

Climate Change, Drought, and Water Supplies in the Western US

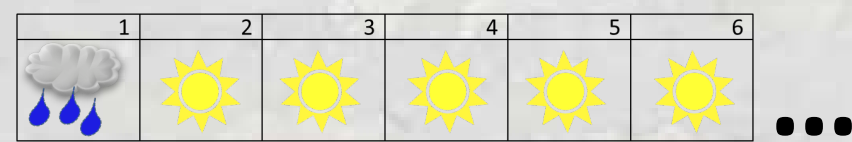
Charles Luce

USDA Forest Service Research



Two Sets of Mechanisms Affecting Drought

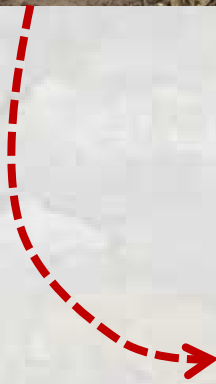
More consecutive dry days



Hotter, drier growing season



Hotter temperatures



Lower, less reliable, and less predictable summer streamflow



Warmer more variable snowpack



Reduced Snow Fraction

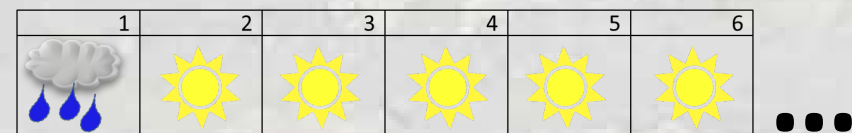


More extreme low winter pptn.

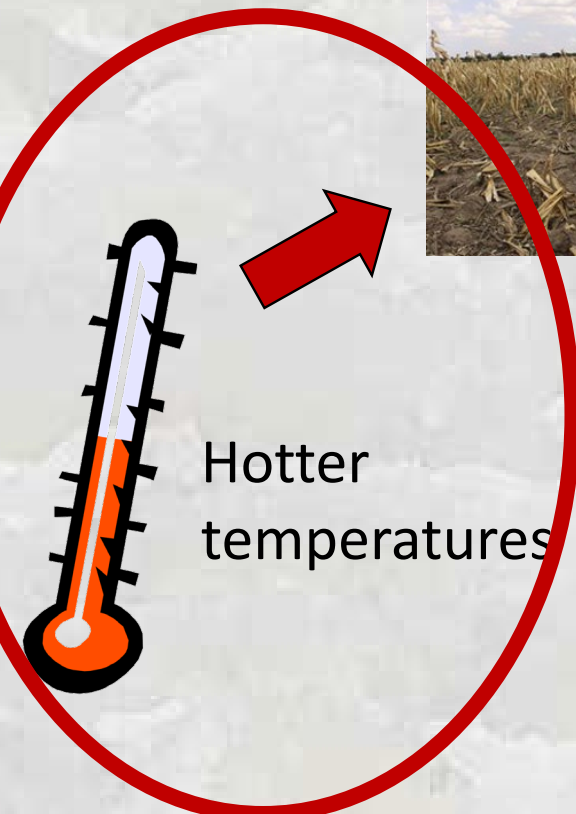


Two Sets of Mechanisms Affecting Drought

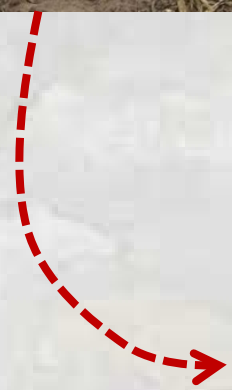
More consecutive dry days



Hotter, drier growing season



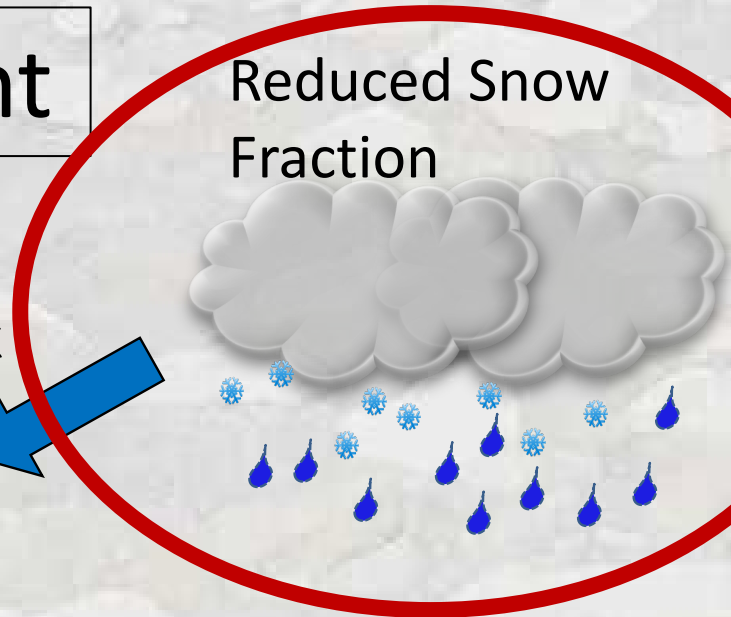
Hotter temperatures



Lower, less reliable, and less predictable summer streamflow

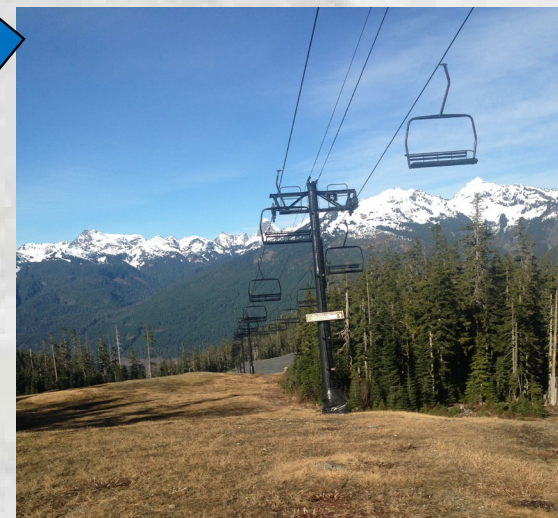


Warmer more variable snowpack



Reduced Snow Fraction

More extreme low winter pptn.



RMA Indemnity Payments

Failure of Irrigation Supply Losses

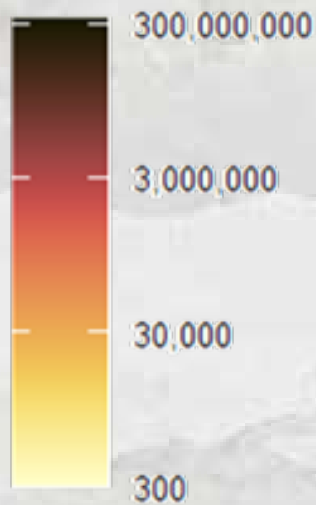
1989-1998

\$0.04 B

\$2.3 B

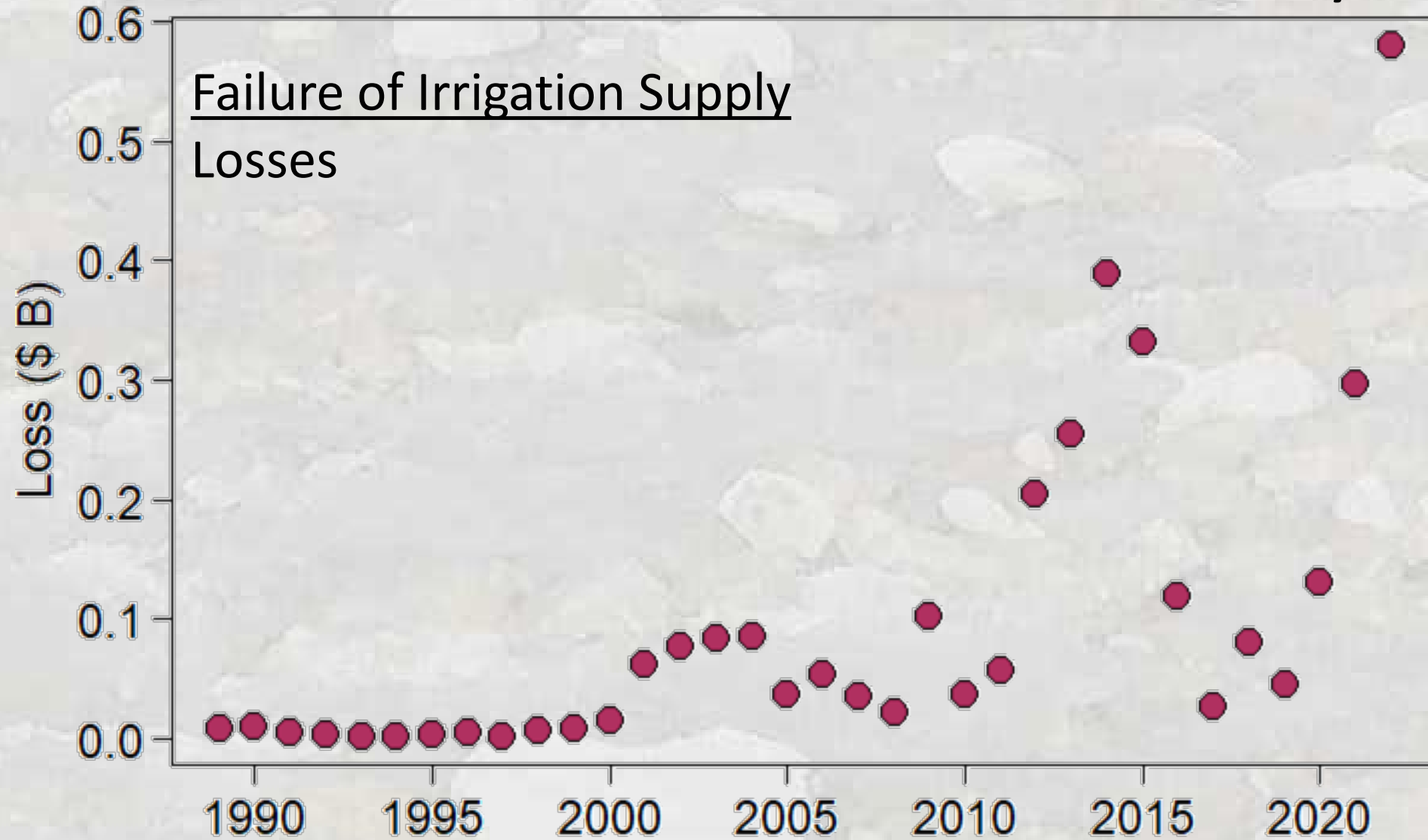
2013-2022

2022 Dollars



Data from Risk Management Agency
<https://swclimatehub.info/rma/about.html>
See Reyes and Elias, 2019

RMA Indemnity Payments



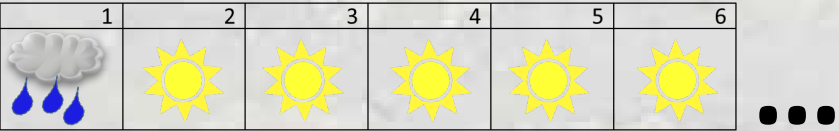
Data from Risk Management Agency

<https://swclimatehub.info/rma/about.html>

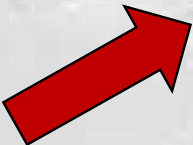
See Reyes and Elias, 2019

Summer Processes I – Warming and Evapotranspiration

More consecutive dry days



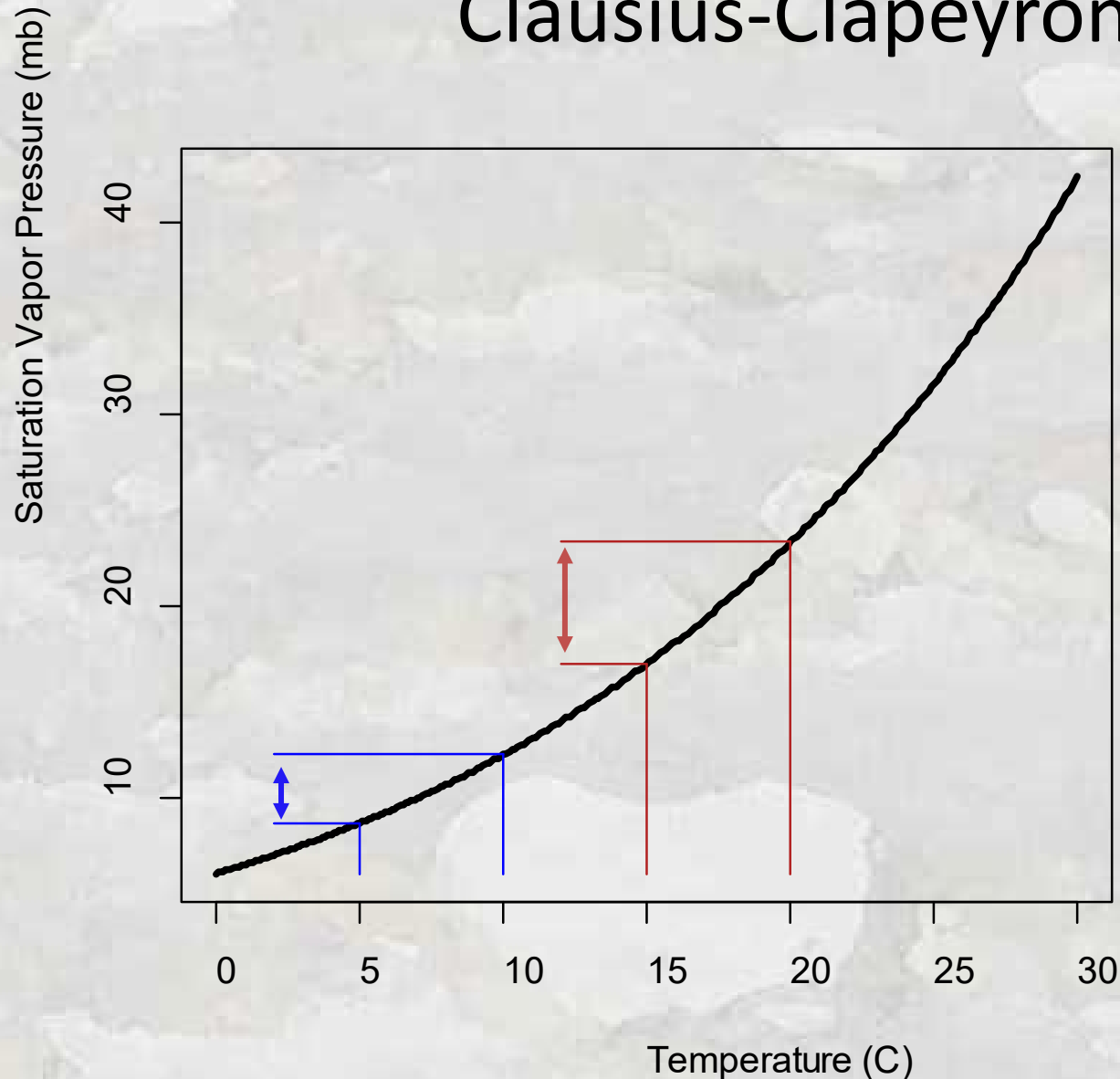
Hotter, drier growing season



Hotter
temperatures

Water Holding Capacity of Atmosphere:

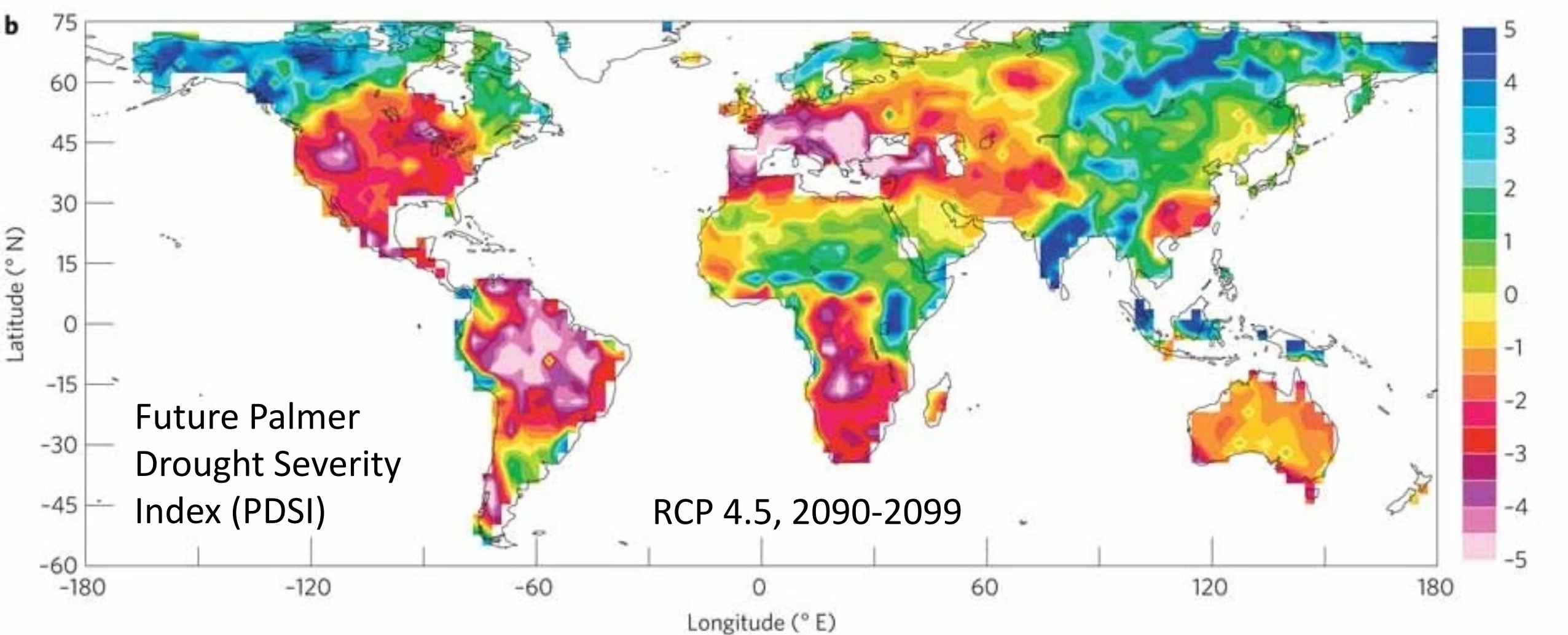
Clausius-Clapeyron - 7%/°C



$$VPD = e_s - e_a$$

At constant RH, VPD will be higher at greater temperatures.

Drought Projection Based on PDSI



“... estimating trends is problematic ... temperature-based methods are flawed, inherently because the temperature state does not uniquely determine the evaporative flux”

-Sheffield, Wood, Roderick 2012

TWO Contexts!

- Irrigated fields
- Rest of landscape

Rest of Landscape

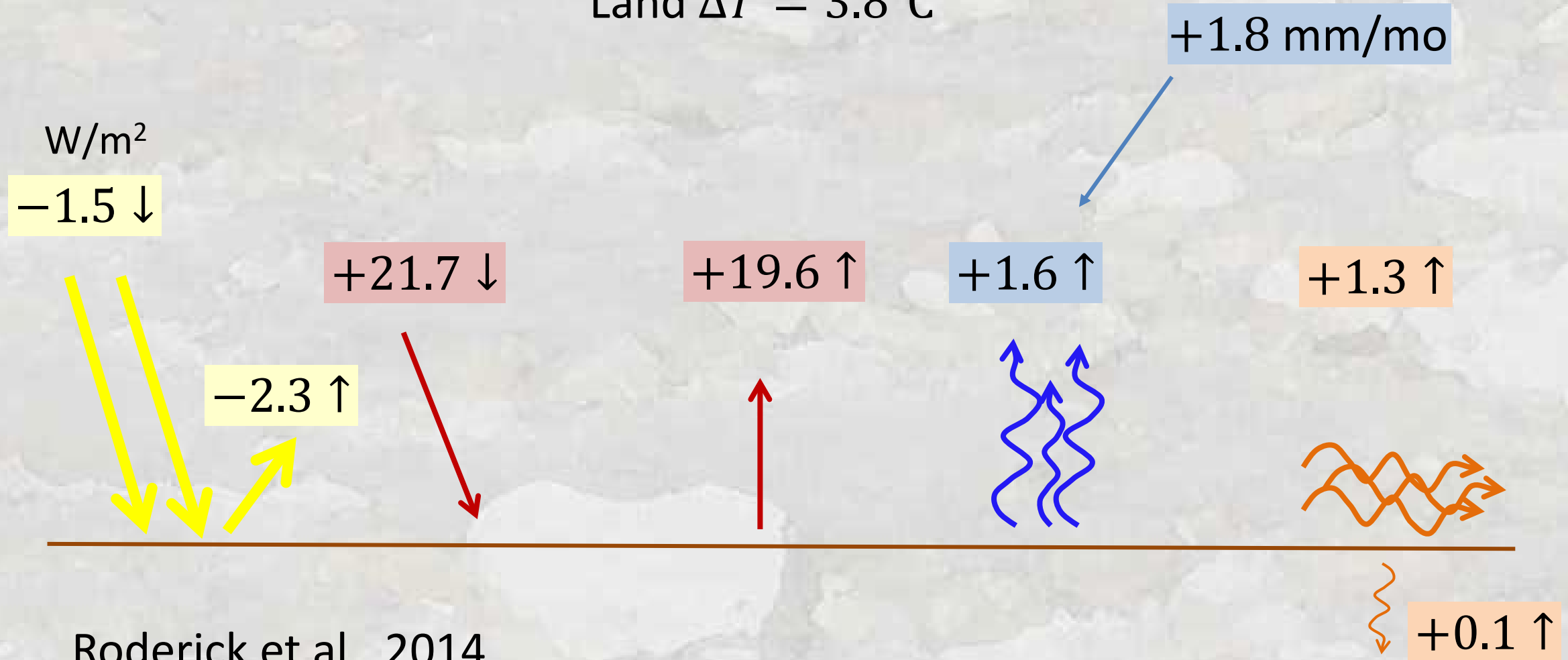


Mackay Idaho
9/8/2020
2:30 PM
61 F
Morning low,
37 F
39% RH
16 MPH

Wet, irrigated crops

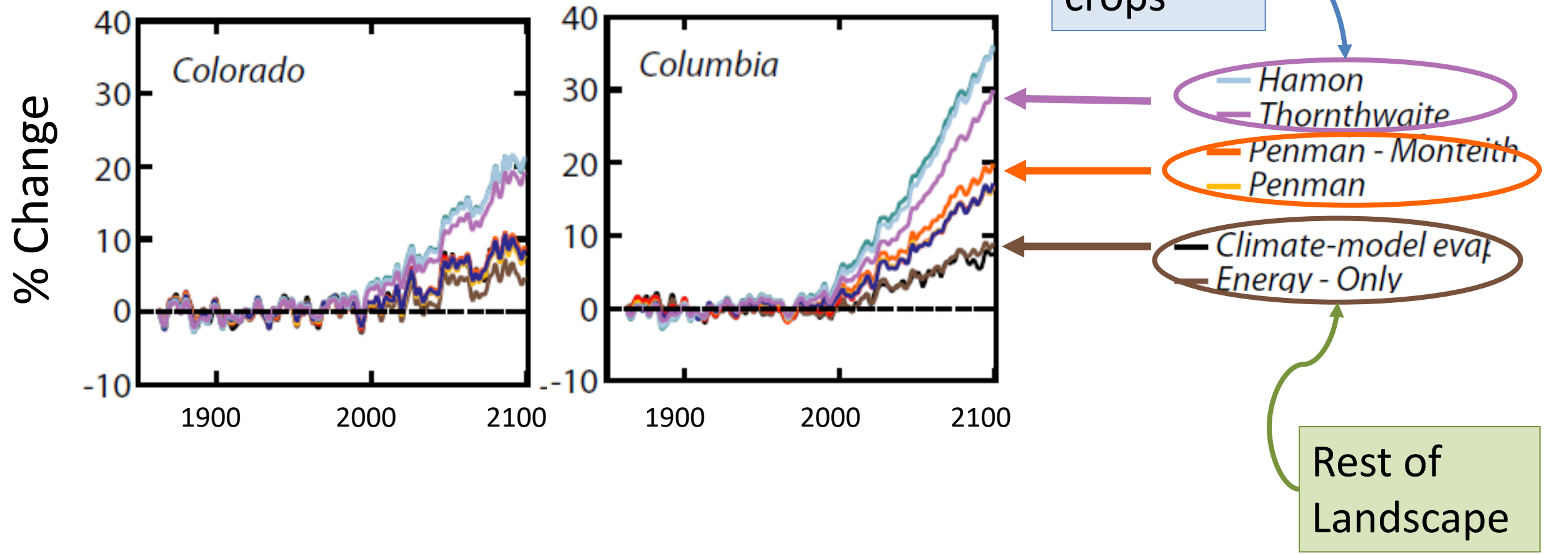
Change in Energy Balance over Land (Rest of Landscape)

For: Global $\Delta T = 2.8^\circ\text{C}$
Land $\Delta T = 3.8^\circ\text{C}$

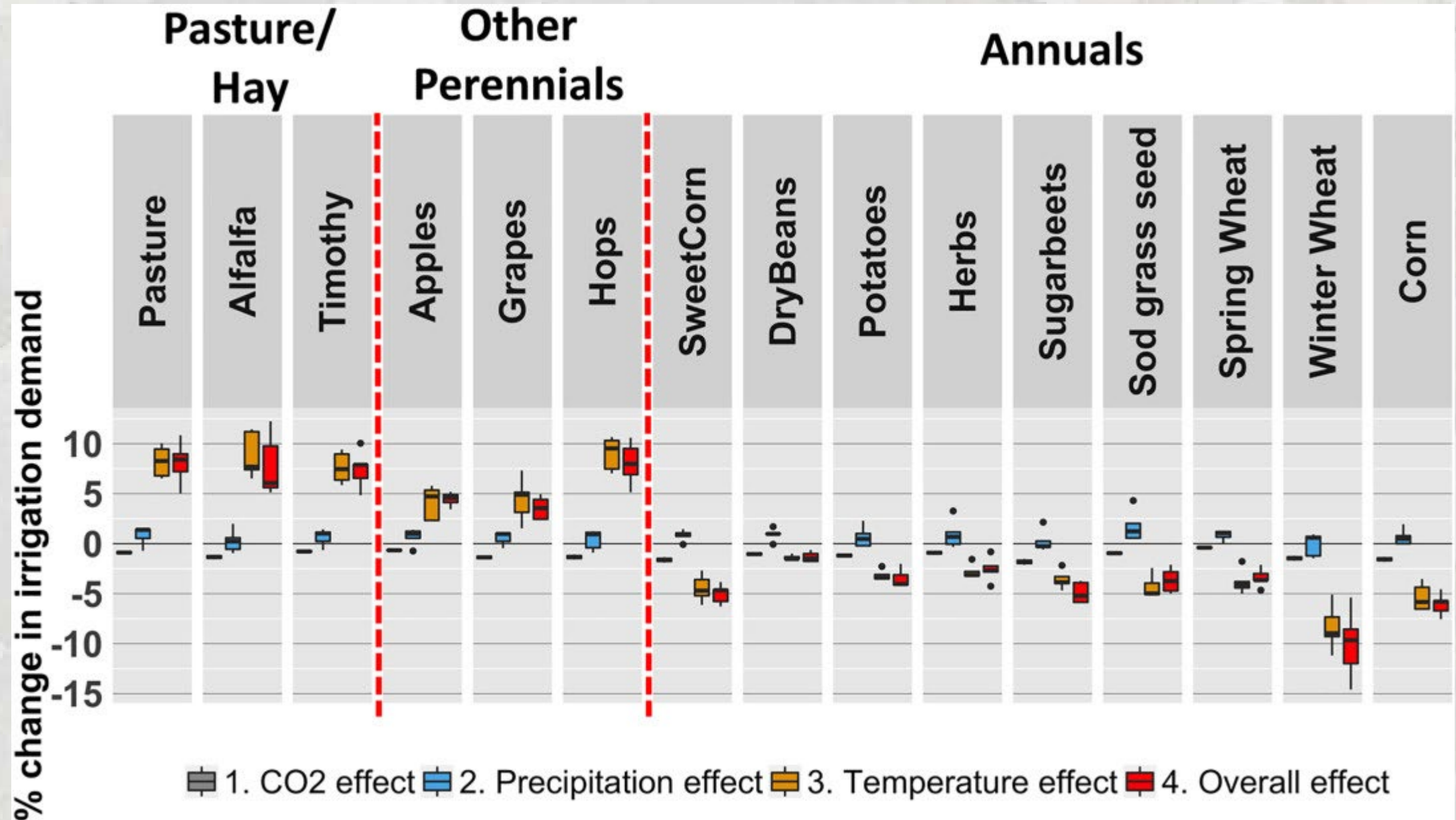


Roderick et al., 2014

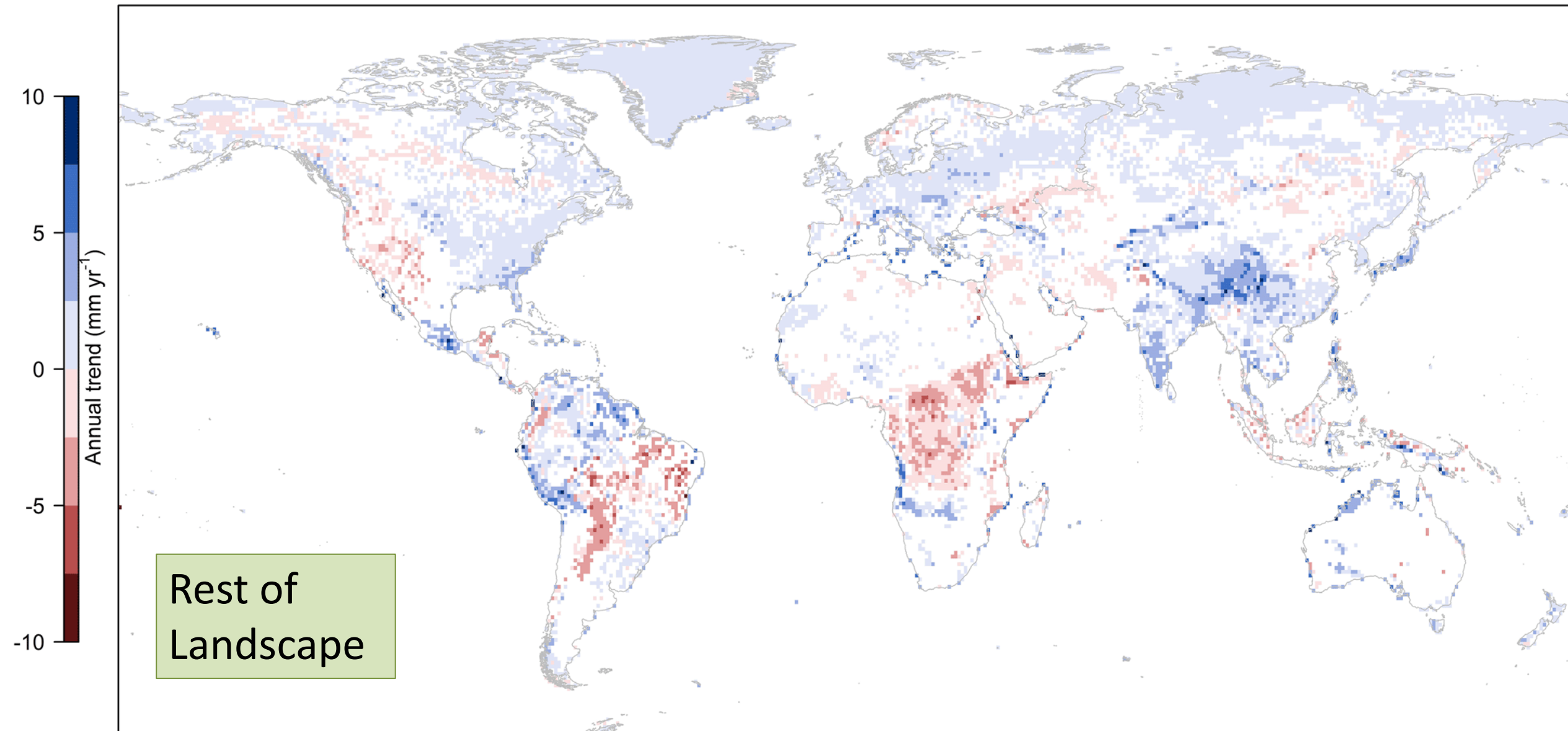
How well does temperature change predict ET change?



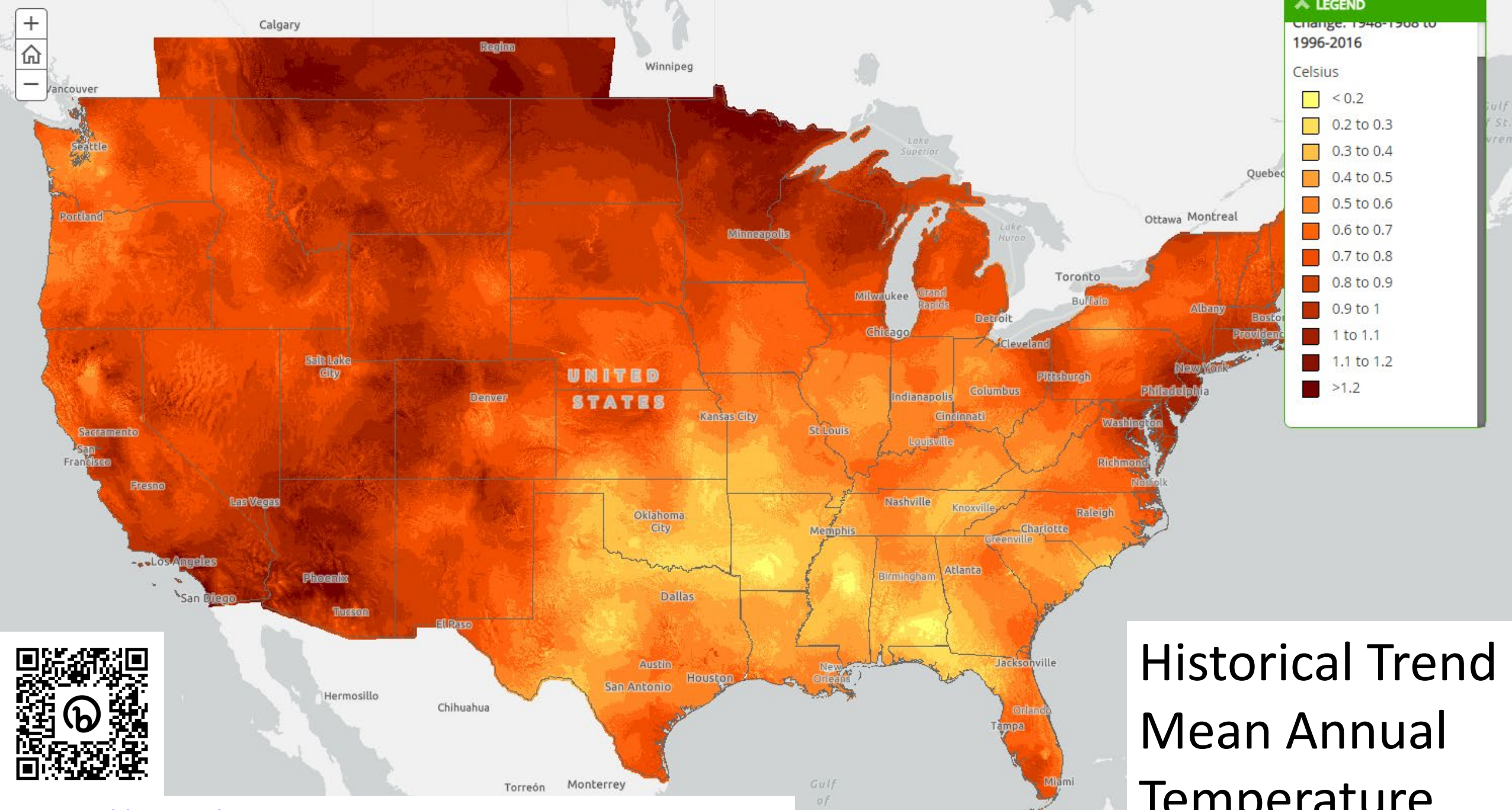
2030s Projected change on irrigation demands in Columbia R. basin



Historical Trends in Evapotranspiration (1980-2018, DOLCE V3)



Hobeichi et al 2021, Robust Historical Evapotranspiration Trends across Climate Regimes



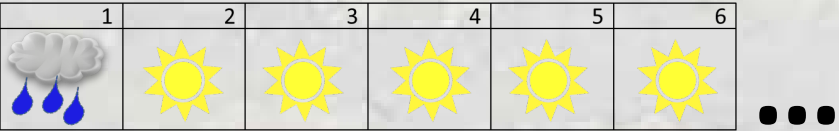
Historical Trend
Mean Annual
Temperature



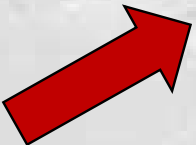
<https://bit.ly/USFSHistoricalTemperatureTrend>

Summer Processes II – Dry Days

More consecutive dry days



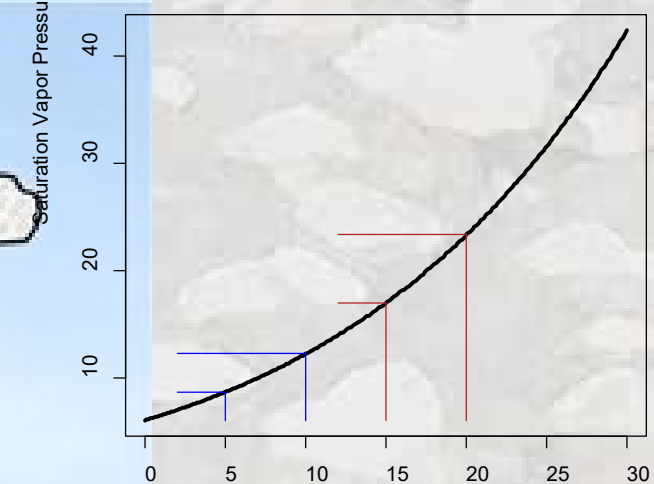
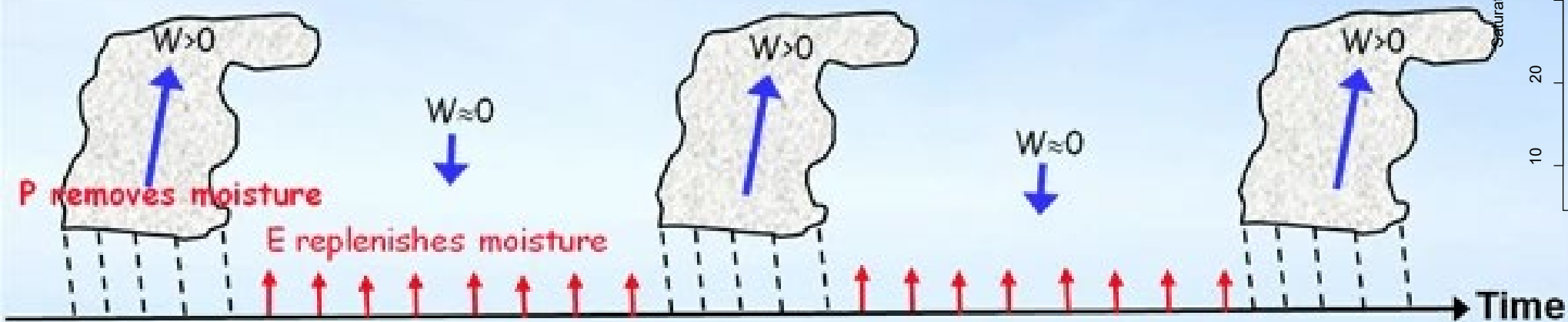
Hotter, drier growing season



Hotter temperatures

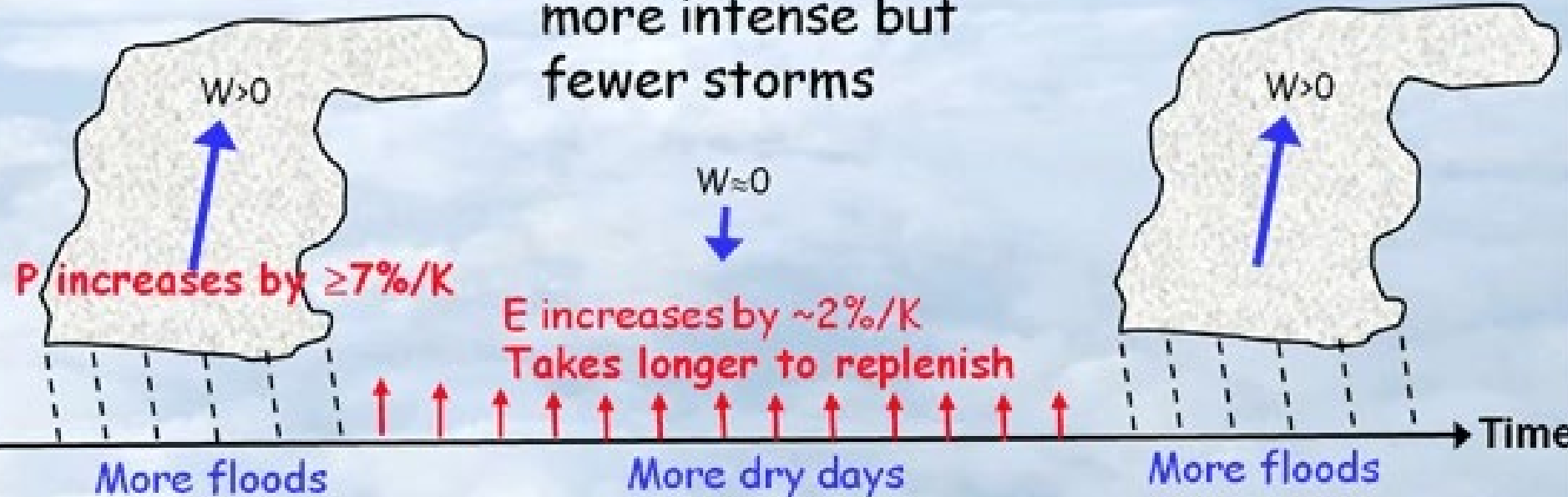


Current Climate

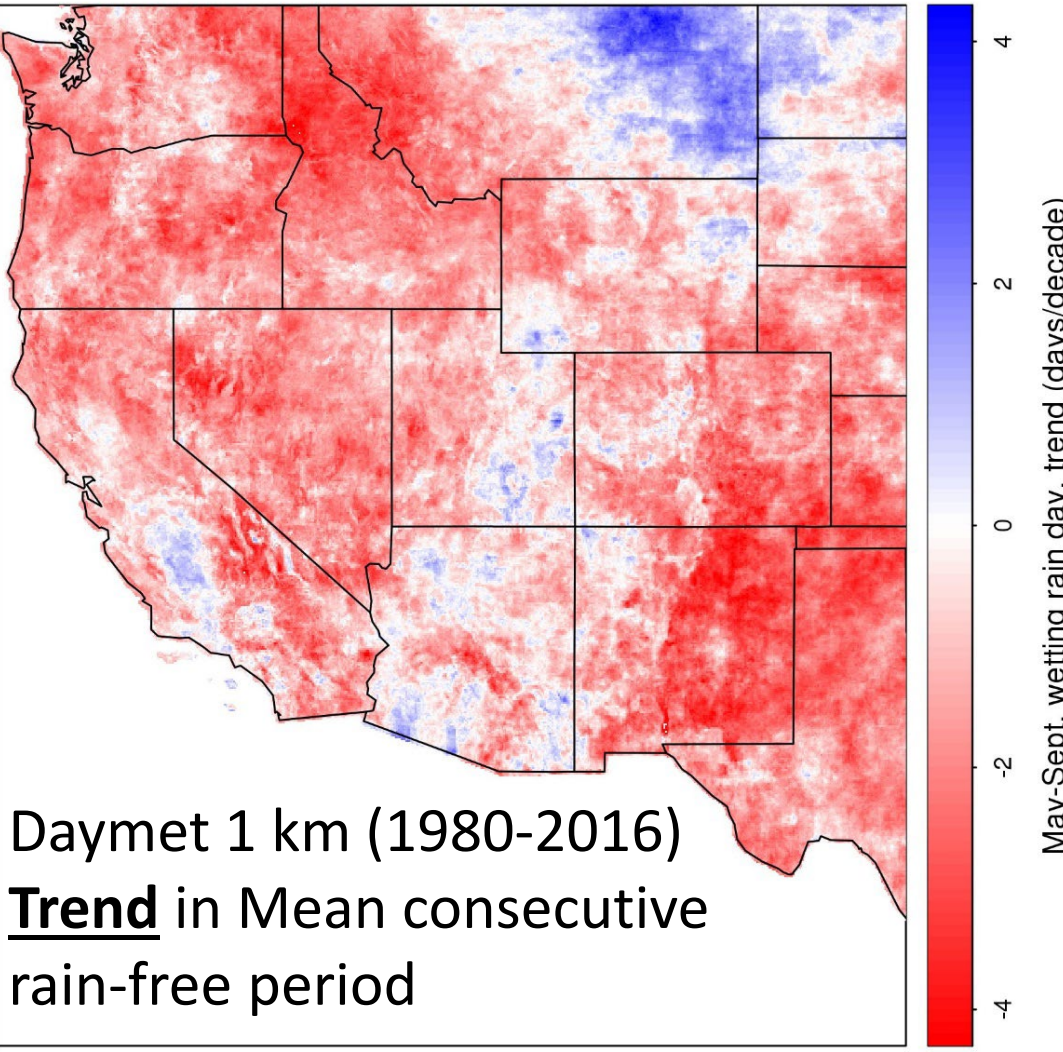


Future Climate

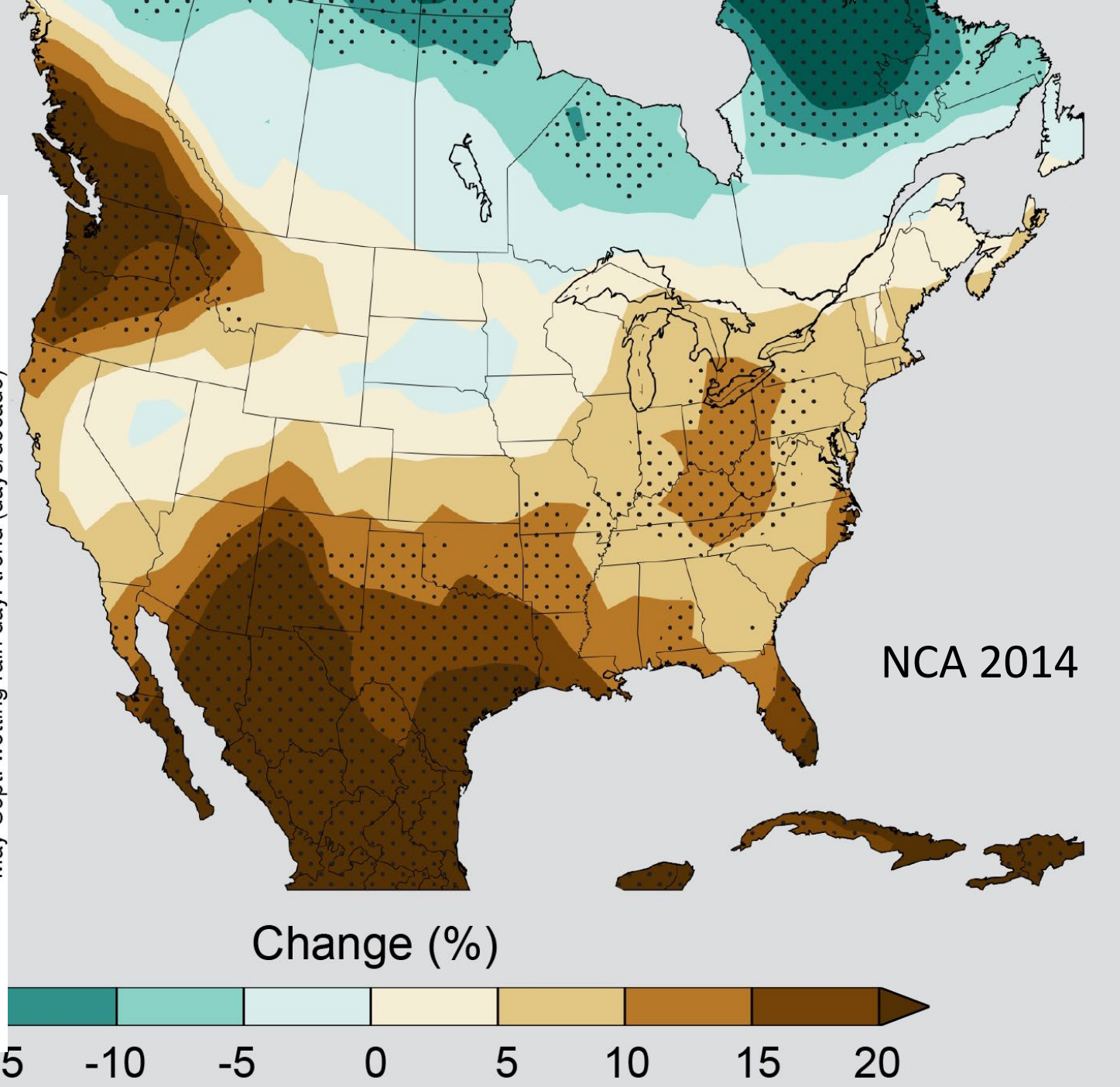
more intense but fewer storms



Change in Number of Consecutive Dry Days



Holden et al., 2018



Winter Processes I – Less Pptn as Snow



Warmer more variable
snowpack



Reduced Snow
Fraction

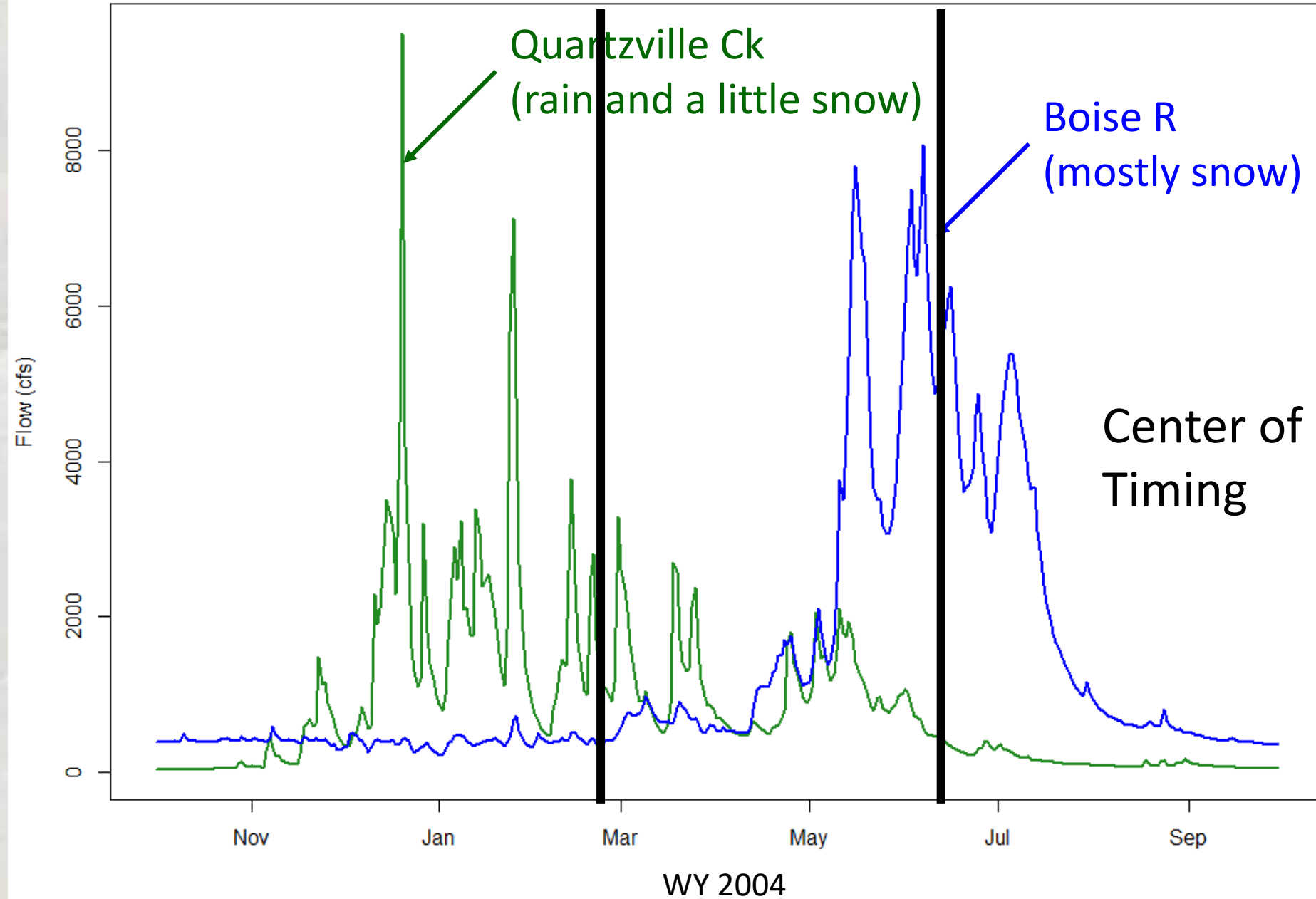


More extreme low
winter pptn.

Lower, less reliable, and less
predictable summer streamflow

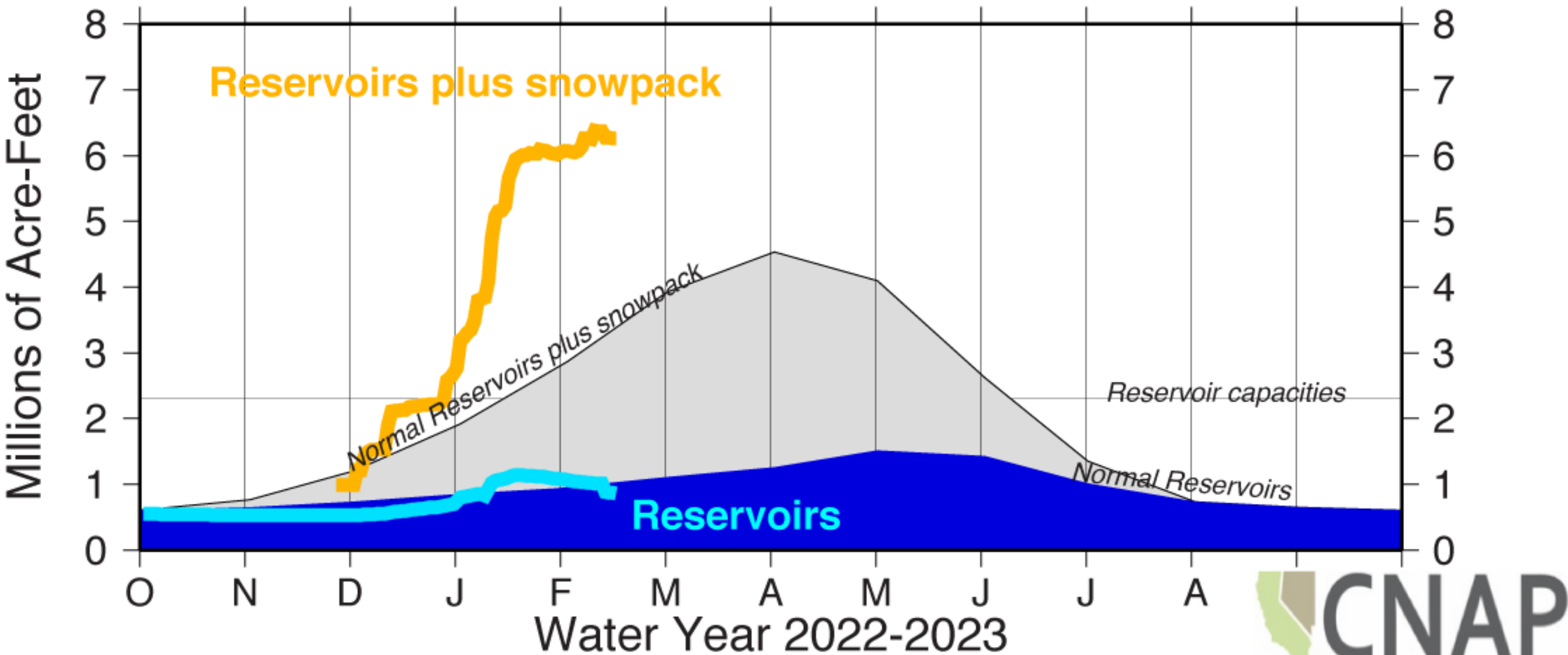


Contrasting Snowmelt Contributions



Southern Sierra reservoirs (5) plus southern snowpack

San Joaquin to Kern Rivers (w/shaded 2000-2015 normals)



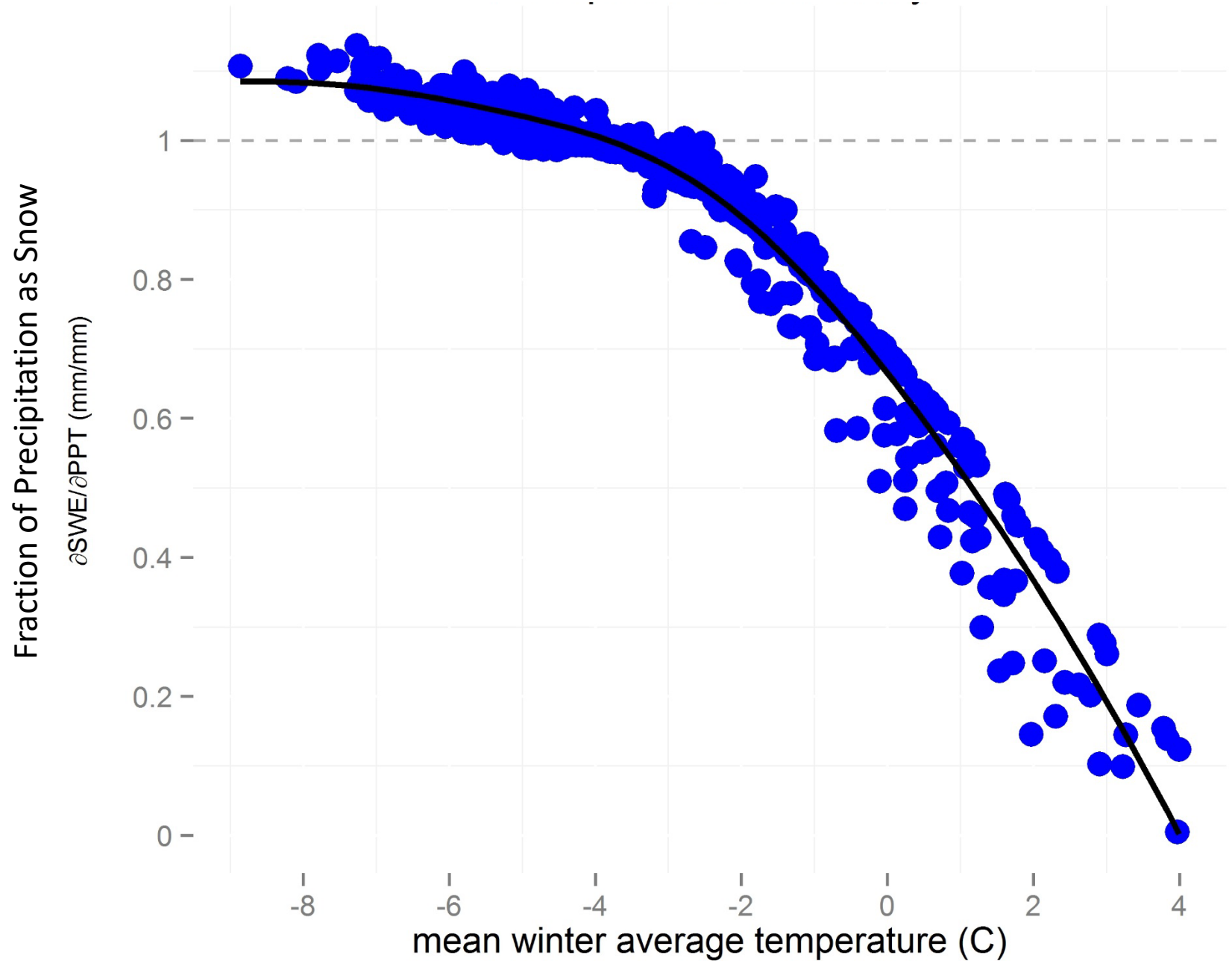
For info: mddettinger at gmail.com



California-Nevada Climate Applications Program
A NOAA RISA team

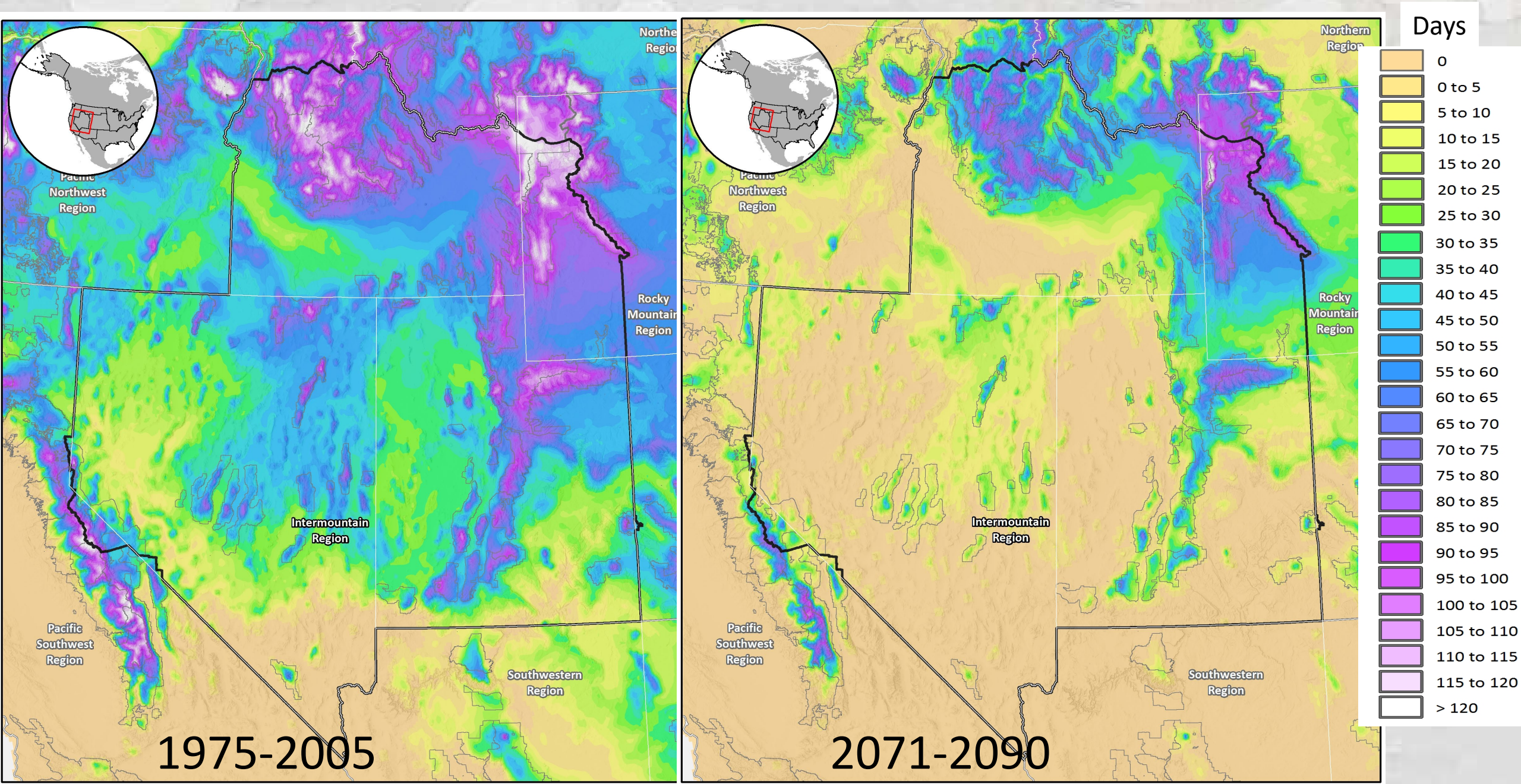
https://cnap.ucsd.edu/storage_in_sierra_ucrb/

Fraction of Winter Precipitation still Snow on Apr 1



Luce et al. 2014
Lute and Luce, 2017

Mean Snow Residence Time (average lifespan of a snowflake)



Winter Processes II – Drier Dry Years



Warmer more variable
snowpack



Reduced Snow
Fraction

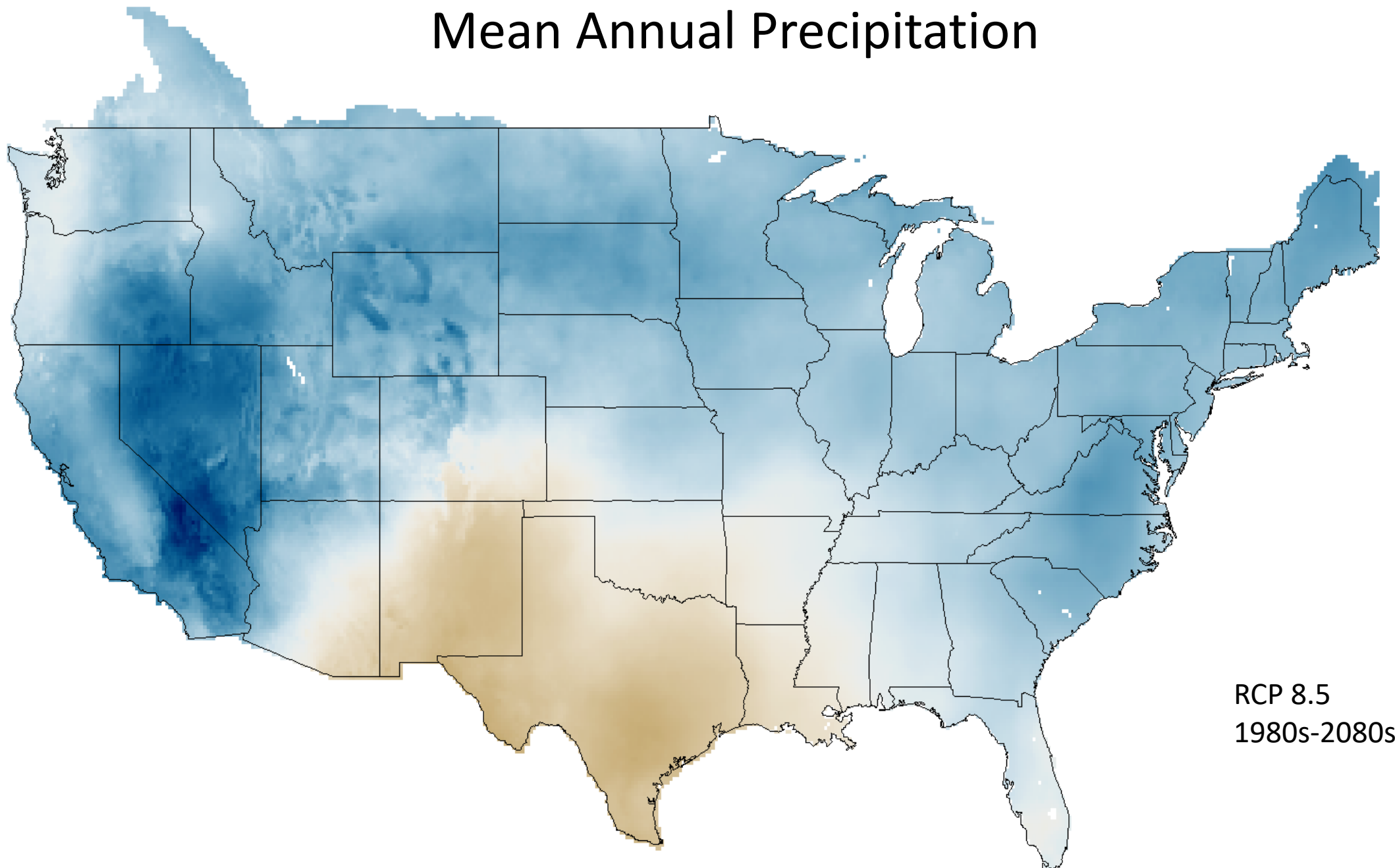


More extreme low
winter pptn.

Lower, less reliable, and less
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Mean Annual Precipitation



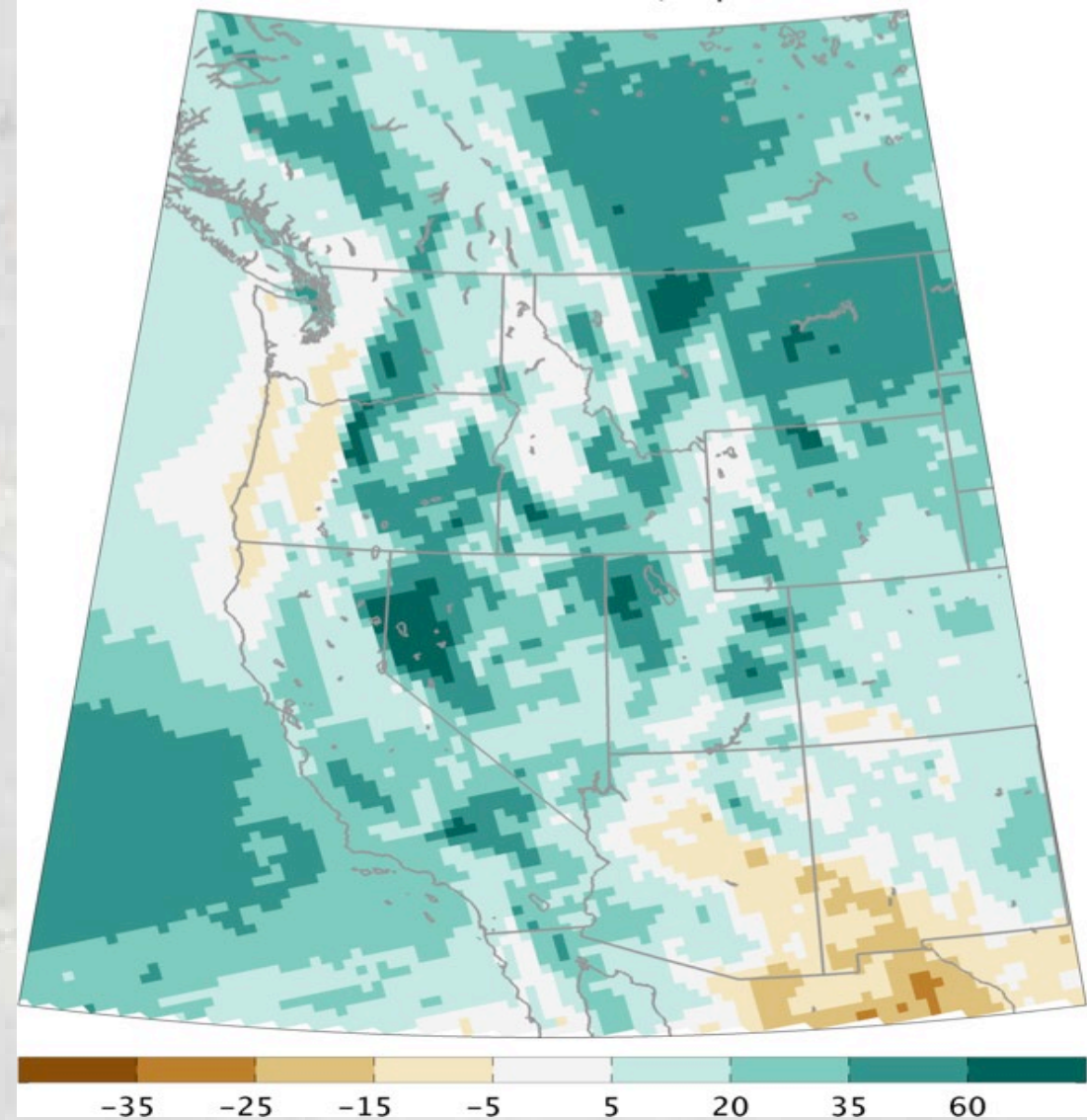
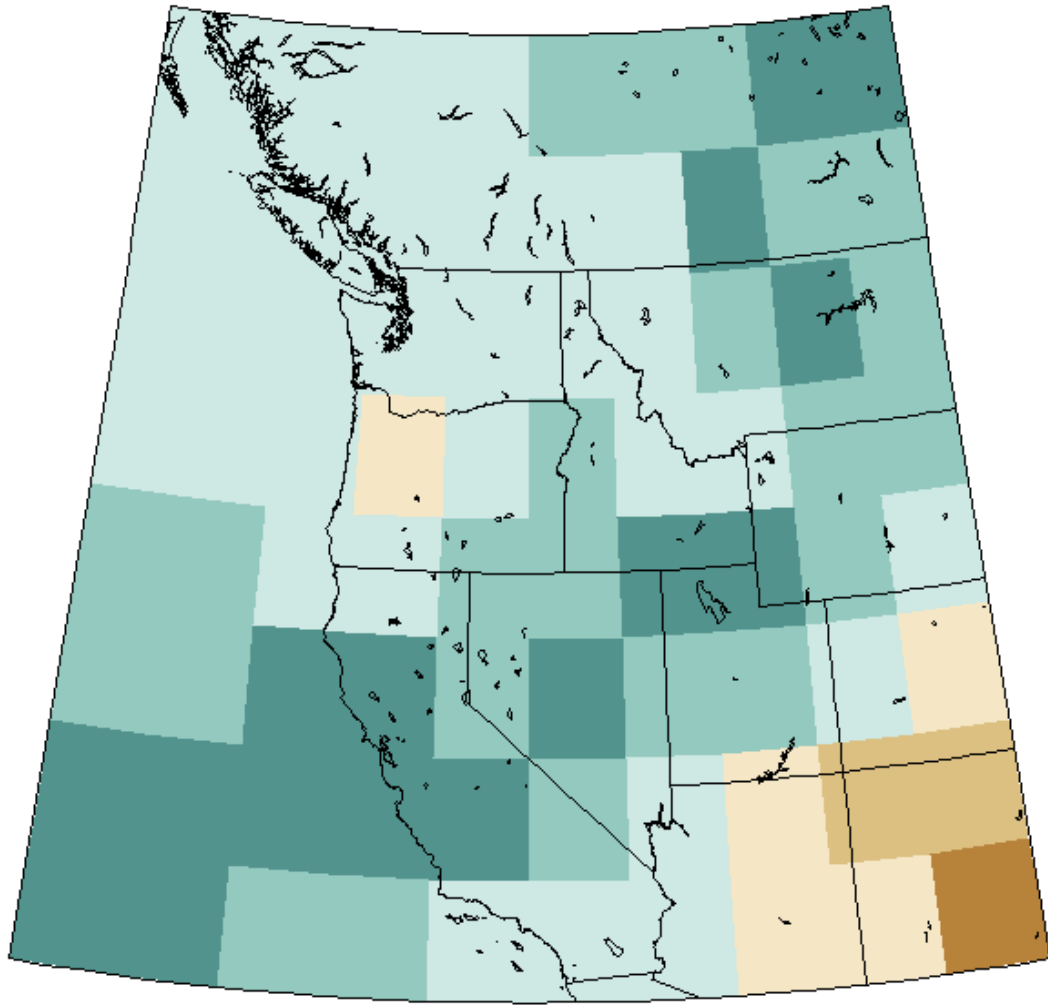
Data from Reclamation, 2014. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections

CanESM2 Oct-Mar Precipitation Change – Wet Model

2041-2070 vs 1971-2000

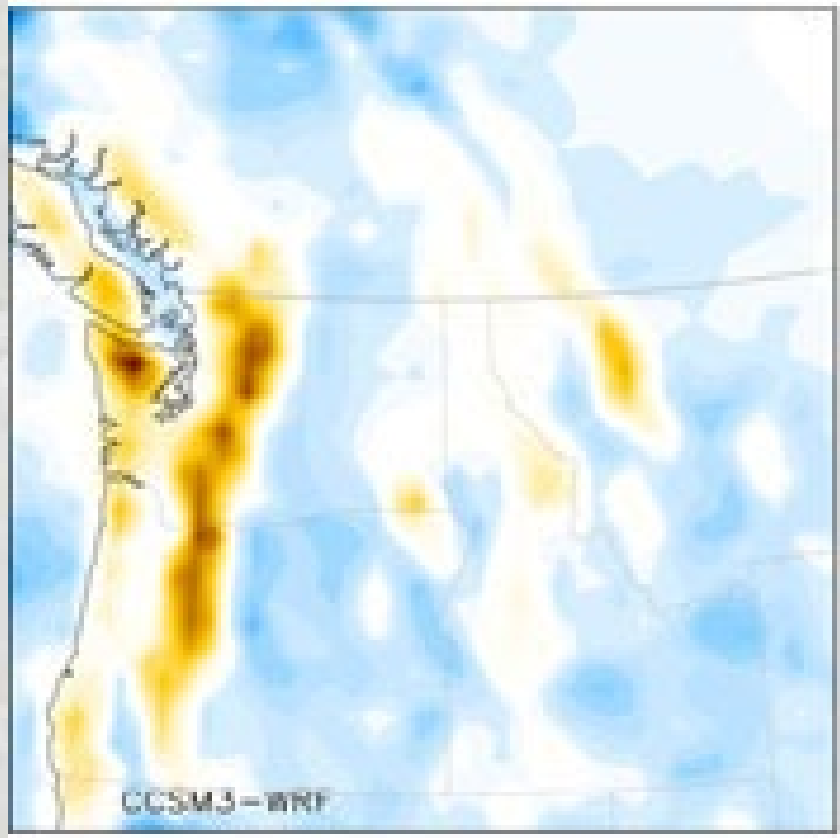
General Circulation Model

Regional Climate Model

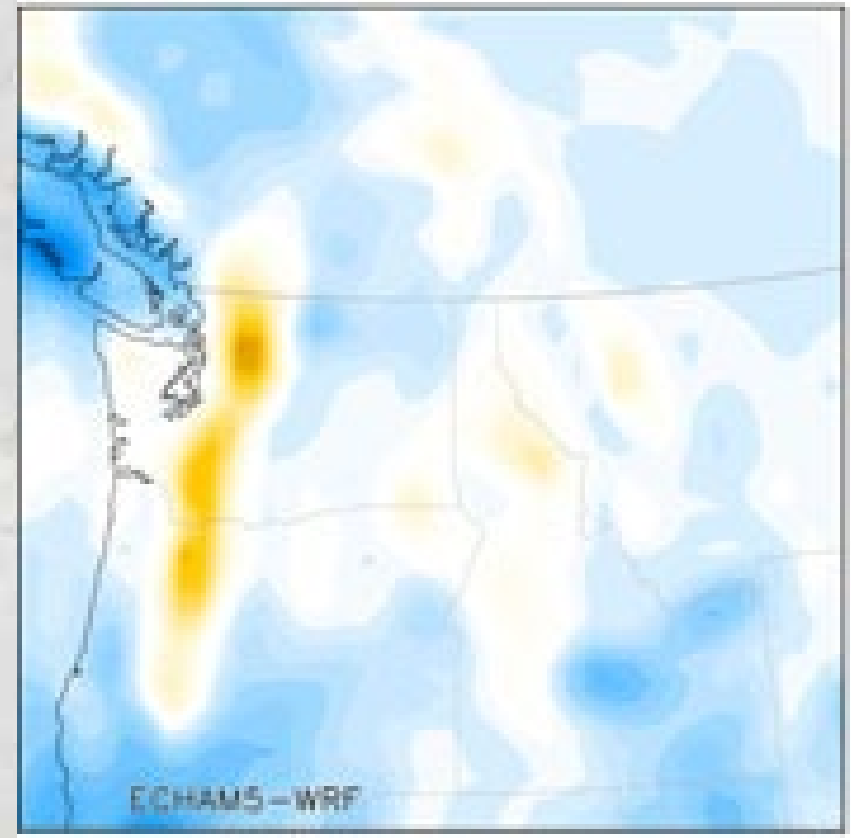


Regional Climate Model Results

DJF Precipitation

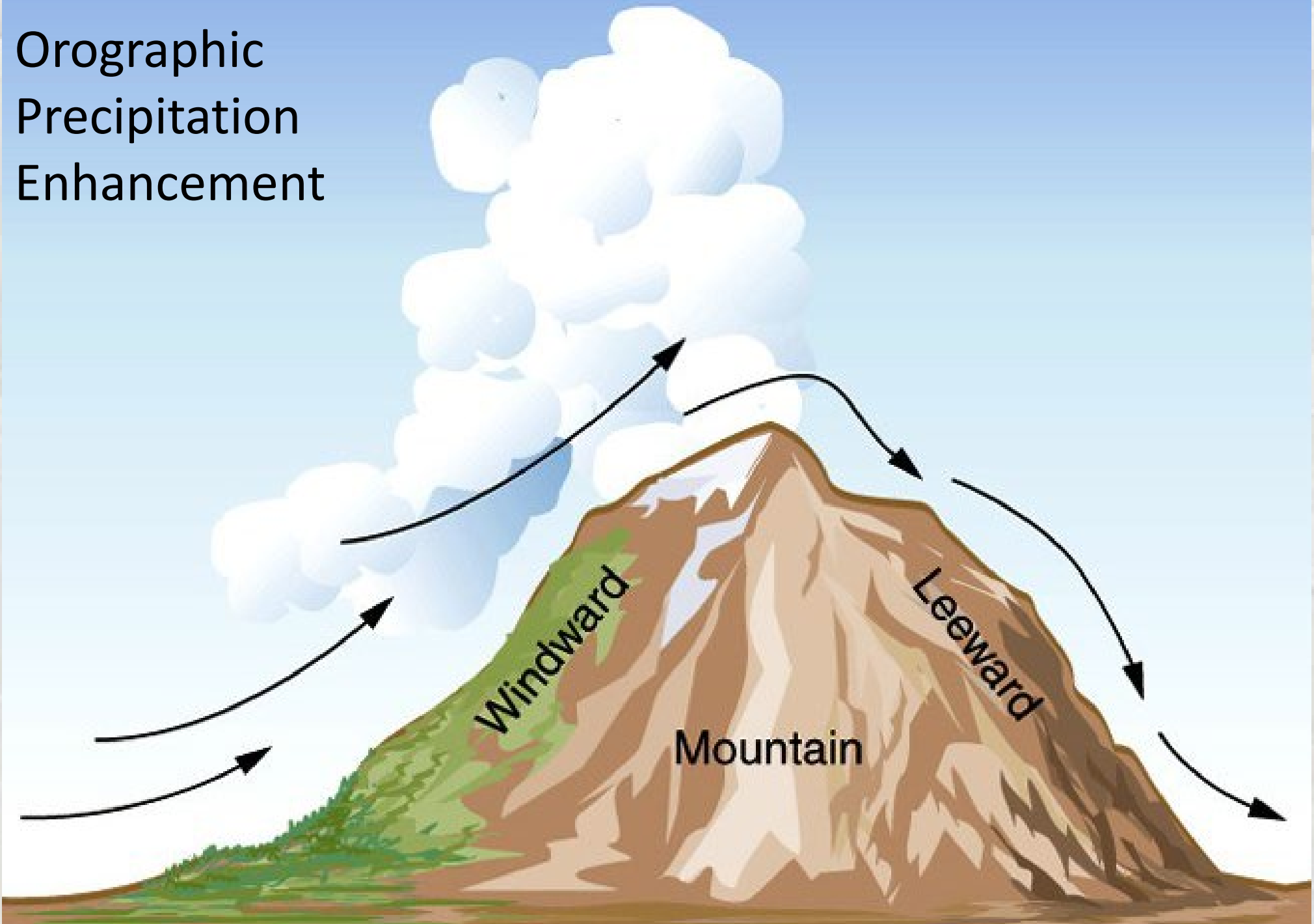


CCSM3 & WRF



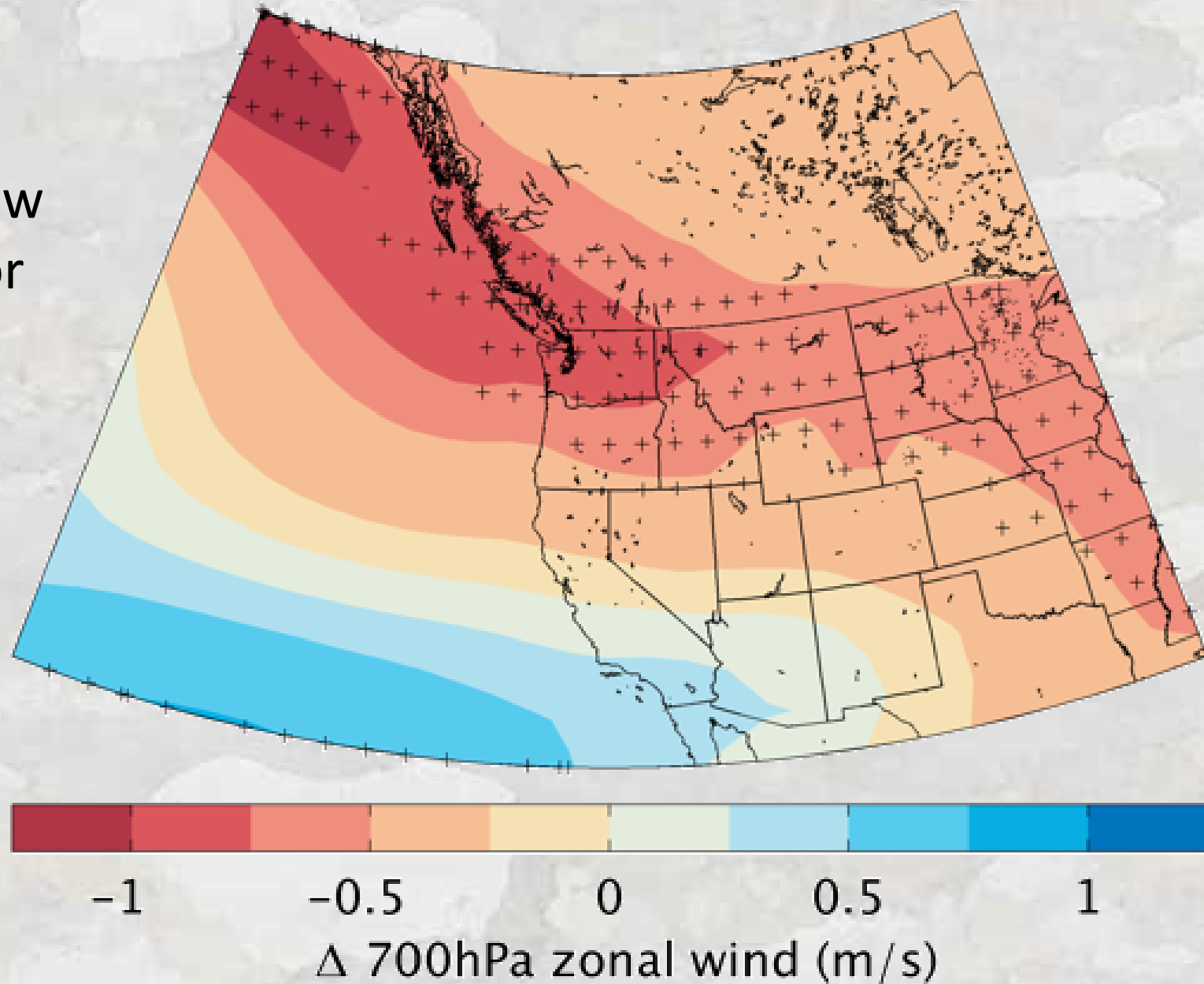
ECHAM5 & WRF

Orographic Precipitation Enhancement

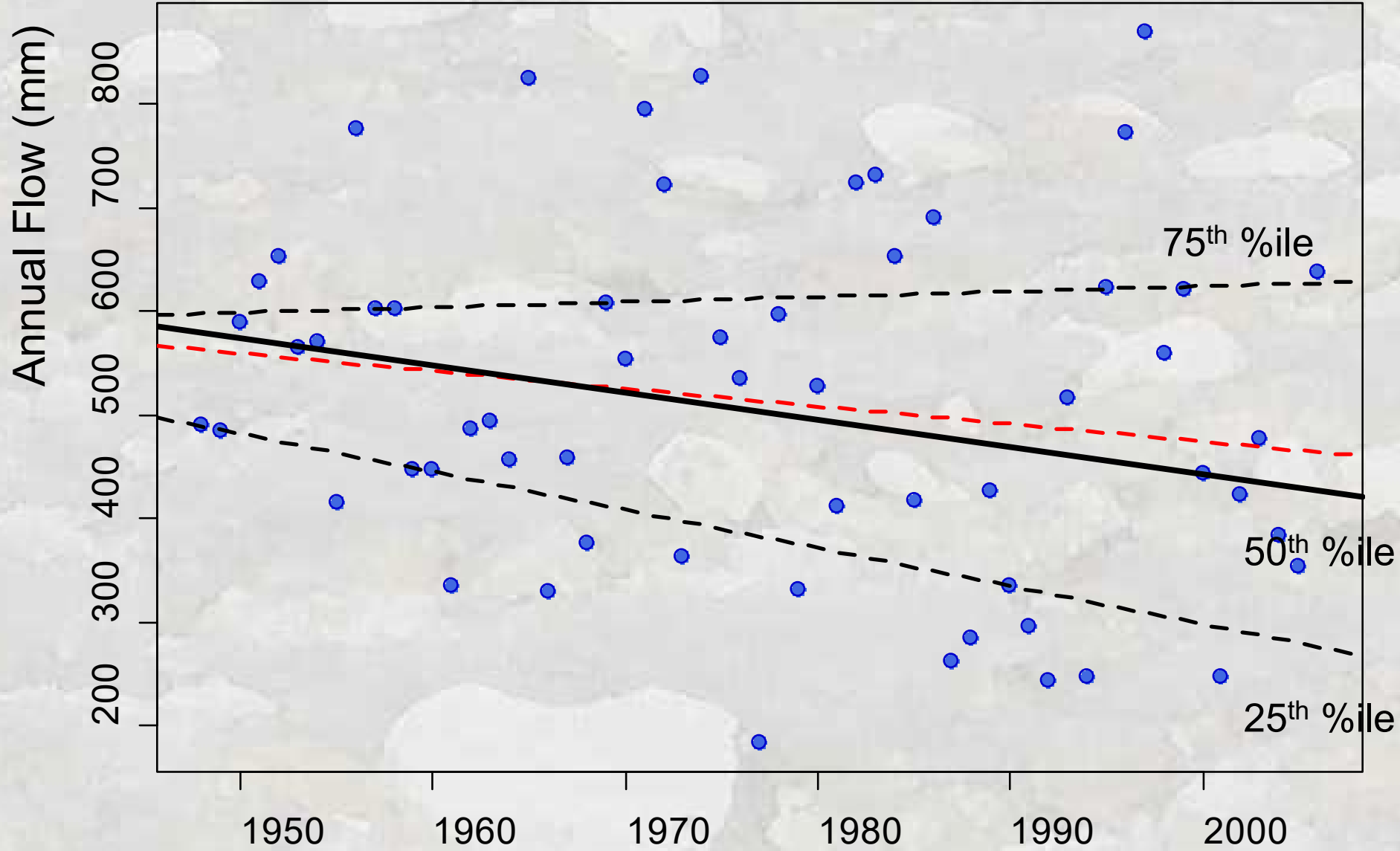


Projected Future Westerly Wind Changes – from GCMs

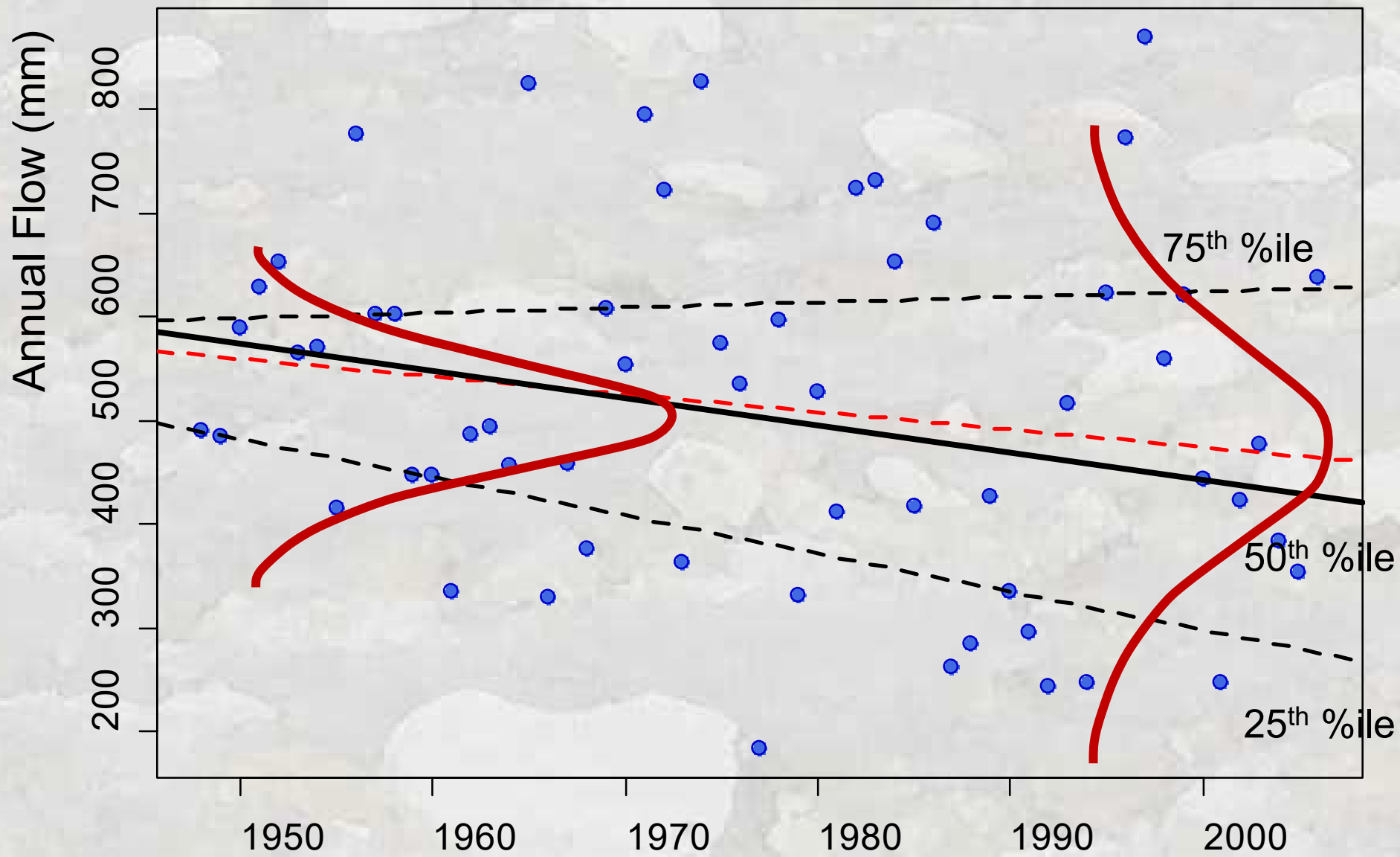
20 of 24
models show
a decline for
the region
studied!

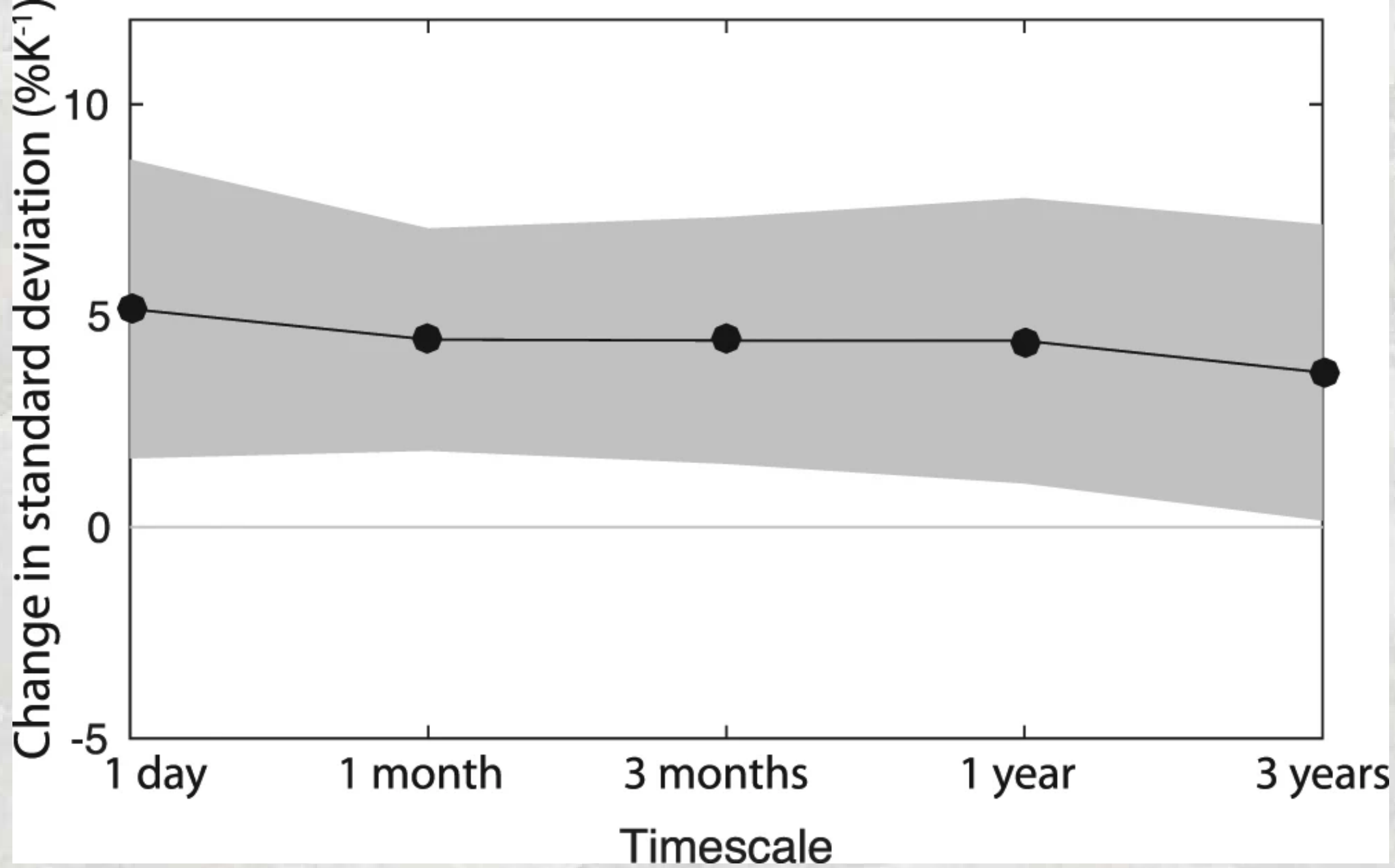


Middle Fork Boise – Trend in Water Yield



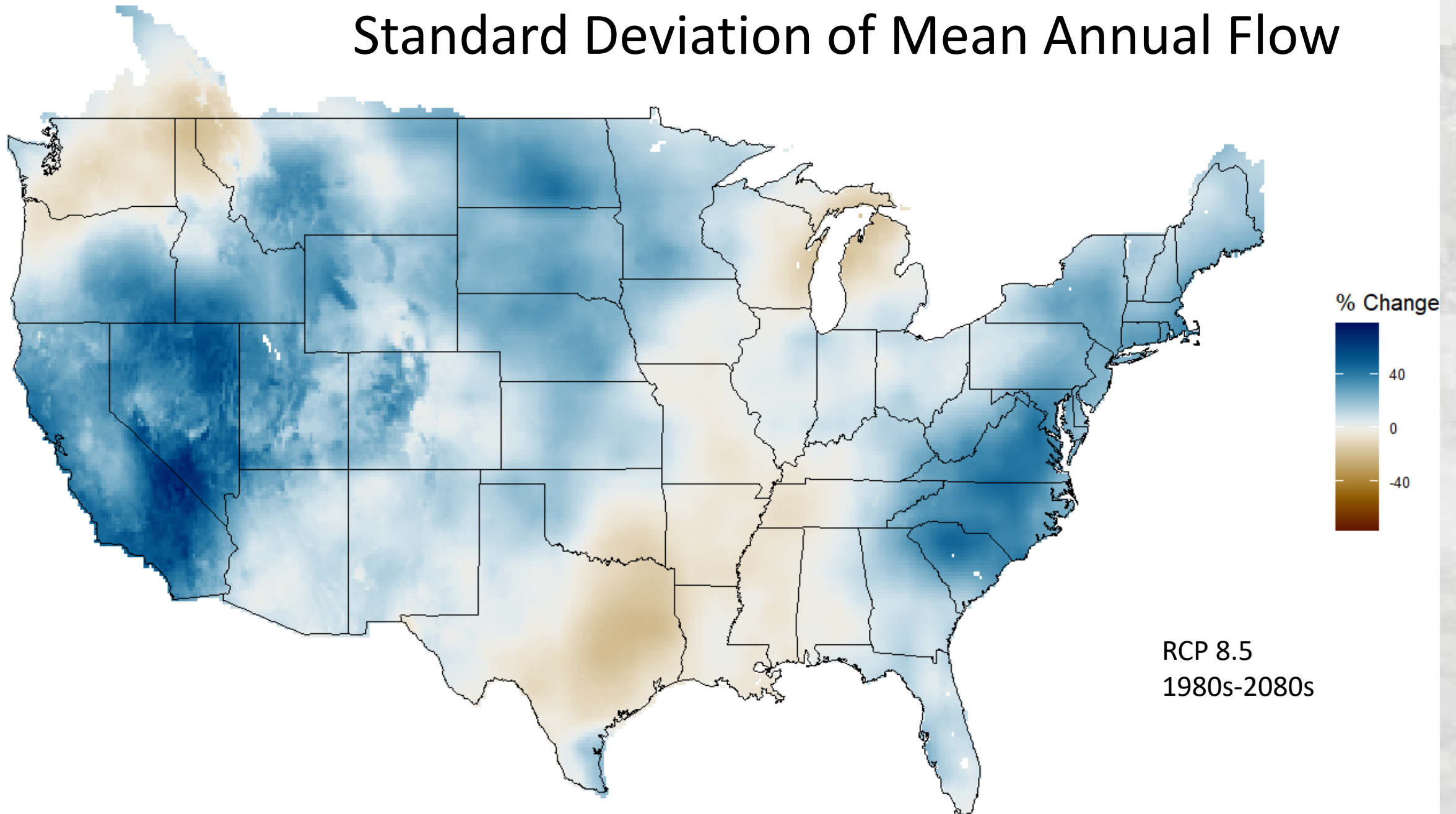
Middle Fork Boise – Trend in Water Yield





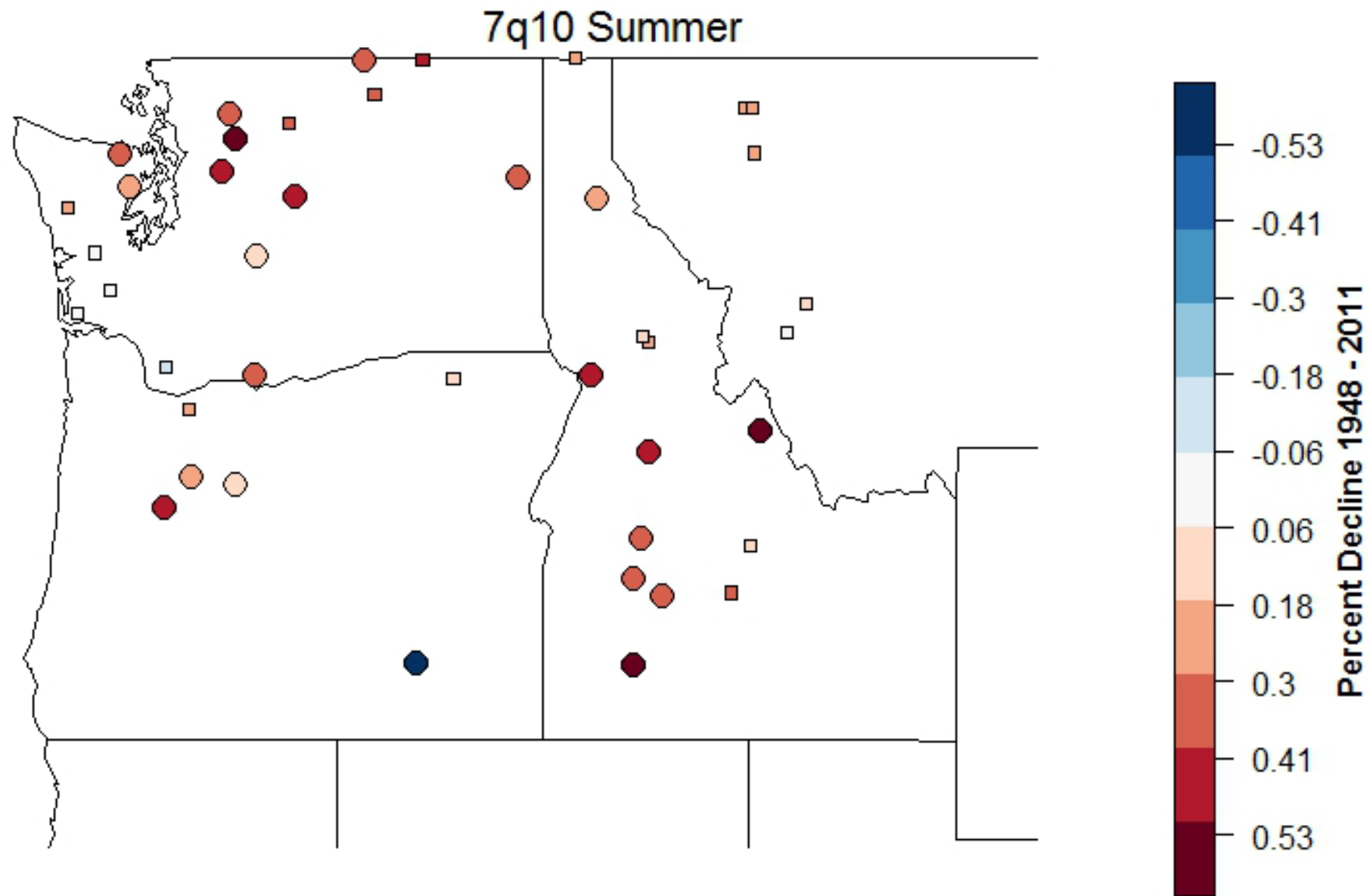
Pendergrass et al. 2017

Standard Deviation of Mean Annual Flow



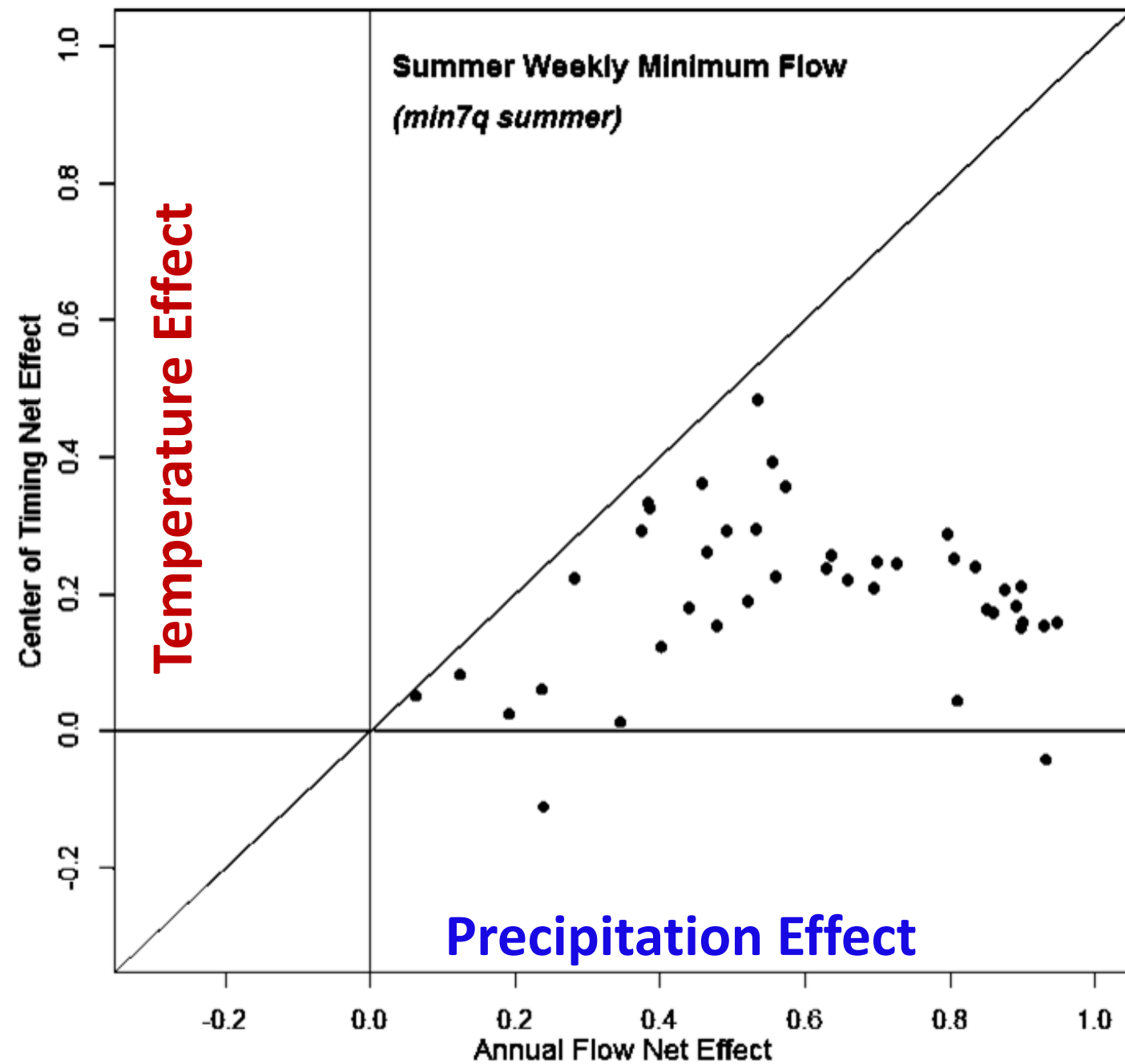
Data from Reclamation, 2014. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections

Historical Trend: Low Flows - Hydrologic Drought



Kormos et al., 2016

Low
Flow
Sensitivity

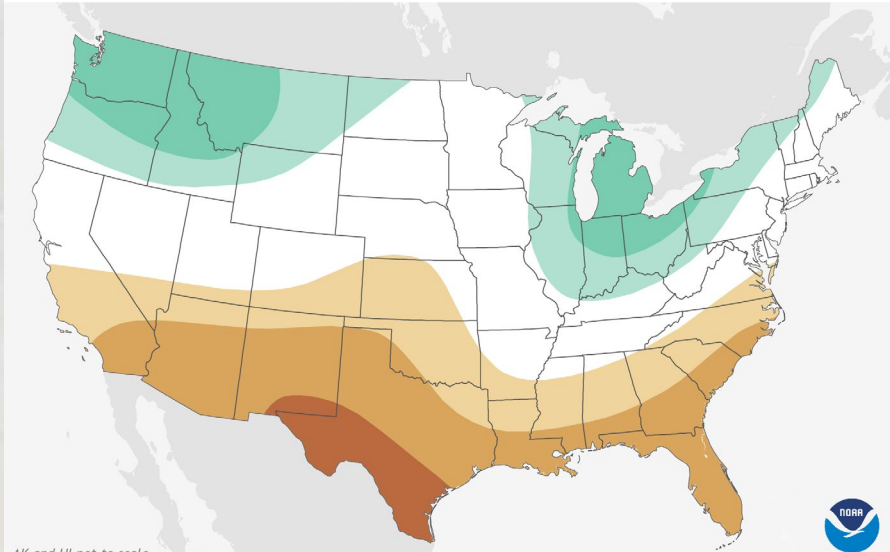


Kormos et al., 2016

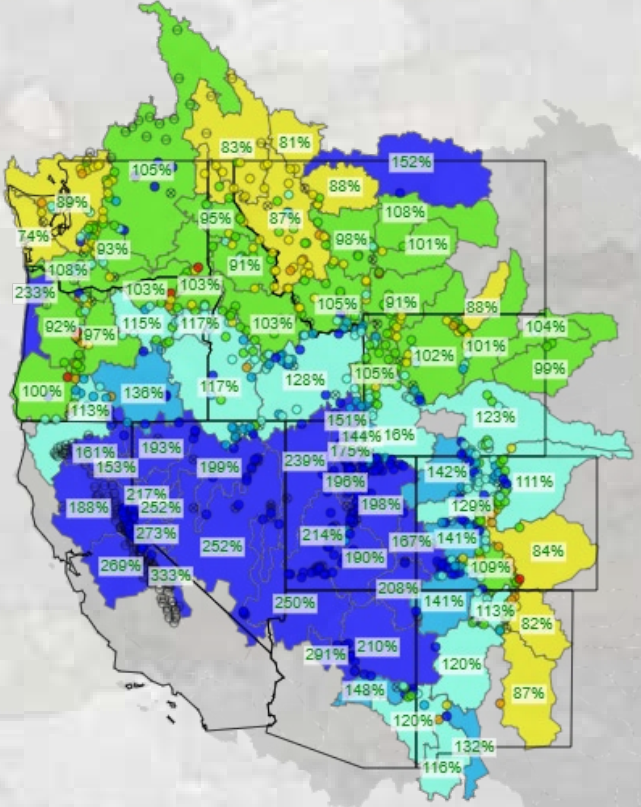
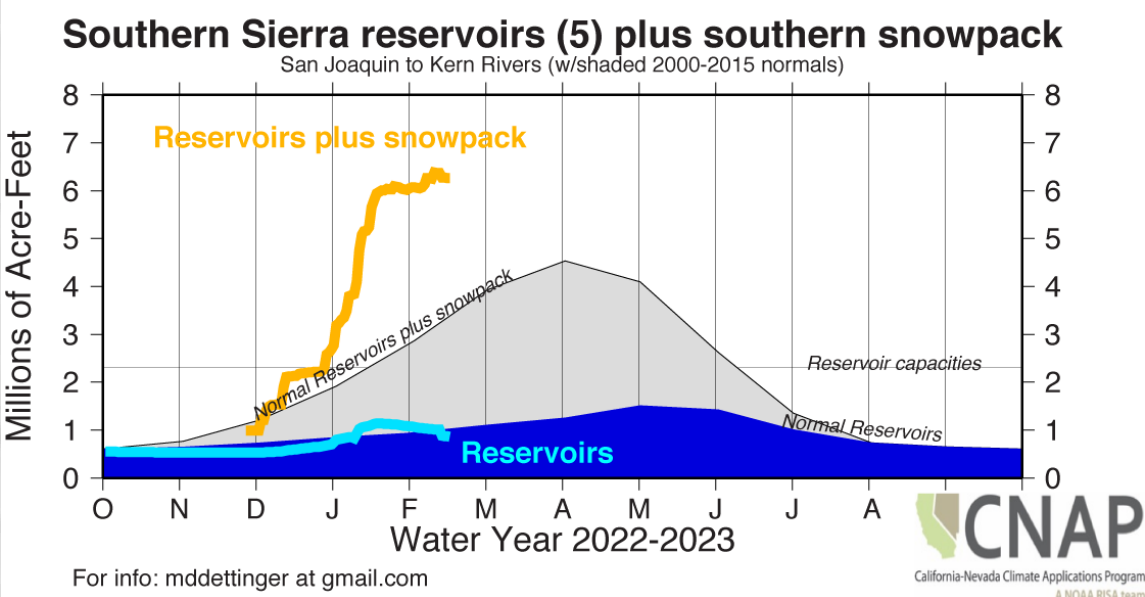
Losing Knowledge, Losing Predictability



Winter 2022-23: U.S. Precipitation Outlook



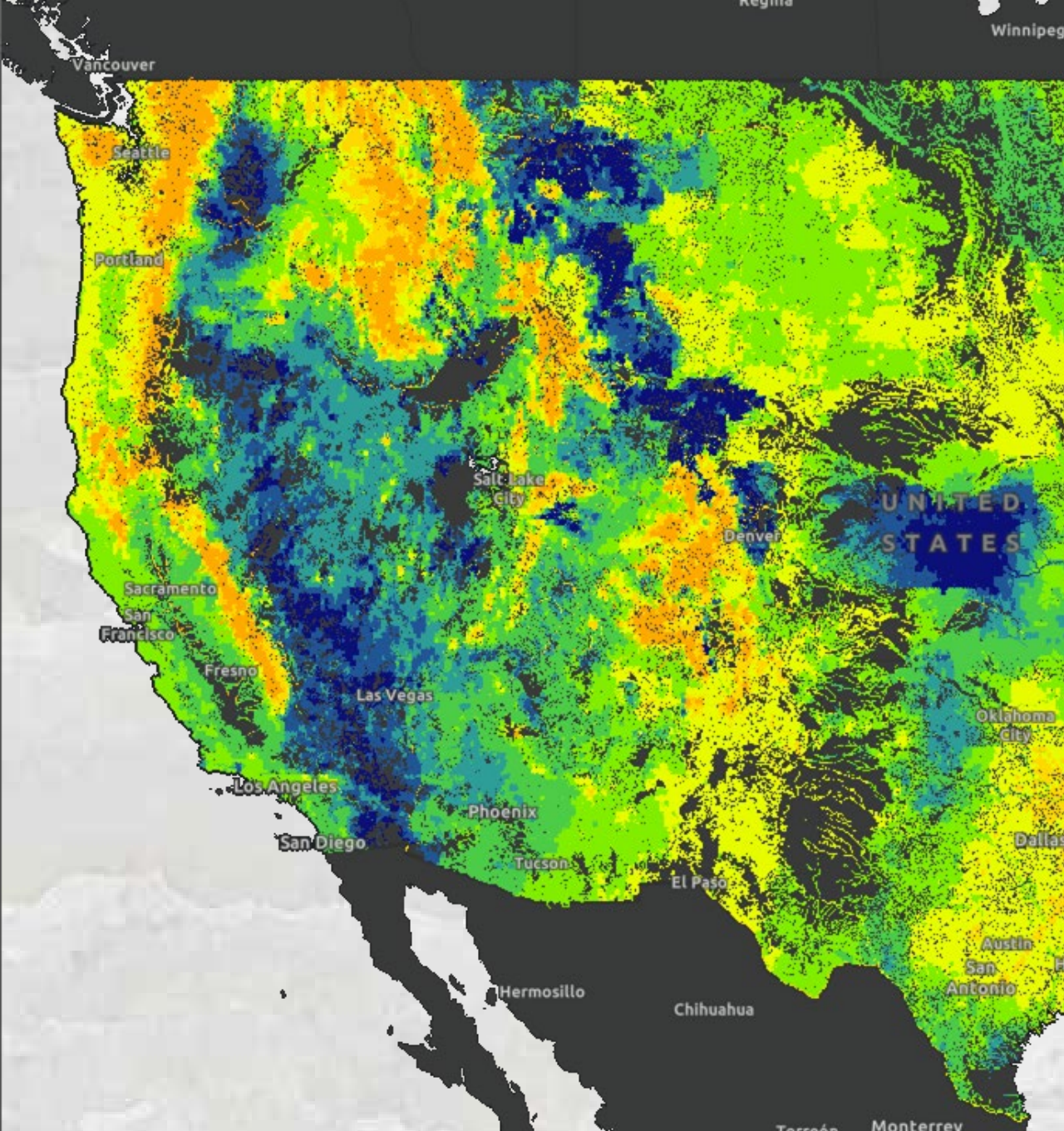
AK and HI not to scale



NRCS

Streamflow

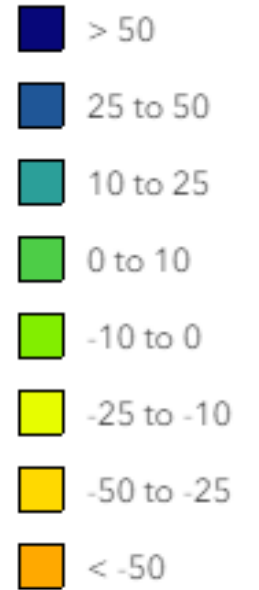




Mean Summer Flow

RCP 8.5
1980s-2080s

Percent Change



https://bit.ly/USFS_StreamflowMetrics



Data from Reclamation, 2014. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections

Sacramento

Feather

Yuba

American

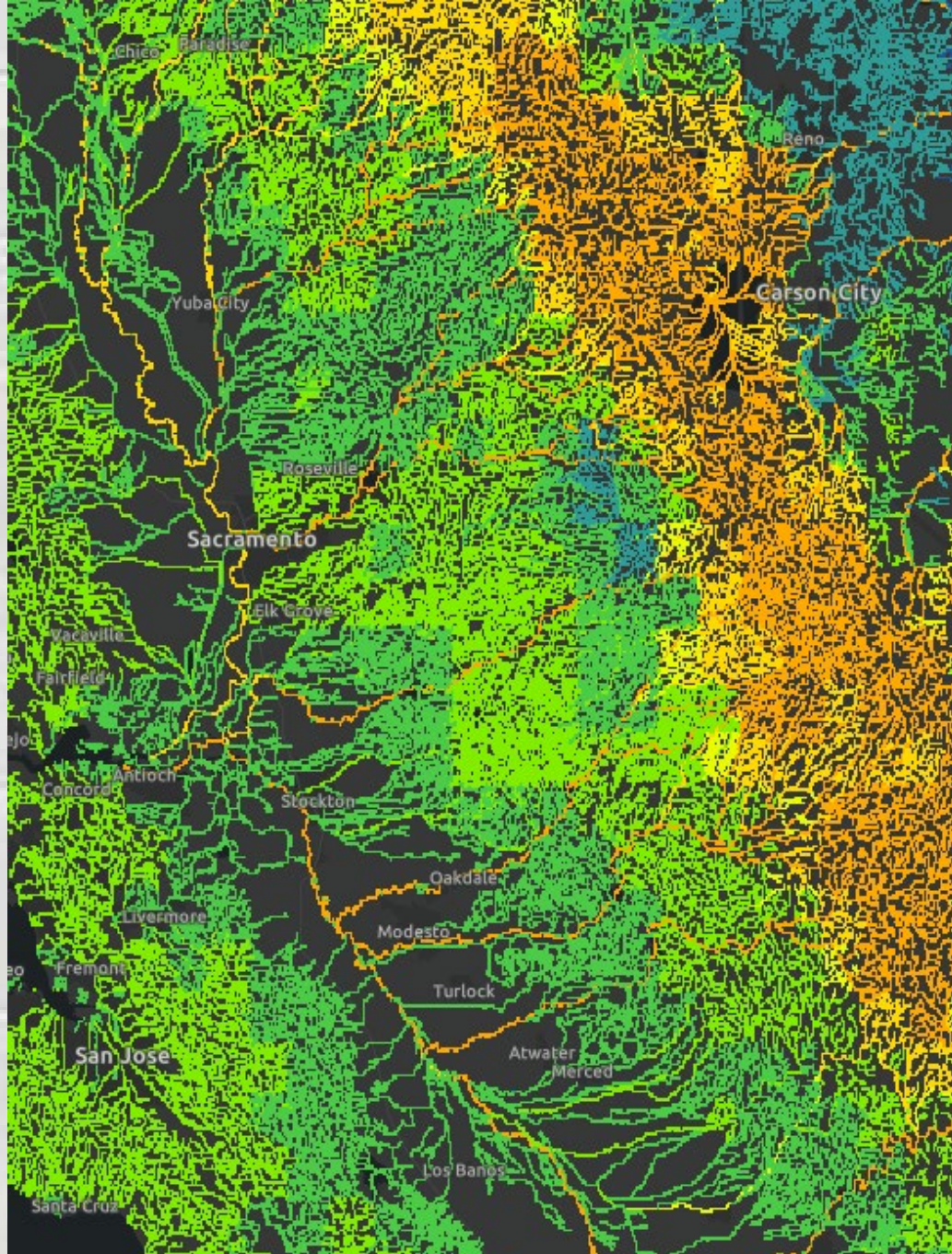
Mokelumne

Stanislaus

Tuolumne

Merced

San Juaqin



Truckee

Carson

Walker

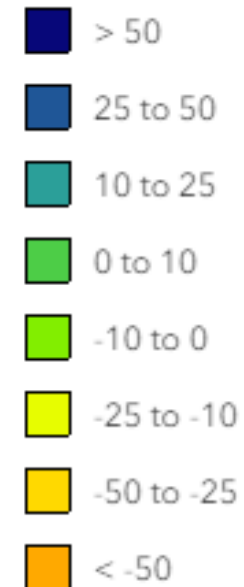
Mean Summer Flow

RCP 8.5

1980s-2080s

Sierra Nevada
and Central Valley

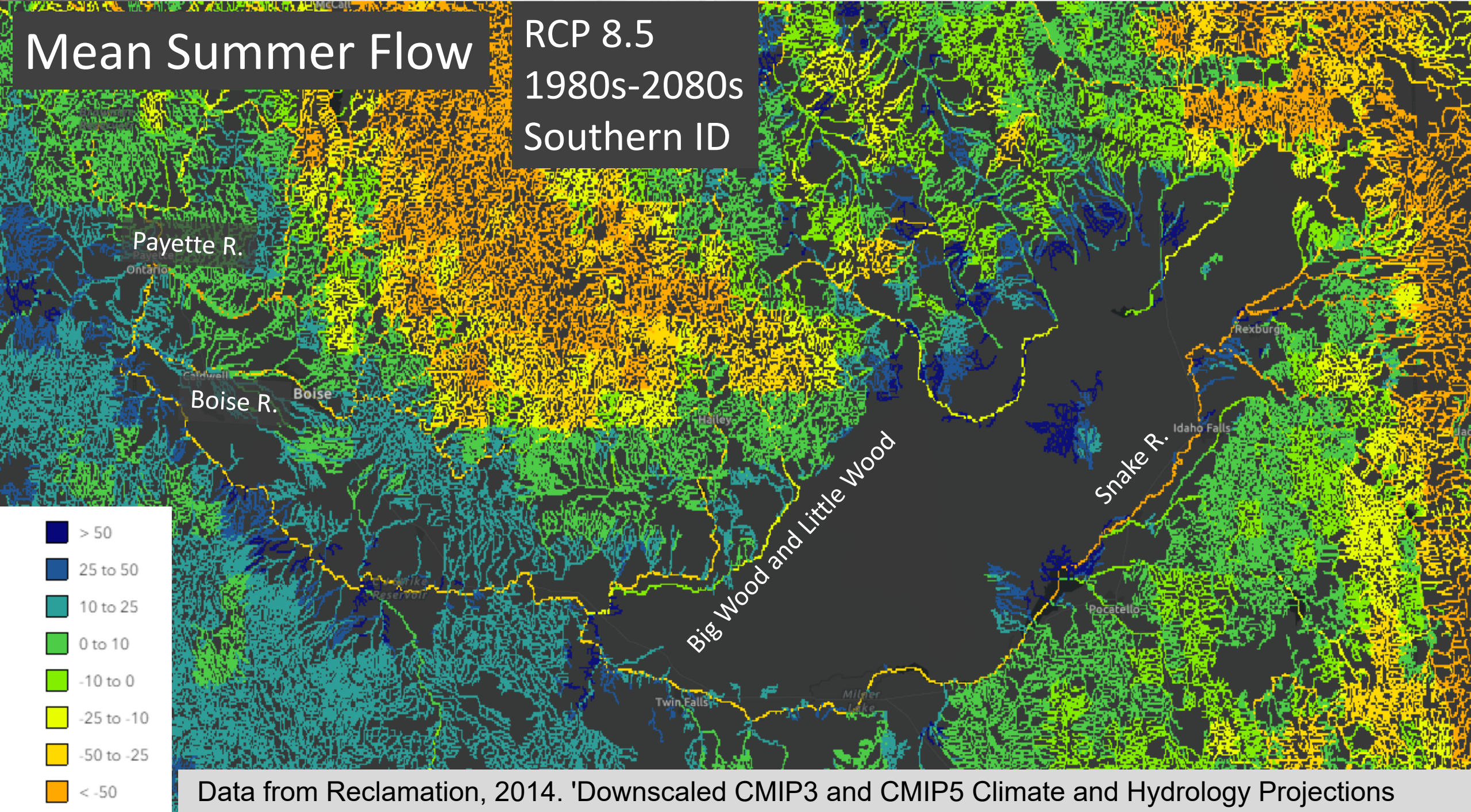
Percent Change



Data from Reclamation, 2014. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections

Mean Summer Flow

RCP 8.5
1980s-2080s
Southern ID



Data from Reclamation, 2014. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections

Mean Summer Flow

Platte R.

RCP 8.5
1980s-2080s

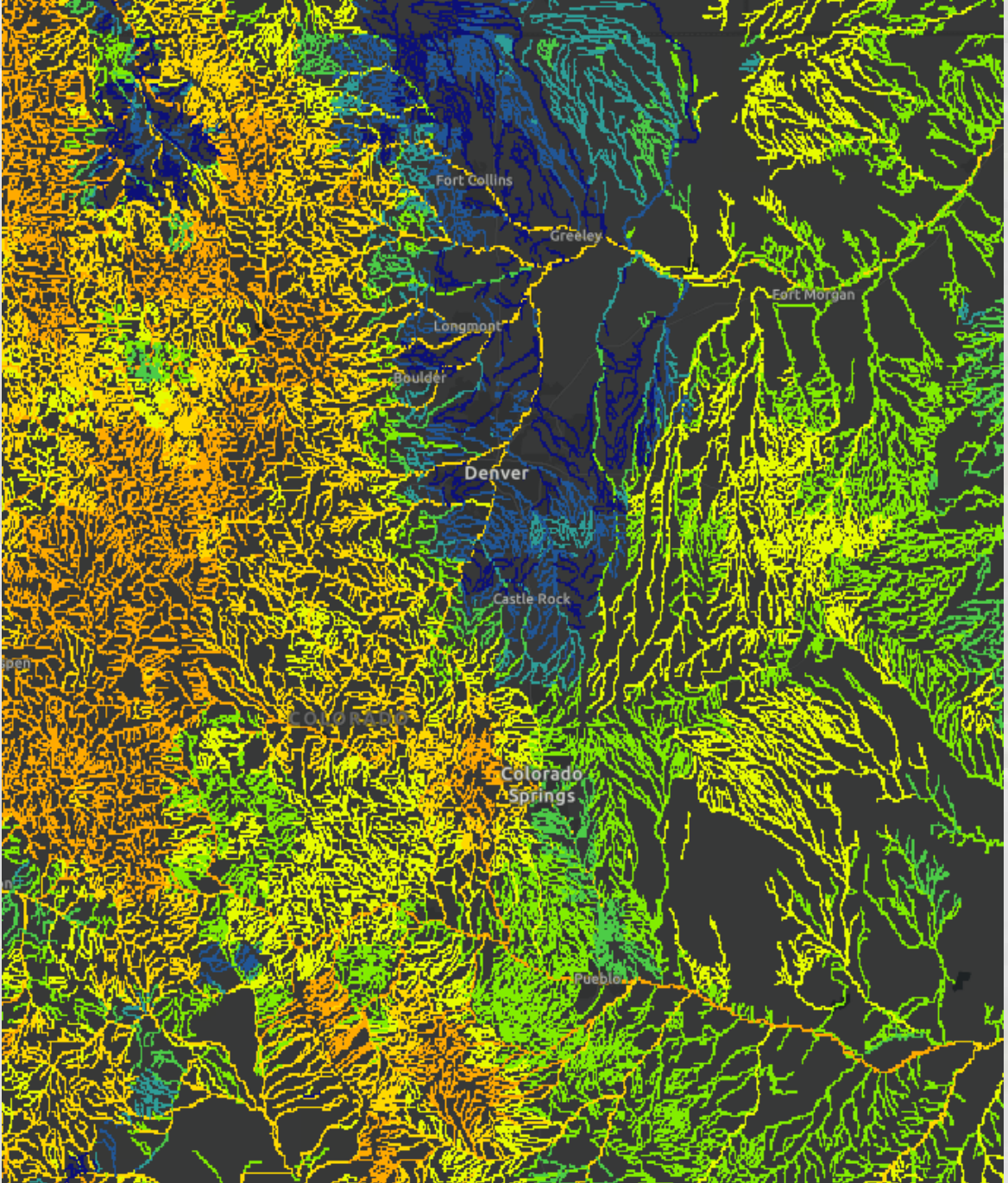
Colorado Rockies

Percent Change



Arkansas R.

Colorado R.



Data from Reclamation, 2014. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections



Adaptation Options



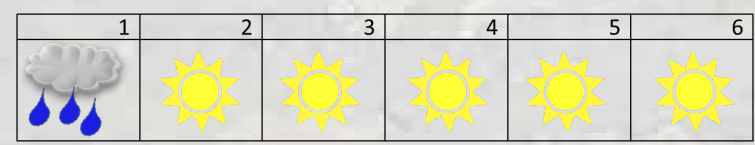
Reservoirs

Managed Aquifer
Recharge

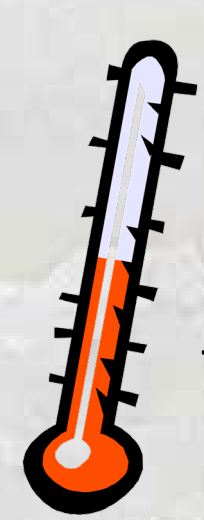


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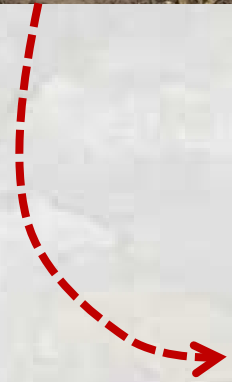
More consecutive dry days



Hotter, drier growing season



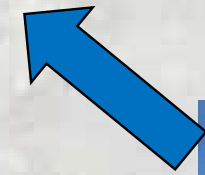
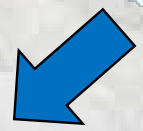
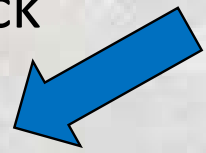
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