Southern Sierra in a new era of fire & climate change:

A longer-term view of links between disturbance, vegetation response & water-cycle shifts in the Southern Sierra under a warming climate

Roger Bales, UC Merced

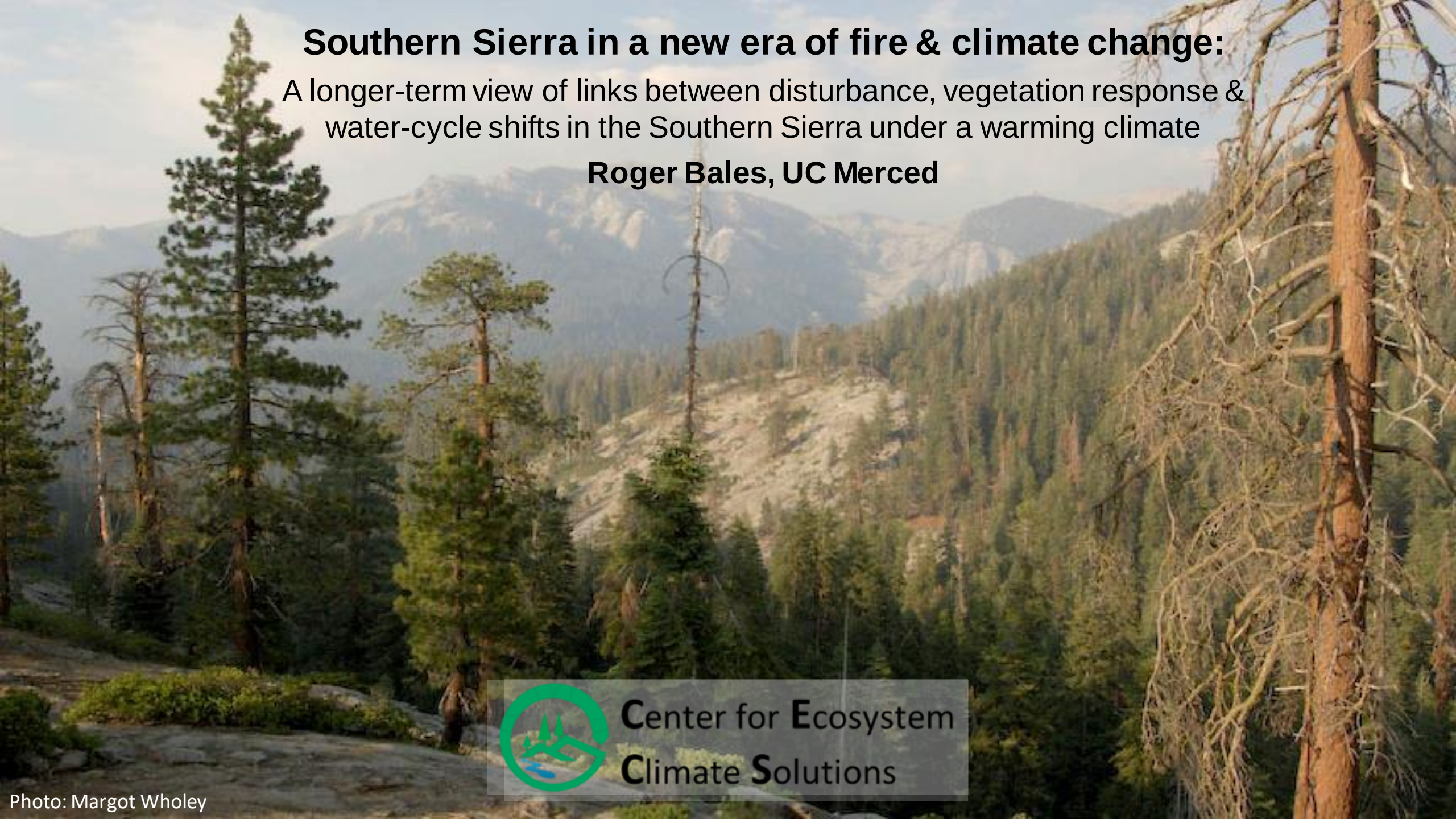


Photo: Margot Wholey

Basic water balance definitions

Precipitation = Evapotranspiration + Runoff + Change in storage

=

+

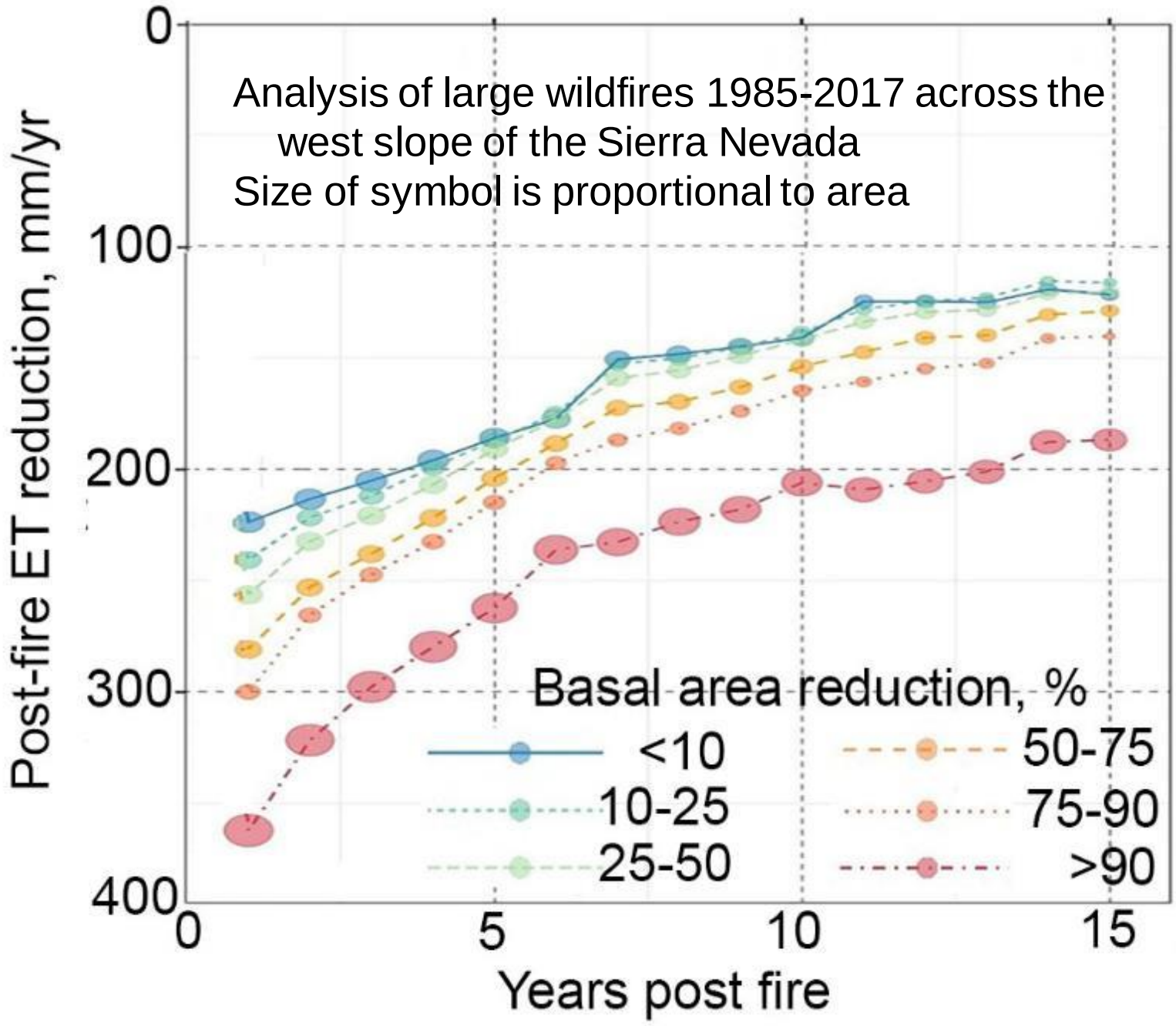
+

Evapotranspiration refers to evaporation, sublimation plus water use by vegetation

ET following wildfire

Evapotranspiration dropped an average of ~250 mm/yr the first year following a wildfire & gradually recovered as post-fire vegetation grew

Besides severity, there is considerable variability across elevation, starting vegetation density, year, latitude

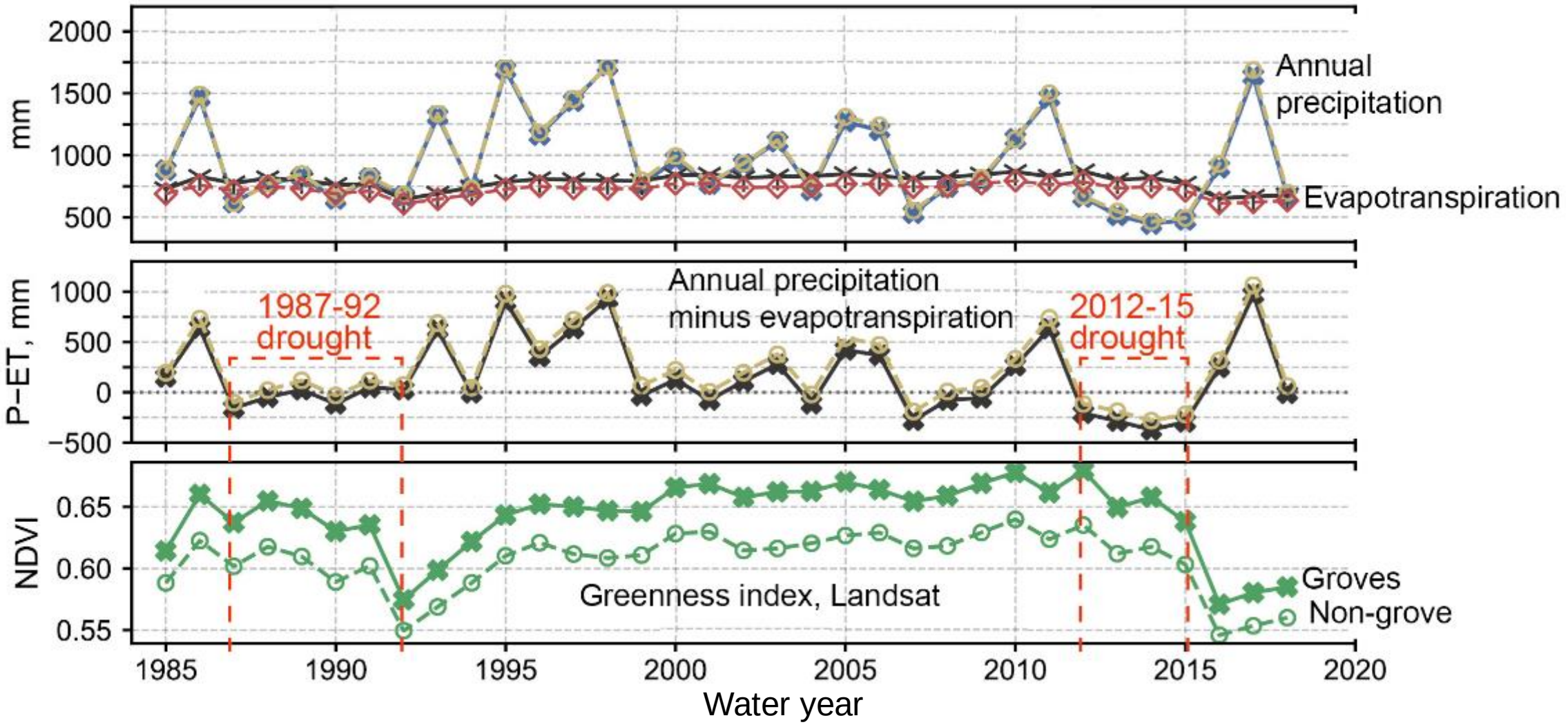


Data: USDA Forest Service R5 Veg Burn Severity BA

Ma et al., 2020, J. Hydrol.

Droughts

Multi-year water deficit (P-ET<0) for Giant Sequoia grove & non-grove areas in 2012-15 drought

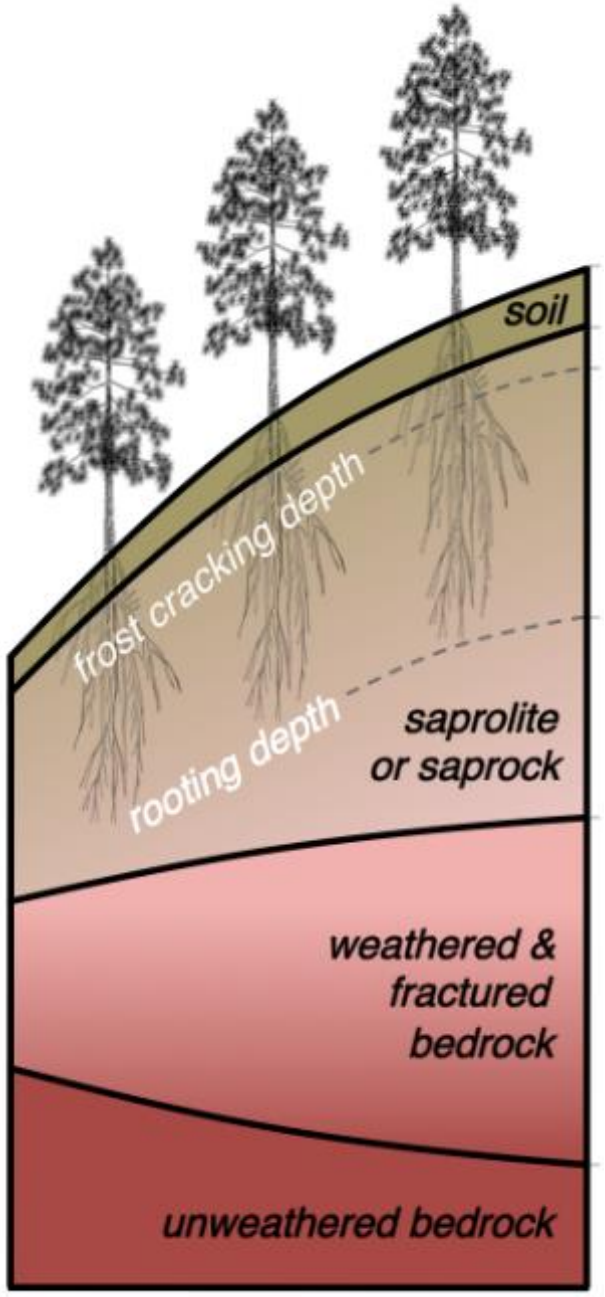


Data: ET based on flux-tower measurements scaled with Landsat NDVI (Ma et al., 2020)

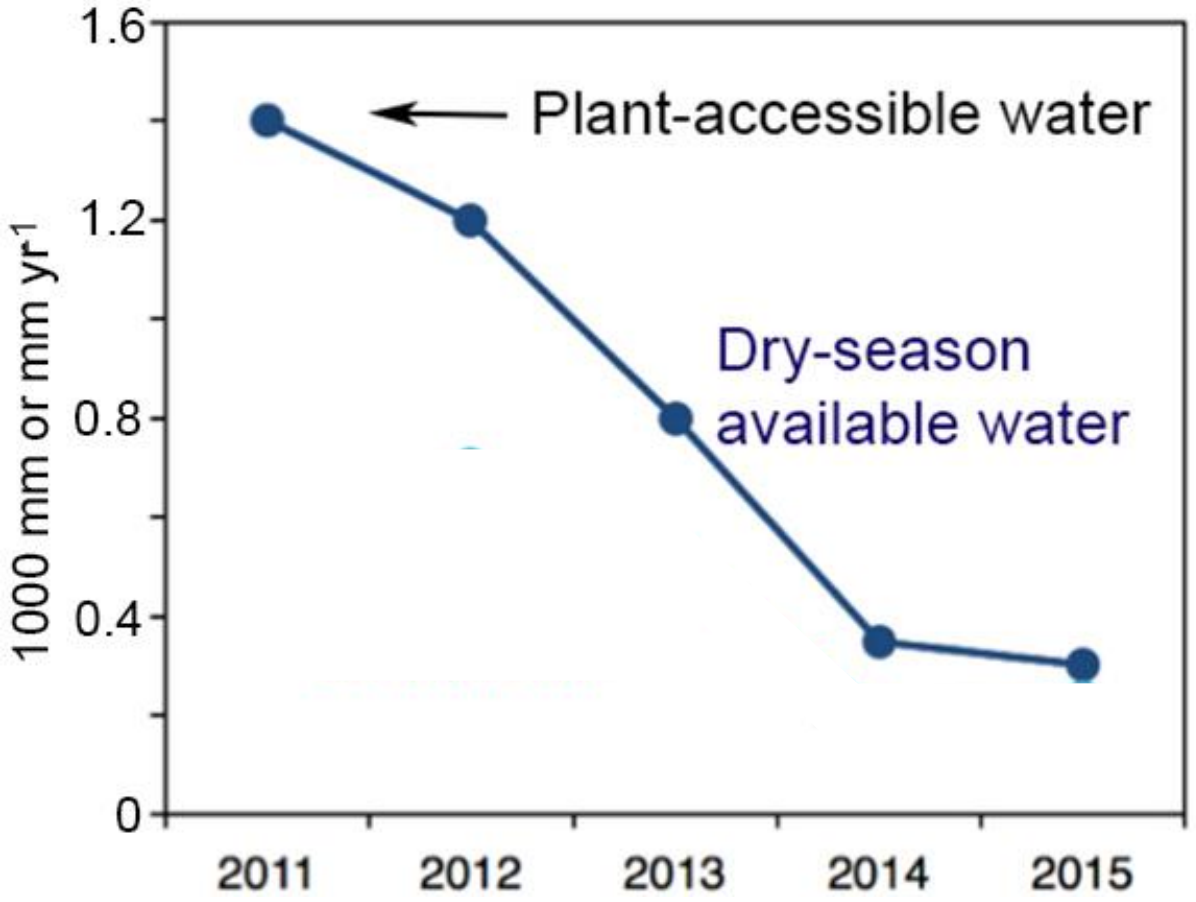
Cui et al., 2022, J.Hydrol.

We assessed Giant Sequoia groves, in part because they are greener & have higher ET than nearby non-grove areas

Critical-zone architecture & water drawdown during drought



Soaproot Saddle, 1100 m elevation, pine-oak forest



Note declines during drought

Klos et al., 2018

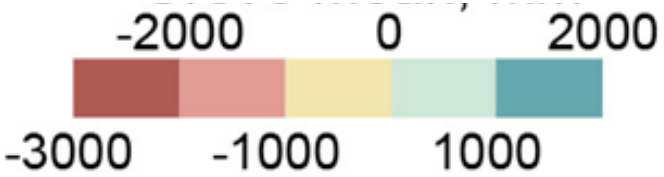
Distribution of cumulative P-ET for 78 groves in 2 droughts

Cumulative P-ET represents the total water deficit to meet ET over the multi-year drought

Lines shows distribution of values for 30-m pixels in each grove & colors indicate mean

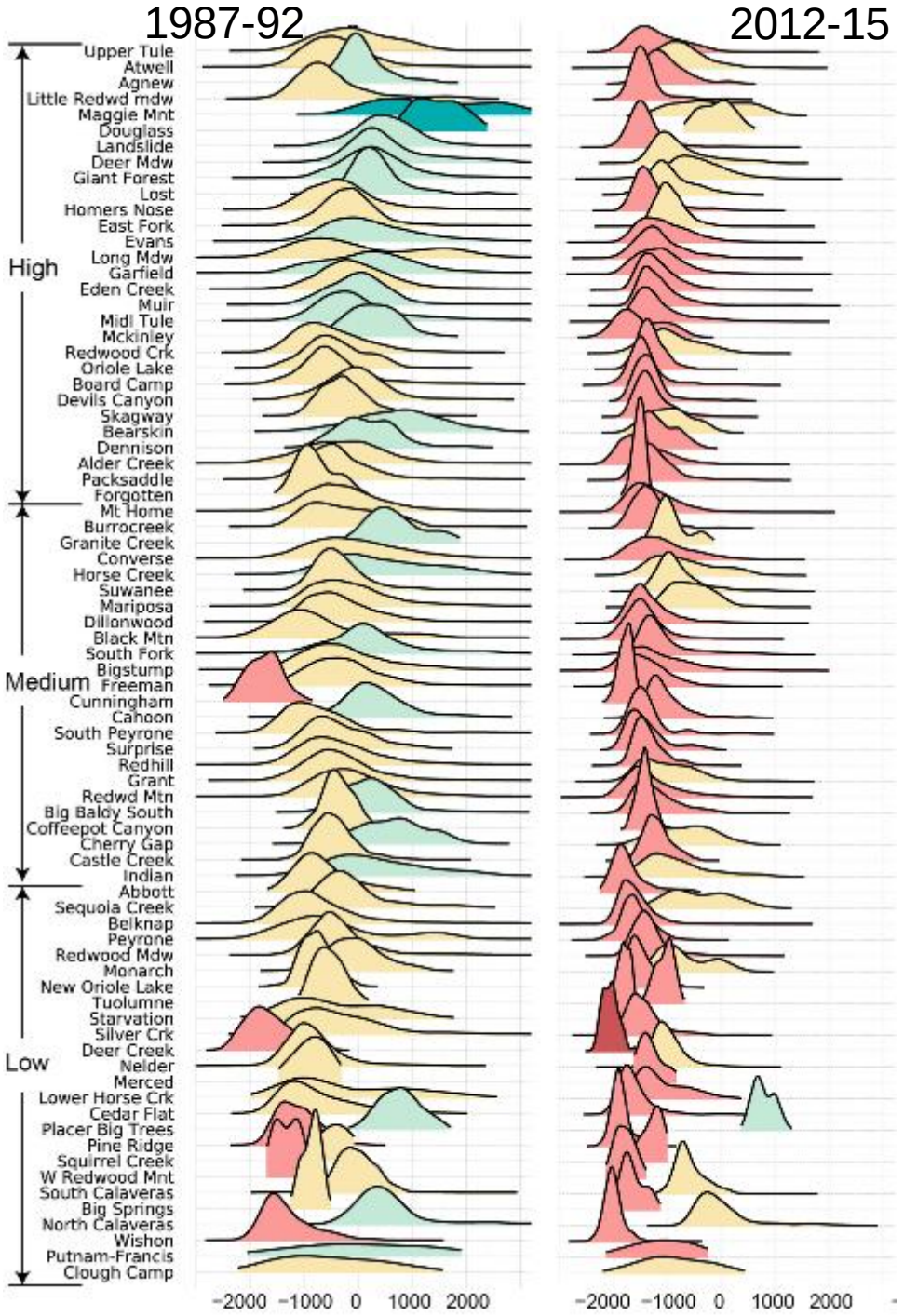
Values as low as -3000 mm are equivalent to depletion of root accessible water down as much as 10-m depth

Mean cumulative P-ET, mm



P-ET index adapted from Goulden & Bales, 2018

Cui et al., 2022, J.Hydrol.



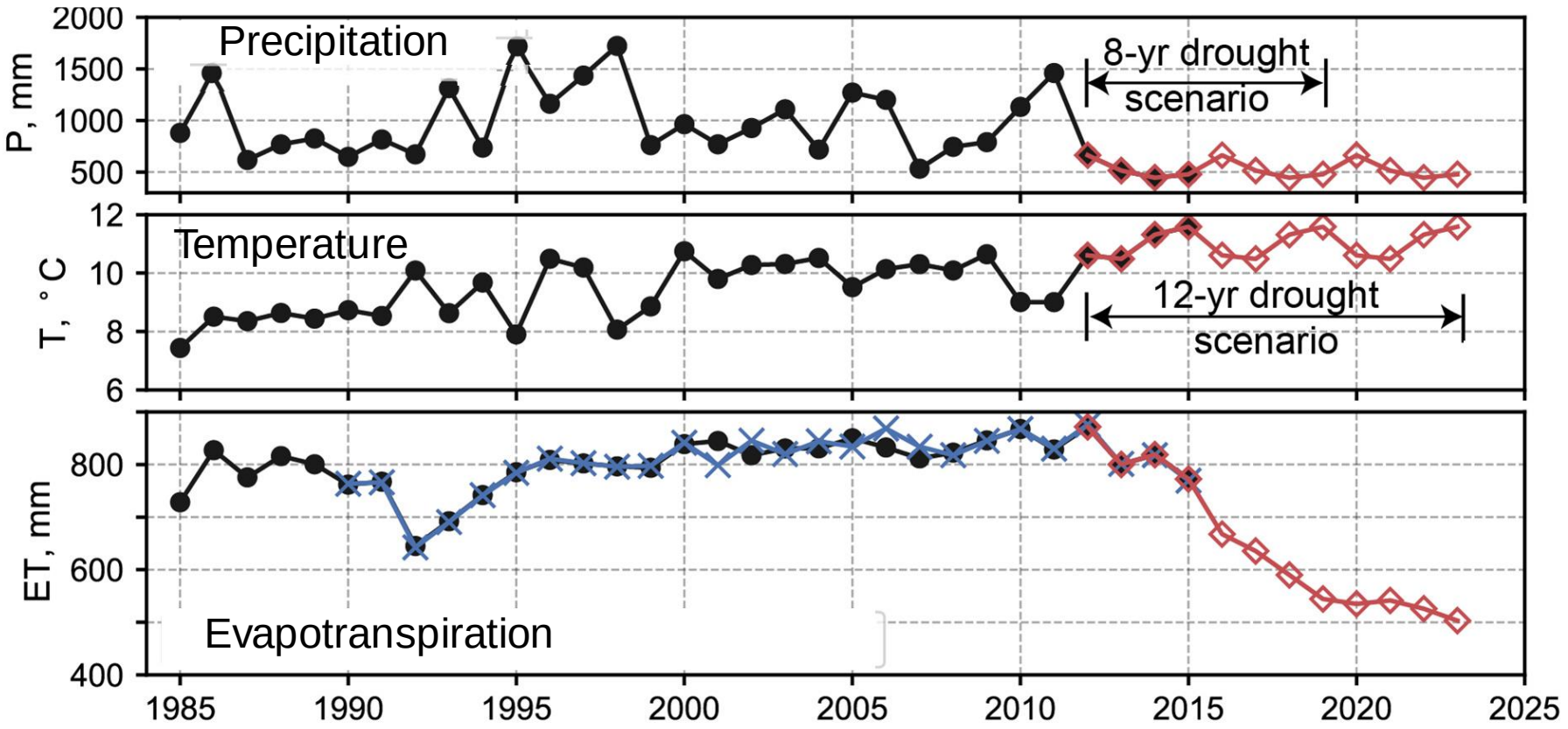
Simulating a longer drought

Extend 2012-15 drought 4 or 8 more years, with same precipitation & temperature

Trained a deep-learning Long Short-Term Memory model to project ET during hypothetical extended-drought scenarios

Declines in ET due to depletion of root-accessible water storage

Longer, hotter droughts will increase tree mortality

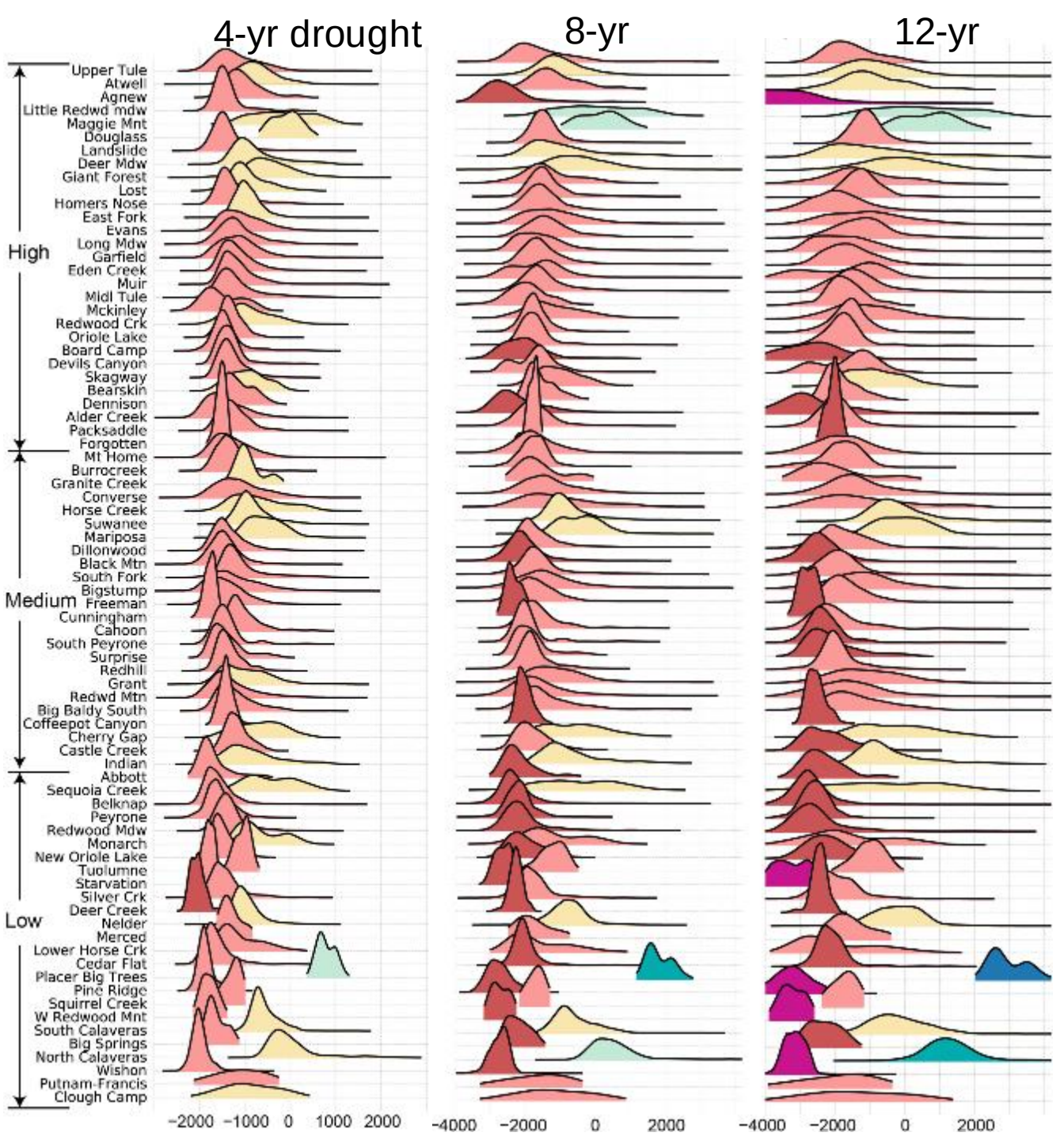


Cui et al., 2022, J.Hydrol.

Mapping the extended drought scenarios onto the 78 groves

- Cumulative P-ET represents the total water deficit to meet ET over the multi-year drought
- Lines shows distribution of values for 30-m pixels in each grove & colors indicate mean
- Parts of most groves show large negative values of cumulative P-ET during 8-yr & 12-yr droughts, with lower elevations affected more
- Most groves show a projected decrease in ET

Mean cumulative P-ET, mm



Cui et al., 2022, J.Hydrol.

What are you exploring?

- ◉ Current and recent conditions
- ○ Vulnerabilities
- ○ Expected effects of management

What conditions do you want to see?

▲ Overview of Ecosystem Issues

- ◉ Fuel, biomass and water composite

▲ Vegetation Type

- ○ Overview of vegetation type
- ○ Fraction herbaceous
- ○ Fraction tree
- ○ Fraction shrub

▼ Management / Disturbance History

▲ Carbon Fluxes

- ○ GPP
- ○ NPP tree
- ○ NPP shrub
- ○ NPP herb

▲ Water Fluxes and Supply

- ○ Actual evapotranspiration
- ○ Runoff amount
- ○ Water shortfall
- ○ Soil moisture

▲ Carbon Stocks

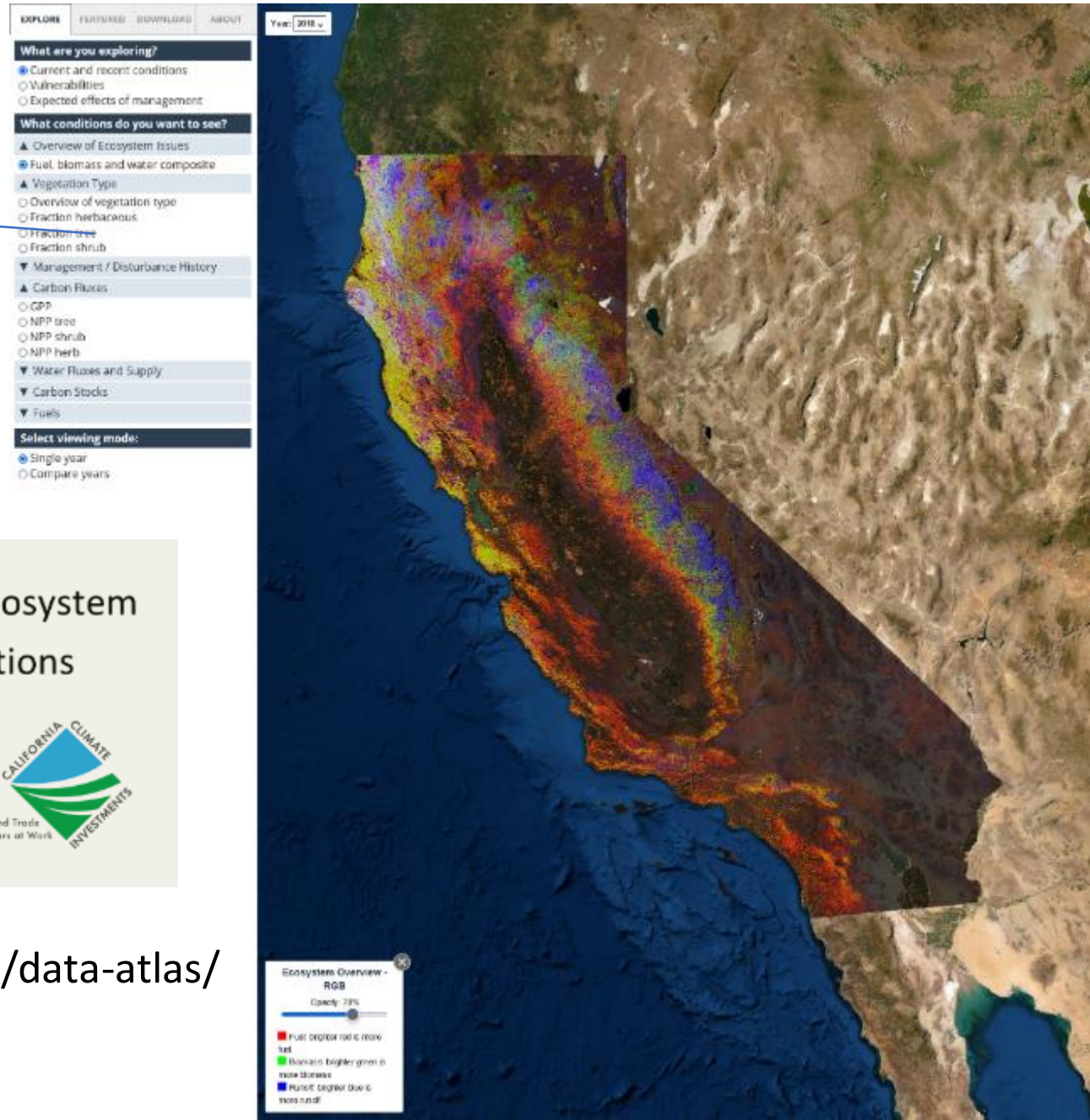
- ○ Live
- ○ Dead
- ○ Tree Biomass
- ○ Shrub Biomass
- ○ Standing Snags
- ○ Fine Woody Detritus
- ○ Coarse Woody Detritus

▲ Fuels

- ○ Fuel type and amount
- ○ Coarse
- ○ Fine
- ○ Herbaceous

Select viewing mode:

- ◉ Single year
- ○ Compare years



Center for Ecosystem Climate Solutions

CALIFORNIA STRATEGIC GROWTH COUNCIL

CALIFORNIA CLIMATE INVESTMENTS
Cap and Trade Dollars at Work

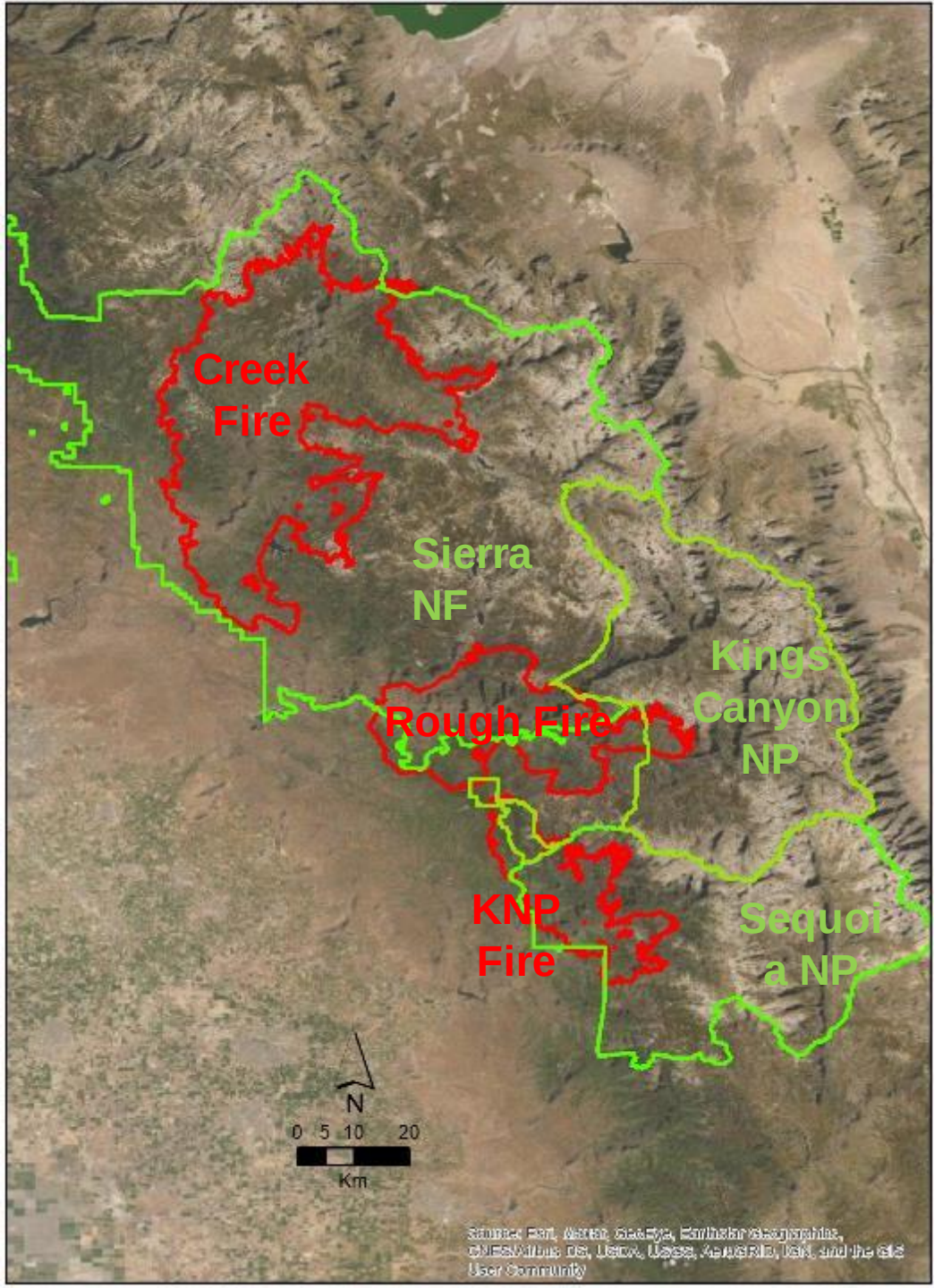
https://cecs.ess.uci.edu/data-atlas/

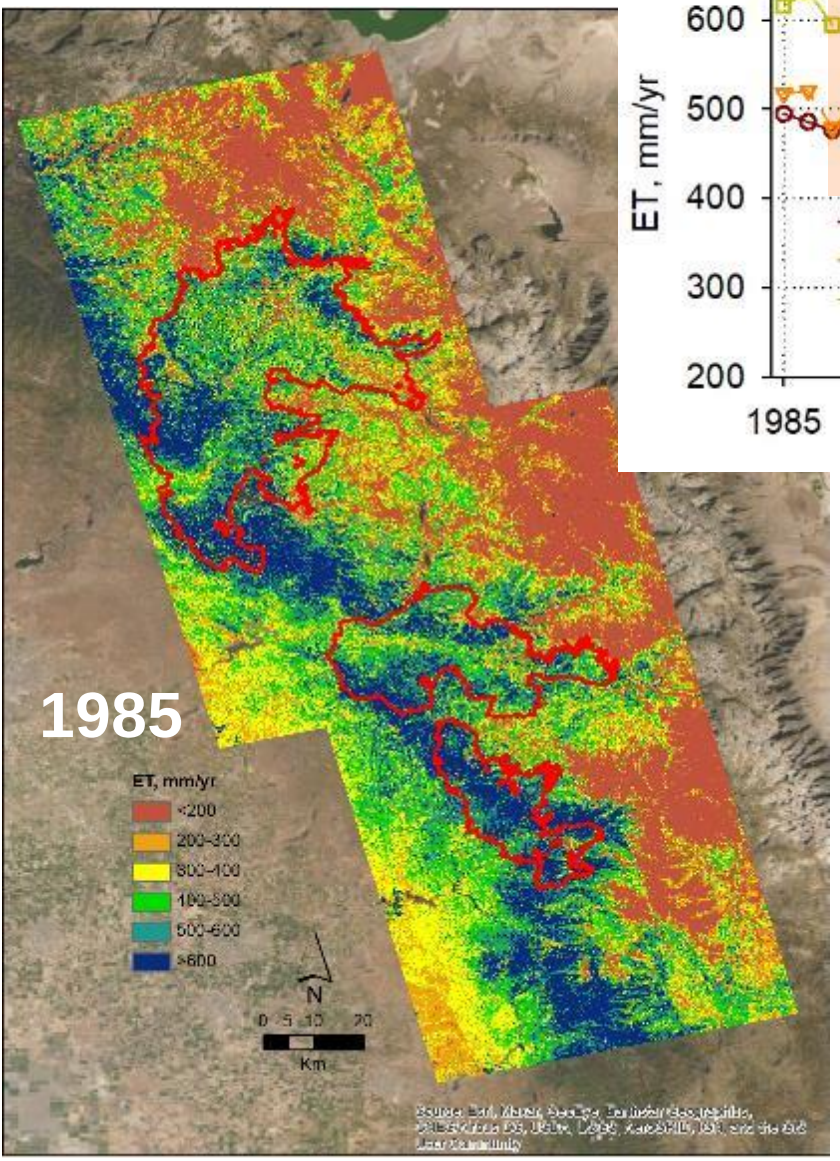
Changes in southern Sierra Nevada evapotranspiration

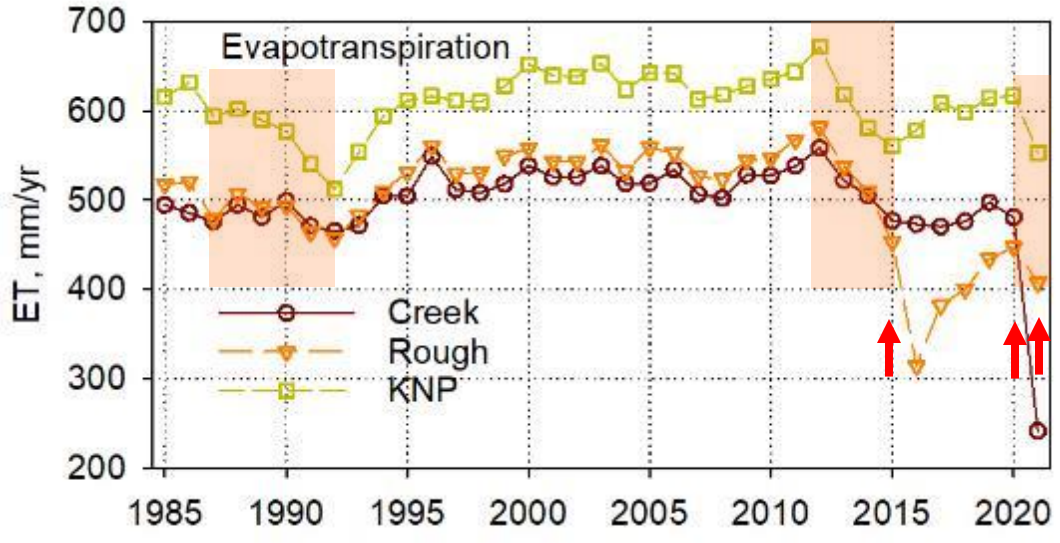
Warming temperatures, drought & wildfire all drive changes in ET

Examine conditions 1985-2021 in 3 areas that have experienced disturbance recently

Data: Center for Ecosystem Climate Solutions (CECS), 1985-present
Developed largely by Mike Goulden, UCI
https://california-ecosystem-climate.solutions/





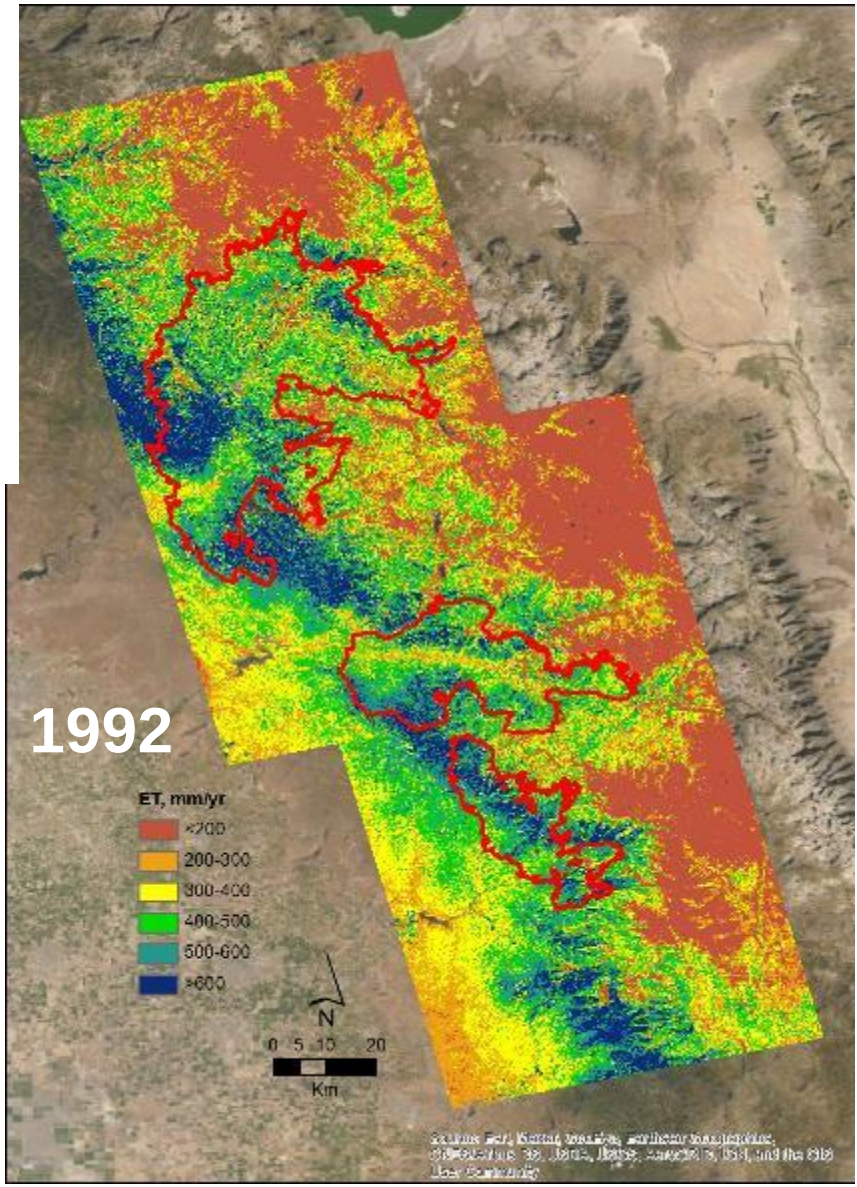


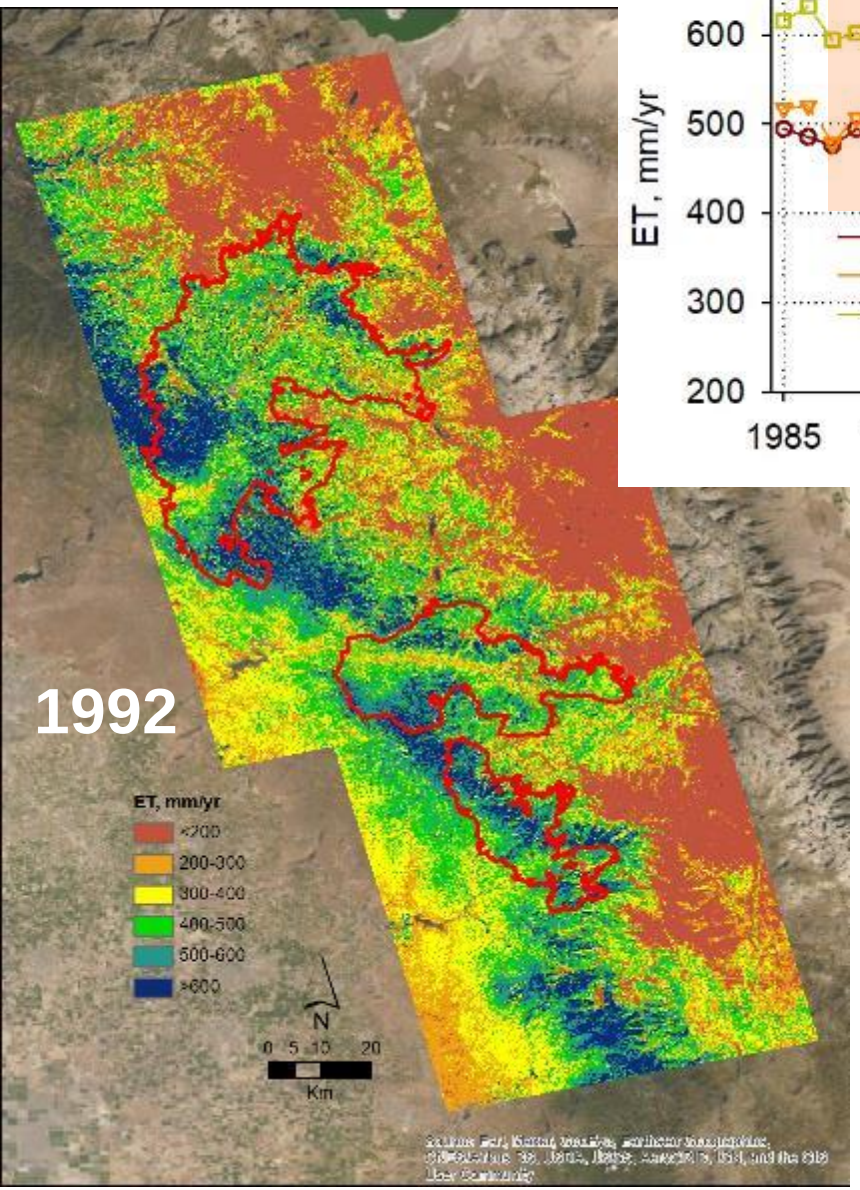
Drought

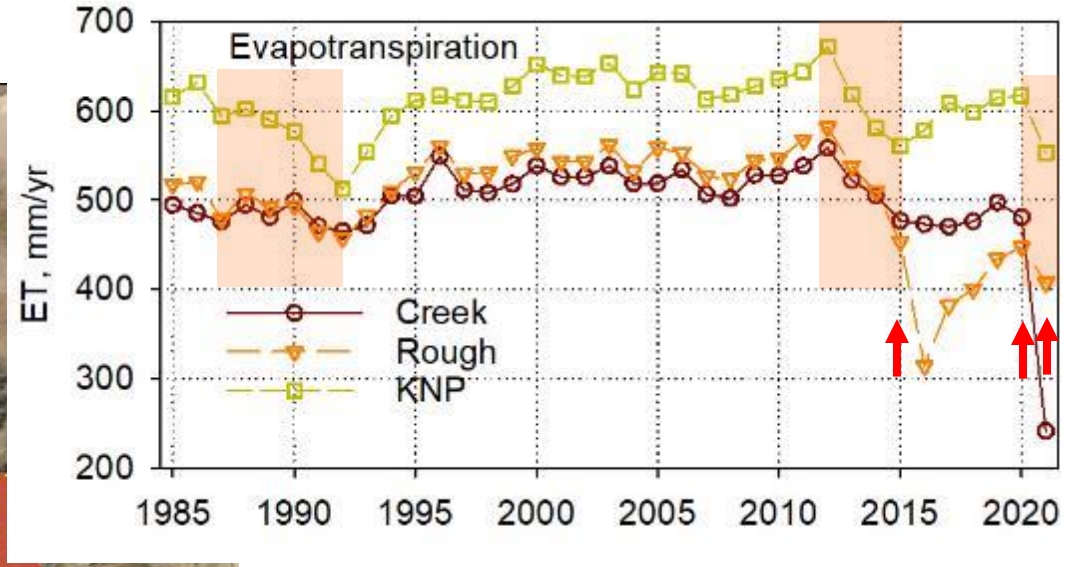
Wildfire

ET, mm/yr
<200
200-300
300-400
400-500
500-600
>600

Decline in ET during drought





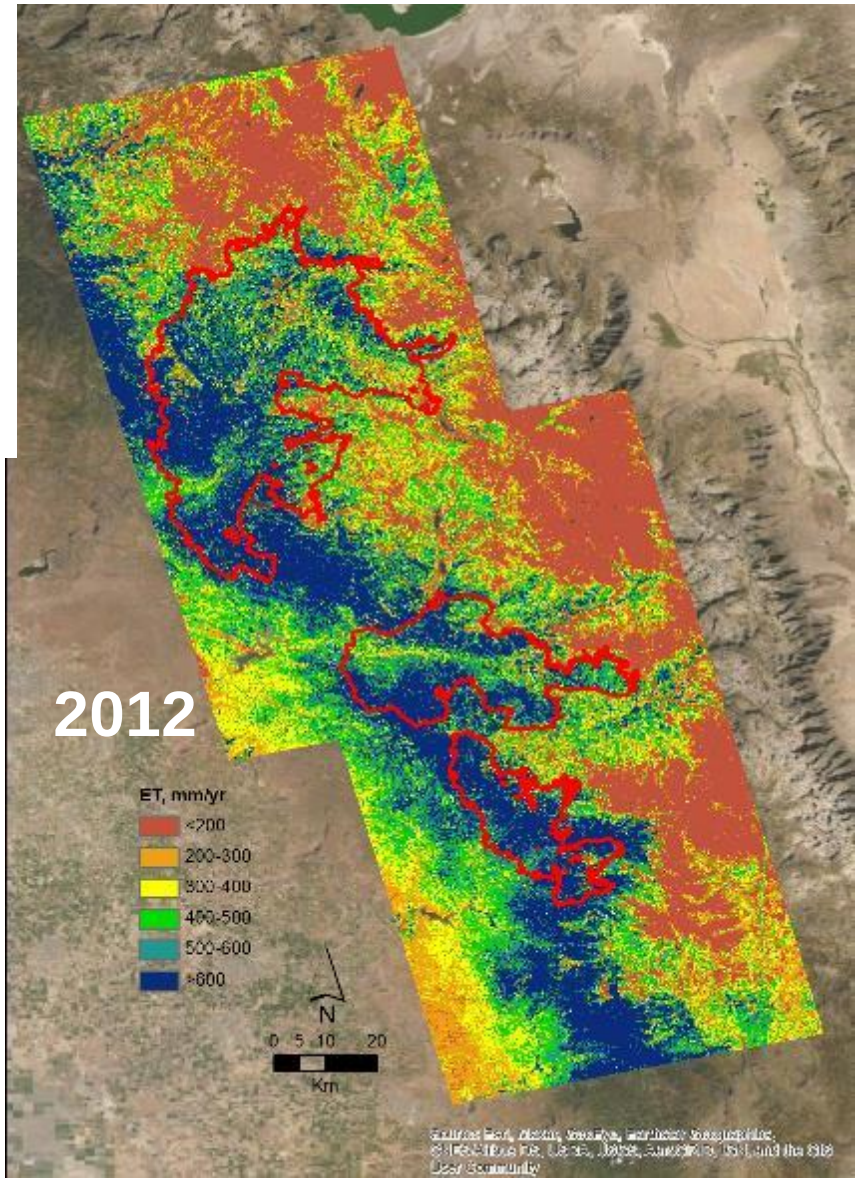


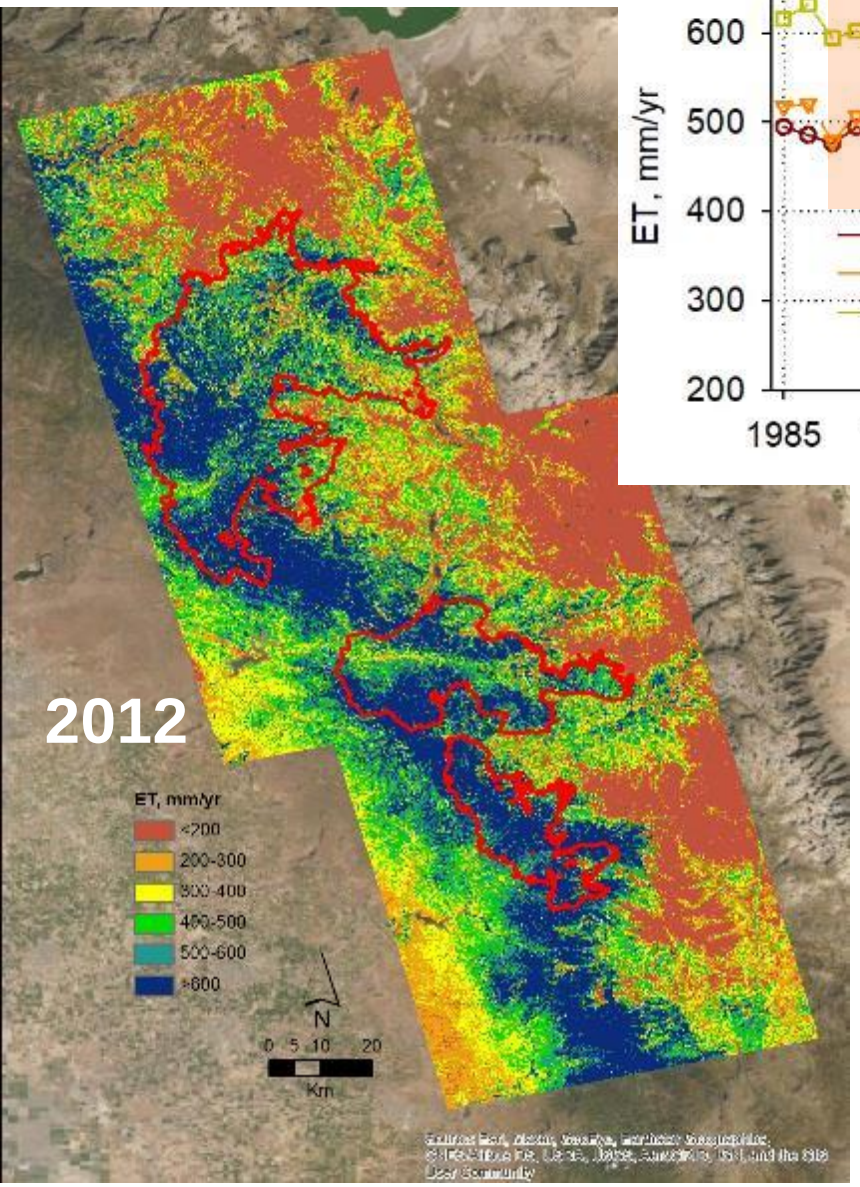
Drought

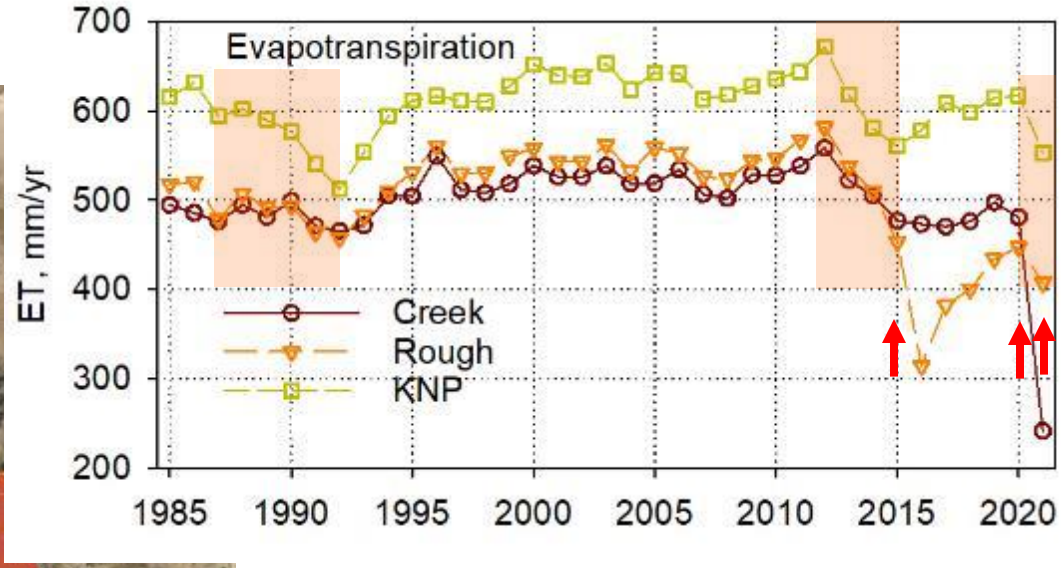
Wildfire

ET, mm/yr
<200
200-300
300-400
400-500
500-600
>600

Increase in ET over 20-yr wetter period





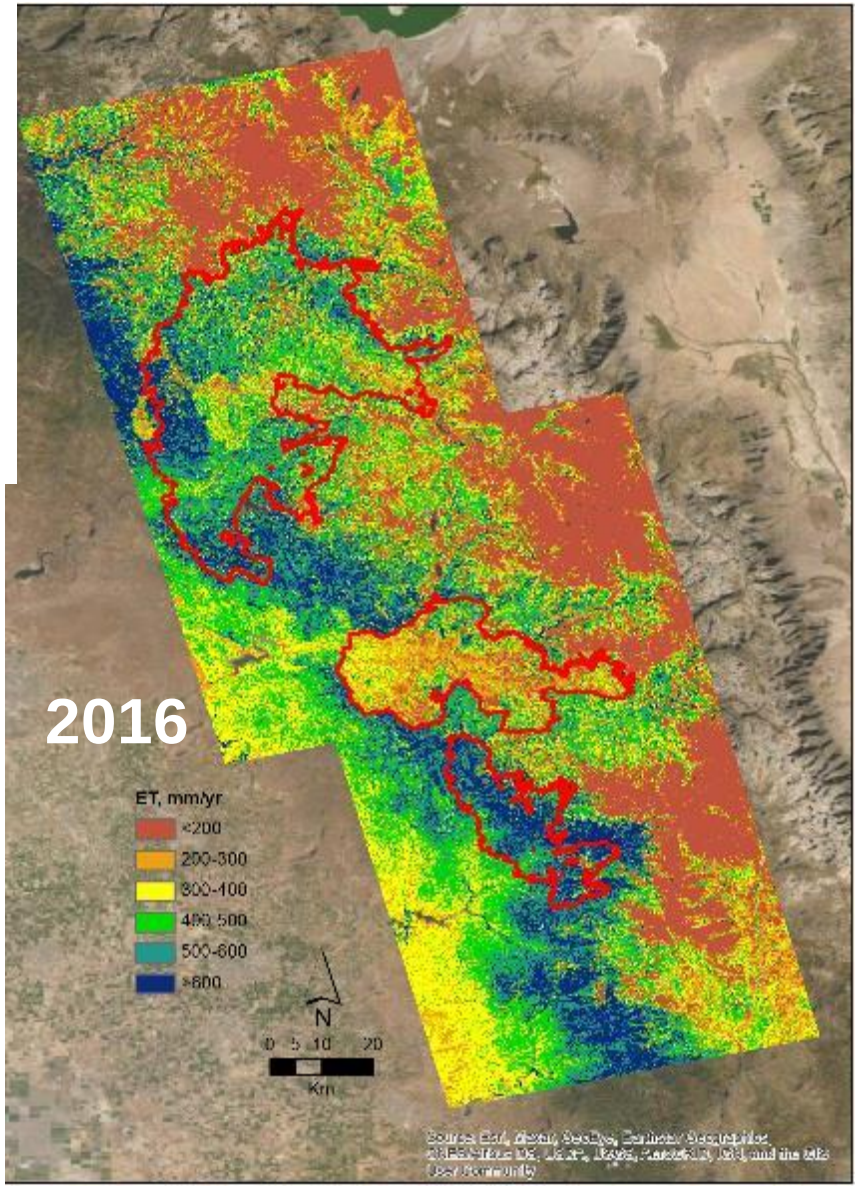


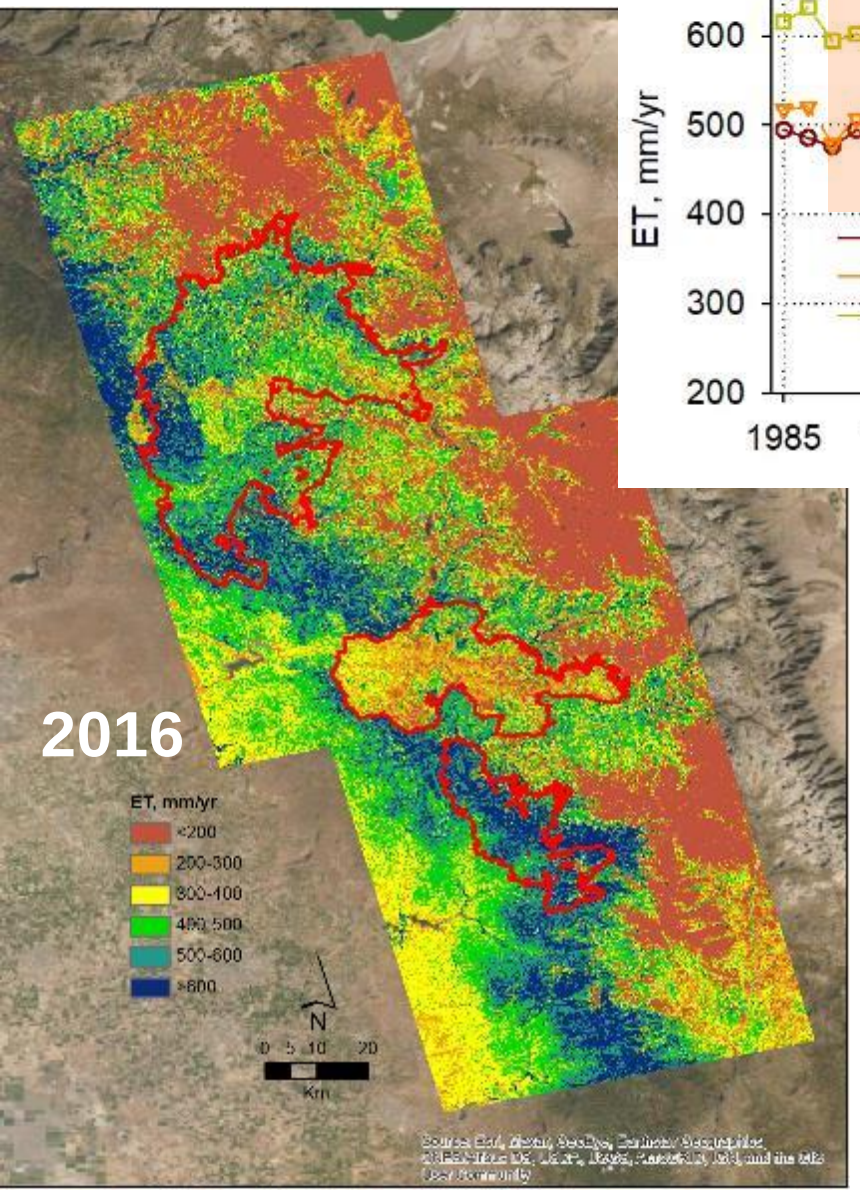
Drought

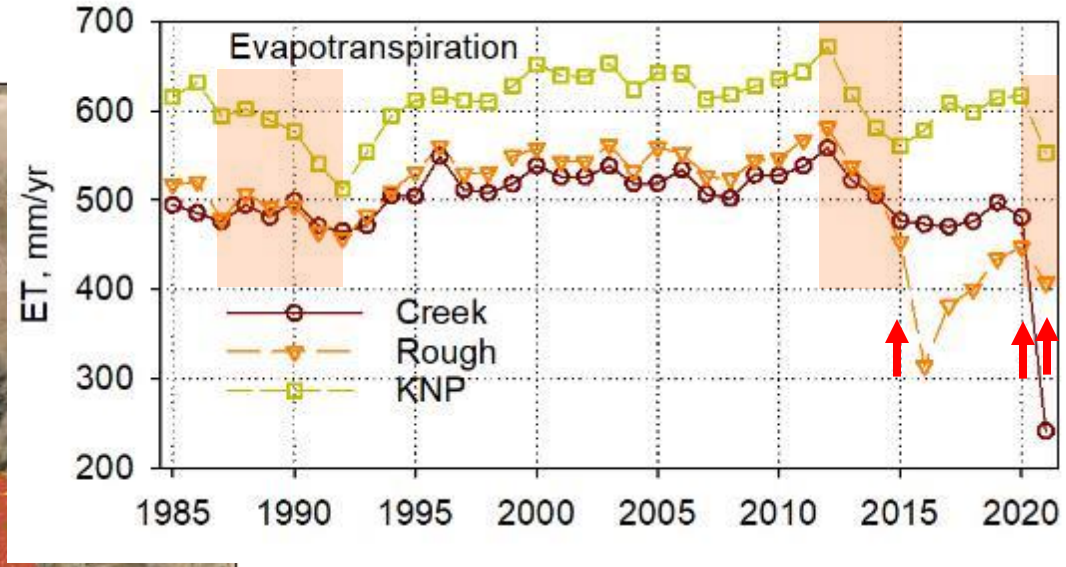
Wildfire

ET, mm/yr
<200
200-300
300-400
400-500
500-600
>600

Decline ET due to drought & Rough Fire – runoff increased





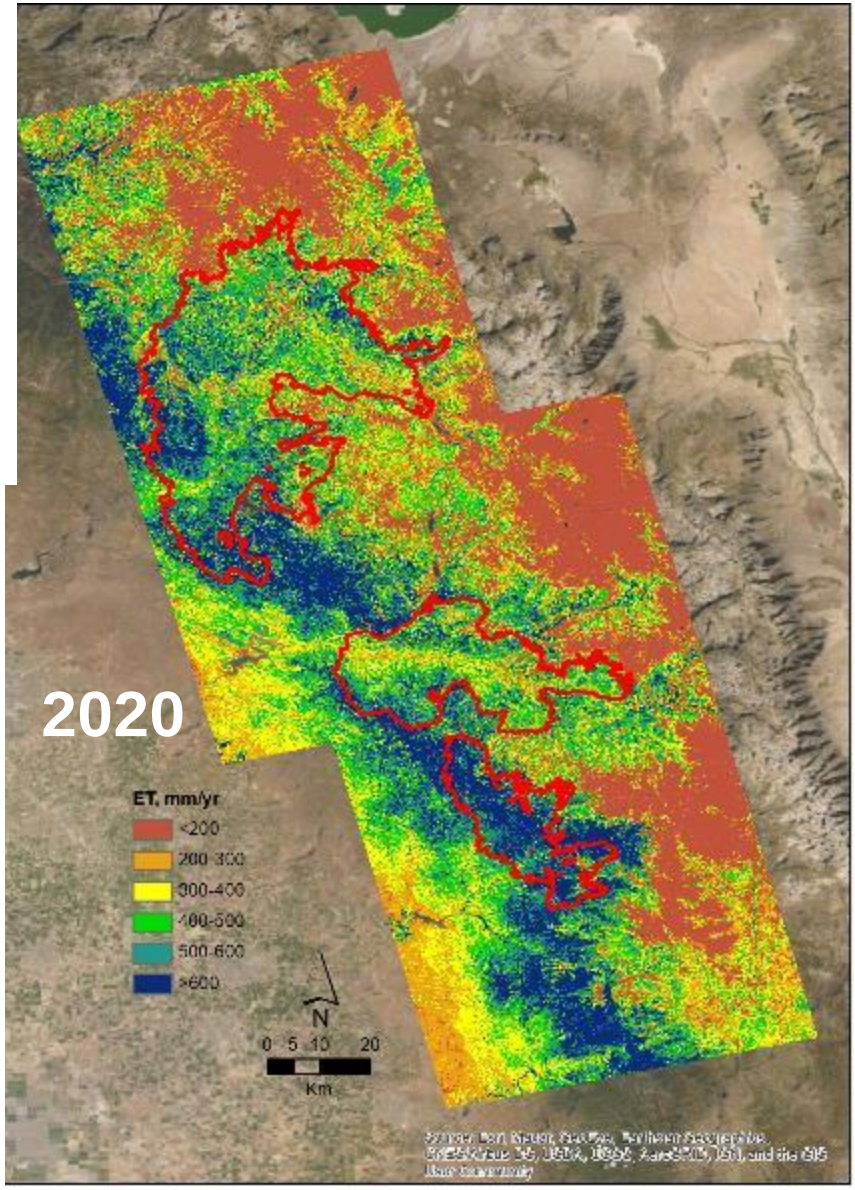


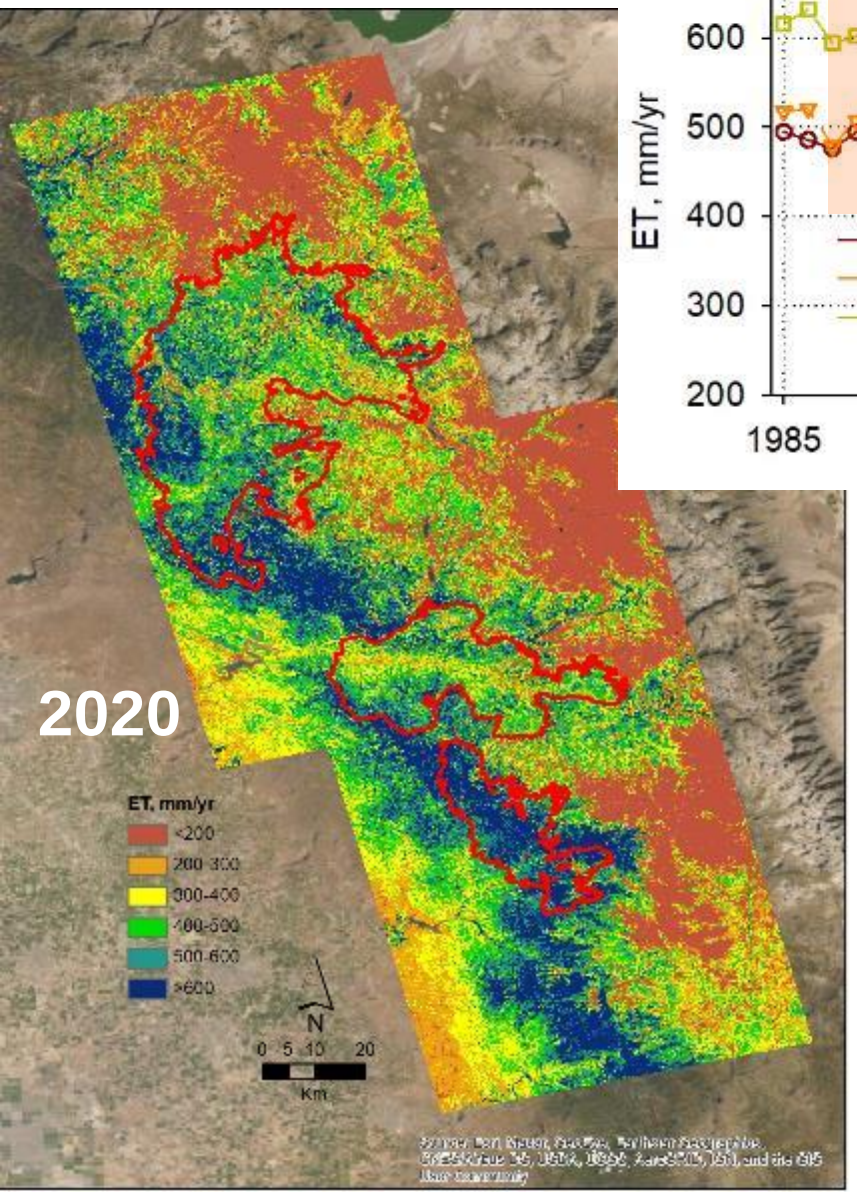
Drought

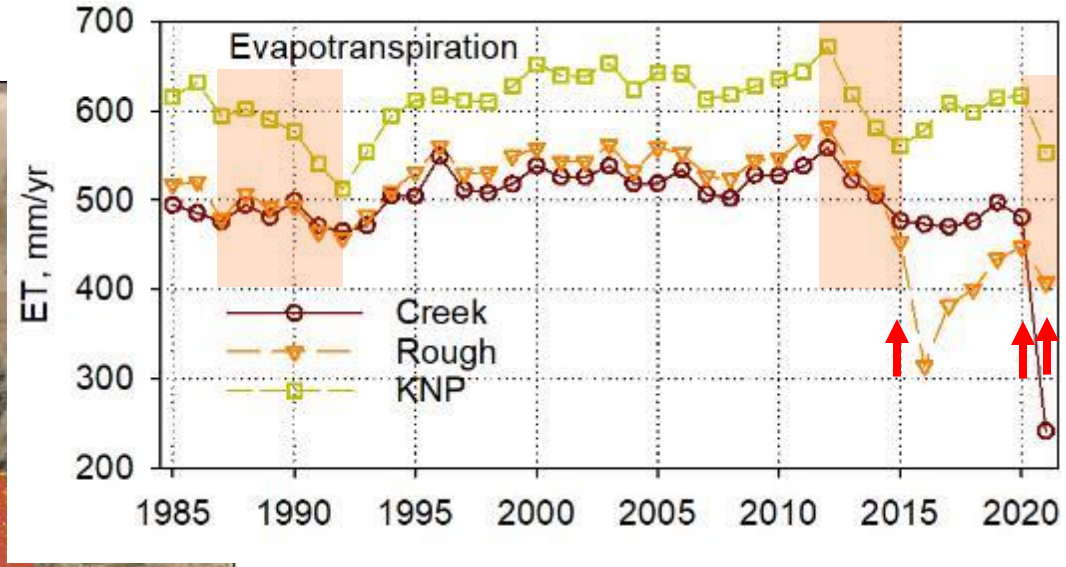
Wildfire

ET, mm/yr
<200
200-300
300-400
400-500
500-600
>600

Increase in ET with regrowth after drought & Rough Fire





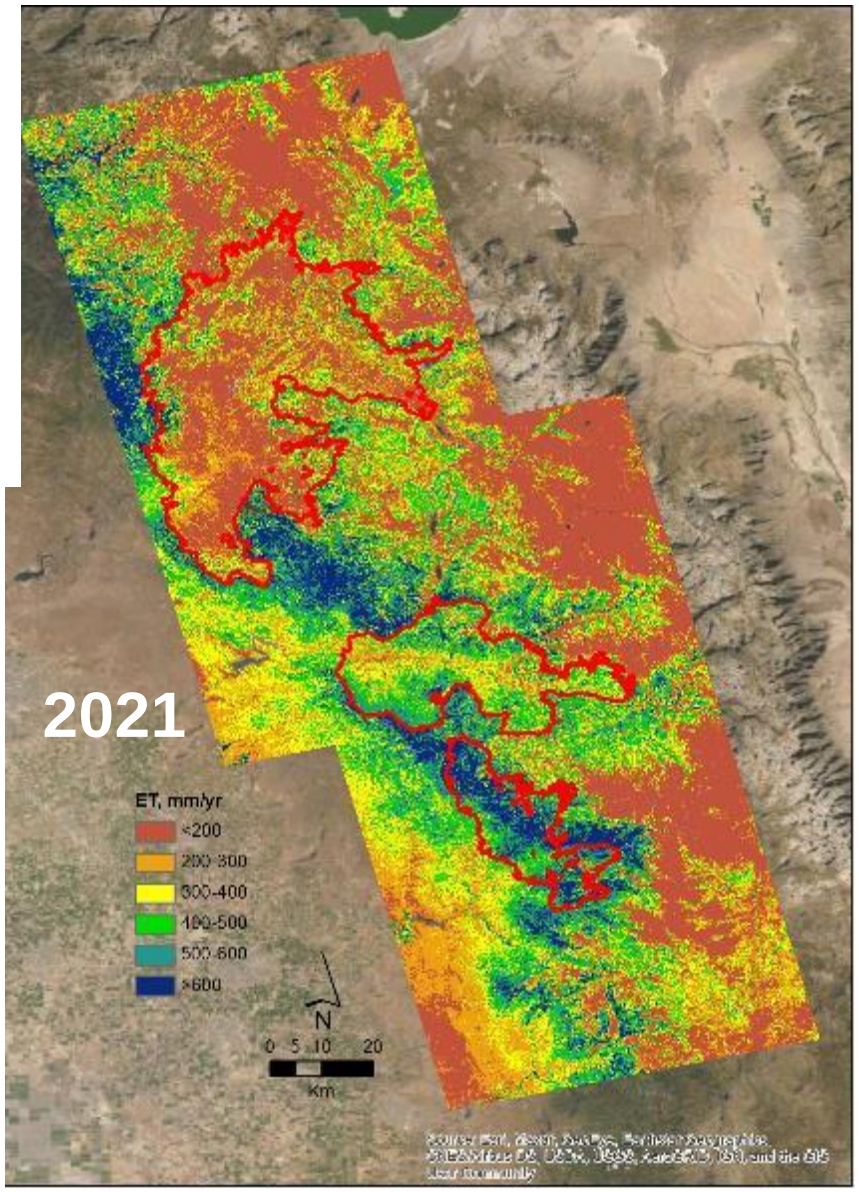


Drought

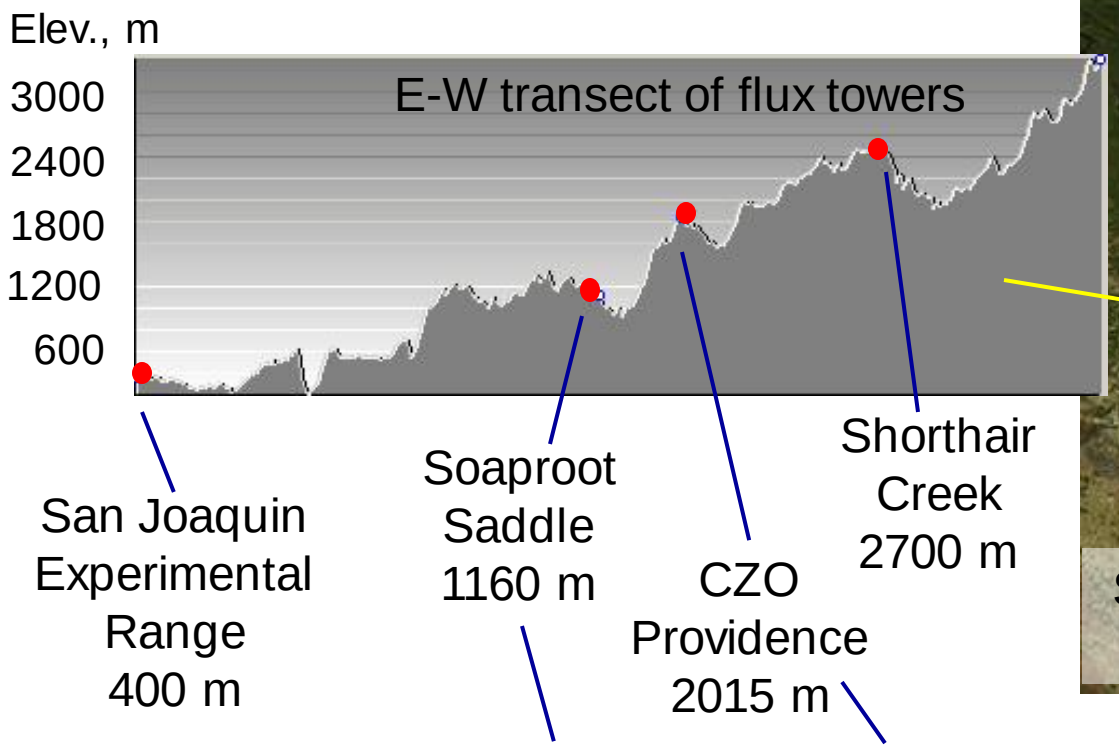
Wildfire

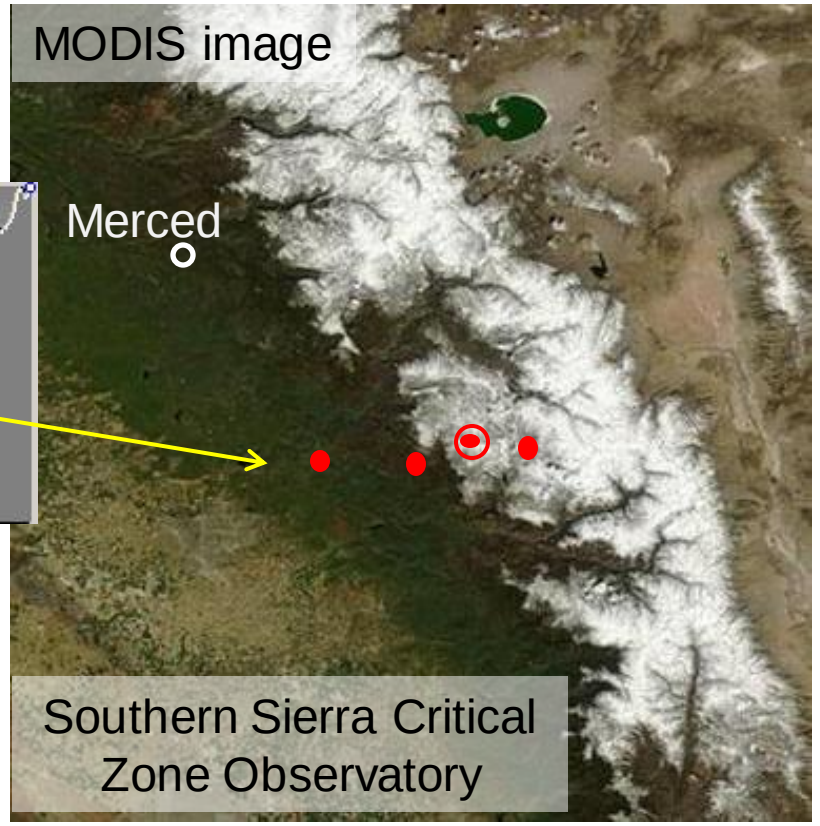
ET, mm/yr
<200
200-300
300-400
400-500
500-600
>600

Decline in ET due to drought & Creek Fire – runoff increased



Gridded ET is based on measurements

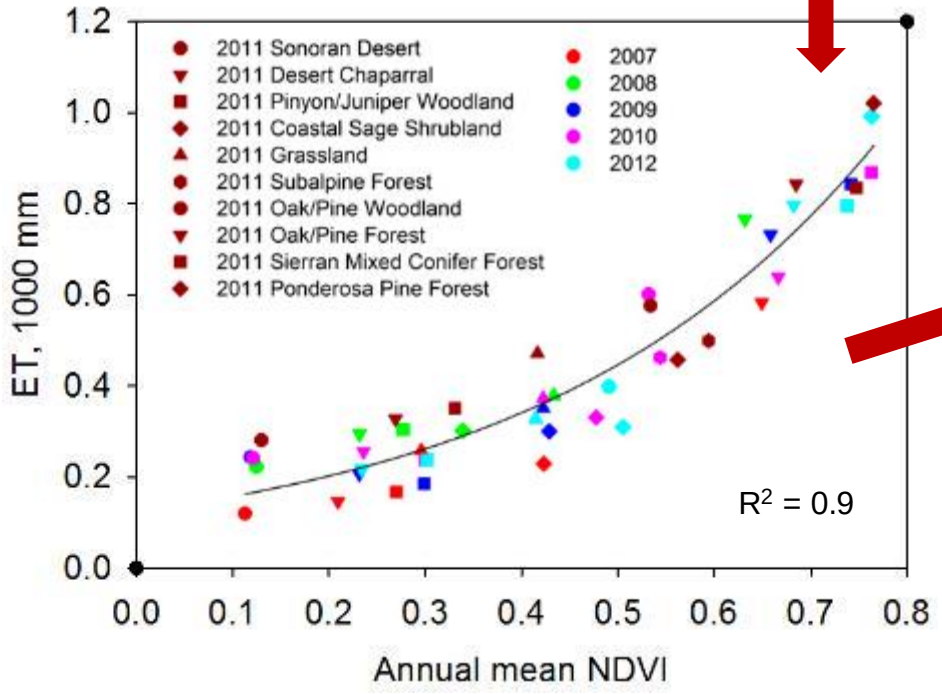




Ground measurements of precipitation, evapotranspiration, discharge, soil-moisture storage, snowpack storage, 2008-2019, some continuing


Providence,
2015 m

Gridded evapotranspiration product

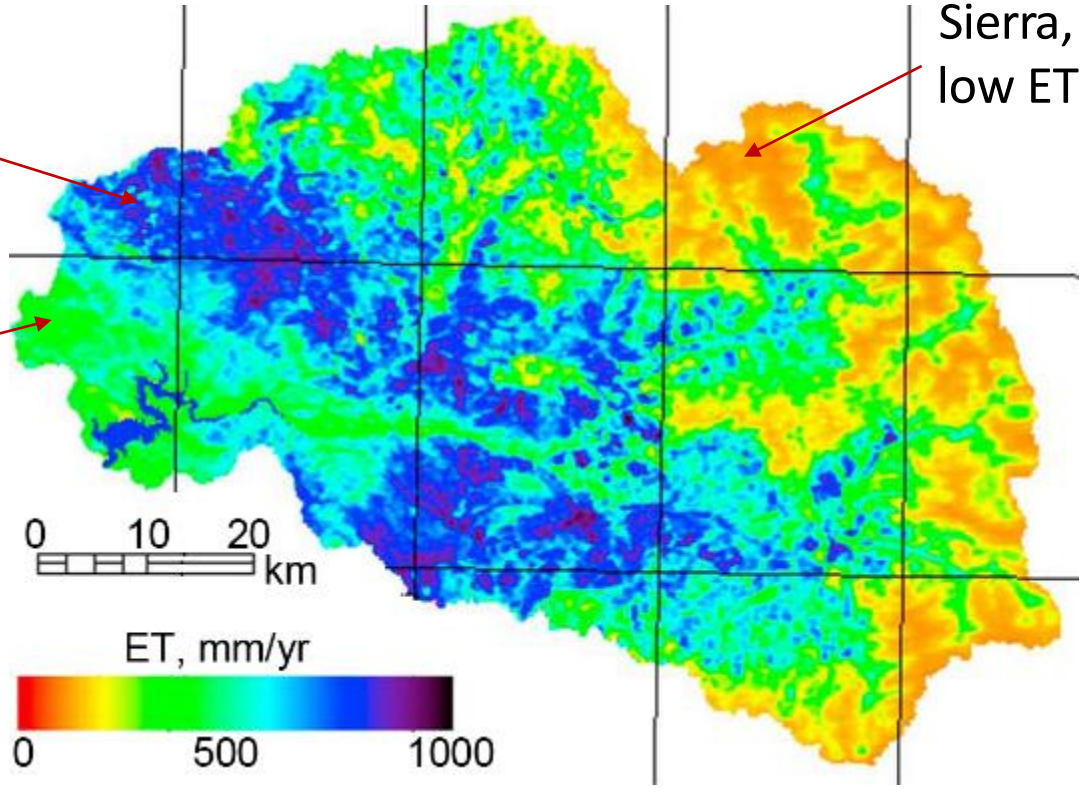


ET for Kings River basin (WY2010)

Mixed conifer, highest ET

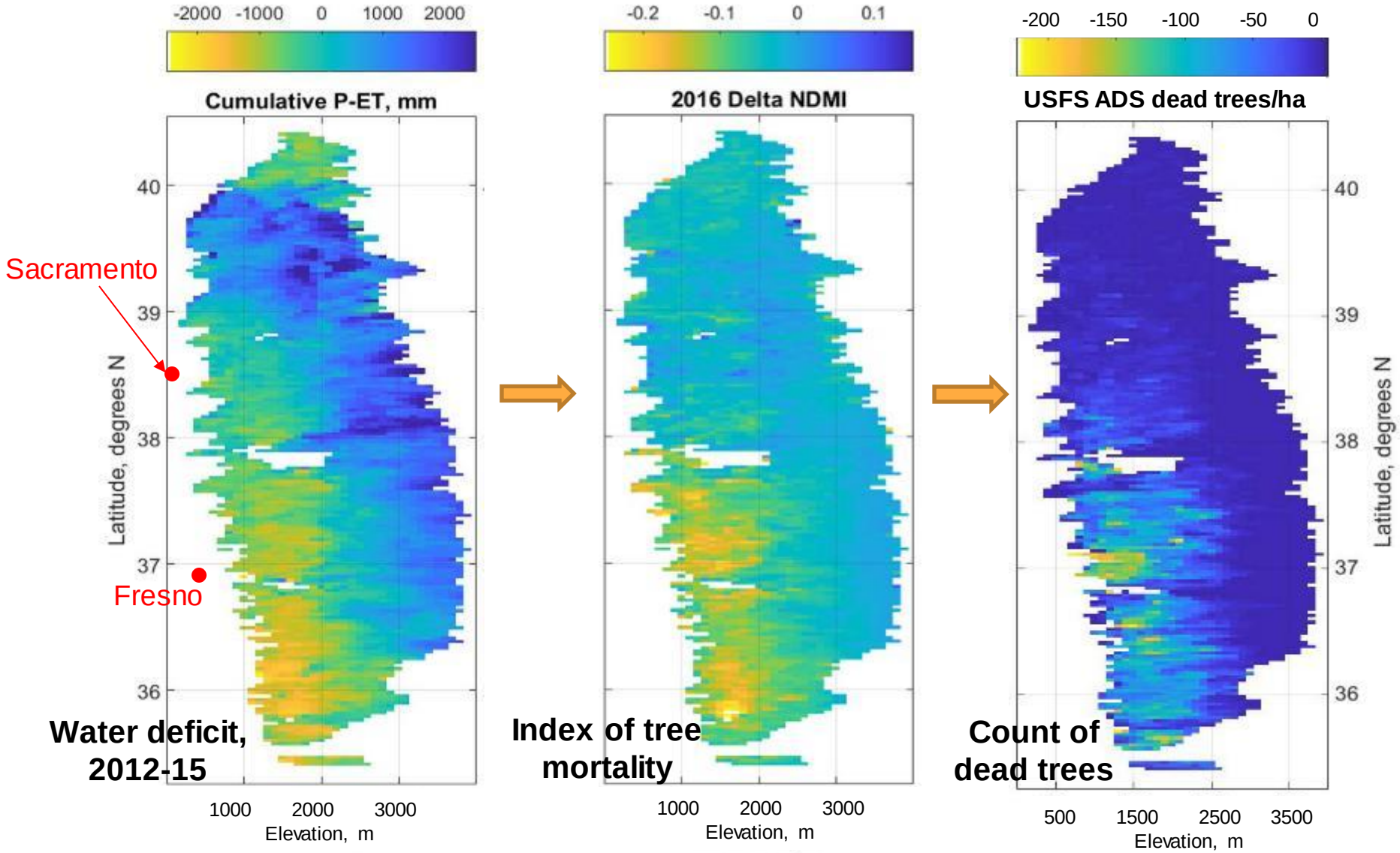
Oak savannah, moderate ET

High Sierra, low ET



Goulden & Bales, 2014

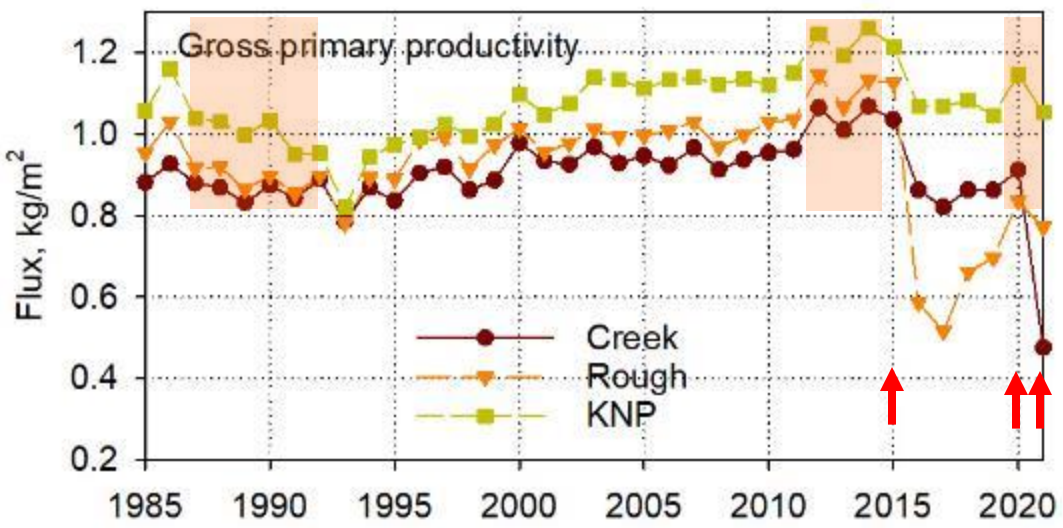
Moisture stress vs. canopy dieback across Sierra Nevada



Large fires masked out

Goulden & Bales, 2019

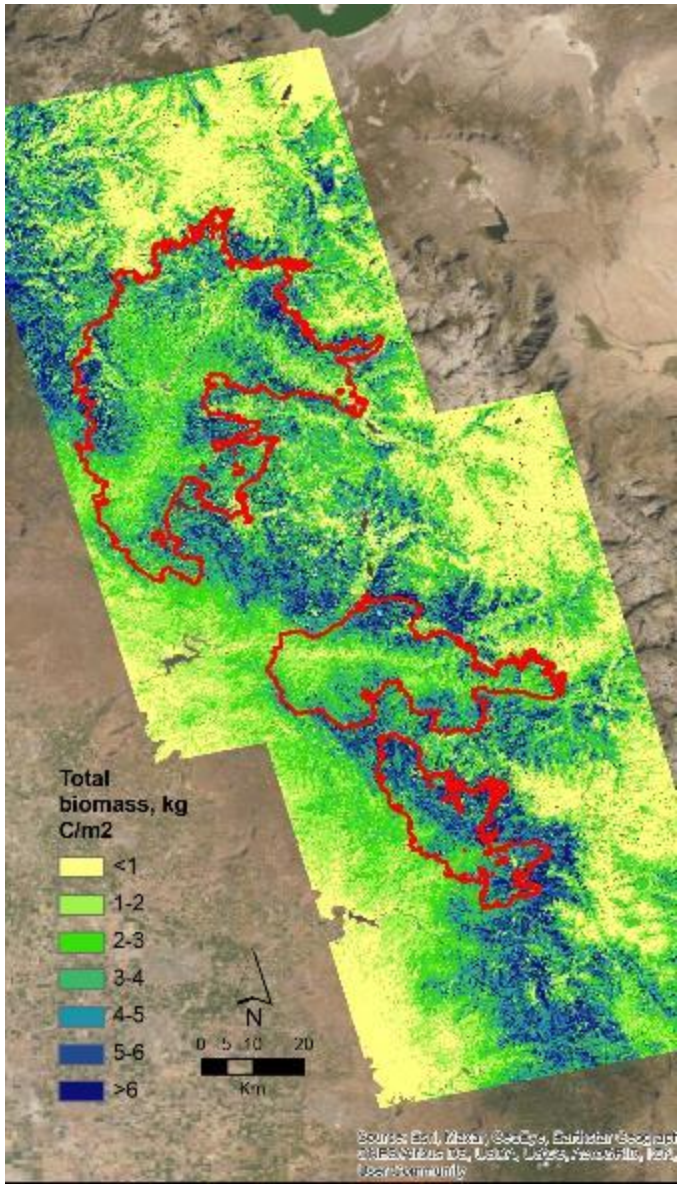
Trends in fuels & fire



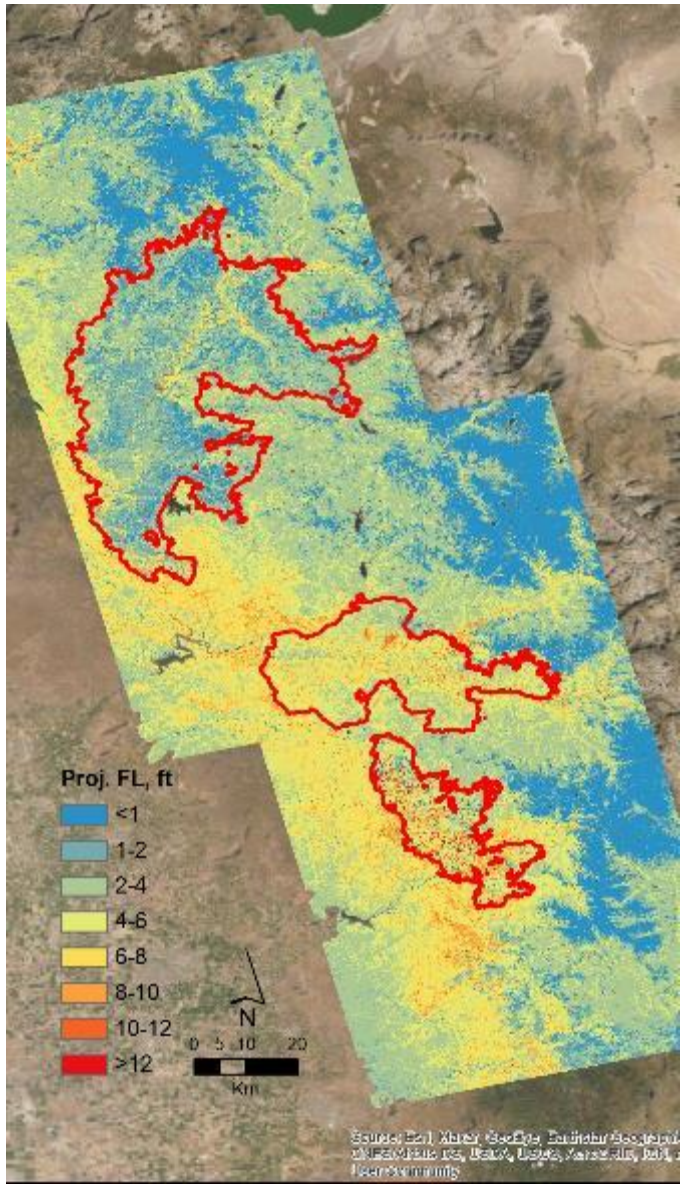
Drought Wildfire

GPP is dominated by trees
NPP shows a similar pattern

Total biomass, 2021



Projected flame length, 2021



(increasing trend over time)

Summary & take-home points

1. **Actual evapotranspiration** (ET) is a primary response variable for managing southern Sierra Nevada forests
   - The data available are not perfect, but are credible & actionable

2. **Cumulative P-ET** is a direct & primary drought-response & prediction variable
   - It is a forward-looking index that can be projected using climate modeling & scenarios for management actions & disturbance

3. In a warming climate, the southern Sierra will have **lower vegetation densities**, in part limited by water
   - Those densities will be maintained through either more-active management or high-severity wildfire

4. **Water-related benefits** of forest thinning are large & result from fuels treatments done to reduce projected wildfire severity
   - Wildfires & drought-induced mortality also provide benefits for downstream water users (but also risks)

5. Managing southern Sierra forests for **multiple benefits** will be very expensive & provide large benefits
   - More-accurate data & tools to inform multi-benefit planning, prioritization, monitoring, assessment are now available

North Yuba partnership

Partnerships facilitate planning, permitting, financing, implementation, monitoring, research, communication, public support

J. Alvarez photo

Lookout above New Bullards Bar, July 2021