Snow and Drought: What the Past Can Tell Us About the Future?

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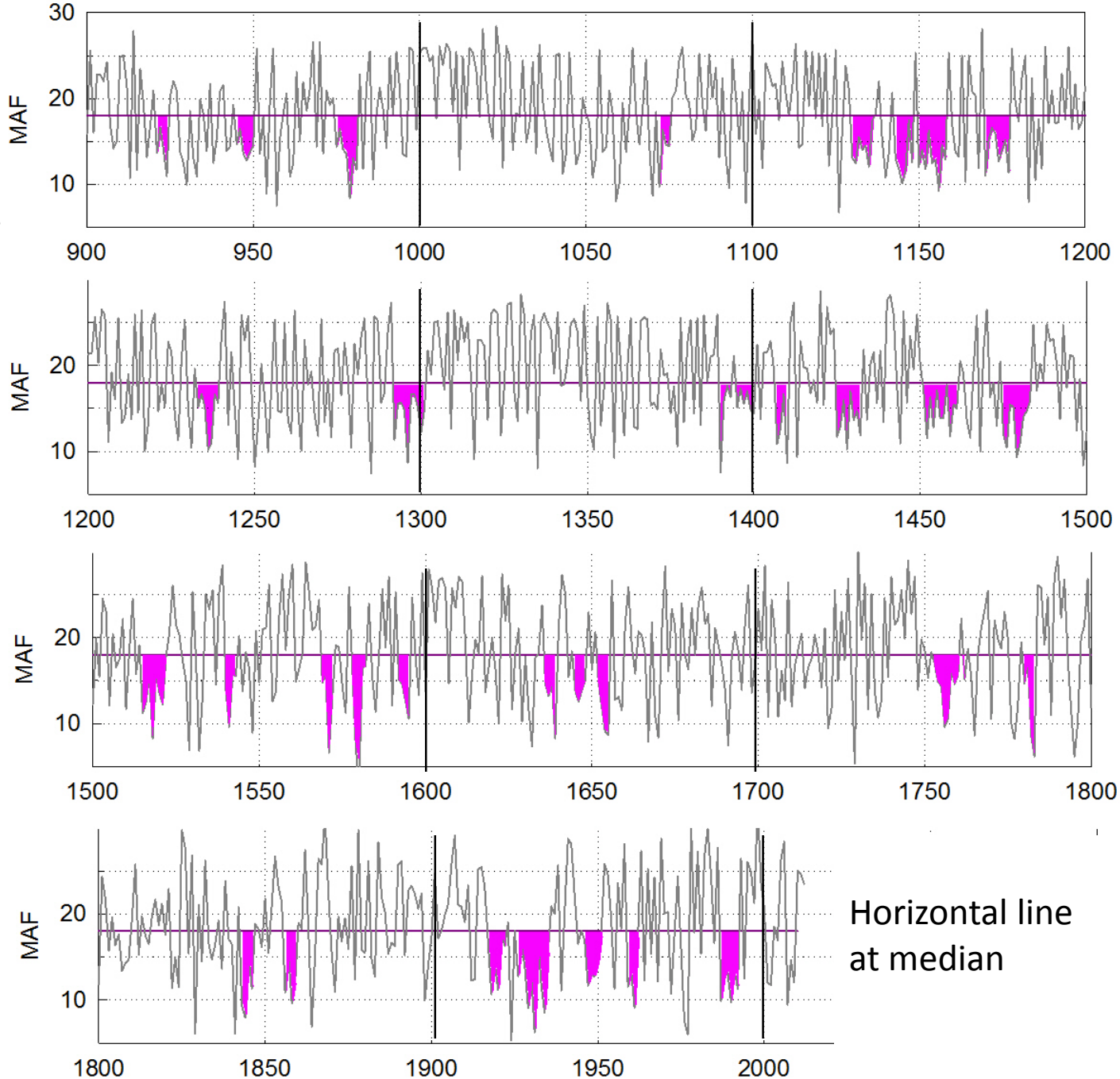
Overview

- Brief introduction of current CA drought
- Snowpack Sensitivity to Temperature
- Effects of Climate Warming on Snowpack and Snow Covered Area
- Conclusions

1100 yr drought record

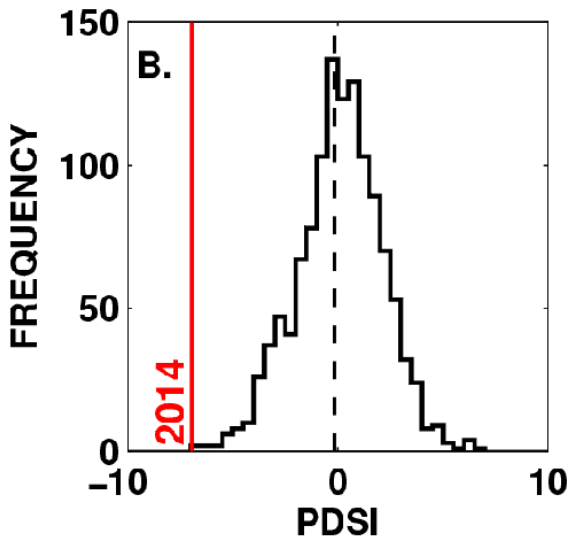
Reconstructed flows of Sacramento R.
Color shading marks below-median periods ≥4 yr
1-5 per century



Horizontal line at median

Meko et al. 2014 report

Current (2014) the most severe in last 1200 yr

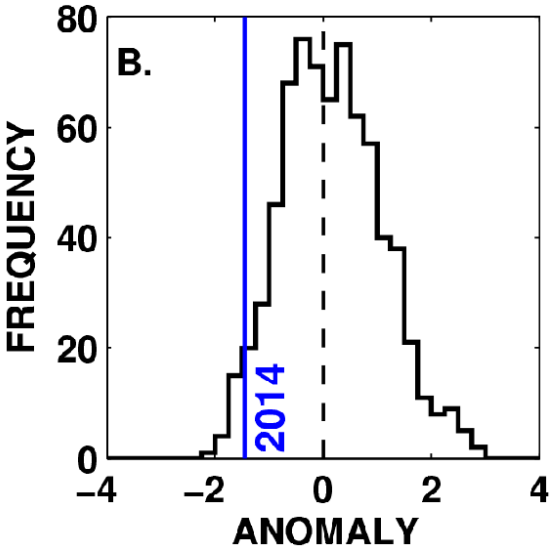


Regional North American Drought Atlas PDSI for Central & Southern Calif. (Cook et al., 2010)

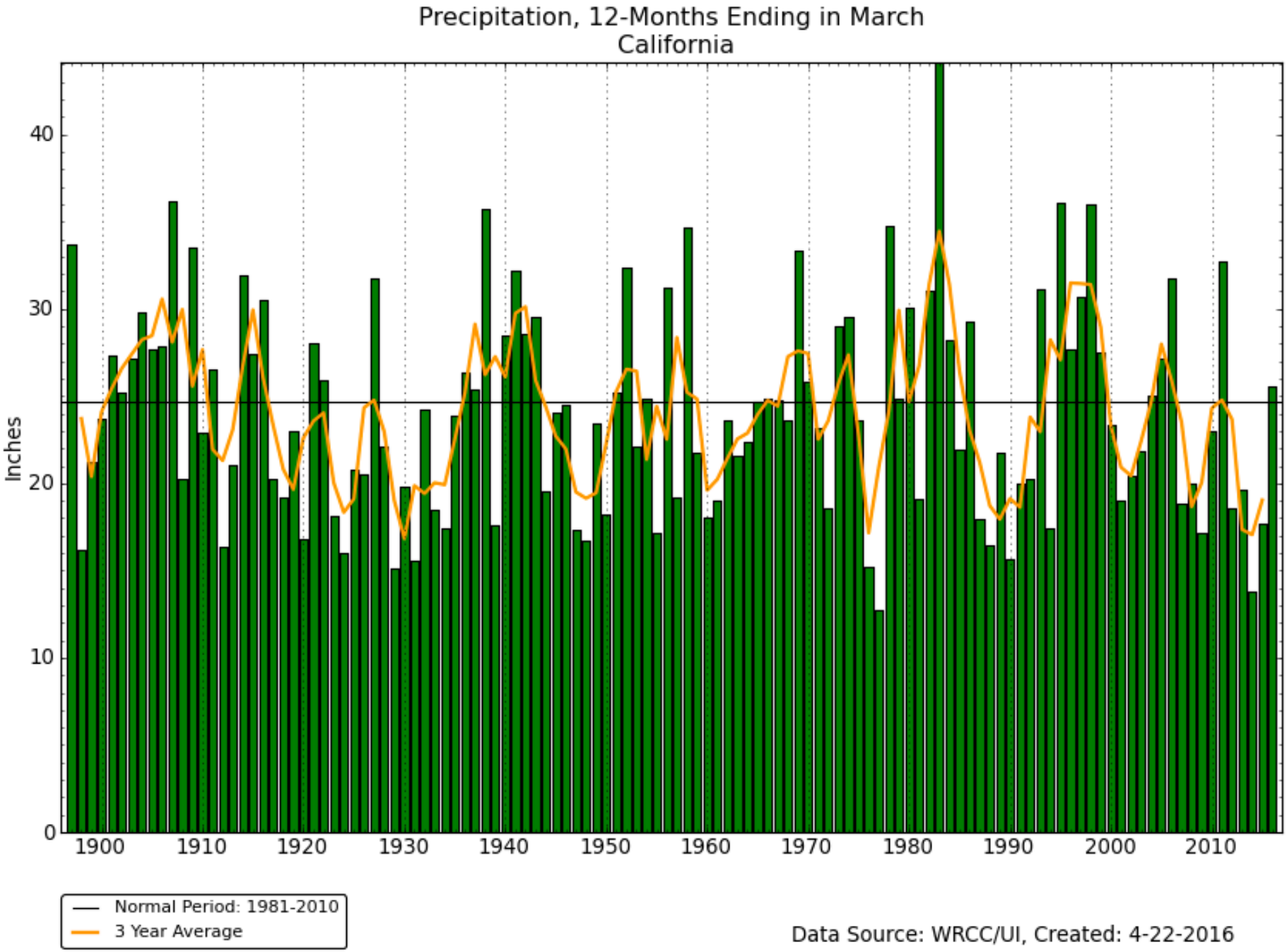
Average 4-yr drought return interval ~40 yr (range: 5-240 yr)

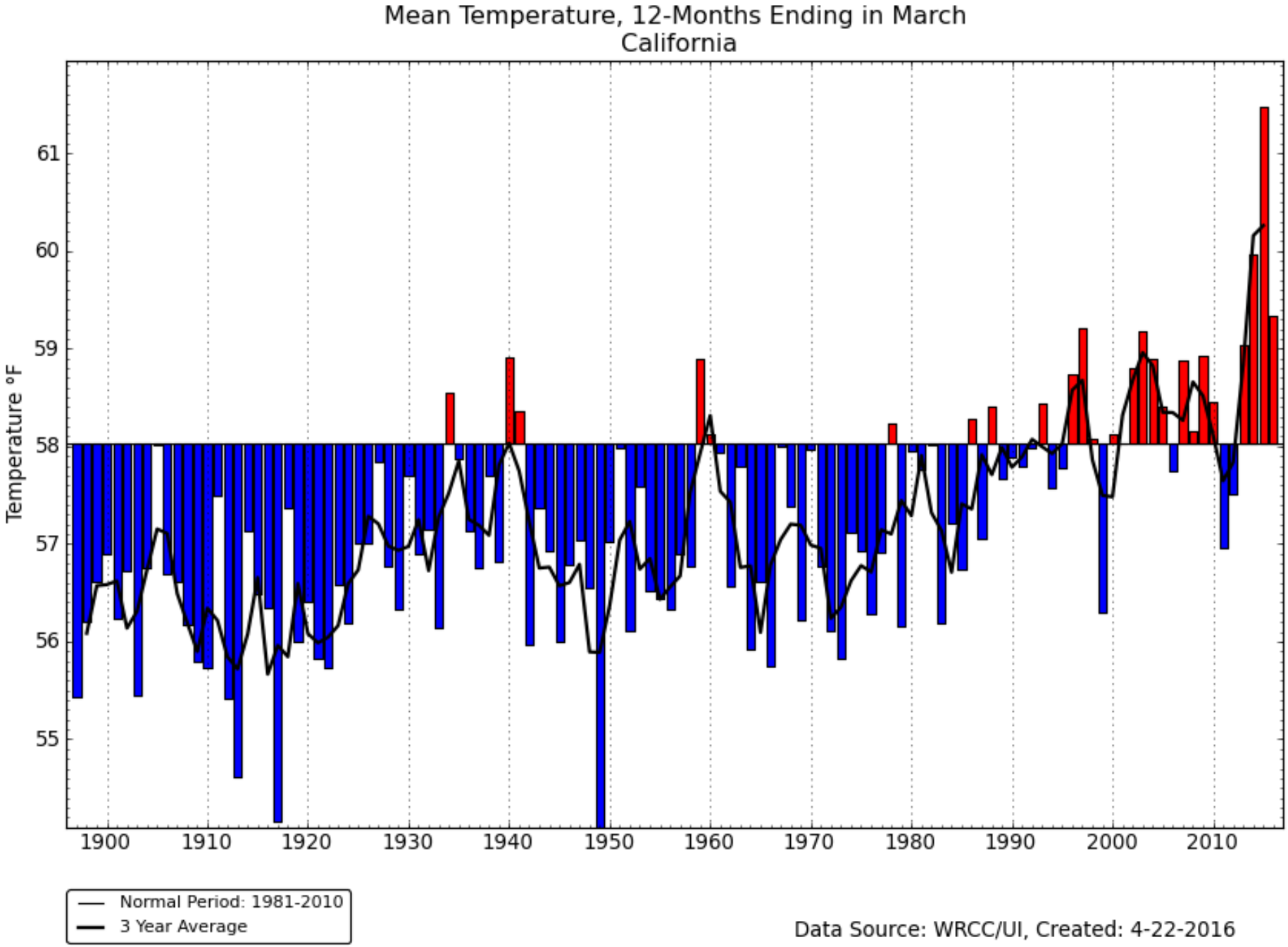
Blue oak reconstructed Oct-Jun mean precipitation anomalies from Central & Southern Calif.

Precipitation within range of natural variability

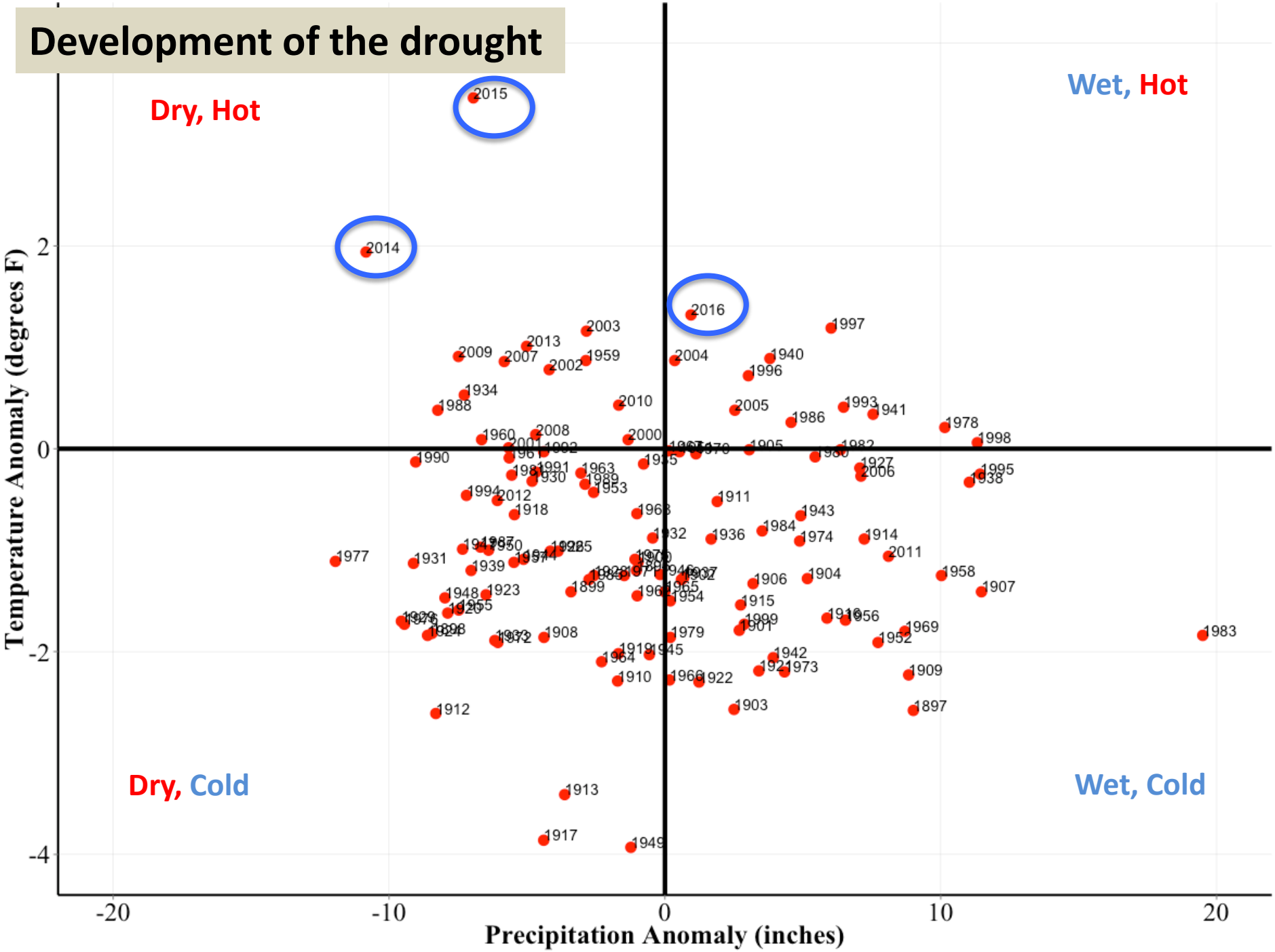


Griffin & Anchukaitis, 2014

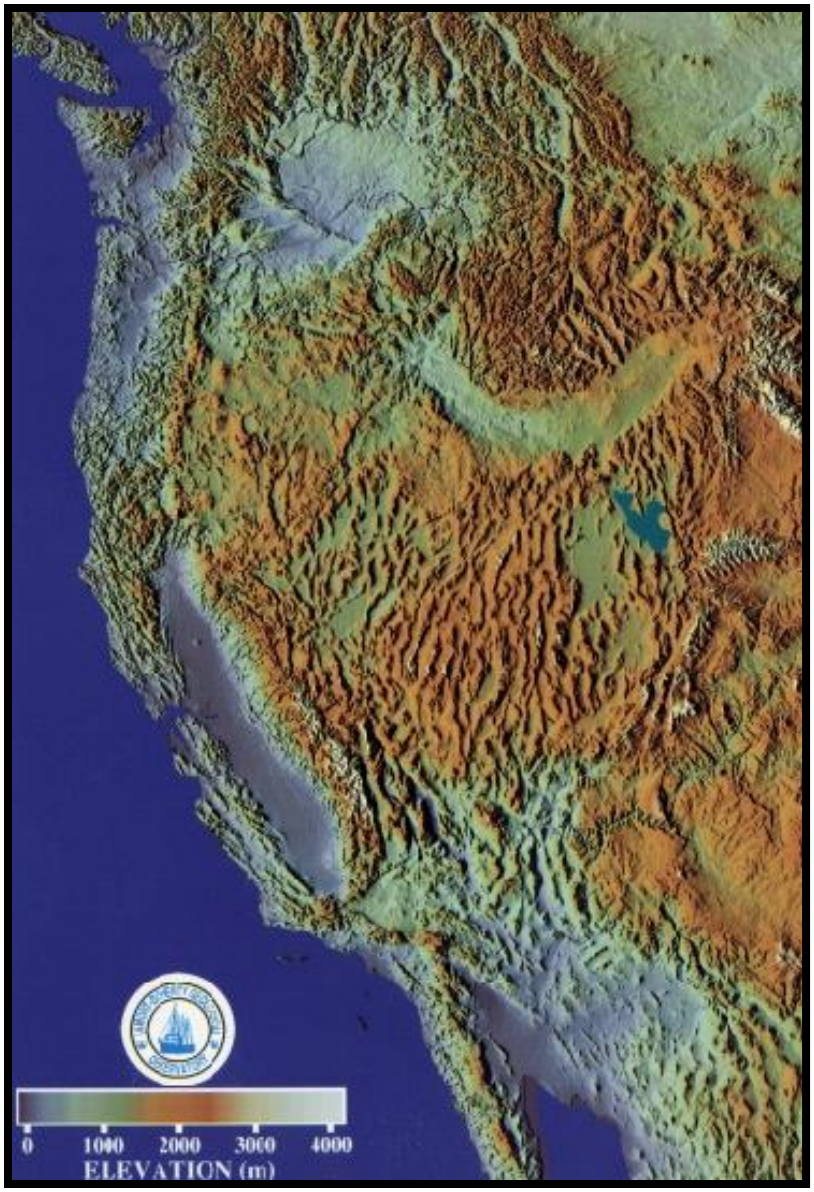

Precipitation, 12-Months Ending in March
California
Inches
0
10
20
30
40
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Normal Period: 1981-2010
3 Year Average
Data Source: WRCC/UI, Created: 4-22-2016

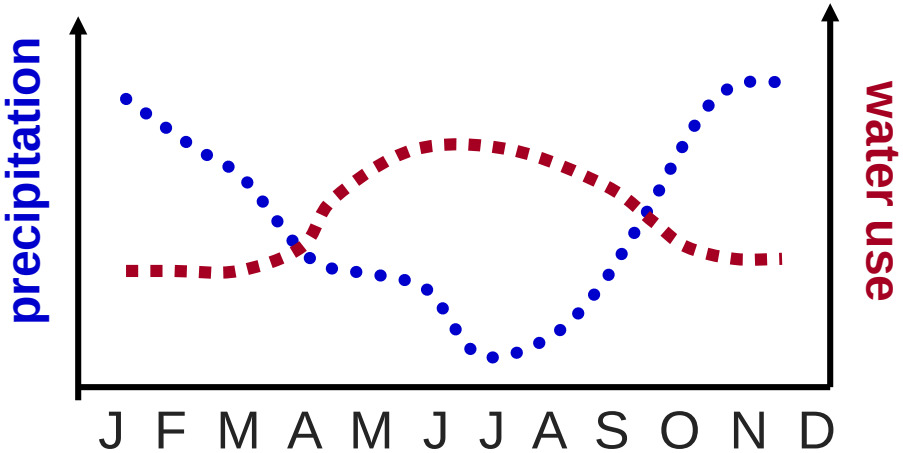

Mean Temperature, 12-Months Ending in March
California
Temperature °F
61
60
59
58
57
56
55
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Normal Period: 1981-2010
3 Year Average
Data Source: WRCC/UI, Created: 4-22-2016

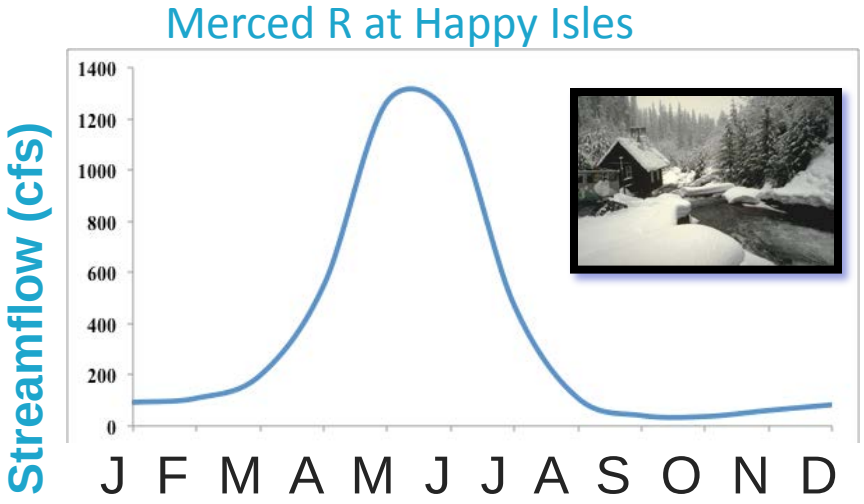
Development of the drought



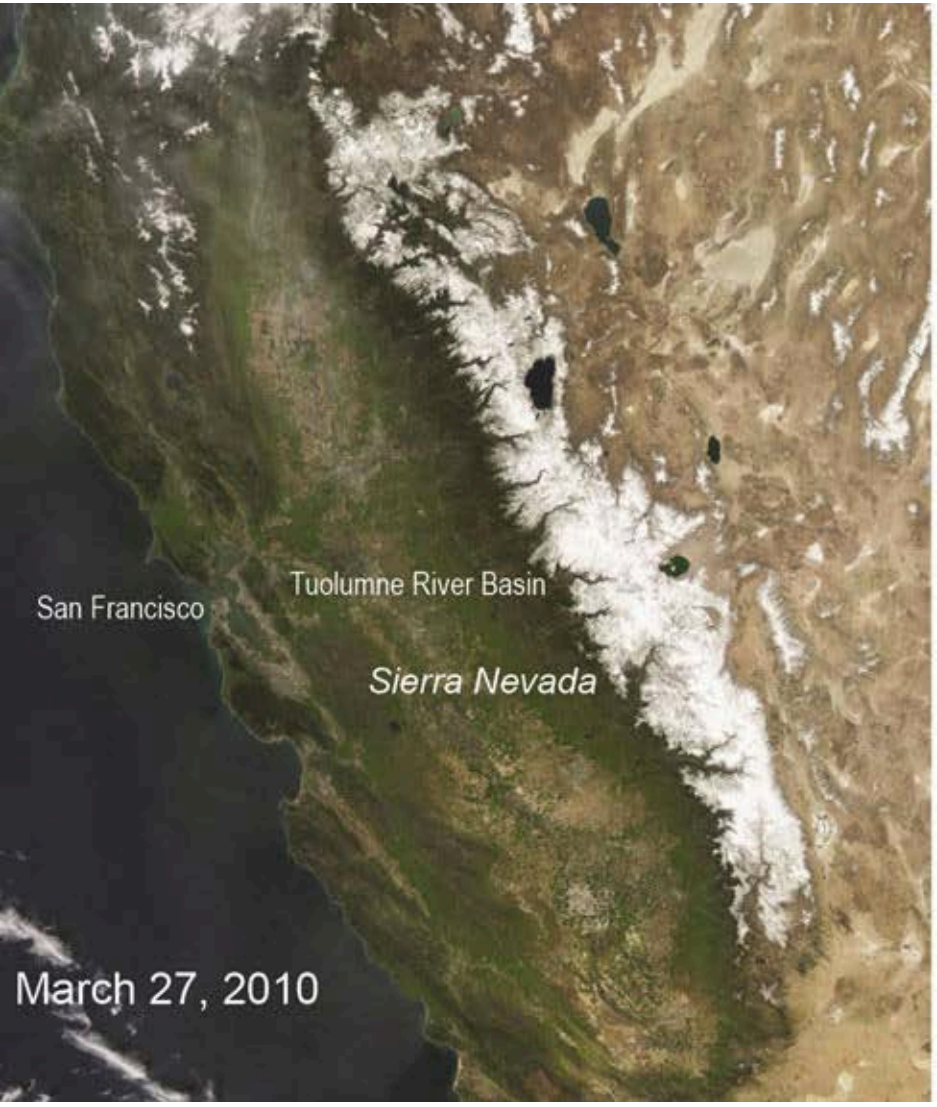
The paradox of water in the West…

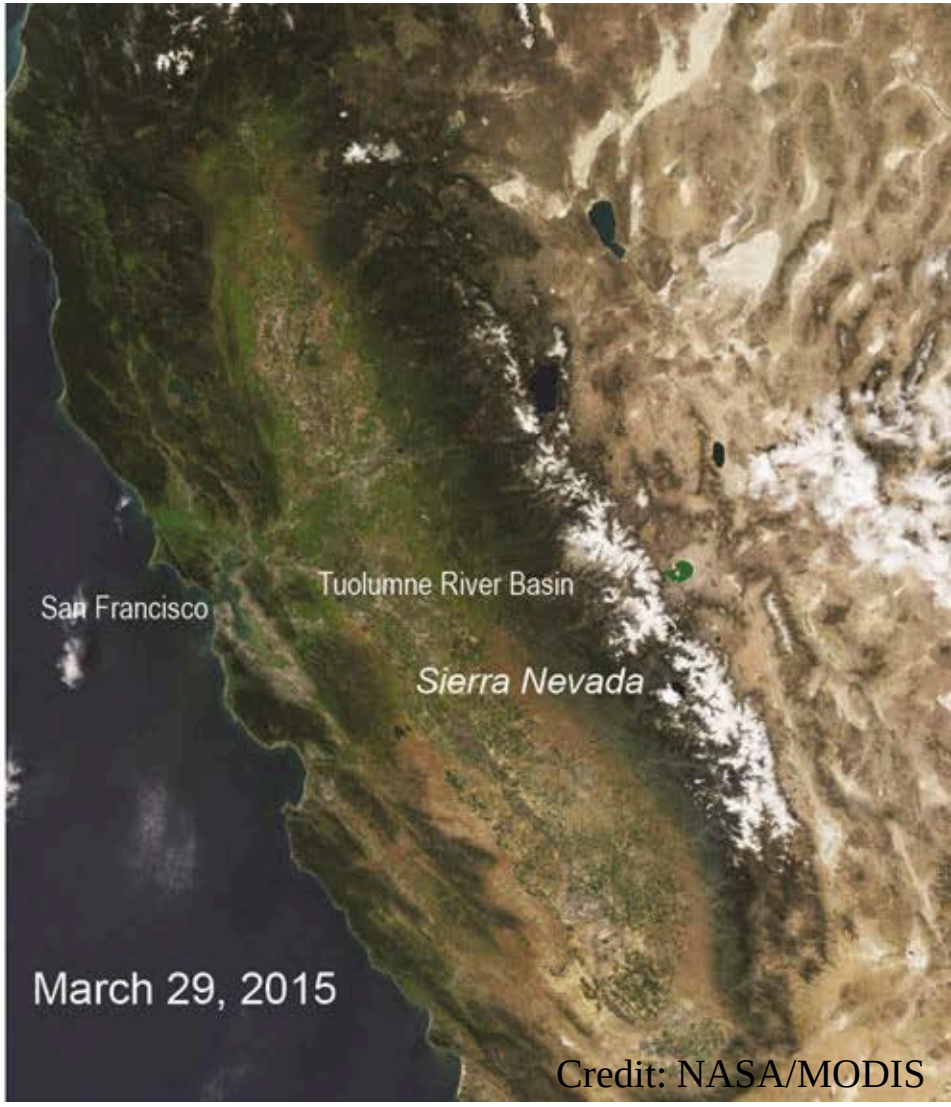






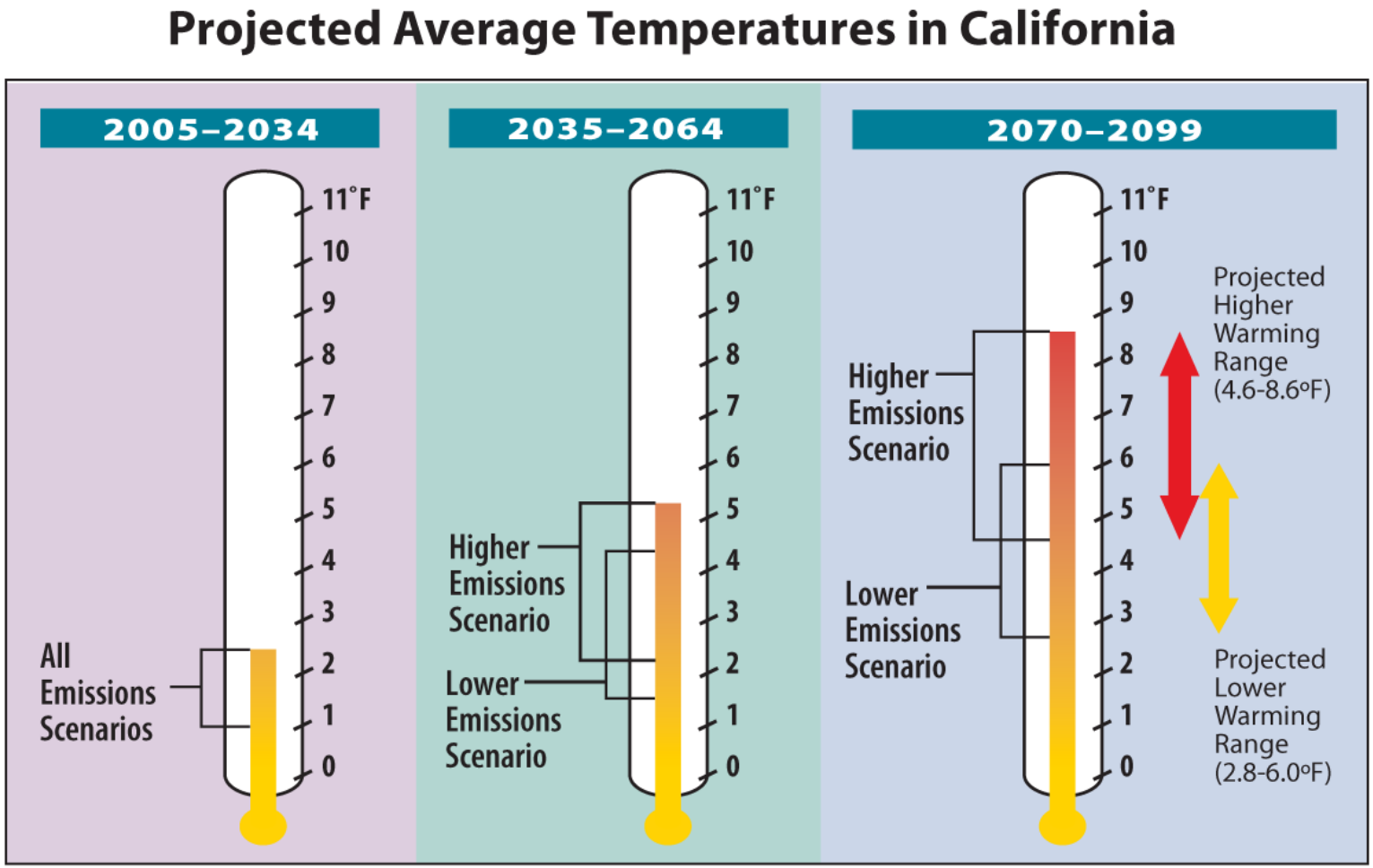
Sierra Nevada Snowpack Shrinks to Lowest Level in 500 Years (Belmecheri et al., 2015)





Credit: NASA/MODIS

Climate warming scenarios for California



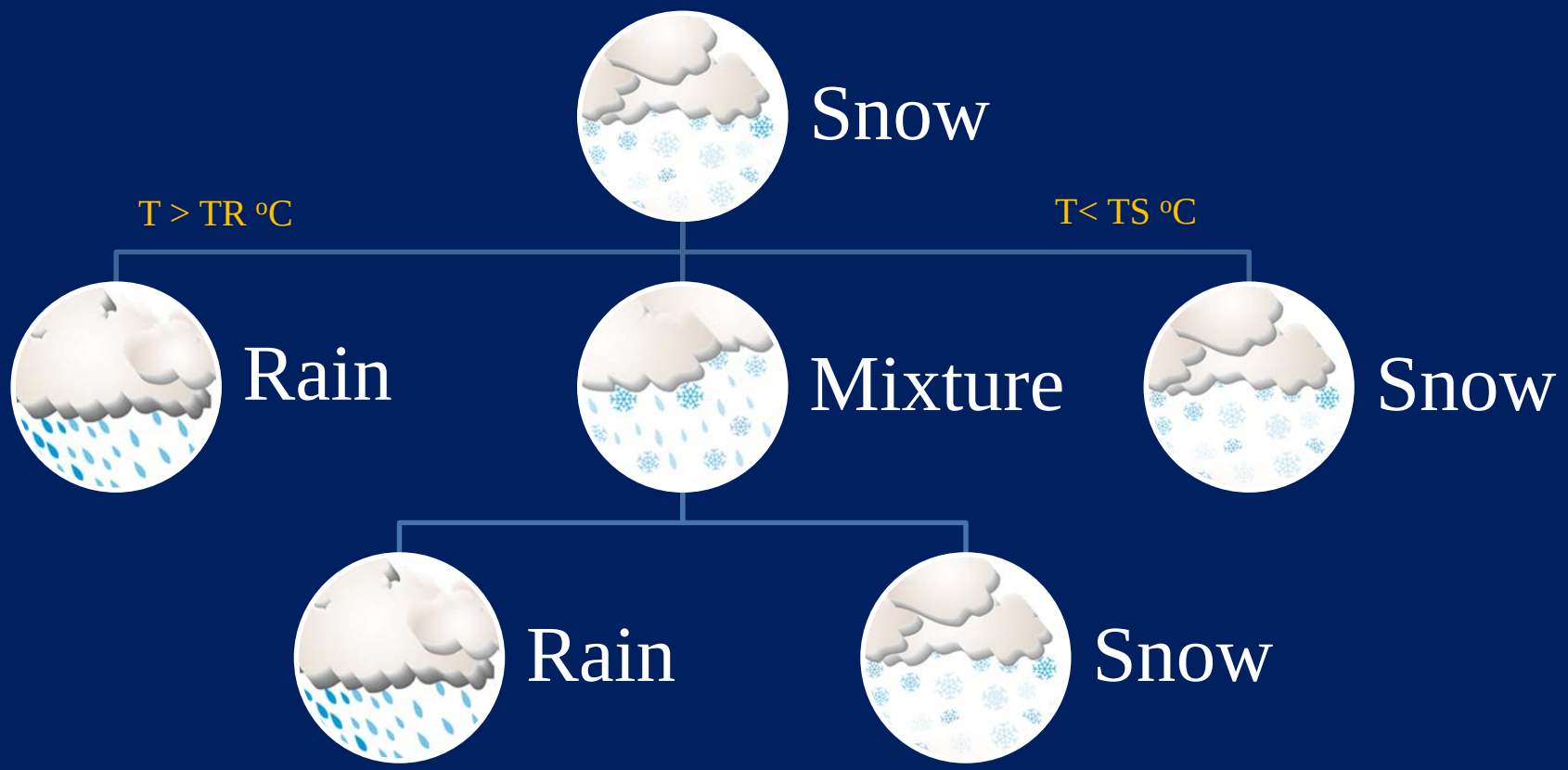
California is expected to experience dramatically warmer temperatures during this century. The figure shows projected increases in statewide annual temperatures for three 30-year periods. Ranges for each emissions scenario represent results from state-of-the-art climate models.

Increase above 1961-1990 average

Source: CA Climate Change Center

Sensitivity of Precipitation Phase to Climate Warming

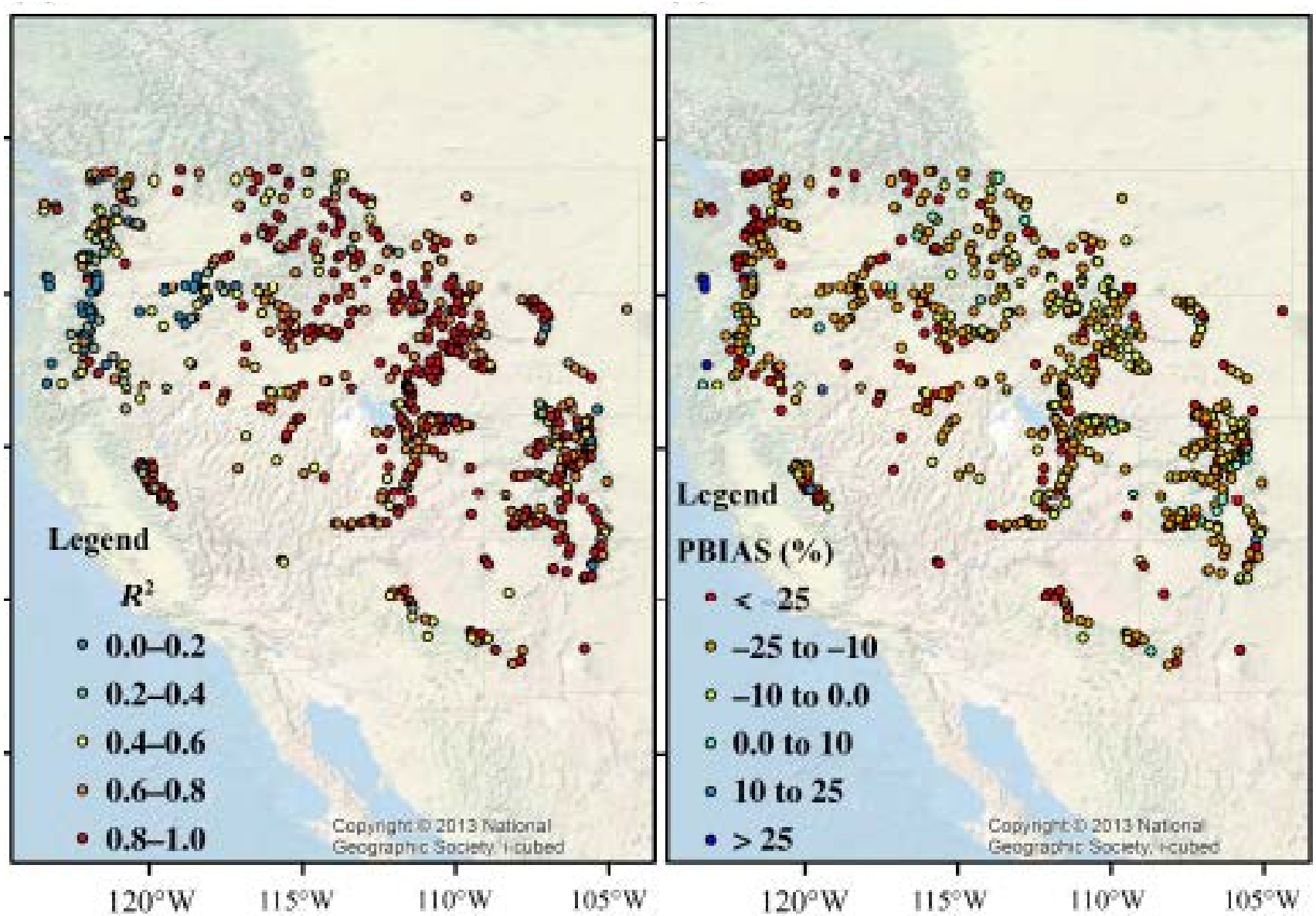
- Precipitation type can be classified based on wet day temperature (T) threshold:



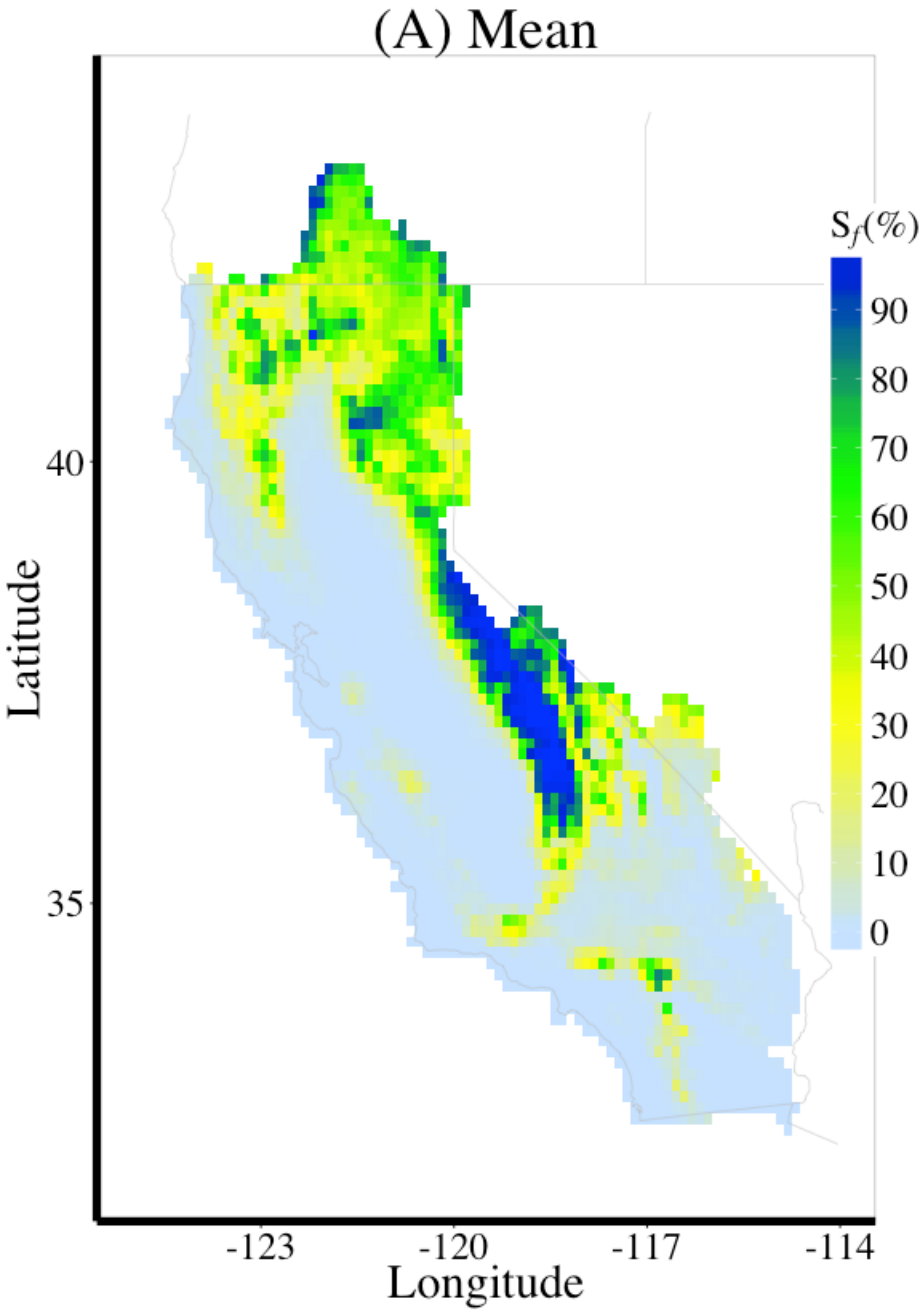
The annual winter season S_f was calculated as:

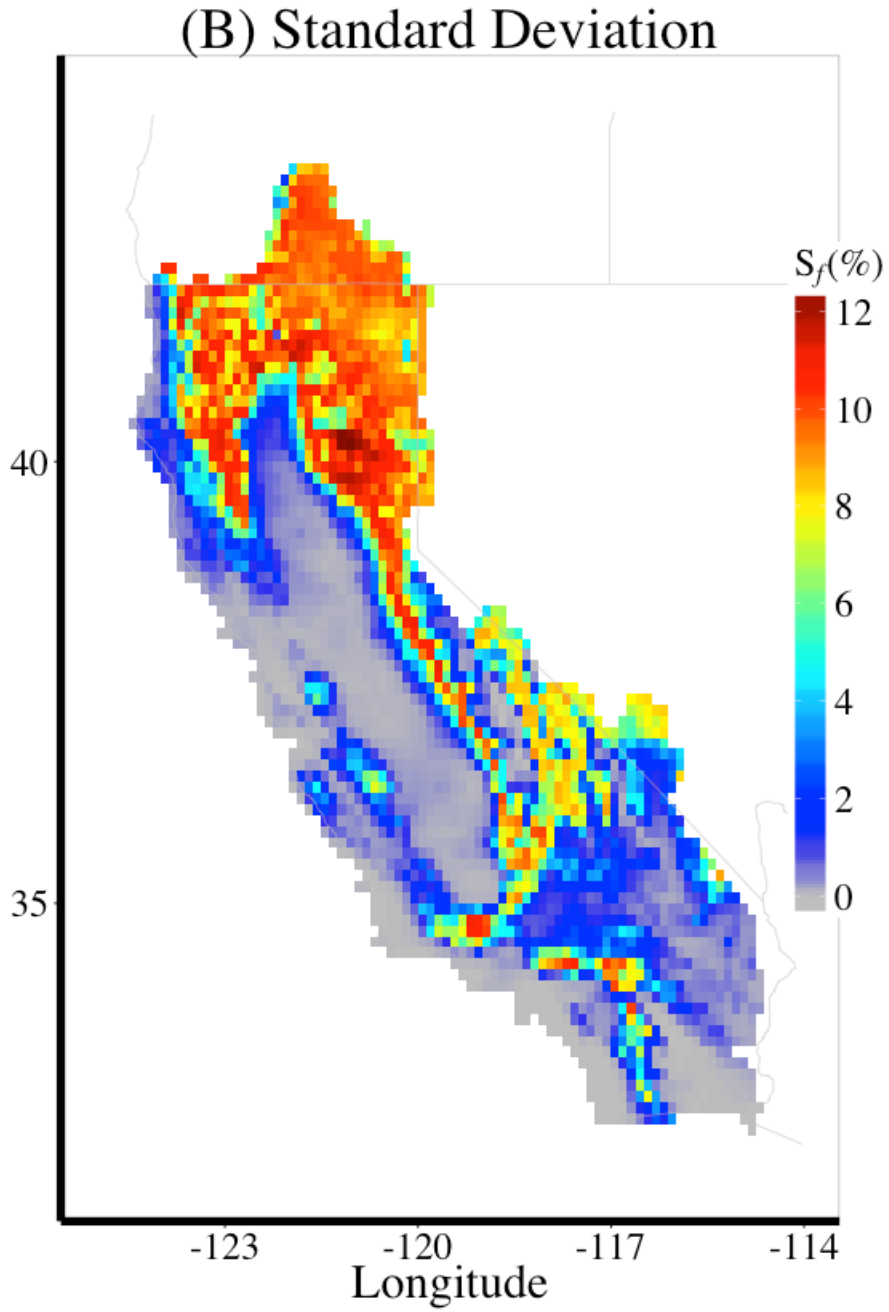
$$S_f\,(\%) = \frac{\sum_{i=1}^{n} \mathrm{SFE}_i}{\sum_{i=1}^{n} \mathrm{P}_i} \times 100$$

Precipitation Phase Model Validation



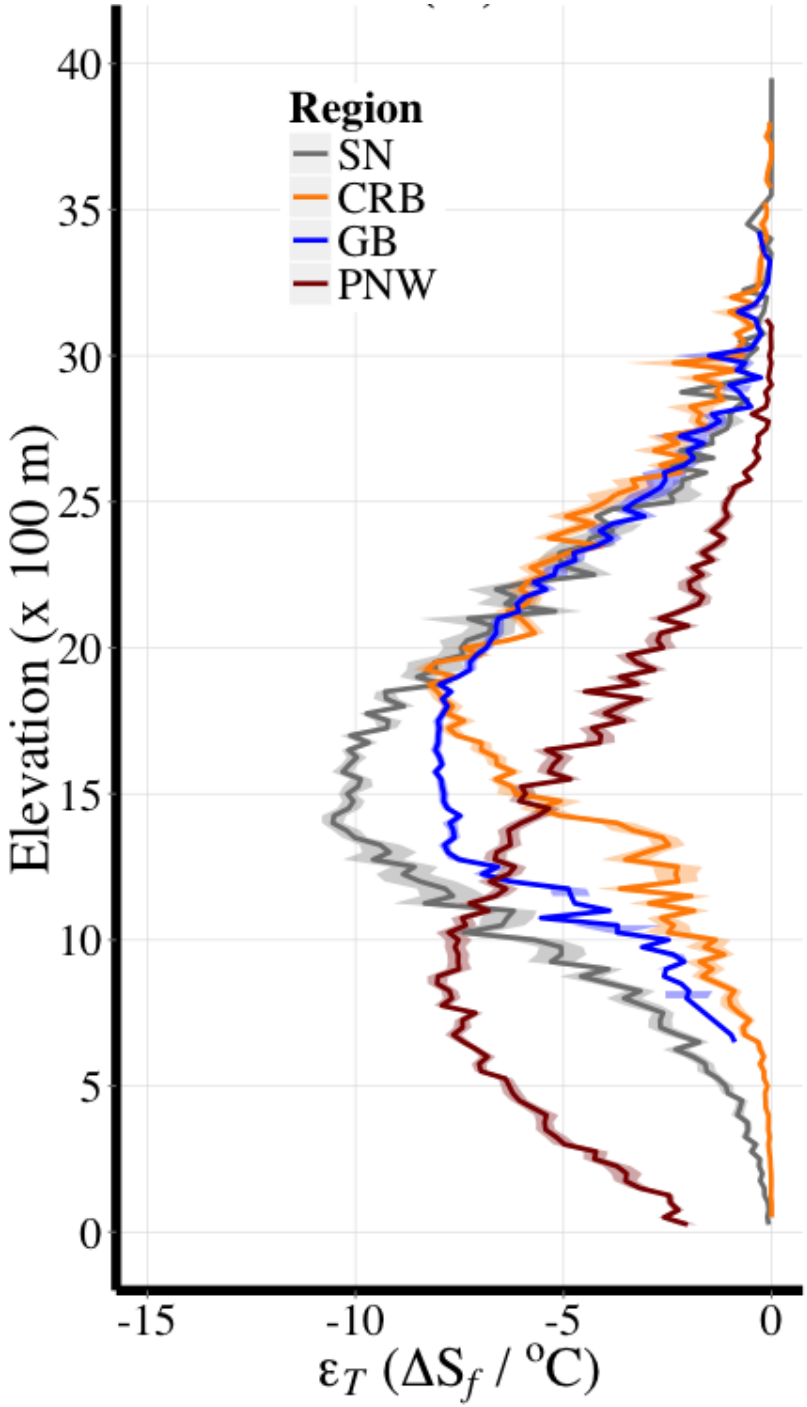
Sensitivity of Precipitation Phase to Temperature

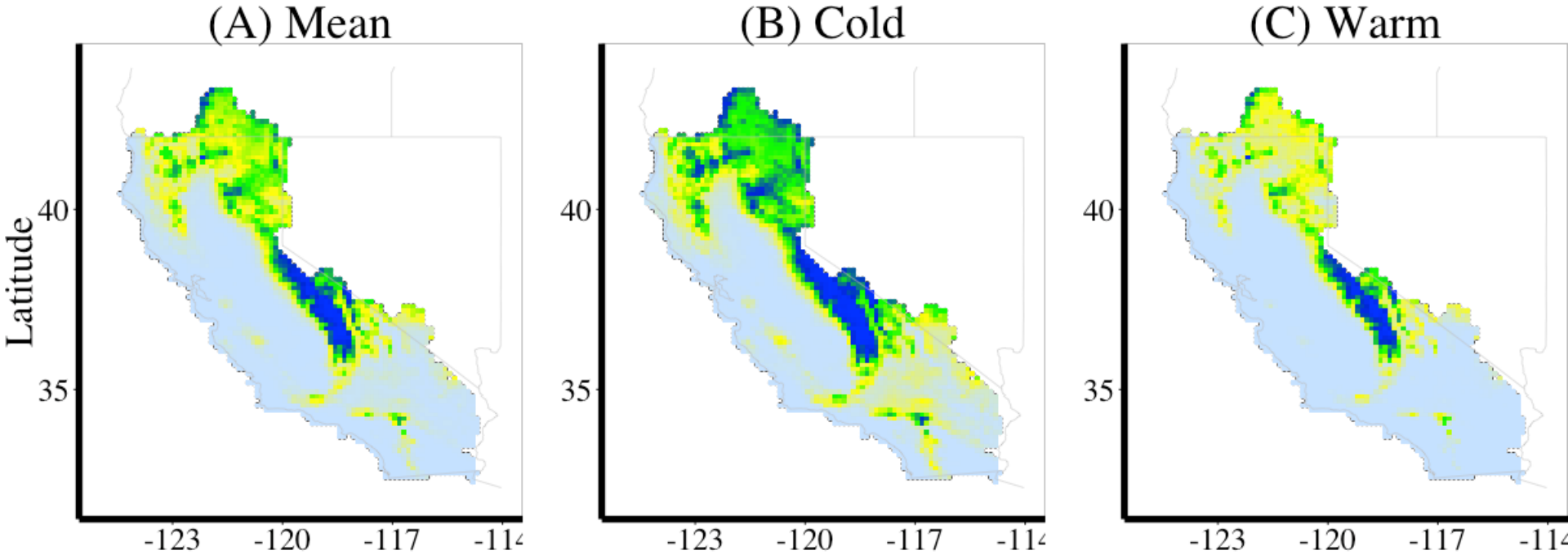


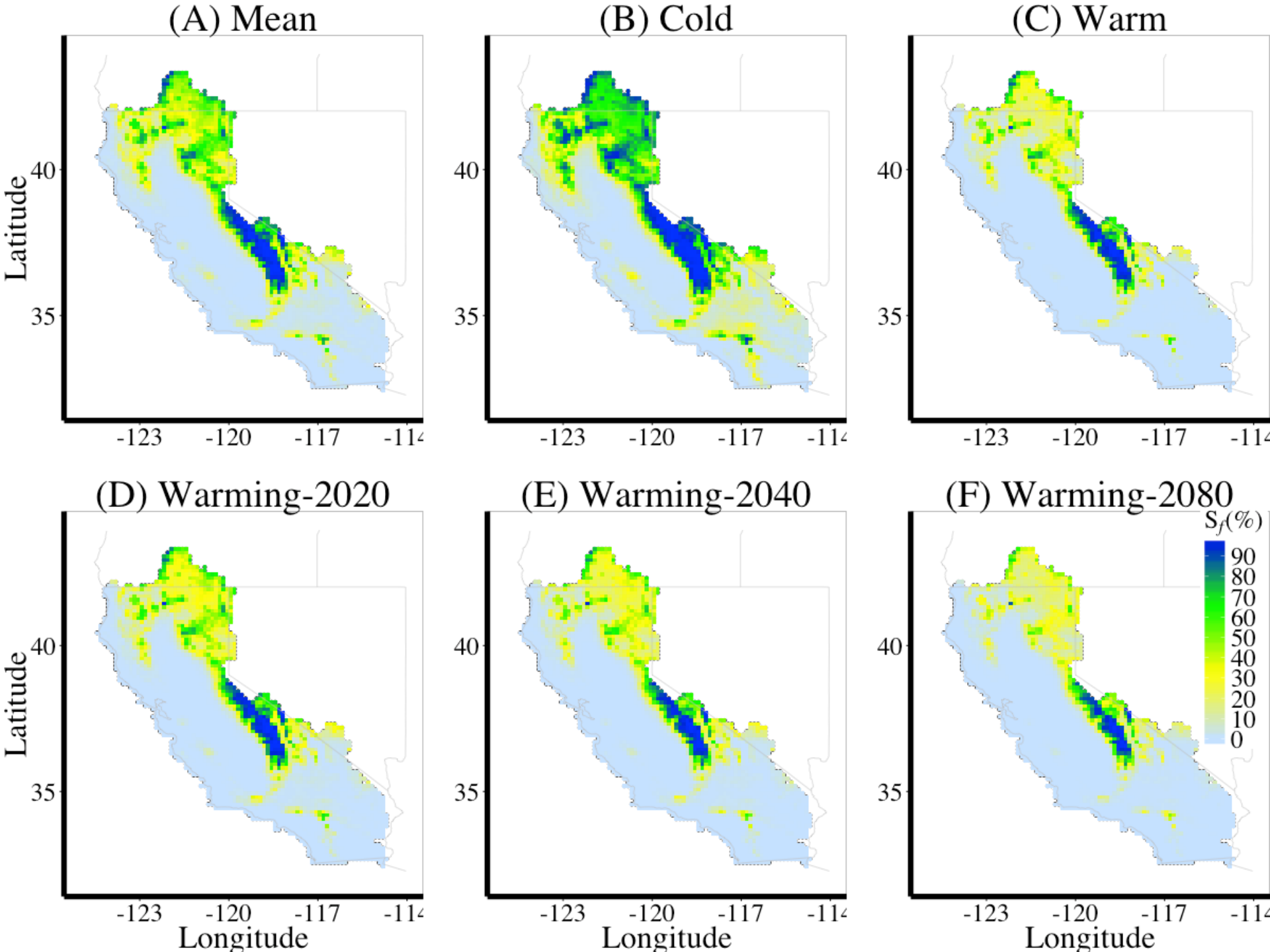


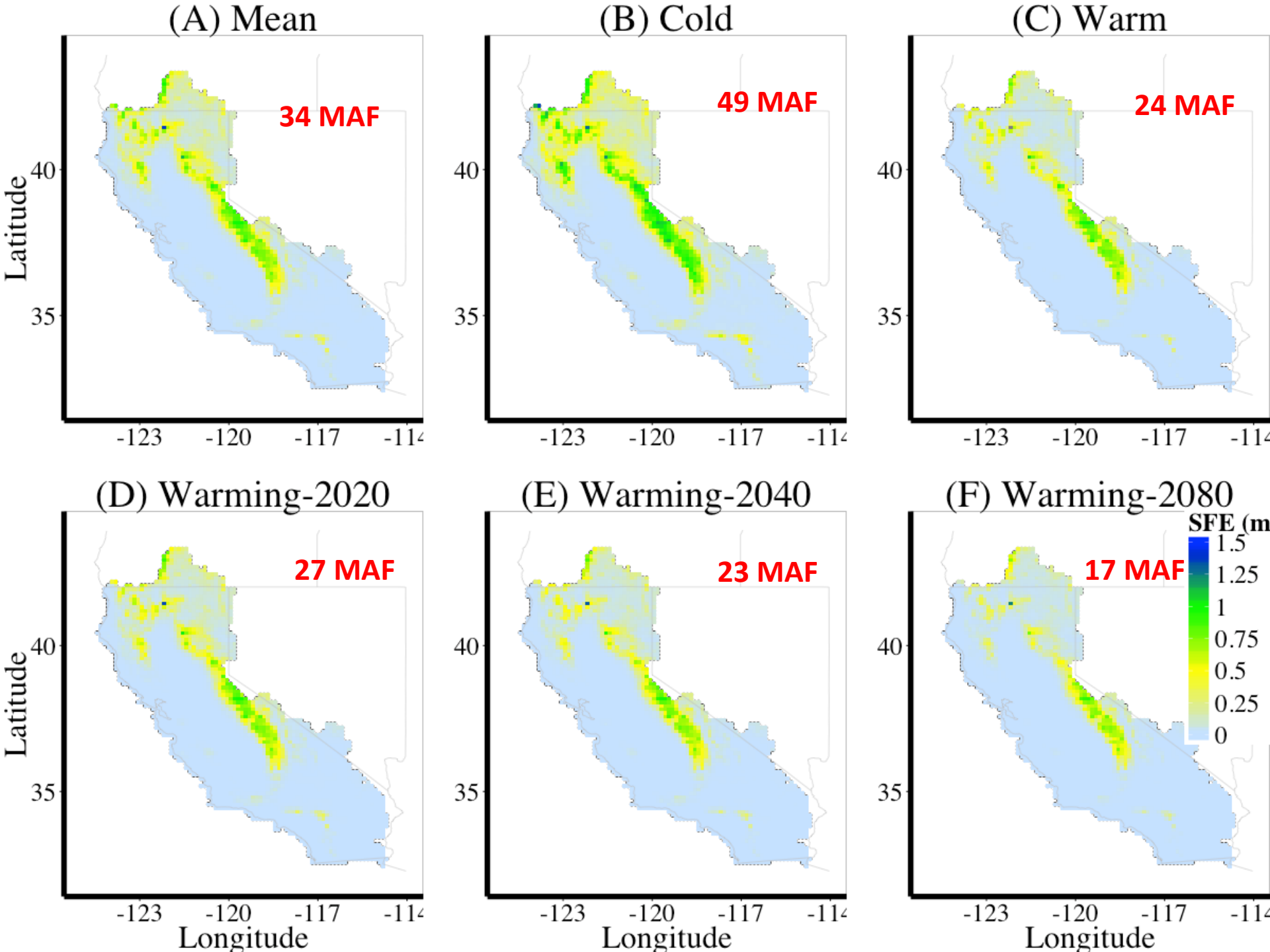
Sensitivity of Precipitation Phase to Temperature

Phase of precipitation in mid-elevations (1000-2000 m) of SN is most sensitive as compared to other regions of the western US

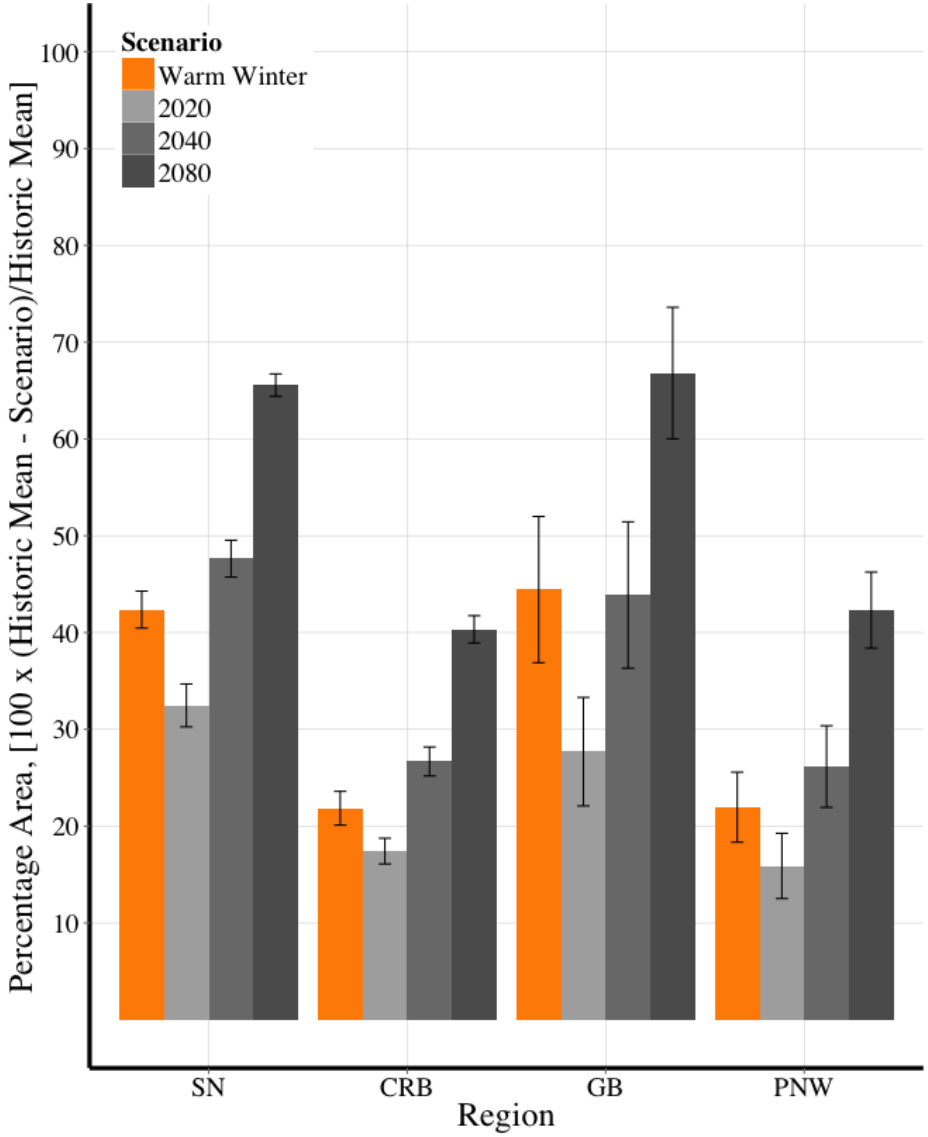



(A) Mean
(B) Cold
(C) Warm
Latitude
40
35
-123
-120
-117
-114


(A) Mean
(B) Cold
(C) Warm
(D) Warming-2020
(E) Warming-2040
(F) Warming-2080
Latitude
Longitude
40
35
-123
-120
-117
-114
S_f(%)
90
80
70
60
50
40
30
20
10
0

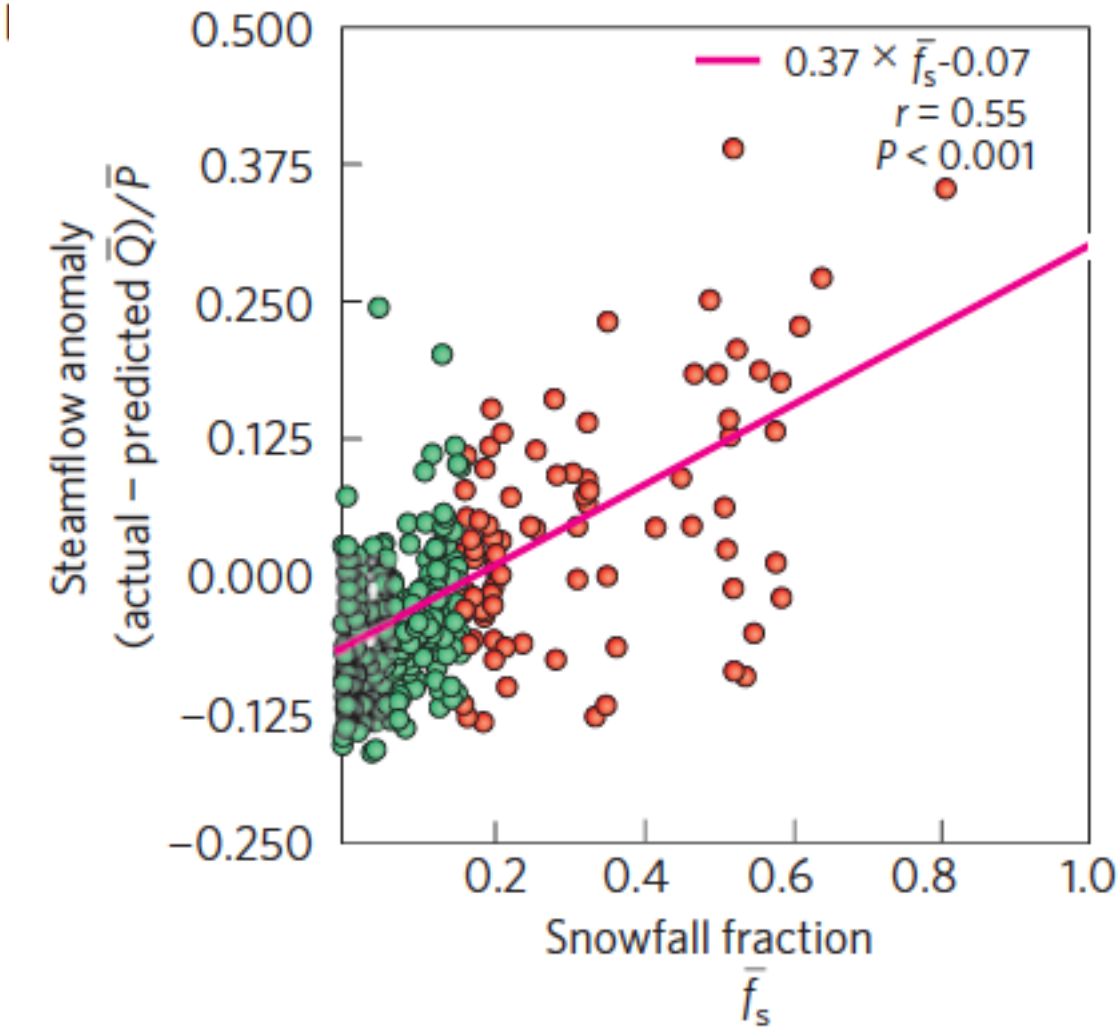

(A) Mean
34 MAF
(B) Cold
49 MAF
(C) Warm
24 MAF
(D) Warming-2020
27 MAF
(E) Warming-2040
23 MAF
(F) Warming-2080
17 MAF
SFE (m
1.5
1.25
1
0.75
0.5
0.25
0
Latitude
40
35
-123
-120
-117
-114
Longitude

Decline in Snow covered area



Between 30-65% decline in snow covered areas (defined as the areas where 50% or more precipitation falls as snow)

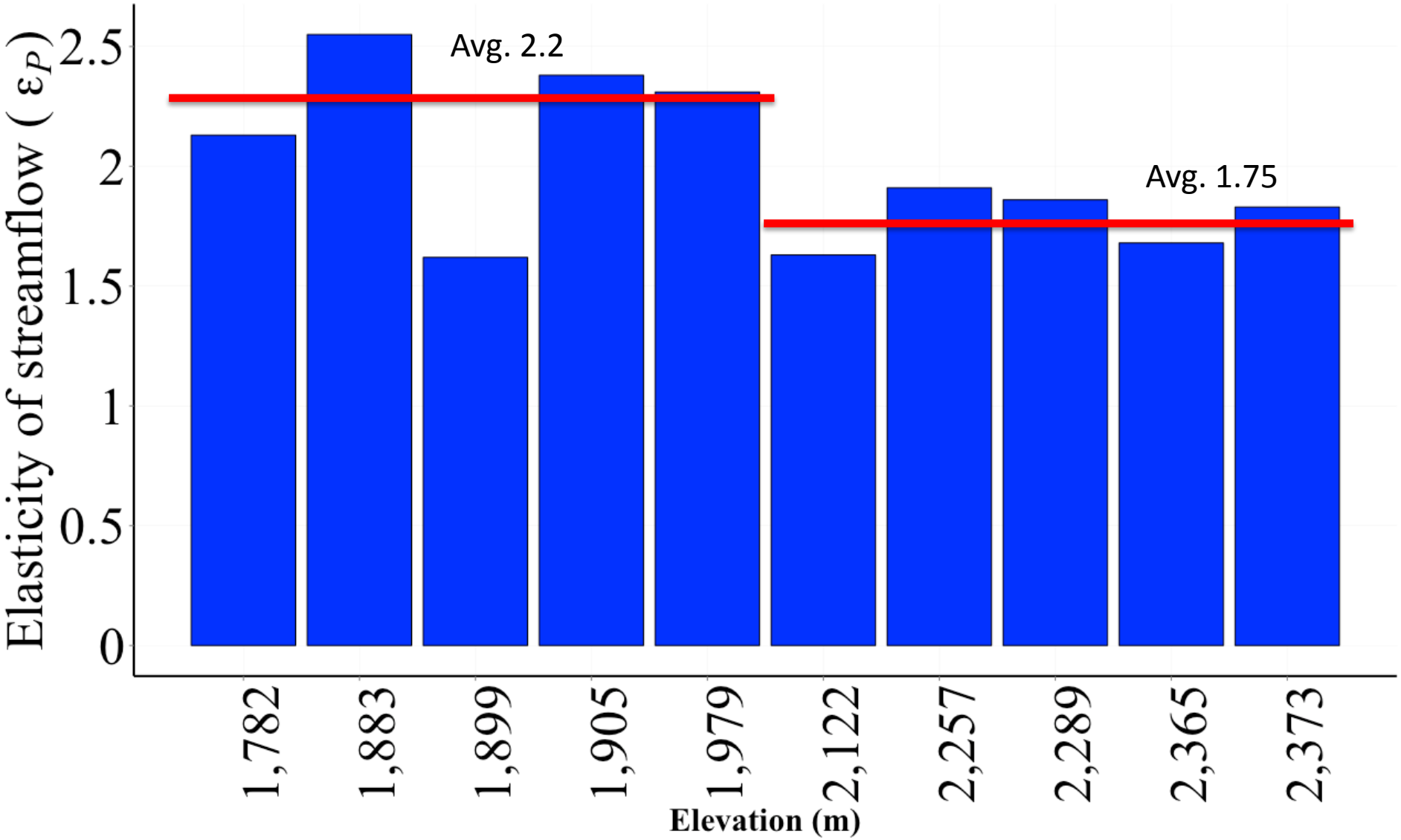
A precipitation shift from snow towards rain leads to a decrease in streamflow



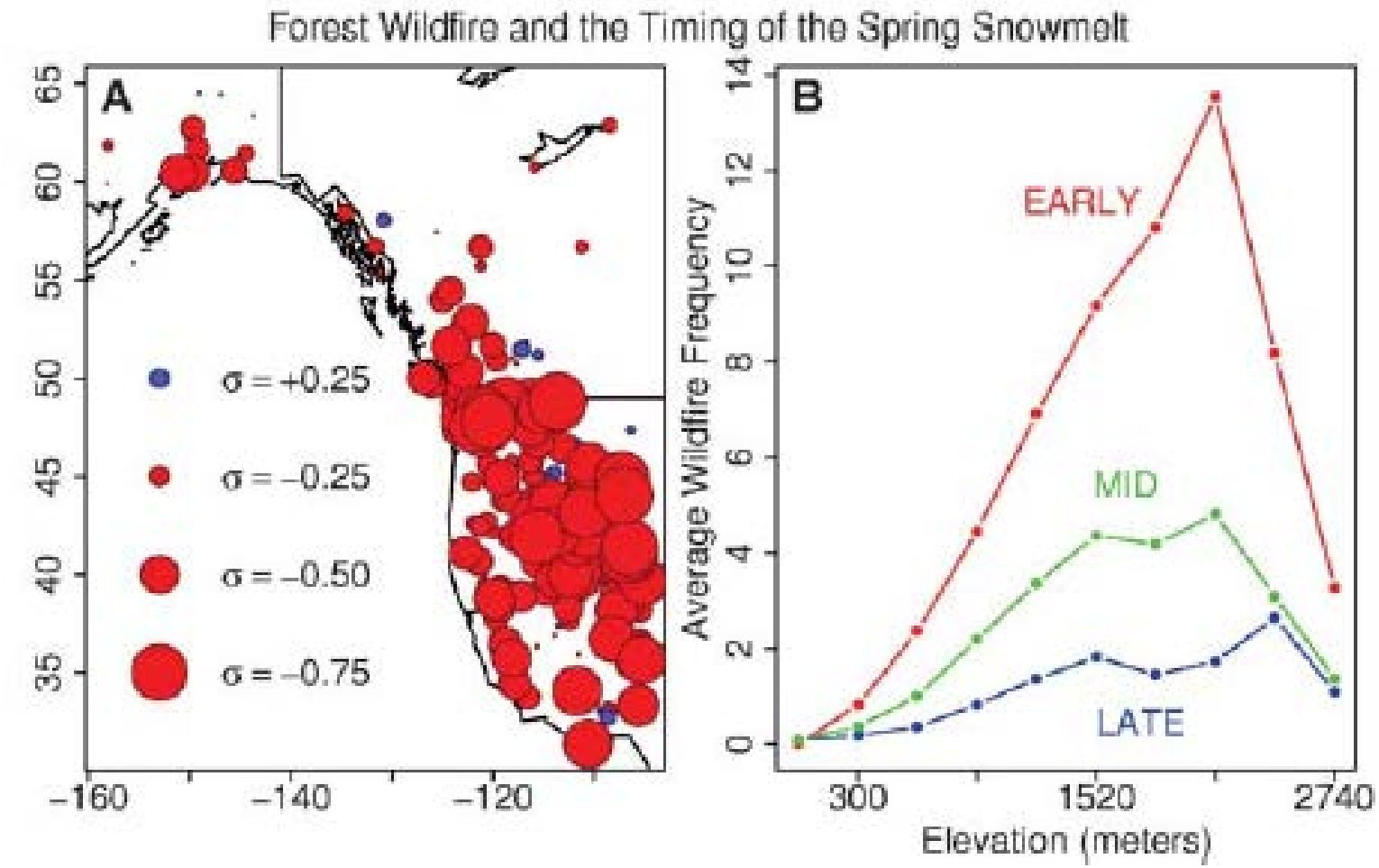
An average increase in normalized streamflow (Q/P) of
0.37 per unit increase in snow fraction

Berghuijs et al., 2014

Higher SWE/P, later melt out, and lower ET makes high elevation catchment less susceptible to annual drought



Timing of snowmelt is highly correlated with wildfire frequency



Westerling et al., 2006

Conclusions

- Warming temperatures have amplified the current drought
- Precipitation phase in mid-elevations (1000-2000 m) of SN is most sensitive to temperature as compared to other regions of the western US
- Historical variability in proportional snowfall closely resembles the projected 2040-warming scenario (+1.8 ∘C)
- By 2080s (+3.0 ∘C), mountain snowfall will be reduced to 17 MAF, 30% lower than the average snowfall in 10 warmest years.

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Reform forest fire management

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DOI: 10.1126/science.aab2356

US Forest Service Prevents Its Own Scientist From Talking About Study

Amy Quinton

Thursday, September 17, 2015 | Sacramento, CA | Permalink

LISTEN 3:

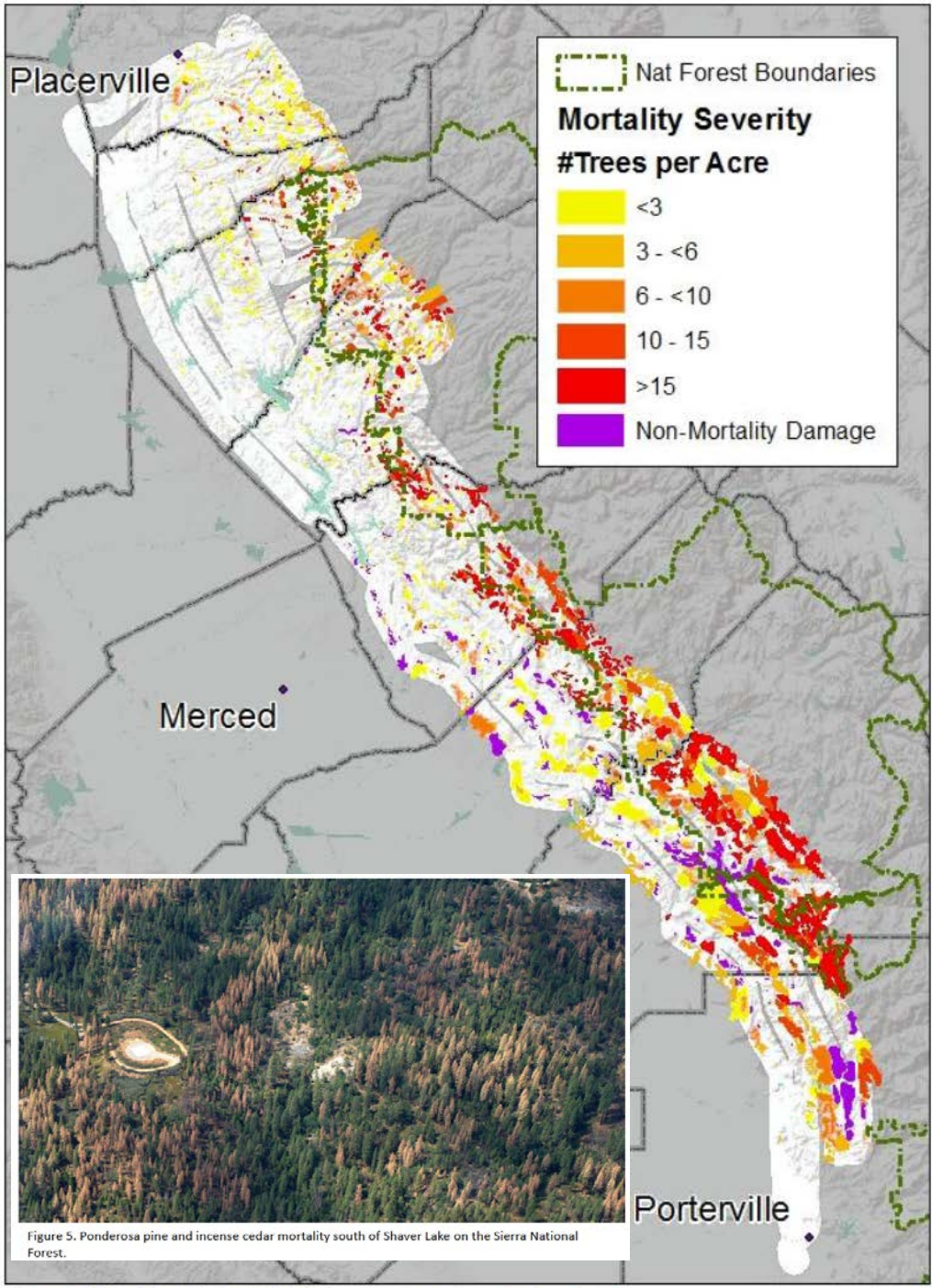
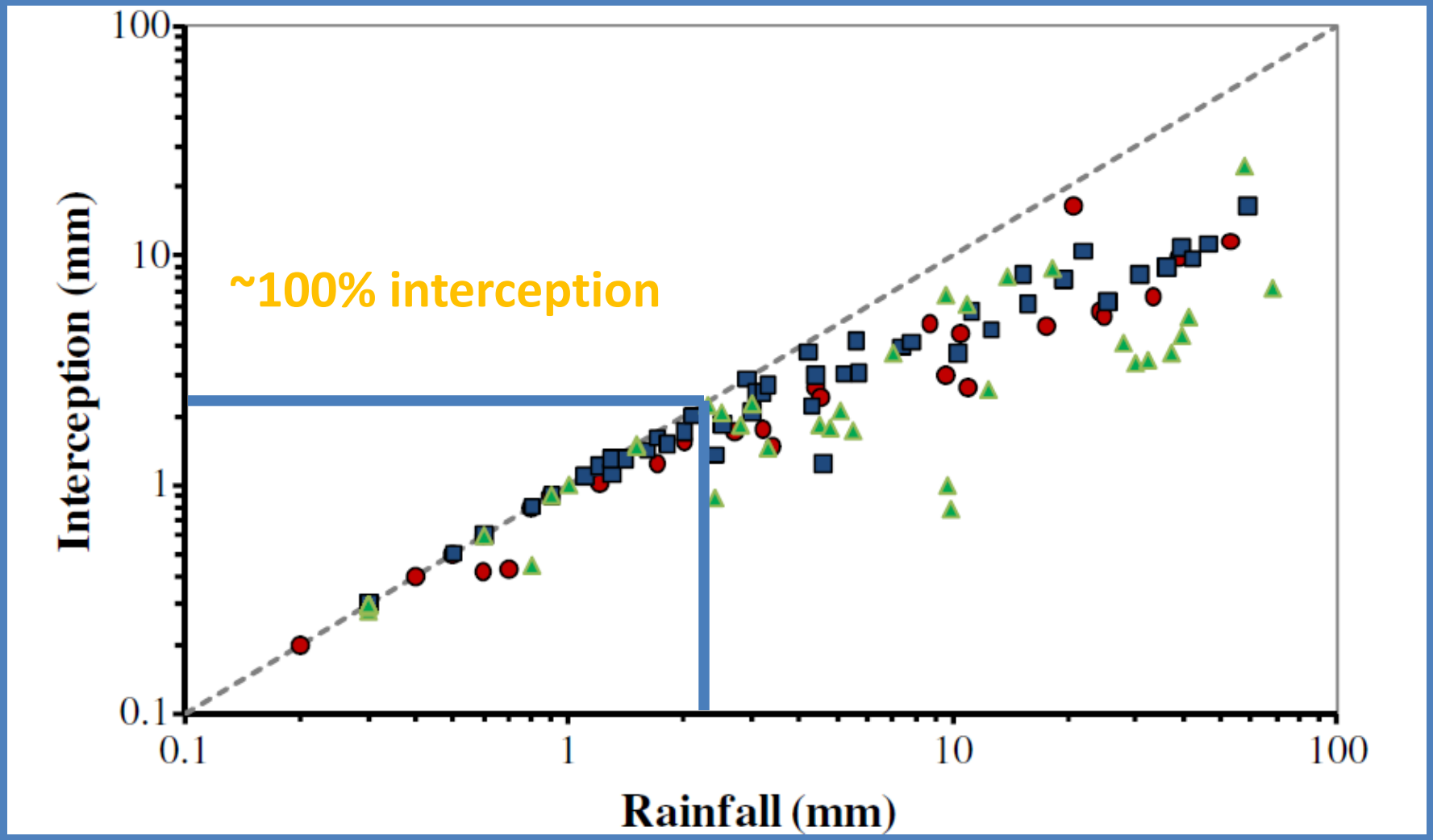


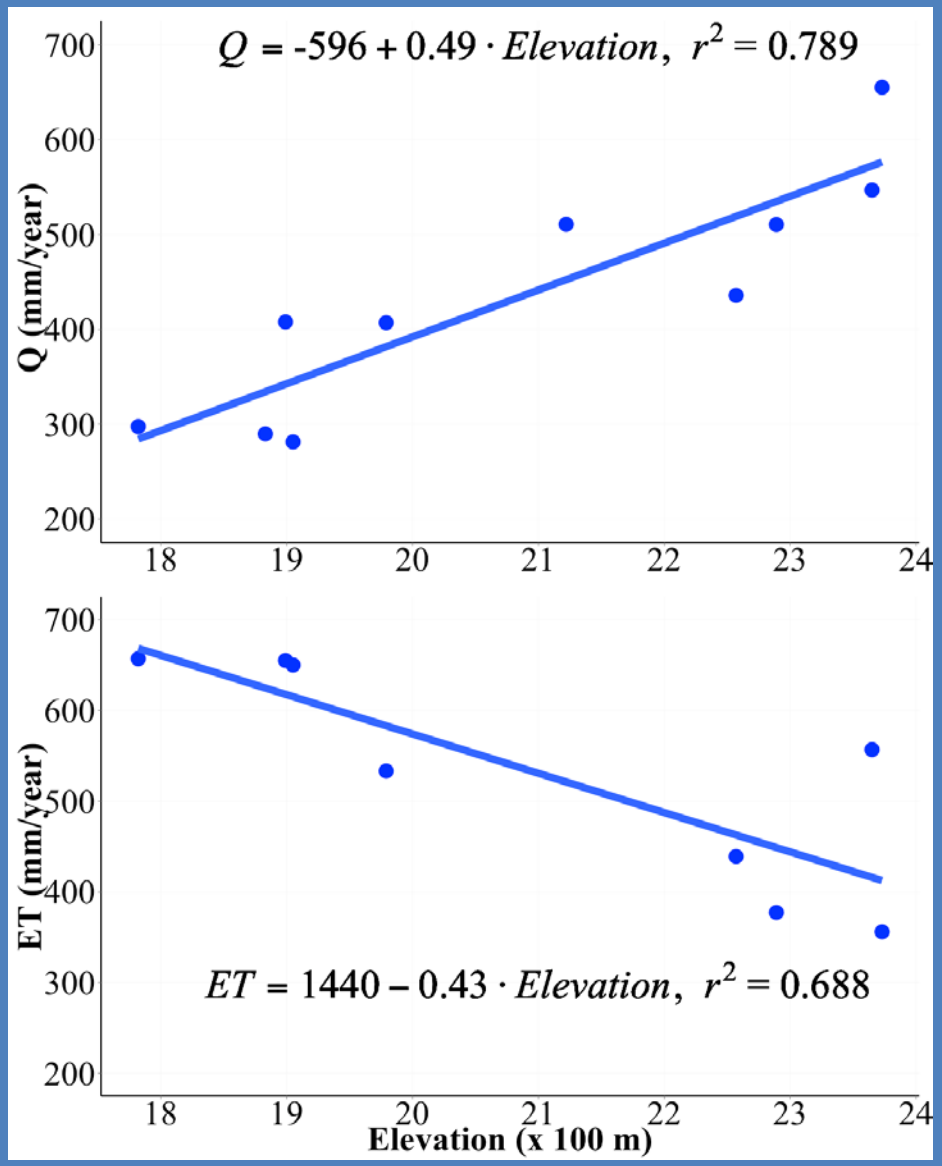
Figure 5. Ponderosa pine and incense cedar mortality south of Shaver Lake on the Sierra National Forest.

Figure 3. Map of area Surveyed depicting tree mortality and other damage.

Almost all low-intensity (2.5 < mm) precipitation is intercepted by trees



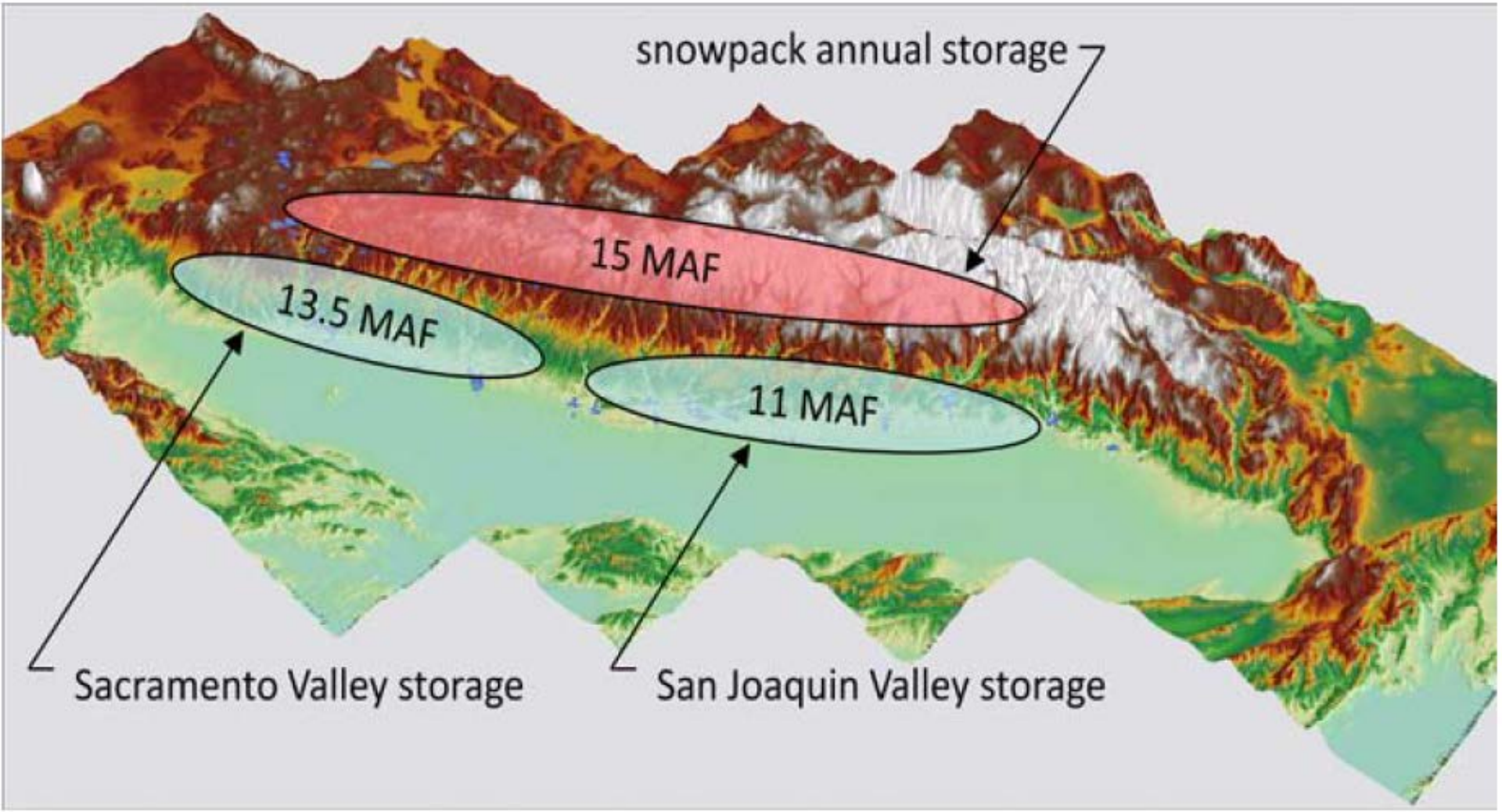
Safeeq, M. & A. Fares, 2014

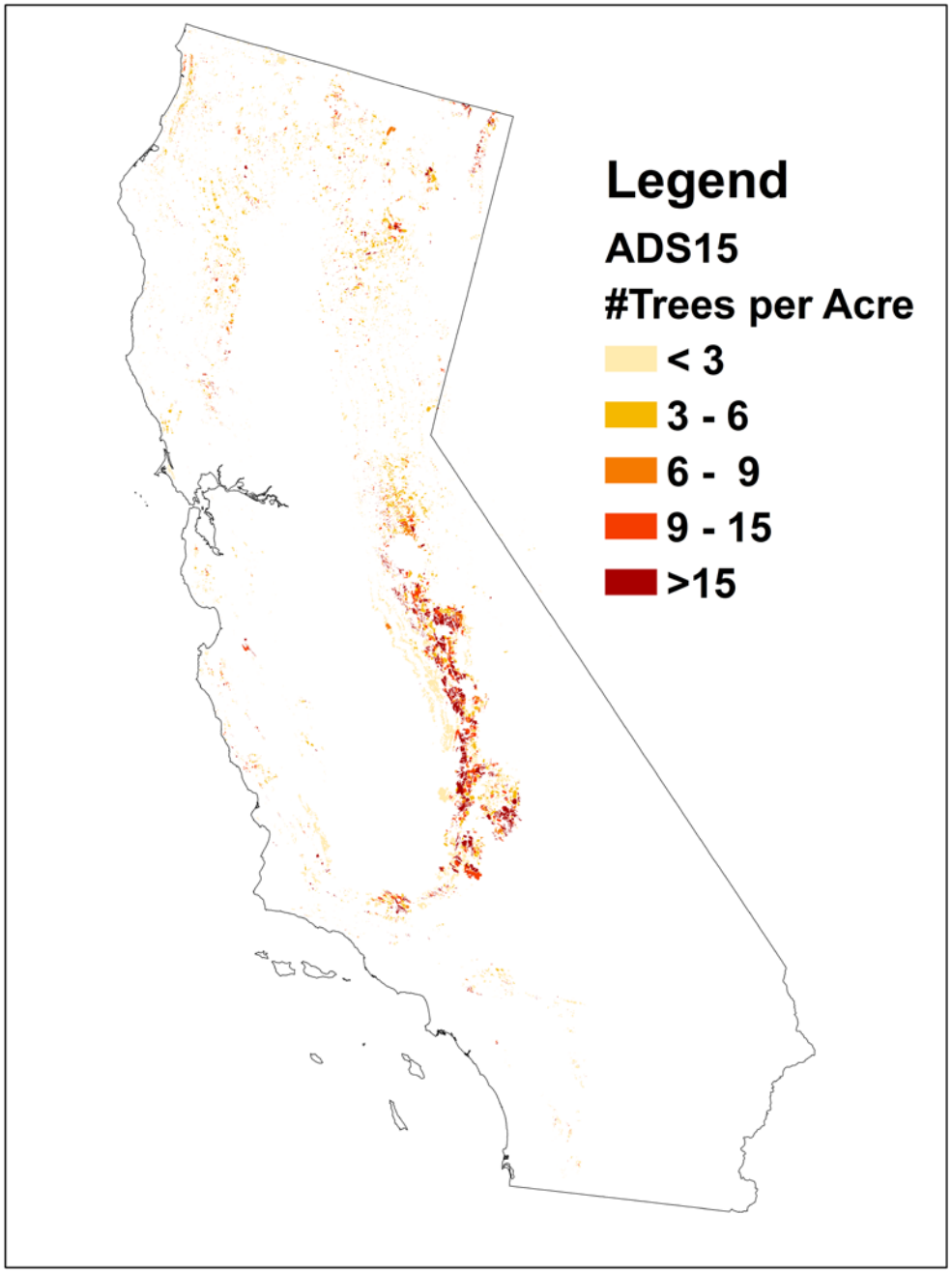


Water balance shows an increase in discharge with elevation, despite no observed precipitation gradient.

Increase in discharge with elevation is comparable to the decline in ET

Storage capacity of the Sierra Nevada snowpack in comparison to dams and reservoirs (Bales et al., 2011)




Legend
ADS15
#Trees per Acre
< 3
3 - 6
6 - 9
9 - 15
>15