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Topic. Core CZO measurements, data management and integration

Investigator. Roger Bales & Martha Conklin

Students & research staff. Matt Meadows, UG assistant, data manager, postdoc

Scope.

Field installations & support. Core measurements made by the CZO team compliment those done by the KREW team. One focus is the water balance instrument cluster, which is anchored by an eddy-correlation flux tower but with ground measurements extending 1-2 km from the tower. The flux tower will provide point measurements of water, energy and carbon exchange with the atmosphere, which will be extended outward using the meteorological, snow/soil, remotely sensed and other spatial data. The proposed instrument cluster will include three embedded sensor networks, one located in the vicinity of the tower, one at a lower elevation with cold-season precipitation a mix of rain and snow lower met station vicinity) and one at a higher snow-dominated elevation upper met station vicinity). Measurements that are part of the instrument clusters include: snow depth, air temperature, solar radiation (open and under canopy), reflected radiation, soil moisture, temperature and matric potential (multiple depths), sap flow. Across the meadow and stream sections it is planned to measure water level, temperature, electrical conductivity in piezometers. Measurements on the tower include wind speed and direction, atmospheric water vapor flux, CO₂ flux, shortwave and longwave radiation (incoming/outgoing), precipitation, relative humidity, barometric pressure.

Data management. CZO data are archived in a digital library: https://eng.ucmerced.edu/snsjho.

K-12 Education & outreach. The main focus will be training instructors of the Yosemite Institute (YI) in critical zone processes, with a particular focus on mountain hydrology. The instructors are trained twice a year in September and January for a period of a week. We will review YI’s teacher training and current activities, develop modules linked to the CZO that the instructors will incorporate into their activities, and train instructors in use of the materials. We will focus on activities that stress the mountain water cycle, the role of the Sierra Nevada snowpacks to CA water supply and their vulnerability of the snow to climate change.

University education. We plan to develop at least three university earth science “case studies” using data and observations obtained from the CZO. One module will combine a basic energy balance with state of the art technology, Raman-backscatter distributed temperature sensing, in a montane stream. Concepts to be stressed include the spatial heterogeneity of the stream as well as the role of obtaining system “snapshots” in time. These case studies will provide teaching notes for educators and will be posted on the CZO website; we will also post them on websites provided by professional organizations. These case studies will seek to provide earth science educators and students with current, peer-reviewed material.

CZO integration. The core office will also maintain a web site to facilitate project communications, organize an annual meeting of Southern Sierra CZO investigators, maintain communication with PSW, communicate with the press and stakeholders, represent the CZO at professional meetings (when invited), and coordinate with NSF, the other CZO’s and the CZO steering committee.

Funding. Largely CZO.

Schedule, including field work. Ongoing

Manuscripts in progress & planned. TBD
**Topic.** Core KREW measurements and data management

**Investigator.** Carolyn Hunsaker

**Students & research staff.** Tom Whitaker, field hydrologist

**Scope.** PSW has agreed to share basic, relevant data with the CZO team and science community. Data that PSW is developing include: stream stage & discharge, meteorology, stream channel characteristics, stream condition inventory, stream physical habitat (macroinvertebrates), erosion & sedimentation, geology, soils & litter, shallow soil water chemistry, snowmelt & rain chemistry, streamwater chemistry, riparian & upland vegetation, fuel loading, algae & periphyton.

**Schedule, including field work.** Ongoing

**Manuscripts in progress & planned.** See below.
**Topic.** Modeling of water and nutrient cycles

**Investigator.** Christina Tague

**Students & research staff.** TBD

**Scope.** Modeling will be carried out using RHESSys, a spatially distributed, dynamic model of coupled eco-hydrologic processes. Included in the model are mechanistic representations of vertical hydrologic processes (interception, soil and litter evaporation, canopy transpiration, infiltration, vertical drainage); lateral redistribution of moisture and nutrients and streamflow production; and soil and vegetation carbon and nitrogen cycling (http://fiesta.bren.ucsb.edu/~rhessys/). The CZO provides an opportunity to better integrate field measurements and analysis within a spatial modeling framework. My broad general goals are to collaborate with other CZO scientists and use the model to: i) contribute to the site selection of new monitoring locations by using the model to develop hypothesis about where significant gradients in response variables are likely to occur, ii) contribute to the spatial scaling of measurements by estimating spatial patterns of response variables, and iii) estimate response variables for a range of climate and land-cover scenarios. It will be very important to use field measurement to try to improve the model by: i) reducing uncertainty in model inputs and parameters, ii) contributing to quantification of model uncertainty, and iii) refining where necessary model structure (or representation of specific hydrologic and biogeochemical cycling processes). The general approach will begin with looking at streamflow hydrology, followed by eco-hydrologic processes (e.g. transpiration) and then finally carbon and nitrogen cycling. Initial work will use the model as is - later work will incorporate measured data to try to improve model performance.

**Heterogeneity and spatial resolution.** At what spatial resolution must we resolve heterogeneity in snow accumulation and melt in order to capture streamflow responses to climate variation and differences in streamflow responses between study watersheds? The first step is to calibrate RHESSys using currently available inputs: DEM, basic vegetation and soils map, meteorological station data, to predict streamflow and variation in streamflow between the 4 instrumented watersheds. I will use GLUE type Monte-Carlo approaches for calibration and generate uncertainty bounds around streamflow predictions. I will also use some non-traditional streamflow metrics to try to better constrain model parameters, considering both peak and low flow metrics and year-to-year variation in these. I will also compare model estimates of ET, and storage discharge relationships with those derived by Jim using his hydrograph recession analysis techniques. I will repeat this model analysis using different model resolutions. Ideally it would also be useful to include estimate of very fine (meter) scale heterogeneity in snow cover and melt rates. The goal here is to examine sensitivity of streamflow predictions to modeling unit resolution and incorporation of variance within finest scale model units.

**Streamflow and climate.** What is the relationship between modeled streamflow and climate in site watersheds? How will streamflow in these watershed change under a warmer climate? Using the calibrated model of streamflow from above, we will estimate streamflow behavior under a range of climate conditions. Empirical analysis of streamflow data (in progress by Tom Whitaker) can provide a baseline analysis of climate-streamflow relationships. I will compare model predictions to this baseline analysis and highlight model weaknesses. If model performance is adequate, I will then use the model to estimate streamflow behavior under a warmer climate – initially using uniform increases in temperature (based on projections for California). Ideally it would be useful to also drive the model with downscaled GCM data.
**Spatial properties of vegetation.** How well does current model predict spatial patterns of vegetation LAI throughout the watersheds? As a carbon cycling model, RHESSys can be used to predict spatial patterns of vegetation leaf, stem and root carbon stores. Evaluation of model performance will help to determine where additional data must be incorporated to come up with reasonable estimates of vegetation productivity. Ancillary data such as remote sensing derived maps of canopy cover, for example, can be useful in estimating where soil depth is sufficient to support vegetation (something that must currently be prescribed in the model). LAI data for comparison can be derived from remote sensing data. It may also be useful to compare model predictions with vegetation surveys by the KREW team.

**Spatial variability in ET.** How does the modeled relationship between climate and evapotranspiration vary spatially within study watersheds? How well does model capture seasonal and spatial variation in vegetation water use evident from sap flow sensor measurement? I will use the model calibrated using streamflow, with any improvements associated with LAI comparison above, to estimate spatial patterns of ET and their relationships with peak annual SWE and growing season temperature. Results from this analysis could be used to plan addition instrumentation associated with vegetation water use. There should also be a linkage with spatial soil moisture and sap flow.

**Nutrient export.** How well does RHESSys modeling capture streamflow nitrate export signatures, including seasonal patterns and differences between the watersheds? Can these signatures be used to better constrain model hydrologic parameters? Given that these are fairly “clean” streams this question may not be that informative but is needed as a baseline model run. There may be other tracers that can be used to as part of biogeochemical calibration? Explore this with Fengjing and Carolyn, who are working on 3 papers.

**Biogeochemical stores and fluxes.** How well does the current model predict dynamics evident in plot scale measurements of biogeochemical stores and fluxes including plot sampling of soil carbon and nitrogen stores, flux tower estimates of NEP and ET etc. Note that it is unlikely that a model that is parameterized based on fairly coarse-scale data (10-m DEM etc.) will be able to accurate estimate point scale measurements of something like soil decomposition rates or soil moisture. There are several options – if there are sufficient, and stratified, samples – then comparison between sample means and modeled data may be reasonable. Alternatively, we can use intensively monitored sites to fully parameterize the model – and test whether, given these parameters the model performs as expected. For example, do equations used to estimate decomposition rates perform well if we assign temperature, moisture and soil carbon and nitrogen stores. Any adjustments based on this detailed analysis can then be incorporated in the model and would improve larger (watershed) scale distributed estimates. Suggestions from ecologically oriented Co-PIs on how this might best be done welcome.

**Spatial patterns and aggregation of biogeochemical fluxes.** Given model estimates of spatial patterns of these biogeochemical fluxes (NPP, NEP, Nexport, nitrification/denitrification) how representative (in a spatial sense) are these plot measurements likely to be?\[5\] how reflective are they of basin scale aggregate carbon and nitrogen fluxes. How do model estimates of aggregate basin and spatial patterns of biogeochemical fluxes (nitrate export, carbon sequestration) change as assumptions about vertical and lateral hydrologic connectivity change? This final question is I think is in many ways the most interesting one from a modeling perspective and will be the place where we can use model-measurement relationships to try to say something about the role of flowpaths, macropores, upland-riparian connectivity etc. Understanding the hydrologic function of the subsurface critical zone is a key challenge –
the model provides a mechanistic way of exploring the implications of different conceptual and quantitative models of subsurface hydrology. Measured data can be used to try to suggest which of these different models is realistic.

**Funding.** Largely CZO.

**Schedule, including field work.** The first 2 tasks are for year 1.

**Manuscripts in progress & planned.** Tasks 1-2 will yield 2 manuscripts. The main data sets needed for tasks 1-2 are the streamflow and meteorological data from KREW, the GIS data and soils information.
**Topic:** Near-surface soil-water processes

**Investigator:** Jan Hopmans, UCD

**Students & research staff.** Peter Hartsough (postdoc), Armen Malazai (PhD student); possibly assisted by other graduate students and staff to support field work.

**Scope.**

**Soil moisture monitoring.** Based on experience at Wolverton, we will deploy a dense network of MPS-1 water potential sensors (Decagon) around selected trees. The denser sensor networks compliment the transects of sensors already installed around representative trees, and are intended to better assess spatial and temporal variations at the root-zone scale, and to evaluate differences in soil moisture regime between tree species, slope and elevation, and prescribed burning. This newly developed water potential sensor uses the Echo probe technology embedded in a ceramic disk, to indirectly determine soil water potential. In 2008, we started a careful laboratory calibration to assess precision and variation among sensors. We propose to install a grid of 5x5 MPS sensors at 2 depths for a total of 50 sensors around a selected tree or cluster of trees at 1-m horizontal spacing (instrumented area is about 16 m²). In addition, we propose to test and deploy clusters of EchoTE soil moisture sensors (Decagon), to complement water potential sensors with the soil moisture sensors at corresponding locations. In addition to soil moisture, sensors will measure soil temperature and soil electrical conductivity (EC), to express total ion soil solution concentration. All sensors will be connected to EM50 for data processing and wireless transmission to core Campbell dataloggers that collect other instrument cluster data in addition to the tree root measurements. Soil sensors will be coupled with tree sap flow and/or dendrometers to evaluate tree ET as related to spatially-variable root zone conditions.

**Soil water flux measurements.** We are developing new soil moisture and water flux sensors that use a heat pulse technique to infer near-surface soil moisture, from relatively simple temperature measurements. Combined, careful deployment of these sensors allows estimation of water and biogeochemical fluxes across topographic transects that span both rainfall and snowfall dominated elevations. A recent laboratory experiment demonstrates the potential of the HPP technology for water flux measurements at around 1 cm/day or lower. Deployment to be determined.

**Soil physical characterization.** For each of the selected instrumentation cluster sites, we will conduct a soil physical characterization campaign, including soil texture, organic matter content, soil bulk density, saturated hydraulic conductivity, and collection of core samples for laboratory measurement of soil water retention curves. This will be done, using replicate soil samples at various selected soil depths and for selected cluster sites.

**Root water uptake modeling.** Another significant contribution of our research involves improved simulation modeling of water- and nutrient (i.e. nitrate) uptake by tree roots, allowing for both compensated and active uptake by roots, as opposed to the conventional hydrological approach to only allow for passive nutrient uptake (strictly coupled with root water uptake). In 2008 and 2009, our laboratory will conduct controlled experiments to test the new modeling approach. No doubt, that vegetation control by uptake, in addition to soil water transport will affect the magnitude of biogeochemical fluxes through both the summer and winter season.

**Funding.** CZO, with significant leveraging from ongoing NSF Biocomplexity award 0410055-Development of multi-functional heat pulse probe for ecological and hydrological monitoring of plant root zones. Soil moisture sensors will be purchased as part of instrument cluster grant.
Schedule, including field work. The first soil moisture array will be installed in late spring 2008. We propose to move cluster of sensors between trees and locations, on an annual basis.


Further papers TBD.

Topic. Physical controls on water and carbon exchange and plant production

Investigator. Mike Goulden, UCI

Students & research staff. Anne Kelly (PhD student, UCI); Greg Winston (Specialist, UCI)

Scope.

Continuous micrometeorological measurements (Goulden, Winston). We will deploy at least one and as many as three eddy covariance towers to continuously measure the fluxes of water vapor, energy and CO₂. The first tower will be installed near the upper SE corner of the Providence 301 watershed in summer 08. Additional towers may be installed at a lower elevation, likely in a Blue Oak-Pine woodland, which receives very little snow, and at higher elevation, in a Red Fir forest at the Teakettle Experimental forest, which receives mostly snow. The measurements at the Providence site will be especially helpful for understanding the biophysical controls on land-atmosphere exchange. The measurements at a lower, rain dominated site, and an upper, snow dominated site, will be especially helpful for understanding the interactions between type and amount of precipitation, and vegetation phenology, seasonality, physiology, and production. Most of the instruments required for the towers are already available at UCI.

In collaboration with other CZO researchers, the eddy covariance ET measurements and sap flow measurements will be used to examine the above and below canopy fluxes of water, with an emphasis on the transition period from snowcover to no snowcover. Measurements of soil moisture, soil water potential, sap flow, and ET will be integrated to quantify how soil water controls ET. It is thought that shallow soil water (top 15 cm of the profile) is the primary source for bare soil evaporation. Soil water at greater depths, depending upon the root distribution of vegetation, is the source of transpiration. Soil moisture and potential vary greatly through space (horizontally and vertically), so a distributed network of probes will be used to understand the patterns of water content.

As transpiration and carbon assimilation are linked (through water use efficiency of vegetation), spatio-temporal variability of the soil water reservoir also controls carbon fluxes. We expect that cold temperatures in the winter and the availability of soil water in the late summer are the dominant direct controls on plant photosynthesis. We predict that CO₂ uptake will peak in spring and early summer, decline moderately in late summer, and remain near zero in winter. We also expect that the availability of water in the surface organic horizons is the dominant direct controller of decomposition. We predict that decomposition will peak in winter and spring and decline markedly in summer. We expect that the summer drought will have a more pronounced effect on decomposition than on plant gas exchange, and that net carbon accumulation will peak in mid to late summer. Sap flow velocity measurements, performed in conjunction with the flux tower studies, are part of the overall effort to close the water budget. Comparisons to meteorology, snowpack, soil moisture and temperature will be used to better understand the effective controls on tree growth and transpiration.

Experiments and observations to understand the relative importance of total precipitation vs the snow to precipitation ratio in controlling tree physiology and production. Anne Kelly, an incoming PhD student at UCI, is currently planning her doctoral research. Anne’s immediate plans are to spend summer 2008 surveying the vegetation along an elevation gradient at 400’ intervals using belt transects. These observations will be compared with similar measurements she made during her MS thesis in Southern California’s Santa Rosa Mountains. These
observations will familiarize Anne with the local vegetation and geography, and should help her formulate ideas for her thesis.

Anne’s longer-term interests are focused on understanding the effects of climate change on montane vegetation. One possible question Anne may choose to focus on within the CZO is the effect of total precipitation vs the snow to precipitation ratio in controlling tree physiology and production. Evidence is accumulating that the snow line is moving up in western mountains, and that the fraction of total precipitation that falls as snow is declining at some elevations. The duration of snow cover is thought to have a strong impact on the phenology, seasonality, physiology, and production of montane forest. For example, Red Fir dominates in areas that receive predominantly snowfall, presumably because snow increases summer soil moisture, which reduces stress and allows continued gas exchange. A reduction in the proportion of precipitation falling as snow with climate change should increase the midsummer stress experienced by trees, resulting in increased mortality at the lower edges of species’ ranges. Anne’s MS work indicates a similar phenomenon has already started in Southern California’s Santa Rosa Mountains (Kelly and Goulden, in press, PNAS).

Anne’s research strategy is still developing, though it may include the following: (1) Historical comparisons to determine the interannual relationships between total precipitation and the fraction of precipitation falling as snow, and tree ring width. (2) Analyses of the tower observations to determine the interannual relationships between total precipitation and the fraction of precipitation falling as snow, and the onset of summer drought stress, as indicated by canopy gas exchange. (3) Spatial observations on individual trees to determine the relationships between the duration of local snow, and the onset of summer drought stress, as indicated by sap flow, water potential, and diameter increment. (4) Snow melt manipulations, to determine the effect of accelerated snowmelt on sap flow, water potential, and diameter increment.

**Funding.** Instrument cluster grant, CZO, plus instruments from UCI.

**Schedule, including field work.**

Summer 2008 – Winston and Merced collaborators install flux tower instruments and sap flow.
Kelly survey vegetation along elevation gradient; prototype snowmelt infrastructure;
investigate possible upper and lower tower sites.

Summer 2009 and beyond – Kelly conducts PhD research. Towers may be installed at upper and lower site, probably starting at the lower site.

**Manuscripts in progress & planned.** TBD. (include data sets used/needed)
**Topic.** Surface-groundwater interactions

**Investigator.** Martha Conklin, UCM

**Students & research staff.** Ryan Lucas, grad student; Reed Maxwell, collaborator (LLNL), Scott Tyler, collaborator (UNR), Craig Clemmens, collaborator (SJSU)

**Scope.** A series of meadow experiments and measurement campaigns are planned, beginning with the already instrumented Long Meadow and extending to the smaller P301 meadow.

**Groundwater exchange in Long meadow.** The objective of this experiment is to determine variations in diel temperature change, inflow and outflow of groundwater into the stream, quantify interactions between vegetation and water, and understand the water balance in Long meadow. To do this, we will exploit temperature as a hydrologic tracer using a distributed temperature sensor (DTS) and Tidbits, plus use data from piezometers and observation wells (temperature and pressure). The experiment will consist of laying an optical cable in the stream running the length the meadow, from the meadow inlet to the stream junction with Wolverton Creek. An additional cable will be run in Wolverton Creek from the junction upstream. This DTS system provides stream temperatures with high resolution and high accuracy over the length of the stream. Once in place, the cable will be undisturbed for about 5 days. Additional supporting measurements will be point measures of temperature and continuous flow measurements. The DTS system includes a computer, two 1-km long fiber optic cables and a power source. The tidbits will be deployed by mounting them to 2.5-m bamboo stakes speared into the meadow soil. Additional tidbits may be anchored to 10-cm concrete or metal discs and placed in the bottom of standing pools of water. Stage measurements will be made with Solinst leveloggers, which are already in place. These will be related to flow by measuring a velocity profile of the stream or conducting a salt dilution tracer experiment before and after the DTS deployment. Some Tidbits may be left in the stream or standing pools after the DTS deployment to evaluate temperature changes as the stream and meadow dry out. During the deployment of the DTS and Tidbits the research team will conduct salt dilutions to assess streamflow, perform an ice slug test, and assess ET with tent experiments and with a mobile flux tower. The ice slug test will consist of placing one approximately 30 kg slug of ice at the high point of the stream and tracking its movement with the DTS system. ET will be evaluated with both ET tent measurements and with a mobile flux tower. The evapotranspiration tent experiment uses a dome structure (~4 m diameter by 2 m high) encasing two 100-watt window fans (50 cm by 50 cm) and one Licor 7500 open-path infrared gas analyzer (IRGA). The fans are set on cinder blocks and the IRGA is mounted on a tripod 50 cm above the ground surface. The ET tent system will be powered by deep cycle marine batteries. The ET tent will be deployed in up to six locations in the meadow for up to four hours at a time. The mobile flux tower will be no more than 3 m in height and be mounted on a tripod base no more than 3 m diameter. The tower will be powered by attached solar panels. The mobile flux tower will be deployed in one selected location in the meadow for the duration of the five day experiment.

**Groundwater exchange in P301 meadow.** Before an experiment is done we need to instrument it. A scoping trip to the site is planned in May 2008, with instrument deployment planned for September.

**Funding.** CZO, with leveraging from collaborators.

**Schedule, including field work.** The Long meadow experiment will begin July 5, 2008 or shortly thereafter.

**Manuscripts in progress & planned.** TBD. (include data sets used/needed)
Topic. Snowpack and snowmelt controls on nitrogen cycling in soil  
Investigator. Dale Johnson, UNR  
Students & research staff. TBD  
Scope. (updated 8/22/08) After reconsideration of project priorities/budgets, and consultation with the other investigators, the work plan has been modified from the original plan to manipulate snowpack duration to one that focused on spatial variability in nutrients on several scales and a pilot study to investigate the potential for inconspicuous, nutrient-laden runoff, as seen frequently in the eastern Sierra Nevada. The new work plan consists of four basic components: 1) analysis of soil samples taken from a gridwork across the entire watersheds; 2) a pilot study of runoff in selected locations, 3) an analysis of spatial variability in nutrient availability in the scale of meters or less, and 4) measurement of resin-based fluxes of N and P in conjunction with detailed soil moisture measurements being made by other investigators in the project.

Analyses of soils from the KREW grid. On the broadest spatial scale, funding from this project will analyze soils taken from XXX grid points on the KREW watersheds, and, along with data laboriously collected in quantitative soil pits at these grid points, convert soil nutrient contents to a kg ha$^{-1}$ basis. As of this writing, total C, total N, NH$_4^+$, and NO$_3^-$ analyses have been completed and funding for year two will allow analyses for extractable P (Bray No. 1 and bicarbonate), sulfate, exchangeable calcium, magnesium and sodium (1 M ammonium acetate extracts). This data will not only allow us to place results of the more intensive studies described below into context for the CZO project, but also allow USFS researchers to place the results of several years of nutrient flux data collected with resin lysimeters (Susfalk and Johnson, 2002).

Runoff and meter-scale measurements of spatial variability in nutrients. Forests in the KREW watersheds are similar in many ways to those in the eastern Sierra Nevada (see text box for background), including hydrophobicity of mineral soils in summer and lack of rooting in O horizons in many forests. Thus, we hypothesize that:

1. Runoff through the O horizons over the mineral soil will occur in KREW watersheds, as it does in eastern Sierran ecosystems;
2. Runoff will have high concentrations of inorganic N and P, as in the eastern Sierran ecosystems; and
3. Infiltration of nutrient-rich runoff into preferential flowpaths will create hot spots of nutrient availability in O horizons and mineral soils.

In order to test these hypotheses, we are conducting a pilot study which includes runoff collections (Figure 1) and a resin-based study of small-scale spatial variability in O horizon and soil nutrient levels at two sites in the KREW/CZO system: 1) the upper meteorological station and 2) Prenart lysimeter site P301. These sites were chosen because 1) they have now or soon will have a substantial amount of ancillary data to compare these results with and 2), of equal importance, they will be accessed frequently during the snowmelt season where frequent sampling of runoff collectors will be necessary. This pilot study includes three runoff collectors at each site and one 6 x 6 m plot within which resin-based nutrient sampling to investigate the possibility of hot spots will be conducted. Twenty-eight grid points in the latter plots have been instrumented with Plant Root Simulator (PRS™) anion- and cation exchange membrane probes (Western Ag Innovations, Inc) and Unibest mixed bed resin capsules, both places within the O horizon. The gridpoints include 16 on a 2 x 2 m interval and 12 additional grid points in the...
Background on spatial variability in nutrients

The measurements of runoff and (sub)meter-scale variability in nutrient availability are closely conceptually linked and therefore are described together. By way of background, Schimel and Bennett (2004) built upon the hot-spot and hot-moment concept described by McClain et al (2003) and others and posed a new paradigm for plant-microbial competition where trees can effectively compete with soil microbes by invading N-rich microsites (hot spots) that exist at least temporarily (hot moments) even in relatively N-limited conditions. Roots, with their elongated structure and exploratory habit can presumably tap into these hot spots and hot moments, and thereby might effectively mine the soil for N over time.

We believe that hot spots and hot moments are characteristic of nutrient cycling in Sierran ecosystems for the reasons described below. However, we also believe that the new paradigm posed by Schimel and Bennett (2004) for plant-microbial competition is moot for the many Sierran forest ecosystems. Because of the extreme summer drought, rooting is often entirely absent in the forest floors Sierran forests; thus, decomposition and vegetation uptake processes are spatially discoupled, and the intense competition for N between roots and decomposers which characterizes the more humid forest soils is absent. Because of this vertical discoupling, nutrients released during decomposition in O horizons are not immediately taken up and can be solubilized by rain or snowmelt to create solutions with very high inorganic N and P concentrations. Miller et al. (2005, 2006) have installed runoff collectors at the O horizon – mineral soil interface at many sites throughout the eastern Sierra Nevada and found that, contrary to common textbook knowledge that runoff in forest ecosystems is minimal, runoff over the mineral soil and through the root-free O horizon and over the top of the mineral soil is very common, not only during snowmelt when soils may be saturated but also during summer storms when mineral soils are extremely hydrophobic. Not only is runoff routinely collected, but concentrations of ionic N and P in these solutions are often extraordinarily high, including \( \text{NH}_4^+ \) (concentrations as high as 87 mg N L\(^{-1}\)) and ortho-P, (concentrations as high as 13 mg P L\(^{-1}\)), ions that are strongly adsorbed to mineral soils and are therefore found in very low concentrations in soil solution only a few cm deeper into mineral soil. We believe that these high concentrations of ionic N and P are a result of mineralization of N and P in the O horizons, and because rooting is absent in the O horizons mineralized N and P is not taken up as it would be in more mesic ecosystems. We also believe that fire exclusion over much of the 20th century in these systems has resulted in litter buildup that has provided an increasing source of nutrients in this runoff, perhaps contributing to the well-documented deterioration of water quality in nearby Lake Tahoe (Goldman, 1981; Miller et al., 2005, 2006). We are not as yet able to precisely quantify the area from which this interflow runoff is generated nor can we pinpoint where it infiltrates. We hypothesize that this interflow could be a major factor in the creation of hot spots if it enters into the mineral soil via preferential flow paths (Burcar et al., 1994a), or alternatively could be a significant source of mineral N to streams, perhaps contributing to the peaks in mineral N concentrations that are sometimes seen during cycles of snowmelt runoff (e.g., Johnson et al., 1998).
collected at snowmelt, at which time we will collect them, remeasure O horizon depth, and collect soil samples at 0-5, 5-10, and 10-15 cm beneath each grid point. Soil samples will be analyzed for water content (gravimetric), C, N, NH4, NO3, and extractable P (Bray No. 1 and bicarbonate).

Measurement of resin lysimeter fluxes in conjunction with detailed soil moisture measurements. The KREW project as well as many others in the eastern Sierra Nevada mountains (Murphy, et al., 2006 a and b) and elsewhere (Johnson et al., 2003; Kjonnas 200x) use resin-based lysimeters as cheap and low-maintenance method of measuring nutrient leaching fluxes. The resin-based methods rely on the ability of resins to capture nutrients that can later be extracted, and, with measurements of the lysimeter collection area, converted to a kg ha⁻¹ flux. While resin-based flux measurements are cheap and convenient, they provide no information as to the relative contributions of water flux and nutrient concentrations in soil solution to the total fluxes measured. Thus, we have installed resin lysimeters of the design described by Susfalk and Johnson (2002) near the “tree” were very detailed measurements of soil moisture are being made as well. Specifically, we have installed resin lysimeters at the outer perimeter of 10 of the 12 “spokes” of the wheel of sensors installed around the “tree”. After consultation with the students and technicians at the site, we concluded that the resin lysimeters could not be installed within the spokes of the wheel because of the level of disturbance involved (a footprint of about 20-25 cm diameter needed to install the lysimeters, and thus we installed them at the perimeter of the wheel. These lysimeters will be removed and extracted after snowmelt to see of the fluxes correspond to any indicators of soil moisture status made in the nearby collectors.

Funding. CZO

Table 1. Schedule of Activities

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<thead>
<tr>
<th>Activity</th>
<th>2008-9</th>
<th>2009-10</th>
<th>2010-11</th>
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<tbody>
<tr>
<td></td>
<td>Sum</td>
<td>Fall</td>
<td>Win</td>
</tr>
<tr>
<td>Analyze KREW soils for C, N, NH4, and NO3</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyze KREW soils for other nutrients</td>
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<tr>
<td>Establish and instrument plots</td>
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<tr>
<td>Collect data</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Analyze data</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Preliminary analysis and reports</td>
<td>X</td>
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<td></td>
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<tr>
<td>Re-evaluate and modify designs and re-install equipment for subsequent years</td>
<td>X</td>
<td></td>
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<tr>
<td>Final report and publication</td>
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Schedule, including field work.
We have started this research in the August of 2008. After a winter season of data collection, we will evaluate protocols and designs, modify as needed, and re-install equipment during the following summer seasons. The intent is to not only capture data worthy of publication in its own right, but also to continue to refine and develop sampling techniques most suitable for nutrient work in snow-dominated Sierran ecosystems.

Manuscripts in progress & planned: TBD (include data sets used/needed)

Literature Cited
Johnson, D.W., P. J. Hanson, D.E. Todd, Jr. 2002. The effects of throughfall manipulation on soil leaching in a deciduous forest. J. Environ. Qual. 31: 204-216
**Topic.** Nitrogen fluxes from soil

**Investigator.** Ben Houlton, UCD

**Students & research staff.** TBD

**Scope.** We will use natural N isotopic variations in dissolved inputs, soils and stream waters to examine the dominant vectors of N inputs and losses from the forested watersheds. Since microbial denitrification strongly fractionates N stable isotopes, the $^{15}\text{N}/^{14}\text{N}$ ratio of streamwater N is elevated relative to N inputs when this process is important. We will also use measures of O isotopes in nitrate to further examine gaseous N production in soils and streams. For example, our previous work indicates that denitrification elevates both the $^{18}\text{O}/^{16}\text{O}$ and $^{15}\text{N}/^{14}\text{N}$ of nitrate, imparting a slope ~0.6 on these isotope systems. In combination, these isotopic measurements will be used to inversely model N gas fluxes across snow vs. rainfall dominated forests.

For sampling, we will sample streams across seasons and conditions to examine for temporal dynamics of N isotopes in losses. We will monitor the $^{15}\text{N}/^{14}\text{N}$ and $^{18}\text{O}/^{16}\text{O}$ of N deposition inputs based on collectors established at various locations within the watersheds. Finally, we will measure the isotopic composition of N in plant leaves and soils, and combine these measures with out input-output analyses and models to construct budgets of the N cycle.

**Biological isotopic fractionation.** A key issue in using natural isotopes of N to quantify terrestrial N cycle processes involves the isotopic effect of N gaseous losses, particularly via denitrification. We will use soil cores incubated in the field under anaerobic conditions to determine the isotopic effect of denitrification across the watersheds. Our past work has demonstrated that the isotopic effect of this process can vary between 20 per mil to 10 per mil.

**Nitrogen isotopic modeling.** Combining the isotopic information collected across the various scales of sampling, we will use N budget models such as DAYCENT and DNDC, and integrate N data to integrate with RHESSys to further constrain the flux of N inputs and losses from the watersheds. Funding is largely CZO, through Hopmans, with leveraging from UCD.

**Schedule, including field work.** We will begin collecting preliminary samples in the fall of 2008. Sampling will then intensify over the next two years, shaped by our preliminary findings.

**Manuscripts in progress & planned:** TBD (include data sets used/needed)
**Topic.** Baseline hydrologic, sediment and geochemical characterization

**Investigator.** Carolyn Hunsaker, PSW

**Students & research staff.** Tom Whitaker, Fengjing Liu, others TBD

**Scope.** Although this work is part of PSW’s original KREW project, doing it is essential to progress on CZO research and one or more of the CZO investigators will assist as needed.

**Hydrologic characteristics.** Elevational transition of mixed rain/snow to snow, seasonal transitions, snowmelt to baseflow, time lags in the system, seasonal responses to precipitation.

**Sediment.** Analysis of sediment data from sediment ponds, turbidity, sediment fences, headcuts and bank pins. Also modeling.

**Geochemical characteristics.** Annual cycle of geochemistry, sources of streamflow across catchments, flow paths result in chemical differences, seasonality of streamflow sources. Can mixing models help us determine if KREW is over sampling (frequency), identifying important nutrients to sample for?

**Funding.** Leveraged, PSW.

**Schedule, including field work.** Ongoing. Goal is to complete as much related to papers 1-6 during 2008 as possible. Field measurements will continue.

**Manuscripts in progress & planned.**

1. **Hydrologic response of rain-snow transition and timing of snowmelt and streamflow.** Whitaker and Hunsaker (Bales assist). Uses daily/hourly discharge data, temperature data from met stations, precipitation data.

2. **Sediment basin, turbidity & suspended sediment.** Hunsaker and Whitaker. Annual measurements from sediment basins and continuous turbidity data.


5. **Sources of stream water across rain-snow transition – streamflow generation.** Liu and Hunsaker. Use EMMA, diagnostic tools of mixing models, ion data. Need sampling of wells first.

6. **Nutrient response to streamflow sources; nutrients as reflection on biological activity.** Hunsaker and Liu.
Topic. Water, geochemical cycles, and upscaling of in-situ measurements

Investigator. Roger Bales, UCM

Students & research staff. Peter Kirchner, PhD student

Scope. In cooperation with KREW researchers, we will estimate components of the water and geochemical cycles in the Providence catchments, as noted above. Parallel observations will take place at the Wolverton watershed of Sequoia National Park for cross comparison between the rain snow-transition and snow-dominated ecosystems.

Patterns of snowcover and soil moisture. It is our hypothesis that spatial variations in tree canopy cover are as important as slope and aspect for variability in snowcover and soil moisture. An implied hypothesis is also that soil moisture patterns will be influenced by patterns of snowcover accumulation and depletion in a predictable manner (the Hydrus 1D model will be used to aid in interpretation of soil moisture data). Soil moisture measurements will also help to discriminate snow versus rain. Our spatially dense measurements of snow depth and soil moisture are placed to capture the variability in physiographic features and vegetation across the catchments as part of our core measurement program. Radiation will be quantified by using a combination of insitu sensors and a portable canopy imager such as the CI-110 by CID, Inc. We will also place tidbit temperature loggers on grid and ordinal patterns in key locations to provide a mesoscale record of snowmelt. It is also thought that soil moisture and ET respond systematically to differences in water inputs and energy balance along gradients of elevation and aspect. That is, distributed system responses to seasonal transitions, changes in soils and vegetation, and longer-term climate changes are predictable based on physiographic features and soils/vegetation characteristics. However, within those gradients, heterogeneity caused by differences in bedrock and vegetation not captured by modeling will limit that predictability.

Upscaling of forest snowcover and soil moisture distribution. Scaling depends to some extent on how well distributed measurements capture the inherent variability across a catchment. The high frequency and spatially dense core measurements will provide the basic data for this. Synoptic measurements conducted at mesoscales will provide the ability to bridge these high-frequency data to larger scales. Synoptic surveys of snow soils, and bedrock using non-invasive geophysical methods, will be used, to characterize the snow covered area and the vadose zone on a broader spatial scale. These findings will provide a basis for linking our high frequency temporal measurements with high spatial resolution satellite images.

Evapotranspiration. In addition to flux tower and sap flow measurements, we will examine ET by analysis of diel variations in streamflow across seasons following the approach outlined previously by J. Kirchner. In addition to data analysis, we will use the RHESSys watershed model to integrate data, investigate partitioning between ET and streamflow, and predict watershed behavior, as noted above.

Geochemical processes. It is our hypothesis that the distribution of soil moisture throughout the catchments controls the extent of coupling among the carbon and nitrogen cycles, as well as the weathering and mobility of ions. Because soils beneath the snowpack normally remain moist and unfrozen, snow-dominated sites will have higher rates of litter decomposition, nutrient cycling and solute production compared to rain-dominated sites, where soil drying limits decomposition and weathering rates and thence coupling (this is not explicitly planned to be part of P. Kirchner’s dissertation).

Funding. Largely CZO.
Schedule, including field work Ongoing. Core instrumentation in the Wolverton watershed was completed in 2007. Mesoscale surveys of snow distribution, and soil moisture were conducted in 2007 and 2008 and will continue through 2009. Real-time communication links with data loggers are planned for late 2008.

Manuscripts in progress & planned.

1. **Hydrologic response of snowmelt, streamflow, and evapotranspiration in a snow dominated forested catchment.** Kirchner, Bales. Uses CZO core measurement data from the Wolverton watershed: discharge, meteorologic parameters, snow depth, precipitation, soil moisture, and sap flow. Water chemistry data collected 2006-present will also be used.

2. **Snow accumulation and melt distribution in forest ecosystems.** Kirchner, Bales. Uses CZO core measurement data from the Providence and Wolverton watersheds: radiation, snow depth, precipitation, and soil moisture, coupled with synoptic surveys of depth and snow water equivalent and long-term data collected at the snow courses and pillows.

3. **Mesoscale representation of snow and soil moisture in forested ecosystems.** Kirchner, Bales. Uses same datasets as above in addition to repeated geophysical surveys conducted at target locations throughout the Wolverton watershed. If LIDAR or hyperspectral imagery of the study areas becomes available prior to publication they will be used also.
**Topic. Physical weathering rates**

**Investigator. Jim Kirchner, ETH & UCB**

**Students & research staff.** TBD (possibly Cliff Riebe at UWyo for cosmogenic isotope survey)

**Scope.** As a reference point for annual and short-term measurements, we will calculate long-term (5,000-30,000 year) sediment and solute fluxes for the study catchments using cosmogenic nuclide methods. We will assess the quantitative importance of rare extreme events by comparing the long-term averages (measured by the cosmogenic nuclide methods) with the distributions of flux measurements on annual and shorter time scales. We will assess the importance of fire and post-fire responses by comparing flux measurements in the thinned versus control and the burned versus unburned catchments. The long-term measurements based on cosmogenic nuclides will used to test for site-to-site differences in "background" rates of erosion and weathering between the burned and unburned catchments, and thus will be vital for quantifying the effects of burning. Funding is CZO with leveraging from ETH possible.

**Schedule, including field work.** TBD

**Manuscripts in progress & planned.** TBD. (include data sets used/needed)
**Topic.** Snow processes

**Investigator.** Noah Molotch, UCLA

**Students & research staff.** Keith Musselman, PhD student

**Scope.**

*Wolverton basin snow distribution.* Snow surveys and mapping.

*Providence Creek studies.* TBD

**Funding.** Largely leveraged

**Schedule, including field work.** Wolverton Creek in progress. Providence Creek TBD.

**Manuscripts in progress & planned.** TBD (include data sets used/needed)
**Topic.** Cross-CZO comparison of C cycling

**Investigator.** Beth Boyer, PSU

**Students & research staff.**

**Scope.** TBD. Funding mainly leveraged from other sources.

**Schedule, including field work.** TBD

**Manuscripts in progress & planned.** (include data sets used/needed)
**Topic.** Biogeochemical processes/cycling

**Investigator.** Discussions with additional investigators in progress

**Students & research staff.** TBD (graduate fellowship available at UC Merced)

**Scope.** TBD.

**Schedule, including field work.** TBD

**Manuscripts in progress & planned.** (include data sets used/needed)