Climate Change and Southwest Rangelands: Past, Present, and Future

Climate and Rangelands Workshop

January 25, 2006
San Carlos, Arizona

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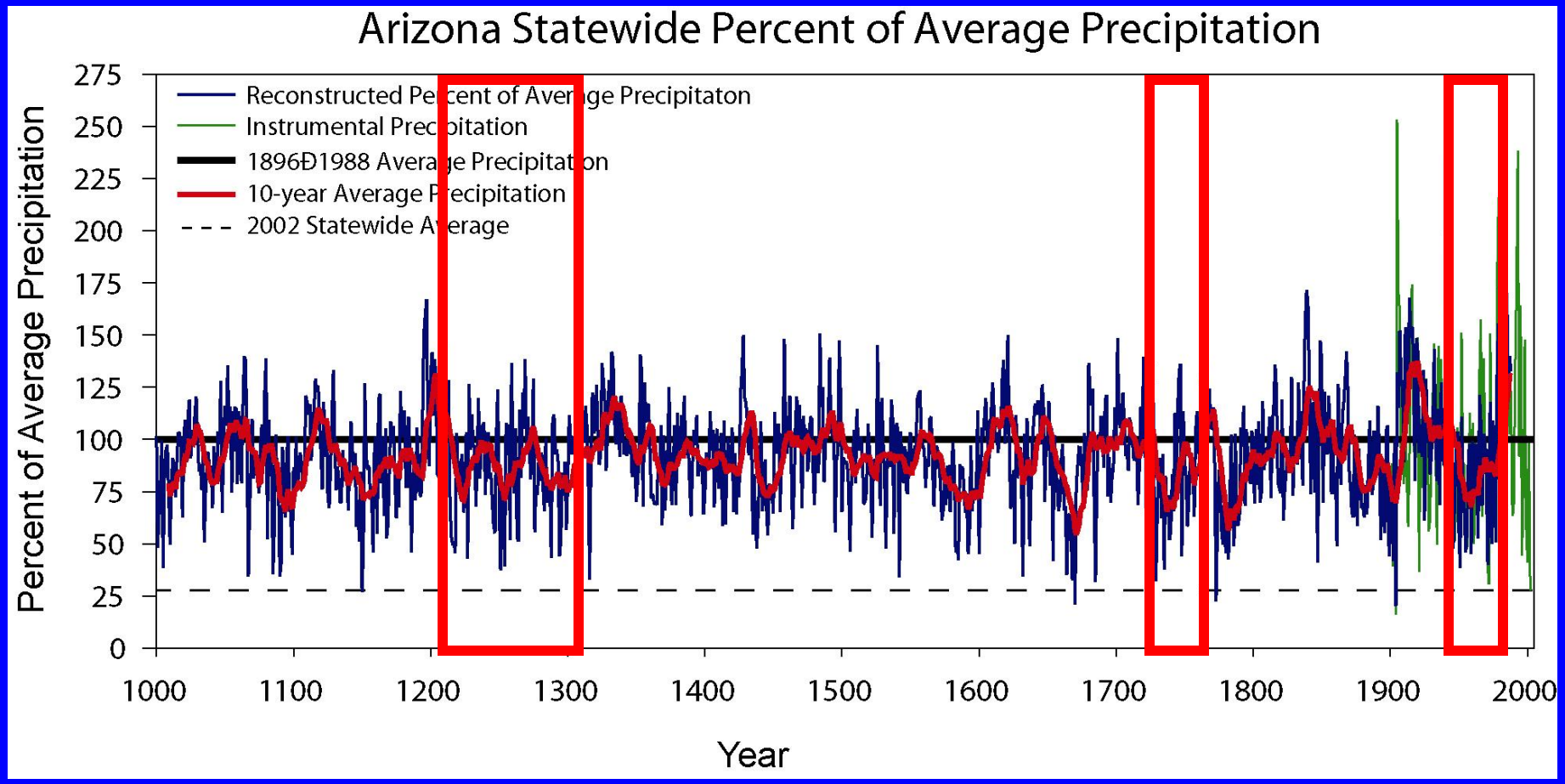
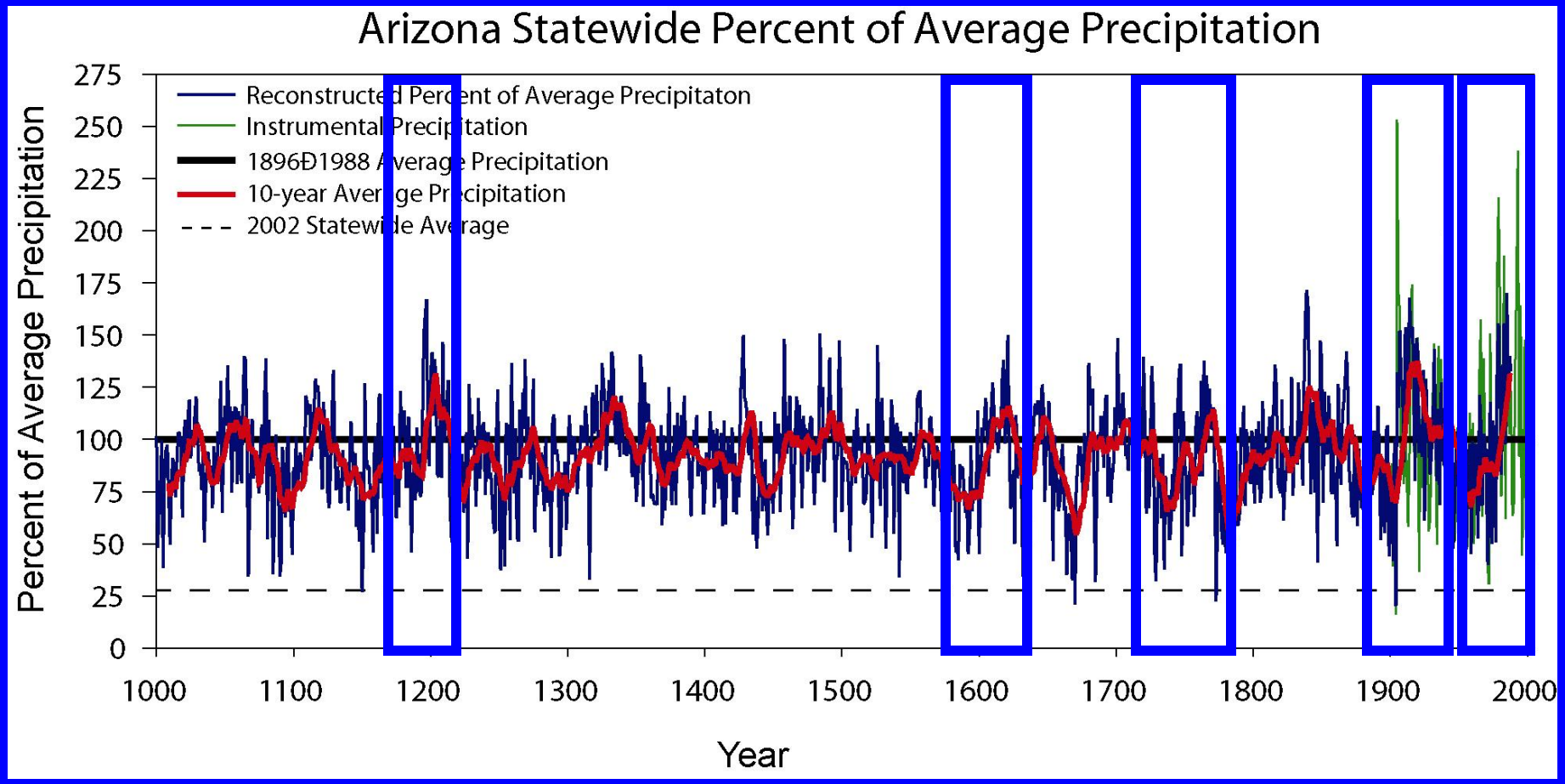
CLIMAS: Climate Assessment for the Southwest
Institute for the Study of Planet Earth, University of Arizona

Arizona Drought



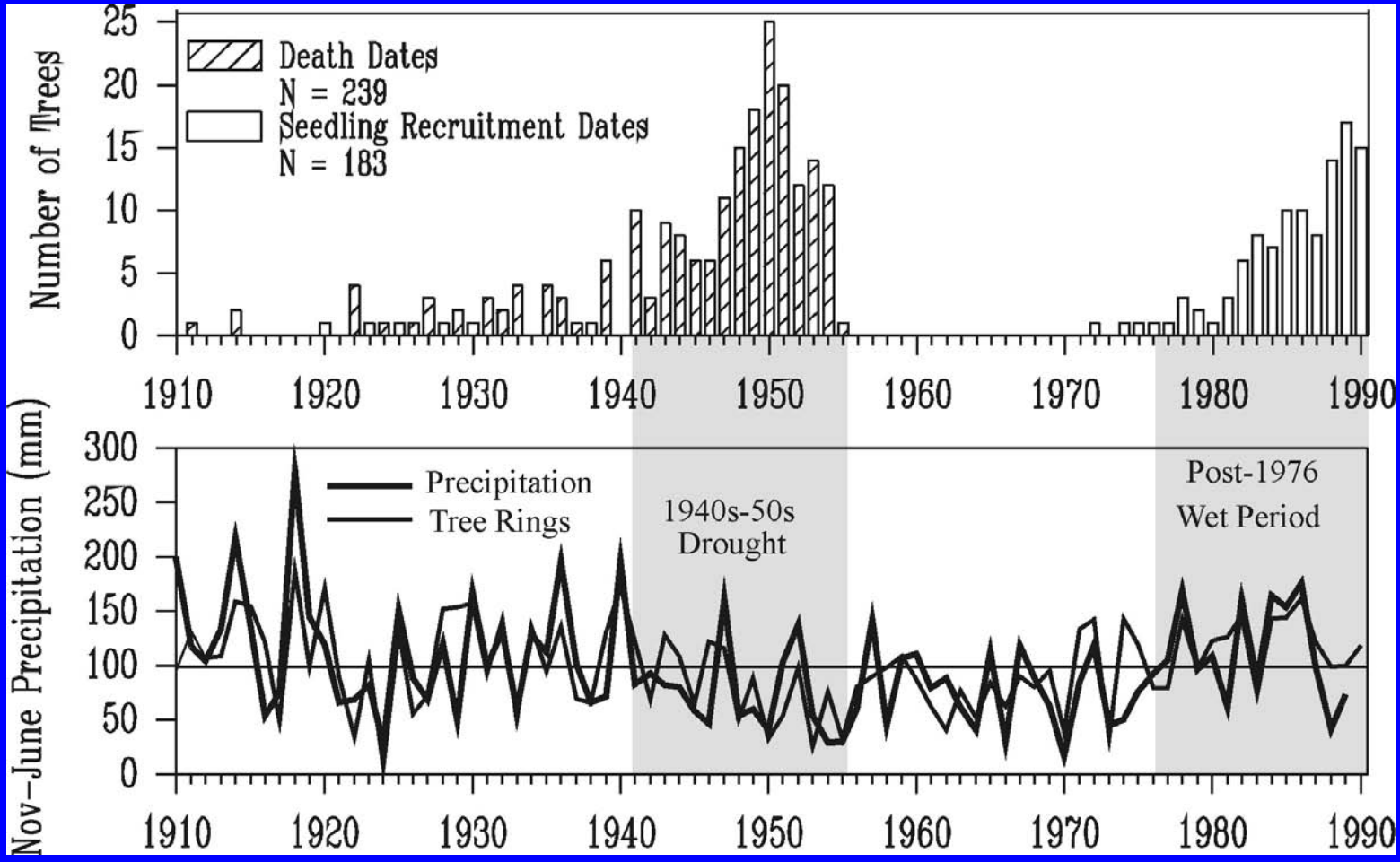
Data: CLIMAS/University of Arizona Laboratory of Tree-Ring Research

Arizona Wet Periods



Data: CLIMAS/University of Arizona Laboratory of Tree-Ring Research

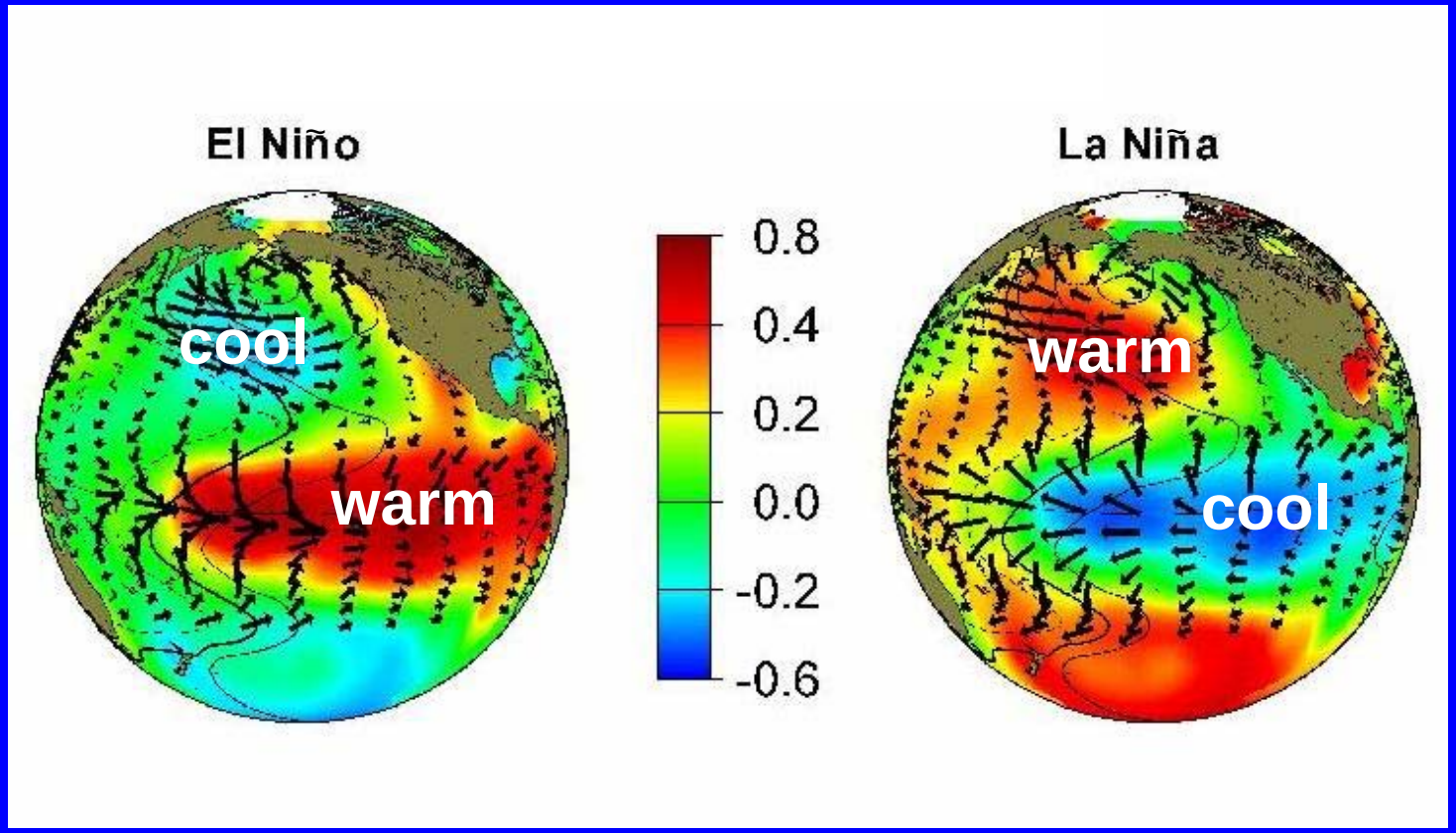
1950s New Mexico Tree Mortality Resetting the Ecosystem Clock



Courtesy of Tom Swetnam (University of Arizona) and Julio Betancourt (USGS)

Climate Variations

El Niño-Southern Oscillation (ENSO)

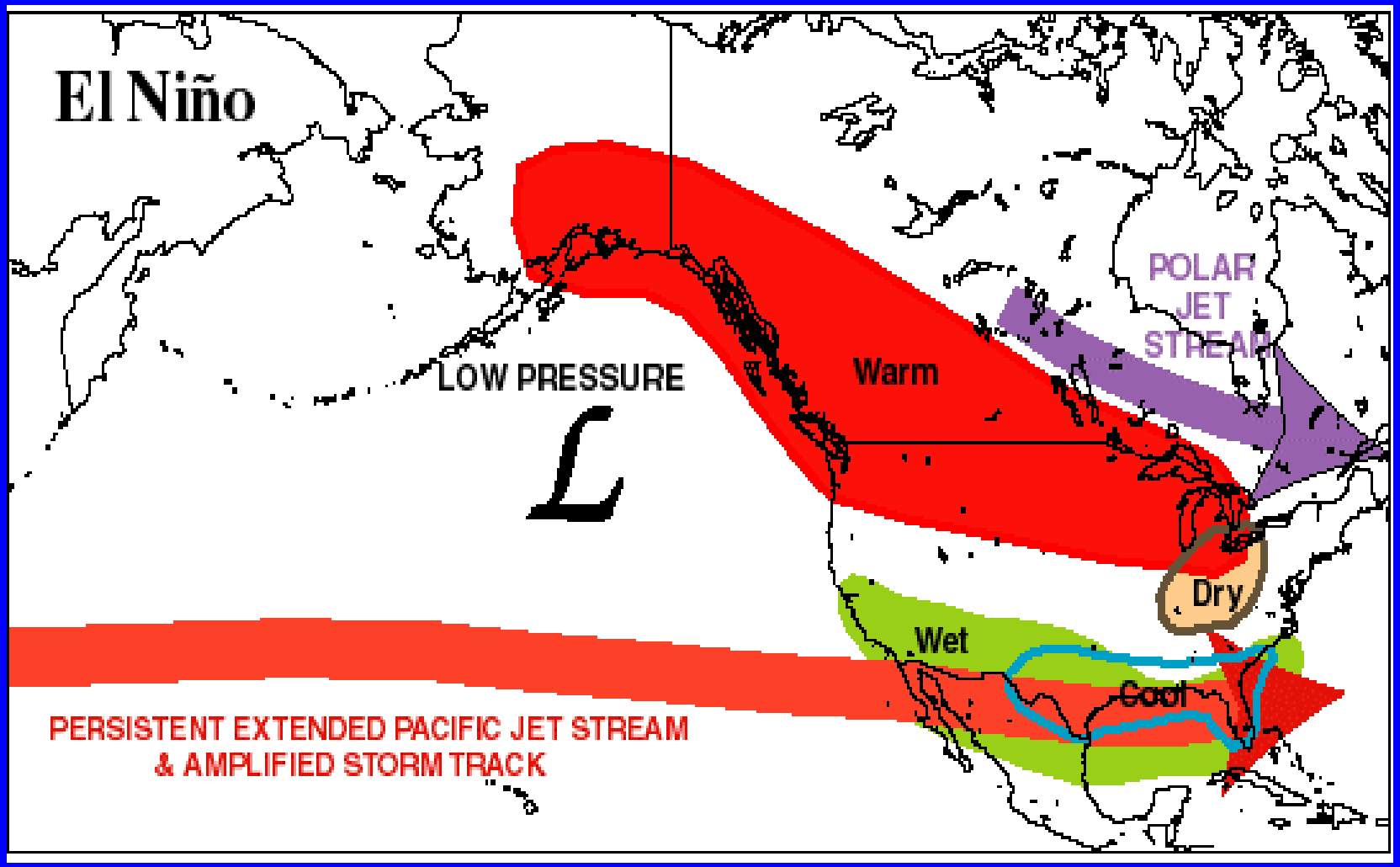


- Persistent changes
- Duration 1-3 years
- Occur every 2-7 years

Slide courtesy of Greg McCabe, USGS

El Niño: Winter Effects U.S.

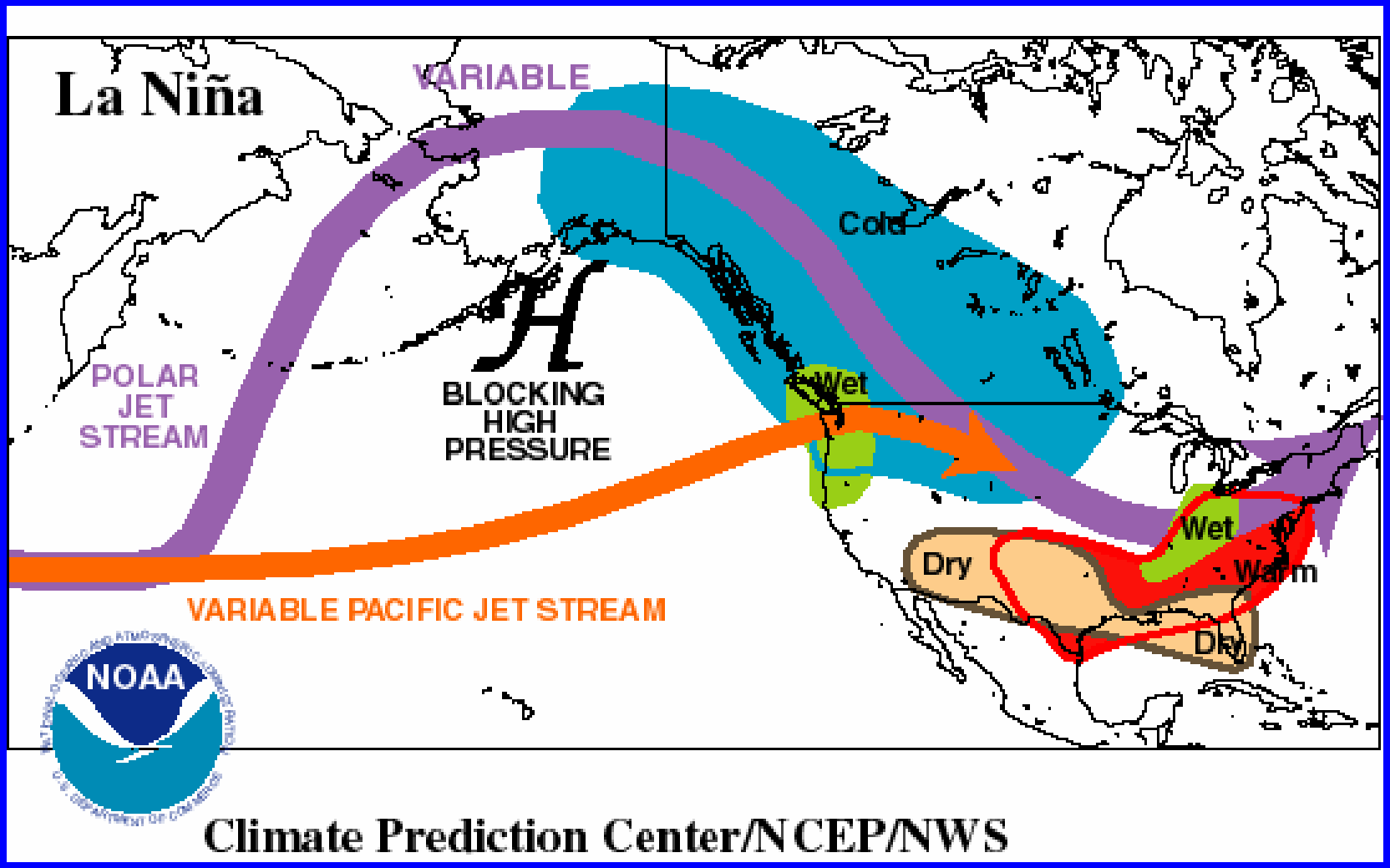
- **Increased groundwater, less pumpage**



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

La Niña: Winter Effects U.S.

- **Drought circulation pattern**

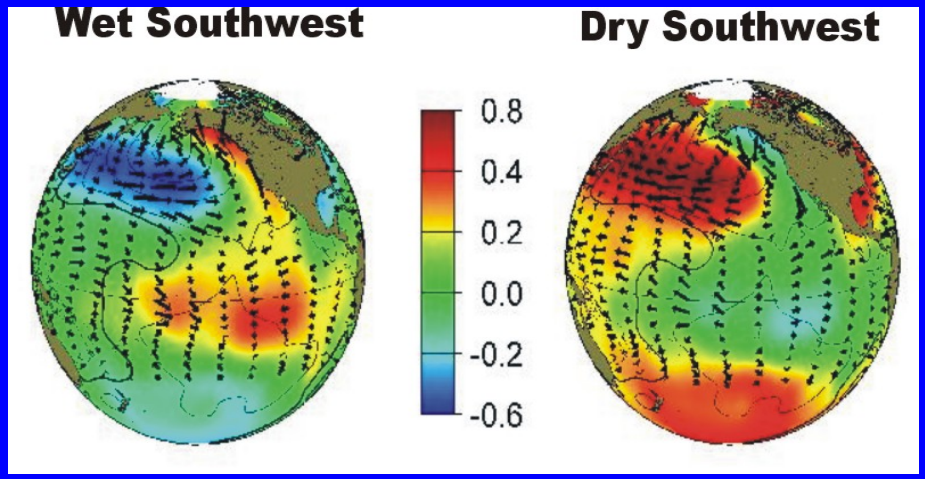


Source: NOAA Climate Prediction Center
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/winter25%25.gif

Decadal Variations

Pacific Decadal Oscillation (PDO)

- **Discovered in 1990s**
- **20-30 year changes**
- **Likely Mechanisms:**
  - ENSO
  - Kuroshio Current
  - Aleutian Low



Courtesy of N. Mantua – University of Washington
Mantua et al., 1997 *Bulletin of the American Meteorological Society*

Pacific Decadal Oscillation (PDO)

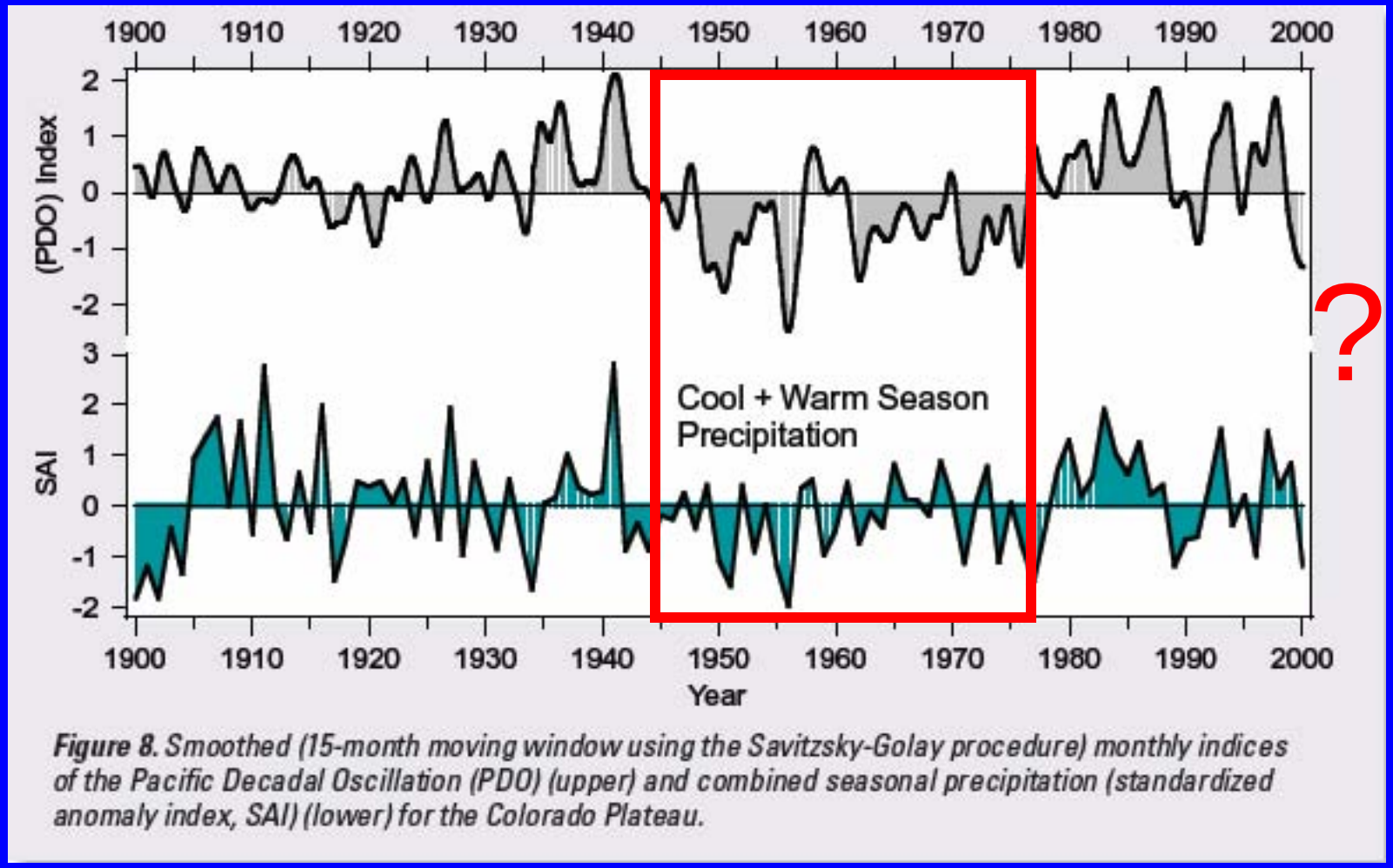
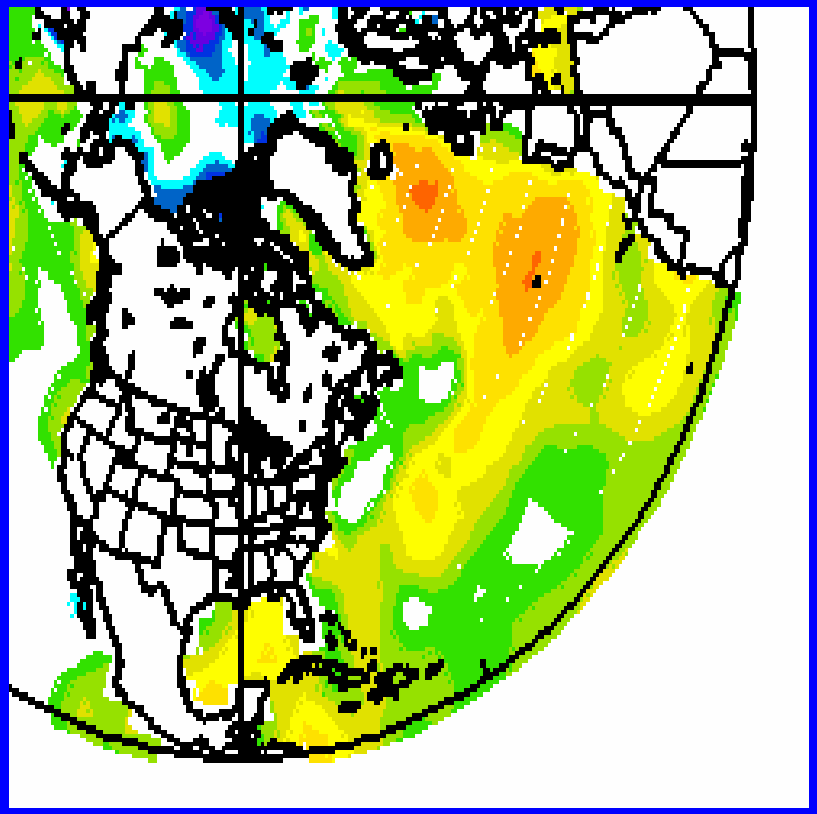


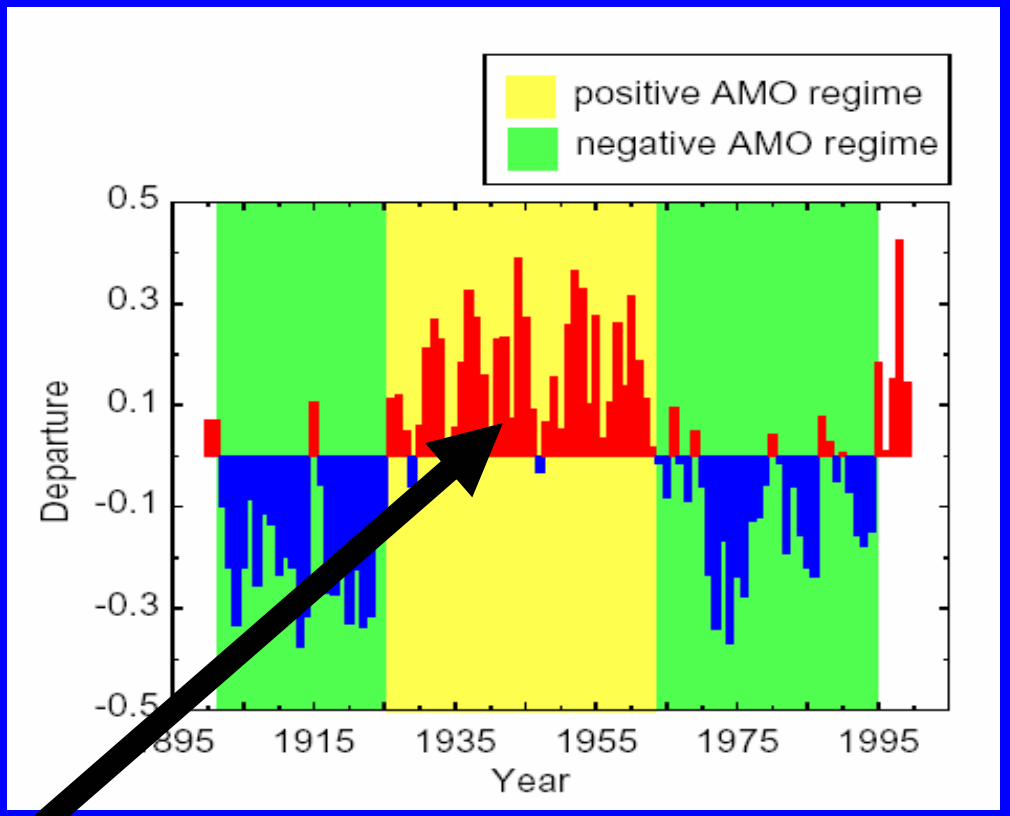
Figure 8. *Smoothed (15-month moving window using the Savitzsky-Golay procedure) monthly indices of the Pacific Decadal Oscillation (PDO) (upper) and combined seasonal precipitation (standardized anomaly index, SAI) (lower) for the Colorado Plateau.*

Hereford and Webb (2002), USGS

Atlantic Multidecadal Oscillation - AMO

Positive AMO Phase





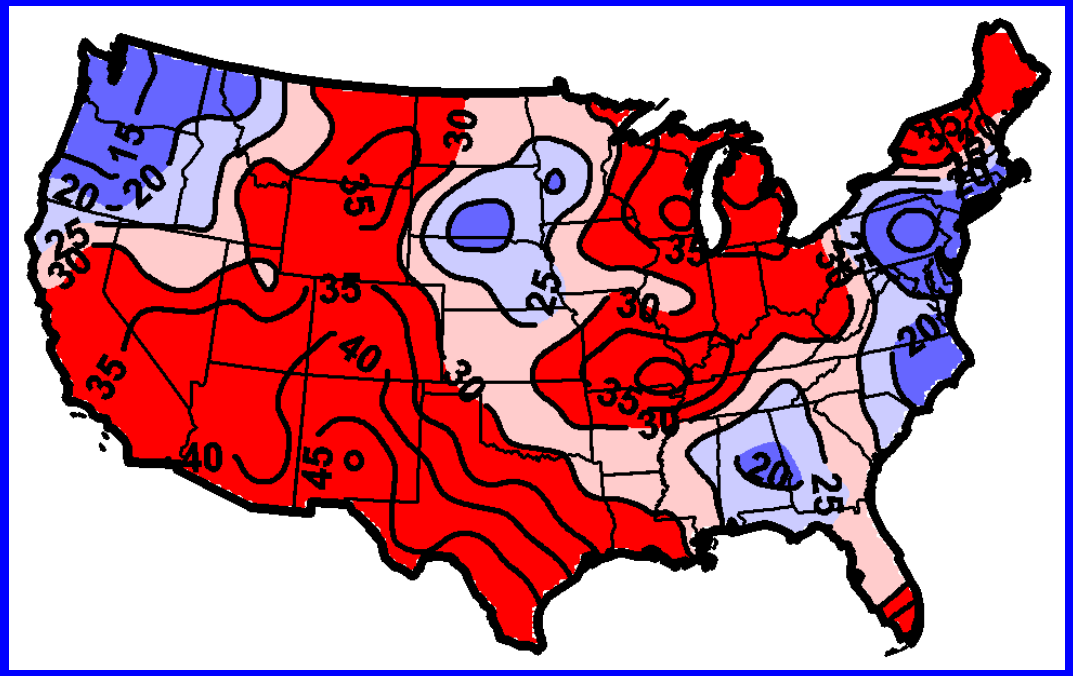
- West: Warm, dry, high pressure
- Associated with 1950s and late-1500s droughts

Slide courtesy of Greg McCabe, USGS

USGS science for a changing world

PDO (neg.) AMO (pos.) Combination

Drought Frequency % (25 = expected)



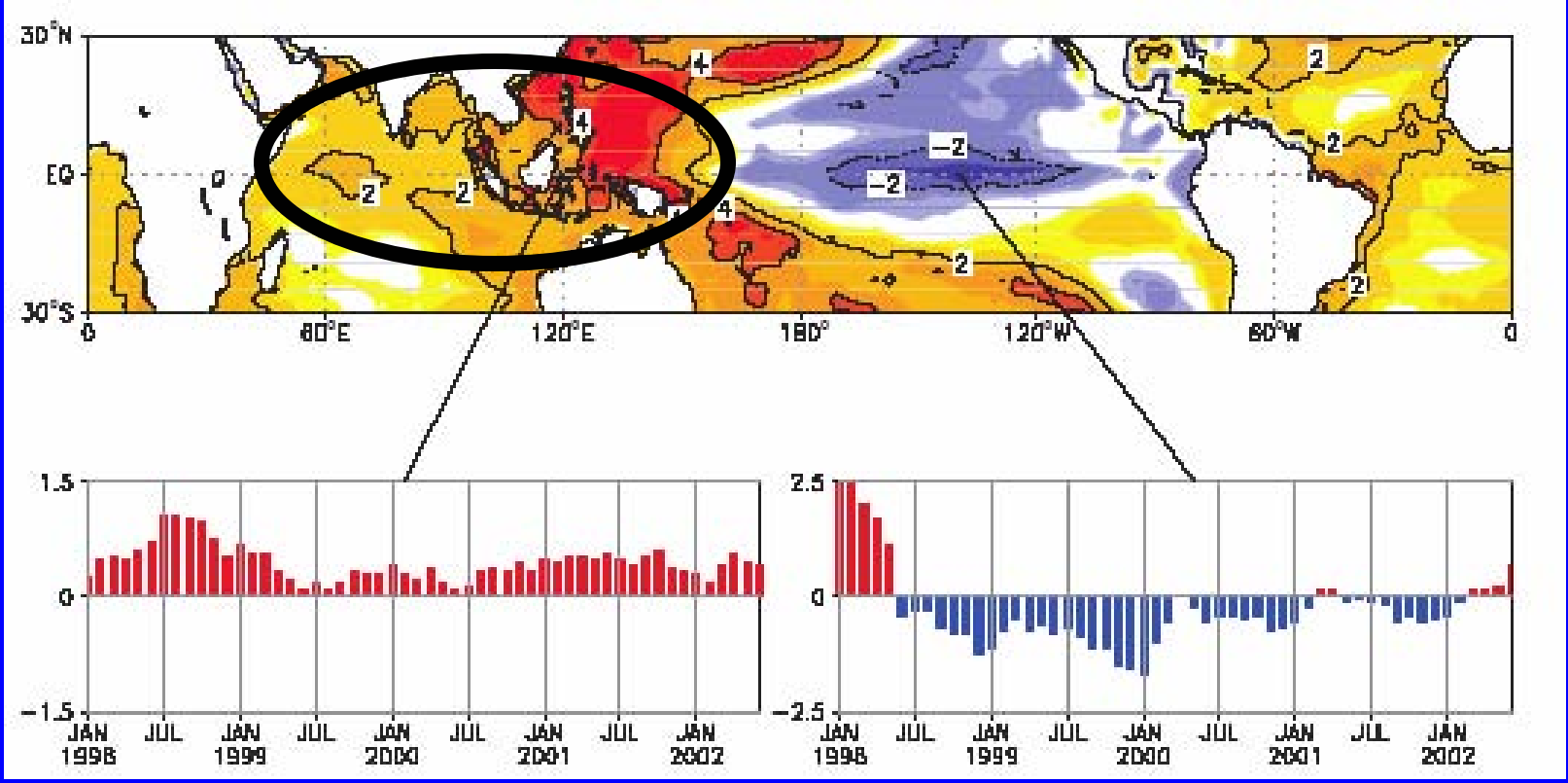
high drought frequency

low drought frequency

McCabe et al., 2004 Proceedings of the National Academy of Sciences

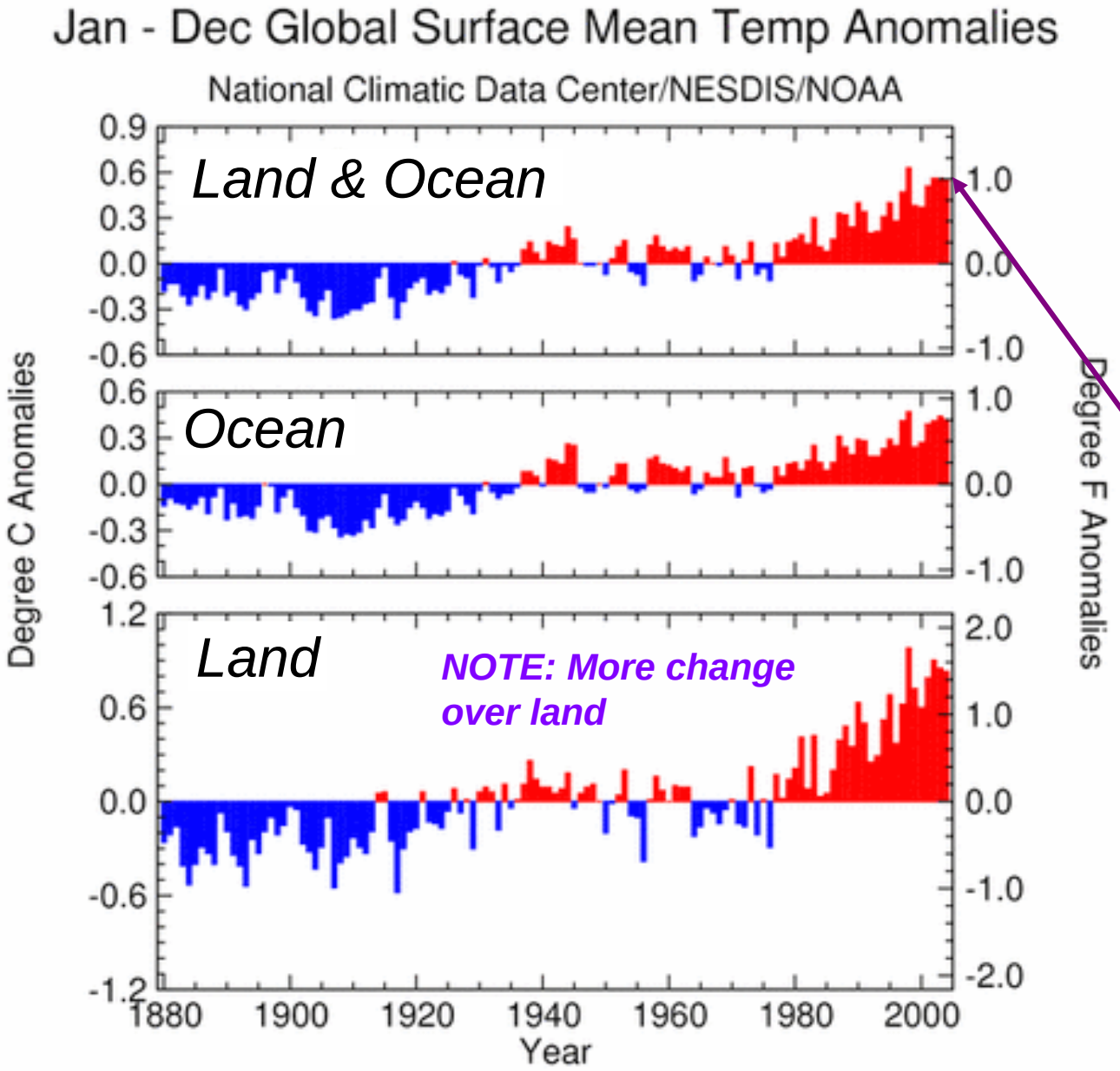
The Perfect Ocean for Drought

Martin Hoerling[1]* and Arun Kumar[2]



Science (2003)

Observed Climate Change: Global and Hemispheric to the Southwest



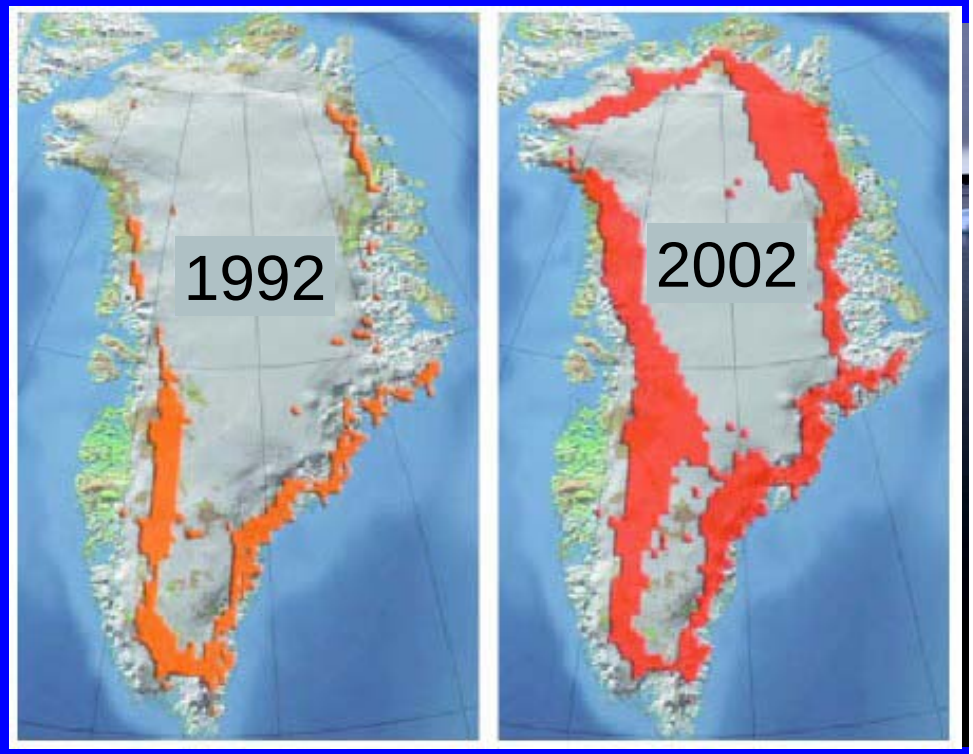
2004 = 4th warmest on record

8 of top 10 warmest years have occurred in the last decade!

Courtesy of Jonathan Overpeck, UA-ISPE

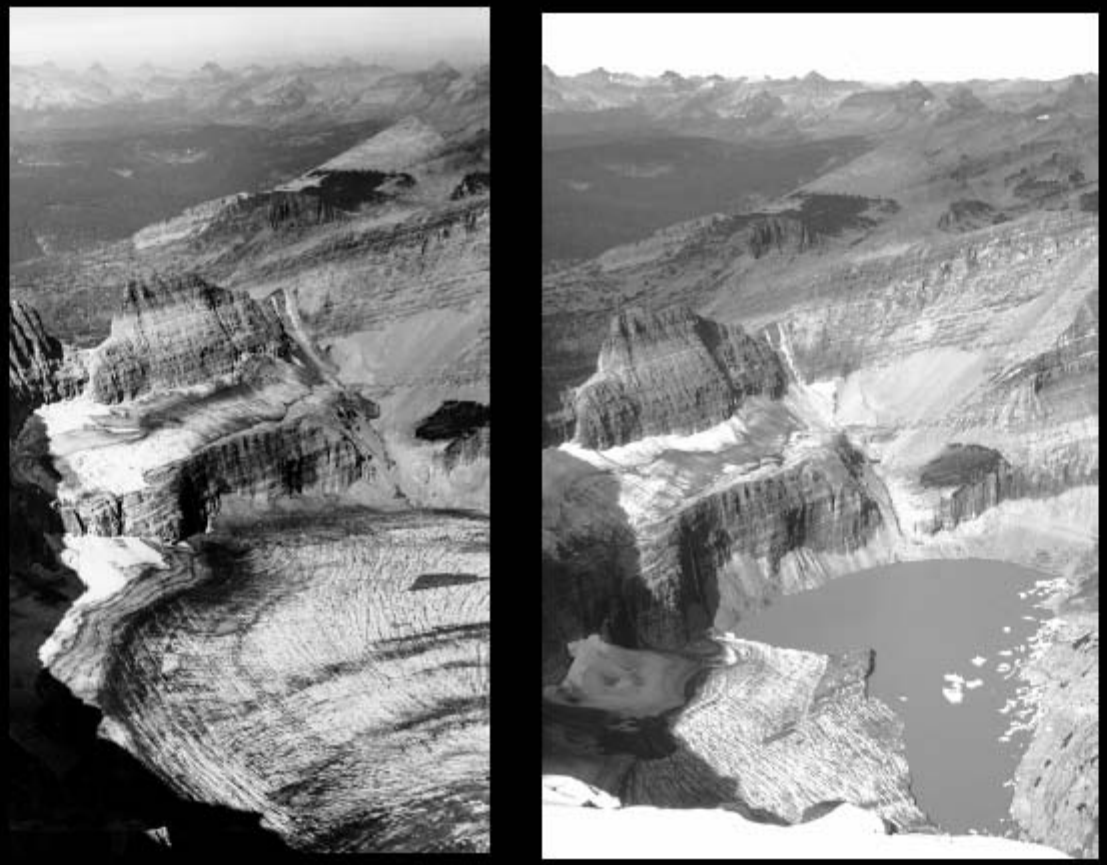
Climate Warming in the Arctic: Significant and Accelerating

- **Warming greatest on planet**
- **Arctic Sea Ice Pack:** *thinned by 40% in last 50 years*
- **Greenland Ice Sheet:** *ditto, 16% increase in melt area between 1979 and 2002*



Arctic Impacts of Arctic Warming, Cambridge Press, 2004

Grinnell Glacier
Glacier National Park, 1938 - 1998

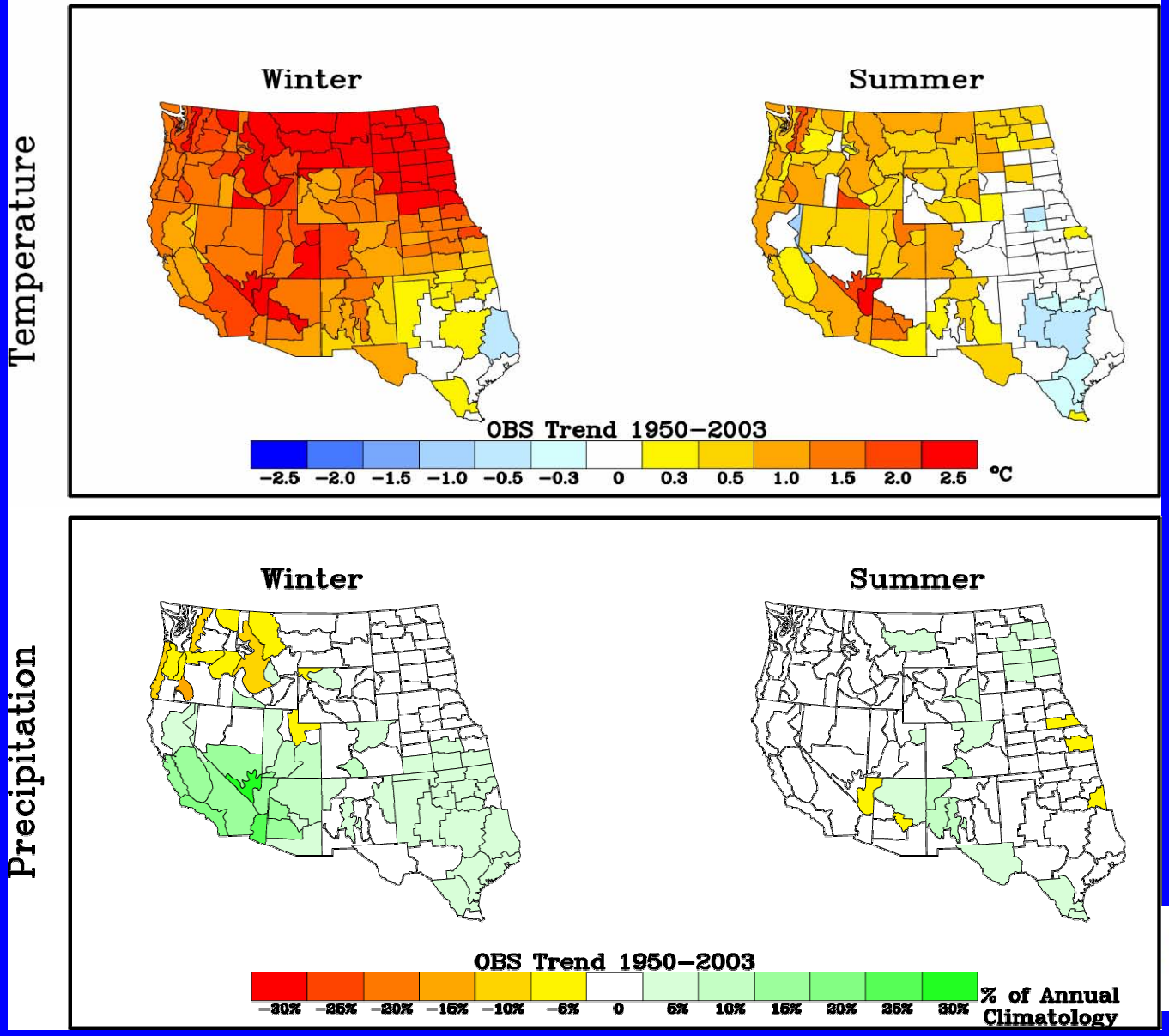


1938 T.J. Hileman

1998 D. Fagre

Courtesy of Andrew Fountain, 2004 MTNCLIM Conference

Western U.S. Mostly Warmer and Wetter Since 1950

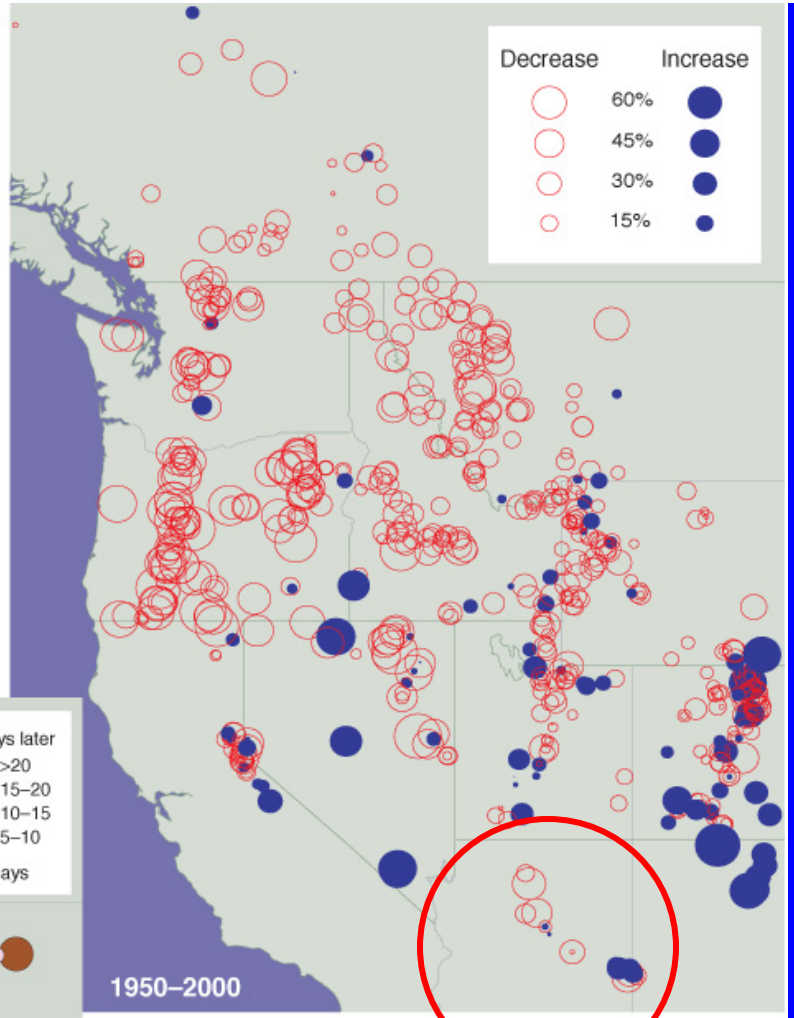


Courtesy of M. Hoerling & J. Eischeid unpublished

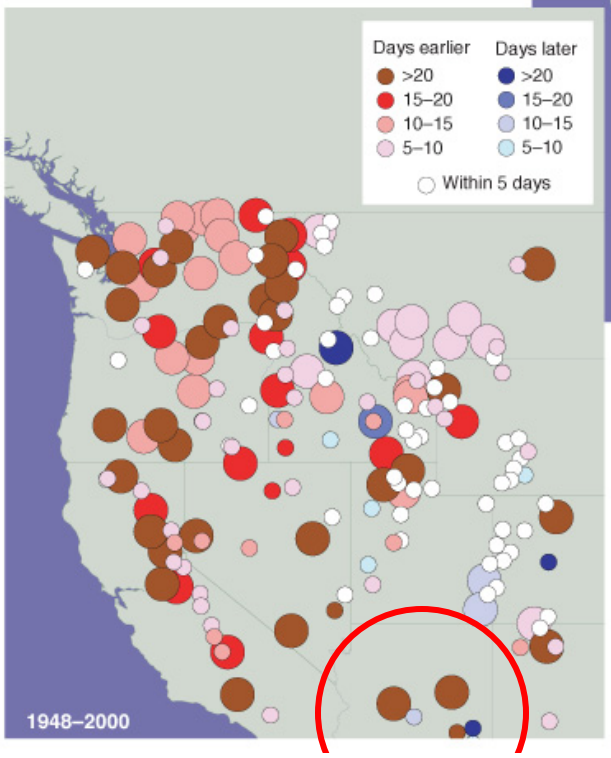
Climate Diagnostics Center

Observed Changes in Snowpack Depth and Snowmelt Timing (1950 to 2000)

Change in spring snowpack depth



Change in timing of peak spring snowmelt

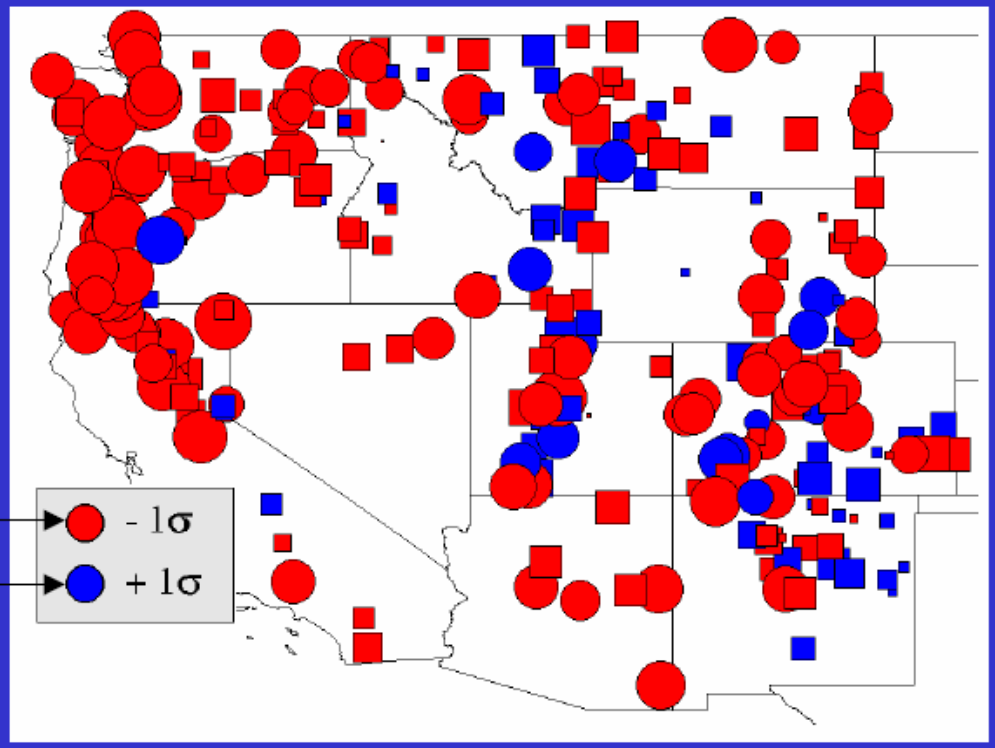


Major reductions/ retreats in most of Arizona

From: Service, 2004; adapted from Mote, Hamlet and Clark, 2004

2. Trends in Nov-Mar Snowfall Fraction

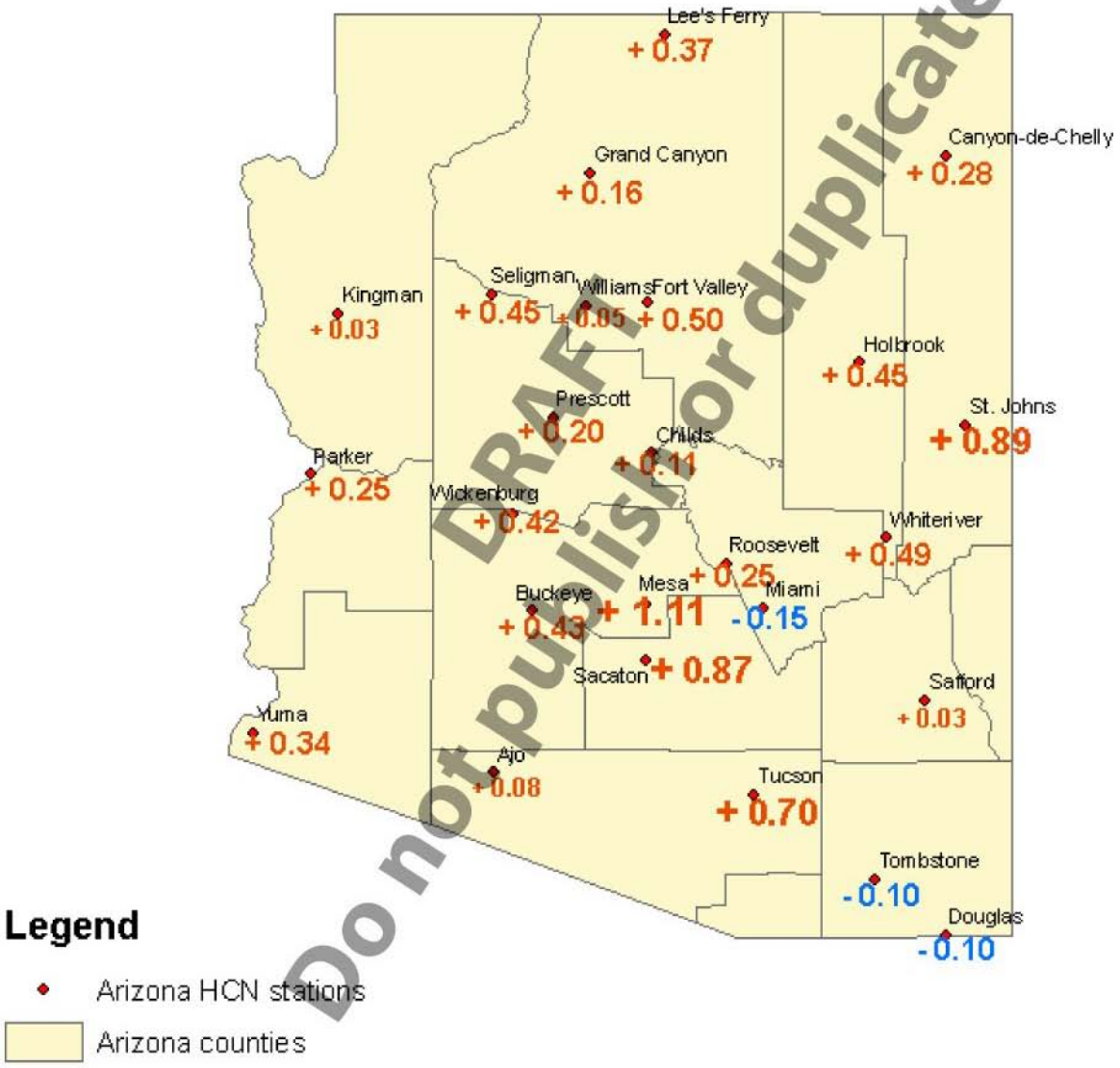
Shift from Snowfall to Rainfall



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.

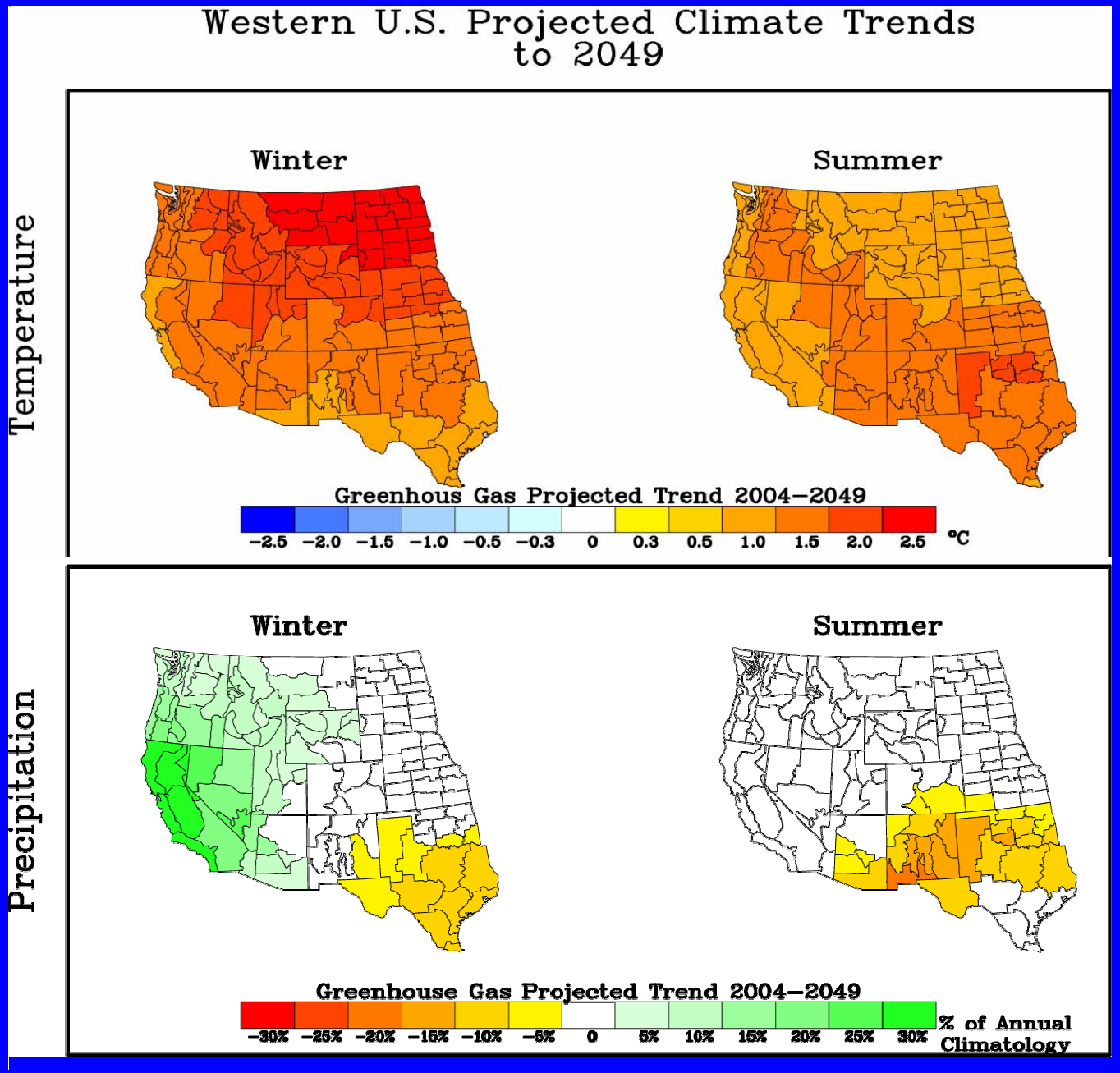
Courtesy of Noah Knowles, USGS

Winter (DJF) MIN T Trends 1931-2002



Courtesy of Casey Thornbrugh, CLIMAS

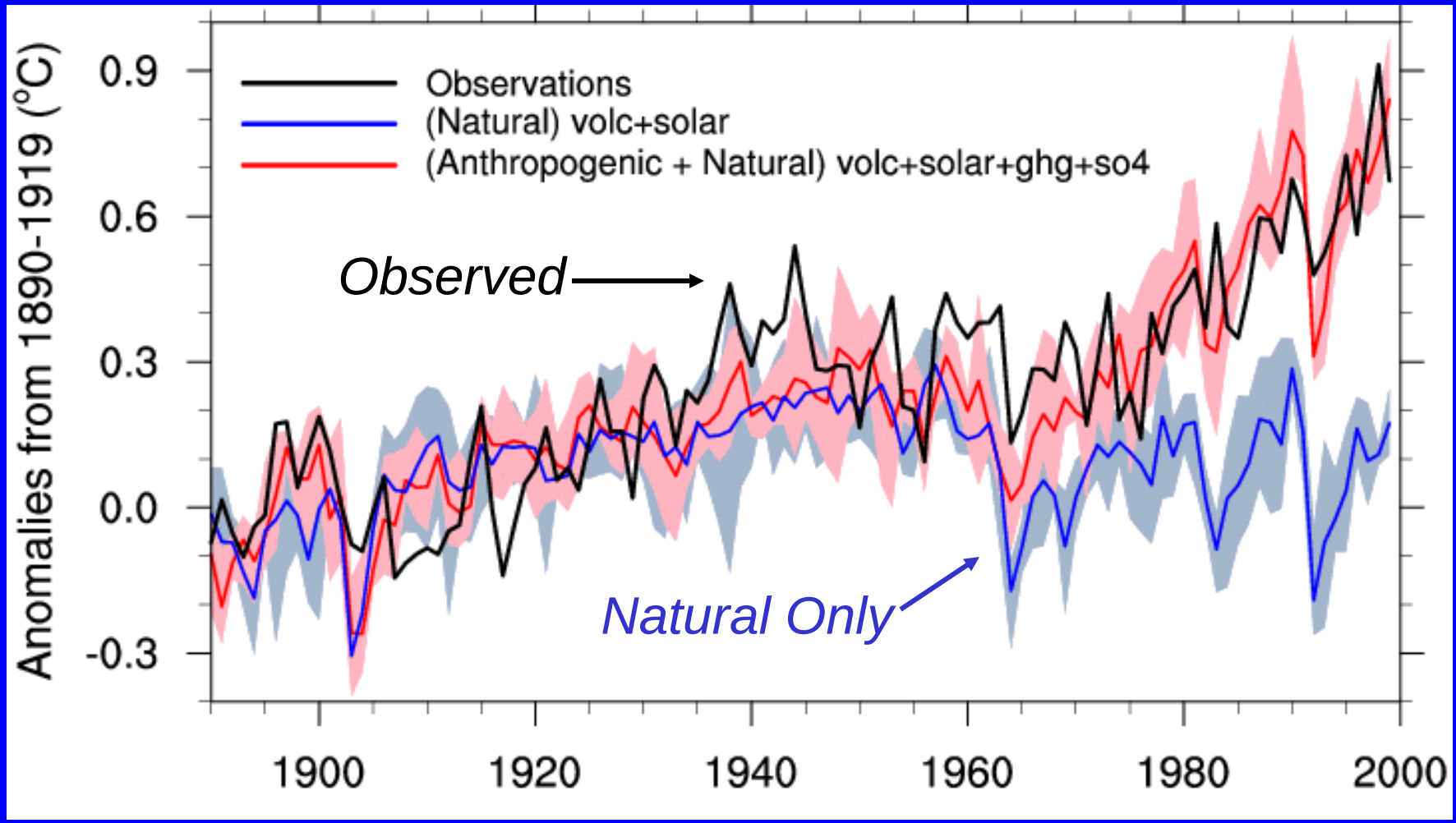
Climate Change Projections for the Western U.S.



Hoerling and Eischeid, NOAA Climate Diagnostics Center

PCM - 20th Century Experiments

Forcings: Combined Natural-Anthropogenic and Natural Only

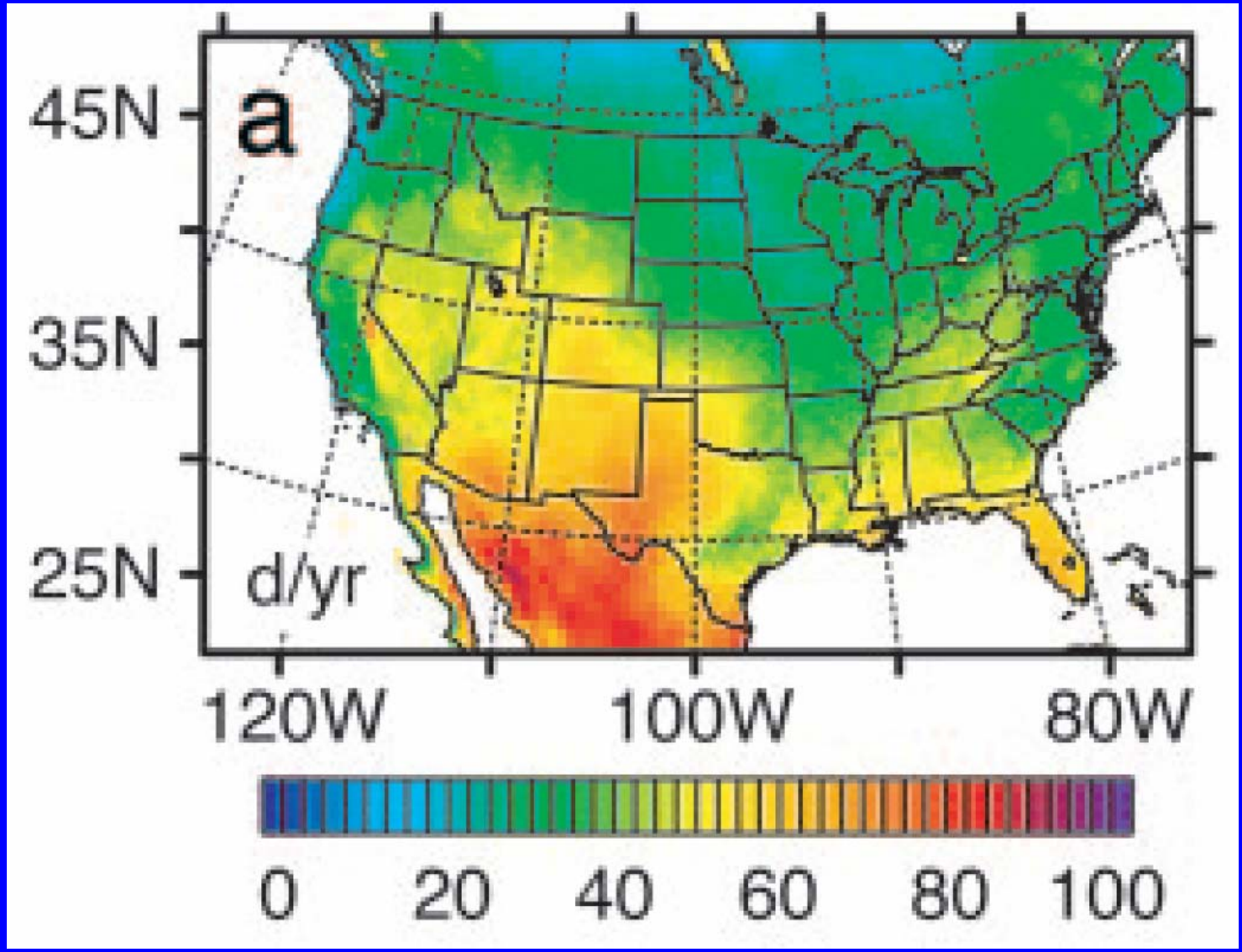


Meehl et al. (2004)

Climate Change: Extreme Events

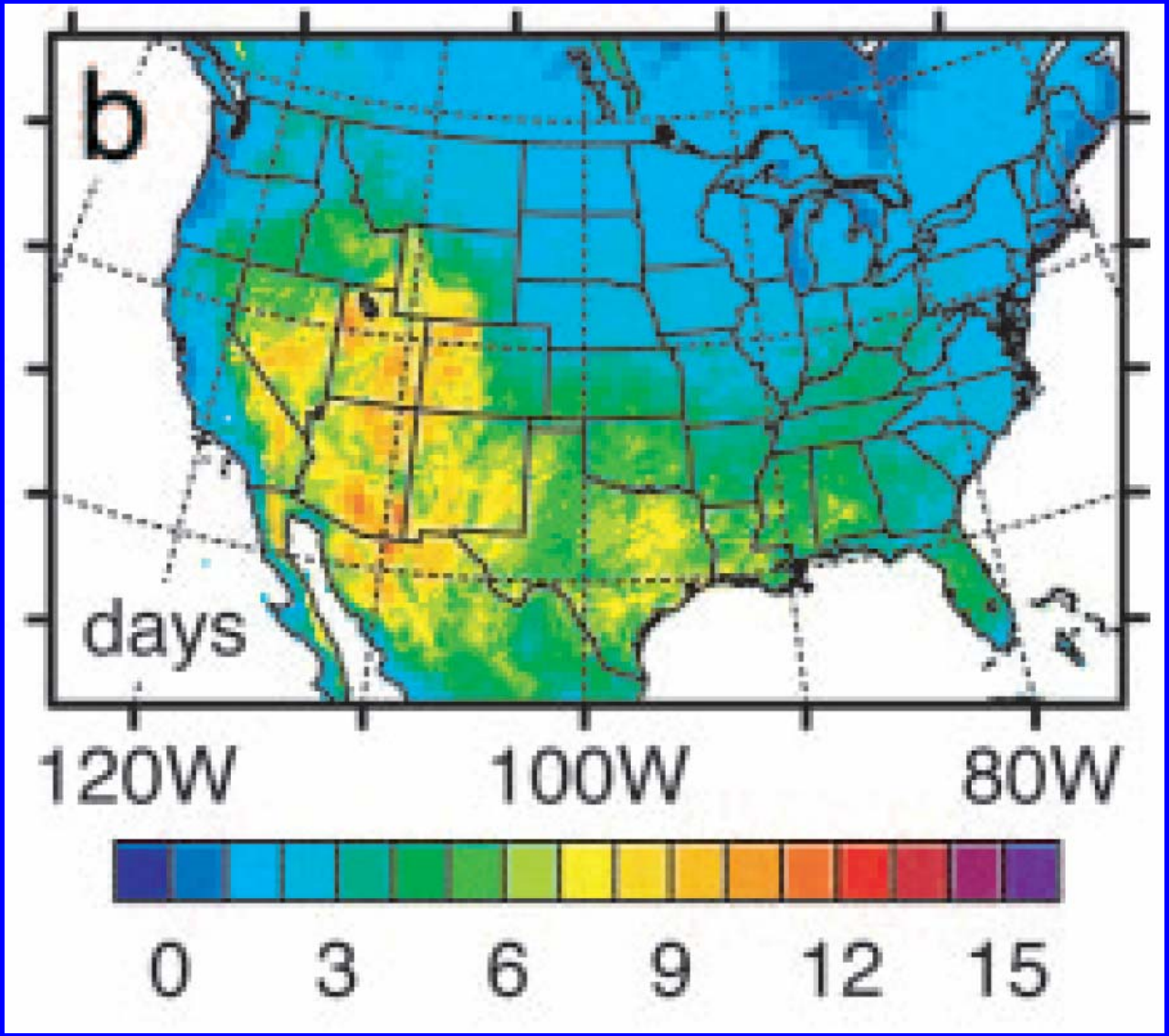
- 2071-2095 vs. 1961-1985 (RF)
- Extremes: top or bottom 5% of RF
  - Heat waves
- Dry days: less than 1 mm/day

Diffenbaugh et al., 2005
Proceedings of the National Academy of Science



More Heat Events

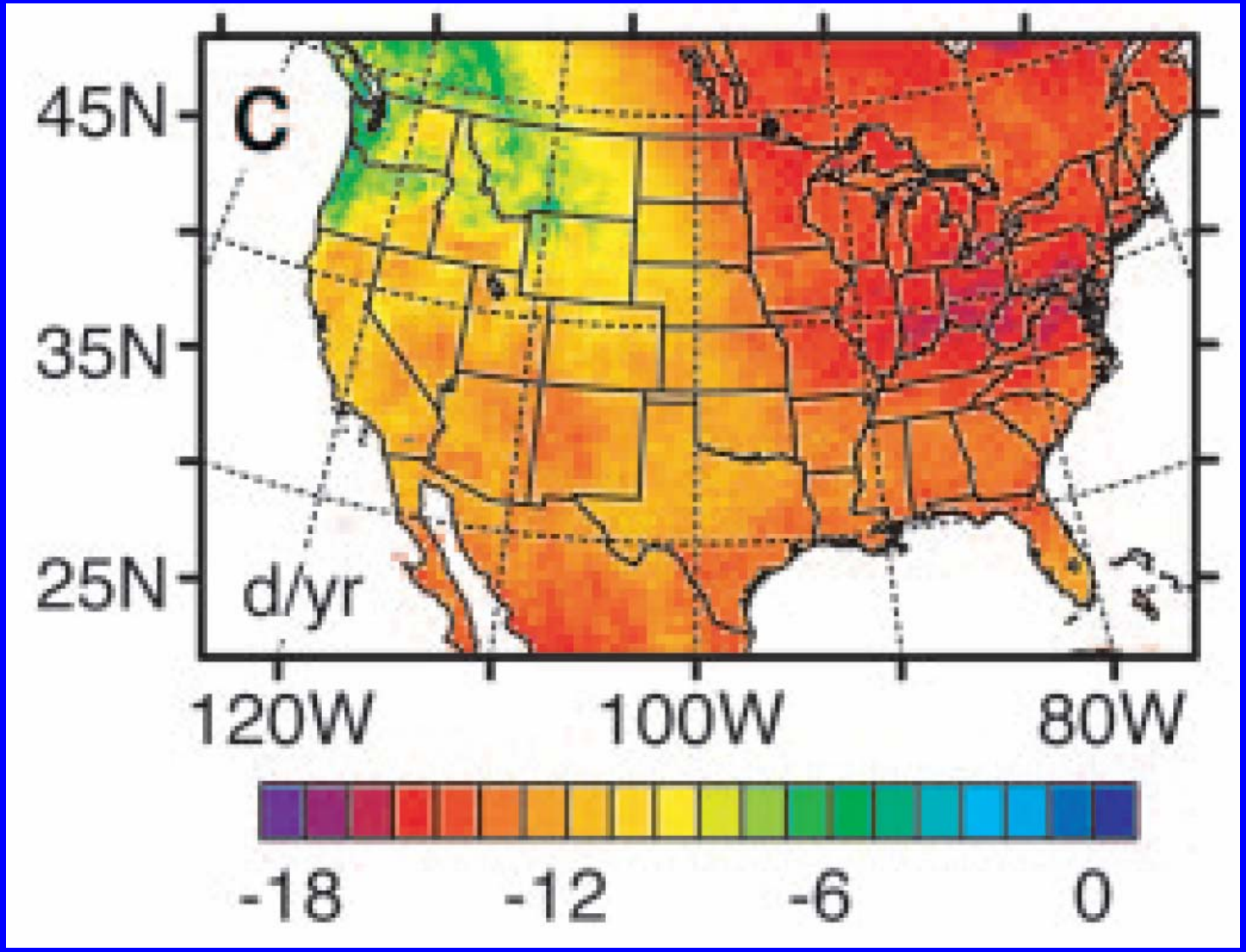
Diffenbaugh et al., 2005
Proceedings of the National Academy of Science



Longer Heat Waves

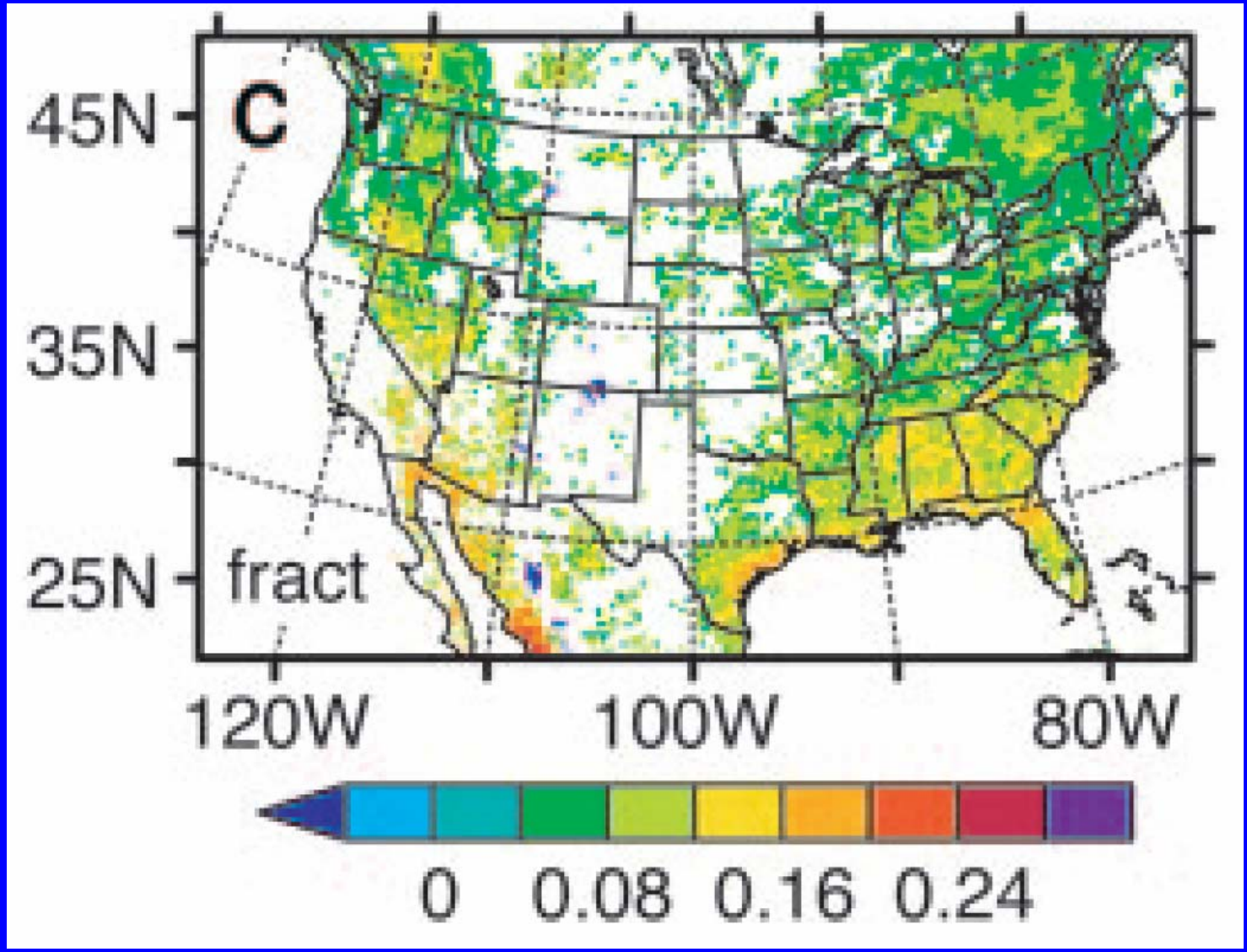
Diffenbaugh et al., 2005

Proceedings of the National Academy of Science



Fewer Cool Events

Diffenbaugh et al., 2005
Proceedings of the National Academy of Science



More Precipitation in Extremes

Diffenbaugh et al., 2005

Proceedings of the National Academy of Science

Summary

Paleoclimate

Drought

- Past droughts were longer and more severe than 20th century
  - *Higher temperatures, greater aridity*
  - *La Niña*
    - *Warmer world?*

Climate Change

- **Observed changes in the Southwest**
  - Relatively subtle, but real
  - Ocean regime changes
- **Observed climate change and models show**
  - Earlier snowmelt
    - *More precipitation falling as rain*
  - Increased temperatures
  - Increased precipitation
    - *Increased hydrological cycle*

Climate Change Extremes

- Increased temperatures
  - *More high temperature days*
  - *Longer heat waves*
- Increased precipitation
  - *Increased precipitation extremes*

Implications for Ecosystems

- **Regime Changes**
  - Affect landscape for long periods of time
  - Complex overlay of disturbance impacts
- **Increasing Temperatures**
  - Stress
  - Species' ranges
- **More precipitation in high extremes**
  - Runoff
  - Erosion

Doom or Opportunity?

- **Katrina:**
  - We had the science
  - We anticipated the event

Doom or Opportunity?

- **Katrina:**
  - We had the science
  - We anticipated the event
  - We did not reduce vulnerability or increase resilience

Challenge

- How do we integrate climate change knowledge into management decisions…
- Given a lack of information on the spatial scales of management units?

Acknowledgments

- Ben Crawford, Casey Thornbrugh, CLIMAS
- Martin Hoerling, NOAA-CDC
- Jonathan Overpeck, UA ISPE
- Tom Swetnam, UA LTRR
- Julio Betancourt, USGS
- Noah Knowles, USGS
- Noah Diffenbaugh, Purdue University

Thank You For Your Attention

Any Questions?

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CLIMAS
Climate Assessment Project for the Southwest

References and Materials Cited

Intro Slides (1-4)

Slides 2-3

Original data produced by Fenbiao Ni and colleagues, as part of the CLIMAS project. Published citation: Ni et al., 2002. Cool-season precipitation in the southwestern USA since AD 1000: comparison of linear and nonlinear techniques for reconstruction. *International Journal of Climatology*, Vol. 22, Issue 13, pp. 1645 – 1662. Data analysis available at the CLIMAS website http://www.ispe.arizona.edu/climas/research/paleoclimate/product.html. Data available from the NOAA Paleoclimatology Program http://www.ncdc.noaa.gov/paleo/treering.html

Slide 4

From analyses by Tom Swetnam (University of Arizona Laboratory of Tree-Ring Research) and Julio Betancourt (USGS Desert Research Laboratory, Tucson, Arizona).

Climate Variations (Slides 6-8)

Slide 6

From a presentation by Greg McCabe (USGS) at the “Improving the Application of Science in Western Drought Management & Planning” conference, Tempe, Arizona, 2004. http://www.westgov.org/wga/initiatives/drought/tempe.htm

Slides 7-8

Slides from the NOAA Climate Prediction Center. For more information on El Niño-Southern Oscillation, see: http://www.elnino.noaa.gov/

Decadal Variations (Slides 10-14)

Slide 10

Citation: Mantua, N. et al., 1997. A Pacific Interdecadal Climate Oscillation With Impacts on Salmon Production. *Bulletin of the American Meteorological Society* **78**: 1069–1079.

Slide 11

Citation: Hereford, R., R.H. Webb, and S. Graham. 2002. Precipitation history of the Colorado plateau region, 1900-2000. USGS Fact Sheet 119-02. http://pubs.usgs.gov/fs/2002/fs119-02/.

Slide 12

From a presentation by Greg McCabe (USGS) at the “Improving the Application of Science in Western Drought Management & Planning” conference, Tempe, Arizona, 2004. http://www.westgov.org/wga/initiatives/drought/tempe.htm

Slide 13

McCabe, G. J., M. A. Palecki, et al. (2004). "Pacific and Atlantic Ocean influences on multidecadal drought frequency in the United States." Proceedings of the National Academy of Sciences 101(12): 4136-4141.

Slide 14

Hoerling, M. and A. Kumar (2003). "The Perfect Ocean for Drought." Science 299: 691-694.

Observed Climate Change (Slides 16-22)

Slide 16

Courtesy of Jonathan Overpeck, Institute for the Study of Planet Earth, University of Arizona. Data from the National Climatic Data Center.

Slide 17

Courtesy of Jonathan Overpeck. From: Impacts of a Warming Arctic - Arctic Climate Impact Assessment http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=0521617782

Slide 18

Fountain, A., F.D. Granshaw, D. Percy, 2004. Contemporary glacier change in the American West. Mountain Climate Sciences Symposium, Lake Tahoe, California. http://www.x-cd.com/mcss04/S07.html

Slide 19

From a presentation by Martin Hoerling (NOAA Earth Science Research Lab) at the "Improving the Application of Science in Western Drought Management & Planning" conference, Tempe, Arizona, 2004. http://www.westgov.org/wga/initiatives/drought/tempe.htm

Slide 20

Mote, P. W., A. F. Hamlet, M. Clark, and D. P. Lettenmaier. 2005. Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society* 86(1):39-49.

Observed Climate Change (Slides 16-22)

Slide 21

From a presentation, entitled “Trends in Snowfall versus Rainfall for the Western United States” by Noah Knowles (USGS) at the American Geophysical Union annual meeting, December 2005, San Francisco, CA. http://www.fs.fed.us/psw/cirmount/meetings/agu/pdf2005/knowles_talk_agu2005.pdf

Slide 22

Courtesy of Casey Thornbrugh, CLIMAS. Arizona Historical Climatology Network station minimum temperature trends for December-February.

Climate Change Projections for the Western US (Slides 24-30)

Slide 24

From a presentation by Martin Hoerling (NOAA Earth Science Research Lab) at the "Improving the Application of Science in Western Drought Management & Planning" conference, Tempe, Arizona, 2004. http://www.westgov.org/wga/initiatives/drought/tempe.htm

Slide 25

Stott, P. A. et al., 2001. Attribution of twentieth century temperature change to natural and anthropogenic causes. *Climate Dynamics* 17, 1–21.

Slide 26-30

Diffenbaugh, N. S., J. S. Pal, et al. (2005). "Fine-scale Processes Regulate the Response of Extreme Events to Global Climate Change." Proceedings of the National Academy of Sciences 102(44): 15774-8.