


# ***Global Warming and Montana Ecosystems: Its all about water balance***

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College of Forestry and Conservation  
University of Montana***



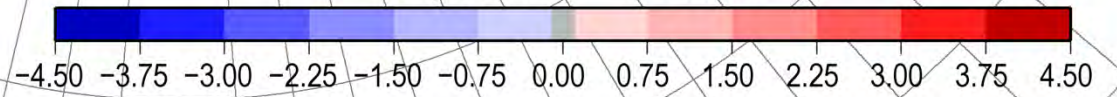
***CCS 203***

***September 1, 2010***

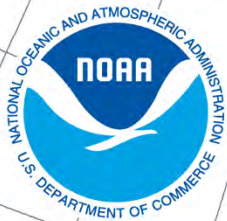
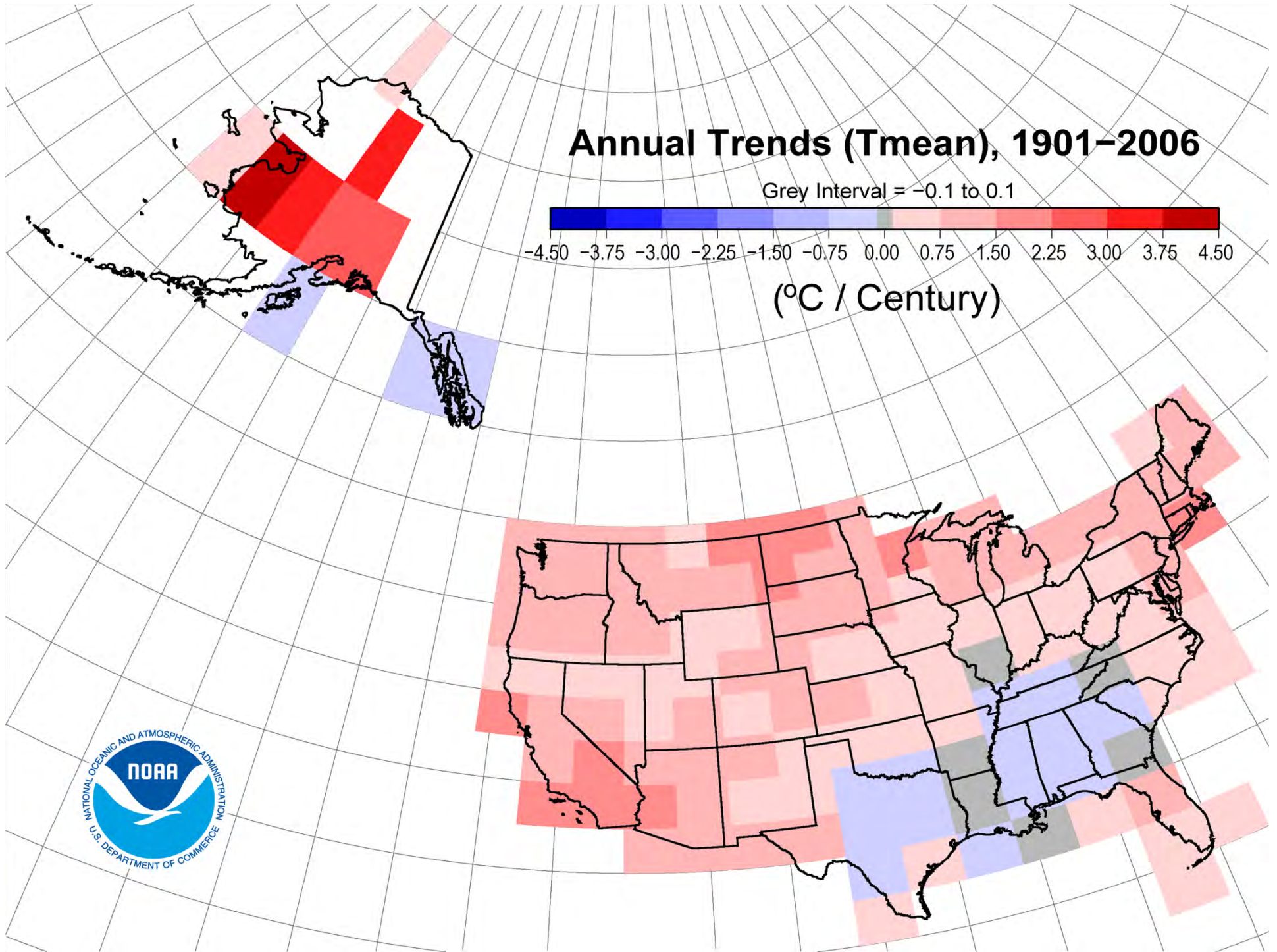


# Annual Trends (Tmean), 1901–2006

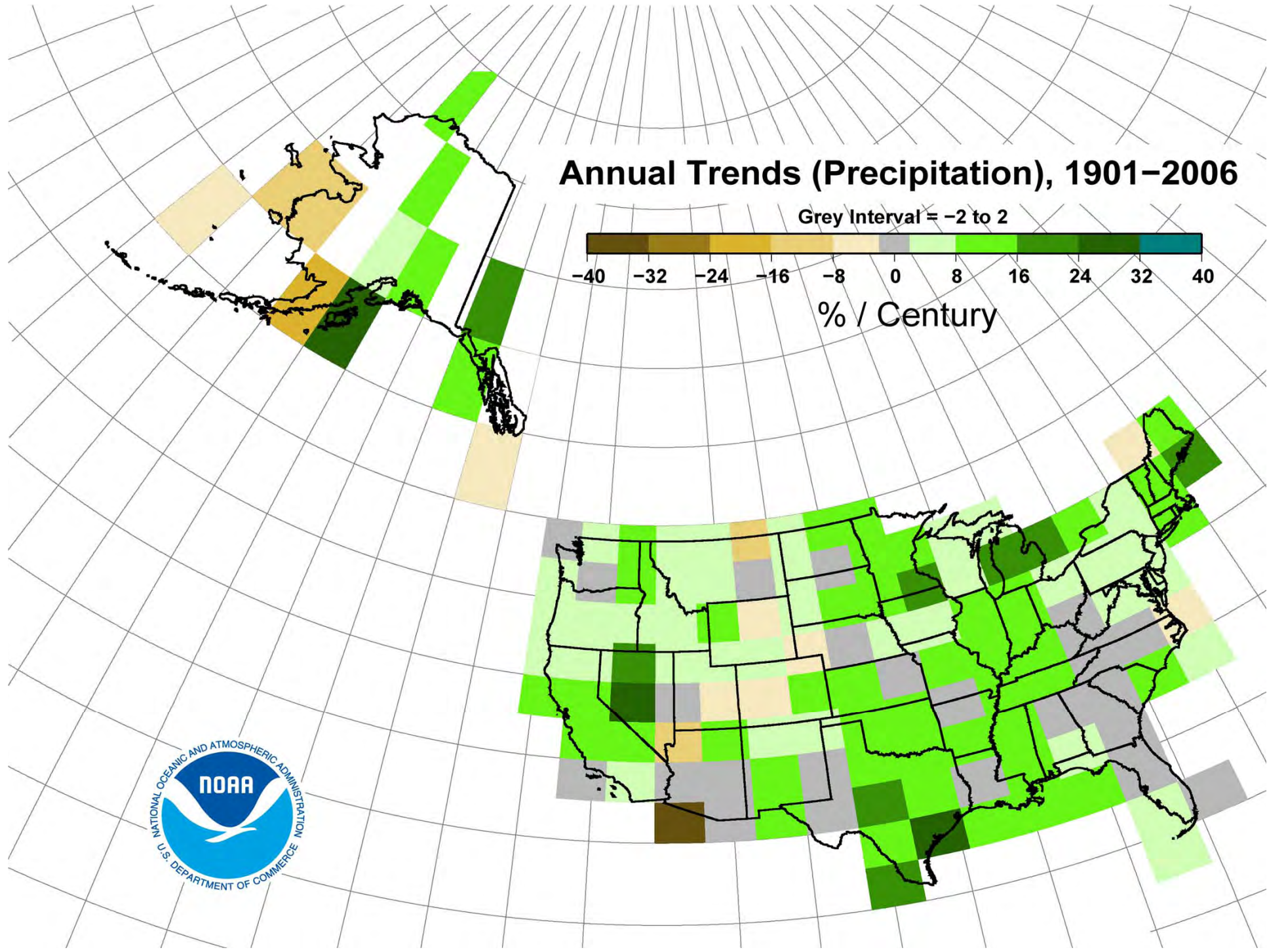
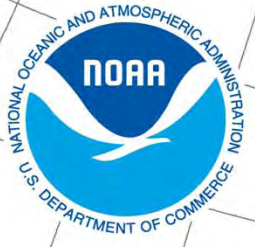
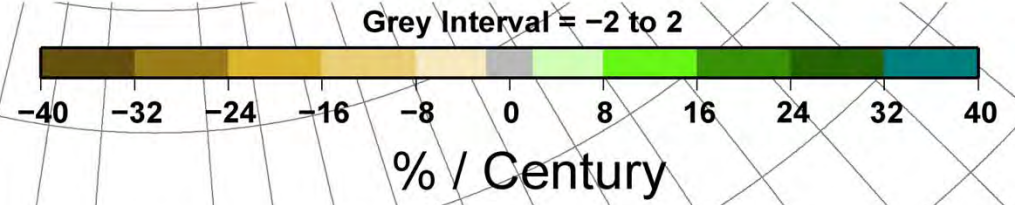
Grey Interval = -0.1 to 0.1



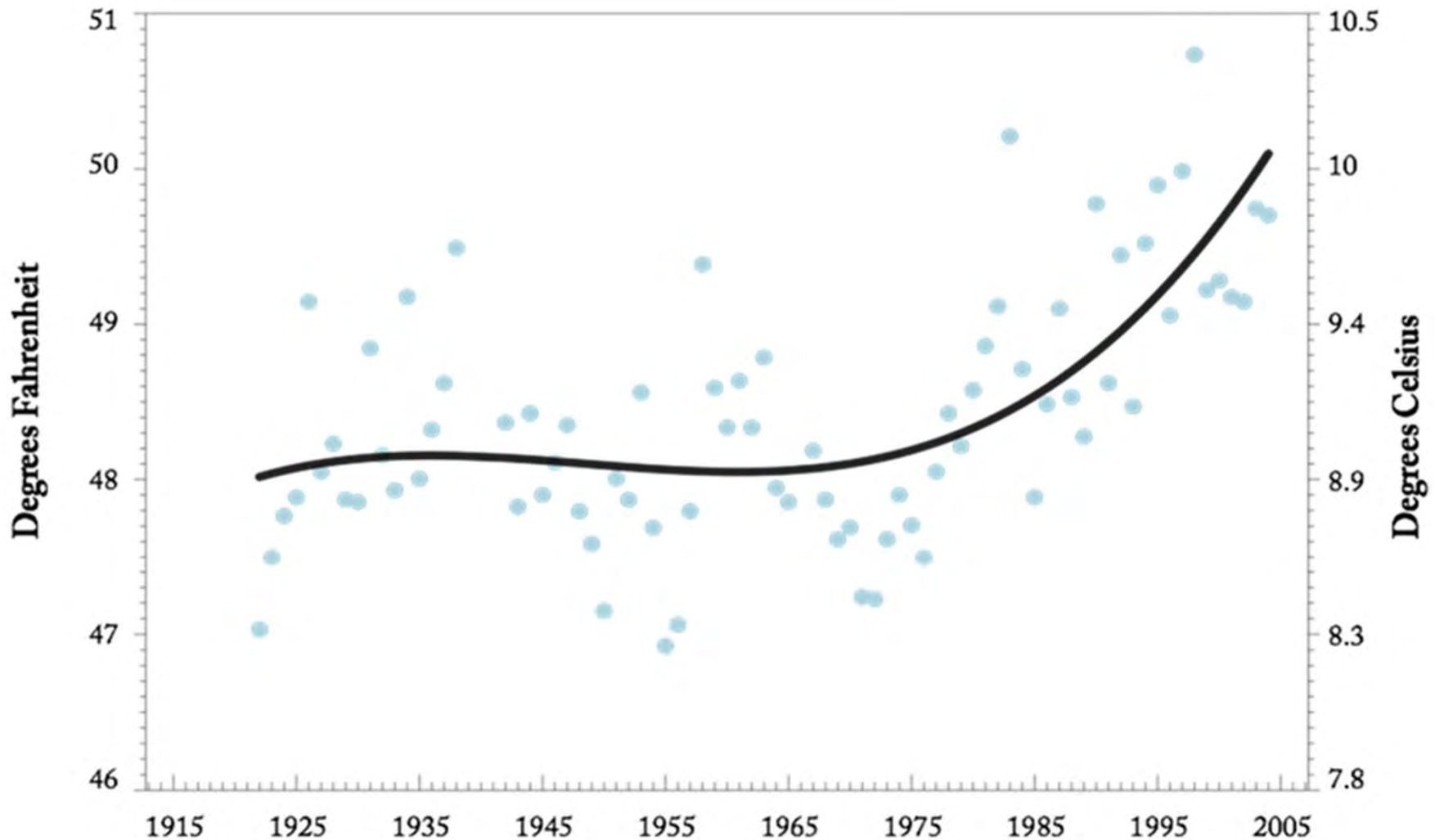
(°C / Century)



# Annual Trends (Precipitation), 1901–2006



# Sea Surface Temperature (Race Rocks lighthouse, Victoria)



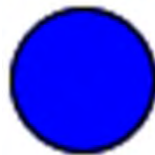
# Map Legend

## Legend

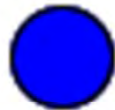
Temperature based on trend per decade (°F)  
Precip. & SWE based on % change over selected period

Temp. Decreasing  
SWE/Precip. Increasing

-1.0+°  
100+%



-0.5°  
50%

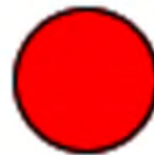


0 to -0.1°  
0 to 10%



Temp. Increasing  
SWE/Precip. Decreasing

1.0+°  
-100+%




0.5°  
-50%

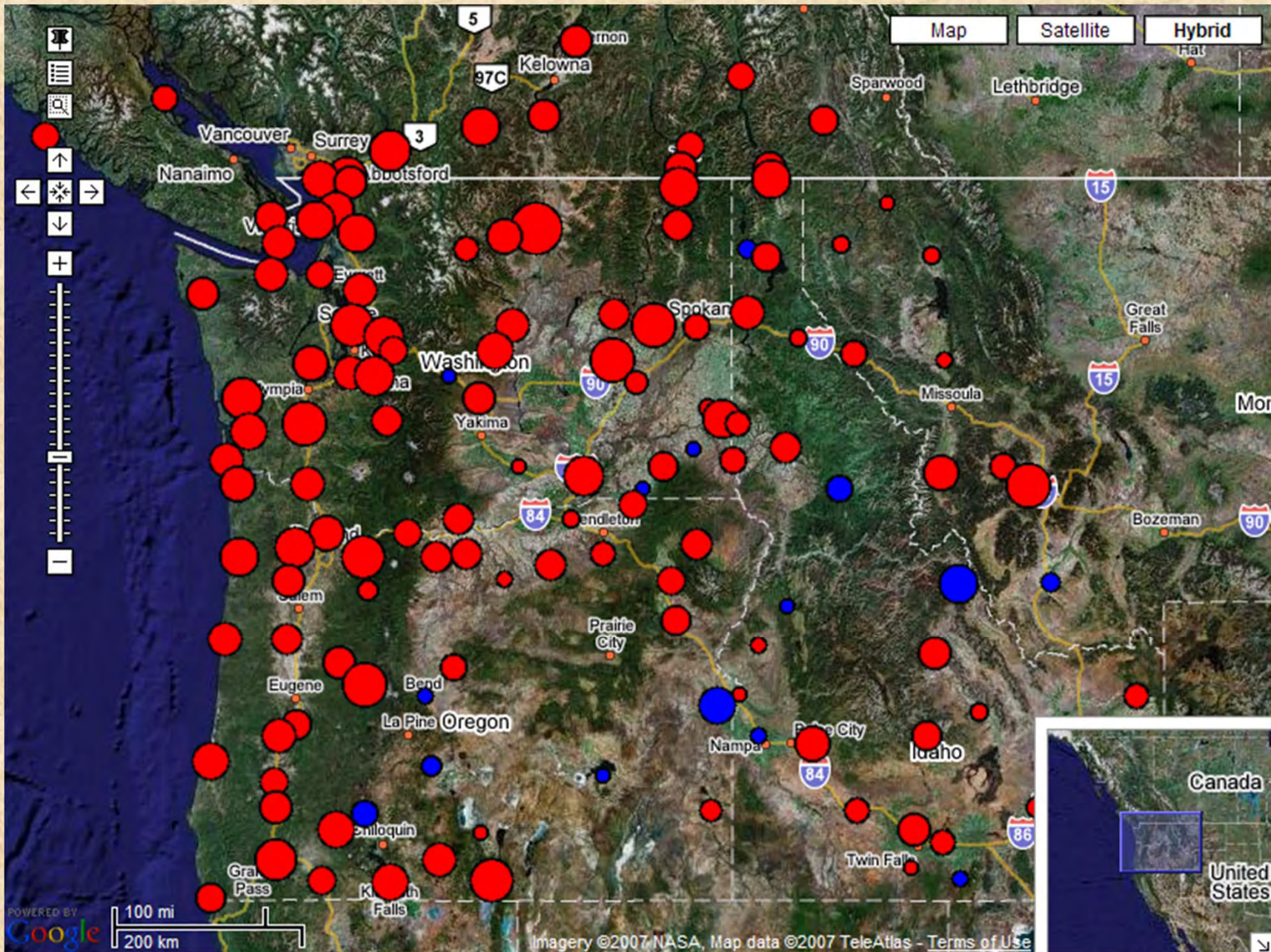


0 to 0.1°  
0 to -10%

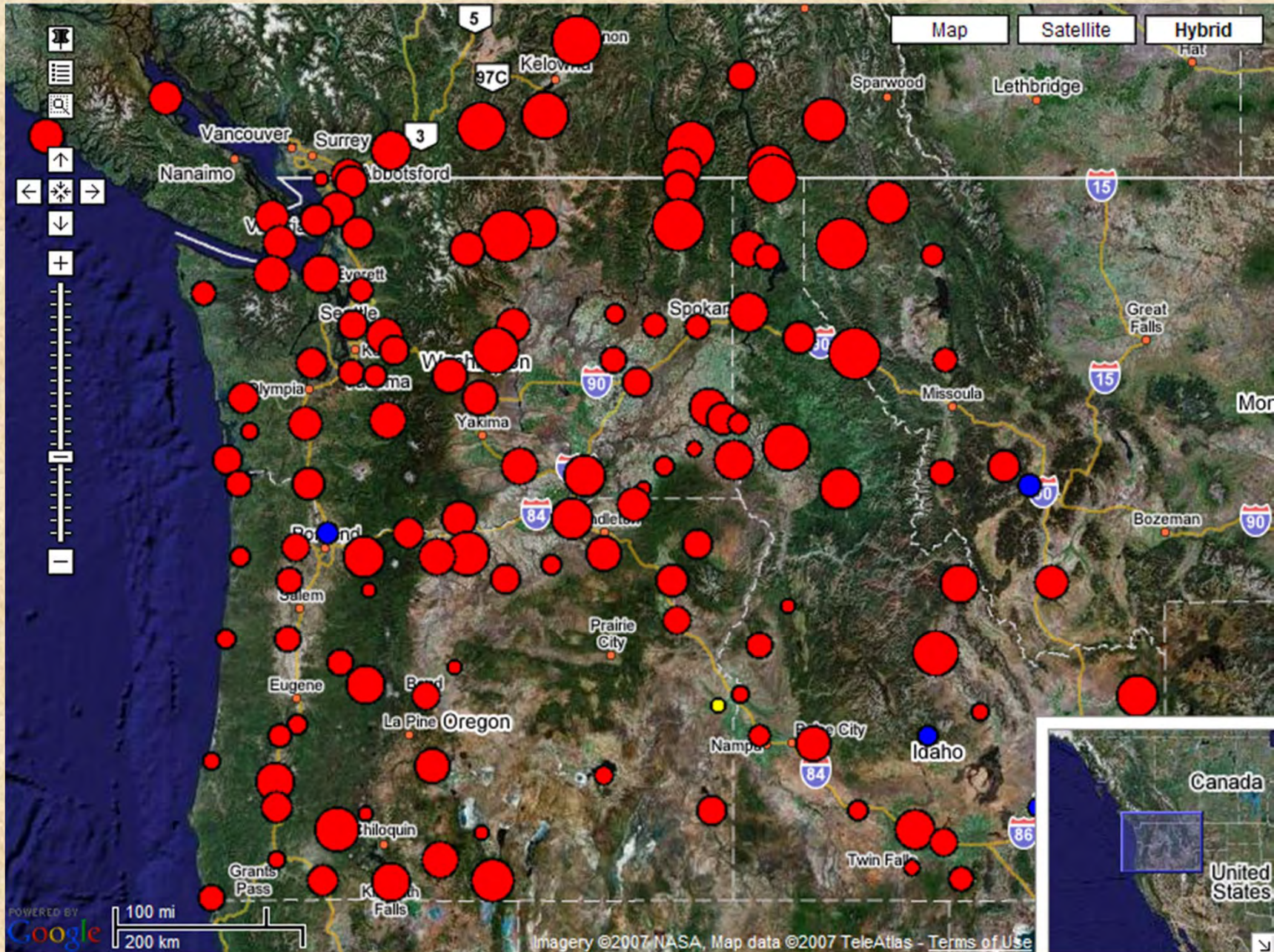


 No Change/Trend

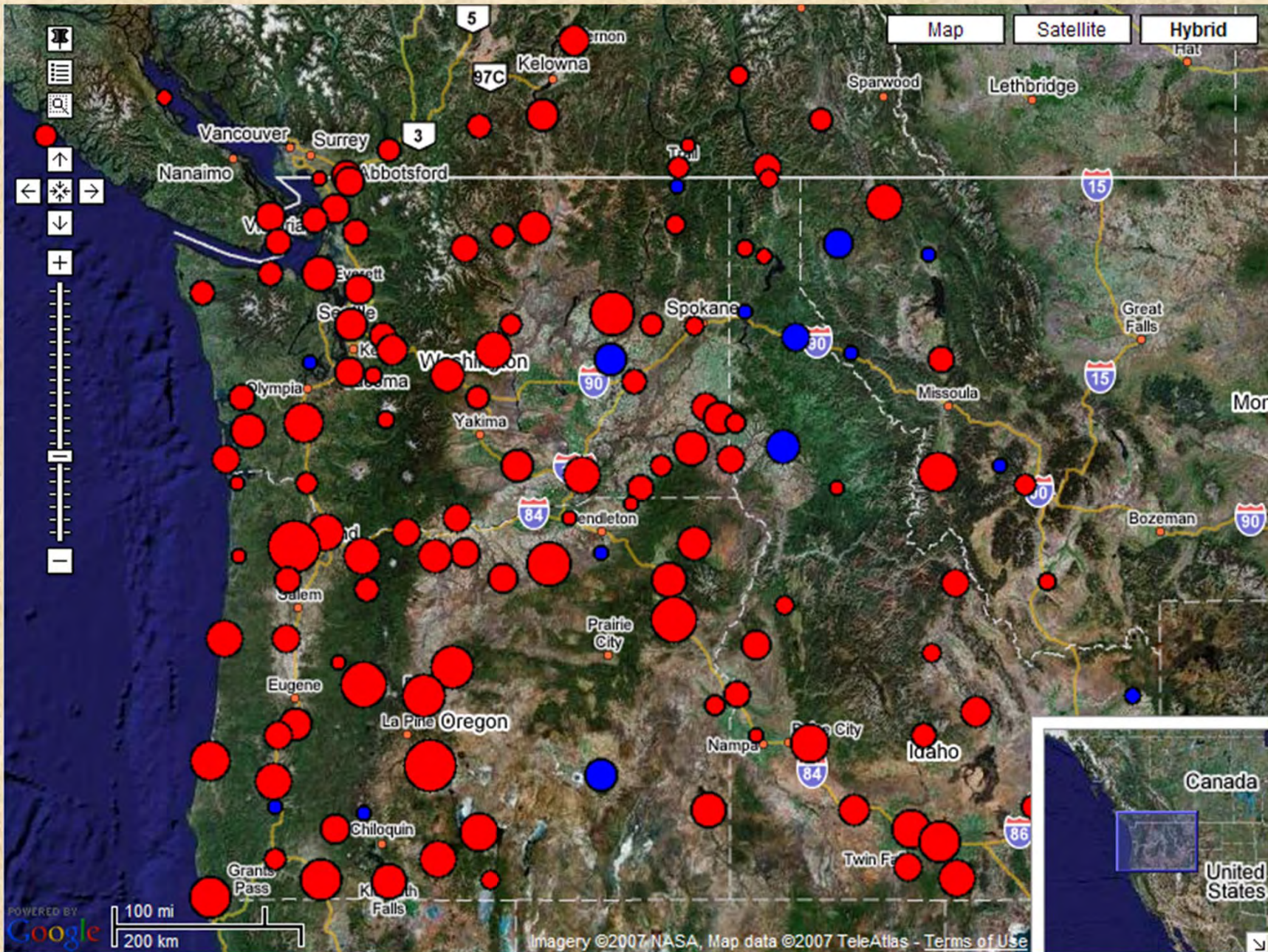
# Winter Max Temperature Trend Analysis: 1915-2003



# Winter Min Temperature Trend Analysis: 1915-2003

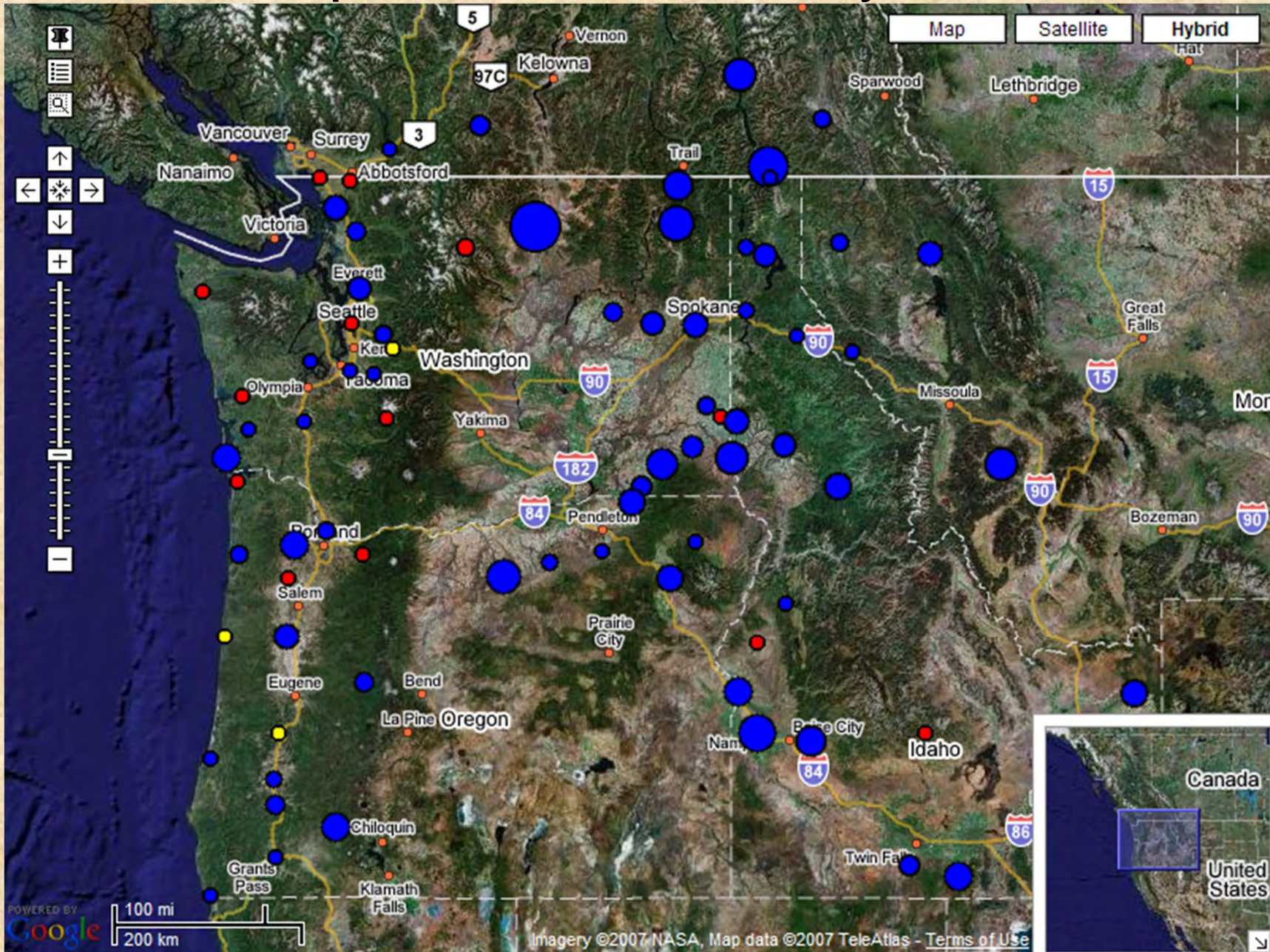


# Summer Max Temperature Trend Analysis: 1915-2003



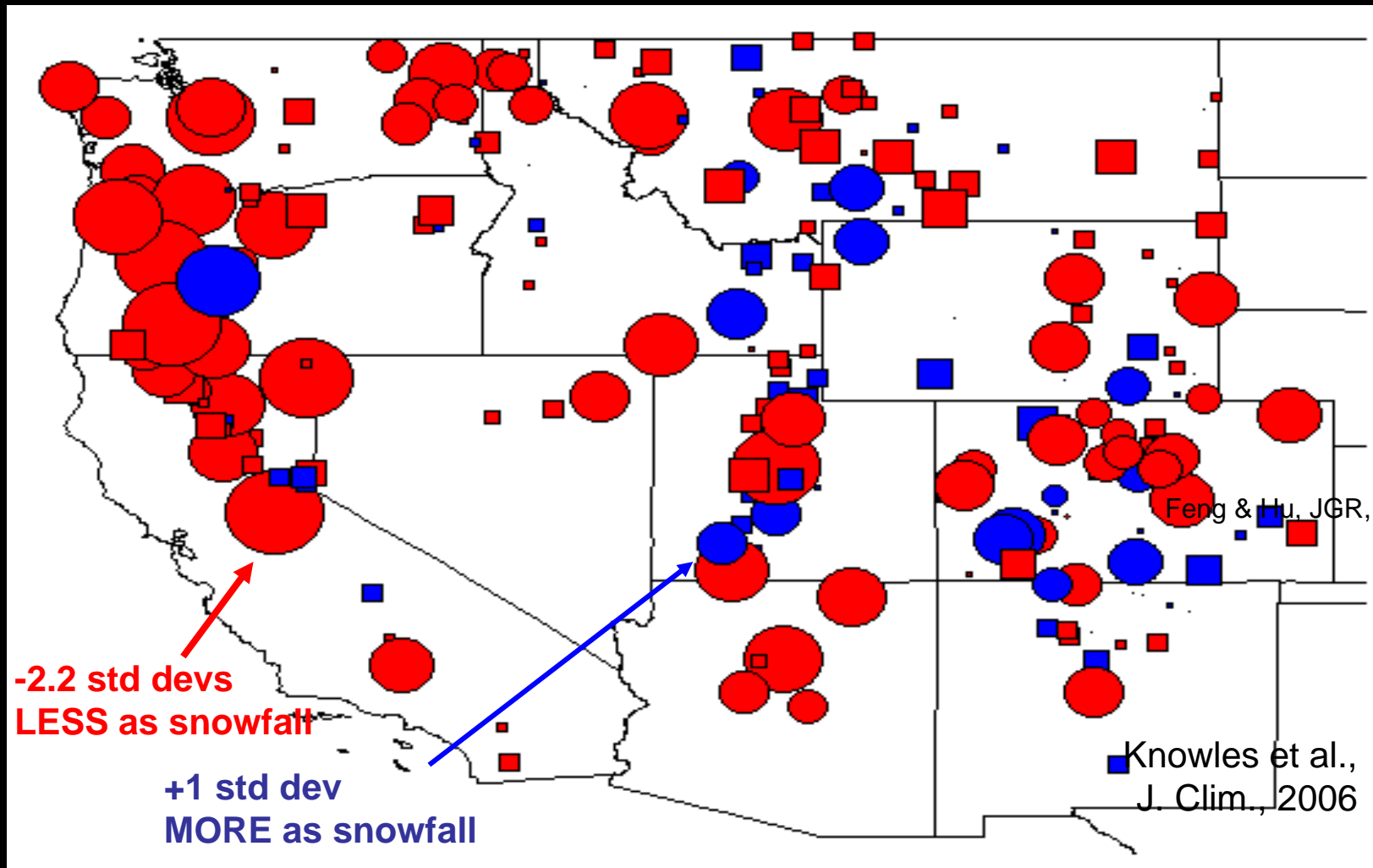


# Annual Precipitation Trend Analysis: 1915-2003

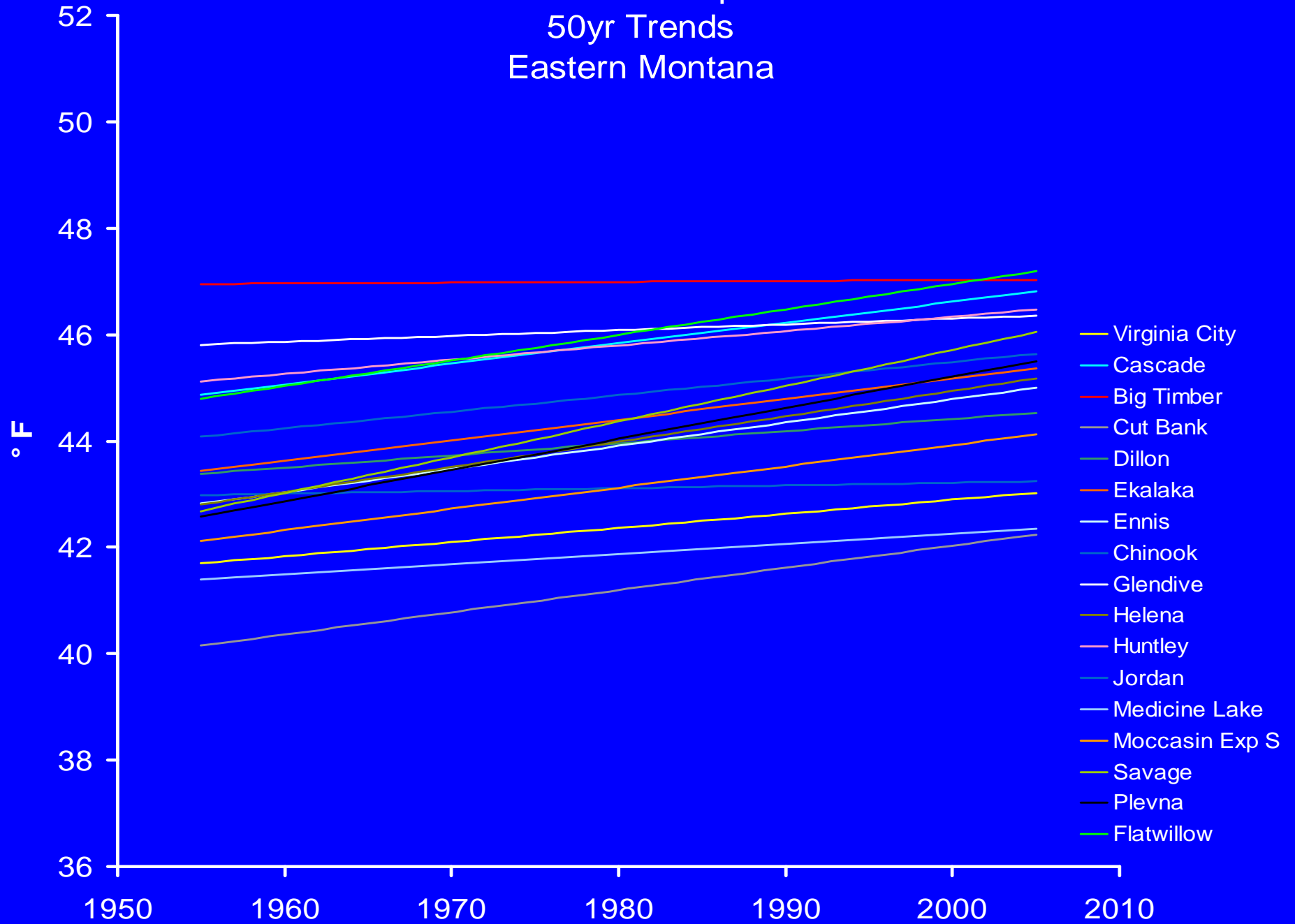


This recent warming already has driven significant hydroclimatic changes.

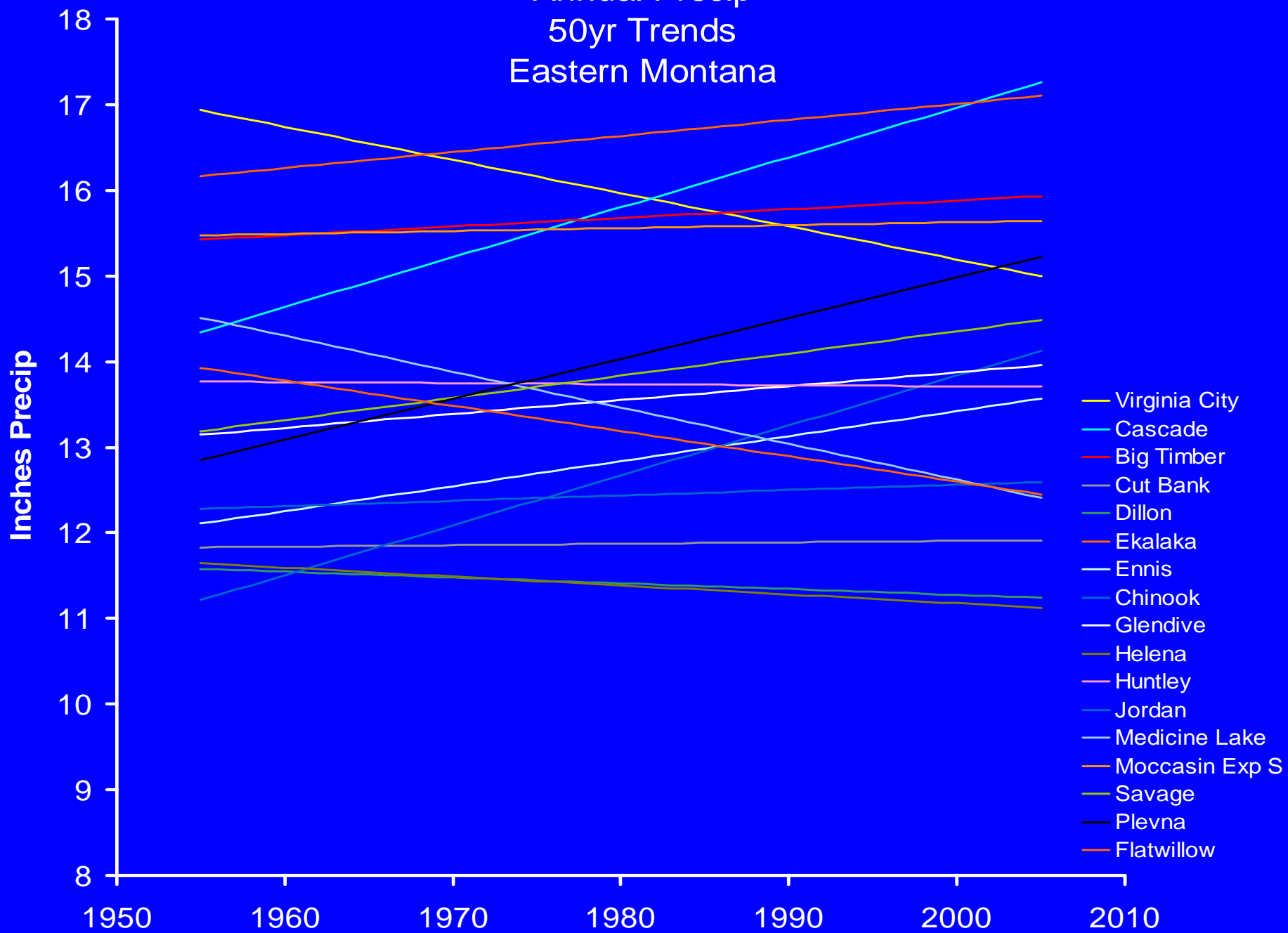
--> **Less snow/more rain**



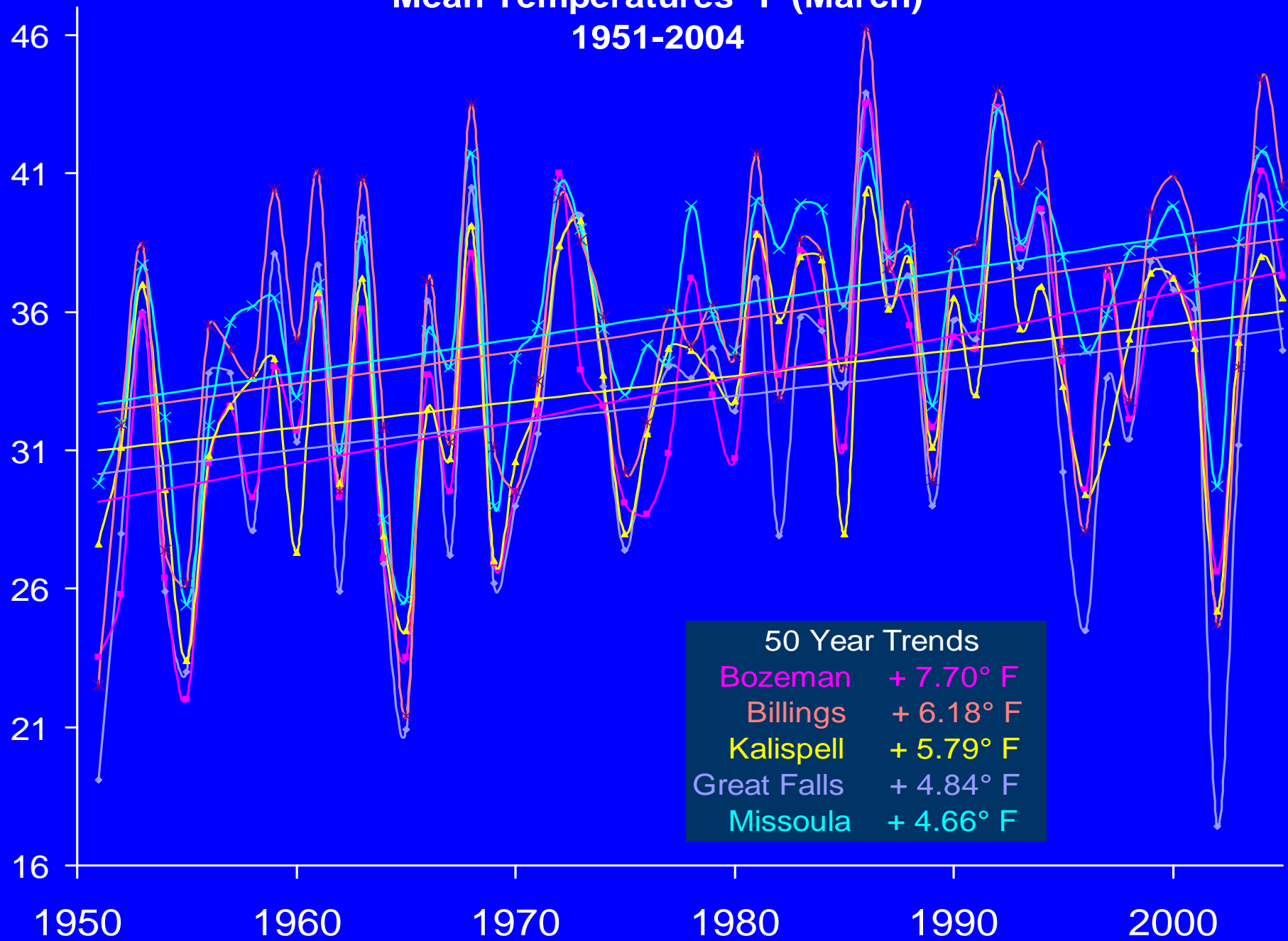
# Annual Mean Temperature 50yr Trends Eastern Montana



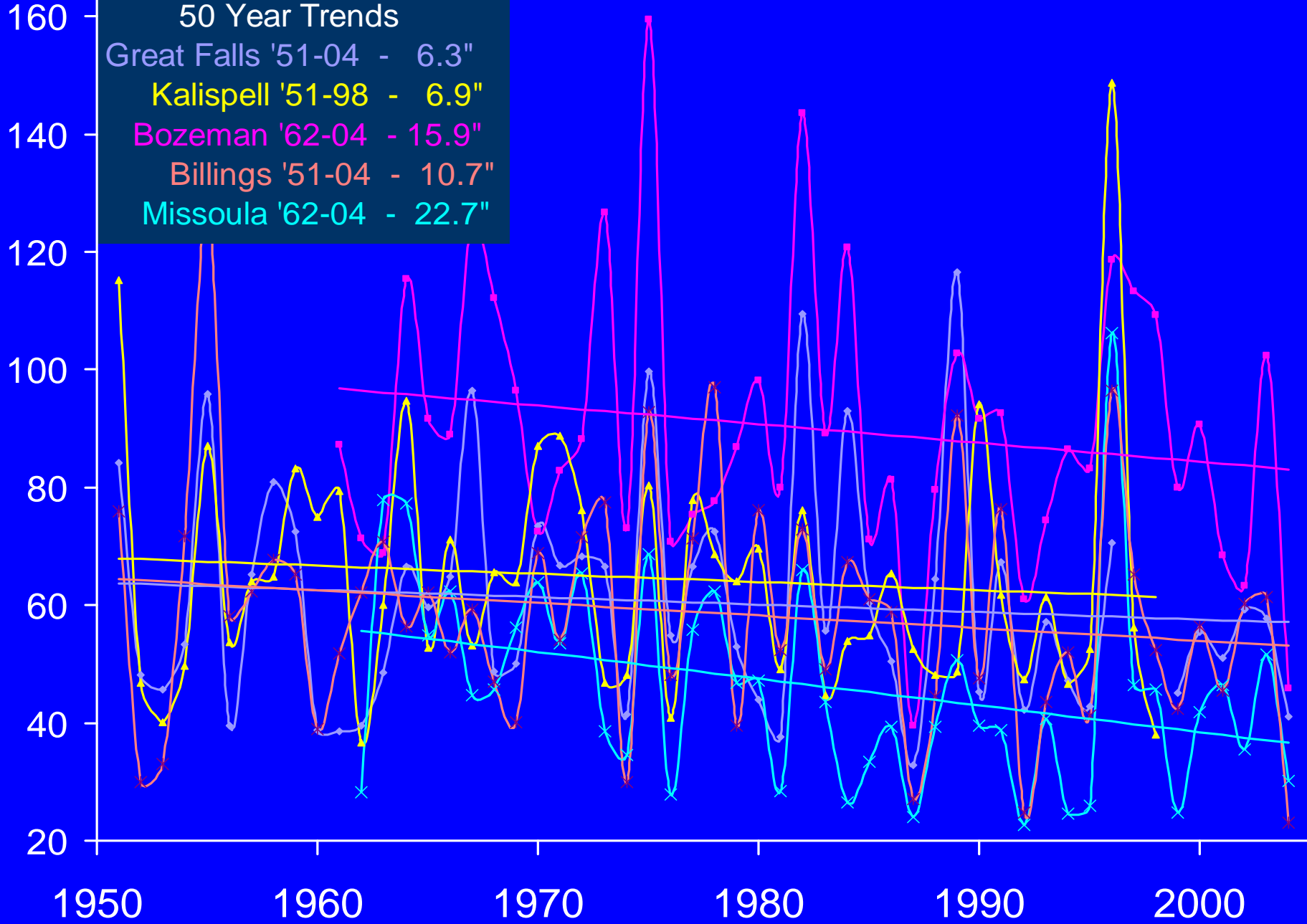
# Annual Precip 50yr Trends Eastern Montana



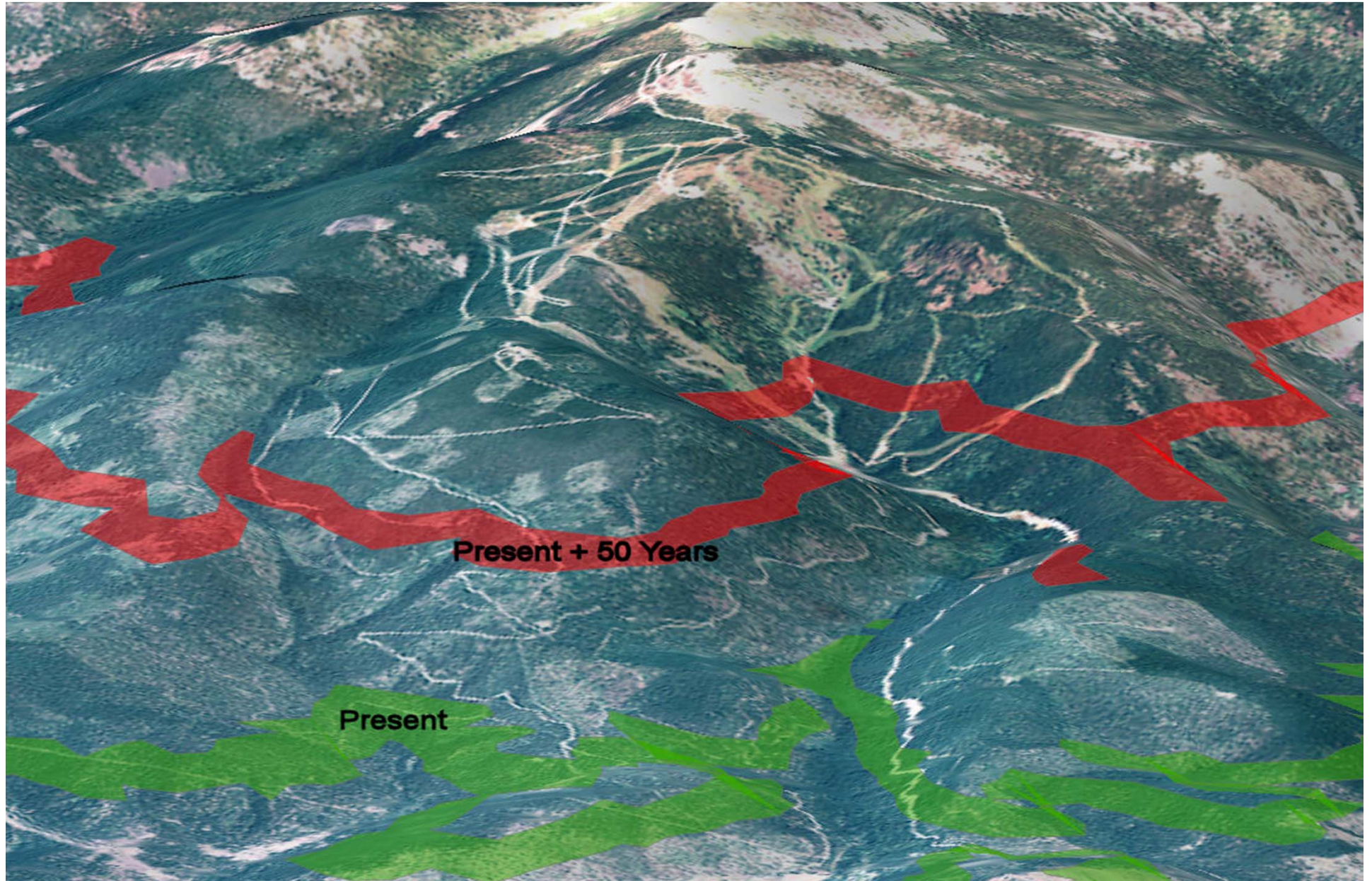
# Mean Temperatures °F (March) 1951-2004



# Total Snowfall (Inches)



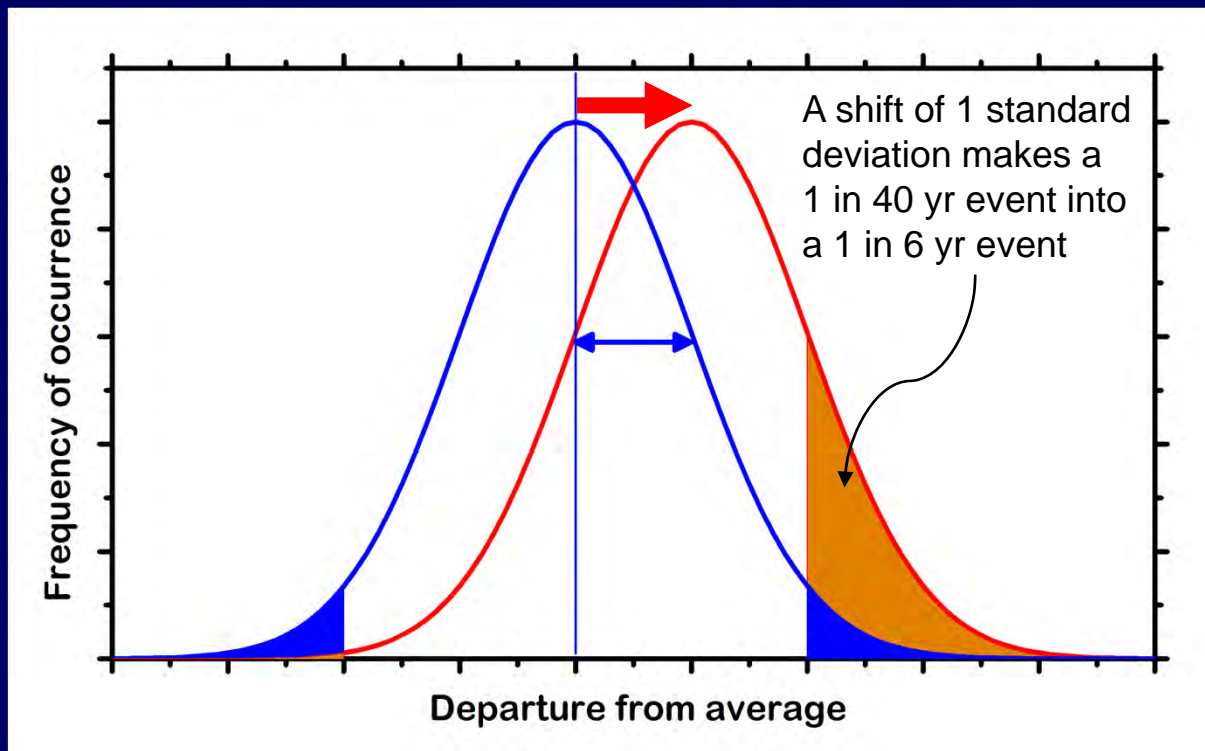
# MARCH SNOWLEVEL AT SNOWBOWL 2005, 2055



# Calculus of extremes

The distribution of weather events around the climatic average often follows a 'bell-shaped' curve.

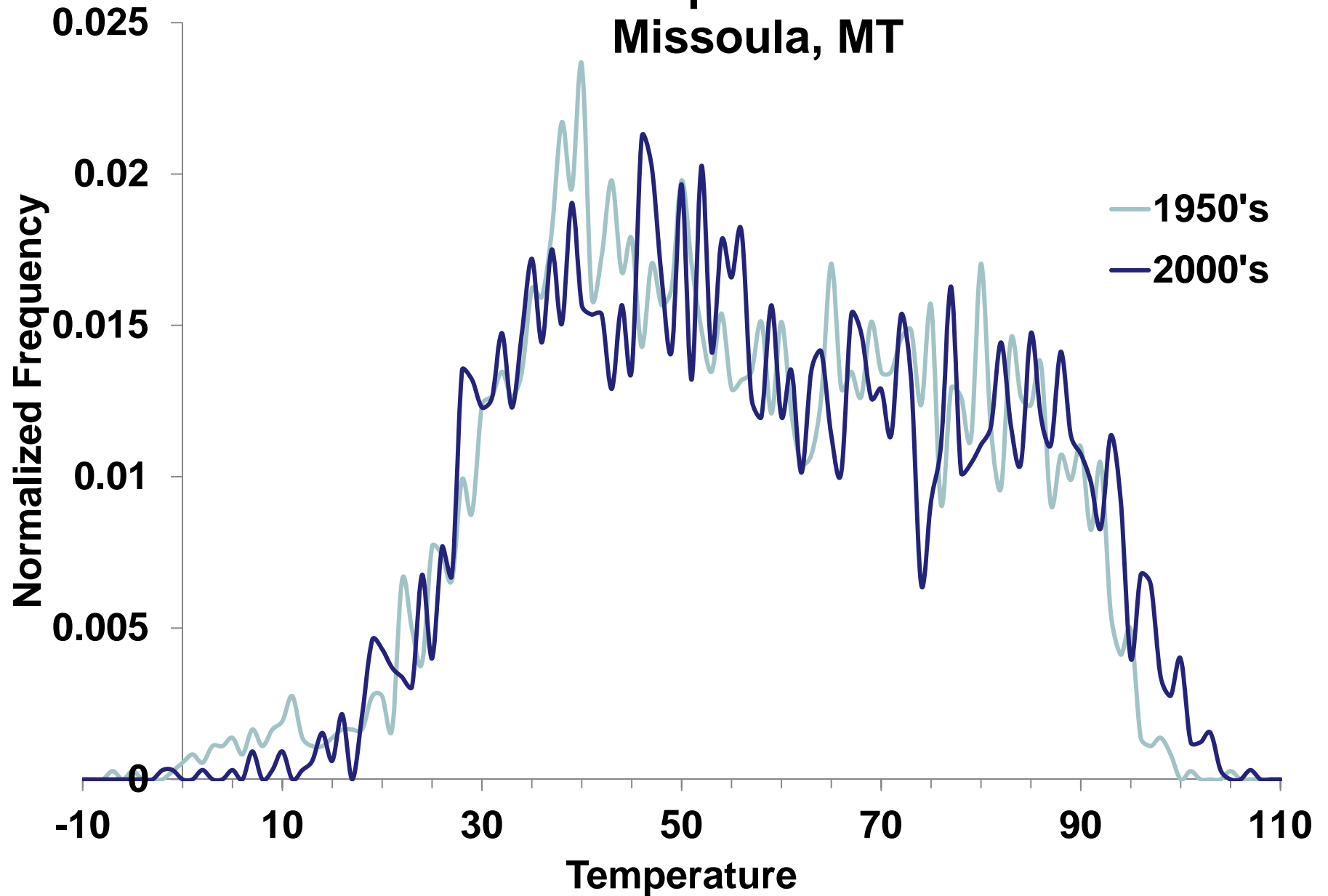
Climate change can involve change in the average, or the spread around the average (standard deviation), or both.



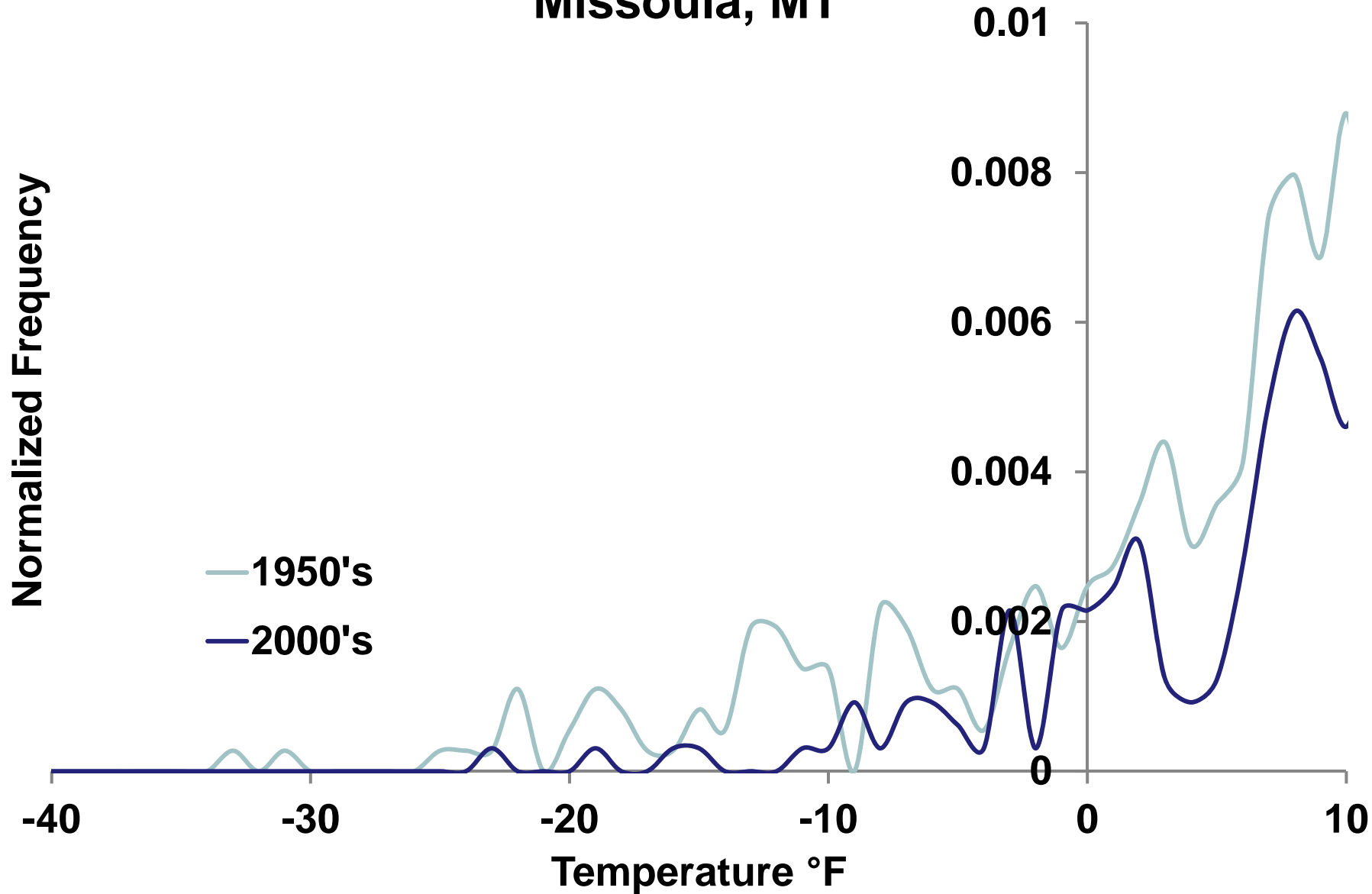
A shift in the distribution of temperatures has a much larger relative effect at the extremes than near the mean.



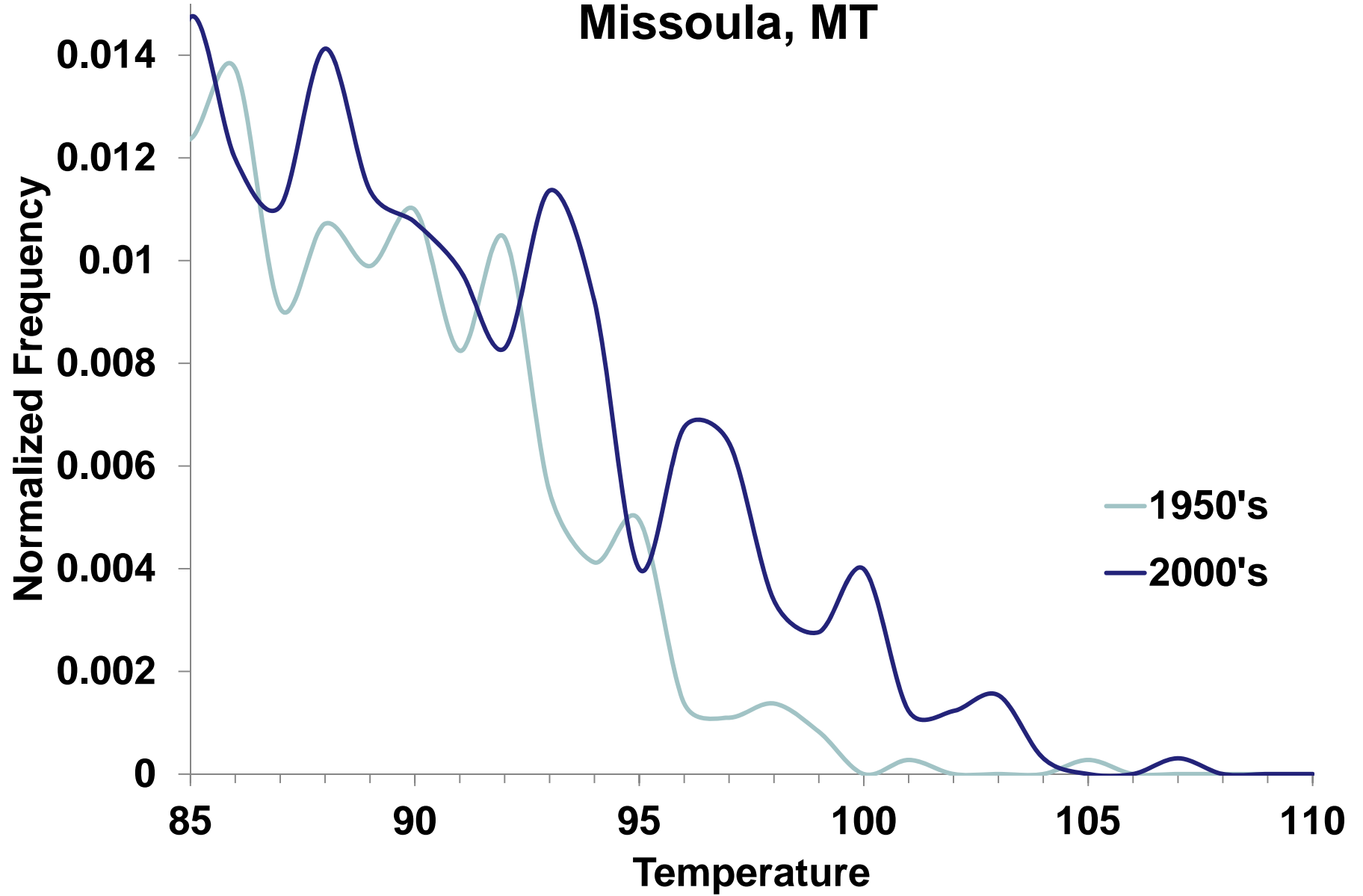
# Maximum Temperature Distribution Missoula, MT



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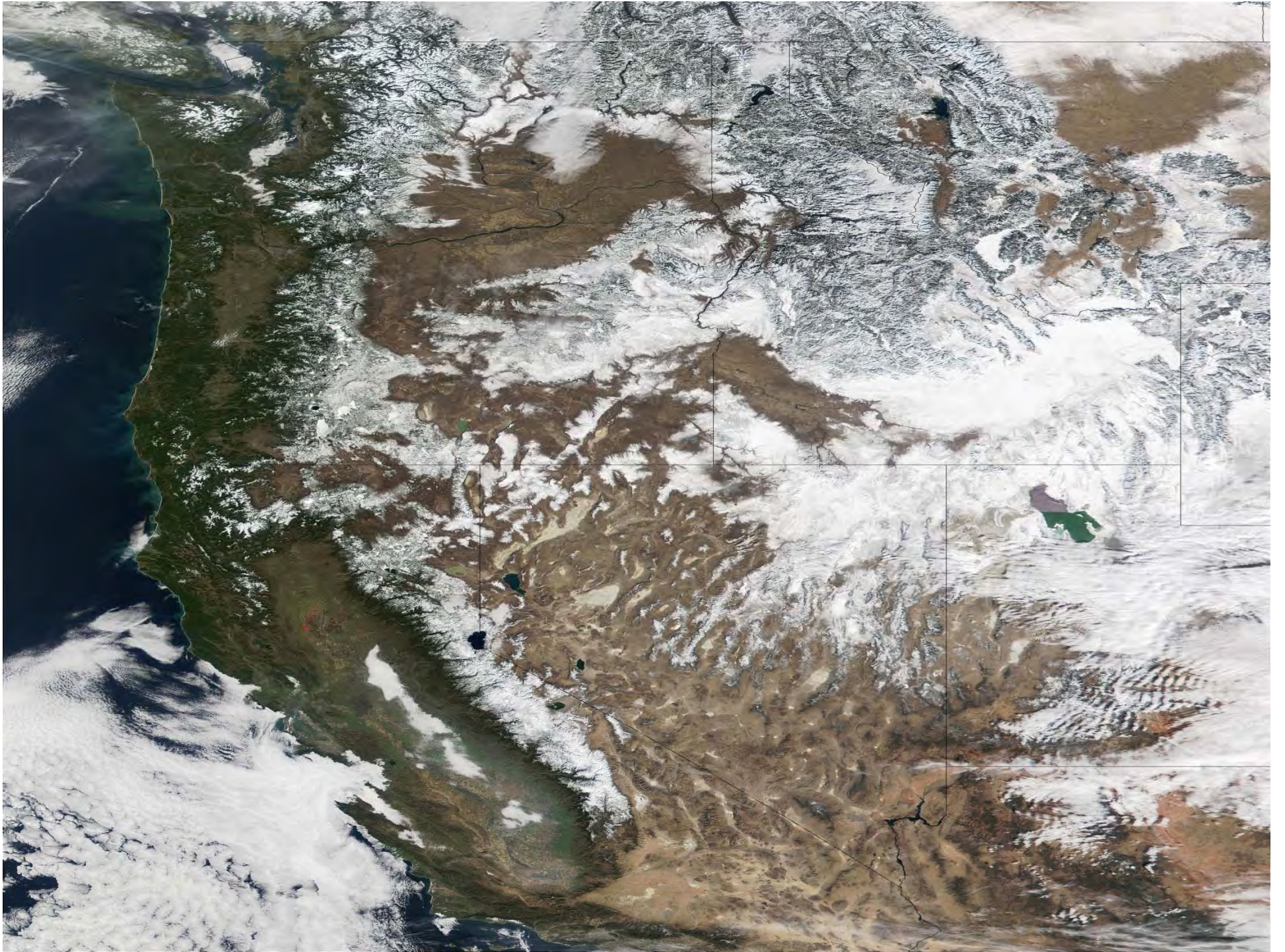


# Missoula July 07 Records

- Hottest Temperature Ever – 107
- Warmest Night Ever – 71
- Average Temp – 78.1 – 11.2 F above average
  - Breaks the old record by 3.3F
- Most number of 100 F days – 11
  - Old record – 6 in 1936
- Most number of nights 60F and above – 18
  - Old record – 10 in 1985
- Driest July on record at Missoula Airport
  - 0.03” – old Airport record is 0.09”

From Gene Petrescu, NWS, Missoula

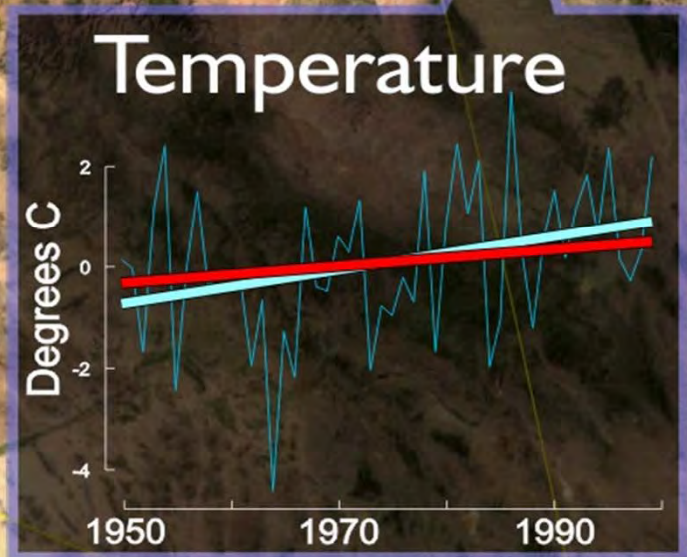
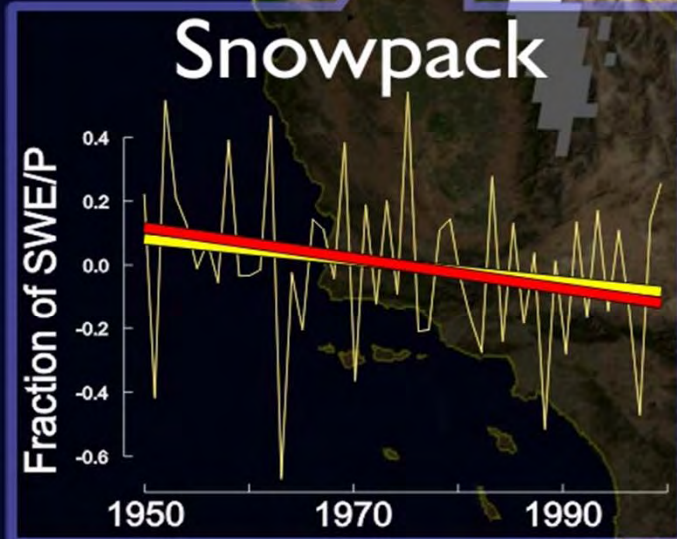
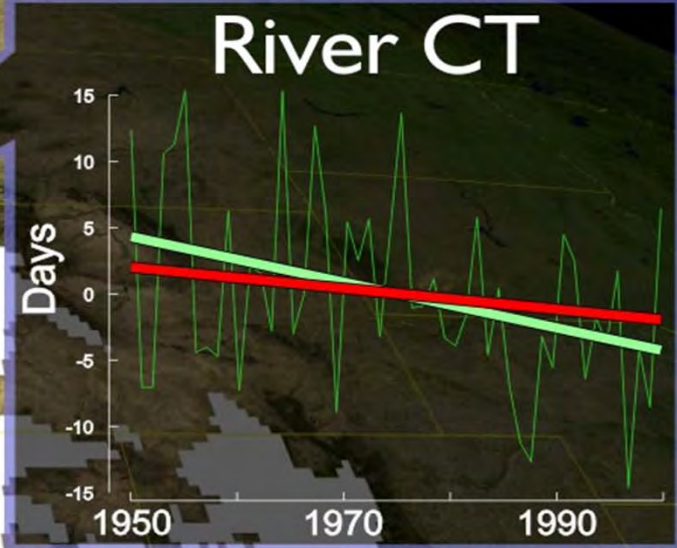
**THIS WILL BE A NORMAL JULY IN 2050!!**



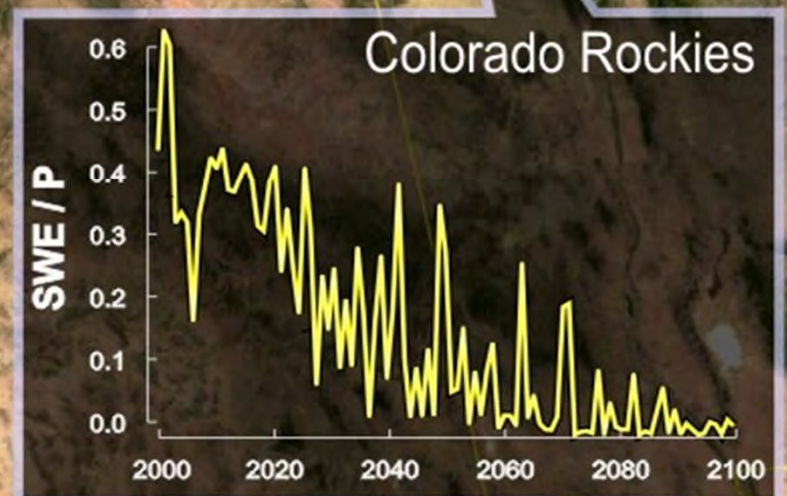
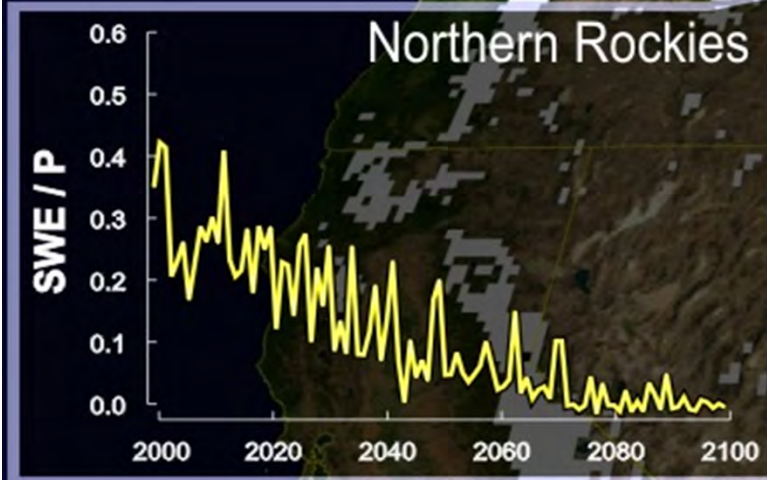
March 4 2007, 7,000ft, North-slope  
Bitterroot Mtns, Montana



1950 - 2006

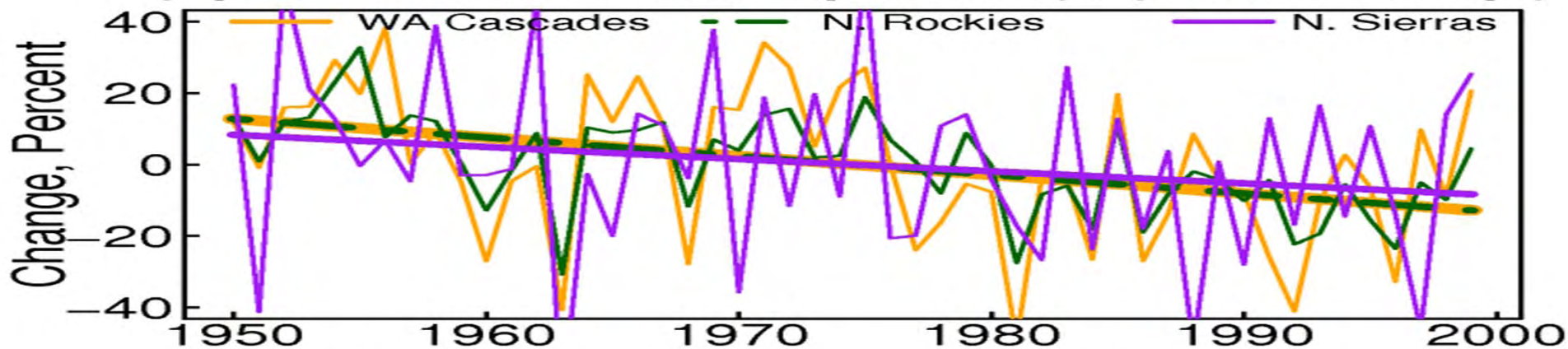


# April 1<sup>st</sup> snowpack 2000 - 2100

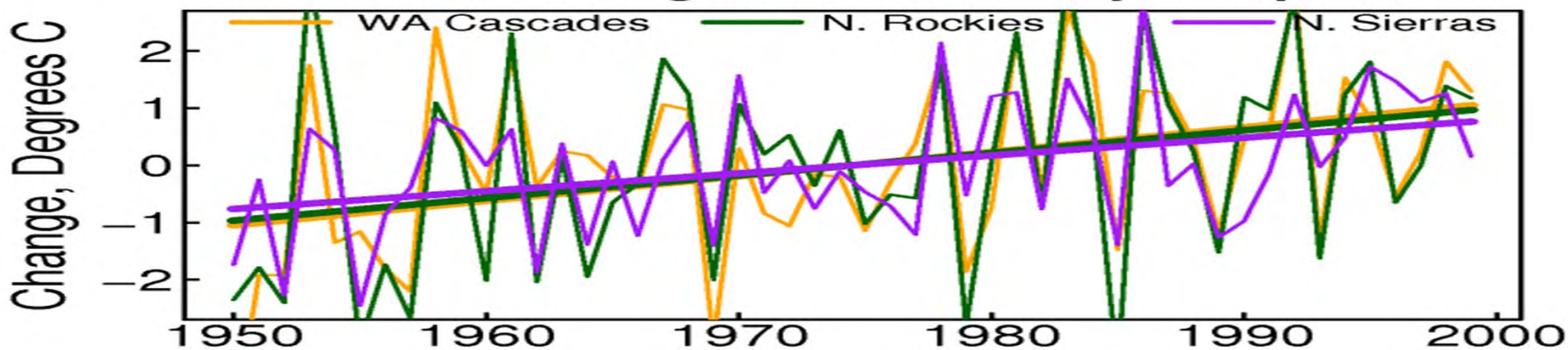




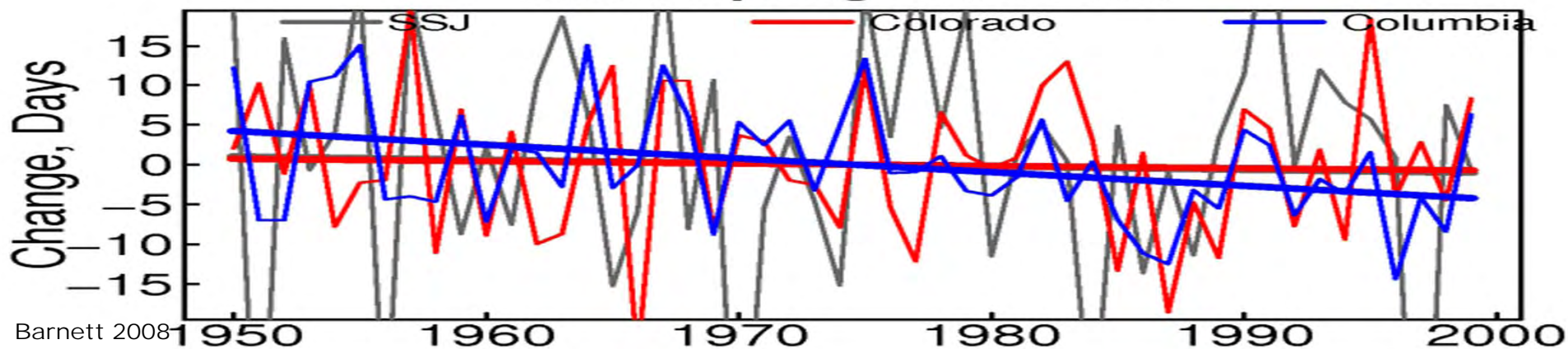
**(April 1st Snow Water Equivalent) / (Winter Precip.)**



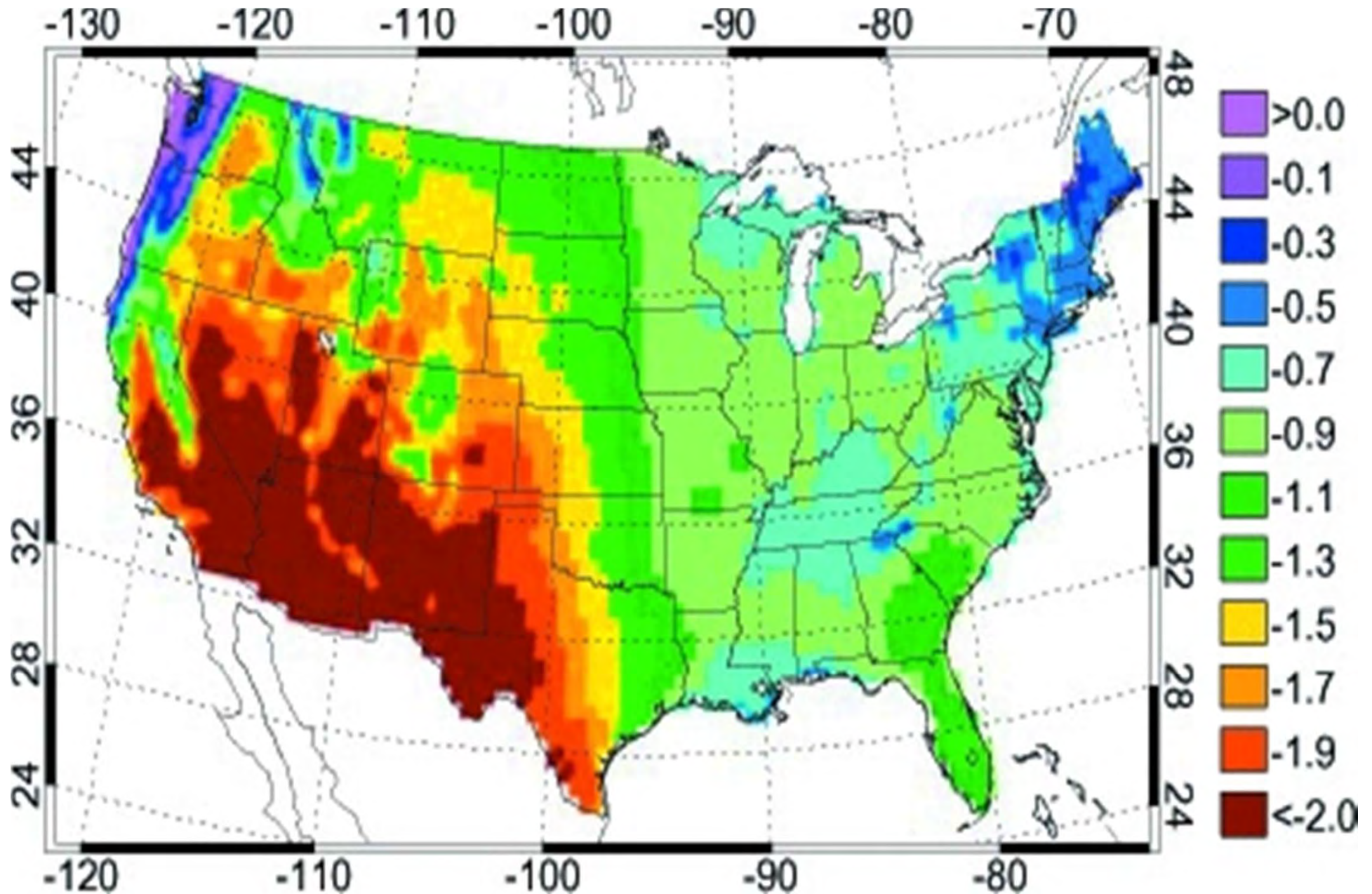
**Jan–Feb–Mar Avg. Minimum Daily Temperature**



**River Spring Peak Flow**

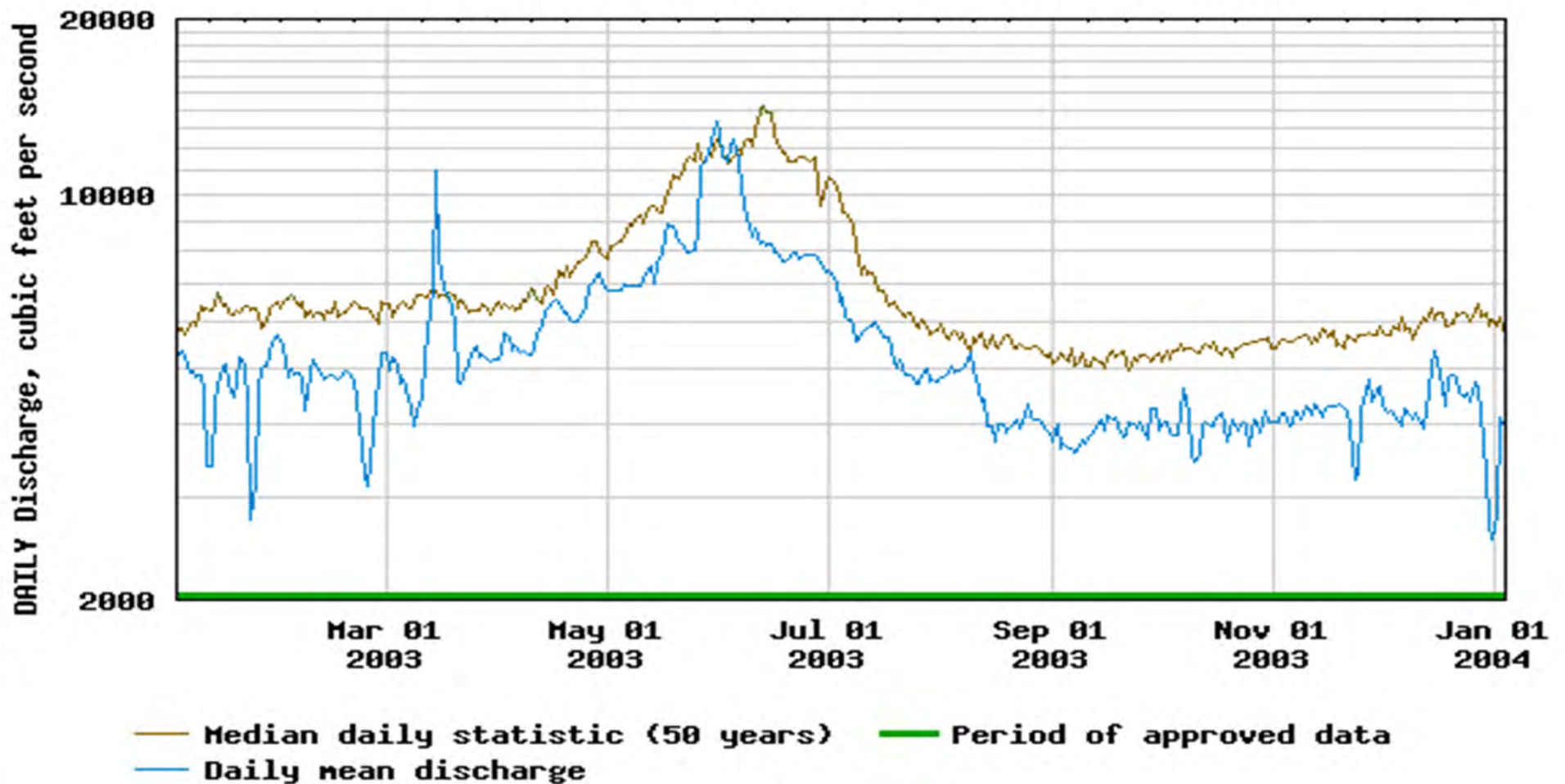


# Geographic Variation in Annual Water Balance (Precip - *Potential* ET, meters per year)

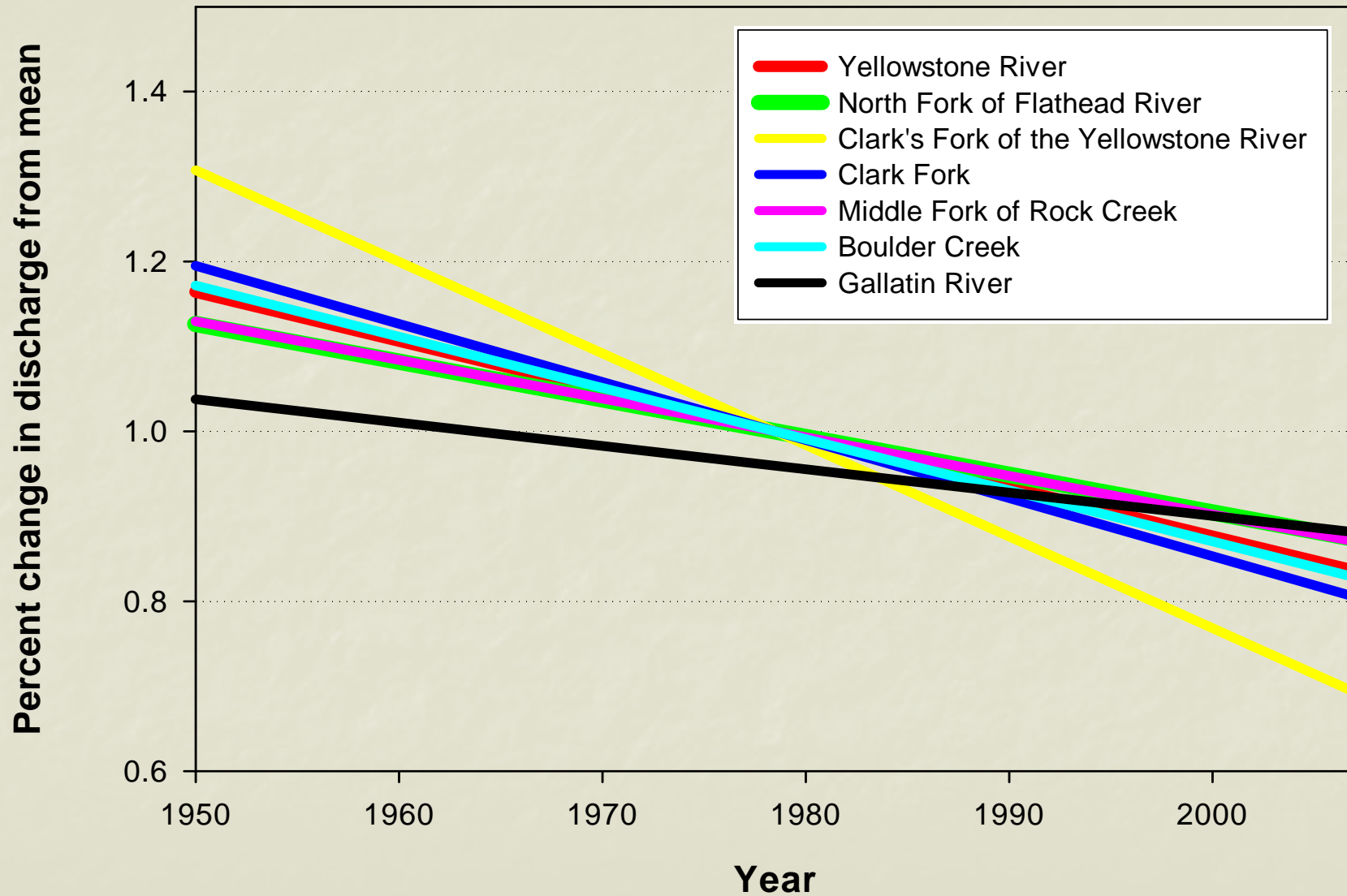


# MONTANA'S STREAMFLOW IS DECREASING AND PEAKING EARLIER

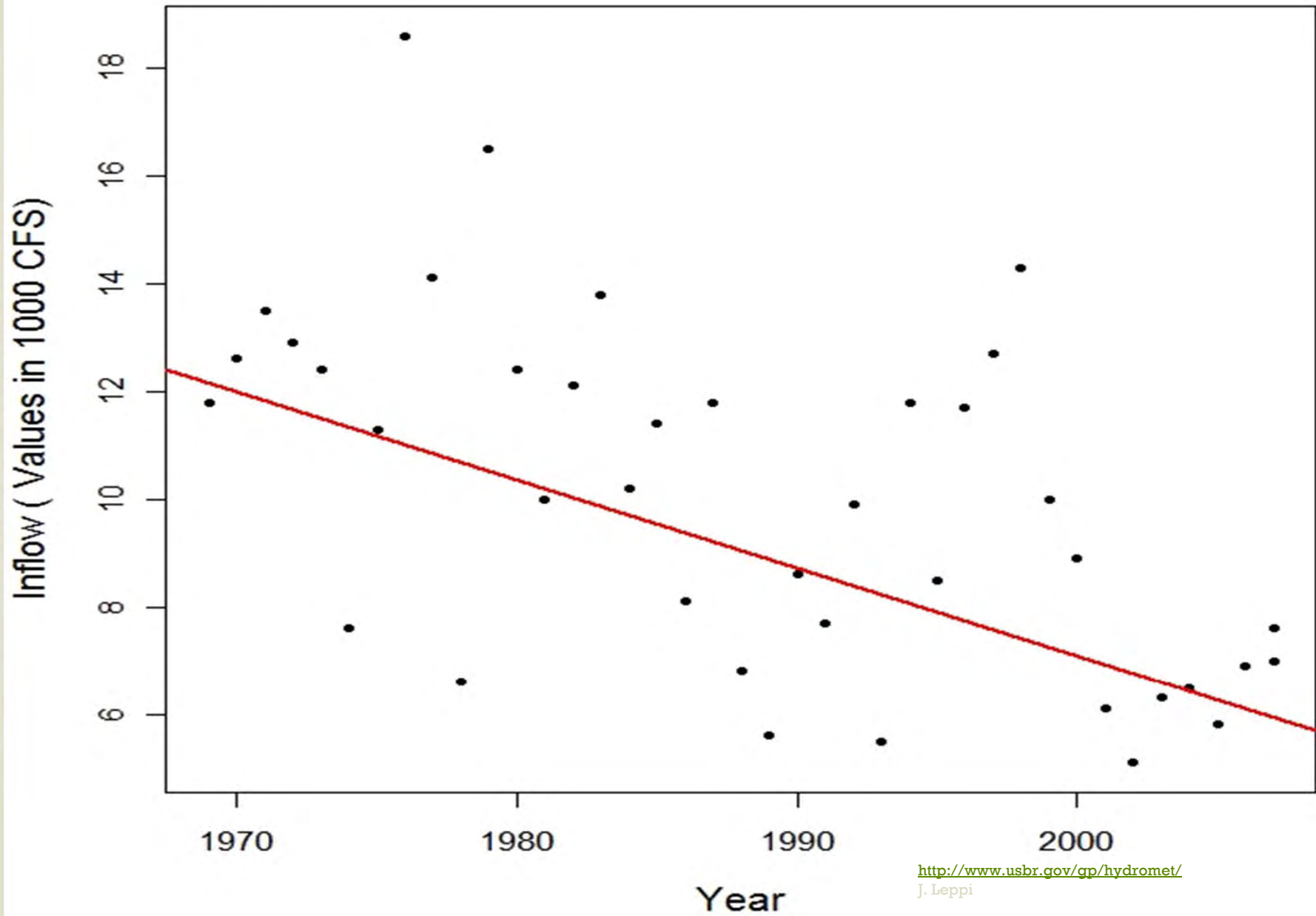
USGS 06090300 Missouri River near Great Falls MT



# Montana Mean August stream Discharge 1950-2007



## Fort Peck Reservoir Mean Annual Inflow 1968-2007



<http://www.usbr.gov/gp/hydromet/>

J. Leppi

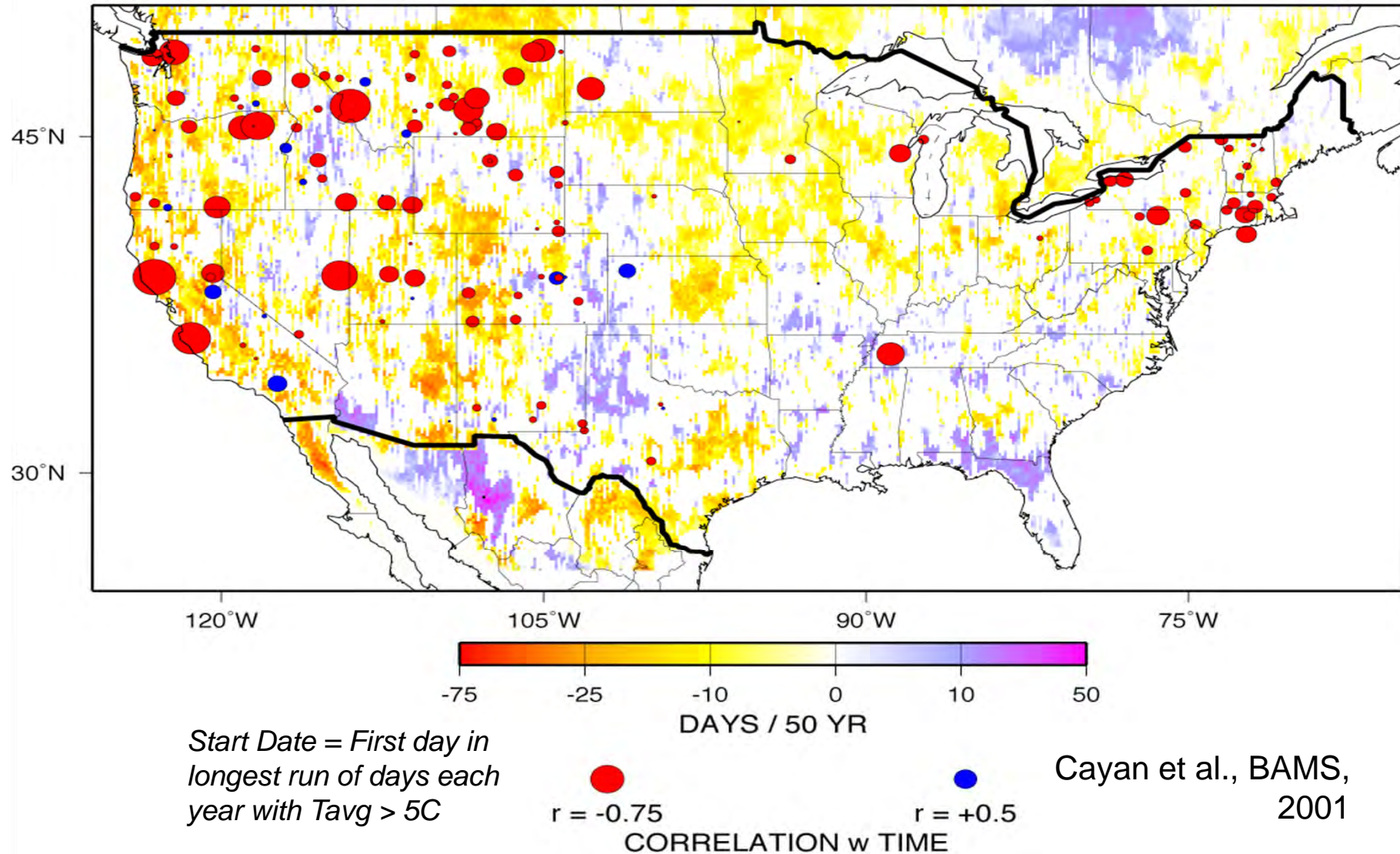
# ECOSYSTEM RESPONSES



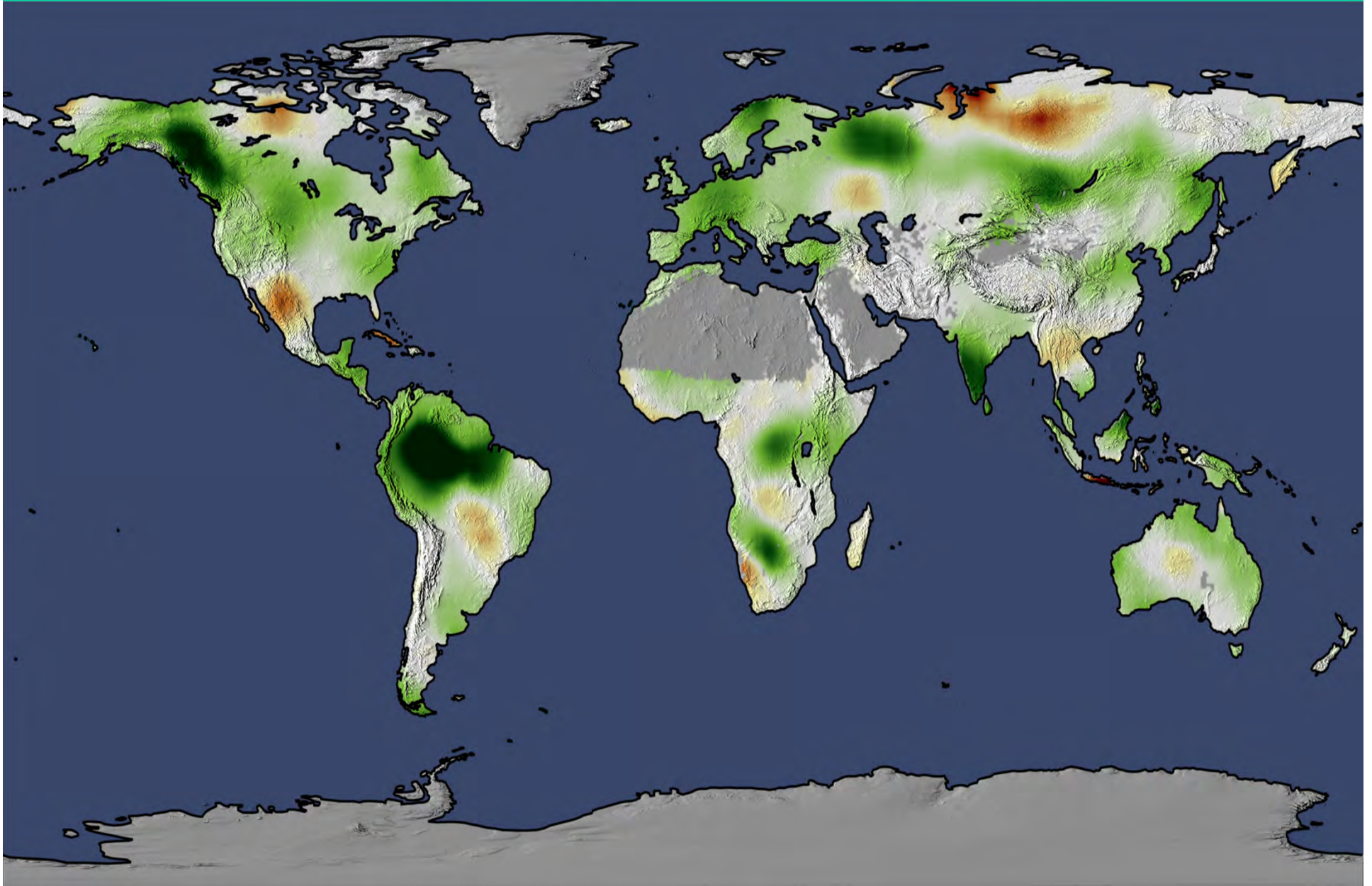
2007 6 8

# The warming has lengthened growing seasons and hastened green-up dates.

SHADES: TRENDS OF BEGIN DATE OF GROWING SEASON, 1950-99, FROM TEMPERATURES  
DOTS: TRENDS IN LILAC FIRST-BLOOM DATES (Sites with 20+ yrs of record)



## Change in Terrestrial NPP from 1982 to 1999.



Nemani et al., Science June 6<sup>th</sup> 2003



# Space Shuttle picture of Montana Fires August 13, 2007



Livingston, MT



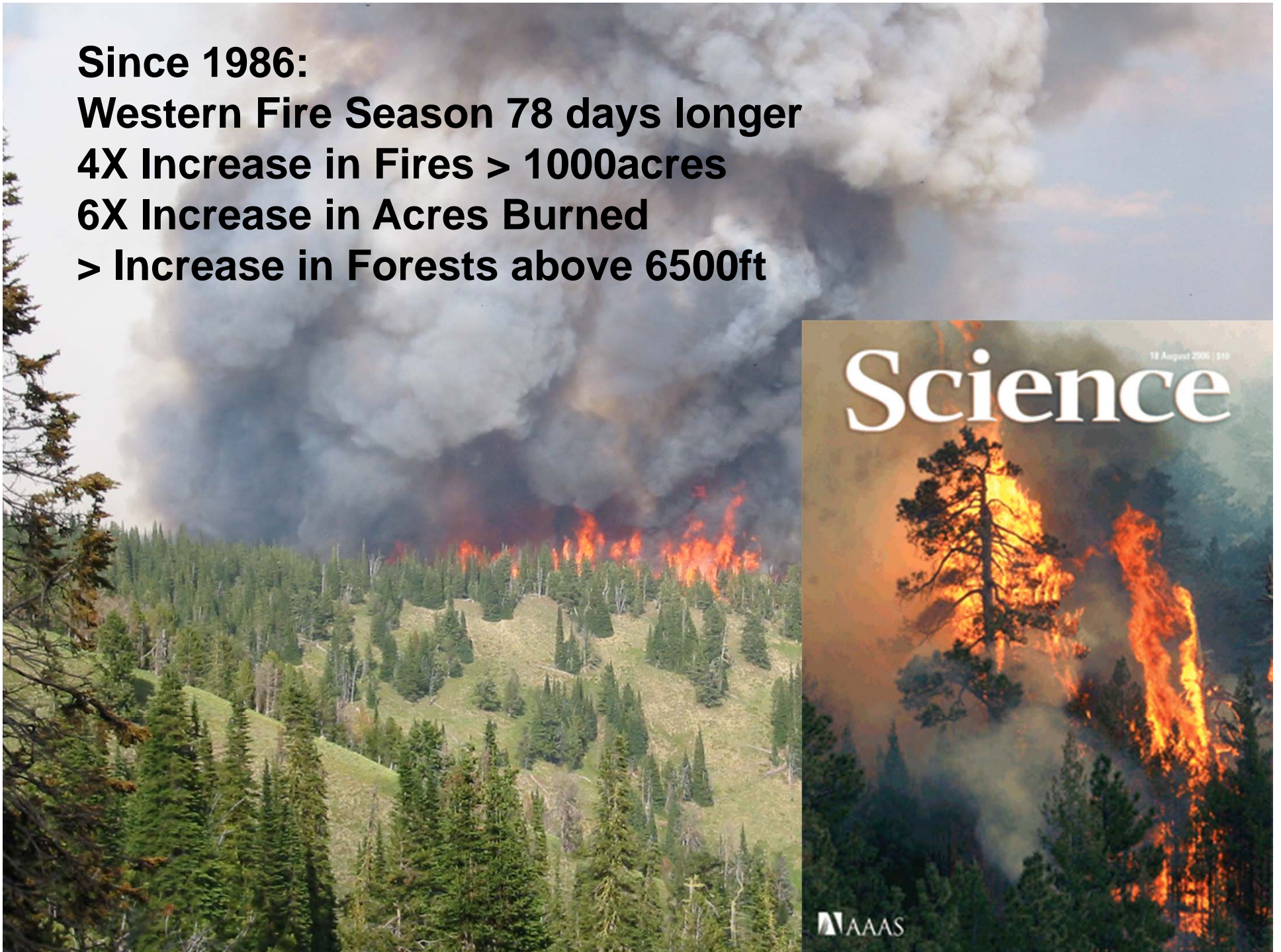
**Since 1986:**

**Western Fire Season 78 days longer**

**4X Increase in Fires > 1000acres**

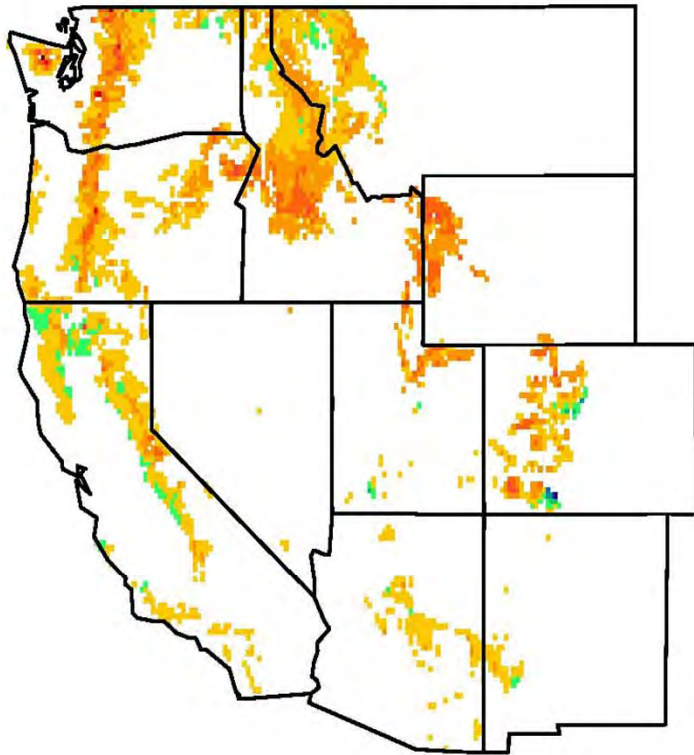
**6X Increase in Acres Burned**

**> Increase in Forests above 6500ft**



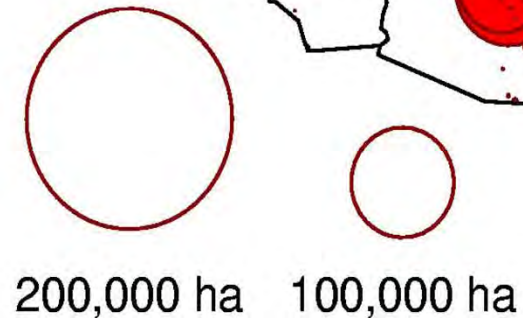
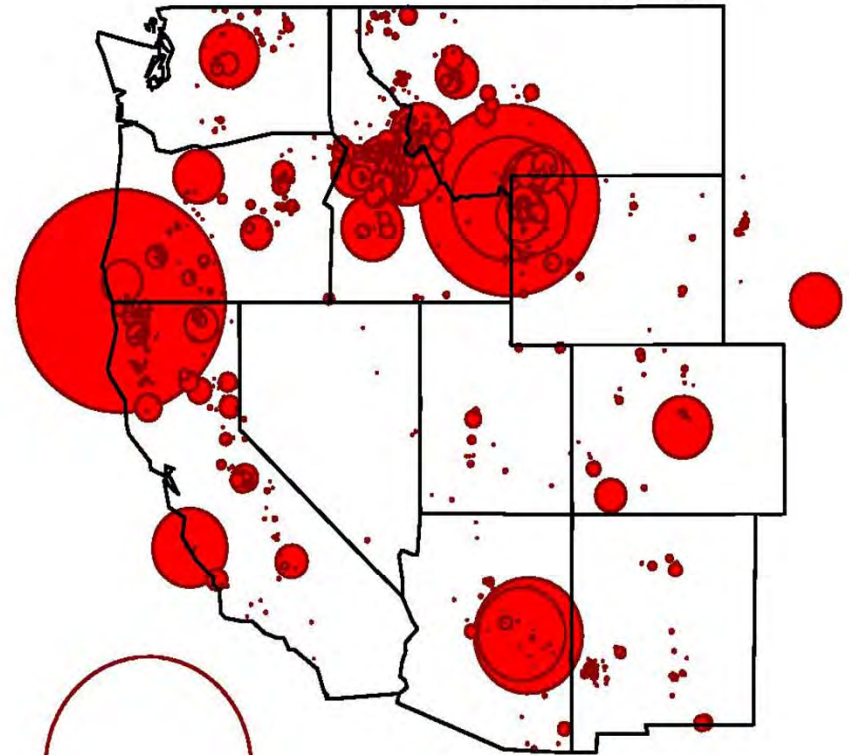
# Wildfires accelerate 1970 – 2003 with early snowmelt, longer, drier summers

Change in Average Moisture Deficit  
1987–2003 versus 1970–1986

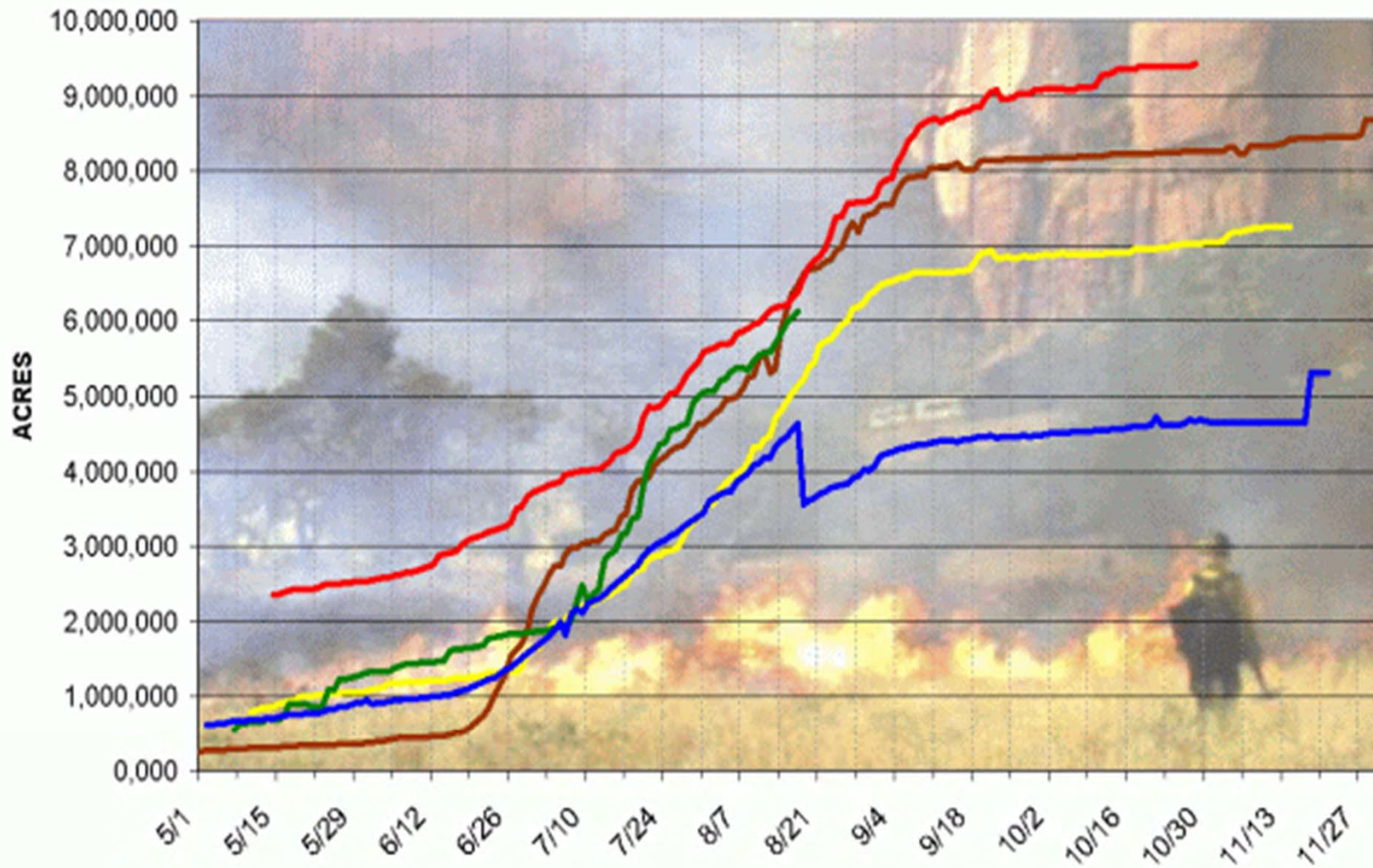


percent change scaled by forest area

Large Forest Wildfires  
in Years with Early Spring



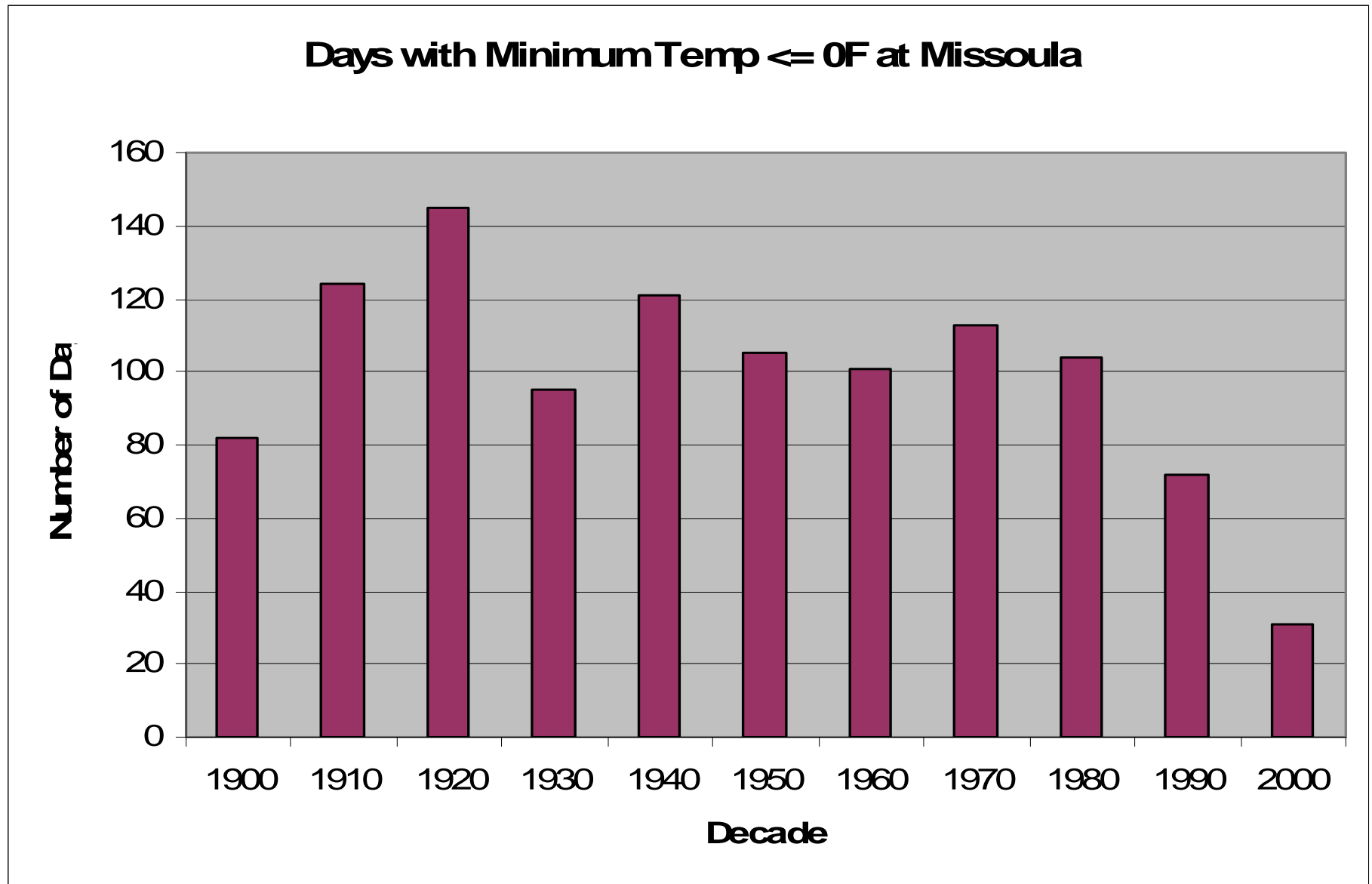
# WILDLAND ACRES BURNED 2007



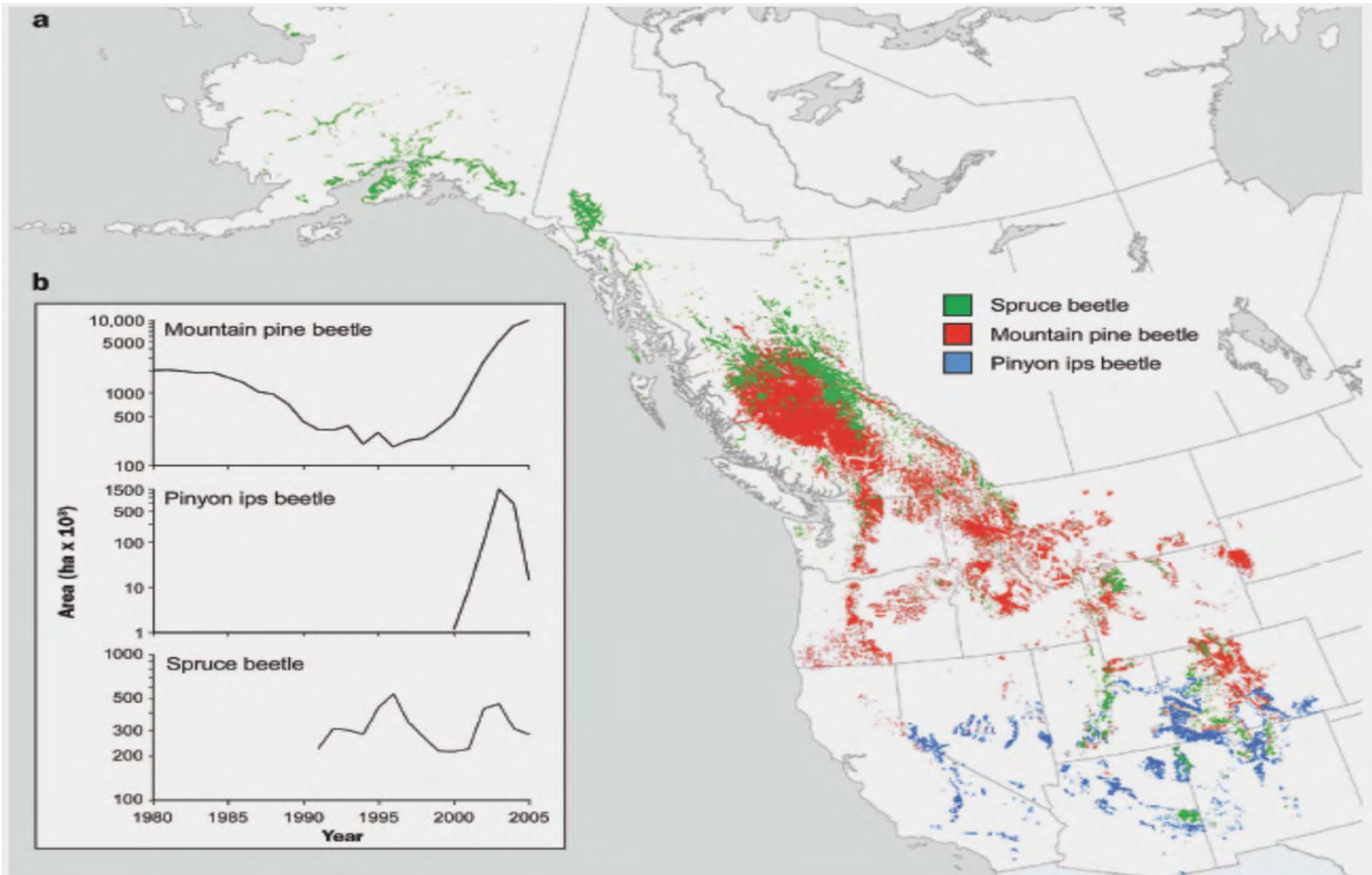
August 17, 2007



# DAYS/Decade <0degF



From Gene Petrescu, NWS, Missoula

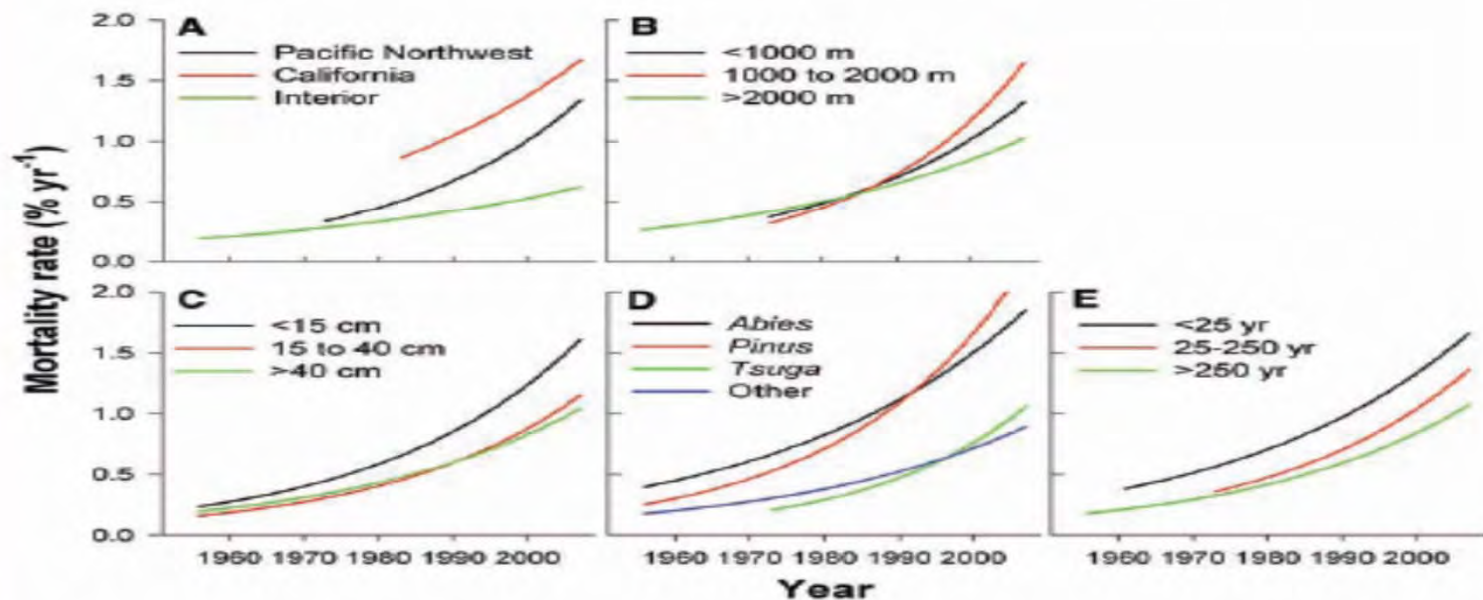
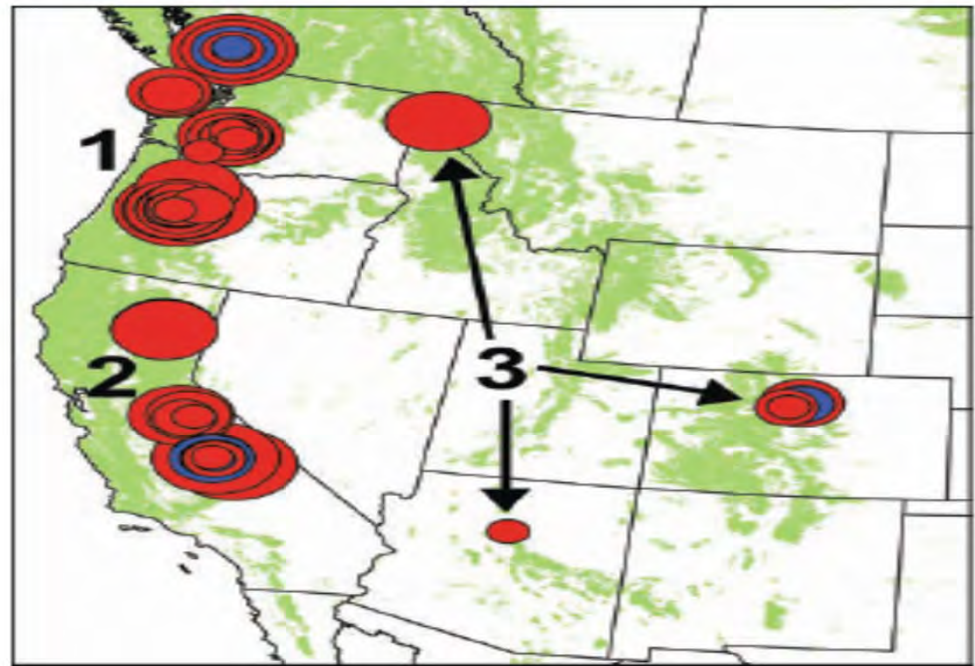


**Figure 1.** Recent mortality of major western conifer biomes to bark beetles. (a) Map of western North America showing regions of major eruptions by three species. (b) Sizes of conifer biome area affected by these three species over time. Data are from the Canadian Forest Service, the British Columbia Ministry of Forests and Range, and the US Forest Service.

Whitebark  
Pine  
Dubois WY  
Aug 08



**Fig. 1.** Locations of the 76 forest plots in the western United States and southwestern British Columbia. Red and blue symbols indicate, respectively, plots with increasing or decreasing mortality rates. Symbol size corresponds to annual fractional change in mortality rate (smallest symbol,  $<0.025 \text{ year}^{-1}$ ; largest symbol,  $>0.100 \text{ year}^{-1}$ ; the three intermediate symbol sizes are scaled in increments of  $0.025 \text{ year}^{-1}$ ). Numerals indicate groups of plots used in analyses by region: (1) Pacific Northwest, (2) California, and (3) interior. Forest cover is shown in green.

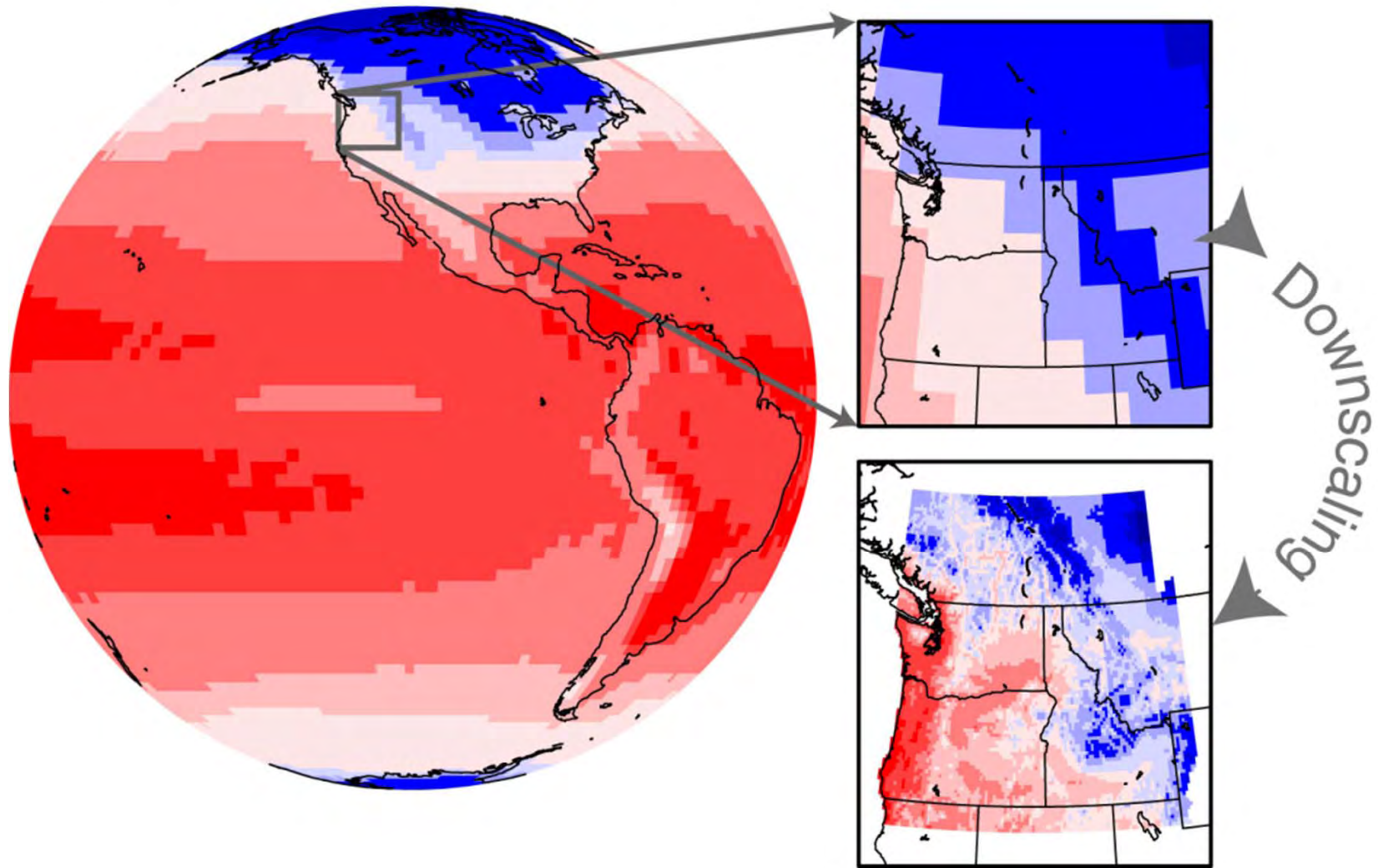


**Fig. 2.** Modeled trends in tree mortality rates for (A) regions, (B) elevational class, (C) stem diameter class, (D) genus, and (E) historical fire return interval class.



# Downscaling global models for regional studies

Global Climate Model Air Temperature

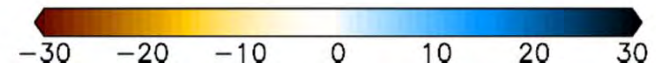
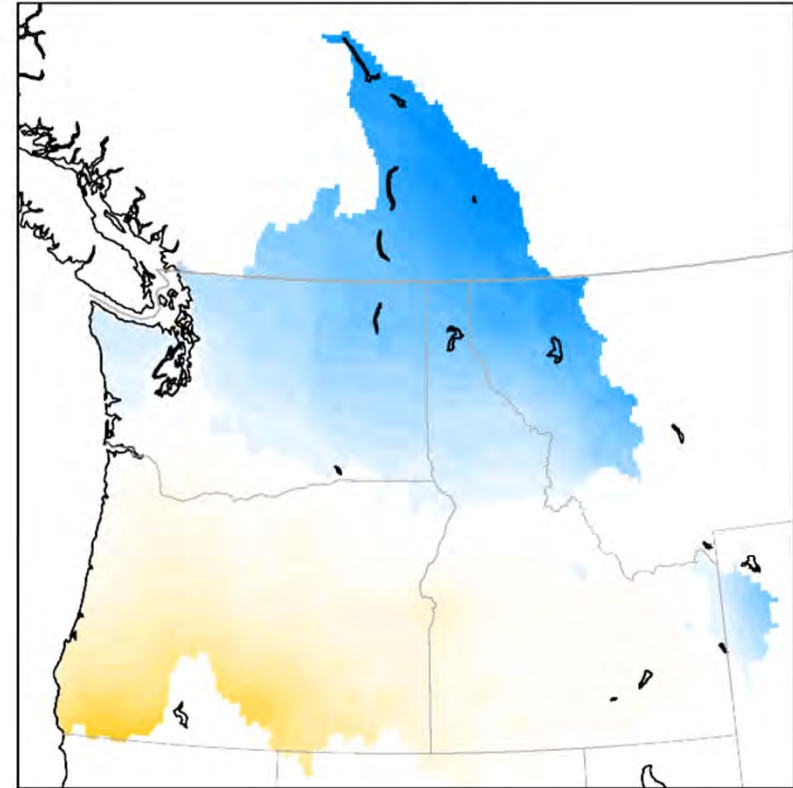
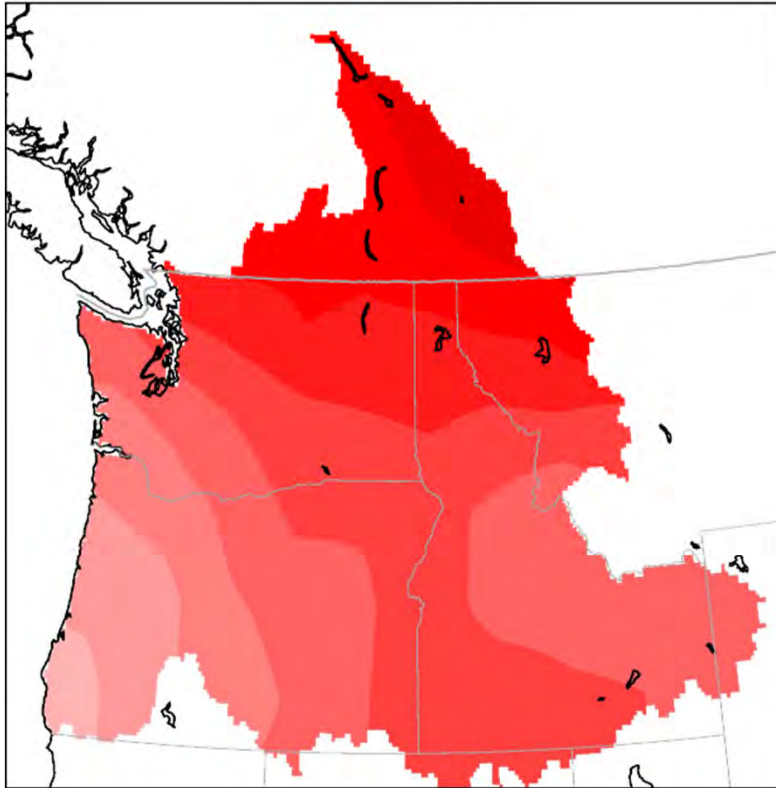


# Downscaling -- Winter

DJF Difference to 2040 CCSM3

Temp (C)

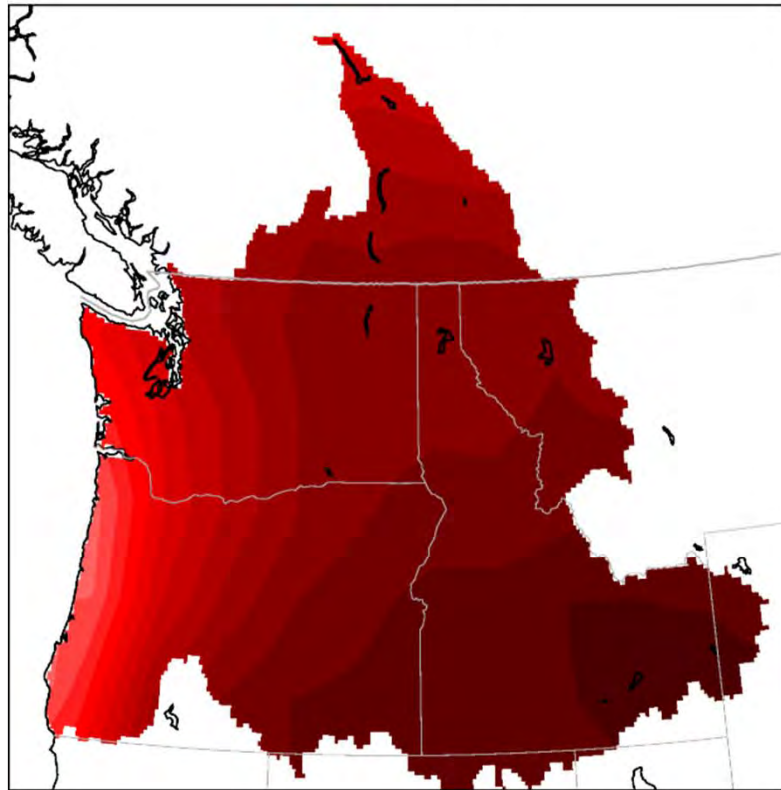
Precip (%)



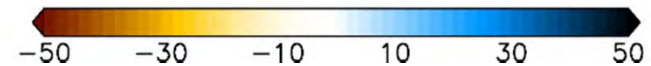
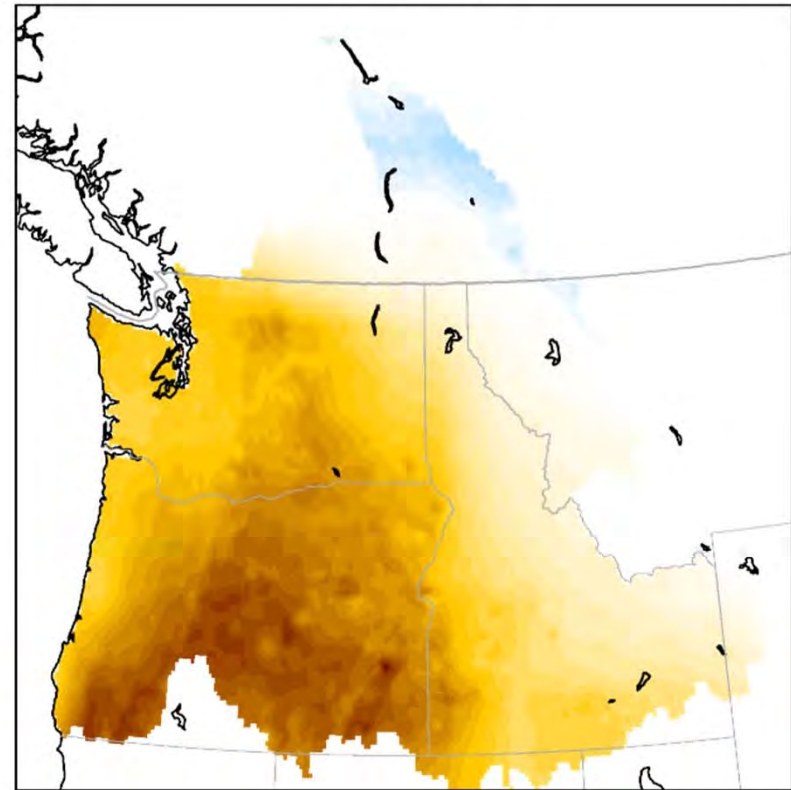
# Downscaling -- Summer

JJA Difference to 2040 CCSM3

Temp (C)



Precip (%)



By 2050 Global Climate Models project Montana to be 5deg F. warmer in summer, but receive 10% less rainfall  
*40% Increase in Summer Evaporative Demand!!*

## ***Water Management Recreation versus Agriculture***



**The MonDak Region has an enormous amount of potential for irrigation development.**

# Montana Ecosystem Responses To Climate Trends

Water balance and  
Disturbance dynamics  
Will be more important than  
pure temperature responses

