Climate Threats to the Colorado River

Tribal Lands Climate Conference
National Wildlife Federation
Cocopah Indian Tribe

December 5, 2006
Somerton, AZ

Brad Udall
Director
University of Colorado Western Water Assessment
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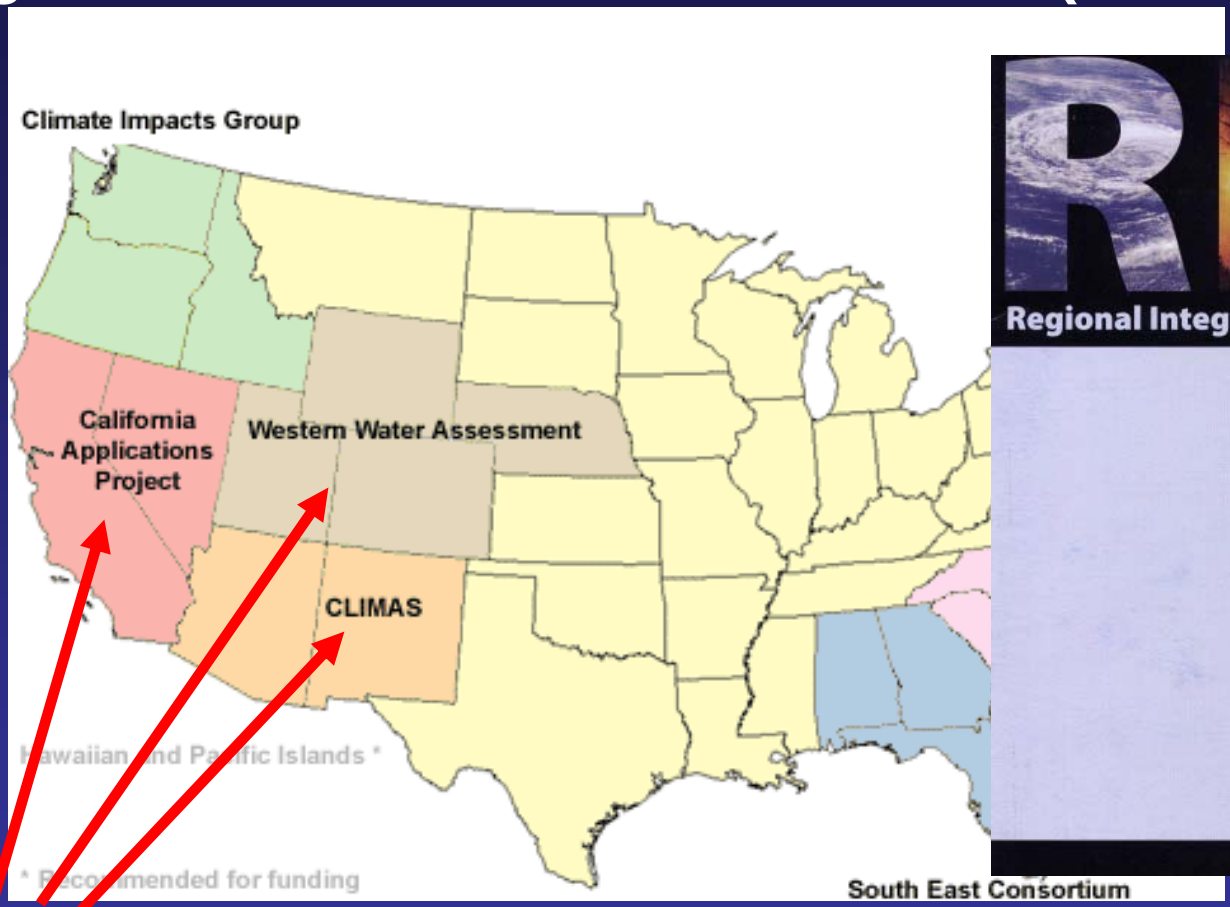
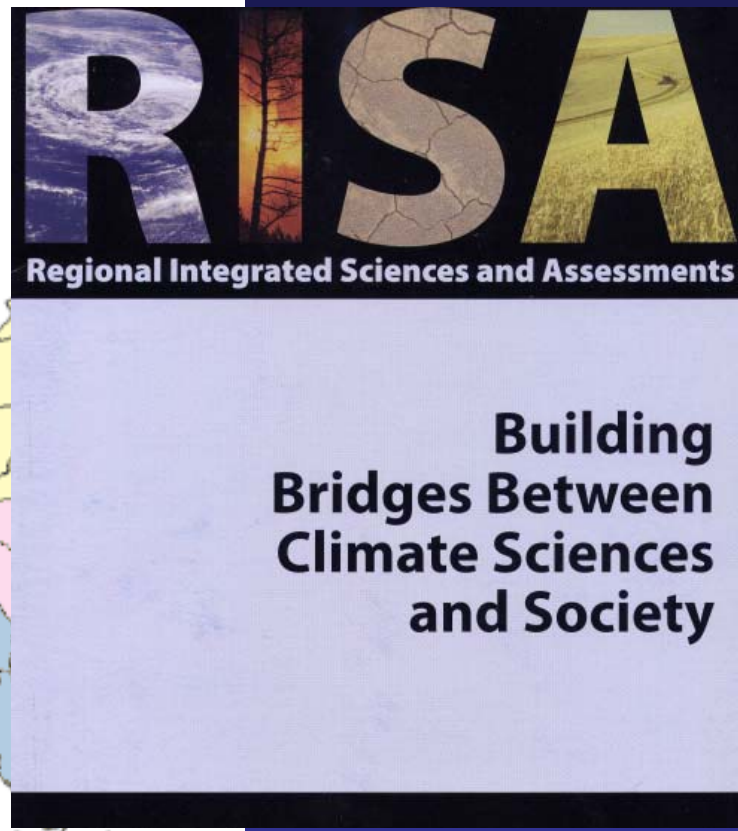
Western Water Assessment

Colorado
University of Colorado at Boulder

NOAA

Western Water Assessment one of 8 Similar NOAA Regional Integrated Sciences and Assessments ("RISA") Programs.





3 RISAs are located in the Colorado River Basin

http://www.climate.noaa.gov/cpo_pa/risa/

The Natural Resources Law Center

Dedicated to Informing and Influencing Natural Resources Law and Policy

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Native Communities and Climate Change: Legal and Policy Strategies for Protecting Tribal Legal Rights

This report will be published by the NRLC next year and will incorporate the latest data from the Intergovernmental Panel on Climate Change (IPCC) (expected in Spring, 2007).

Specifically, the report focuses on how climate change will affect tribal legal rights and how tribes might address these issues through legal and policy measures.

-First, the study discusses generally-applicable measures such as climate change litigation and various legislative (statutory) approaches.

-Second, the report uses 4 regional case studies—Alaska, Pacific Northwest, Southwest, and Florida—to discuss how the effects of climate change will impact tribes differently in each of these areas, as well as legal and policy measures more narrowly-tailored to address these specific issues.

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For more information, a one-page synopsis is available today from Jonathan Hanna, NRLC Research Associate.

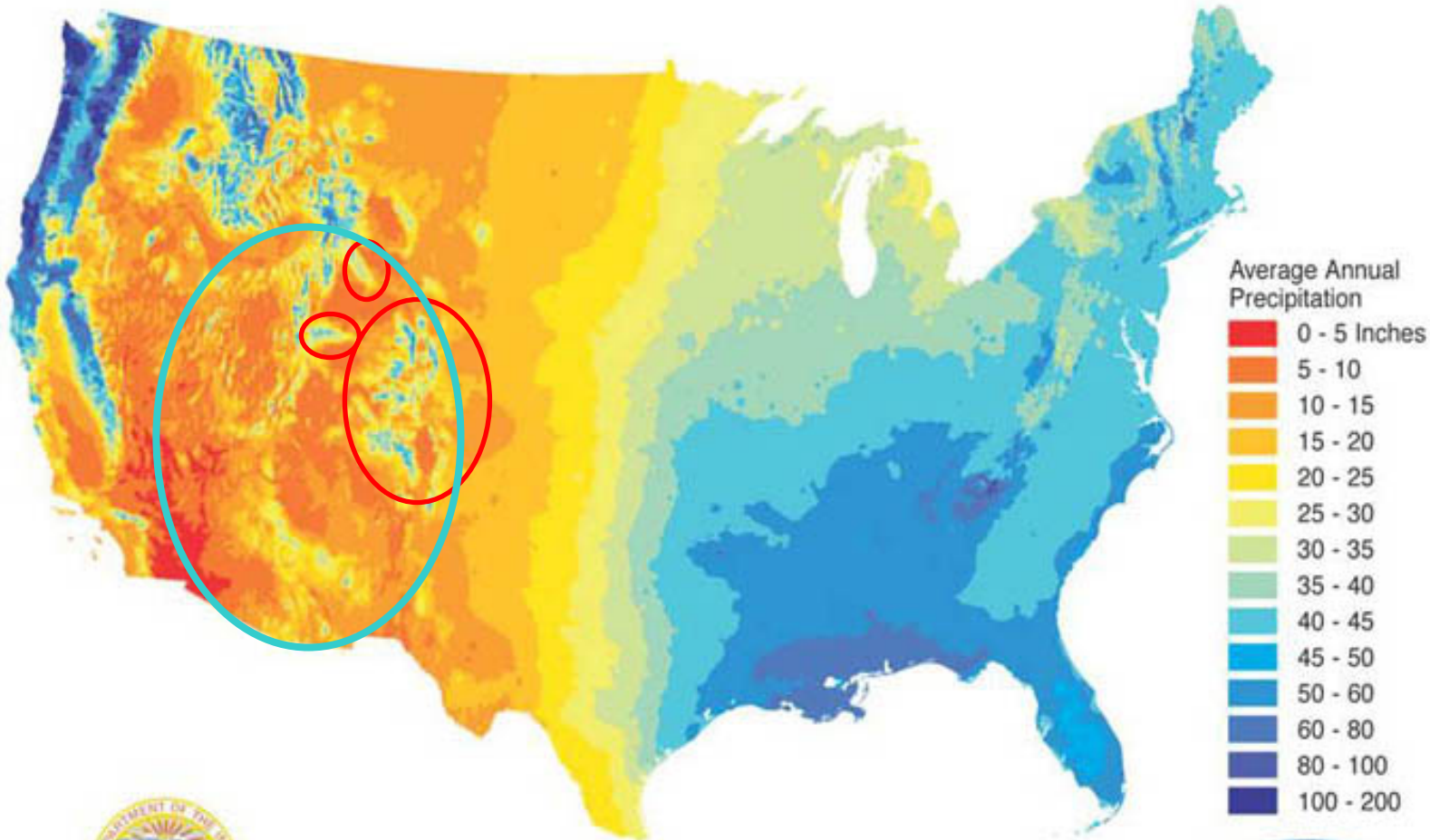
In addition, a draft of the report will be posted soon on the NRLC website at http://www.colorado.edu/law/centers/nrlc/pubs.htm to give tribes and other interested parties an opportunity to comment on the report before final publication.

When the report is posted on-line, readers will be able to submit comments electronically. Alternatively, comments or other inquiries can be sent directly to Jonathan Hanna at hannajm@colorado.edu.

Overview

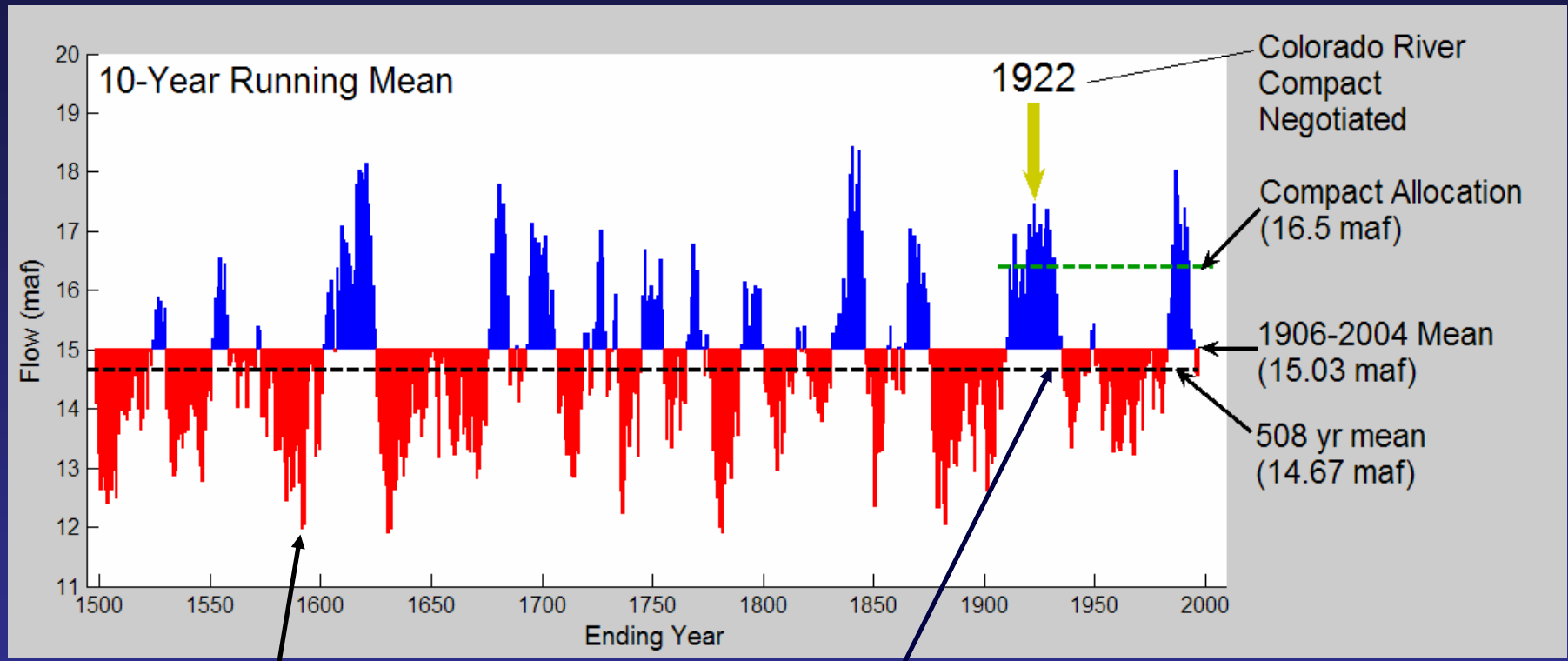
- The Source of the Colorado's Waters
- Talking Trees -- Lessons from the Distant Past
- The Variable and Warm Climate of the Recent Past
- The Future of Snow
- Hydrology and Climate Change Connections
- Climate Change Studies on the Colorado River
- Some Ideas for the Future

Average Inches of Annual Precipitation in the United States 1961-1990



Source: USDA-NRCS: http://www.ftw.nrcs.usda.gov/prism.html

Reconstructed Flows at Lees Ferry

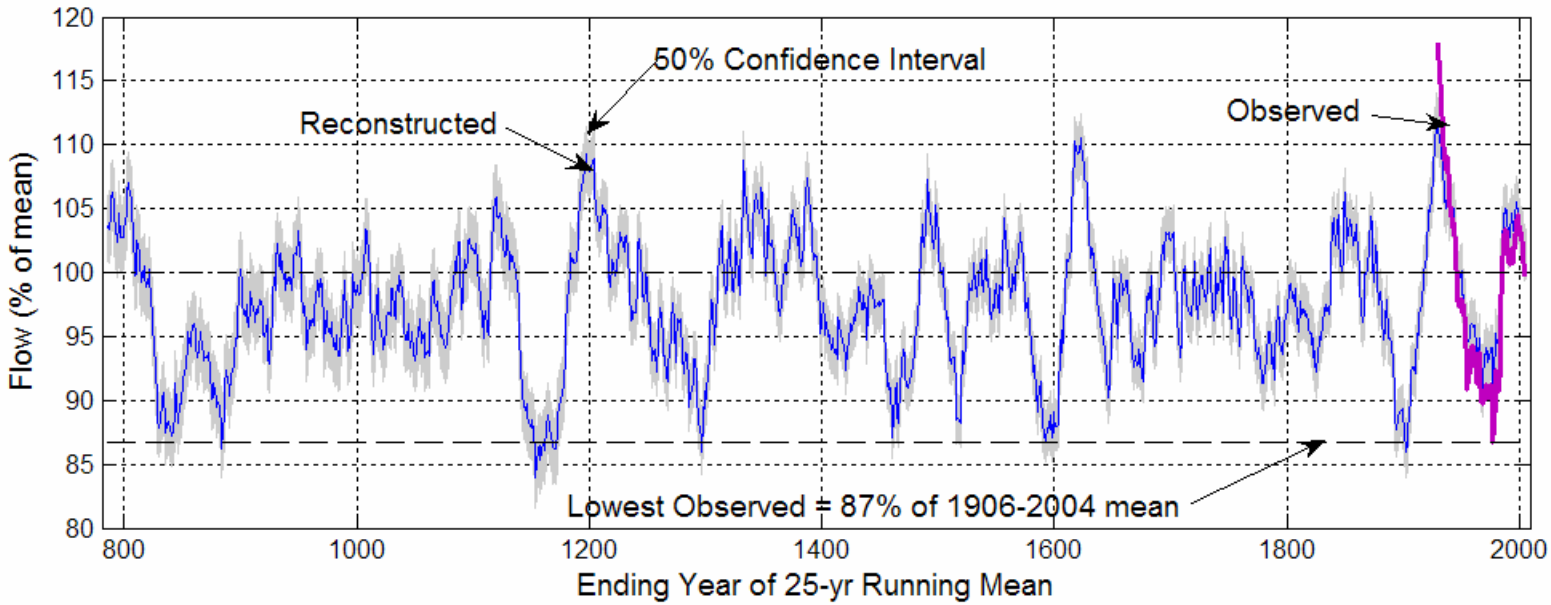


Severe Sustained Droughts

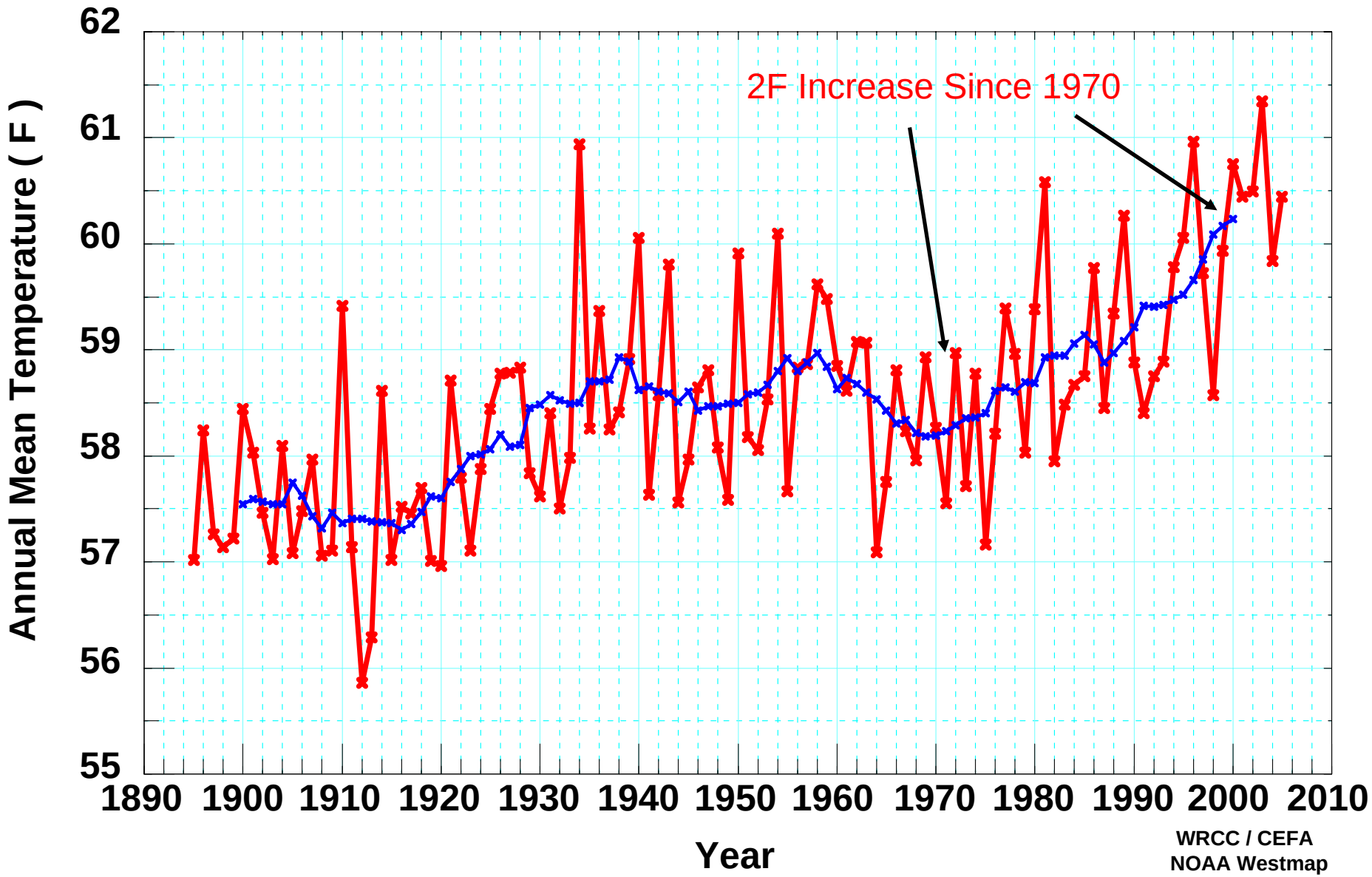
Lower "Long-Term" Mean

After Woodhouse et al. 2006.

Reconstructed Flows at Lees Ferry Using Dead Wood

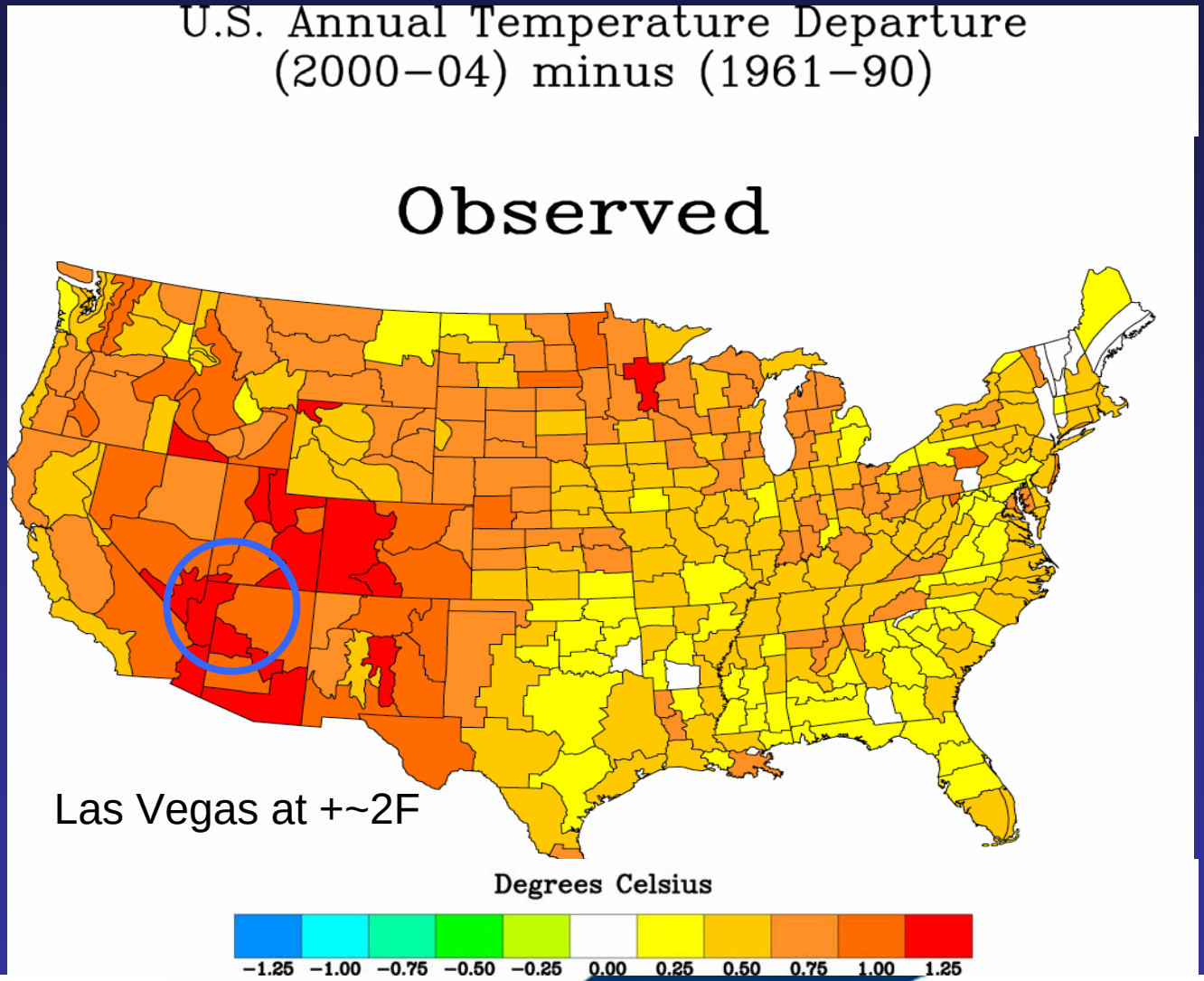


- The observed flows themselves emphasize the importance of multi-decadal swings in runoff
- Extension of the record identifies a maximum intensity drought centered near A.D. 1150 (This drought also apparently hit the southern Sierra Nevada of California)
- Changing modes of variability defy an easy definition of “normal”



Kelly Redmond, DRI

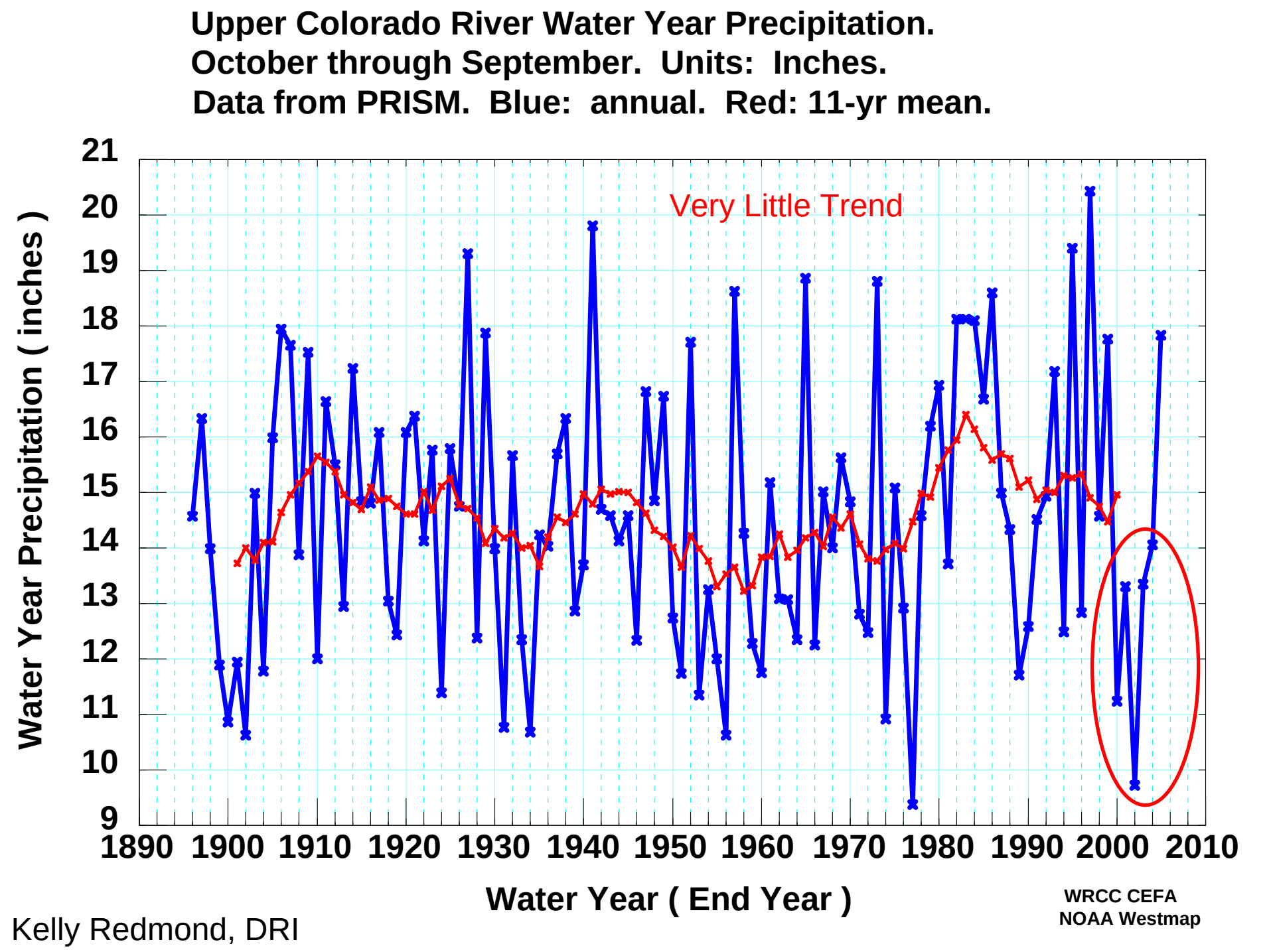
Last 4 Years Were Warm !



Western Water Assessment

Marty Hoerling, NOAA

Colorado
University of Colorado at Boulder


Upper Colorado River Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 11-yr mean.
Very Little Trend
Water Year Precipitation (inches)
Water Year (End Year)
21
20
19
18
17
16
15
14
13
12
11
10
9
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
WRCC CEFA
NOAA Westmap
Kelly Redmond, DRI

2004 Snowpack Vanishing Act

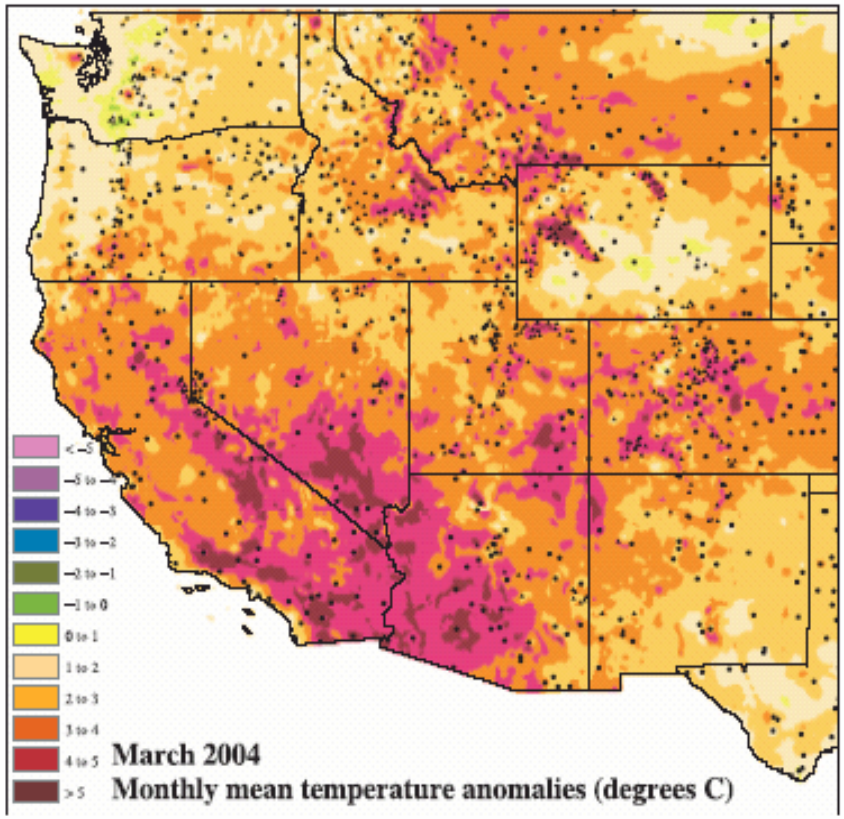


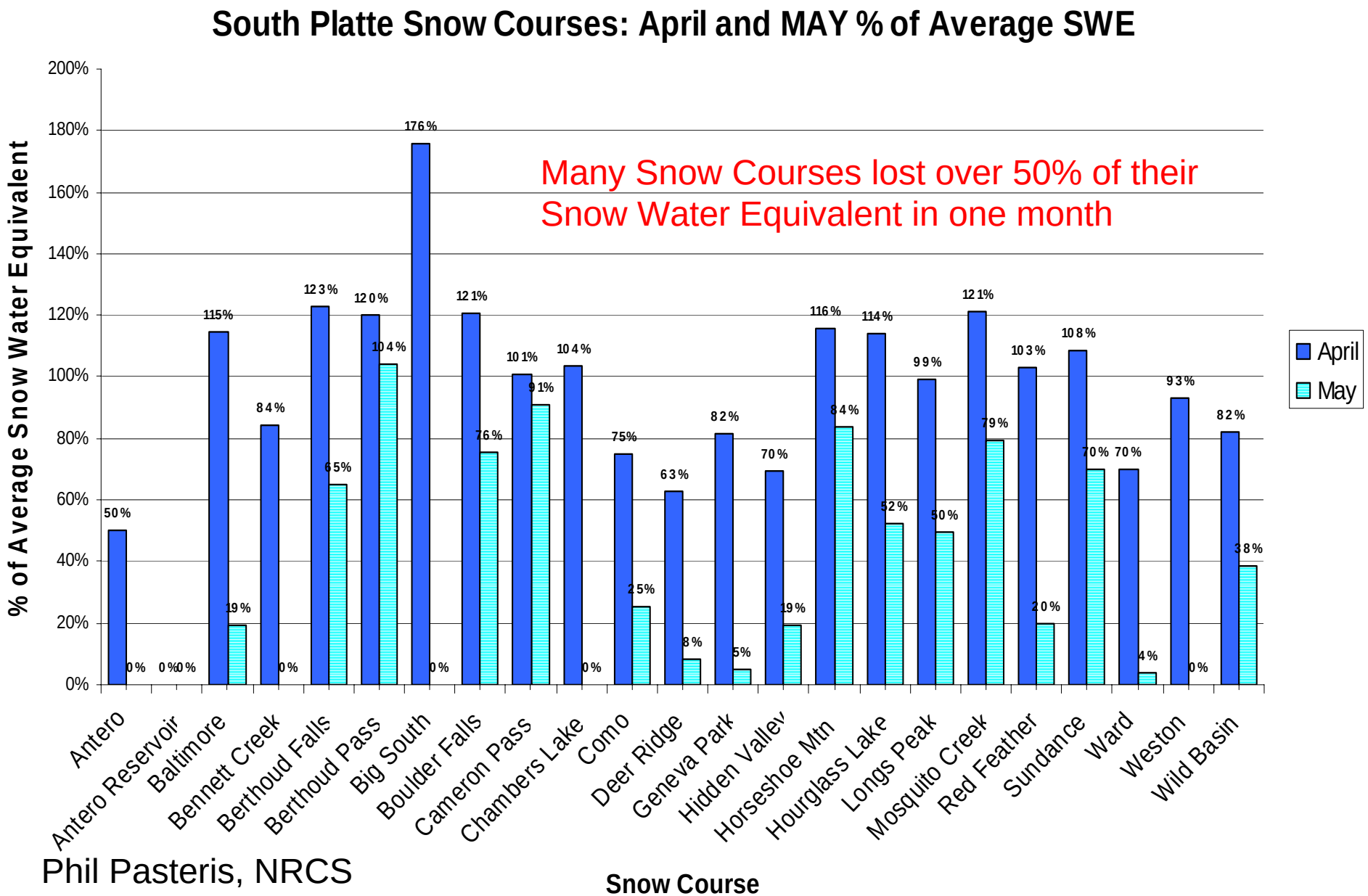
Fig. 1. March 2004 observed monthly mean temperature anomalies in degrees Celsius. NRCS SNOTEL sites are shown as triangles, and NWS sites are shown as circles. Contours are derived using the PRISM system (http://www.ocs.orst.edu/prism/).

Table 1. Summary of Mountain Snowpack (Snow Water Equivalent) Changes Between 1 March and 1 April 2004.

State/Area	*Statewide % of Average, 1 March 2004*	*Statewide % of Average, 1 April 2004*	*Statewide % of Average, Change*
Arizona	74	22	-51
Sierra/Tahoe	113	70	-35
Colorado	90	64	-26
Idaho	105	81	-25
Montana	93	78	-16
Nevada	118	64	-54
New Mexico	80	37	-43
Oregon	126	96	-30
Utah	109	70	-39
Washington	93	86	-7
Wyoming	91	71	-19

Rapid snowpack reduction. Record warmth and dryness combine in March 2004. (Pagano, Pasteris, Redmond, Dettinger, EOS)

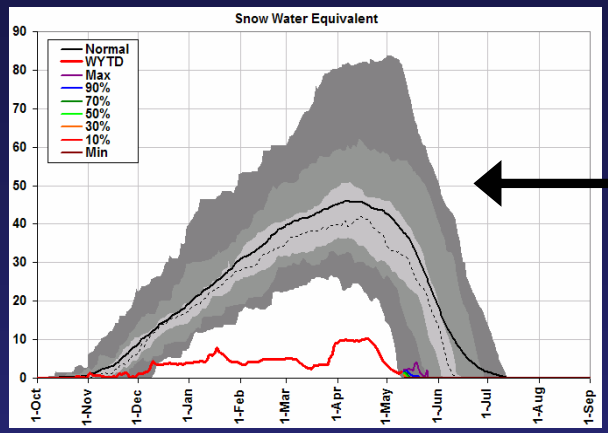
2006 Snowpack Vanishing Act



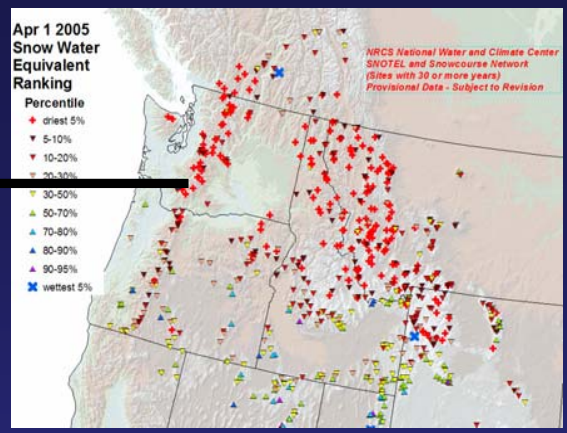
Phil Pasteris, NRCS

Snowpack Observations 2005

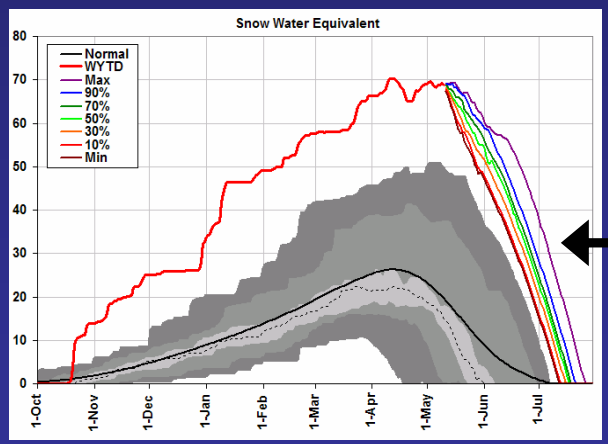
2005 in Red, All other Years in Gray



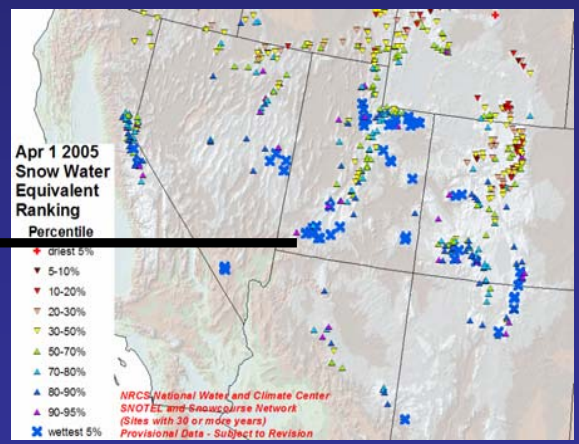
Stampede Pass, WA SNOTEL



Record Low PNW Snowpacks



Midway Valley, UT SNOTEL



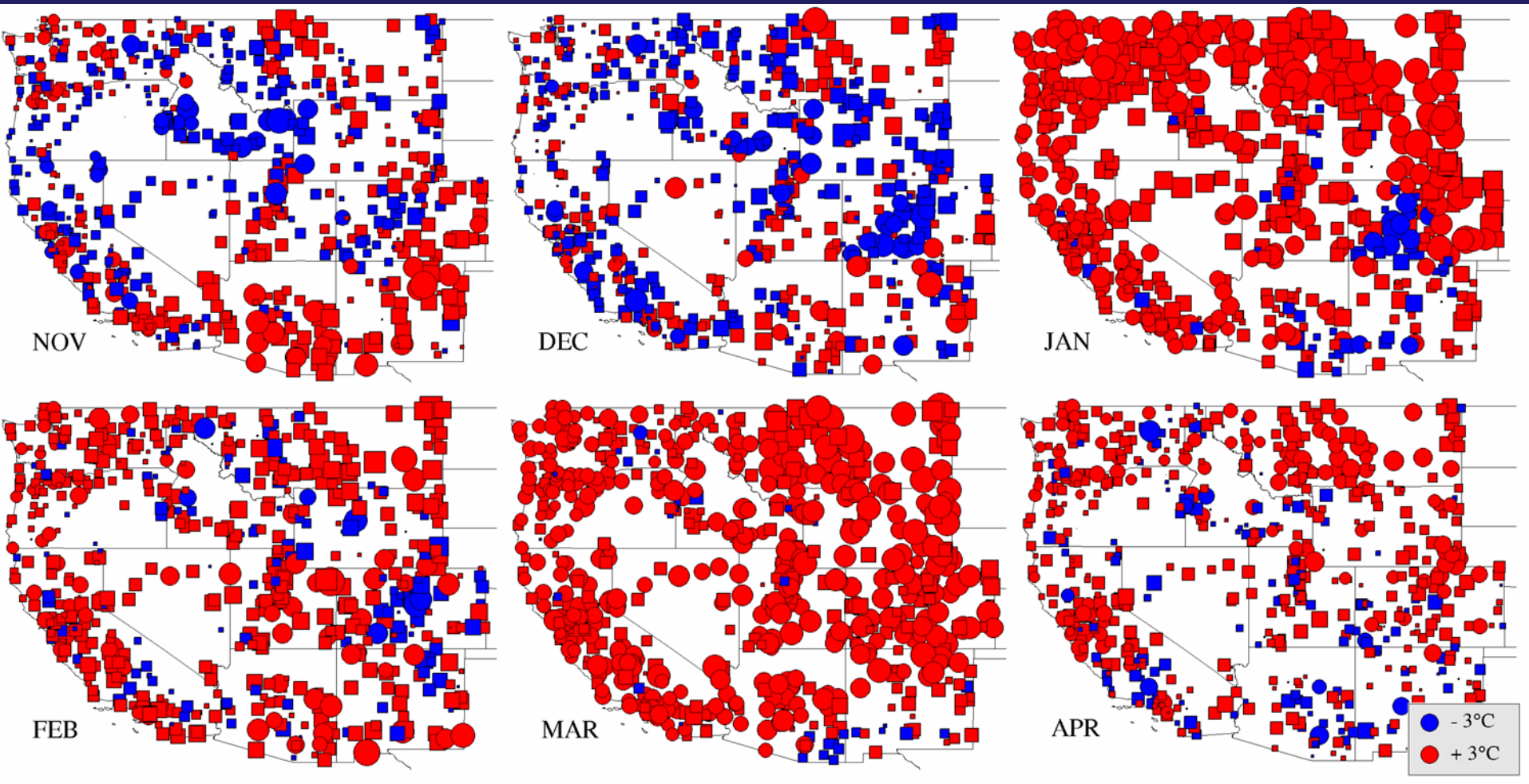
Record High SW Snowpacks

Trends in Snowfall versus Rainfall in the Western United States

Journal of Climate, Sept 2006

Knowles, Dettinger, Cayan

Monthly Averaged min temps 1949-2004



Hydrology 101

- Science of Water Movement around Earth
  - Evaporation, Precipitation, Sublimation, Evapotranspiration, Infiltration, Runoff

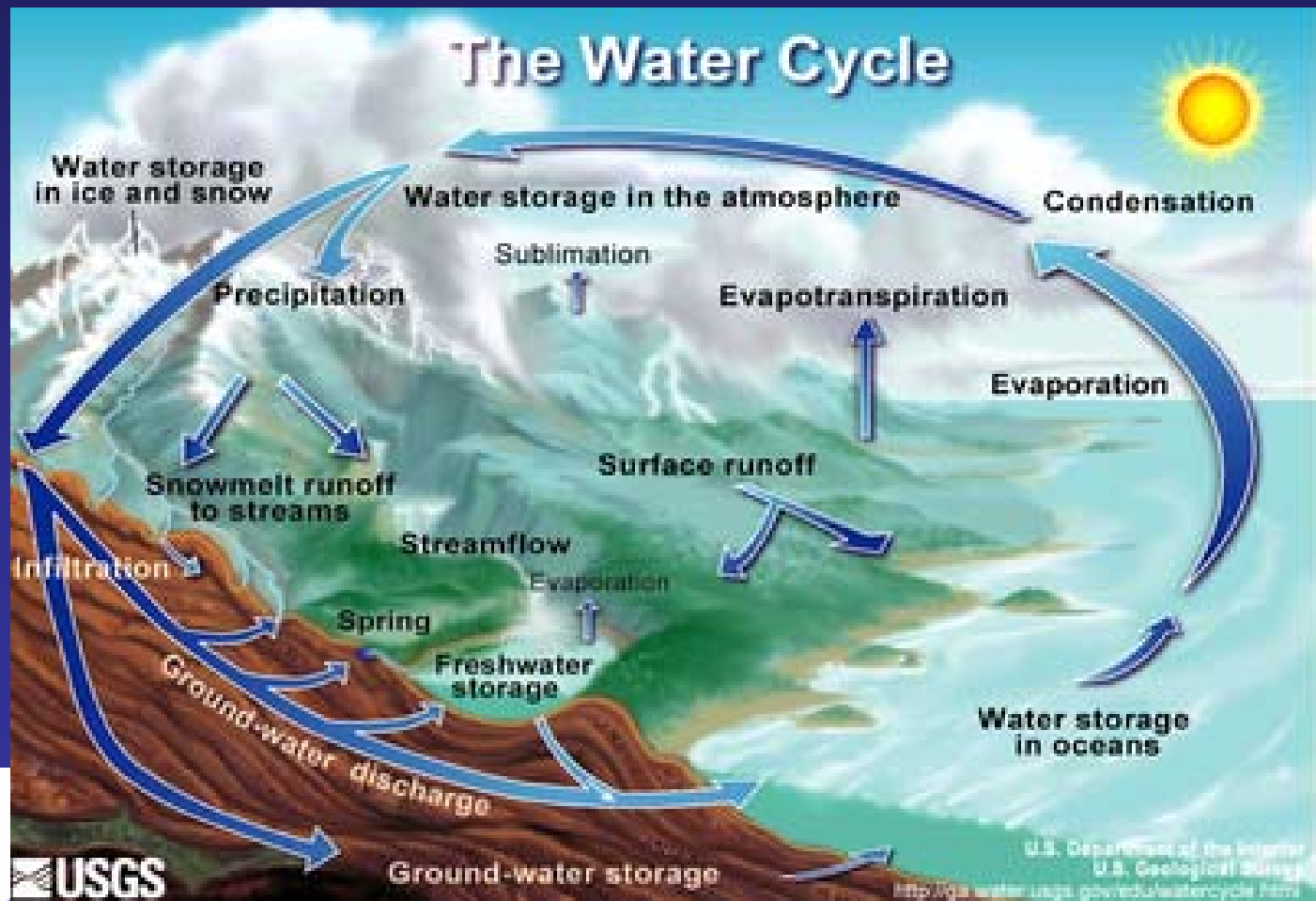
- Water Forms:

Vapor, Clouds, Snow, Liquid, Ice

-Largest movement of any substance

-Moves Energy around the globe

-Not distinct from weather and climate



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Hydrologic Cycle Changes in Warmer World

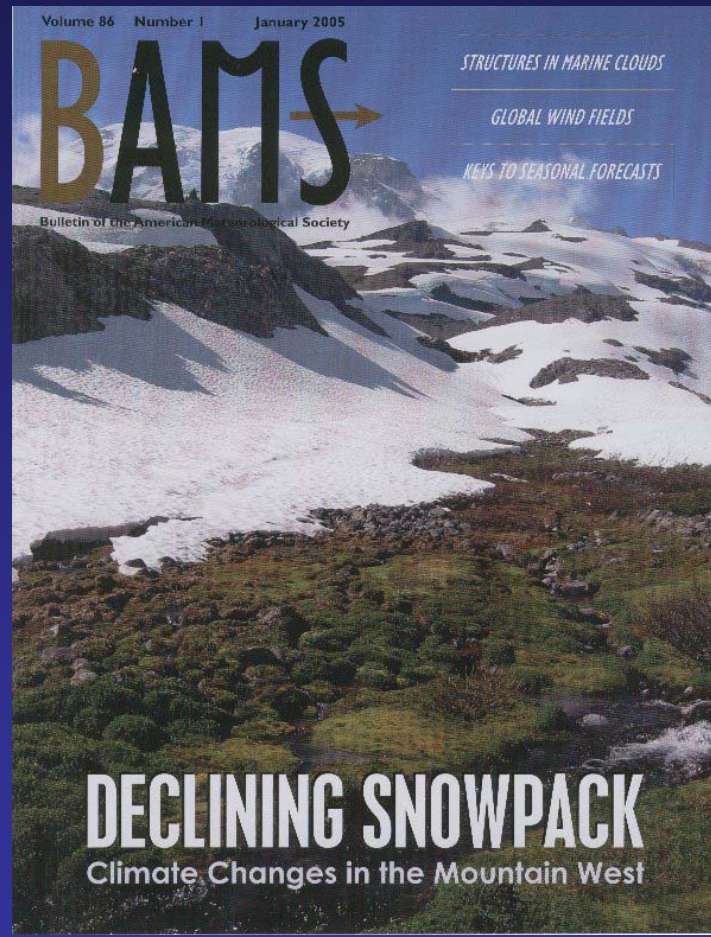
- Extra Warmth (=Energy) Means enhanced hydrologic cycle
  - Higher Temps Increase Atmosphere Moisture holding capacity
  - Higher Temps imply Globally Increased Evaporation
  - Precipitation must increase globally (But not necessarily regionally)
  - More Intense Precipitation - Floods
  - More Intense Drying - Drought
    - Mid-Continental Summertime Drying
    - Increased Evaporation Will Increase Water Demand
  - More Rain, Less Snow
  - Earlier Snowmelt

A Profusion of Recent Snow Related Journal Articles

- Trends and Variability in snowmelt runoff in the western United States – McCabe and Clark
- Changes in Snowmelt Runoff timing in Western North America Under a “Business as Usual’ Climate Change Scenario – Stewart, Cayan, Dettinger
- Seasonal Shifts in Hydroclimatology over the Western United States – Regonda, Rajagopalan, Clark, Pitlick
- **Declining Mountain Snowpack in Western North America – Mote, Hamlet, Clark, Lettenmaier**
- **Trends in Snowfall versus Rainfall in the Western United States - Knowles, Dettinger, Cayan**

Declining Snowpack – Bulletin of Amer. Met. Society 2005

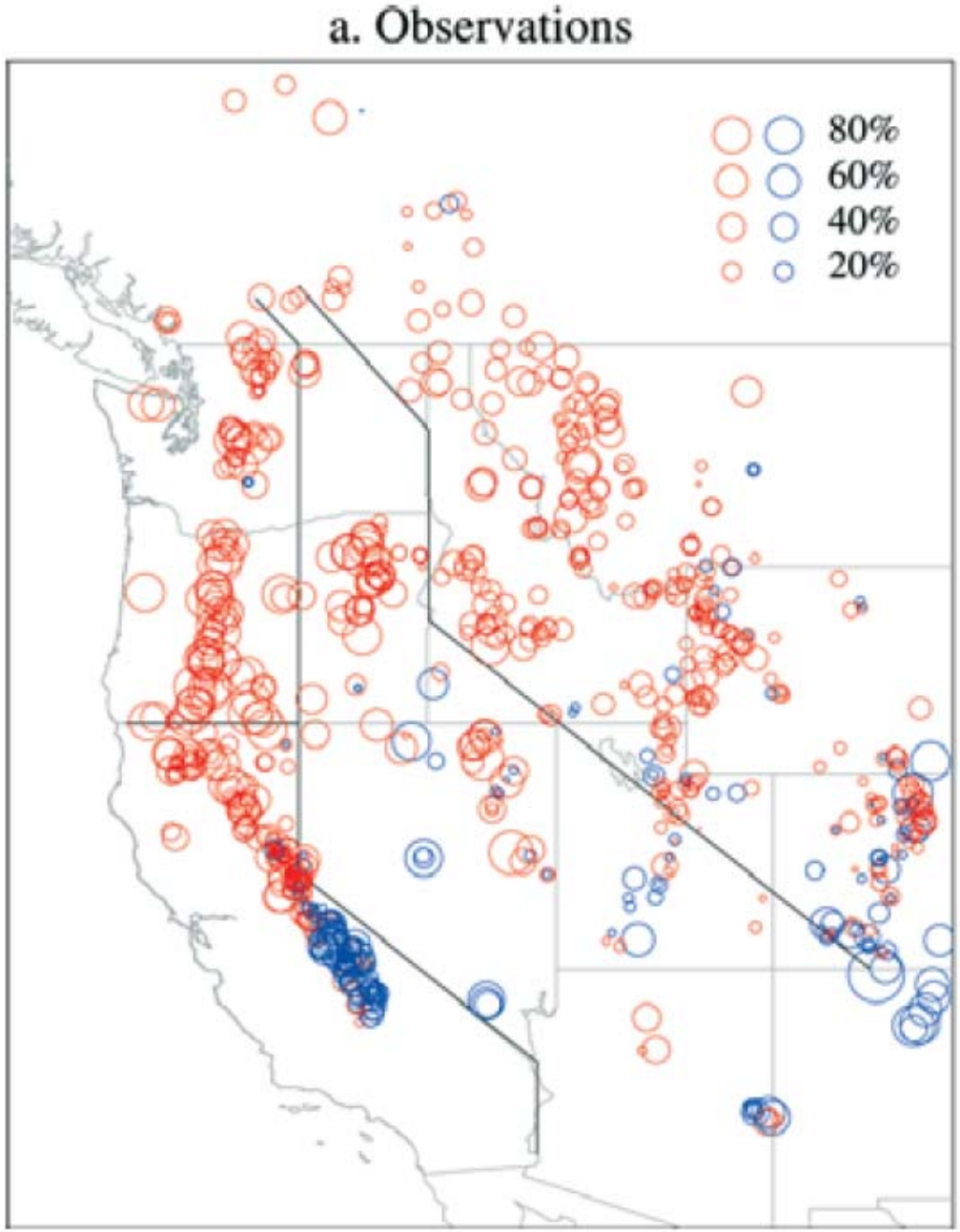
- Widespread Declines in Snowpack, especially since 1950.
- Models point to warming as cause.
- Consistent with rising ghg and will almost certainly continue.
- Likely that losses continue or accelerate with highest losses in milder climates and lowest losses in high peaks of northern Rockies and Southern Sierra.



Source: Mote, et al.

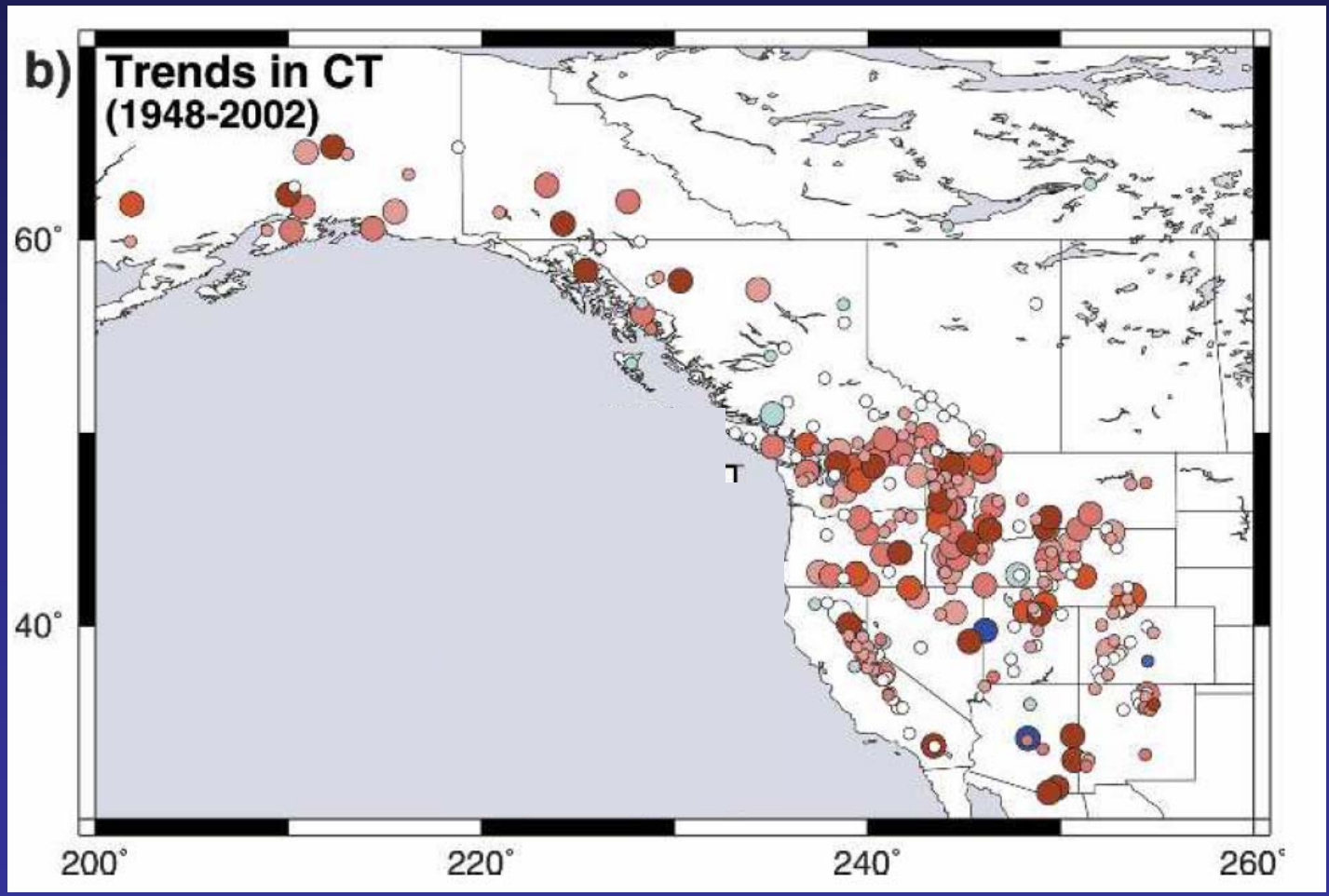
Declining Snowpack

Changes in April 1, Snow Water Equivalent over last 50 years



Source: Mote, et al.

Earlier Spring Runoff



Source: Stewart, et al. 2005

Colorado River Climate Change Studies over the Years

- Dracup, 1977
- Stockton and Boggess, 1979
- Revelle and Waggoner, 1983
- Gleick, 1988
- Nash and Gleick, 1991
- Nash and Gleick, 1993
- Christensen et al, 2004
- Milly, 2005
- Hoerling, 2006
- Christensen et al, 2007

As True Today as then -- Nash and Gleick 1993

- "The regional impacts of these (climate) changes will vary and cannot yet be predicted with much confidence; however, existing global climate models indicate that temperature increases in central North America will exceed the increase in the global mean, and will be accompanied by reduced summer precipitation and soil moisture. (IPCC, 1990)"

- "Despite recent advances in modeling the atmosphere, large uncertainties remain about the details of regional hydrological changes. Until large –scale climate models improve both their spatial resolutions and their hydrologic parameterizations, information on the effects of global climatic changes on hydrologic sub-basins can best be produced using detailed, basin-specific hydrologic models."

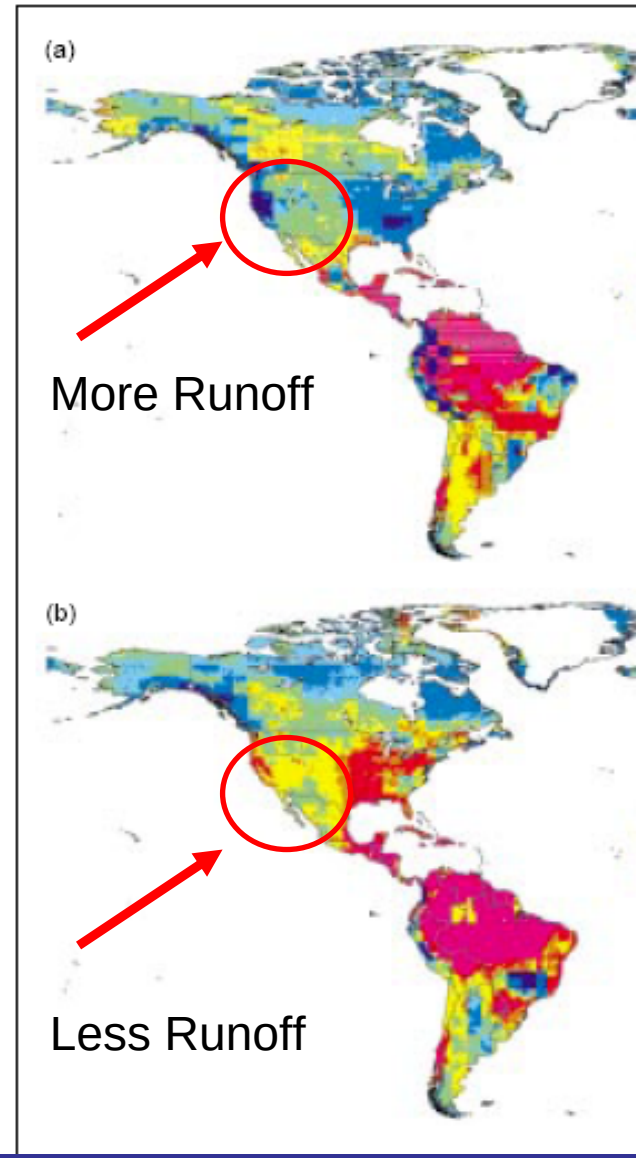
- Nash and Gleick Page 1.

Observations about Colorado River Studies

- Some Studies use Statistics, Some Climate Models, Some Combined
- Many assumptions about the future
- “National Assessment” and IPCC (~ 2001) suggested more precipitation possible
- Current Models show little change in total precipitation
- Depending on analysis this leads to either small or quite large reductions in streamflow
- Increases in Precipitation are needed to counteract Drying Trend from Warming
- Most show some future reduction in flows ranging from about -10% to greater than -50%

What we used to think about the Colorado River Basin…

- Intergovernmental Panel on Climate Change 2001 “Third Assessment Report” Results for 2 Models Shown
- Inconsistent Results for Runoff in the Colorado River Basin
- Mid-continental location, topography, computer power all limit our ability to understand regional climates



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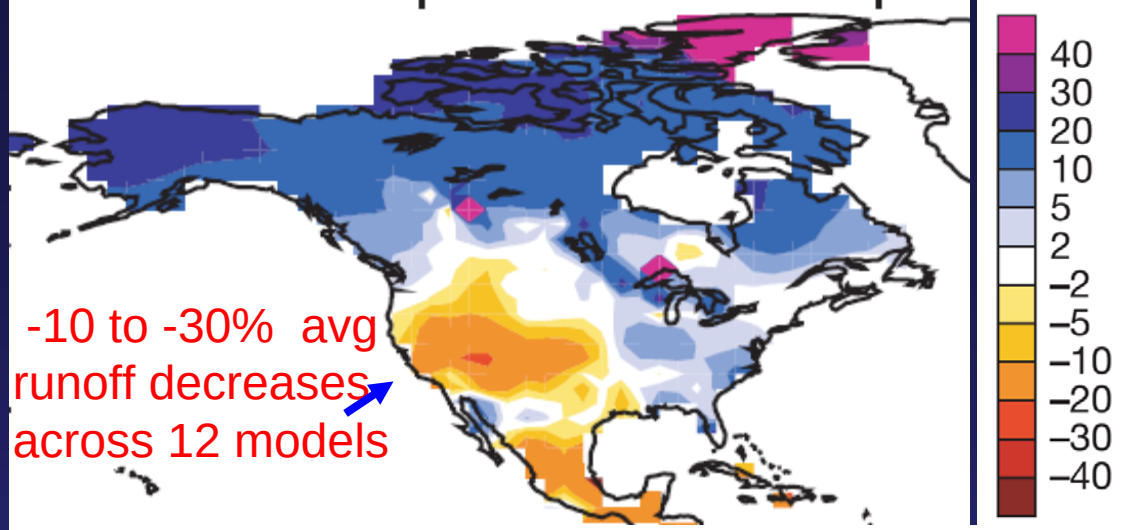
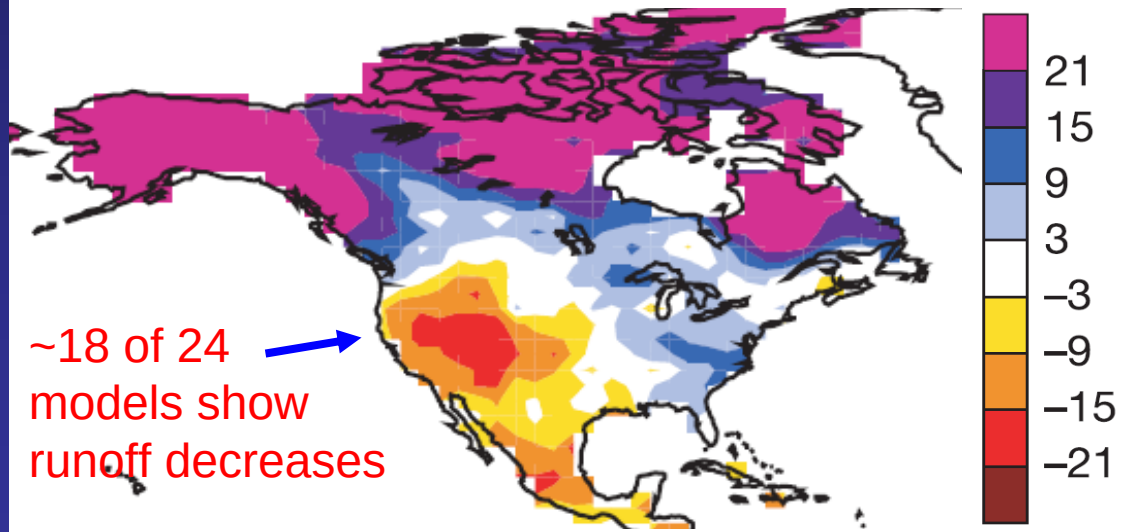
Current Thinking

- PRELIMINARY Results -- lots of additional analysis required. Models are not predictions.
- 10 to 30% Less Runoff
- About ¾ of Models Agree
- Decreases in runoff due to temperature increases, perhaps small precipitation declines
- Dryness consistent with world-wide poleward movement of deserts from ~30 N/S Latitude



Relative Change in Runoff 2041 to 2060 relative to 1900-1970 Runoff from 12 Models



Number of Models Runs showing a positive change minus number showing negative change. ("-" = dry agreement)

Milly, et al, Nature 2005

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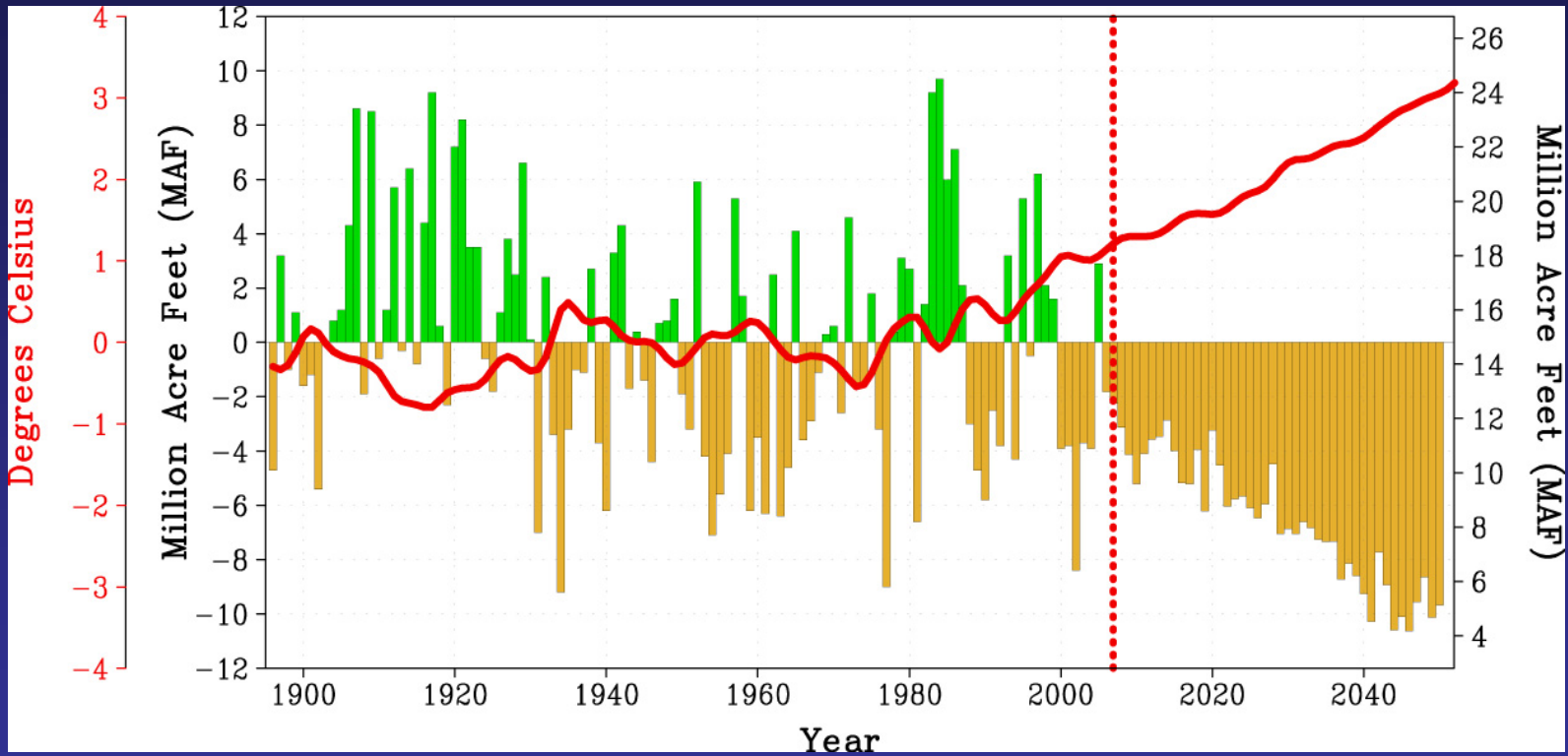
Hoerling's Eye-Opening Results



Long Term Policy Issues

- Lower Basin Supply Issues
  - Currently Depend on Excess from Upper Basin to meet demands
  - Arizona remaining Native American Reserved Rights Settlements
  - Nevada very little capacity to absorb shortage
  - Very Fast Population Growth
  - Colorado River Tribes in Strong Position
  - Other Tribes Dependent on Central Arizona Project at Risk
- Upper Basin Supply Issues
  - Tremendous uncertainty re future hydrology and LB deliveries
  - Colorado Front Range Municipalities 30+% Dependent on CR
  - Fast (Not “Very Fast”) Population growth depends on using additional water
  - Compact Penalties for Overusing Water
  - Uncertain Supply for Colorado Tribes participating in Animas La Plata
- Colorado River Delta
  - No flow in most years and none likely for years to come

Talk Summary

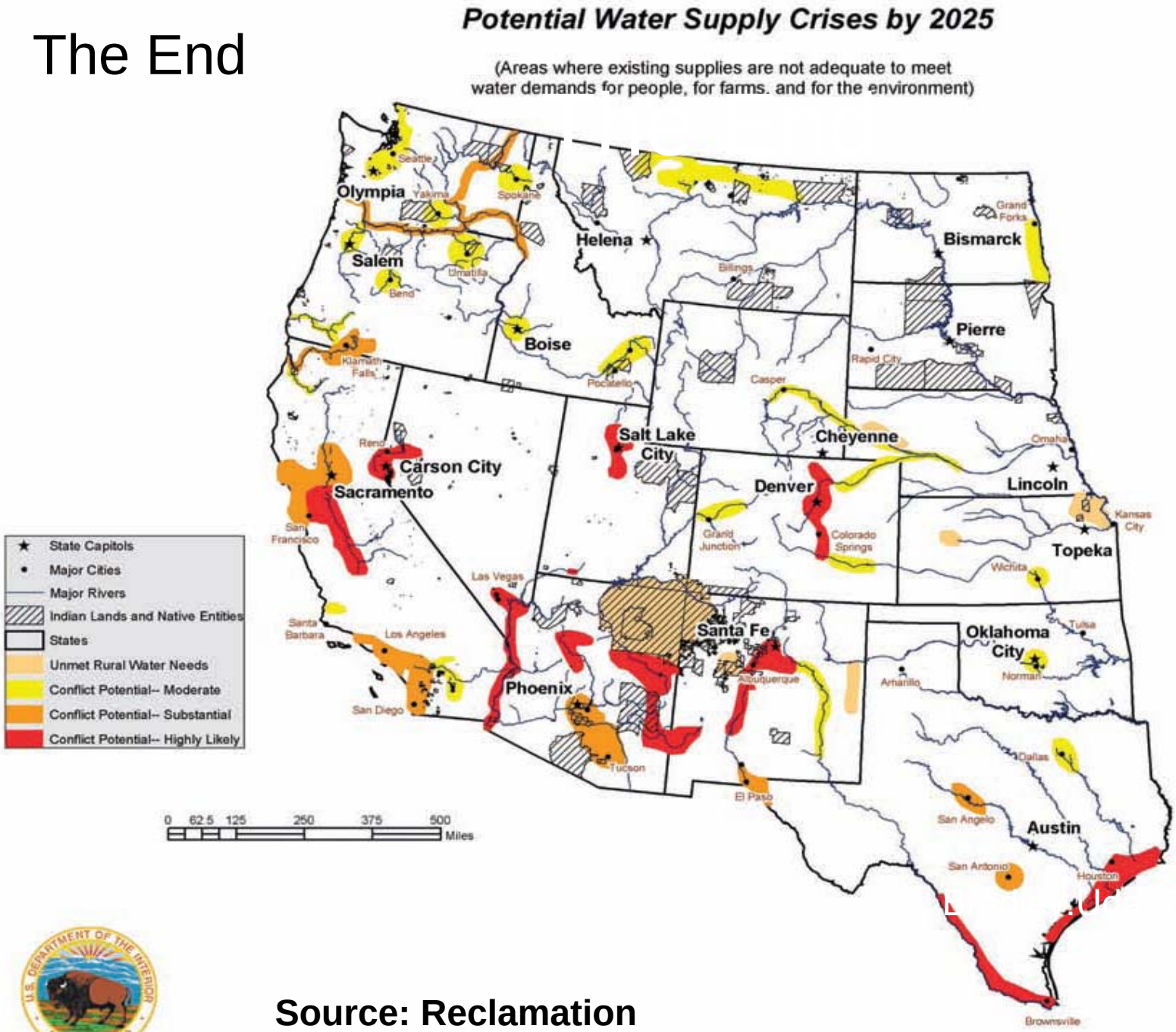
- Bedrock Principle of water planning is stable climate
- Small mountainous areas in the West are responsible for most of the snow-melt dominated Colorado River runoff
- Paleoclimate tells us that we can't depend on "normal"
- Recent climate has been warm, especially in the spring
- Future warming should continue and exceed warming in many parts of the country
- Western Snowpacks have been declining, but Colorado headwaters less noticeable
- Snow expected to melt sooner, and proportion of annual precipitation that occurs as rain will increase
- Climate, Weather, Water and very interconnected
- Most Climate Change Studies have suggested that drought is likely to be more common in the future on the Colorado River, even if total precipitation stays the same
- Future Water Management is likely to be challenging

“This Dog Believes”

- Michelle Nijhuis, High Country News
- From Pika’s Viewpoint

“Pika”

The End



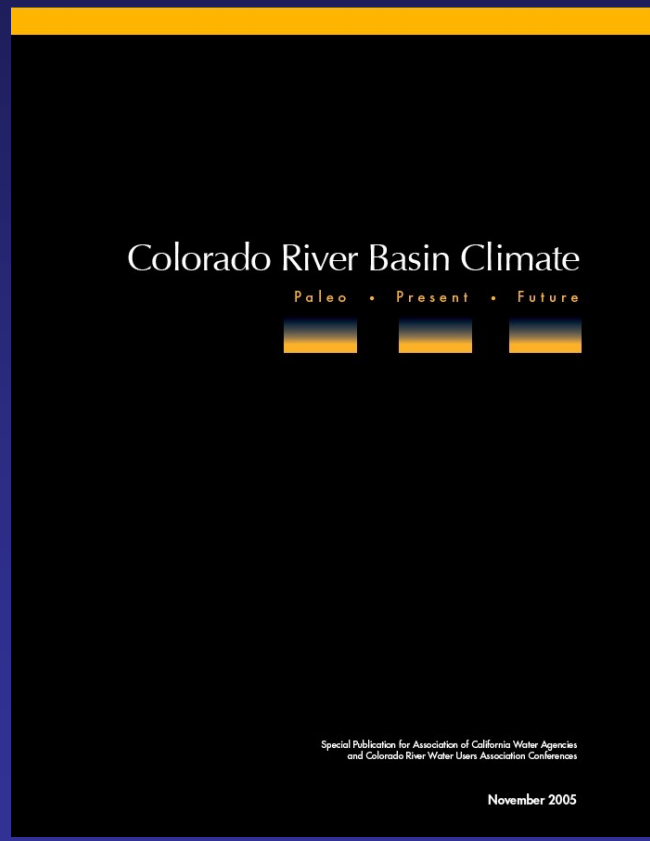
Source: Reclamation

May 200

Extra Slides

Highlight -- Products

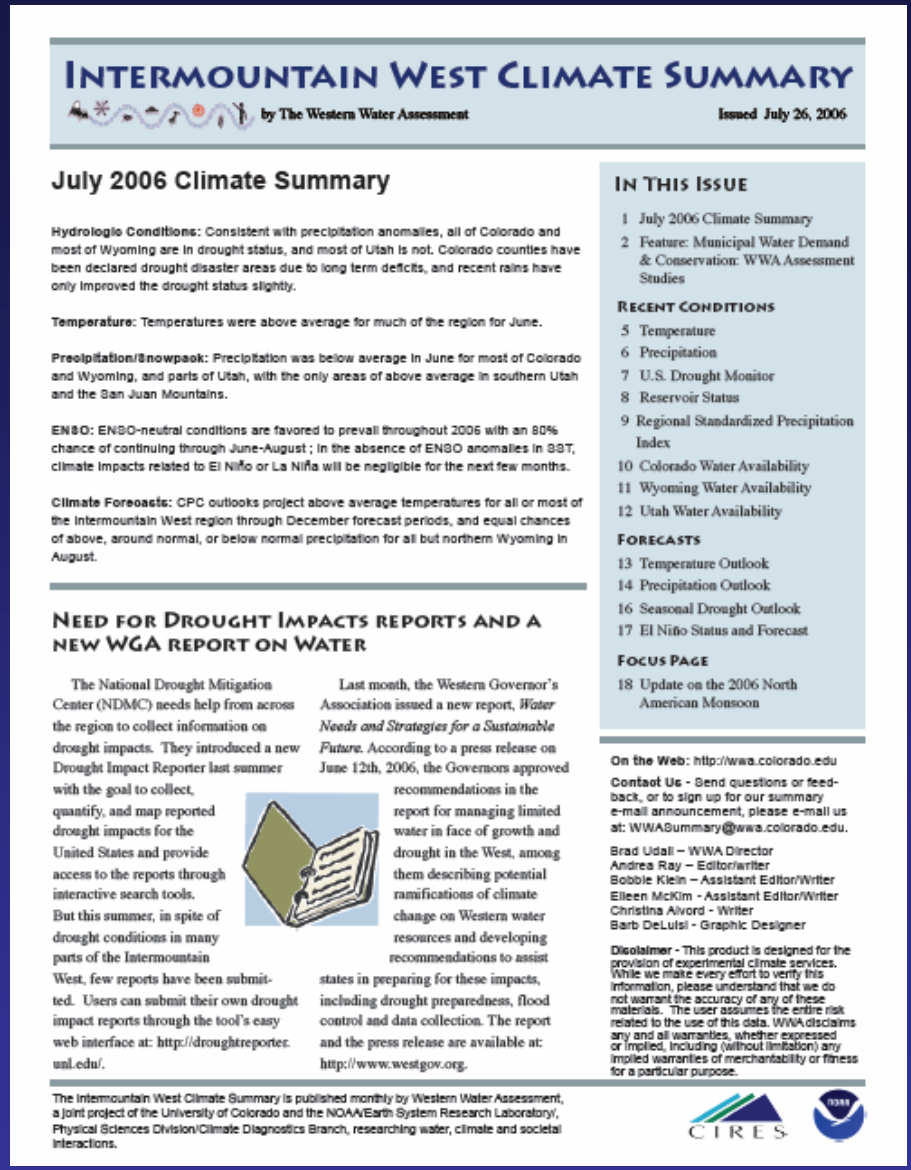
- Colorado River Climate Booklet w/ CADWR
- Intermountain Climate Summary and Southwest Climate Outlook
- Seasonal Forecasts
  - http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/
- Forecast Evaluation Tool



WWA Product – Intermountain West Climate Outlook

Covers CO, UT, WY
Feature Articles
Temperature Past Month
Precipitation Past Month
US Drought Monitor
Reservoir Status
Colorado Water Availability
Temp Outlook
Precipitation Outlooks
El Nino Status

Thanks to: NOAA, State Engineers, NRCS,



INTERMOUNTAIN WEST CLIMATE SUMMARY

by The Western Water Assessment — Issued July 26, 2006

July 2006 Climate Summary

Hydrologic Conditions: Consistent with precipitation anomalies, all of Colorado and most of Wyoming are in drought status, and most of Utah is not. Colorado counties have been declared drought disaster areas due to long term deficits, and recent rains have only improved the drought status slightly.

Temperature: Temperatures were above average for much of the region for June.

Precipitation/Snowpack: Precipitation was below average in June for most of Colorado and Wyoming, and parts of Utah, with the only areas of above average in southern Utah and the San Juan Mountains.

ENSO: ENSO-neutral conditions are favored to prevail throughout 2006 with an 80% chance of continuing through June-August ; In the absence of ENSO anomalies in SST, climate impacts related to El Niño or La Niña will be negligible for the next few months.

Climate Forecasts: CPC outlooks project above average temperatures for all or most of the Intermountain West region through December forecast periods, and equal chances of above, around normal, or below normal precipitation for all but northern Wyoming in August.

Need for Drought Impacts Reports and a new WGA Report on Water

The National Drought Mitigation Center (NDMC) needs help from across the region to collect information on drought impacts. They introduced a new Drought Impact Reporter last summer with the goal to collect, quantify, and map reported drought impacts for the United States and provide access to the reports through interactive search tools. But this summer, in spite of drought conditions in many parts of the Intermountain West, few reports have been submitted. Users can submit their own drought impact reports through the tool's easy web interface at: http://droughtreporter.unl.edu/.

Last month, the Western Governor's Association issued a new report, *Water Needs and Strategies for a Sustainable Future*. According to a press release on June 12th, 2006, the Governors approved recommendations in the report for managing limited water in face of growth and drought in the West, among them describing potential ramifications of climate change on Western water resources and developing recommendations to assist states in preparing for these impacts, including drought preparedness, flood control and data collection. The report and the press release are available at: http://www.westgov.org.

In This Issue

On the Web: http://wwa.colorado.edu

Contact Us - Send questions or feedback, or to sign up for our summary e-mail announcement, please e-mail us at: WWASummary@wwa.colorado.edu.

Brad Udall – WWA Director
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Eileen McKim - Assistant Editor/Writer
Christina Alvord - Writer
Barb DeLuisi - Graphic Designer

The Intermountain West Climate Summary is published monthly by Western Water Assessment, a joint project of the University of Colorado and the NOAA/Earth System Research Laboratory/, Physical Sciences Division/Climate Diagnostics Branch, researching water, climate and societal interactions.

CIRES

Available at: Wwa.colorado.edu

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University of Colorado at Boulder

NOAA

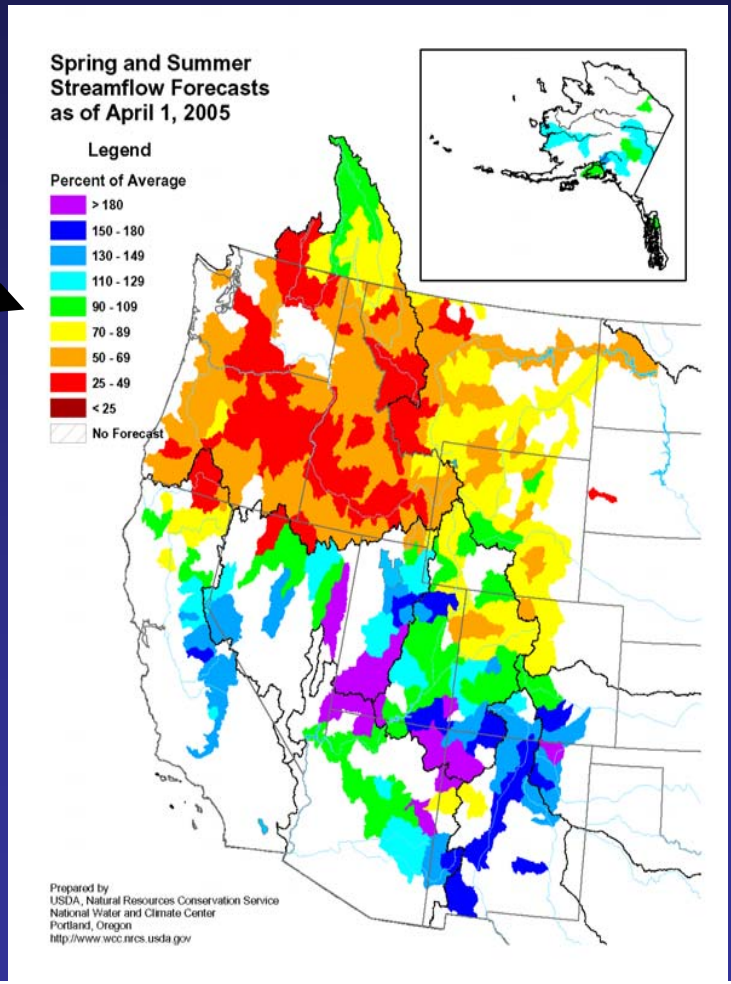
Water Supply Forecast Category Expansion

Before 1965 this map
had 3 categories

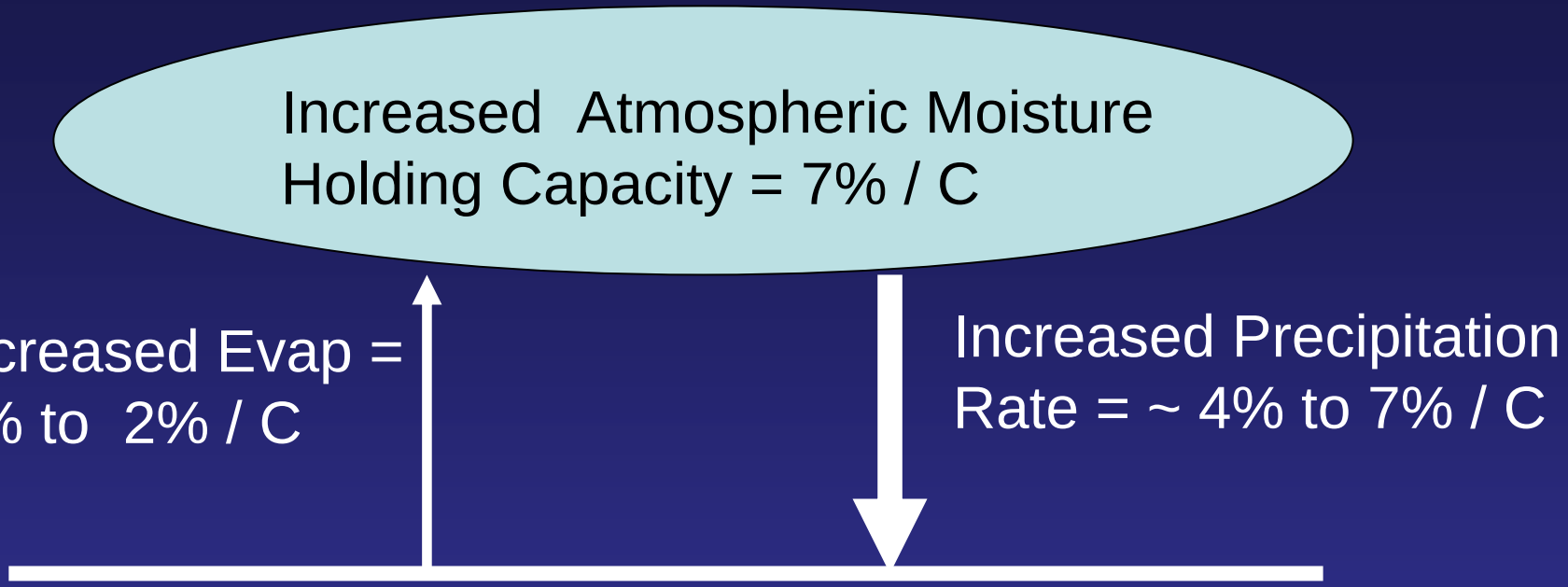
1965-2001
had 5 categories
(<70% to >130%)

2002-2004
had 7 categories
(<50% to >150%)

2005
now has 9 categories
(<25% to >180%)



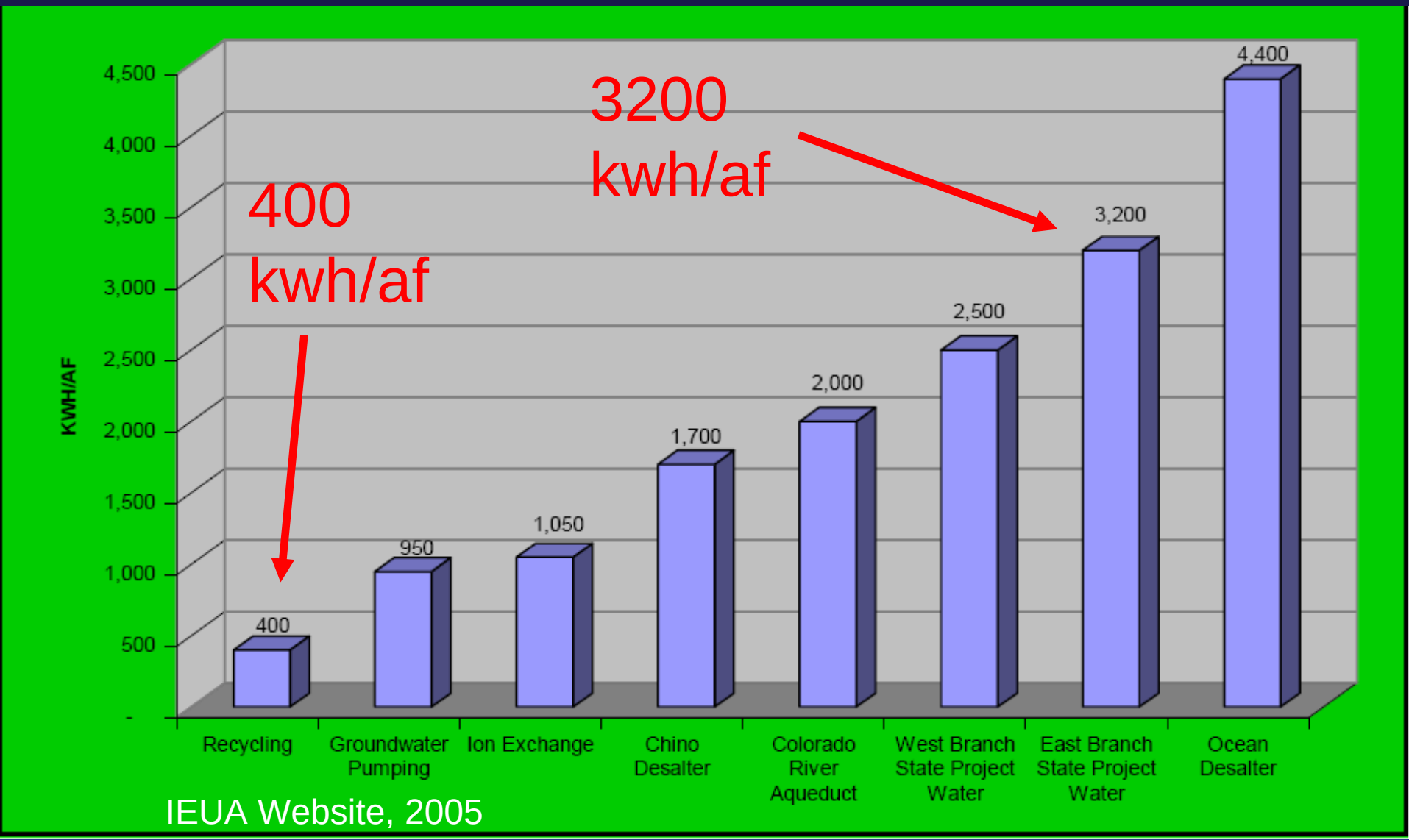
New Precipitation Extremes



Man Bites Dog: How Does Water Use Affect Climate?

- Energy Used to Pump, Pressurize, Treat, Heat Water
- In California Water Use Consumes
  - 20% of all electricity
  - 30% of all natural gas,
  - Diesel for 120,000 cars/year
- Saving Water Saves Lots of Energy
- Consider: carbon caps likely at least on electric power production
- Increased Price will reduce demand, other feedbacks possible.

Inland Empire Utility Agency Energy Intensity (kwh/af)



IEUA Website, 2005

Bibliography - 0

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- Brown, B.: 1988, Climate Variability and the Colorado River Compact: Implications for Responding to Climate Change, in Societal Responses to Regional Climatic Change, Glantz, M. ed., Westview Press, Boulder, CO.

Bibliography – 1

The Discovery of Global Warming, Spencer R. Weart, Harvard University Press, 2003. The entire book is available for free at: http://www.aip.org/history/climate/. It contains lots of interesting and very readable material. Provides a good perspective on the course of the discussion over many, many years.

The Two Mile Time Machine, Ice Cores, Abrupt Climate Change, and Our Future, Richard Alley, Princeton University Press, 2000. Fascinating, well-written, highly recommended.

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"Can we defuse the global warming time bomb?", Jim Hansen, 2003 http://pubs.giss.nasa.gov/abstracts/2003/Hansen.html. An enlarged version of his 2004 Scientific American article. Very good. Hansen has been a strong proponent of doing something to stop warming.

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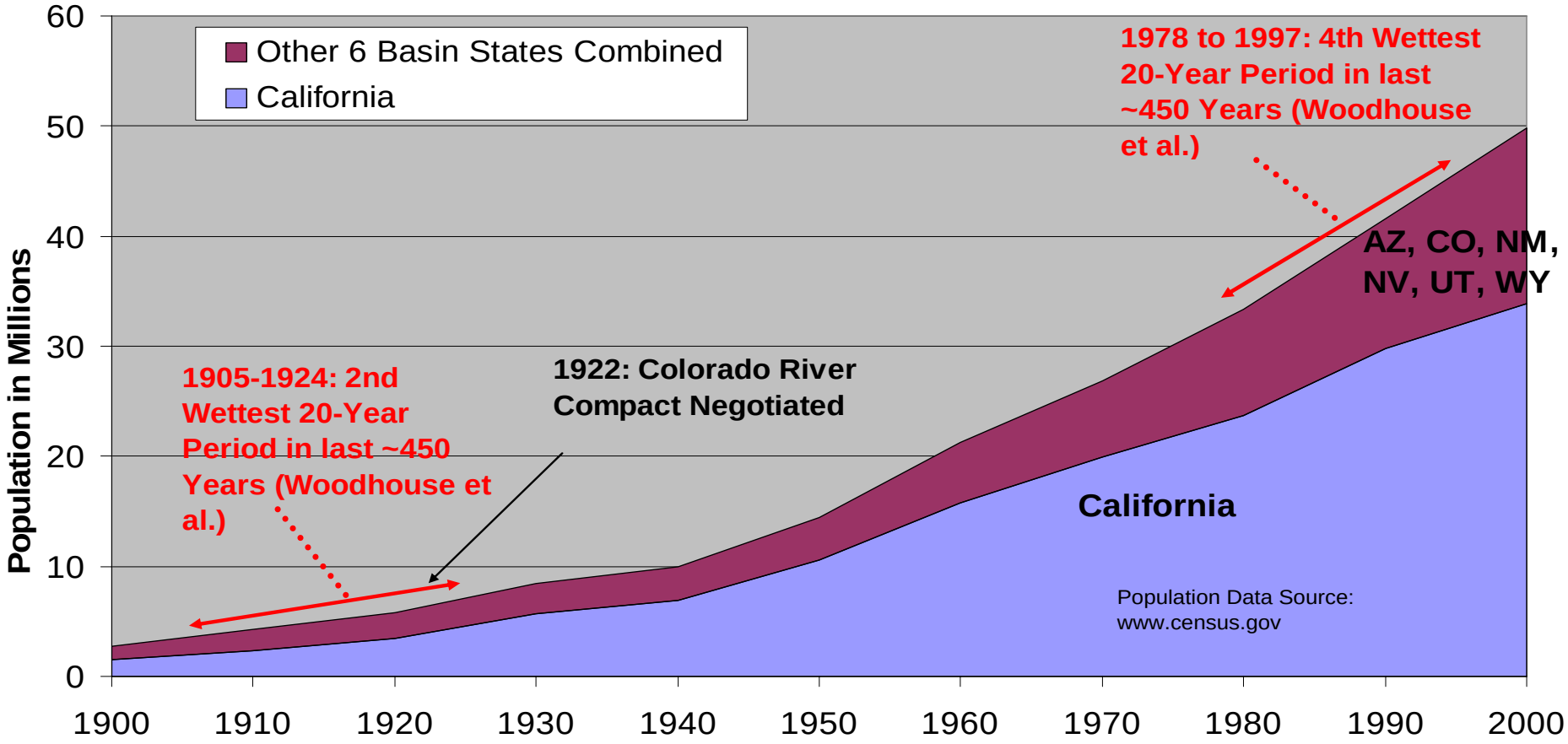
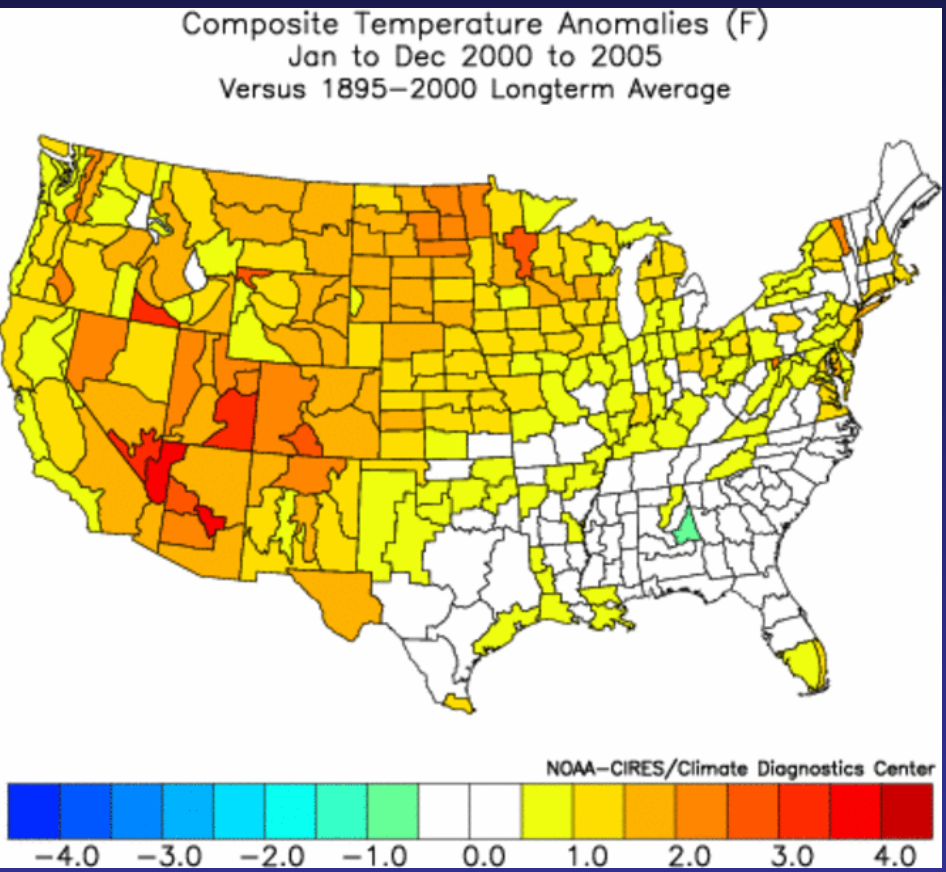
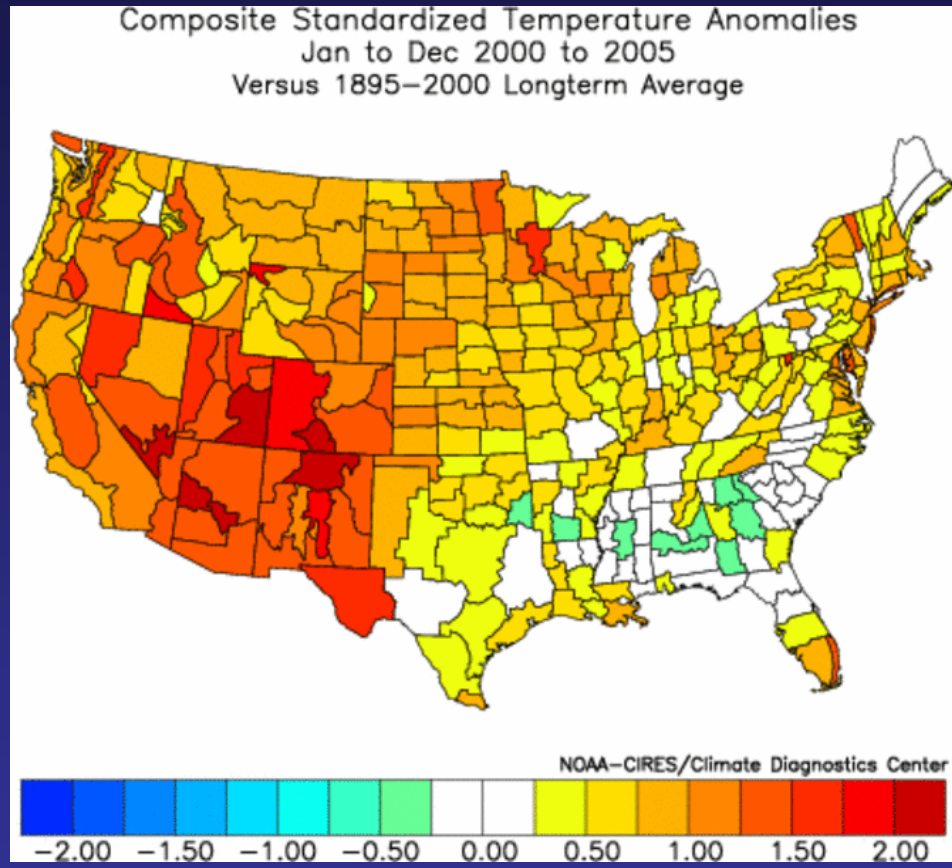
Population Growth of Colorado River Basin 1900-2000



Annual Mean Temperatures, 2000-2005.
Departures from 1895-2000 Mean.





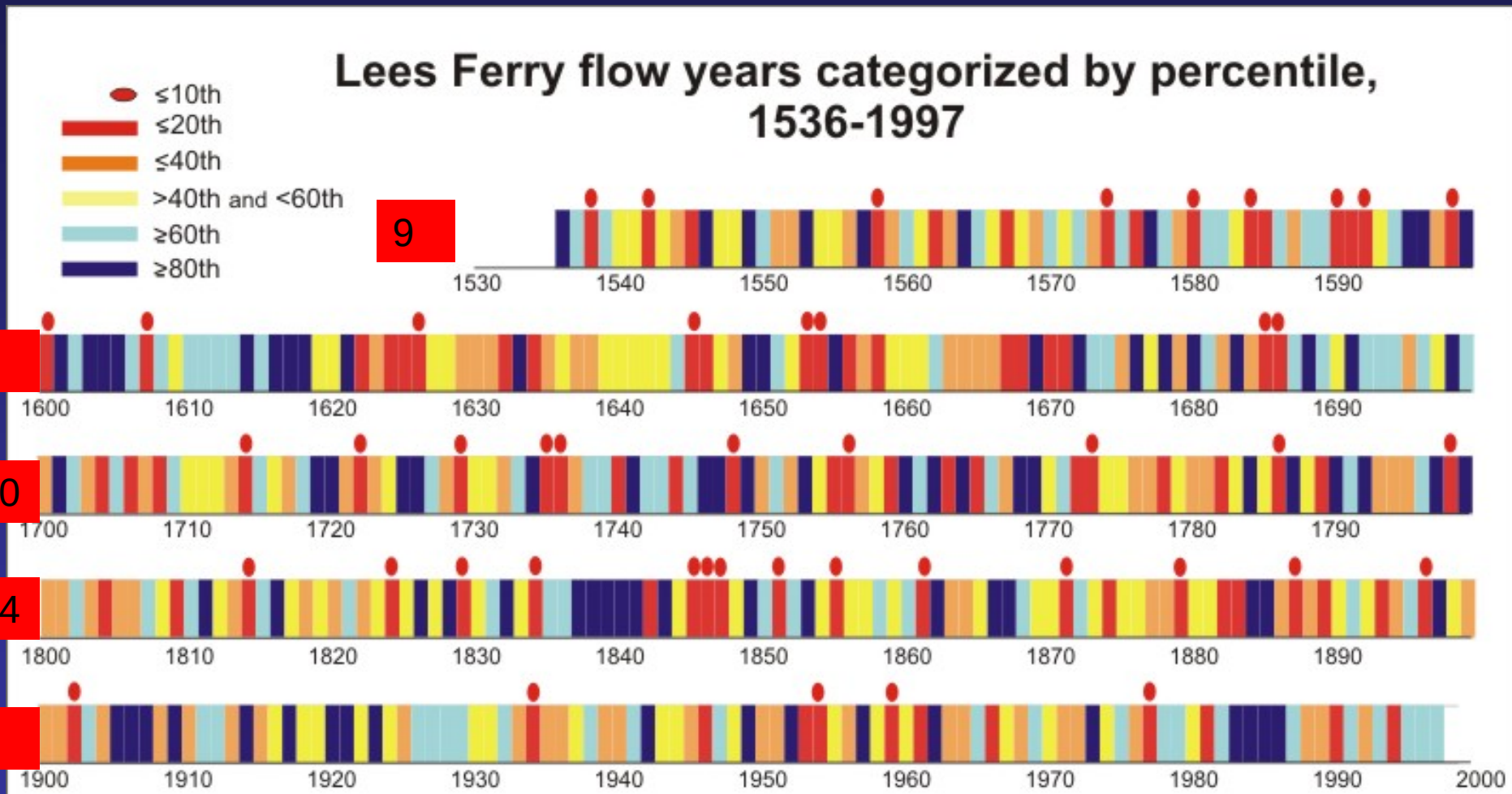
Non-standardized. Units: Degrees F. **Normalized (standard deviations).**

The West dominates recent U.S. warming.

Western Water Assessment

Colorado
University of Colorado at Boulder

There are other ways to examine features of the Lees Ferry streamflow reconstruction



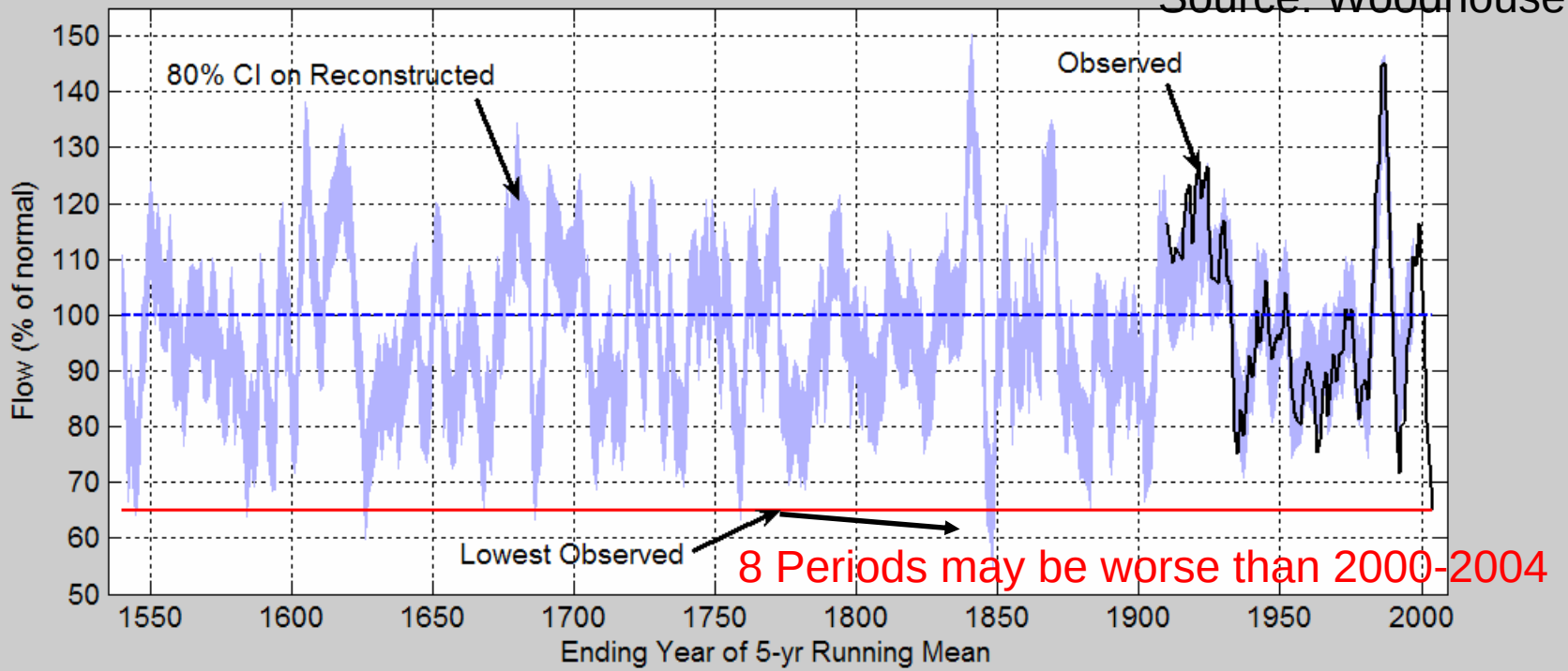
Extreme events are not evenly distributed over time

Source: Woodhouse

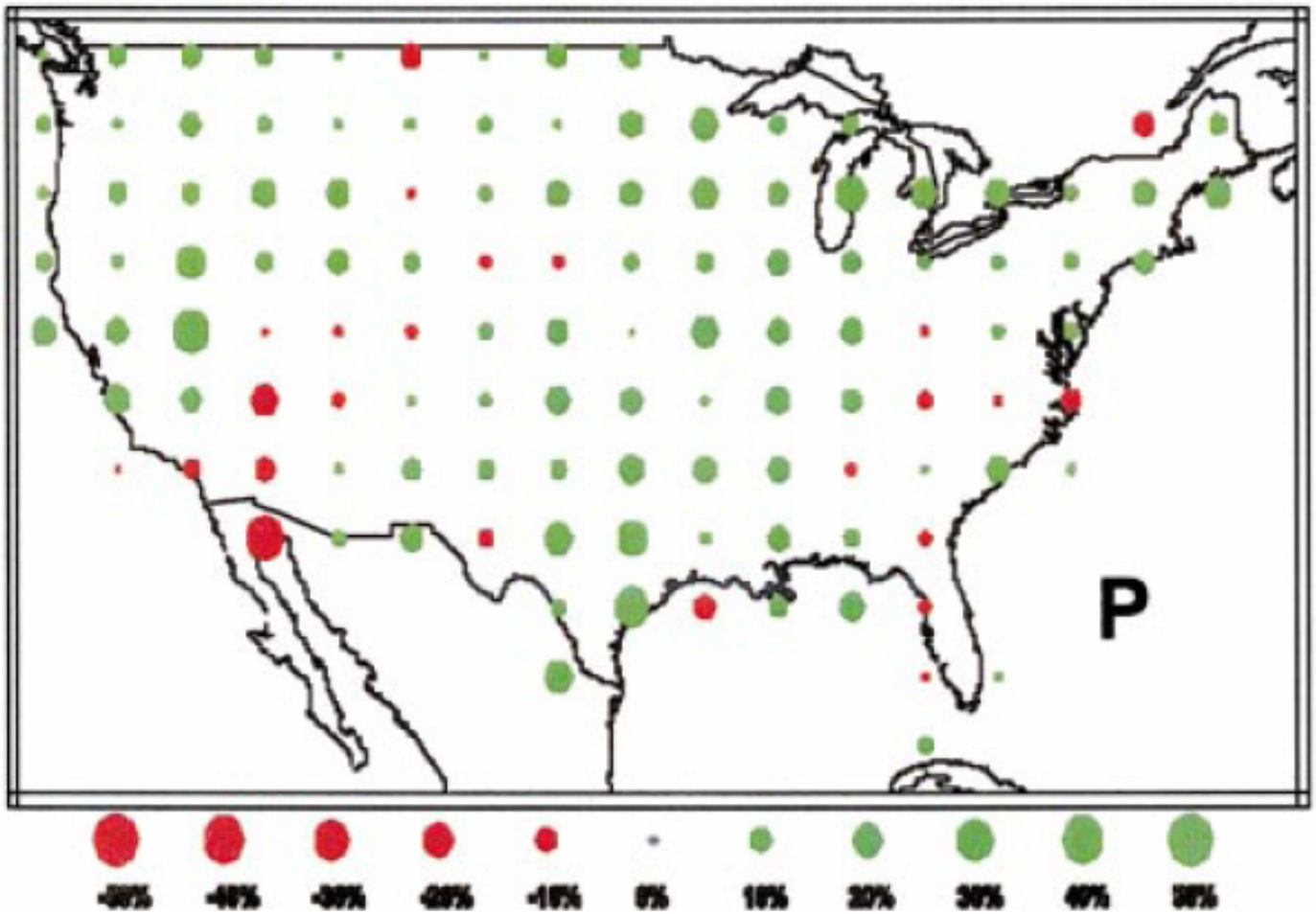
Lees Ferry Reconstruction, 1536-1997
5-Year Running Mean

Assessing the 1999-2004 drought in a multi-century context

Source: Woodhouse



100 Year Trend in Annual Precip



Western Water Assessment

Groisman, 2004

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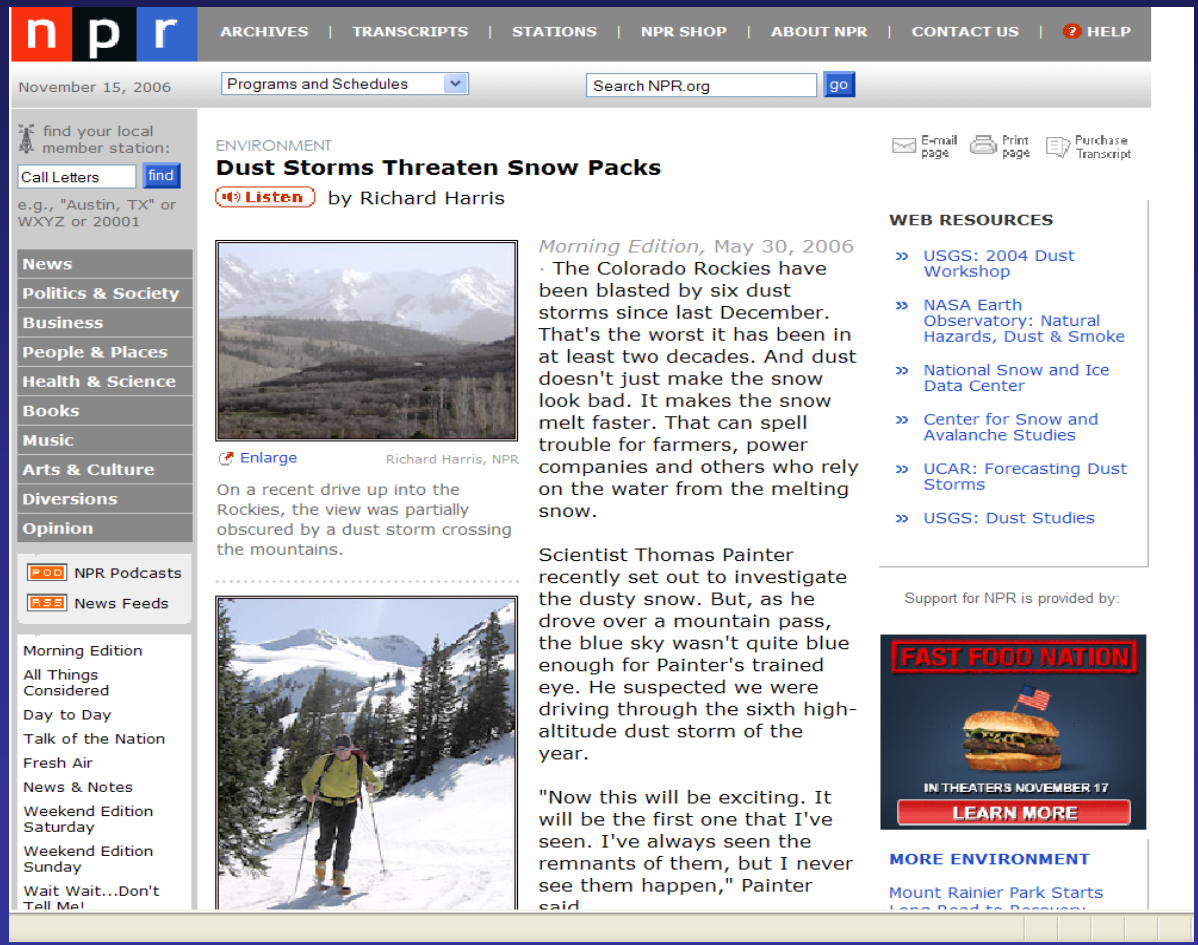
NOAA

‘Dust Storms Threaten Snowpacks’

Preliminary Findings:

- snow melt may occur up to 3 weeks earlier if significant dust
- strong connection with drought in Southwest



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ENVIRONMENT

Dust Storms Threaten Snow Packs

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Enlarge Richard Harris, NPR

On a recent drive up into the Rockies, the view was partially obscured by a dust storm crossing the mountains.

Morning Edition, May 30, 2006 · The Colorado Rockies have been blasted by six dust storms since last December. That's the worst it has been in at least two decades. And dust doesn't just make the snow look bad. It makes the snow melt faster. That can spell trouble for farmers, power companies and others who rely on the water from the melting snow.

Scientist Thomas Painter recently set out to investigate the dusty snow. But, as he drove over a mountain pass, the blue sky wasn't quite blue enough for Painter's trained eye. He suspected we were driving through the sixth high-altitude dust storm of the year.

"Now this will be exciting. It will be the first one that I've seen. I've always seen the remnants of them, but I never see them happen," Painter said.

WEB RESOURCES

- USGS: 2004 Dust Workshop
- NASA Earth Observatory: Natural Hazards, Dust & Smoke
- National Snow and Ice Data Center
- Center for Snow and Avalanche Studies
- UCAR: Forecasting Dust Storms
- USGS: Dust Studies

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