Climate Trends in Northern California: How Do We Manage for the Future?

Forest Management and Watershed Science Symposium
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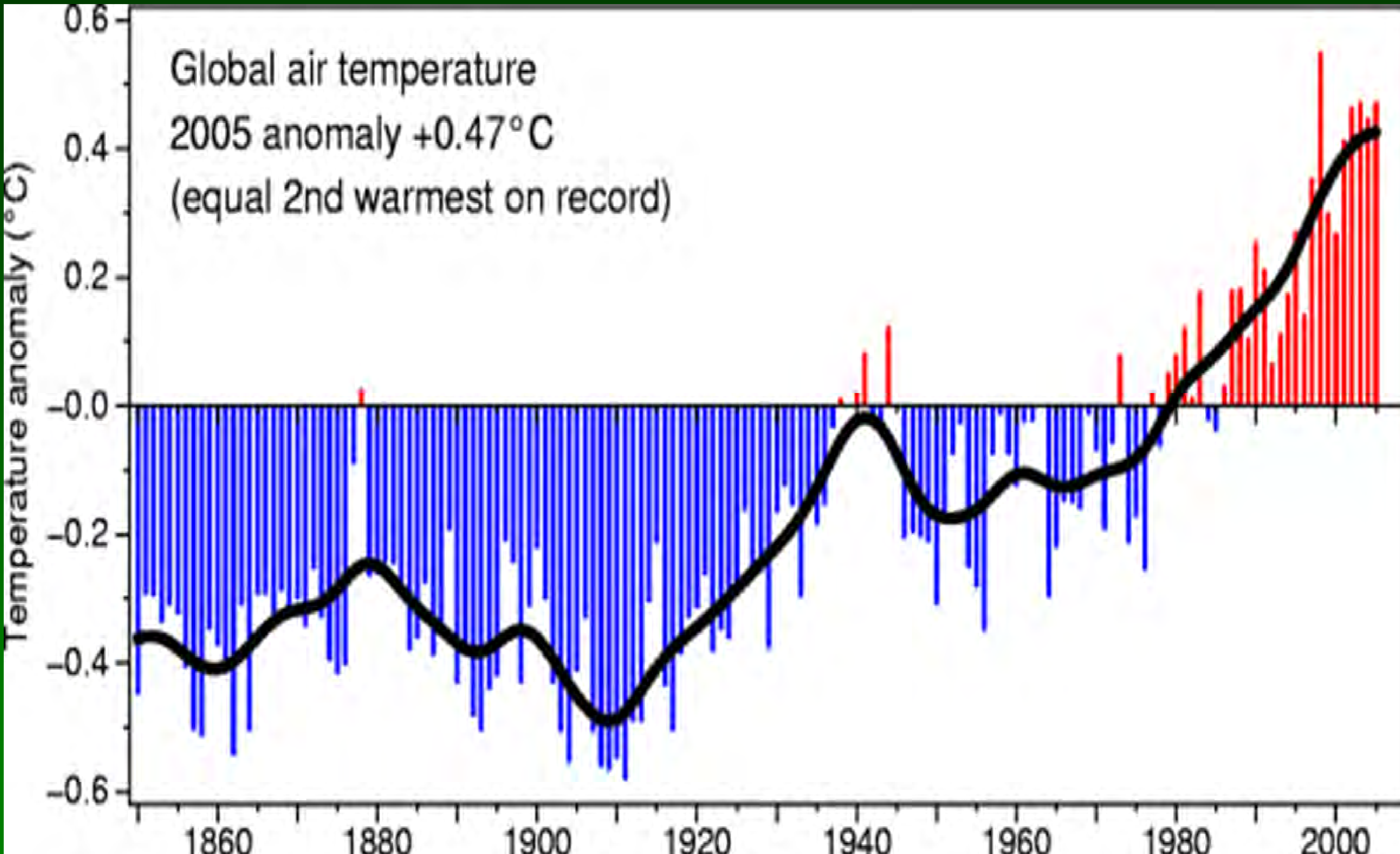
Global air temperature
2005 anomaly +0.47°C
(equal 2nd warmest on record)
Temperature anomaly (°C)
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
1860
1880
1900
1920
1940
1960
1980
2000


The glacier was here in
Le glacier était ici en
1992

Outline

- Observed trends in climate in Northeastern CA
- Observed trends in climate-driven processes: hydrology, fire, vegetation
- Projected future trends
- Management options

A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests

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I. Local trends in climate over the past century

Province Weather Station Data

The data presented in this section are derived from eight weather stations located in the Sierra Cascade Province, comprised of the Plumas, Lassen, and Modoc National Forests (Fig. 1).

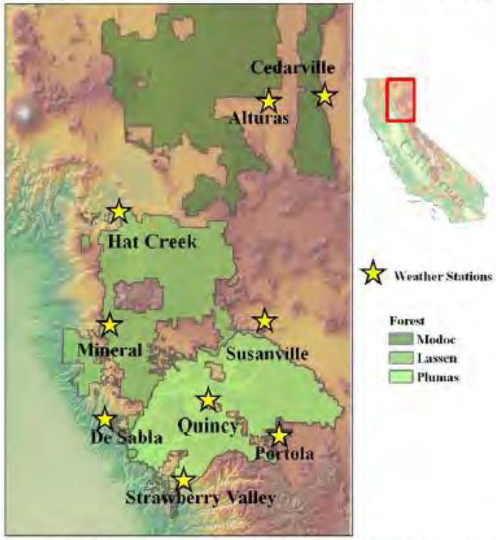
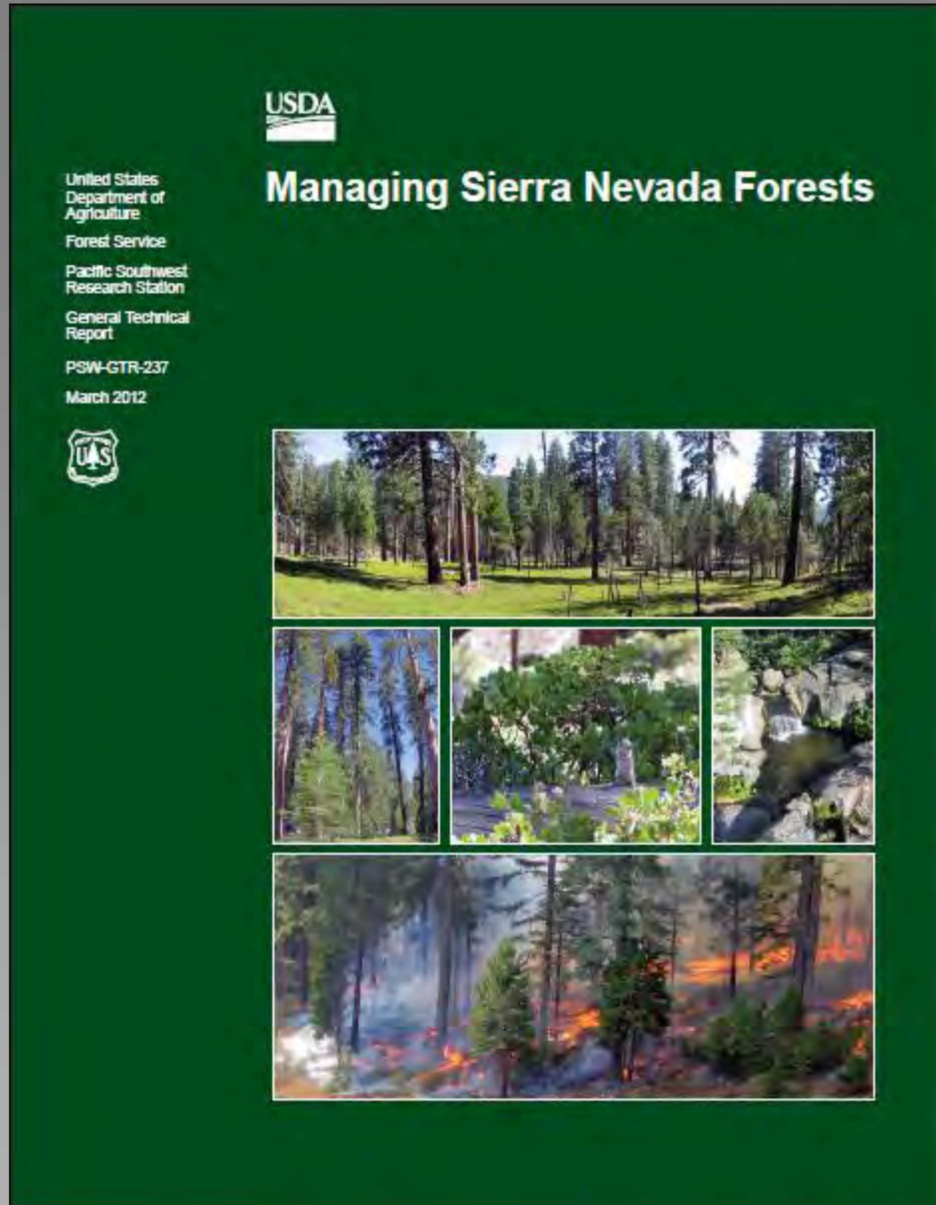


Figure 1. Locations of weather stations across the Sierra Cascade Province evaluated in this report.

Stations were chosen based on their geographic location and on the length and completeness of their records. In order to best represent the wide range of elevations and vegetation types found within the Sierra Cascade Province, we focused our analyses on stations located in different biogeographical regions and at opposite extremes of the province's elevation gradient. Data collected from individual stations within each climate region are presented to illustrate local

*Correspondent to contact for more information regarding this document.

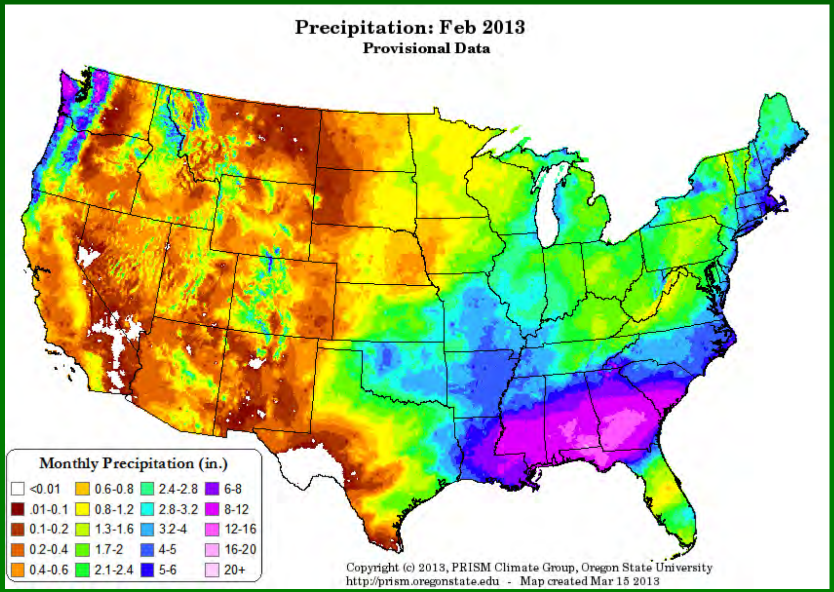
http://fsweb.r5.fs.fed.us/program/ecology/climate/



North, Malcolm, ed. 2012. Managing Sierra Nevada forests. Gen. Tech. Rep. PSW-GTR-237. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 184 pp.

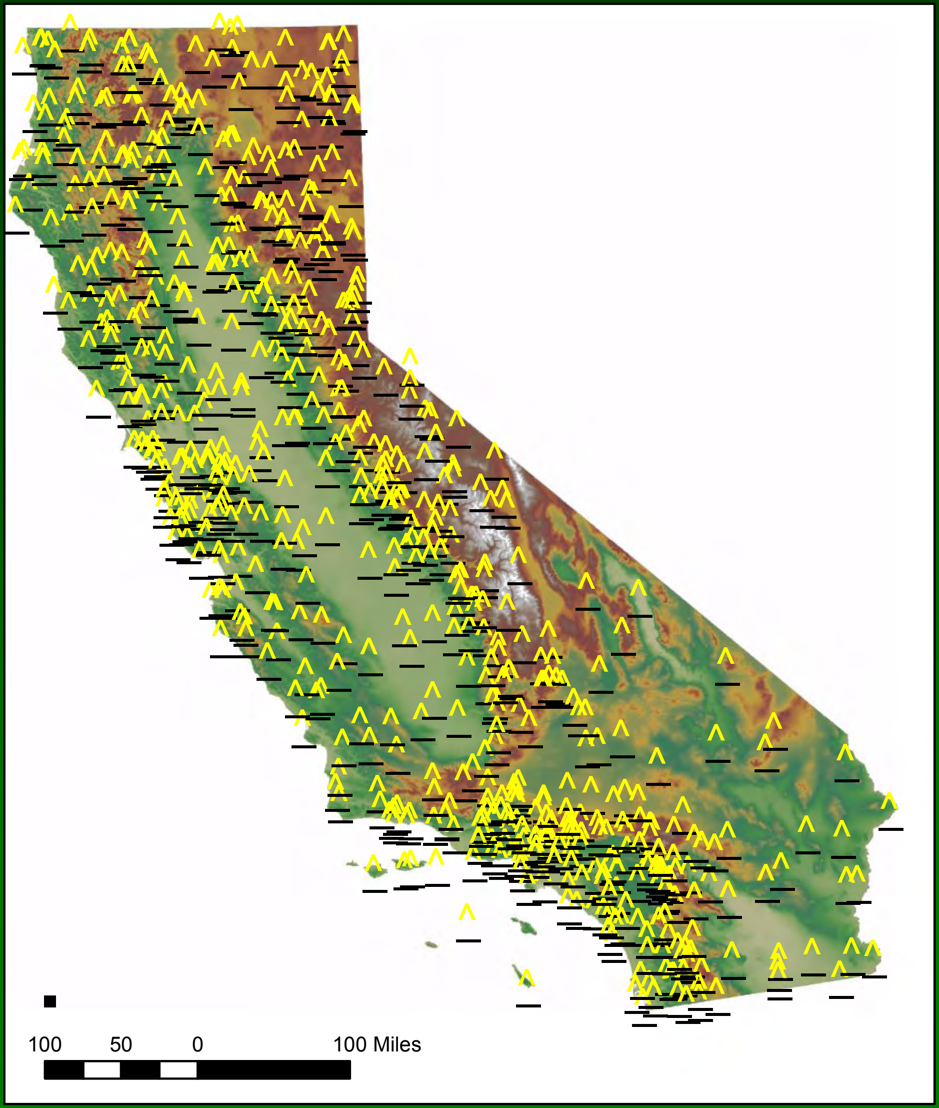
Observed Trends in Climate

- Weather Station Data
- Spatial Climate Grid Data (PRISM)

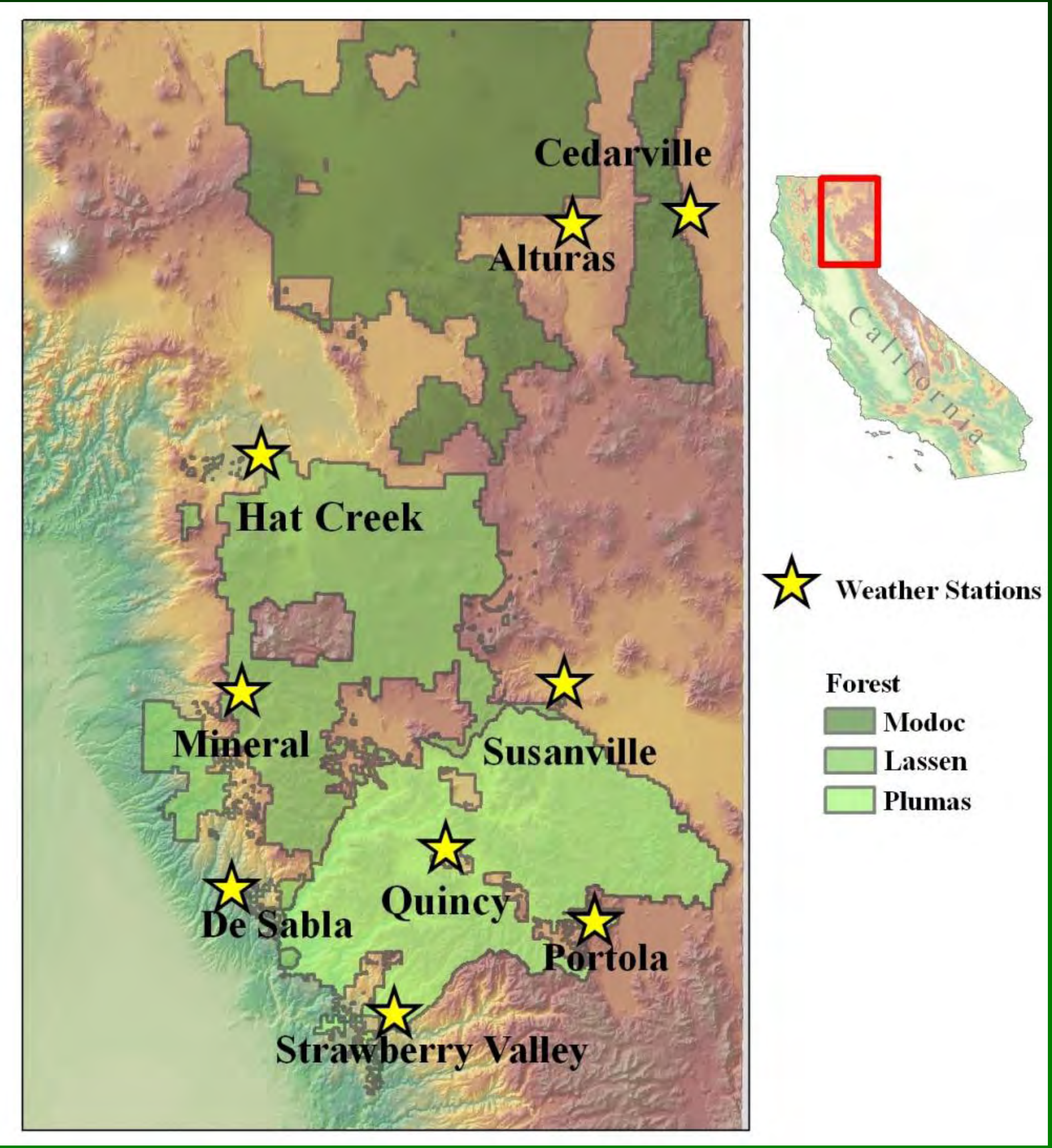


Remote Automated Weather Station

California Weather Stations

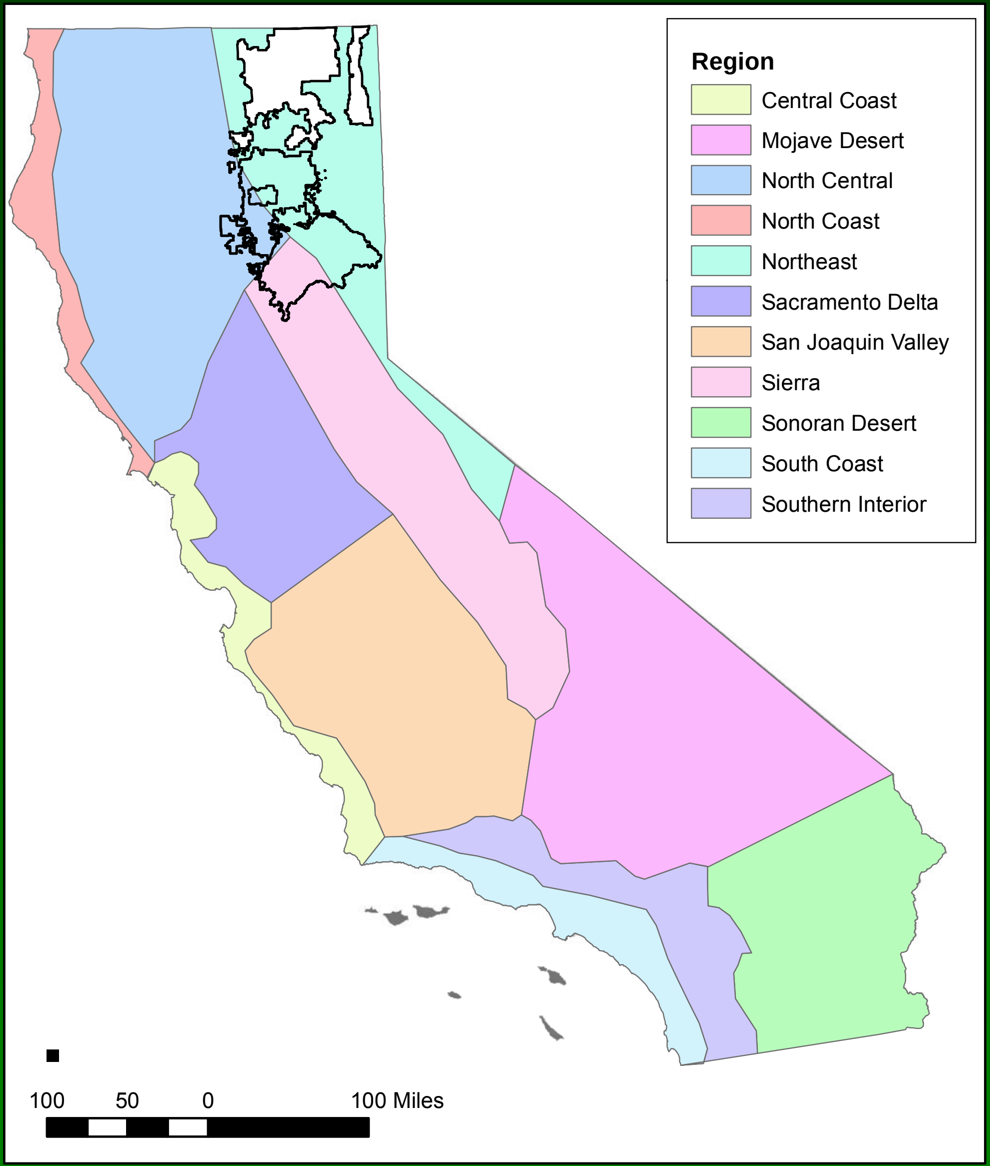


COOP and RAWS Stations: Western Regional Climate Center
www.calclim.dri.edu/ccacoop.html



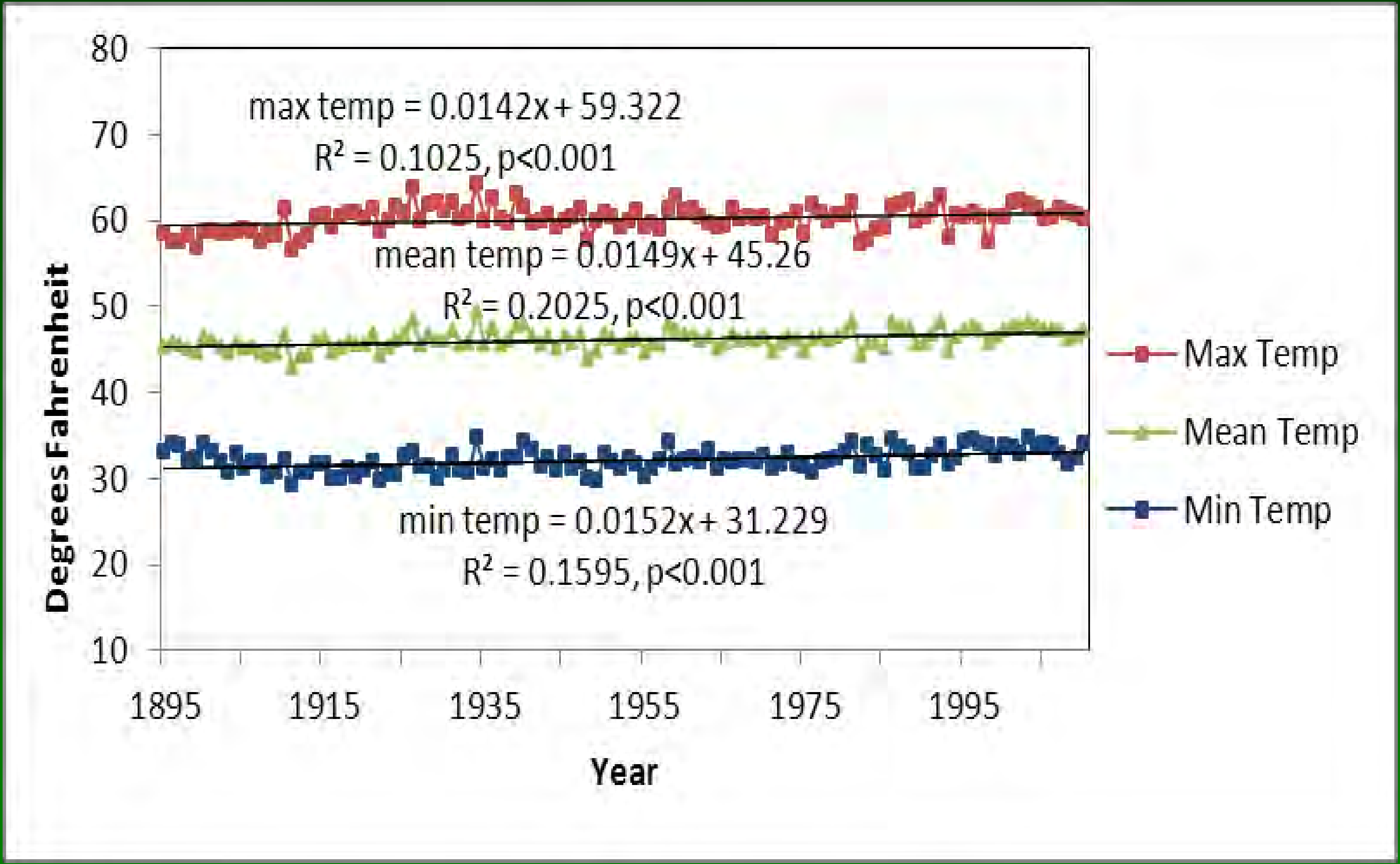
Cedarville
Alturas
Hat Creek
Mineral
Susanville
Quincy
De Sabla
Portola
Strawberry Valley
California
Weather Stations
Forest
Modoc
Lassen
Plumas

Climate Regions

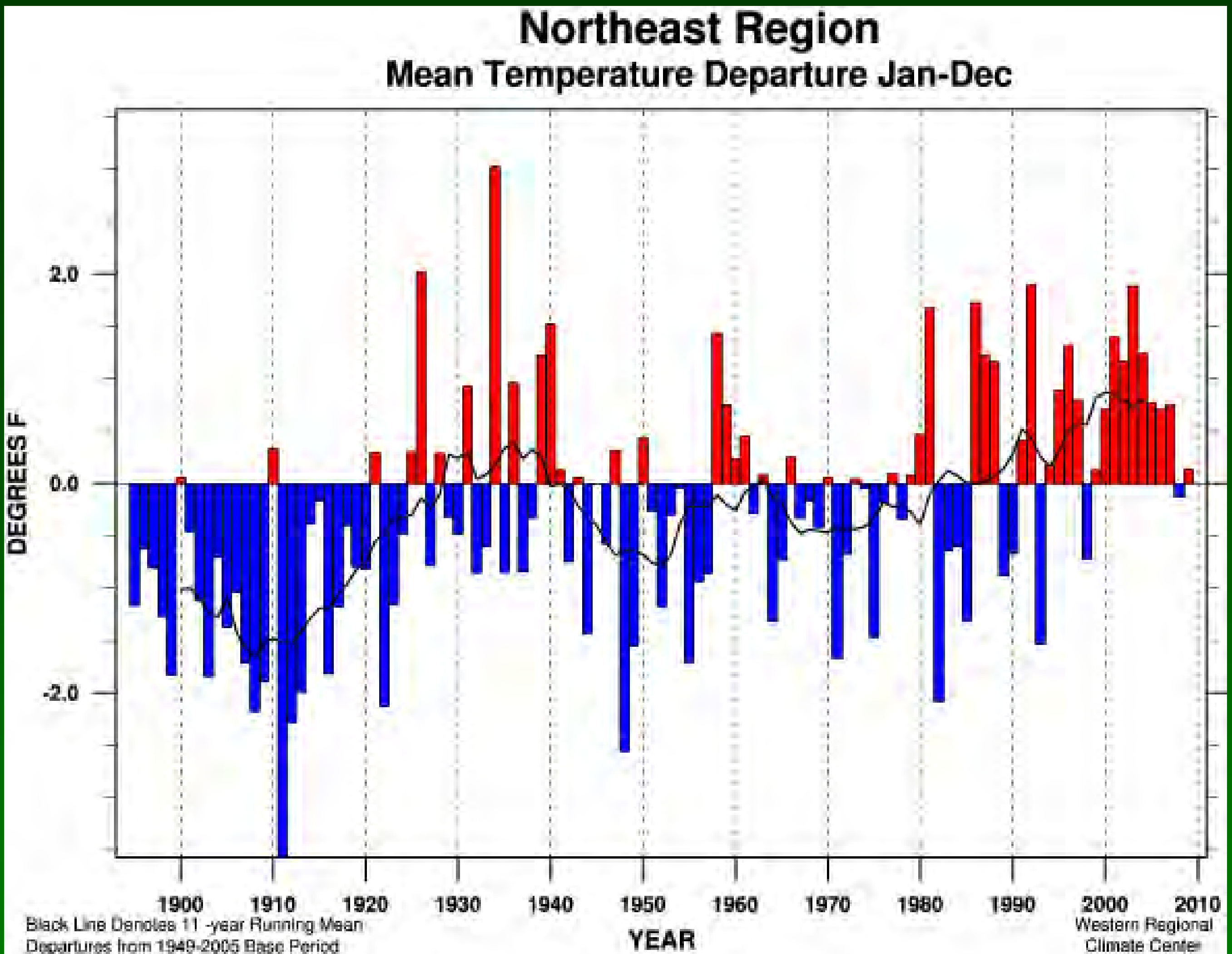


Abatzoglou *et al*. 2009

Trends in Temperature: Weather Stations

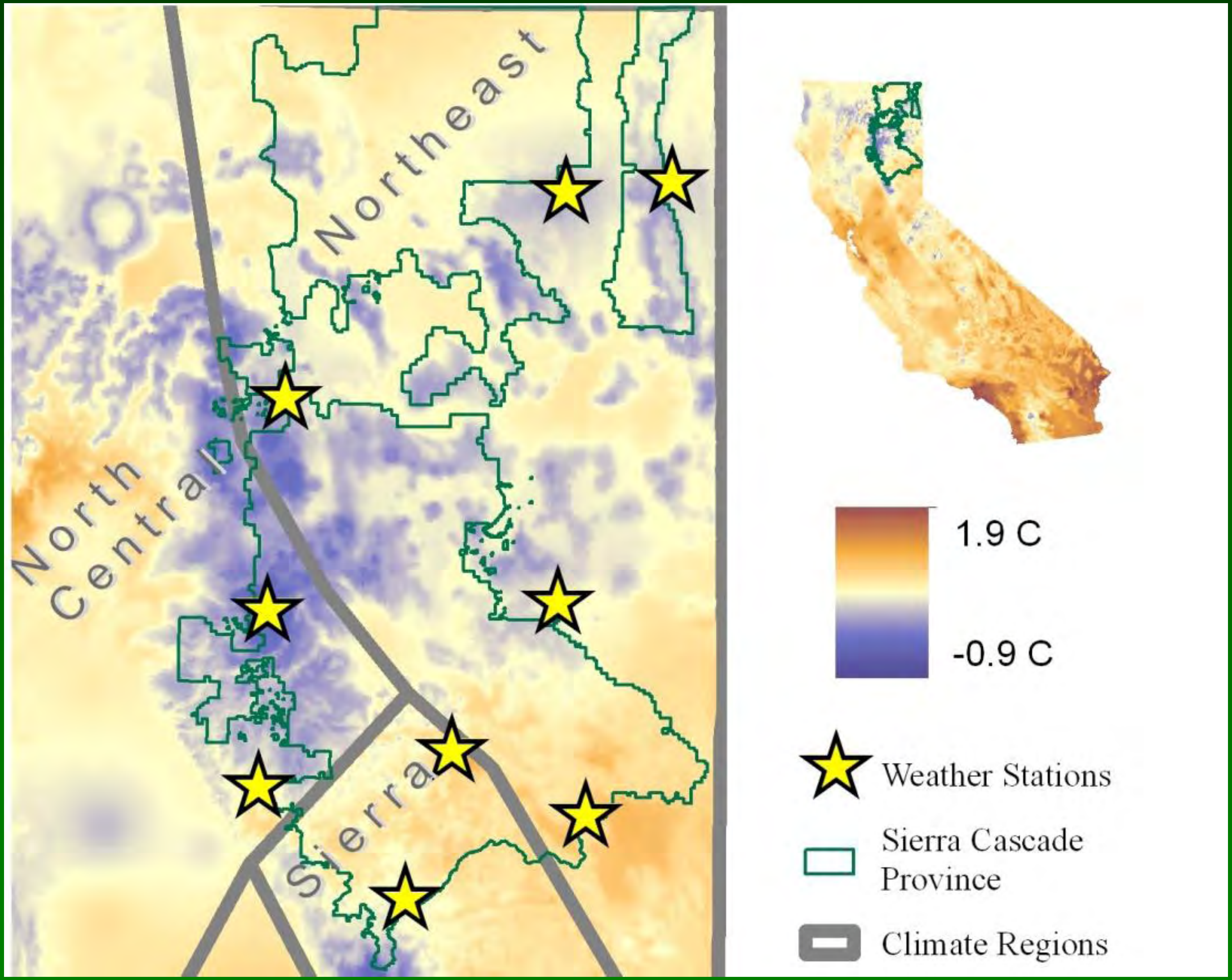


Northeast Climate Region

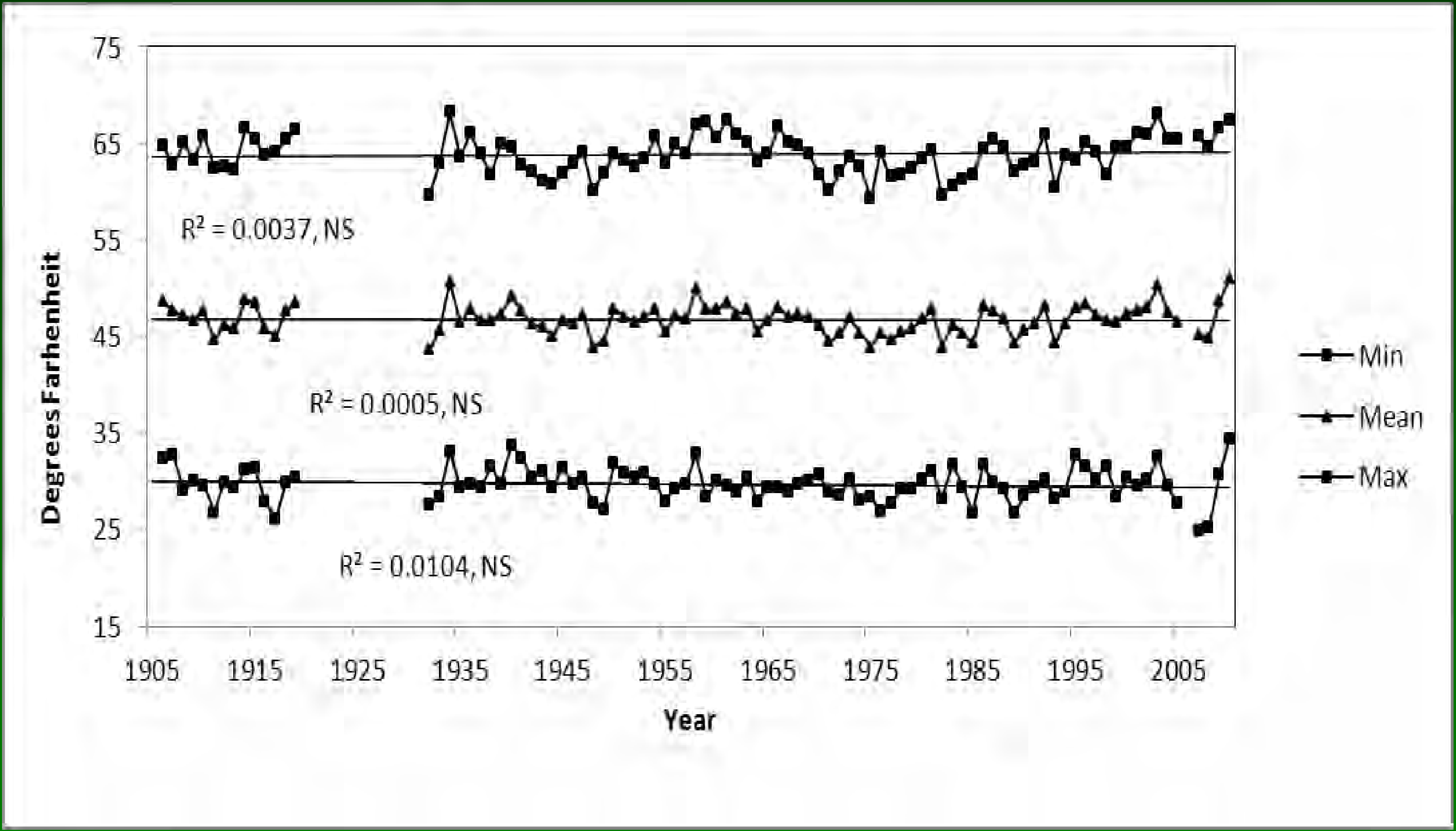


Linear Trend 1895-present		+ 1.48 ± 0.55 °F/100yr	
Linear Trend 1949-present		+ 2.27 ± 1.30 °F/100yr	
Linear Trend 1975-present		+ 3.74 ± 3.32 °F/100yr	
Warmest Year		49.4 °F (+ 3.0 °F) in 1934	MEAN 46.4 °F
Coldest Year		42.8 °F (- 3.6 °F) in 1911	STDEV 1.00 °F
Jan-Dec	2009	46.5 °F (+ 0.1 °F)	RANK 79 of 115

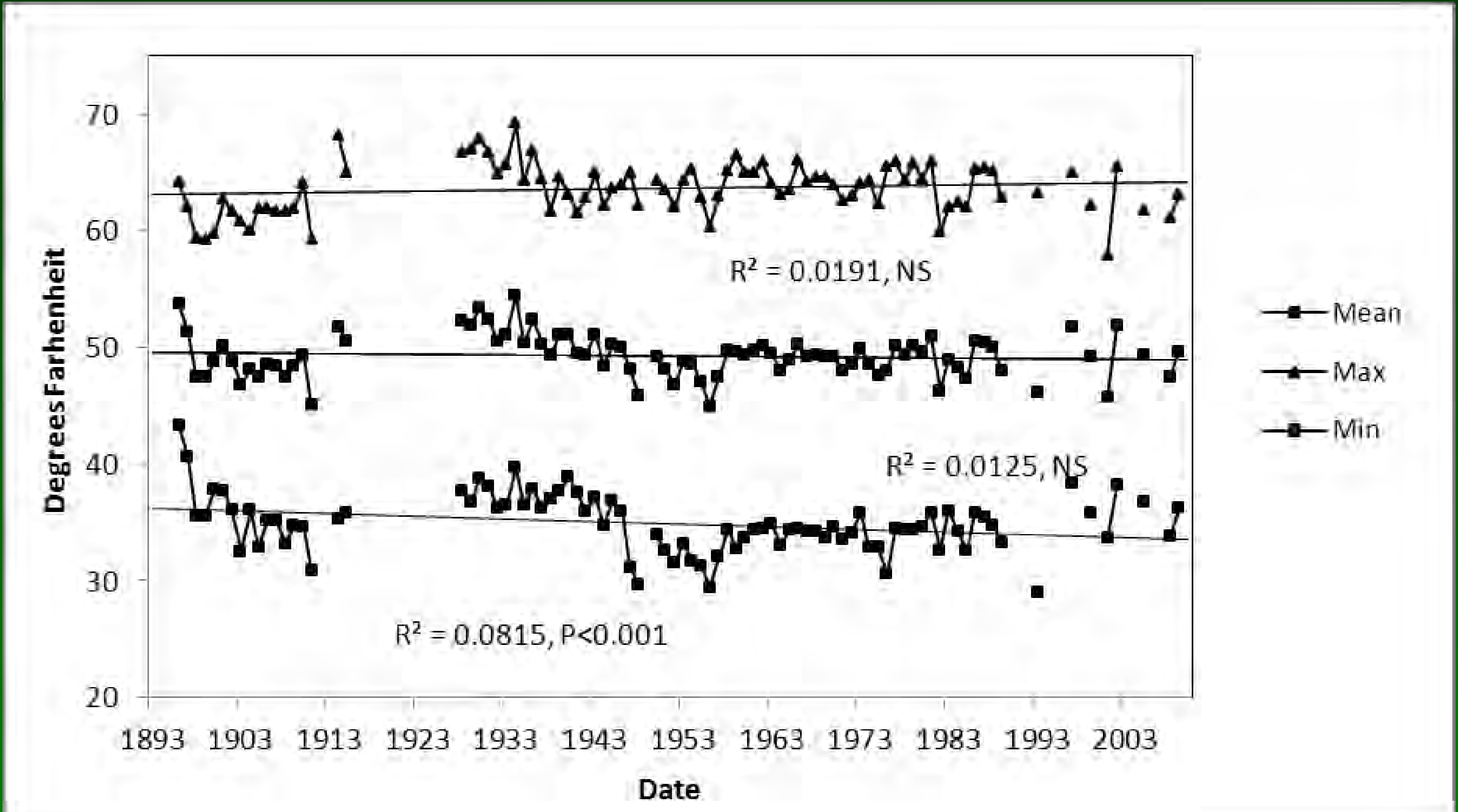
Trends in Temperature: PRISM



Mean temperature change between the 1930's and 2000's

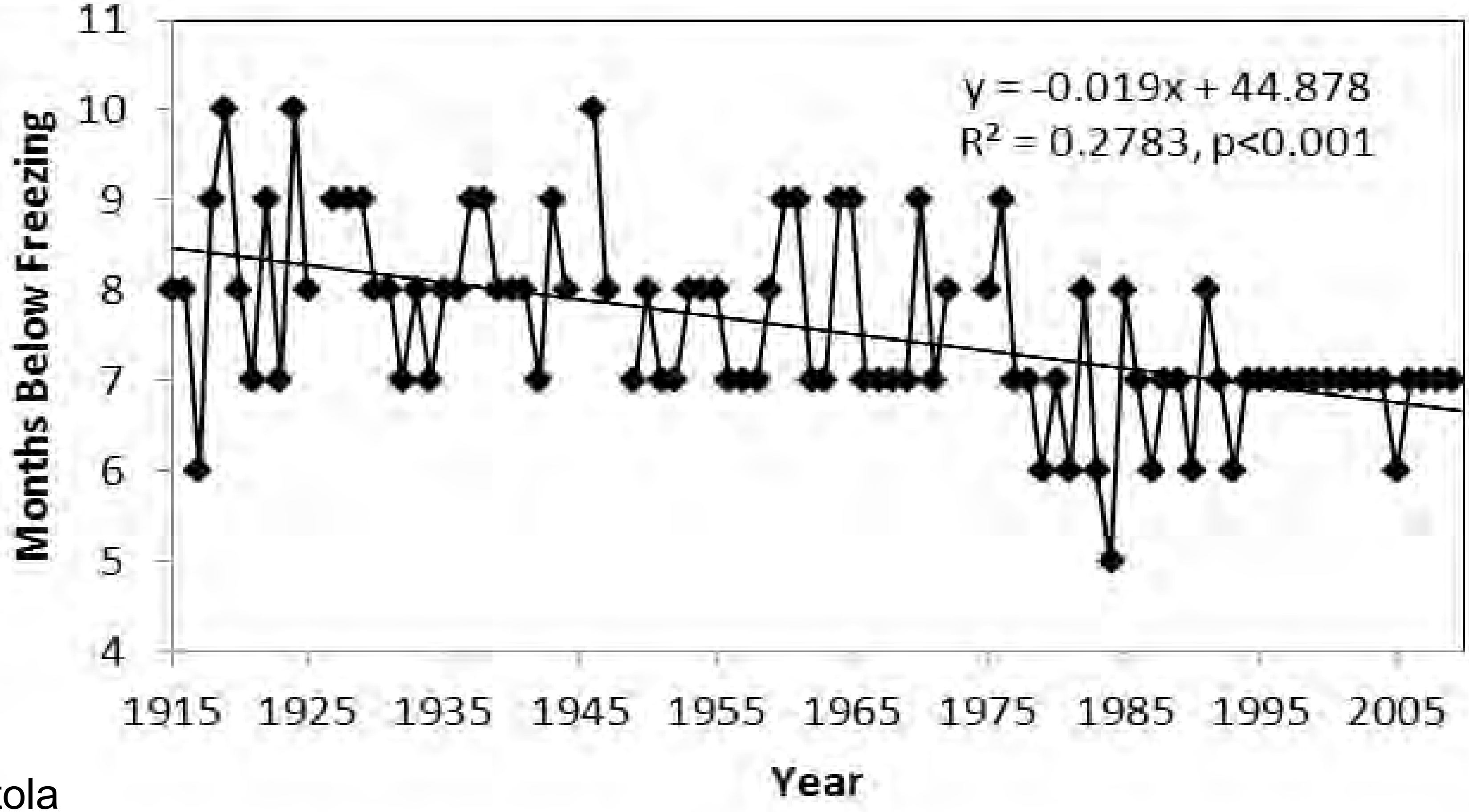


Alturas Temperature Trends: 1905-2010



Susanville Temperature Trends: 1896-2010

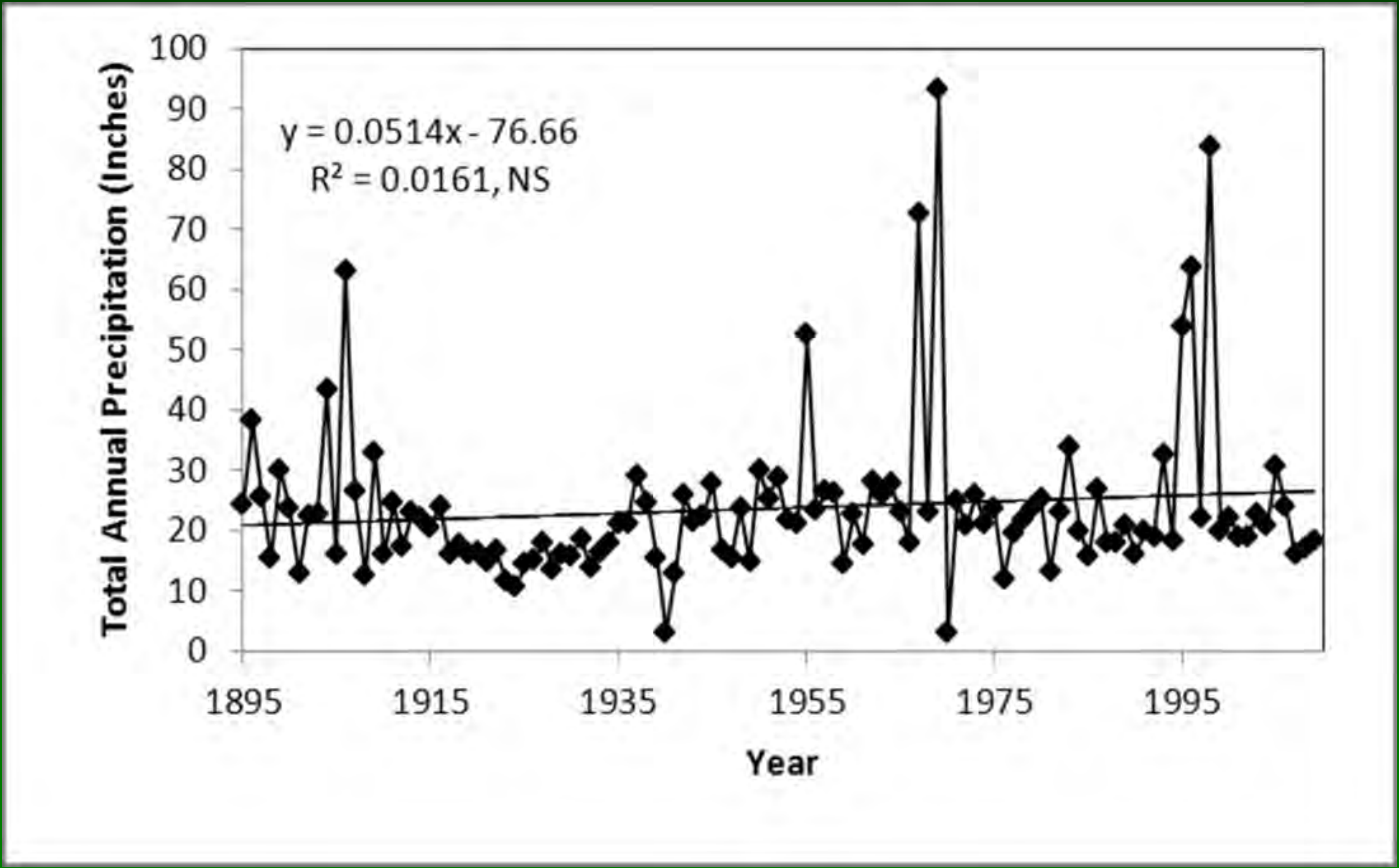
Trends in Temperature: Months Below Freezing



Portola

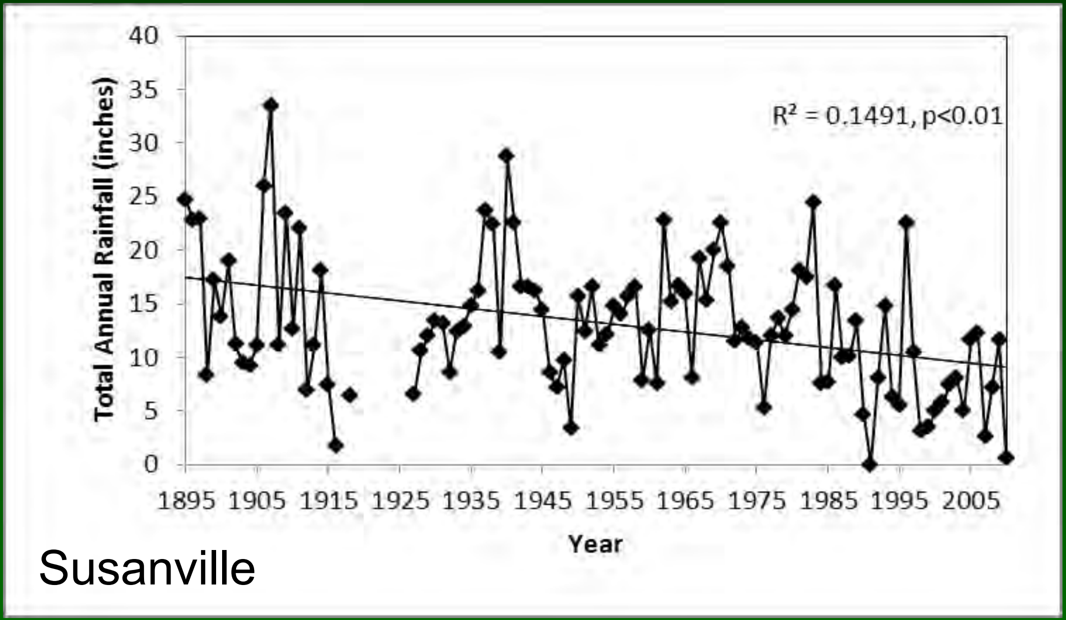
Precipitation

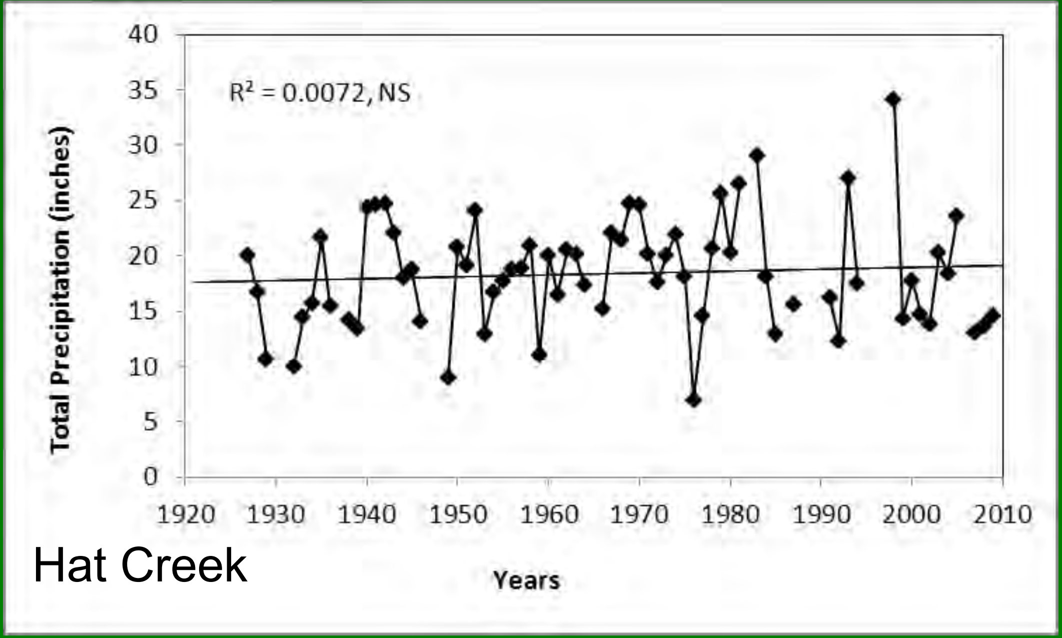
Trends in Precipitation: Weather Stations



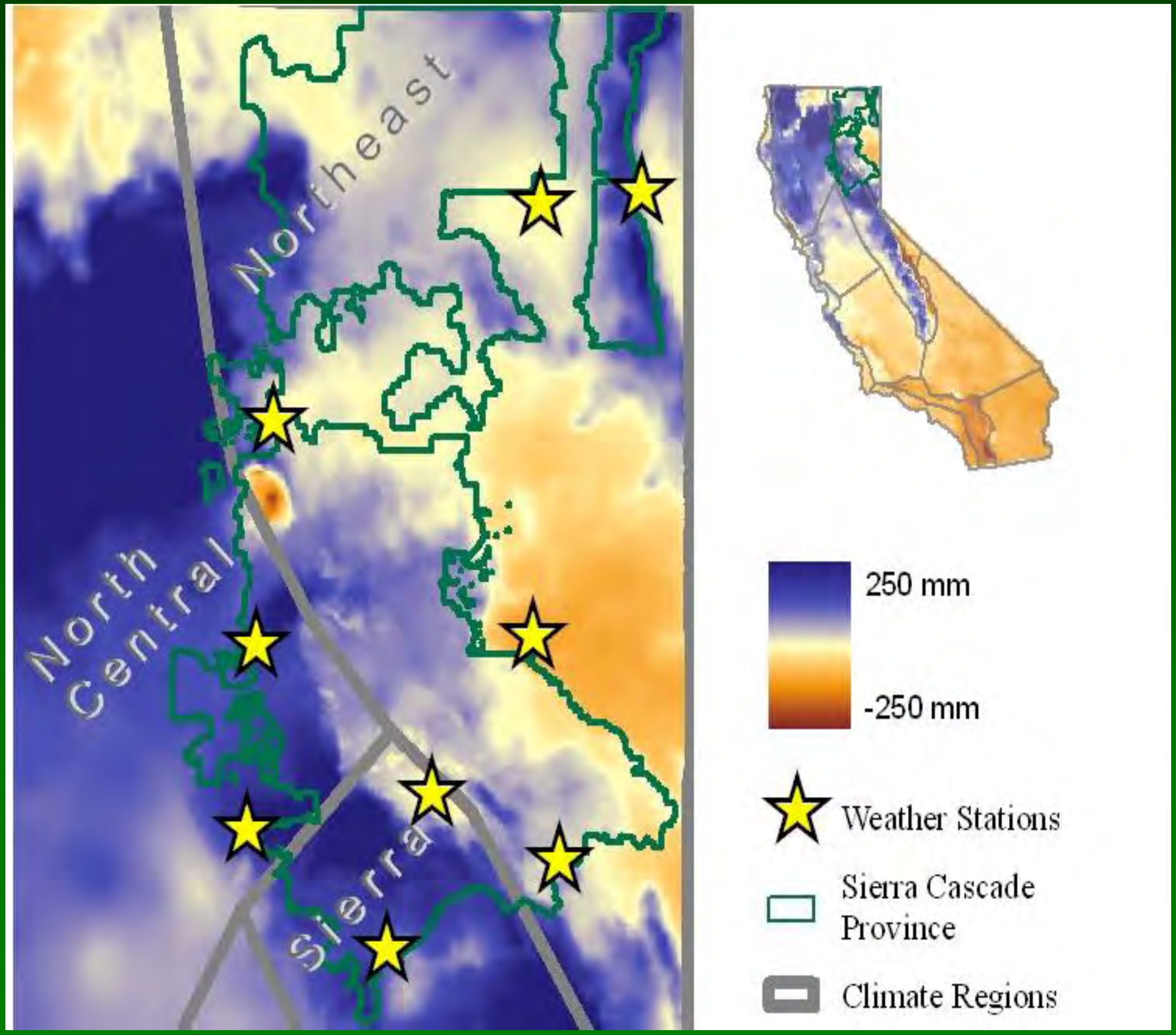
Northeast Climate Region

Trends in Precipitation: Weather Stations



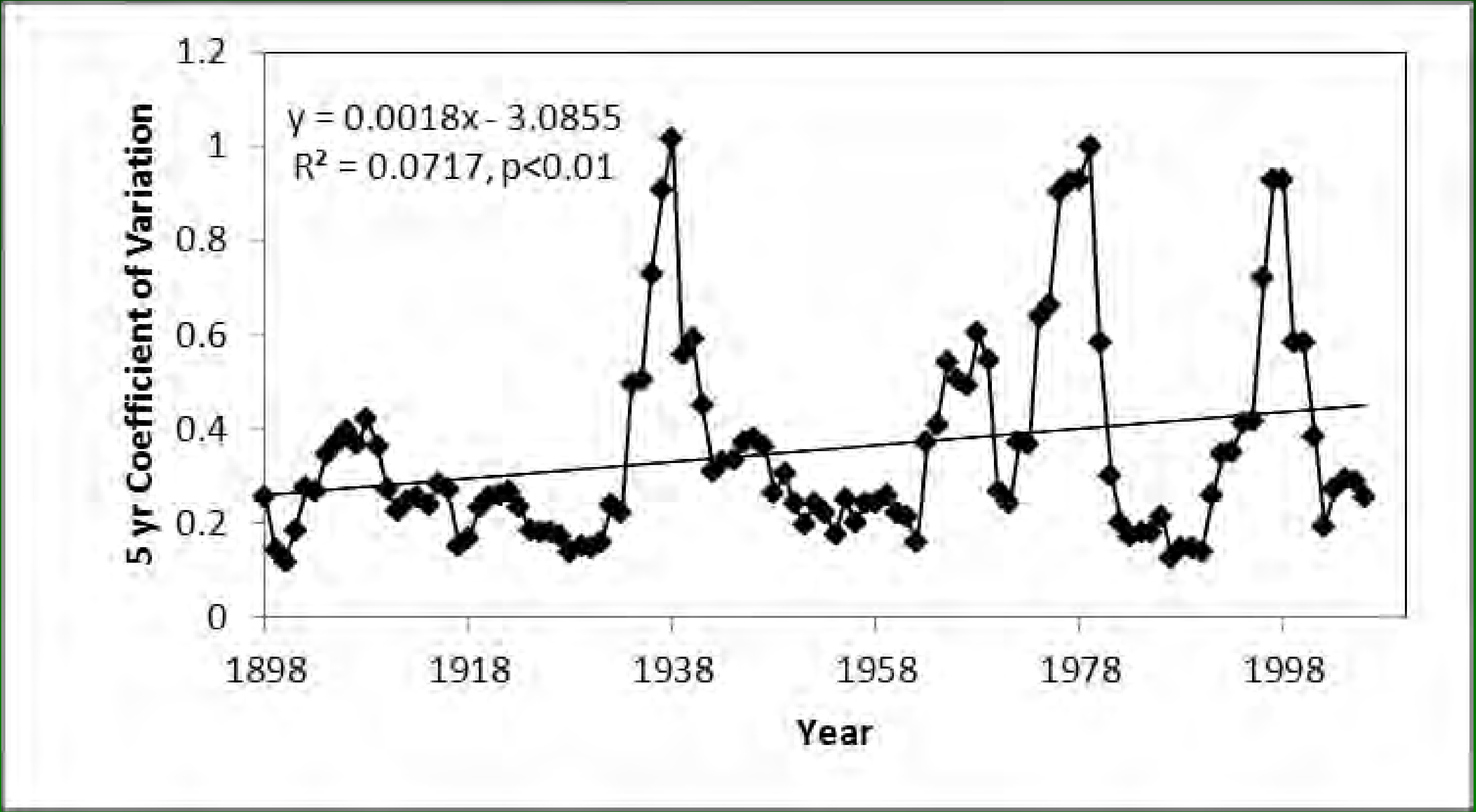


Trends in Precipitation: PRISM



Mean precipitation change between the 1930's and 2000's

Trends in Precipitation: Variation

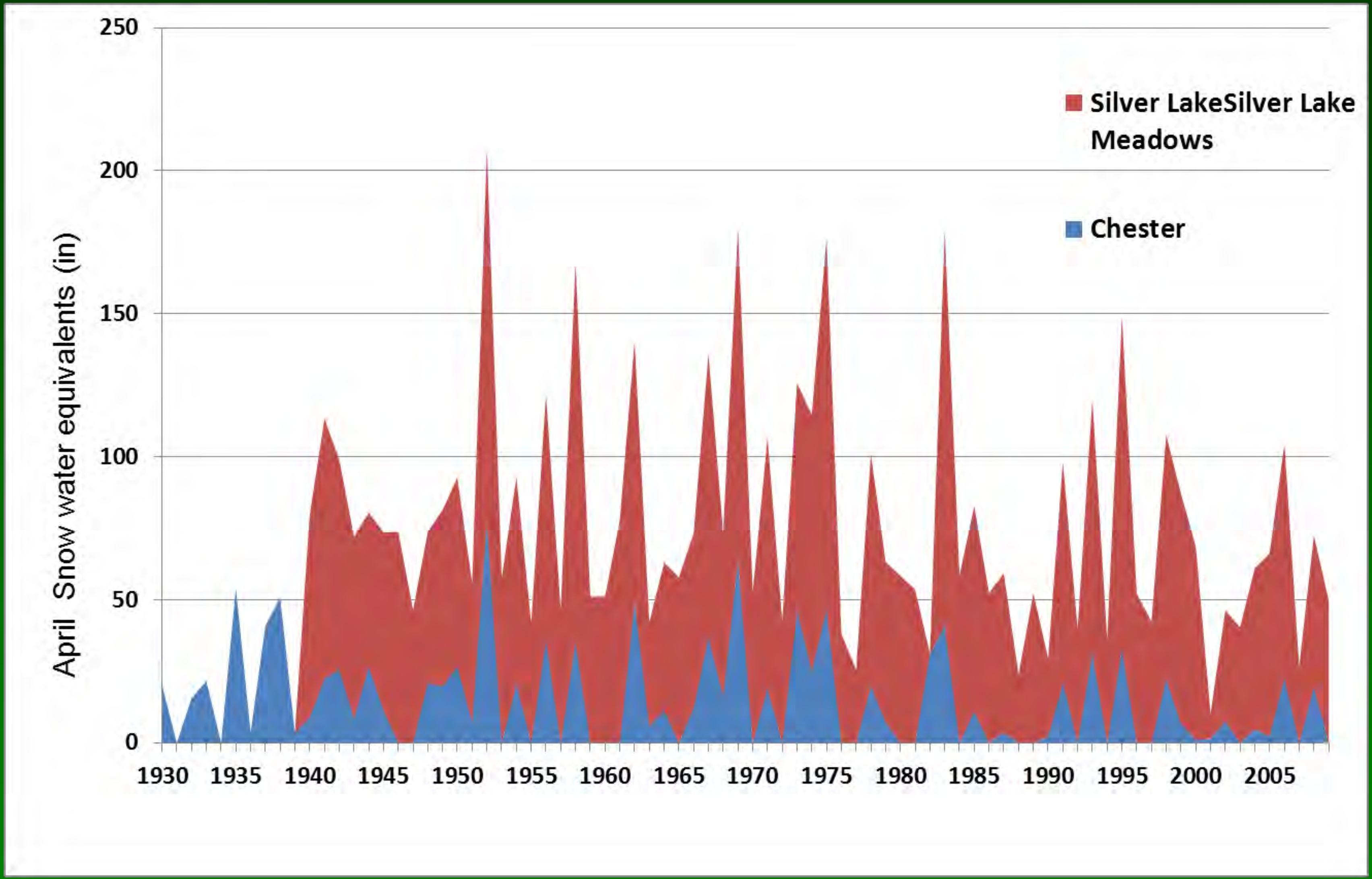


Northeast Climate Region

Trends in Snowfall: Weather Stations

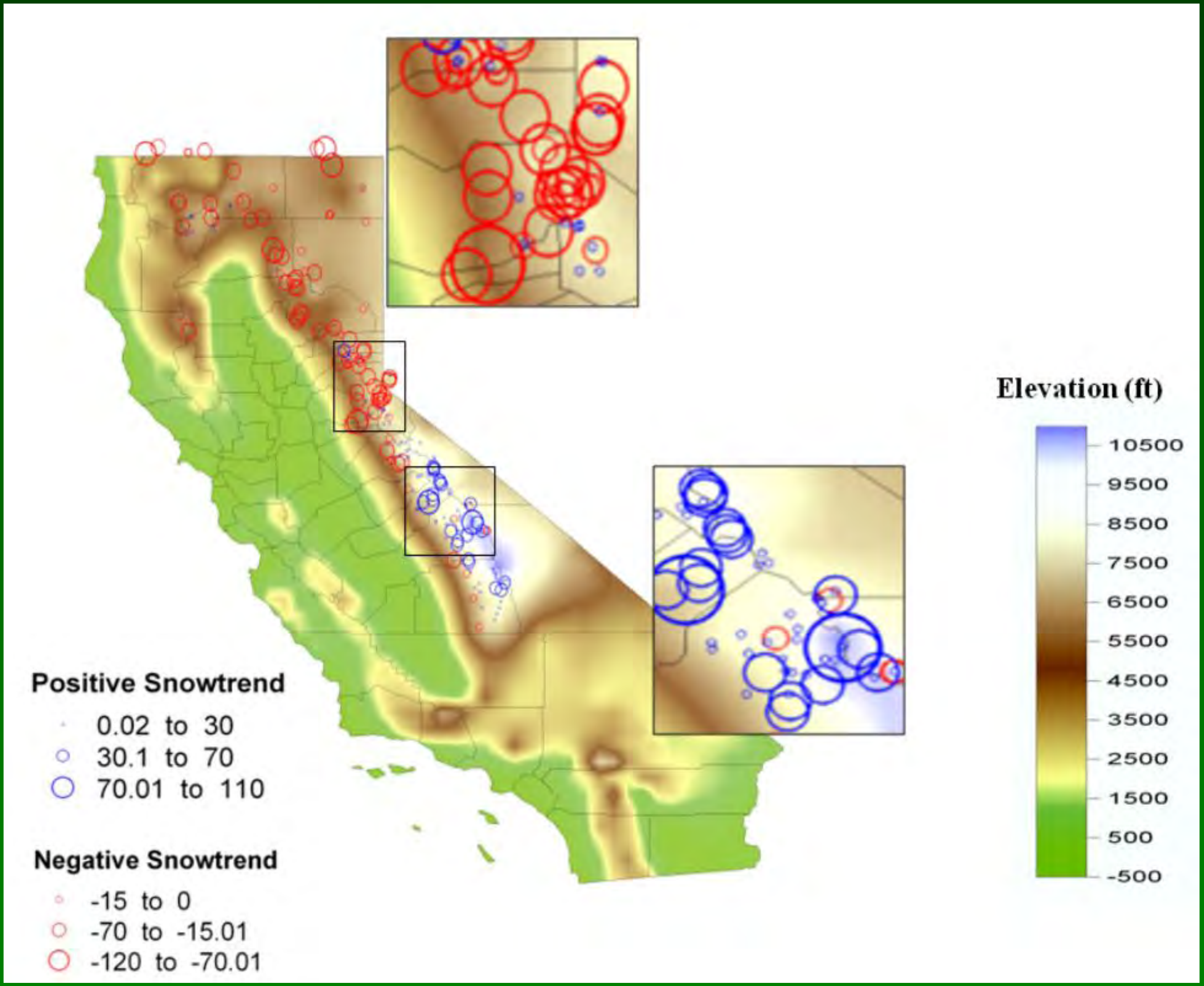
Station	Climate Region	Total Annual Snowfall
Mineral	North Central	NS
De Sabla	North Central	-53***, R^2=0.23
Alturas	Northeast	NS
Cedarville	Northeast	-48***, R^2=0.42
Hat Creek	Northeast	-38***, R^2=0.26
Susanville	Northeast	-62***, R^2=0.41
Portola	Northeast	-31*, R^2=0.08
Quincy	Sierra	-50*, R^2=0.09
Strawberry	Sierra	NS

Trends in Snowfall: Snow Surveys



California Cooperative Snow Surveys:
http://cdec.water.ca.gov/snow/index.html

Trends in Snow Water Equivalent



From 1950-1997, Moser et al. (2009)

Summary of Observed Trends

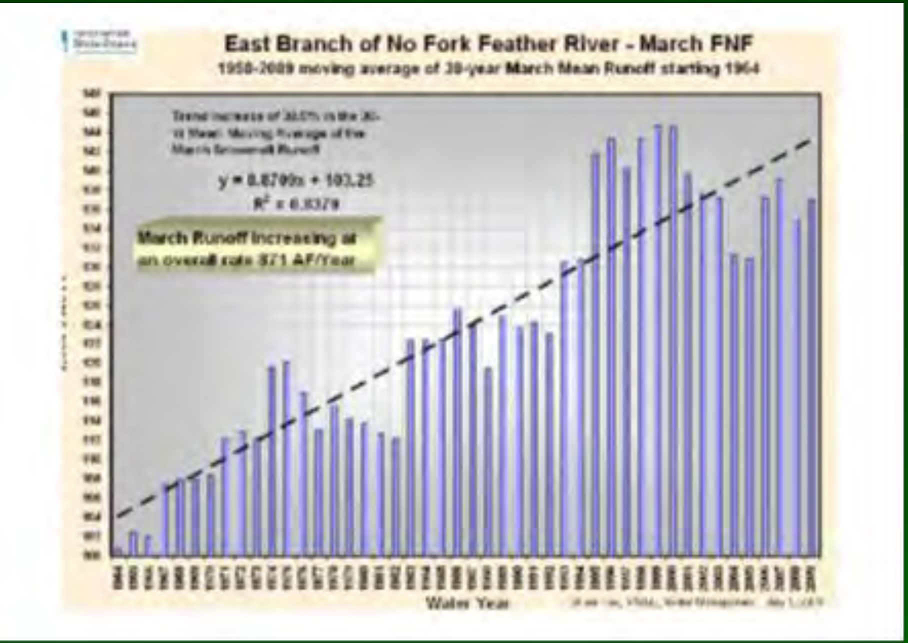
- Increasing temperatures at regional scale: varies by location
- No significant change in precipitation at regional scale: varies by location
- Increasing variation in precipitation
- Decreasing snow pack

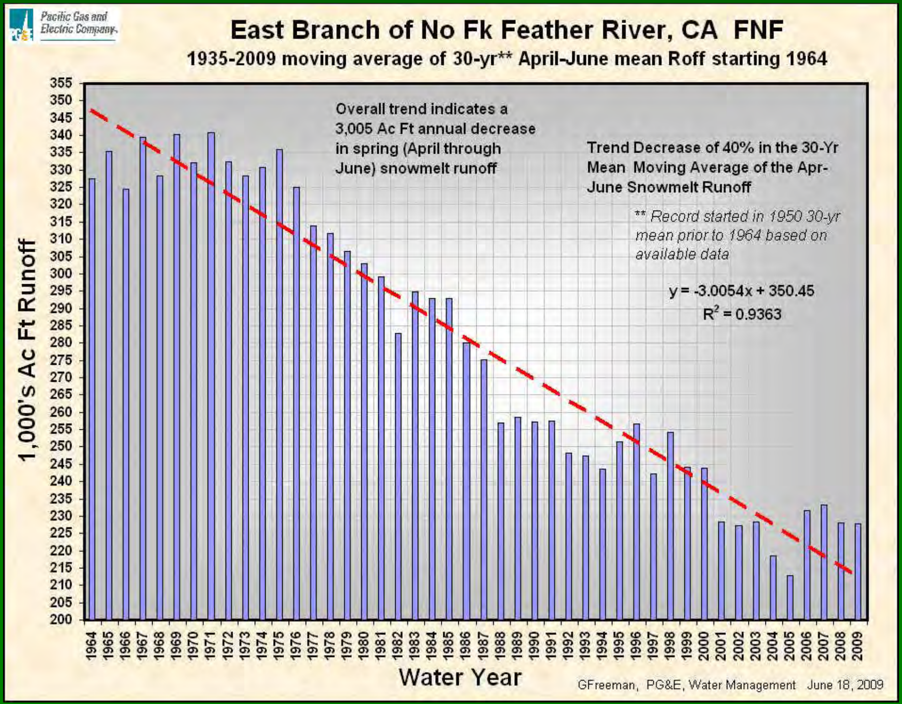
Observed Climate Related Trends

- Hydrology
- Fire
- Vegetation
- Insects/disease
- Wildlife

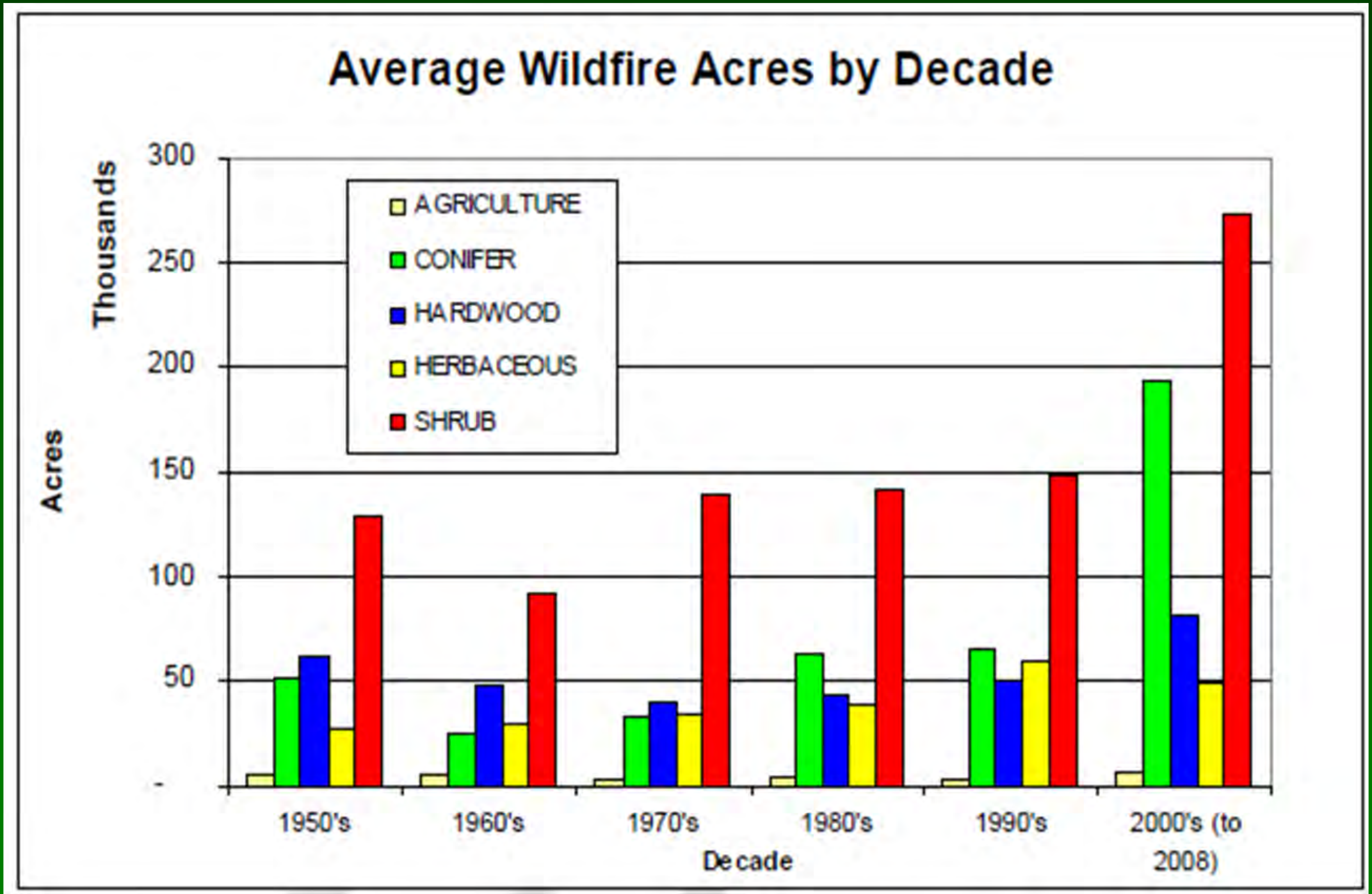
Observed Trends: Hydrology

- Loss of winter snow pack
- Peak run-off occurring 10-15 days earlier
  - Particularly for watersheds near winter freezing temperatures
  - Volcanic basins (Pitt River watershed) may be somewhat buffered

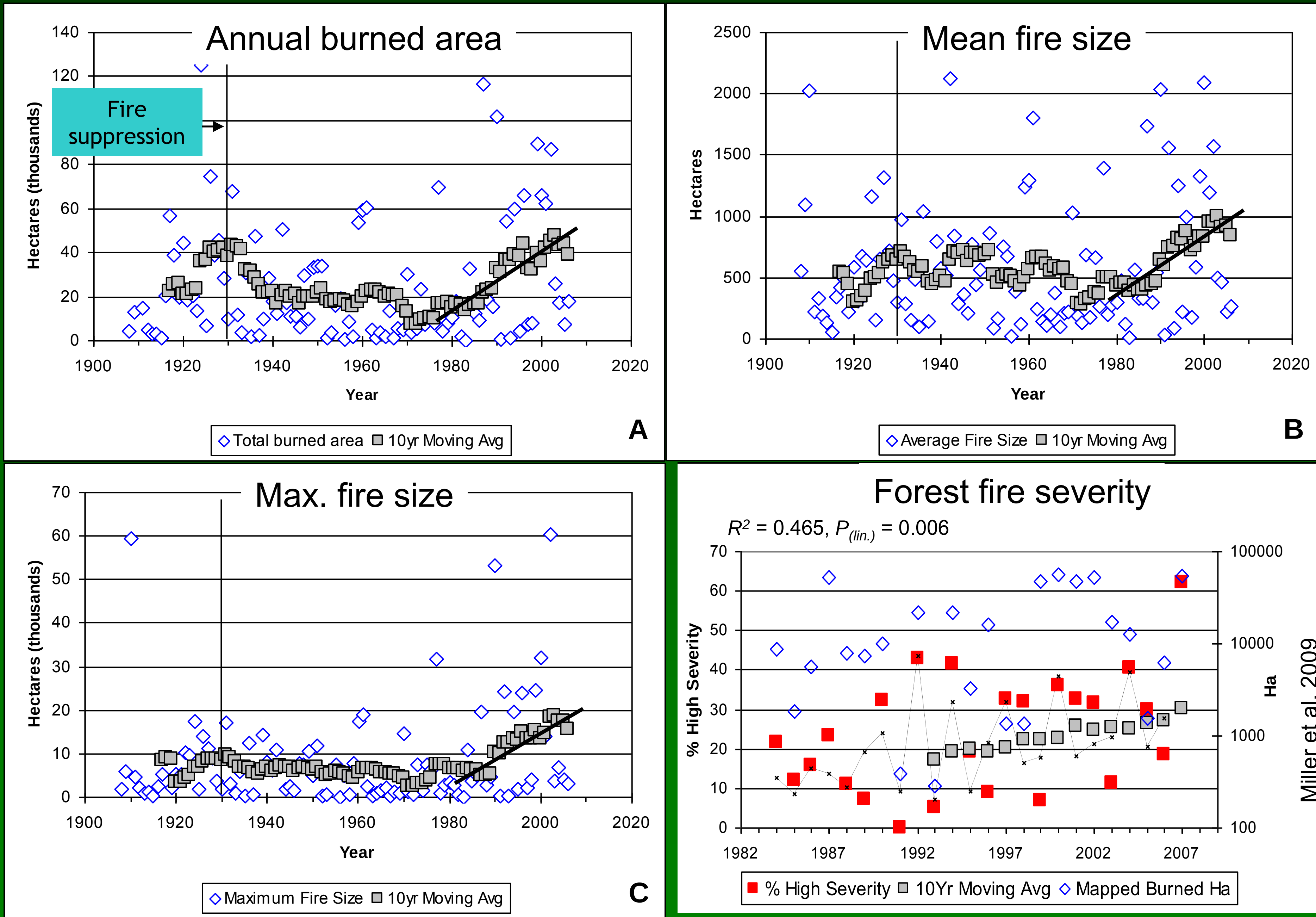

East Branch of No Fork Feather River - March FNF
moving average of 30-year March Mean Runoff starting 1964
y = 0.8709x + 103.25
March Runoff Increasing at an overall rate 871 AF/Year
Water Year


Pacific Gas and Electric Company
East Branch of No Fk Feather River, CA FNF
1935-2009 moving average of 30-yr** April-June mean Roff starting 1964
Overall trend indicates a 3,005 Ac Ft annual decrease in spring (April through June) snowmelt runoff
Trend Decrease of 40% in the 30-Yr Mean Moving Average of the Apr-June Snowmelt Runoff
** Record started in 1950 30-yr mean prior to 1964 based on available data
y = -3.0054x + 350.45
R² = 0.9363
1,000's Ac Ft Runoff
355 350 345 340 335 330 325 320 315 310 305 300 295 290 285 280 275 270 265 260 255 250 245 240 235 230 225 220 215 210 205 200
1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
Water Year
GFreeman, PG&E, Water Management June 18, 2009

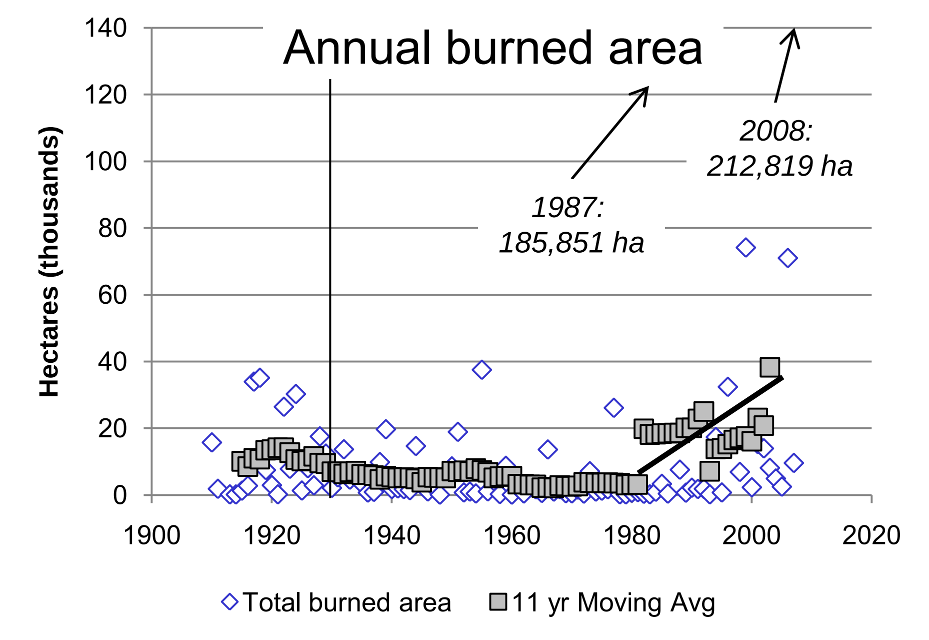
Observed Trends: Fire

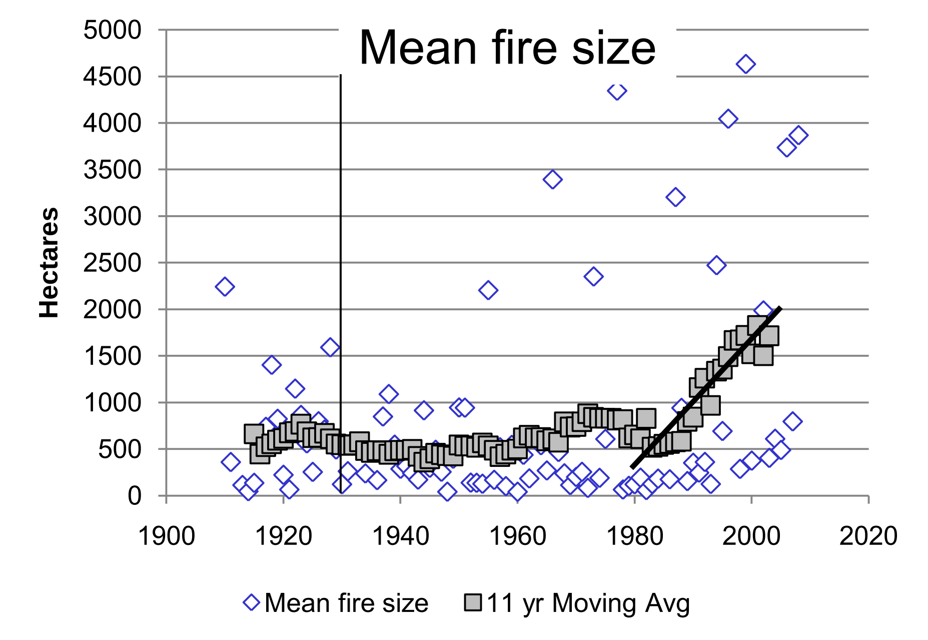


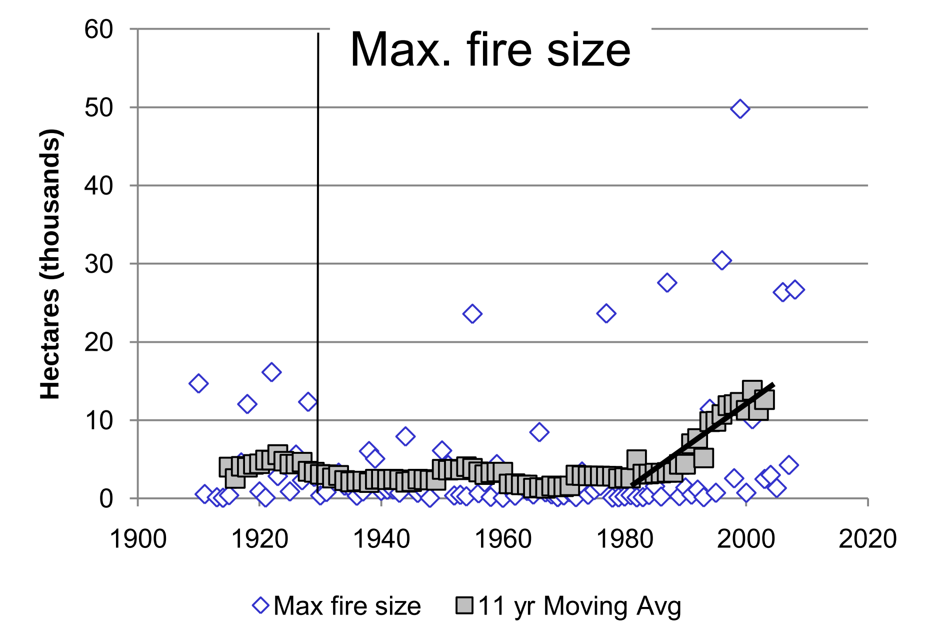
Sierra Nevada: Trends in fire area and severity

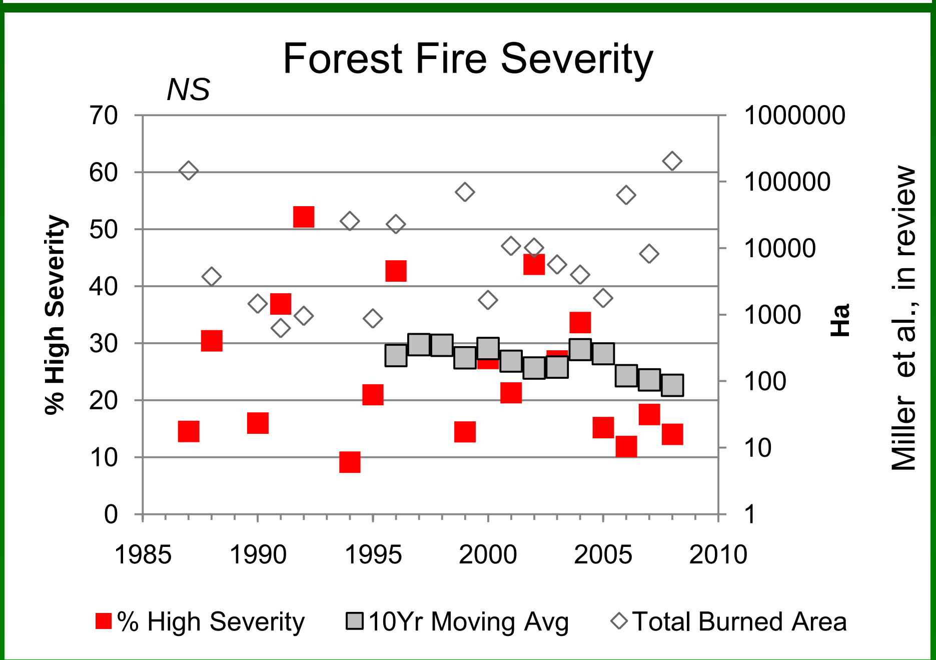


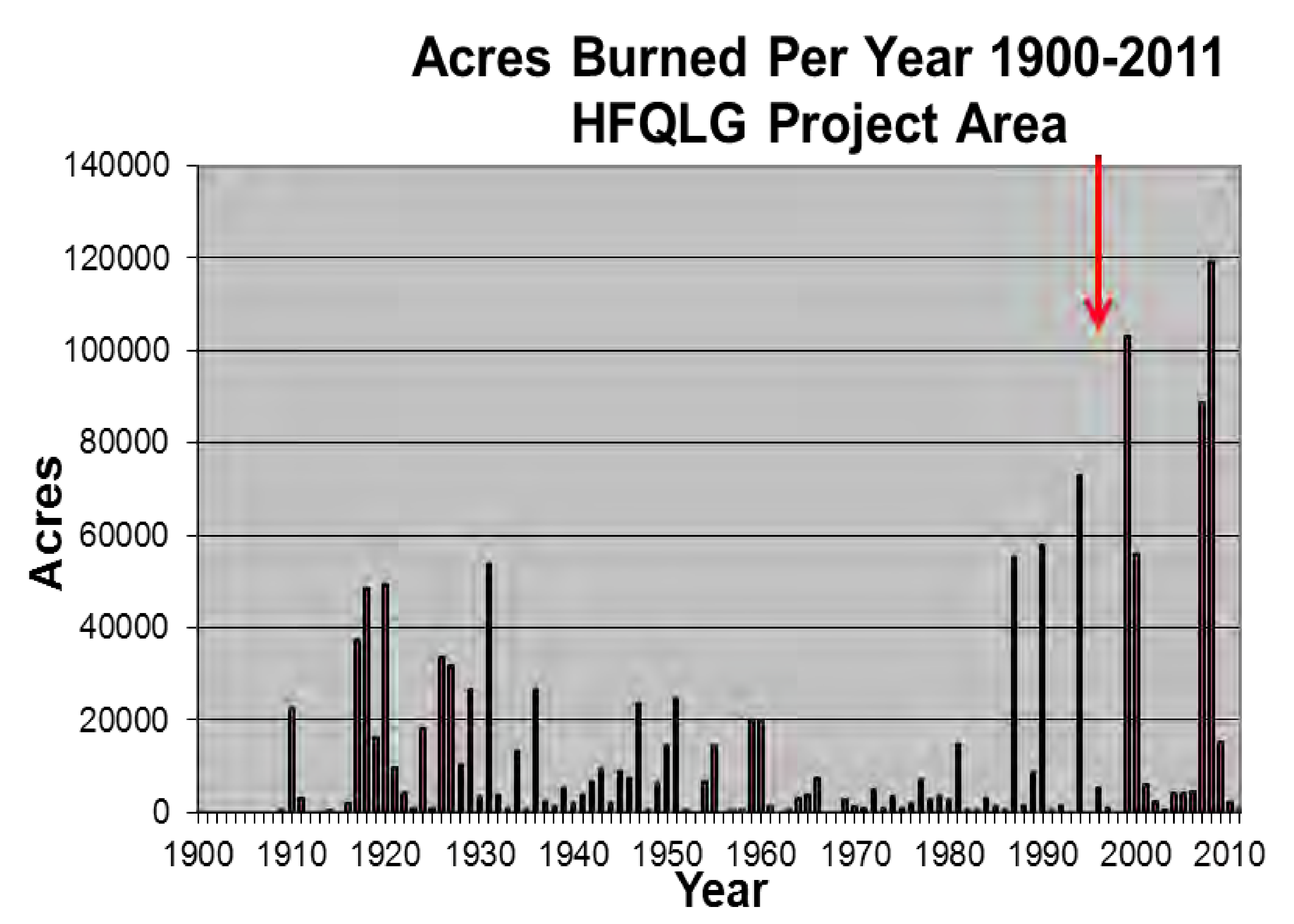
Klamath Mountains: trends in fire area and severity

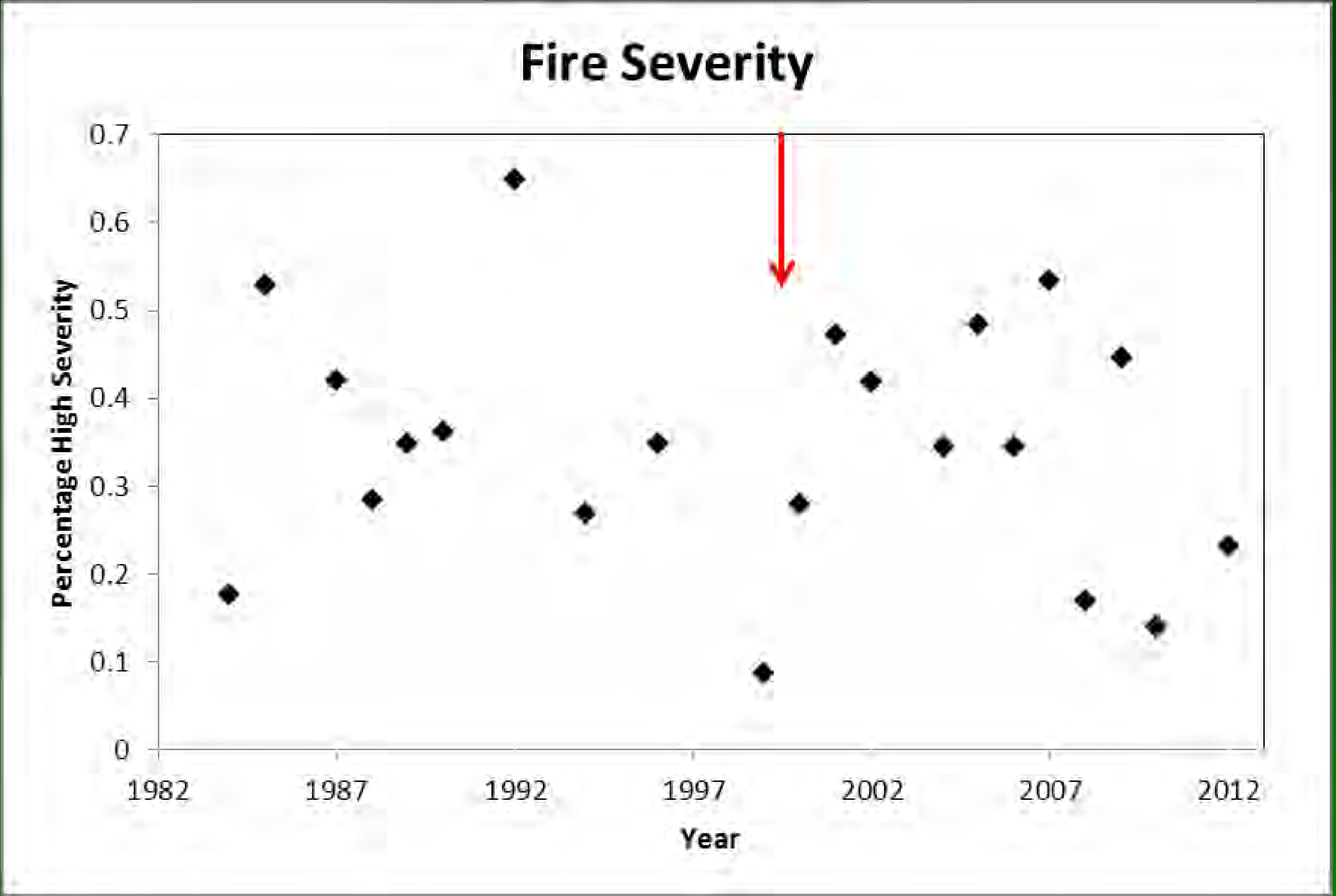






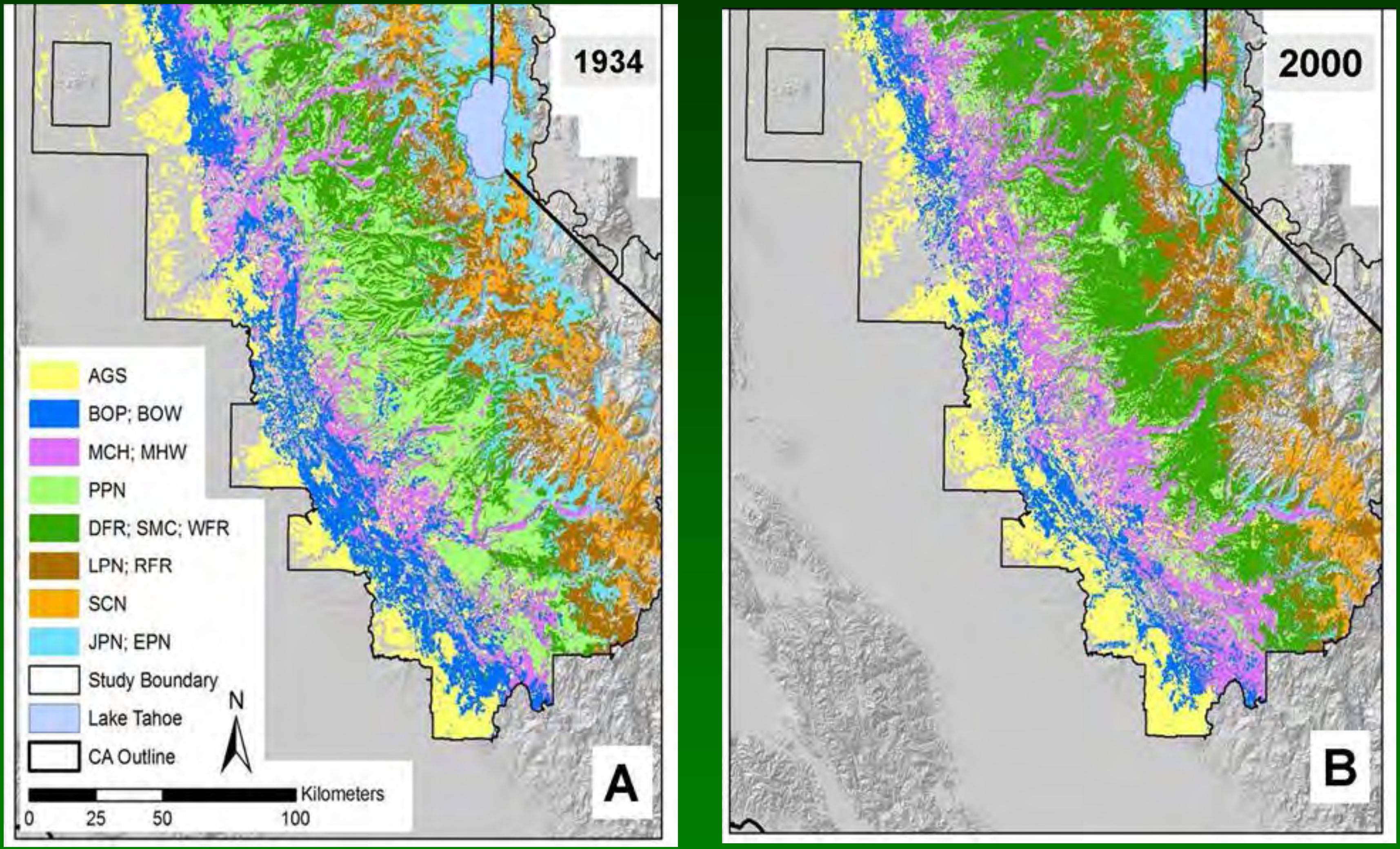



Acres Burned Per Year 1900-2011
HFQLG Project Area
Acres
140000
120000
100000
80000
60000
40000
20000
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year



Fire Severity
Percentage High Severity
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1982
1987
1992
1997
2002
2007
2012
Year

Observed Trends: Vegetation

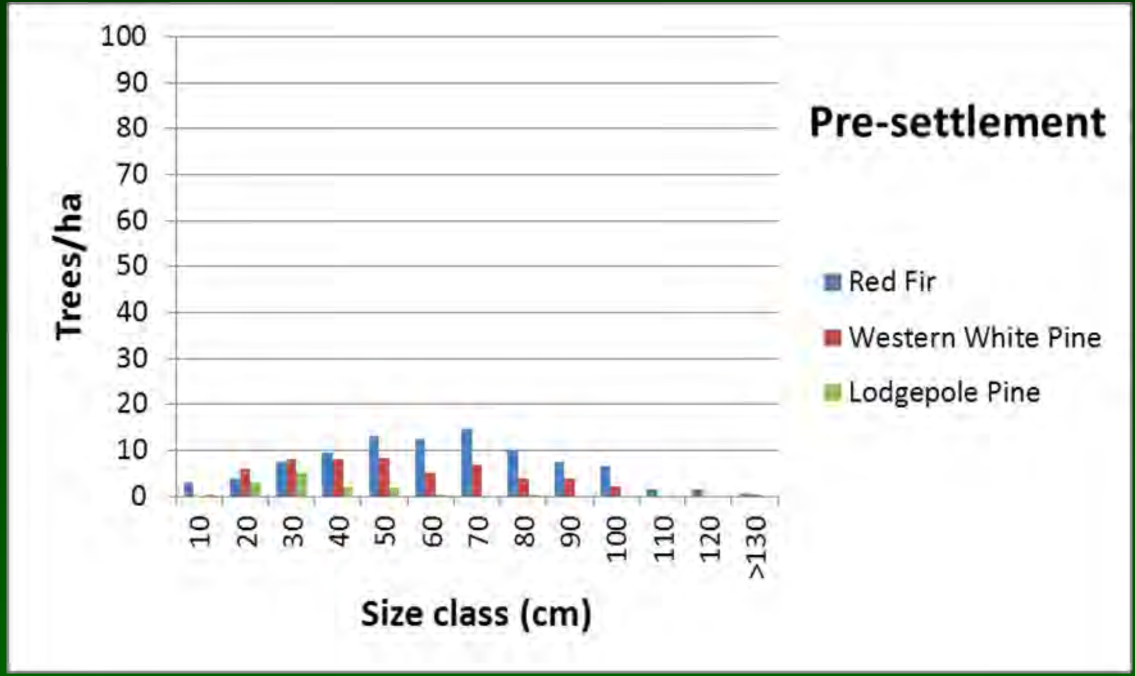


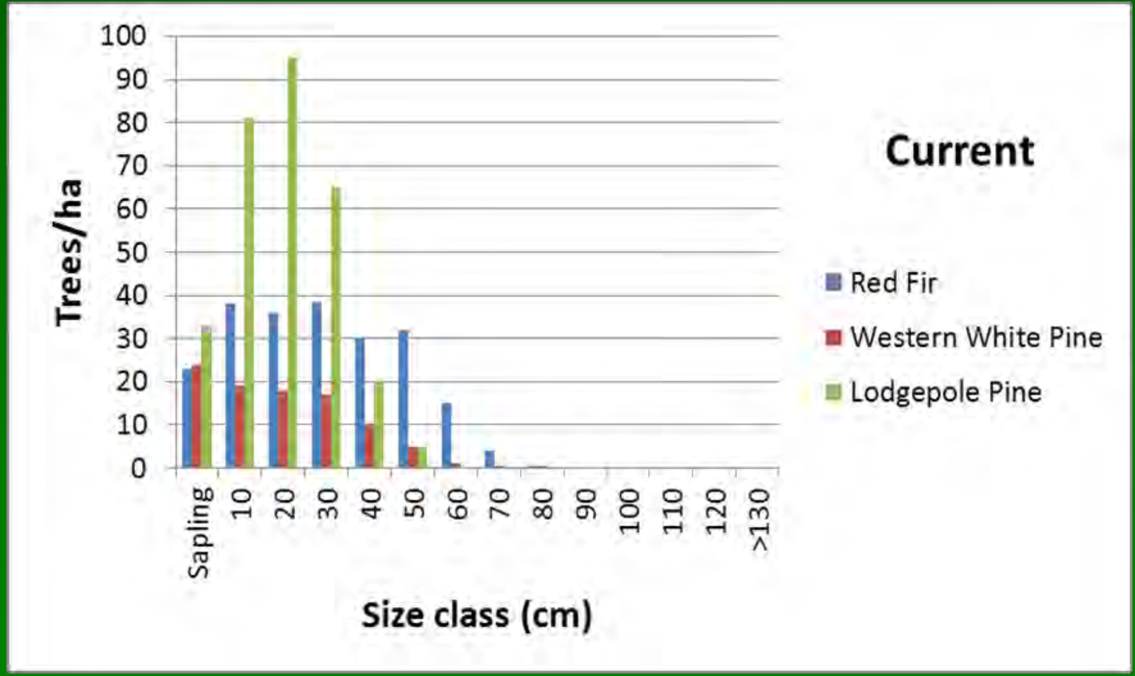
Distribution of major vegetation types in 1932-1936 (A) and 2000 (B), from Bouldin (1999).

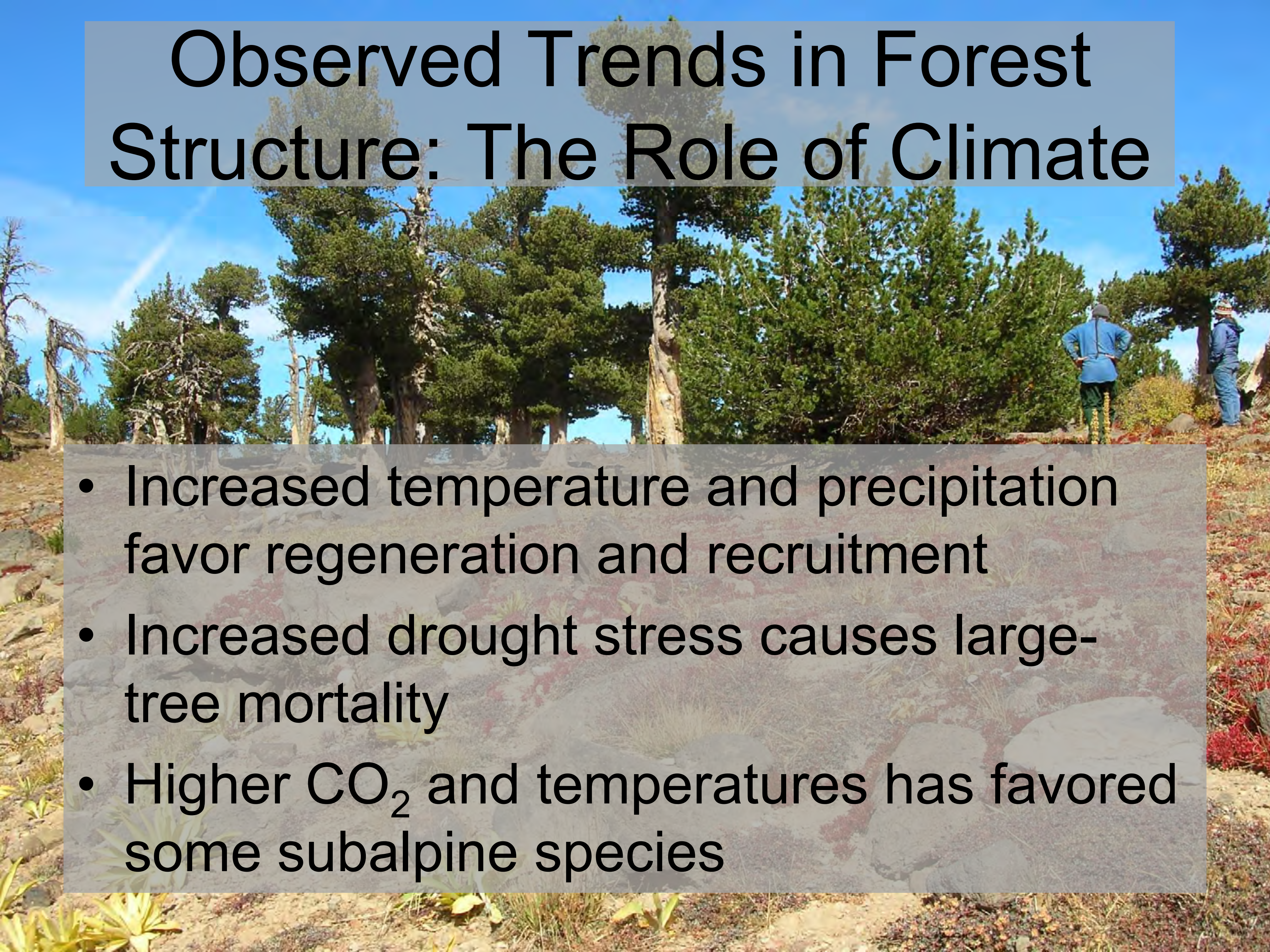
Observed Trends in Forest Structure: 1930-2000

- Increased density, cover and basal area
- More small trees, fewer large trees
- Increased mortality of large trees in most forest types
- More shade tolerant species
- Decreased mortality rates for some subalpine species
- Decreased spatial heterogeneity

Bouldin (1999), Van Mantgem (2009), Dolanc et al. (2012)


Pre-settlement
Trees/ha
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
110
120
>130
Size class (cm)
Red Fir
Western White Pine
Lodgepole Pine


Current
Trees/ha
100
90
80
70
60
50
40
30
20
10
0
Sapling
10
20
30
40
50
60
70
80
90
100
110
120
>130
Size class (cm)
Red Fir
Western White Pine
Lodgepole Pine

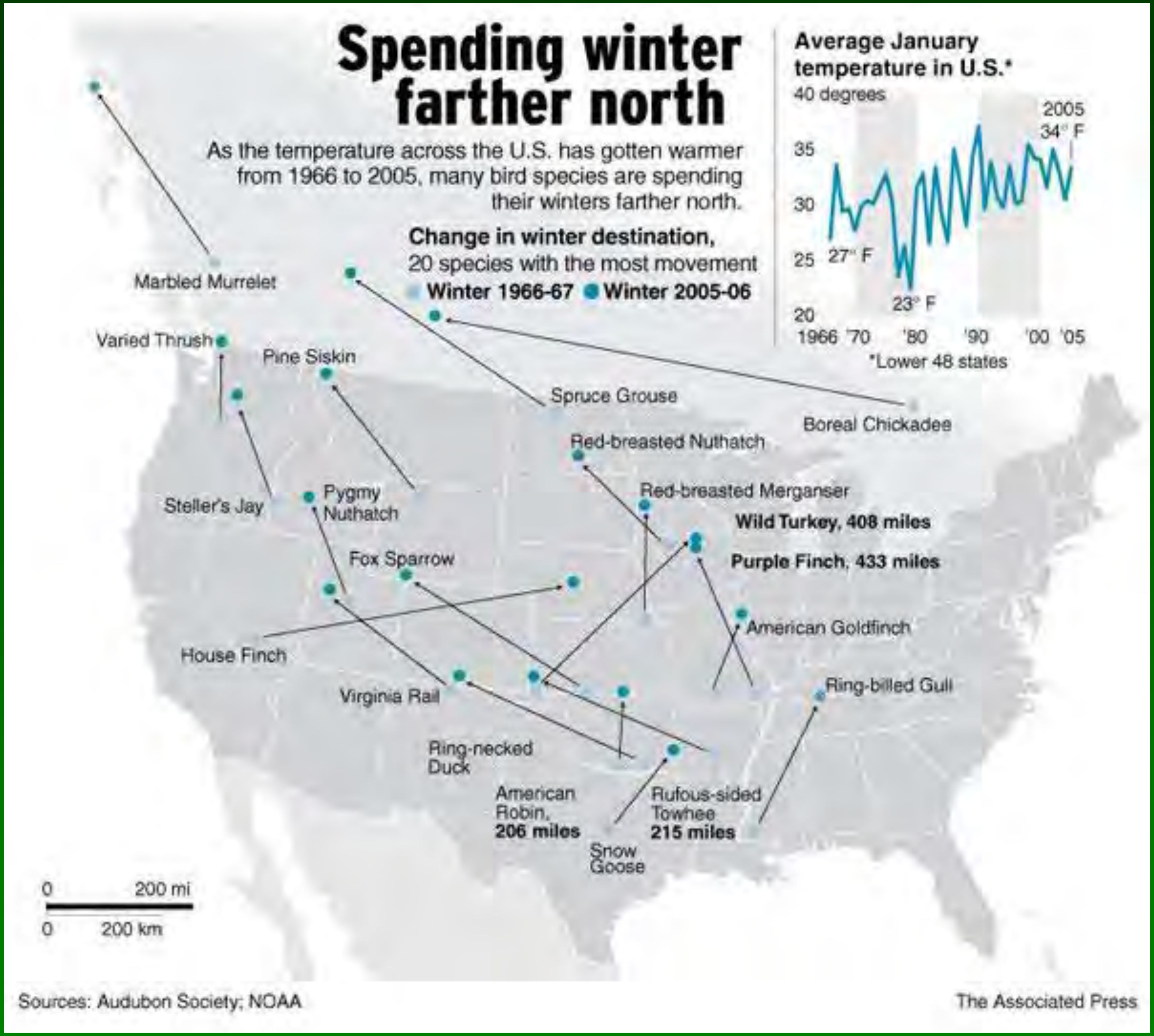


Observed Trends in Forest Structure: The Role of Climate

- Increased temperature and precipitation favor regeneration and recruitment
- Increased drought stress causes large-tree mortality
- Higher CO_2 and temperatures has favored some subalpine species

Observed Trends in Vegatation: Juniper Invasion

Observed Trends in Insects and Disease



National Audubon Society (2009)

Observed Trends in Wildlife 1914-2000

- Geographic ranges shifted up in elevation
- Some high-elevation species exhibited range contraction
- Several low-elevation species expanded their range upslope
- Species responses differed

Moritz et al. (2008)

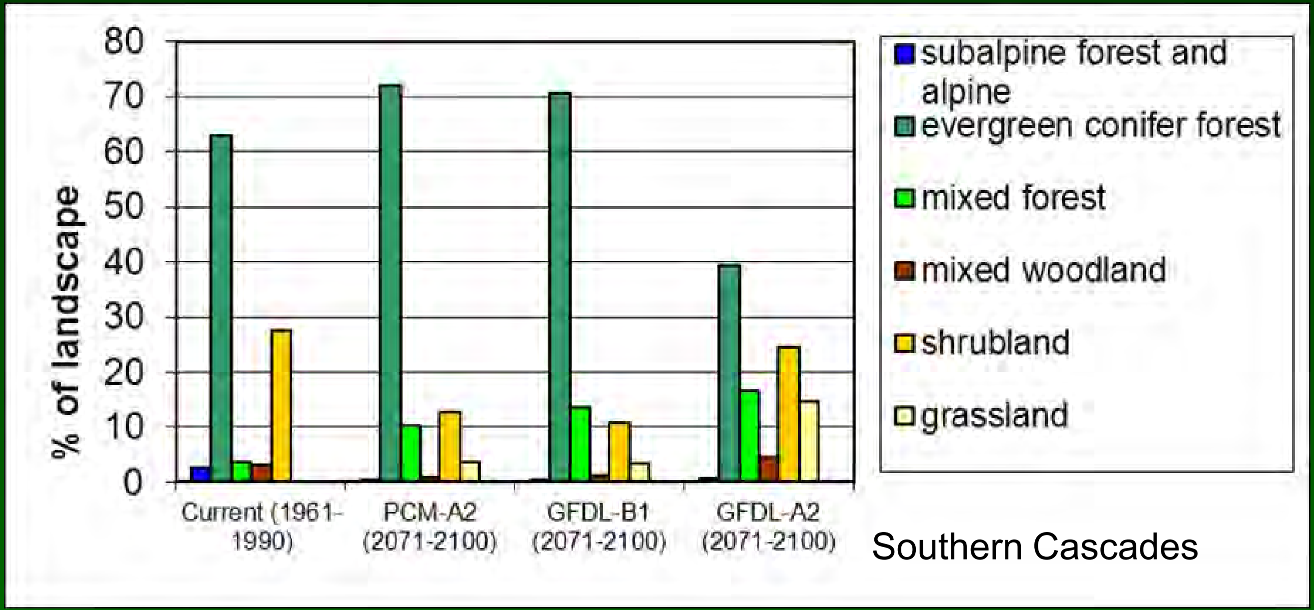
Summary of Observed Trends

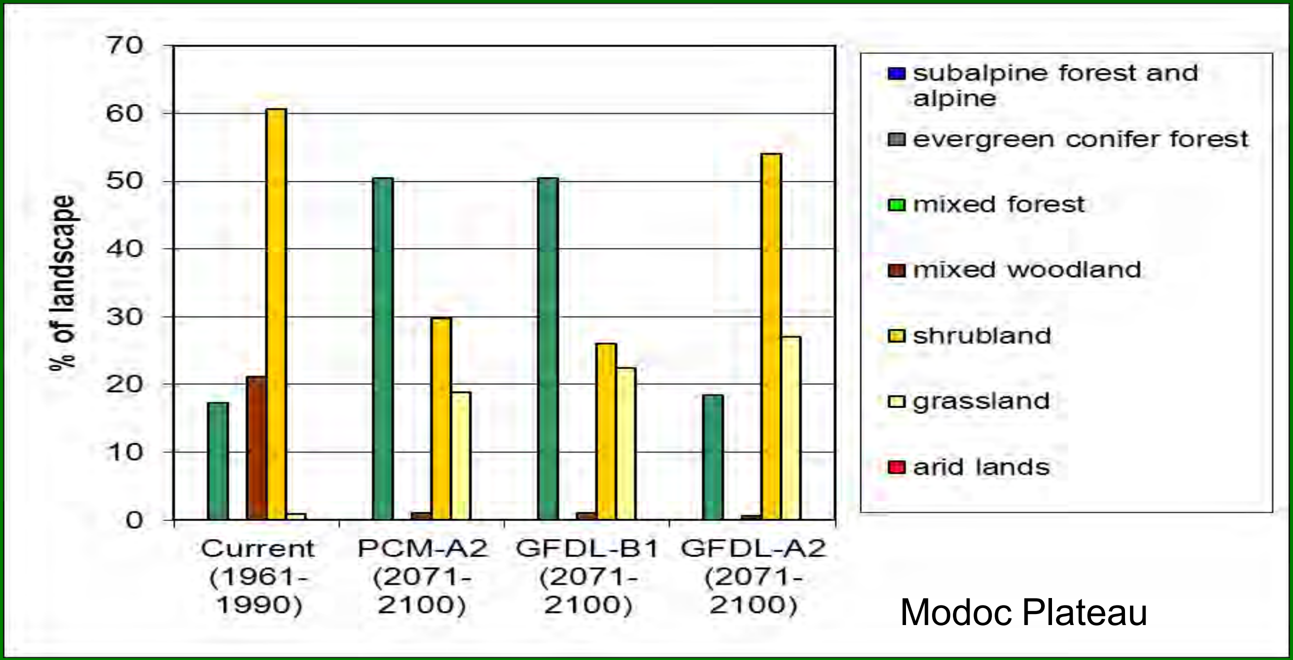
- Earlier peak run-off
- Increased fire activity
- Shifts in species composition and distribution
- Denser forests with more small trees
- Increased mortality of large trees*
- Increased insects and disease
- Wildlife species moving north/upslope and range contraction

Summary of Projected Future Trends

- Increased temperatures
- Lower snowpack, earlier runoff, more extreme events
- Increased fire size and extent
- Increased drought stress
- Expansion of juniper and invasive grasses
- Increased insects and disease
- Range contraction of wildlife species

Projected Future Trends: Vegetation



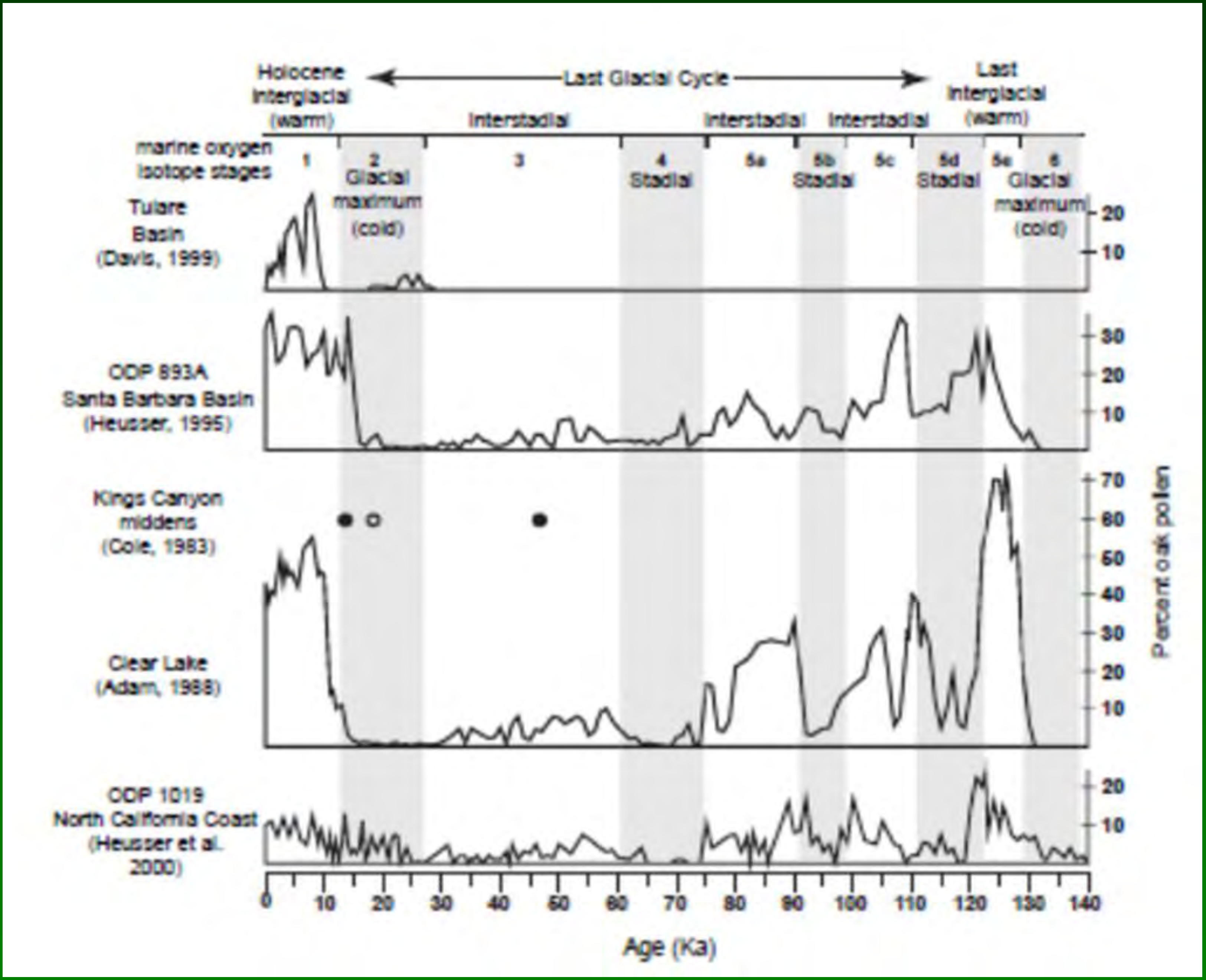


Management Options

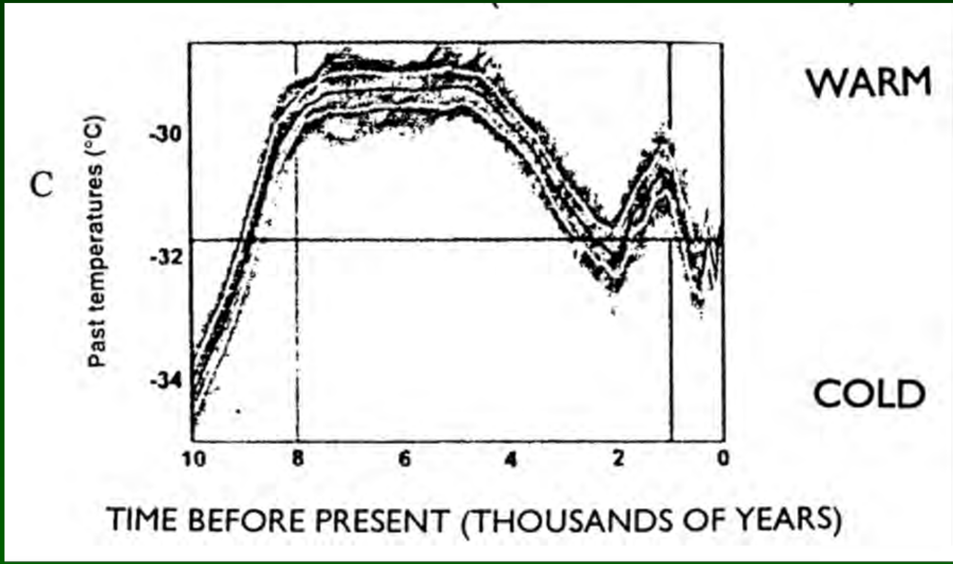
- Reduce non-climatic stressors
  - Decrease stand densities, particularly of small trees
  - Reduce fuel loads
  - Restore hydrologic systems, wetlands
  - Restore stream bank vegetation
  - Protect intact habitats, corridors, reduce fragmentation

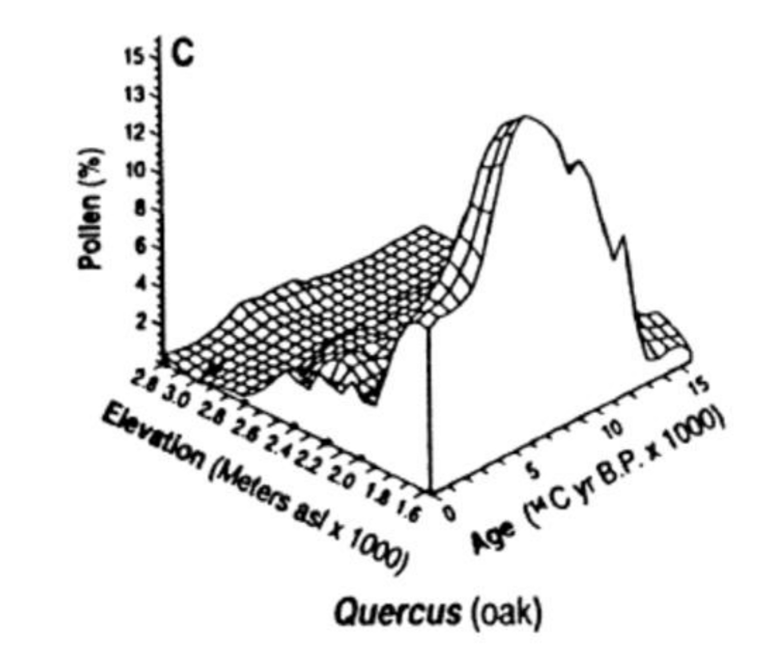
Management Options: Can the past inform the future?

- The past may give us insight into how things work
- Ecosystems are dynamic over time
- Specific species or habitats that occurred in the past may not occur in the future
- Processes that promoted resilience in the past are likely to do so in the future



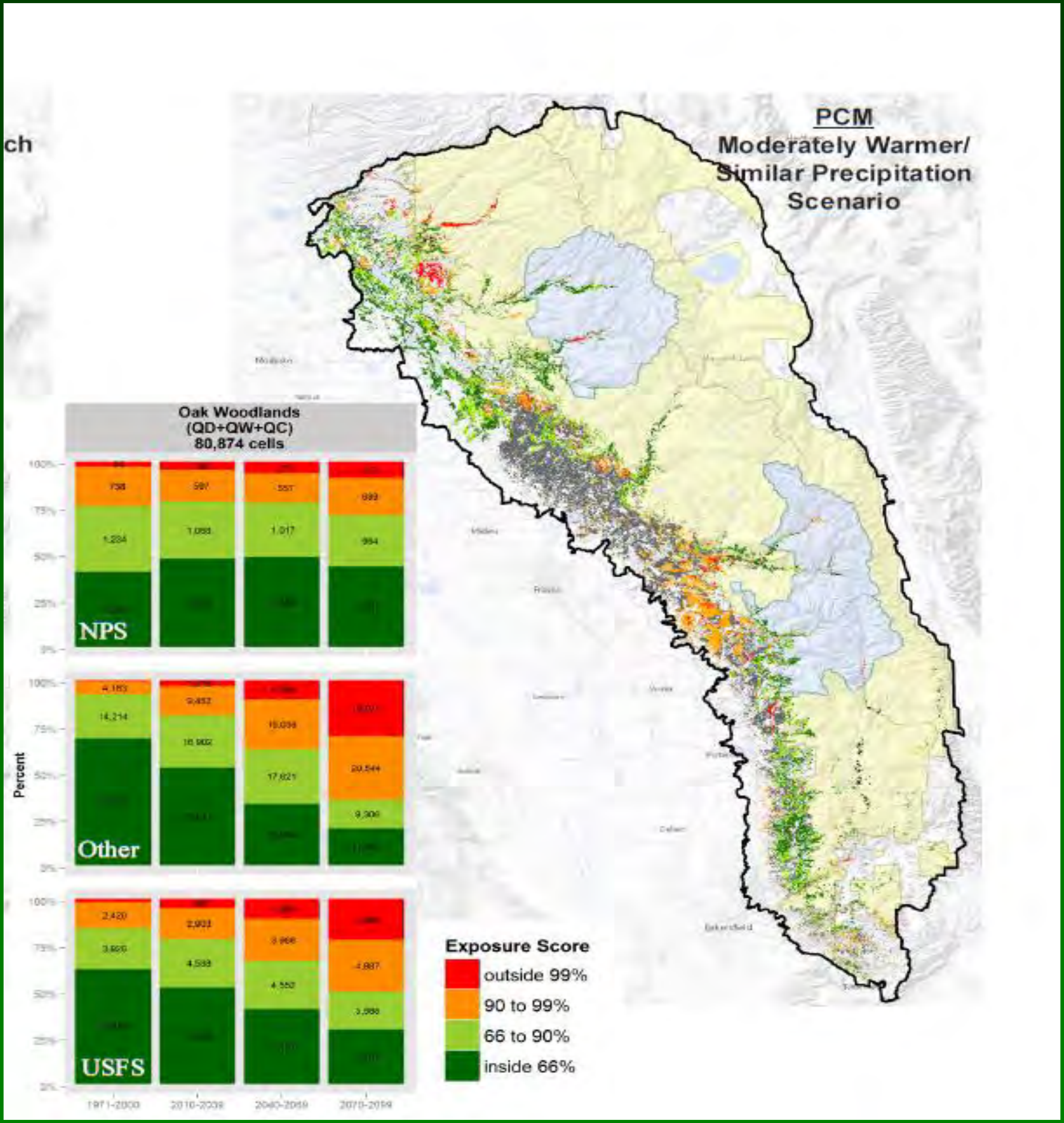
From Millar and Woolfenden (1999)



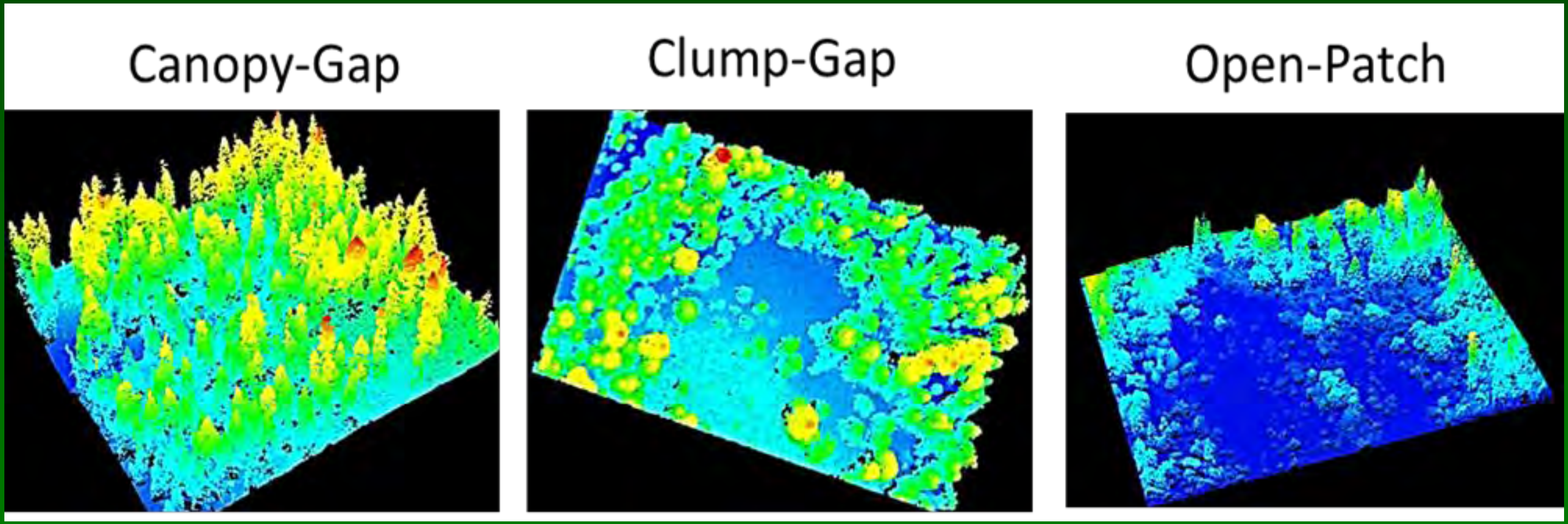


From Millar and Woolfenden (1999)

Predicted Refugia



Heterogeneity



From Kane et al. (2013)

Beaver Creek Pinery - Ishi Wilderness Area

Photos courtesy of Carl Skinner, PSW Redding

Lessons From the Past

- Manage for habitat connectivity and migration corridors as climate refugia
- Manage for increased heterogeneity
  - Forest structure
  - Wildlife habitat
  - Fuel loading
  - Species composition
  - Restore ecological processes, such as fire

Summary of Management Options

- **Enhance ecosystem resilience and sustainability by removing or reducing non-climate related stressors**
- **Historical ecology can provide insight into the way things work rather than the ways things were**
- **Focus on restoring process (e.g., fire, hydrology) rather than structure**
- **A key management focus should be restoration of heterogeneity**

Thank you!
Questions?