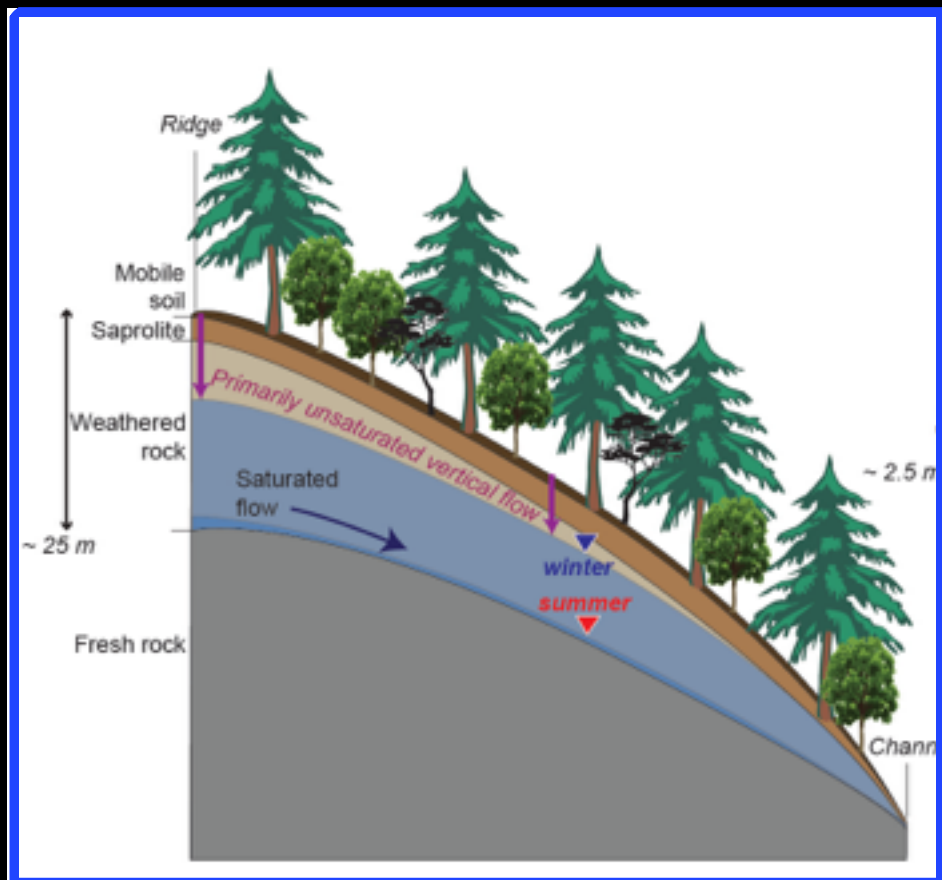
Rock Moisture and Runoff

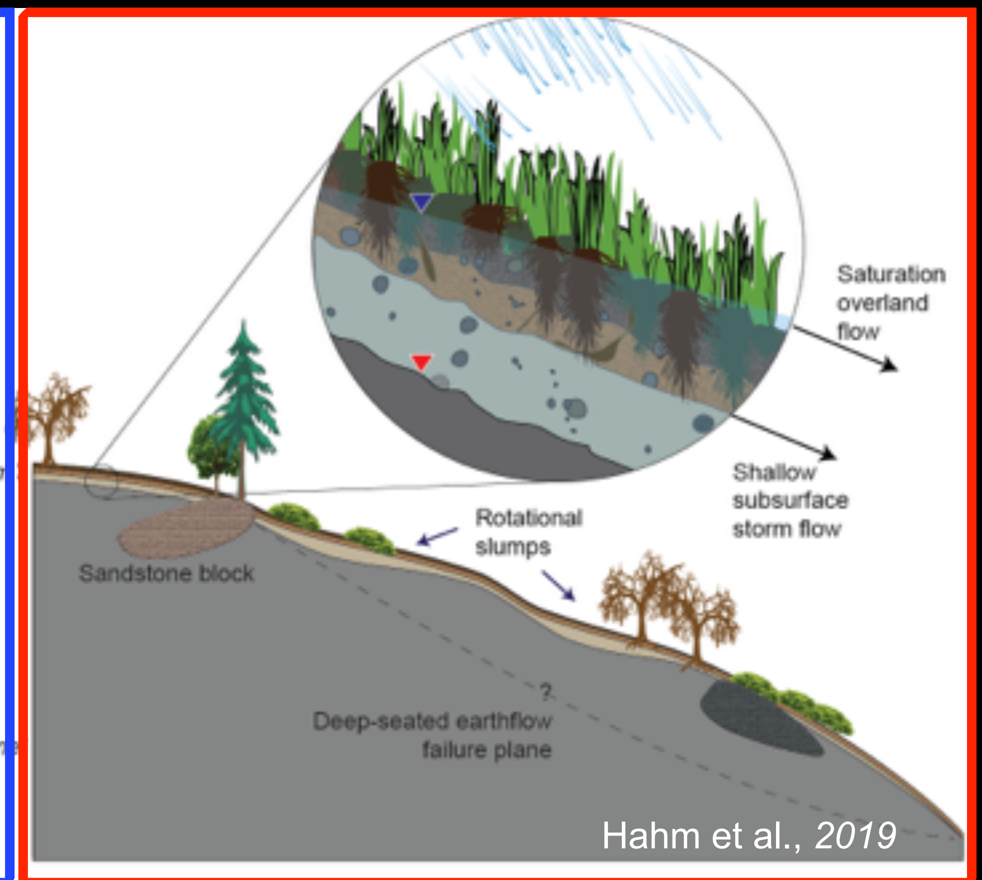
CZO | EEL RIVER CRITICAL ZONE OBSERVATORY

Supported by the National Science Foundation

Coastal Belt



Central Belt



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Assistant Professor, Geology Department, Humboldt State University
SRF Workshop
August 17 2019

Collaborators: Daniella Rempe, David Dralle, Jesse Hahm, Sky Lovill, Todd Dawson, Bill Dietrich

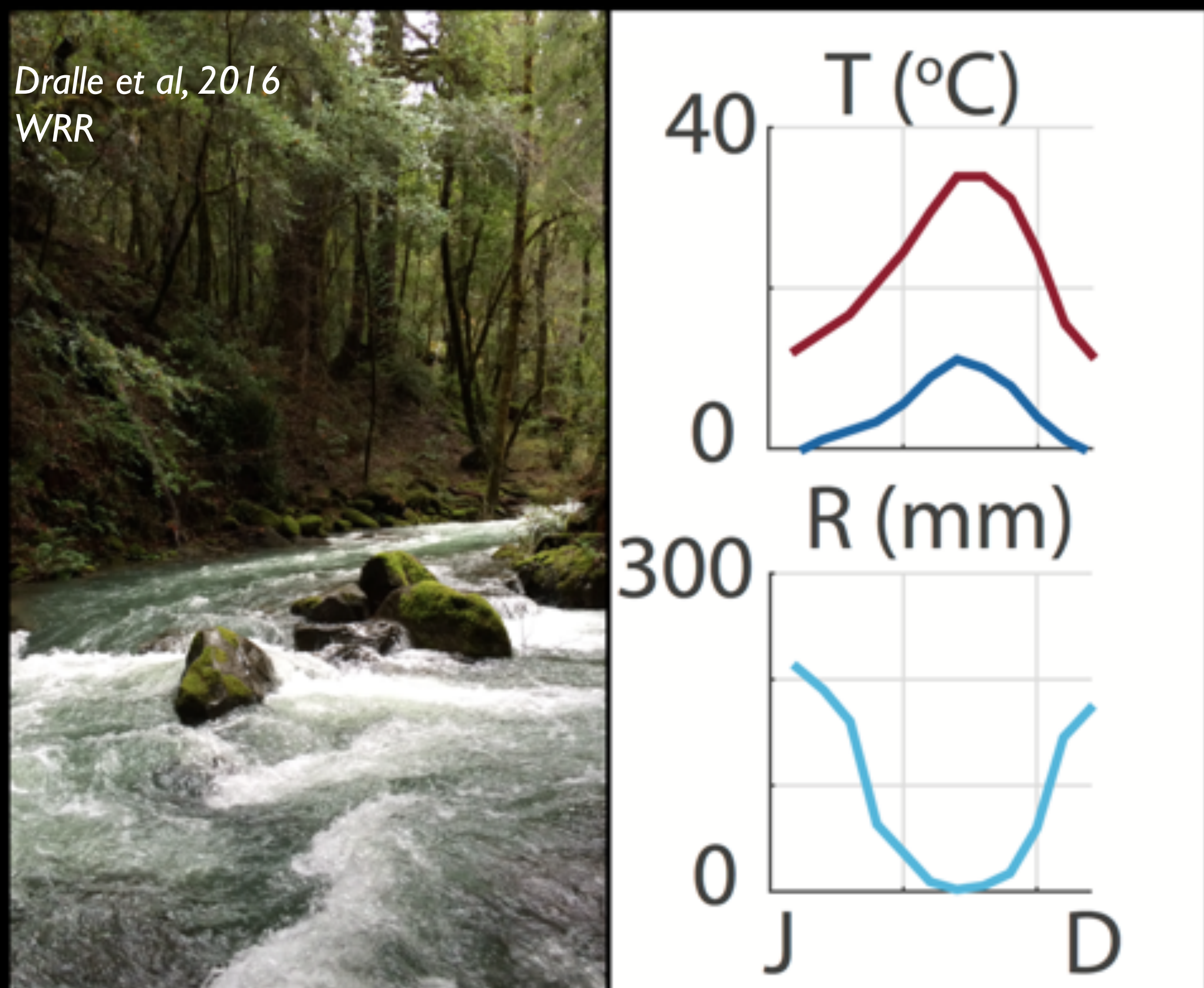
What is Rock Moisture?

Soil Moisture: volume of water/total volume (voids, solids, and water)

Rock Moisture: volume of water/ total volume (voids, solids, and water)

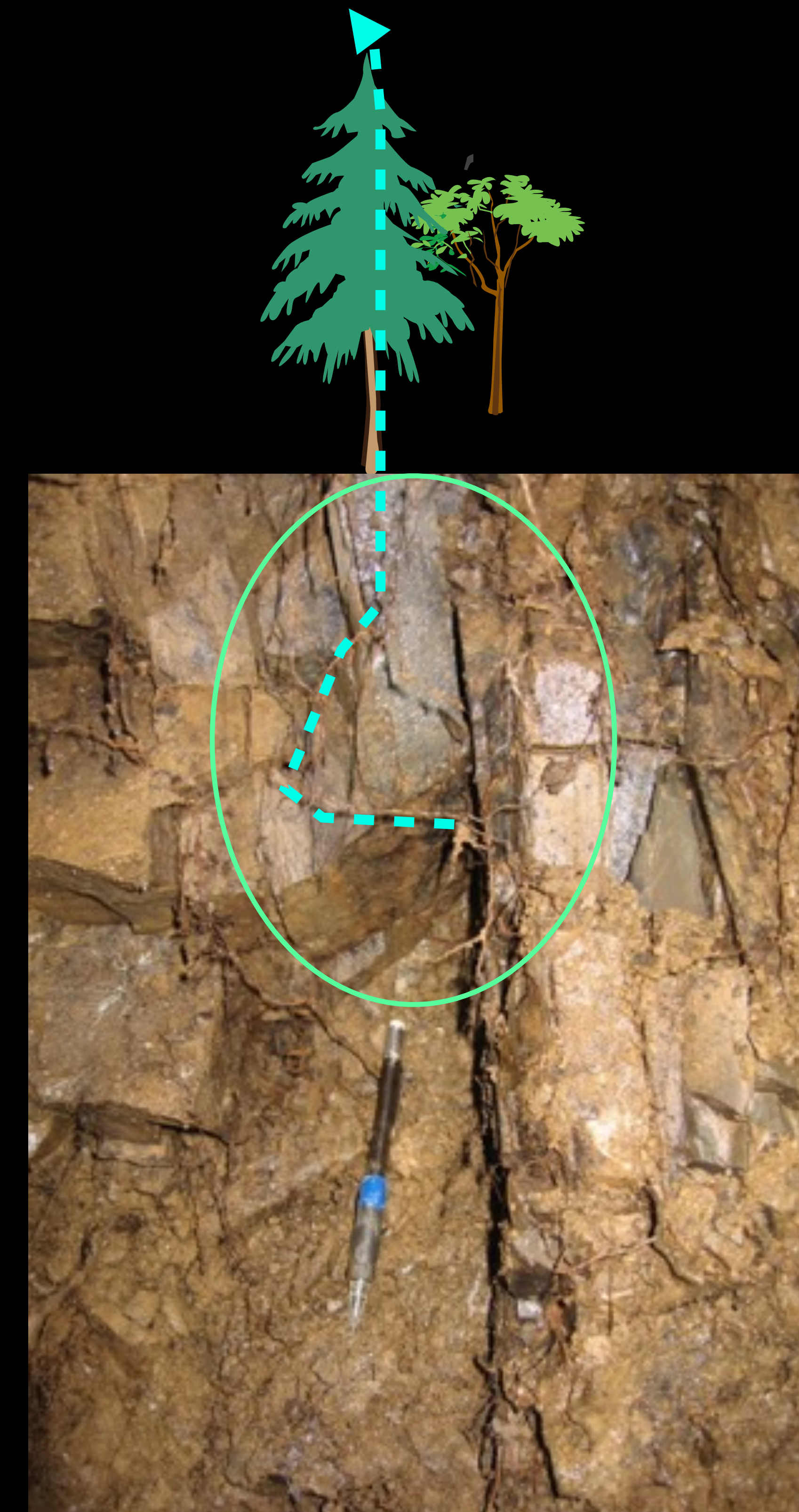
Why does Rock Moisture Matter?

1.Why does Rock Moisture Matter?



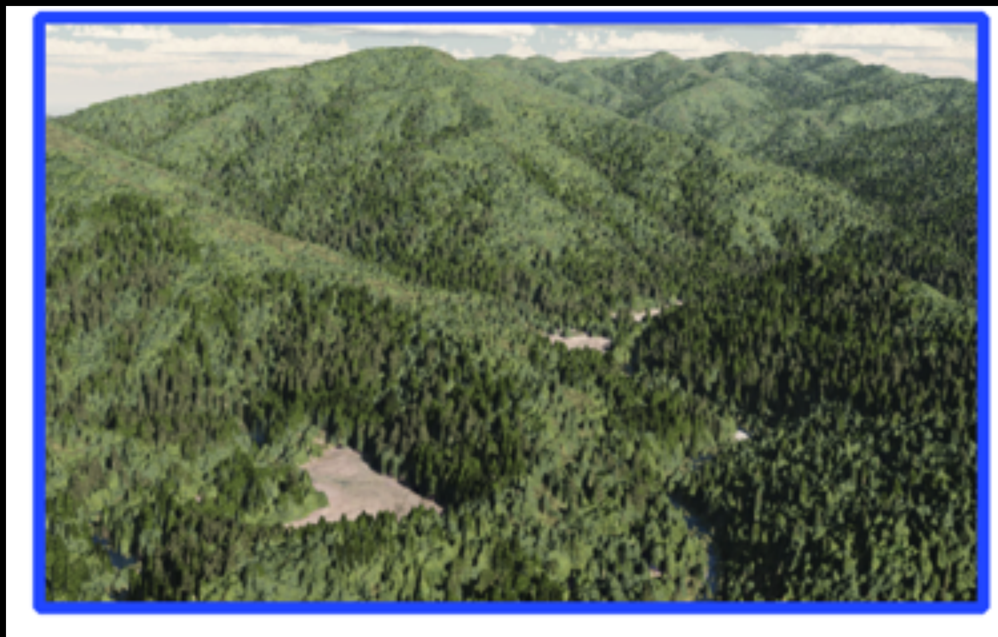
In Mediterranean Climates, moisture demand is out of phase with moisture supply

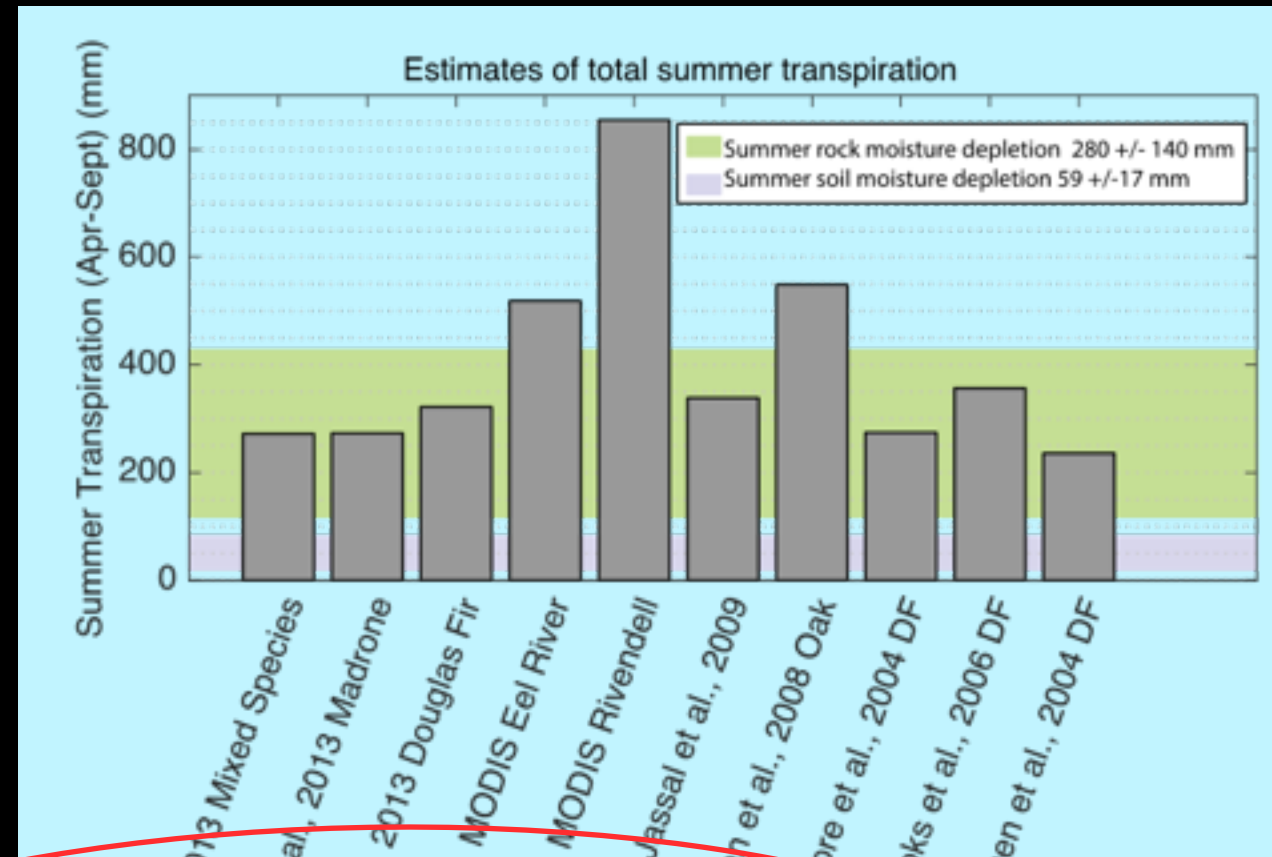
On hillslopes with relatively thin soils (<0.75 m), where do trees get their water?

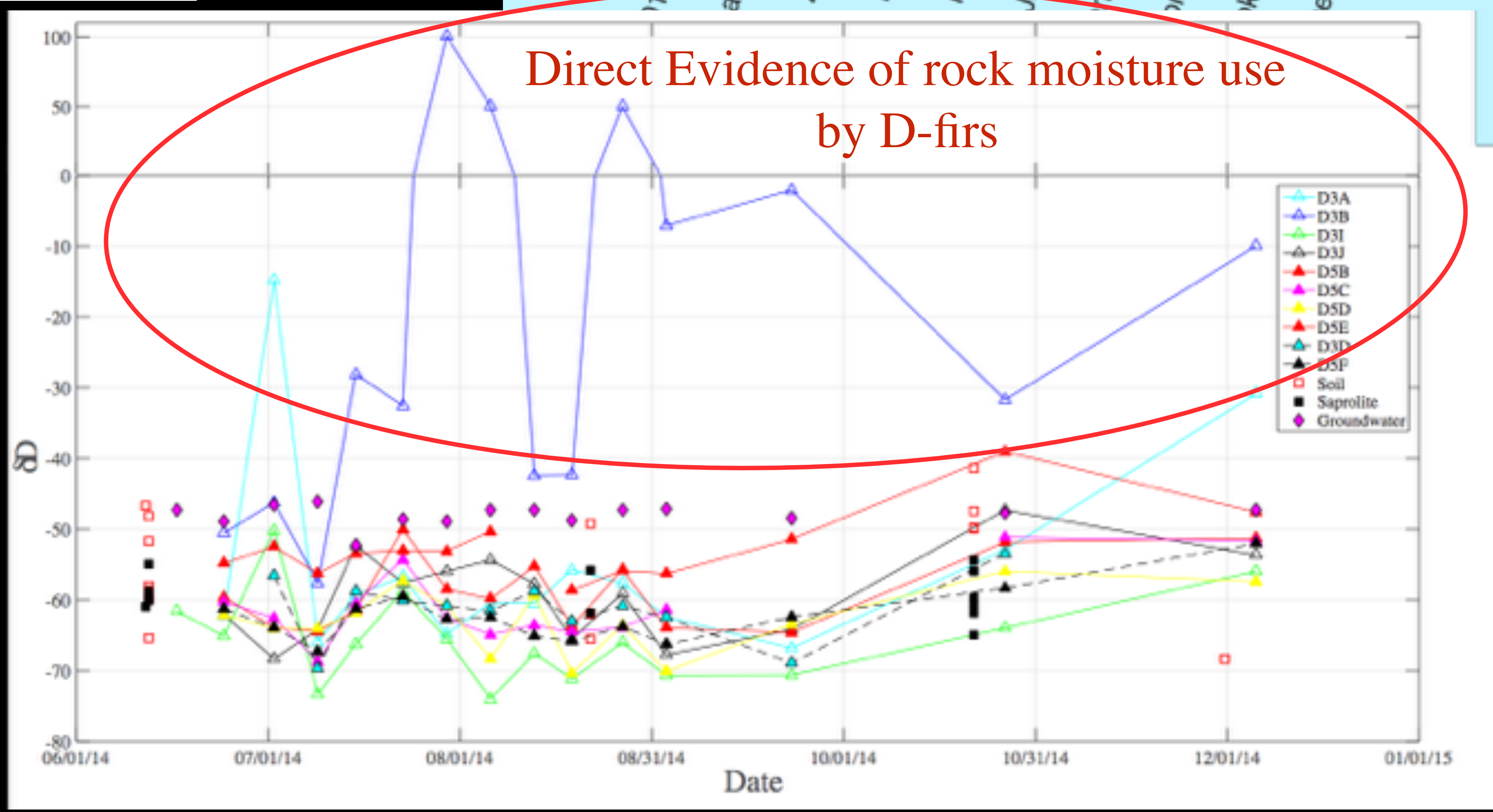


1.Why does Rock Moisture Matter?

Coastal Belt - Elder Creek





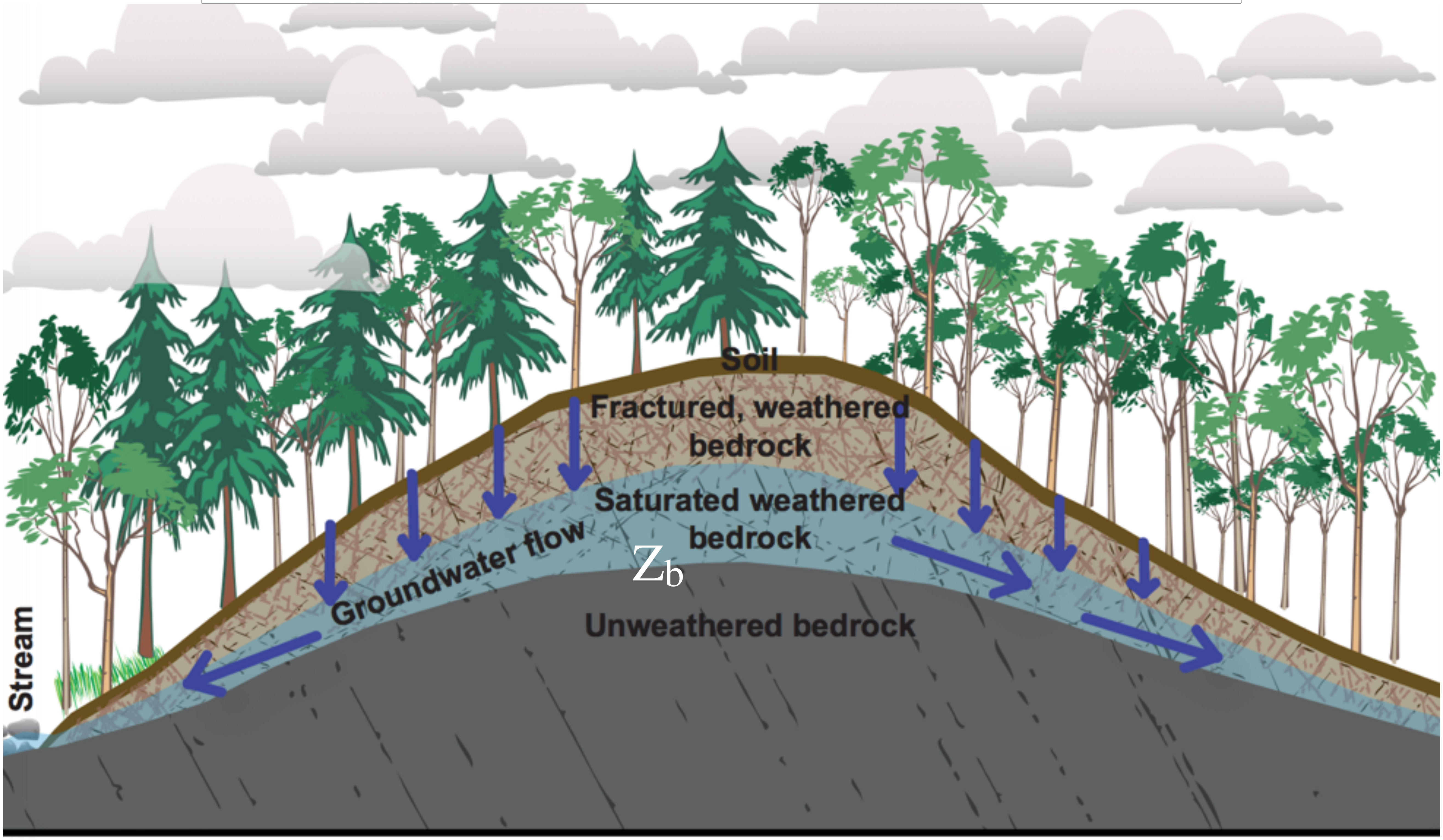


Trees in California Rely on Rock Moisture

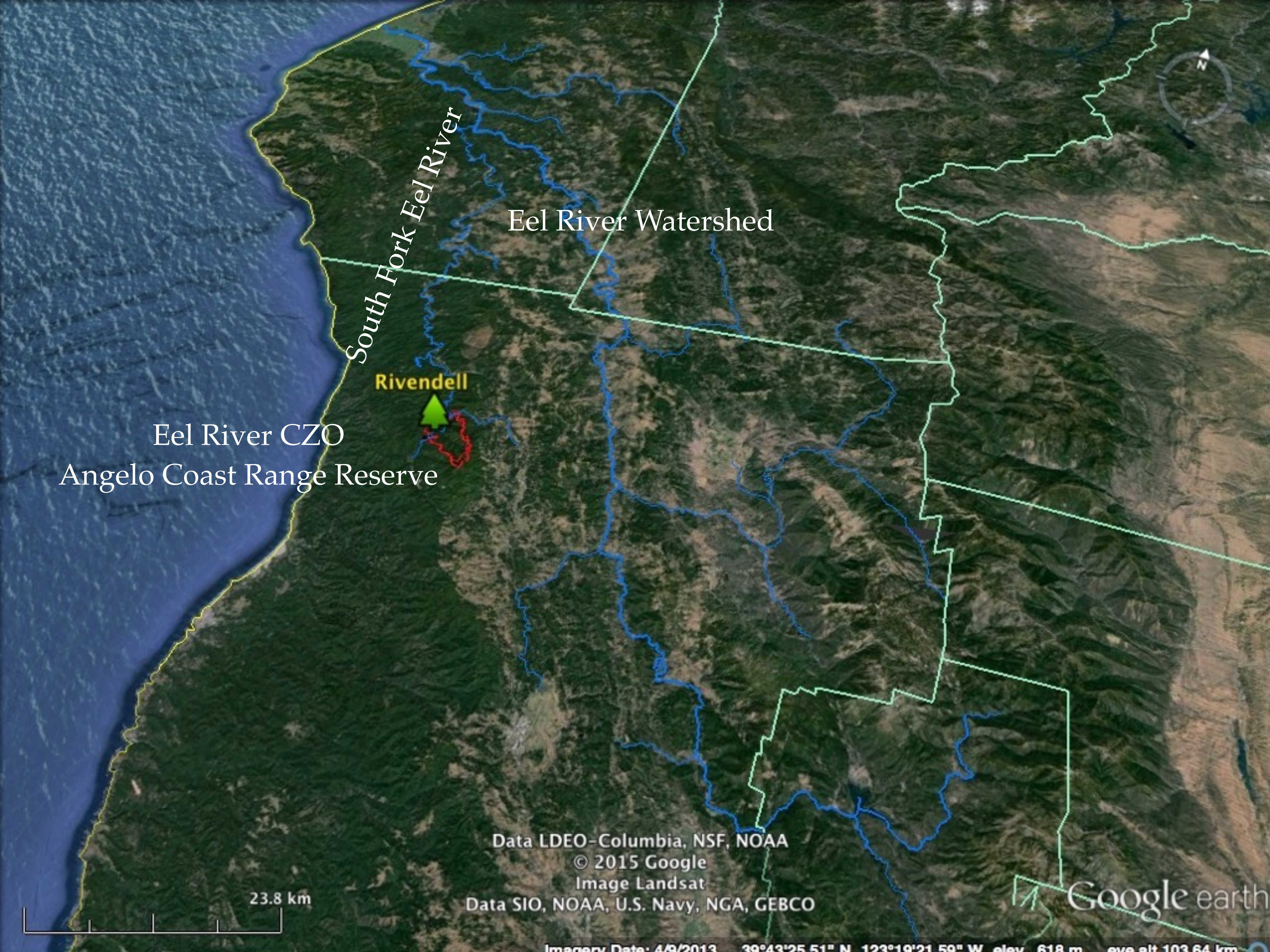
Also, *Jones and Graham*, 1993; *Zwieniecki and Newton*, 1996; *Witty et al.*, 2003; *Rose et al*, 2003

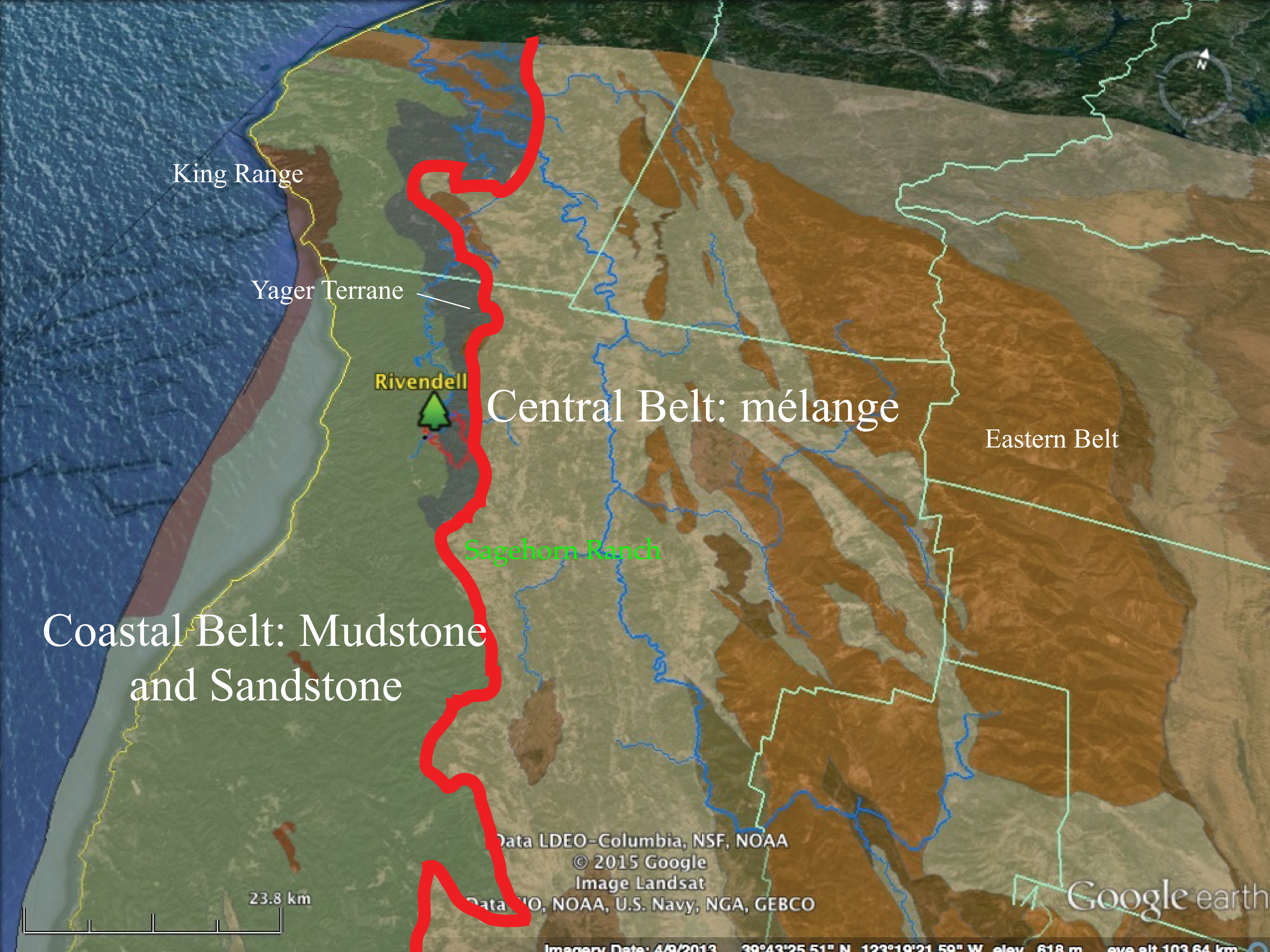
2.Why does Rock Moisture Matter?

Differences in tectonic history lead to differences in Critical Zone Thickness

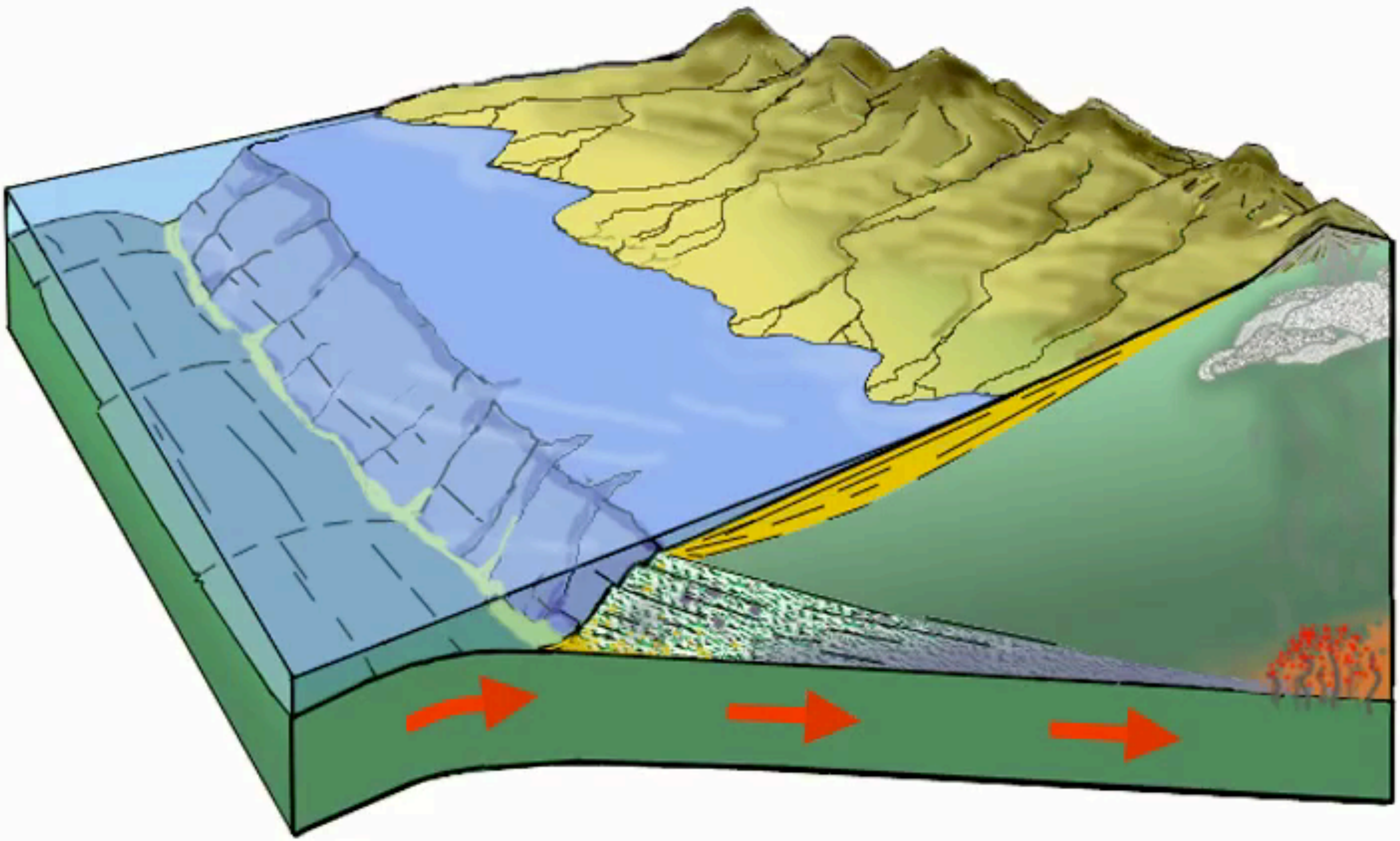


Modified from Rempe


South Fork Eel River
Eel River Watershed
Rivendell
Eel River CZO
Angelo Coast Range Reserve
Data LDEO-Columbia, NSF, NOAA
© 2015 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
23.8 km
Google earth


King Range
Yager Terrane
Rivendell
Central Belt: mélange
Eastern Belt
Sagehorn Ranch
Coastal Belt: Mudstone and Sandstone
Data LDEO-Columbia, NSF, NOAA
© 2015 Google
Image Landsat
23.8 km
Google earth

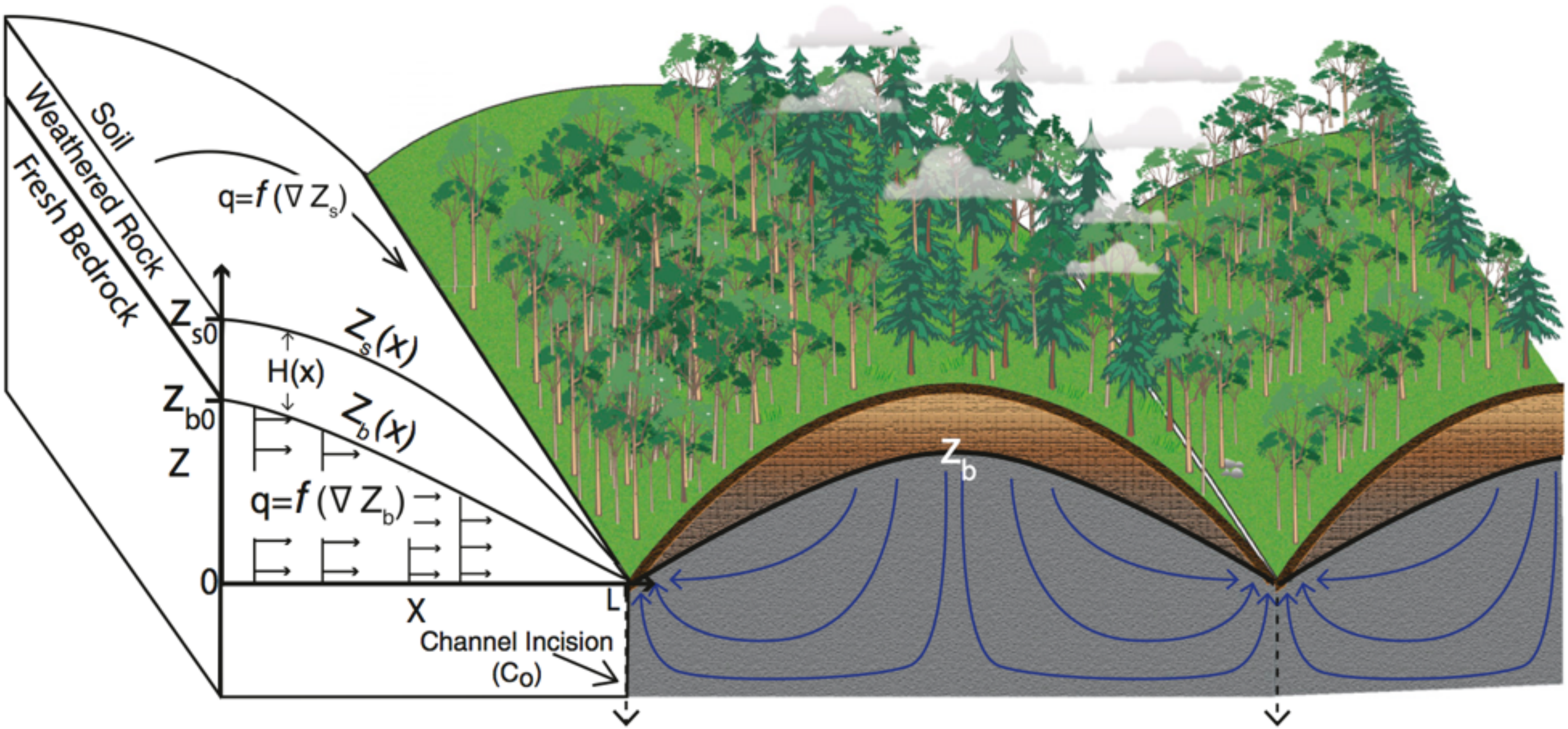
Subduction Zone and the History of Central Belt and Coastal Belt



Atwater

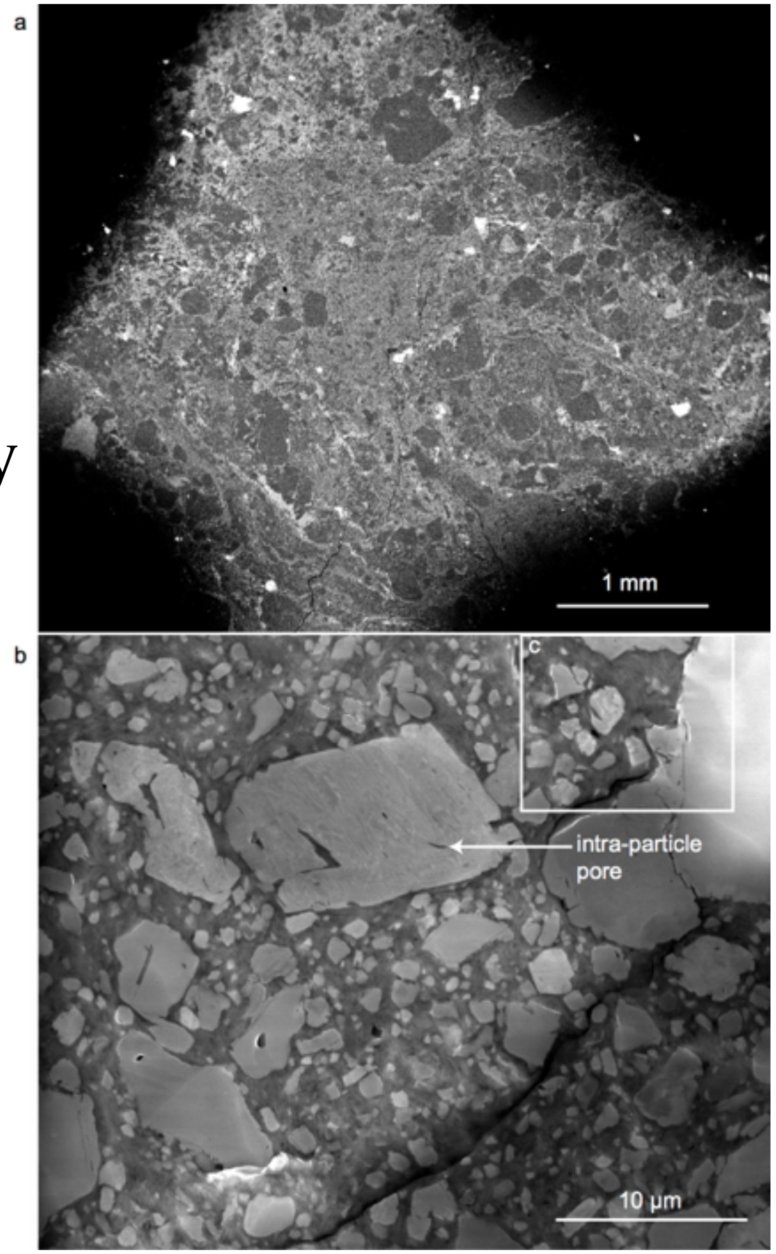
How does the critical zone develop?

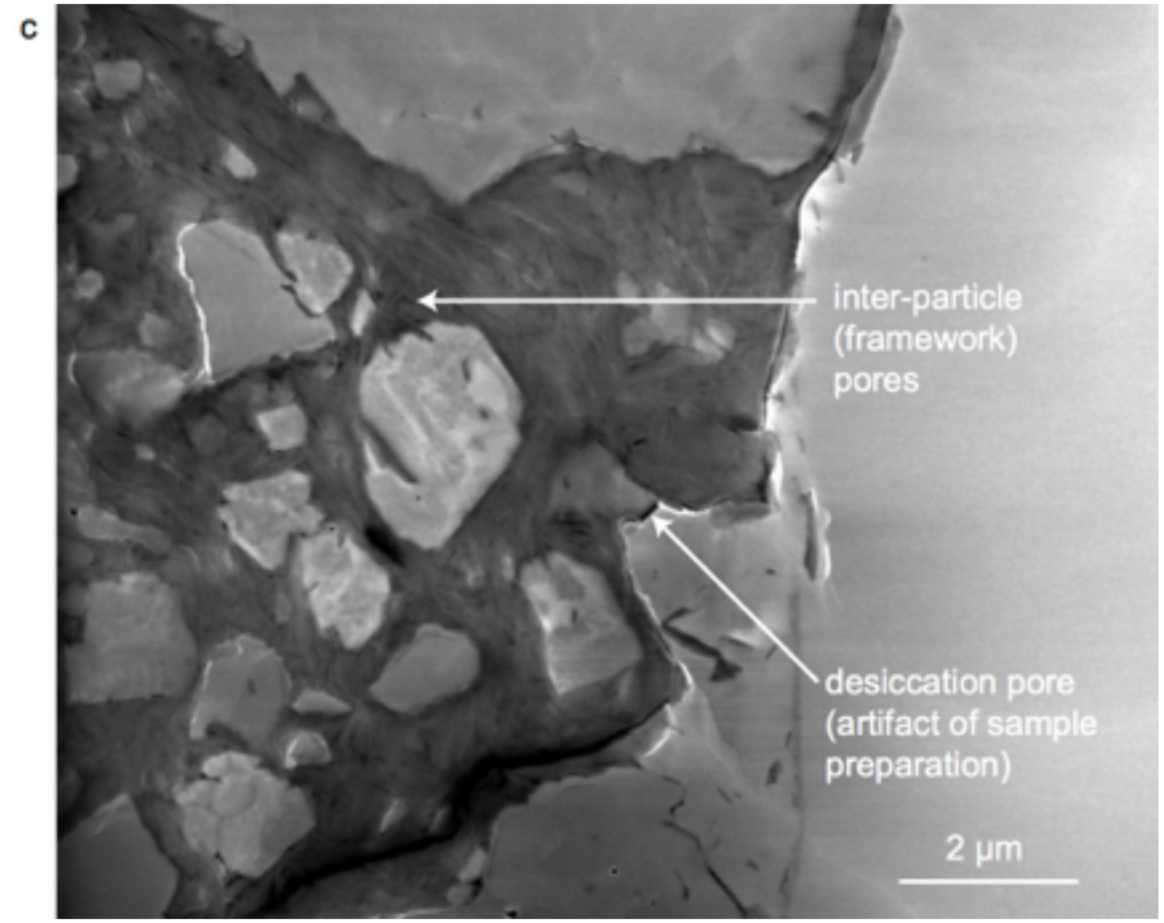
A bottom-up control on fresh-bedrock topography under landscapes



Rempe and Dietrich, PNAS, 2014

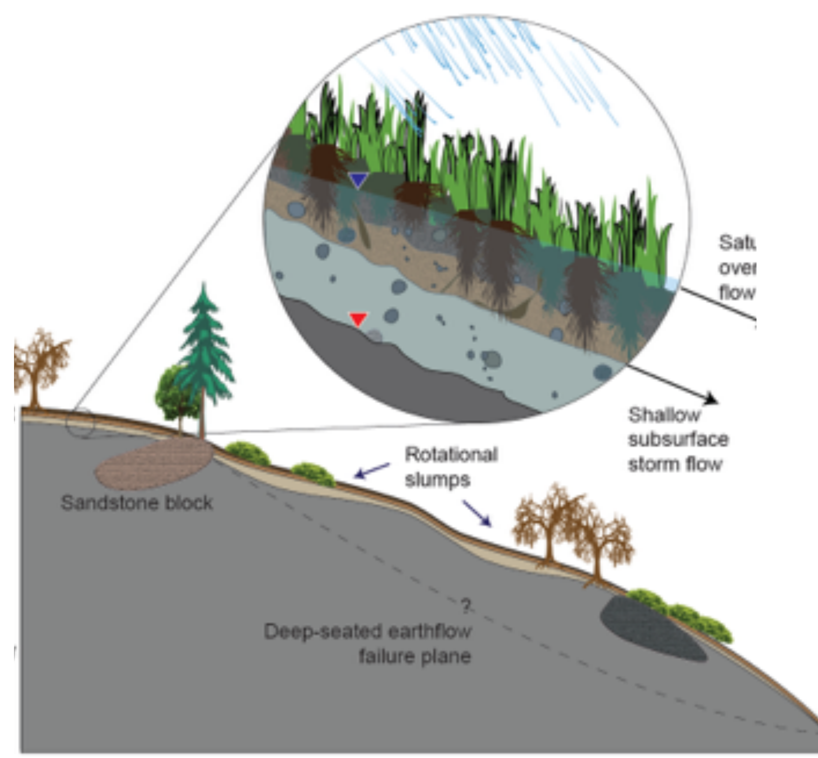
Important control on drainage of fresh rock is permeability, which can vary by many orders of magnitude in rocks.

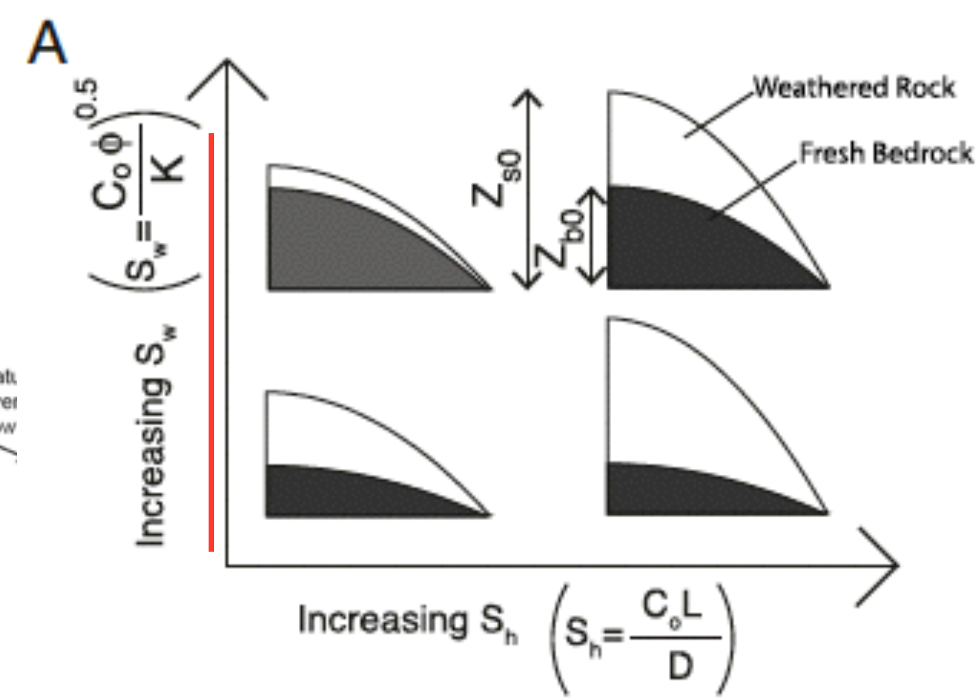




Central belt melange matrix has extremely limited intrinisic porosity, very low permeability

K_{fresh} is smaller below Z_b in Central Belt than in Coastal Belt





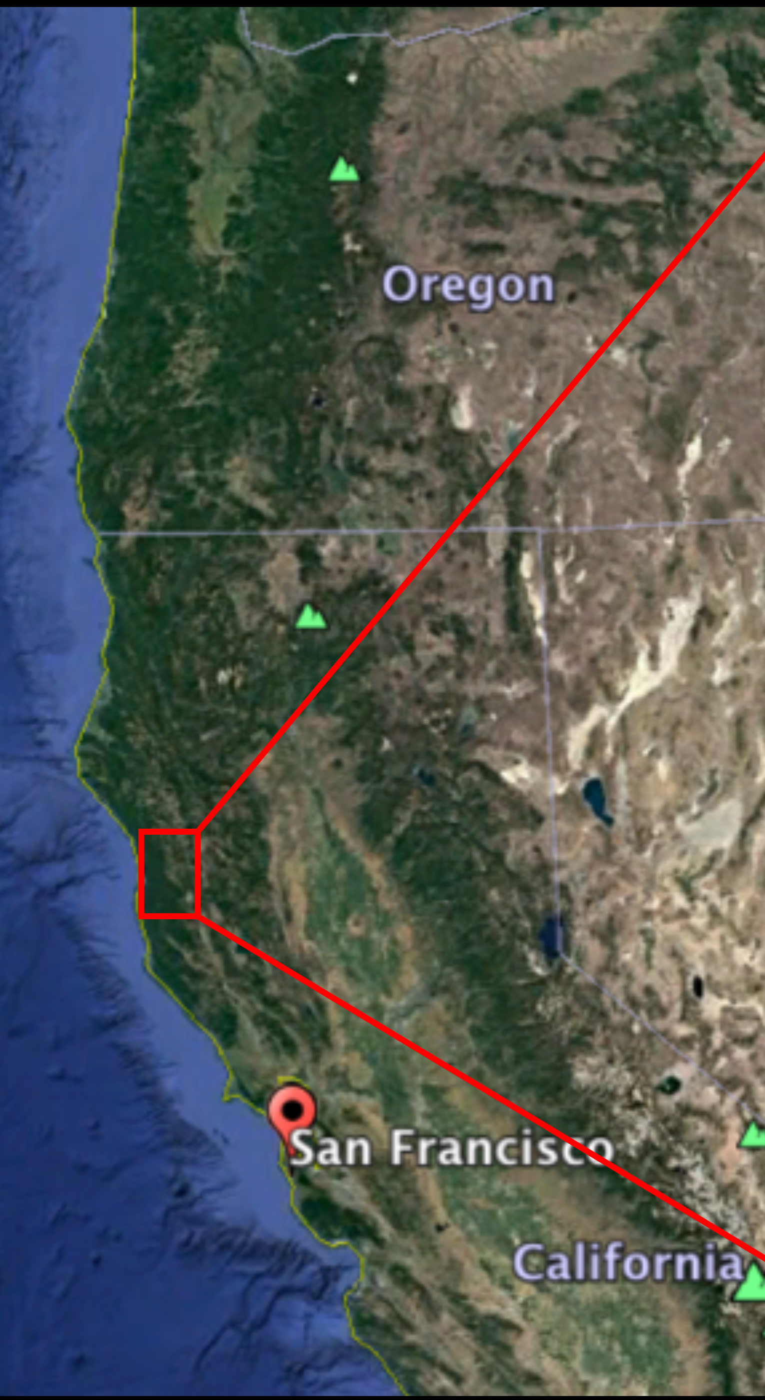
Lower K_{fresh}, Z_b closer to surface, thinner critical zone

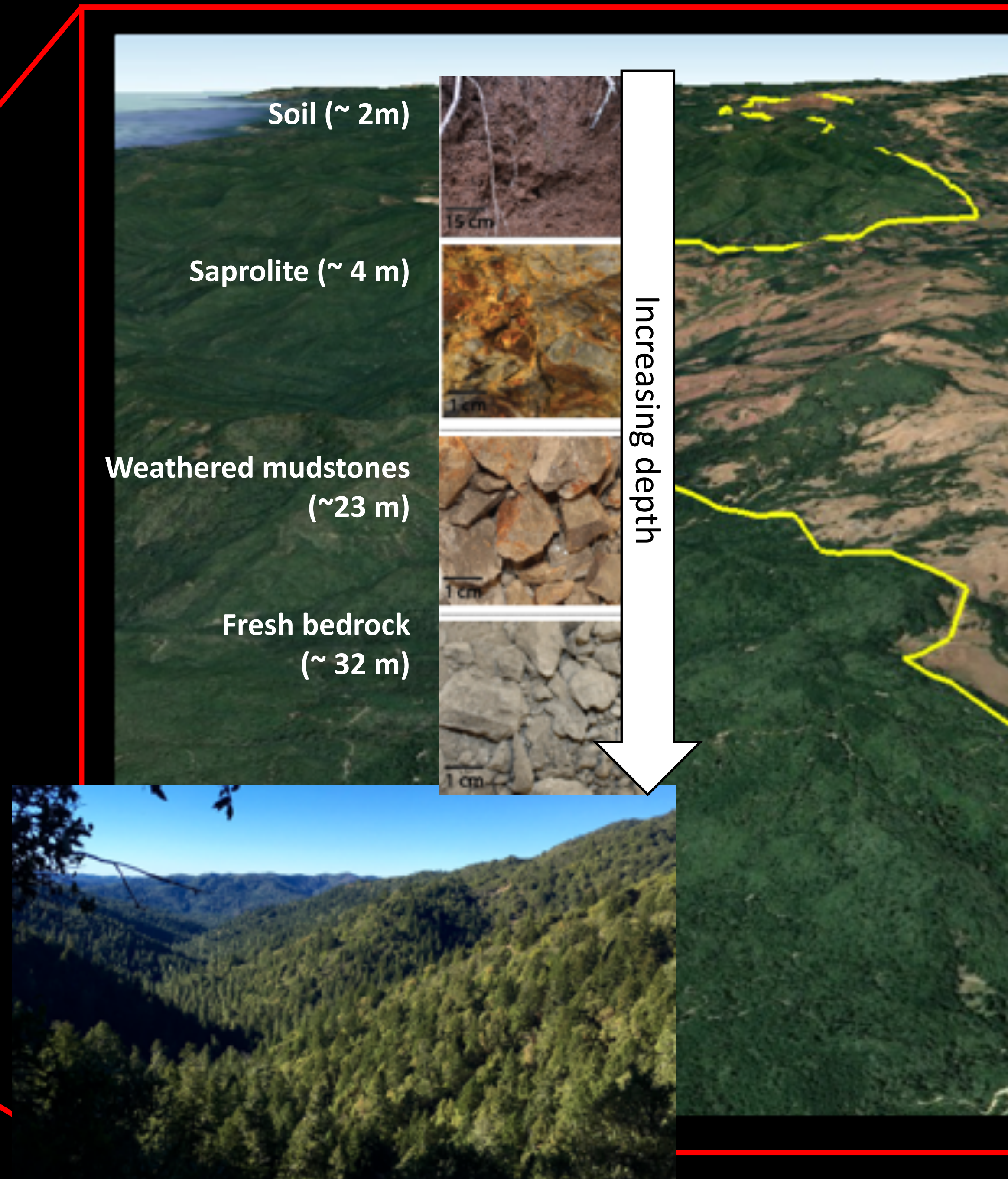
Hahm, Rempe, Dietrich 2017

Tectonic history controls Critical Zone thickness

THIN Critical Zone
Central Belt mélange

THICK Critical Zone
Coastal Belt mudstones and sandstones

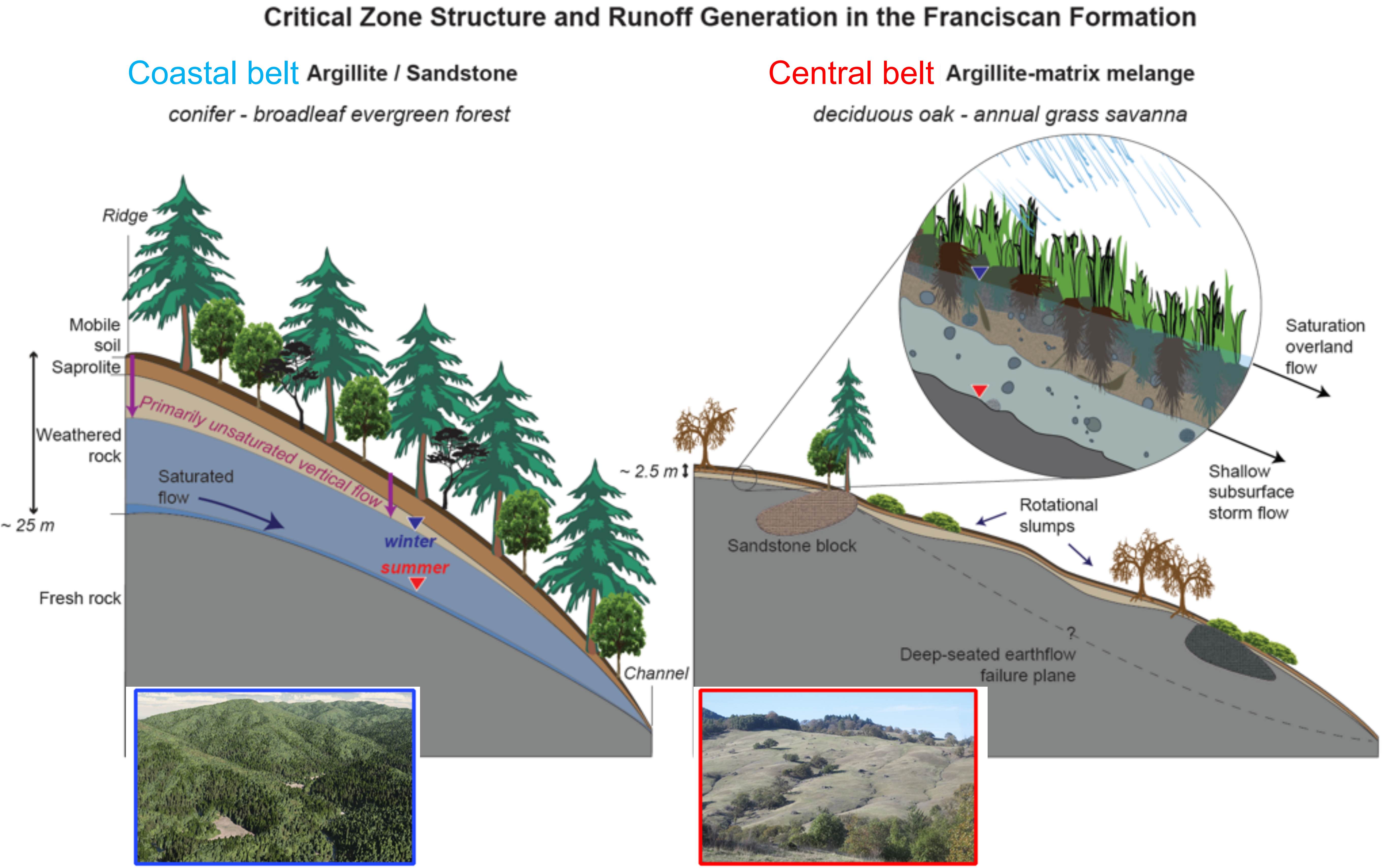




Dralle, Lovill

2.Why does Rock Moisture Matter?

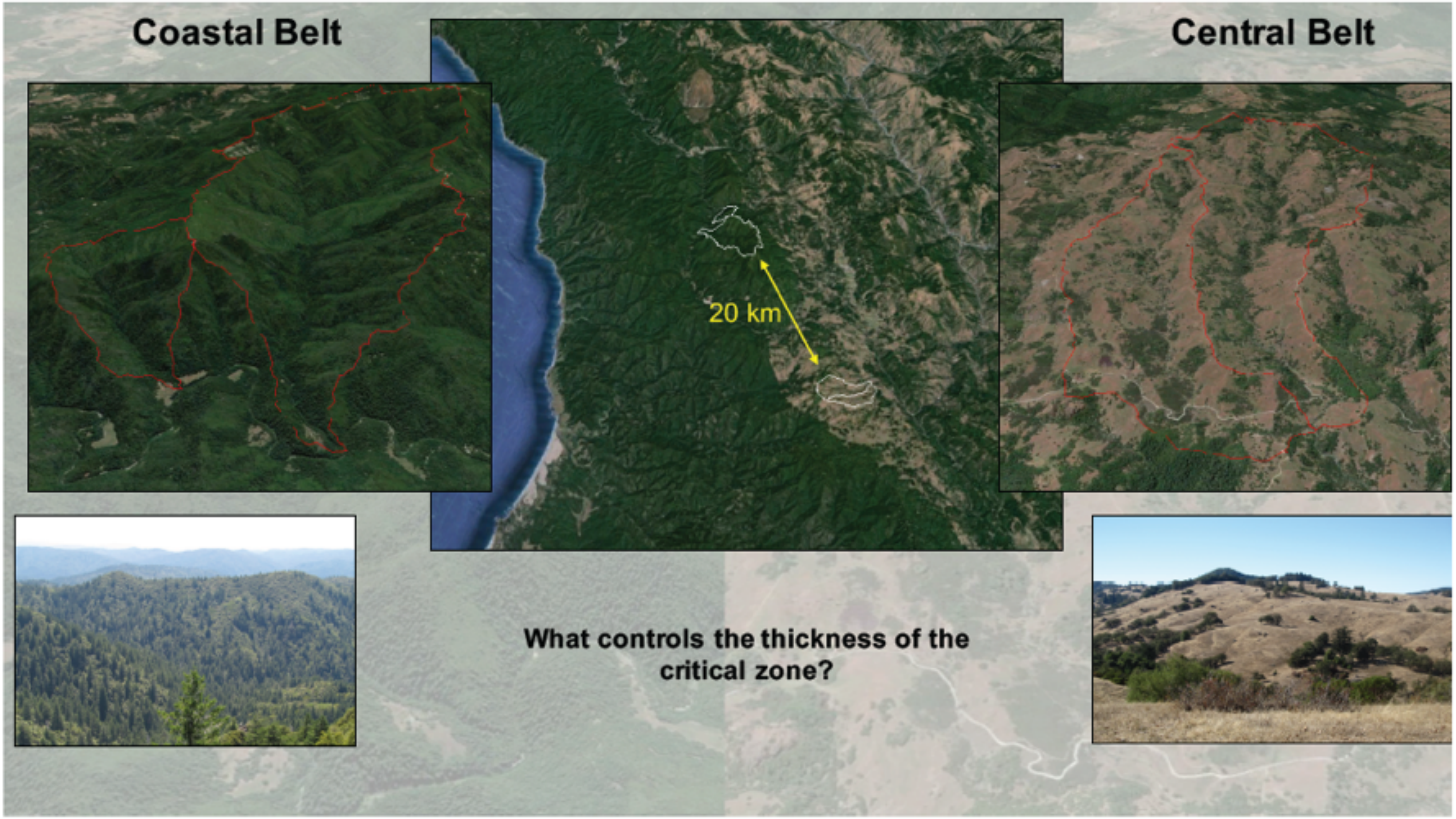
Thickness of Critical Zone controls storage capacity, drives runoff generation, base flow



Salve et al., 2011, Rempe and Dietrich, 2014; Oshun et al. 2016, Rempe and Dietrich, 2018, Oshun et al,. in prep

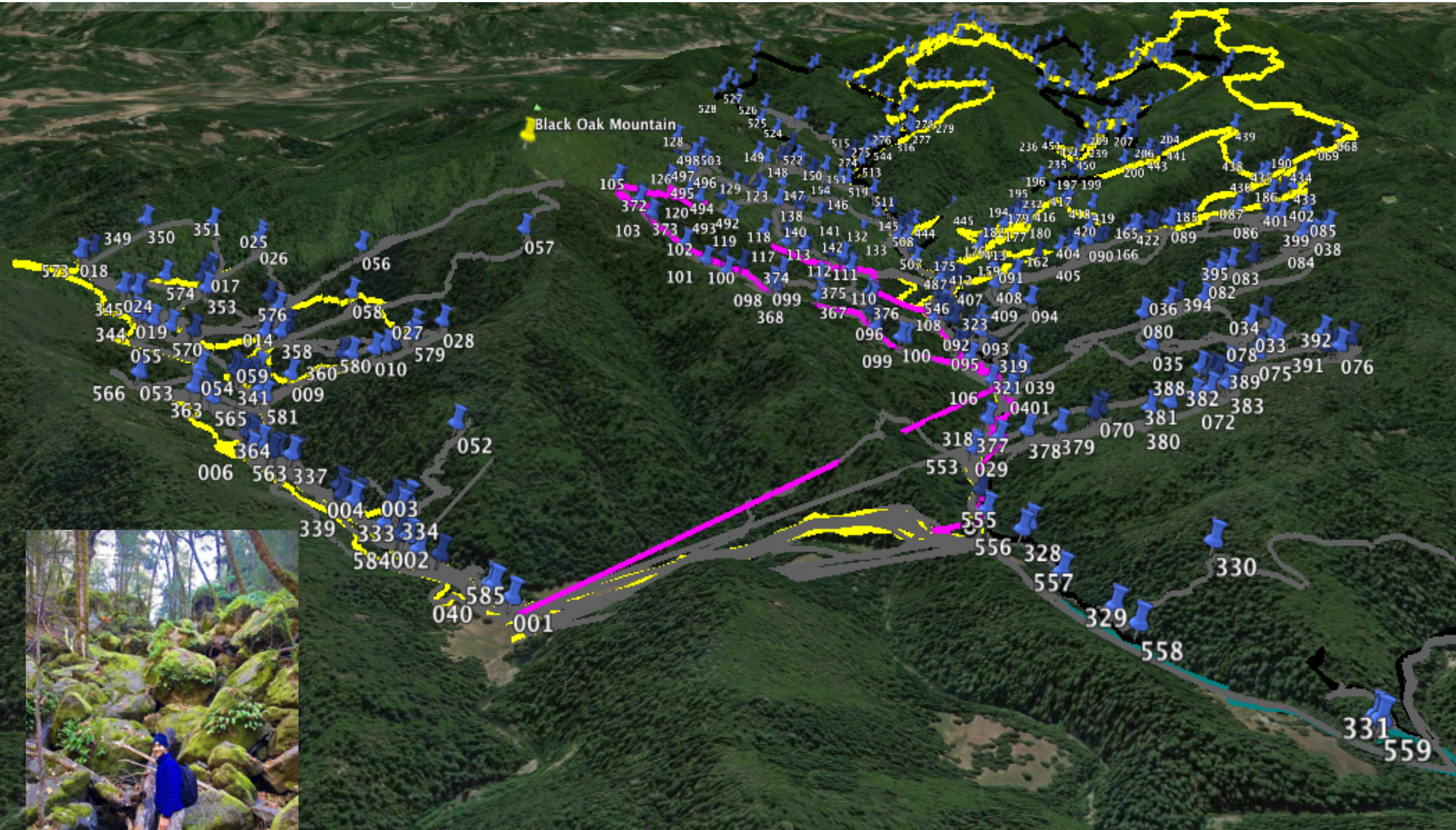
Hahm et al., *2019.*

Results of CZ thickness on baseflow



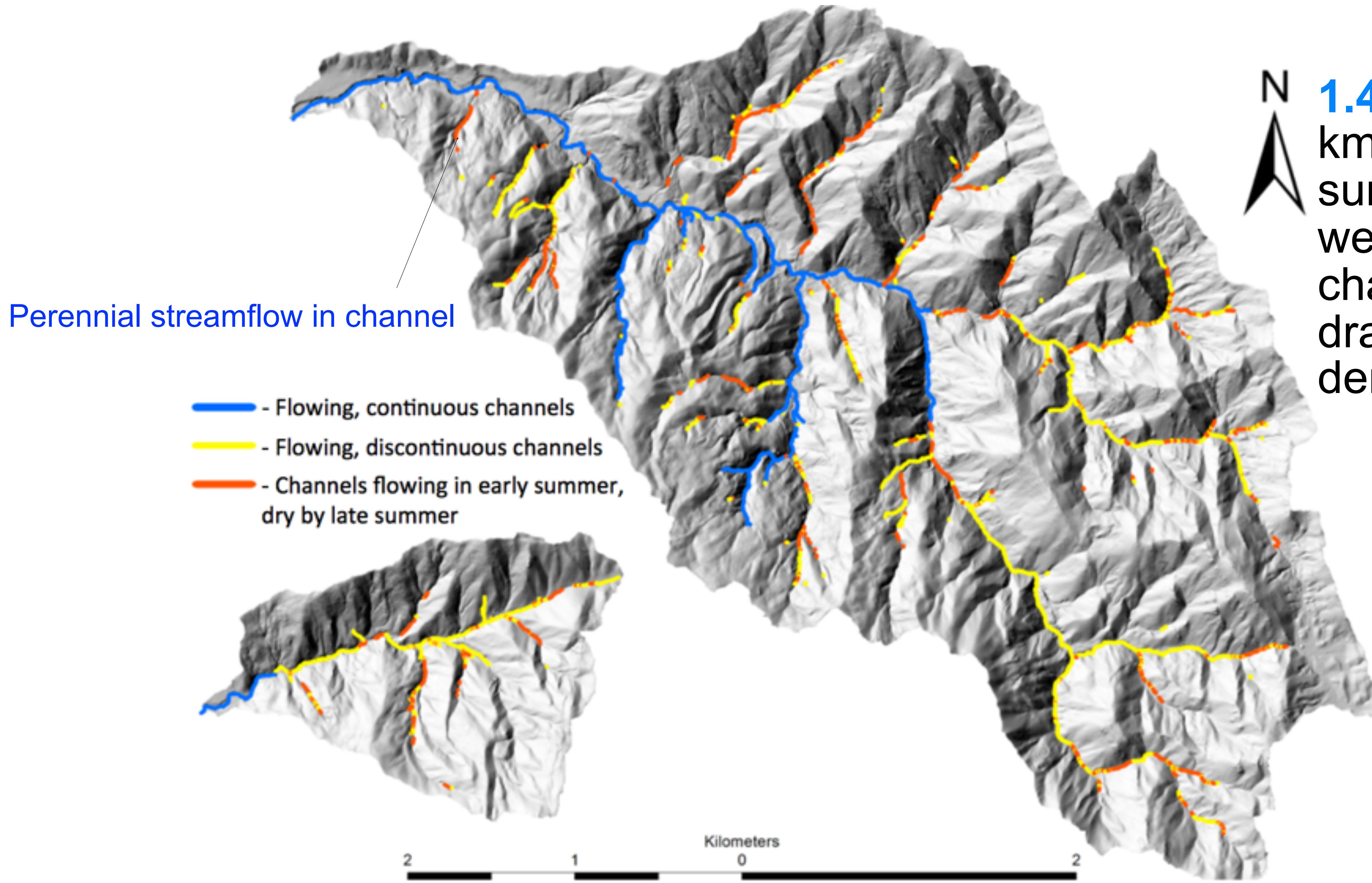
Lovill et al 2018, WRR

2012 Data Points and Routes



Lovill et al 2018, WRR

Coastal belt wetted channel drainage density at end of summer

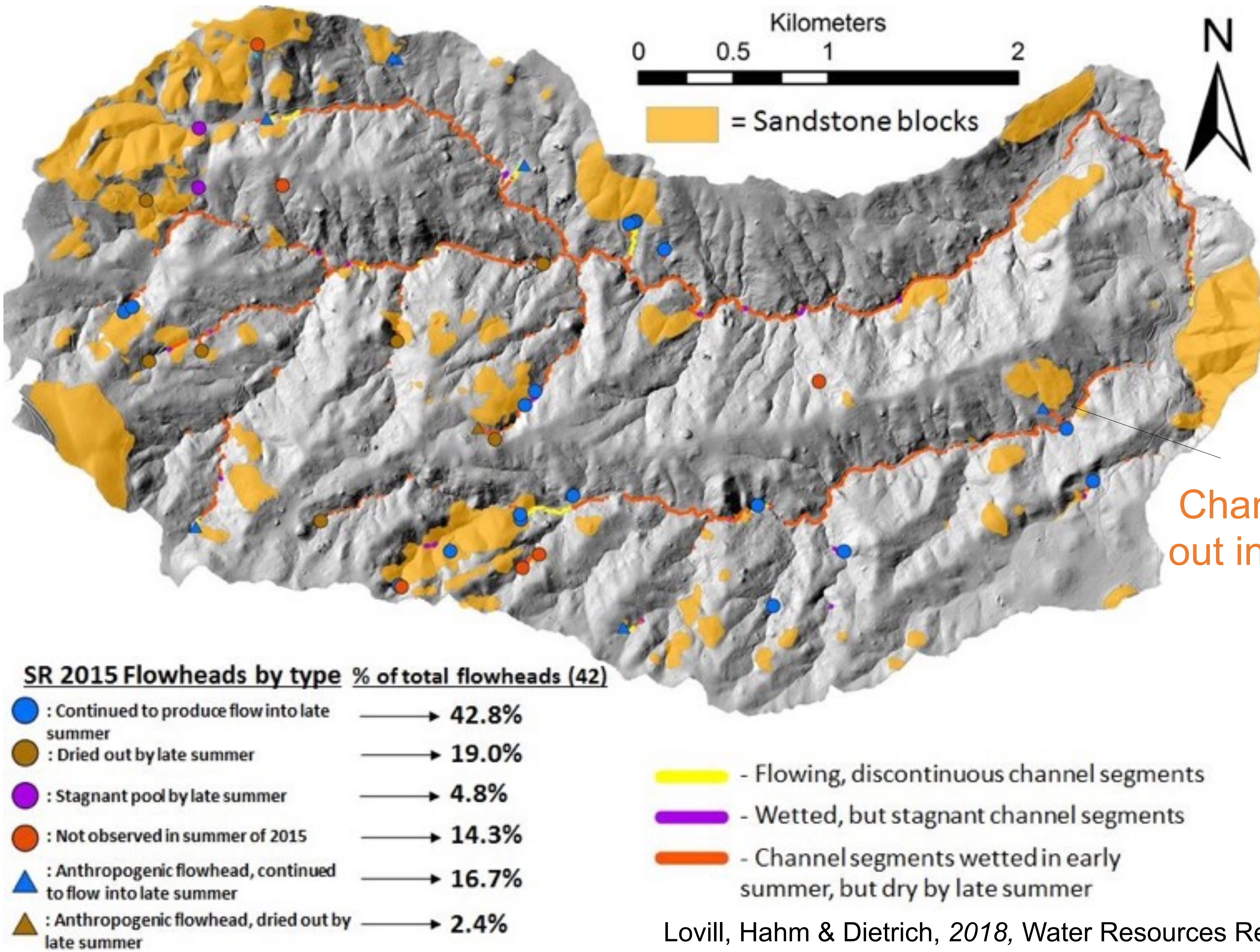


1.43 km / km^2 end of summer wetted channel drainage density

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

Central belt wetted channel drainage density at end of summer

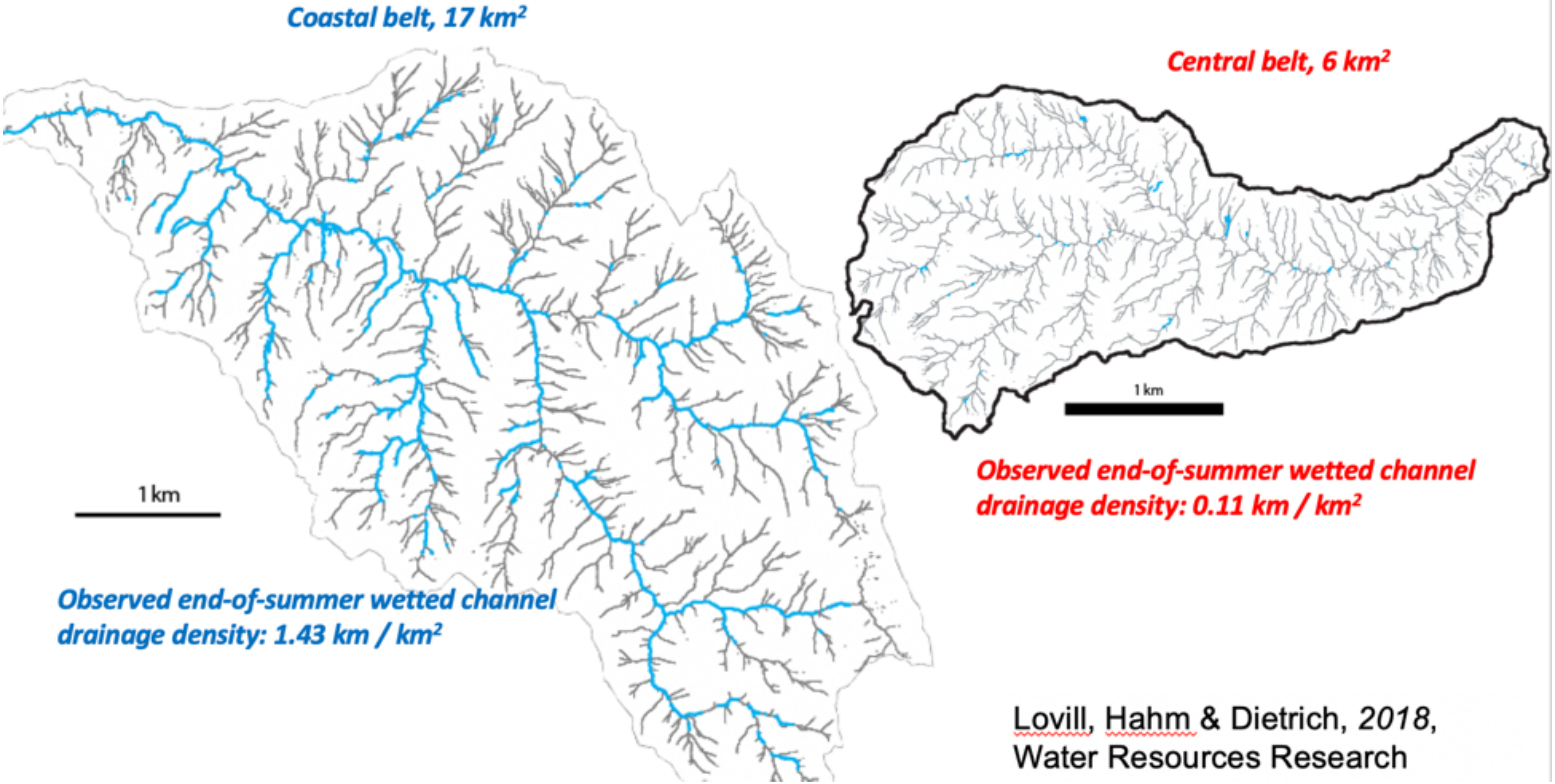
0.11 km / km^2 end of summer wetted channel drainage density



Channels dry out in summer

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

Habitat extent: wetted channel dynamics

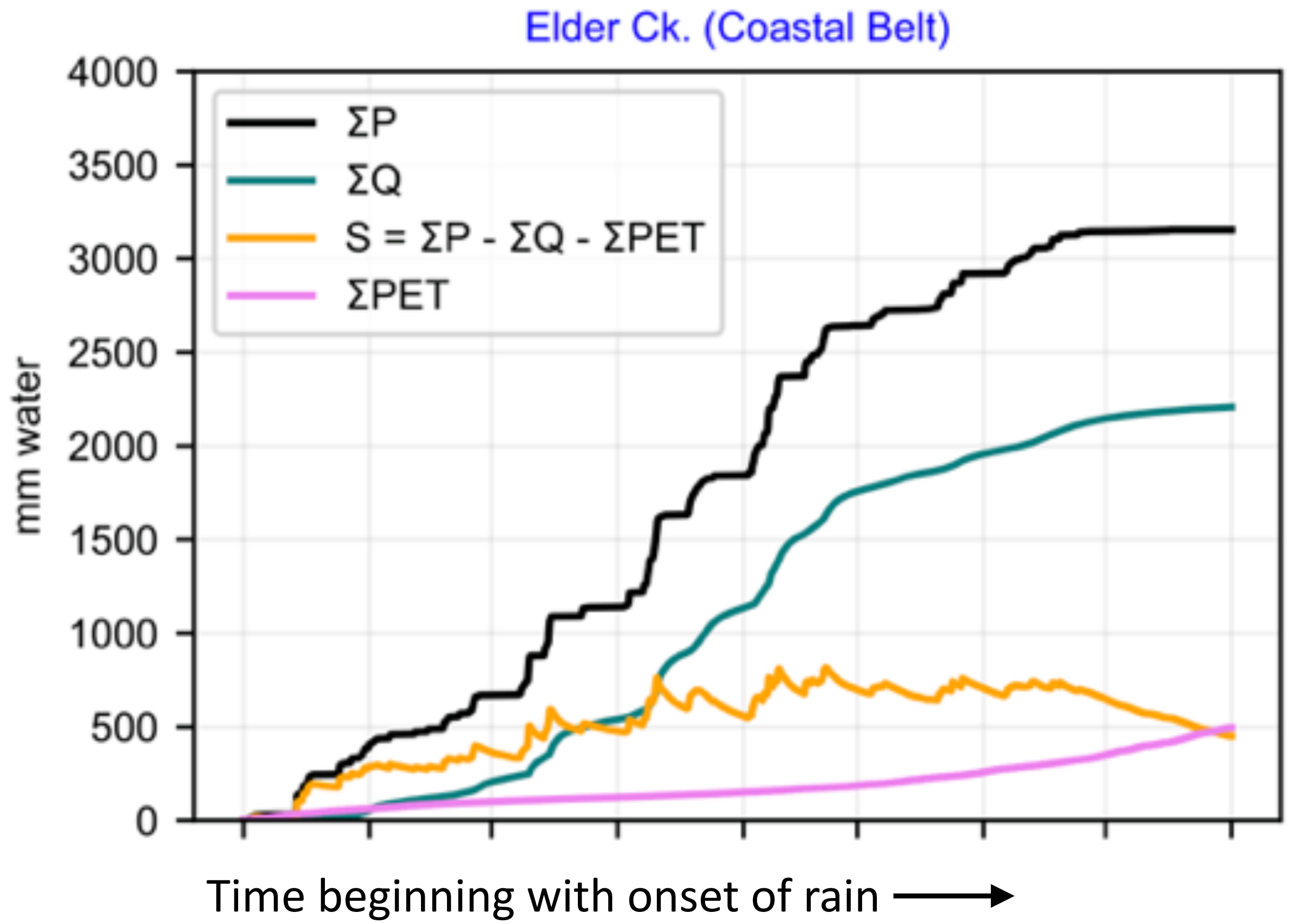


Lovill, Hahm & Dietrich, *2018*, Water Resources Research

Dralle's approach to calculating hillslope water storage

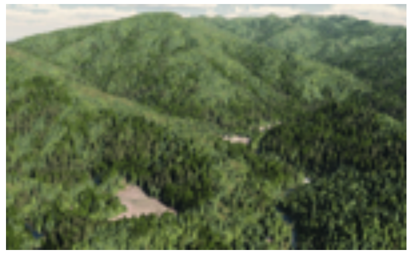
Change in storage = IN – OUT

$$= \int_0^t (P - Q - E)dt$$

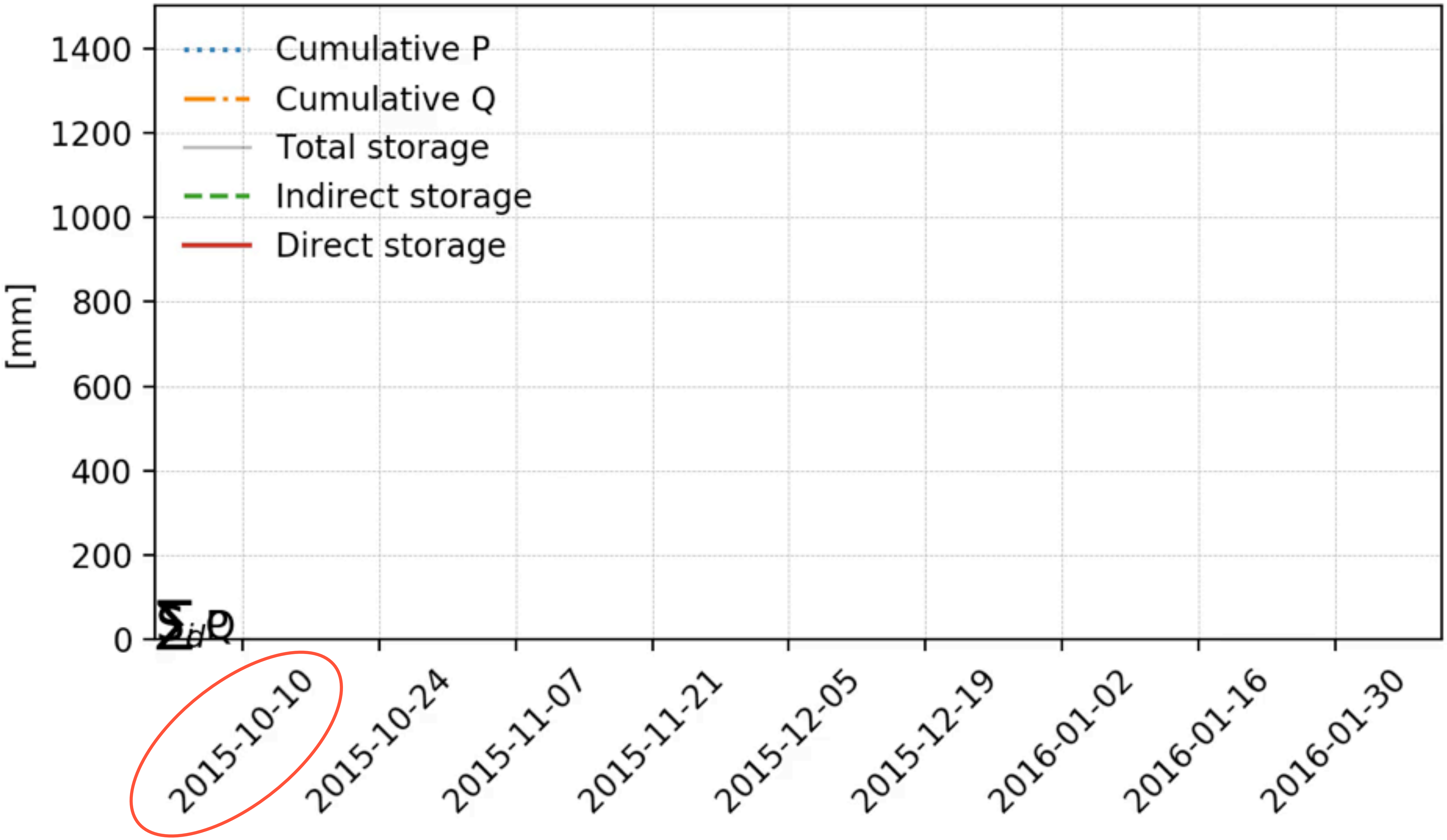


Dralle, 2018

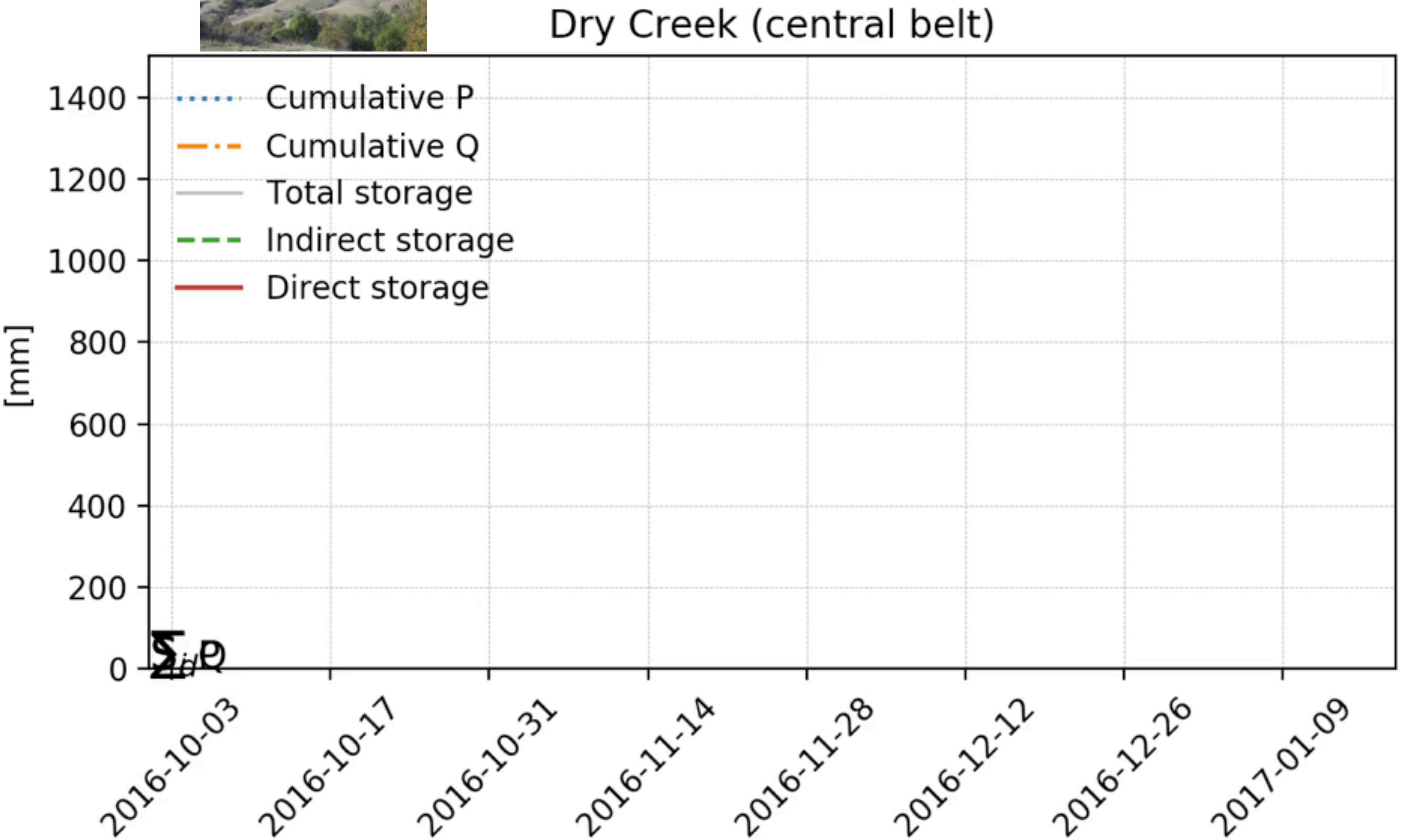
Dralle et al, 2018 HP



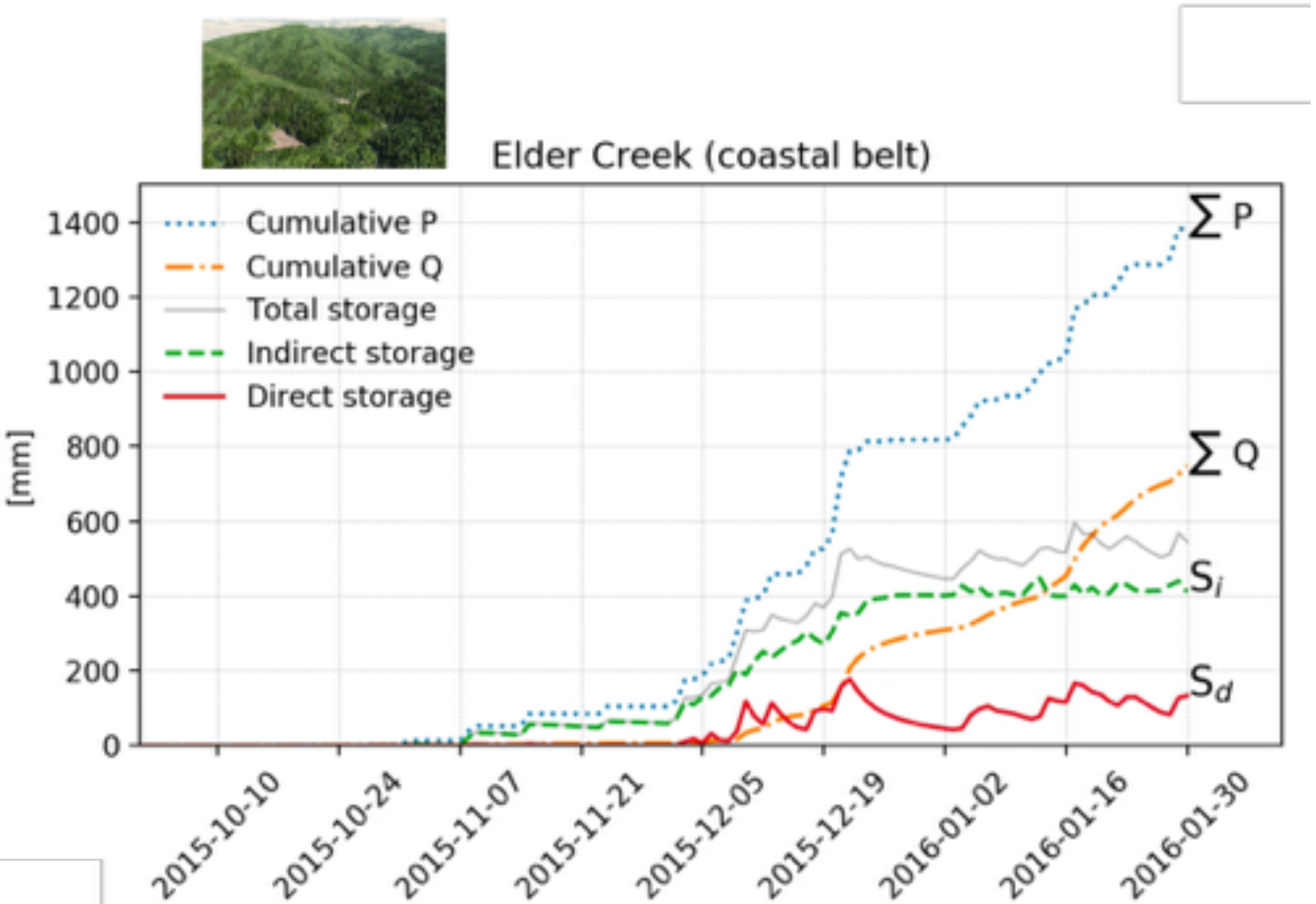
Elder Creek (coastal belt)

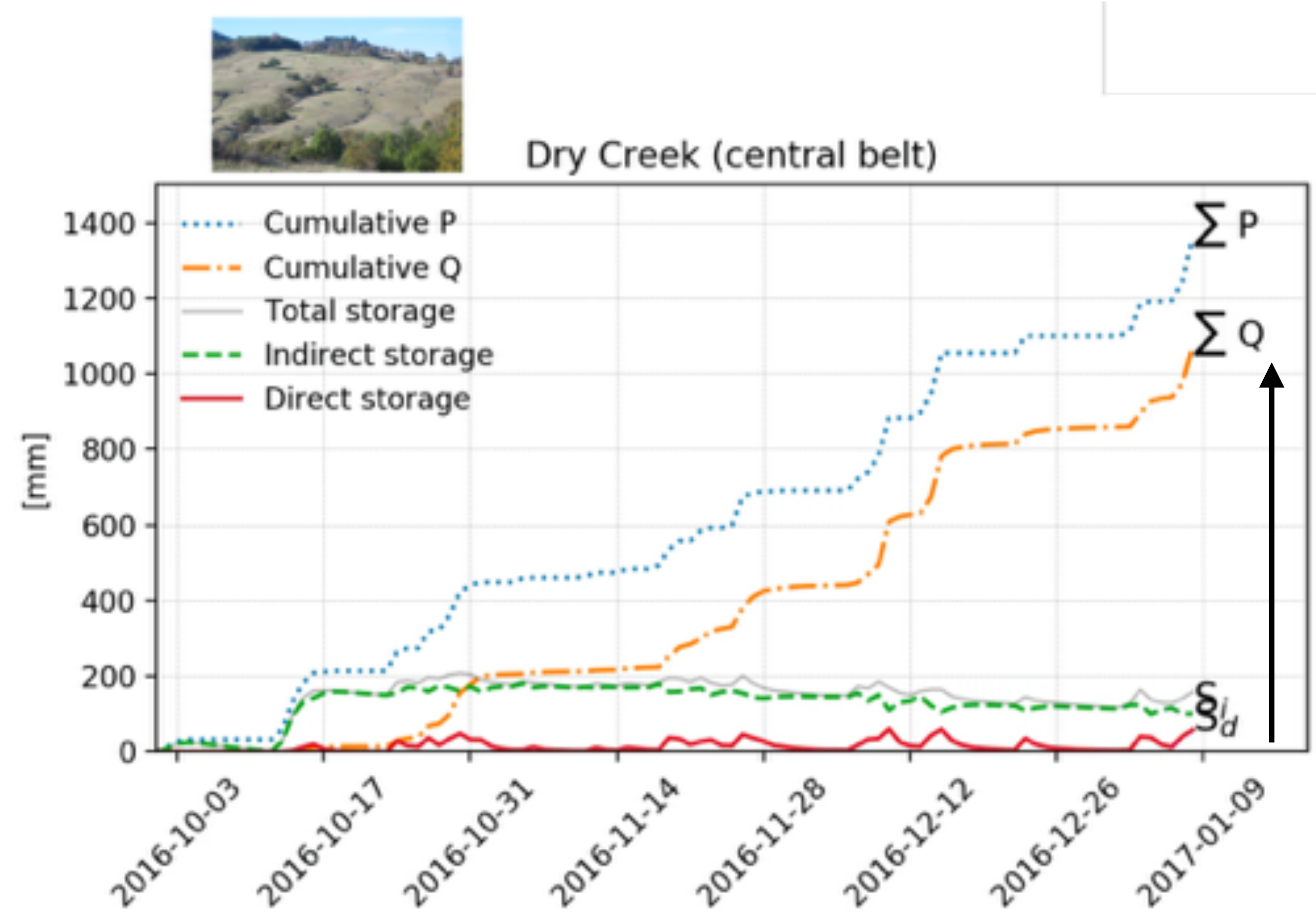


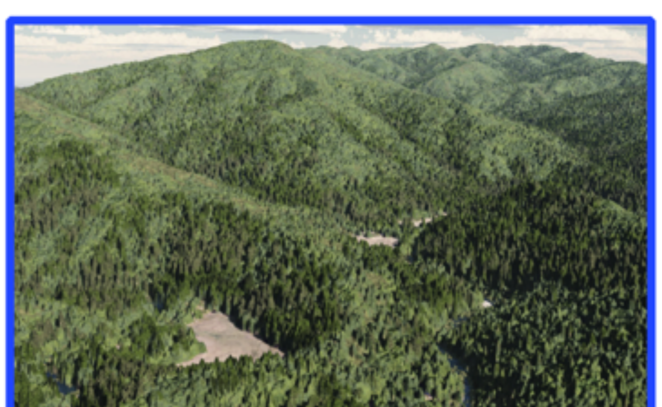
Dralle et al, 2018 HP



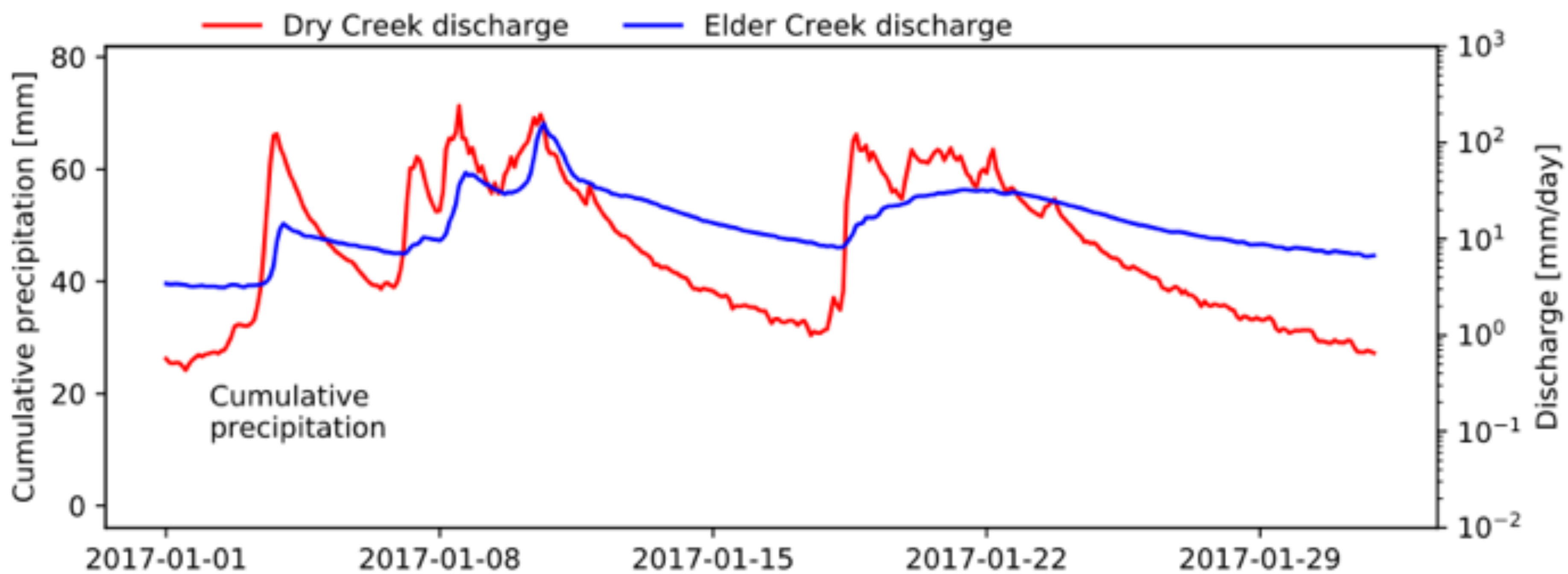
Larger direct storage in Coastal Belt, much, much larger indirect storage in coastal belt



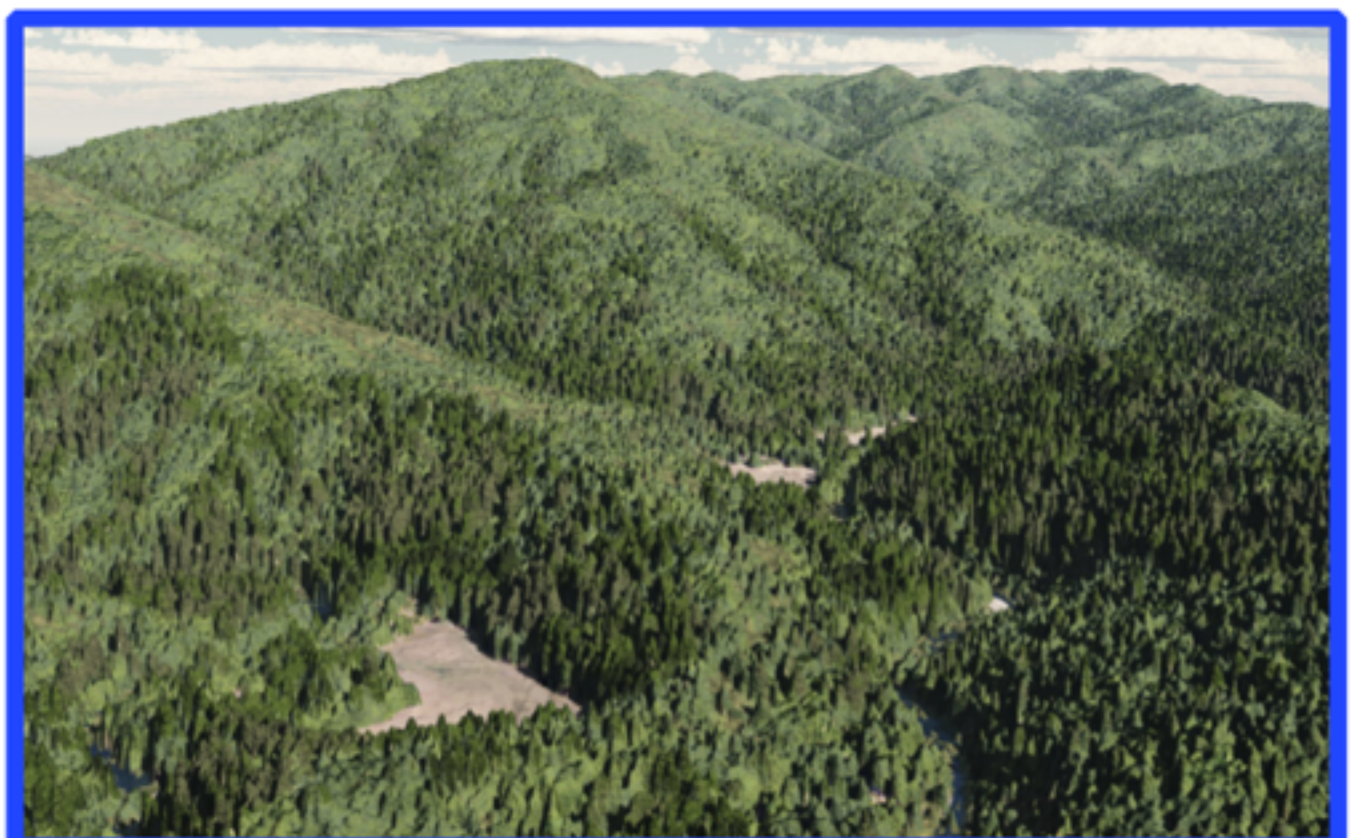




A landscape with a thicker Critical Zone *maintains* base flow in a Mediterranean Climate



Runoff - Discharge normalized by Drainage Area

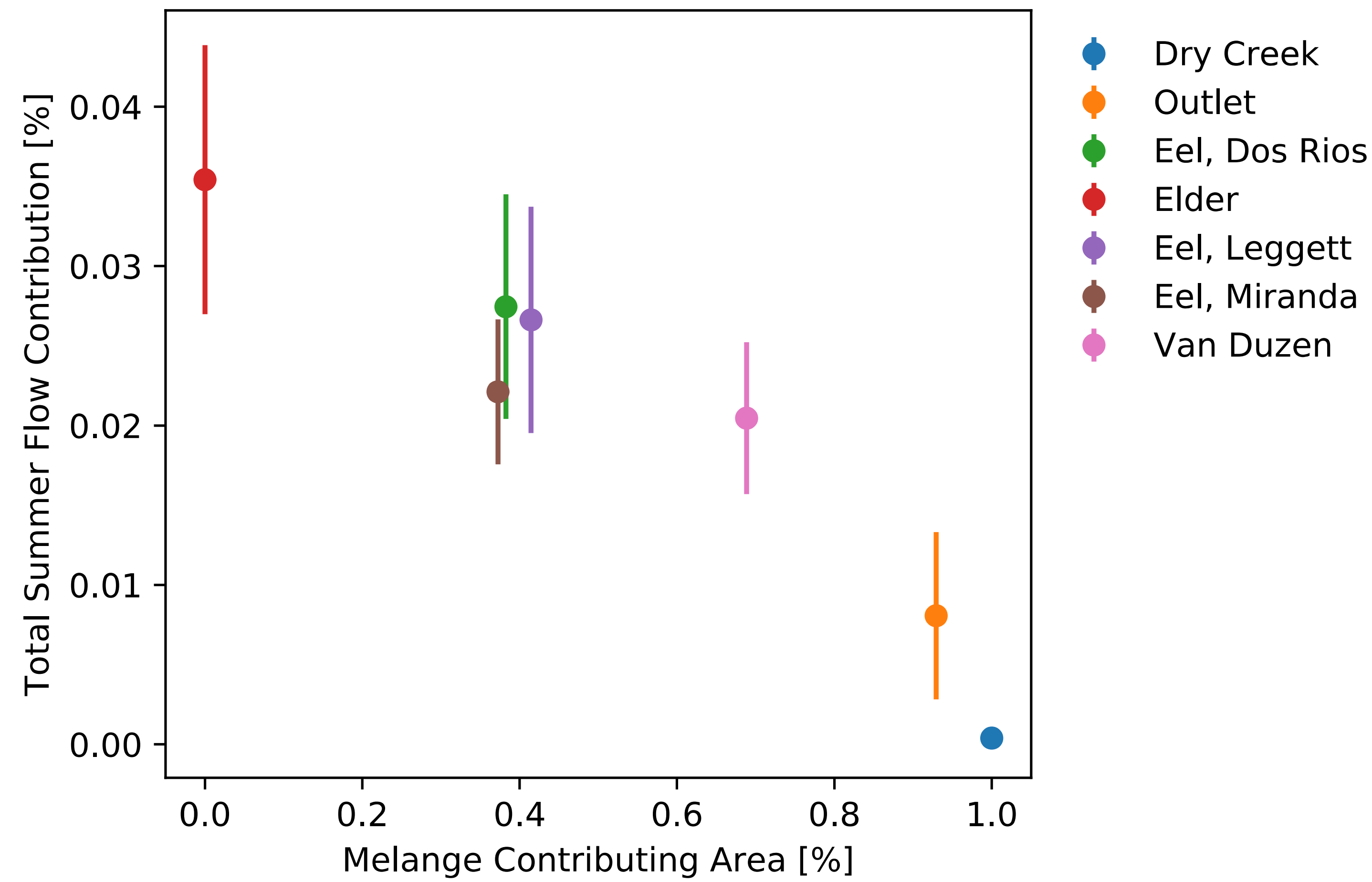


Water Storing Landscape

Water Shedding Landscape

Lovill, Hahm, Dralle

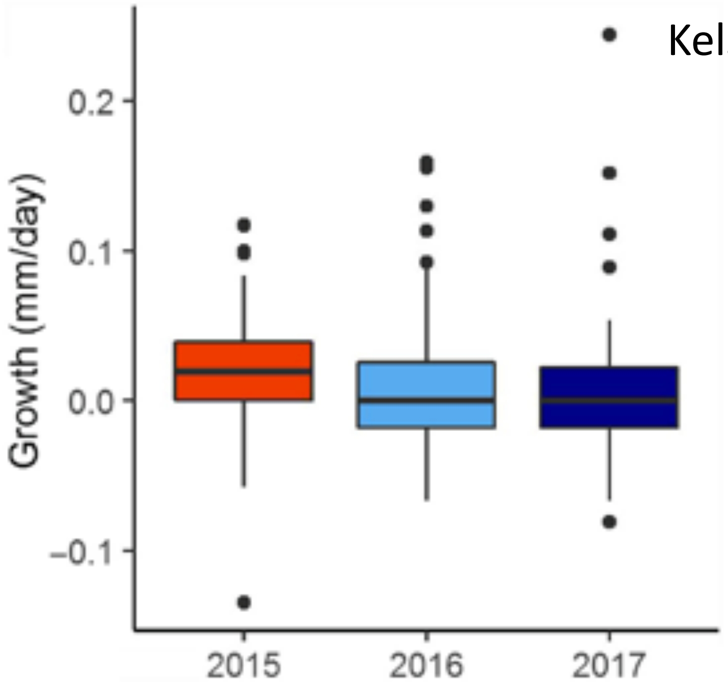
Influence of mélange on summer base flow



Increasing contribution of mélange to runoff

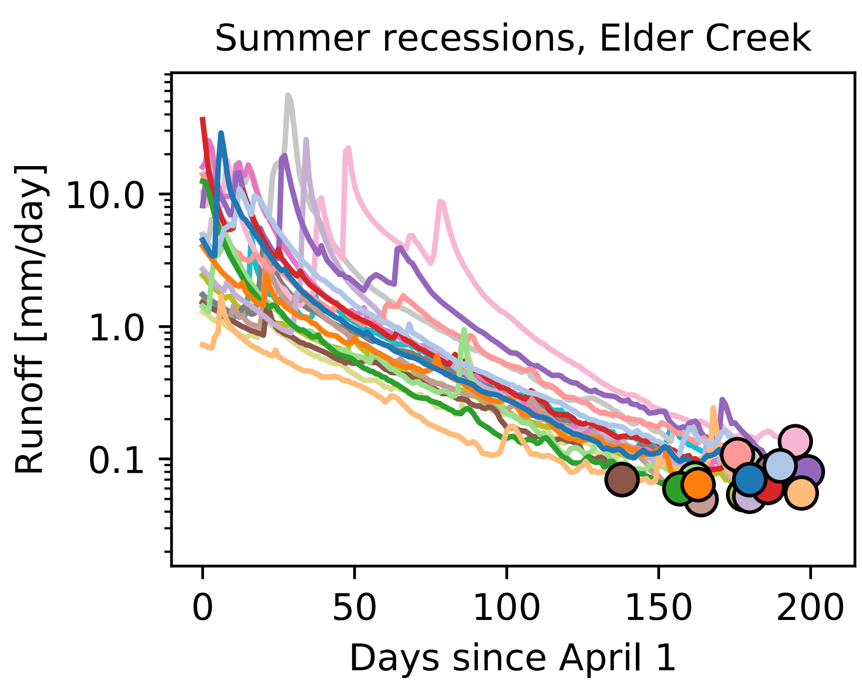
Dralle, Hahm Rempe, in prep

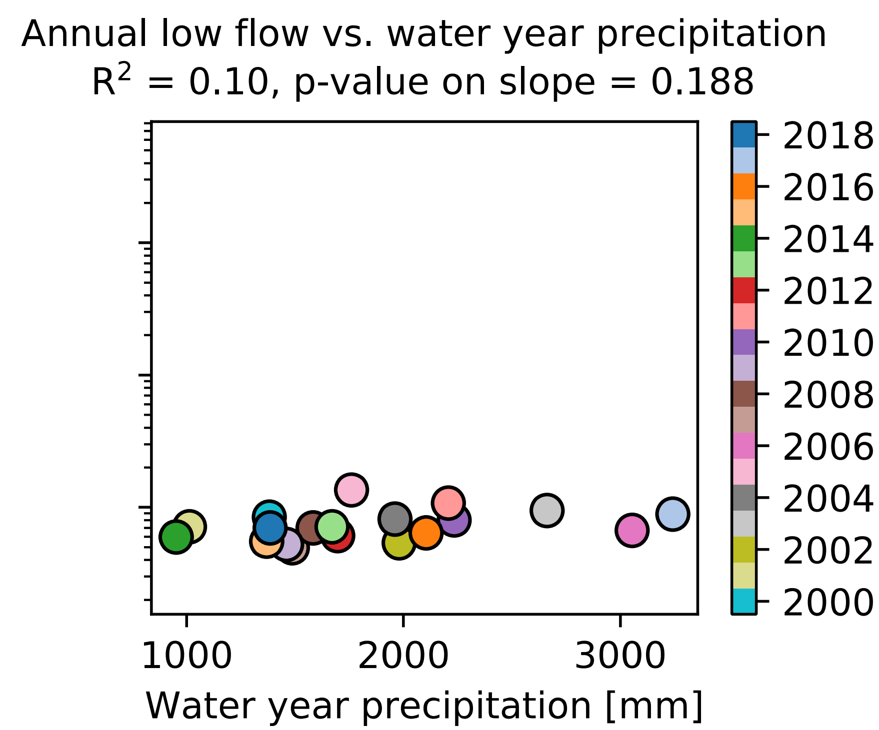
Baseflow in Storage Capacity Limited Streams is Insulated from Seasonal Variability in Rainfall



Kelson and Carlson, Ecosphere, 2019

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





Late summer runoff does not correlate to *total* precipitation

Hahm, Dralle, Rempe et al. in prep

Summary

- Rock Moisture provides critical summer moisture to vegetation
- Tectonic history influences critical zone thickness, and water storage capacity
- Mélange landscapes are ‘water shedding’, Coastal Belt ‘water storing’
- If average precipitation >> storage capacity, landscapes will exhibit resilience to inter-annual precipitation variability

Unknowns/opportunities

- What is the relationship between tree water uptake and streamflow?
- What is the storage capacity in the subsurface across large scales?
- Total winter precip. does not affect baseflow, what does?