Observations from drought in the Sierra Nevada: evapotranspiration, climate & regolith weathering

Roger Bales

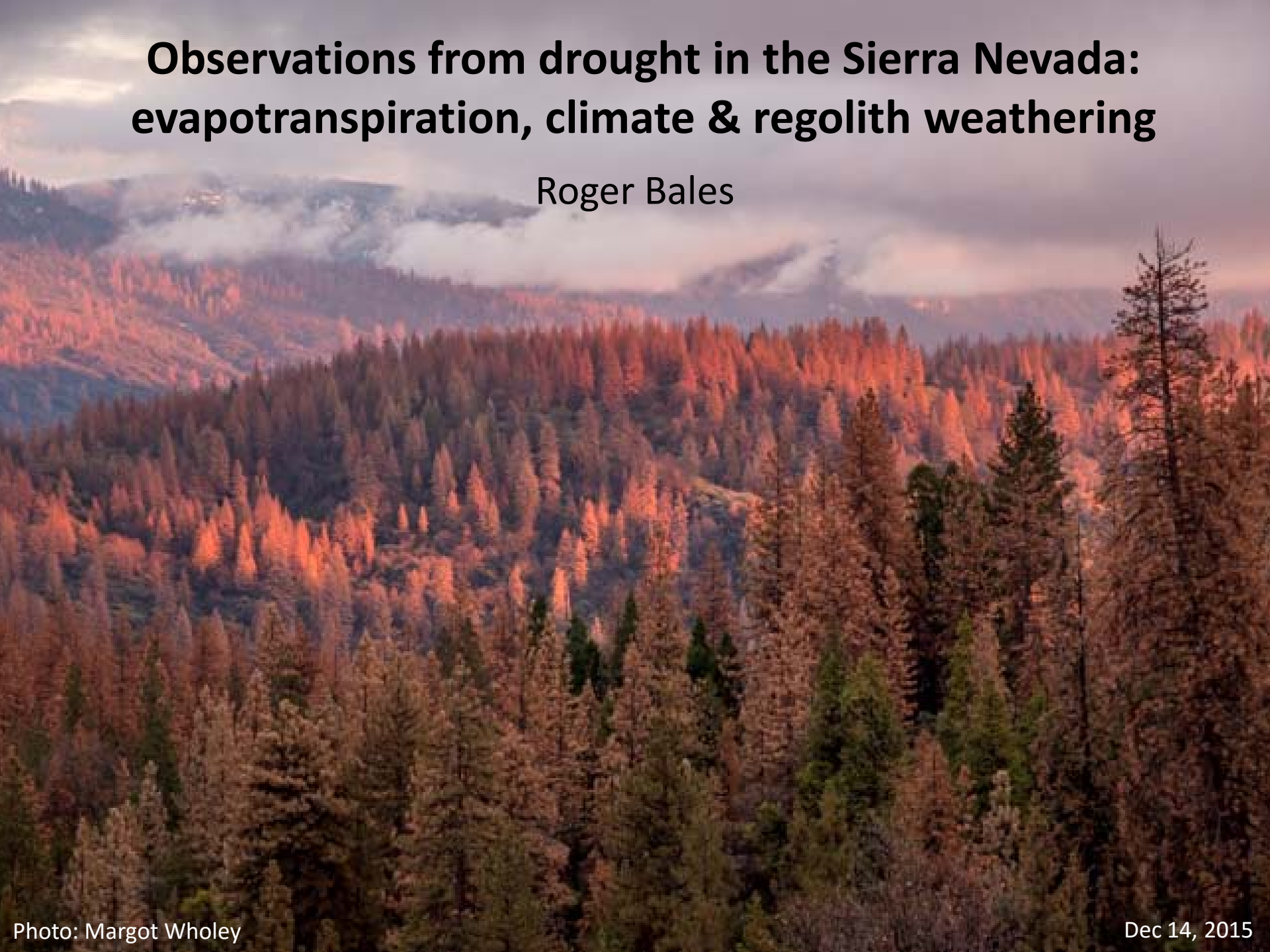


Photo: Margot Wholey

Dec 14, 2015

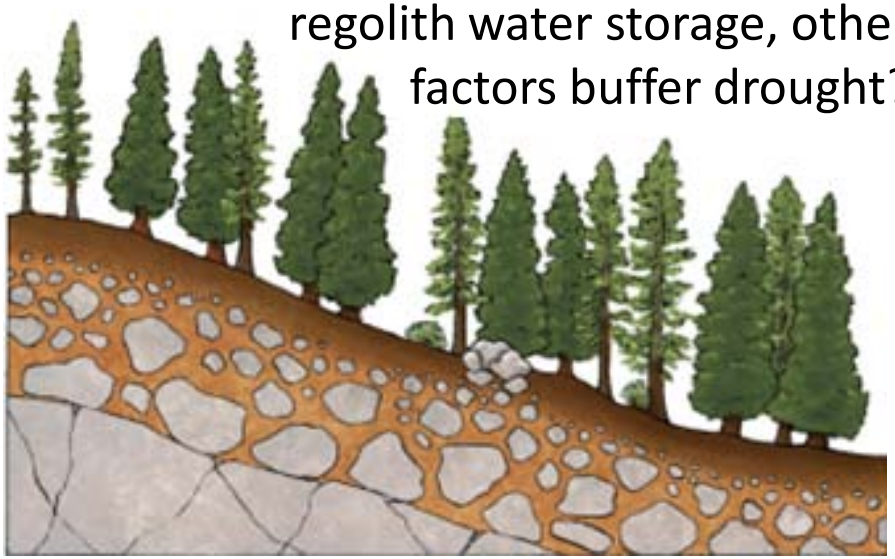
Questions motivating research

Response of southern Sierra water cycle to drought?

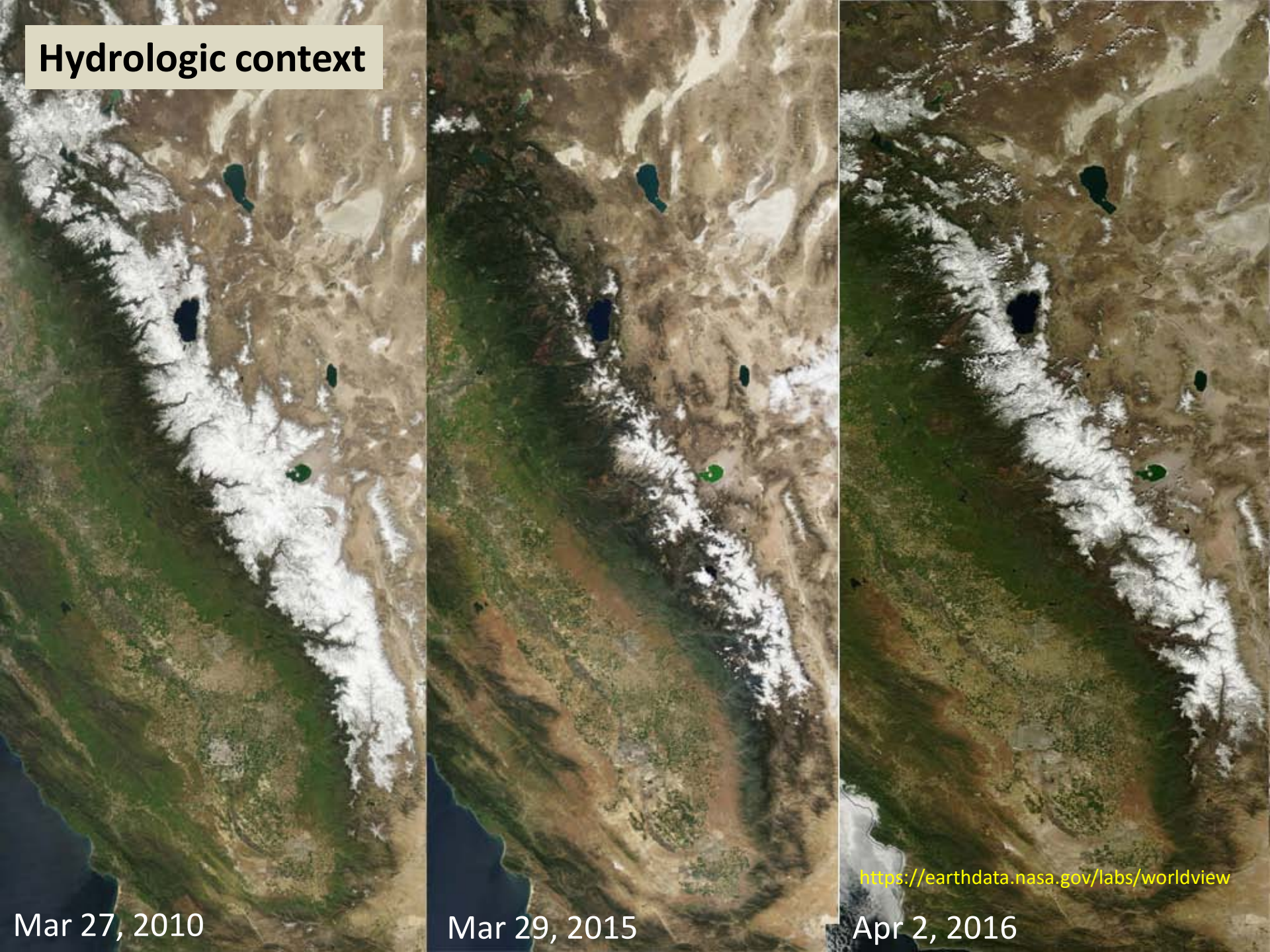
Is the ongoing mortality a new pattern, or a natural cycle?

How does forest vegetation cope with extended dry periods?

How do forest density, regolith water storage, other factors buffer drought?

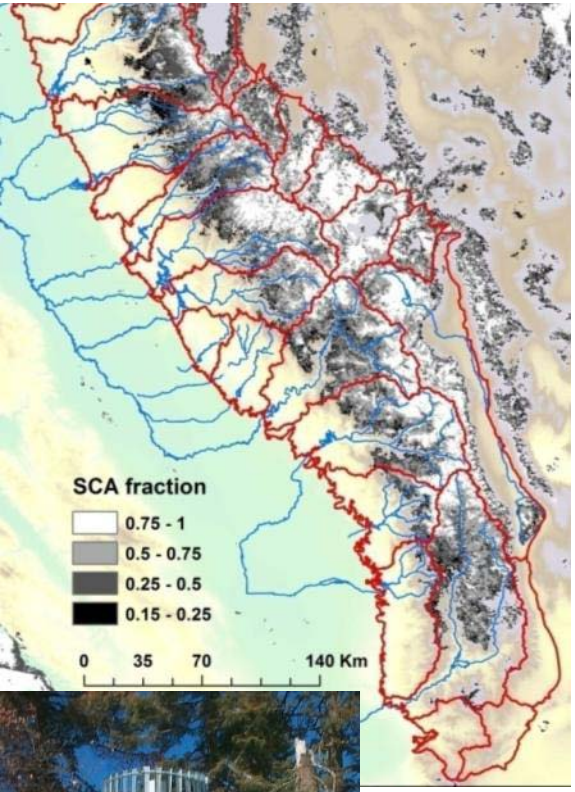


Hydrologic context



Basic water balance

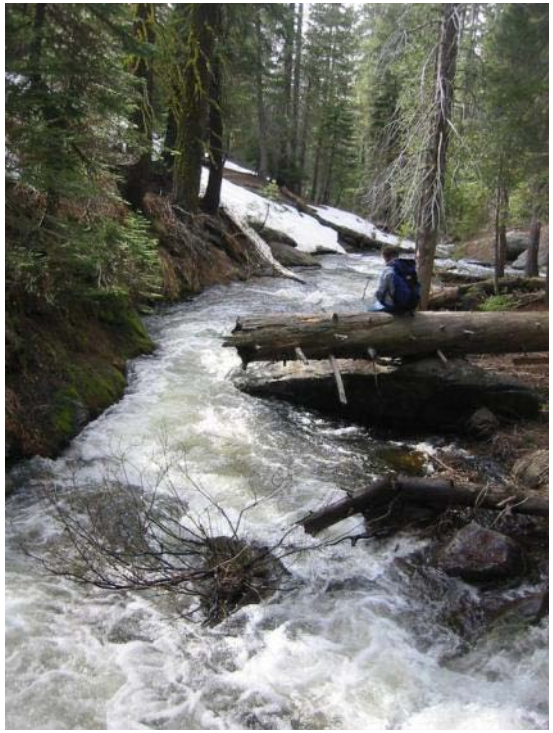
Precipitation = Evapotranspiration + Runoff + ΔStorage



snow
& rain

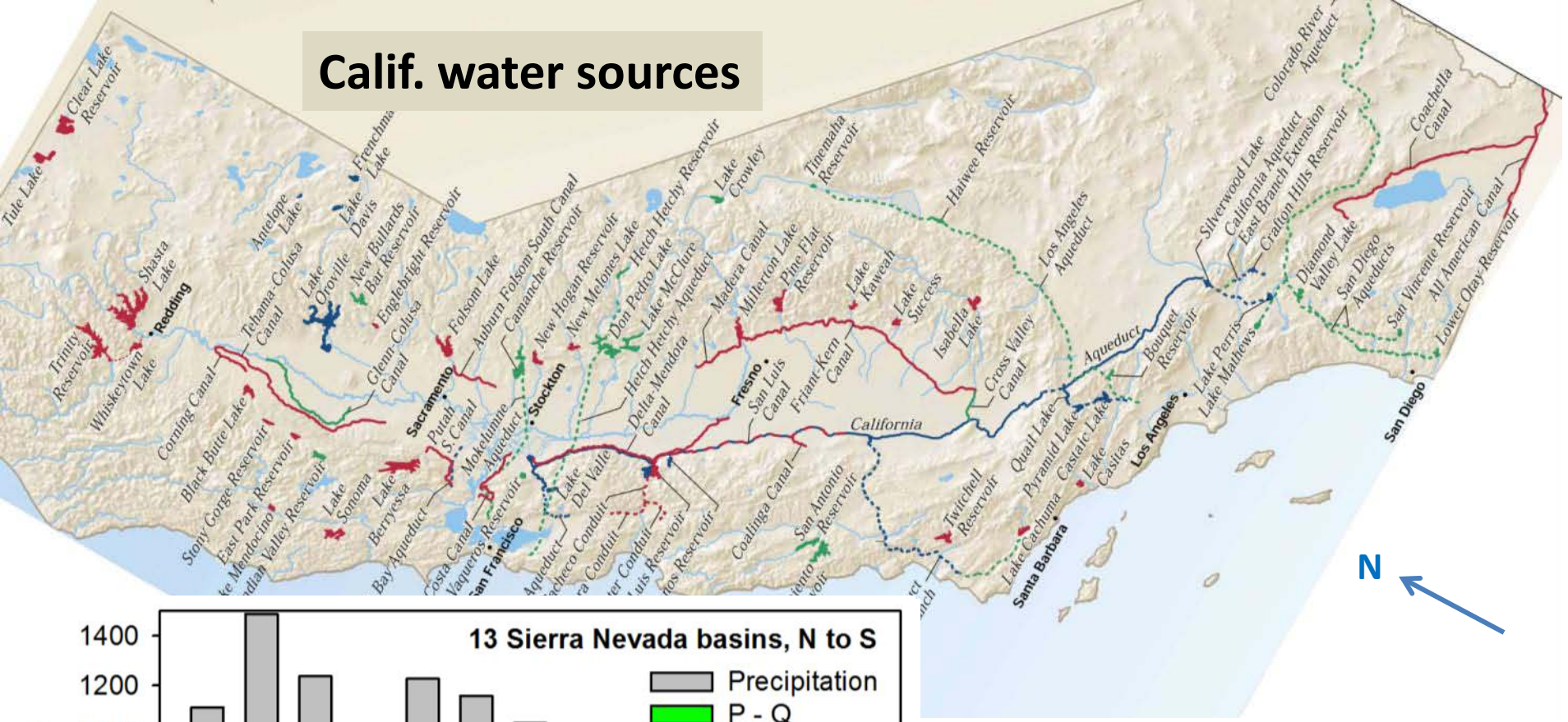
=

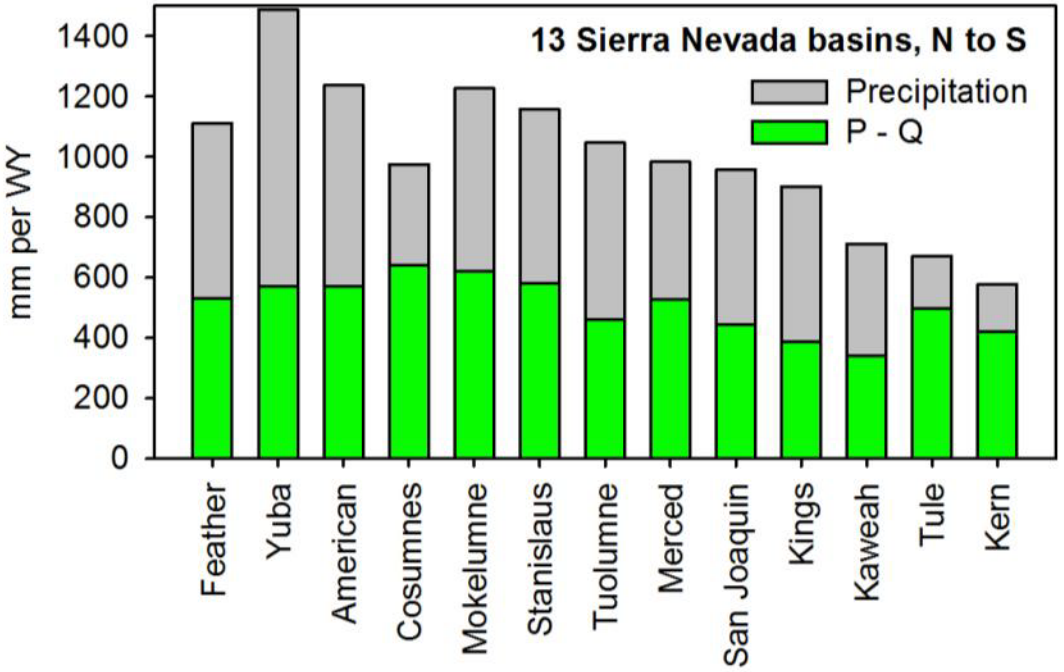
+



<u>Evapotranspiration</u> refers to evaporation, sublimation plus water use by vegetation

Calif. water sources





More precipitation & runoff north of Delta

More water use south of Delta

CA Water Plan, 2013

Applied water use

Precip: 200 MAF
Applied: 80 MAF

31% Wild & Scenic Rivers

2% Managed Wetlands

9% Instream Flows

49% Aquatic Environment

7% Required Delta Outflow

41% Irrigated Agriculture

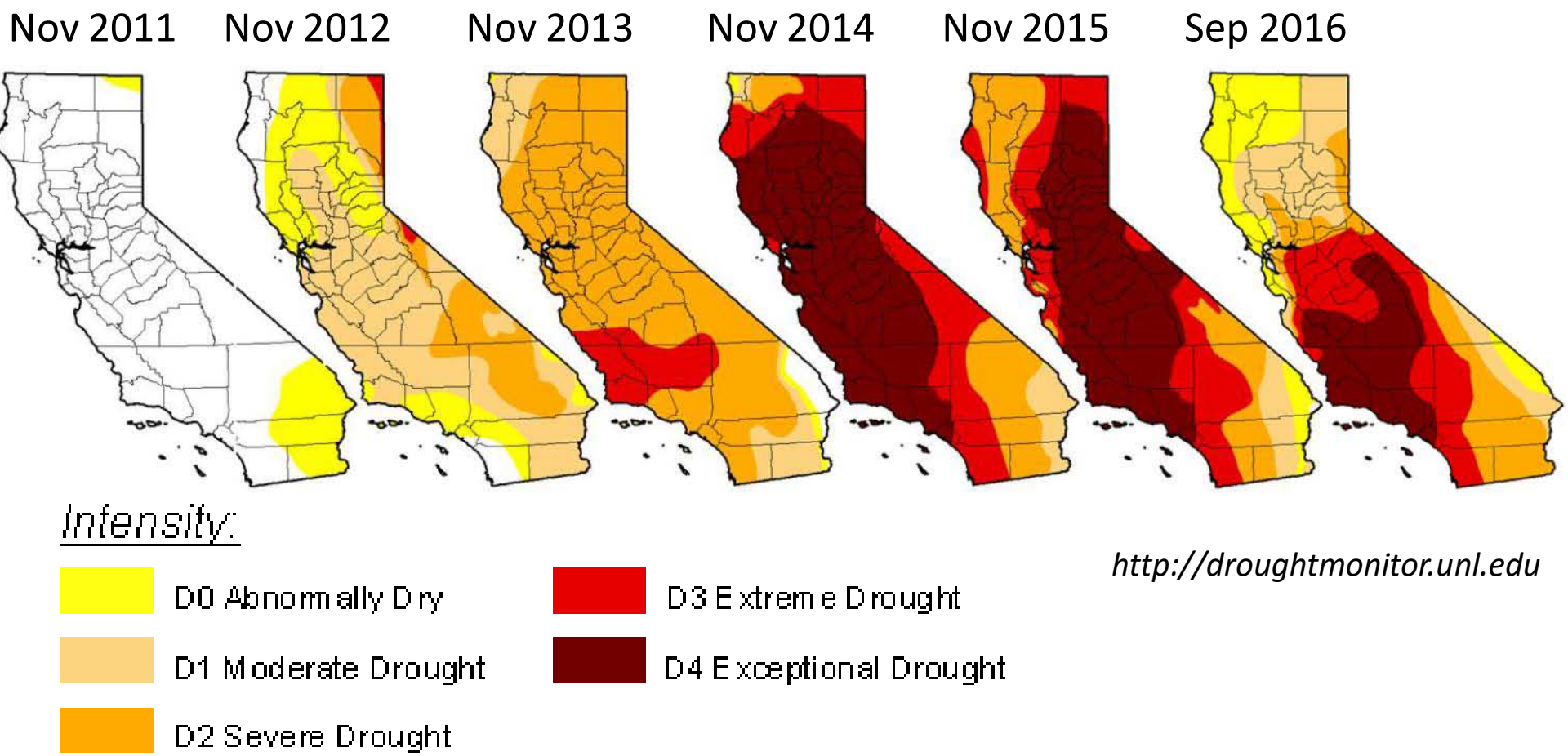
This water produces food for consumption in urban areas while also providing terrestrial and aquatic habitat for a multitude of species.

10% Urban

Water supplies:
Agriculture: 80% (33 MAF)
Urban 20% (8 MAF)

Data from DWR, adapted from Nor. Cal. Water Assn.

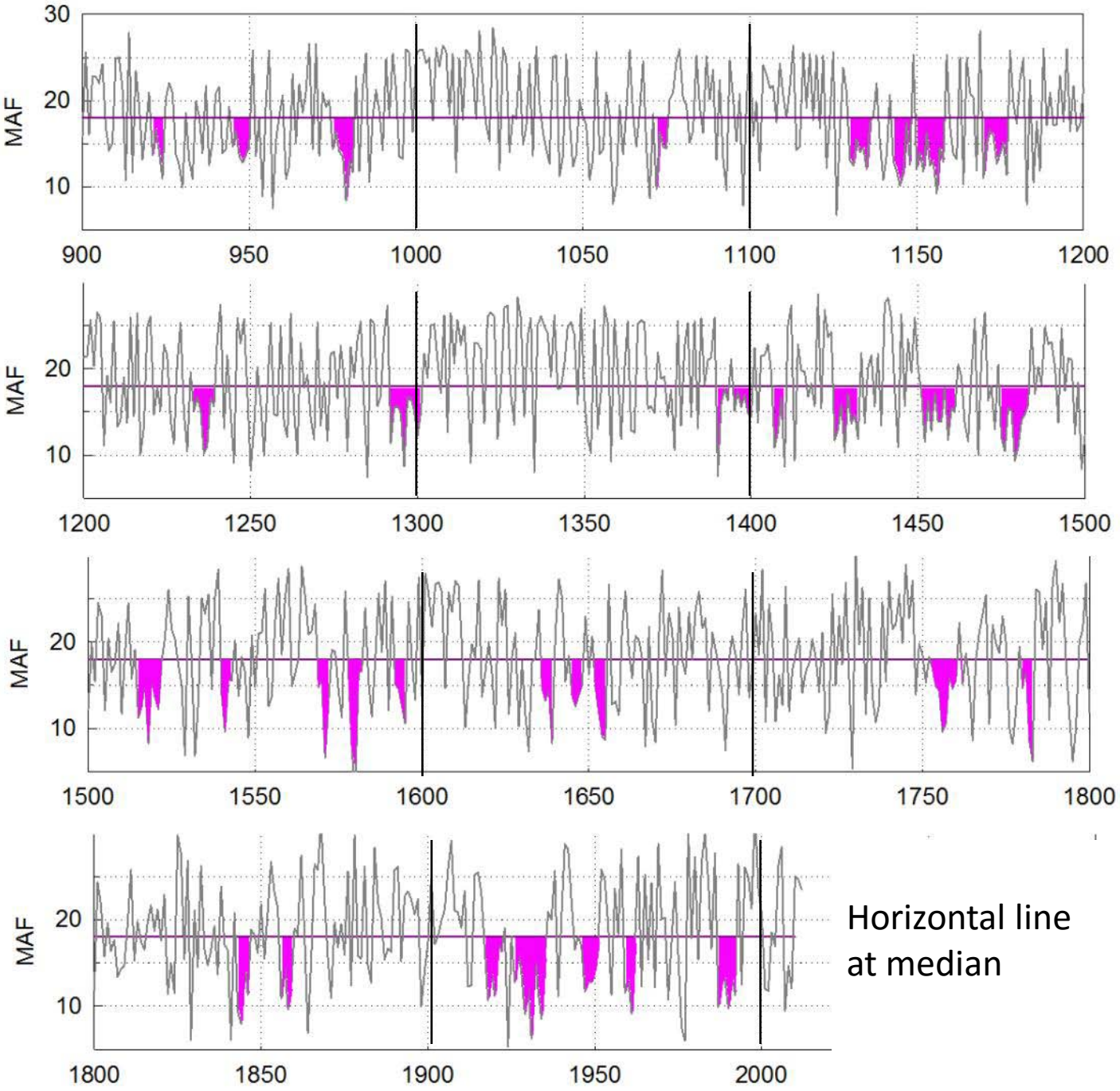
Development of the drought



Drought originates from a deficiency of precipitation over an extended period of time – usually a season or more – resulting in a water shortage for some activity, group, or environmental sector

1100 yr drought record

Reconstructed flows of Sacramento R.
Color shading marks below-median periods ≥4 yr
1-5 per century



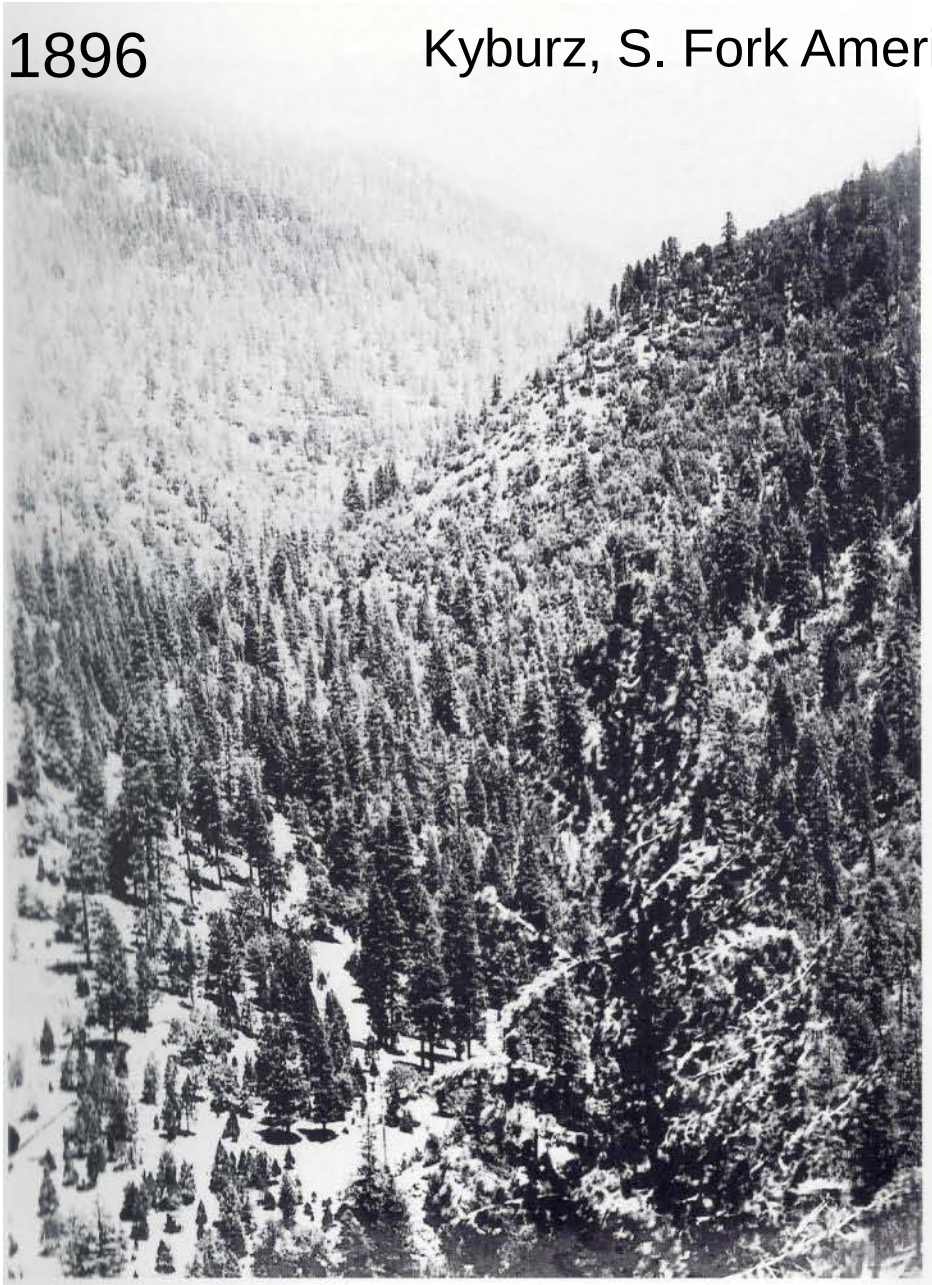
Horizontal line at median

Meko et al. 2014 report


The current experiment:
2011-2015 drought
Photo: Margot Wholey
Dec 14, 2015

Context: century-long experiment: suppressing fire

1896 Kyburz, S. Fork American R., 5000’ 1993



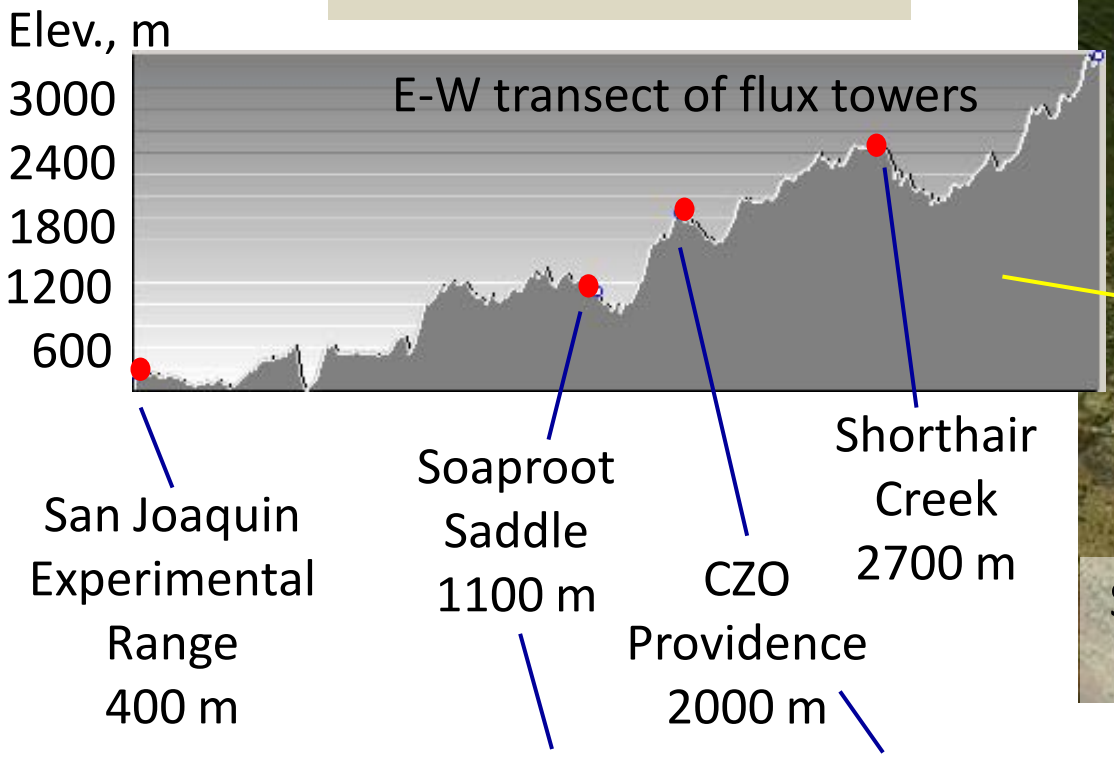
Photos from G. Gruell

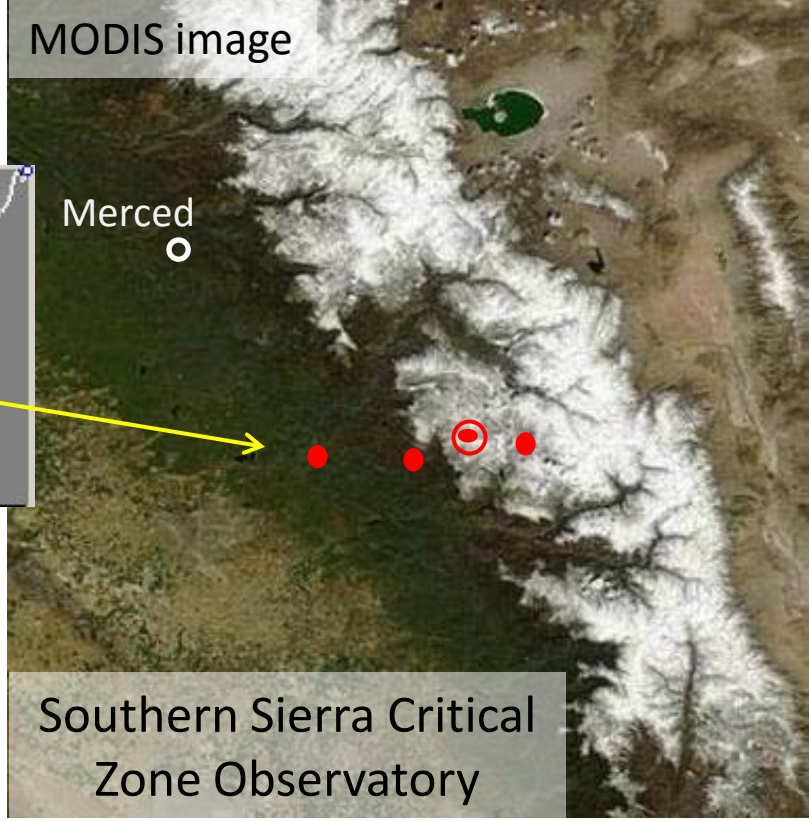
Photo: Margot Wholey

Dec 14, 2015


Photo: Margot Wholey
Dec 14, 2015

Field measurements





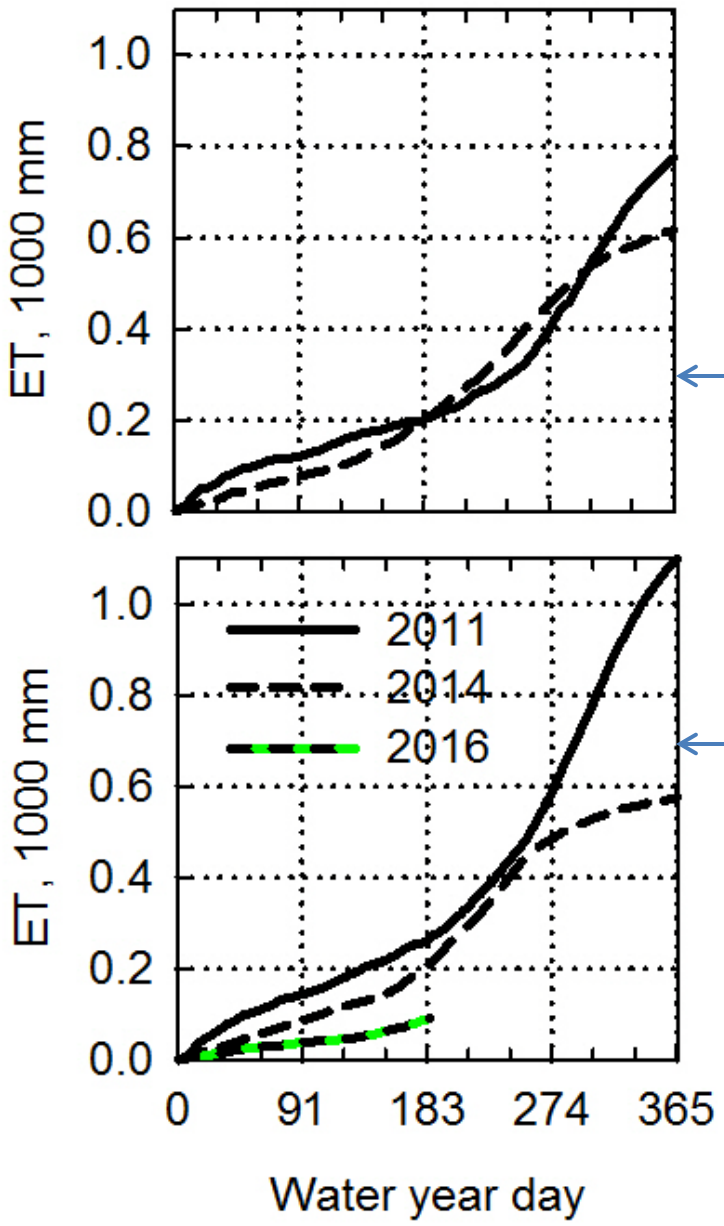
Ground measurements of precipitation, evapotranspiration, discharge, soil-moisture storage, snowpack storage

(Shorthair not available)

Flux-tower measurements

Cumulative water-year evapotranspiration (ET)

- 2011 (wet)
- 2014 (3rd drought yr)



Mixed-conifer forest, 2000 m
2152 vs 634 mm precip
20% drop in ET

Pine-oak forest, 1100 m
1320 vs 390 mm precip
47% drop in ET

Bales et al., almost submitted

Scaling evapotranspiration (ET)

Conceptual

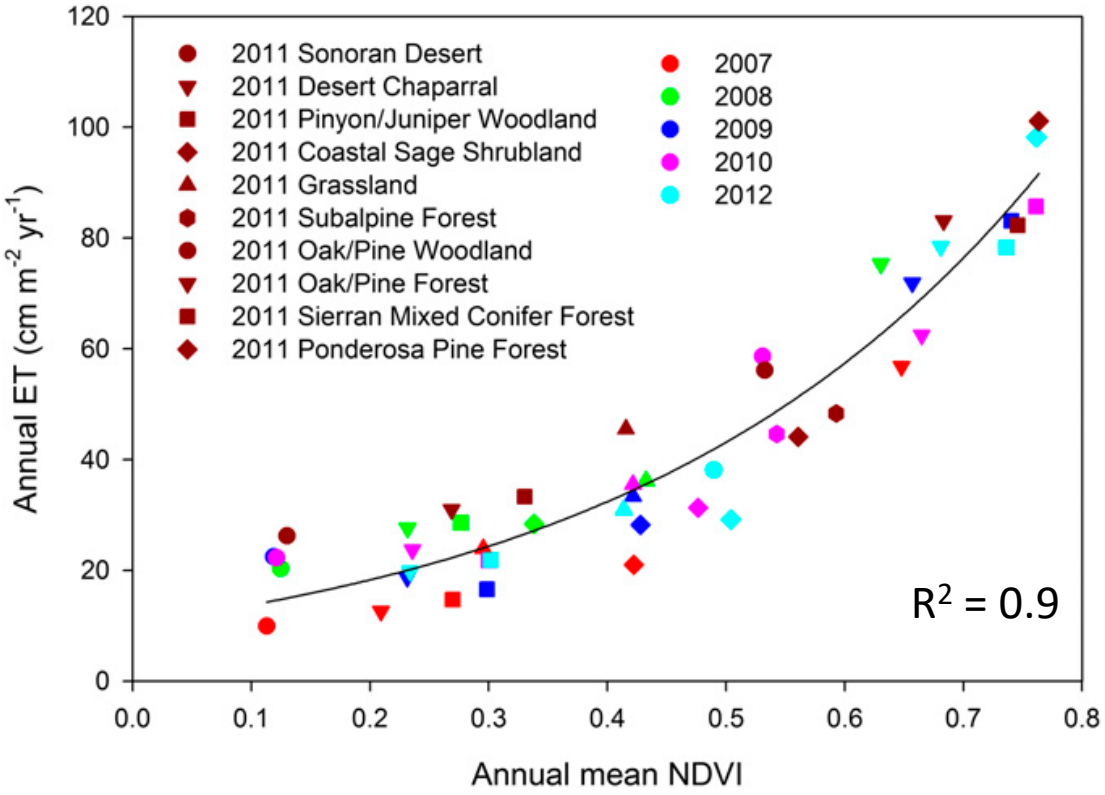
High LAI ⟷ High ET & NPP

Feedback over a few yr

High LAI → High NDVI

NDVI indicates ET needed to support the current LAI

Annual ET measured by flux towers, correlated with MODIS NDVI (greenness)

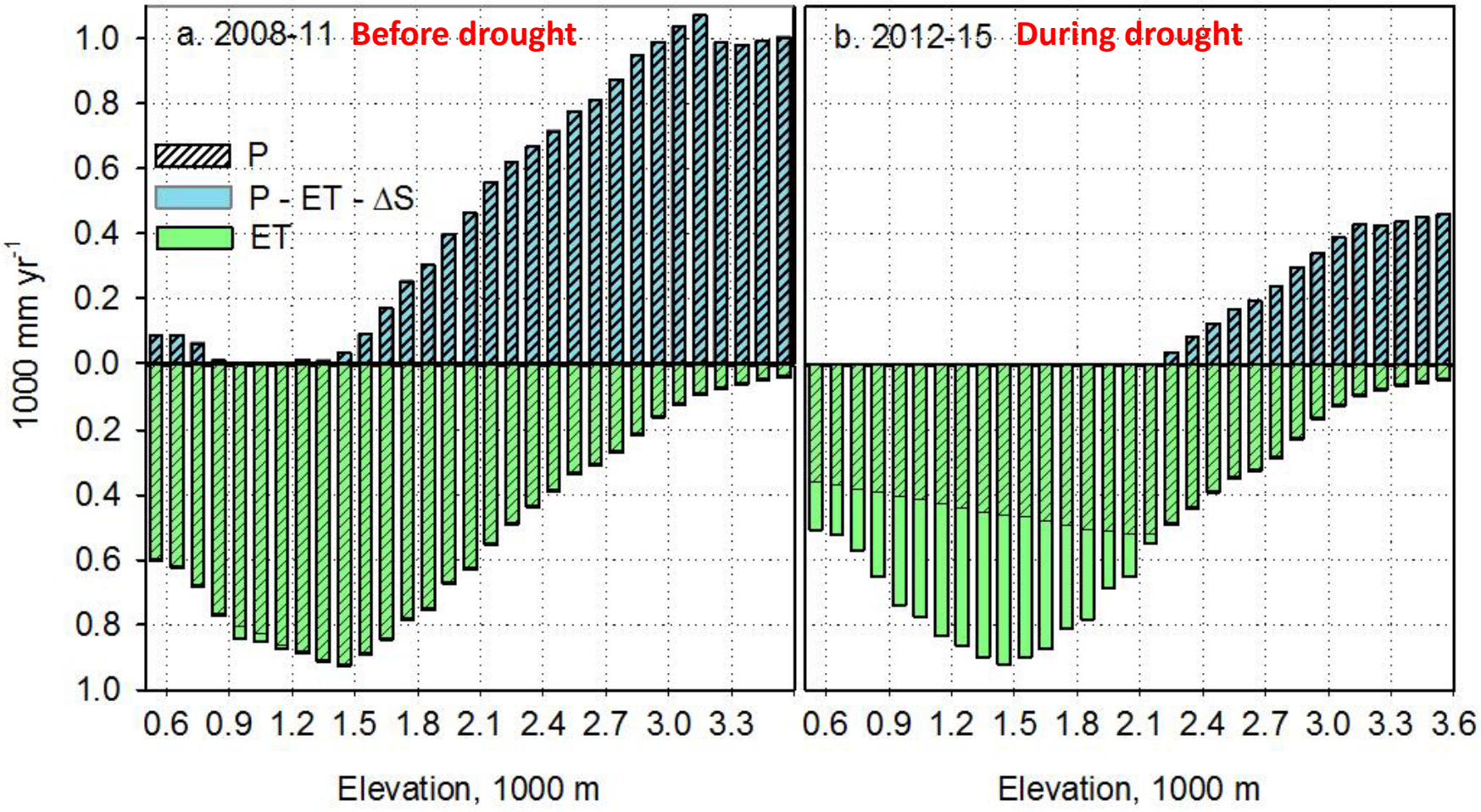


ET calculated across the southern Sierra using this calibration

Goulden & Bales, 2014

Kings R. basin water balance

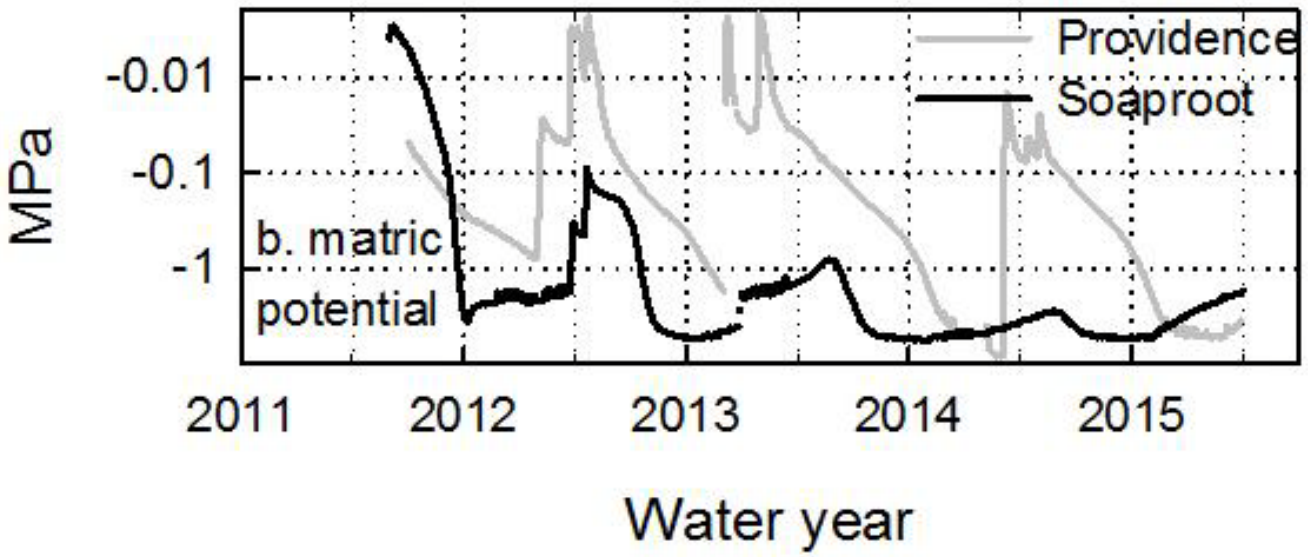
$$P = ET + Q - \Delta S$$



Bales et al., almost submitted

Soil moisture & matric potential

Matric potential at 2-m depth at Providence showed recharge during drought, but not at Soaproot



Soil moisture also showed gradual decline during drought, and no recharge below 1-m depth at Soaproot

Bales et al., almost submitted

Interpretation

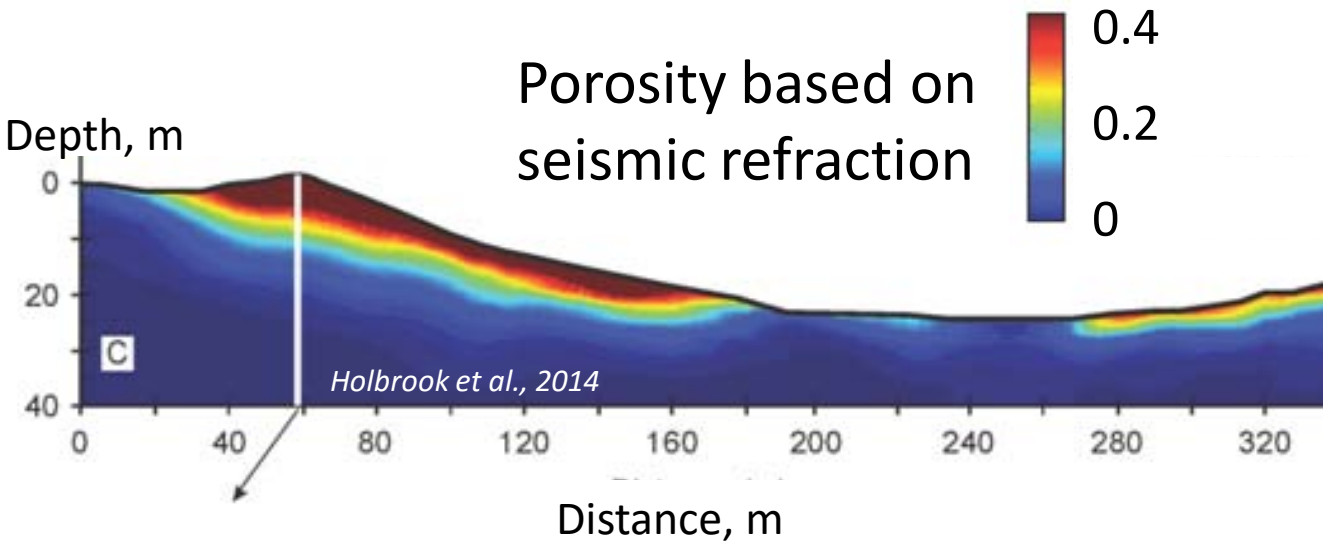
Regolith storage buffers drought if mean annual precipitation exceeds annual evapotranspiration

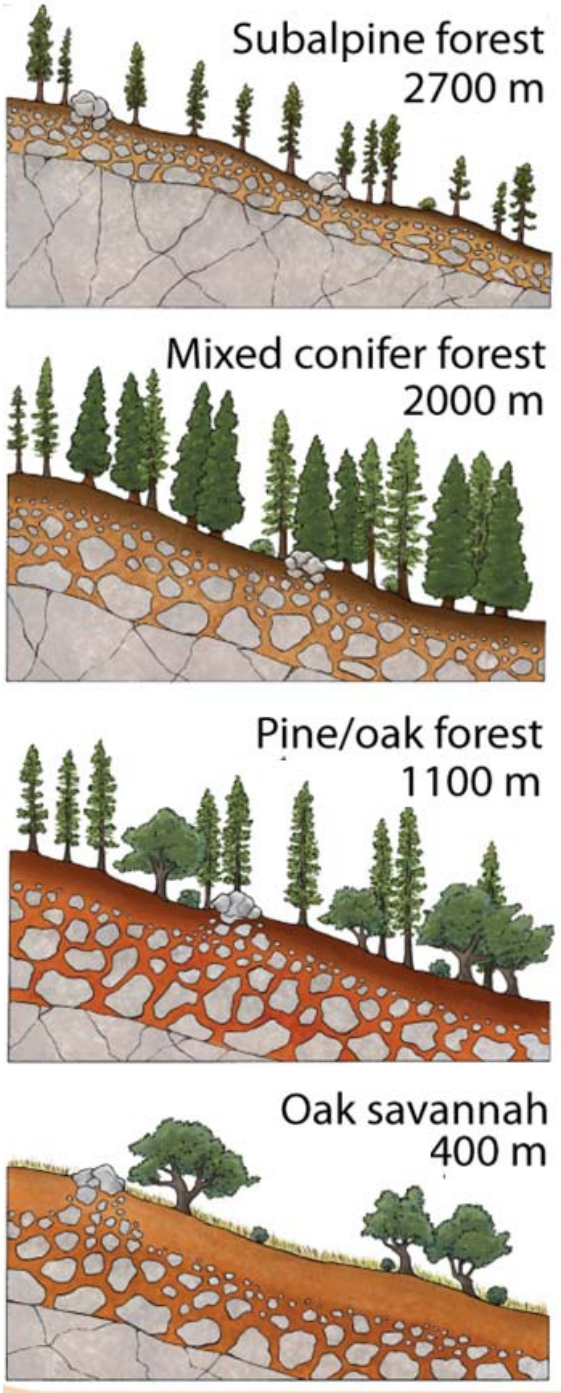
Tree dieoff greatest where recharge to deeper root zone was limited

Parts of the forest reached a tipping point


Management response:
restore (thin) forest → reduce ET
Thinned unit w/ control in background
E. Knapp photo

Predict where forests are resilient vs vulnerable

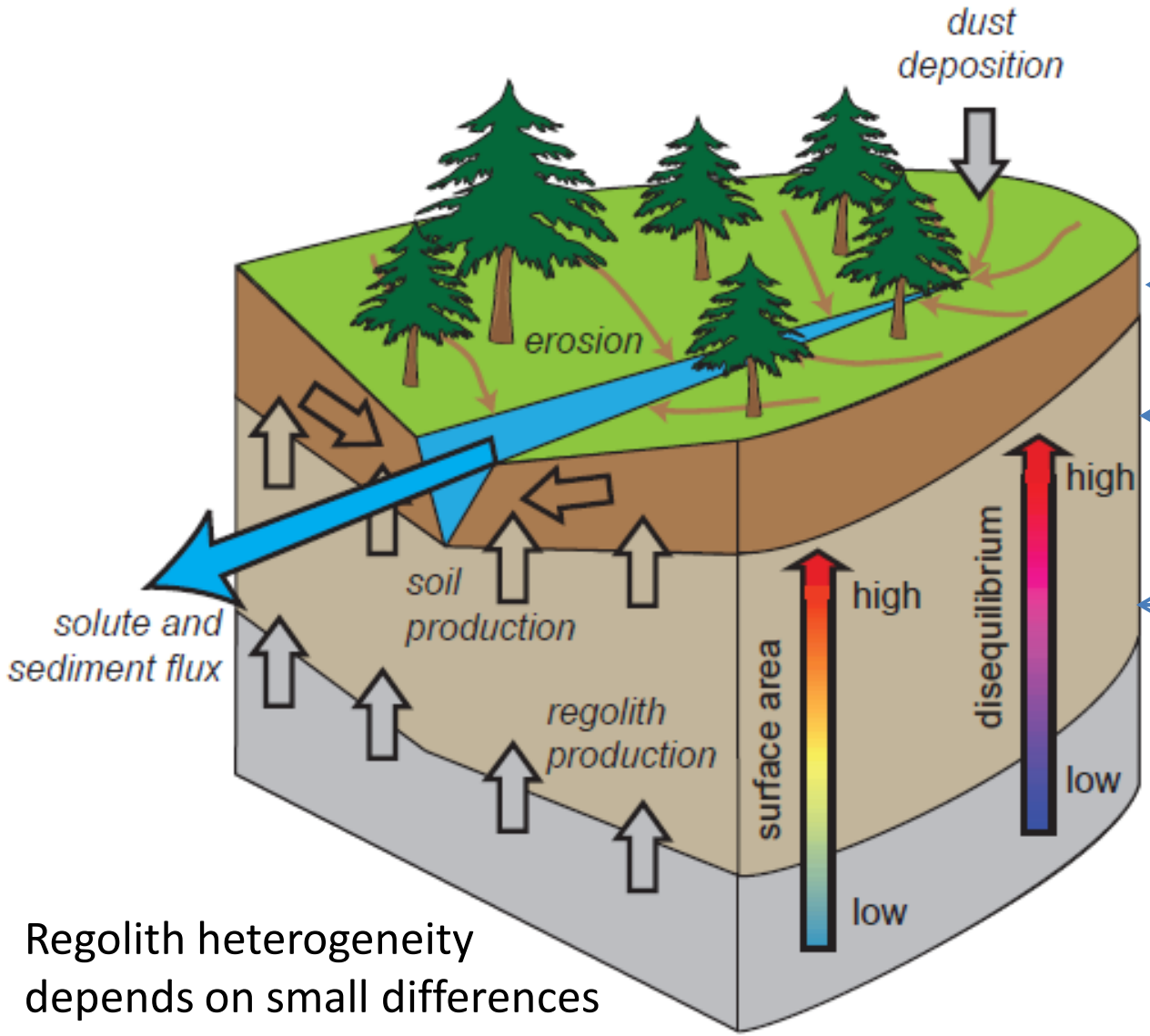




Predictions require spatial information:

- Climate (precipitation & temperature)
- Vegetation density
- Evapotranspiration
- Regolith water storage

Next: predicting regolith attributes



	Chemical weathering	Fracturing & physical damage
Increasing role of organisms		Disaggregation
Advection dominated		Multiple factors
Diffusion dominated		Tectonic & topographic stress

Regolith heterogeneity depends on small differences in bedrock composition, weathering & dust deposition

Adapted from Riebe et al., 2016

Acknowledgements: M. Conklin & many collaborators, students; research support through NSF Critical Zone Observatory and other sources.

UC WATER
Security and Sustainability Research Initiative

UC MERCED SNRI
SIERRA NEVADA RESEARCH INSTITUTE