of winter snow storage. However snow estimates in forested environments demonstrate a high level of uncertainty due to the limited number of in-situ observations and the inability of most remote sensing platforms to retrieve reflectance under dense vegetation. Snow under forest canopies is strongly mediated by forest cover and decoupled from the processes that dictate accumulation and ablation of snow in open locations, where almost all precipitation and meteorlogic measurements concerning snow are made. Snow accumulation is intercepted by vegetation until it accumulates to a depth equal to or greater than the height of the vegetation, is reduced by the amount of sublimation or evaporation occurring while on the canopy and is redistributed beneath the canopy at a different density or as liquid water. Ablation processes are dictated by the energy environment surrounding vegetation where sensible heat is mediated by shading of short wave radiation.

Final ID: H21B-1179

Elevation-dependent controls on snowmelt partitioning and vegetation response inferred from satellite observations *(Invited)*

N. P. Molotch;[1, 2]; *B. Guan;*[2]; *E. Trujillo;*[1];
1. Geography / INSTAAR, University of Colorado, Boulder, CO, United States.
2. Jet Propulsion Laboratory / CAL TECH, Pasadena, CA, United States.

Body: In many mountainous regions snowmelt is a primary driver of hydrological and ecological processes. The timing and magnitude of snowmelt influences the partitioning of water into hydrological pathways such as evapotranspiration, overland flow, and ground water recharge. This partitioning dramatically impacts ecosystem services by altering water availability in the root zone during the spring transition and throughout the growing season. To improve knowledge of the relationships between snowmelt timing, hydrological flowpaths, and vegetation response, we analyzed the effect of snowmelt timing on runoff production and vegetation greenness in montane environments of the Western United States. The analysis combines yearly peak NDVI derived from the Global Inventory Modeling and Mapping Studies (GIMMS), MODIS-based NDVI observations, and estimates of snowpack distribution from ground stations and remote sensing. In this regard, we show that the strongest temporal relationships between snowmelt timing and vegetation greenness are obtained for the middle elevation range between 2000 m and 2600 m (R-squared values greater than 0.5) with significantly weaker relationships above this region. This finding suggests a switch from water limitations at the lower elevation to energy limitations at the highest elevations. Complimentary spatial analyses indicate that the timing of snowmelt also shows a statistically significant relationship with the spatial distribution of forest greening for individual years (R-squared ~ 0.3). These results indicate that runoff production from middle elevations may be significantly lower than higher elevations as longer growing seasons and higher potential evapotranspiration at lower elevations maintain soil moisture deficits. These results indicate that the sensitivity of runoff generation, forest greening, and carbon uptake to changes in climate may exhibit tipping points associated with elevation.

URL : http://instaar.colorado.edu/mtnhydro/Mountain_Hydrology/Home.html

Final ID: B21I-07

Consequences of warming and altered snowmelt timing on soil CO2, CH4, and N2O fluxes in the Sierra Nevada rain-snow transition zone

J. C. Blankinship; [1, 2]; *E. P. McCorkle;* [3]; *M. W. Meadows;* [2]; *R. G. Lucas;* [3, 2]; *S. C. Hart;* [1, 2];
1. School of Natural Sciences, University of California-Merced, Merced, CA, United States.
2. Sierra Nevada Research Institute, University of California-Merced, Merced, CA, United States.
3. Environmental Systems Graduate Program, University of California-Merced, Merced, CA, United States.

Body: The legacy of winter warming on summer soil greenhouse gas emissions remains unclear. Effects of winter warming on summer hydrology and biogeochemistry may be most obvious in rain-snow transition zones (i.e., areas between more severe and less severe winters) and in a Mediterranean-type climate with almost no summer precipitation. We therefore simulated climatic warming in the rain-snow transition zone of the Sierra Nevada Mountains in California by: (1) moving a mixed conifer forest soil down in elevation from predominantly snow to equal amounts of precipitation as rain and snow; and (2) manipulating the timing of spring snowmelt, both earlier using black sand and later using white Tyvek cloth. Moving soil cores down in elevation induced an increase in fall, winter, and spring mean soil temperature of 1.4 °C, with little change in summer temperature or annual precipitation, and increased soil CO2 emission by 32% during snow-free periods between August 2010 and June 2012. Warming also increased CH4 uptake by 48%, but had no effect on N2O fluxes. Our field manipulations of snowmelt timing significantly affected soil moisture and CO2 emission during the growing season. The 2-week (WY 2011) and 3-week (WY 2012) advancement of snowmelt at the high elevation site caused drier soils and 10-35% less CO2 emission during the subsequent growing season. Snowmelt timing had no effect on the other two greenhouse gases measured. Our results suggest that climatic warming in snow-dominated ecosystems of the Sierra will likely increase net greenhouse gas emission from the soil to the atmosphere in the short-term. However, continued advancement of the snowmelt date, without a concomitant increase in precipitation, will likely constrain the extent of the temperature-induced increase in greenhouse gas fluxes.

Final ID: H31G-1198

Integrating soil water measurements from plot to catchment scale in a snow-dominated, mixed-conifer forest of the southern Sierra Nevada.

M. W. Meadows; [1]; *P. C. Hartsough;* [2]; *R. C. Bales;* [1]; *J. W. Hopmans;* [2]; *A. I. Malazian;* [2];
1. Sierra Nevada Research Institute, University of California, Merced, CA, United States.
2. Land, Air, and Water Resources, University of California, Davis, CA, United States.

Body: Soil moisture was measured in the southern Sierra Nevada using cosmic-ray, time domain reflectometry (TDR), dielectric, neutron probe, and gravimetric or volumetric sampling techniques. These techniques are compared to develop better a understanding of shallow (0-50 cm) soil moisture and to determine the feasibility of decoupling vegetation moisture storage from soil-moisture storage within the cosmic-ray signal. Multiple embedded sensors (TDR and dielectric) were deployed across varying soil depths, aspects, and canopy covers to capture spatial and temporal variations of soil volumetric water content within the spatial range of a COsmic-ray Soil Moisture Observing Systems (COSMOS). Soil samples were collected within the COSMOS footprint for calibration and comparison during the COSMOS installation, June 2011. Through a one-year period, June 2011-June 2012, area-average volumetric water contents observed by COSMOS were compared to real-time, in situ observations of soil moisture using TDR and dielectric sensors, and with measurements of soil moisture taken periodically during surveys within the COSMOS footprint. Surveys of soil moisture in the upper 40 cm of soil were made along transects around the COSMOS with handheld TDR and gravimetric sampling techniques. A neutron probe was also used to measure soil moisture at 14 locations within the COSMSO footprint.

Results show that the COSMOS and the embedded sensor networks effectively observed trends of snow disappearance and soil drainage throughout the summer and fall, and track diurnal and seasonal trends in the near-surface soil profile. The addition of snow during the winter of WY2012 complicates the COSMOS signal. Timber harvest during spring and summer 2012 appear to have no immediate effect on shallow soil moisture throughout the area. However, we had anticipated that the loss of water stored in vegetation during timber harvest would be apparent in the COSMOS signal, which should include water stored in vegetation. Three possible causes for the lack of moisture change are: 1) too few trees were removed; 2) canopy vegetation left on the forest floor had approximately equal water content as tree-stem wood removed; 3) tree-root water storage remained relatively unchanged.

This research is part of the NSF-supported Southern Sierra Critical Zone Observatory, which is co-located within the U.S. Forest Service, Kings River Experimental Watershed.

URL: https://eng.ucmerced.edu/czo/index.html

Final ID: H31G-1208

Strategic sampling of microclimate, soil moisture and sapflux for improving ecohydrological model estimates in the California Sierra

K. Son; [1]; *C. Tague;* [1];
1. Bren School of Environmental Science & Management, University of California, Santa Barbara, Santa Barbara, CA, United States.

Body: Warming temperatures in the western United States had lead to reduced snow accumulation and earlier snowmelt, altering the timing and magnitude of vegetation water use and productivity. Eco-hydrologic models are key tools used to estimate the magnitude and spatial pattern of these responses and to project future responses to climate change. These models, however, require field measurements in order to estimate model parameters, evaluate model uncertainty and error and where needed, refine model representations of specific processes. Mountain watersheds, however, have high spatial heterogeneity in atmospheric forcing, topography, vegetation and soil properties over relatively short spatial scales, and field measurements are limited by cost, feasibility and accessibility. Thus, a key challenge in these environments is to combine strategically designed field measurements with model parameterization and evaluation.

Our research site is the Southern Sierra Critical Zone Observatory (SSCZO) is situated at the rain-snow to the snow-dominated transition zone. We applied Regional Hydro-Ecologic Simulation System (RHESSys) at this site to develop a strategy for field data collection that is explicitly directed at evaluating and improving model estimates of spatial heterogeneity in ecohydrologic processes including soil moisture and transpiration. We used initial model estimates to identify clusters of eco-hydrologic similarity and then defined sampling sites based on these clusters. The collected data are used to improve the ecohydrologic predictions (soil moisture, transpiration and streamflow) and reduce the model predictive uncertainty. Model sensitivity analysis and comparisons with CZO-flux tower data and distributed soil moisture and sapflux data highlight the importance of adequate representation of micro-climate patterns as controls on summer moisture deficits, transpiration and net primary productivity for the SSCZO watersheds. To support improved representation of micro-climate forcing patterns in models, we have collected additional air temperature and relative humidity data in the SSCZO watersheds using twenty-three micro-climate sensors (HOBO). The collected data are used to refine the climate inputs in order to improve the ecohydrolgic predictions in the SSCZO watersheds.

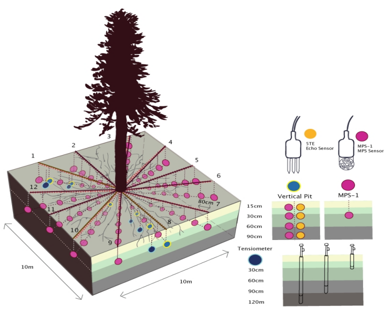
Final ID: H31G-1211

Paired tree and soil instrumentation: what can we learn from two instrumented sites across various gradients in a forested catchment

P. C. Hartsough;[1]; *E. Roudneva;*[1]; *A. I. Malazian;*[1]; *M. W. Meadows;*[2]; *R. C. Bales;*[2]; *J. W. Hopmans;*[1];
1. LAWR, Univ of California, Davis, CA, United States.
2. Sierra Nevada Research Institute, University of California, Merced, CA, United States.

Body: Extensive instrumentation both below and above ground across a forested catchment in the Southern Sierra Critical Zone Observatory (SSCZO) within the Kings River Experimental Watershed (KREW) begins to untangle the complex relationship between precipitation, water storage and transpiration as it relates to water availability from deeper sources. The first instrumented site (CZT-1) includes a White Fir (Abies concolor) situated on a flat ridge with access to deep soil moisture. Monitoring and modeling of shallow and deep soil regions confirm that there is significant soil water available from 100-400cm as the tree exhausts water from shallower depths. A root excavation and limited drilling show roots distributed from 30-150cm with limited roots available to access deeper soil water and water stored in the saprolite. At a second instrumented site, CZT-2, a Ponderosa Pine (Pinus ponderosa) was instrumented with a similar suite of sap flow and soil sensors. The CZT-2 site is on a slight slope and is characterized by shallow soils (<90cm) with extensive cobbles and bedrock outcrops with limited access to deeper soil or saprolite water. The second site also sits in the open while the first site is more protected in a closed forest. The two sites show different responses to changes in rain and snow loading from above as well as soil drainage and water depletion from below across a wet to dry transition. They also have different thresholds for transpiration shut down both due to late season water deficit and also during winter periods where air temperatures are high enough to permit photosynthesis. Sap flux and extensive soil water content and water potential measurements around both trees as well as evapotranspiration measurements from a 50m flux tower located adjacent to the two instrumented trees, show little water limitation during wet years and only moderate water limitation during a drought year. Access to deeper water storage pools is confirmed by modeling results across the soil/tree/atmosphere continuum.

URL: http://hartsough.lawr.ucdavis.edu/



Final ID: C32B-04

Seasonal and inter-annual snowmelt patterns in the southern Sierra Nevada, California *(Invited)*

K. N. Musselman; [1, 2]; *N. P. Molotch;* [3, 4]; *S. A. Margulis;* [2];
1. Centre for Hydrology, Coldwater Field Station, University of Saskatchewan, Kananaskis Valley, AB, Canada.
2. Civil and Environmental Engineering, UCLA, Los Angeles, CA, United States.
3. Geography and INSTAAR, University of Colorado Boulder, Boulder, CO, United States.
4. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States.

Body: In the Sierra Nevada, seasonal snow represents a critical component of California's water resource infrastructure in that it affords reliable water during otherwise arid summers. Complex spatial, seasonal and inter-annual snowmelt patterns determine when and where that meltwater is available. Our knowledge of snowmelt dynamics is typically limited to what we can infer from sparse, point-scale snow measurement stations. Limitations such as these motivate the use of numerical snowmelt models. We evaluate the ability of the Alpine3D model system to represent three years of snow dynamics over an 1800 km2 area of Sequoia National Park. The domain spans a 3600 m elevation gradient and ecosystems ranging from semi-arid grasslands to massive sequoia stands to alpine tundra. The model results were evaluated against data from a multi-scale measurement campaign that included airborne LiDAR, clusters of snow depth sensors, repeated manual snow surveys, and automated SWE stations. Compared to these measurements, Alpine3D consistently performed well in middle elevation conifer forests; compared to LiDAR data, the mean snow depth error in forested regions was < 2%. The model also simulated the snow disappearance date within two days of that measured by regional automated sensors. At upper elevations, however, the model tended to overestimate SWE by 50% to as much as 100% in some areas and the errors were linearly correlated (R2 > 0.80, p<0.01) with the distance of the SWE measurements from the nearest precipitation gauge used to derive the model forcing. The results suggest that Alpine3D is highly accurate during the melt season and that precipitation uncertainty may be a critical limitation on snow model accuracy. Finally, an analysis of seasonal and inter-annual snowmelt patterns highlighted distinct melt differences between lower, middle, and upper elevations. Snowmelt was generally most frequent (70% - 95% of the snow-covered season) at the lower elevations where snow cover was episodic and seasonal mean melt rates computed on days when melt was simulated were generally low (< 3 mm day-1). At upper elevations, melt occurred during less than 65% of the snow-covered period, occurred later in the season and mean melt rates were the highest of the region (> 6 mm day-1). Middle elevations remained continuously snow covered throughout the winter and early spring, were prone to frequent but intermittent melt, and provided the most sustained period of seasonal mean snowmelt (~ 5 mm day-1). The melt dynamics (e.g. timing and melt rate) unique to these middle elevations may be critical to the local forest ecosystem. Furthermore, the three years evaluated in this study indicate a marked sensitivity of this elevation range to seasonal meteorology, suggesting that it could be highly sensitive to future changes in climate.

Final ID: C32B-07

Connecting the snowpack to the internet of things: an IPv6 architecture for providing real-time measurements of hydrologic systems *(Invited)*

B. Kerkez; [1]; *Z. Zhang;* [1]; *C. Oroza;* [1]; *S. D. Glaser;* [1]; *R. C. Bales;* [2];
1. CEE, UC Berkeley, Berkeley, CA, United States.
2. Sierra Nevada Research Institute, UC Merced, Merced, CA, United States.

Body: We describe our improved, robust, and scalable architecture by which to rapidly instrument large-scale watersheds, while providing the resulting data in real-time. Our system consists of more than twenty wireless sensor networks and thousands of sensors, which will be deployed in the American River basin (5000 sq. km) of California. The core component of our system is known as a mote, a tiny, ultra-low-power, embedded wireless computer that can be used for any number of sensing applications. Our new generation of motes is equipped with IPv6 functionality, effectively giving each sensor in the field its own unique IP address, thus permitting users to remotely interact with the devices without going through intermediary services. Thirty to fifty motes will be deployed across 1-2 square kilometer regions to form a mesh-based wireless sensor network. Redundancy of local wireless links will ensure that data will always be able to traverse the network, even if hash wintertime conditions adversely affect some network nodes. These networks will be used to develop spatial estimates of a number of hydrologic parameters, focusing especially on snowpack. Each wireless sensor network has one main network controller, which is responsible with interacting with an embedded Linux computer to relay information across higher-powered, long-range wireless links (cell modems, satellite, WiFi) to neighboring networks and remote, offsite servers. The network manager is also responsible for providing an Internet connection to each mote. Data collected by the sensors can either be read directly by remote hosts, or stored on centralized servers for future access. With 20 such networks deployed in the American River, our system will comprise an unprecedented cyber-physical architecture for measuring hydrologic parameters in large-scale basins. The spatiotemporal density and real-time nature of the data is also expected to significantly improve operational hydrology and water resource management in the basin.

Final ID: C33C-0683

Sampling design and optimal sensor placement strategies for basin-scale SWE estimation

B. Kerkez; [1]; *S. C. Welch;* [1]; *R. C. Bales;* [2]; *S. D. Glaser;* [1]; *K. E. Rittger;* [3]; *R. Rice;* [2];

1. CEE, UC Berkeley, Berkeley, CA, United States.
2. Sierra Nevada Research Institute, UC Merced, Merced, CA, United States.
3. California Institute of Technology, Jet Propulsion Laboratory, La Cañada Flintridge, CA, United States.

Body: We present a quantitative framework by which to assess the number of required samples (sensors), as well as their respective locations, to most optimally estimate spatial SWE patterns using sensor networks across the 5000 sq. km American River basin of California. To inform the selection of future sensor locations, 11 years of reconstructed, spatially dense (500 x 500 m resolution) SWE data were used to develop metrics of historical SWE distributions. The historical data were split into eight years of training and three years of validation data, clustering the data set to derive spatial regions which share similar SWE characteristics. Rank-based clustering was compared to geographically-based clustering (sub-basin delineation) to determine the existence of stationary covariance structures within the overall SWE dataset. Within each cluster, a quantitative sensor-placement algorithm, based on maximizing the metric of Mutual Information, was implemented and compared to a randomized placement approach. Gaussian process models were then trained to evaluate the efficacy of each placement approach. Rank based clusters remained stable inter-annually, suggesting that rankings of pixel-by-pixel SWE exhibit stationary features that can be exploited by a sensor-placement algorithm. Rank-based clustering yielded 200 mm average root mean square error (RMSE) for twenty randomly selected sensing locations, outperforming geographic and basin-wide placement approaches, which generated 460 mm and 290 mm RMSE, respectively. Mutual Information-based sampling provided the best placement strategy, improving RMSE between 0 and 100 mm compared to random placements. Increasing the number of rank-based clusters consistently lowered average RMSE from 400 mm for one cluster to 175 mm for eight clusters, for twenty total sensors placed. To optimize sensor placement, or to inform future sampling or surveying strategies, we recommend a strategy that couples rank-based clustering with Mutual Information-based sensor placement.

Final ID: C33D-0684

Effects of forest structure on snow accumulation and melt derived from ecohydrological instrument clusters across the Western US *(Invited)*

N. P. Molotch; [1, 2]; *K. N. Musselman;* [3, 1]; *P. B. Kirchner;* [4]; *R. C. Bales;* [4]; *P. D. Brooks;* [5];
1. Geography / INSTAAR, University of Colorado, Boulder, CO, United States.
2. Jet Propulsion Laboratory / CAL TECH, Pasadena, CA, United States.
3. Civil and Environmental Engineering, University of California, Los Angeles, Los Angeles, CA, United States.
4. Sierra Nevada Research Institute, University of California, Merced, Merced, CA, United States.
5. Hydrology and Water Resources, University of Arizona, Tucson, AZ, United States.

Body: In the higher elevations of the western U.S., seasonal snow accumulation provides the primary source of water input to the terrestrial ecosystem. Recent changes in climate and vegetation cover (e.g. fire suppression, beetle infestation, fire) have potentially large, yet unrealized implications for water availability and ecosystem health. In this regard, we have developed a series of ecohydrological instrument clusters to measure snow depth, soil moisture and temperature, sap flow, and fluxes of carbon, water vapor, and energy. Clusters deployed across elevational transects in the Sierra Nevada and Rocky Mountains provide the measurements needed to understand the impacts of forest structure on snowmelt dynamics and broader ecohydrological feedbacks. These observations indicate that snow accumulation is greater in open versus under canopy locations (29% greater on average) but snow ablation rates (sublimation and melt) are also greater in open areas (39% greater on average). Therefore snow water equivalent differences between open versus under canopy locations were generally lower than snowfall differences. As a result of these competing factors, snow disappearance timing is more similar in open versus sub-canopy areas then would be expected based on snow accumulation differences alone. The time-space evolution of differences in snow water equivalent between under canopy and open areas, therefore, is a function of the magnitude of the differences between open and sub-canopy snow accumulation (i.e. input terms) versus differences between open and sub-canopy snowmelt and sublimation (i.e. loss terms). The magnitude of the differences in these two terms in open versus under canopy positions is dictated by several physiographic and climatic factors which vary across a variety of scales. This presentation will synthesize observations from diverse climatic and physiographic regimes to develop the conceptual models of snow-vegetation interactions needed for testing a variety of climate and land cover change hypotheses.

URL : http://instaar.colorado.edu/mtnhydro/Mountain_Hydrology/Home.html

Final ID: B34C-07

Lateral redistribution of dissolved vs. complexed organic matter with soil erosion

E. Stacy; [1]; *S. M. Meding;* [2]; *C. T. Hunsaker;* [3]; *D. W. Johnson;* [4]; *S. C. Hart;* [1]; *A. A. Berhe;* [1];

1. University of California, Merced, Merced, CA, United States.
2. University of Arizona, Tucson, AZ, United States.
3. United States Forest Service, Pacific Southwest Research Station, Fresno, CA, United States.
4. University of Nevada, Reno, Reno, NV, United States.

Body: Erosion can alter the principal mechanisms of organic matter storage and persistence. The influence of soil erosion on the global carbon (C) cycle is the result of three ecologically relevant factors: (1) changes in molecular composition of the organic matter (OM); (2) physical protection of OM within aggregates and pores; and (3) organomineral associations of OM with soil minerals through chelation and/or cation-bridging. Previous research has shown that prevalent OM stabilization mechanisms vary by landform position, where long-residence times of OM were associated with aggregation and cation-bridging in eroding positions, while OM in low-lying depositional areas was protected through burial and association with metal oxides. However, it is still unclear how OM stabilization mechanisms shift with extended transport from the source watershed. We addressed this issue by comparing soil from slope transects with sediment captured after it was transported from watersheds in the southern Sierra National Forest. Using a sequential extraction procedure, we separated organic particles (OP) and OM fractions that were water-extractable (free), aggregate-protected, or bonded to mineral surfaces through cation bridging to assess differences in stabilization mechanisms between landform positions and sediment. While the C:N ratio is consistent between years and watersheds, absolute C and N concentrations vary more in sediments than in the soils. Confirming previous work, there was little difference in free OP fraction between landform positions. However we found that this free OP fraction was often enriched in the sediment samples over the soils from the source watershed; the intensity of this signal differed by year. In addition, organomineral bonding also differed between sediments and soils. Of the five major polyvalent ions (Ca, Fe, Mg, Mn, and Al) that we measured in liquid extracts, calcium and iron were more closely correlated to C concentrations in sediments than in soils. Preliminary analysis of particle size distribution indicates that soil texture, particularly silt, is a controlling factor for C storage in complexed OM. Because these entisols and inceptisols have little clay, the potential for OM stabilization through these mechanisms is likely higher in other soils. Understanding which mechanisms of OM stabilization dominate before and after erosion will allow us to estimate the changing decomposition potential of this OM – including whether it results in a net carbon source, or a carbon sink, as seen in several other ecosystems.

Final ID: B34C-08

Erosion of bulk and pyrogenic C from upland forested Sierra Nevada ecosystems *(Invited)*

A. A. Berhe; [1]; *E. Stacy;* [1]; *M. McClintock;* [1]; *A. Newman;* [1]; *S. C. Hart;* [1]; *C. T. Hunsaker;* [2]; *D. W. Johnson;* [3];
1. University of California, Merced, Atwater, CA, United States.
2. US Forest Service, PSW, Fresno, CA, United States.
3. University of Nevada, Reno, Reno, NV, United States.

Body: Erosion of bulk and pyrogenic carbon (C) impose significant controls on storage and persistence of soil organic matter (SOM) in eroding watershed. The extent of both bulk and BC export from eroding watersheds depends on amount and composition of SOM, association of SOM with reactive soil minerals in eroding slope profiles, the type and rate of erosion, and time since and severity of past fires. Currently, we have very little data on the relative lateral distribution and export of bulk vs. pyrogenic C from eroding upland, fire-affected forested ecosystems. Here, we will present data on the amount and composition of soil material eroded from eight first-order watersheds in the mixed-conifer zone of the Sierra National Forest in the Kings River Experimental Watershed. Our results show that there is large variability in nature of exported material – including ratio of bulk sediment vs. BC content, chemical composition of SOM, rate of export of reactive soil minerals, and overall sediment export across the watersheds that is not directly related to watershed size or climatic variability.

Final ID: EP41C-0812

Combining natural experiments in source lithology with laboratory tumbling to quantify sediment resistance to comminution and its role in downstream fining

J. D. Beyeler; [1]; *L. S. Sklar;* [1]; *C. S. Riebe;* [2];
1. Geosciences, SF State University, San Francisco, CA, United States.
2. Geology and Geophysics, Univ. of Wyoming, Laramie, WY, United States.

Body: Mountain rivers convey sediment from alpine headwaters through valleys to basins, providing both erosive tools for fluvial incision and protective alluvial cover depending on sediment supply. It is widely observed that particles reduce in size during fluvial transport, directly influencing bed sediment grain size distributions and thus channel morphology, habitat quality, and the sedimentary record of climatic and tectonic effects on landscapes. However it is difficult to quantify the contribution of comminution to downstream fining of bed material due to the confounding effects of sediment resupply from hillslopes and sorting by size selective transport. Here we take advantage of natural experiments where lithologic contacts create discrete upstream source areas of particular rock types, such that downstream of the contact we can exclude hillslope resupply and isolate the evolution of grain size distributions due to particle breakdown. Where the upstream source area supplies two or more rock types of differing durability, we can use the relationship between lab measurements of size reduction and tensile strength to distinguish in the field between sorting and particle comminution. We are applying this approach in the Sierra Nevada of California, where plutonic and metamorphic bedrock vary in durability and outcrop in favorable configurations for this natural experiment. For all rock types in this study, we measure rock tensile strength in the laboratory with Brazilian tensile splitting tests and quantify comminution as exponential mass loss coefficients from barrel tumbling experiments. In the field we measure size reduction of bed material through pebble counts by rock type, which are combined with downstream travel distances for a field estimate of sediment fining rates. We then compare field results with laboratory strength measurements and tumbling abrasion coefficients to estimate field size reduction due solely to comminution. Our field and lab results will help establish an empirical scaling relationship between lab and field comminution rates for the same rock types, and will be useful in developing and testing theory for predicting how comminution rates vary across watersheds and by lithology.

Final ID: EP41D-0821

Effects of bedrock nutrient density on vegetation and topography in the Sierra Nevada Batholith, California

W. Hahm; [1]; *C. S. Riebe;* [1]; *S. Araki;* [1];
1. Geology and Geophysics, University of Wyoming, Laramie, WY, United States.

Body: Vegetation harnesses solar energy to promote soil stability and regolith production. Mechanistically, vegetation encourages chemical weathering both directly, by releasing organic acids, and indirectly, by stabilizing soils and increasing their contact time with corrosive natural waters. Empirically, global compilations indicate that millennial-scale erosion rates are an order of magnitude faster on average in soil-mantled landscapes compared to bare, exposed-bedrock surfaces. Hence, connections between vegetation and soil cover are central to long-term questions of landscape evolution and short-term issues of sustainability. Yet the factors that regulate the distribution of vegetation, and by extension the soil mantle, are not fully understood. The unglaciated, granitic plutons of the western Sierra Nevada host an unexplained landscape dichotomy, in which forested, soil-mantled hillslopes are juxtaposed with bare, exposed-bedrock hillslopes. Here we present new measurements of bedrock nutrient density that correlate strongly with tree canopy cover within a narrow band of elevation and climate. Bedrock phosphorus concentrations vary by more than an order of magnitude and change abruptly at plutonic contacts. These same contacts frequently mark transitions between vegetated, soil-mantled terrain and exposed bedrock surfaces, similar to sharp vegetative contacts around ultramafic substrates elsewhere in California. Major and minor element enrichment of soil relative to bedrock point to dust as a probable source of nutrients in at least one phosphorus-poor pluton, where sparse stunted forests persist in a landscape otherwise devoid of vegetation. This is consistent with an intrinsic nutrient deficiency that is partly offset by allocthonous nutrient inputs. Our observations are consistent with nutrient availability serving as a regulator that drives landscapes into two stable states. If nutrient availability is sufficient, vegetation takes hold, stabilizing soils against erosion. If nutrient availability is insufficient, such that it limits vegetation, physical erosion can overcome soil production and strip the landscape bare, ultimately slowing the rate of surface lowering. Our measurements of cosmogenic nuclides indicate that exposed surfaces in the western Sierra Nevada are eroding three to ten times slower than adjacent soil-mantled terrain. This implies that linkages between intrinsic bedrock nutrient density and vegetation could regulate relief at the pluton scale. The observation that nutrient density varies sharply among plutons cautions against unqualified use of granitoids as a uniform state factor in studies of weathering and pedogenesis.

Final ID: EP41D-0822

Moving Beyond the Average in Cosmogenic Nuclide Studies of Erosion and Weathering

C. Lukens; [1]; *C. S. Riebe;* [1]; *L. S. Sklar;* [4]; *D. L. Shuster;* [3, 2];

1. Geology and Geophysics, University of Wyoming, Laramie, WY, United States.
2. Earth & Planetary Sciences, University of California, Berkeley, CA, United States.
3. Berkeley Geochronology Center, Berkeley, CA, United States.
4. Geosciences, San Francisco State University, San Francisco, CA, United States.

Body: Quantifying the flux and size of sediment in landscapes is central to understanding the interplay of climate and tectonics in erosion and weathering. Cosmogenic nuclides in stream sediment are widely used to measure spatially averaged erosion rates. Though this use of streams as integrators of erosion has proven powerful, it does not readily capture erosional heterogeneities that, if measured, could yield fresh perspectives on sediment production and transport. Here we show how such heterogeneities can be quantified using cosmogenic nuclides, apatite (U-Th)/He dating, and numerical modeling. As evidence, we present results from Inyo Creek, which drains a small, high-relief catchment in the eastern Sierra Nevada, California. We find that detrital apatite (U-Th)/He ages are markedly older on average in very coarse gravel than in sand. This signature of erosional heterogeneity validates the need to sample and study coarse sediment, particularly when it accounts for a large fraction of sediment flux, as may often be the case in steep catchments. The measured difference in ages at Inyo Creek demonstrates that the coarser sediment is eroded from higher elevations, implying it has a 20% higher cosmogenic nuclide production rate, on average, relative to the sand. This illustrates a potentially significant source of bias in cosmogenic nuclide studies of erosion; if the grain size of eroded sediment from slopes varies with elevation, then altitudinal variations in the nuclide production rates can impart a grain-size dependence on cosmogenic nuclide concentrations in sediment. Our analysis calls for caution in interpreting spatially averaged erosion rates from cosmogenic nuclides measured in a single grain size. It also demonstrates a framework for quantifying heterogeneities in sediment production, flux and size from cosmogenic nuclides and apatite (U-Th)/He ages measured in multiple grain sizes.

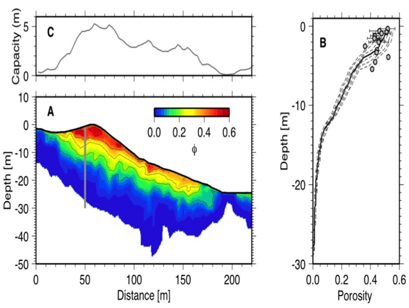
Final ID: EP41I-03

Geophysics in the Critical Zone: Constraints on Deep Weathering and Water Storage Potential in the Southern Sierra CZO

W. Holbrook; [1]; *C. S. Riebe;* [1]; *J. L. Hayes;* [1]; *K. Reeder;* [2]; *D. L. Harry;* [2]; *A. I. Malazian;* [3]; *A. Dosseto;* [4]; *P. C. Hartsough;* [3]; *J. W. Hopmans;* [3];

1. Geology & Geophy Dept. 3006, Univ Wyoming, Laramie, WY, United States.
2. Colorado State University, Fort Collins, CO, United States.
3. UC Davis, Davis, CA, United States.
4. University of Wollongong, Wollongong, NSW, Australia.

Body: Quantifying the depth and degree of subsurface weathering in landscapes is crucial for quantitative understanding of the biogeochemistry of weathering, the mechanics of hillslope sediment transport, and biogeochemical cycling of nutrients and carbon over both short and long timescales. Although the degree of weathering can be readily measured from geochemical and physical properties of regolith and rock, many distributed samples are needed to measure it over broad spatial scales. Moreover, quantifying the thickness of subsurface weathering has remained challenging, in part because the interface between altered and unaltered rock is often buried at difficult to access depths. To overcome these challenges, we combined seismic refraction and resistivity surveys to estimate regolith thickness and generate representative hillslope-scale images of subsurface weathering and water storage at the Southern Sierra Critical Zone Observatory (SSCZO). Inferred seismic velocities and electrical resistivities of the subsurface provide evidence for a weathering zone with thickness ranging from 10 to 35 m (average = 23 m) along one intensively studied transect. This weathering zone consists of roughly equal thicknesses of saprolite (P-velocity < 2 km/s) and moderately weathered bedrock (P-velocity < 4 km/s). We use a rock physics model of seismic velocities, based on Hertz-Mindlin contact theory, to estimate lateral and vertical variations in porosity as a metric of water storage potential along the transect. Inferred porosities are as high as 55% near the surface and decrease to zero at the base of weathered rock. Model-predicted porosities are broadly consistent with values measured from physical properties of saprolite, suggesting that our analysis of the geophysical data provides realistic estimates of subsurface water storage potential. A major advantage of our geophysical approach is that it quickly and non-invasively quantifies porosity over broad vertical and lateral scales. Our results indicate that saprolite is a crucial reservoir of water, potentially storing an average of 3 m of water along a forested slope in the headwaters of the SSCZO.

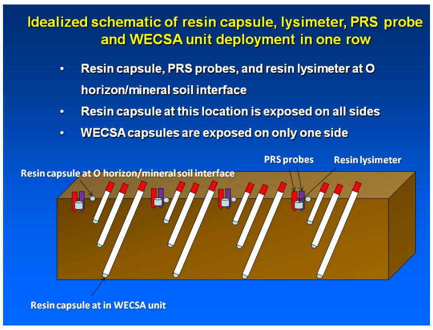


Final ID: B43F-0468

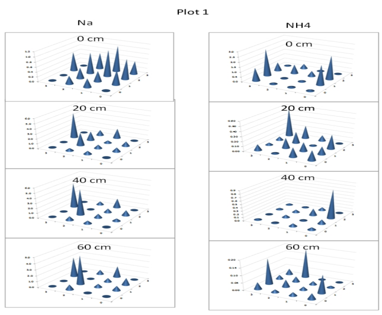
A Three Dimensional View of Nutrient Hotspots in a Sierra Nevada Forest Soil

D. W. Johnson;[1]; *M. W. Meadows;*[2]; *C. Woodward;*[1];
1. Natural Resources and Environm, Univ Nevada Reno, Reno, NV, United States.
2. Sierra Nevada Research Institute, University of California, Merced, CA, United States.

Body: In a previous paper, we explored the variability in O horizons and surface soils in two 6 x 6 m plots in the King's River Experimental Watershed (KREW) in the western Sierra Nevada Mountains of California, one of the Critical Zone Observatory sites. Using both traditional soil coring and resin-based methods, we found that hotspots were common for all measured nutrients, especially in water-extractable fractions. We hypothesized that some of these hotspots were due to preferential infiltration of O horizon interflow. In this study, we expand the sampling space vertically by installing resin capsules at the O horizon/mineral soil interface (as in the past), and at 20, 40, and 60 cm in the soil in 16 gridpoints within a 6 x 6 m grid using the WECSA® Access system. Resins were collected after the first precipitation event in the autumn of 2011 and after snowmelt in the spring of 2012, thus providing a three-dimensional view of soil nutrient availability at two different times in exactly the same locations. The data showed considerable spatial variability at all depths, but also suggested vertical connections of hotspots for certain nutrients in that high values were co-located in the same vertical location at different depths. The data also showed clustering of high nutrient values in the deeper depths after the first precipitation event, suggesting the influence of preferential flow with the first fall wetting front.



Schematic of resin collector array in soil



Na and NH4 concentrations in capsules after first precipitation event.

Final ID: EP43B-0871

Fractures in the Critical Zone: Insights from GPR and seismic refraction surveys

J. T. St. Clair; [1]; *W. Holbrook;* [1]; *C. S. Riebe;* [1];
1. Geology and Geophysics, University of Wyoming, Laramie, WY, United States.

Body: Near-surface weathering profiles integrate tectonic history, past and present climatic conditions, and interactions with the biosphere. The amount of weathering that a rock has undergone controls both the availability of material for transport at the surface and physical pathways for water to interact with material at depth; thus rock damage provides first order controls on landscape evolution. In this study we use seismic refraction and ground-penetrating-radar (GPR) surveys to estimate depths to unweathered bedrock and to investigate the spatial variability of fractures within the saprolite in the Sherman Batholith, SE Wyoming. We use a 48-channel geophone array with a hammer source and perform tomographic inversions of observed travel-times. Our results show that depths to seismic velocities > 4.0 km/s, characteristic of unweathered Sherman granite, are ~10-40 meters. We collect vertically incident GPR data with several antennae with peak frequencies up to 400 Mhz. Depth-migrated images reveal highly damaged saprolite, with fractures penetrating up to 10 meters. We find that fracture density is higher where seismic velocities are lower. We also observe horizontal fractures terminating down dip of weaker reflections, which we interpret as relatively coherent dikes in an otherwise friable saprolite. We hypothesize that these dikes may play an important role in routing water through the subsurface.

Final ID: EP43E-07

Altitudinal increase in size of sediment shed from slopes revealed by tracer thermochronometry

C. S. Riebe; [1]; *L. S. Sklar;* [2]; *C. E. Lukens;* [1]; *D. L. Shuster;* [3, 4];

1. Geology and Geophysics, University of Wyoming, Laramie, WY, United States.
2. Geosciences, San Francisco State Univ., San Francisco, CA, United States.
3. Earth and Planetary Science, University of California, Berkeley, Berkeley, CA, United States.
4. Berkeley Geochronology Center, Berkeley, CA, United States.

Body: The size and flux of sediment influence river incision, channel morphology, and habitat quality and thus are central to the interplay of tectonics, climate, and life in Earth surface dynamics and the sedimentary record. Sediment flux is commonly measured using cosmogenic nuclides, yet there is no complementary approach for quantifying the size of sediment eroded from slopes. This has hindered progress on the fundamental question of what regulates variations in sediment size distributions in landscapes. Here we adapt conventional tracer thermochronometry to quantify how the grain size of sediment eroded from slopes varies across a steep mountain catchment. (U-Th)/He ages of detrital apatite are markedly higher, on average, in gravel than in sand, indicating that particle sizes in eroded sediment increase with elevation in the catchment, consistent with climatic regulation of sediment production. In this and other catchments with altitudinal gradients in eroded sediment size, (U-Th)/He ages measured in a narrow range of particle sizes in the stream can bias thermochronometric interpretations of sediment production and tectonic processes. We show how such biases can be eliminated by measuring (U-Th)/He ages and cosmogenic nuclides together in multiple sediment sizes. By measuring how eroded sediment size varies with altitude in catchments, our approach provides the means to test hypotheses related to the emerging view of hillslope sediment production as a dominant regulator of fluvial processes in mountain streams.

Final ID: B51C-0559

Water and energy gradients produce resilience and thresholds in ecosystem function in the western Sierra Nevada Mountains

A. E. Kelly; [1]; *M. Goulden;* [1]; *R. C. Bales;* [2]; *M. W. Meadows;* [2]; *G. Winston;* [1];
1. Earth System Science, UC Irvine, Irvine, CA, United States.
2. Sierra Nevada Research Institute, UC Merced, Merced, CA, United States.

Body: Energy and water availability are fundamental controls on ecosystem properties such as ecosystem type, water use, phenology, and carbon uptake, allocation, and turnover. How availability of energy and water interact to produce stepwise changes in ecosystem properties across linear climate gradients remains an important question for ecology and predicting impacts of climate change. Previous work has focused on the climatic factors that determine individual species' mortality or locations of individual ecotones, but research is lacking that examines role of energy and water availability in controlling patterns of ecosystem trait shifts across a broad climatic gradient. We studied a 2600-m elevation gradient along the western slope of the Sierra Nevada Mountains in the Southern Sierra Critical Zone Observatory (SSCZO) to understand how water and energy availability interact to influence ecosystem properties across a broad range of climate conditions and ecosystem types. Eddy covariance, vegetation type, forest biomass and production, sap flux, and soil moisture were measured to understand nonlinear ecosystem responses to gradients in energy and water availability. We describe the small differences in temperature and water availability that produce sharp transitions in ecosystem type, productivity, water use, and phenology. Conversely, we describe how broad ranges of temperature and water availability produce stability in ecosystem properties and demonstrate ecosystem resilience to climate change. These findings can better inform predictions of impacts of a changing climate on ecosystem range shifts, mortality, seasonality, carbon cycling, and water use.

Final ID: GC51F-02

The geography of forest drought vulnerability: Integrating modeling and measurements *(Invited)*

C. Tague;[1];

1. Bren School of Env. Science, UC Santa Barbara, Santa Barbara, CA, United States.

Body: Forests are a key provider of ecosystems services throughout the globe. Understanding and ultimately predicting how forest are likely to respond to a changing climate is an active area of interest and research. While some model and empirical studies show increased in forest growth, particularly in temperature limited environments, there are also many studies that show declines in productivity and increased rates of forest mortality in response to greater or more frequent drought stress. Given the importance of water-limitation and drought stress as a control on how forests will respond to a changing climate, models that explicitly link forest productivity with hydrology are essential tools. I will provide an overview of RHESSys, a coupled model of ecosystem biogeochemical cycling and spatially distributed hydrology. RHESSys is an open-source tool that integrates state-of-the art science based understanding of forest structure and function with observational data from multiple sources, including point measures such as streamflow and carbon flux tower data and spatial data from remote sensing products. I will present a number of case studies that use this model to examine the geography of forest drought stress vulnerability. These case studies focus explicitly on eco-hydrologic interactions and demonstrate critical linkages among forest water use, carbon cycling, species-disturbance interactions, local micro-climate patterns and geomorphology. Use of the model provides an integrated systems-oriented perspective on forest drought stress and mortality and allows us to disentangle to relative importance of multiple controls on forest vulnerability. Our case studies also evaluate what management strategies may be most effective at mitigating forest drought stress at stand to watershed scales.

Final ID: GC51F-05

Forest management effects on snow, runoff and evapotranspiration in Sierra Nevada mixed-conifer headwater catchments

R. L. Ray; [1]; *P. C. Saksa;* [1]; *R. C. Bales;* [1]; *M. H. Conklin;* [1];
1. School of Engineering, University of California, Merced, Merced, CA, United States.

Body: We used intensive field measurements and data-intensive hydro-ecological modeling to investigate the impact of forest vegetation management on the sensitivity of snow accumulation, evapotranspiration and discharge at seven headwater catchments in the Sierra Nevada. Catchments are located in dense mixed-conifer forest, at elevations of 1500 – 2100 m, and receive a mix of rain and snow precipitation. Management scenarios for reducing forest density by uniform thinning and forest clearings were implemented in the Regional Hydro-ecological Simulation System (RHESSys). Results obtained using inherent model equations to separate total precipitation into snow and rain underestimated snow water content in some of the catchments, requiring manual input of snow and rain for accurate simulations. Modeling precipitation phase accurately was critical for the current forest condition, as the change in vegetation has differing effects on rain, snow and snowmelt. Results using RHESSys show that light, uniform thinning alone (<20% canopy) may not be enough to change water yield significantly, but this threshold of canopy reduction is lowered by creating gaps in the forest alone or in combination with uniform thinning, and has potential to measurably increase water yield beyond background variation. Clarifying these specific impacts of forest vegetation on snow processes and water yield is essential for simulating forest management in the Sierra Nevada and it shows the forest structure has significant influence on the catchment water balance. However, modifying forest canopy density and canopy cover to calculate average levels of snow water equivalent at a basin-scale may not be detailed enough to incorporate all the complex forest structure effects on snow processes in mountain watersheds.

Final ID: H52E-01

Modeling of Soil and Tree Water Status Dynamics in a Mixed-Conifer Forest of the Southern Sierra Critical Zone Observatory *(Invited)*

J. W. Hopmans; [1]; J. Rings; [1]; T. Kamai; [1]; M. Mollaei Kandelous; [1]; P. C. Hartsough; [1]; J. A. Vrugt; [2];
1. Land, Air and Water Resources, Univ California Davis, Davis, CA, United States.
2. University of California, Irvine, CA, United States.

Body: Trees play a key role in controlling the water and energy balance at the land-air surface. By changing water content of soil and atmosphere, trees influence meteorological, climatological and hydrological cycles. Numerical models allow simulating the relevant hydrological processes; most importantly the movement of water as it is transported through the soil, taken up by roots into the tree and ultimately transpired into the atmosphere along water potential gradients across the soil-root-tree-atmosphere continuum (SPAC). The results of a multi-year deployment of soil moisture sensors to study the hydrologic/biotic interactions in a mixed-conifer forest in the Southern Sierra Critical Zone Observatory (CZO) will be presented. To better understand root-soil water interactions, a mature white fir (Abies concolor) and the surrounding root zone was continuously monitored (sap flow, canopy stem water potential, soil moisture, soil water potential and temperature), to characterize the hydraulics SPAC. In addition, we present a hydrodynamic model, simulating unsaturated flow in the soil and tree with stress functions controlling spatially distributed root uptake and canopy transpiration. To parameterize the in-situ tree water relationships, we combine the numerical model with observational data in an optimization framework, minimizing residuals between modeled and measured observational data.

Final ID: GC54A-05

Critical Zone Observatories (CZOs): Integrating measurements and models of Earth surface processes to improve prediction of landscape structure, function and evolution *(Invited)*

J. Chorover; [1]; *S. P. Anderson;* [2]; *R. C. Bales;* [3]; *C. Duffy;* [4]; *F. N. Scatena;* [5]; *D. L. Sparks;* [6]; *T. White;* [7];

1. Soil, Water and Environmental Science, University of Arizona, Tucson, AZ, United States.
2. Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO, United States.
3. School of Engineering, University of California, Merced, Merced, CA, United States.
4. Civil and Environmental Engineering, Pennsylvania State University, University Park, PA, United States.
5. Earth and Environmental Sciences, University of Pennsylvania, Philadelphia, PA, United States.
6. Plant and Soil Sciences, University of Delaware, Newark, DE, United States.
7. Geosciences, Pennsylvania State University, University Park, PA, United States.

Body: The “Critical Zone” - that portion of Earth’s land surface that extends from the outer periphery of the vegetation canopy to the lower limit of circulating groundwater - has evolved in response to climatic and tectonic forcing throughout Earth’s history, but human activities have recently emerged as a major agent of change as well. With funding from NSF, a network of currently six CZOs is being developed in the U.S. to provide infrastructure, data and models that facilitate understanding the evolution, structure, and function of this zone at watershed to grain scales. Each CZO is motivated by a unique set of hypotheses proposed by a specific investigator team, but coordination of cross-site activities is also leading to integration of a common set of multi-disciplinary tools and approaches for cross-site syntheses. The resulting harmonized four-dimensional datasets are intended to facilitate community-wide exploration of process couplings among hydrology, ecology, soil science, geochemistry and geomorphology across the larger (network-scale) parameter space. Such an approach enables testing of the generalizability of findings at a given site, and also of emergent hypotheses conceived independently of an original CZO investigator team. This two-pronged method for developing a network of individual CZOs across a range of watershed systems is now yielding novel observations and models that resolve mechanisms for Critical Zone change occurring on geological to hydrologic time-scales. For example, recent advances include improved understanding of (i) how mass and energy flux as modulated by ecosystem exchange transforms bedrock to structured, soil-mantled and/or erosive landscapes; (ii) how long-term evolution of landscape structure affects event-based hydrologic and biogeochemical response at pore to catchment scales; (iii) how complementary isotopic measurements can be used to resolve pathways and time scales of water and solute transport from canopy to stream, and (iv) how feedbacks between the Critical Zone, changing climate and changing land use are occurring on timescales relevant to human decisions and policy making.

URL : www.criticalzone.org