

Brief Overview of Arizona Climate

Planning for Local Government Climate Challenges:
Connecting Research and Practice Workshop

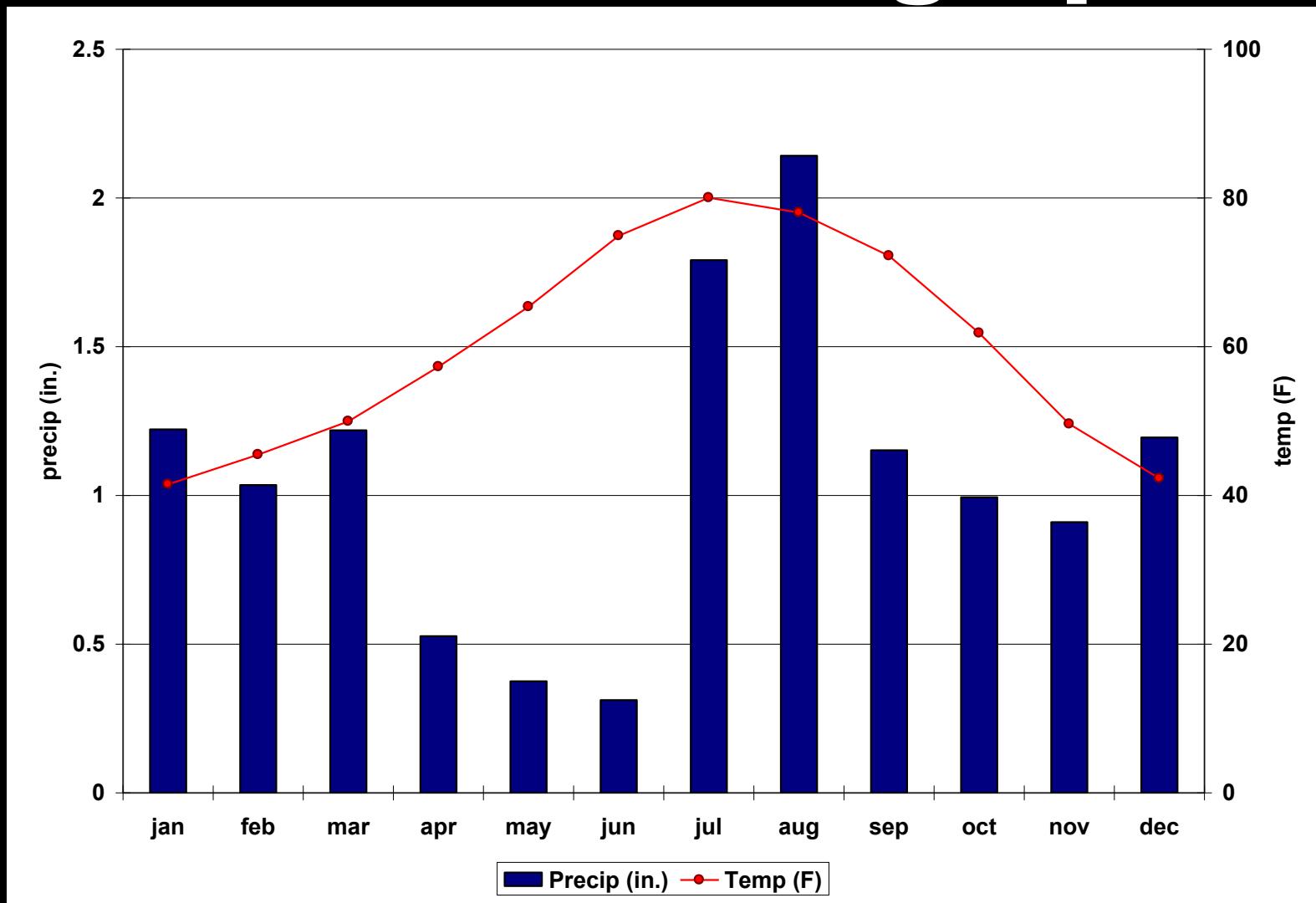
18 October 2012 – Tempe, AZ, USA

Gregg Garfin, The University of Arizona



- AZ climate basics
- Observations
- Projections

Arizona Climograph



Mean Monthly Precipitation
(inches)

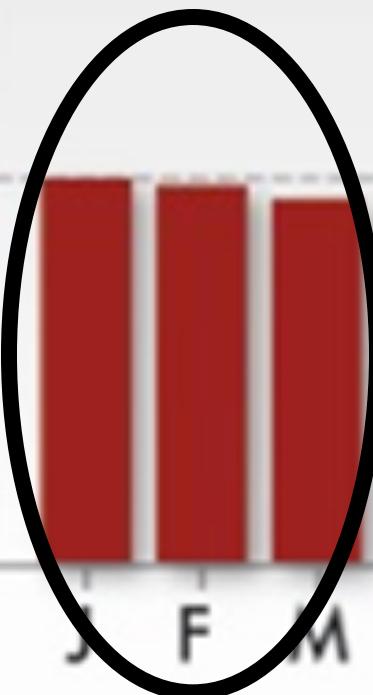
2

1

0

J F M A M J J A S O N D

Month

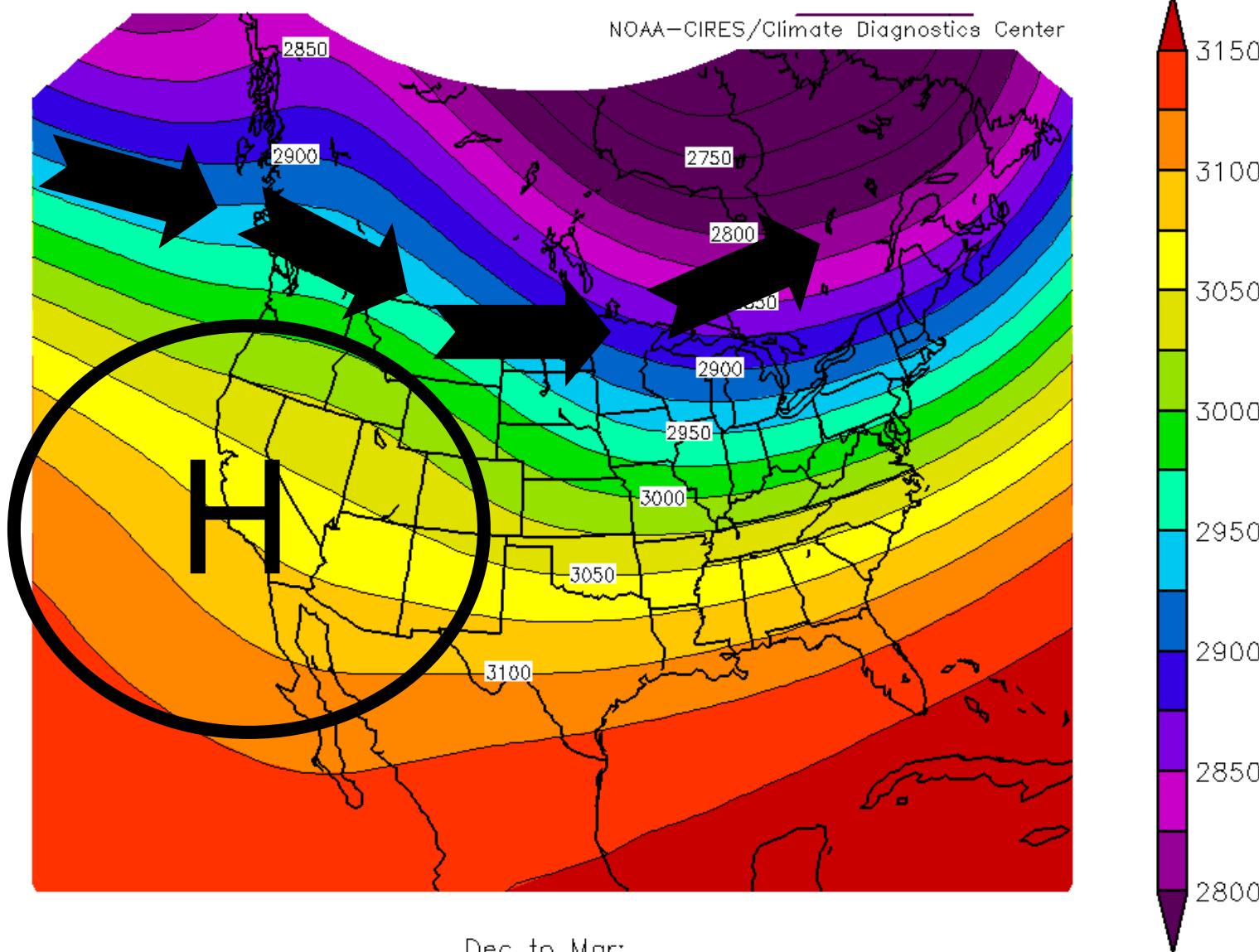


Winter

NCEP/NCAR Reanalysis

700mb Geopotential Height (m) Climatology 1968–1996

NOAA-CIRES/Climate Diagnostics Center







Mean Monthly Precipitation
(inches)

2

1

0

J

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A

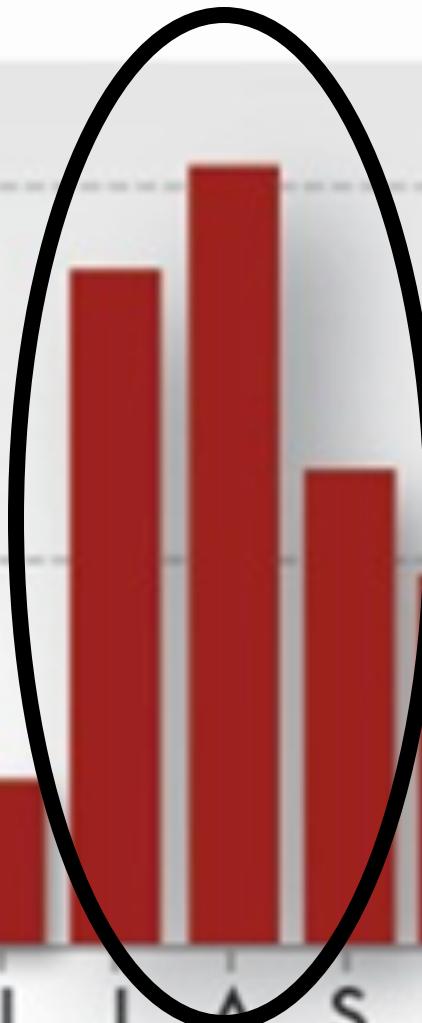
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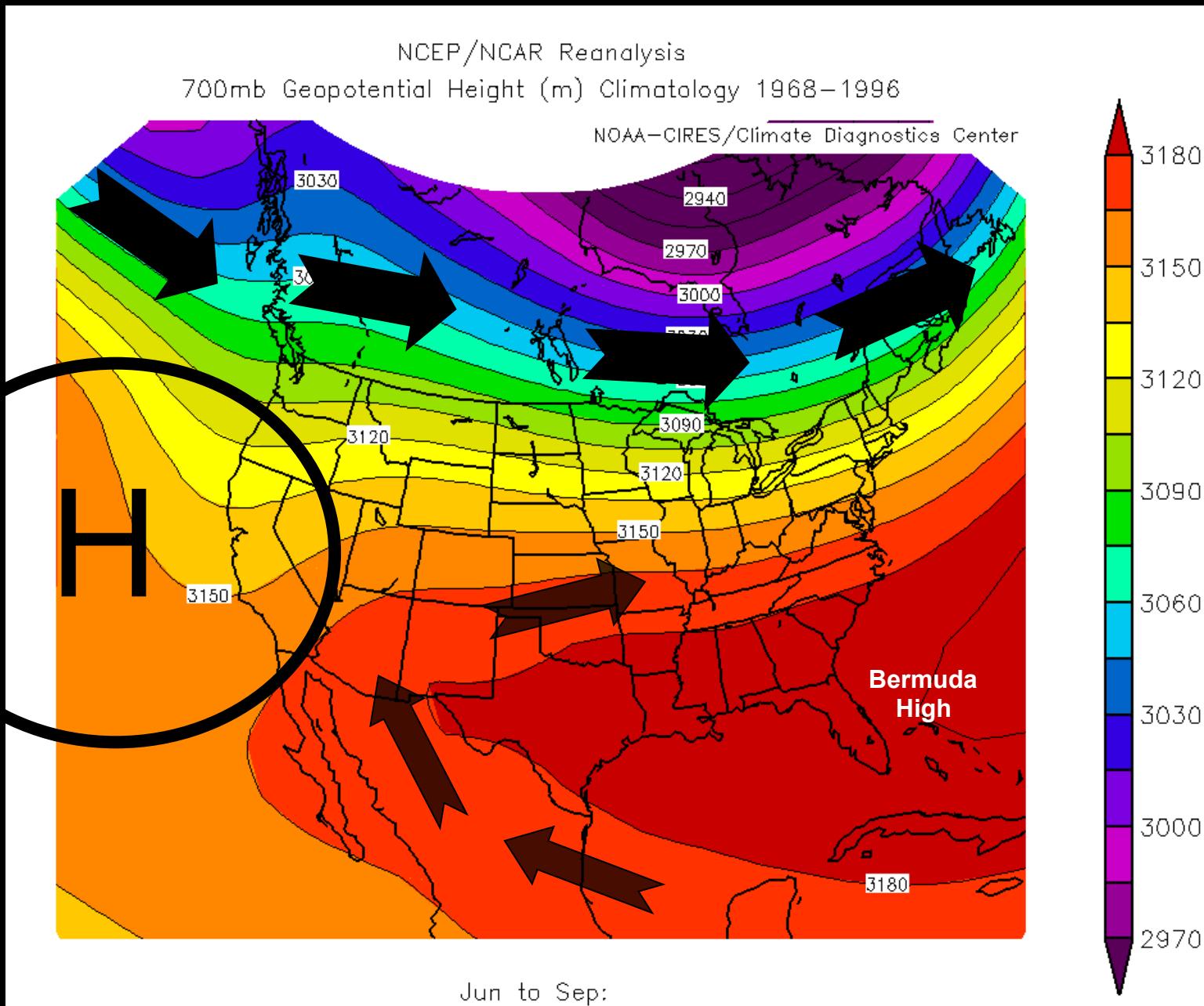
N

D

Month



Summer





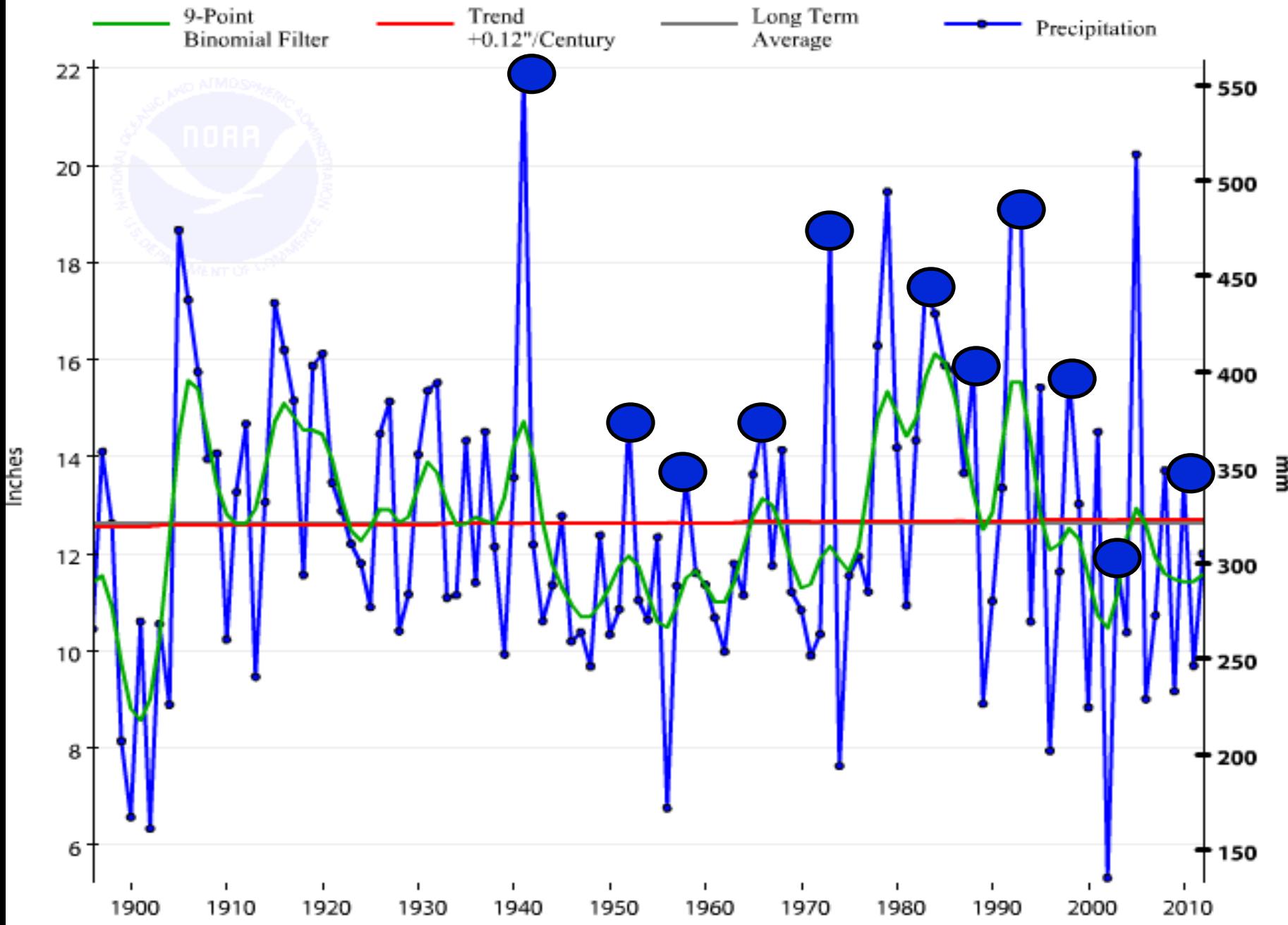
Towering cumulonimbus clouds

Photograph by Corbis Premium Collection/Alamy

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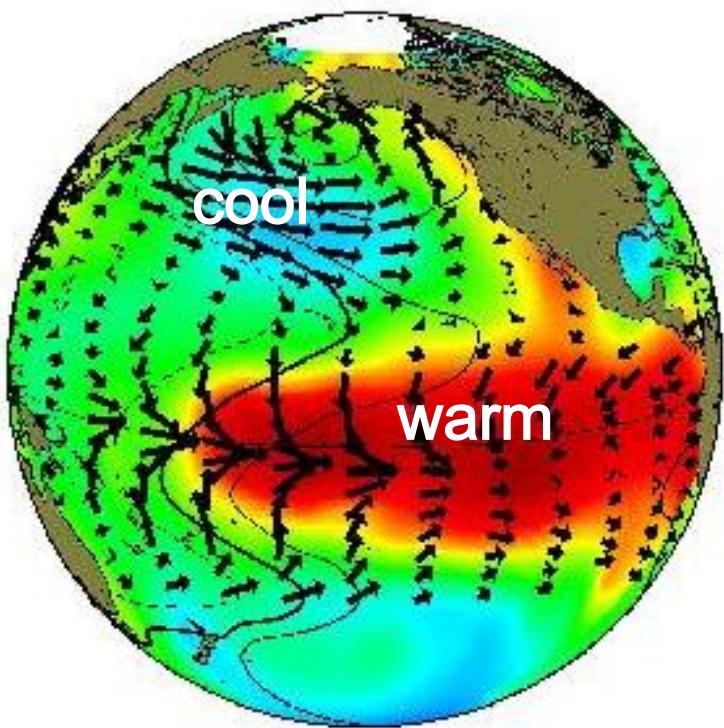
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Arizona, Precipitation, September-August

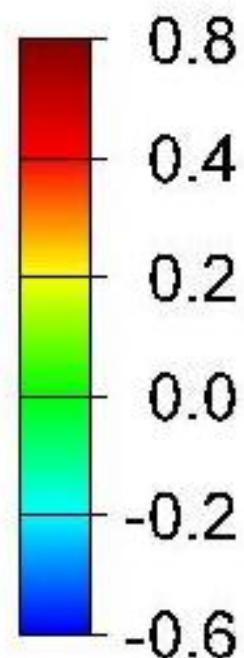
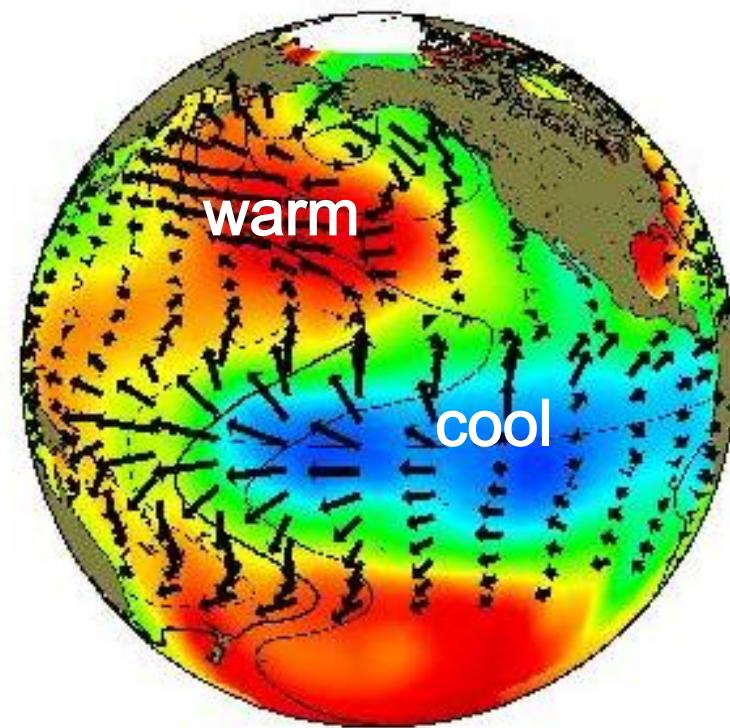


El Niño-Southern Oscillation (ENSO)

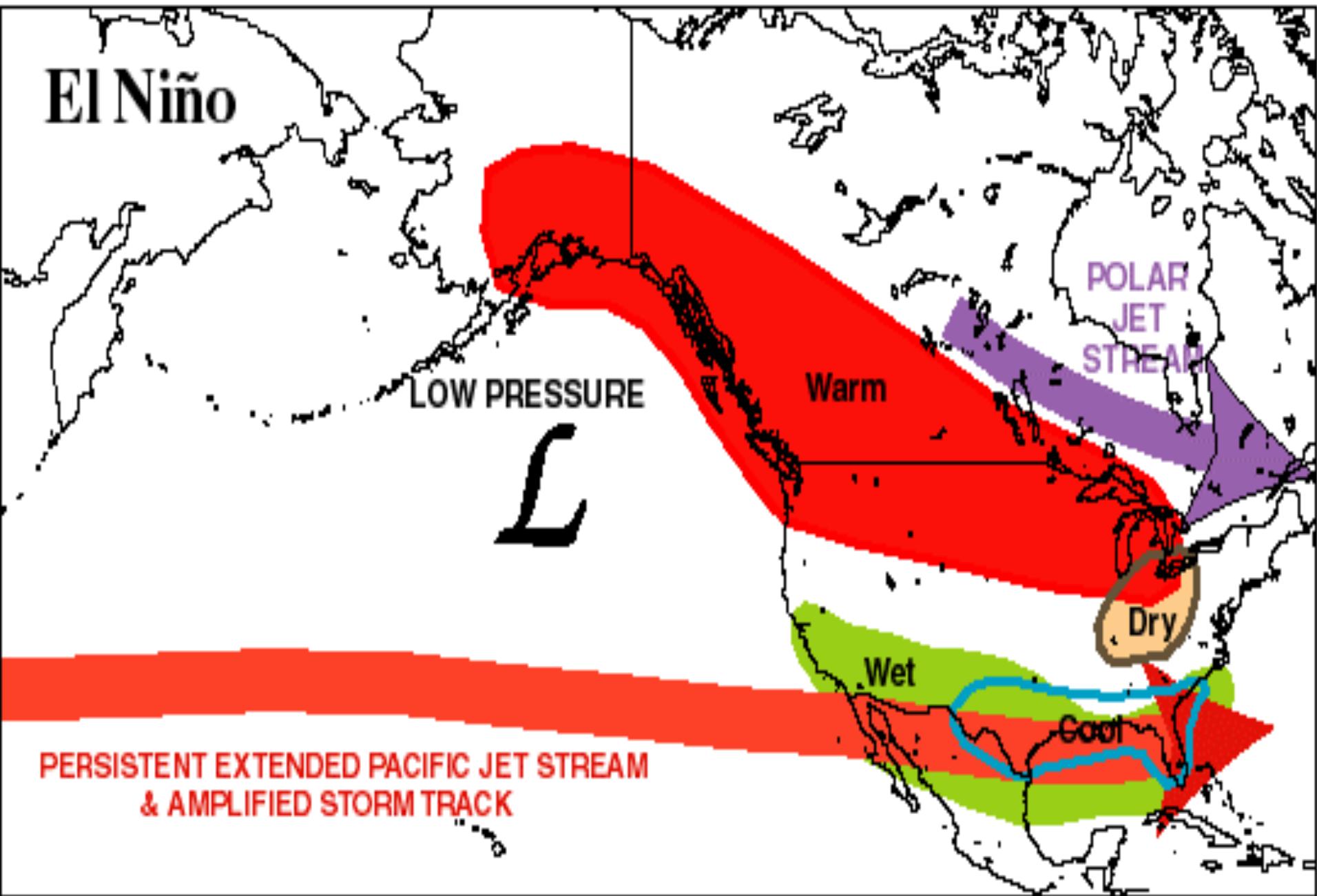
El Niño



La Niña

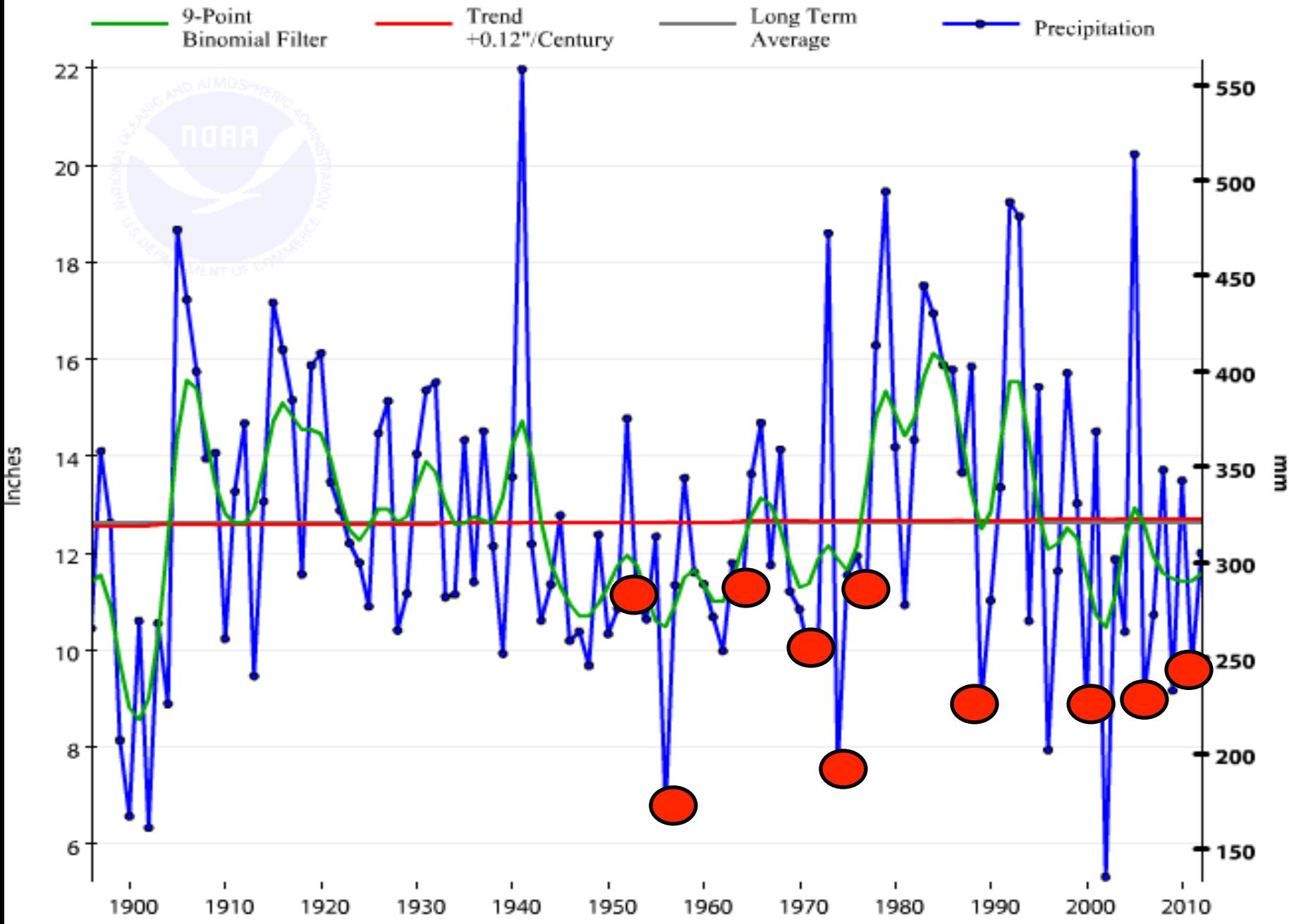


El Niño



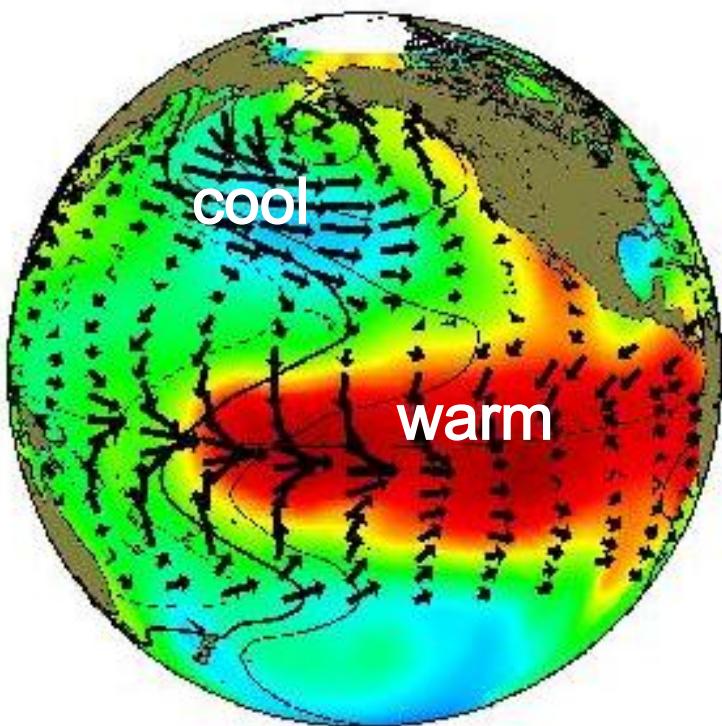
Source: NOAA Climate Prediction Center http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/winter25%25.gif

Arizona, Precipitation, September-August

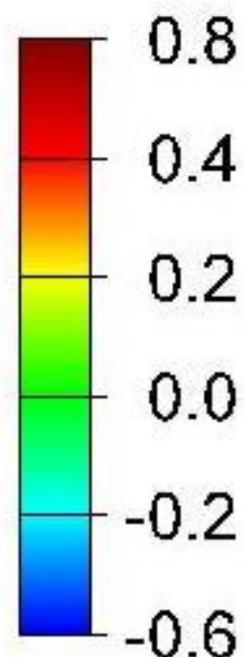
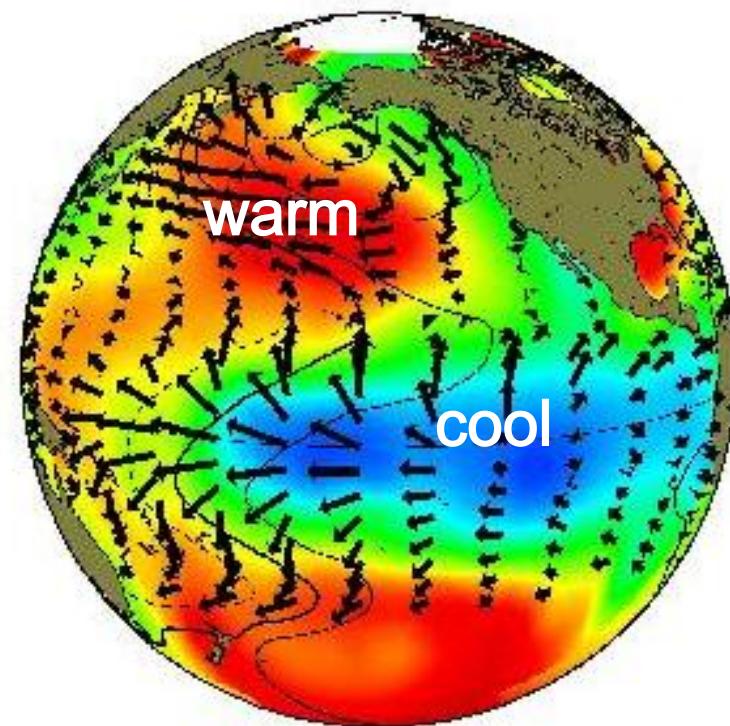


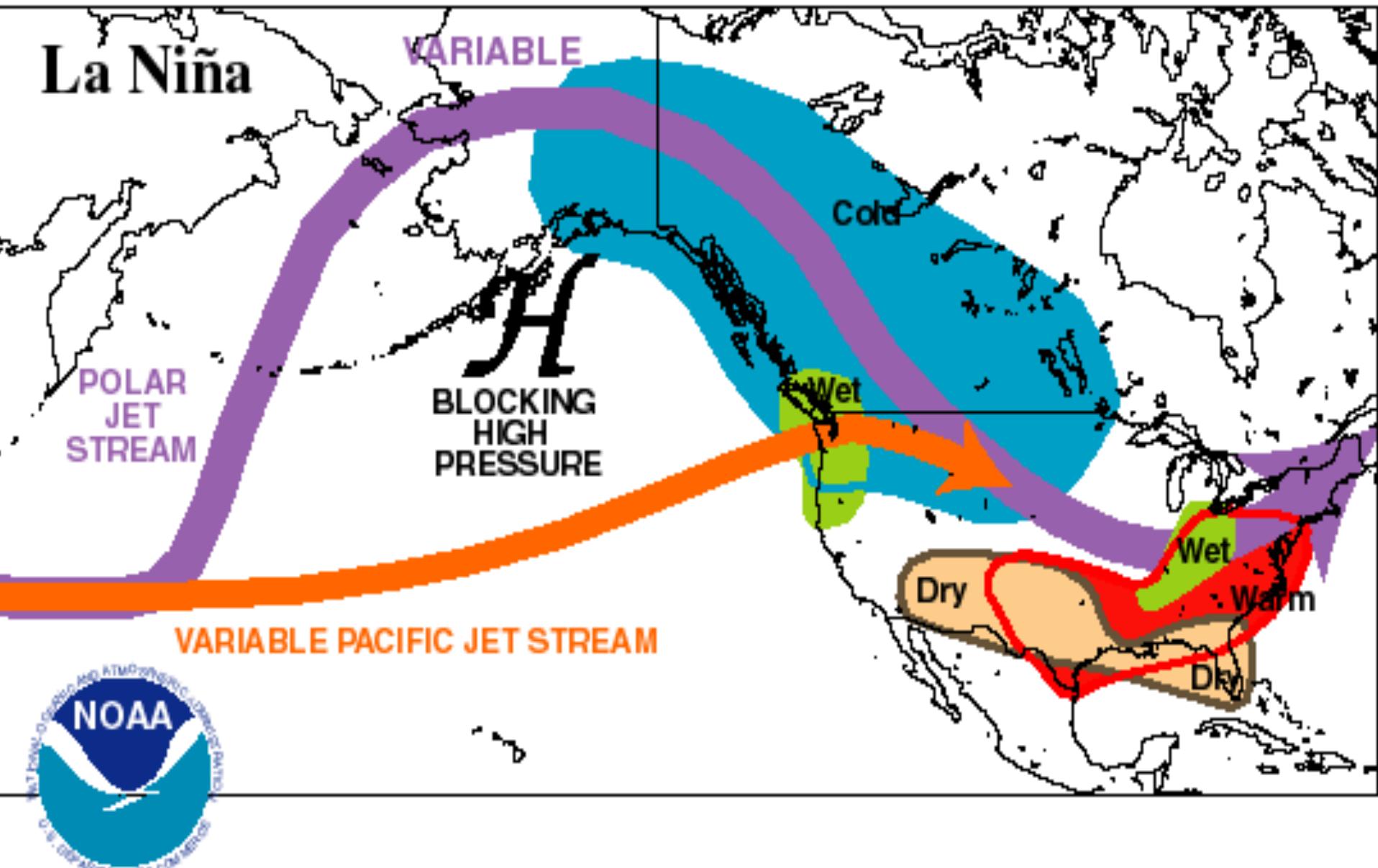
El Niño-Southern Oscillation (ENSO)

El Niño



La Niña

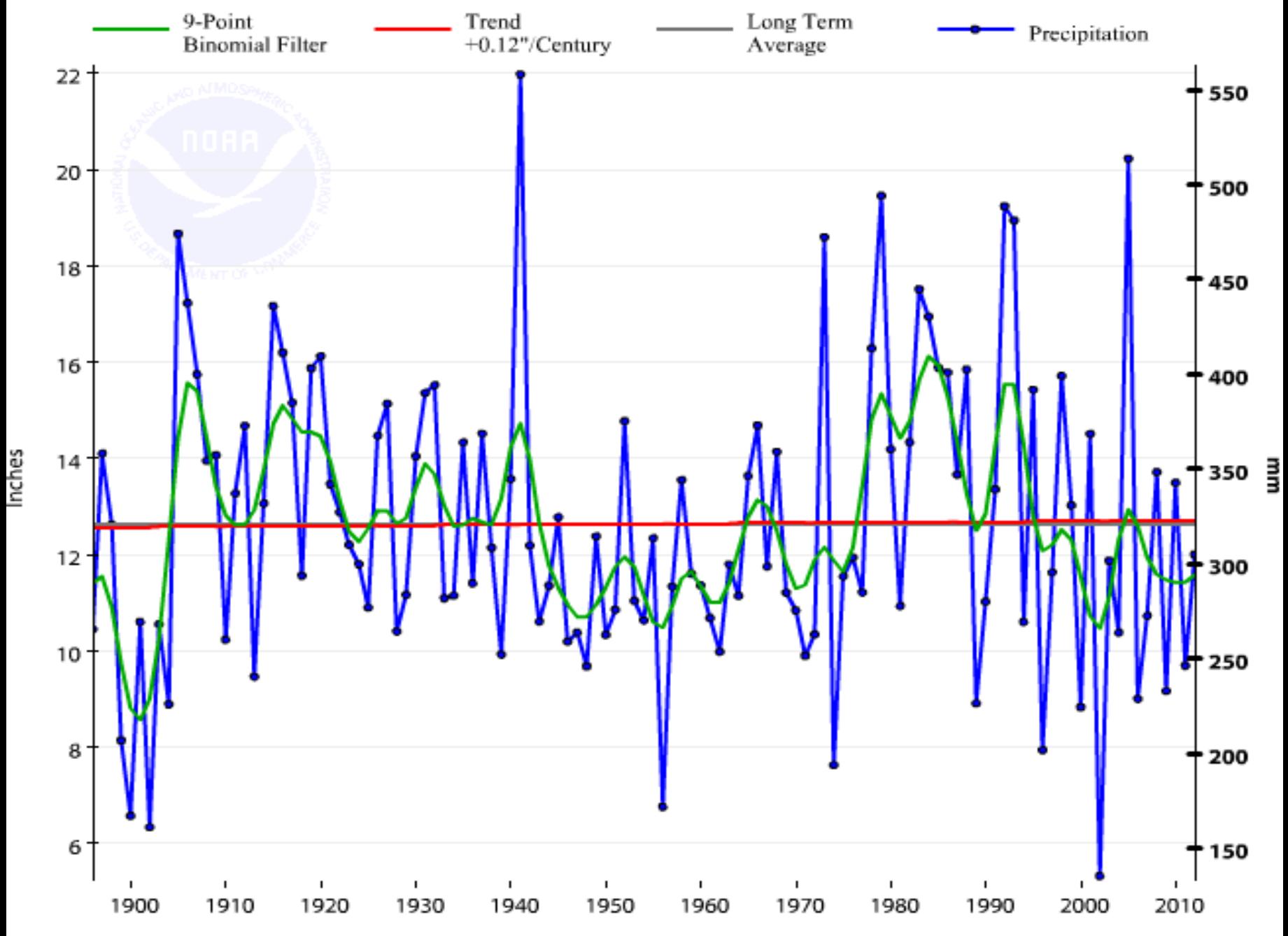




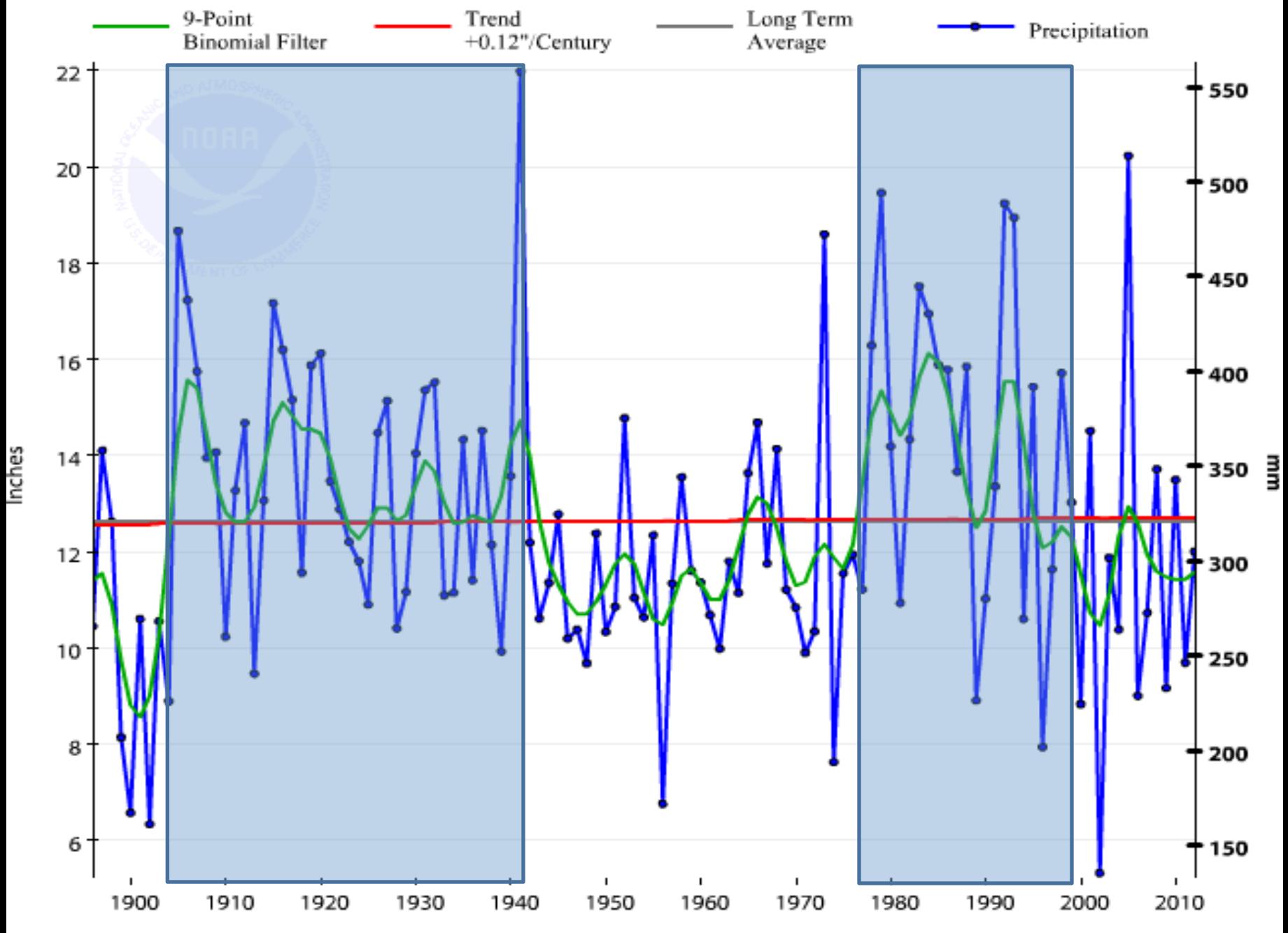
Climate Prediction Center/NCEP/NWS

Source: NOAA Climate Prediction Center http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/winter25%25.gif

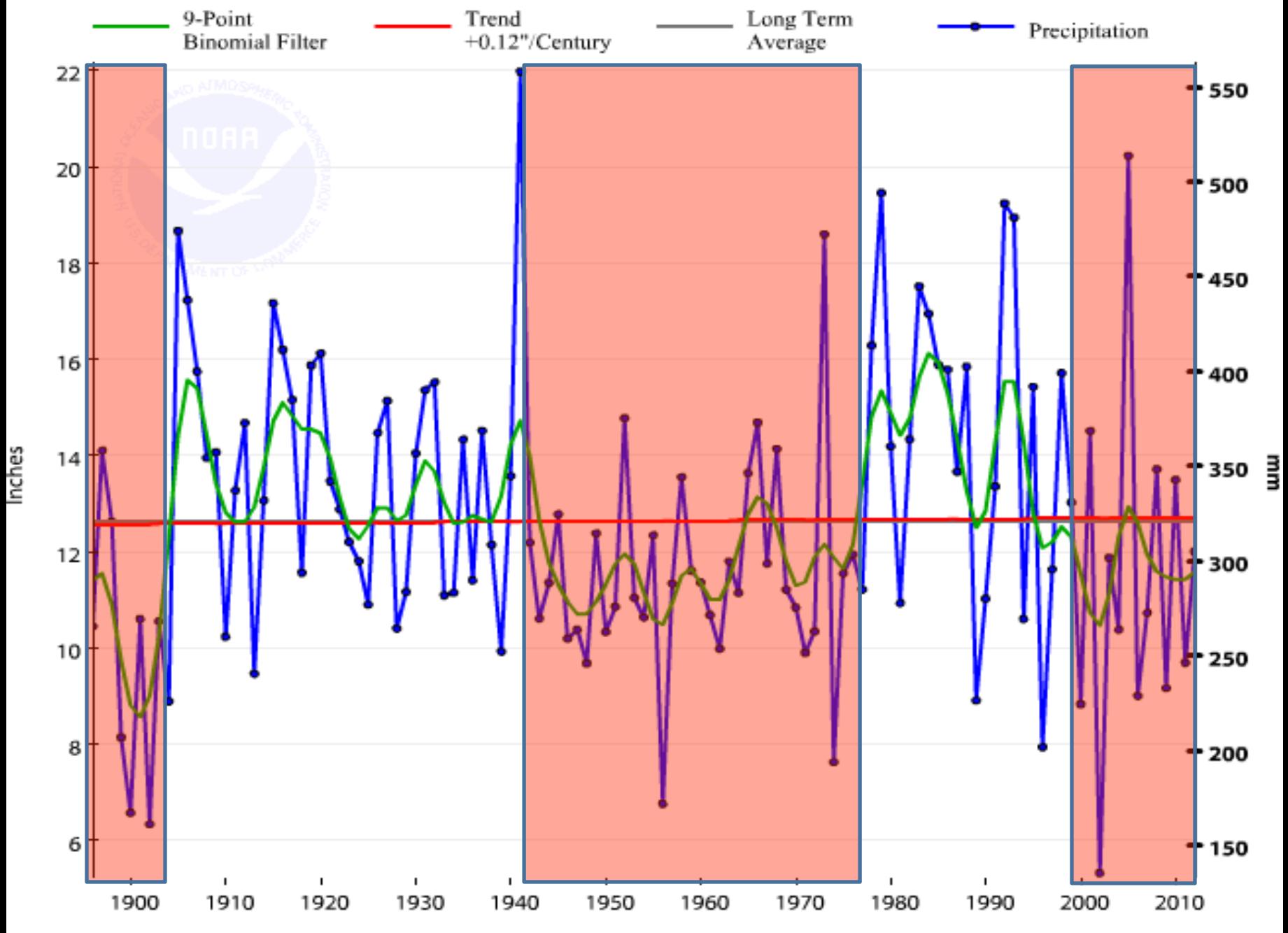
Arizona, Precipitation, September-August



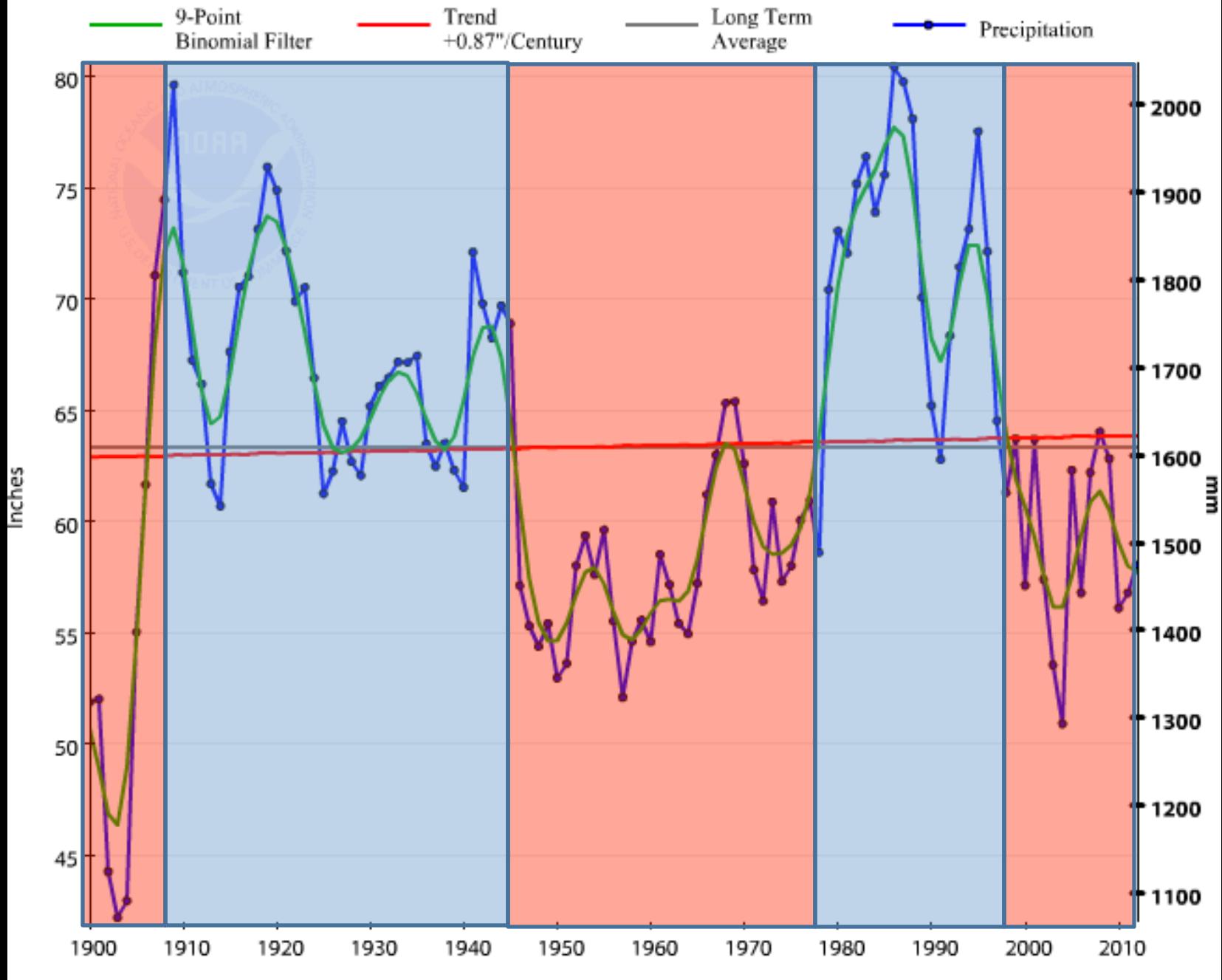
Arizona, Precipitation, September-August



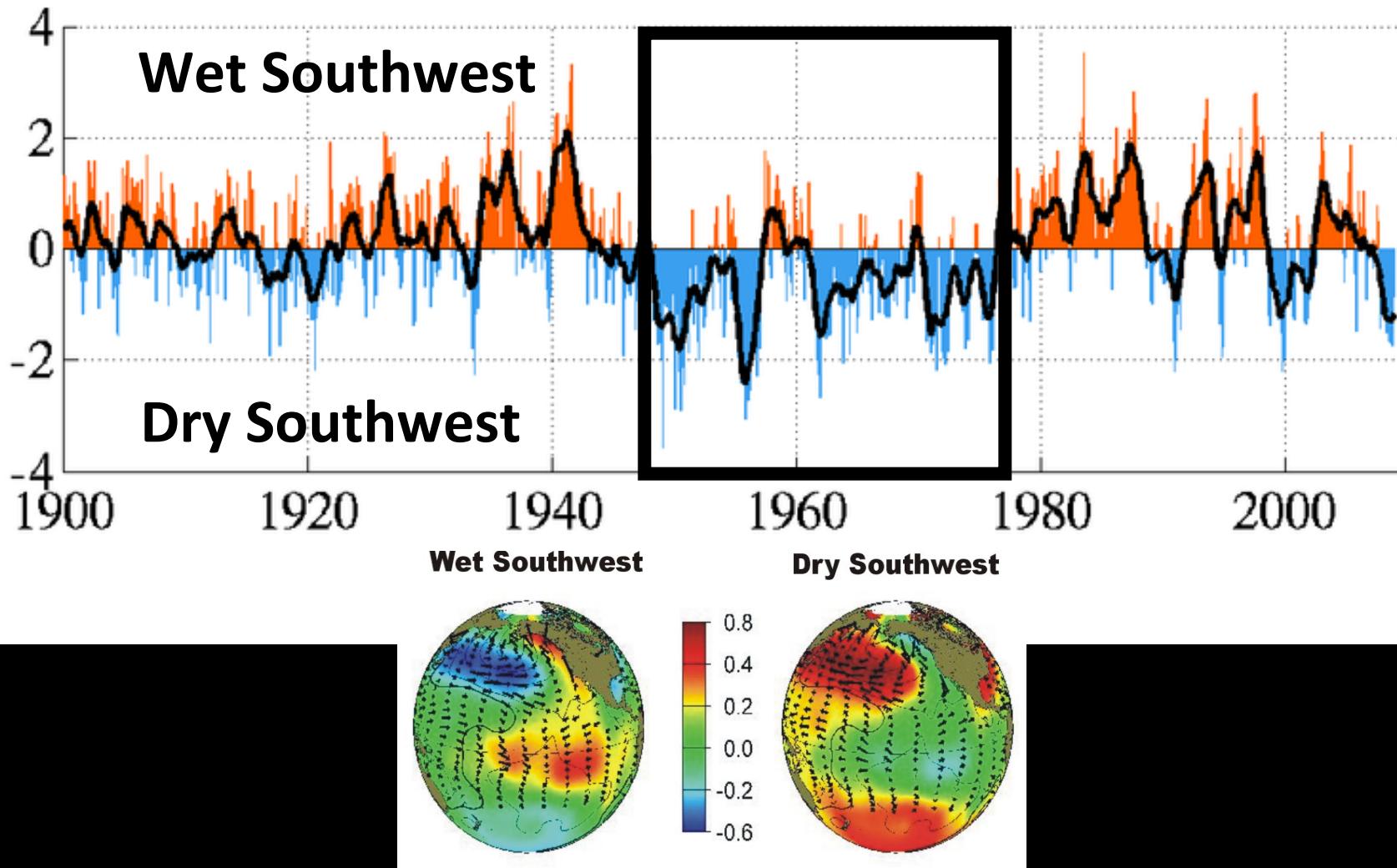
Arizona, Precipitation, September-August



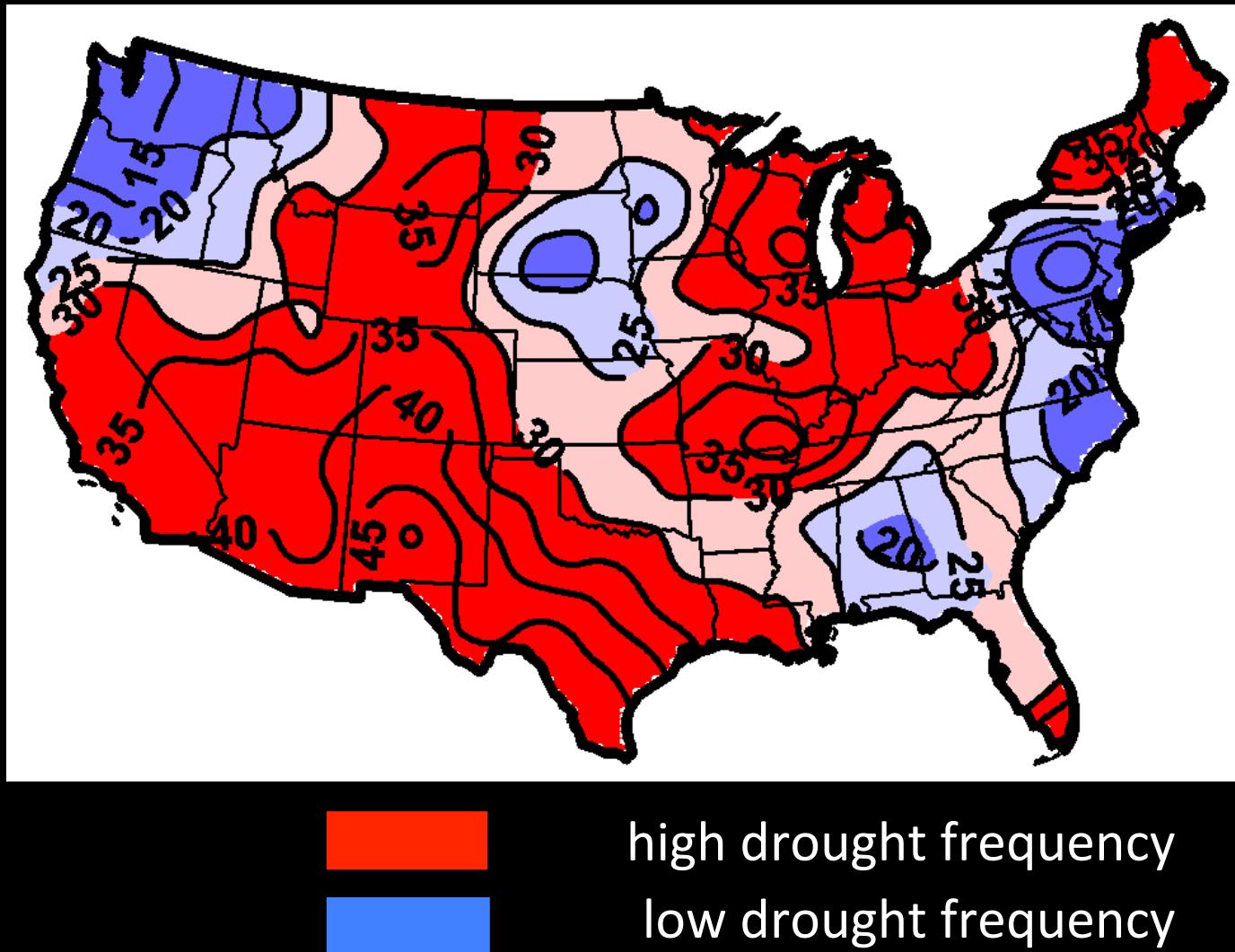
Arizona, Precipitation, 60-Month Period Ending in August



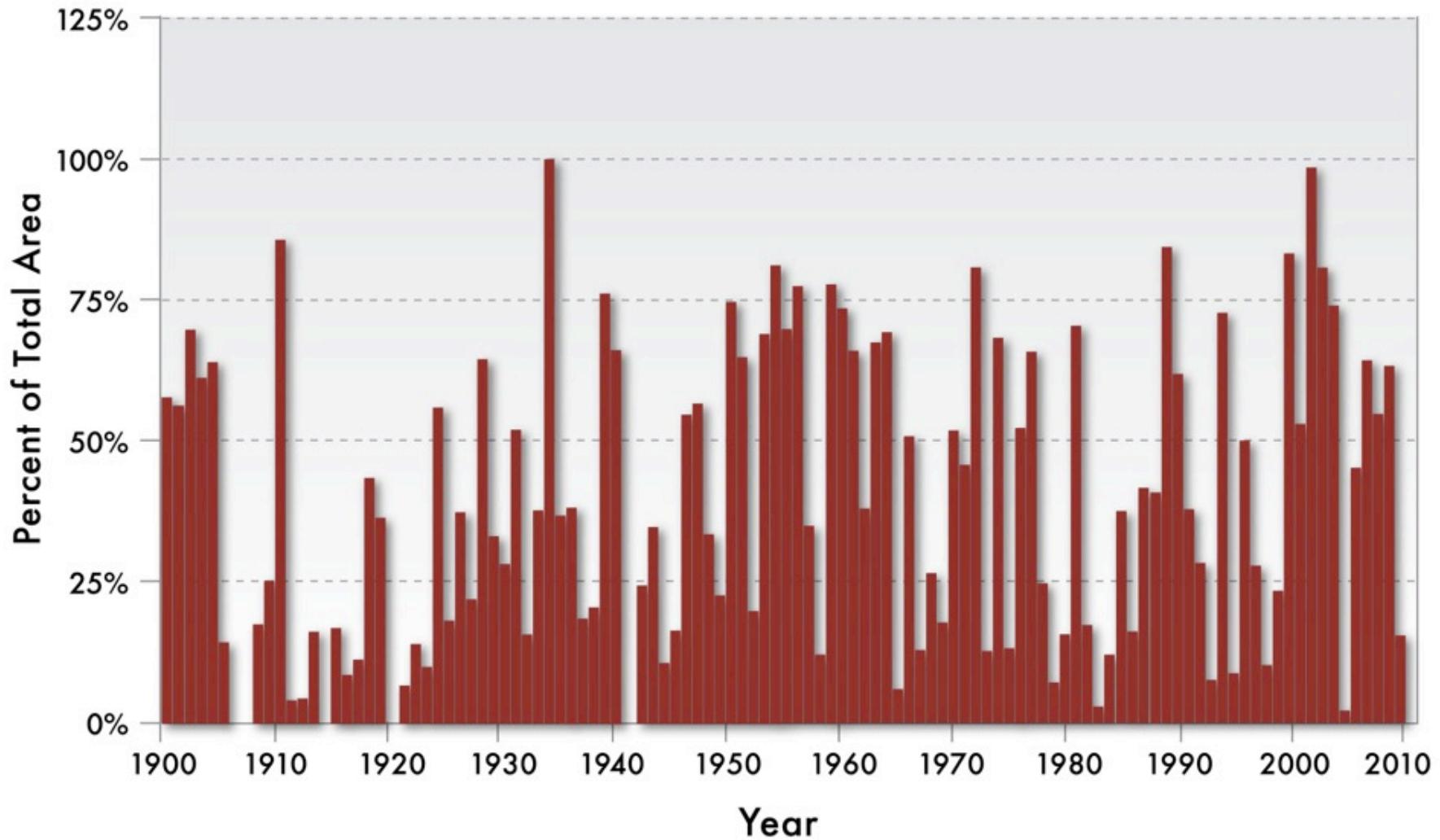
Pacific Decadal Variability - PDO



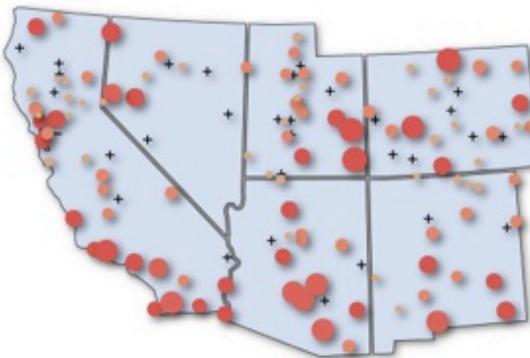
Drought Frequency % (25 = expected)



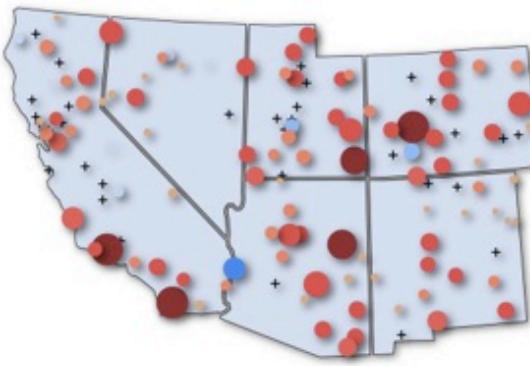
Areal drought coverage: 1900-2010



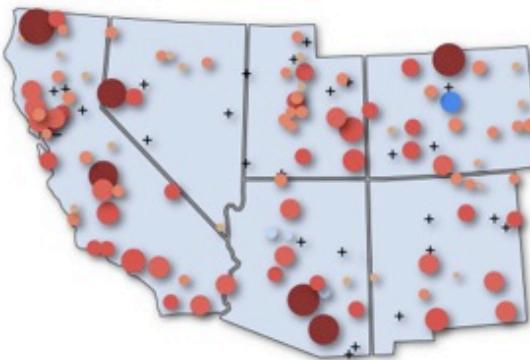
TAVG Trend



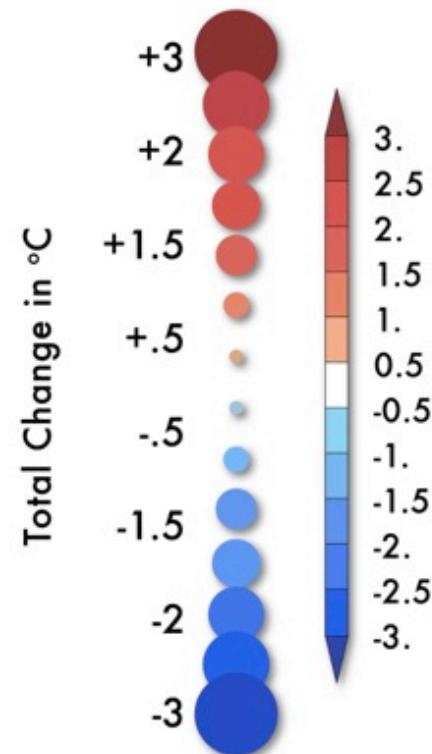
TMAX Trend



TMIN Trend



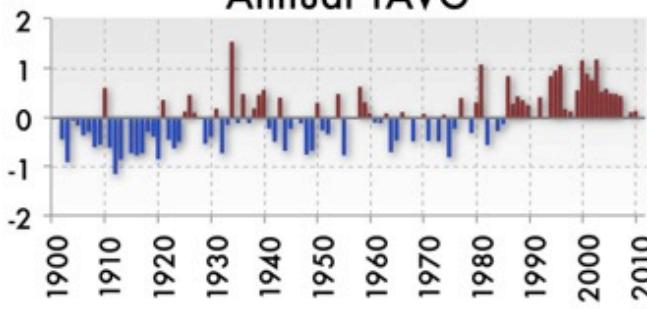
Percentage
Anomaly



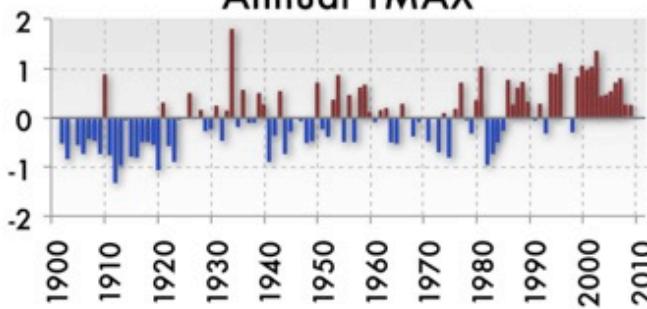
○ Significant Trends at 95%
confidence based on a
parametric t-statistic

⊕ Temperature changes less
than 0.5 °C (5%)

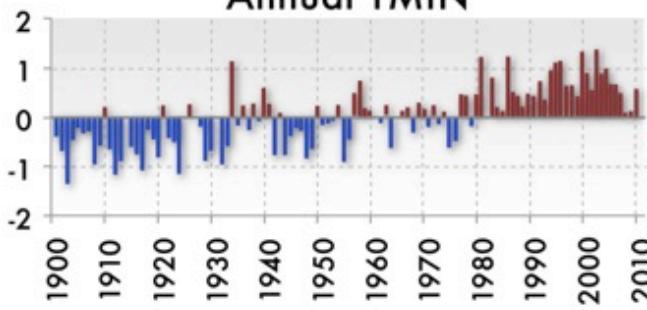
Annual TAVG



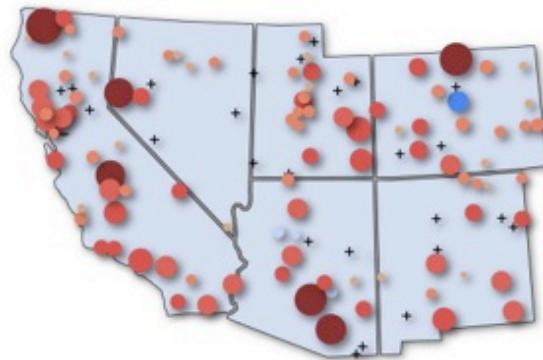
Annual TMAX



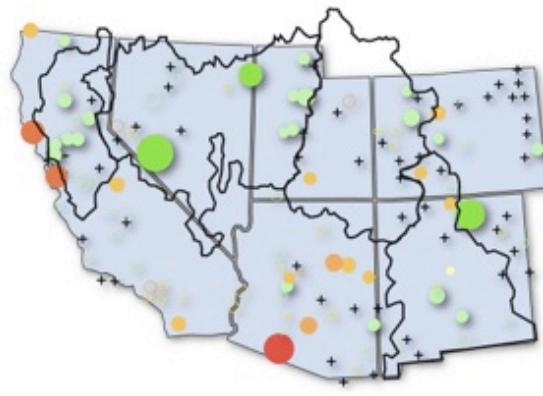
Annual TMIN



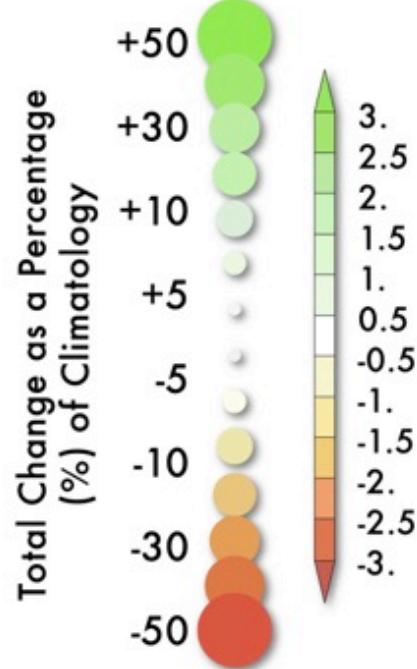
TMIN Trend



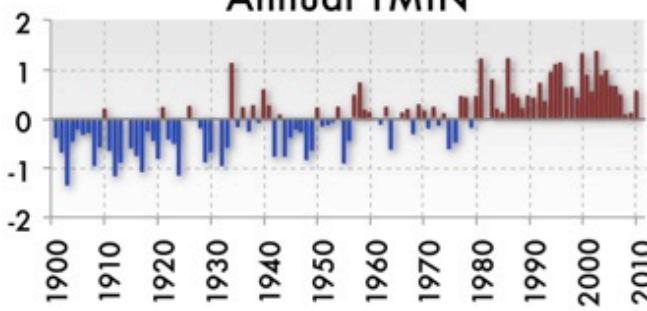
PPT Trend



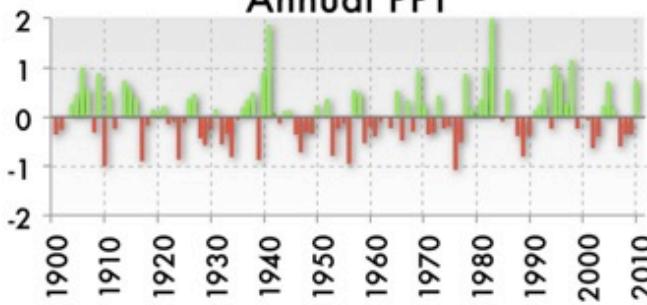
+ Temperature changes less than 0.5°C (5%)



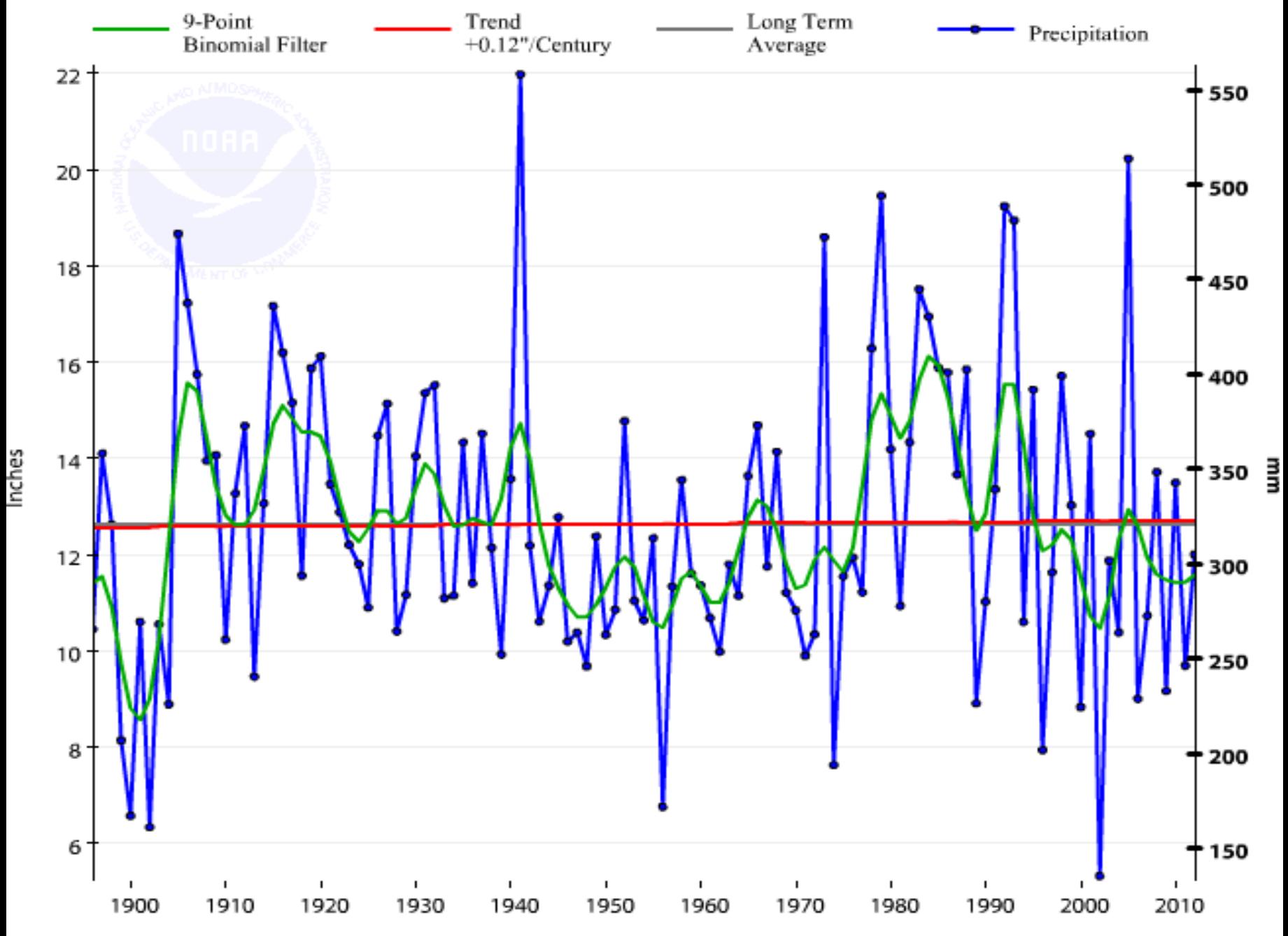
Annual TMIN



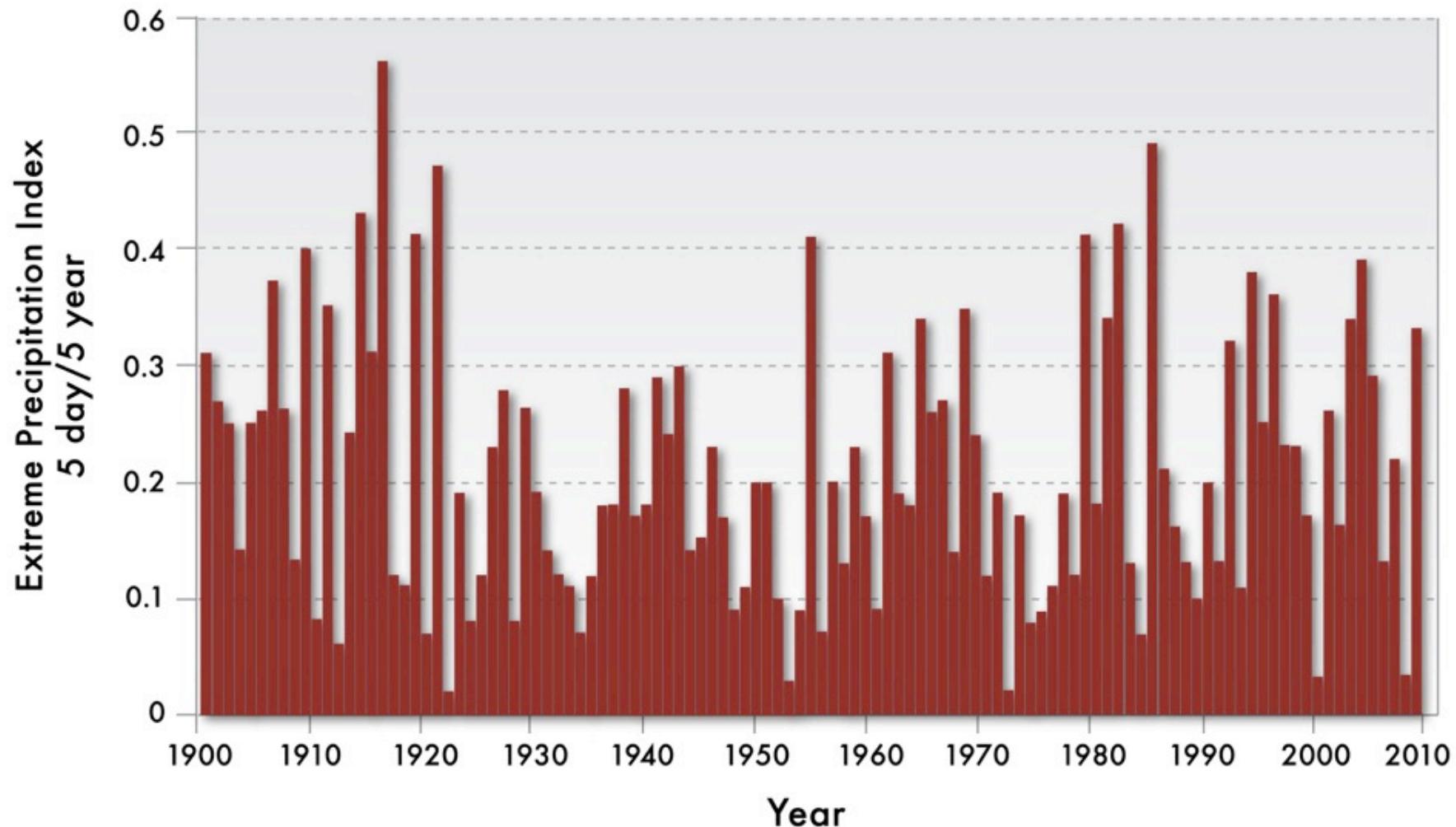
Annual PPT



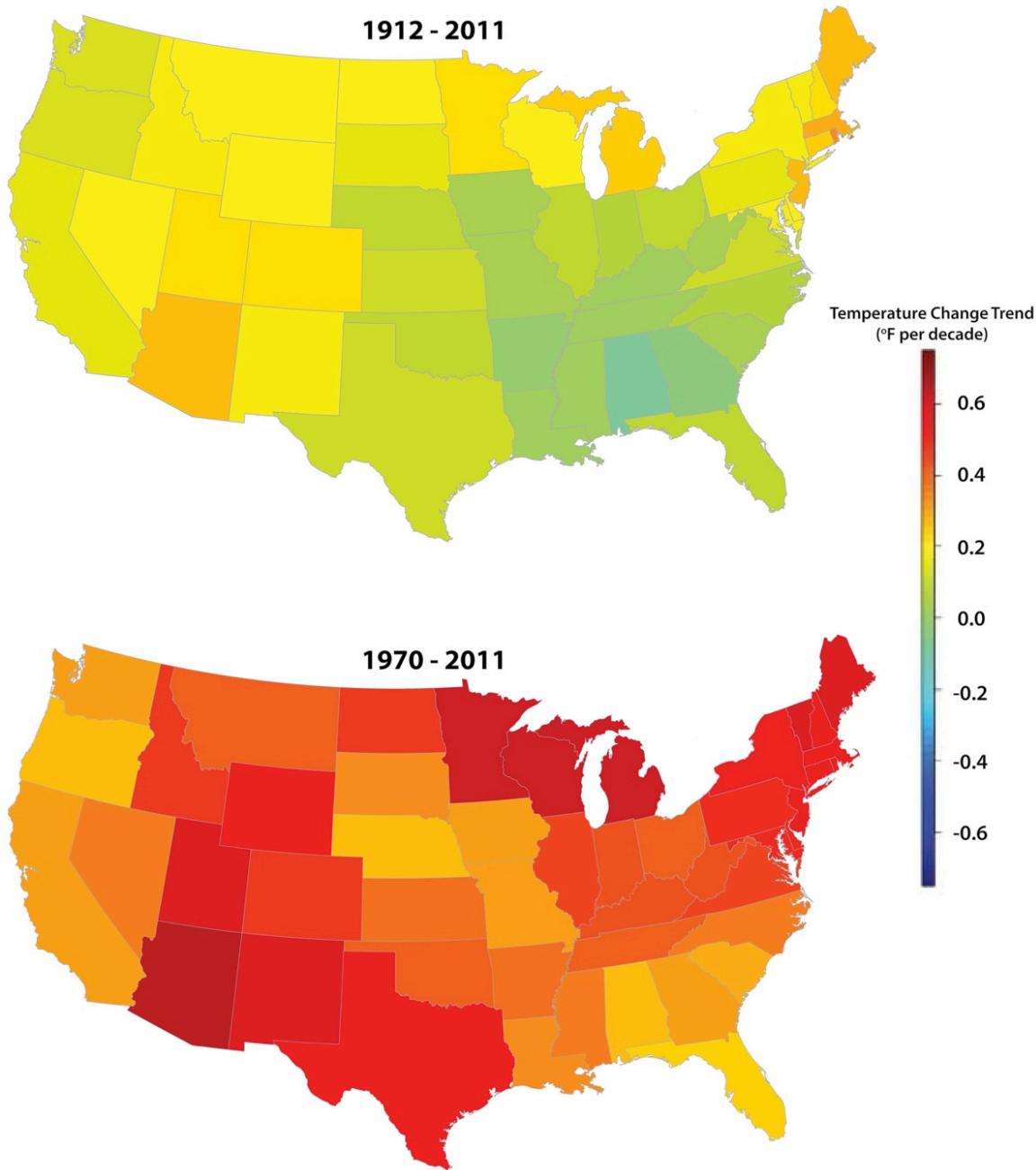
Arizona, Precipitation, September-August



Extreme precipitation events: 1900-2010



Warming Rates Accelerated Everywhere After 1970



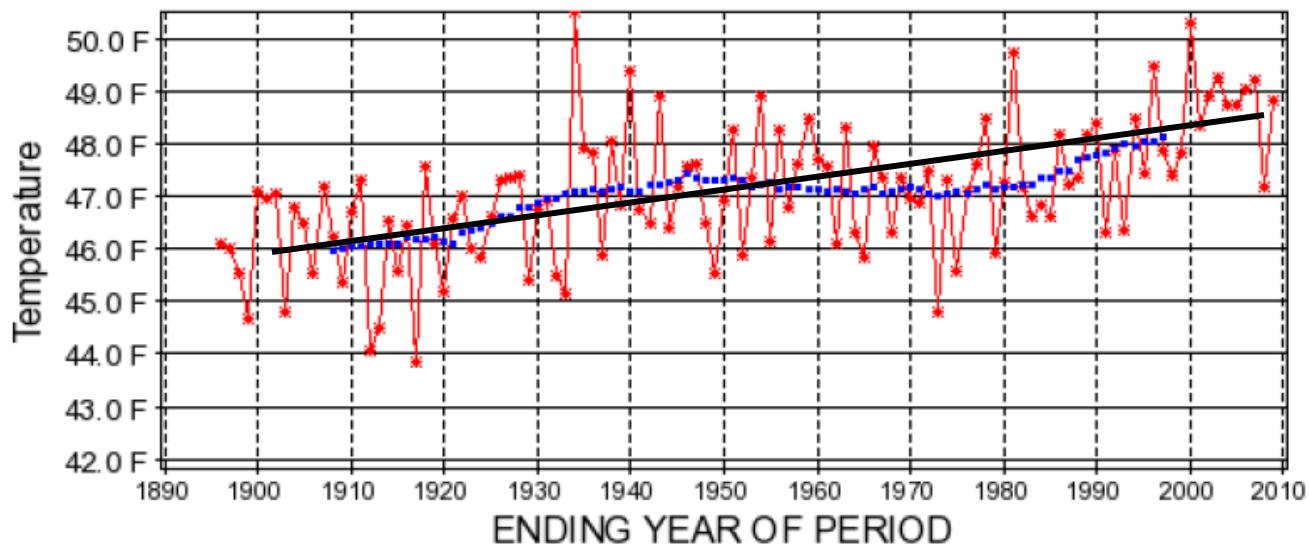
Arizona:

- Outpaced all other states

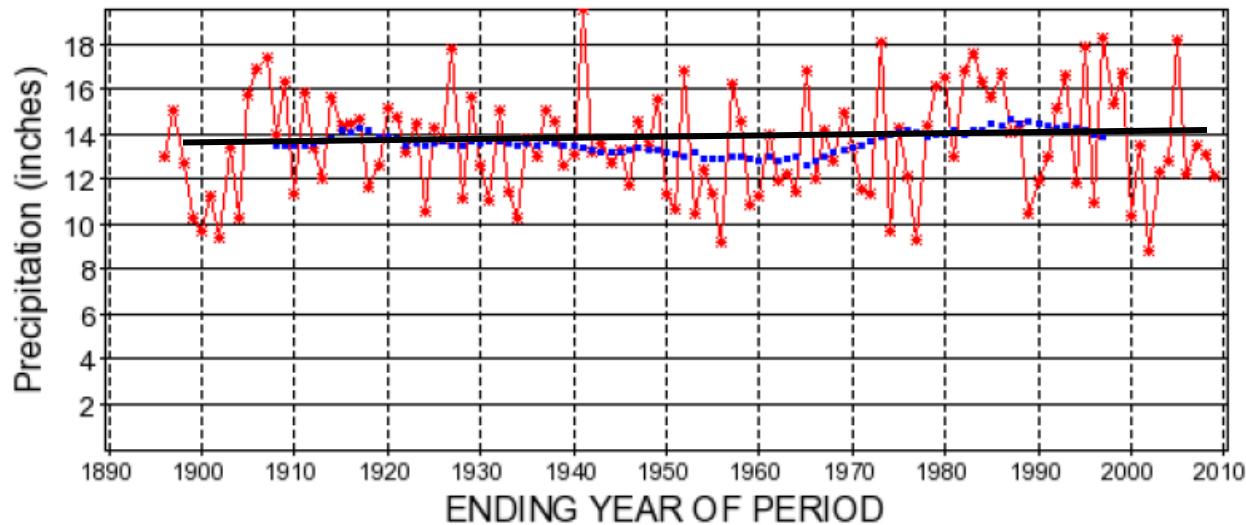
2001-2010

- Fewer cold waves
- More heat waves

Mean Temperature for Colorado Basin (above Lake Mead)
12 month period ending in September



Total Precipitation for Colorado Basin (above Lake Mead)
12 month period ending in September

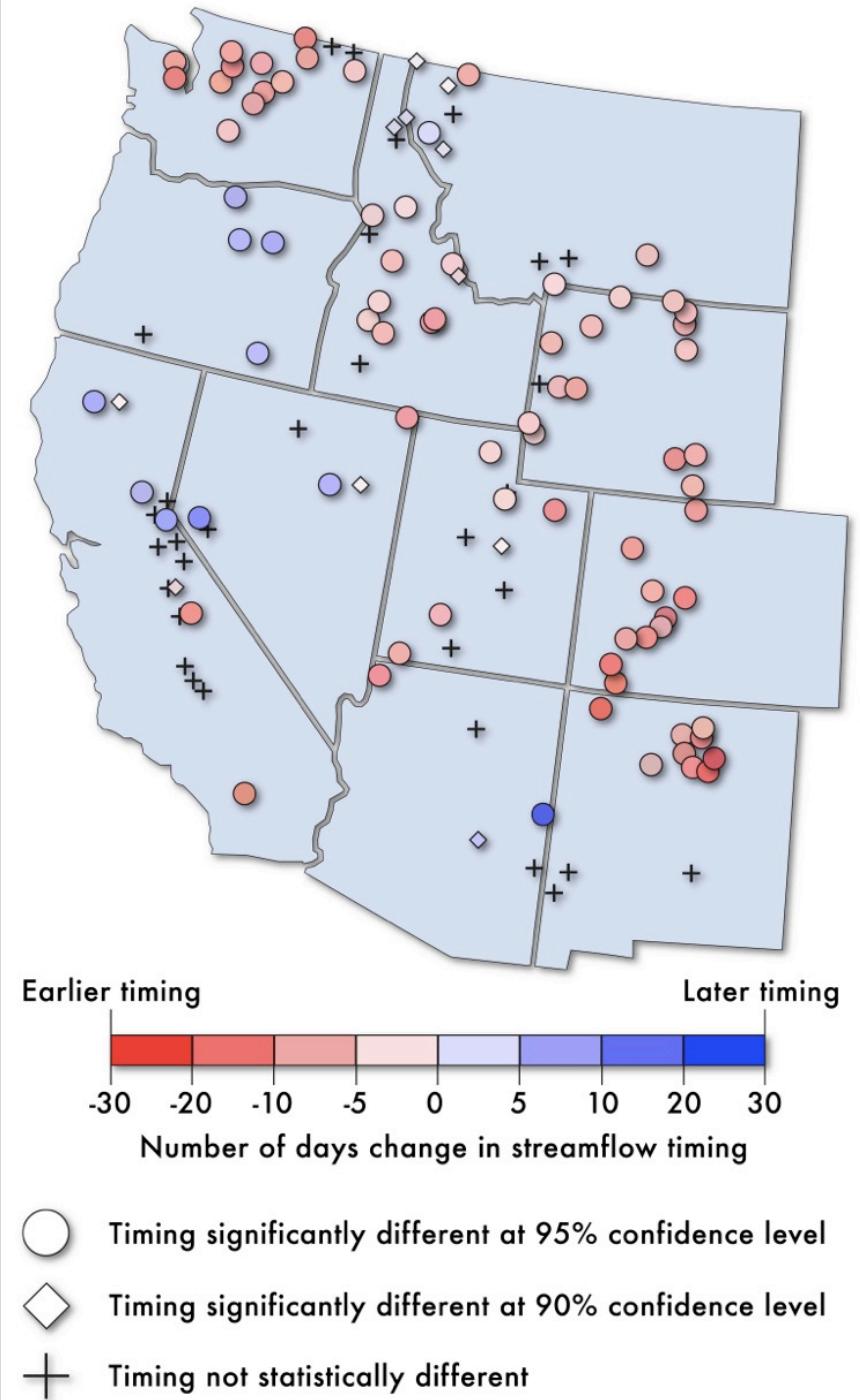


Changes in Streamflow

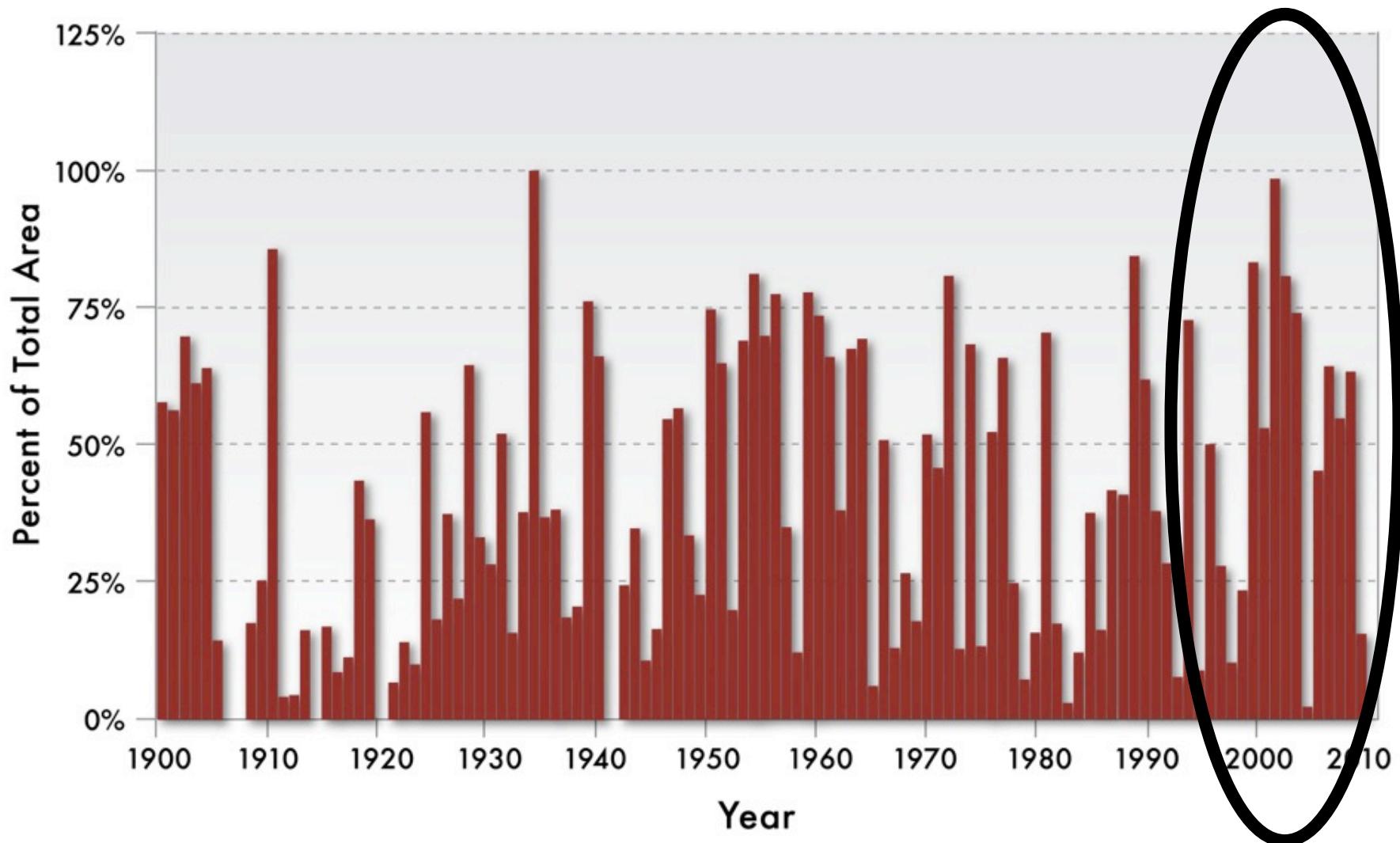
Timing:

2000-2010 vs.

1950-2000



Areal drought coverage: 1900-2010



Massive pinyon pine dieback 2002-2004



Increased temperatures, decreased soil moisture, result in greater stress, longer insect breeding cycles. Once a threshold is crossed massive mortality occurs.

Near Flagstaff
N.S. Cobb

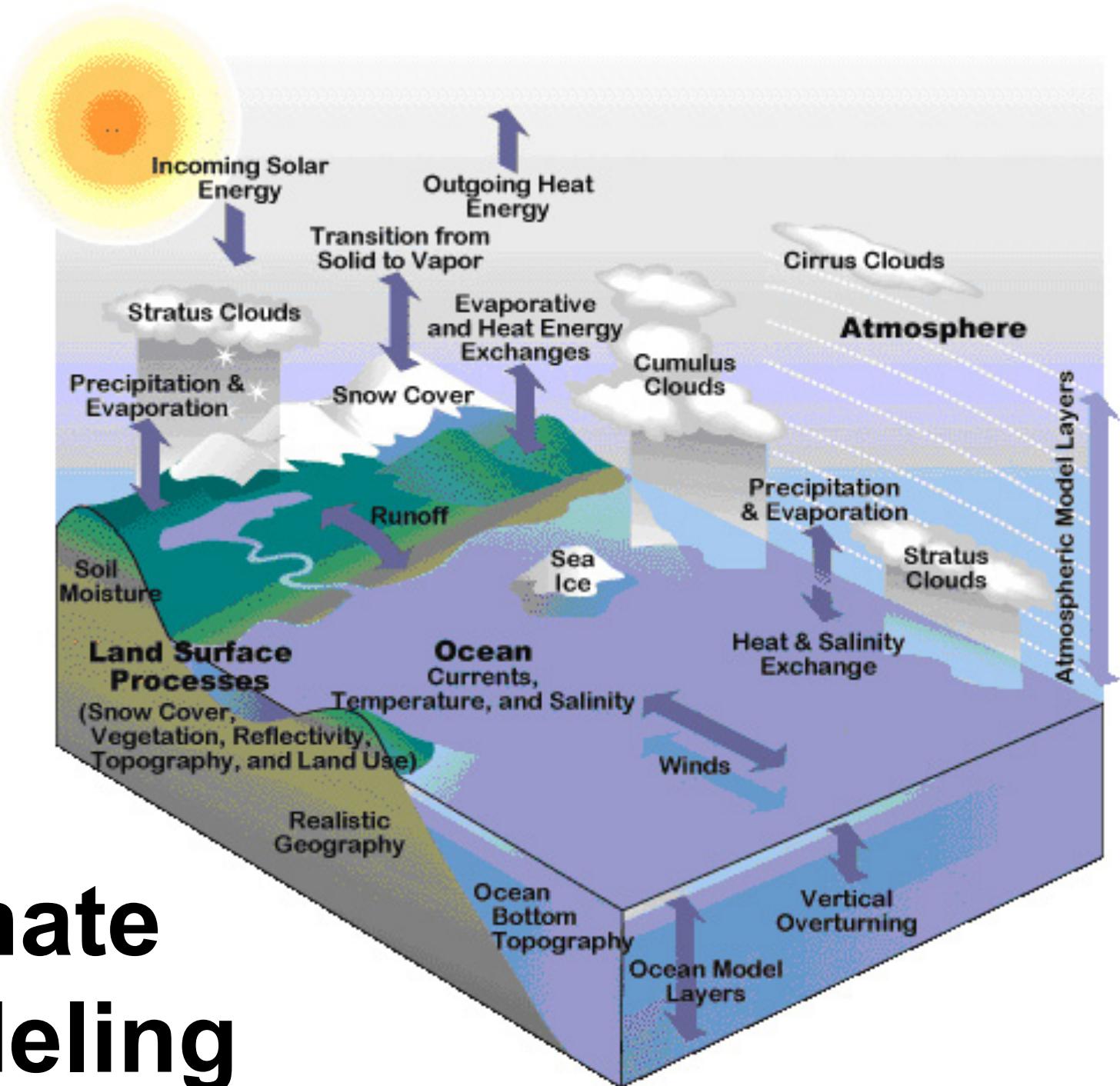


Westerling et al., 2006 *Science*

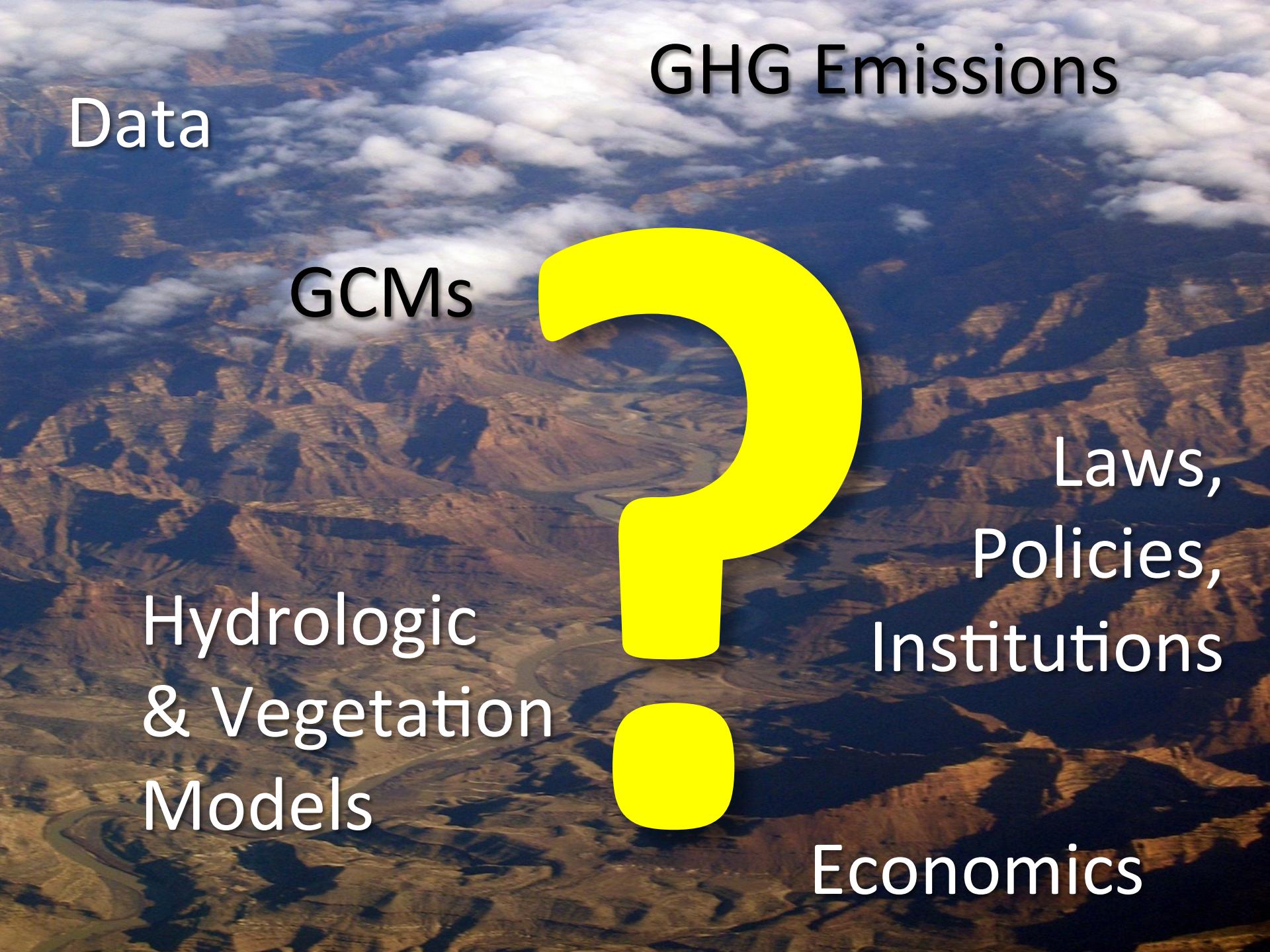
Temperature
is a
hydrologic
variable

Climate Change Projections





Climate Modeling

The background of the image is a photograph taken from an airplane window, showing a winding river or stream bed in the foreground, surrounded by brown, arid land. In the middle ground, there are large, rugged mountains with patches of snow or ice on their peaks. The sky above is filled with white and grey clouds.

GHG Emissions

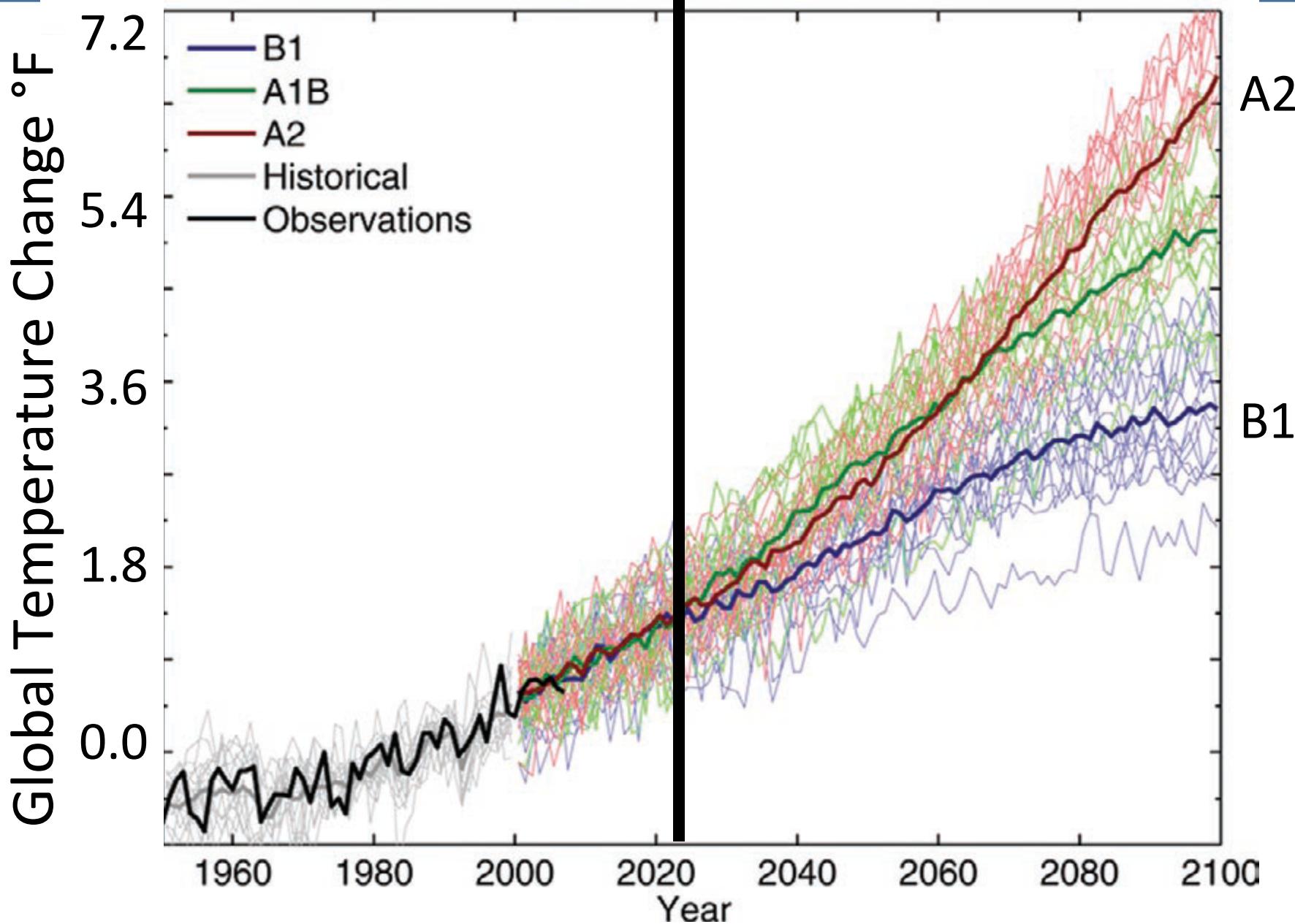
Data

GCMs

Hydrologic
& Vegetation
Models



Laws,
Policies,
Institutions
Economics



Hawkins and Sutton 2009. Bull. Amer. Met. Soc.

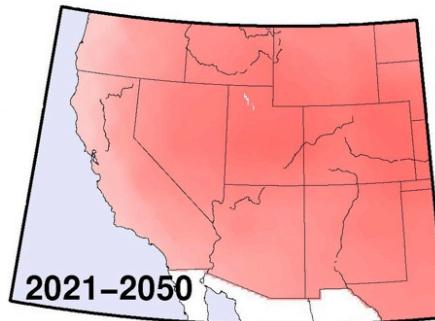


Institute of the
Environment

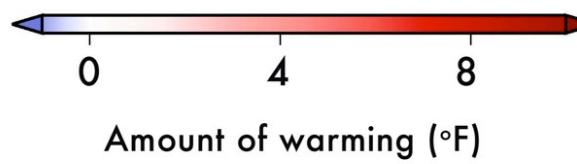
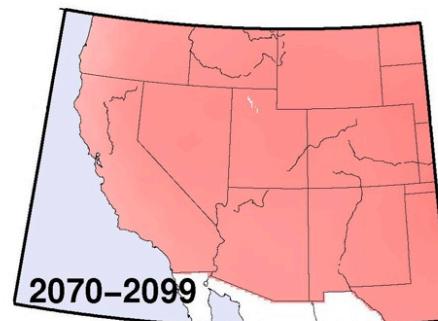
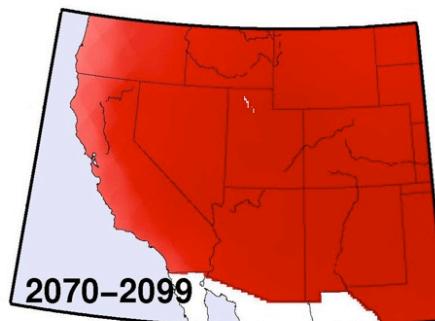
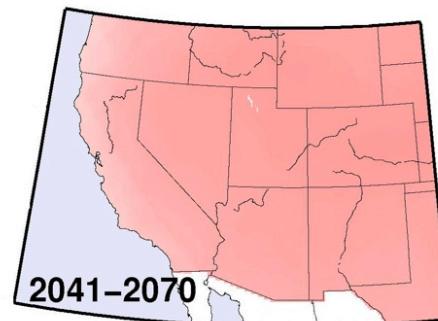
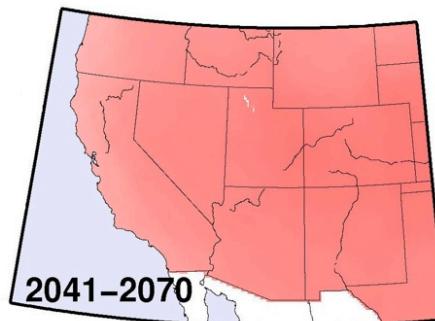
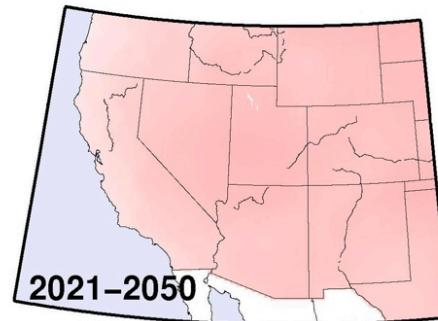
- Big spatial scales
- Temperature
- Not predictions

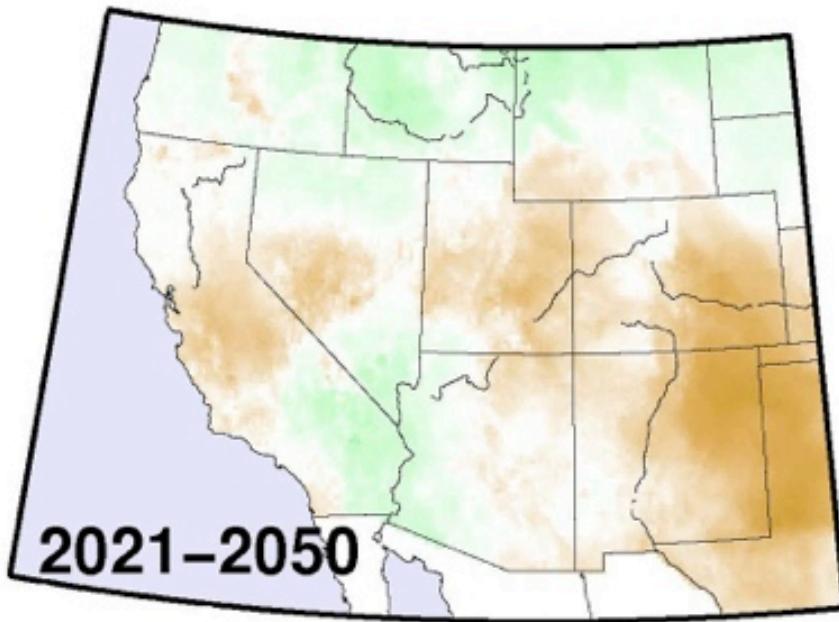
Hotter

High-emissions scenario

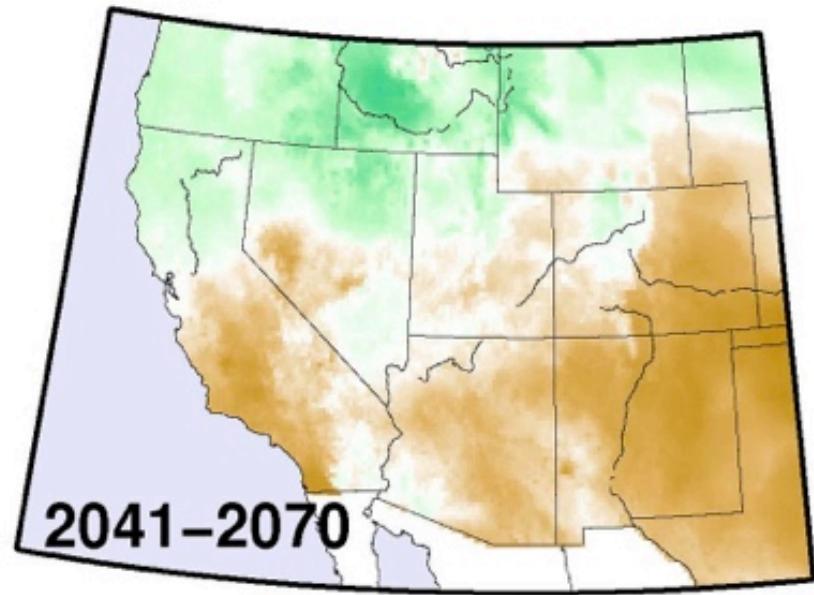


Low-emissions scenario



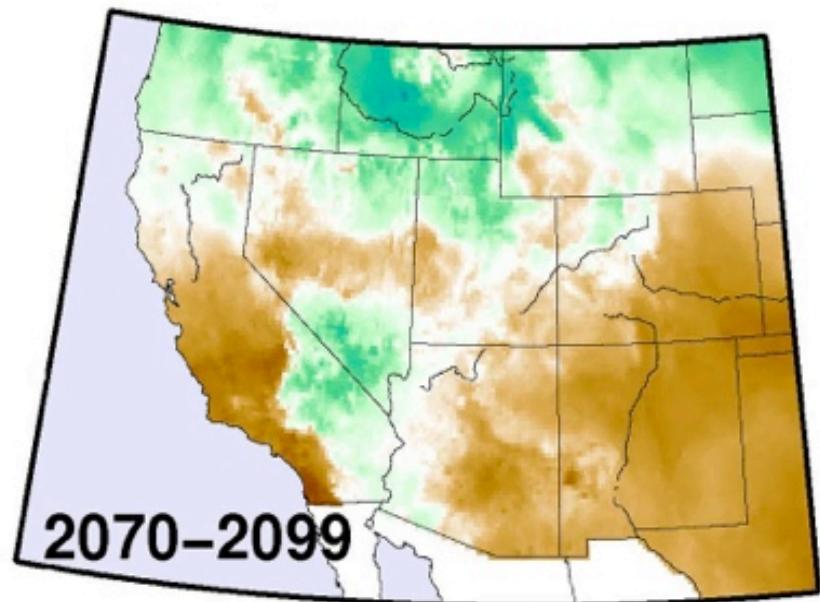
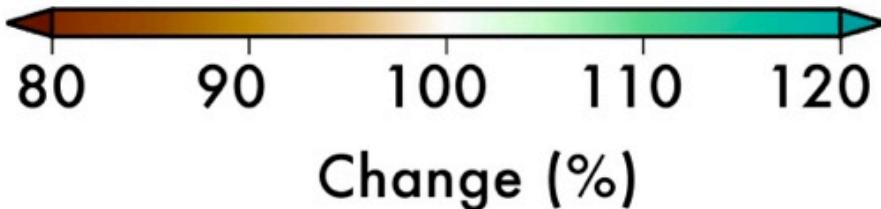


2021–2050



2041–2070

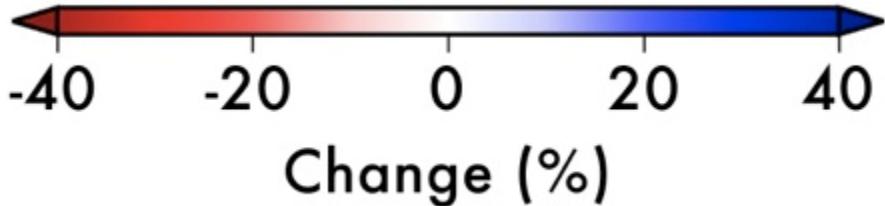
Drier?
La Niña = YES!



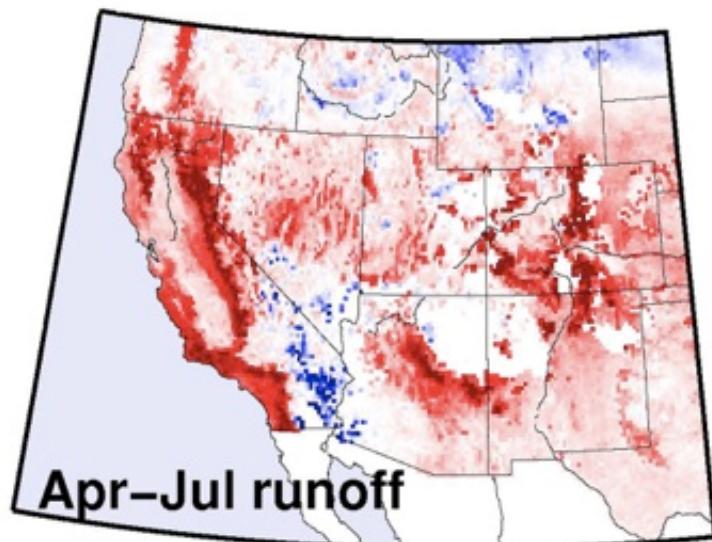
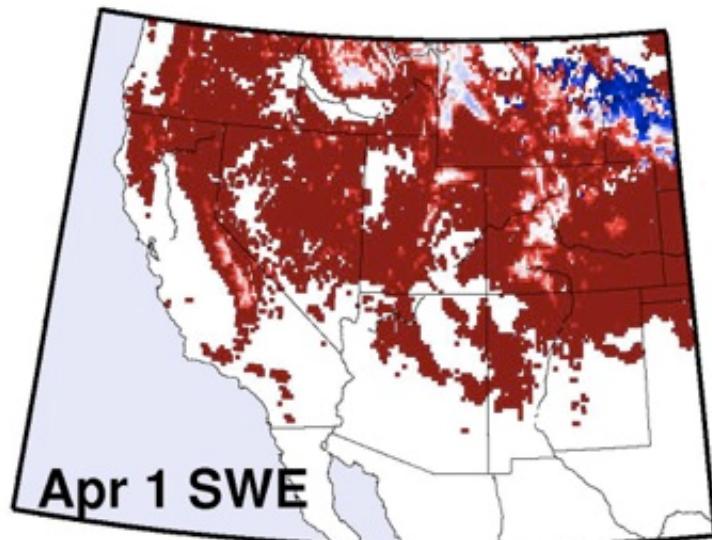
2070–2099

High Emissions Scenario

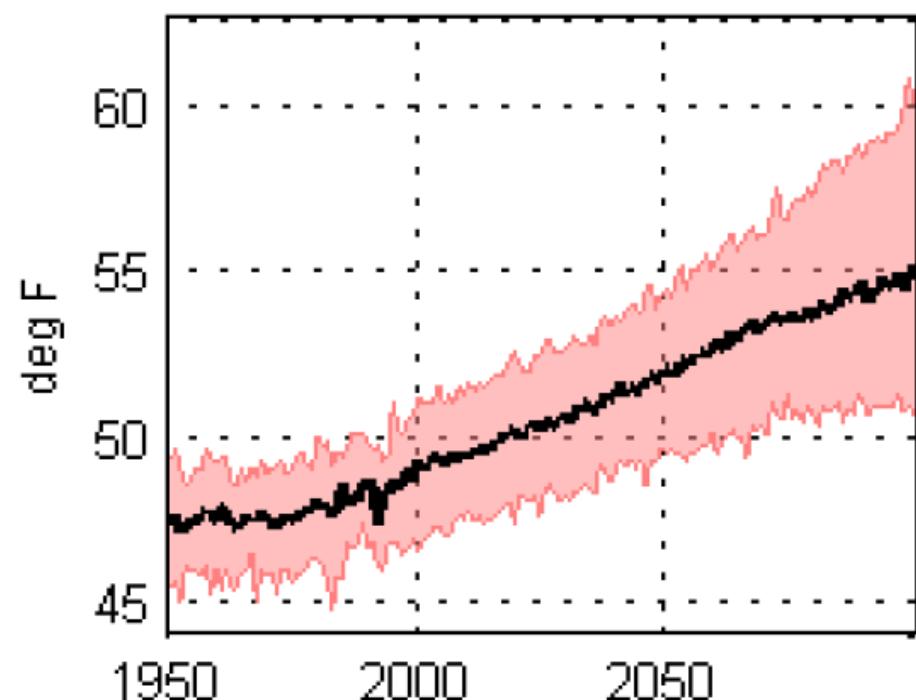
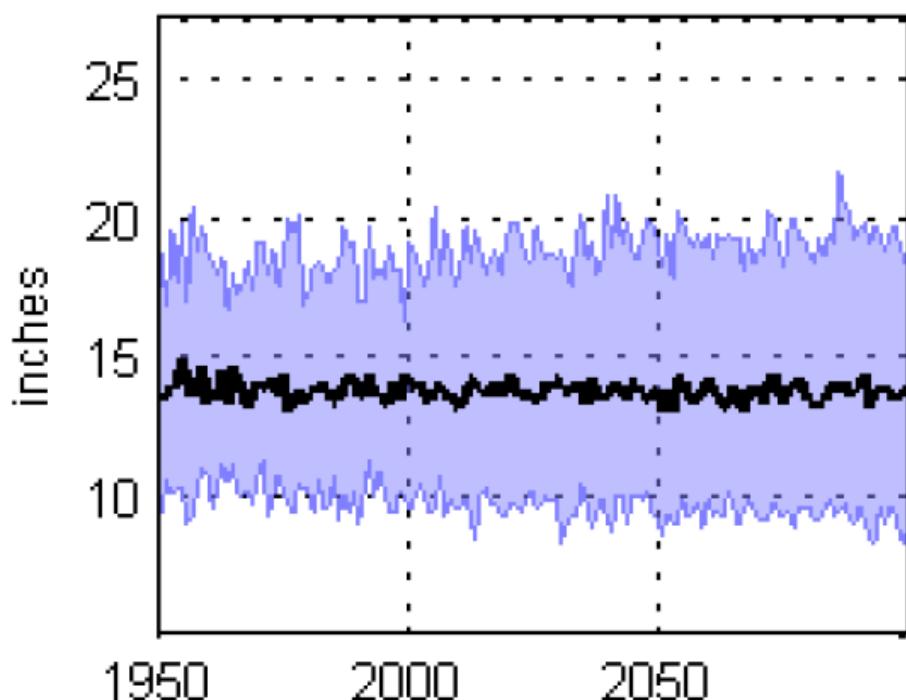
- Less Snow
- Less Water
in Arizona
streams



High emission scenario
2041–2070

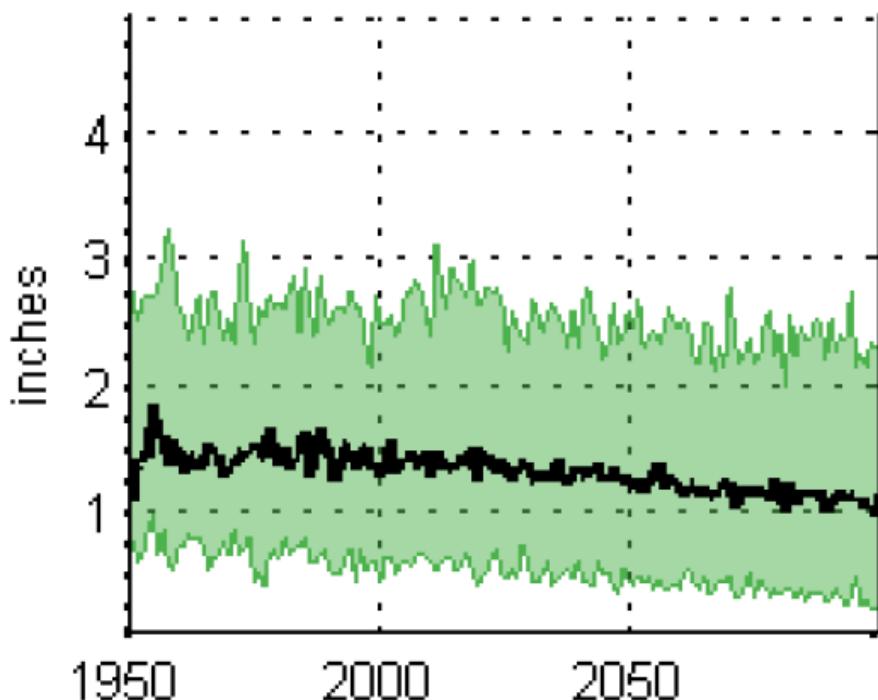


Annual Precipitation Annual Temperature

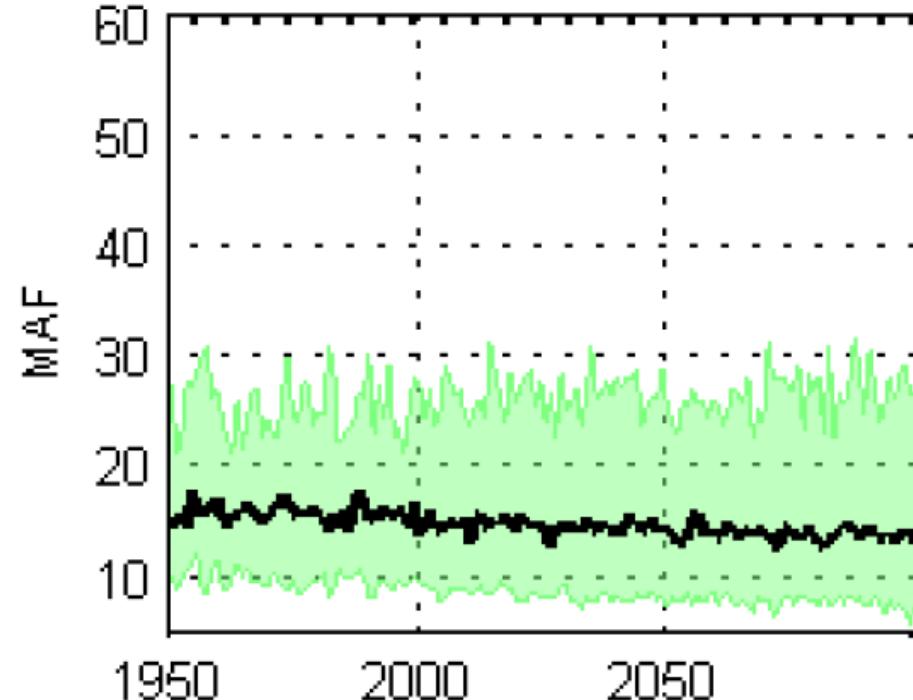


Upper Colorado River Basin

April 1 Snow Water

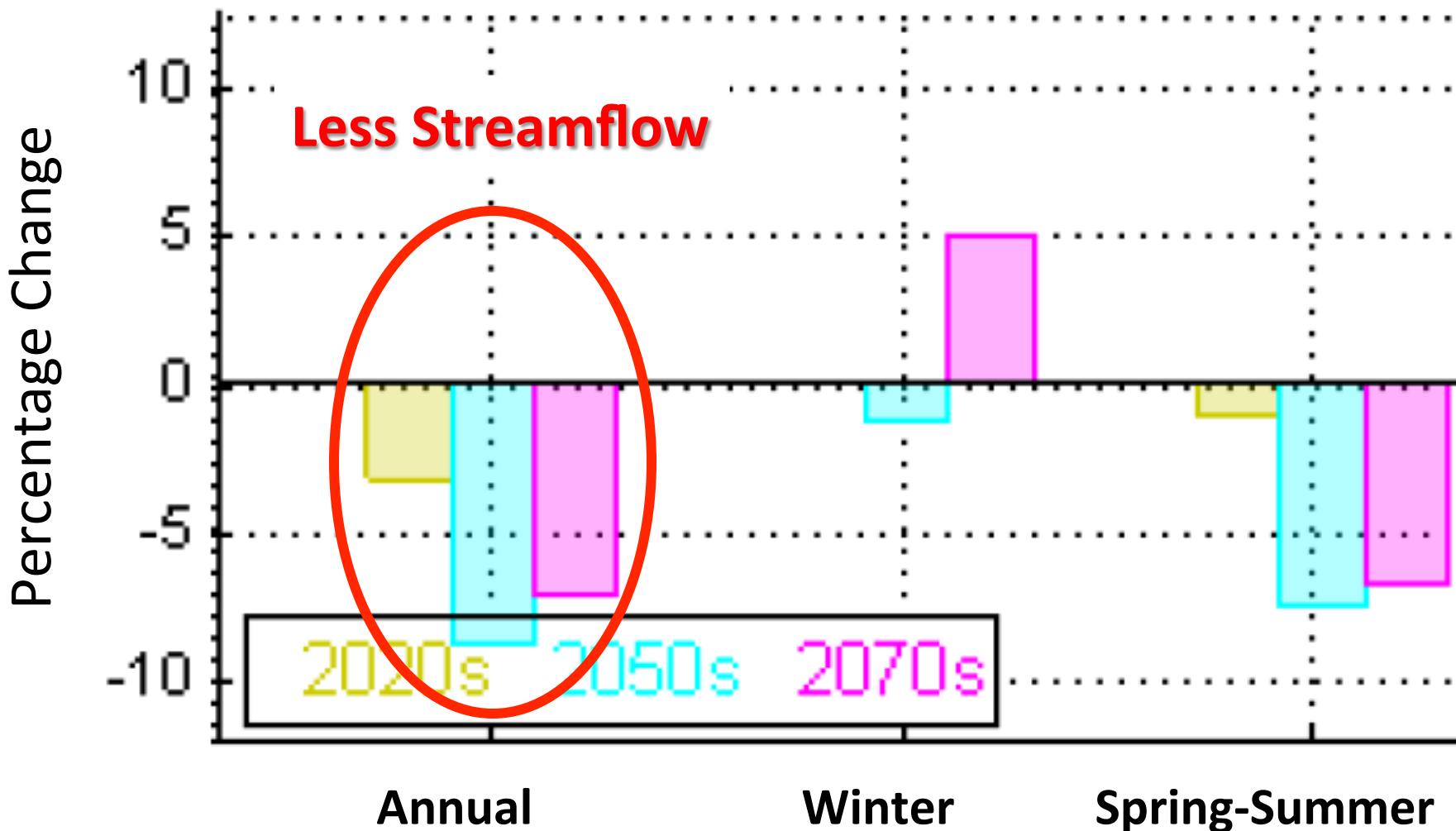


Annual Runoff

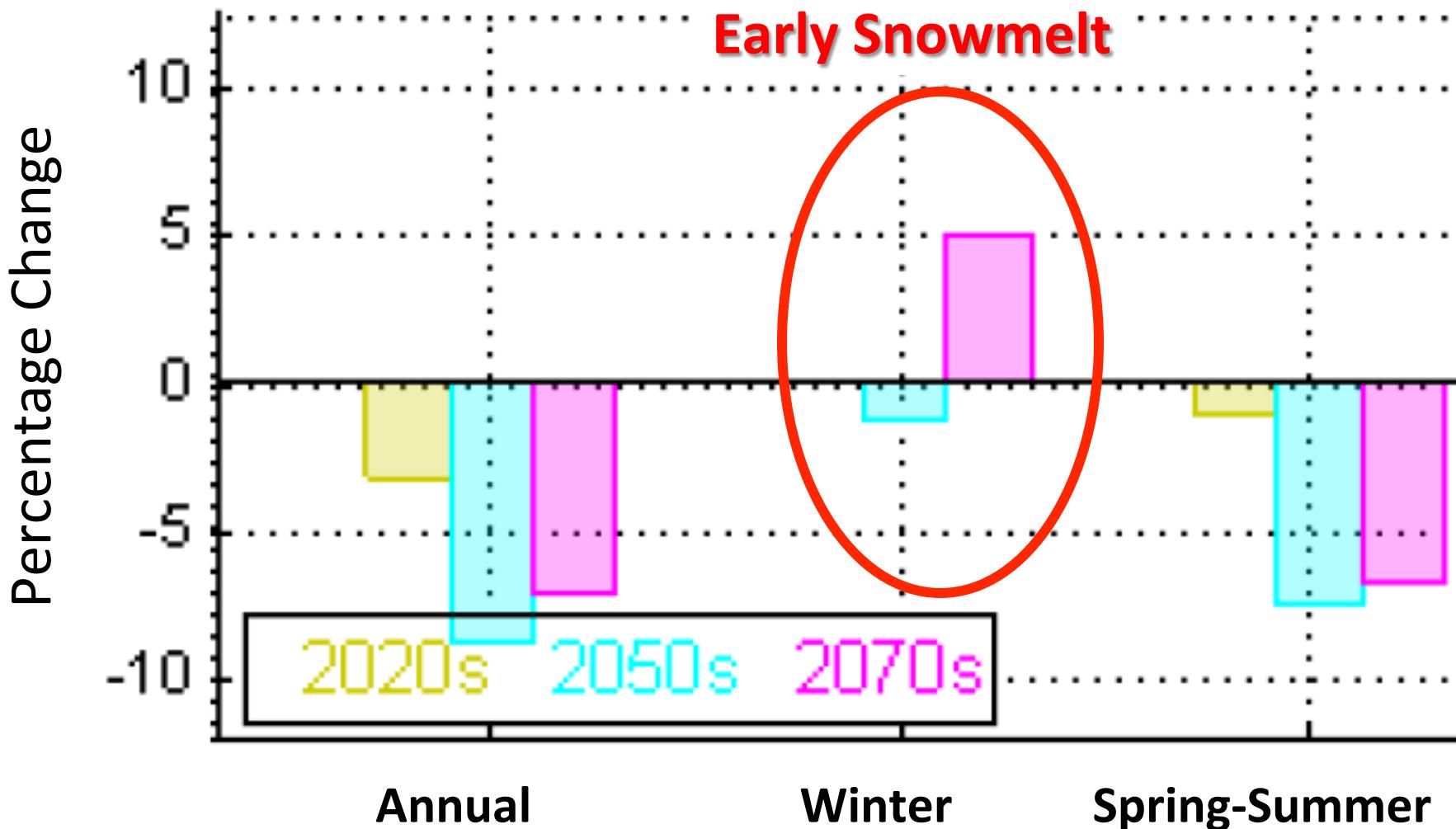


Upper Colorado River Basin

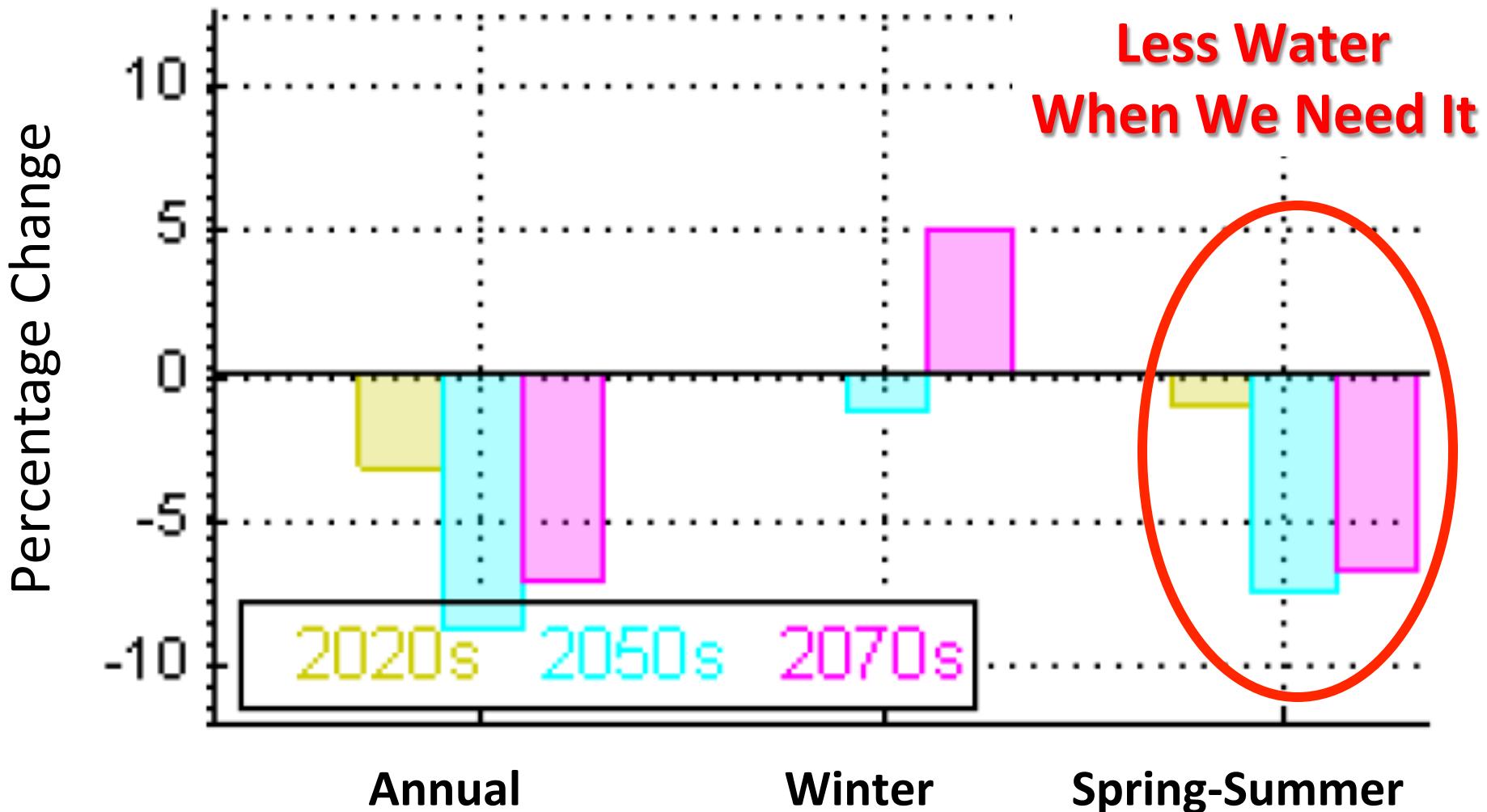
Colorado River at Lees Ferry



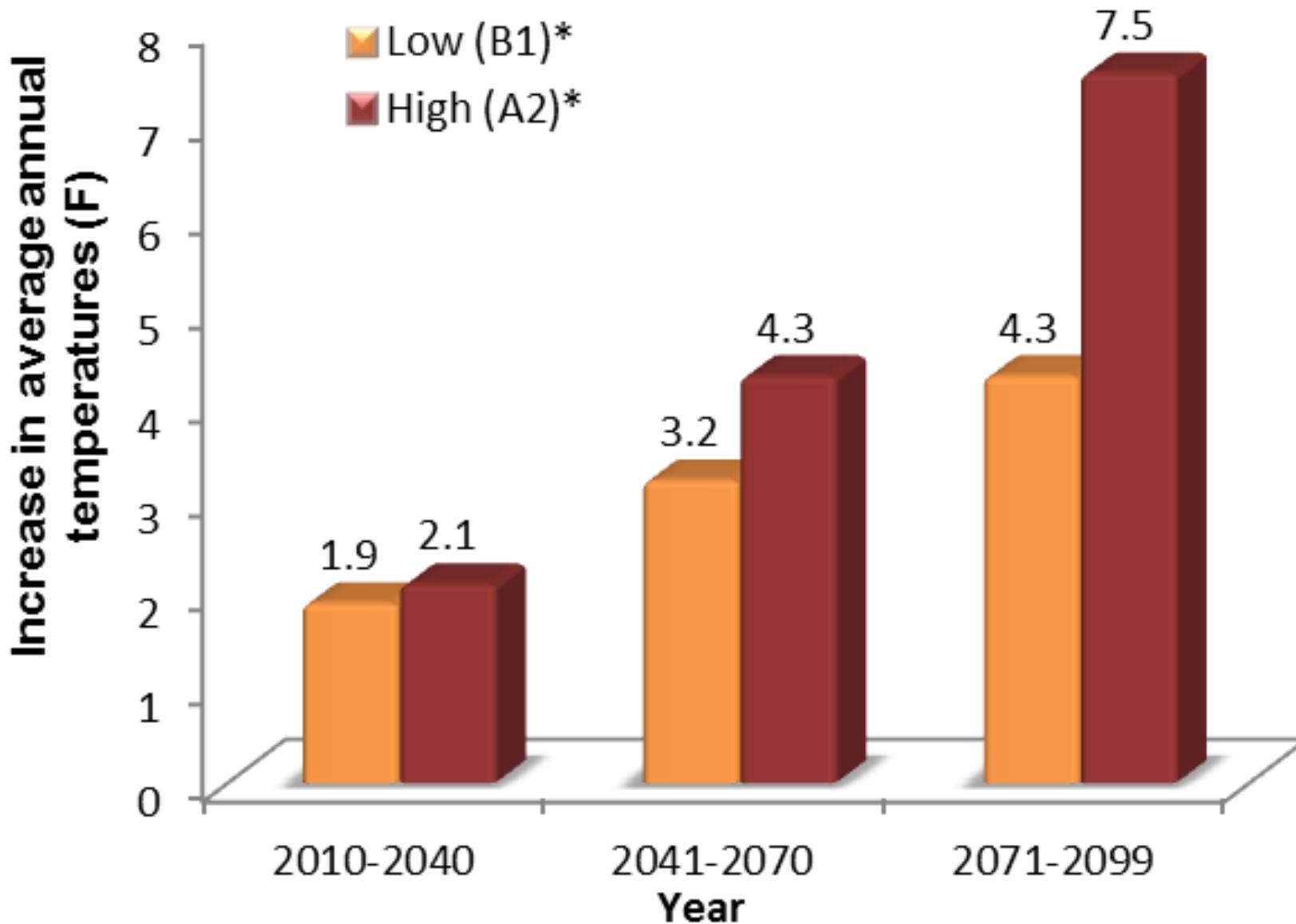
Colorado River at Lees Ferry

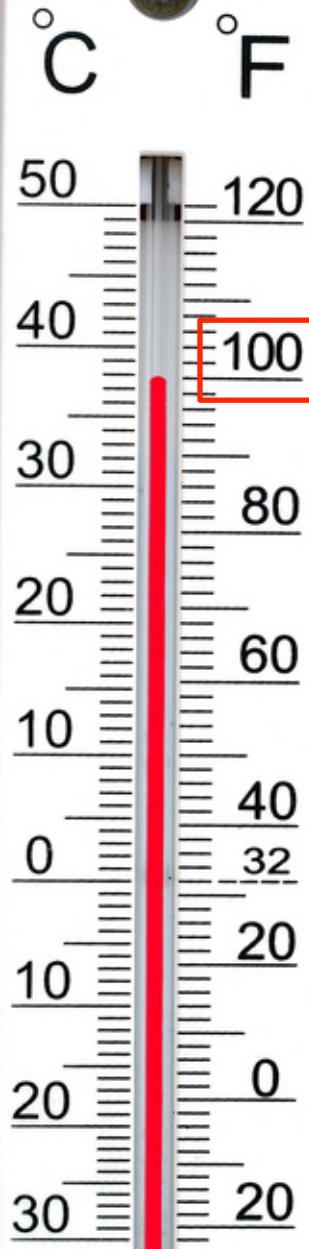


Colorado River at Lees Ferry



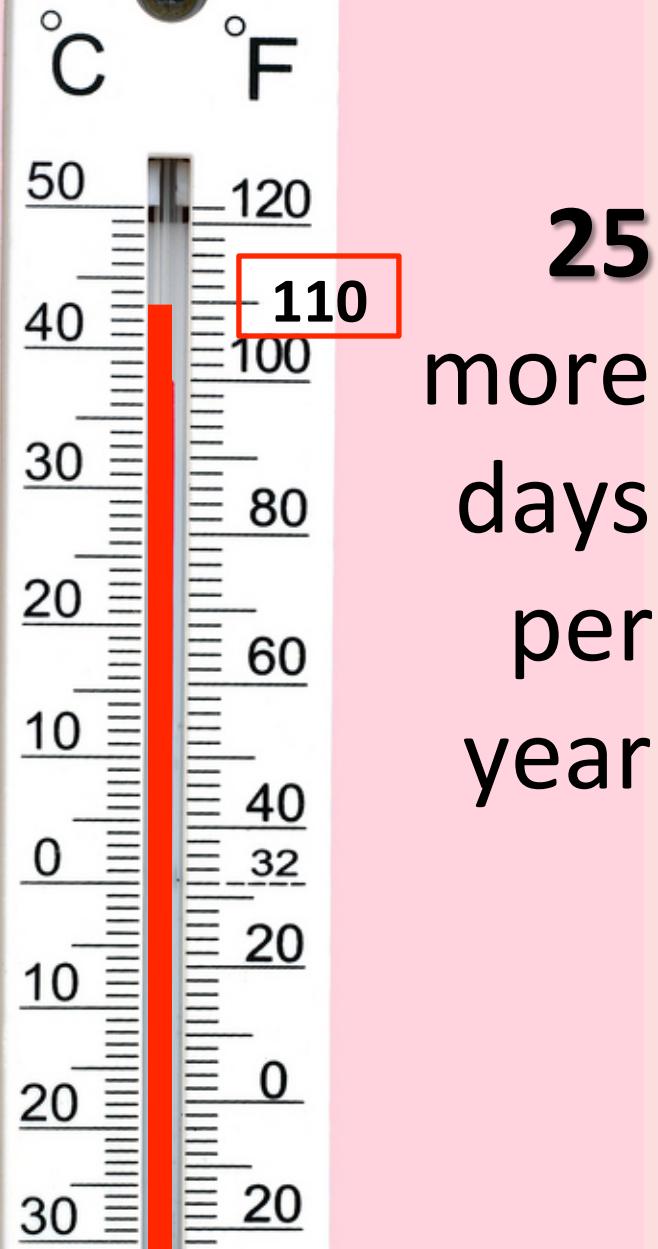
Projected Annual Temperatures in Tucson





34
more
days
per
year

Projected temperature
Extremes for Tucson, AZ
Preliminary analysis by
Carlos Carrillo
and Gregg Garfin,
Univ. of Arizona
Not peer-reviewed



25
more
days
per
year

Max Water Use and Precipitation In Tucson





Towering cumulonimbus clouds

Photograph by Corbis Premium Collection/Alamy

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GEOGRAPHIC

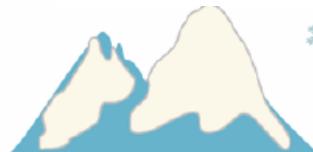
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Temp +



Precipitation +/-

Snow -

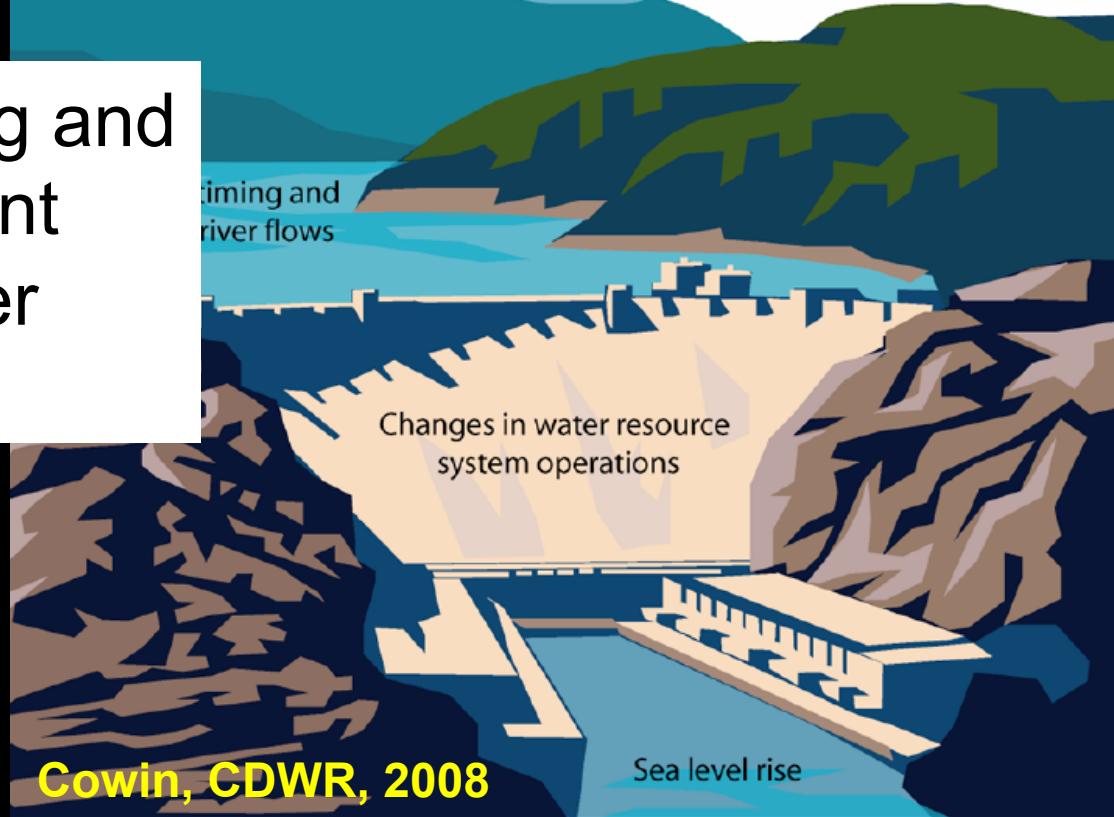


Rain + Snow -



Runoff early

Timing and amount of river flow



Temperature
is a
hydrologic
variable

Southwest Climate Change

southwestclimatechange.org

Land Degradation &... Google Advanced S... UA E-Journals 500 mb Maps Storm... Satellite imagery - ... IPCC WG 3 AR4 Rev... NADM - Great Parna... PORTAL Environme... Other bookmarks

Southwest Climate Change

NET WORK

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SOUTHWEST CLIMATE BLOG

Global Land–Ocean Temperature Index

Why Has Global Temperature Rise Stalled?

March 30, 2012 | Zack Guido | Where has all the heat gone? Eleven of the twelve warmest years on record have occurred since 2000. The average global temperature during this decade has also been the warmest on record, dating back about 130 years. But it... More

Extreme Winter Weather?

March 22, 2012 | Mike Crimmins | Comments

[f](#) [RSS](#) [t](#)

IN THE NEWS

New Southwest Climate Assessment Report Open For Public Review!
Posted March 30, 2012 | Southwest Climate Alliance

Climate Change To Alter the Composition of the Sonoran Desert
Posted March 30, 2012 |

NEW SWCCN BOOKCLUB!

From hacking the planet to adaptation, our next book is [Hot: Living Through the Next Fifty Years on Earth](#) by Mark Hertsgaard. Start reading now and stay tuned for the time and location of the in-person discussion!

(6:13) 11:32 PM 3/30/2012

<http://southwestclimatechange.org/>

Southwest

SW

Climate Assessment



Su
Summary



Ov
Overview

Climate
Variability
& Change

Science &
Society

Ch
Changing
Southwest

We
Weather
& Climate

A photograph of dry, cracked earth.

EV
Evolving
Weather

Impacts &
Vulnerabilities

Fu
Future
Southwest

Ex
Climate
Extremes

Ec
Natural
Ecosystems

Trends in
Climate

A coastal scene showing a rocky shoreline and a body of water.

Co
Coastal
Issues

A photograph of a winding river or stream flowing through a dry, brown landscape.

Wa
Water
Impacts

Mitigation &
Adaptation
Plans

Ag
Agriculture &
Ranching

En
Energy
Impacts

Ur
Urban
Areas

Climate
Scenarios
of the
Future

A photograph of a busy highway with many cars in traffic.

Tr
Transportation
and
Infrastructure

A photograph of a large, dense cloud of dust or smoke.

He
Health
Effects

Bo
Border
Communities

Research
Strategies

A photograph of a desert landscape featuring large rock formations.

A photograph of a mountain range with green vegetation in the foreground.

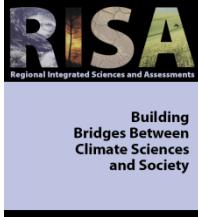
St
Sustainable
Southwest

A photograph of a road with a yellow "CHANGE AHEAD" sign.

Mv
Moving
Forward

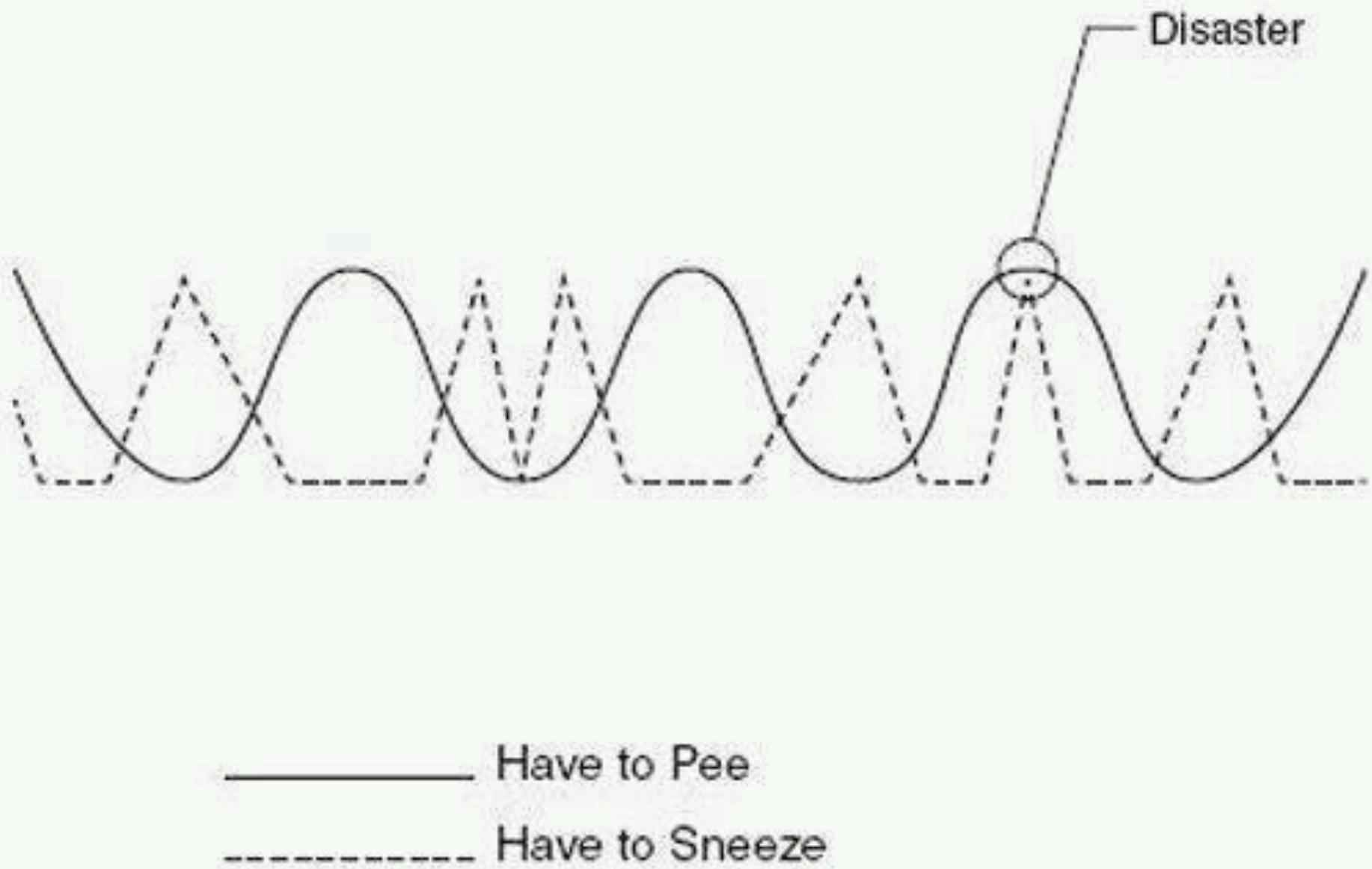
A photograph of a road with a yellow "CHANGE AHEAD" sign.

Un
Addressing
Uncertainty



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The University of Arizona
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520-626-4372



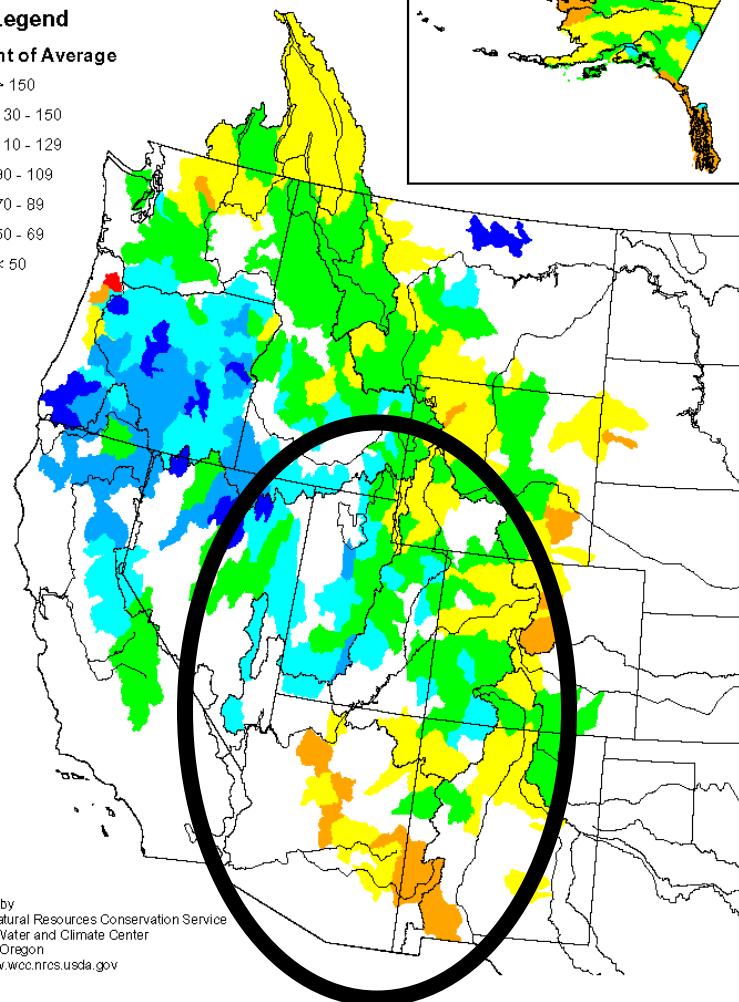


Mountain Snowpack as of March 1, 2004

Legend

Percent of Average

- > 150
- 130 - 150
- 110 - 129
- 90 - 109
- 70 - 89
- 50 - 69
- < 50



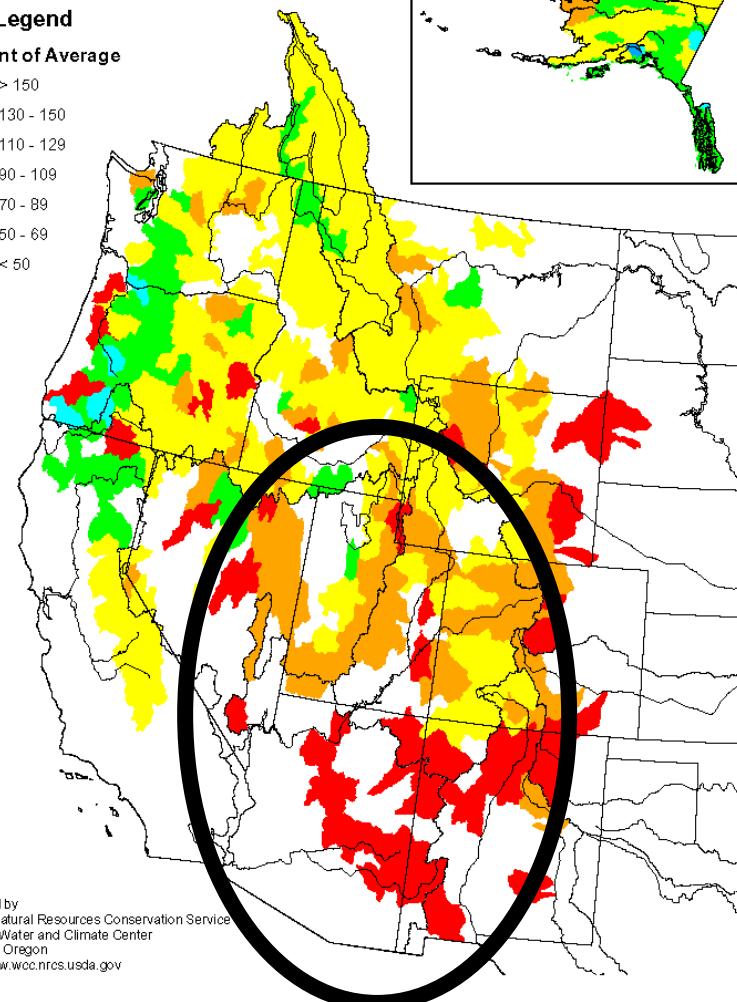
Prepared by
USDA, Natural Resources Conservation Service
National Water and Climate Center
Portland, Oregon
<http://www.wcc.nrcs.usda.gov>

Mountain Snowpack as of April 1, 2004

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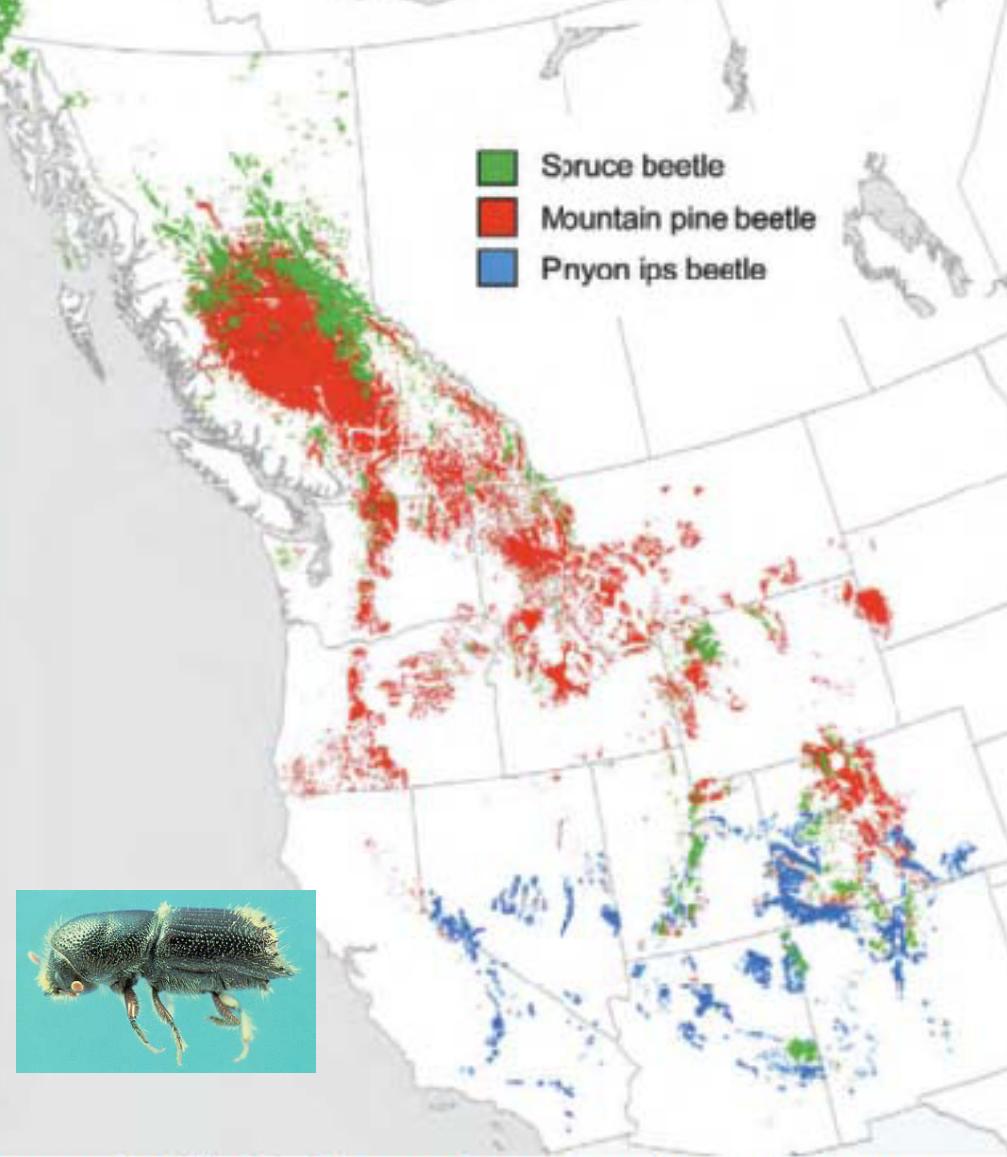
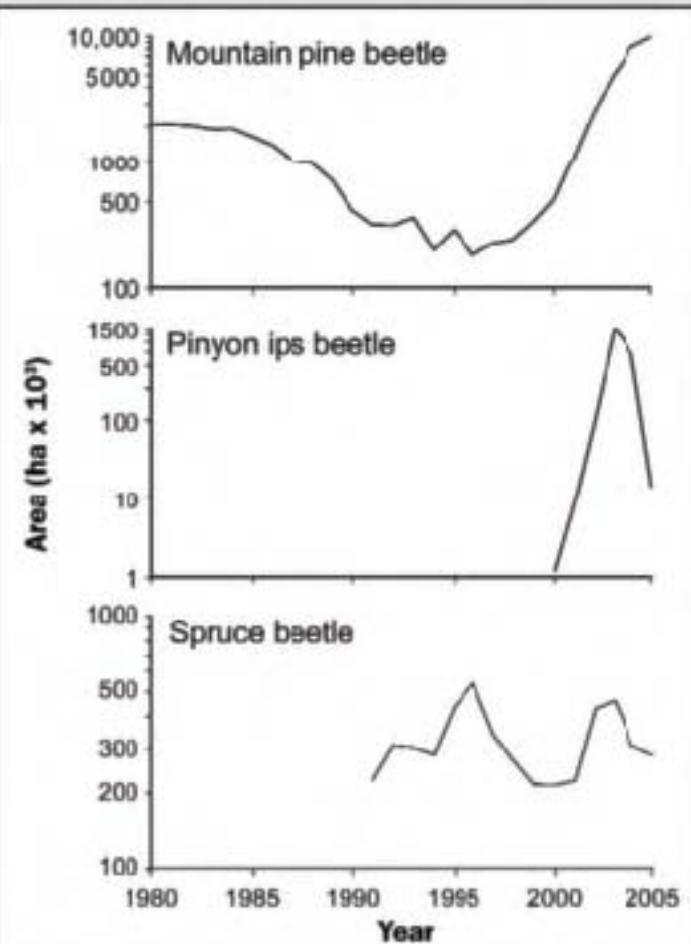


Prepared by
USDA, Natural Resources Conservation Service
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Losses of 30-60% Snow Water Equivalent

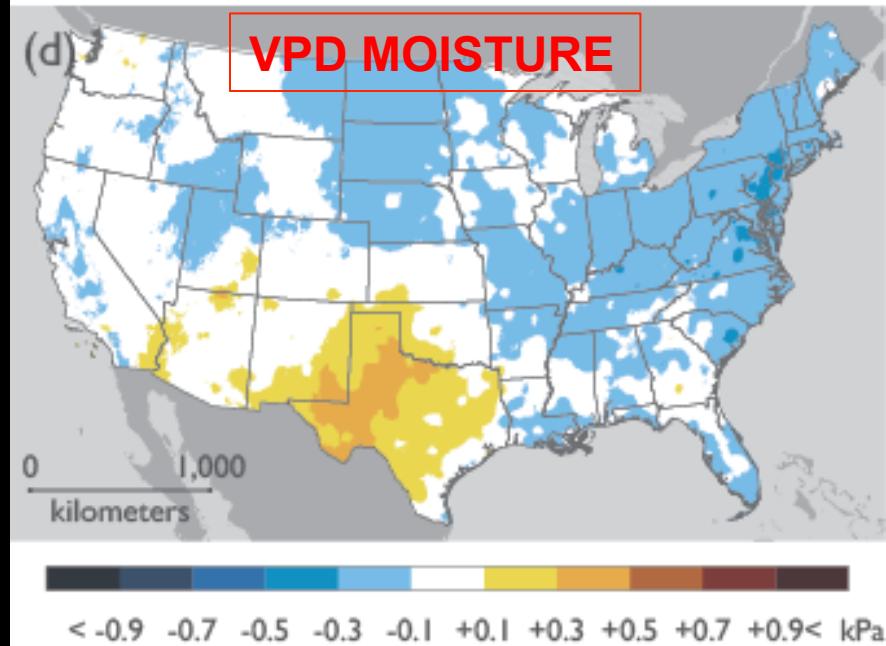
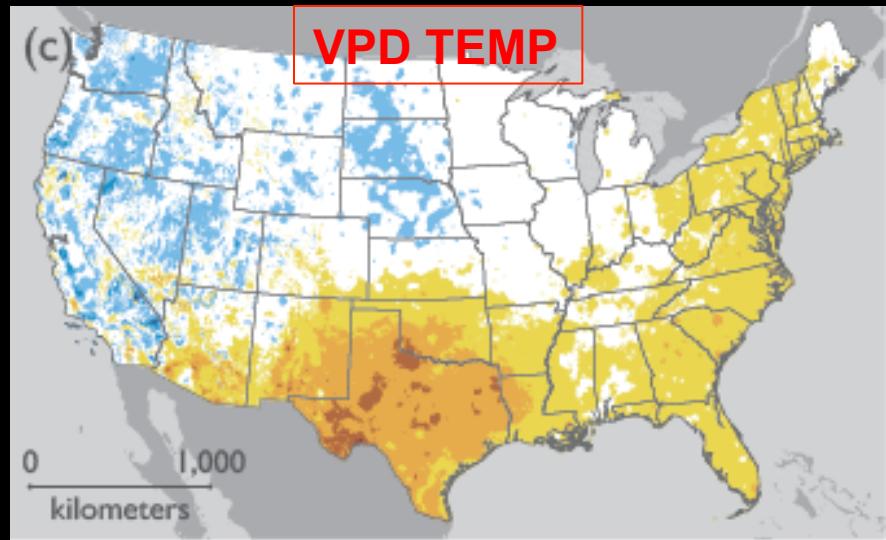
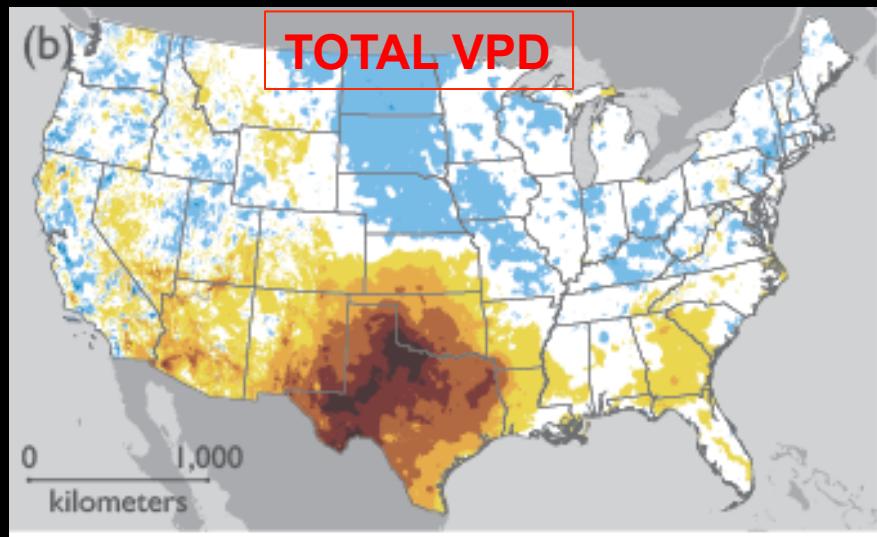
USDA-NRCS National Water and Climate Center

<http://www.wcc.nrcs.usda.gov/wsf/>

b

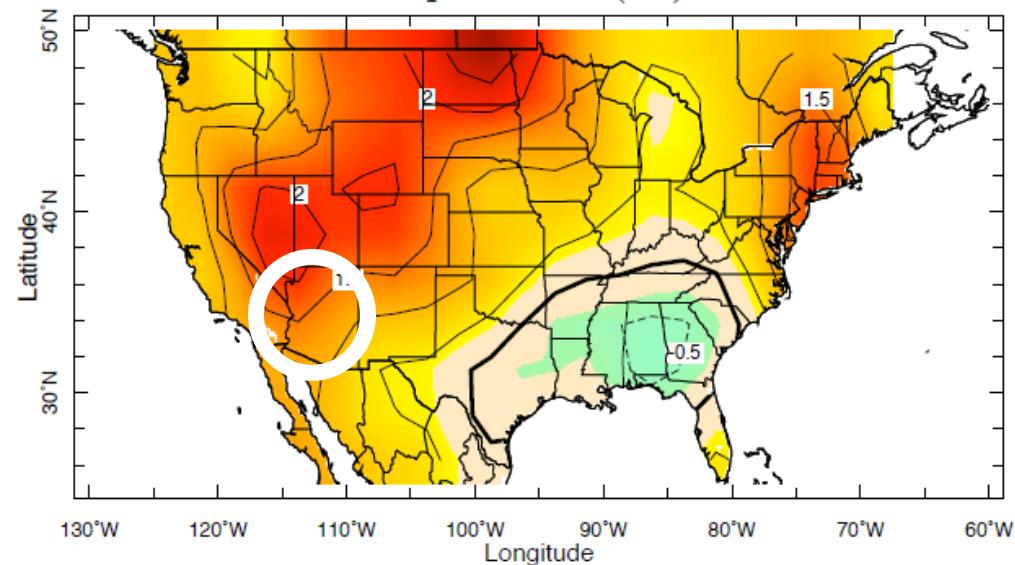
Raffa et al., 2008

Hotter Means Drier: 2011 Drought

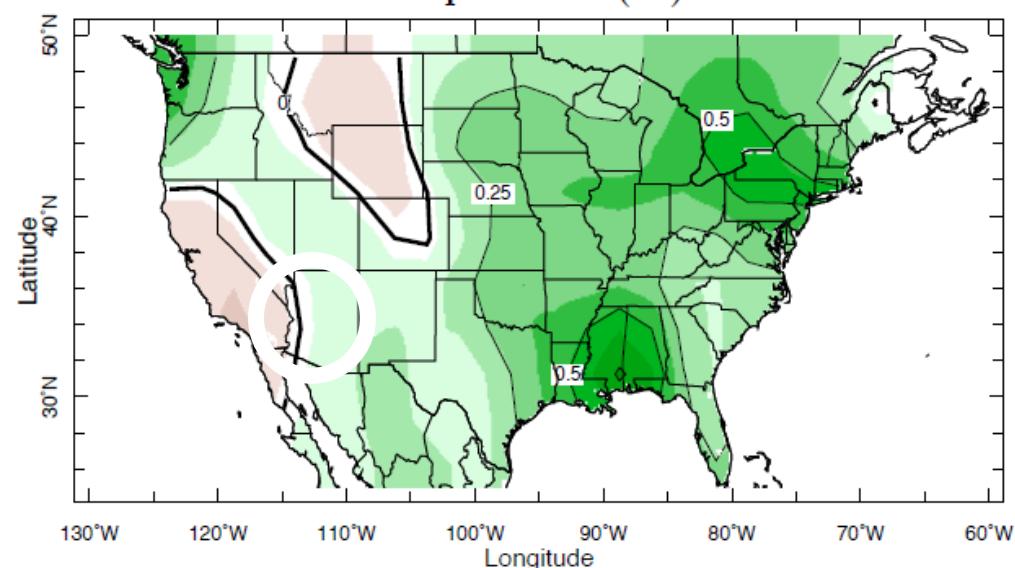


Analysis courtesy of Jeremy Weiss, Jonathon Overpeck, and Julie Cole, Univ. AZ, 2012

Temperature (°F)



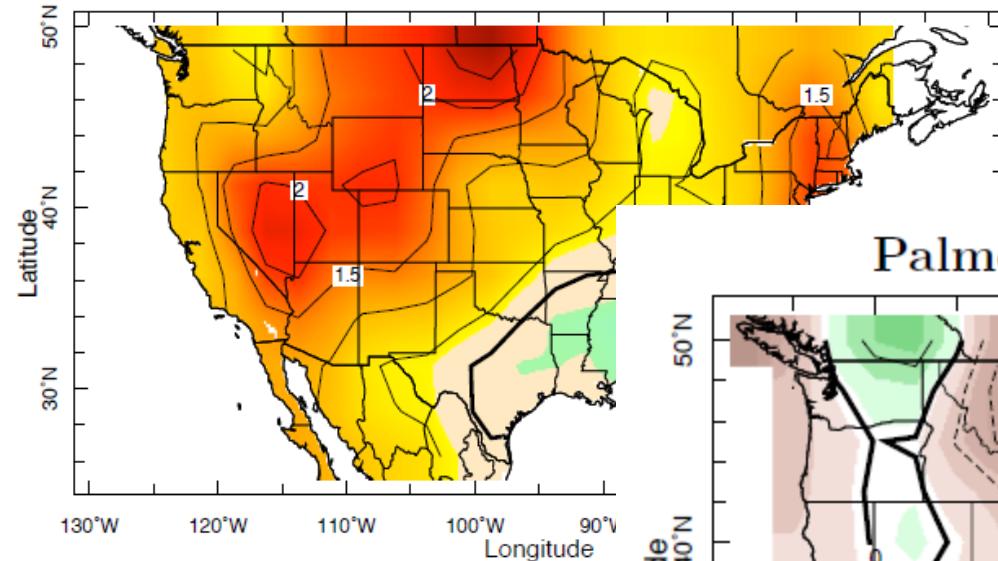
Precipitation (in)



Trend Since 1895

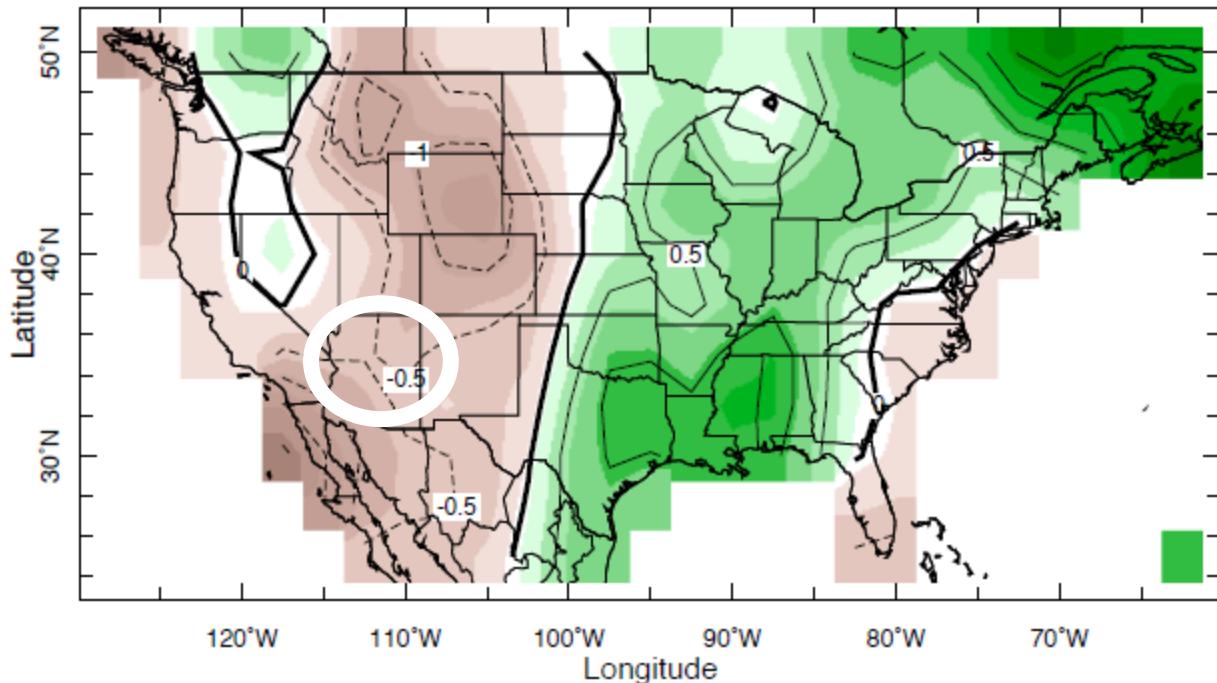
R. Seager (presented at WGA Drought Workshop, September, 2010) Check
<http://www.westgov.org/water> for PDF

Temperature (°F)

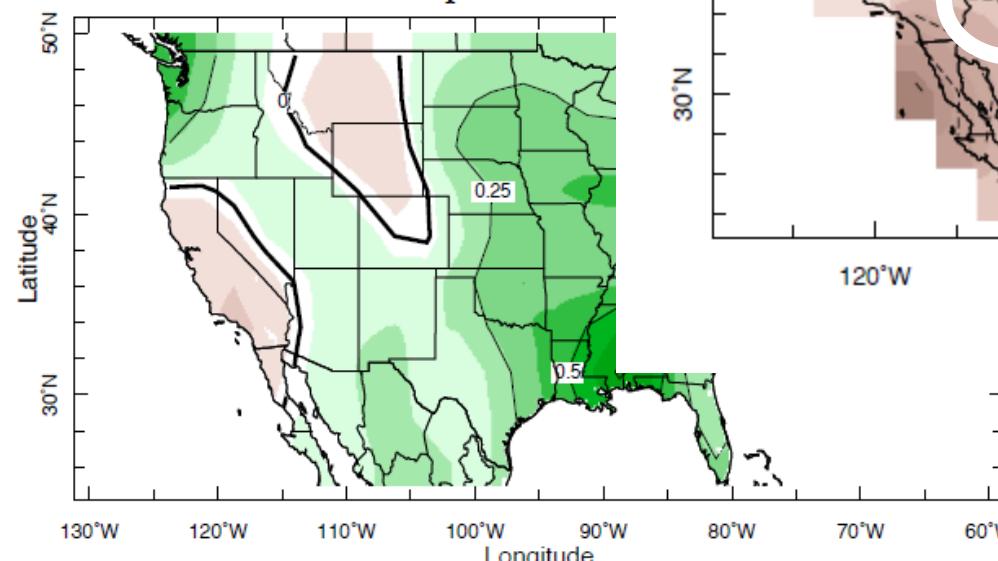


Trend Since 1895

Palmer Drought Severity Index



Precipitation



R. Seager (presented at WGA Drought Workshop, September, 2010) Check <http://www.westgov.org/water> for PDF

