Water & Sierra Nevada forests: Recent study results

1. Introduction: Montane water balances
2. Background: Forests and snow
3. SSCZO: New results

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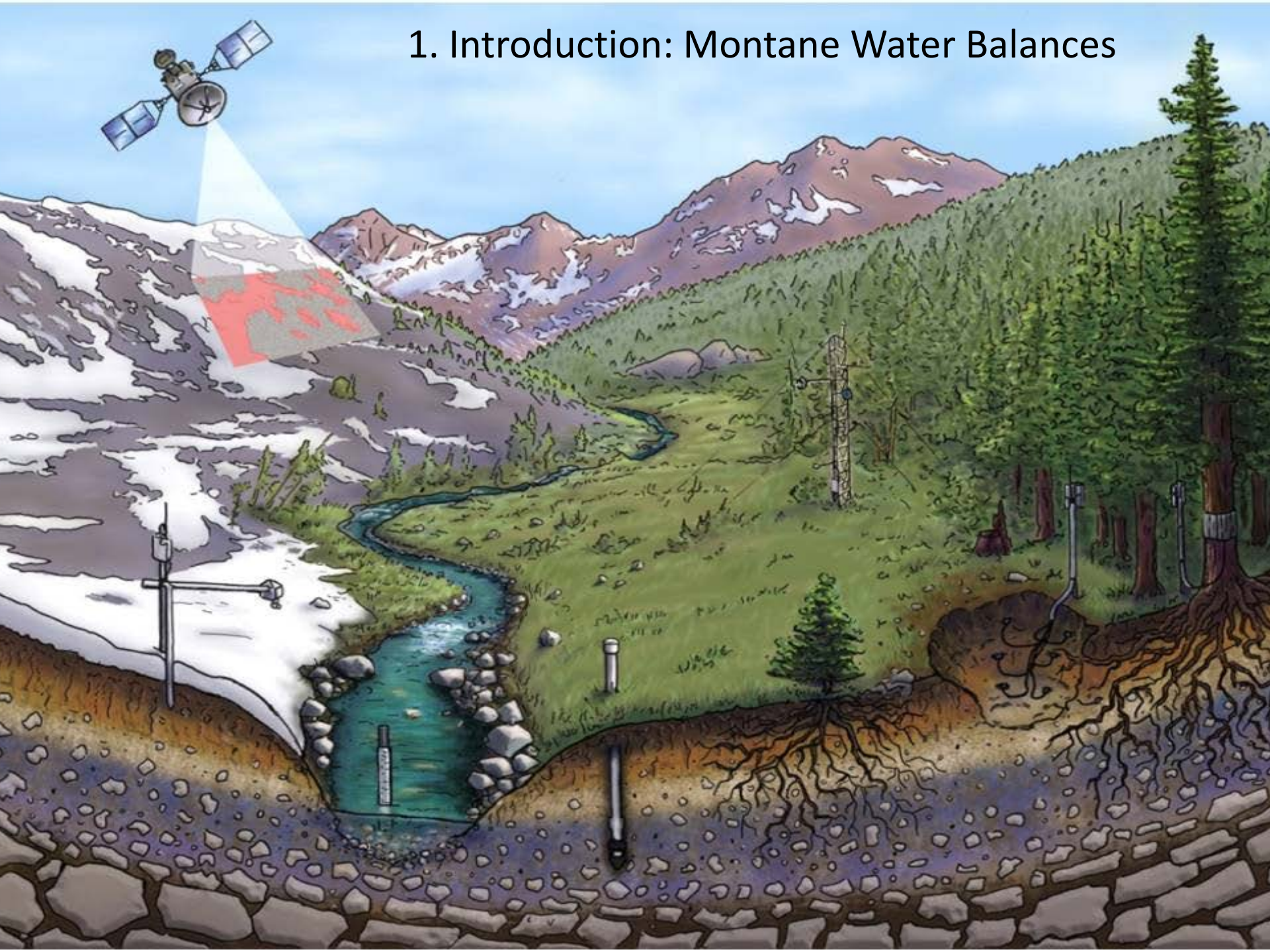
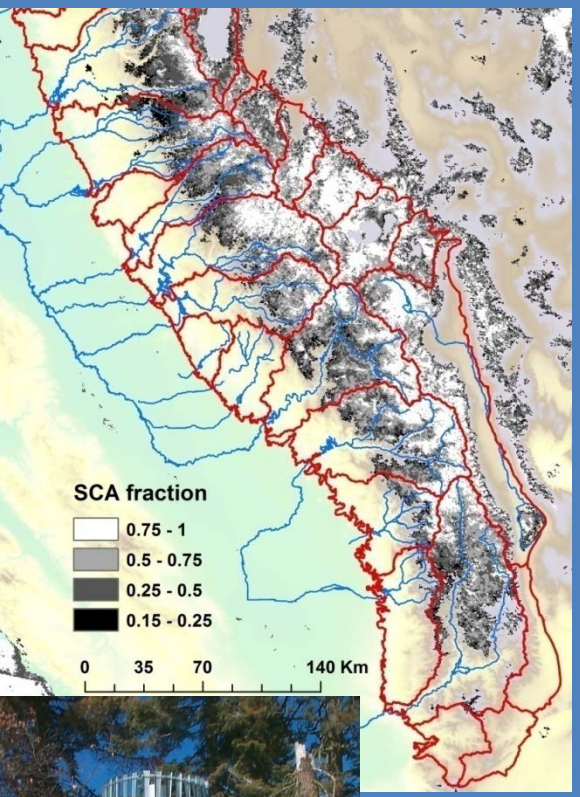
Collaborators: R Bales, UC Merced; S. Glaser, UC Berkeley; & many others

1. Introduction: Montane Water Balances



Basic yearly montane water balance

Precipitation = Evapotranspiration + Runoff



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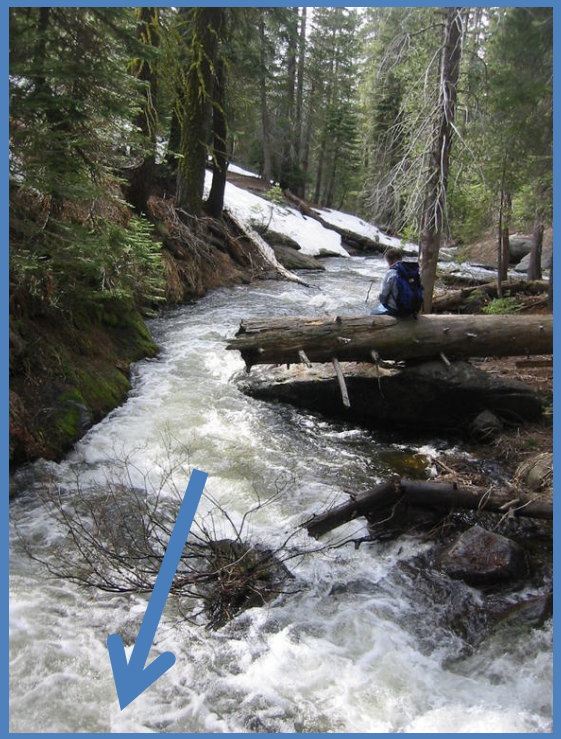
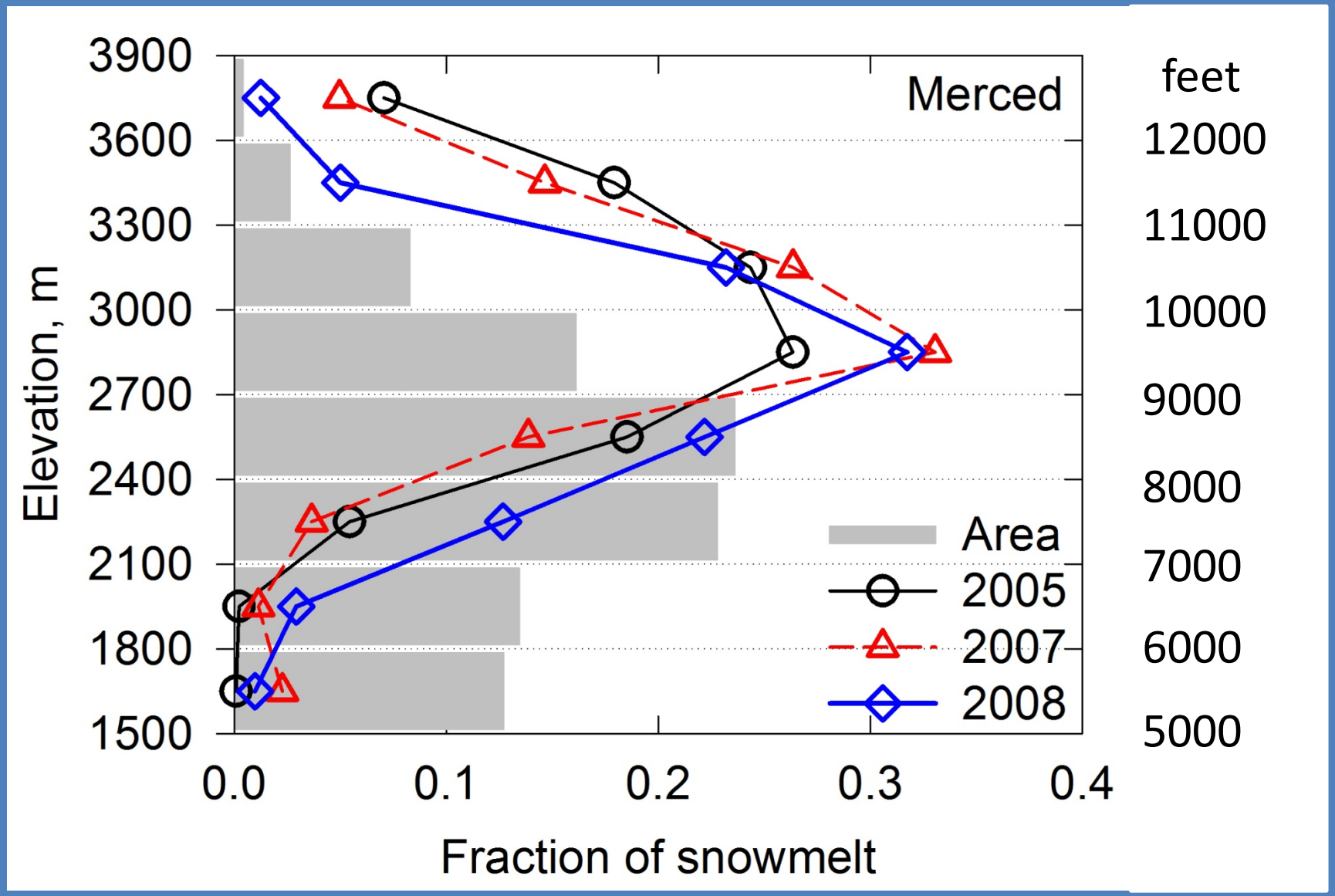


Assumes that shallow infiltrated water is captured in runoff measurement

What elevations provide the most snowmelt?



Based on SNRI research

Major issues facing forest management

1. Information needs
   a. Studies to understand the effects of forest management on water over the wide range of physiographic conditions in California
   b. Pathways for precipitation reaching stream channels
   c. Methods for estimating evapotranspiration across vegetation types
   d. Erosion and sediment transport

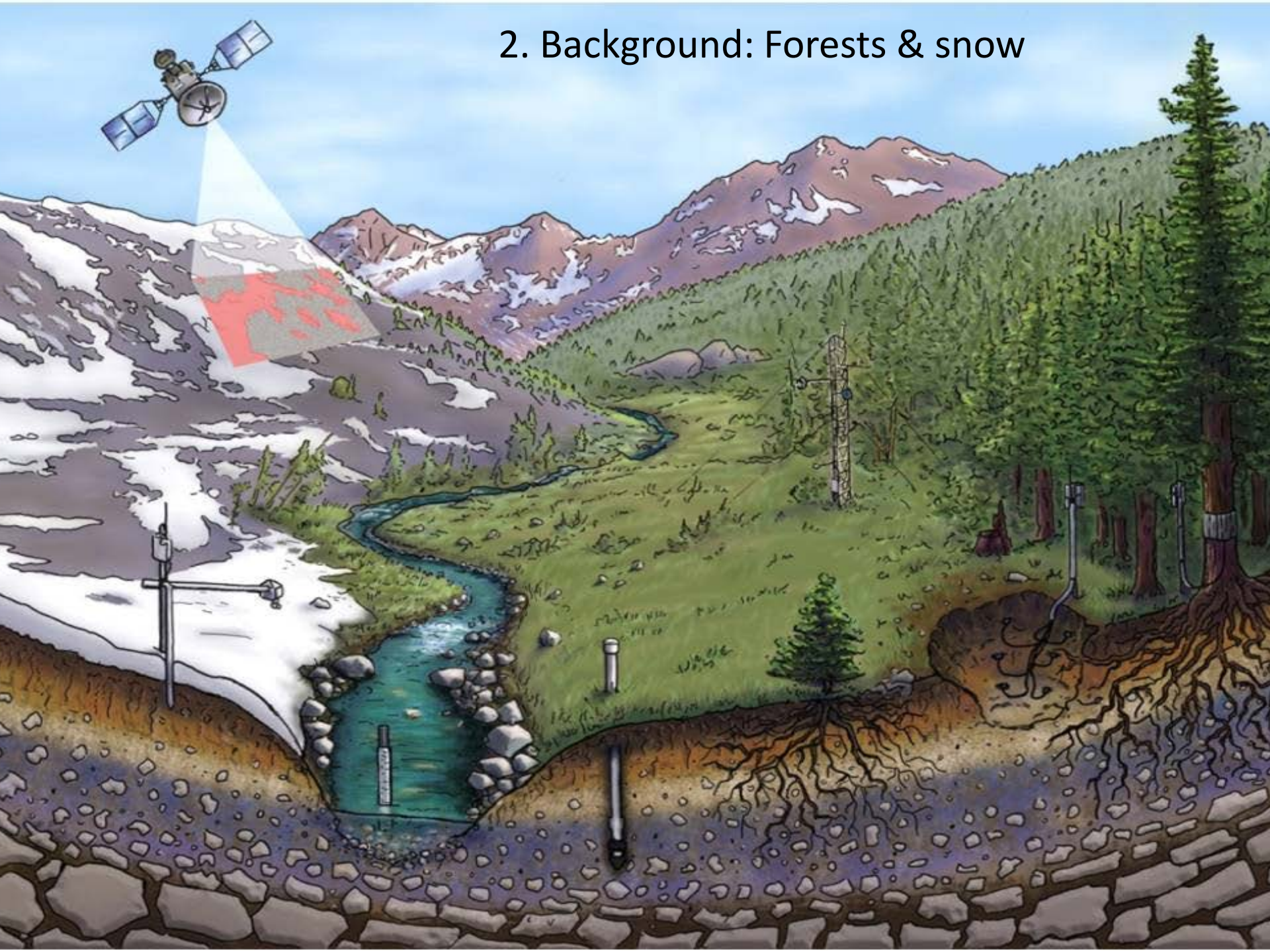
2. Coordination between land owners

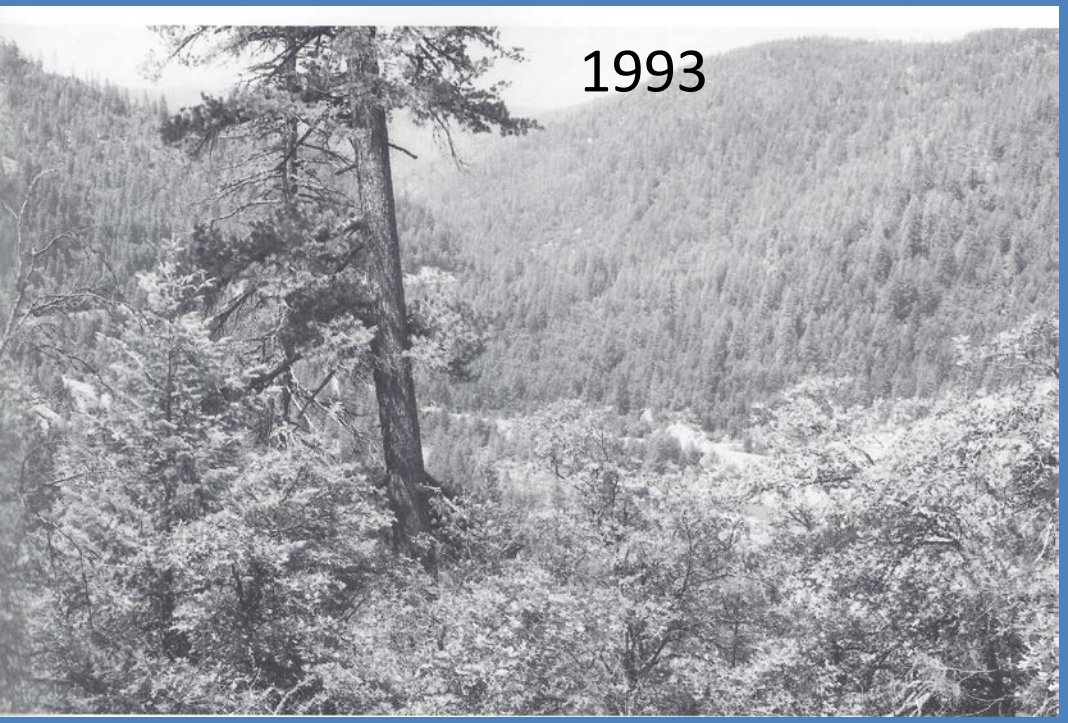
3. Limited funding for forest watershed restoration

4. Regulatory requirements

CA Water Plan Update 160-09, vol 2, ch 23

2. Background: Forests & snow





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?
3. What would the effect of restored forests on water yield?

E. Branch, N. Fork Feather R., 3400'

Photos from G. Gruell

Trees & snow

Trees block low-angle winter sun, retarding snowmelt …

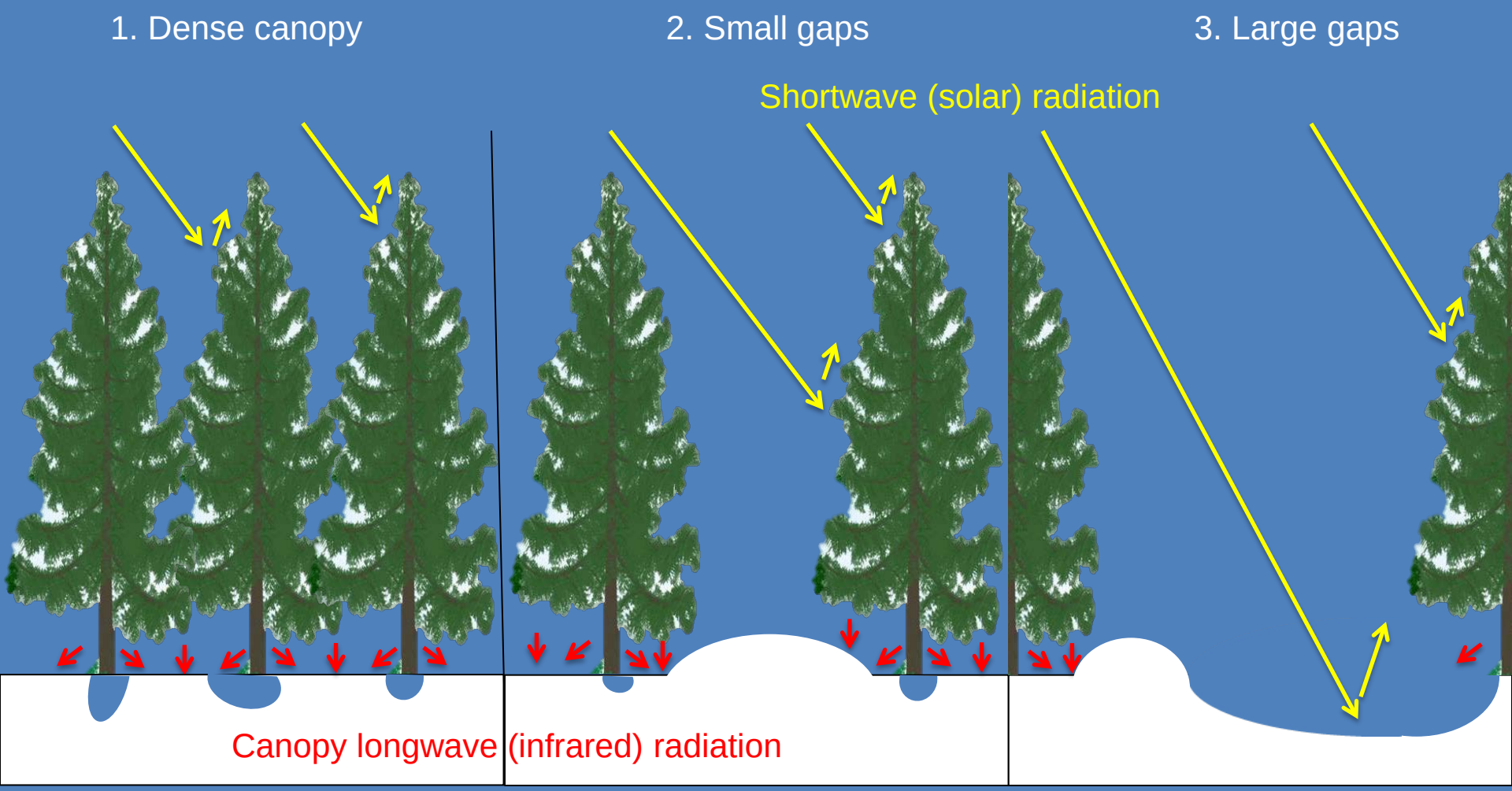
… but intercept snowfall, some of which sublimates (< 20%) …

… and emit longwave radiation that melts snow …

… resulting in tree wells

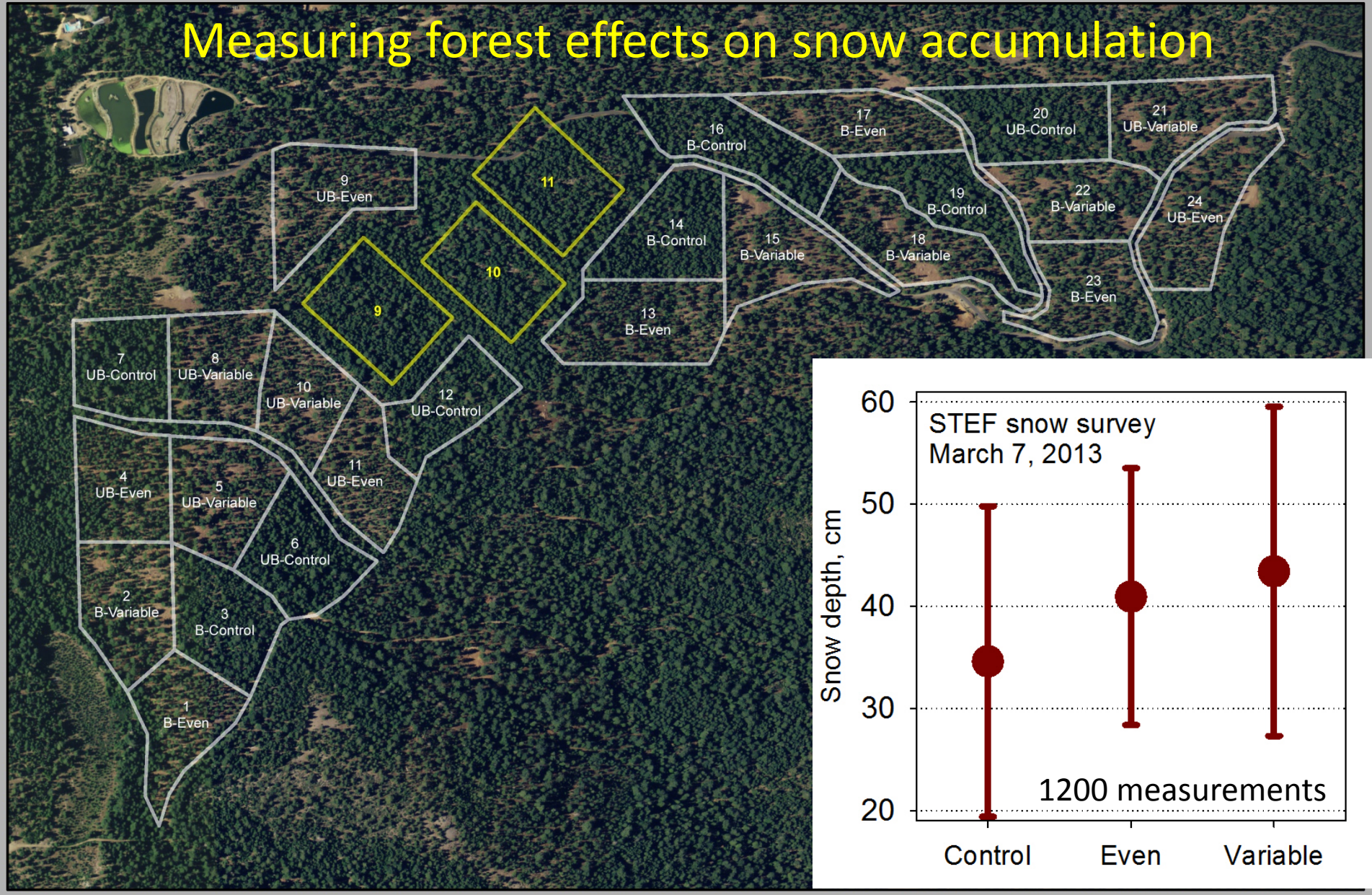
How much snow gets to the ground & how fast does it melt?

3 scenarios for solar & infrared radiation



1. Dense canopy	2. Small gaps	3. Large gaps
Lowest shortwave High longwave	Low shortwave Low longwave	High shortwave Lower longwave

Measuring forest effects on snow accumulation



Legend

- Variable Density Thinning Units
- 1929 Methods Of Cutting Units

Stanislaus - Tuolumne Experimental Forest
Variable Density Thinning Study
Post-Harvest (2012)

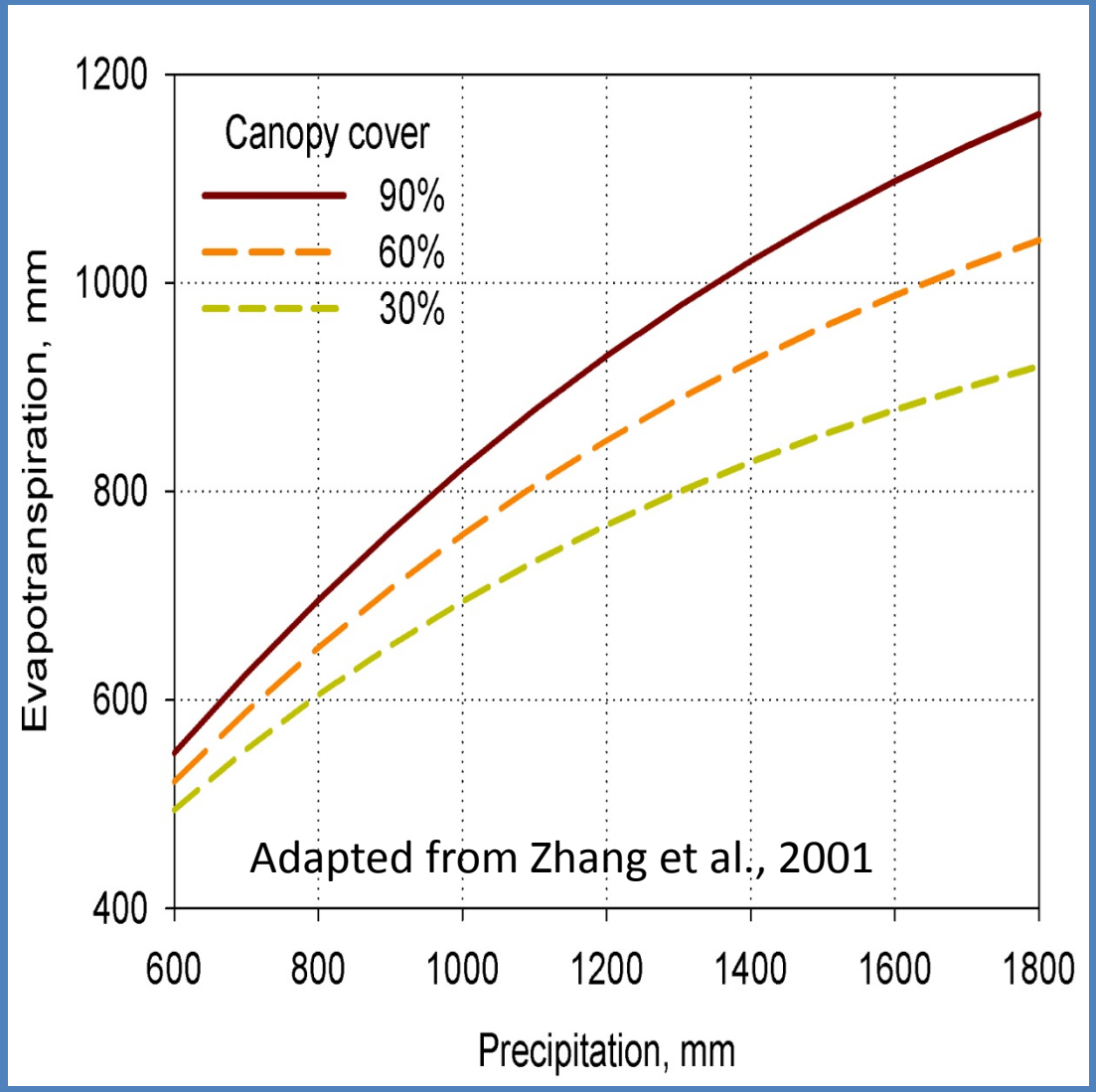
0 50 100 200 300 400 500 Meters

N

Pacific Southwest Research Station

Thinned unit w/ control in background

Vegetation water use: summary from literature



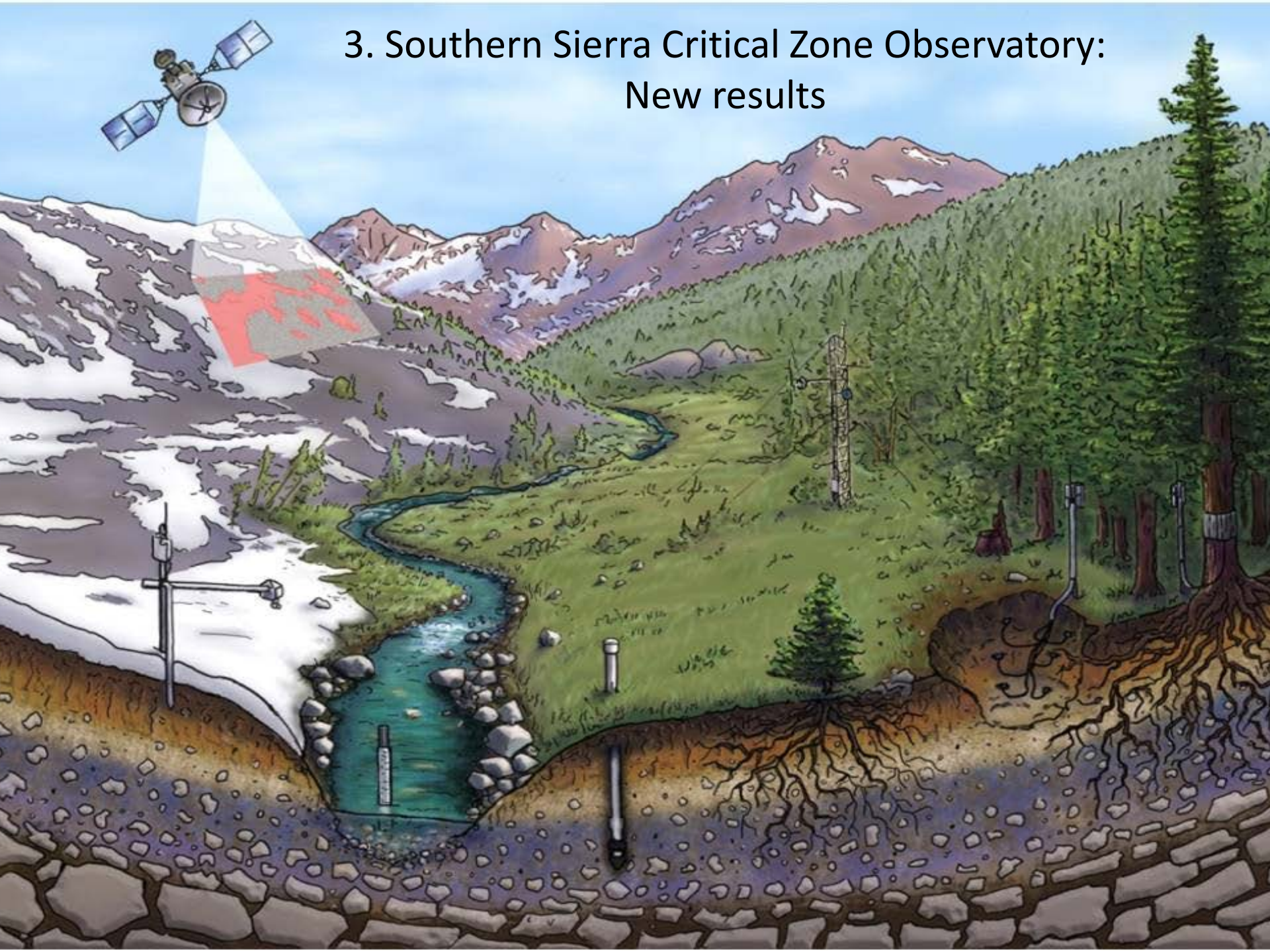
Reducing forest cover by 40% of maximum levels across a watershed could increase water yields by about 9%

Sustained, extensive treatments in dense Sierra Nevada forests could increase water yield by up to 16%

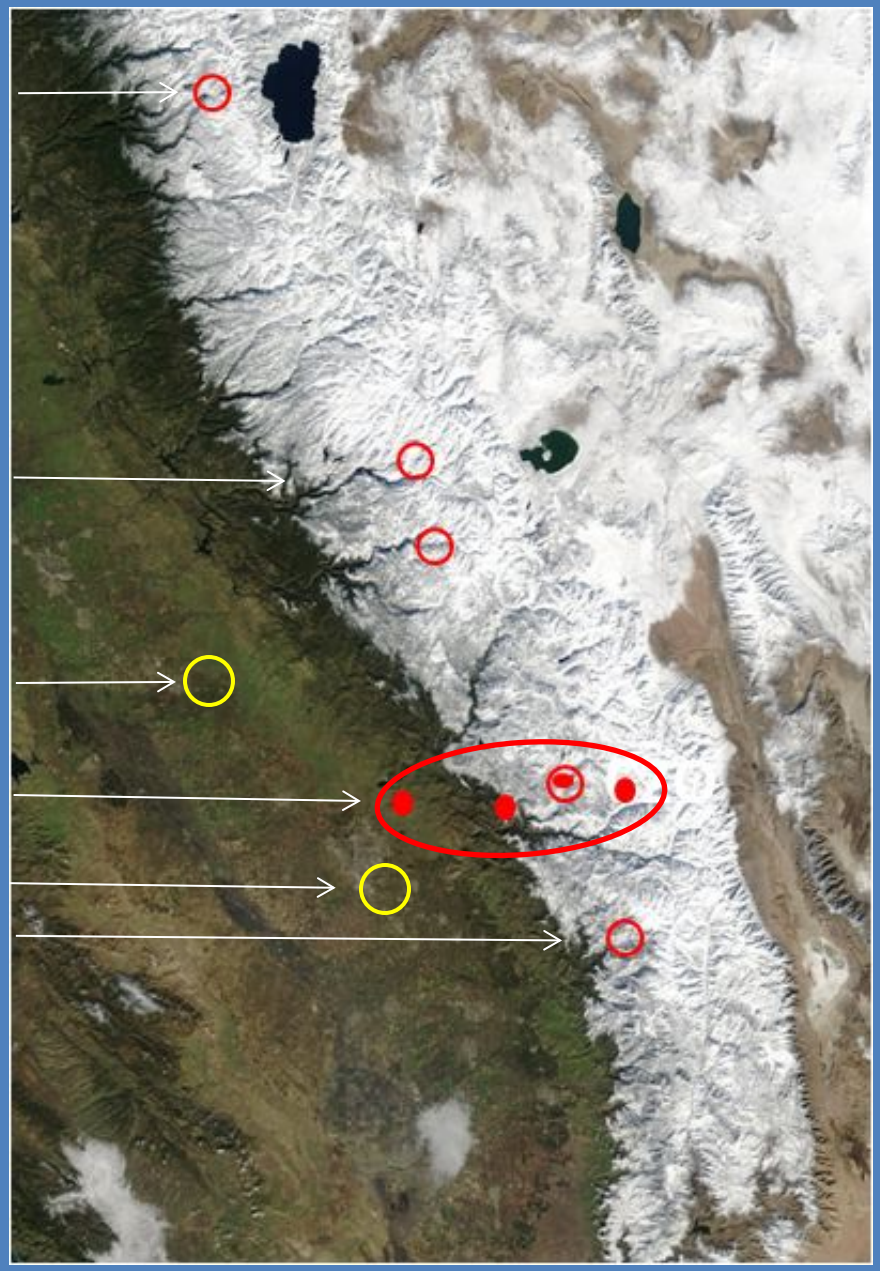
These estimates are based on very limited data

We need a study to determine the appropriate level of treatments

3. Southern Sierra Critical Zone Observatory: New results



SSCZO site location, gradients & infrastructure



MODIS image

4 instrumented sites along steep climate gradient: 12°C, 60 km

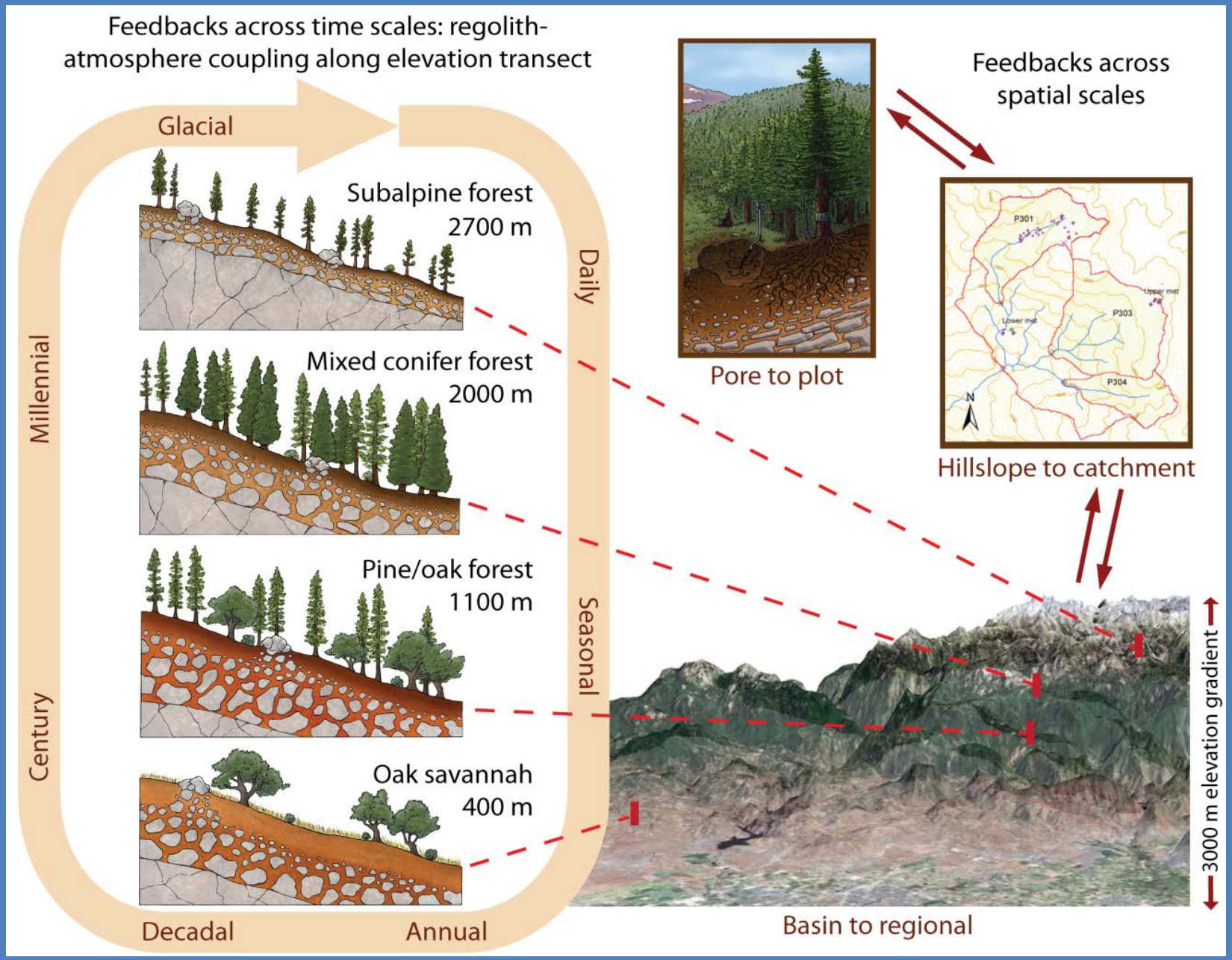
Co-located w/ USFS watershed research site: 8 headwater catchments ~ 100 ha each

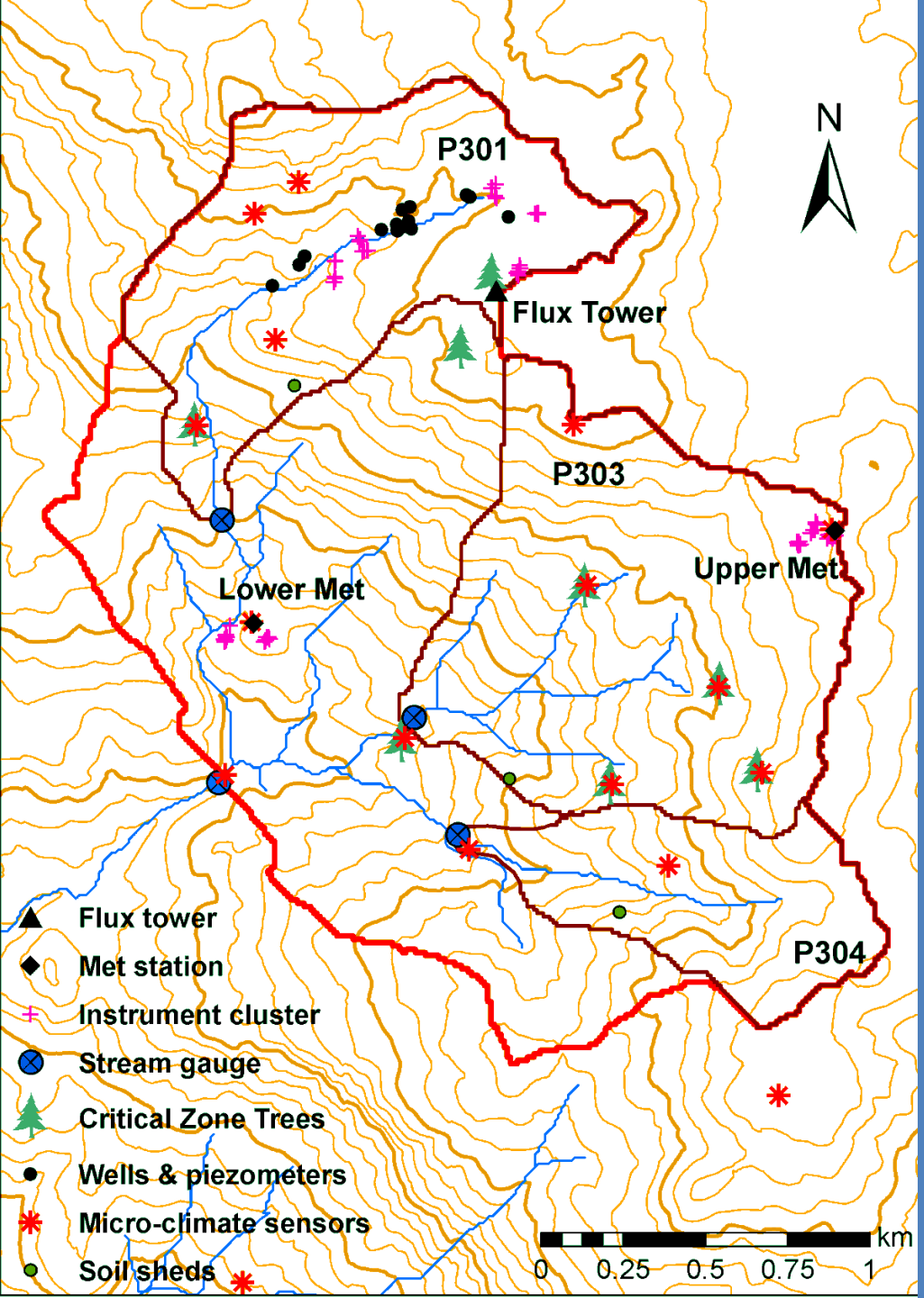
Lower SSCZO site proposed for NEON core

Winter access to upper sites over snow

Open access to data

SSCZO conceptual model

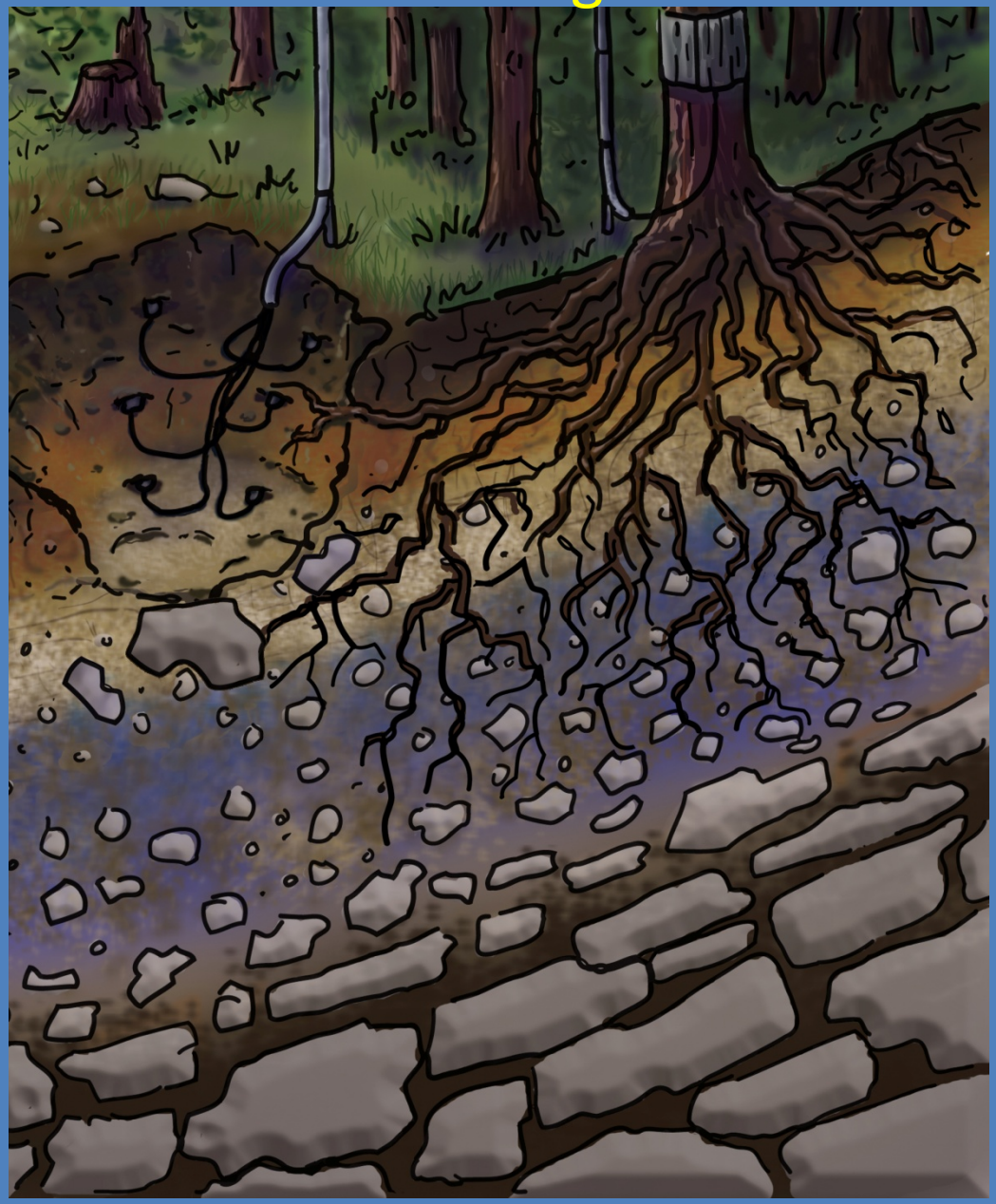




Providence Ck (2000 m) – instrumentation

- 3 headwater catchments w/ stream gauges & water-quality measurements
- 2 met stations
- 60-m tall flux tower
- 60-node wireless embedded sensor network
- 214 EC-TM sensors for volumetric water content
- 113 MPS sensors for matric potential
- 57 snow-depth sensors
- Meadow piezometers & wells
- Sap-flow sensors

Water balance on regolith – characterizing monthly change in subsurface storage

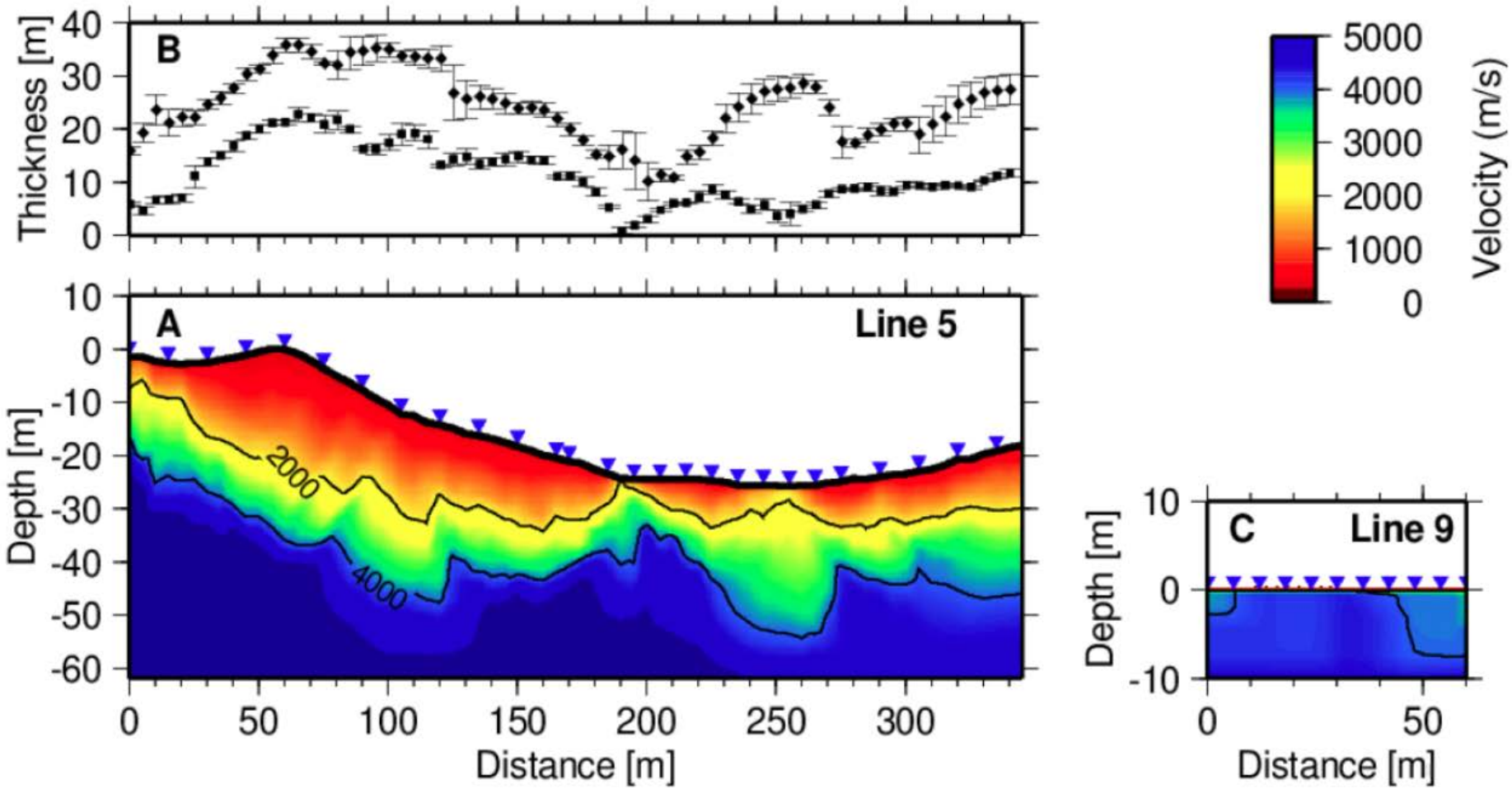


For this talk, monthly change in storage includes moisture stored in the snowpack, shallow regolith & deeper regolith

$$\Delta S = Precipitation - ET - Streamflow - Deep\ drainage$$

Drilling, deeper wells, additional geophysics in progress

Seismic survey results at Providence



Regolith thickness from a seismic survey at the Southern Sierra CZO. Upper panel shows thickness to the 2000 and 5000 m/s velocity profile (Holbrook et al. 2013).

Evapotranspiration

Pine/oak forest
E: 4000’
P_{ave} : 28”
ET: 33”

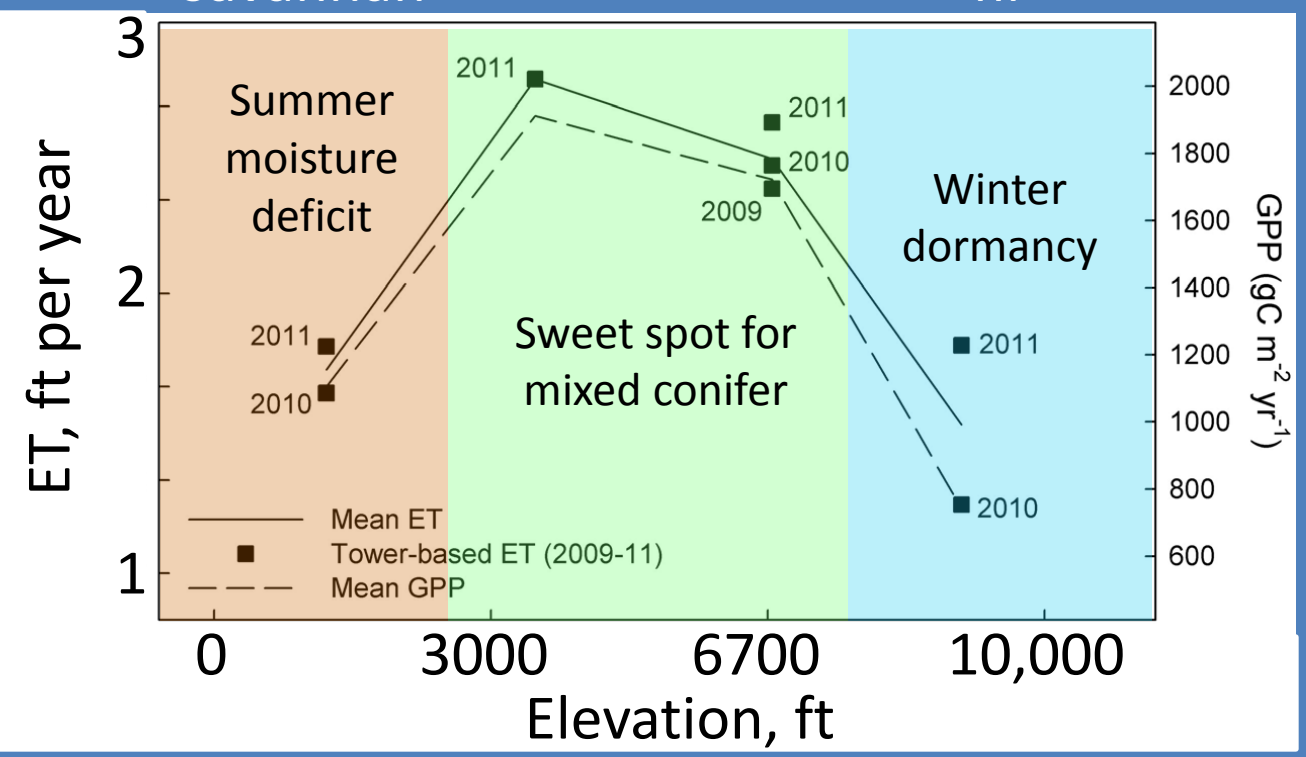
Oak savannah
E: 2000’
P_{ave}: 16”
ET: 20”

Mixed conifer forest
E: 7000’
P_{ave} : 33”
ET: 30”

Subalpine forest
E: 9000’
P_{ave} : 36”
ET: 18”

rain ← → snow

Evapotranspiration (ET) across an elevation transect



Similar ET estimates derive from catchment water balance

Before drought

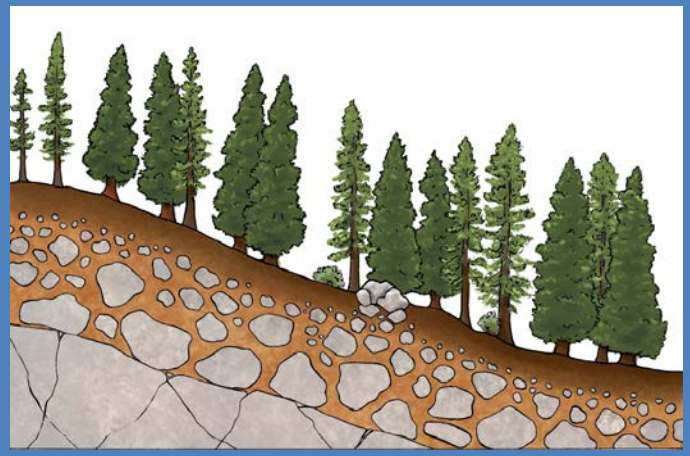
Mid-elevation forests show neither summer nor winter shutdown:

- deep rooting & resiliency to moisture stress
- warmer canopy-level temperatures despite snow

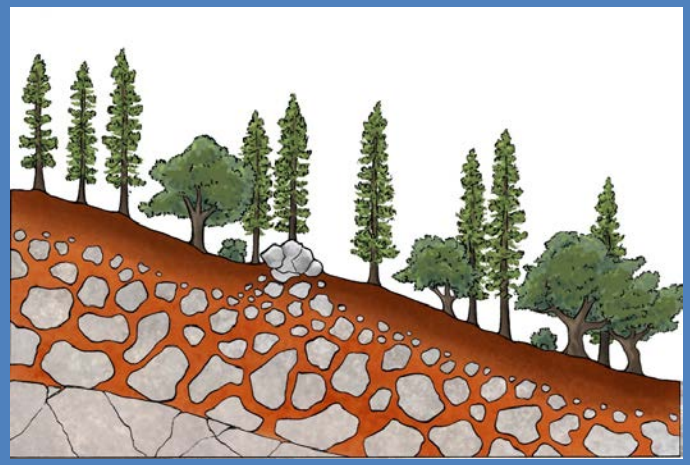
Goulden et al., 2012

Timber harvest summer 2012: uneven-age thinning & removal of 15-20% of biomass

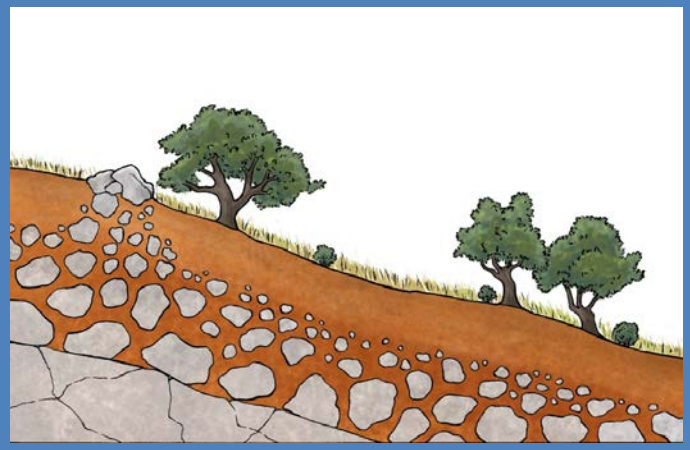
Summary of findings: ET & ΔS



Mixed conifer, 2000 m elevation
Multi-year resiliency to moisture stress
Effect of timber harvest masked by dry year



Pine/oak forest, 1100 m elevation
One-year resiliency to moisture stress
Higher ET than mixed conifer in non-drought year



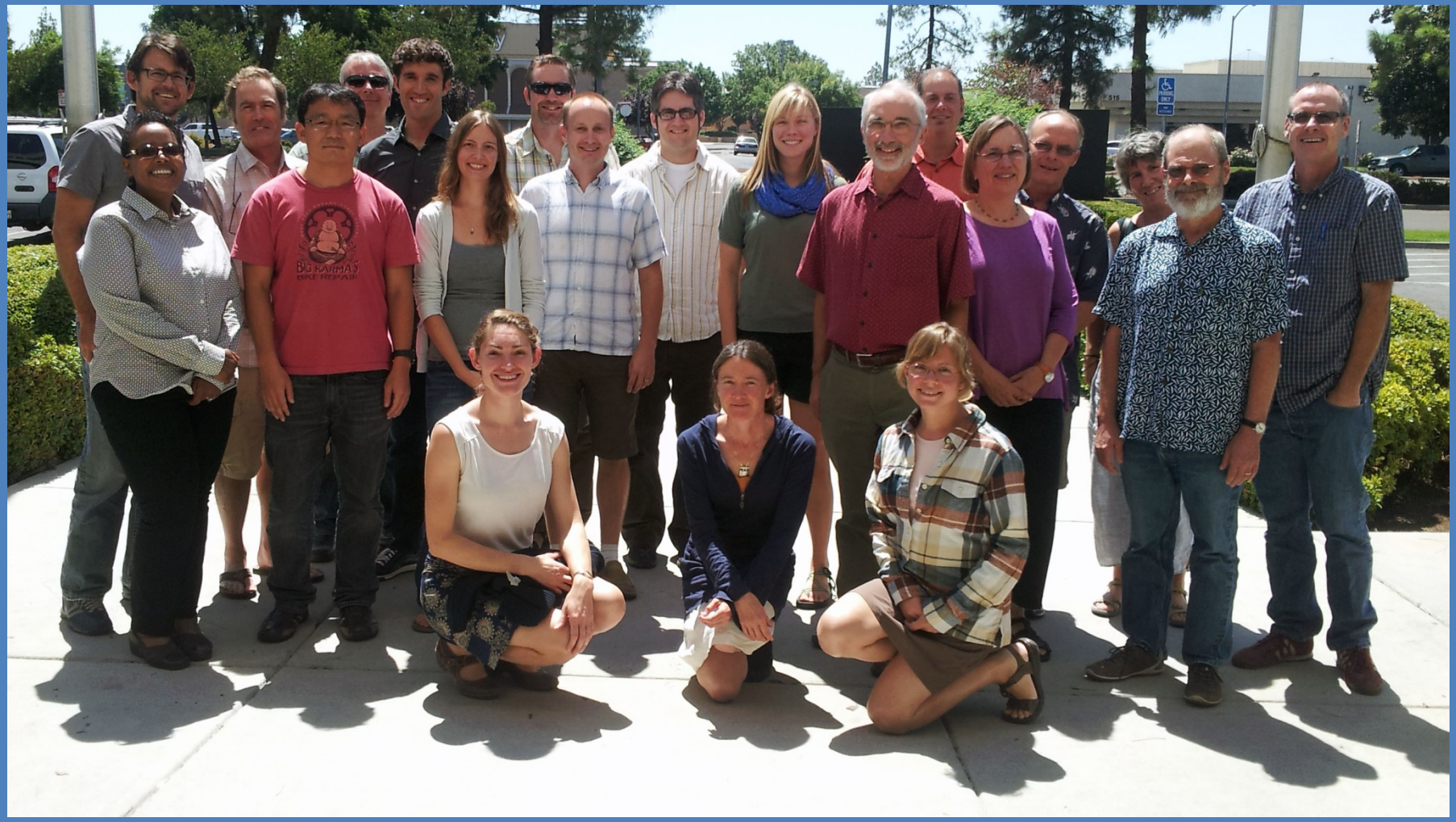
Oak savannah, 400 m elevation
Limited resiliency to moisture stress

Concluding points

What we know about water & forest management

1. Vegetation removal can result in more runoff –but there is a lower limit
2. Vegetation regrowth means less runoff over time
3. Less-dense forests (up to a point) can retain snow longer
4. Colder, snow-dominated areas have lower ET and potentially more runoff/area than lower, rain-dominated areas

Knowledge gaps – lack of quantitative information across different Sierra Nevada mixed-conifer forests

1. How much water is used by vegetation?
2. What is the depth of the regolith and influence on runoff?
3. What are interception, sublimation & evaporative losses?
4. What are the vegetation-thinning effects on the timing of snowmelt & runoff?

SSCZO team