Southern Sierra CZO
What’s new? What’s critical? What’s exciting?

Cross-CZO site visit, April 1, 2014
SSCZO conceptual model

Feedbacks across time scales: regolith-atmosphere coupling along elevation transect

- Glacial
  - Subalpine forest 2700 m

- Millennial
  - Mixed conifer forest 2000 m

- Century
  - Pine/oak forest 1100 m

- Decadal
  - Oak savannah 400 m

- Annual

Feedbacks across spatial scales

- Pore to plot
- Hillslope to catchment
- Basin to regional

3000 m elevation gradient
Interactions between the regolith, plants, and the water cycle

Water storage in saprolite is critical for ET and baseflow for 5 or more months each year. Weathering and plant access to deeper water are critical for sustaining high rates of ecosystem production and largely avoiding summer water stress (over one-third of annual ET).

Observed heterogeneity in transpiration and summer moisture stress between individual trees appears linked to differences in local depth to bedrock and access to deep water.

ET and productivity peak at mid elevation (year round ET) and were reduced at low elevation due to summer moisture stress and at high elevation due to cold stress, consistent with the inverse drought and energy limitation model.
Southern Sierra CZO: “Happy” trees tap deep water

Observations from 4 eddy flux towers

Mid-elevation mixed-conifer forests show neither summer nor winter shutdown:
- deep rooting & resiliency to moisture stress
- warmer canopy-level temperatures despite snow on the ground in winter

Different behavior vs. Boulder & Jemez

Goulden et al., 2012
Interactions between the regolith, biota, and biogeochemistry

Organic C preferentially eroded vs. mineral matter. Lighter precip events mobilize OC from topsoil, vs heavier event for mineral matter from stream banks.

Transfer of intact soil cores to a lower elevation (to simulate a 1.4°C warming) increased microbial activity & thus soil CO₂ efflux by 20-30%, CH₄ consumption by 25-50%, and N₂O efflux by 50-300% over two years.

However, earlier snowmelt (independent of warming) constrained the increase in microbial activity, – reduced soil-water availability during summer growing season
The structure and formation of regolith

Geophysical surveys show evidence of weathering 10-30 m below the surface. Together with CRN erosion rates, this indicates regolith residence times of $10^5$-$10^6$ years.

Cosmogenic nuclides and terrain analysis of the stepped topography of the SSCZO domain show that steps are soil mantled as often as are the treads, and that erosion rates of treads are lower than erosion on steps. This contradicts a classical hypothesis for formation of the stepped topography and calls for a new model of landscape evolution in the region.

Geochemical measurements indicate that the presence of soil is regulated by bedrock nutrient content through its influence on vegetation. Concentrations of phosphorus vary markedly in bedrock, and vegetative density is strongly correlated with bedrock P across climatically and topographically diverse sites.
Vegetation patterns reflect differences in bedrock geochemistry – large concentration differences between plutons
Canopy density is correlated with bedrock P across a suite of mid-elevation sites.

Hypothesis: Bedrock phosphorus provokes a weathering limitation on erosion and thus on landscape evolution through its influence on vegetation.
**Designing the SSCZO**

Development of wireless sensor networks allowed making dense meteorological and hydrologic observations over larger areas. Structured design and strategic sampling facilitated both scaling and robust operation in a remote setting.

We balanced water fluxes at multiple scales. Measurements of precipitation, streamflow, soil moisture and ET within headwater catchments are in good agreement; as are estimates of precipitation, ET and streamflow for the entire upper Kings River basin.

Our design is being replicated at other locations, and is providing a foundation for scaling instrument clusters to the large-basin scale.
Node construction at Alpha site
LiDAR-derived snow depth, Kaweah R. basin

Kirchner et al., in prep.

WY 2010

Elevation, m
Comparison of SWE measured by LiDAR with indirect estimates of SWE & precipitation, Kaweah R. basin

WY 2010

Future: data from distributed, wireless sensor networks, blended with remote sensing data

Calibrated T-index
Energy balance

Kirchner et al., submitted
Broader impacts – education and outreach

SSCZO has active programs of:
- pre-college outreach, including site visits
- undergraduate and graduate research
- presentations at scientific meetings

We are also informing and changing the debate over longer-term drought solutions in California, especially around strategies for:
- forest management and verification of water benefits
- a modern water-supply measurement and accounting system to reduce uncertainties in forecasting and decisionmaking
Some recurring questions around water & forests

1. How will the post-fire water yield differ from before?

2. What will be the water yield w/ climate warming, vs. today?

3. What was the historical water yield prior to fire suppression?

Photos are Rim Fire area

Photos: J. Power & D. Buckley, USFS
Some background questions

1. How different were forests prior to fire suppression vs. today, pre-fire and post-fire?

2. Can we take forests back to pre-fire-suppression conditions?

Upper Yosemite Valley from Columbia Point, 4800′
Thinned unit w/ control in background
Impact of thinning on evapotranspiration & streamflow

P303 headwater catchment, Southern Sierra CZO/KREW, Sierra NF
Rain-snow transition, 2000 m elev
Results based on very-detailed pre-treatment data & hydrologic modeling
5-yr average, 2004-2008
What is the slope of this line in different forests???

Saksa et al., in prep
Individual CZOs have contributed to understanding of the influences of disturbances & of changes in climate on fluxes & stores in critical ecosystems, & to a better predictive ability.

Rich data sets & improved models from the CZOs together provide a better understanding of the bi-directional feedbacks between vegetation structure, regolith properties & climate.
Southern Sierra CZO climate transect

MODIS image

Merced

SSCZO

Subalpine forest

Mixed conifer forest

Pine/oak forest

Oak savannah

4 instrumented sites along steep climate gradient: 12°C, 60 km
CZO average annual precipitation & temperature

![Graph showing precipitation vs. temperature for various locations including Sierra, Boulder, Jemez, Catalina, Reynolds, Shale Hills, Luquillo, and Eel.](image)
Together, the CZO network is can show

- the role of climate versus disturbance on rain, snowfall & snowmelt reaching the ground surface

- the influences of climate, disturbance & regolith properties on partitioning of infiltrated water into evapotranspiration versus streamflow

CZO network results & potential

CZOs enable multi-disciplinary & multi-process integration