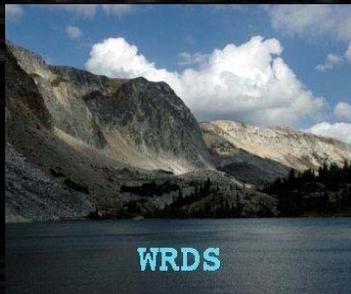


# *Climate Change and Potential Impacts on Western Rivers*

Stephen Gray

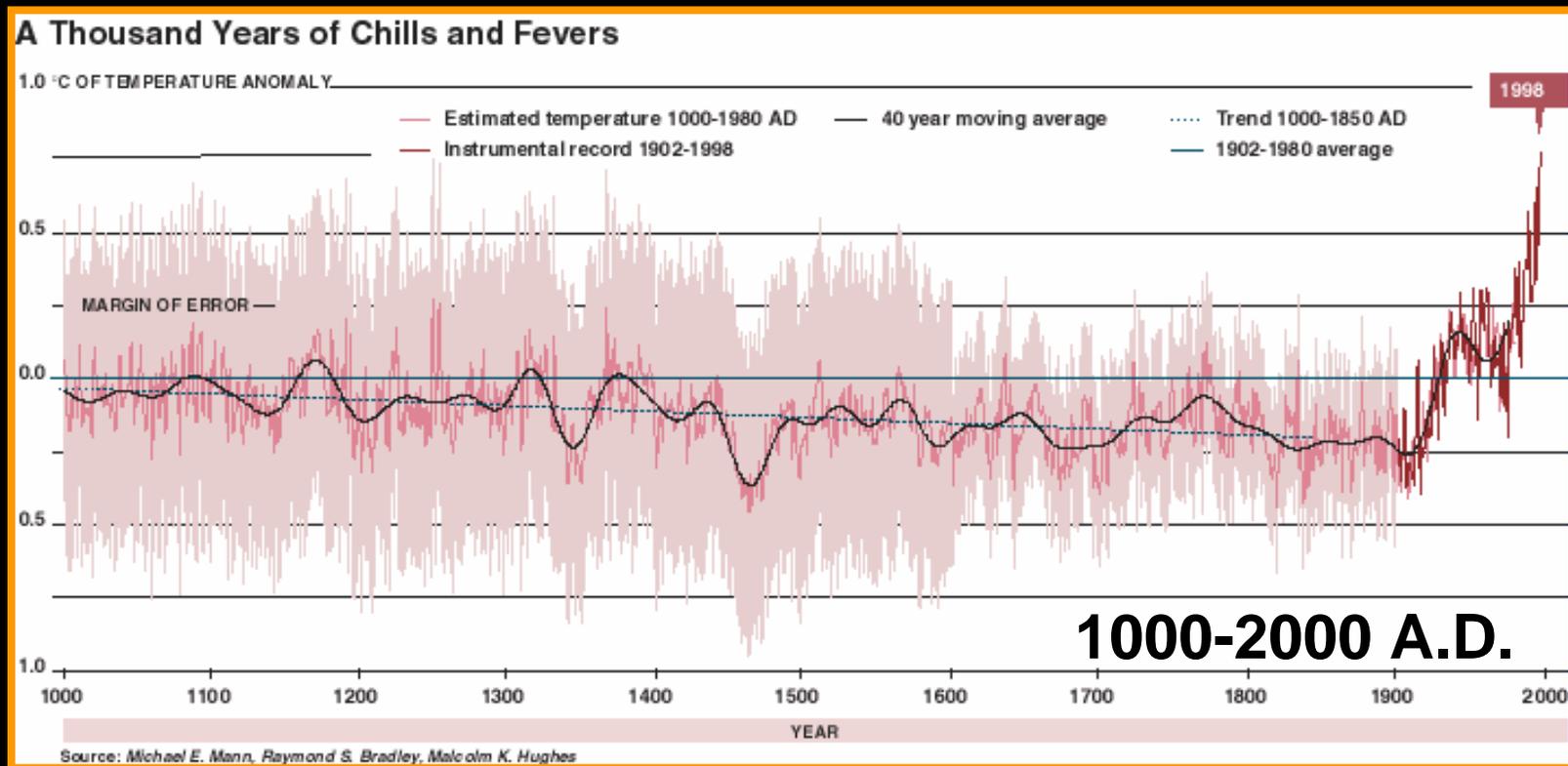
*Wyoming Water Resources  
Data System and Wyoming  
State Climate Office  
University of Wyoming*



# Today's Talk

- Brief review of current science related to the regional impacts of climate change
- Examples of how small changes in climate could have huge impacts water
- Suggestions on future directions for research and policy

# Global Temperature Trends:



Global Average Temperatures have increased by  $>1.0^{\circ}$  over the 20<sup>th</sup> century

# The evidence that the climate is changing *at an unprecedented rate* is incontrovertible and overwhelming

Rising temperatures

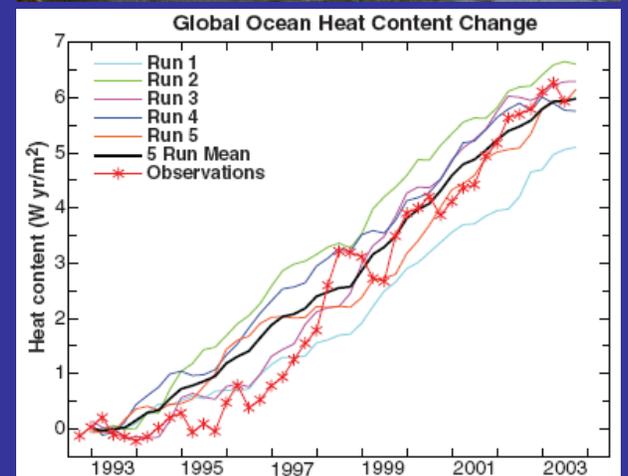
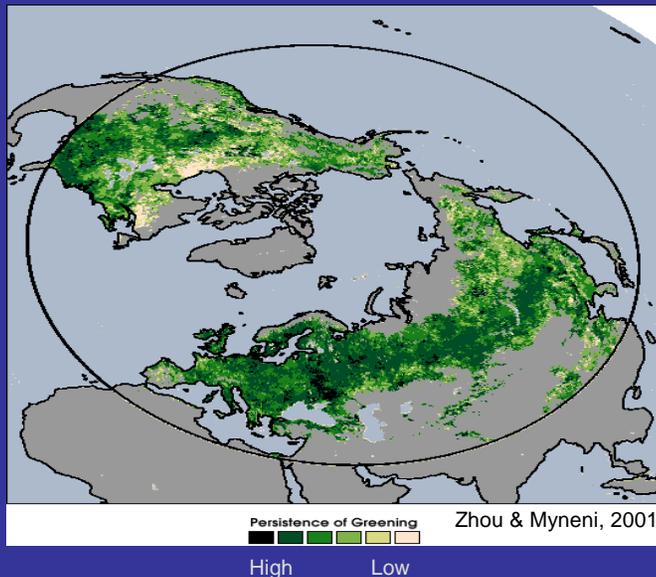
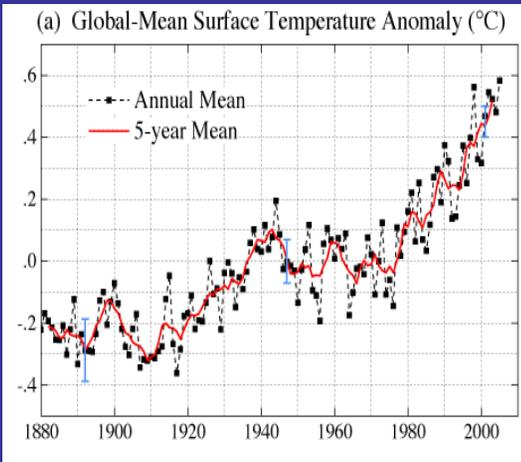
Melting glaciers and sea ice

Rising sea level

Shifting ecological zones

Thawing permafrost

Increasing heat content of ocean water



FROM THE DIRECTOR OF INDEPENDENCE DAY

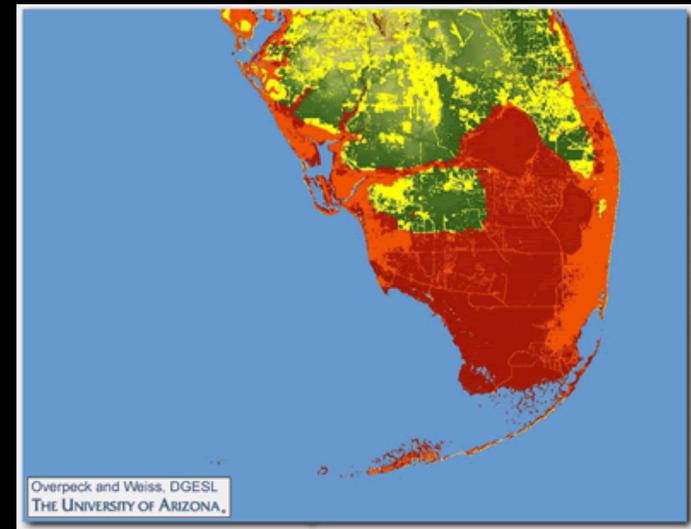
# THE DAY AFTER TOMORROW

MAY 28 WHERE WILL YOU BE?

# Global Climate Change?



**Fact or Fiction:**  
Climate change will have  
the greatest impacts in  
other parts of the world



A photograph of a duck swimming in blue water, with its reflection visible below. The duck is dark-colored with a lighter patch on its neck. The water is a deep blue with some ripples.

## I. What we know...

- Multiple factors make water resources in the western US highly sensitive to climatic change (natural or otherwise)

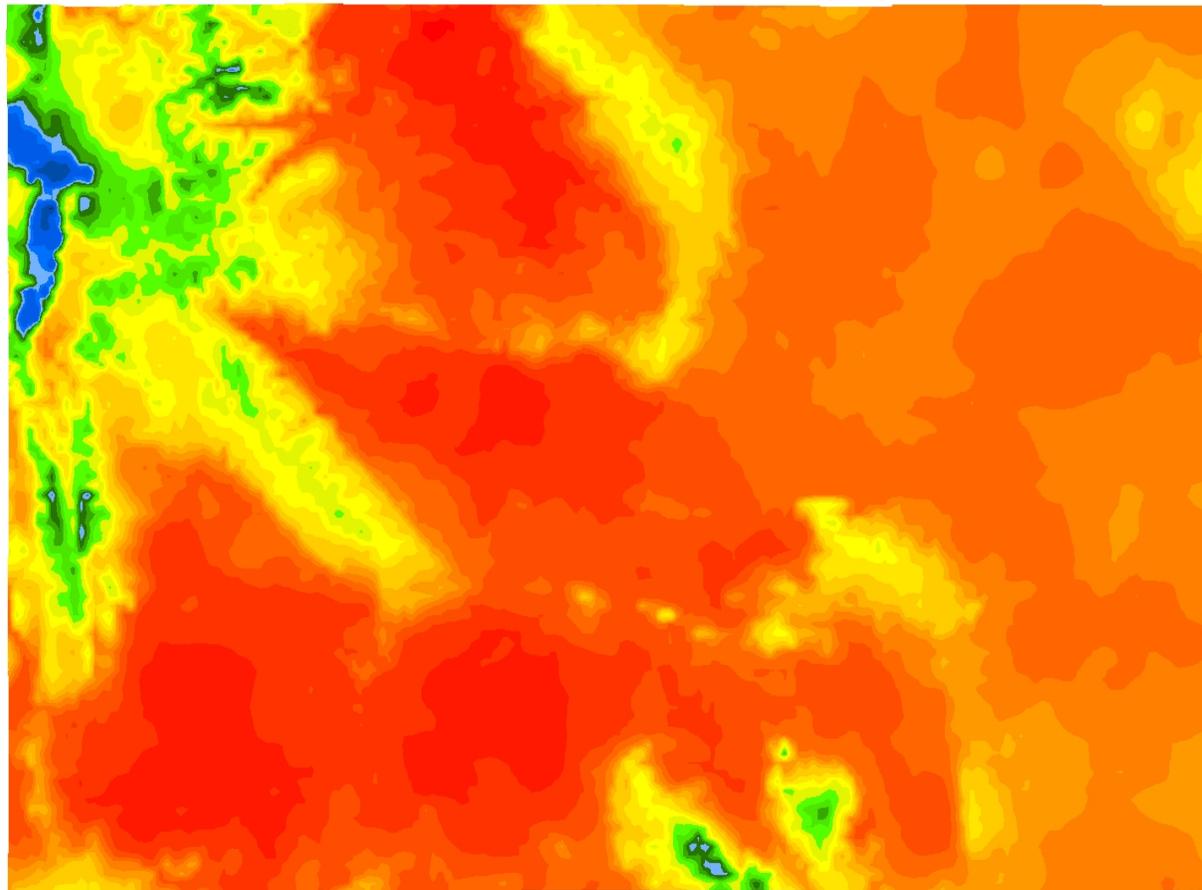
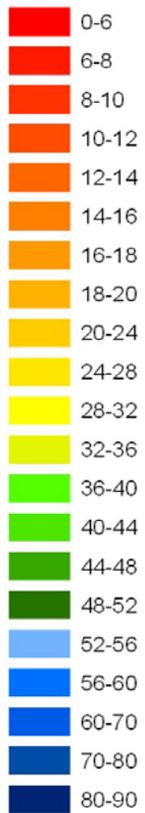
# Vulnerability #1

The West's Desert Climate



# Wyoming Average Annual Precipitation: 1961-1990

Average Annual  
Precipitation  
(inches)



Source: NRCS <http://www.ncgc.nrcs.usda.gov/products/datasets/climate/data/index.html>

## **Wyoming: Areas with < 16" Annual Precipitation**



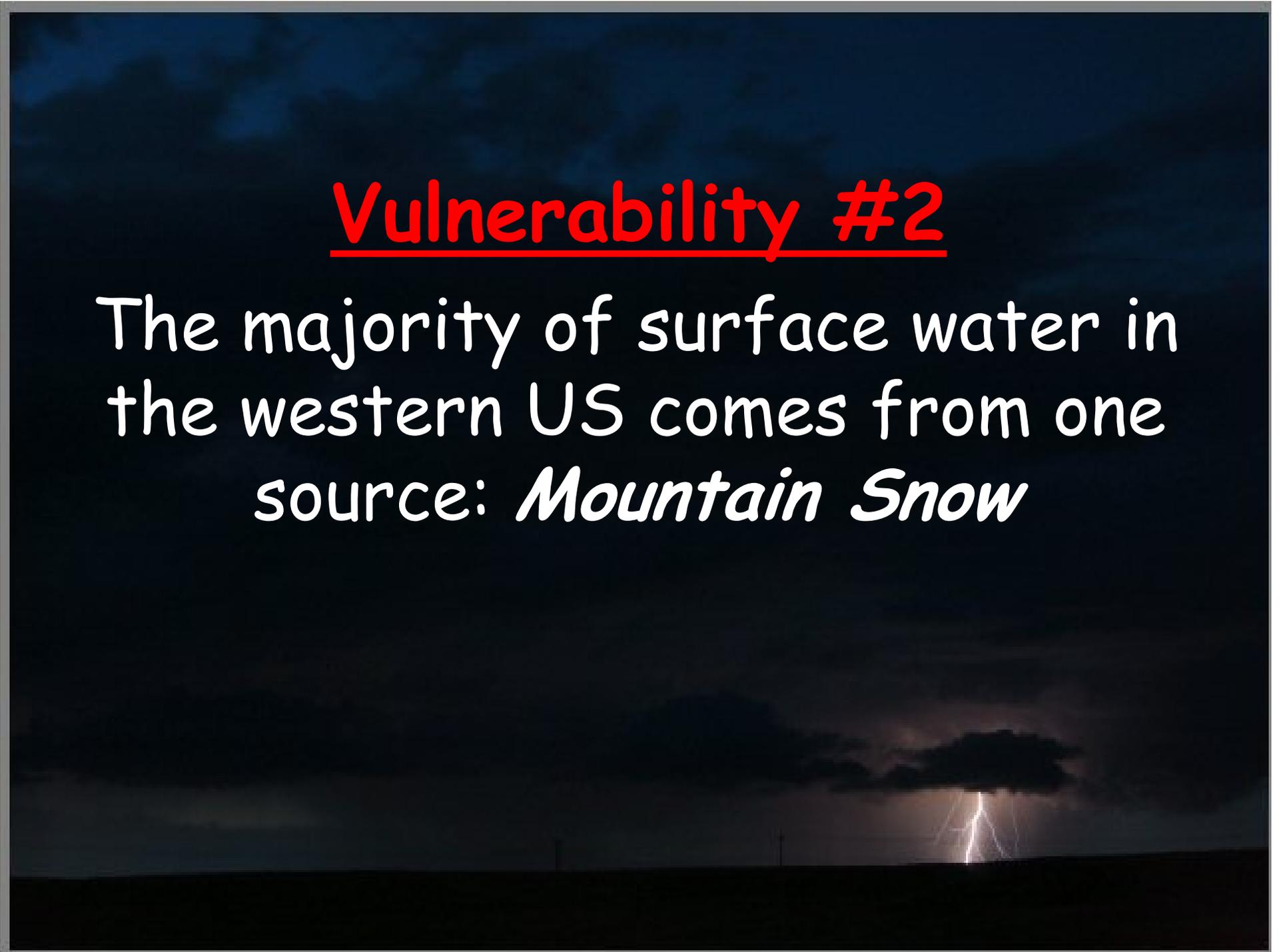
***71% of Wyoming averages less than 16" of precipitation each year***

# Wyoming: 5<sup>th</sup> Driest in the United States

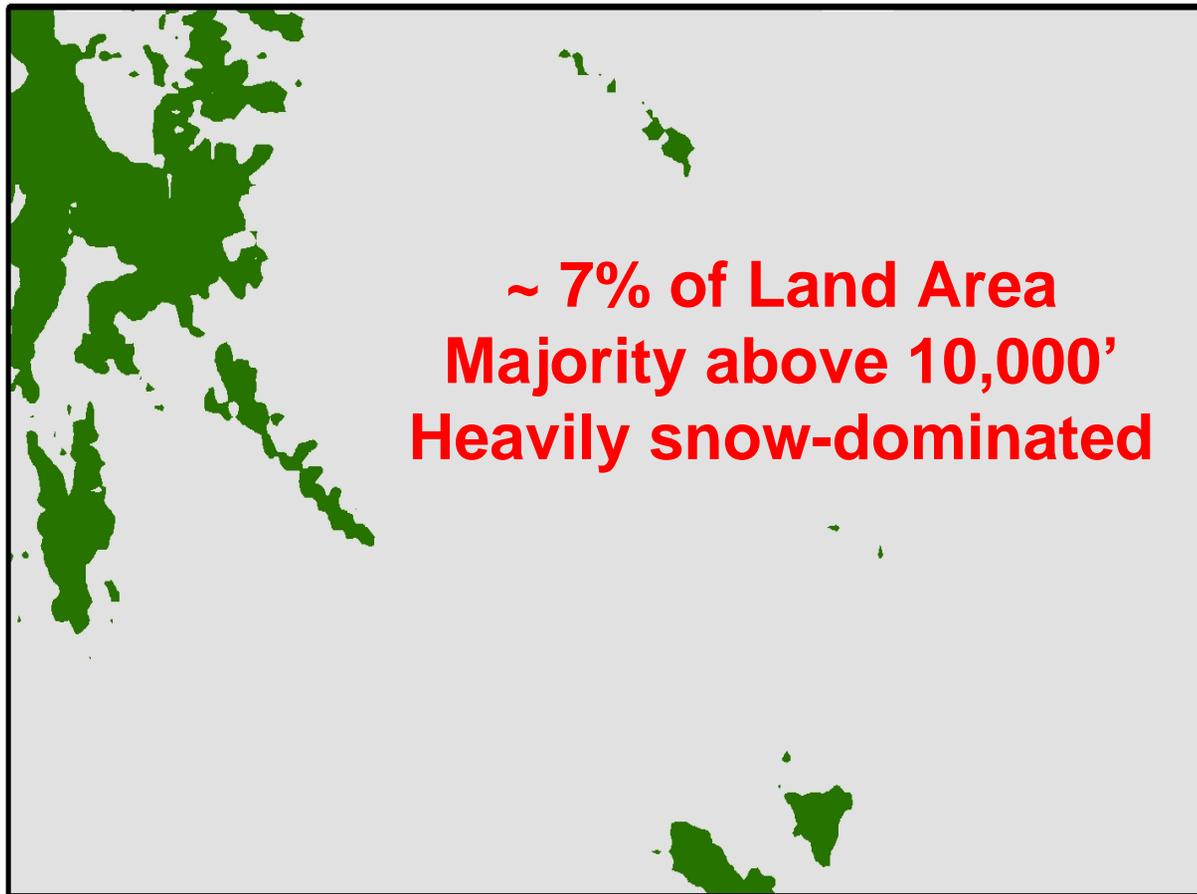
<u>STATE</u>	<u>Rank</u>	<u>Ann PPT</u>
Nevada	1	10.68"
Arizona	2	13.13
Utah	3	13.90
New Mexico	4	14.93
<b>Wyoming</b>	<b>5</b>	<b>16.84</b>
<b>National Average</b>		<b>37.74</b>

## Vulnerability #2

The majority of surface water in the western US comes from one source: *Mountain Snow*



## Wyoming: Areas with > 32" Annual Precipitation



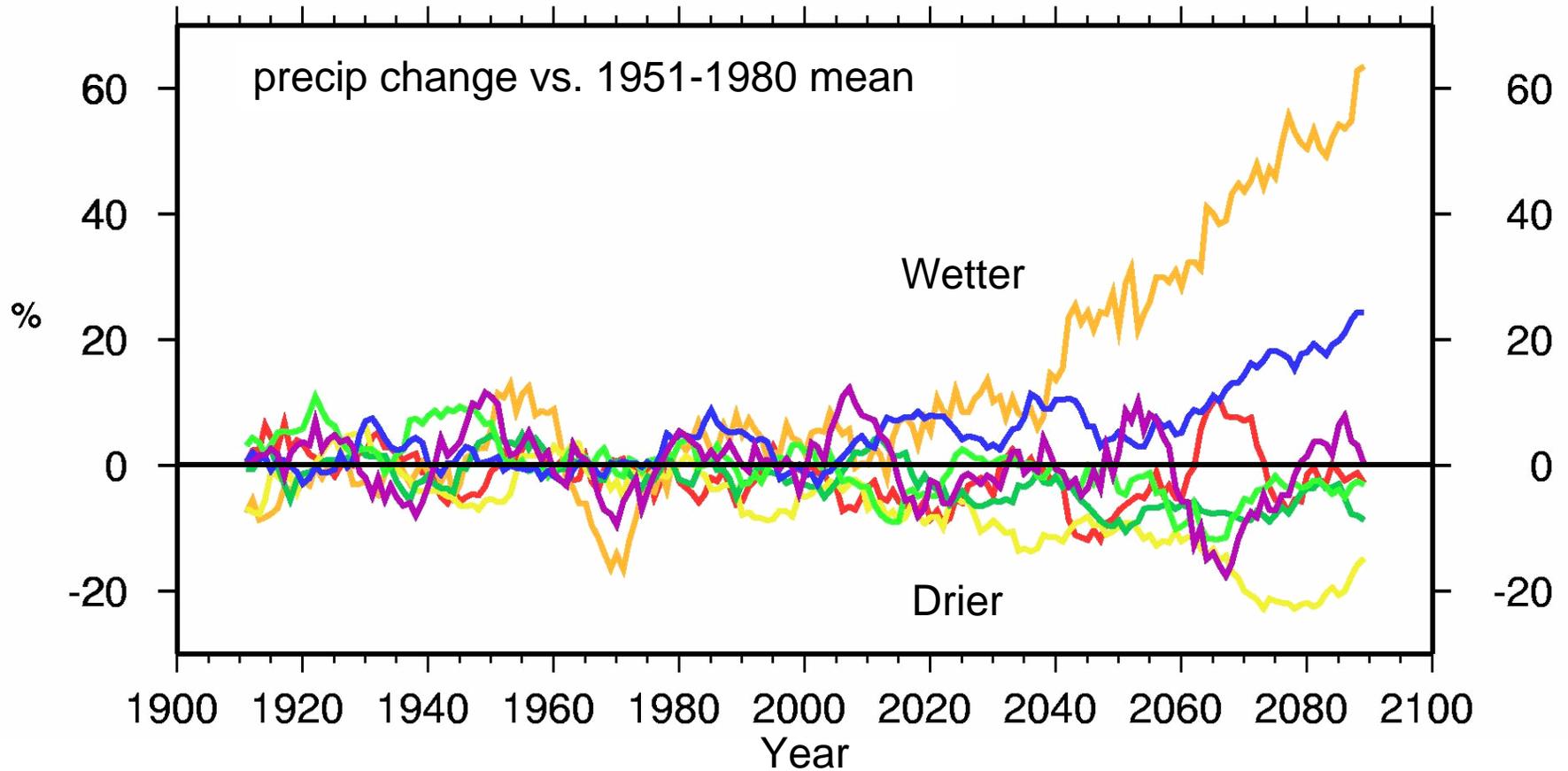
*A very small percentage of Wyoming's land area is responsible for the majority of run-off*



## II. What we know...

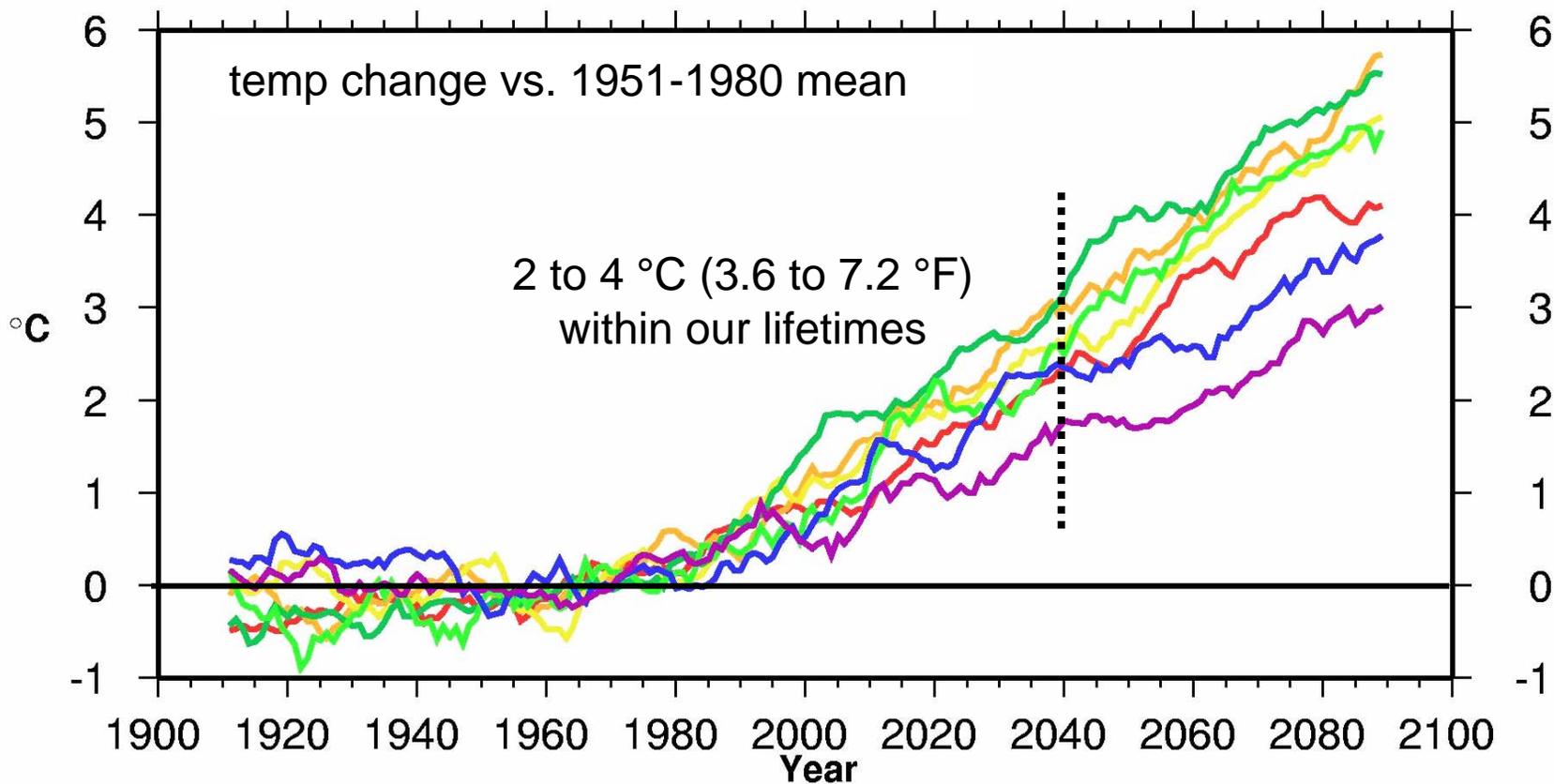
- Some regional-scale effects of global climate change are very difficult to predict
- However, we know enough now to start planning for the future
- Many actions that protect us from the likely impacts of human-caused climate change will also make us more resistant to drought and other forms of natural climate variability

Predictions for future climate in the **Western United States**  
Based on regionalized output from seven leading climate models



***No consensus on future precipitation trends!***

Predictions for future climate in the **Western United States**  
Based on regionalized output from seven leading climate models



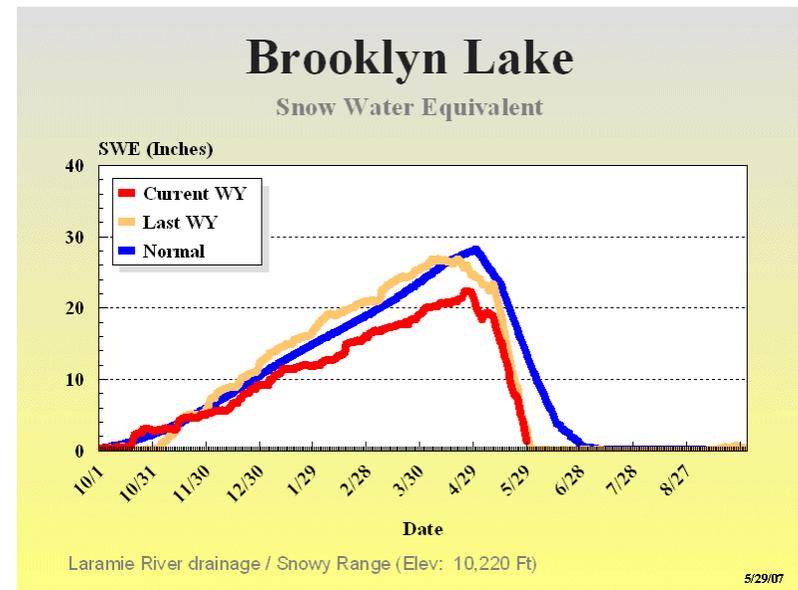
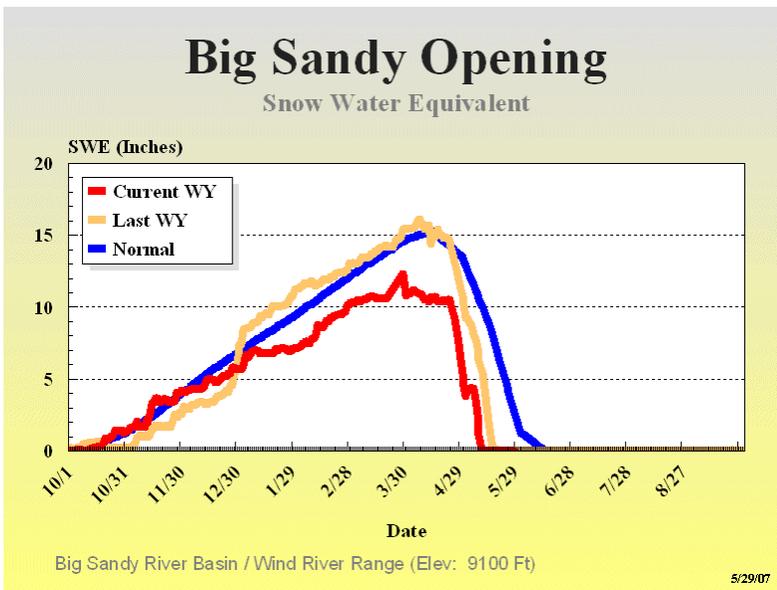
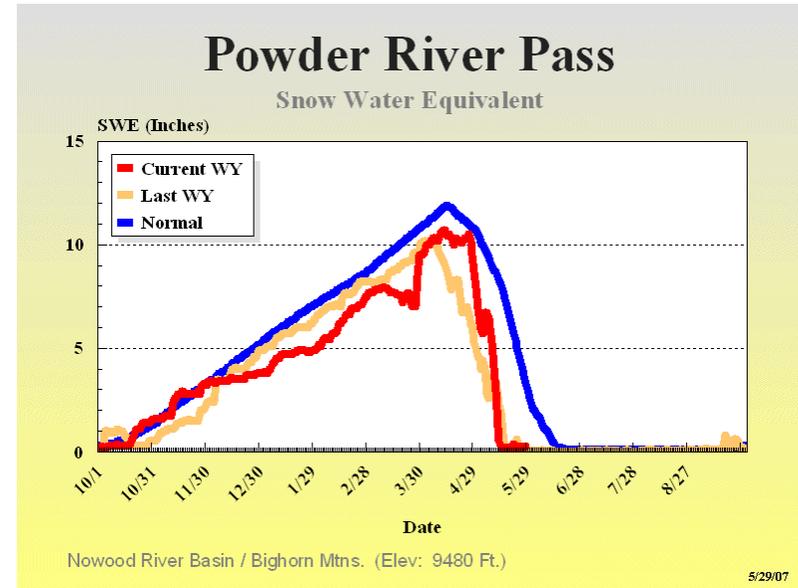
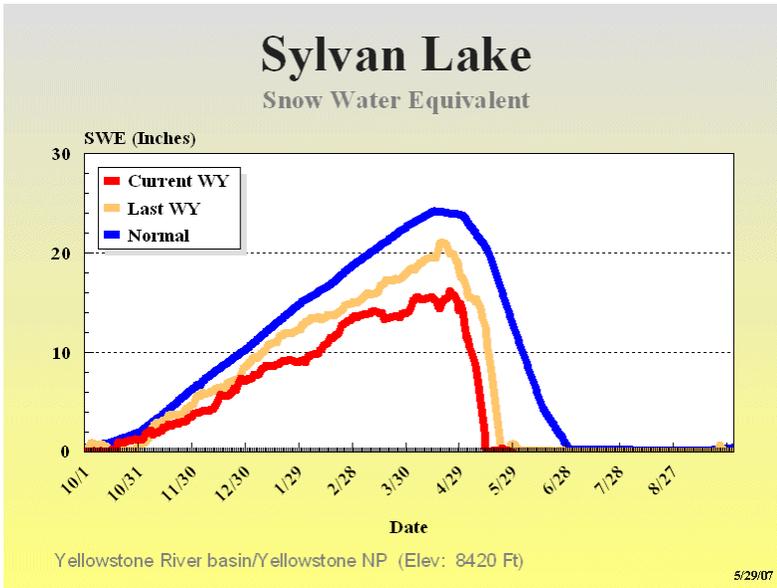
**All assessments agree — the West will be WARMER!**

# Small Warming, Big Changes

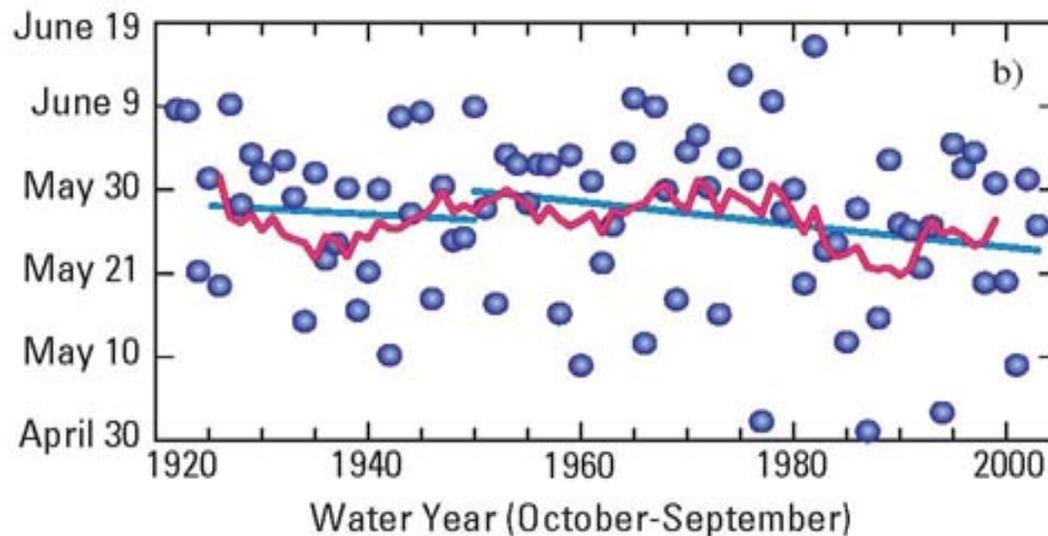
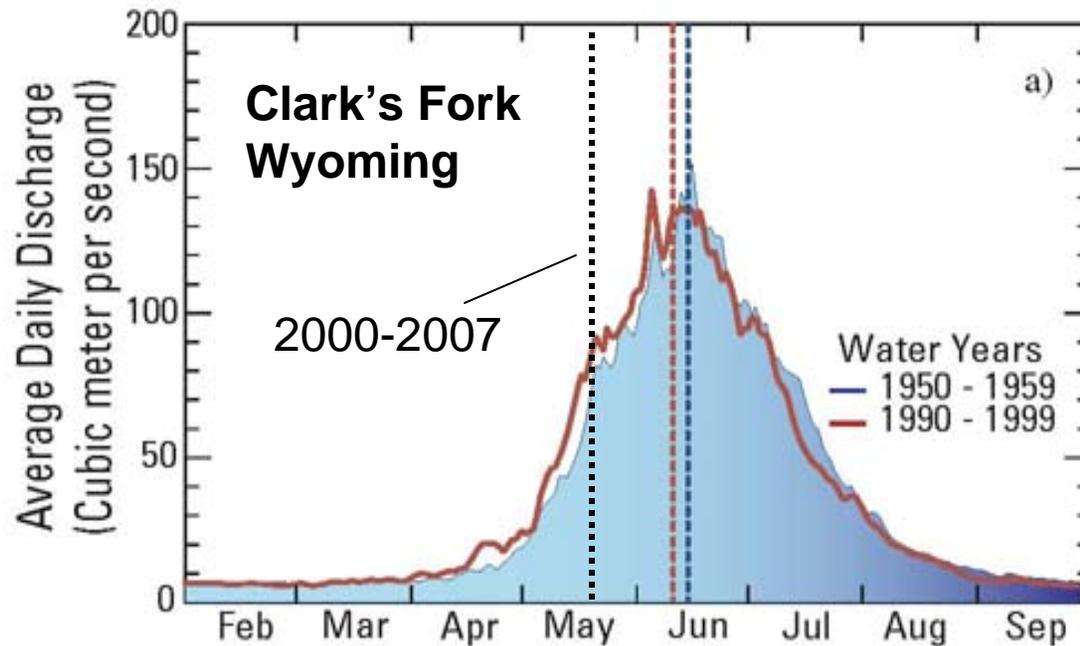
- Small increases in regional temperature would have major consequences for Wyoming's water resources, even in the absence of major precipitation change



# 2007: Melt-out Comes 4 to 8 Weeks Early



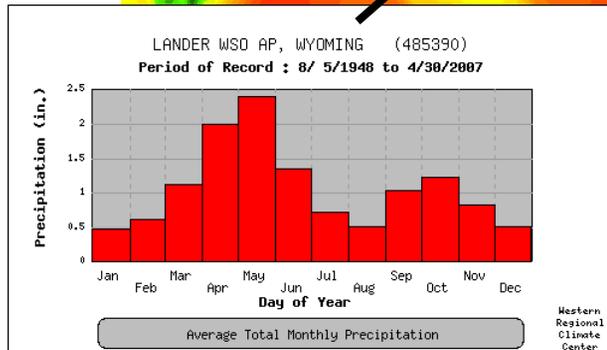
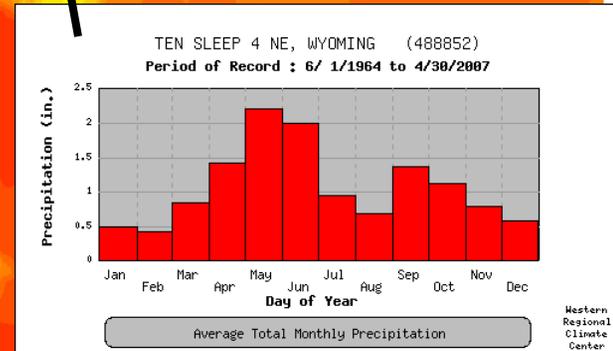
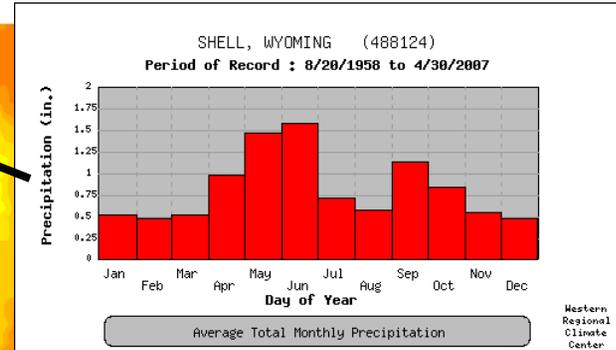
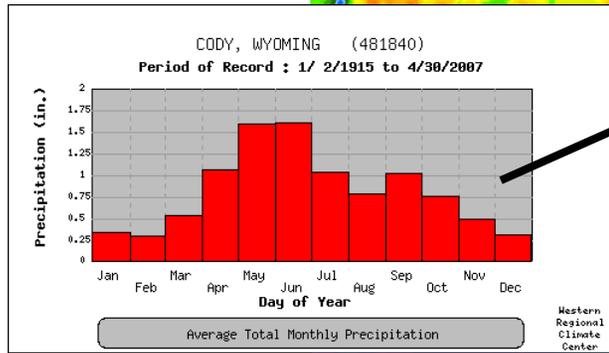
# Warming and the shifting hydrograph



## Consequences:

- Earlier run-off
- Faster run-off
- Diminished late-season flow
- Increased Evaporation

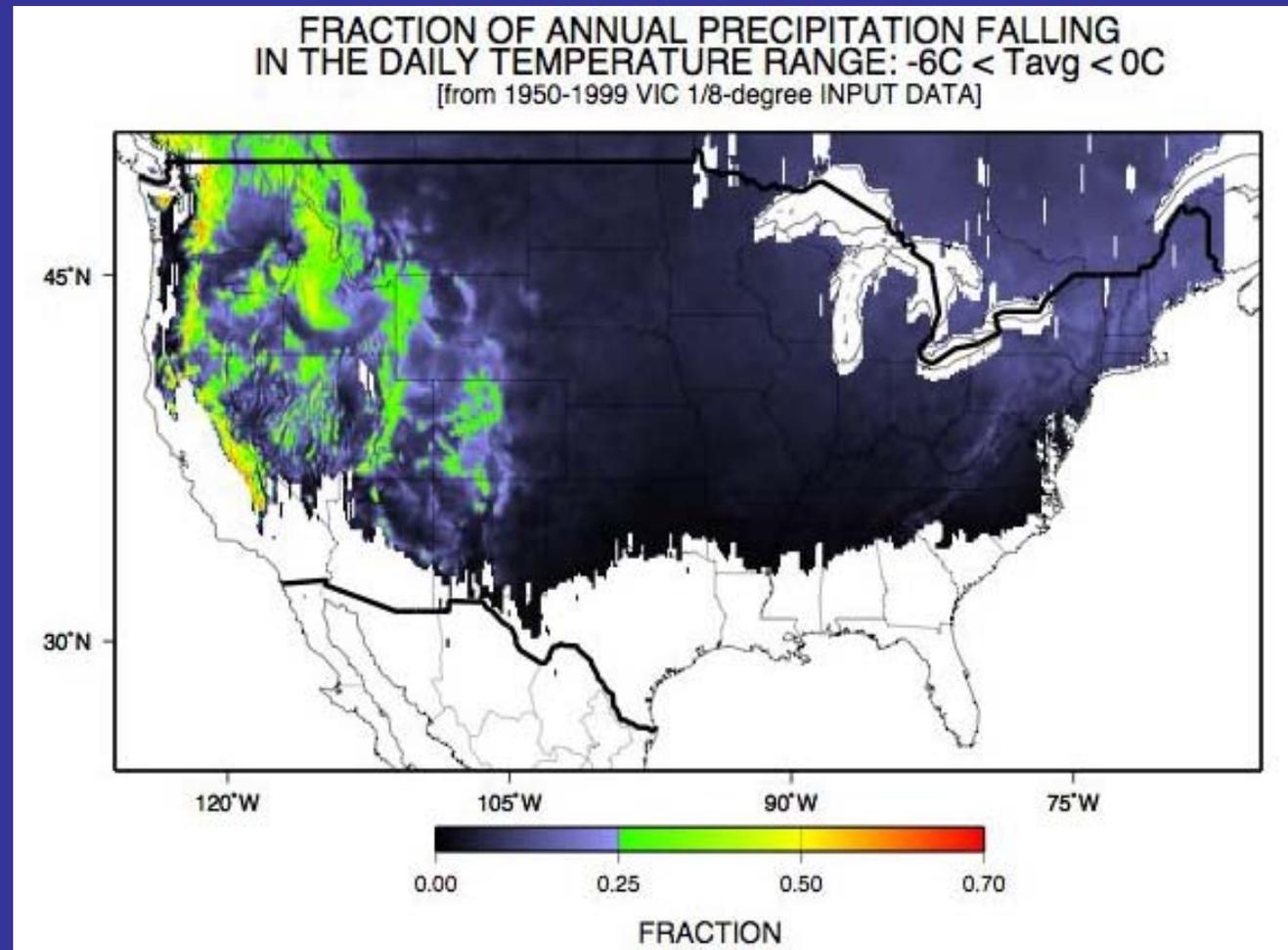
# Seasonality of Precipitation in the Wind-Bighorn Drainage



A significant portion of annual precipitation falls during the late spring when temperatures are near freezing

# Estimating the influence of warming on SNOW vs RAIN

- Widespread shift from snow to rain
- The West is by far the most vulnerable
- Snow to rain transitions of over 25% annual precip would be common

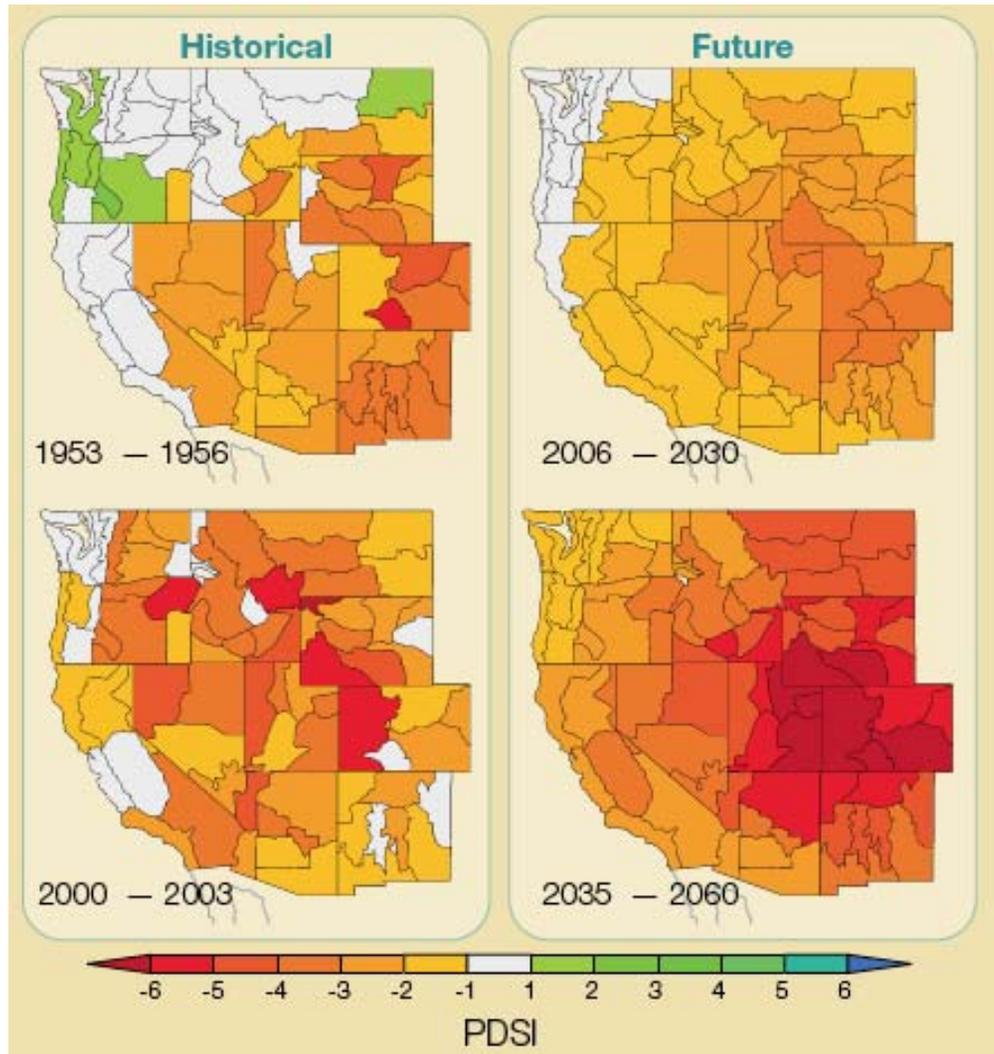


*Derived from UW's  
VIC model daily  
inputs, 1950-1999*

# Rain vs. Snow

- Rain is likely to run off immediately rather than soaking into the soil
- Rain may not be as effective as snow for recharging groundwater supplies
- Shifting towards more rain will likely intensify late-summer droughts
- Switching from snow to rain may have significant consequences for Western ecosystems

# Warming = Perpetual Drought?



No significant change  
In precipitation plus  
1.4 °C temp. increase

**Small increases in  
temperature lead to  
increased evaporation  
and decreased  
water yield to streams**

No significant change  
In precipitation plus  
2.8 °C temp. increase

Calculated Palmer Drought Severity Index Values

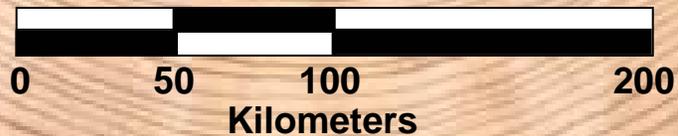
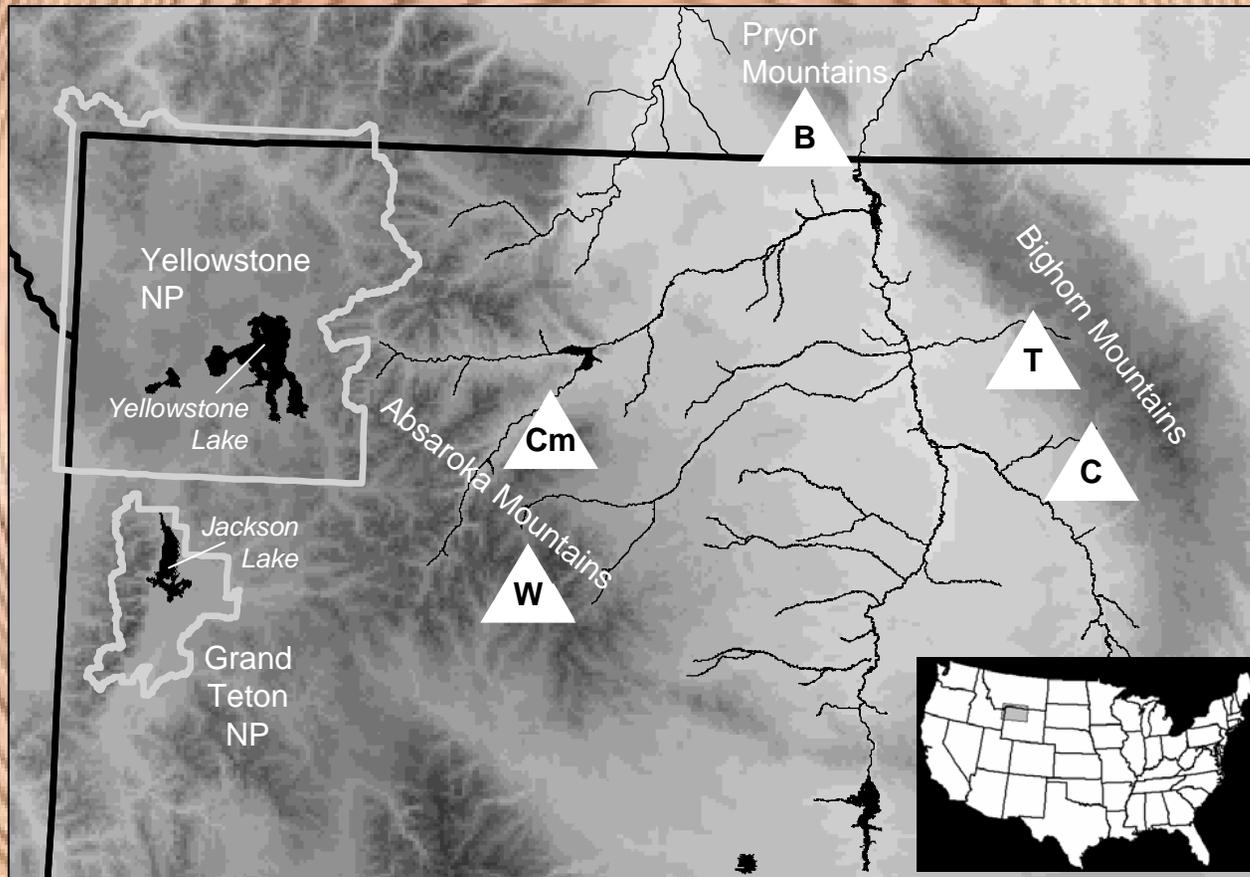


A swan is swimming in a body of water, its reflection visible below. The water is a deep blue color. The swan is positioned in the upper left quadrant of the image.

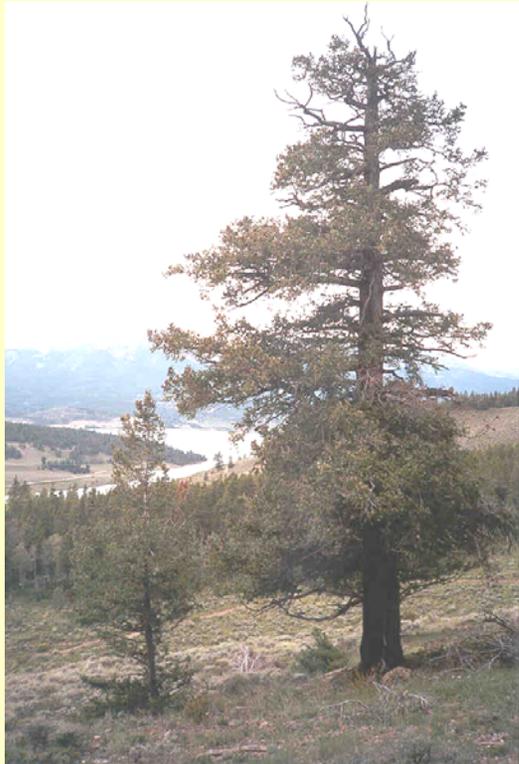
### III. What we know...

- Climate changes significantly over decadal timescales—*even in the absence of increased greenhouse gasses*

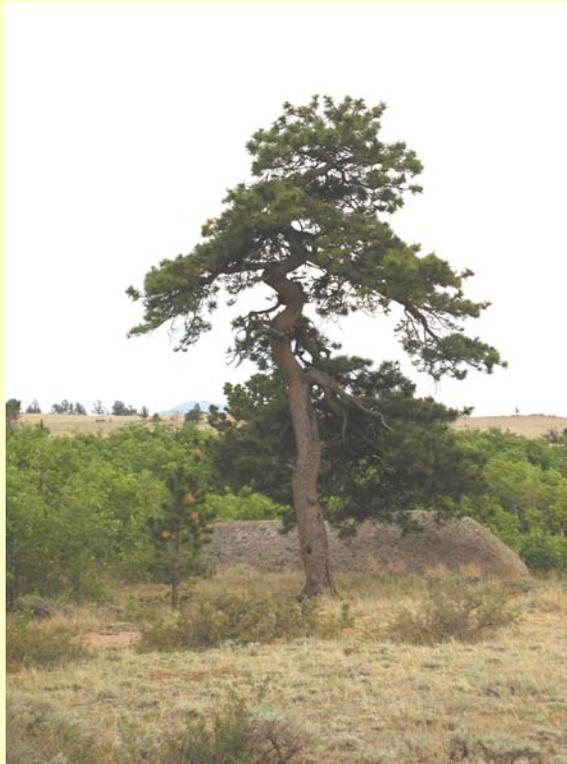
# Regional hydroclimatic variability from Tree rings: Bighorn River Basin



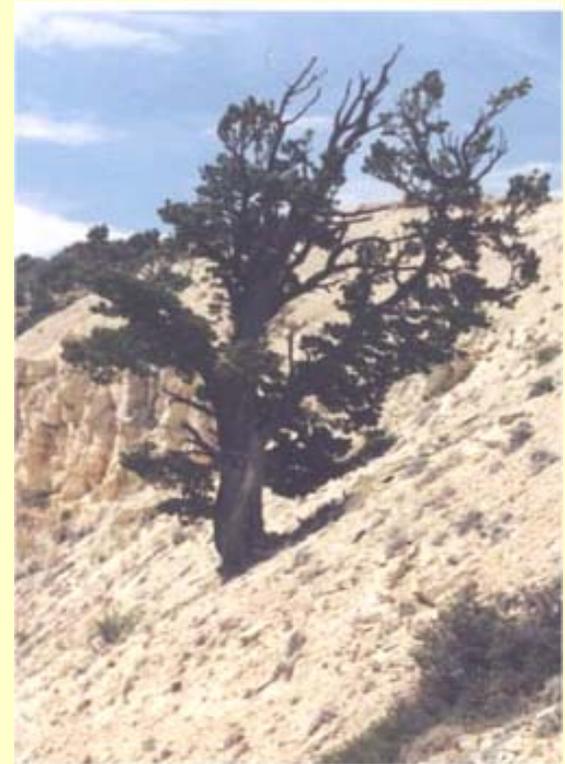
## Moisture-sensitive species in NW Wyoming



**Douglas-fir**  
500-800 years

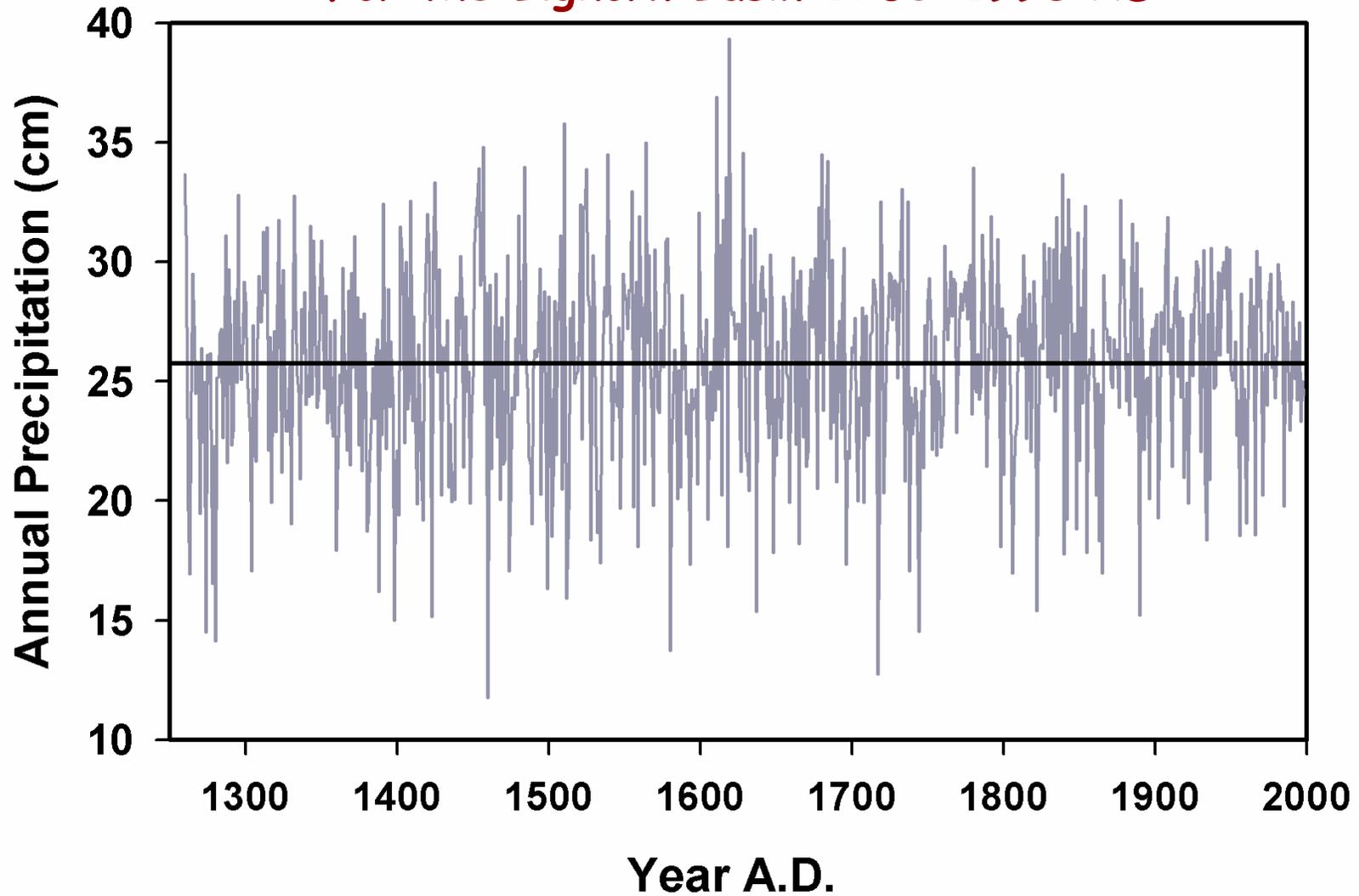


**Ponderosa Pine**  
300-600 years

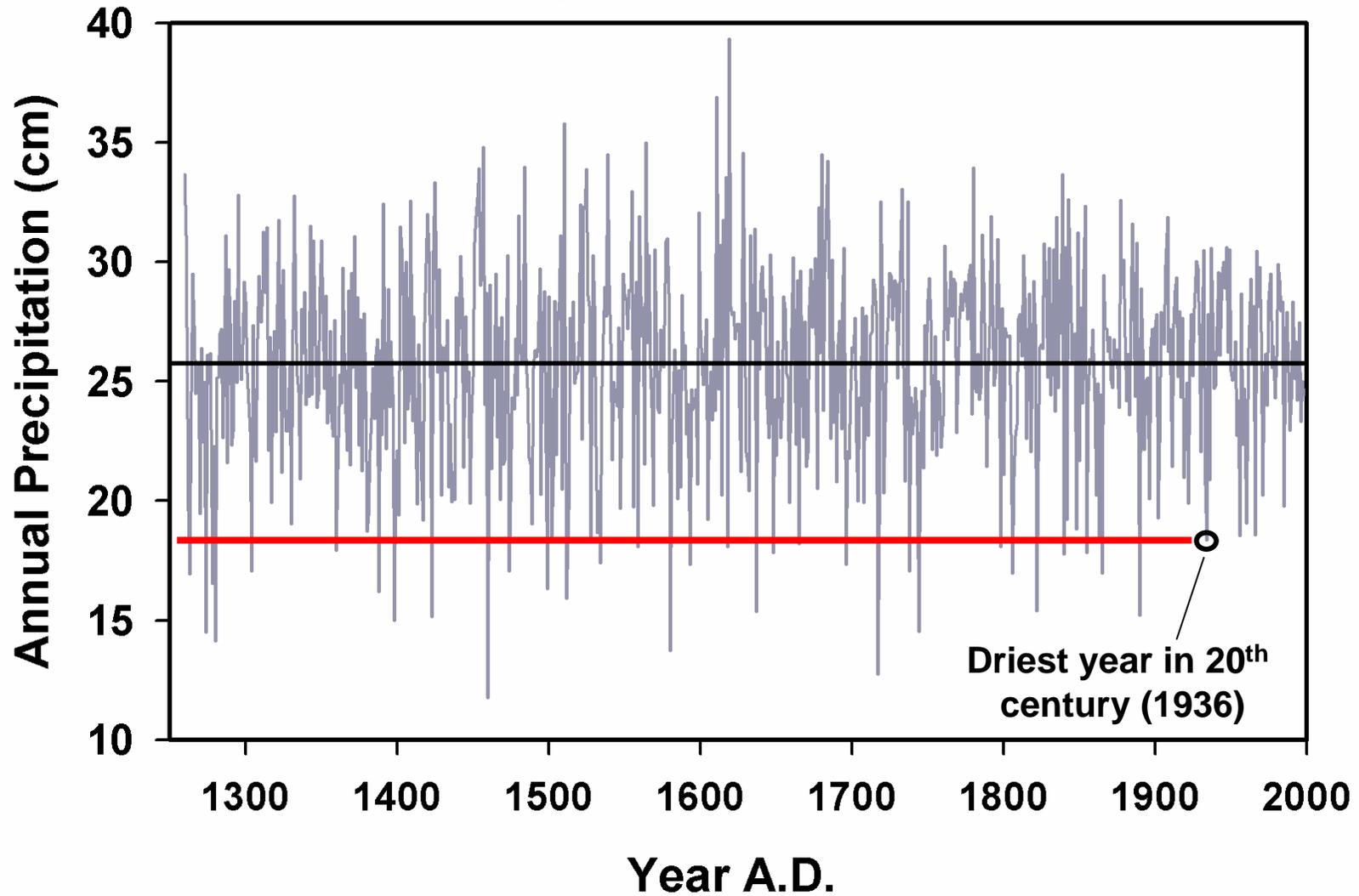


**Limber Pine**  
500-1000+ years

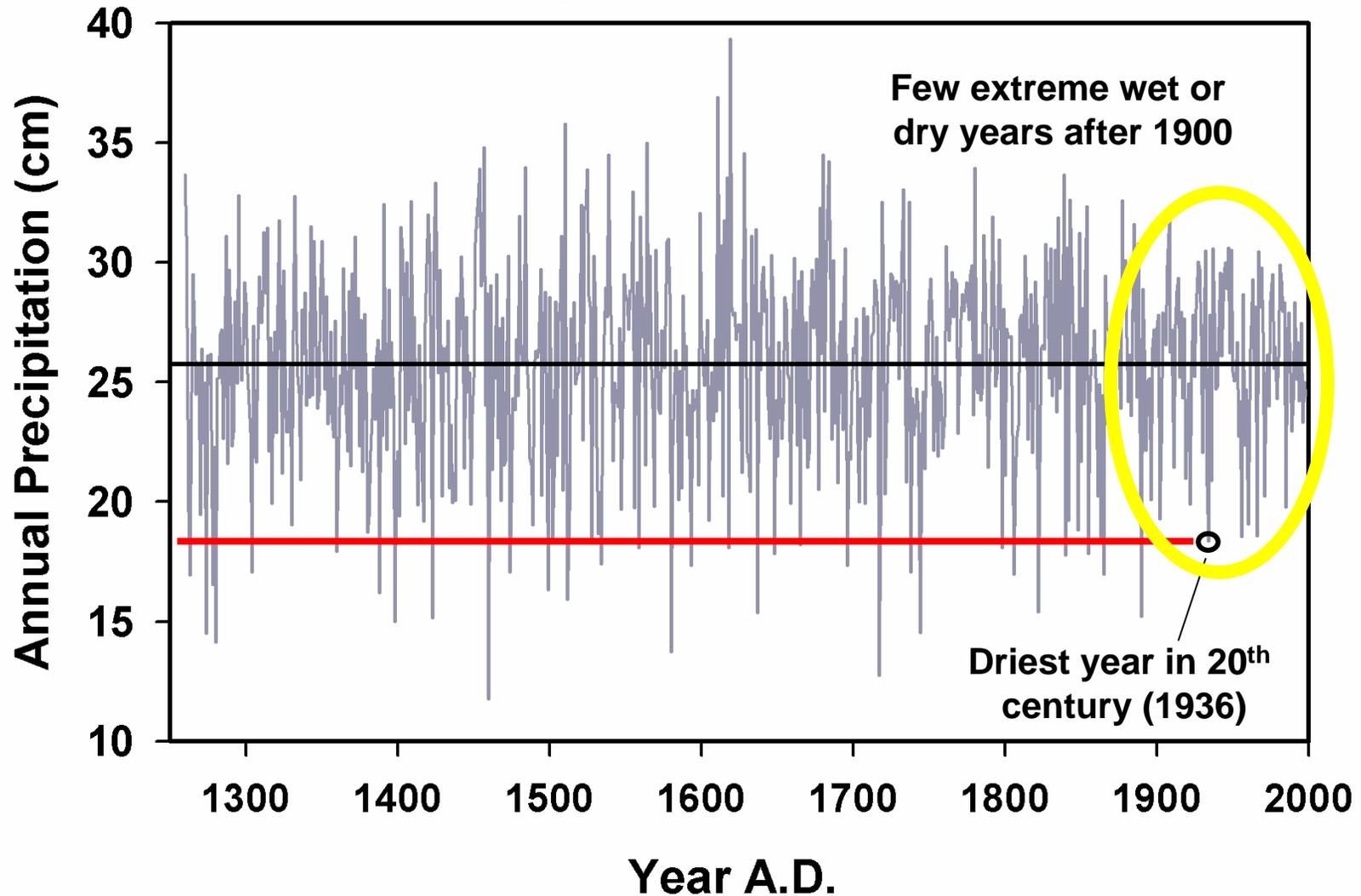
**Reconstructed Annual Precipitation  
For the Bighorn Basin 1260-1998 AD**



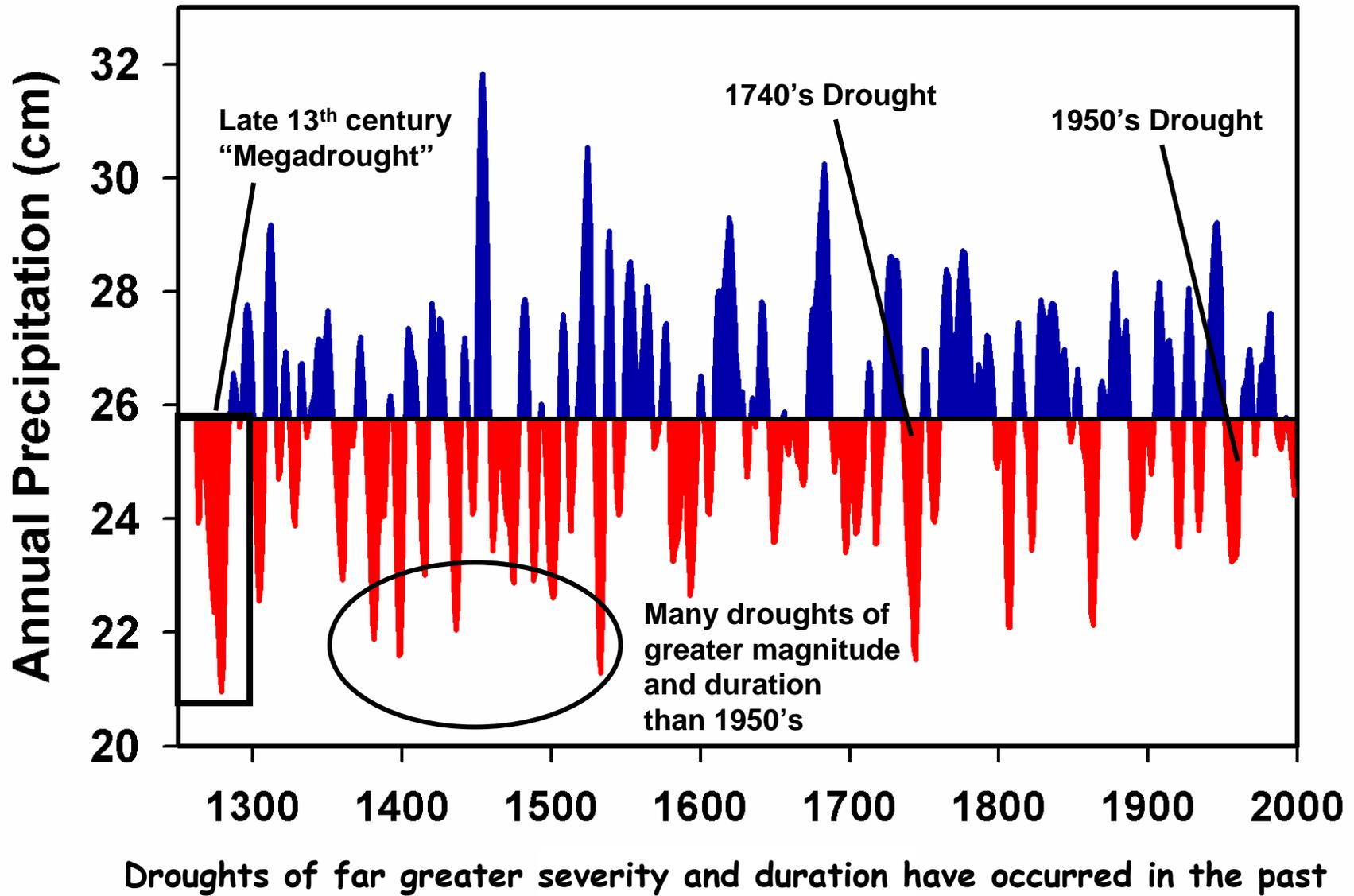
# Reconstructed Annual Precipitation For the Bighorn Basin 1260-1998 AD



# Reconstructed Annual Precipitation For the Bighorn Basin 1260-1998 AD



## Lessons from the Tree-ring Record



# Management, Society and Natural Resources



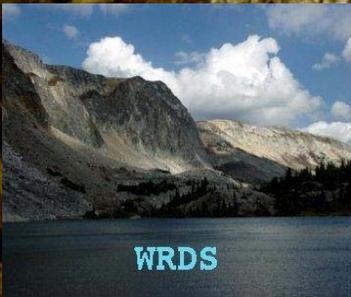
## What we know...

- The earth's climate is changing, and will continue to change for the foreseeable future
- Natural systems on the western US are highly vulnerable to all types of climatic change
- Even the most conservative scenarios for future climatic change could bring major impacts for water and other natural resources in the West

# What we need to know...

- How do current policies make us more/less vulnerable to all types of climatic change (natural and otherwise)?
- How will changing land use, increasing population, disturbance, exotic species, and climate interact to impact natural systems?
- How can we integrate knowledge of long-term variability and change into all aspects of natural resource management?

# Thanks!



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  - Water Resources Data System, WYO Hall 253
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  - [stateclim@wrds.uwyo.edu](mailto:stateclim@wrds.uwyo.edu)