The Salmonid and The Subsurface: The Importance of Rock Type for Understanding and Sustaining Northern California Ecosystems

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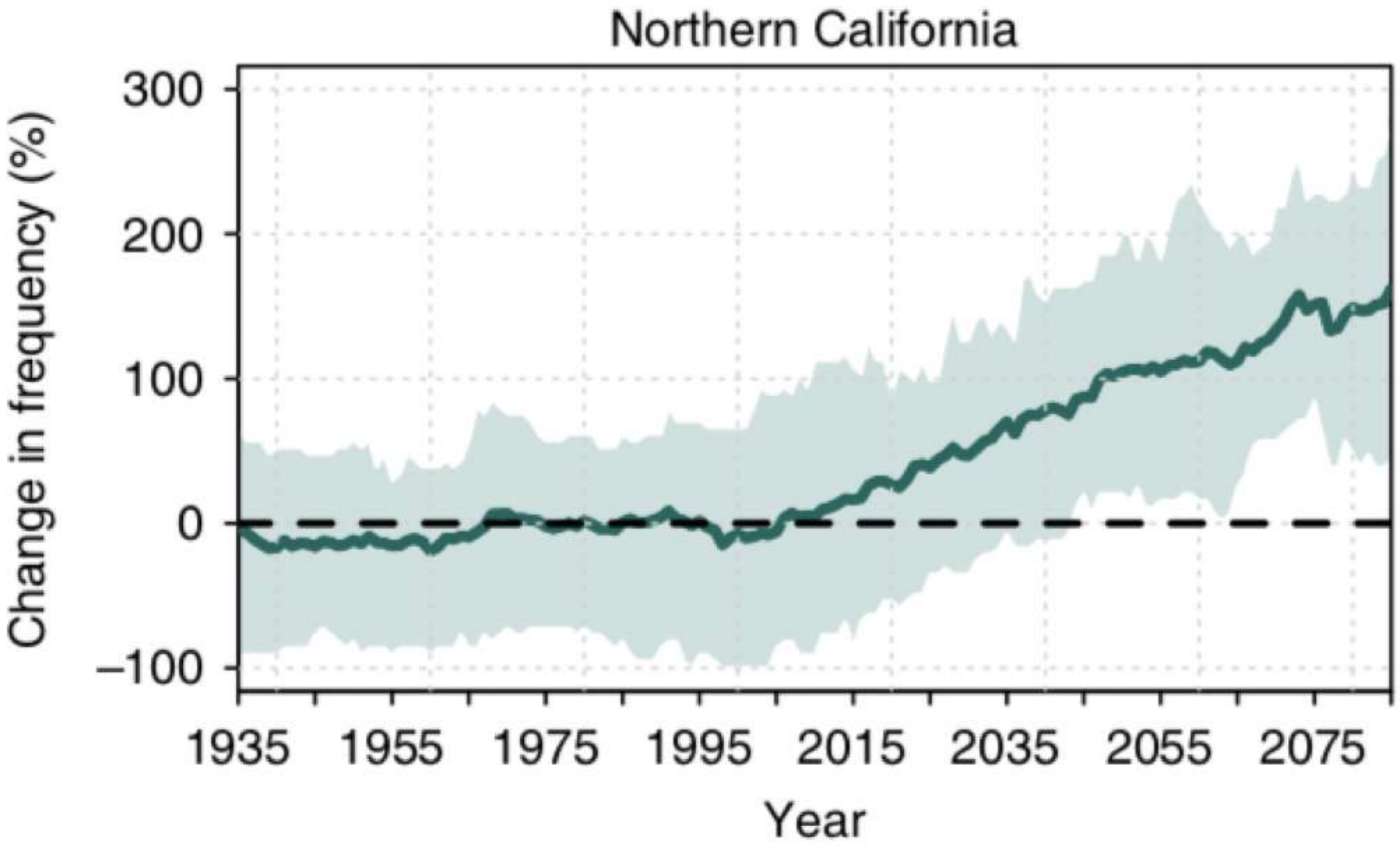
CZO | EEL RIVER
CRITICAL ZONE OBSERVATORY

NSF

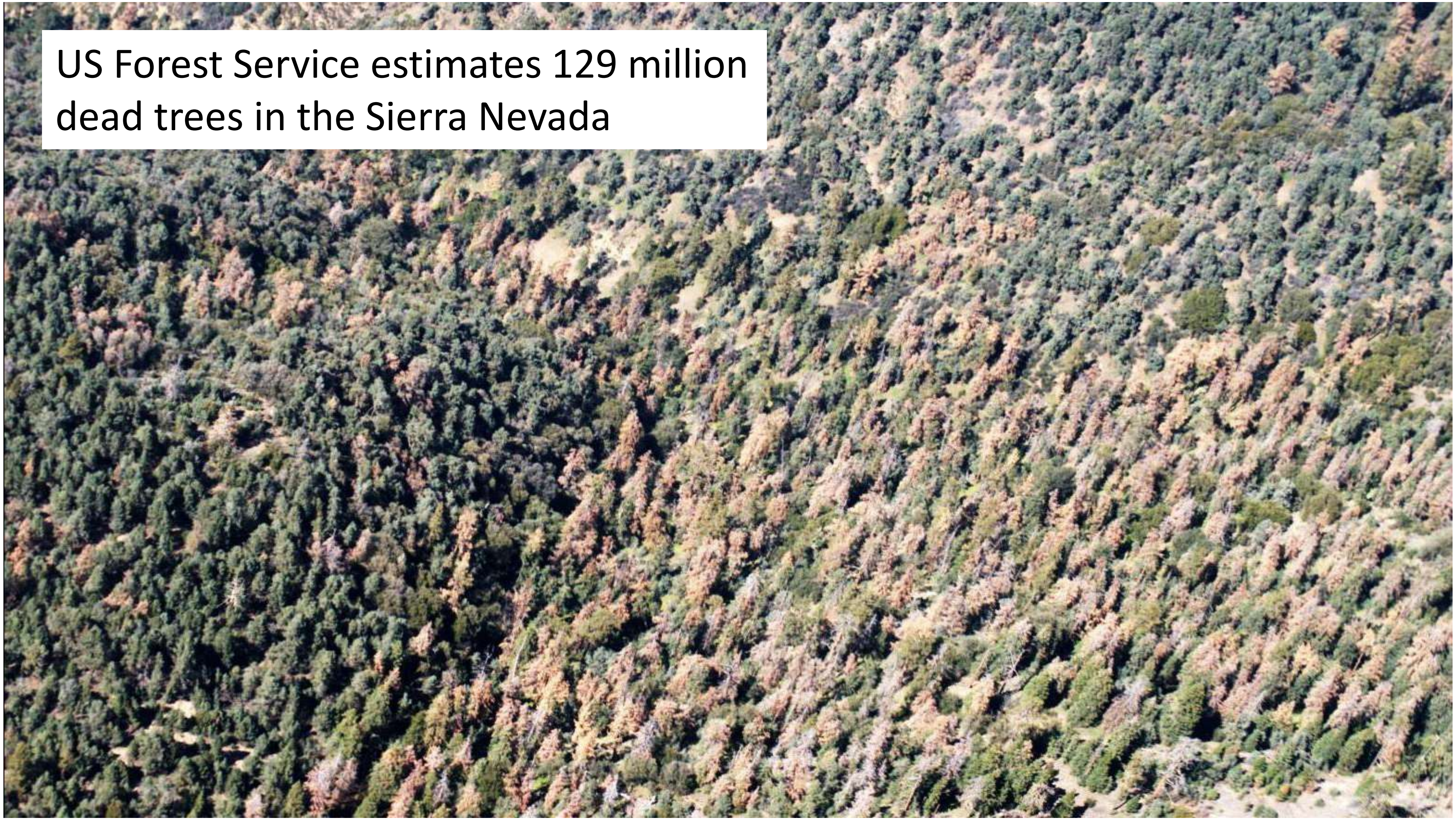
Climate models predict a more volatile California

Extremely-wet wet season frequency



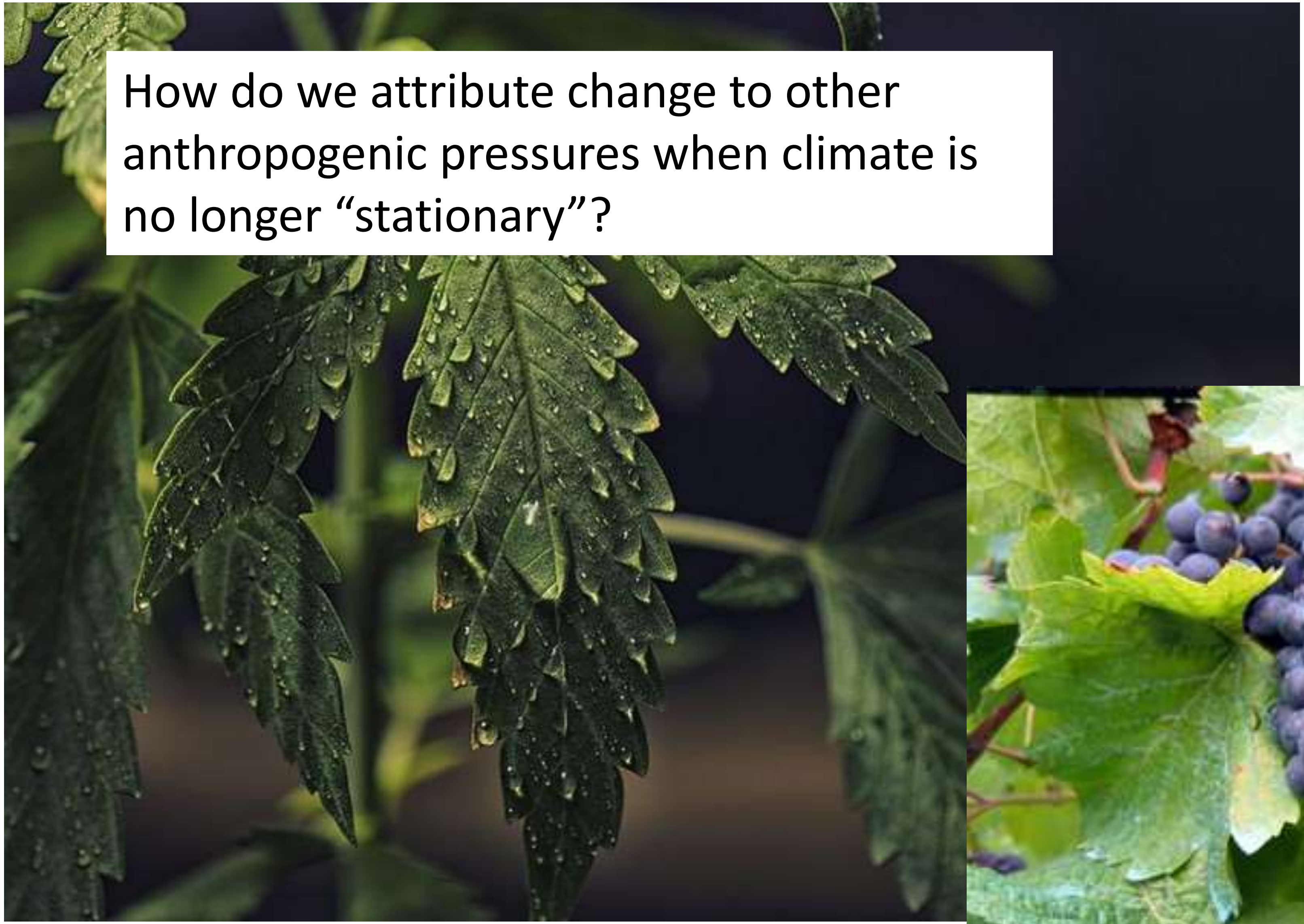
Swain et al, 2018, Nature Climate Change

US Forest Service estimates 129 million dead trees in the Sierra Nevada

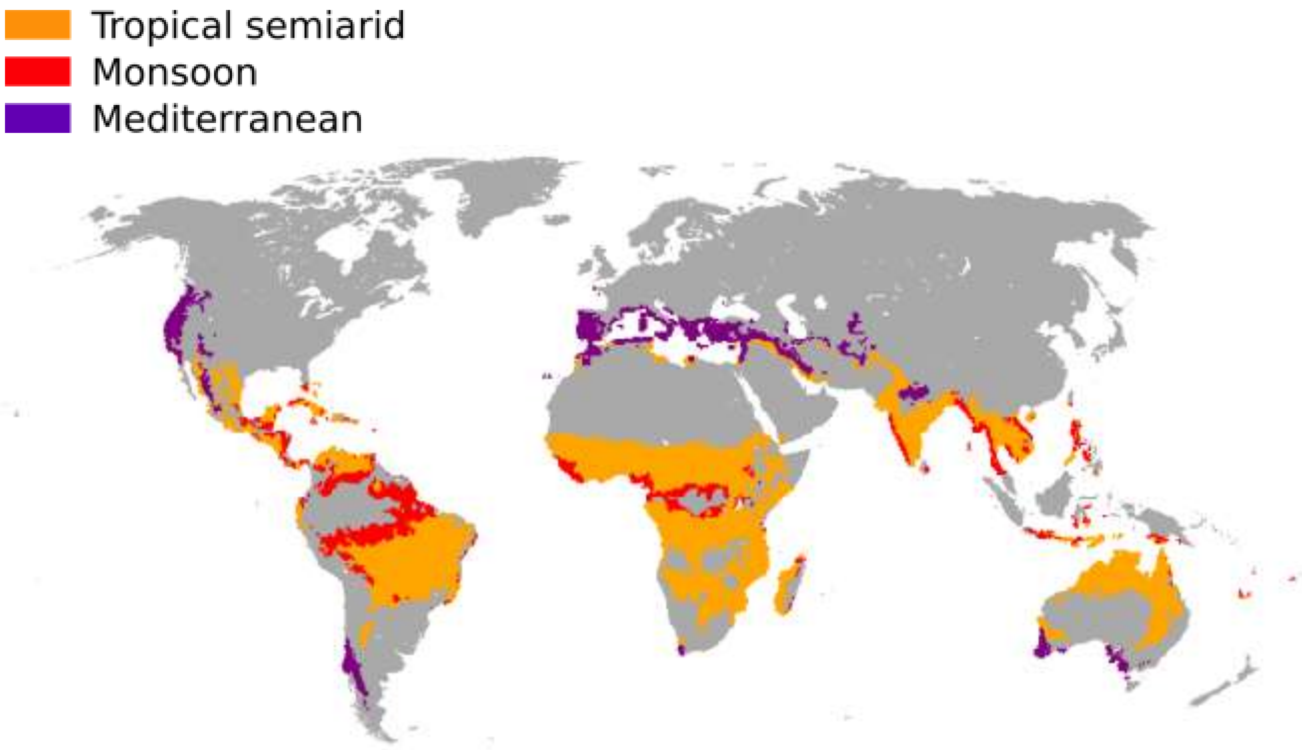


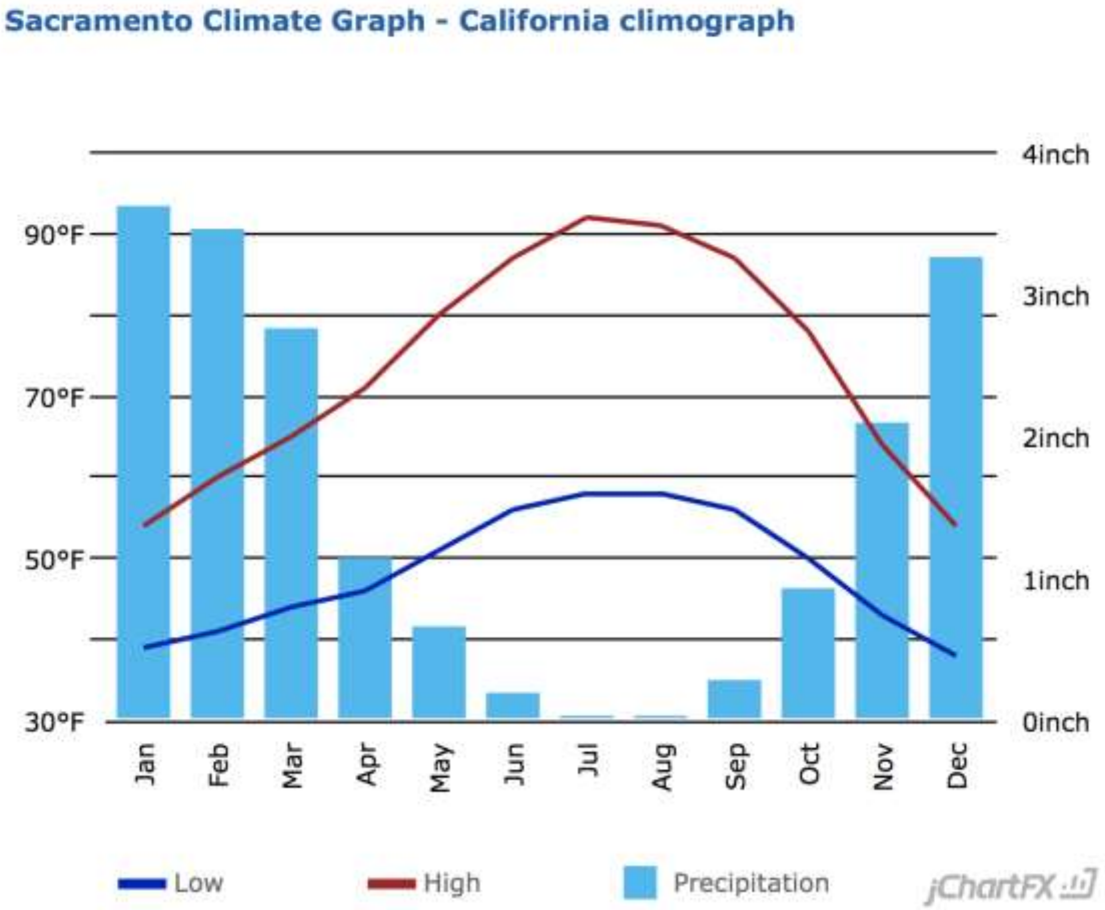
Implications of increased hydroclimatic volatility for salmon-supporting coastal watersheds?

How do we attribute change to other anthropogenic pressures when climate is no longer “stationary”?



The role of the subsurface in Mediterranean climates

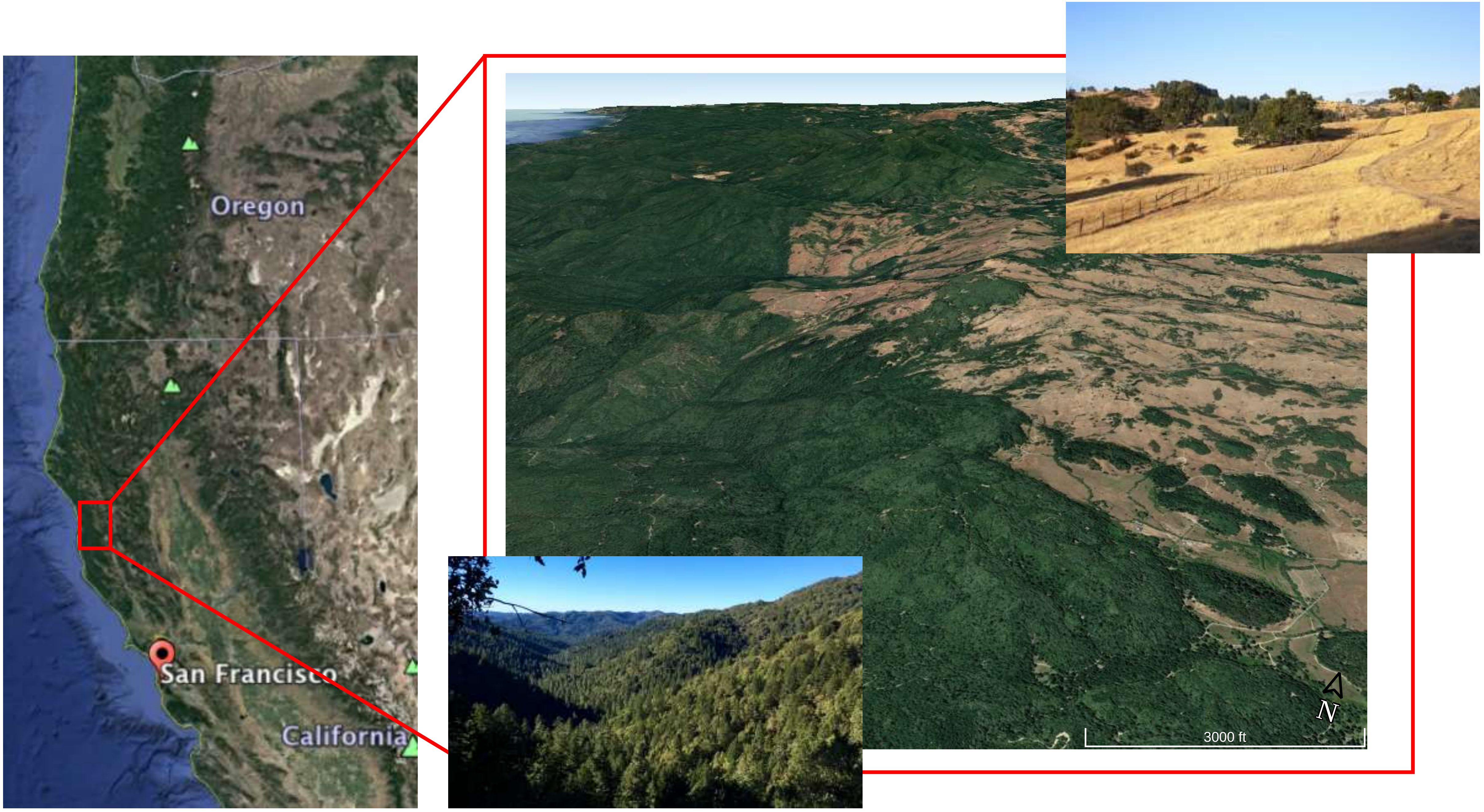


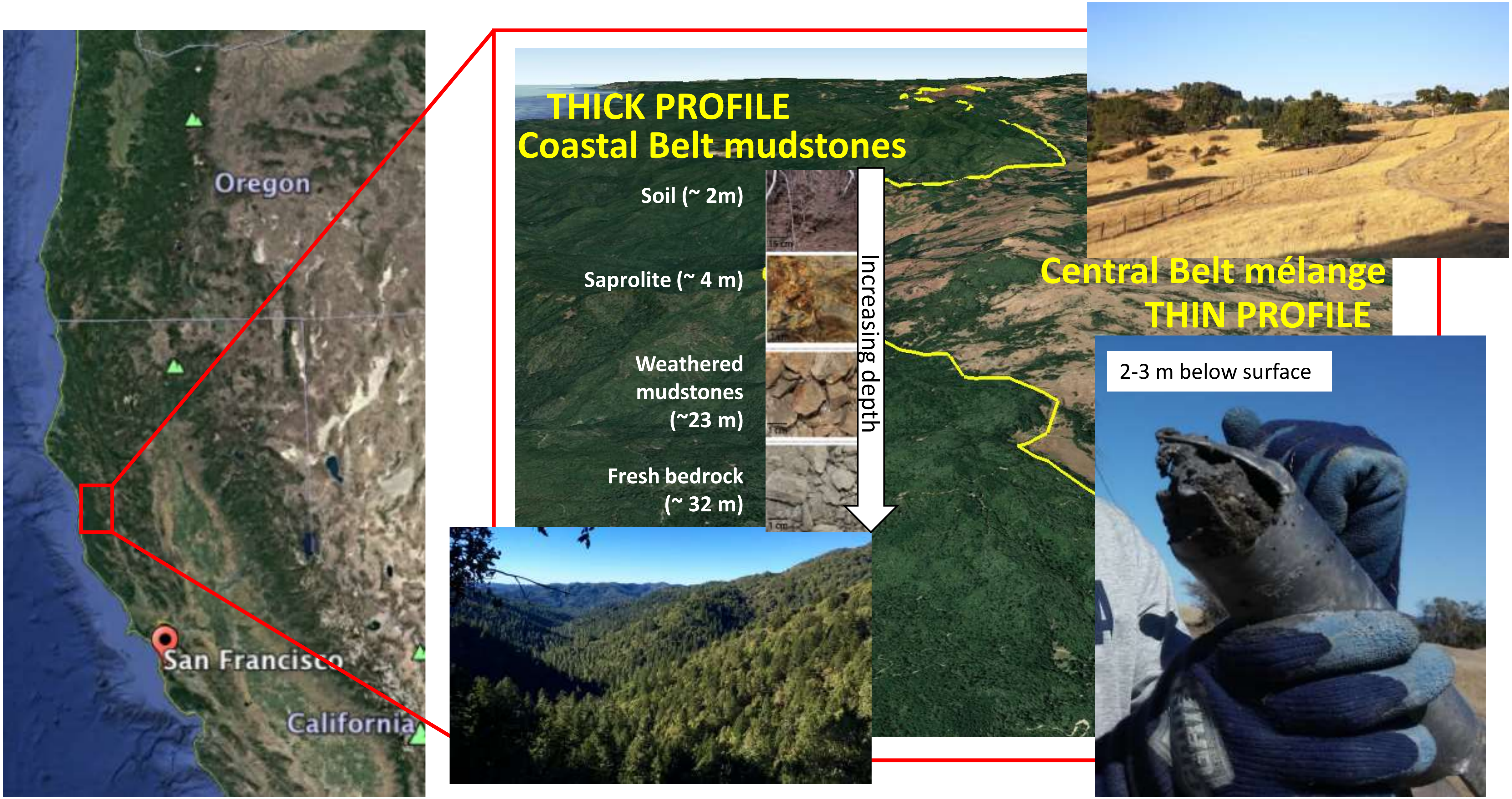


Subsurface water storage capacity

Today:

- Lithology, storage *capacity*, and biogeography
- Storage capacity and aquatic habitat diversity
- Storage capacity mediates the relationship between precipitation variability and annual variations in ecosystem water availability

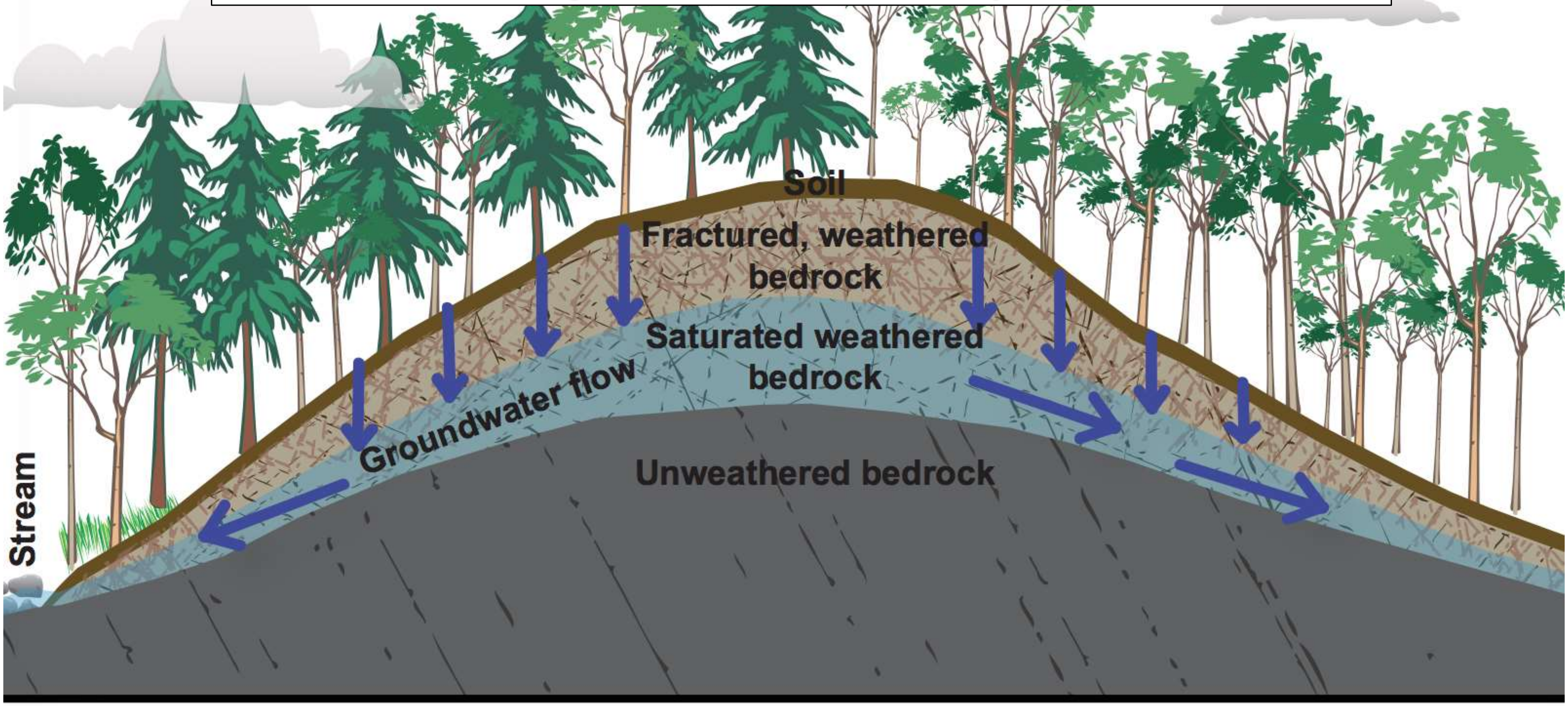

Oregon
San Francisco
California
N
3000 ft



Hahm, Rempe, Dralle, et al, *Water Resources Research,* 2019

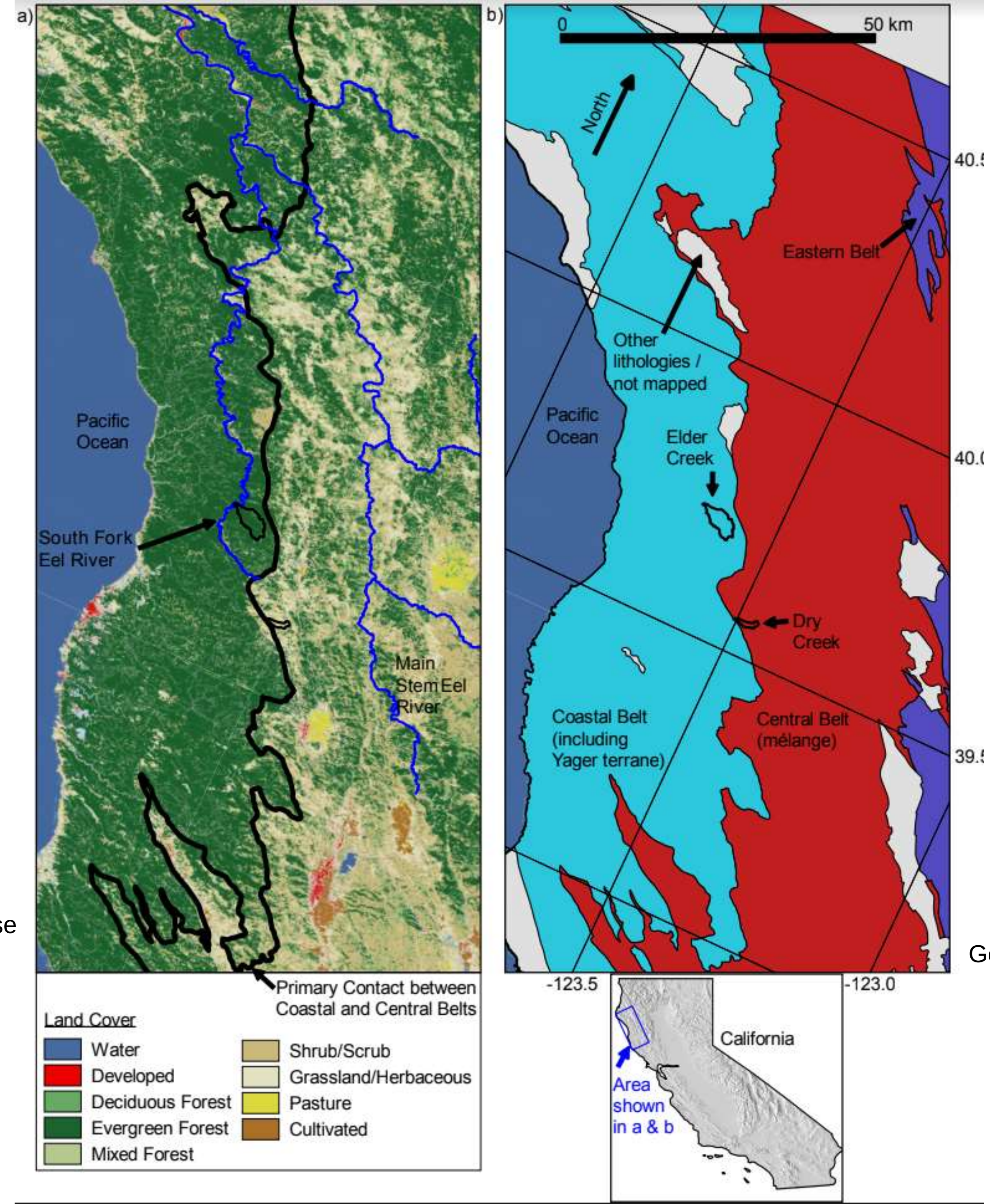
‘unit hillslope’ approach

Hypothesize that commonality of form indicates commonality of Critical Zone (CZ) structure



Conceptual diagram modified from original by Daniella Rempe

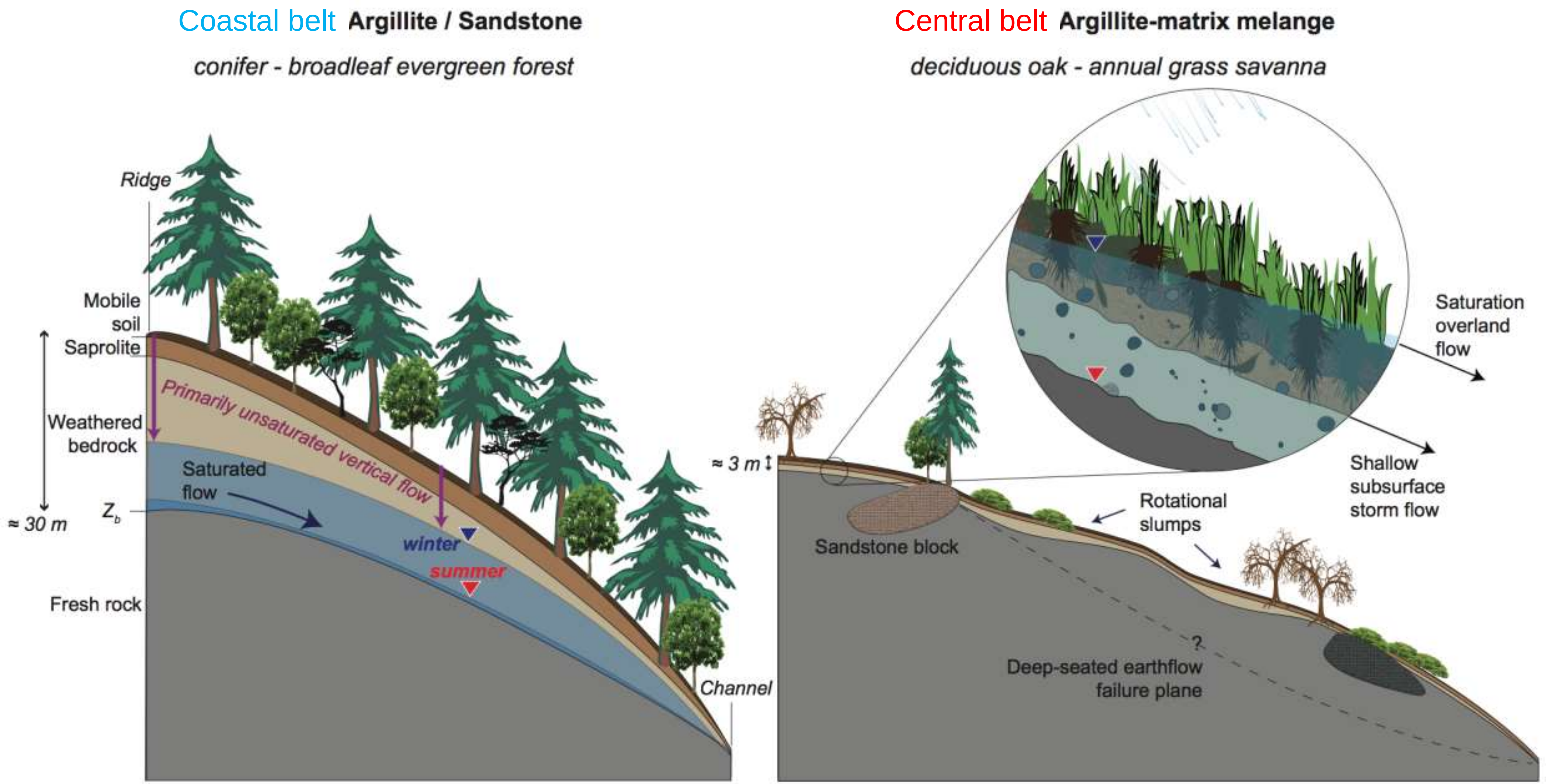
National Land Cover Database data



Geology from Langenheim et al., 2013

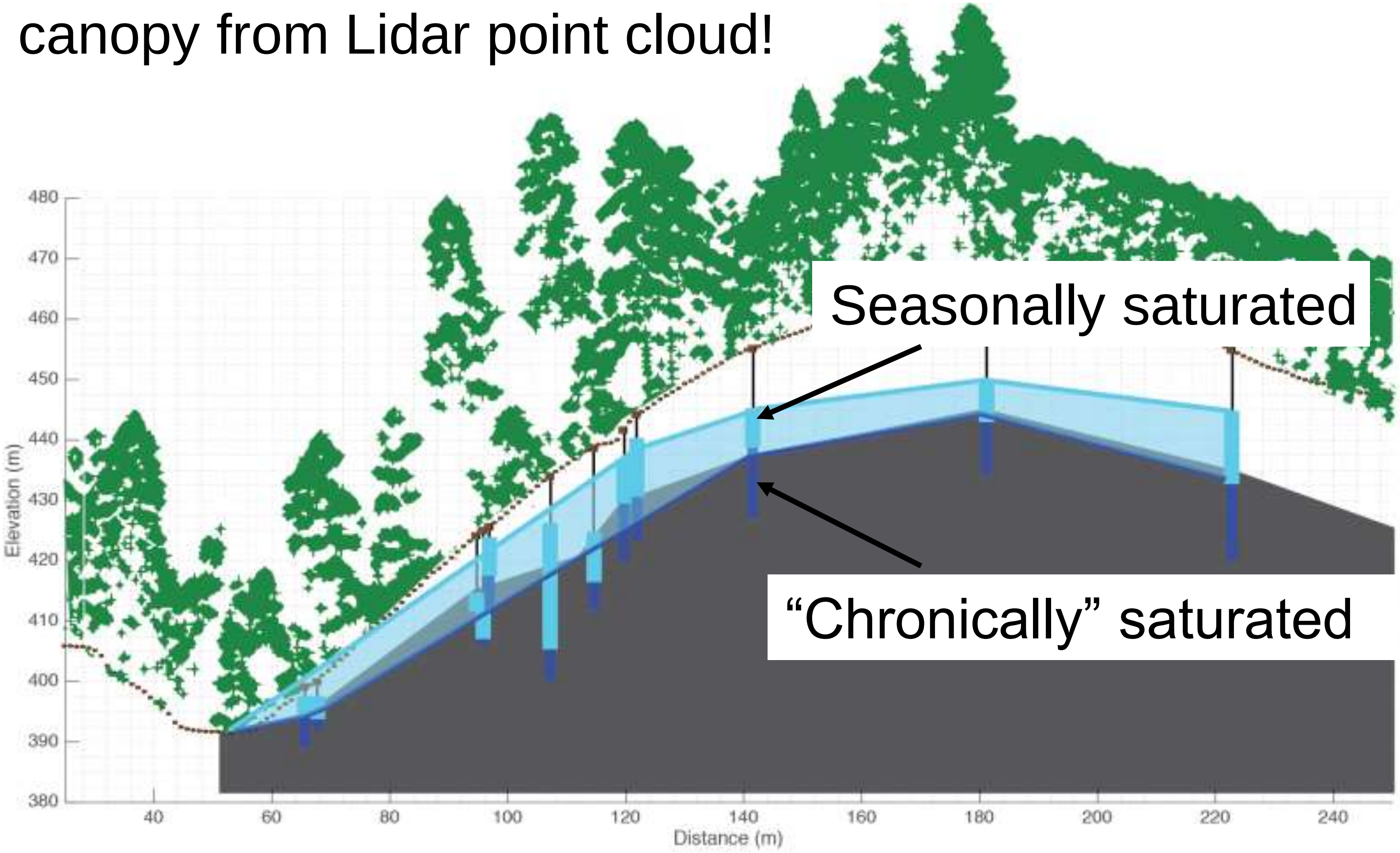
Hahm et al., 2019, *WRR.*

Critical Zone Structure and Runoff Generation in the Franciscan Formation



Hahm, Rempe, Dralle, et al, *Water Resources Research,* 2019

Actual tree canopy from Lidar point cloud!



Daniella Rempe figure, NCALM Lidar

Coastal Belt critical zone, showing seasonal hillslope groundwater table at the base of a thick, weathered rock profile

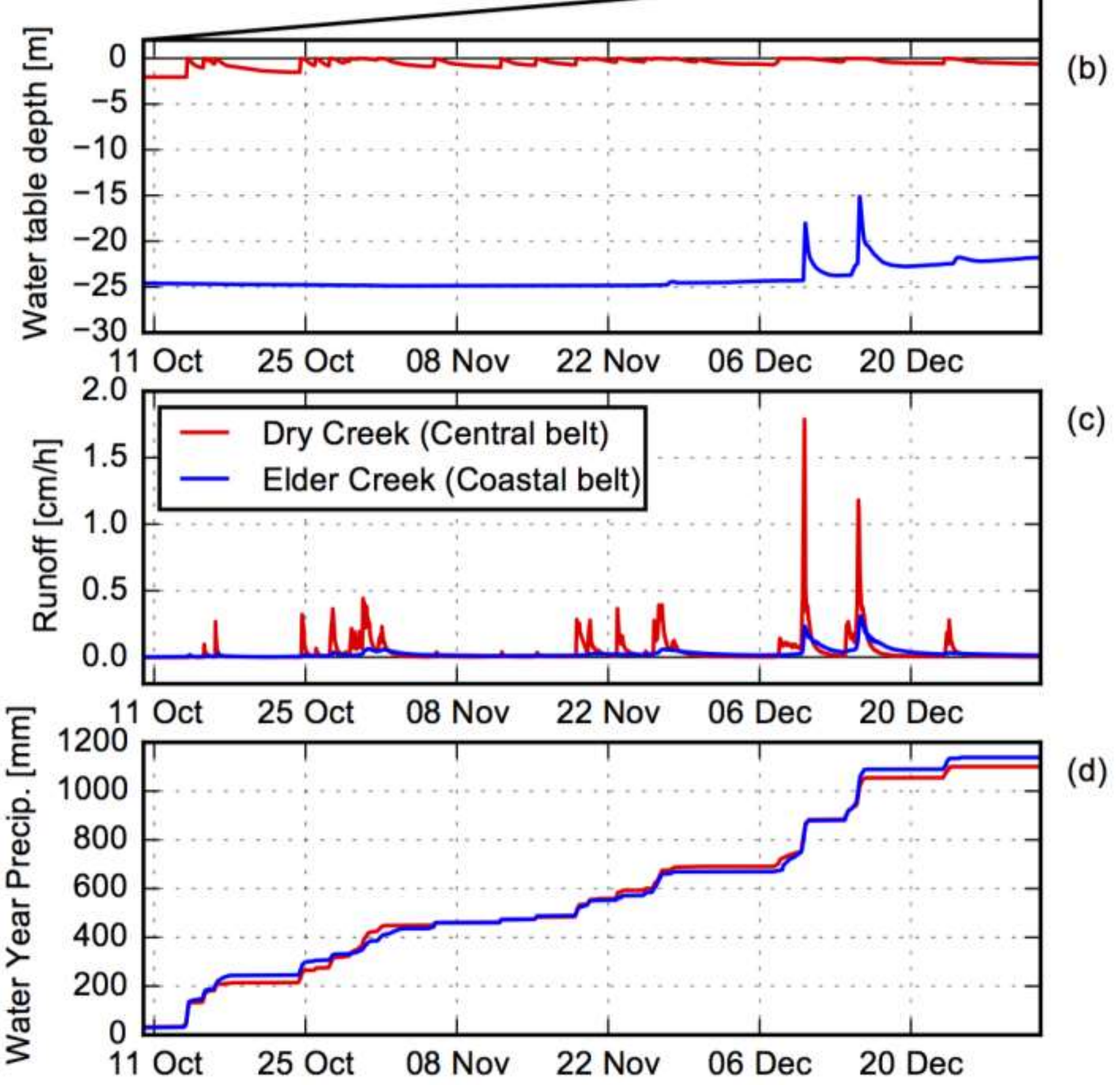


Central Belt critical zone completely saturated in winter, even at topographic ridges

Groundwater

Runoff

Total rainfall



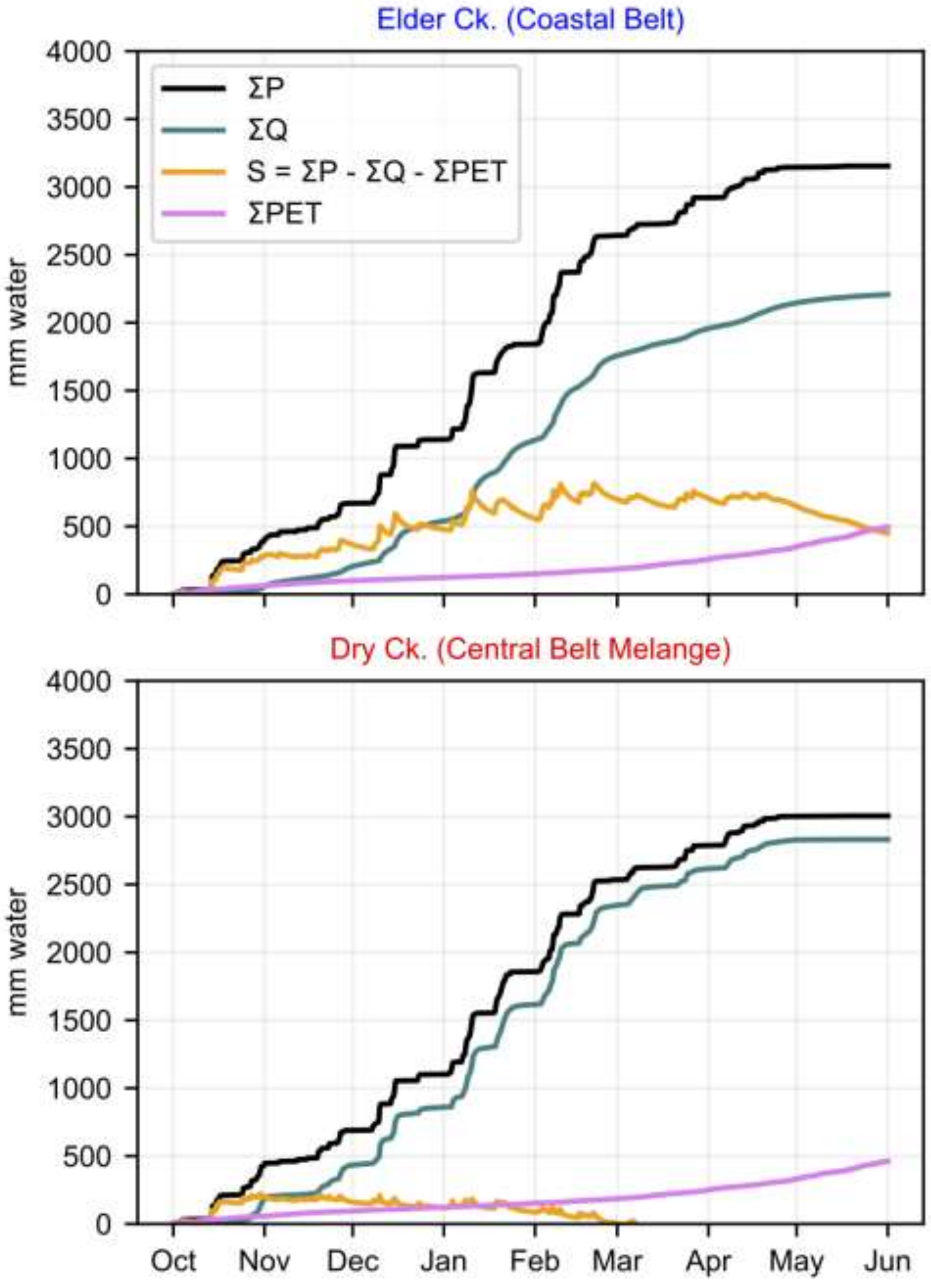
Hahm et al., 2019, *WRR*.

Consistent with catchment-wide storage dynamics

Δ storage (S) = inputs – outputs =
+ precipitation (P)
– runoff (Q)
– evapotranspiration (PET)

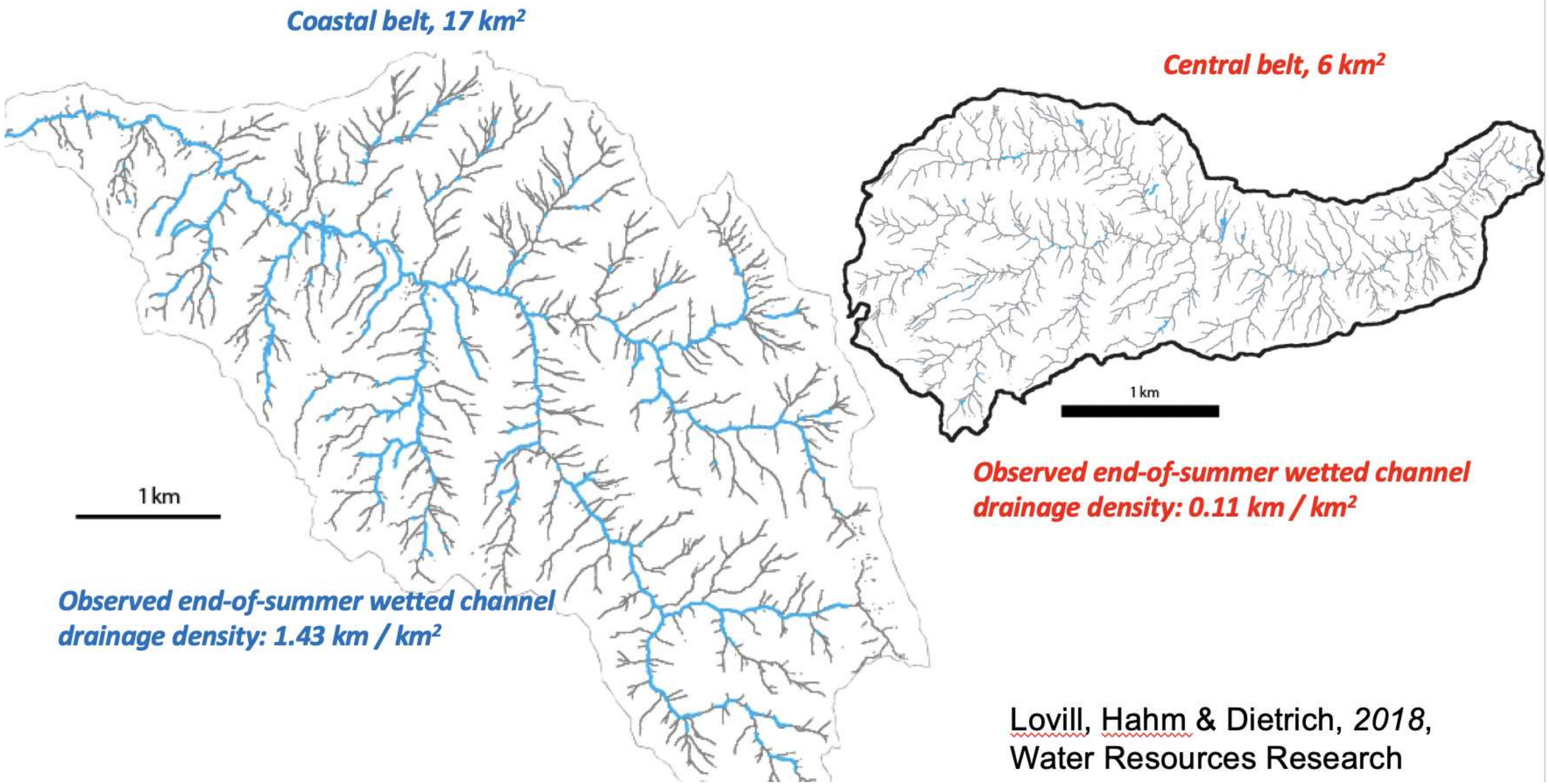
Shown: 2017 water year

Dralle, Hahm Rempe, et al., 2018 (Hydrol. Processes)



PET inferred from Hargreaves method

Habitat extent: wetted channel dynamics

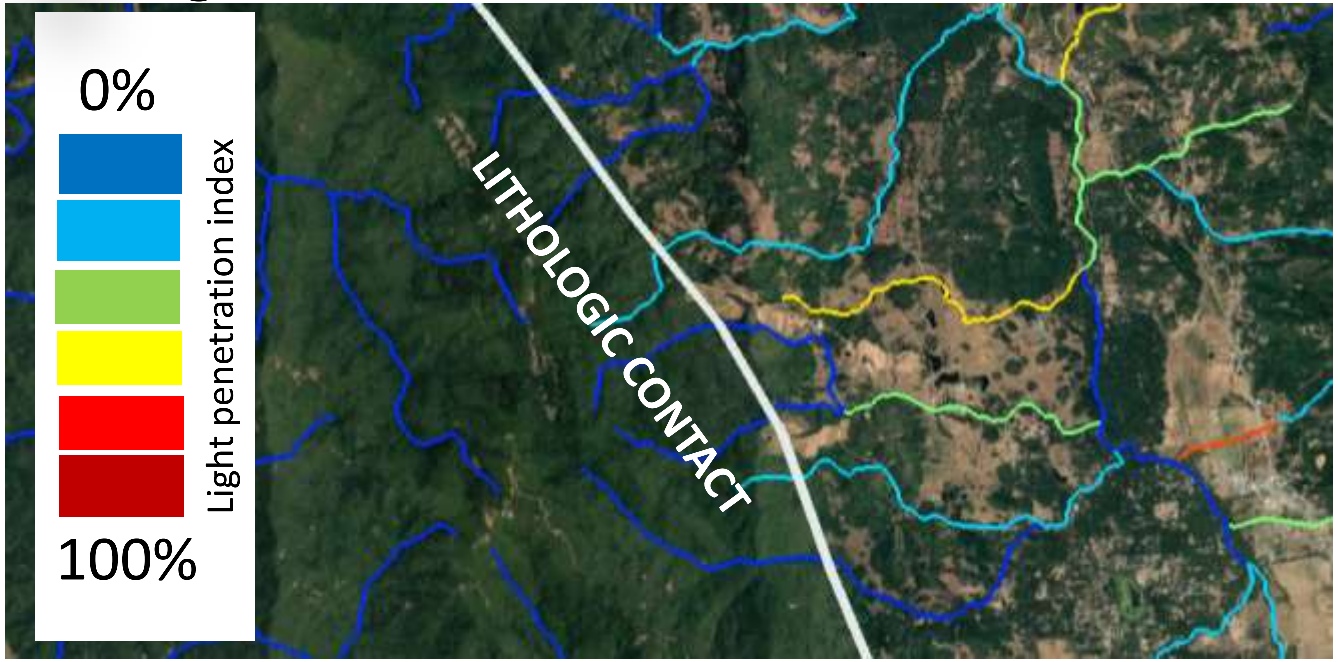


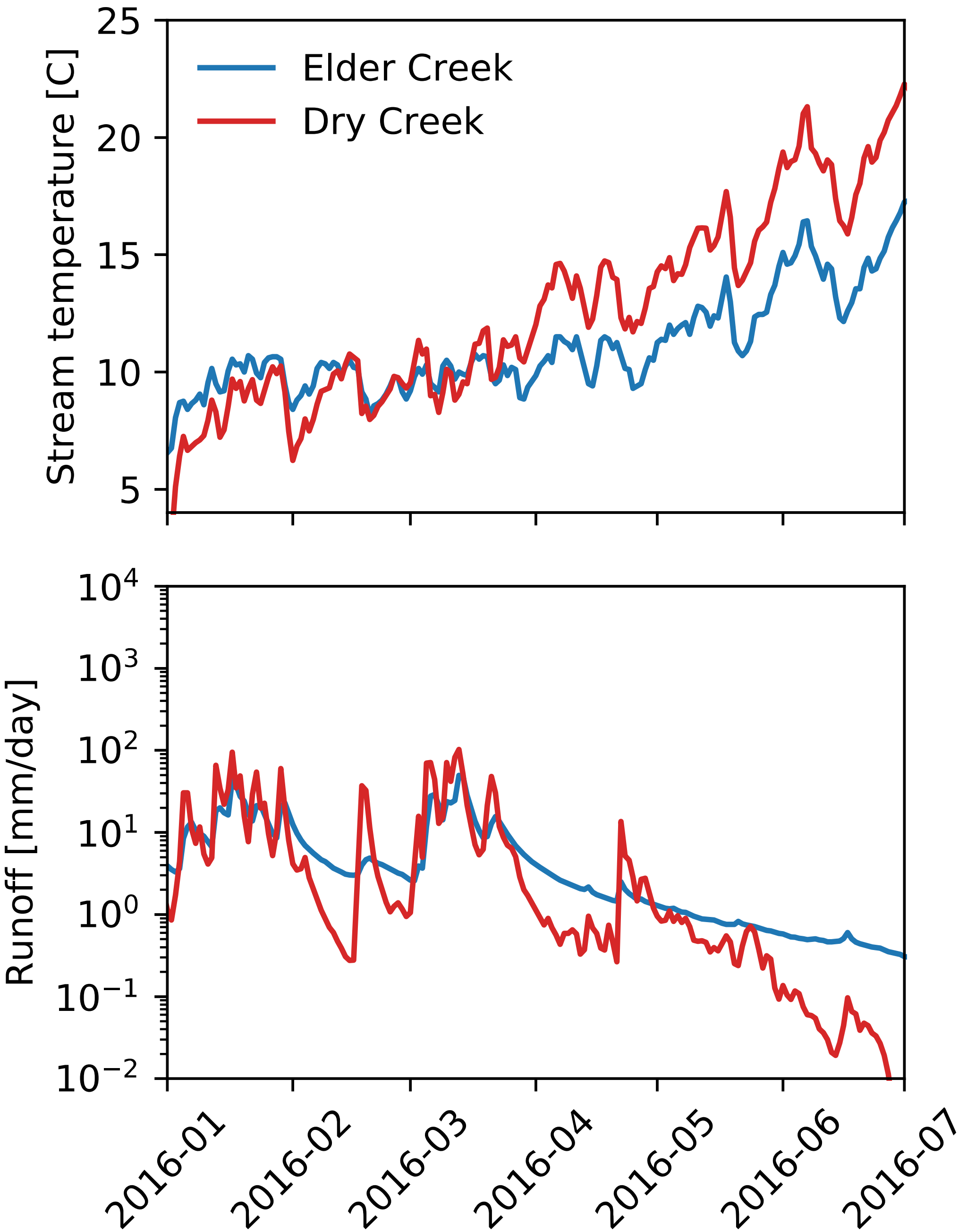
Lovill, Hahm & Dietrich, *2018*,
Water Resources Research

Habitat quality: stream temperature

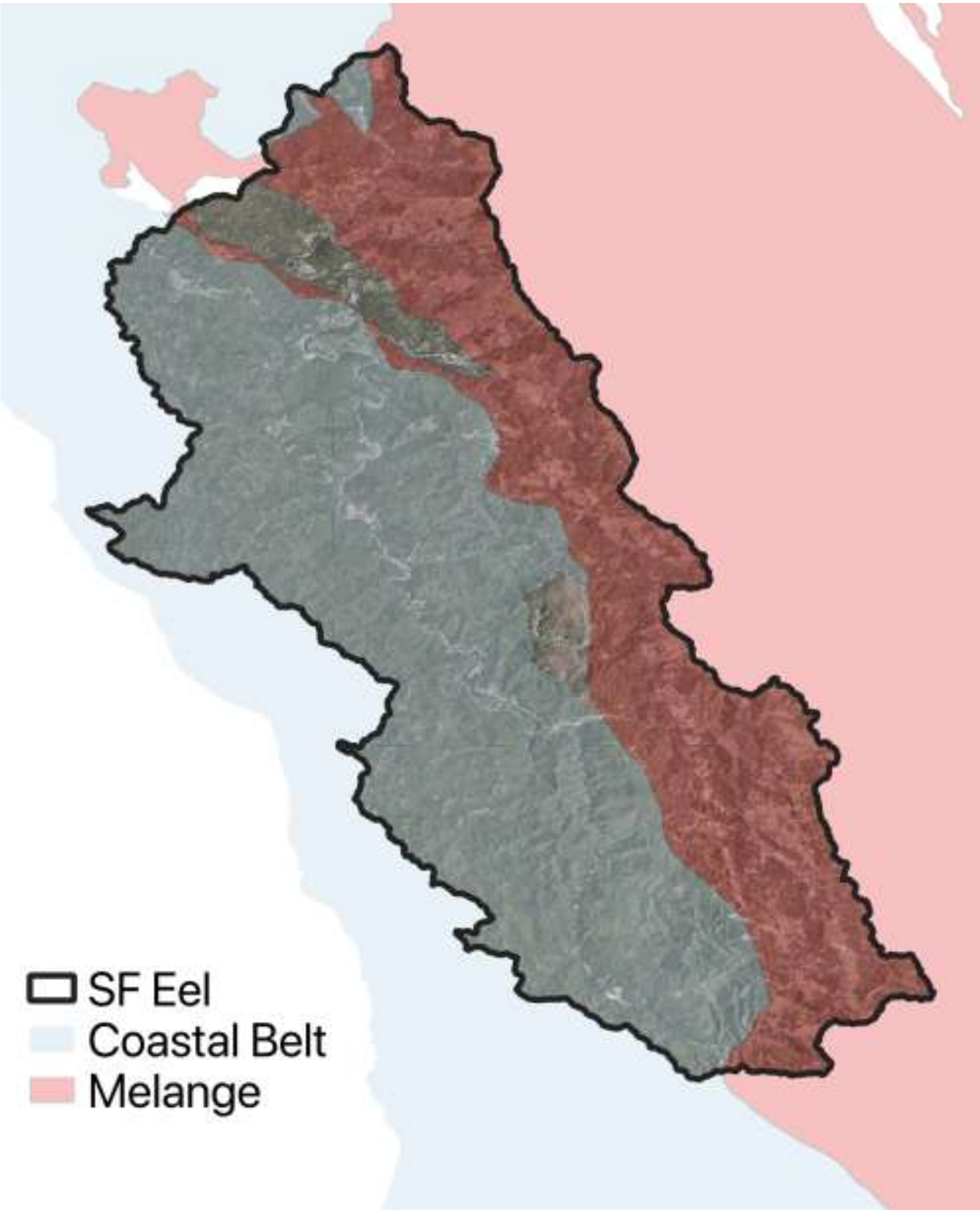
Structure impacts runoff pathways

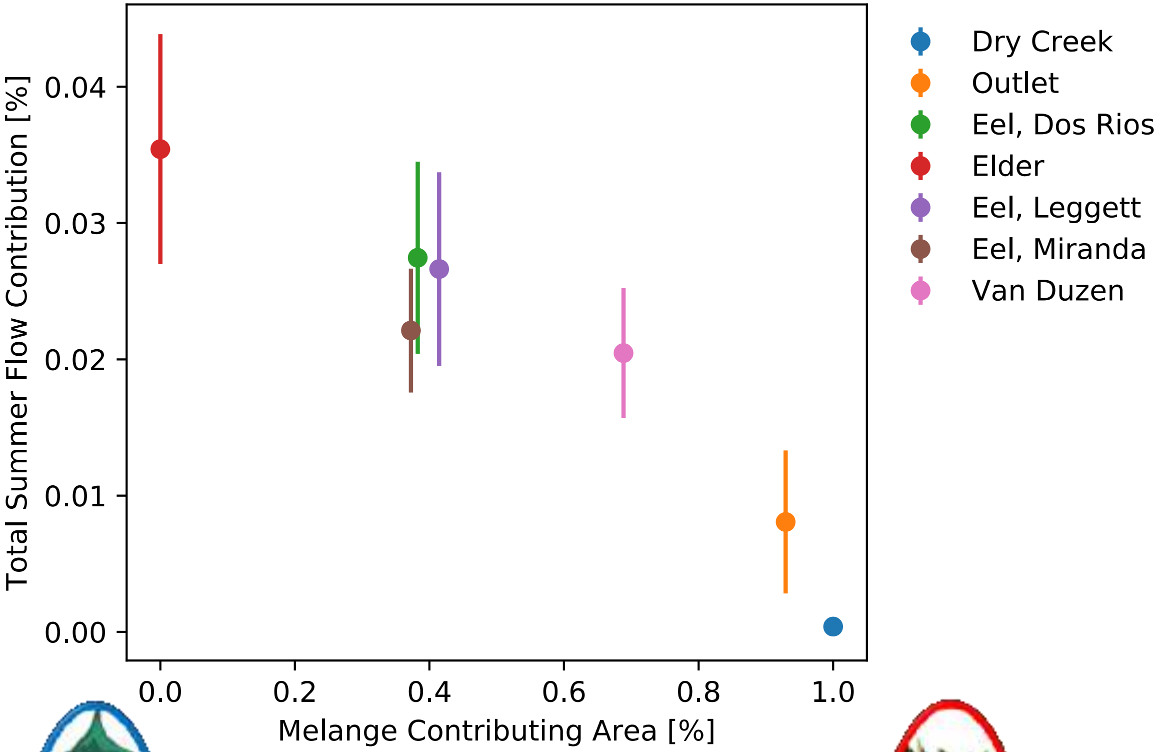
Storage affects radiative environment





Habitat across scales: from “unit-hillslope” to “watershed”

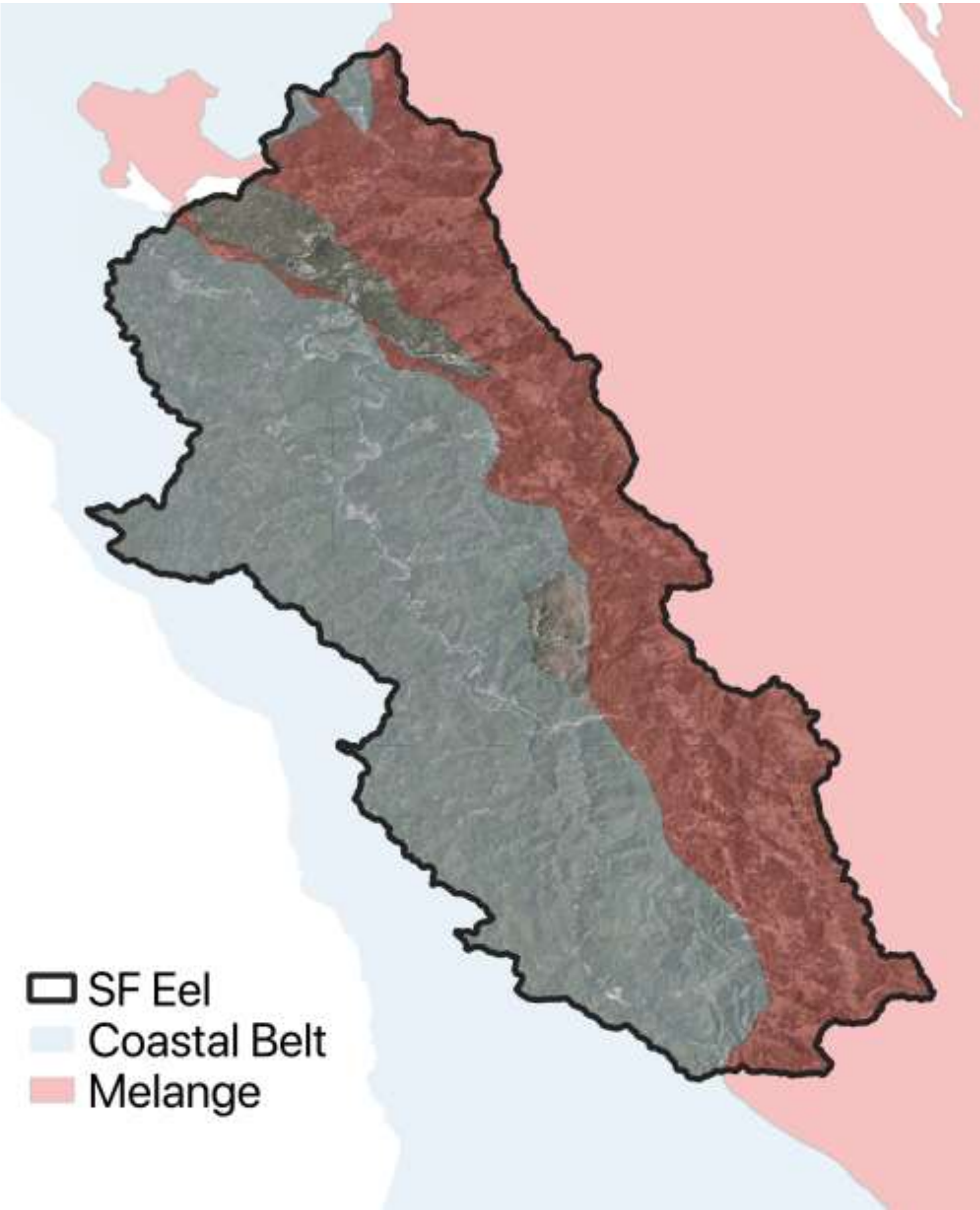




Increasing contribution of mélange to runoff

Dralle, Hahm Rempe, in prep

Implications



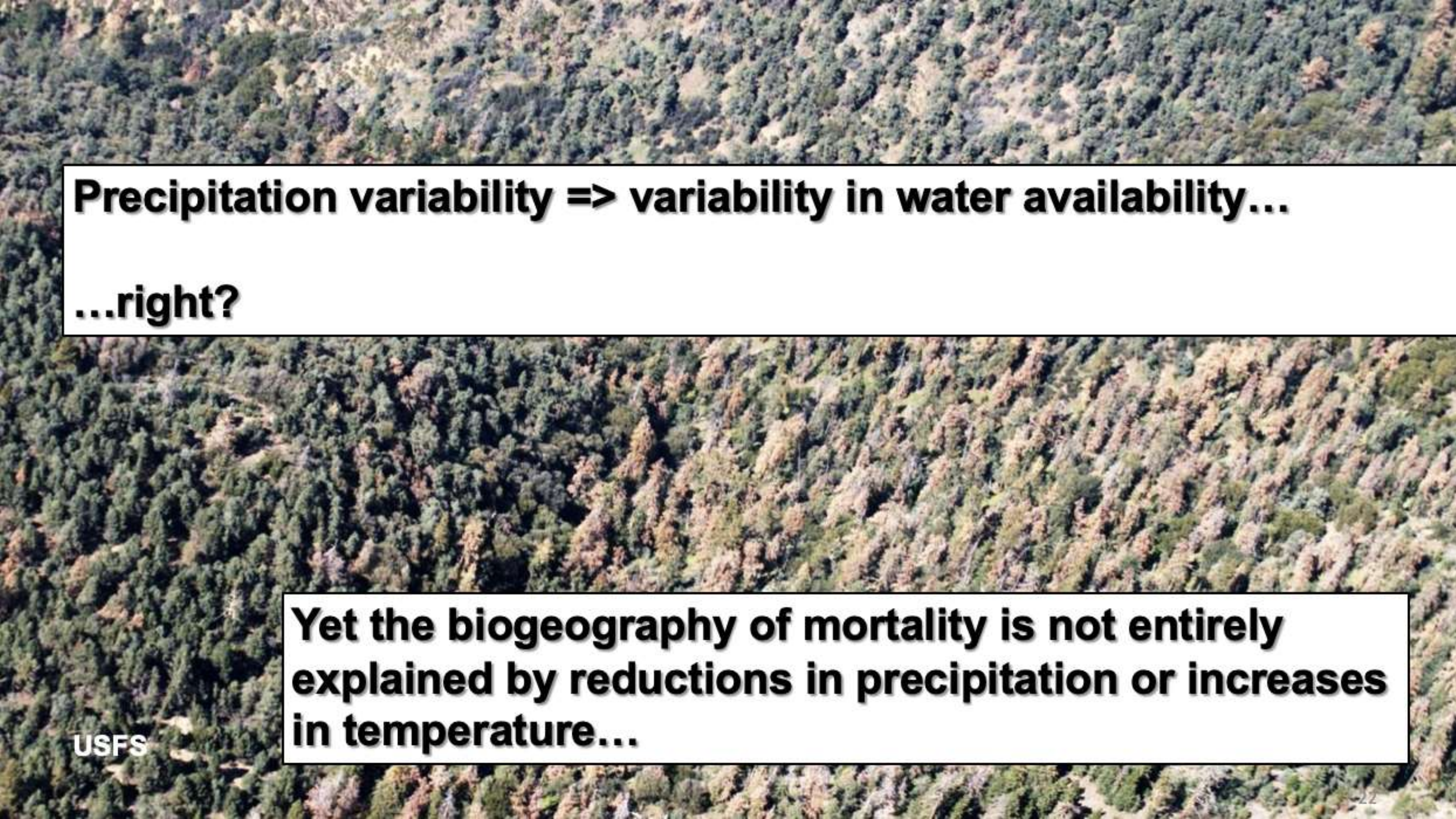
i) Go “beyond the soil” to explain hydro-thermal regimes

ii) “geologic diversity” => “life history” diversity?

iii) Paired catchment studies: Controlling for effects of lithology

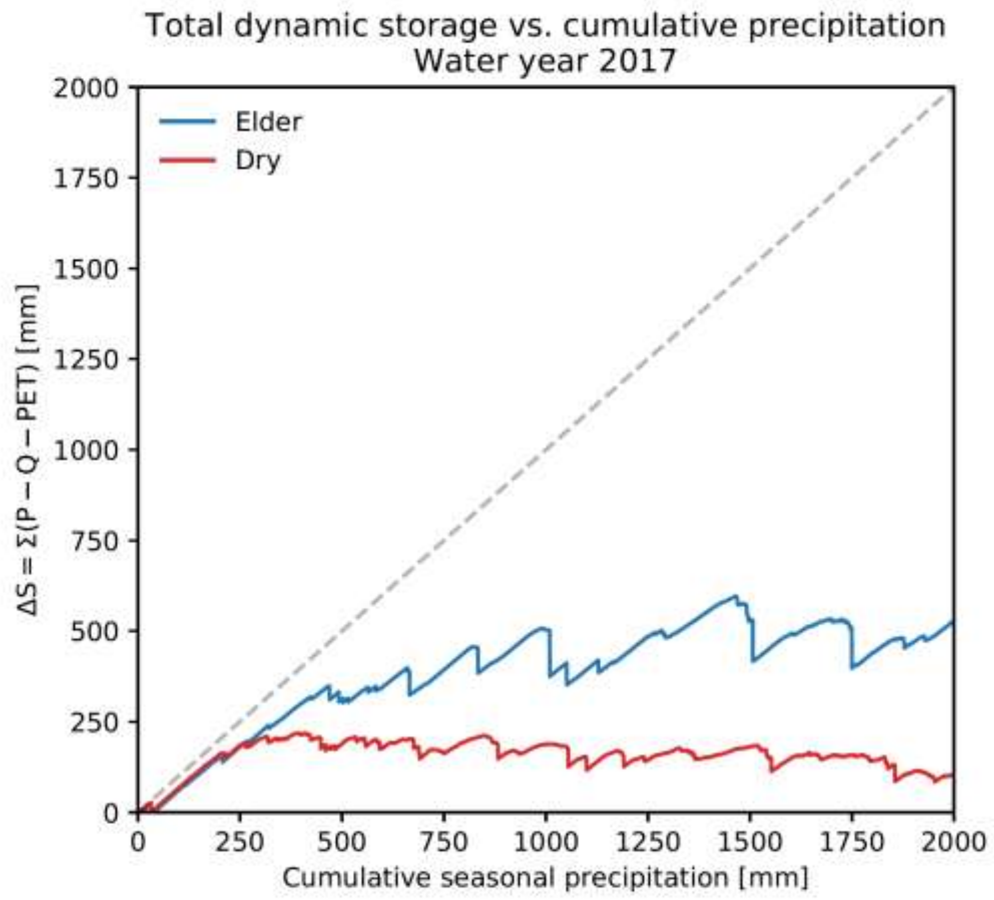
Precipitation variability => variability in water availability…

…right?



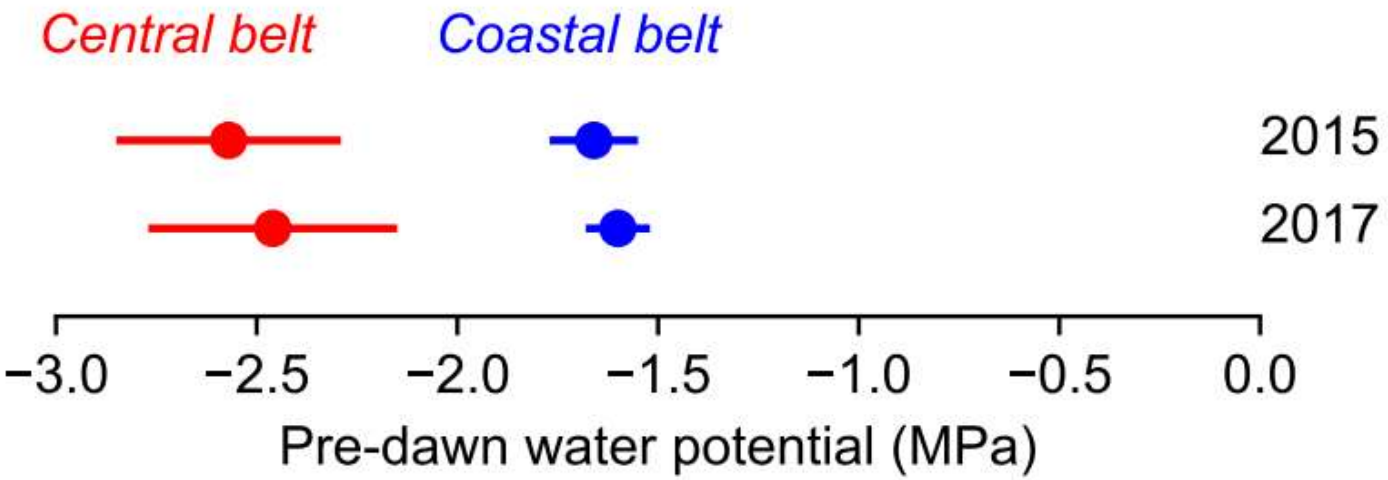
Yet the biogeography of mortality is not entirely explained by reductions in precipitation or increases in temperature…

Clues from the Eel River Critical Zone Observatory: 1: Water storage in catchments and hillslope increases then plateaus with increasing rainfall



Hahm, Dralle, Rempe et al. (in rev.)

2: Plants have indistinguishable end-of-summer water status between years with different rainfall



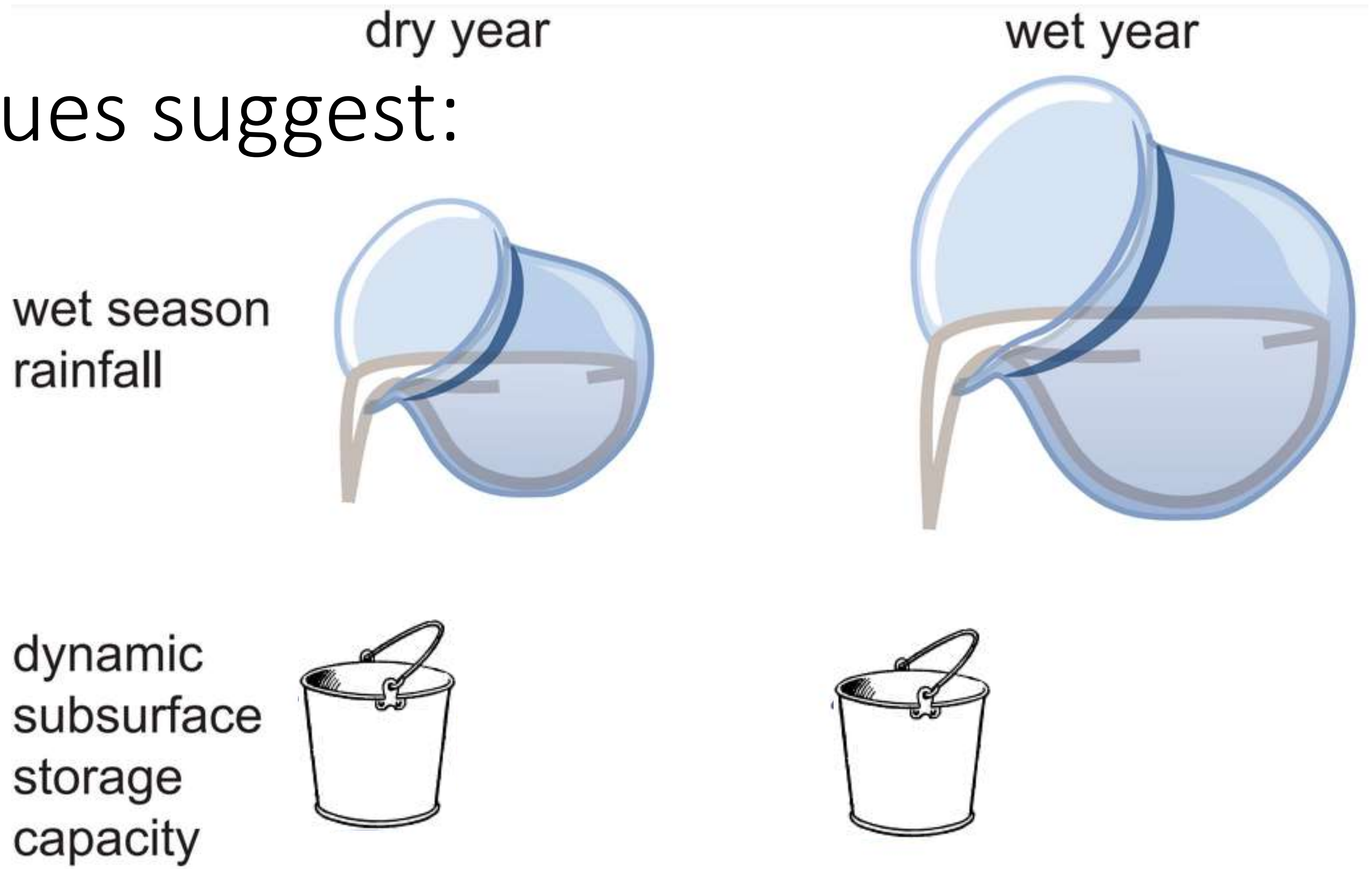
~1600 mm rainfall

~3500 mm rainfall

Hahm, Dralle, Rempe et al. (in rev.)

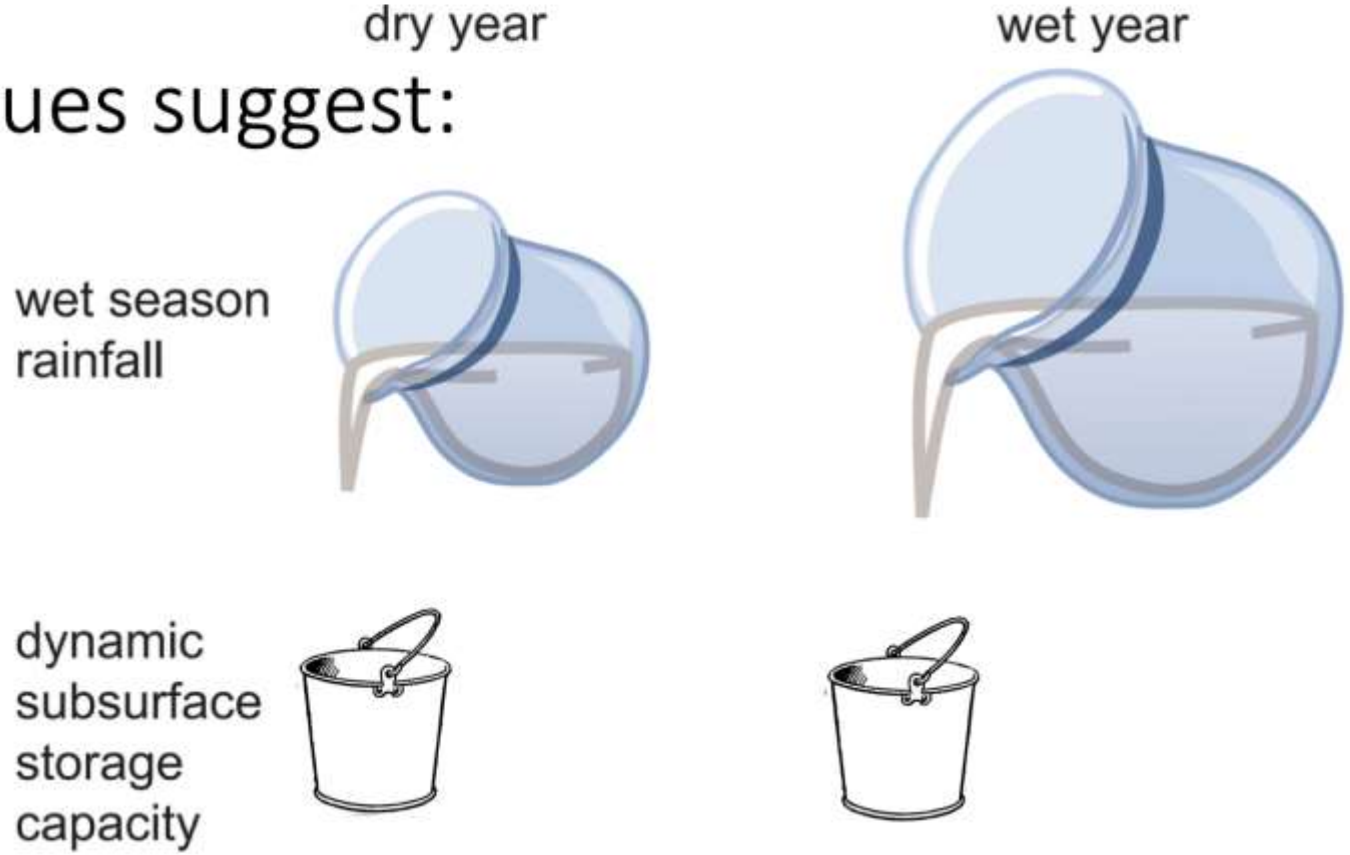

3. Negligible drought mortality

These clues suggest:



Storage capacity replenished in both wet and dry years → common summer water availability

These clues suggest:



Storage capacity replenished in both wet and dry years → common summer water availability

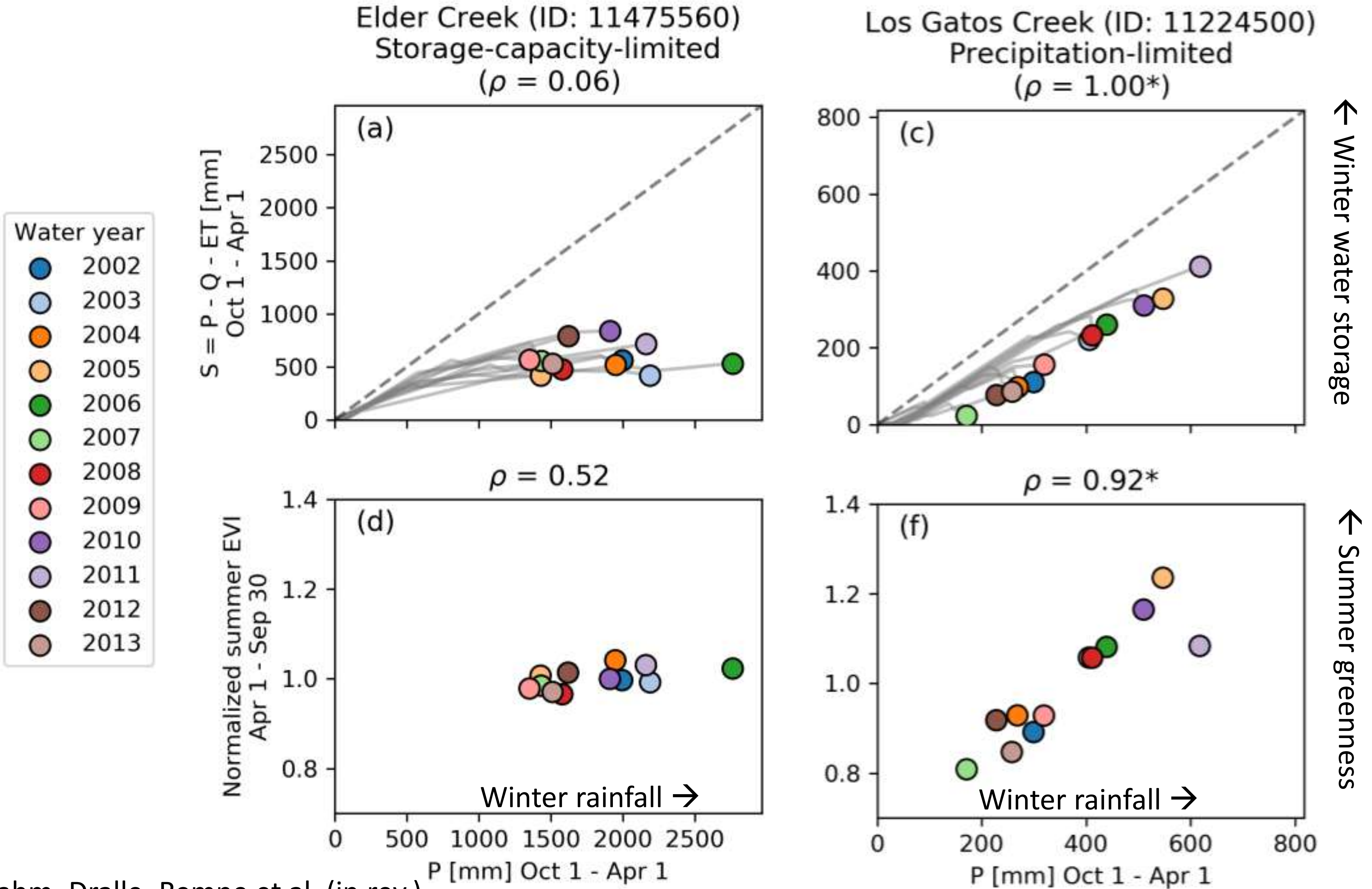
Exploring ‘storage capacity limitation’

- Track water fluxes in all gauged Mediterranean North American catchments without dams, diversions, disturbance, or snow

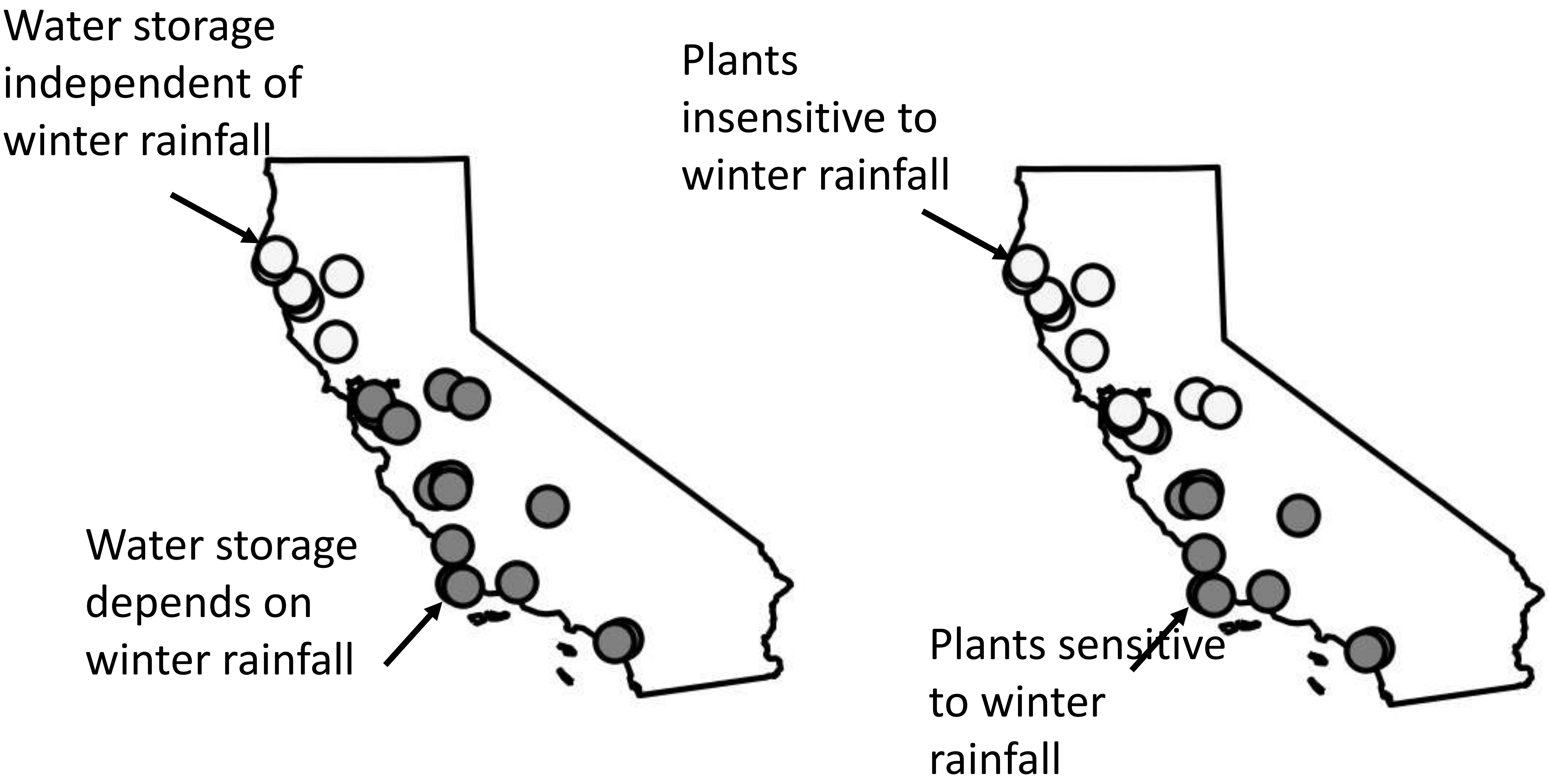
- test the hypothesis that:

  -*if* storage is independent of rainfall (diagnostic of storage-capacity limitation)

  -*then* summer plant productivity and water use, as measured by the enhanced vegetation index (EVI), are also uncorrelated with precipitation.



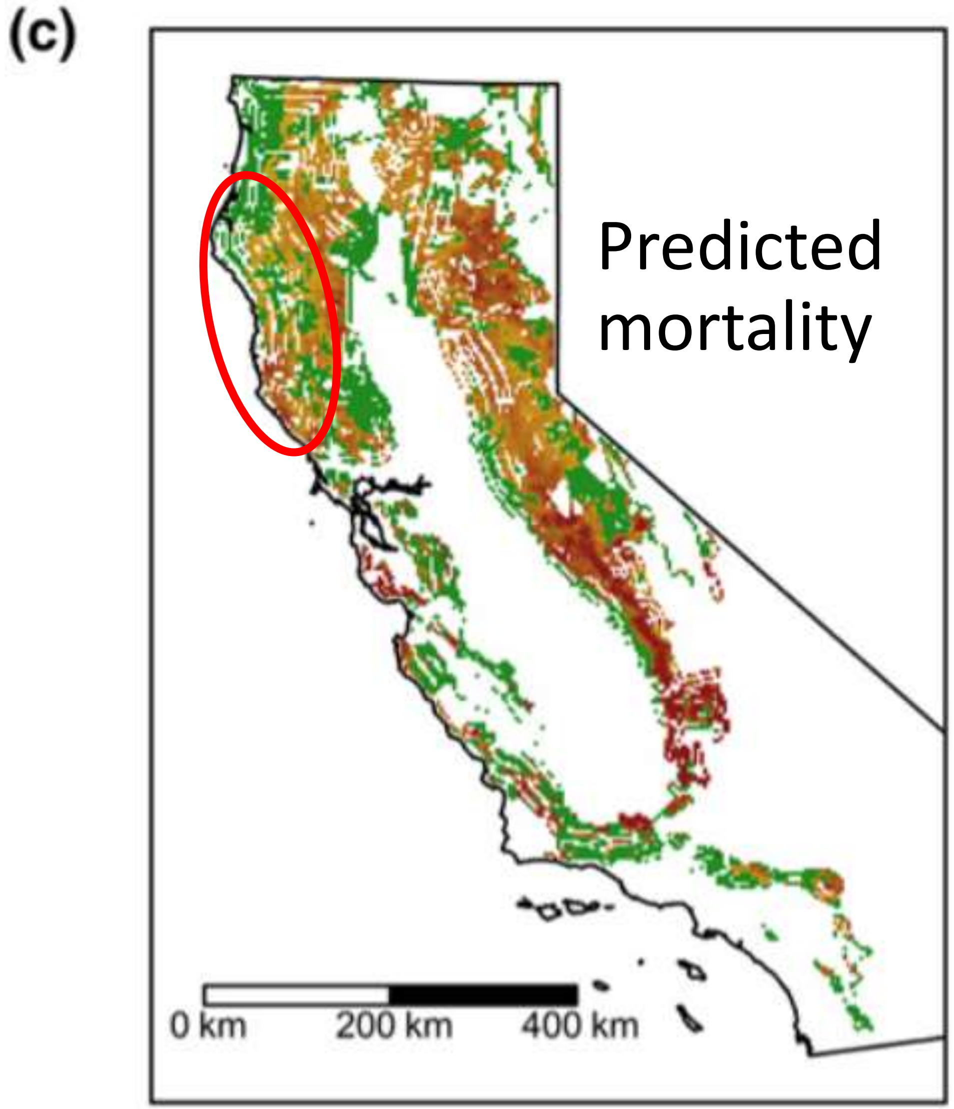
Hahm, Dralle, Rempe et al. (in rev.)

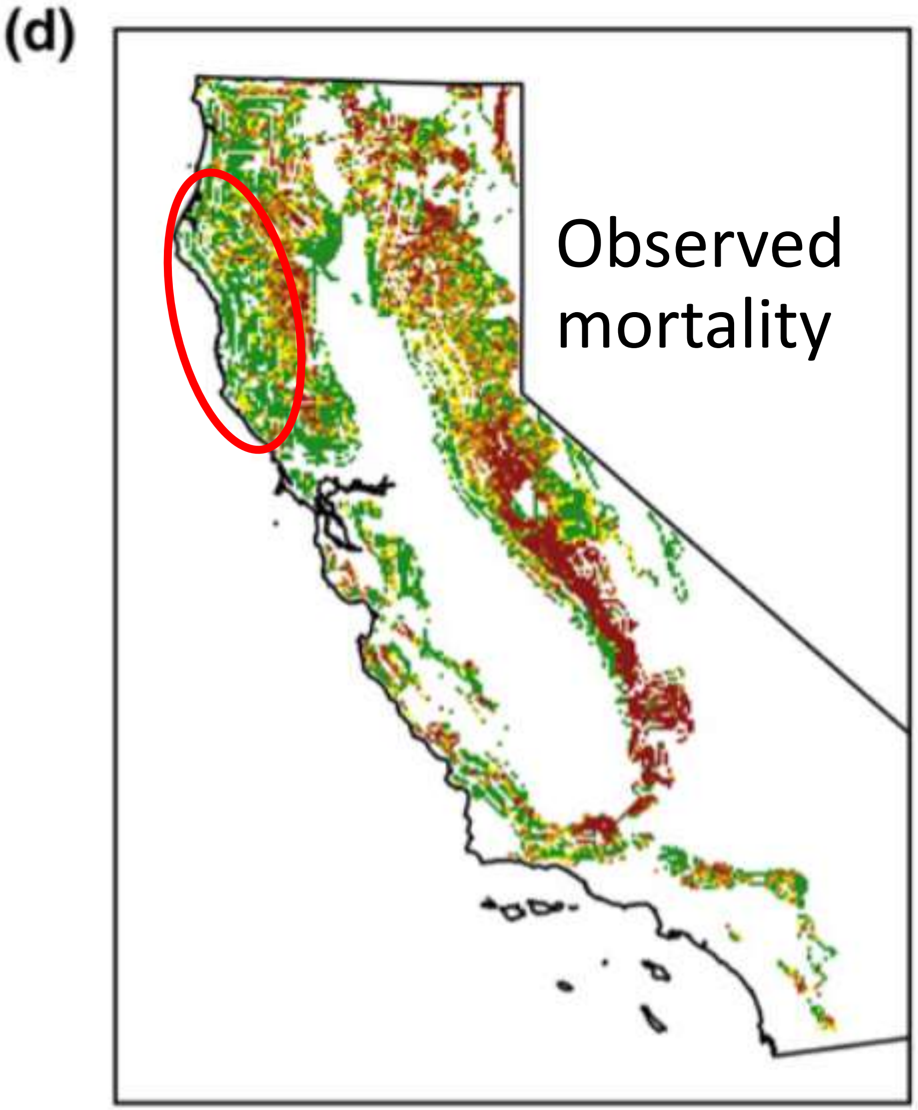


Hahm, Dralle, Rempe et al. (in rev.)

Ecology Letters, (2017) **20**: 78–86 Young et al. doi: 10.1111/ele.12711

Long-term climate and competition explain forest mortality patterns under extreme drought





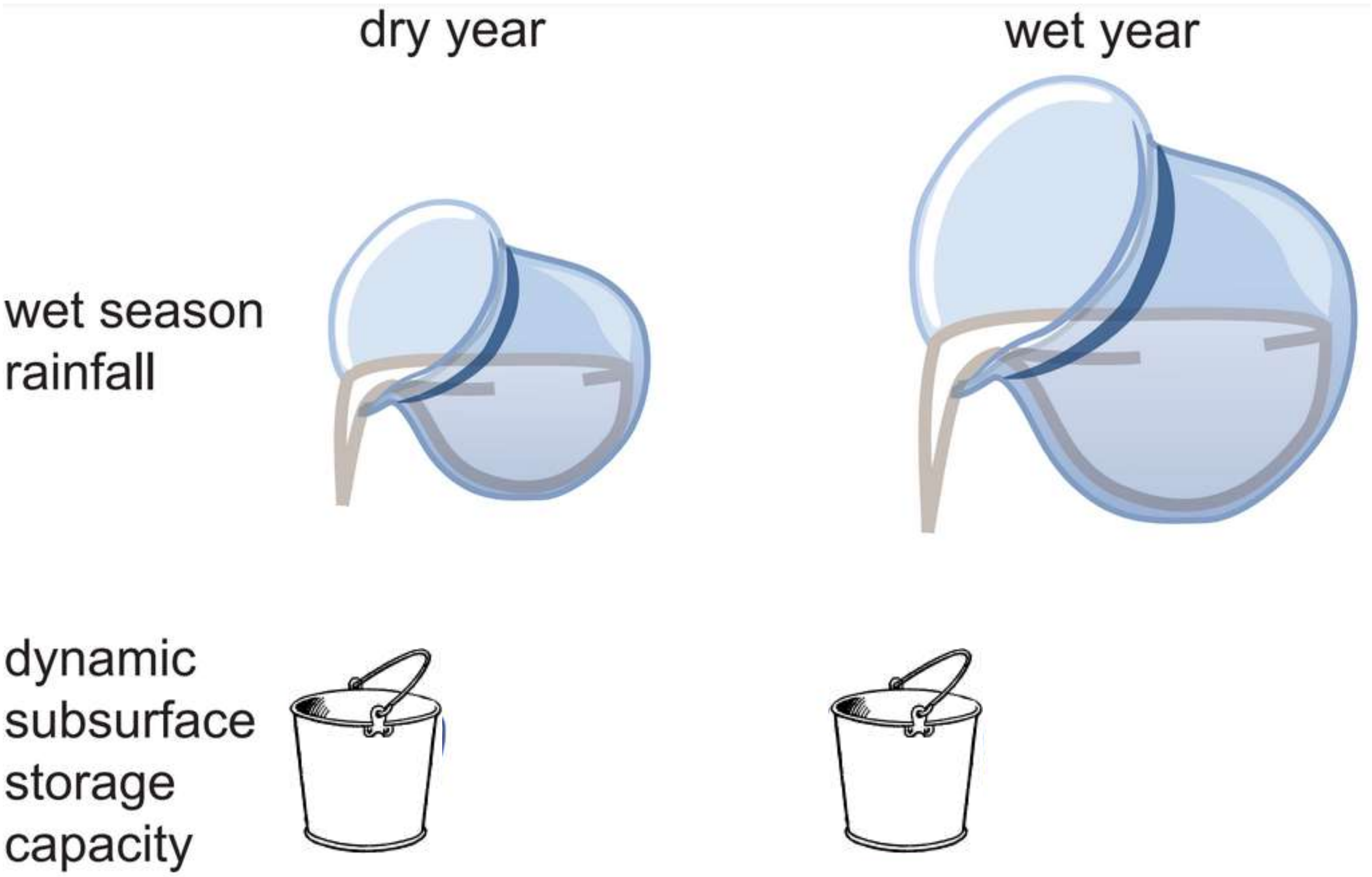
Drought resilience across US Mediterranean catchments mediated by storage capacity

- Contrary to common belief, greater water storage capacity does *not* necessarily shield plants from drought! *Less can be more*

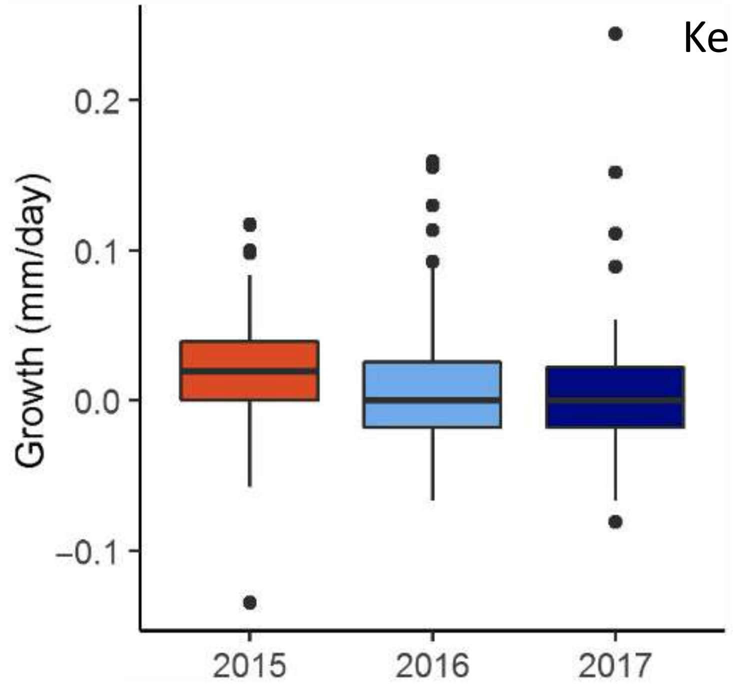
- Detectable without *a priori* knowledge of storage capacity; maps of soil water storage capacity insufficient

- Switch from snow to rain as mountains warm will result in more widespread storage-capacity limitation

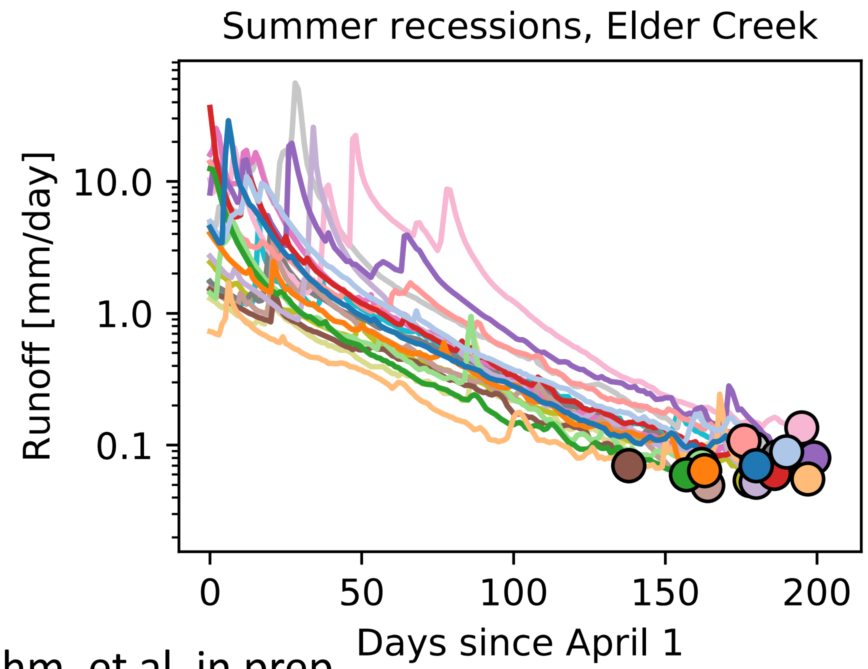
Implications for salmonids?

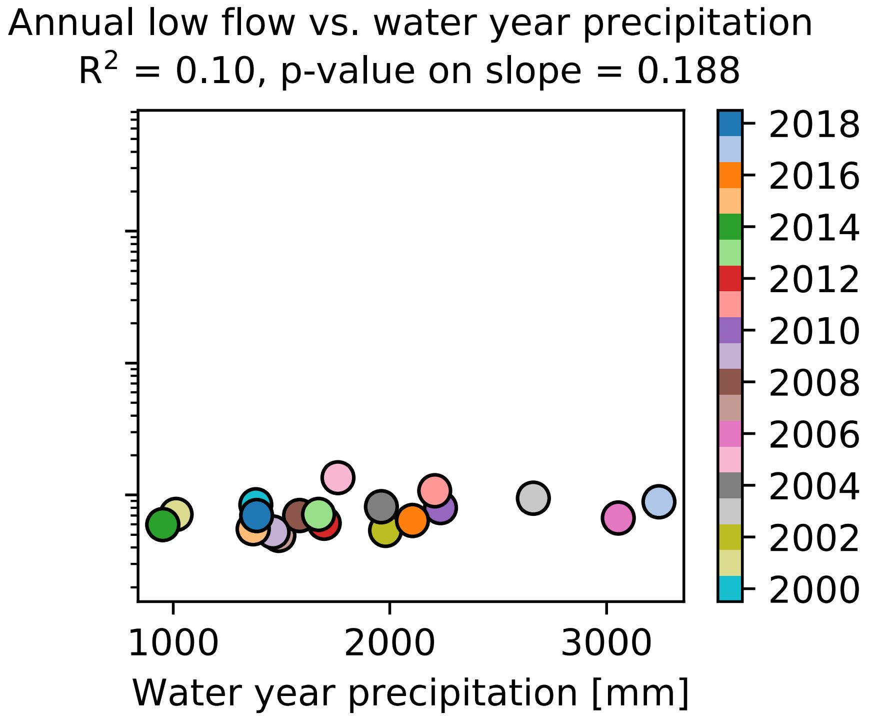


Kelson and Carlson, Ecosphere, 2019



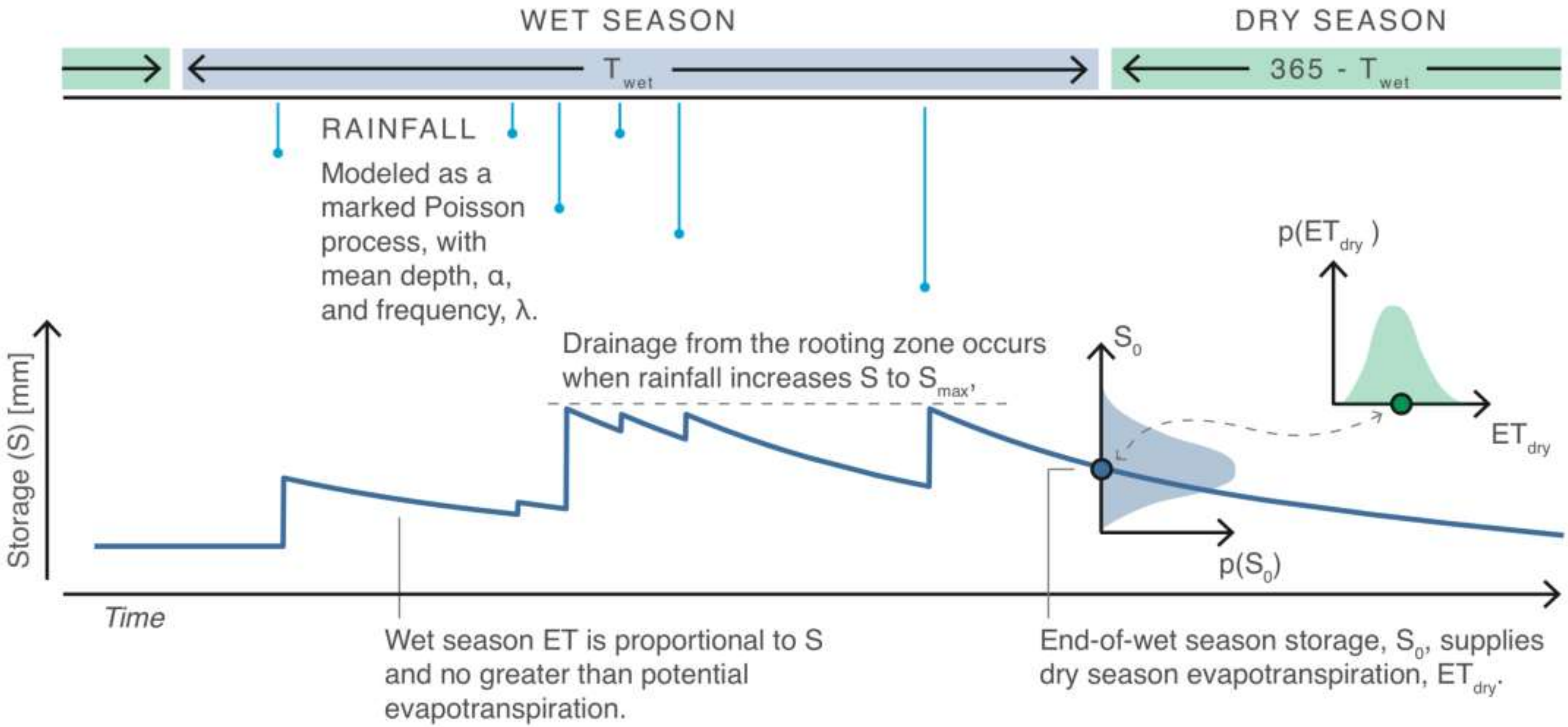
O. mykiss summer growth rates did not vary despite highly variable precipitation





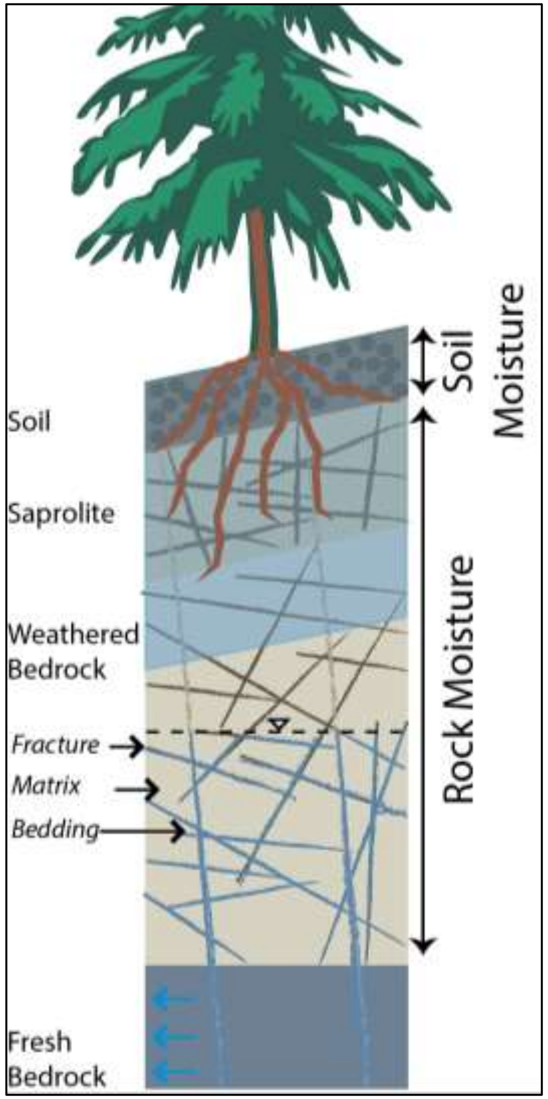
Rempe, Dralle, Hahm, et al, in prep

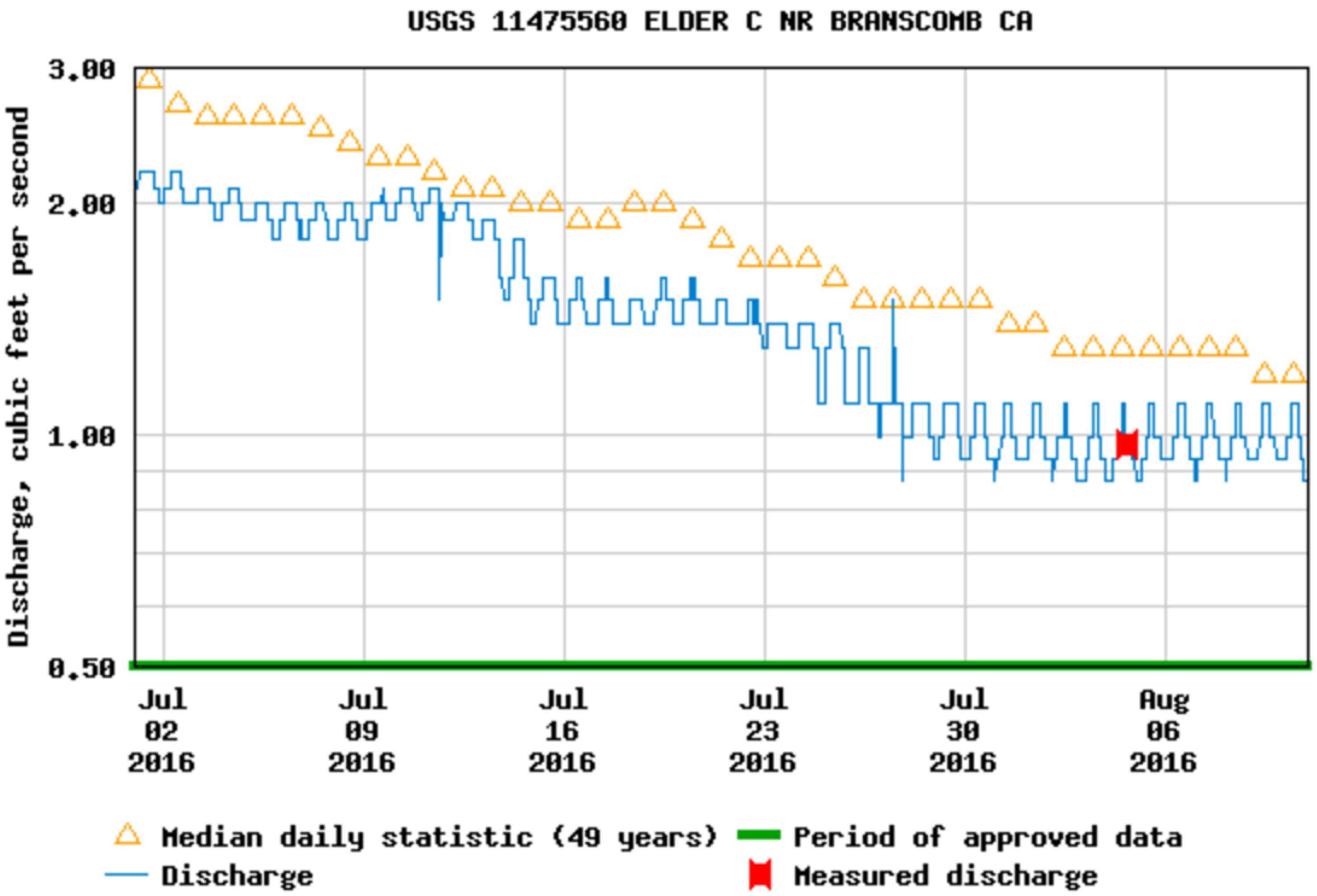
Outstanding questions: The role of *intra*-annual variability



Dralle, Hahm, Rempe, in rev.

<u>Outstanding questions</u>: Dry season tree water use and streamflow





Rempe, 2016

<u>Outstanding questions</u>: Mapping storage capacity at large scales

We lack basic information about the extent of the weathered bedrock zone across upland landscapes, in contrast to shallow, near surface soils which are readily measurable.

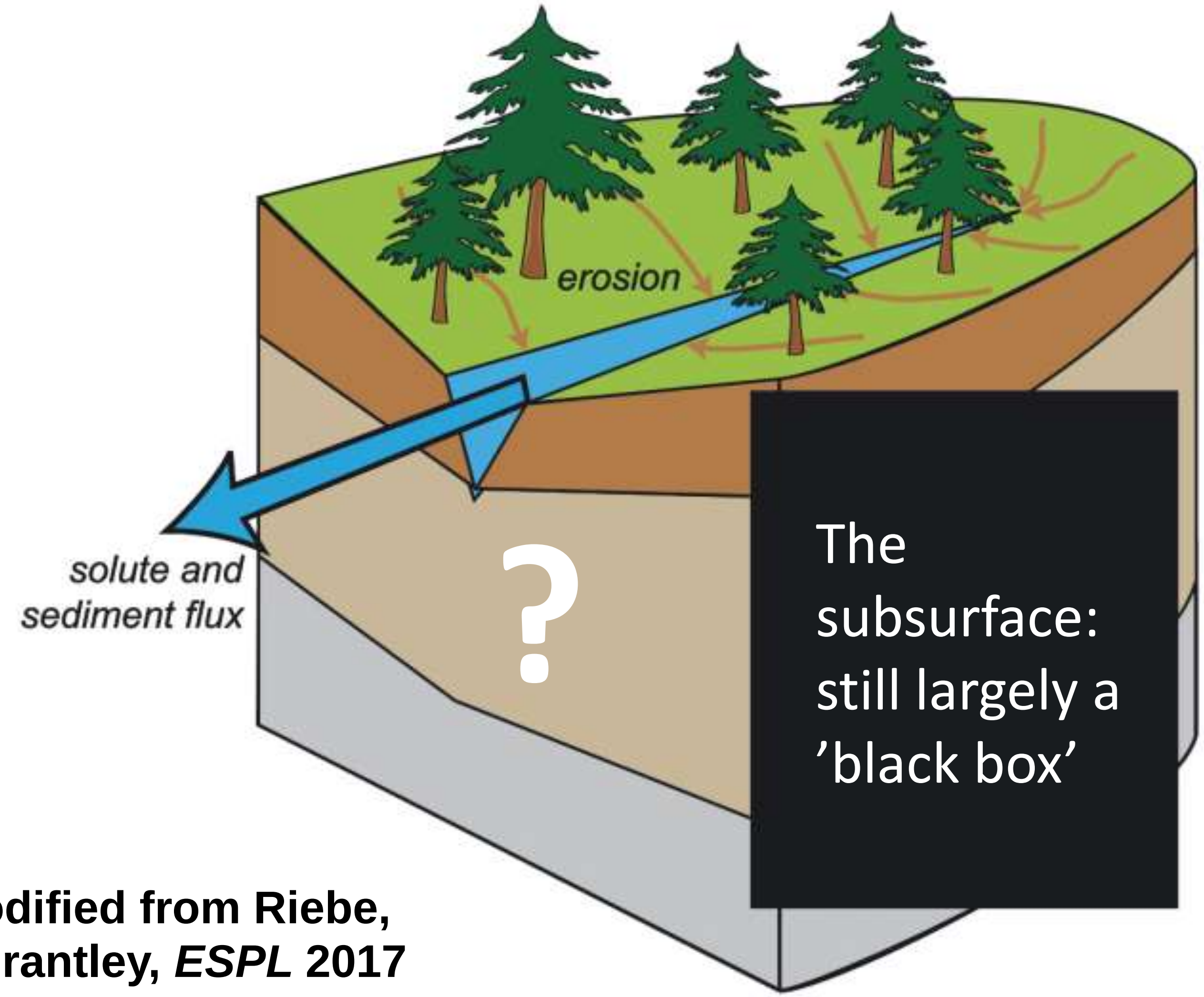


Figure modified from Riebe, Hahm & Brantley, *ESPL* 2017

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