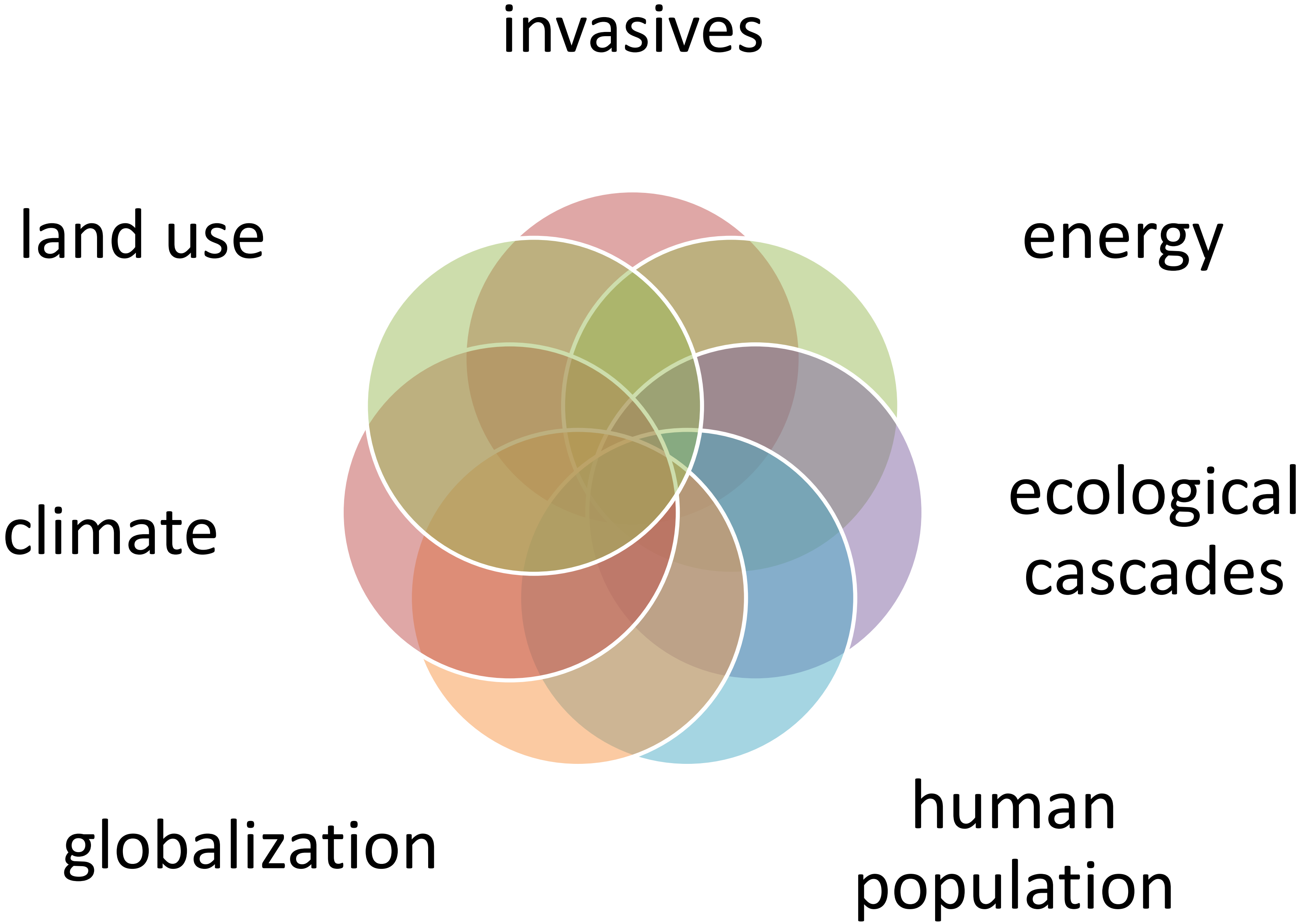
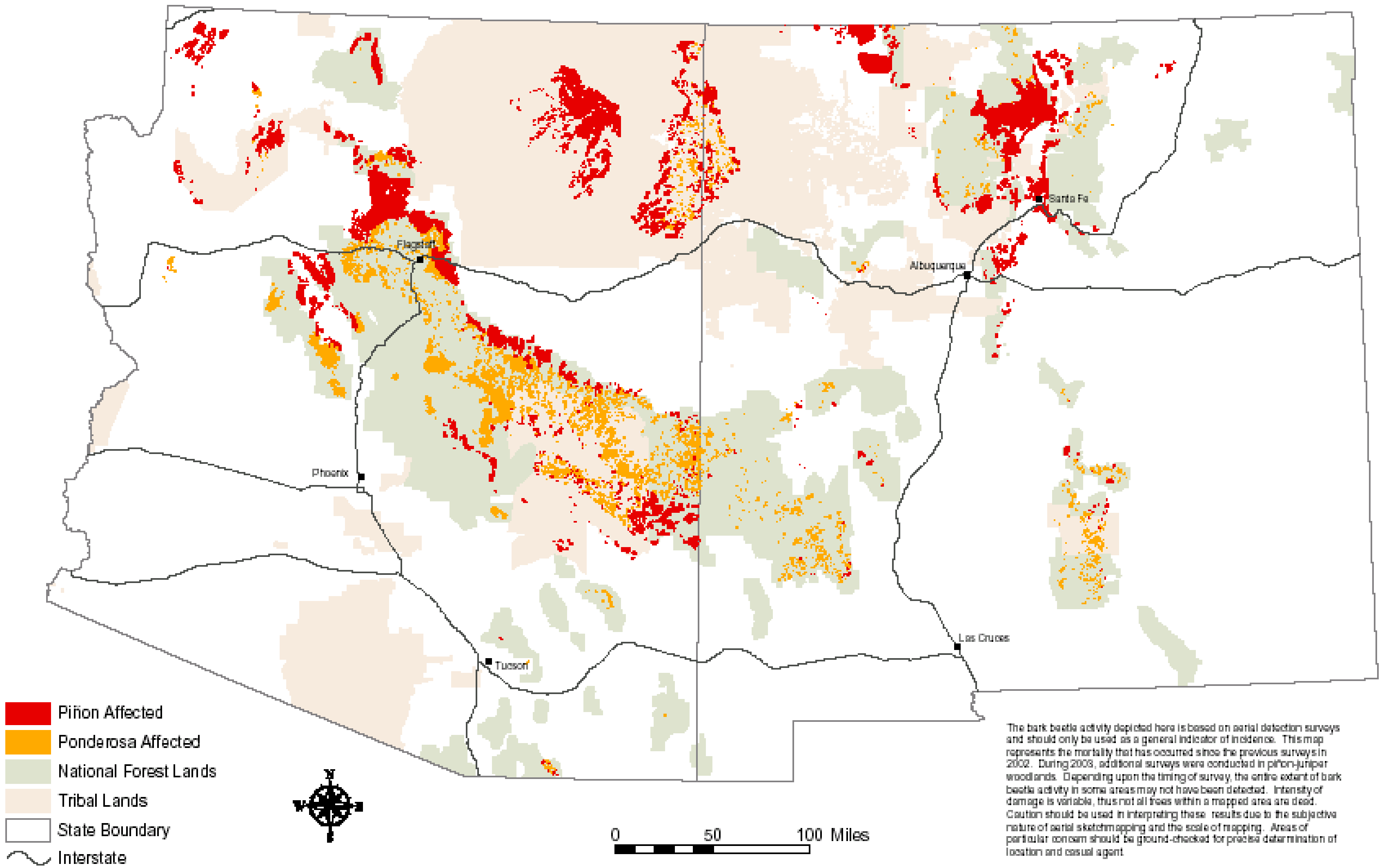
6.2 Fire and climate change

Thanks to the following UA colleagues for assistance with this presentation:

Mike Crimmins, SWES & Arizona Cooperative Extension
Gregg Garfin, Institute for the Study of Planet Earth
Ann Lynch, LTRR/US Forest Service
Tom Swetnam, Laboratory of Tree-Ring Research
Connie Woodhouse, School of Geography and Development


invasives
land use
energy
climate
ecological cascades
globalization
human population

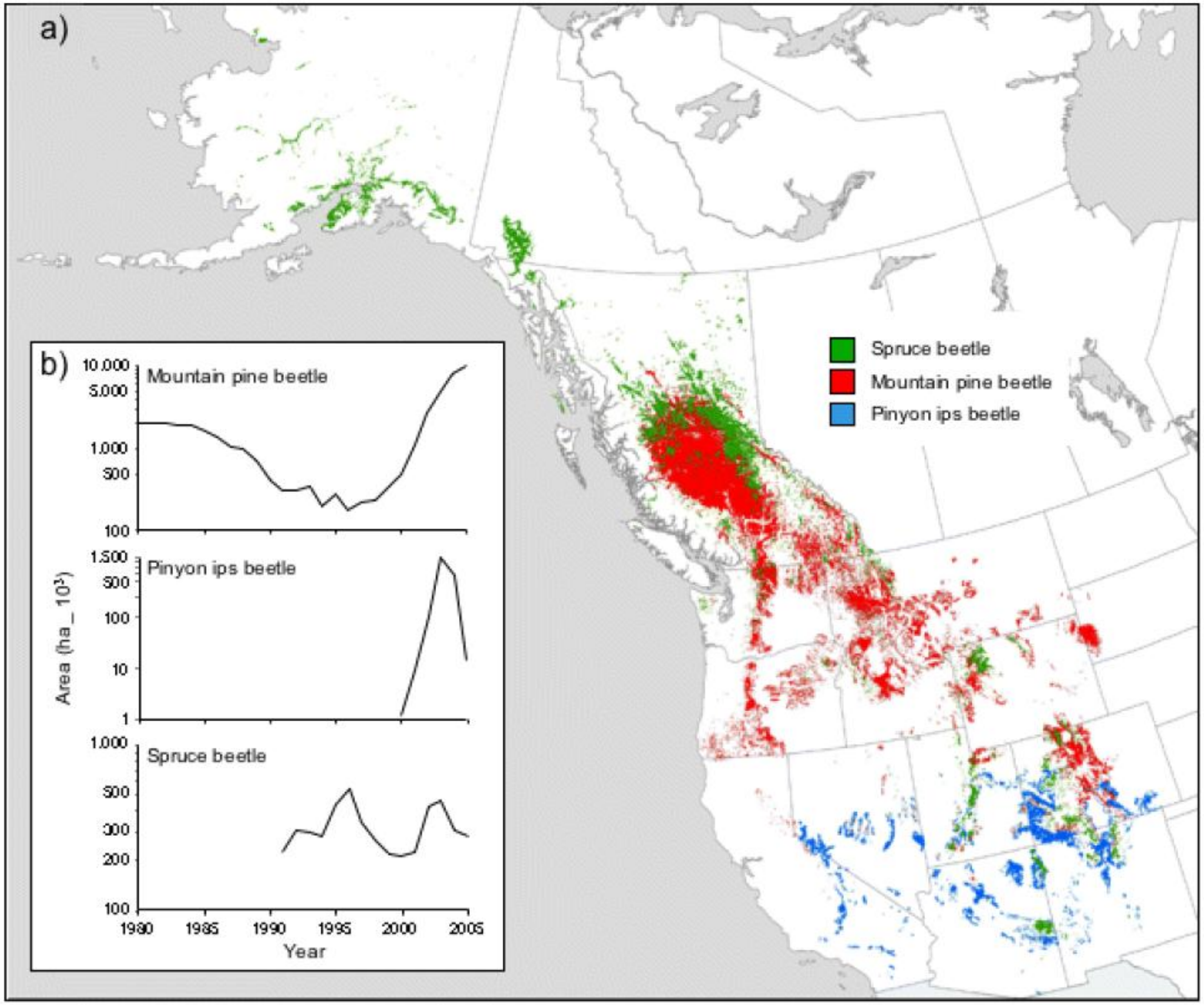
Areas with Bark-Beetle-Caused Piñon and Ponderosa Pine Mortality
Arizona and New Mexico, 2003



The bark beetle activity depicted here is based on aerial detection surveys and should only be used as a general indicator of incidence. This map represents the mortality that has occurred since the previous surveys in 2002. During 2003, additional surveys were conducted in piñon-juniper woodlands. Depending upon the timing of survey, the entire extent of bark beetle activity in some areas may not have been detected. Intensity of damage is variable, thus not all trees within a mapped area are dead. Caution should be used in interpreting these results due to the subjective nature of aerial sketchmapping and the scale of mapping. Areas of particular concern should be ground-checked for precise determination of location and casual agent.

Forest Health Staff
Southwestern Region
USDA Forest Service
9 March 2004

Recent bark beetle infestations appear related to higher temperatures, droughts, and susceptible stand conditions

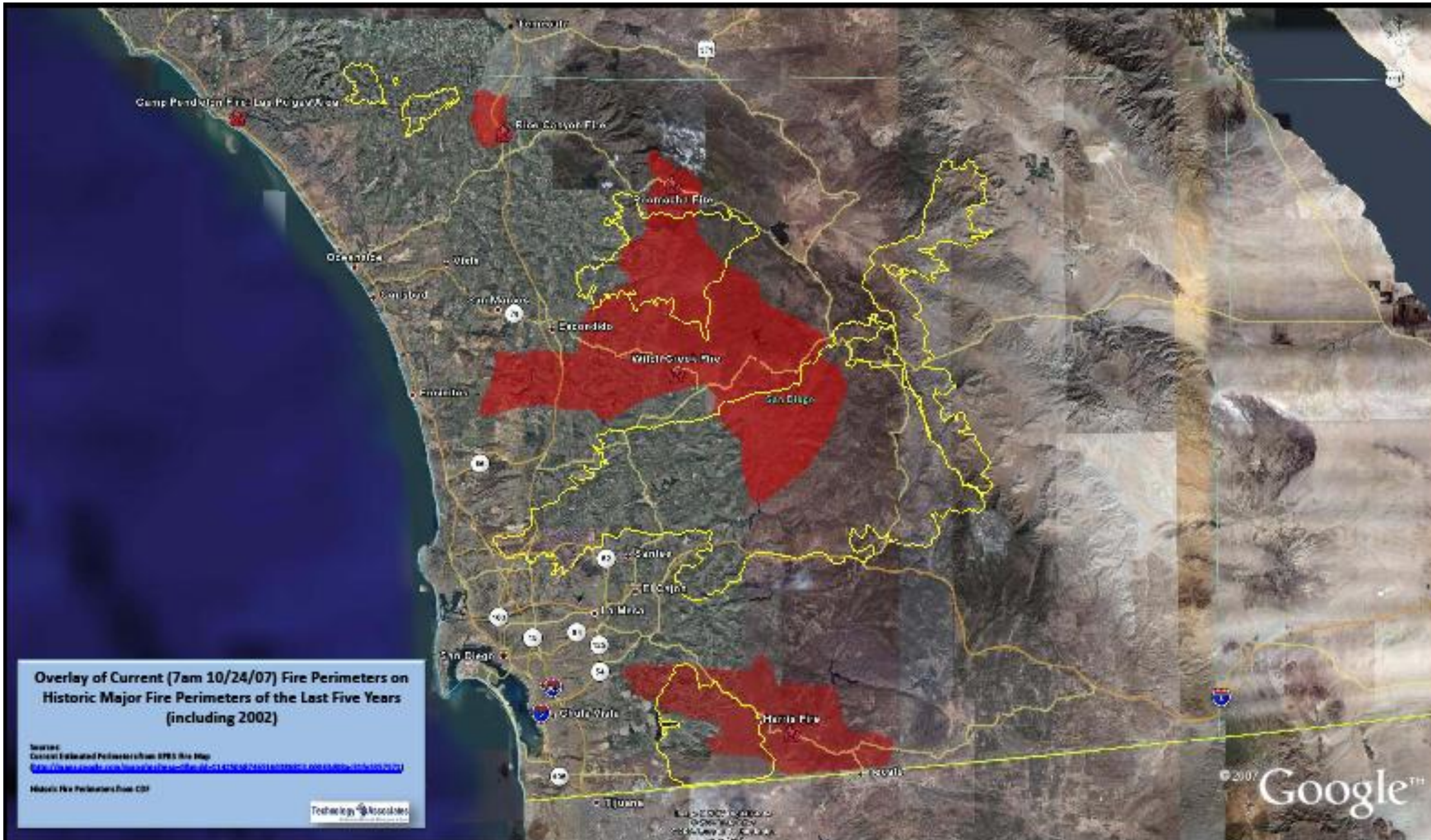


Raffa et al., in review

2003 Aspen Fire, US Forest Service

t-Gibson Fire, AP Photo/Don Ryan

Are these ecological changes "global change" events? And how would we know?



Today we'll look briefly at climate change and ask:

1. How has climate worked as a driver of fire regimes until now?
2. What sort of fire regimes might future climate produce?

Disturbance: A process resulting in an episodic change in population structure or an ecosystem biophysical template.

TREE-RING RECONSTRUCTED PDSI DROUGHT

file:///Users/drdendro/Desktop/Drought%20Atlas%20Additions!/Atlas-PDF

Google

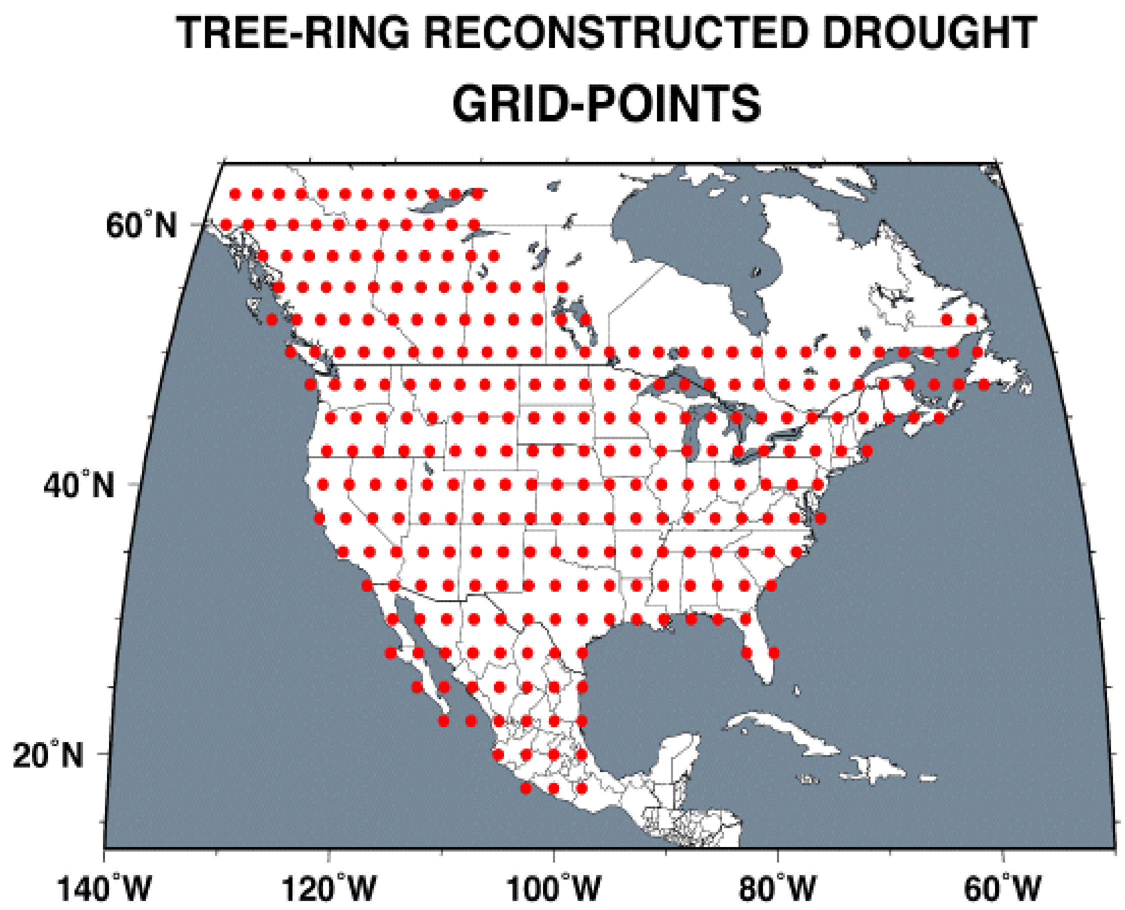
Speeding up Panther HSBC Wilderness Wear Australia »» Ogoplex ...turalGreens Computing u... Mac OS X! Random Forests IBM Fortran

North American Drought Atlas

A History of Meteorological Drought Reconstructed from 835 Tree-Ring Chronologies for the past 2005 years.

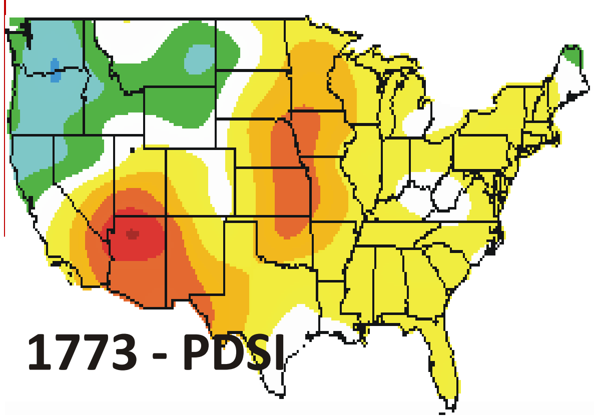
Index

I. Users Manual
II. Introduction
III. Methods
IV. View Time Series Data
V. View Annual Maps
VI. Animation
VII. Data Downloads
VIII. Acknowledgements

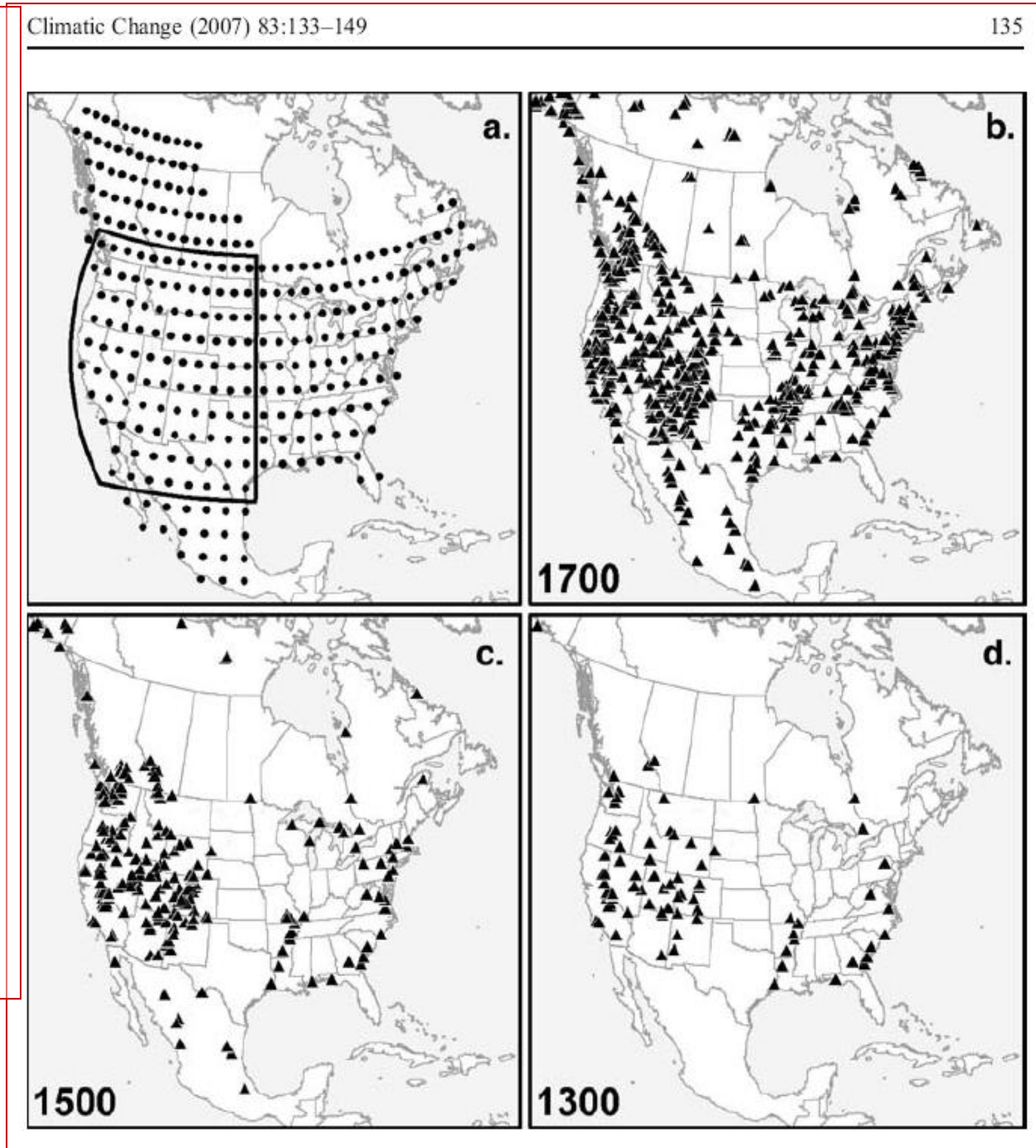


Key point: How do we know climate is changing?

Extensive tree-ring networks allow spatial reconstruction of climate patterns for the past 700+ years.

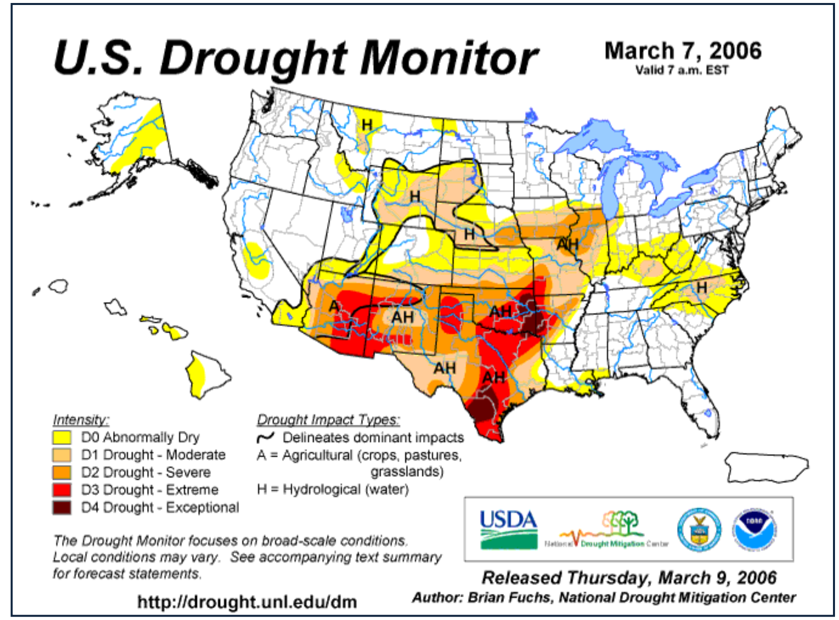


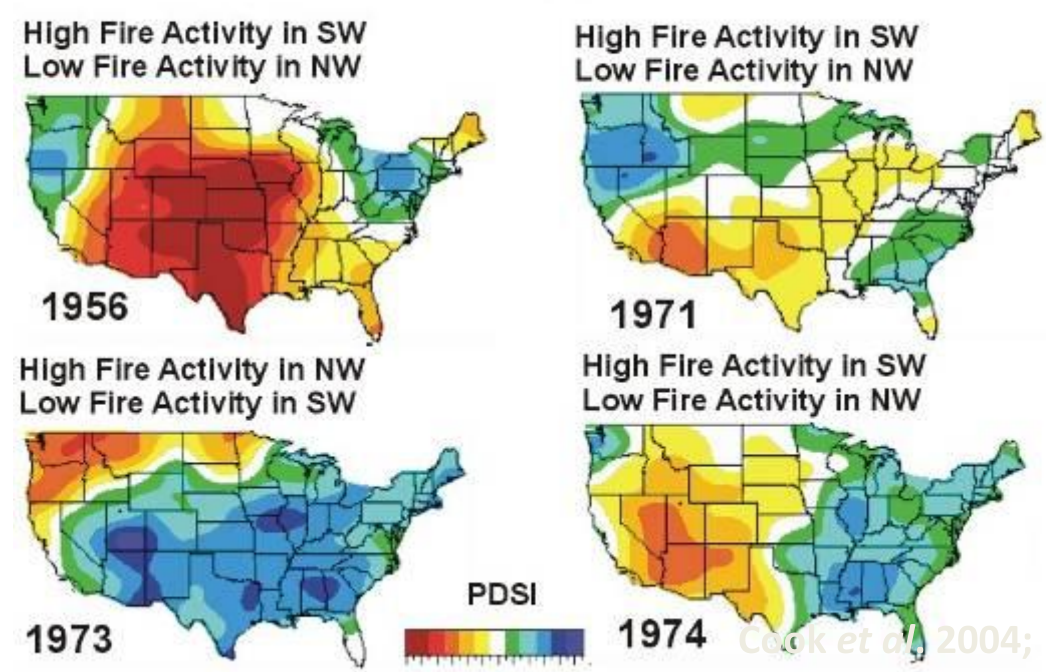
1773 - PDSI



Regional climate **variability** regulates fire occurrence

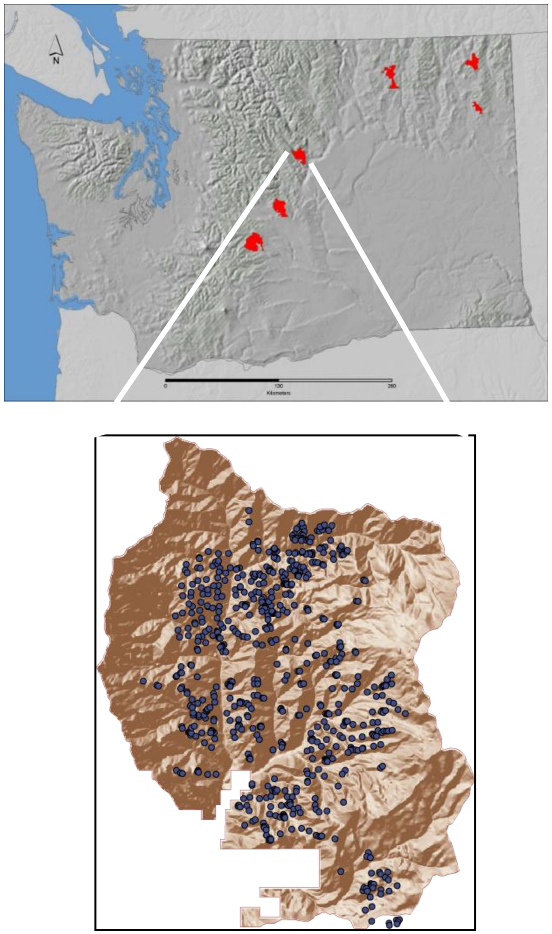
- Spatially coherent variation in PDSI (an index of drought conditions)
- Interannual variation in spatial pattern
- Primary mechanism of synchronous regional fires

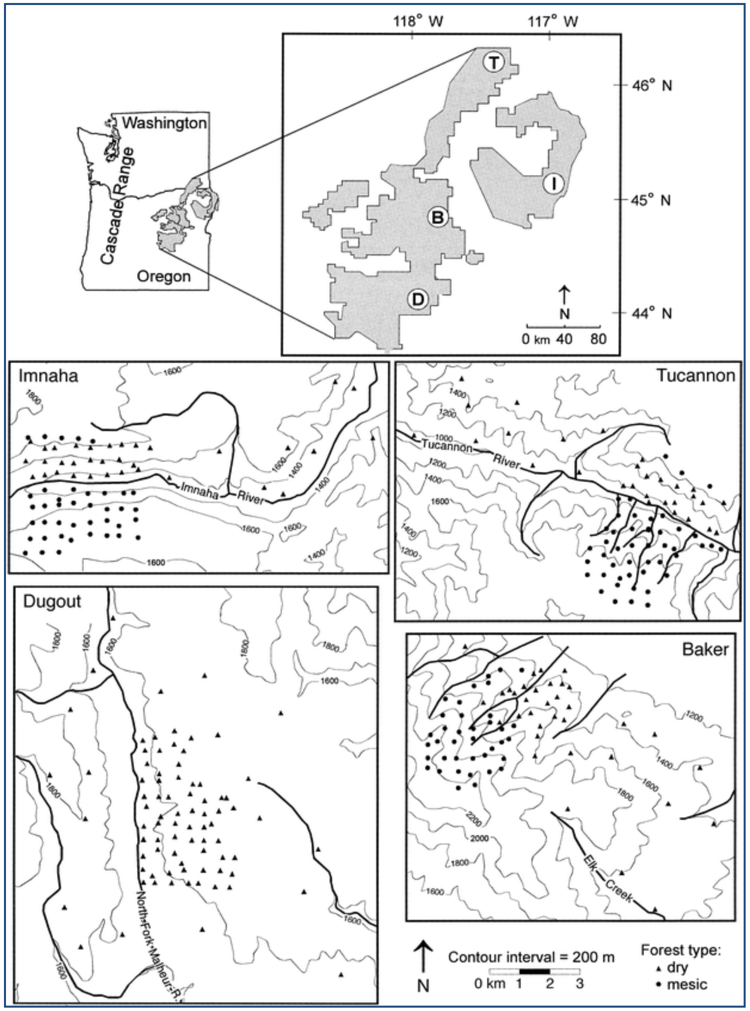


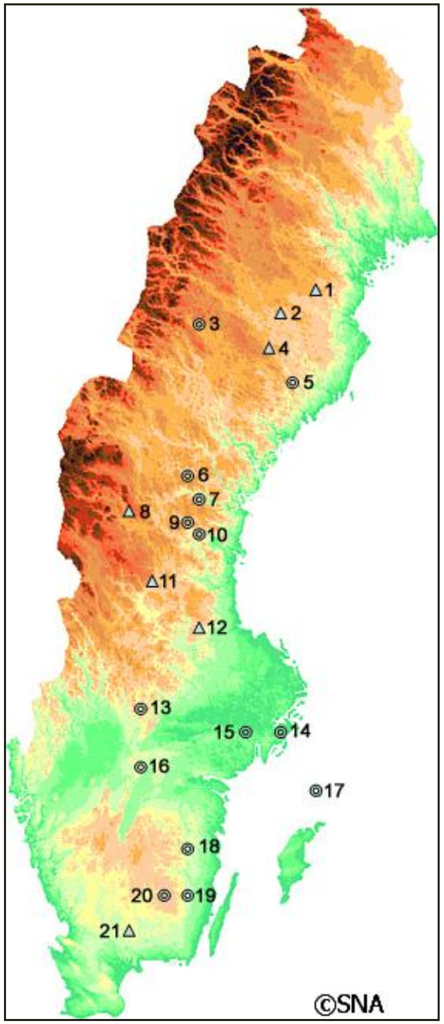


Cook *et al.* 2004; http://www.ncdc.noaa.gov/paleo/pdsiyear.html

Regional fire history networks regions are providing new insights into landscape fire regimes







Hessl et al. 2004; Heyerdahl et al. 2001; Multi-author (Scandinavia); Falk et al. 2010, 2011

Fire and Climate Synthesis (FACS): A major new network for continental paleoecology

- 1,248 sites
- 64 contributors
- 3,248 years (1248 CE – 2011 CE)
- Fire-scar based, focused on frequent-fire systems
- 7 primary forest types
- > 15,000 fire site-years

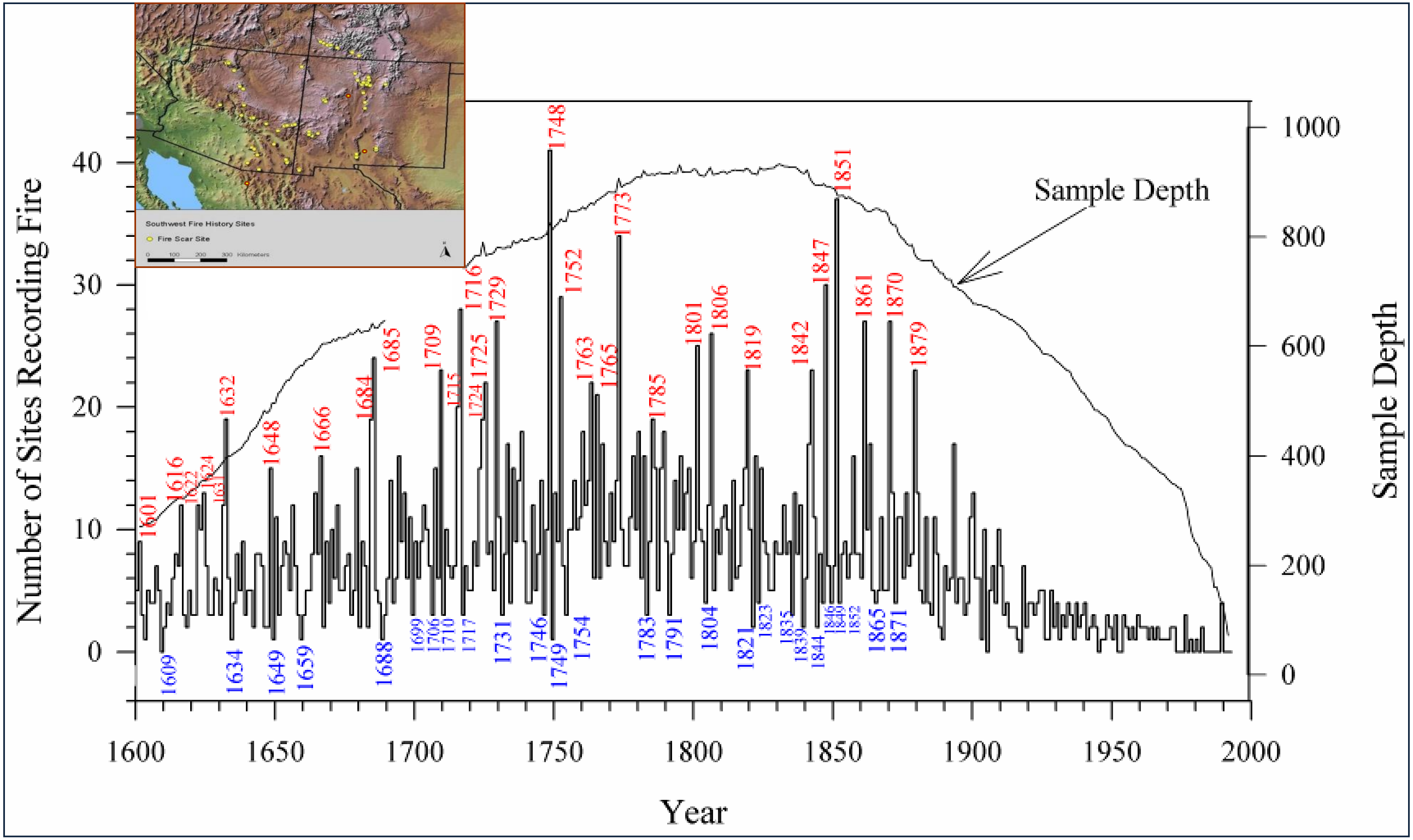
Falk et al. 2010, 2011, in prep.

Occurrence of widespread, west-wide fire years 1650-1900

- Certain years stand out for the extraordinary amount of fire recorded
- Fire recorded at more than 200 sites three times (1748, 1829, 1851)
- When corrected for sample size, fire recorded at ≥ 20 % of sites in 13 years, including 6 times in the 18th century (on average, ~ every 16 yr) and 5 times in the 19th (on average, every 20 yr)

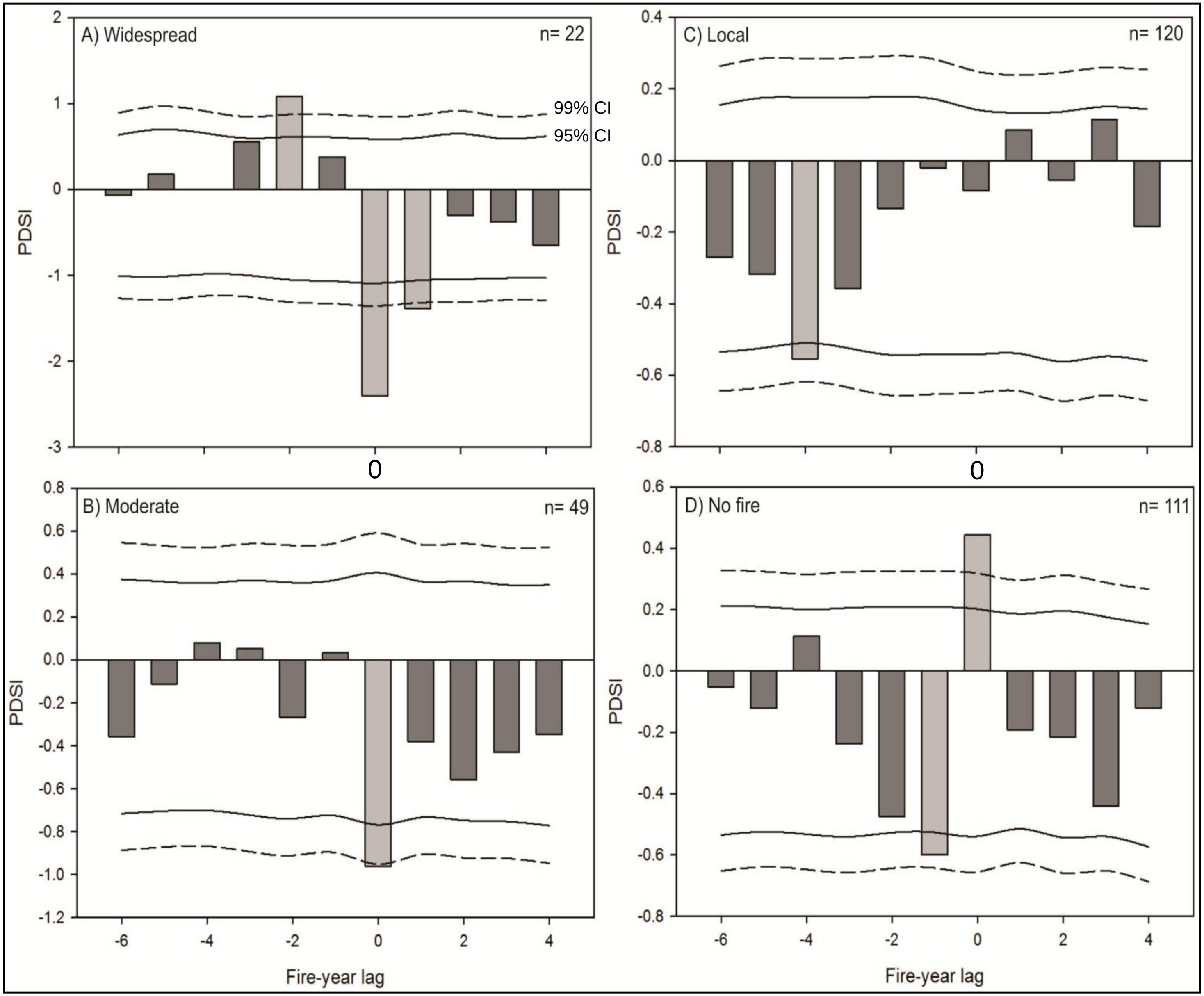
Year	Percent of sites recording fire
1684	21.3
1685	24.1
1729	24.0
1748	31.6
1752	22.2
1763	21.4
1785	24.6
1794	20.5
1822	20.6
1829	24.2
1851	27.2
1870	21.0
1879	23.2

Spatially networks allow us to identify regional <u>synchrony</u> in fire – years when a large proportion of sites record fire

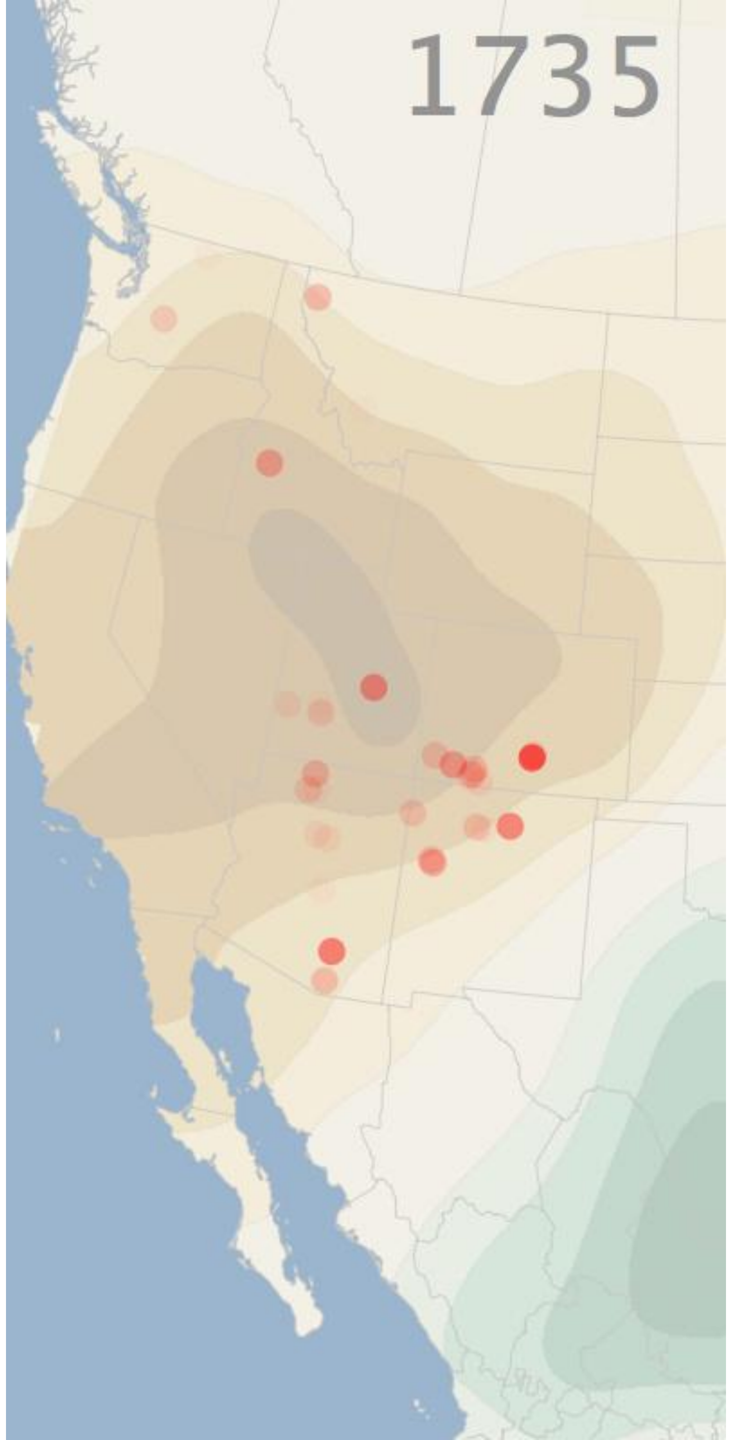


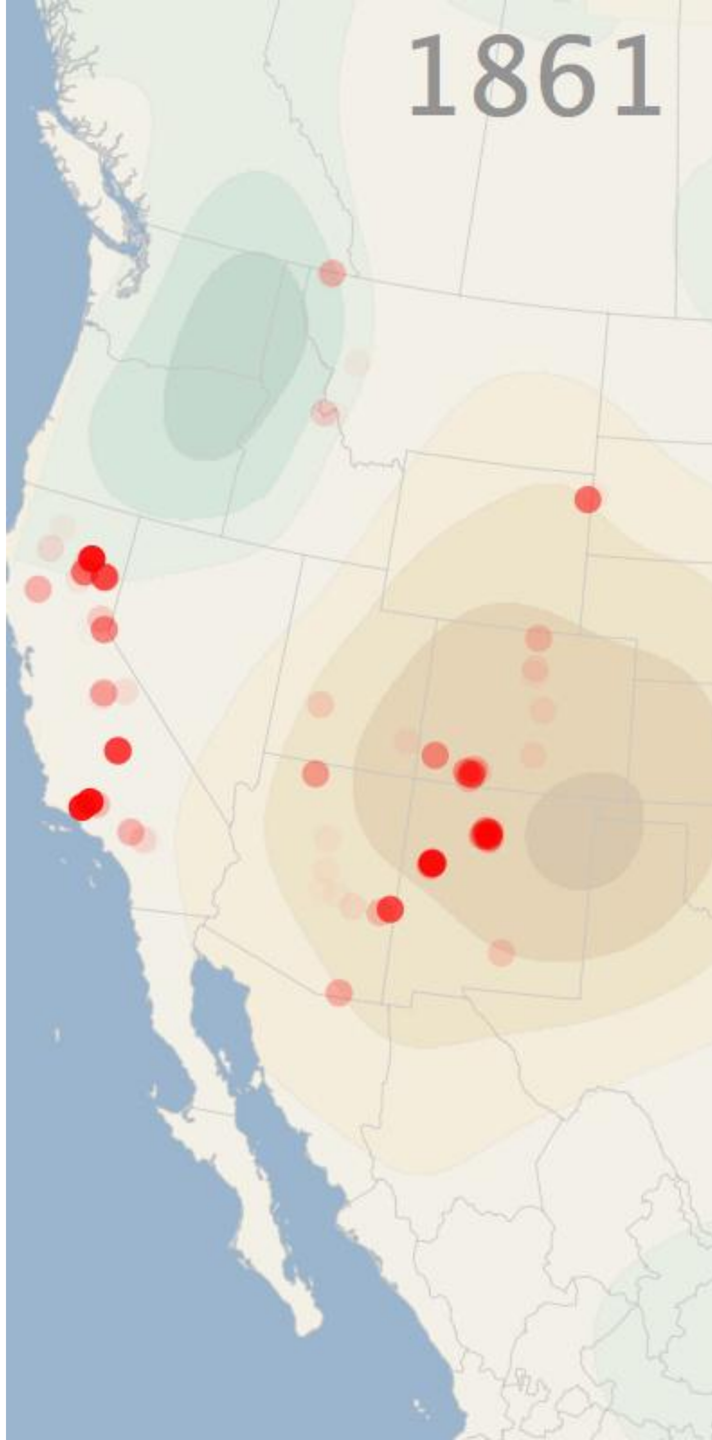
Swetnam & Baisan 2003

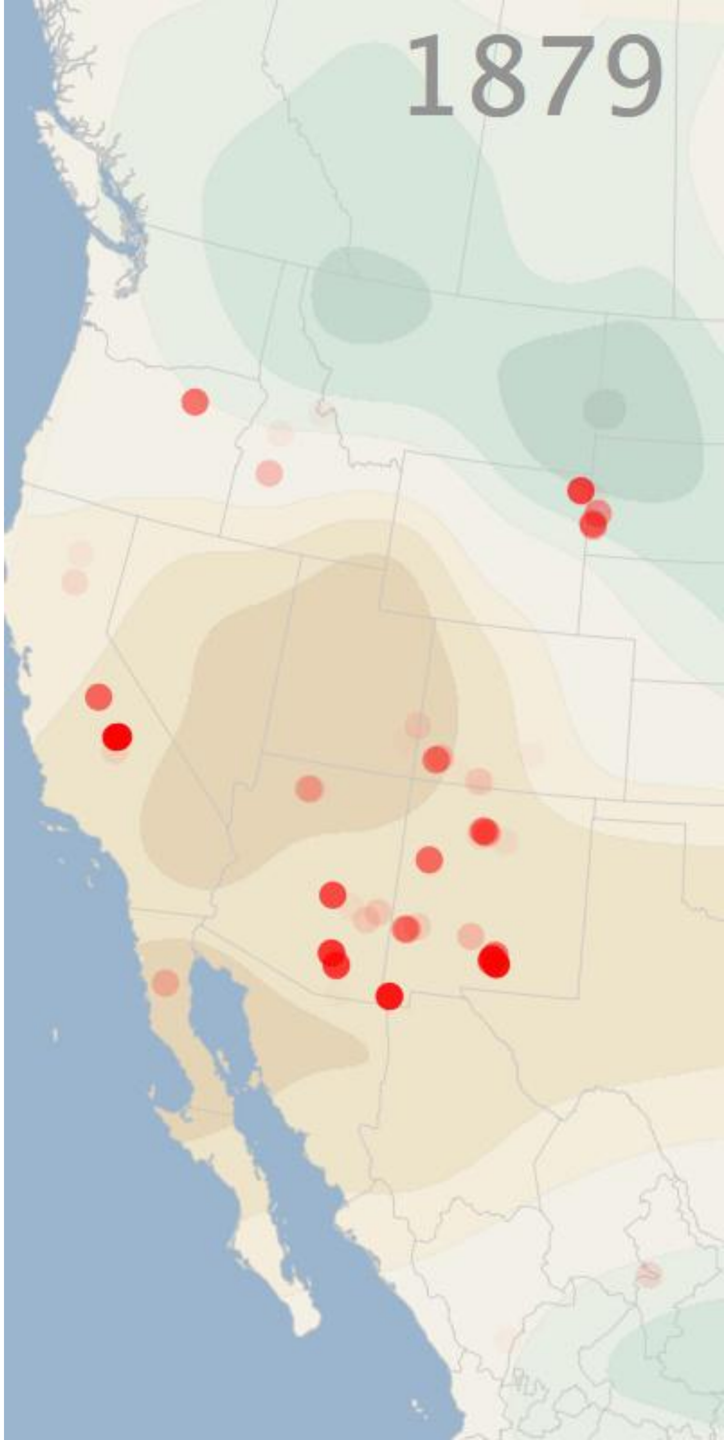
Superposed Epoch Analysis (SEA)



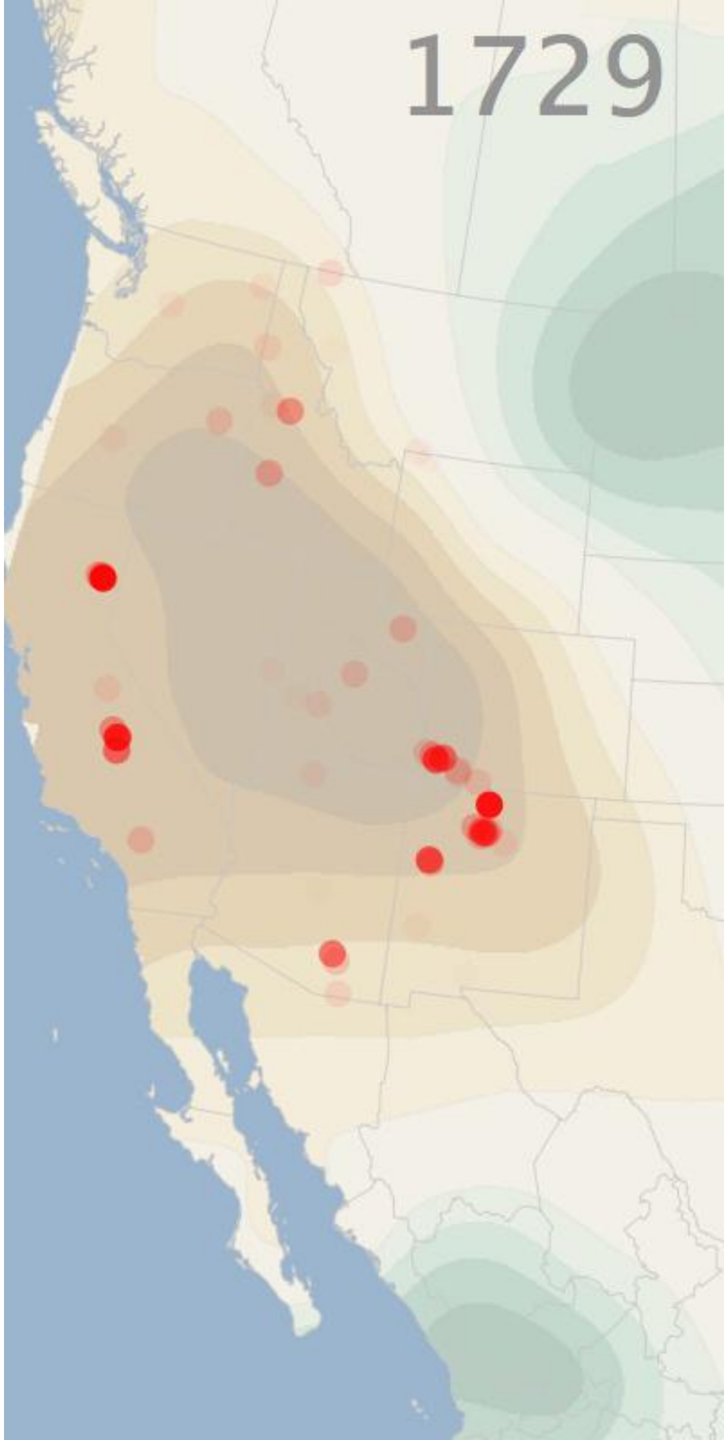
0 = Fire year

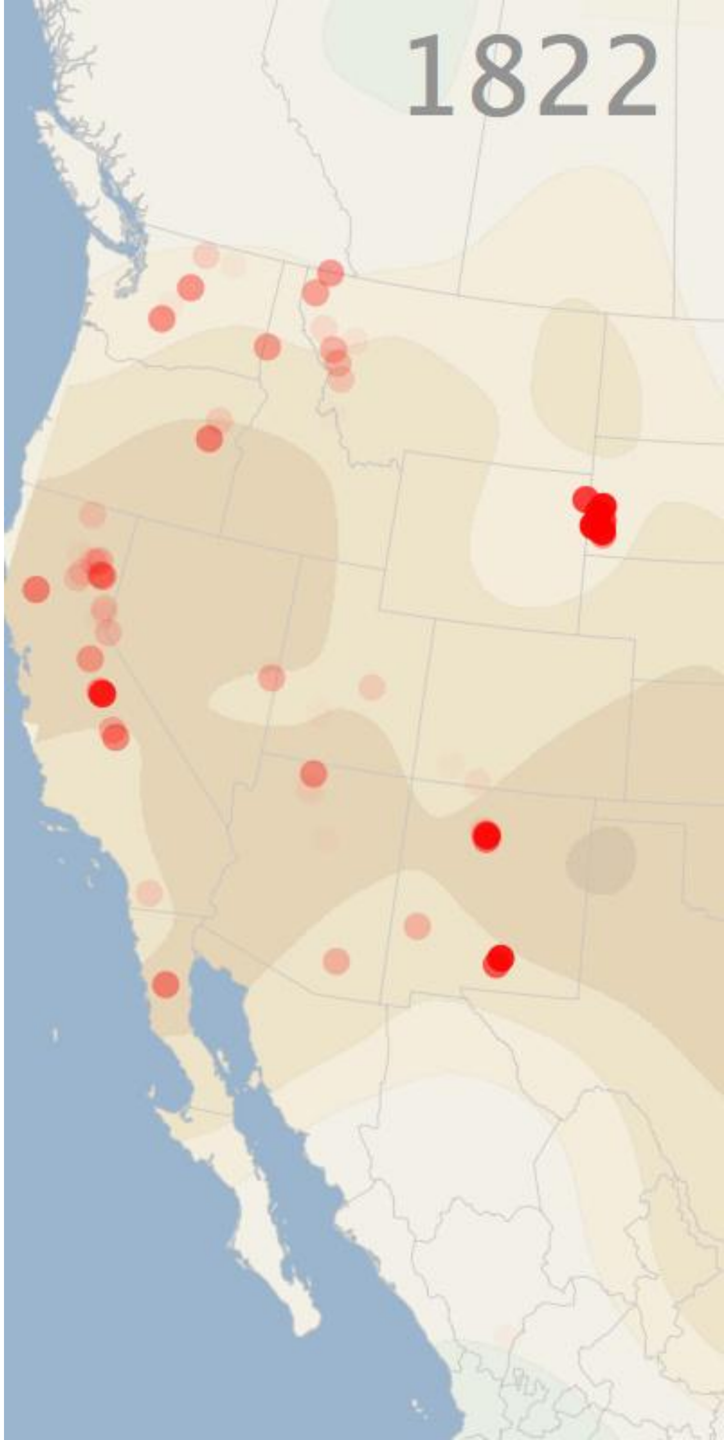

1735

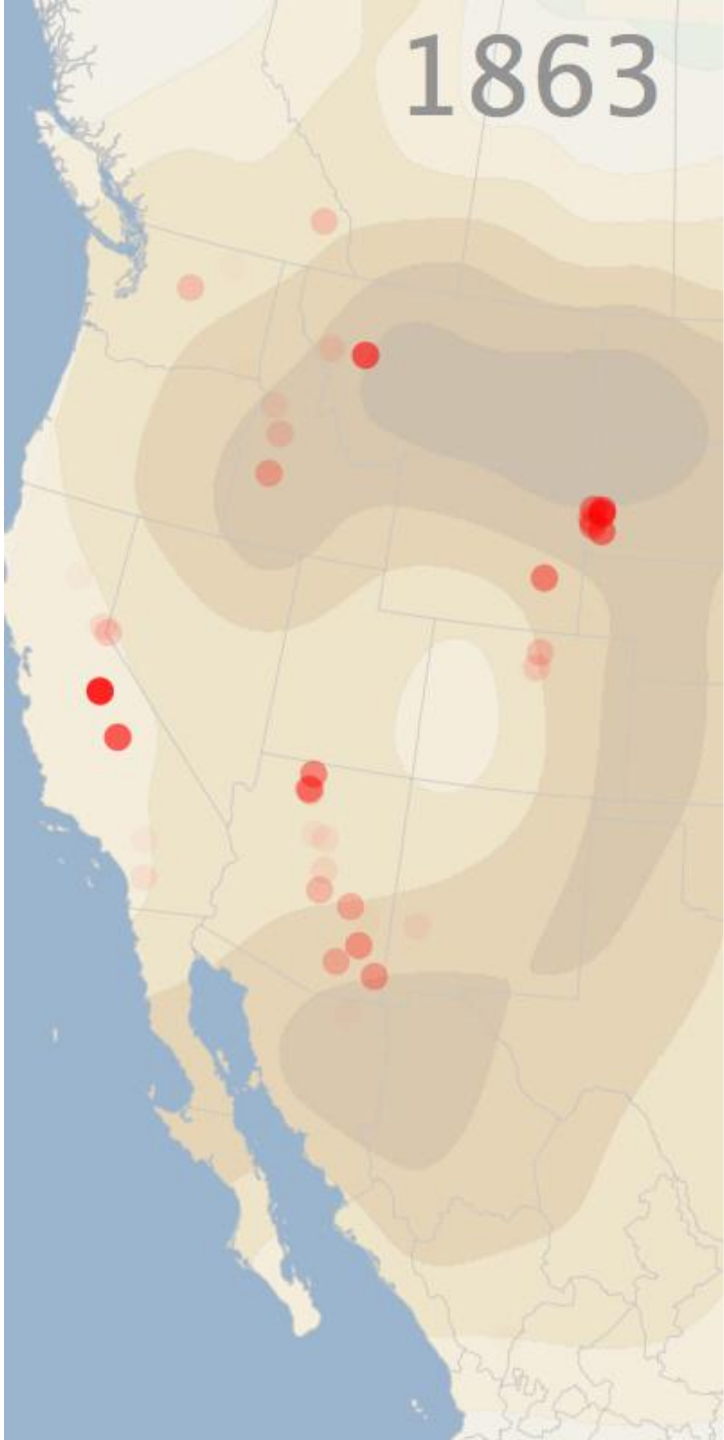

1861

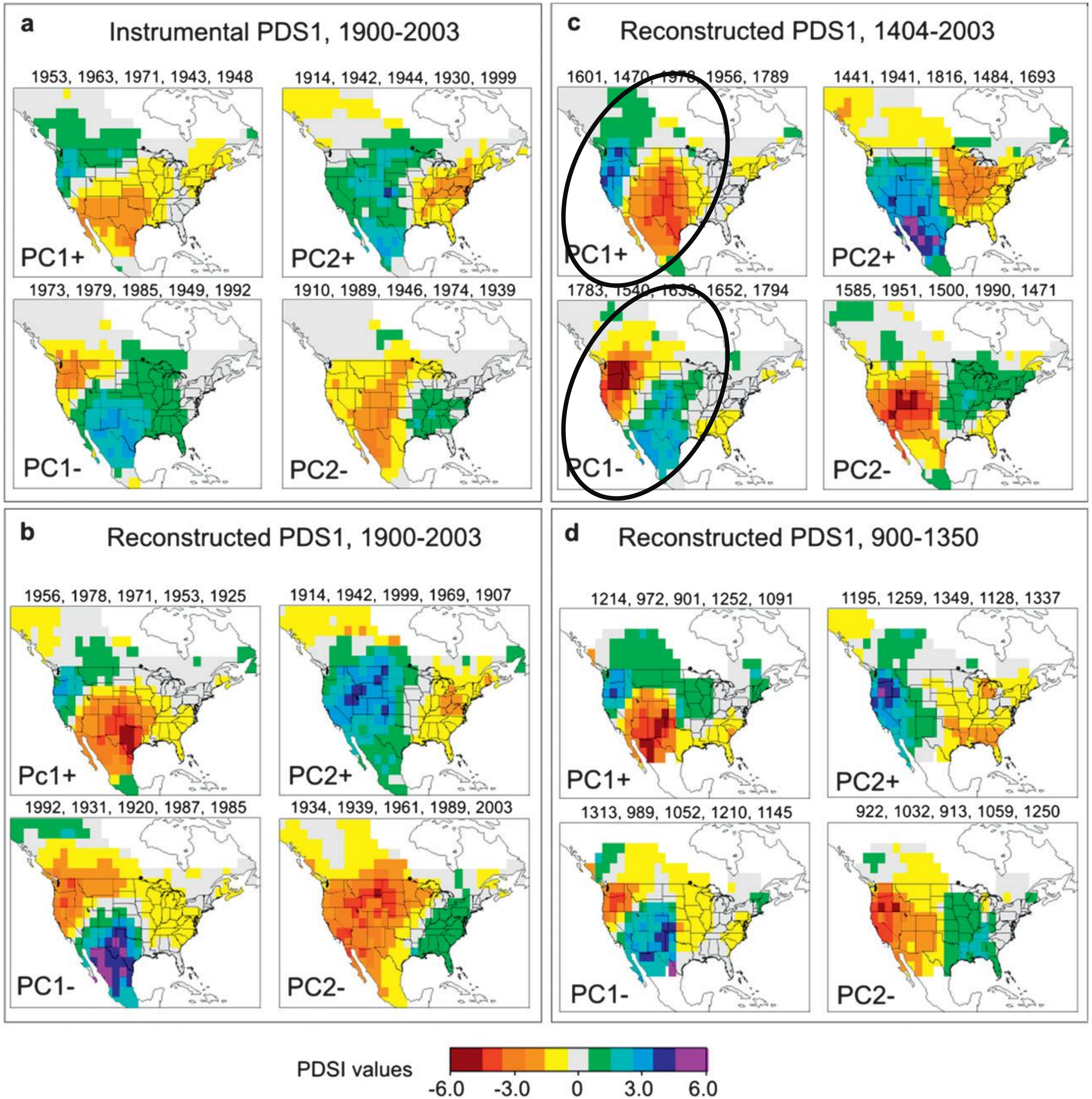

1879

Strong meridional



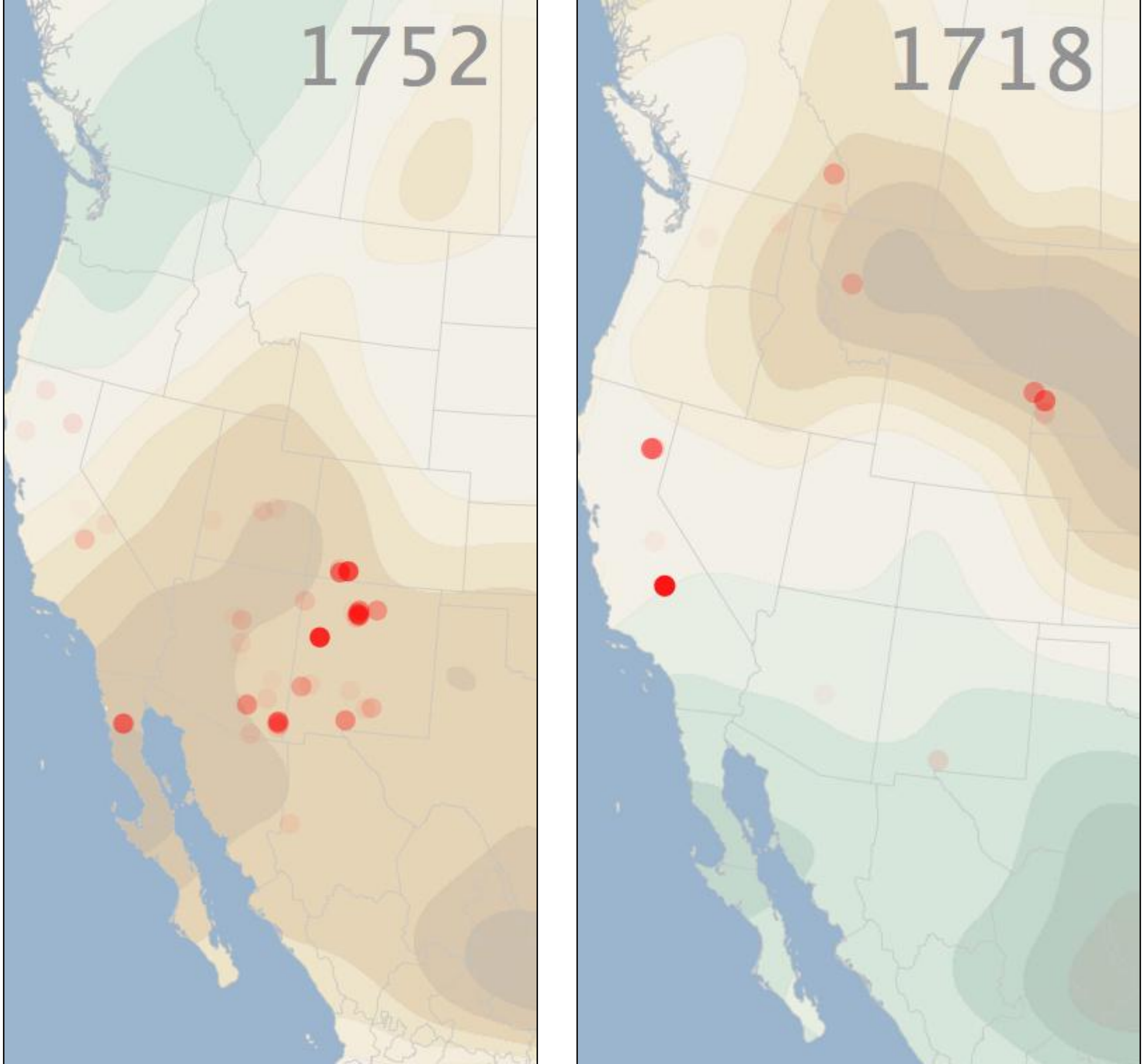

1822


1863

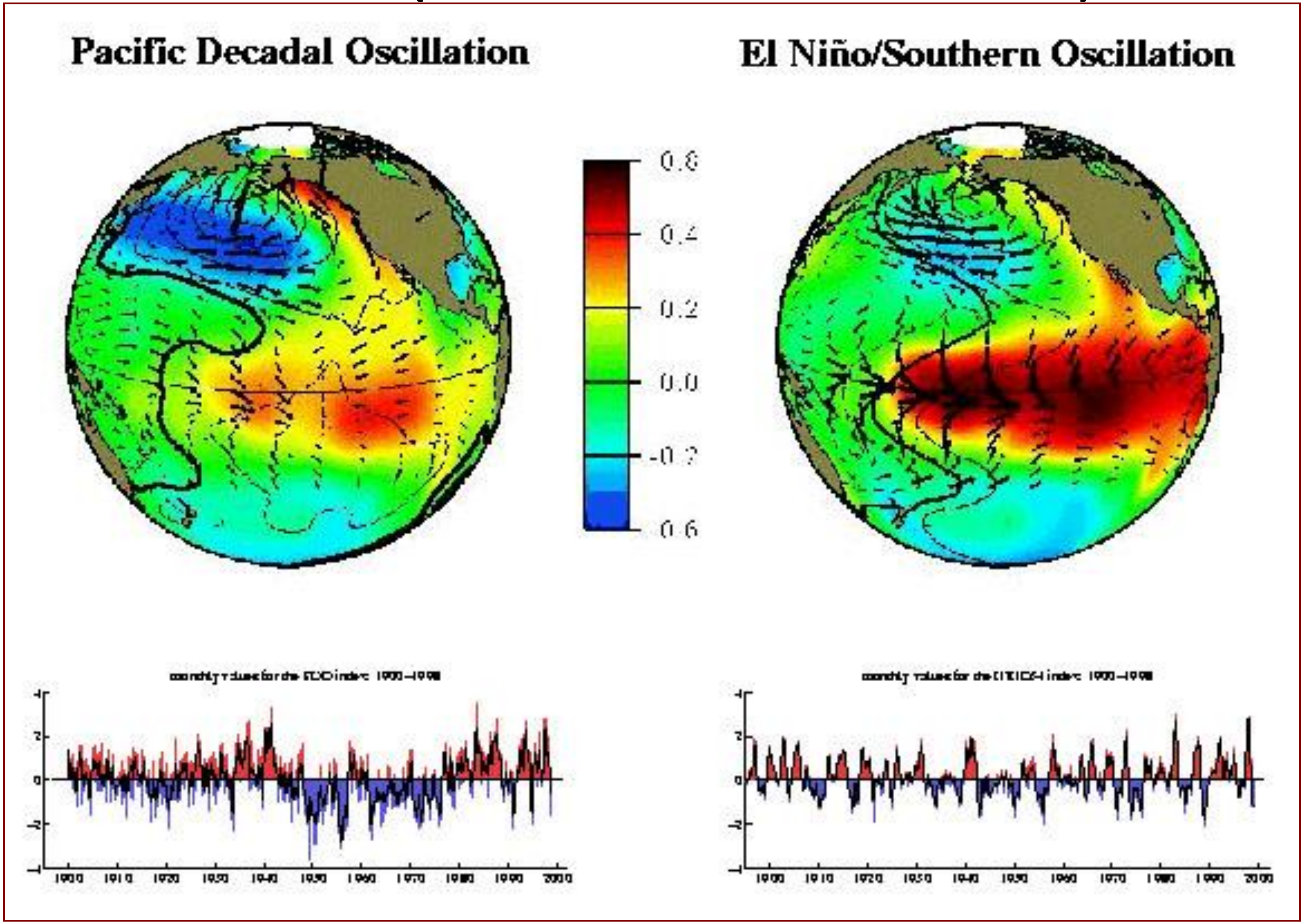


In western North America, fire follows the spatial pattern of drought, which is driven by ocean-atmosphere processes such as the Southern Oscillation

Woodhouse et al. 2009, *Journal of Climate*

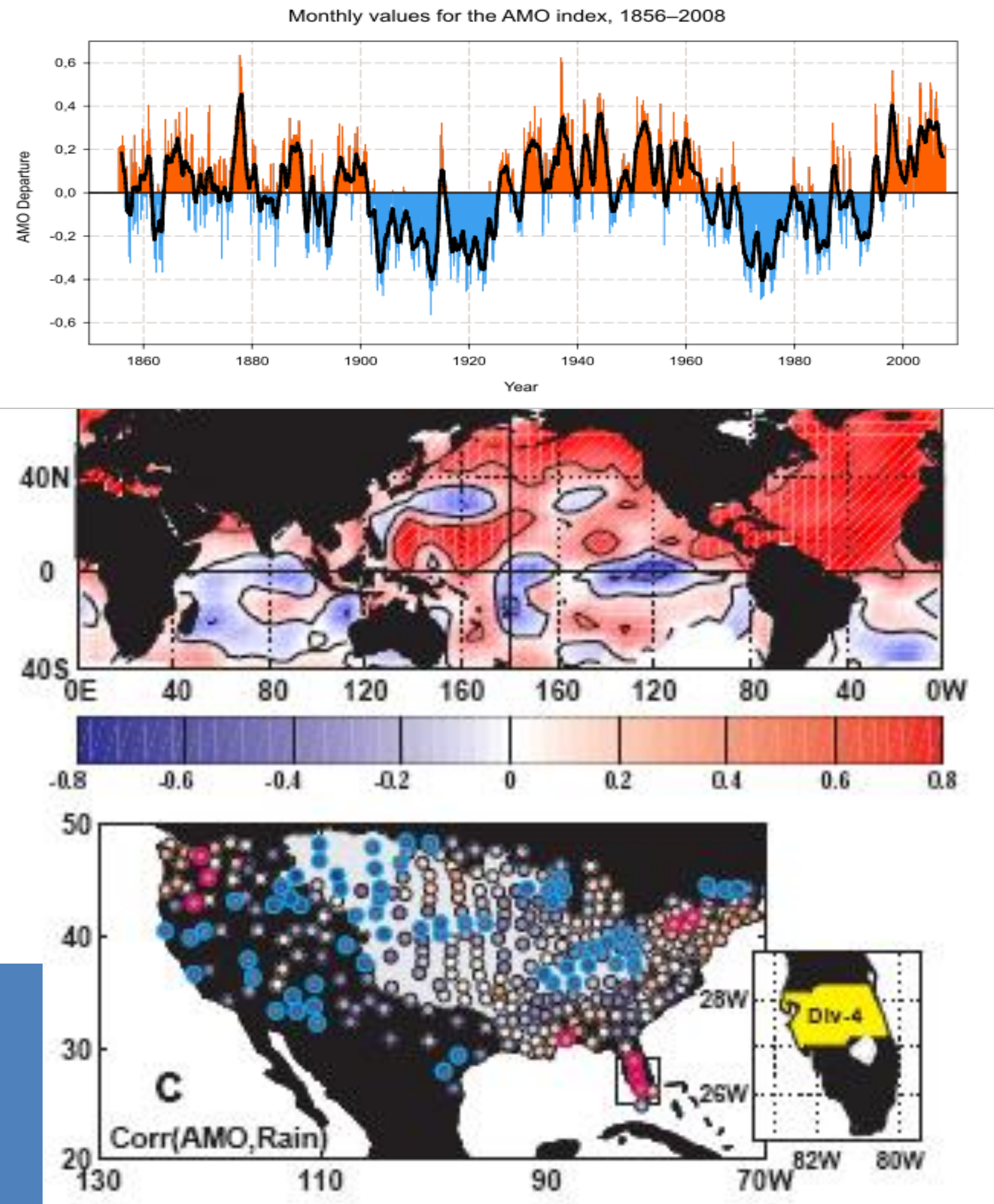

1752
1718

Climate also varies on longer time scales (decadal to millennial)



Atlantic Multidecadal Oscillation

- Average sea surface temperatures for the Atlantic north of the equator
- Influences tropical cyclone periodicities – frequency and intensity
- Associated with patterns of drought in US
- Positive values since ~1993

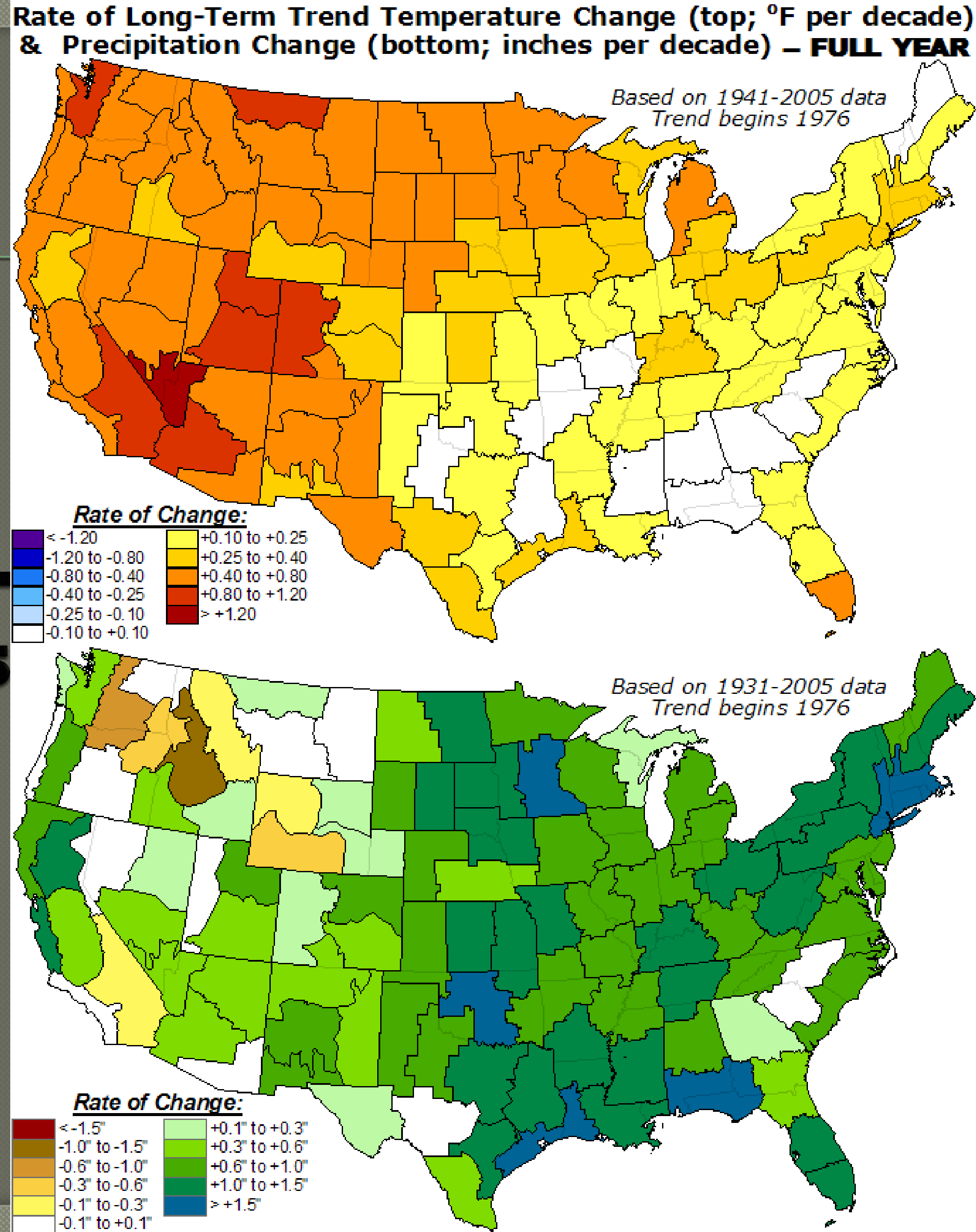


a. 10-yr running mean SSTs
b. Correlation with global annual SSTs
c. Correlation w/ div. precipitation (large circles – 90% sign.

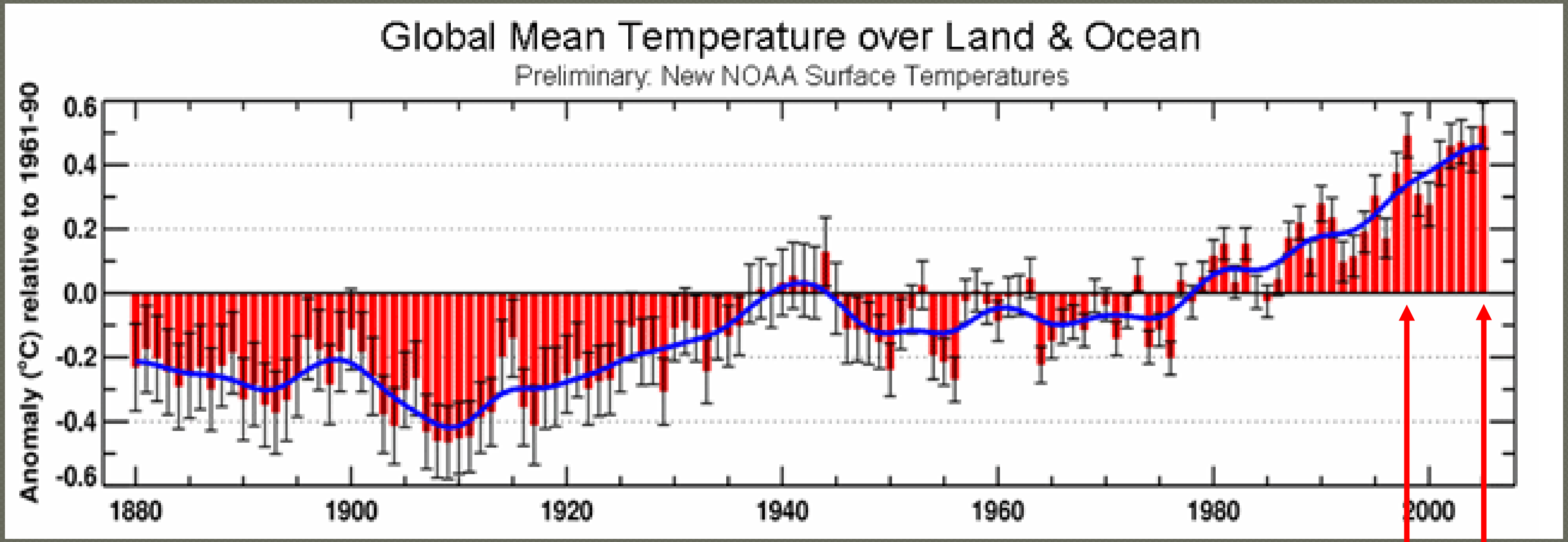
Enfield et al. 2001

What changes in fire regimes will result from climate change?

Observed U.S. Climatic Trends



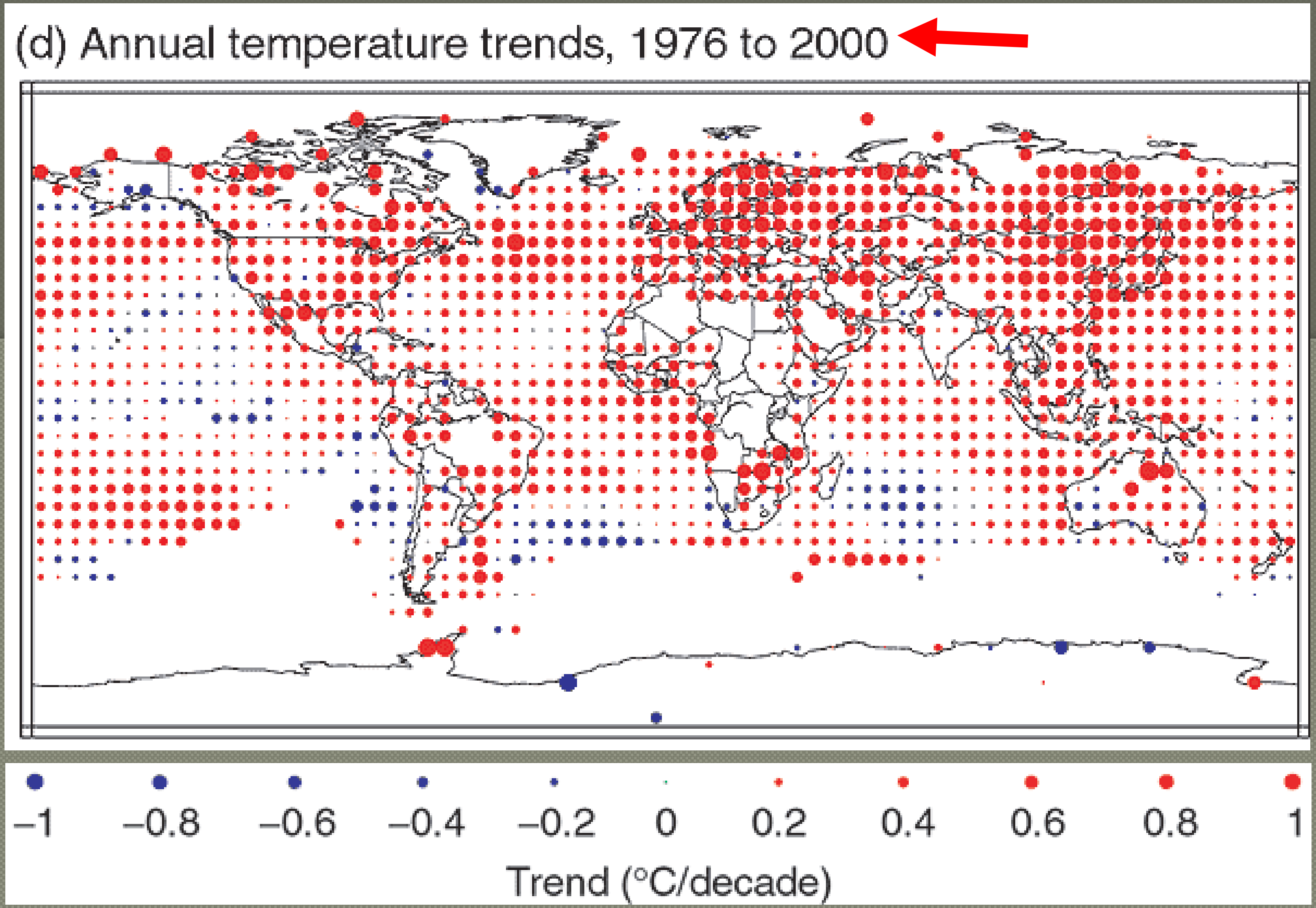
Steady increase in global mean temperature past 120 yr (instrumental data)



http://www.ncdc.noaa.gov/

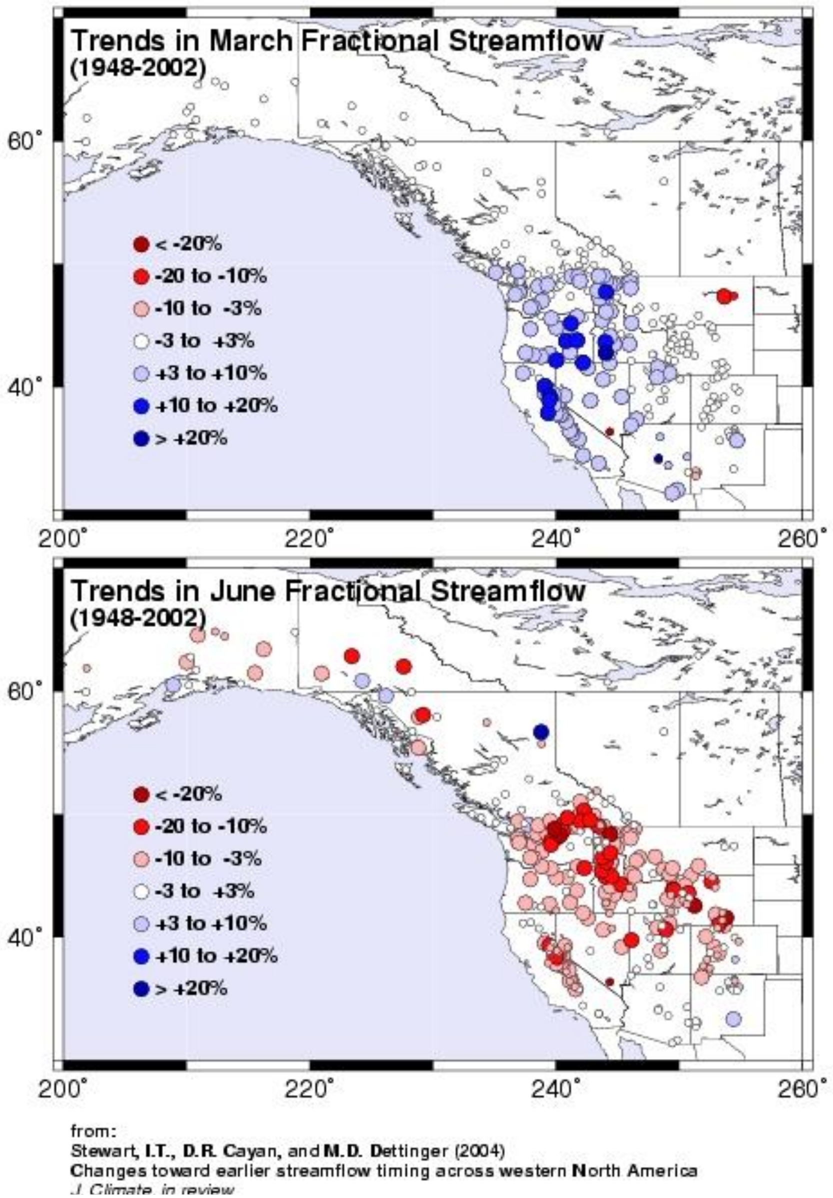
1998 and 2005 tied as warmest on record

Instrumental Observed Temperature Trends - ANNUAL



National Climatic Data Center-IPCC TAR (2001)

Earlier snowmelt



Stewart et al. 2005 Journal of Climate

March streamflow trends (1948-2002)

June streamflow trends

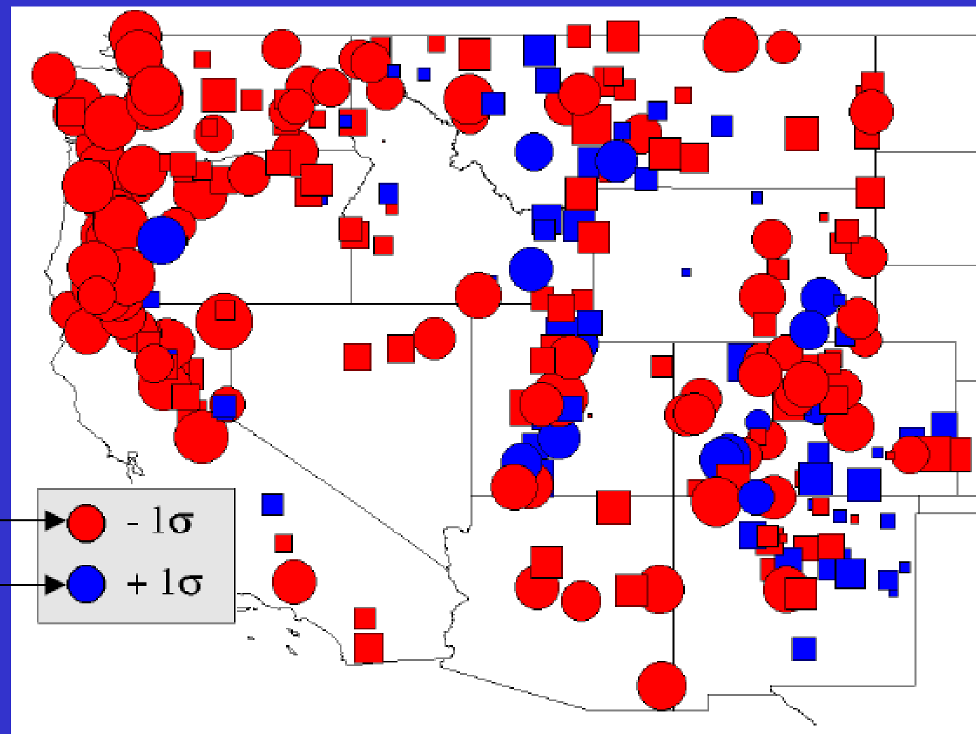
(1948-2002)

Trends in Nov-Mar Snowfall Fraction

Shift from Snowfall to Rainfall

More Rain, Less Snow

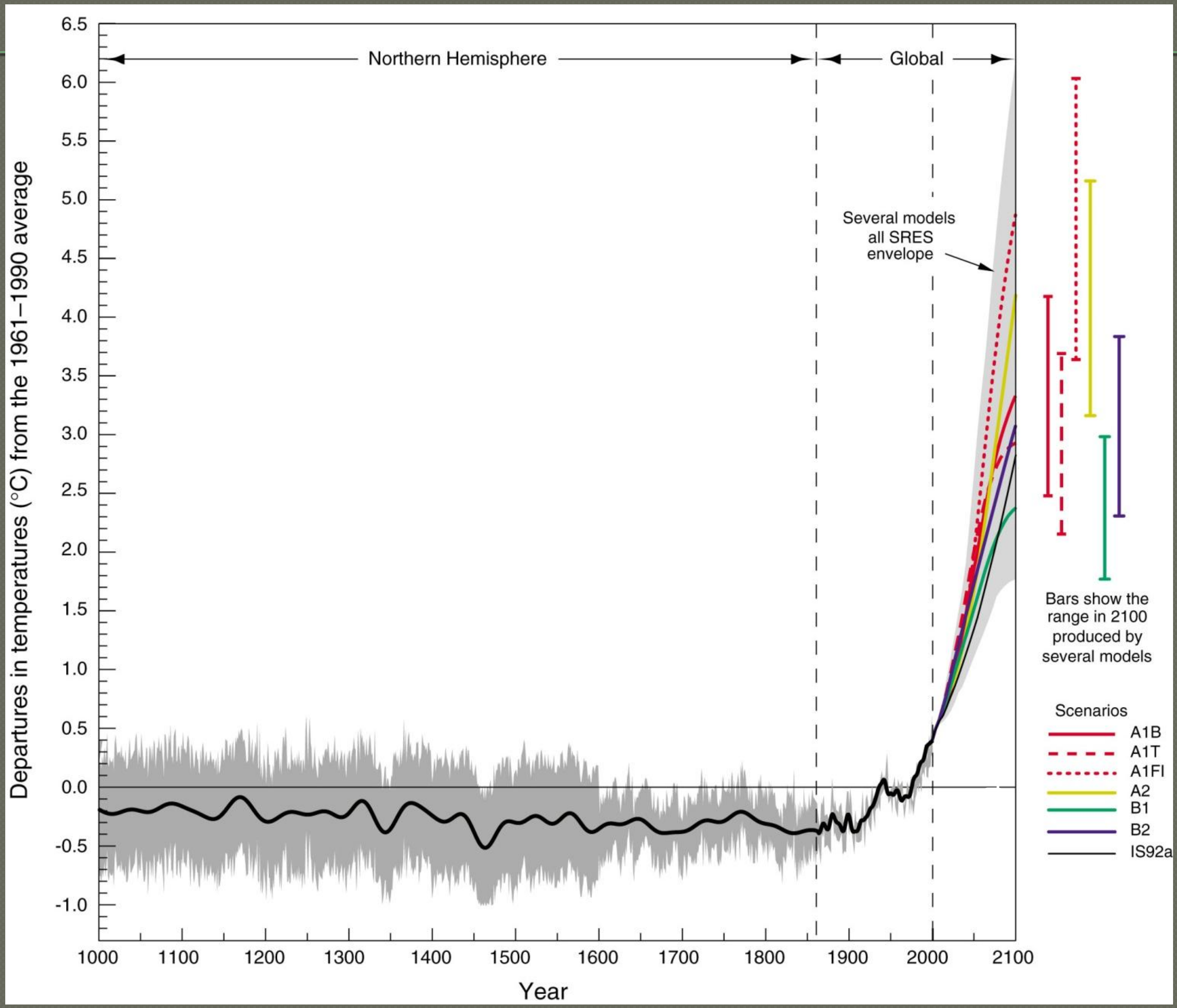
More Snow, Less Rain



Trends in ratio of winter (Nov-Mar) snowfall water equivalent (SFE) to total winter precipitation (rain *plus* snow) for the period WY1949-2004. Circles represent significant ($p<0.05$) trends, squares represent less significant trends.

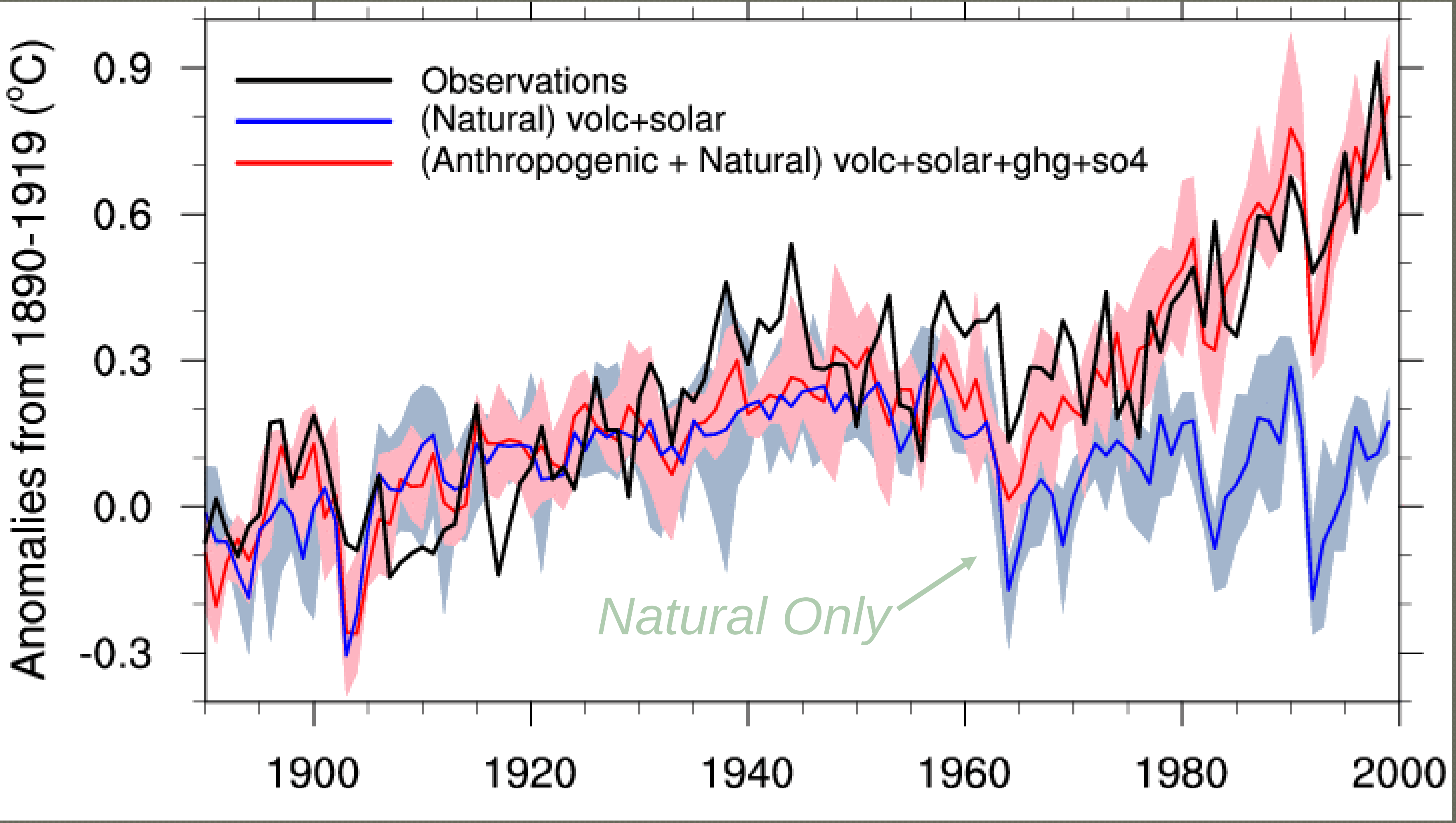
Courtesy of Noah Knowles, USGS

Variations of the Earth's Surface Temperature - 1000 to 2100



Source: IPCC TAR 2001

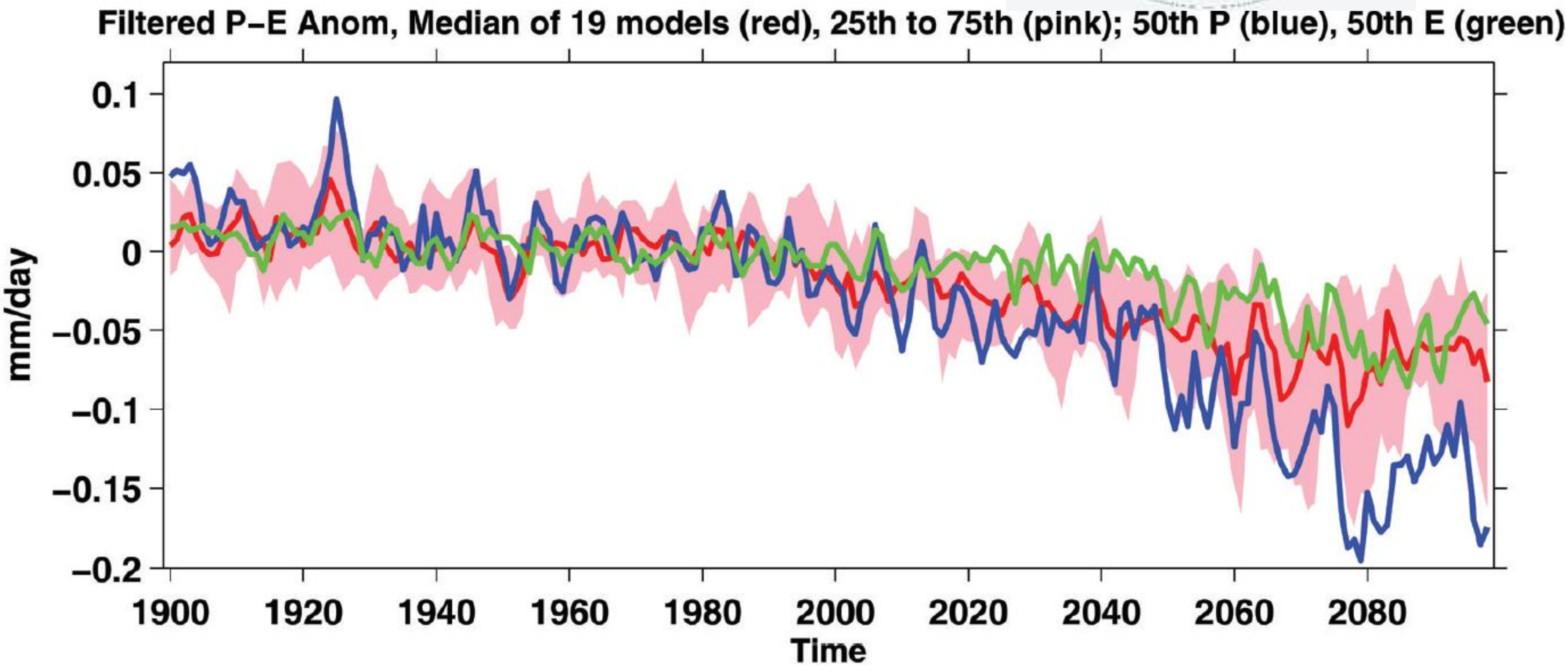
20th Century Experiment: Model global climate with and without anthropogenic GHGs



Stott et al. (2000)

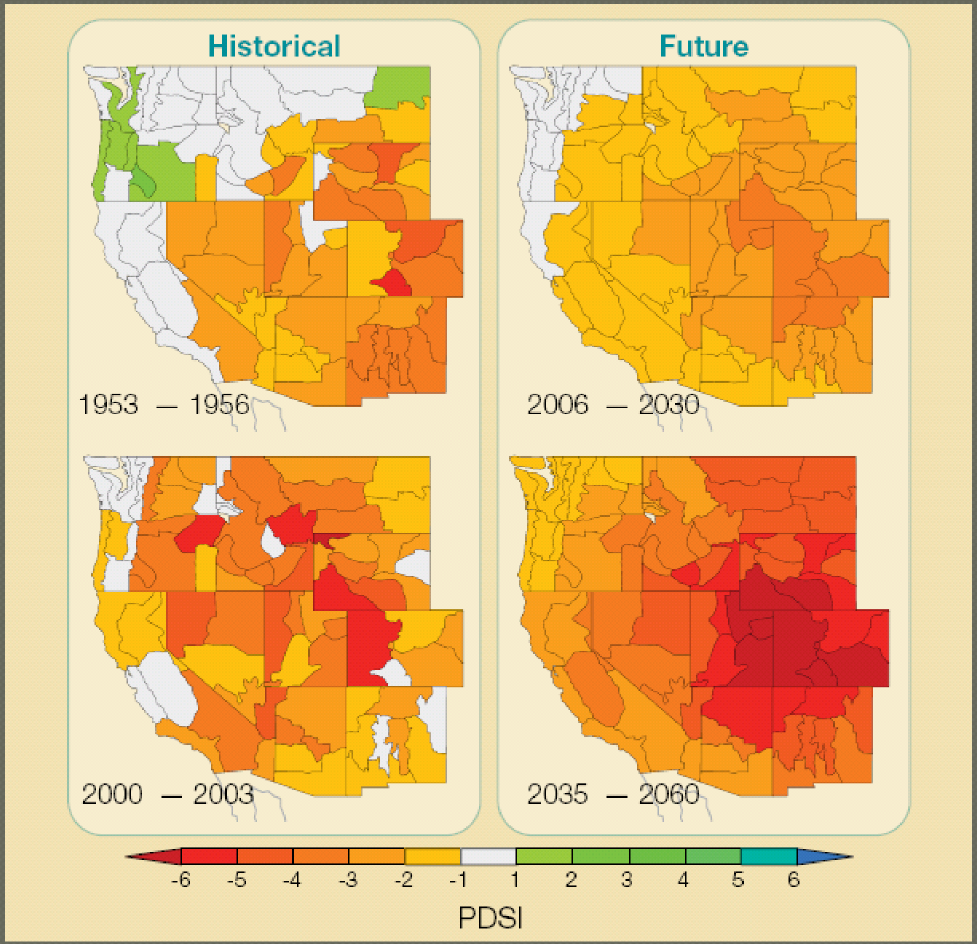
Projected rainfall (downscaled models) for southwestern North America

(Seager *et al.*, 2007, *Science*)



Interactions between temperature and precipitation

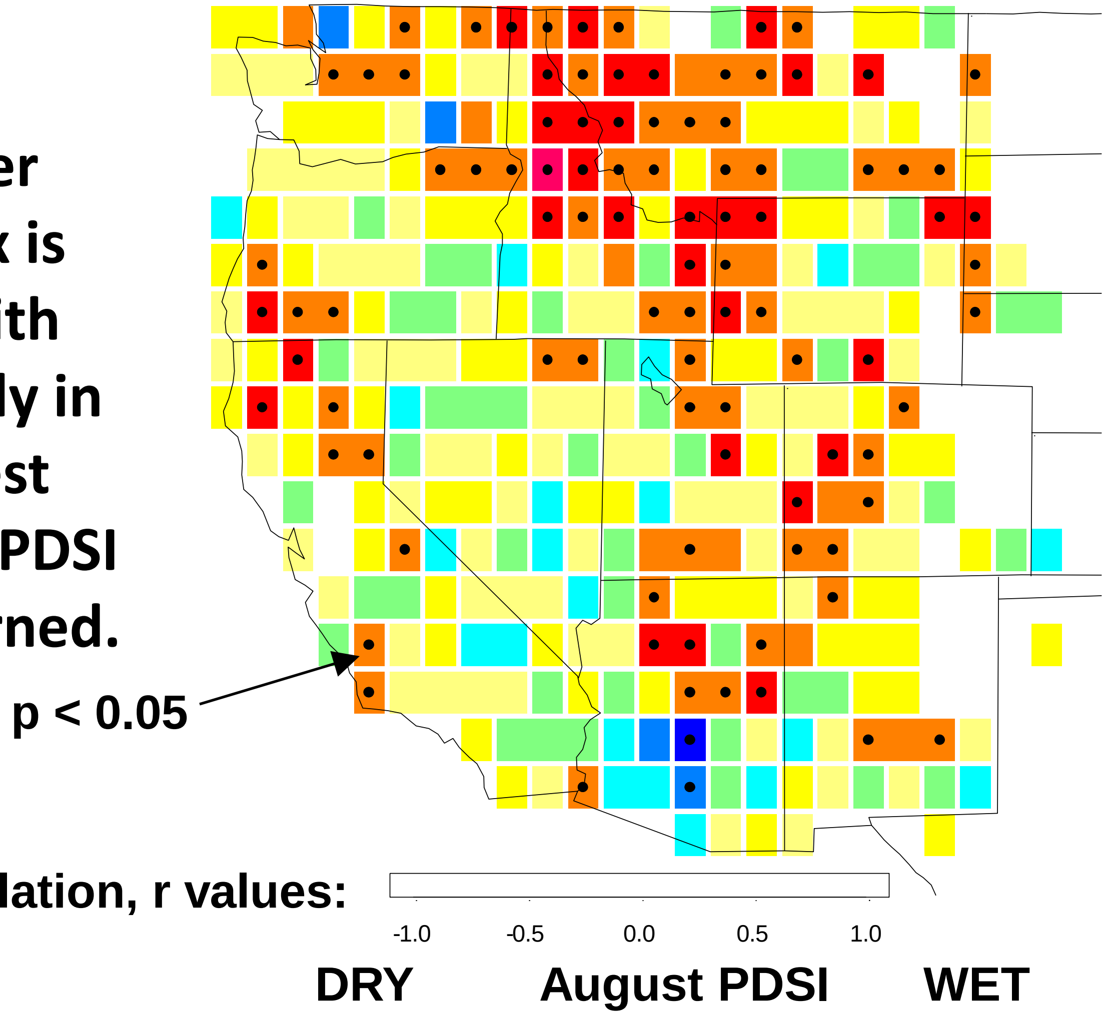
- Confidence in continuation of increasing temperatures
- Projections on precipitation variability are less clear
- Increasing temperatures alone will increase aridity



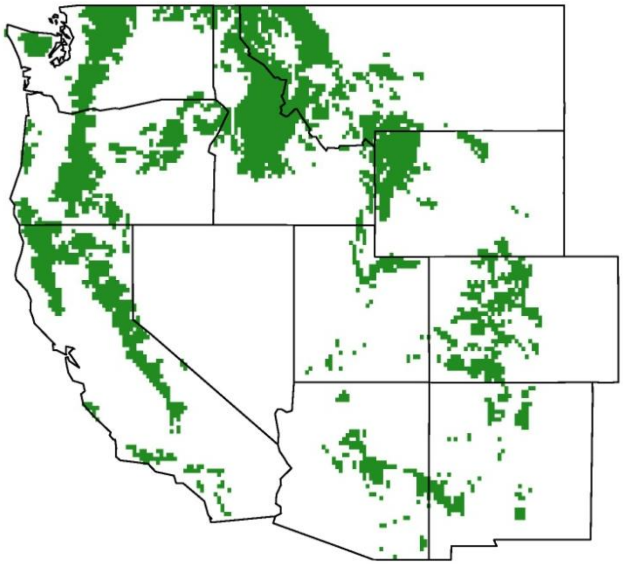
Hoerling & Eischeid 2007

Drought drives fire even today

Current summer Palmer Drought Severity Index is inversely correlated with acres burned, especially in the inter-mountain west (1980-2000) – so LOW PDSI leads to HIGH area burned.

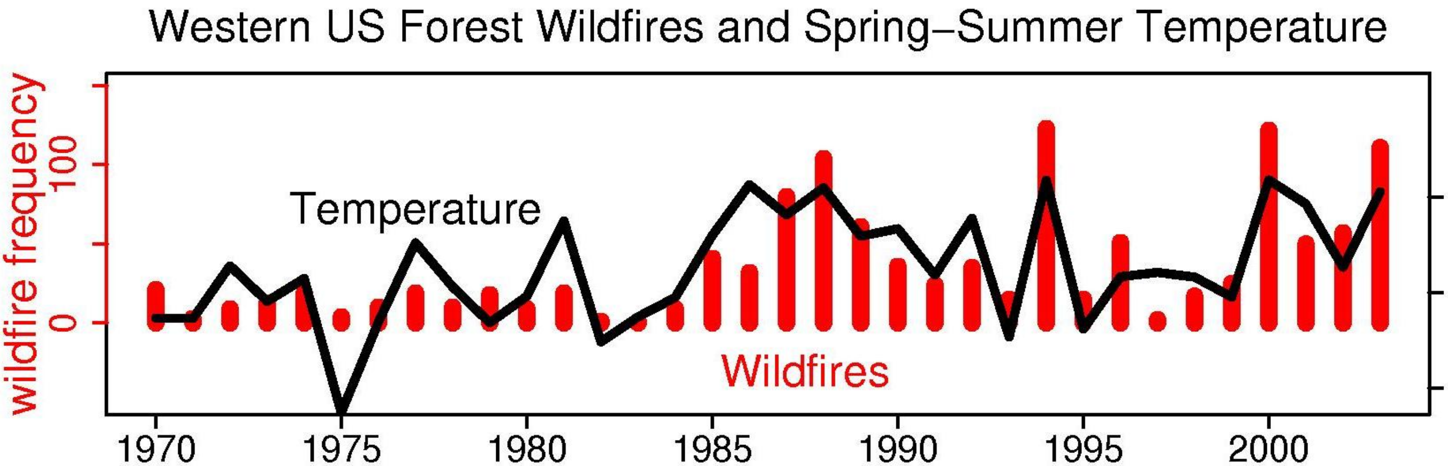


Westerling AL, Gershunov A, Cayan DR, and Barnett, TP. 2002. Long lead statistical forecasts of area burned in western US wildfires by ecosystem province. INT J WILDLAND FIRE 11 (3-4): 257-266.

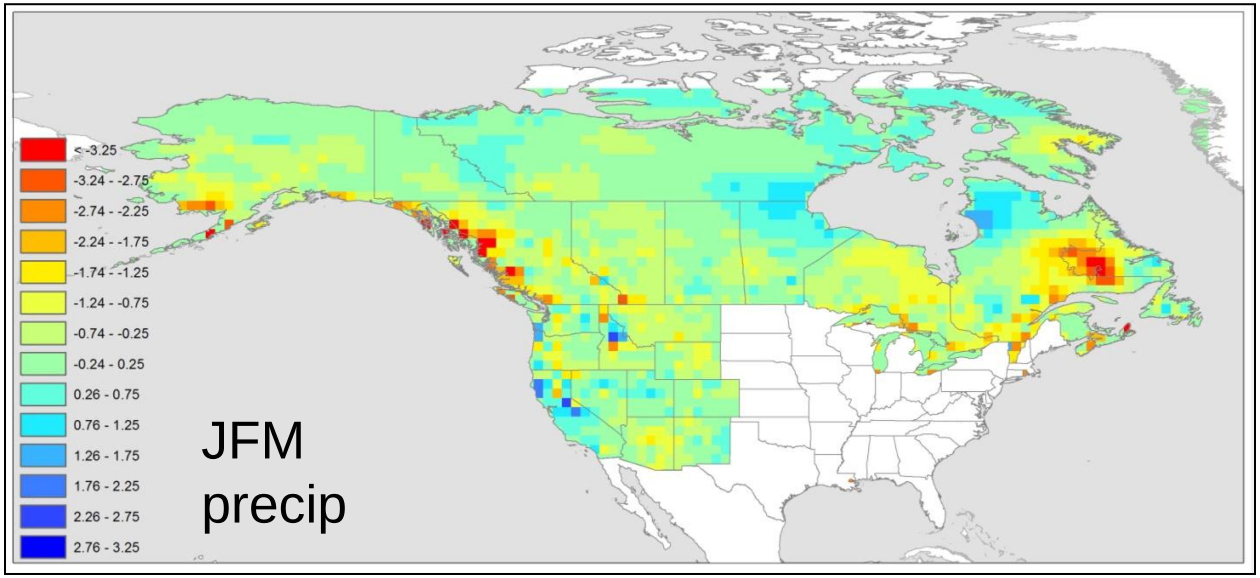


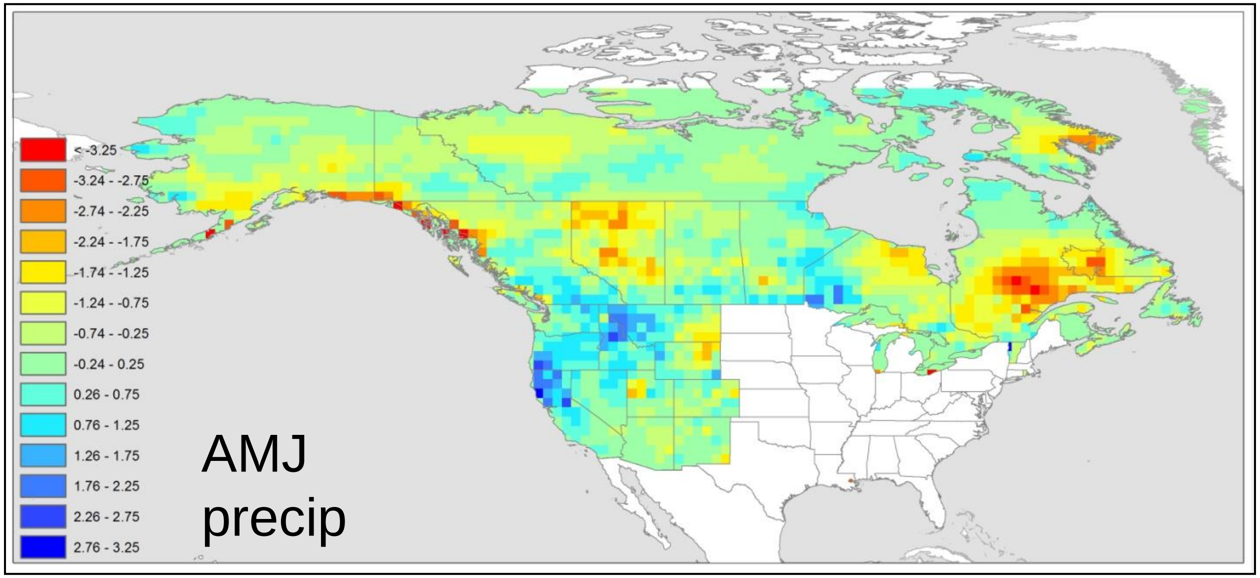
The year-to-year pattern and trend of large fires closely matches the pattern and trend of spring and summer temperature across the West.

Westerling, Hidalgo, Cayan & Swetnam 2006 Science

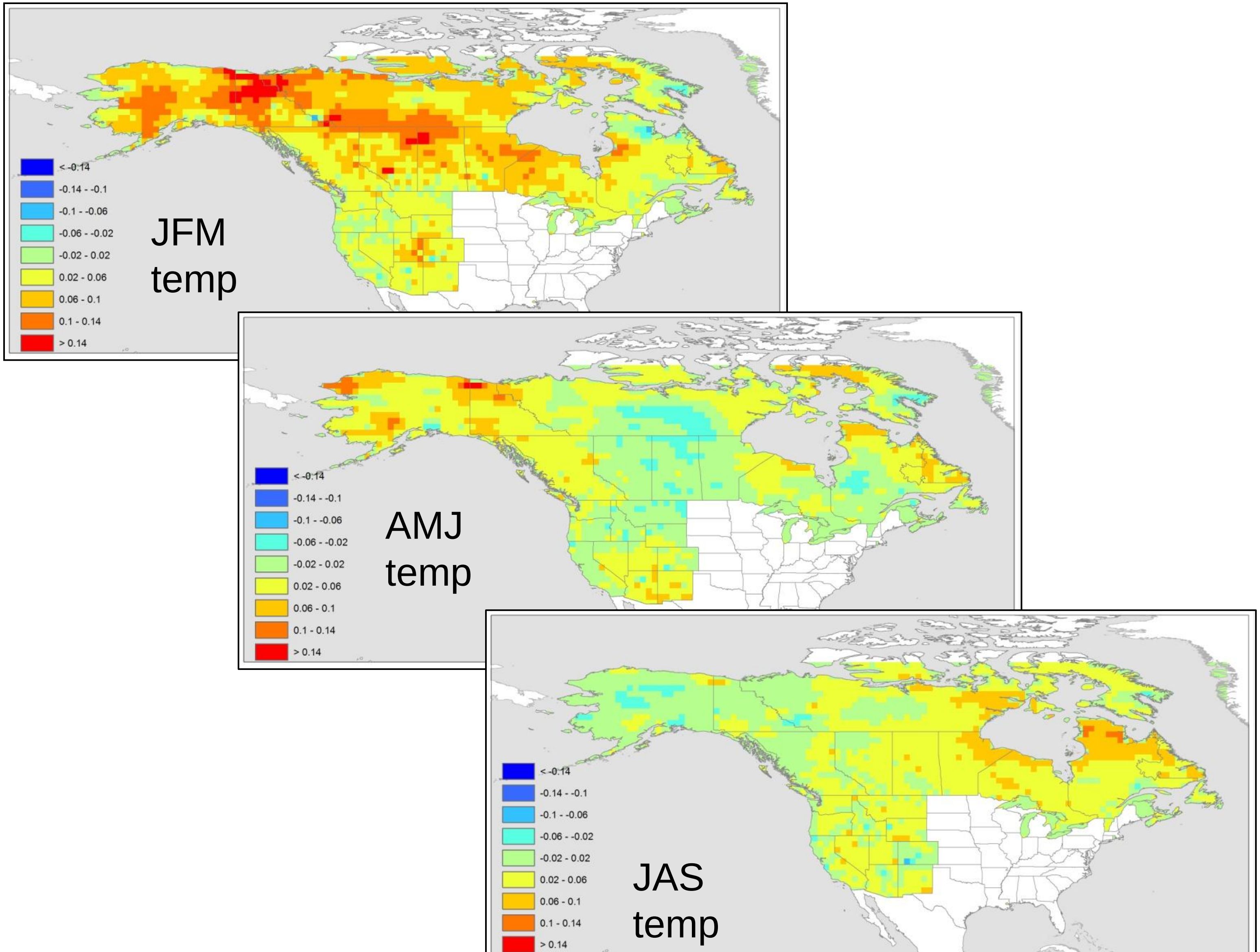


Trends in seasonal precipitation 1972-2004

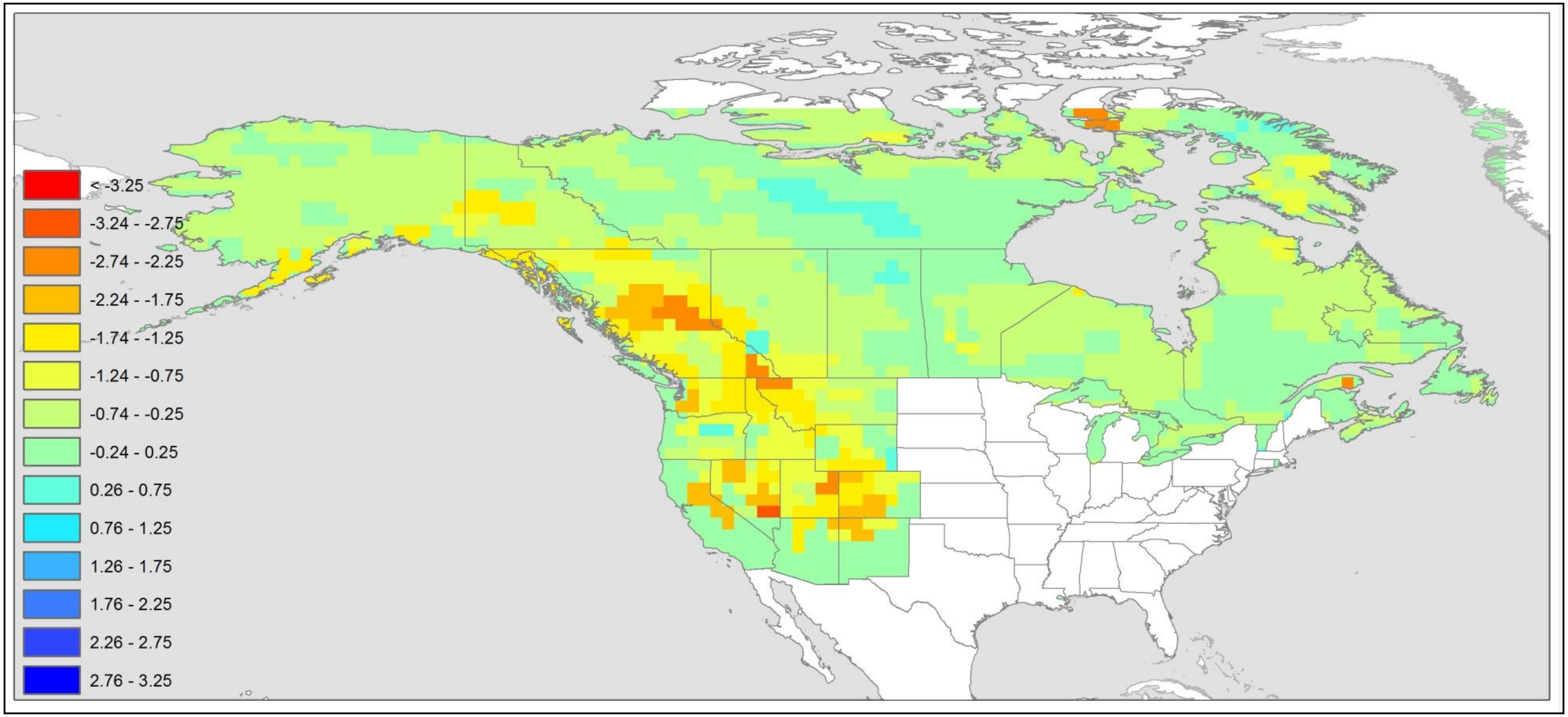




Trends in seasonal temperature 1972-2004

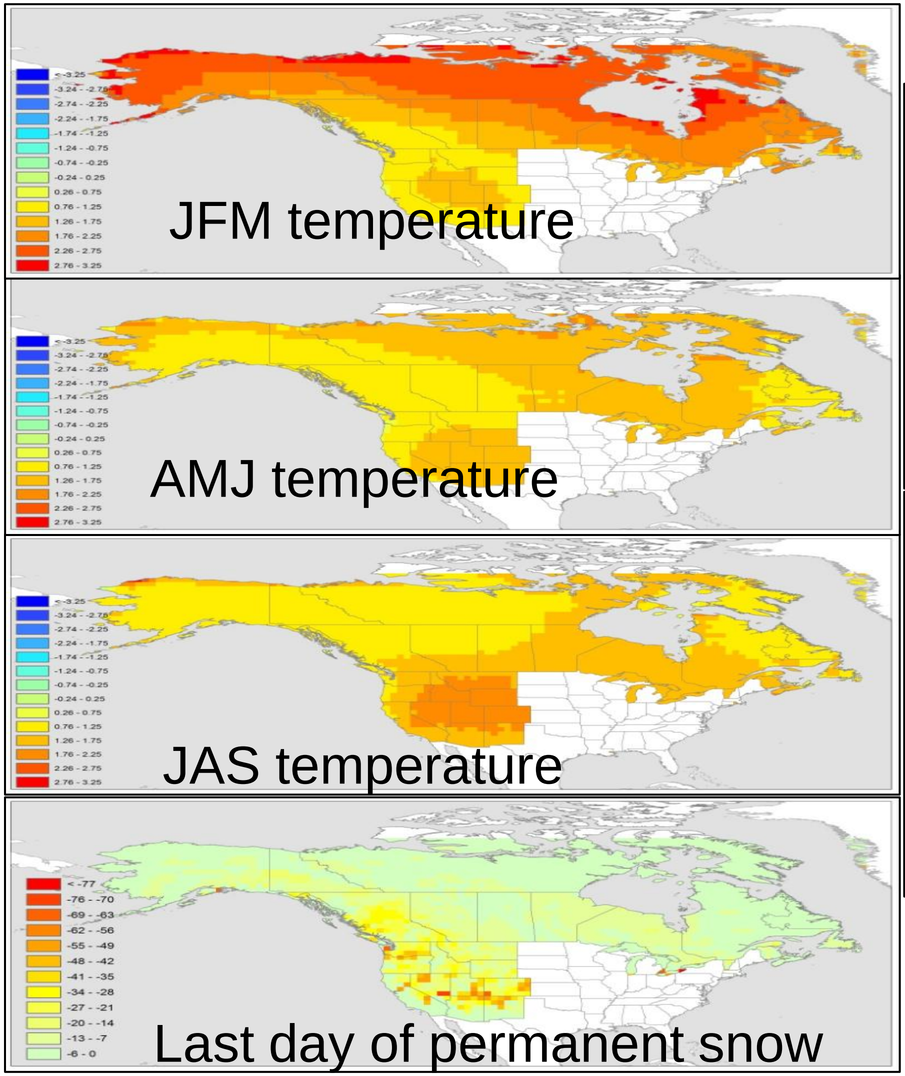


Trends in snowpack duration 1972-2004

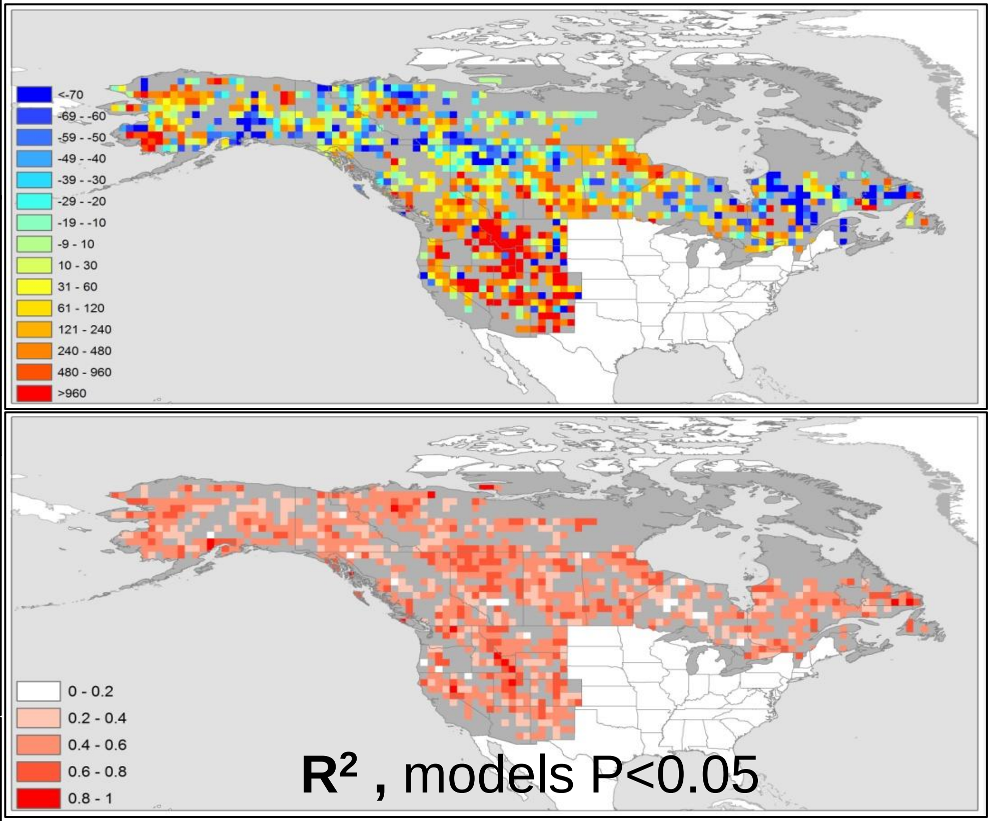


LDPS in days

Projected change in climate (2010-2039 *vs*. 1961-1990), A1B

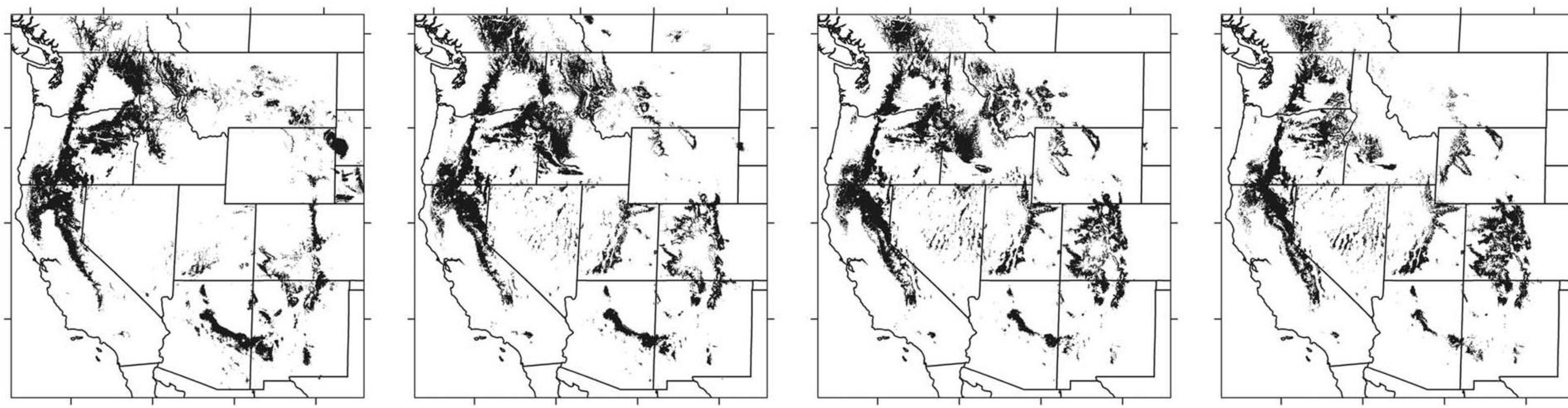


Projected percent change in annual area burned (2010-2039 *vs*. 1961-2004) A1B



Will range shifts for dominant species take fire regimes with them?

Pinus ponderosa



Now 2030 2060 2090

Overall prediction:

- PIPO abundance declines 13% by 2090
- 18% of 2090 distribution is in new areas not currently occupied
- 27 – 36% of current stands remain *in situ*
- *Most lost area is in southern limit of range*

(How) does fire interact with climate change?

CONTRIBUTES:

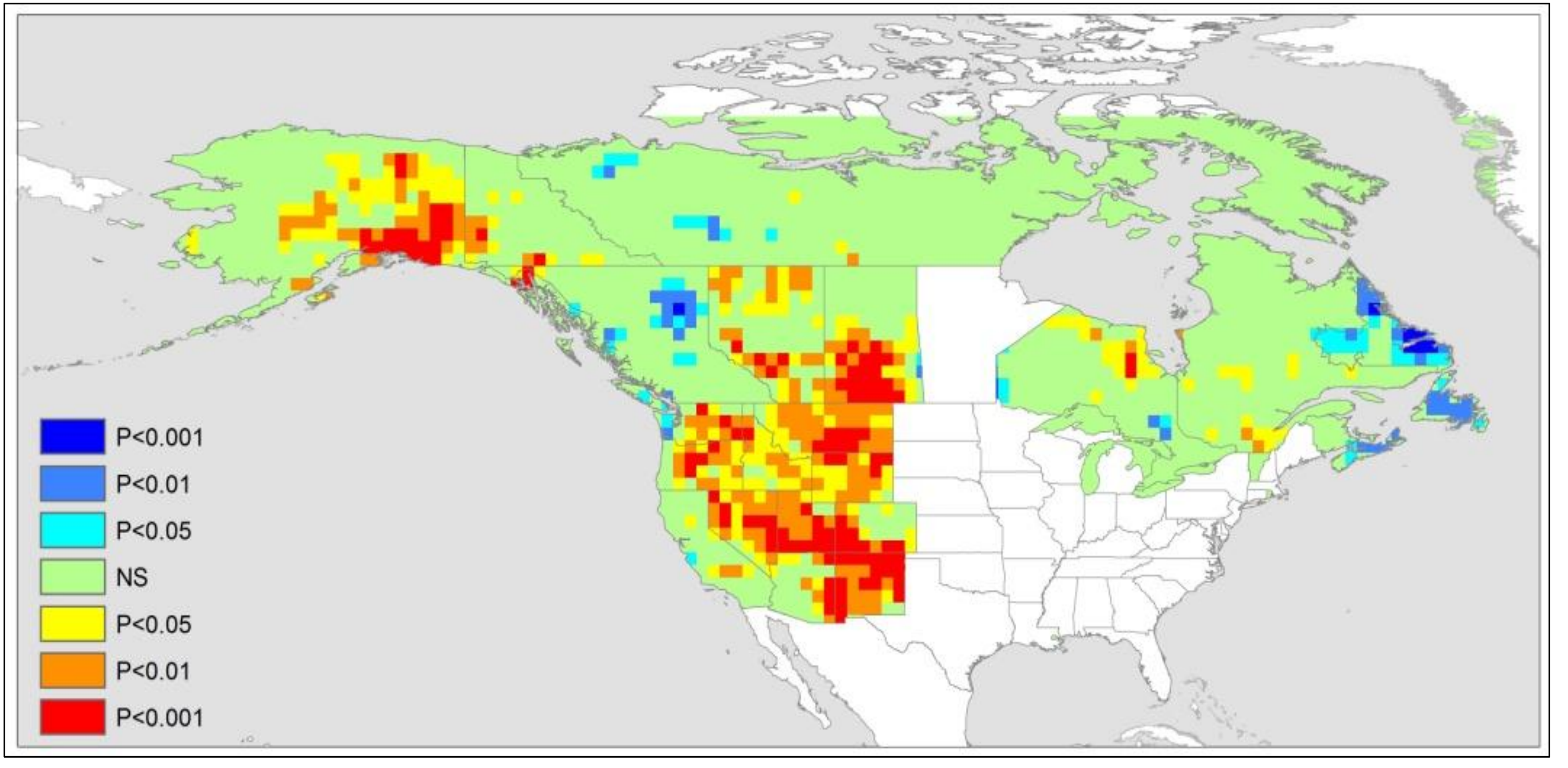
1. Source of CO_2, CH_4, and other GHG emissions to atmosphere
2. Reduces terrestrial carbon sink
3. Type conversions (e.g. forest to shrubland) lead to lower sequestration

MITIGATES:

1. Moderate fires prevent catastrophic large events, help retain biomass
2. Some emission components (particulates) reflect solar influx
3. Allow forests to regulate density and adapt to drier, warmer conditions

1. Last lecture **Monday Nov 26** (guest lecturer Travis Dotson, National Advanced Fire and Resource Institute)
2. Unit VI exam **Wednesday Nov 28** (short)
3. Exercise IV (Mann Gulch) due <u>in class</u> **Wednesday Nov 28**
4. Fire projects due **Friday Nov 30** <u>in class</u>
   1. Written template + electronic presentation file
   2. Looking for 5 volunteers to present that day
   3. I’ll need those presentations by Thursday **Nov 29**
5. Happy Thanksgiving!

Trend in annual area burned 1972-2004



Significance of trend, Mann-Kendall Test