Forests and Water in the Sierra Nevada

Roger Bales,
Sierra Nevada
Research Institute,
UC Merced

Some motivating points

- Water is the highest-value ecosystem service associated with Sierra Nevada conifer forests
- Precipitation & temperature trends are changing the timing & amount of runoff
- Many second-growth forests have dense canopies & growing fire risks

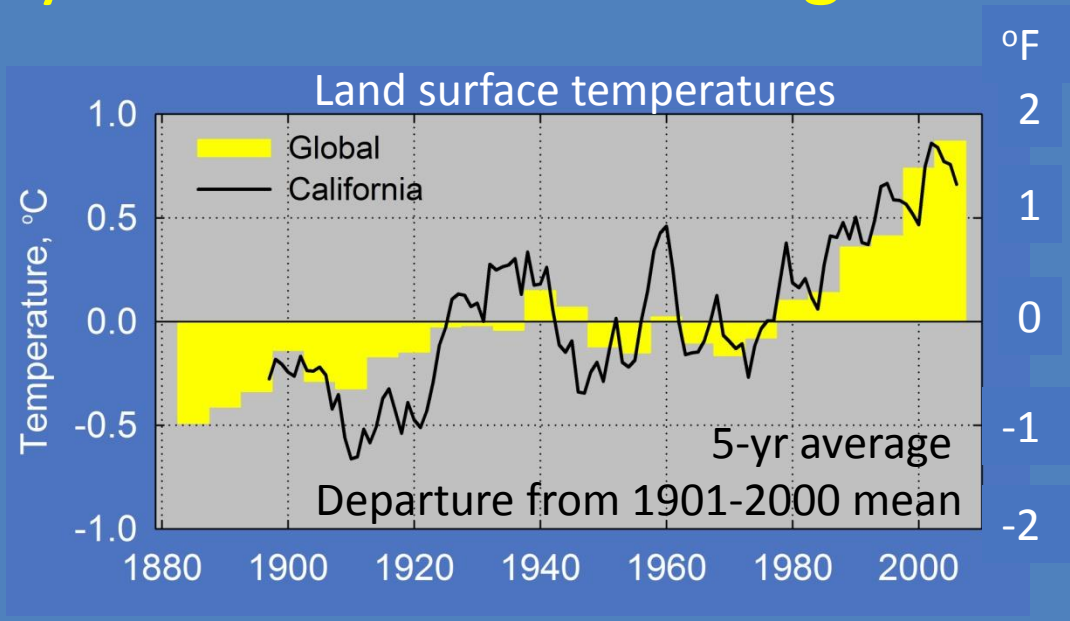
Mountain water cycle & climate warming

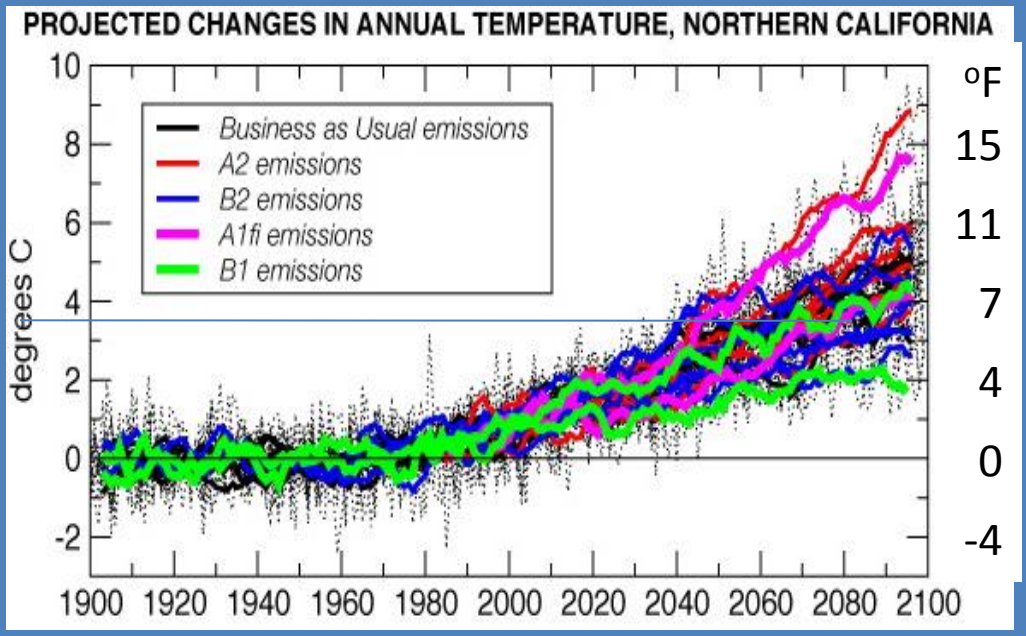
Warming by 2–6°C (4–11°F) drives significant changes:

– rain-vs-snow storms *
– snowpack amounts *
– snowmelt timing *
– flood risk
– streamflow timing *
– low baseflows
– growing seasons *
– recharge?
– drier soil in summer

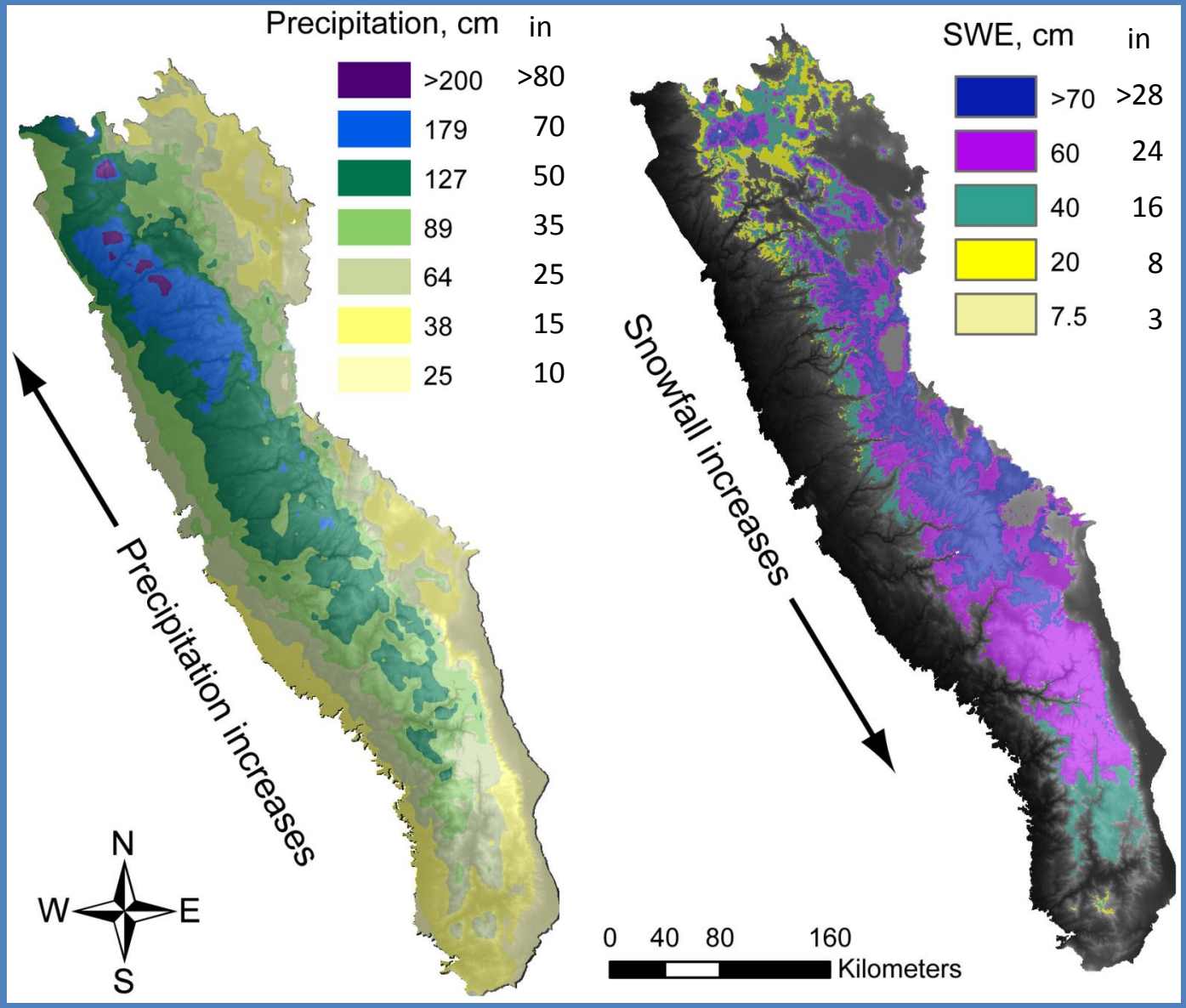
Precipitation changes uncertain

Already observed (*)



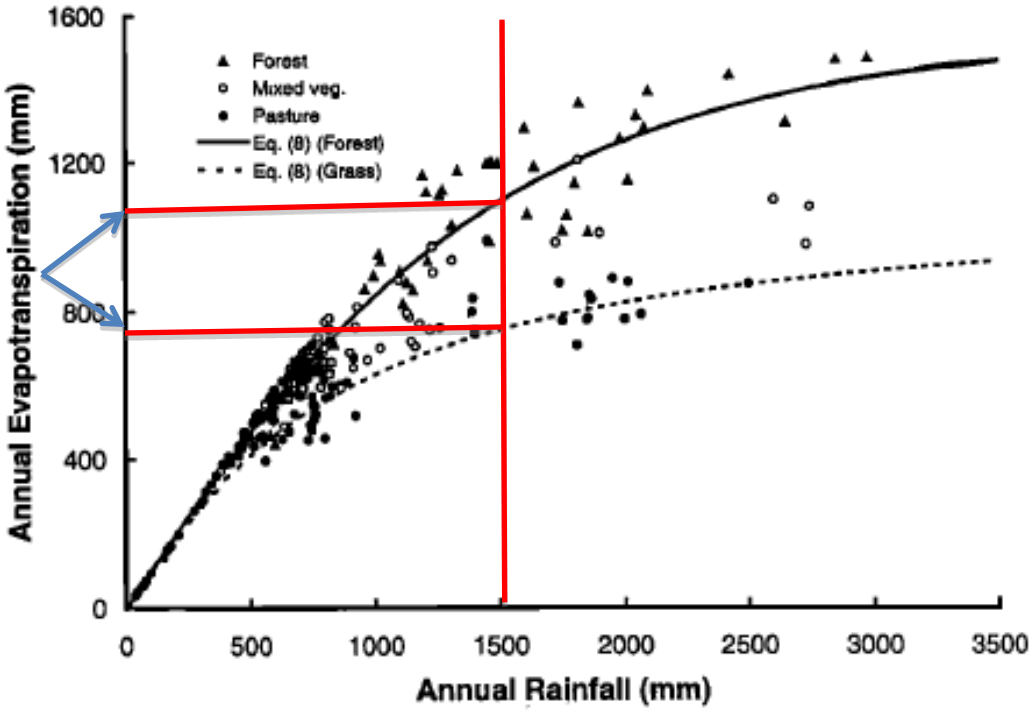


Sierra Nevada precipitation & snow water equivalent (SWE) – climatological estimate



A lot of precipitation falling on dense forests never gets into the streams

~300 mm (1 ft)

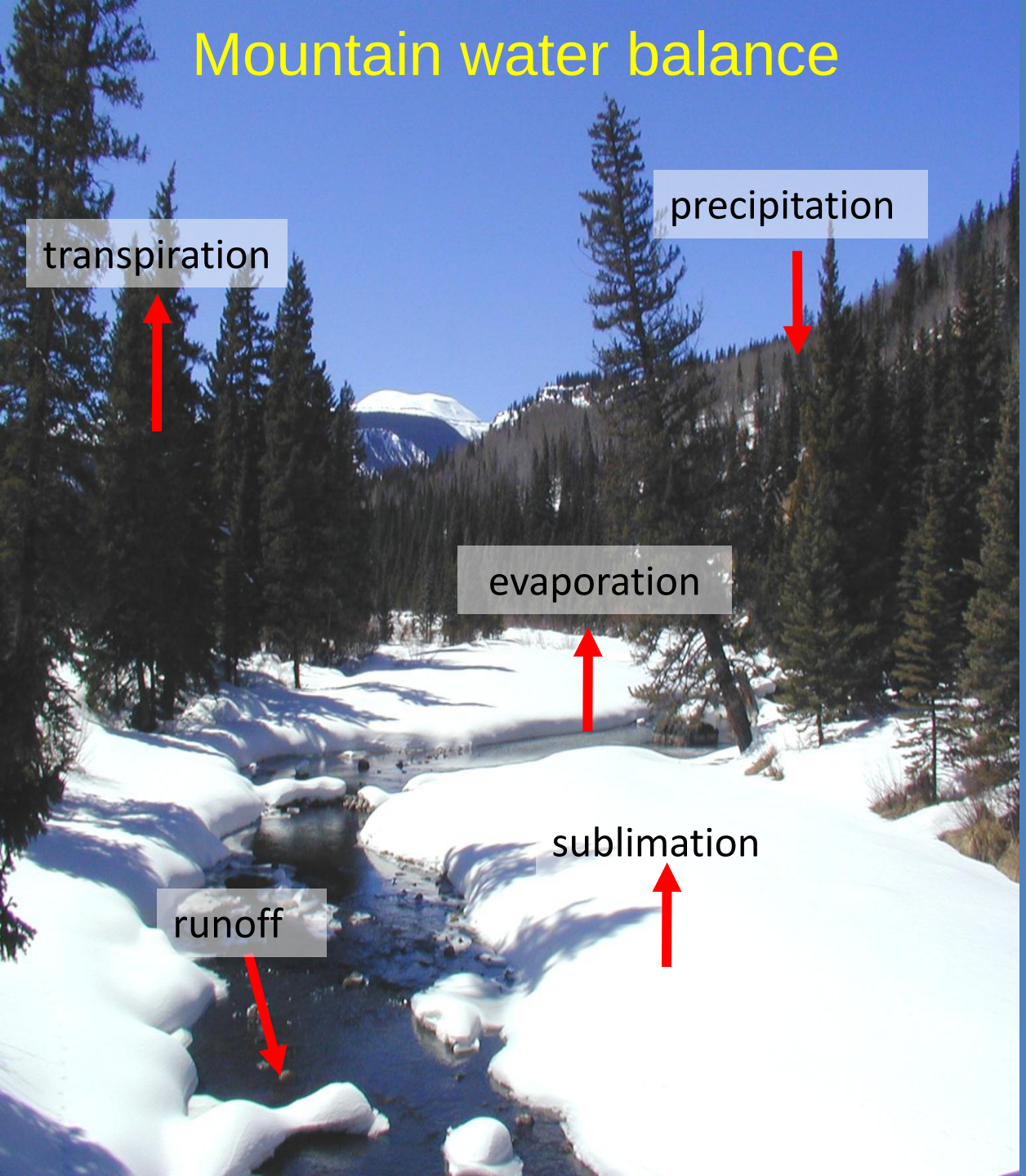


Forest

Grass

Figure 9. Relationship between annual evapotranspiration and rainfall for different vegetation types.

Every acre foot of water that runs through the full set of PCWA turbines generates about 2.8 MWh which is worth ~$130 (5 yr avg price)



Myth:

We can, with a high degree of skill, estimate or predict the magnitude of these quantities

Forest management – principles & assumptions

Produce different stand structures & densities across the landscape using topographic variables to guide varying treatments

- Higher density & canopy cover for local cool or moist areas, w/ less-frequent or lower-severity fire, providing habitat for sensitive species
- Low densities of large fire-resistant trees on southern-aspect slopes
- Thinning based on crown strata or age cohorts & species, rather than uniform diameter limits

An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests

Malcolm North, Peter Stine, Kevin O'Hara, William Zielinski, and Scott Stephens

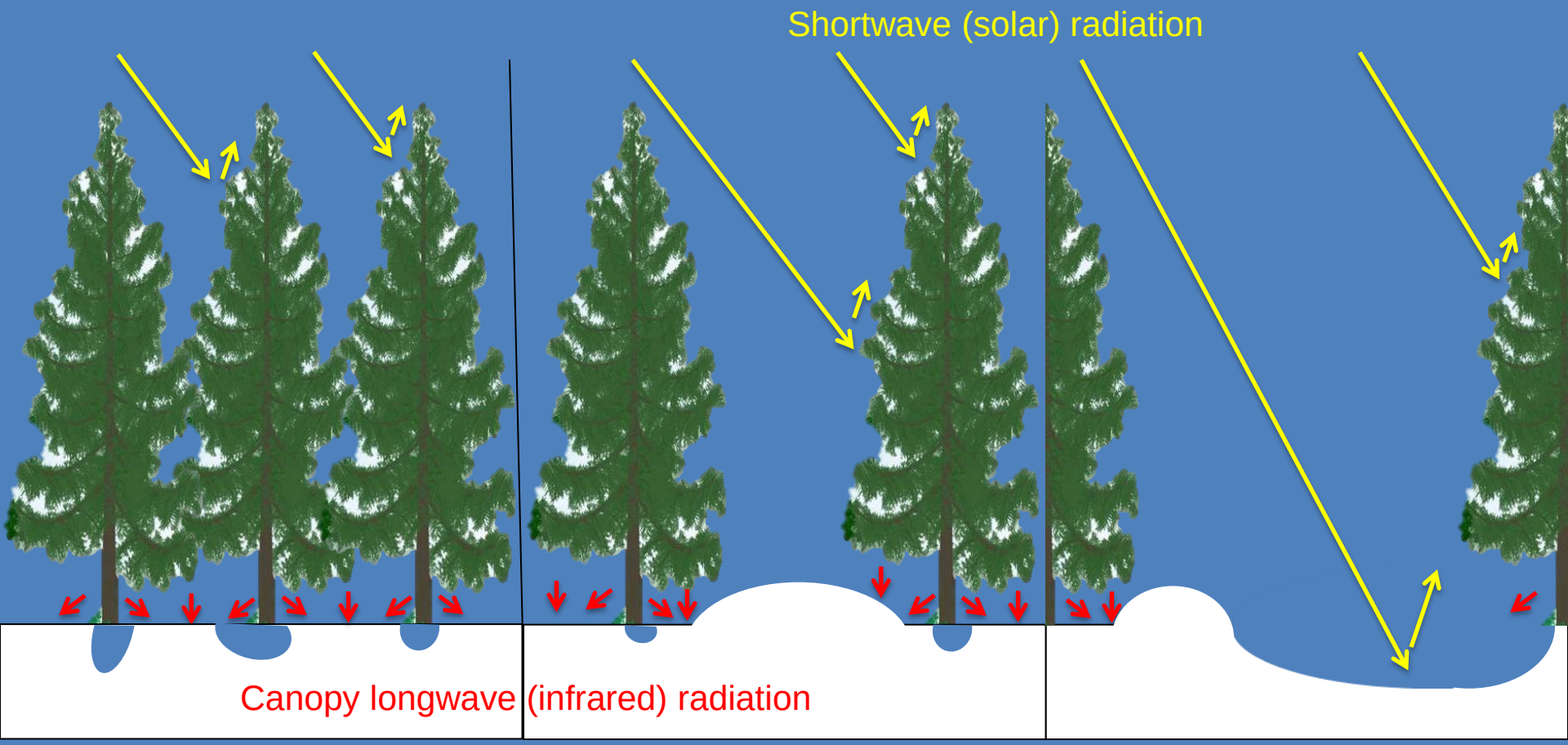
Pacific Southwest Research Station

General Technical Report PSW-GTR-220
March 2009

Such treatments can also enhance water yield & timing of runoff

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

3 scenarios for solar & infrared radiation

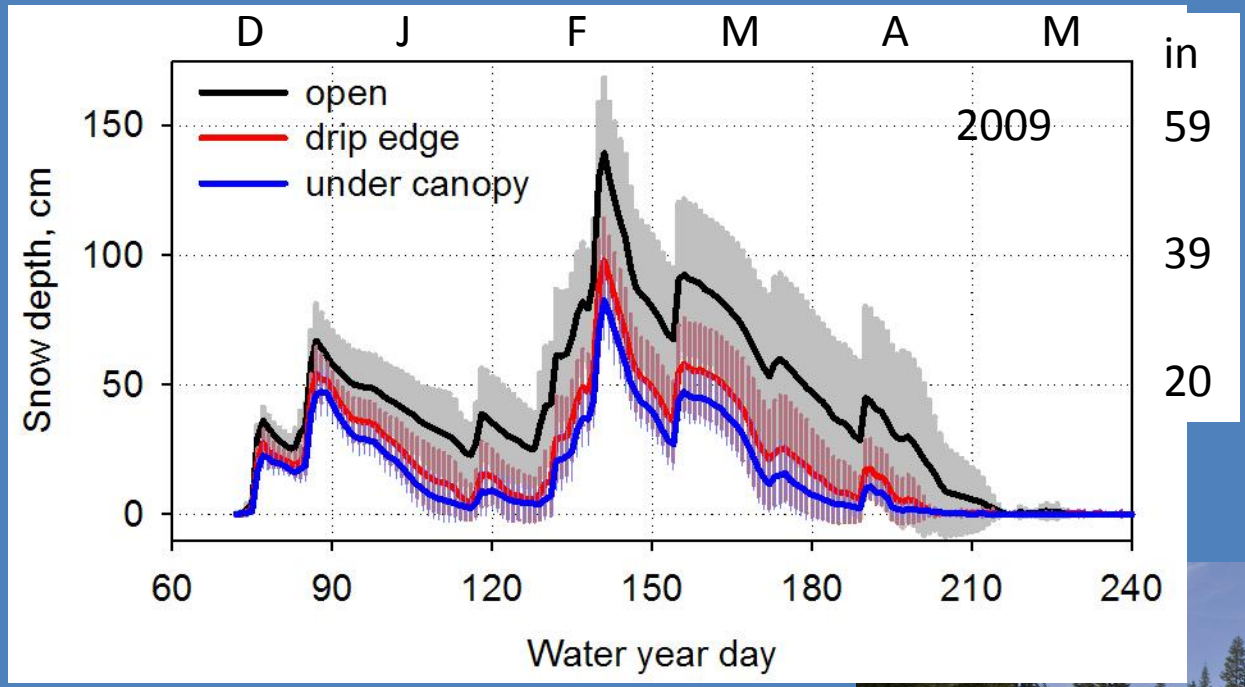


Lowest shortwave
High longwave

Low shortwave
Low longwave

High shortwave
Lower longwave

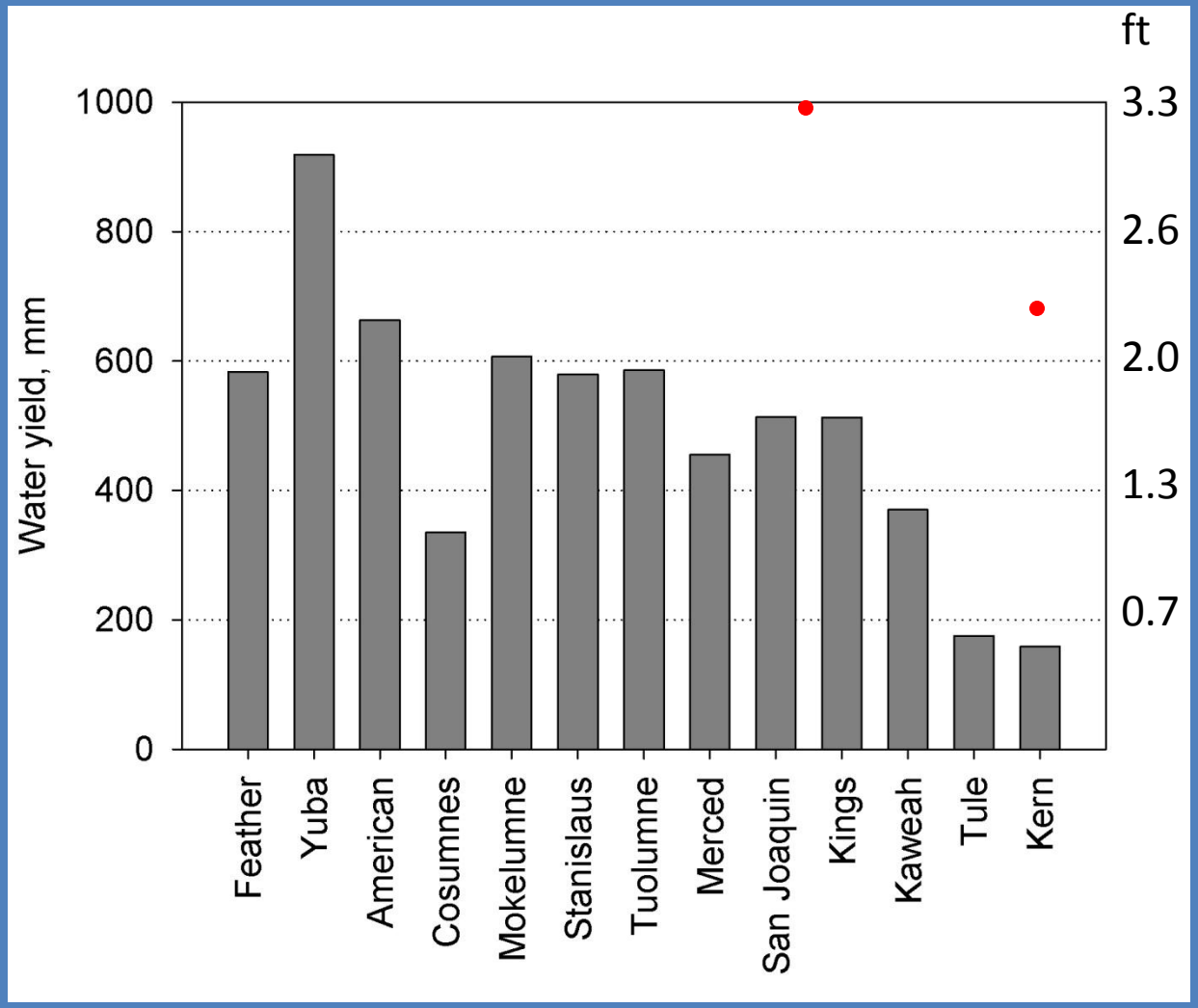
Snow depths in mixed-conifer forest



- Snow depth under canopy only about half to two thirds of that in the open
- Differences of about 40 cm (16 in)

Mean & standard deviation of snow depth over 6-mo period, Southern Sierra Critical Zone Observatory

Sierra Nevada long-term average water yield



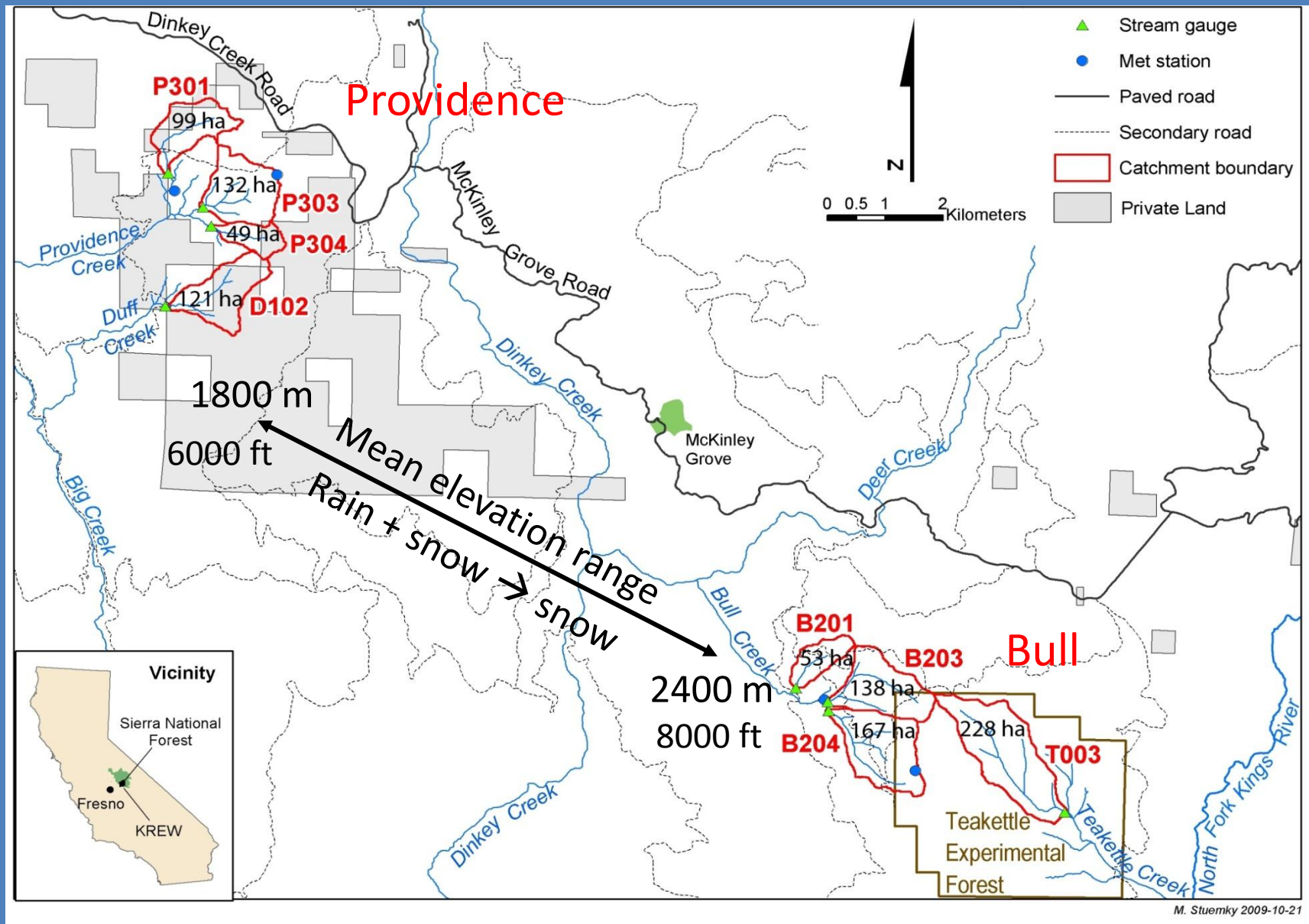
In order to verify the impact of forest management, need to accurately estimate the precipitation, discharge & evapotranspiration

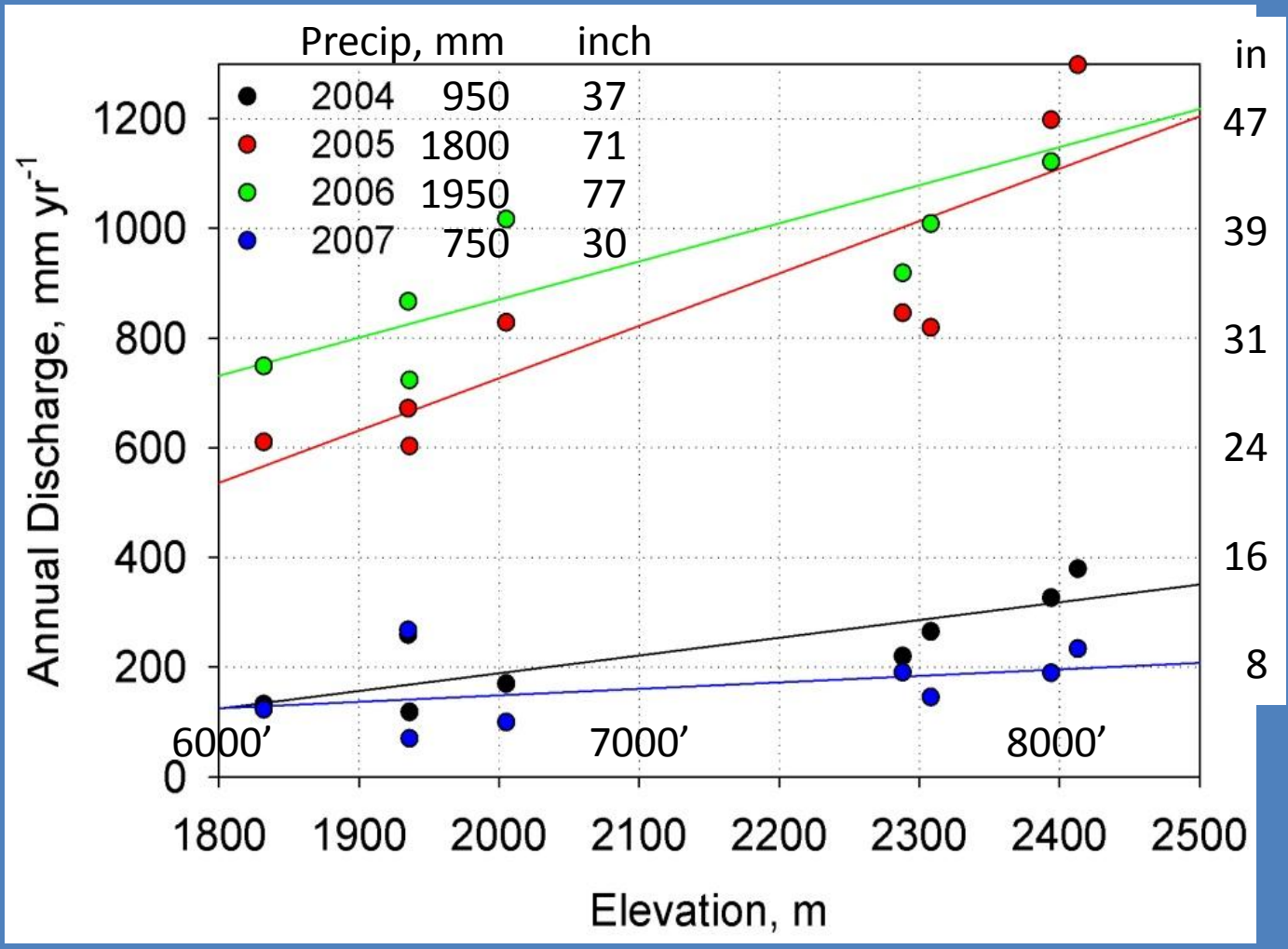
General N – S decrease →

Decreasing precipitation →

Increasing snow →

A closer look at water yield: 8 KREW instrumented headwater catchments





Increase in water yield w/ elevation, from rain to snow dominated

Kings River basin

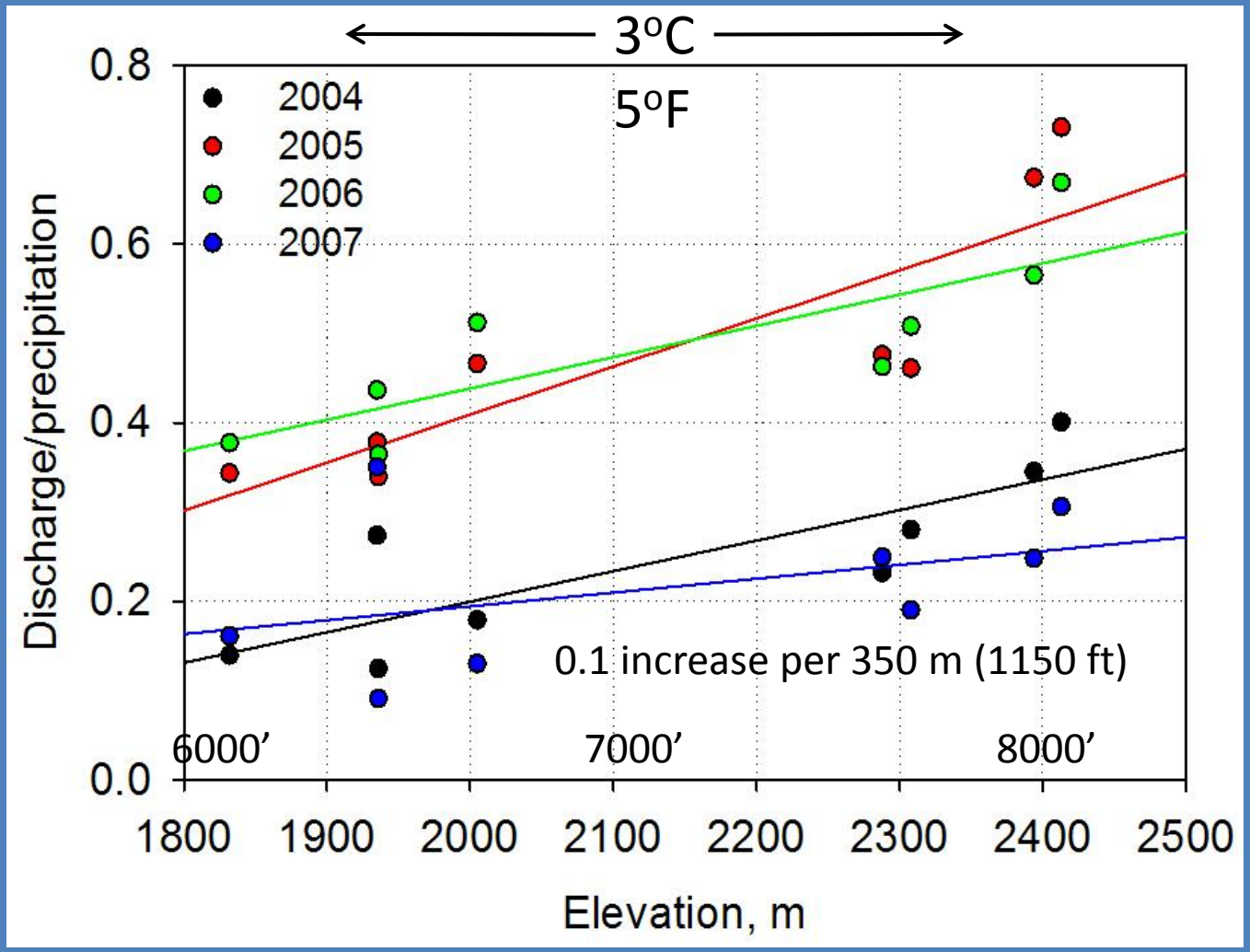
Decreasing temperature →

Increasing snow fraction →

Decreasing vegetation →

Coarser soils →

Hunsaker et al., JAWRA 2012



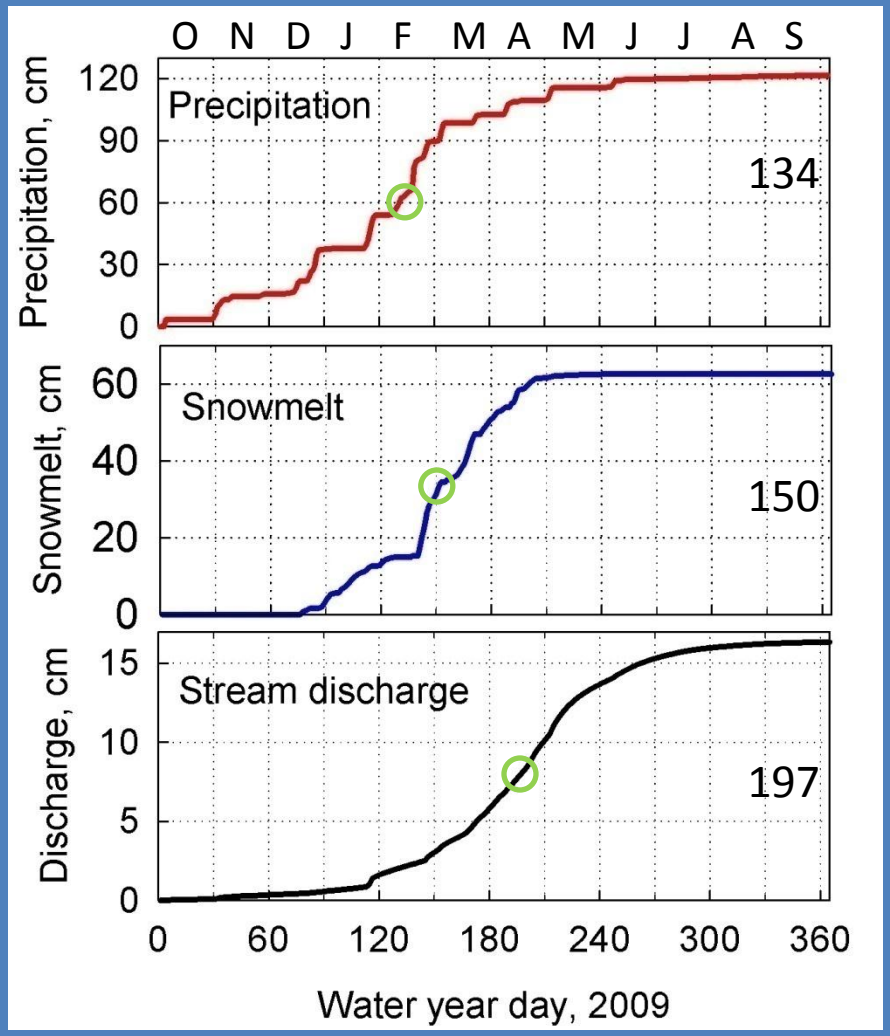
50% more runoff in snow dominated vs. mixed rain-snow catchments

Implication for 2°C warmer climate: Reduce runoff by 10-40% in mixed conifer forest (assuming ecosystems adapt)

Decreasing temperature →
Increasing snow fraction →
Decreasing vegetation →
Coarser soils →

The effect of snowpack storage on runoff timing

Cumulative over one water year



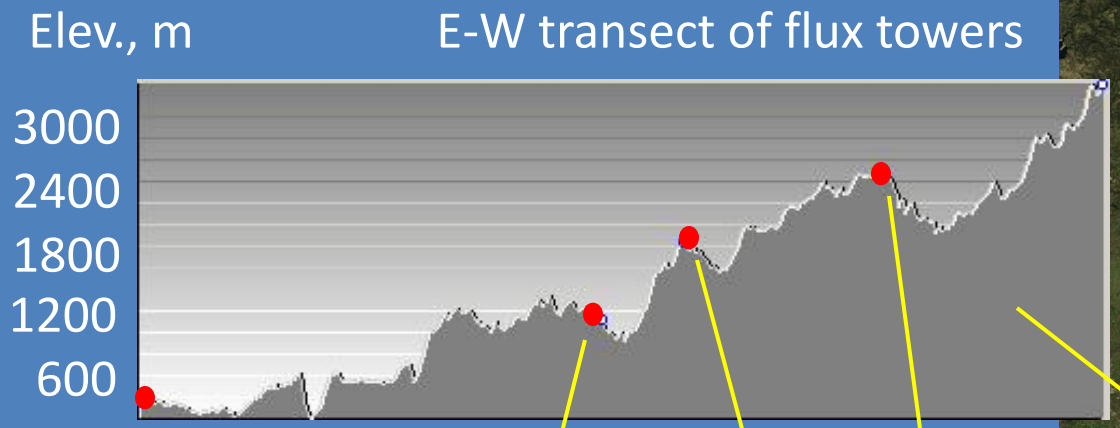
KREW/CZO, P-301 headwater catchment

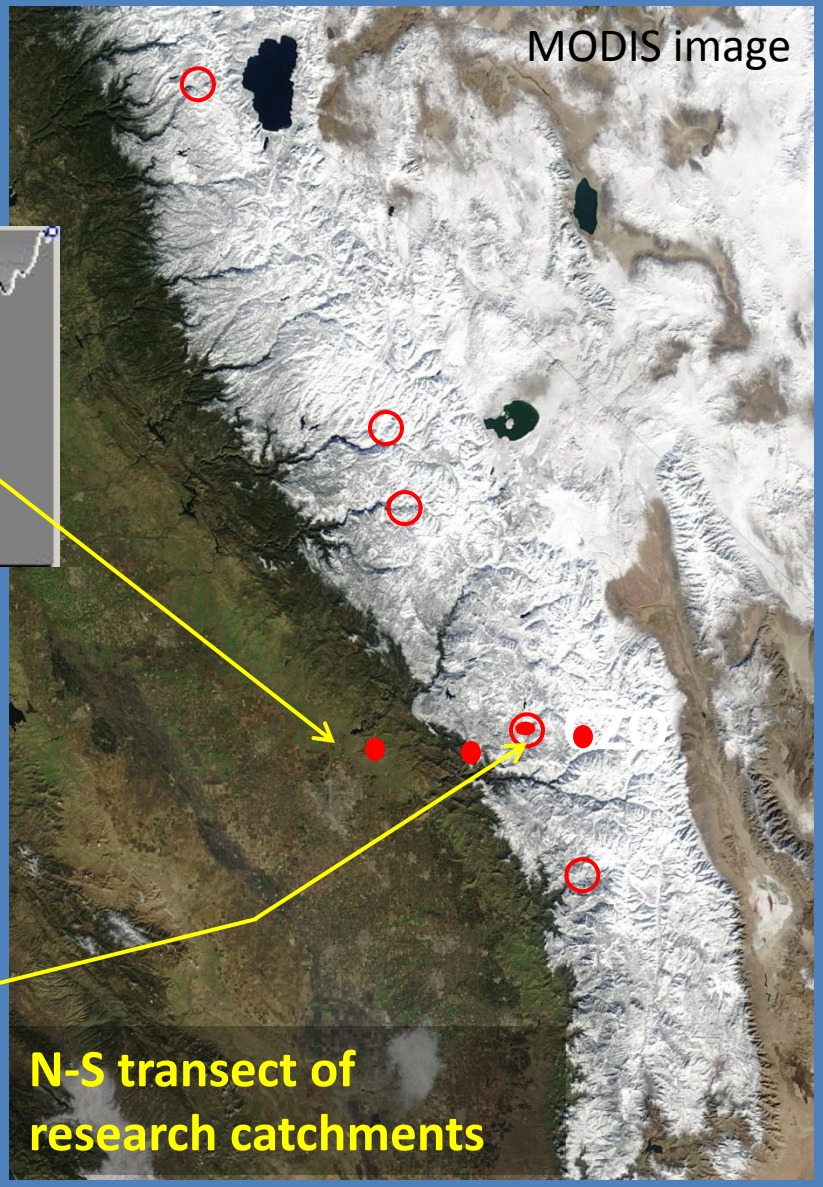
In this rain-snow transition catchment, stream discharge lags precipitation by about 2 months

This lag is expected to decrease by about 1-2 weeks per 1°C (2°F) of warming

How forest management will affect the lag depends on how the energy balance changes

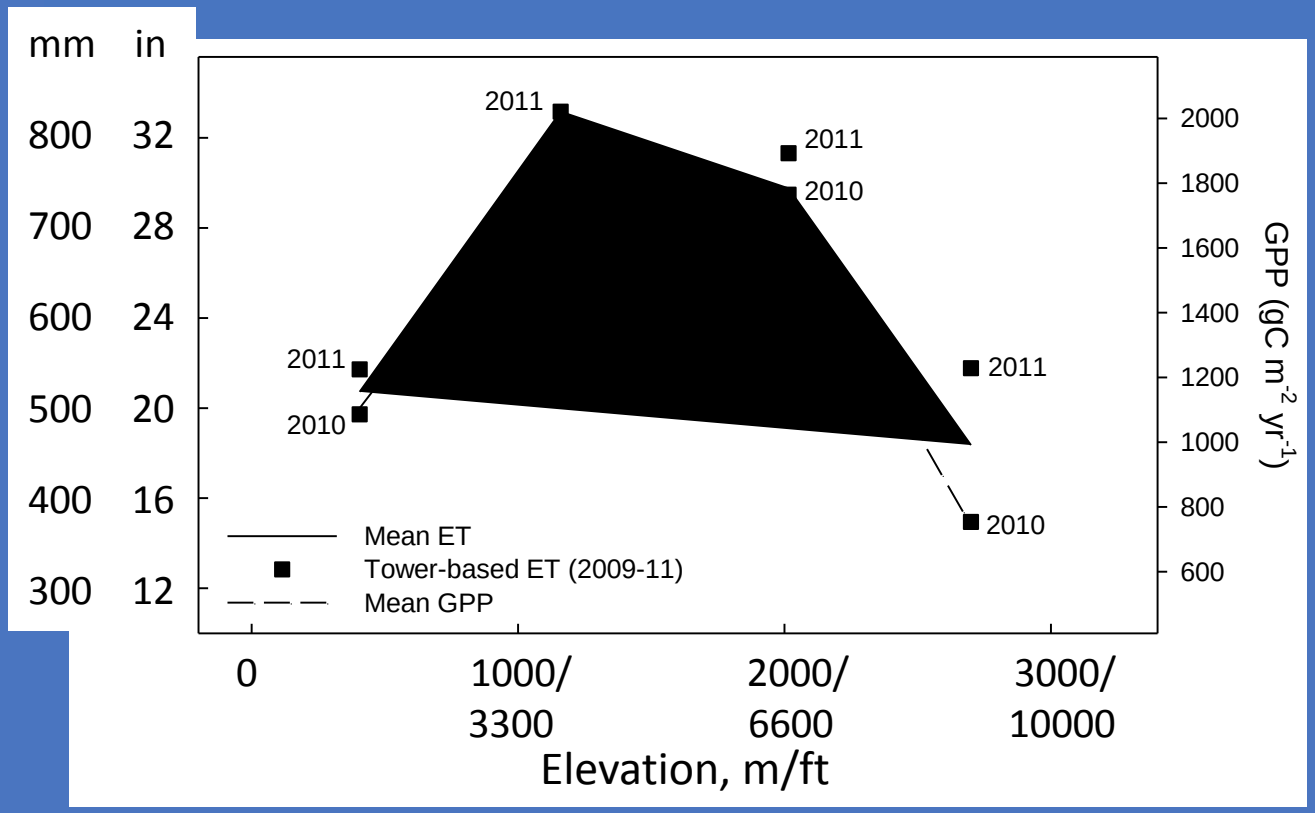
Sierra Nevada research infrastructure – evapotranspiration measurements





Southern Sierra Critical Zone Observatory

Annual evapotranspiration



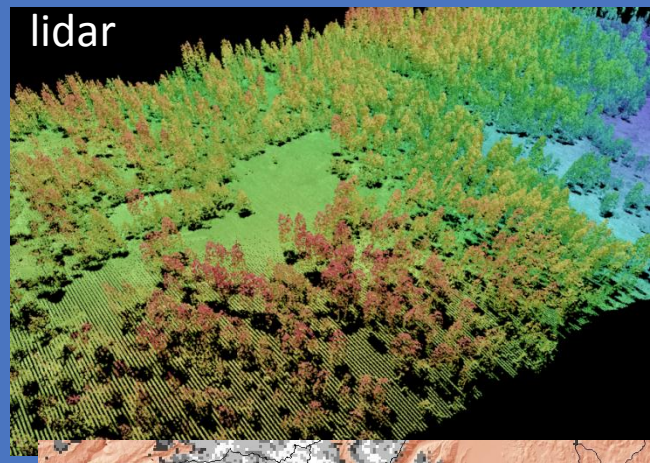
- Highest current evapotranspiration in rain to rain-snow transition region of mixed conifer forest – year-round growth
- Lower elevation is water limited
- Higher elevation is cold limited

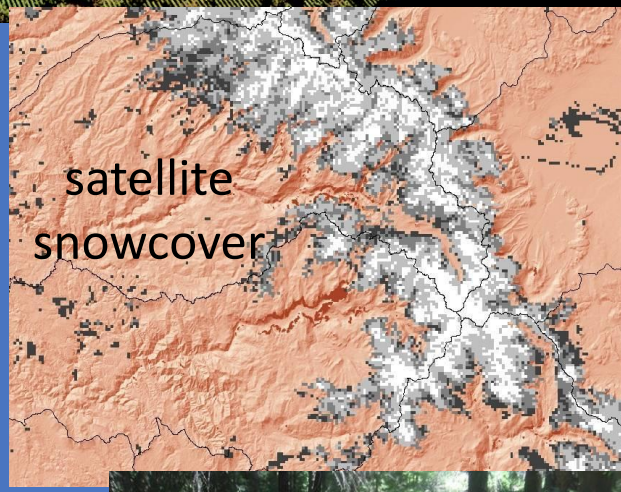
Goulden et al., submitted

Hydrologic research in progress – American River

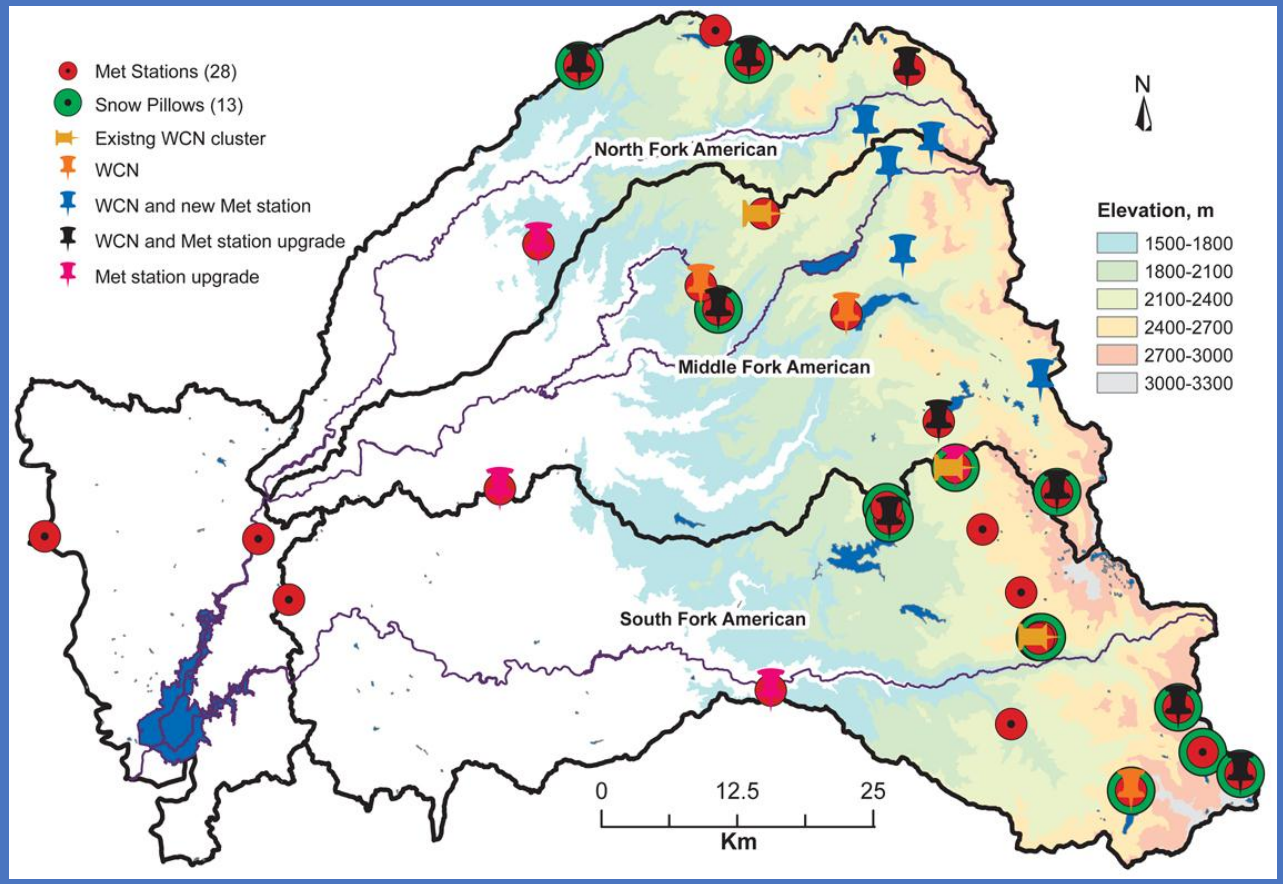
1. Sierra Nevada Adaptive Management Project (SNAMP)
   - Two instrumented headwater catchments in Forest Hill/Duncan Peak area
   - Sierra Nevada Framework treatments
2. Sierra Nevada Watershed Ecosystem Enhancement Project (SWEEP)
   - Phase 2 research to develop treatments & project effects
   - Phase 3 to carry out & evaluate treatments
   - Additional phase 2 planning needed
3. American River basin hydrologic observatory
   - National Science Foundation (NSF) supported infrastructure
   - CA-DWR supported infrastructure

A new generation of integrated measurements

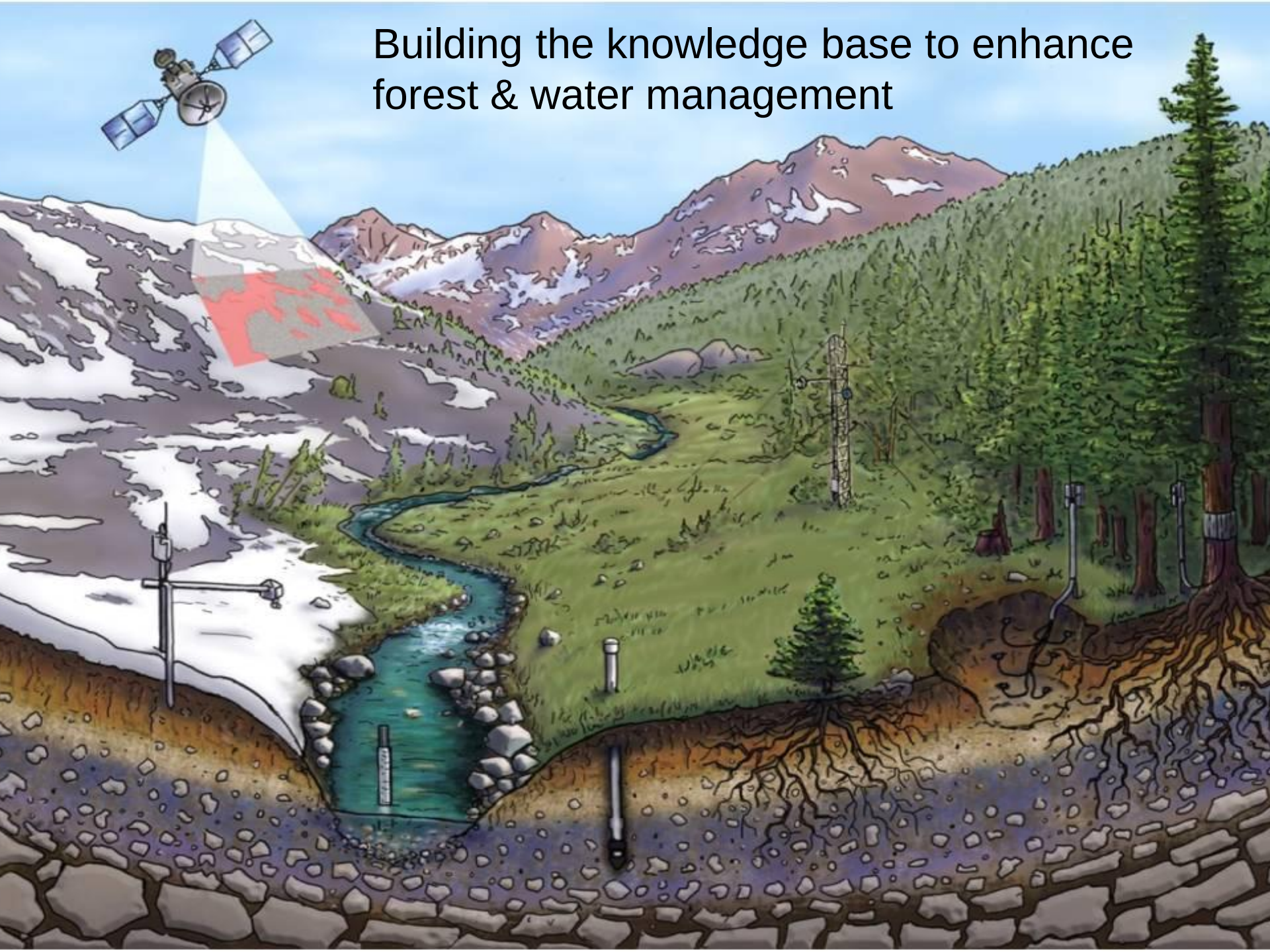




Basin-wide deployment of hydrologic instrument clusters – American R. basin



Strategically place low-cost sensors to get spatial estimates of snowcover, soil moisture & other water-balance components

Network & integrate these sensors into a single spatial instrument for water-balance measurements.

Building the knowledge base to enhance forest & water management