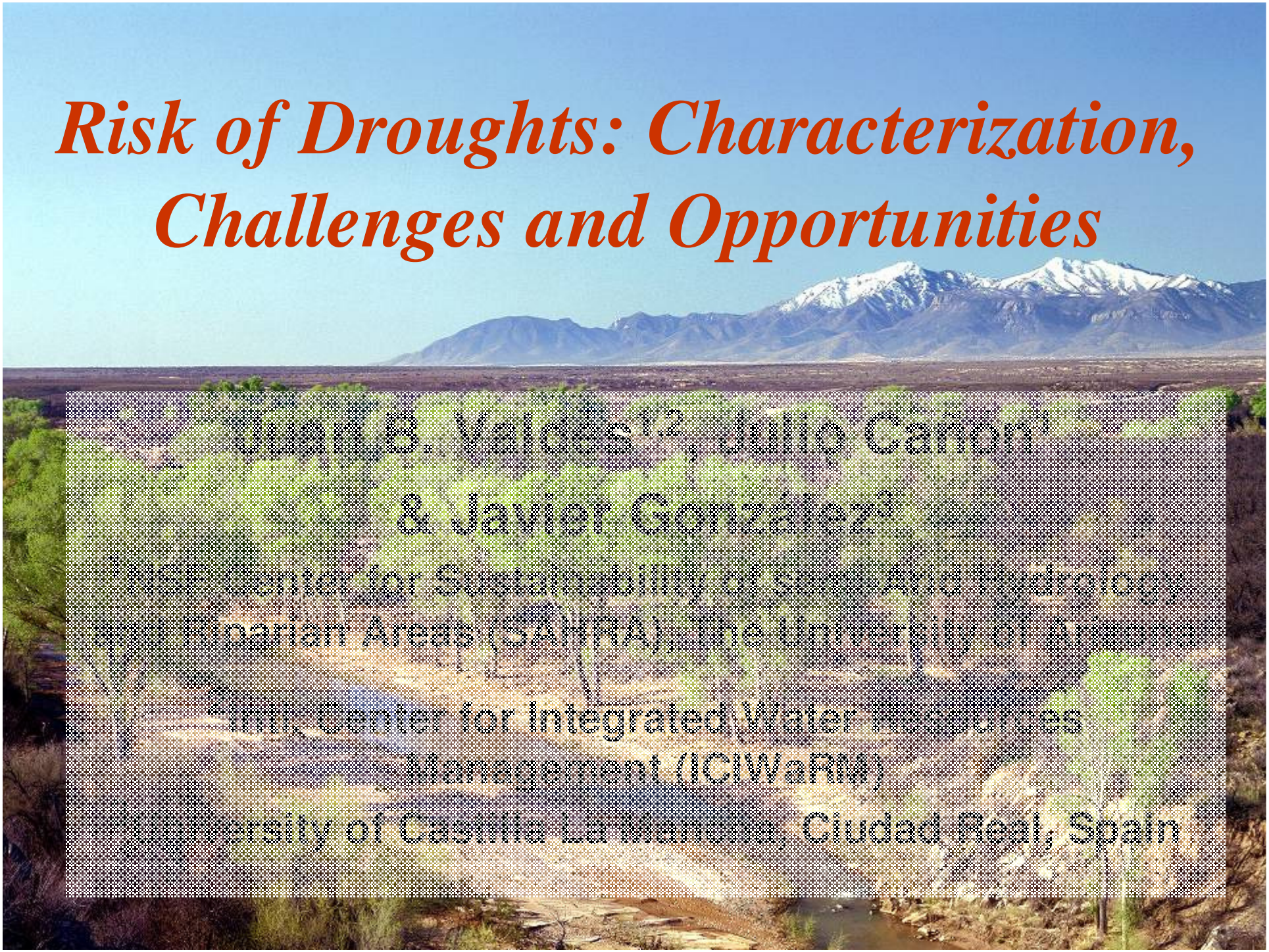
Risk of Droughts: Characterization, Challenges and Opportunities



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& Javier González[2]

[1] Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA), The University of Arizona

[2] Int. Center for Integrated Water Resources Management (ICIWaRM)

University of Castilla La Mancha, Ciudad Real, Spain

Outline

- Drought Characterization Challenges
- Historic Record: Instrumental and Paleo
- IPCC AR4
  - Precipitation
  - Extremes: floods and droughts
- Examples: The Colorado and Conchos basins
- Final Comments

Drought Definition

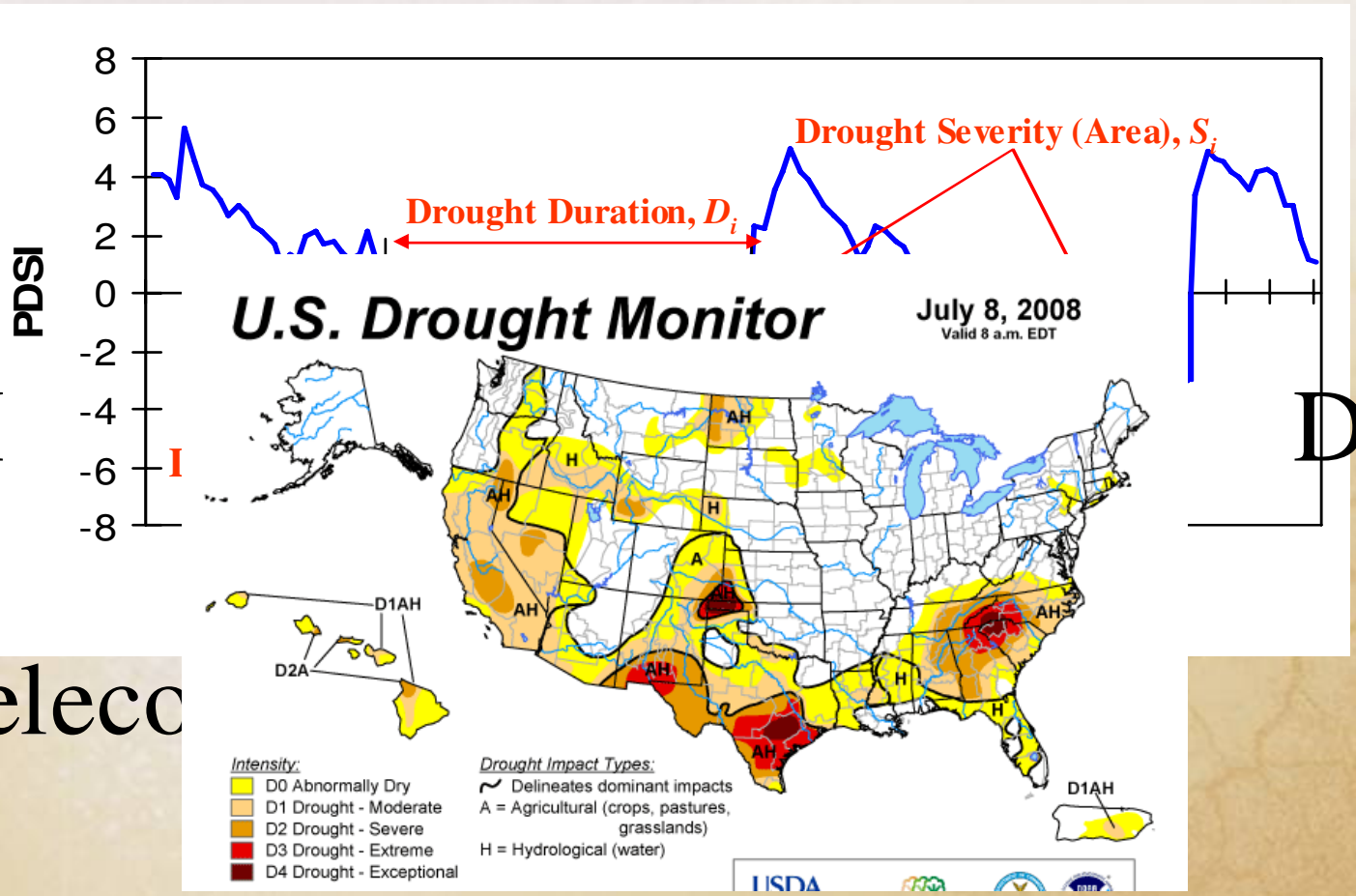
*"A period of **abnormally** dry weather **sufficiently prolonged** for the lack of water to cause **serious hydrologic imbalance** in the affected area"*

(Huschke, R.E., ed. 1959, *Glossary of Meteorology*)

- ***Abnormal***: A hydrologic events that requires long records to characterize
- ***Sufficiently prolonged***: duration characteristic
- ***Serious imbalance***: severity characteristic

Drought Characterization Challenges

- Multiple characteristics: magnitude, duration, intensity/peak
- L
  d
- L
- M
- A
- Telecc

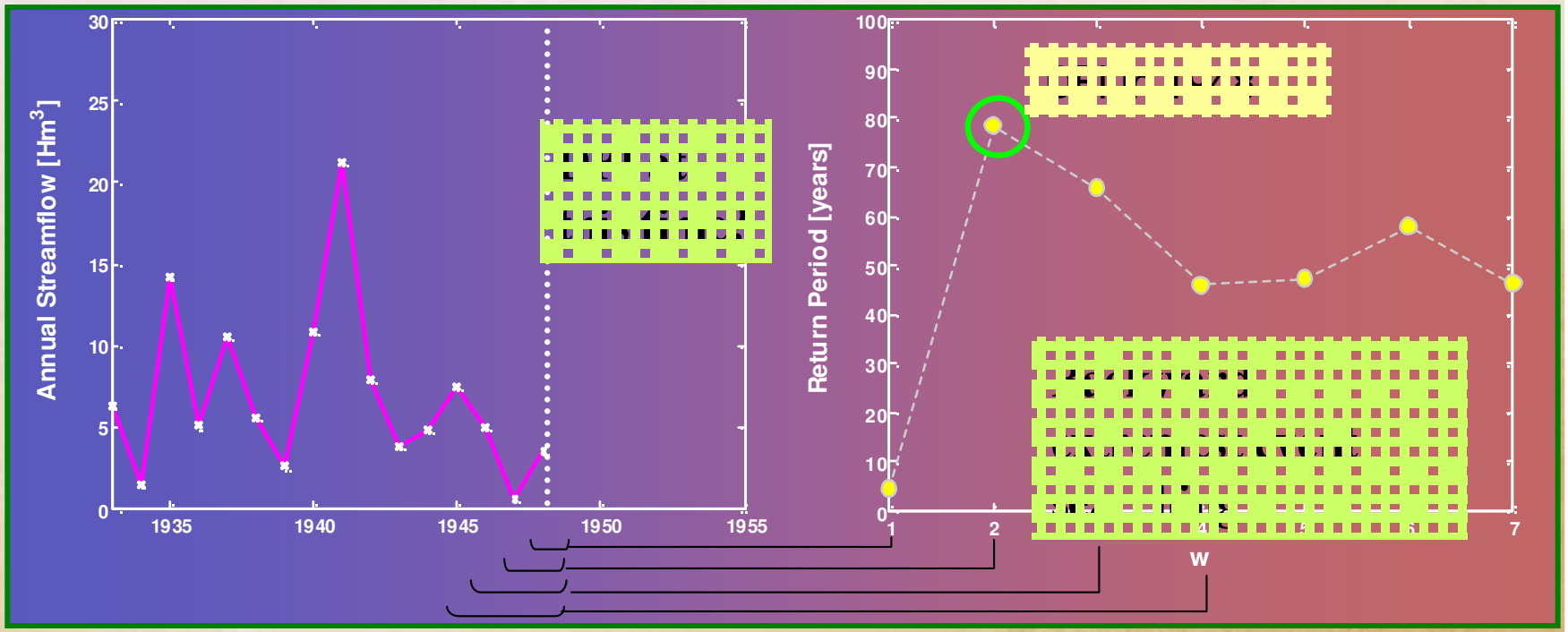


DFI

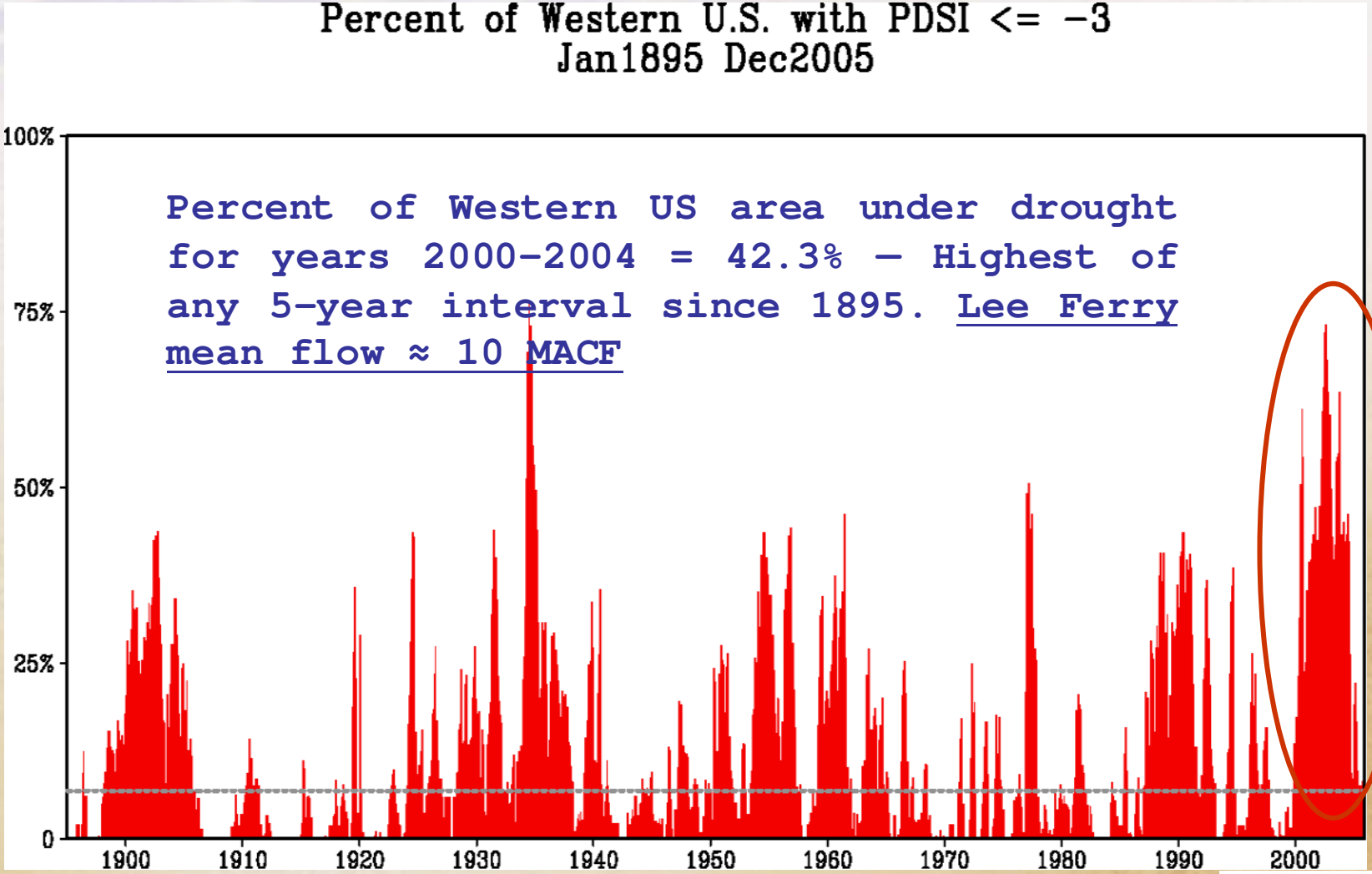
Drought Frequency Index: DFI

The DFI (González and Valdés, 2004, 2007) allows one to:

1. statistically quantify the deviation from normality of multidimensional events
2. represents this deviation as a return period



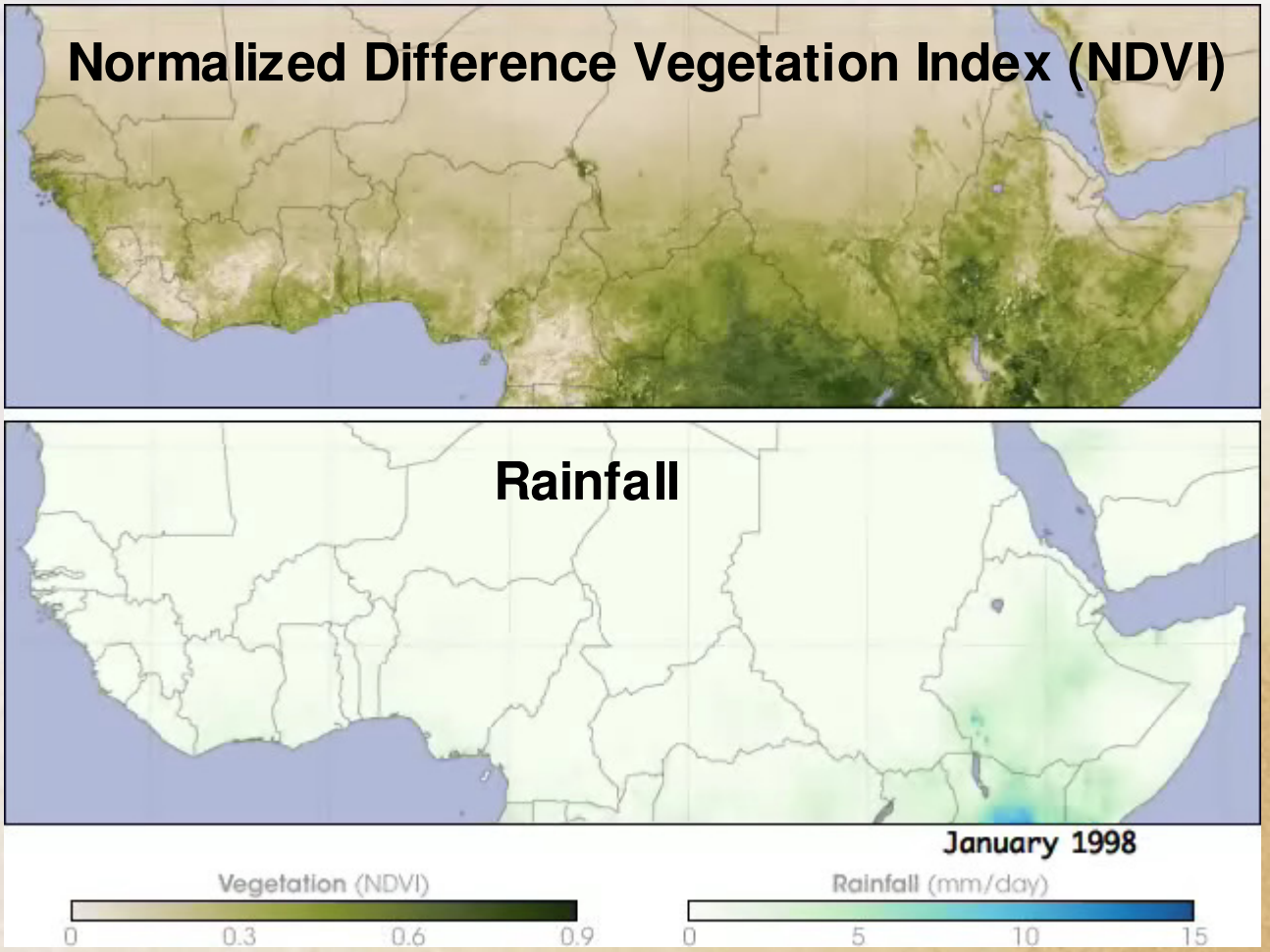
Geographically pervasive



Climate Diagnostics Center

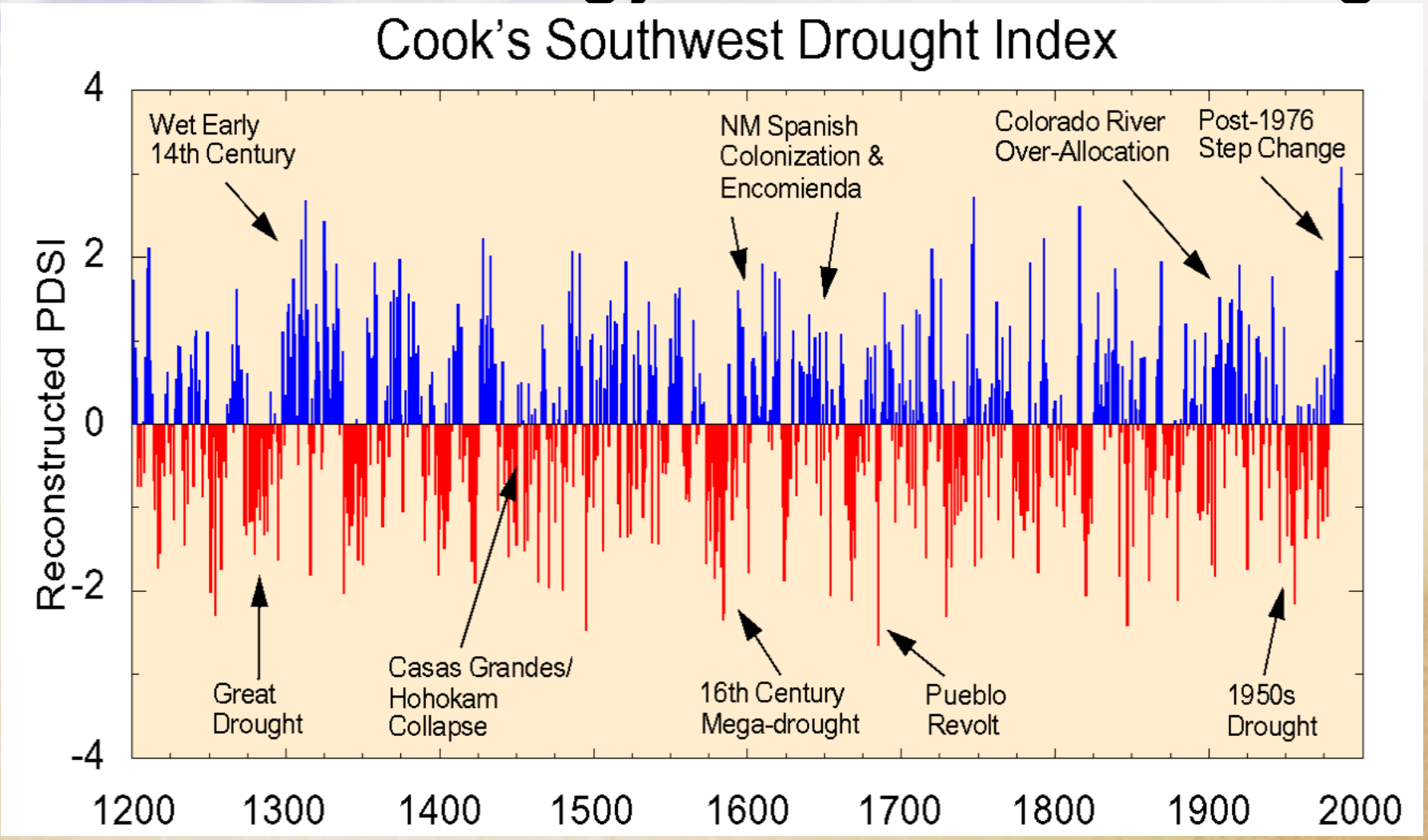
Monitoring vegetation and rainfall patterns

30 years of data reveal seasonal and interannual changes in precipitation and vegetation, but no large-scale desertification.



Vegetation in the Sahel follows seasonal and interannual rainfall patterns. Simon & Allen, 2007

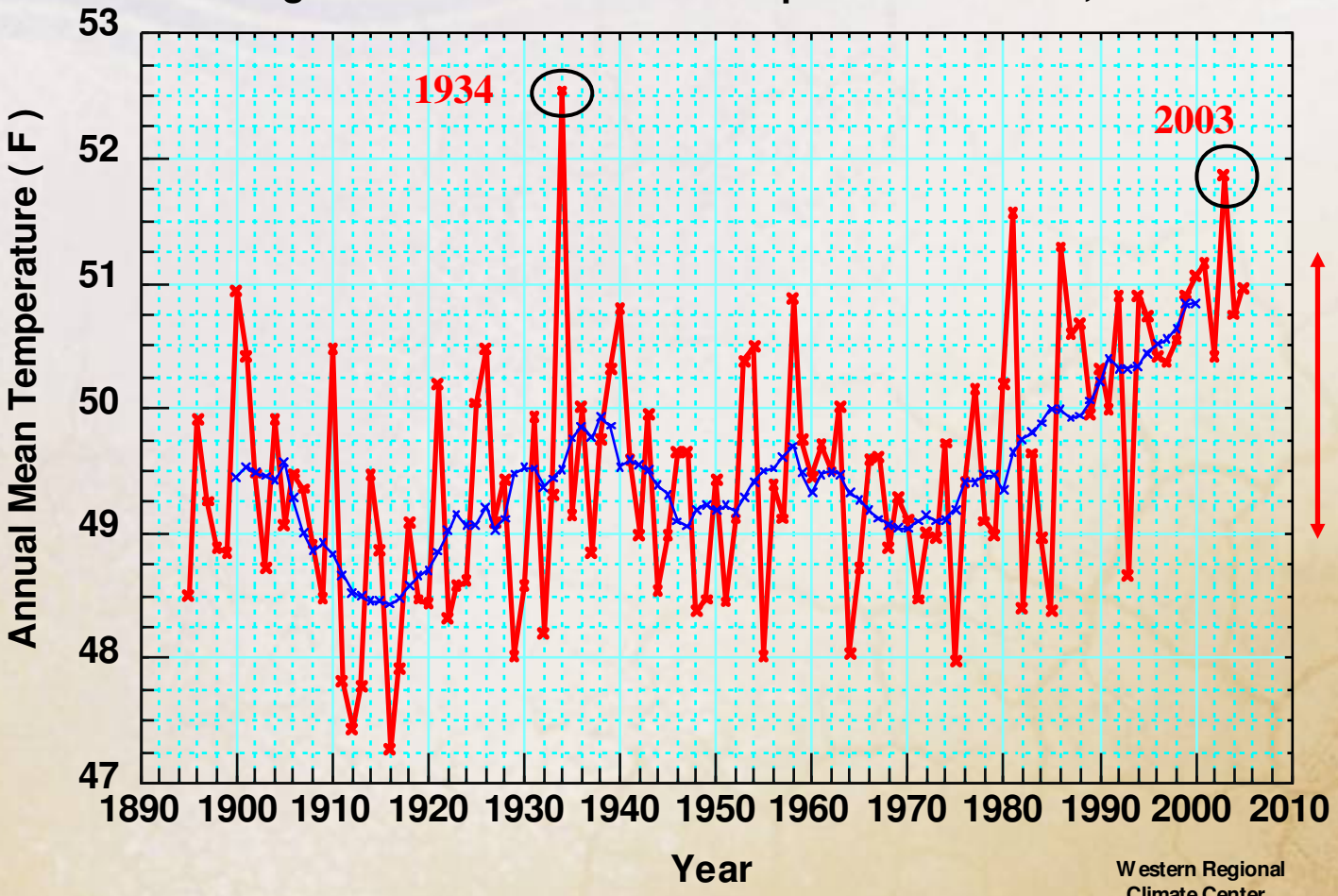
Paleoclimatology based on tree rings



Severe and prolonged droughts often coincide with periods of major social upheaval.

Slide from J. Betancourt

Western United States (11 states) Annual Jan-Dec Temperature
Provisional data from NCDC / CPC. Blue: 11-year running mean.
Units: Deg F. Data source NOAA cooperative network, thru Jan 2006.



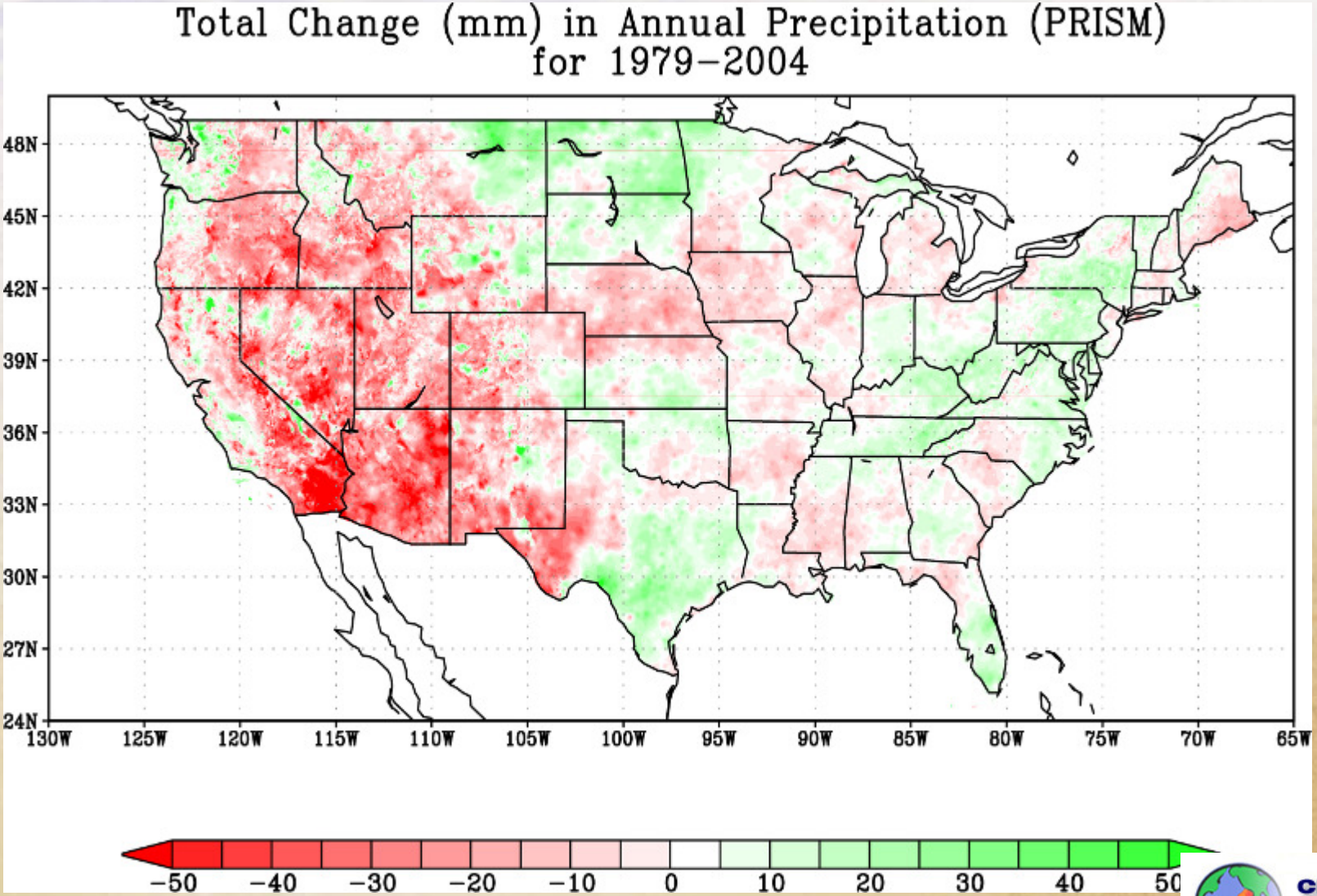
~ 2˚F rise in temperature in the West

Western Regional Climate Center

The Western US has been warming rapidly since the mid-1970's

Climate Diagnostics Center

Precipitation

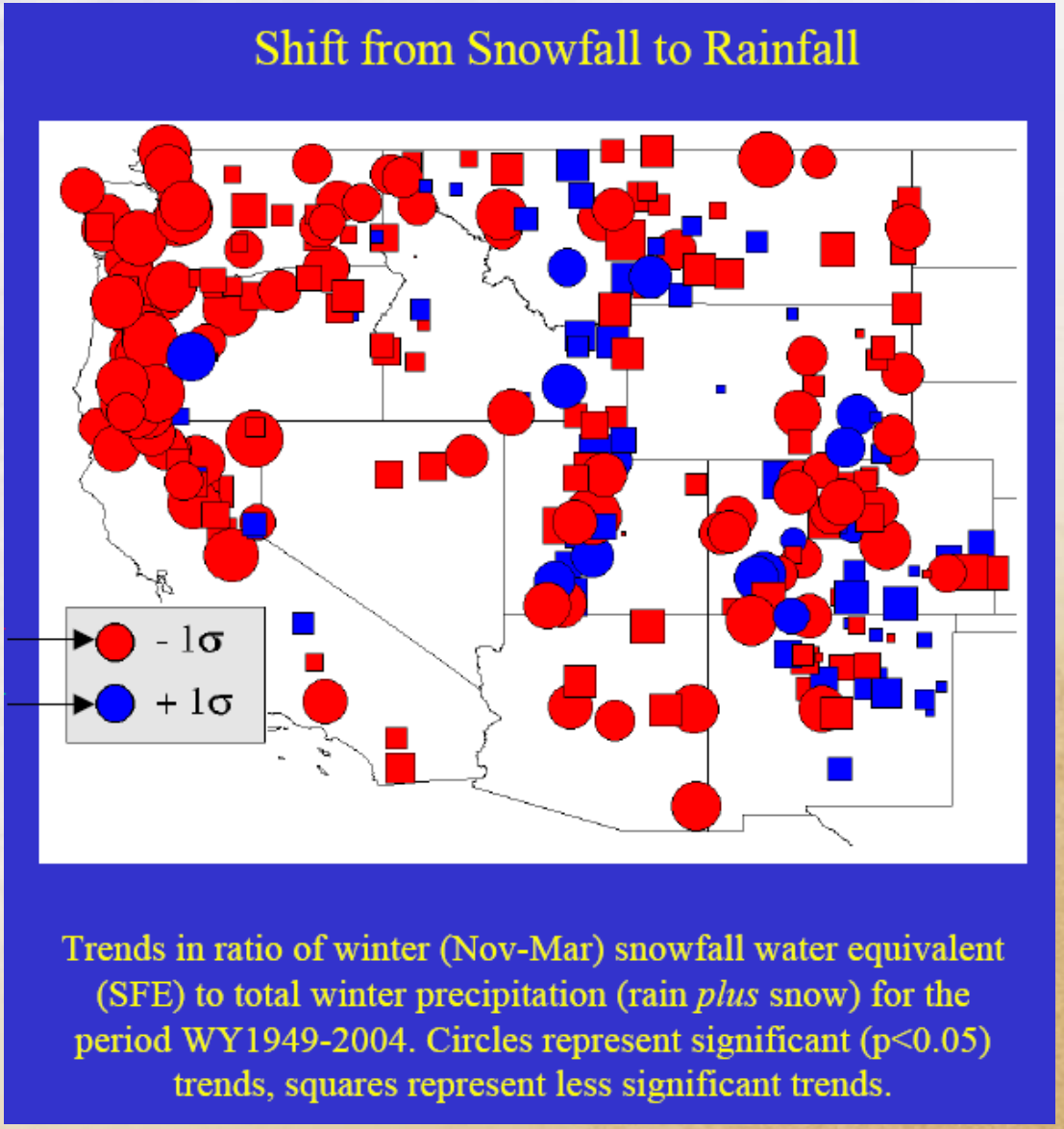


Climate Diagnostics Center

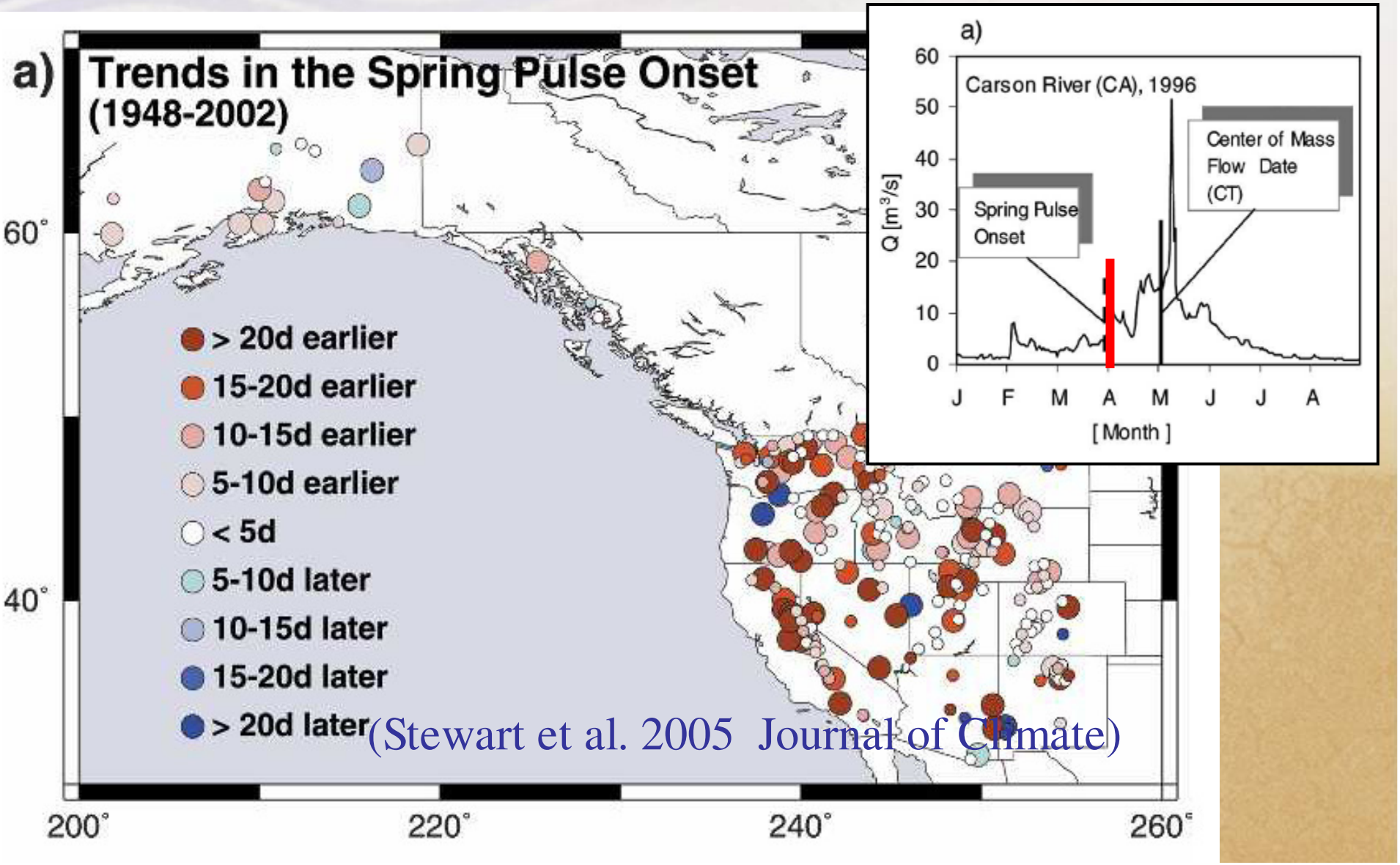
Changes in Type of Precipitation

More Rain, Less Snow
More Snow, Less Rain

(N. Knowles, USGS)



Spring Onset Changes



(Stewart et al. 2005 Journal of Climate)

Summary of Observations: US Southwest

- Change of precipitation from snow to rain
- Earlier onset of spring snowmelt
- Earlier leaf-out dates
- Increased frequency of low flows
- Overall warming, particularly at higher altitudes

How climate change affects water resources

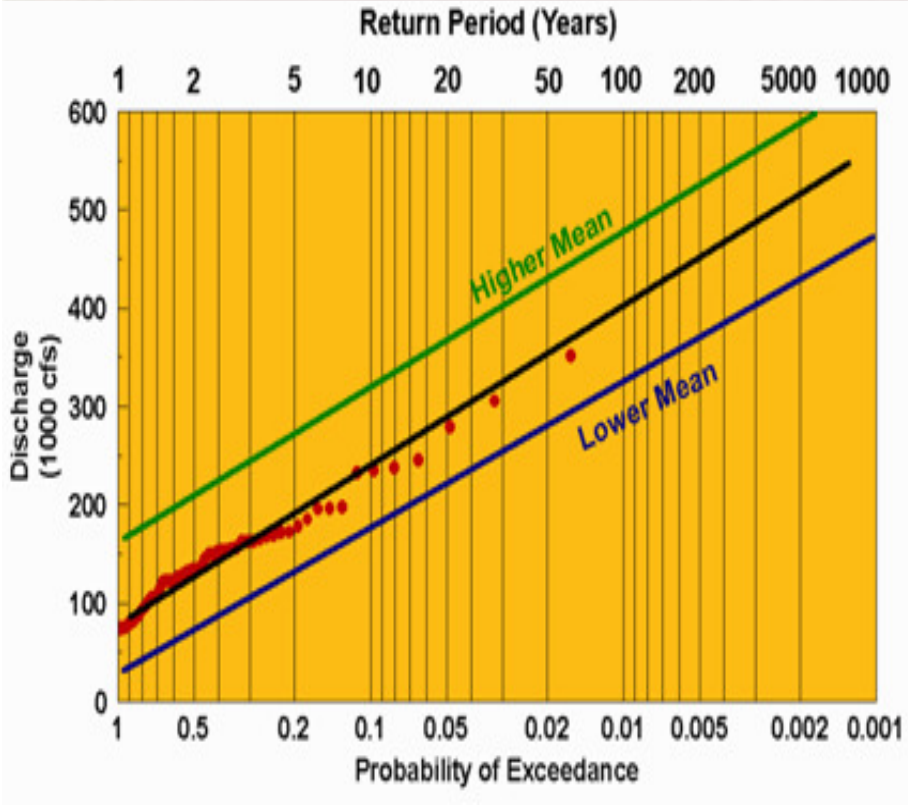
Rising temperatures and changing patterns of precipitation are leaving arid and semi-arid regions more vulnerable to droughts, floods, and crop failure.

The postulated **end of climatic stationarity** means historic data are, at best, less predictive of the future; at worst, dangerously misleading.

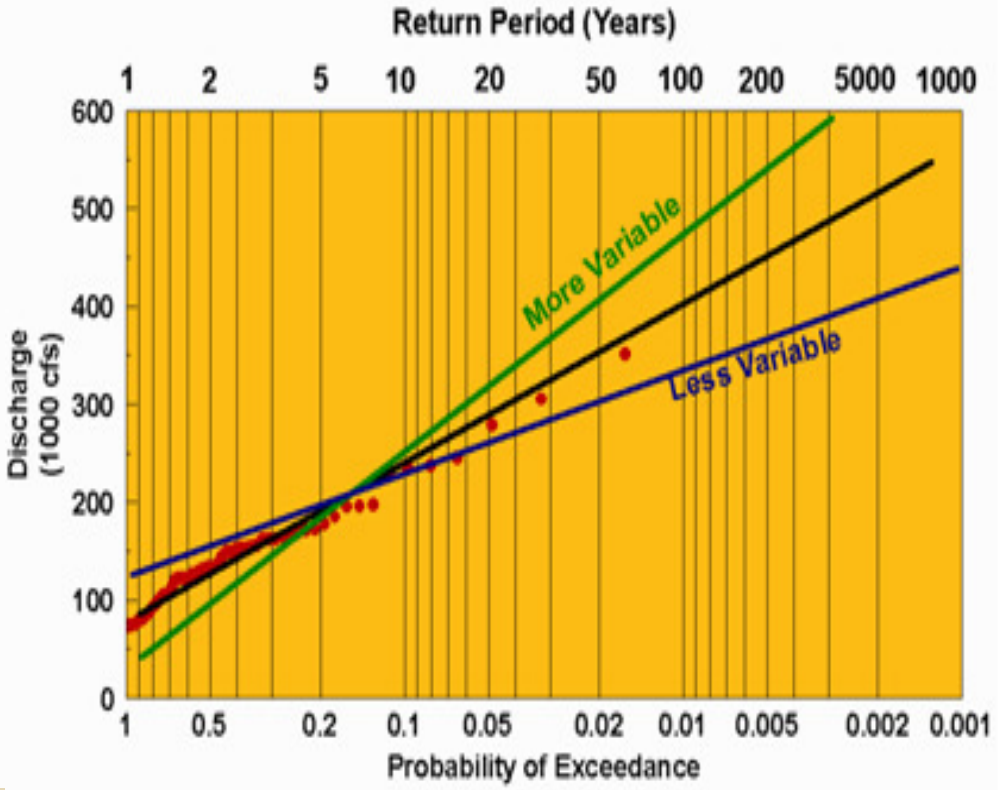
Water-energy nexus is intensifying; new sources of water require more energy; some sustainable energy sources require far more water.

IPCC: "Climate change will intensify the hydrologic cycle"

changes in the averages/ trends



changes in variability (magnitude, severity, duration)



Summary of IPCC Precipitation

- **A robust result, consistent across climate model projections, is that higher precipitation extremes in warmer climates are very likely to occur**

- **Precipitation intensity increases almost everywhere, but particularly at mid- and high-latitudes where mean precipitation also increases**

Floods and Droughts

- "*A warmer climate, with its increased climate variability, will increase the risk of both floods and droughts"* (Wetherald and Manabe, 2002) IPCC AR4, 2007

- As mentioned before, droughts have many definitions and drought risks are influenced by climatic and non-climatic factors

Summary IPCC Droughts

- **Droughts over low- and mid-latitude continental interiors in summer are likely to increase, e.g., the proportion of the global land surface in extreme drought is predicted to increase by a factor of 10 to 30; from 1-3 % at present to 30% by 2090s.**
- **The number of extreme drought events per 100 years and mean drought duration are likely to increase by factors of two and six, respectively, by the 2090s.**
- **A decrease in summer precipitation in southern Europe, accompanied by rising temperatures, which enhance evaporative demand, would inevitably lead to reduced summer soil moisture and more frequent and more intense droughts.**

Drought Recurrence Projections

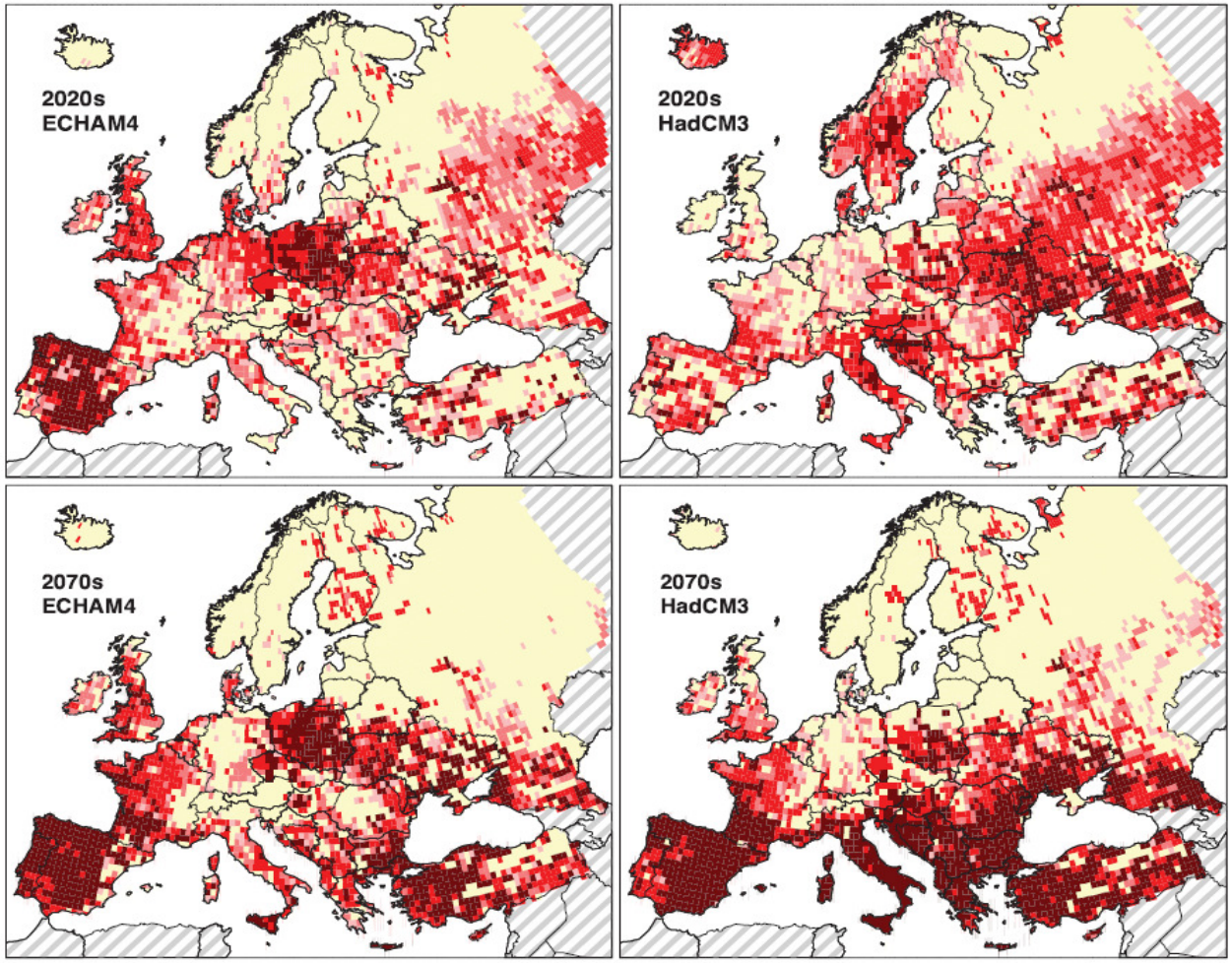


Figure 3.6. *Change in the recurrence of 100-year droughts, based on comparisons between climate and water use in 1961 to 1990 and simulations for the 2020s and 2070s (based on the ECHAM4 and HadCM3 GCMs, the IS92a emissions scenario and a business-as-usual water-use scenario). Values calculated with the model WaterGAP 2.1 (Lehner et al., 2005b).*

Example: Colorado River Basin

(NRC, 2007)

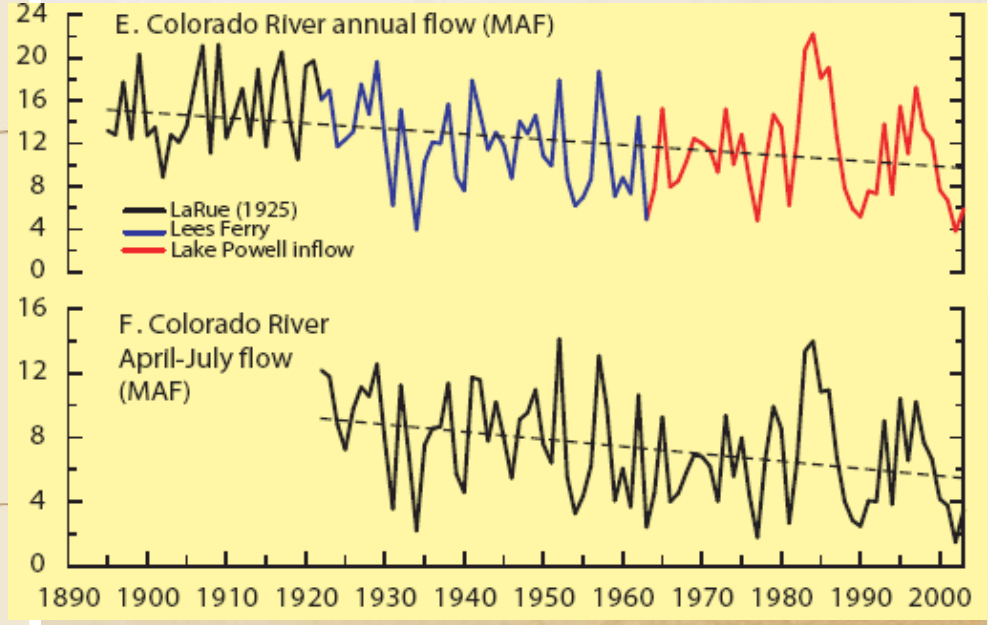
Colorado river allocations:

Upper basin: 7.5 MAF (9.3 BCM)

Lower basin: 7.5 MAF (9.3 BCM)

Mexico: 1.5 MAF (1.9 BCM)

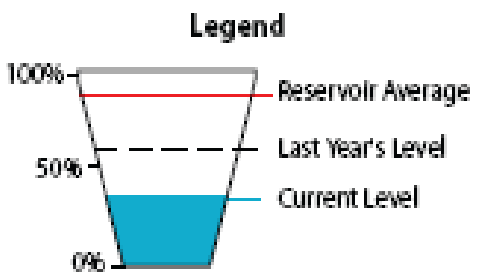
Total 16.5 MAF (20.5 BCM)



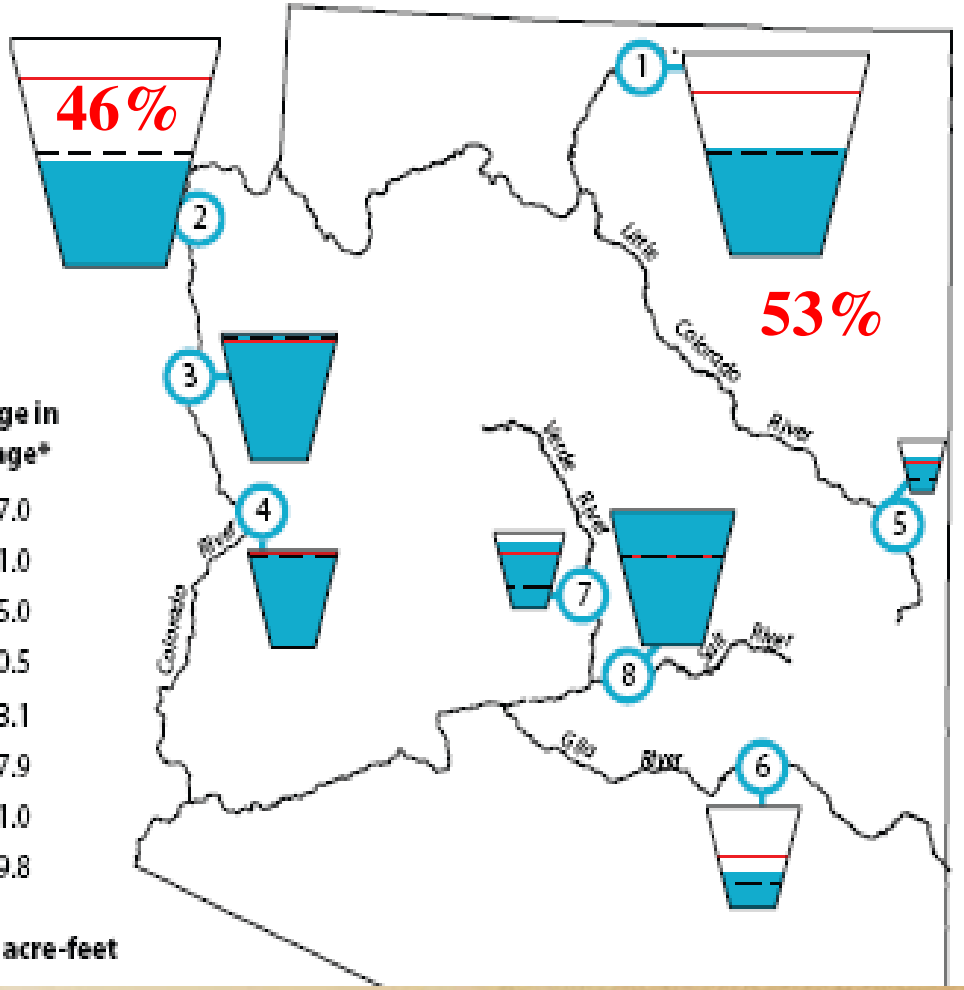
(USGS, 2004)

Colorado Basin Reservoir Status

Figure 6. Arizona reservoir levels for May 2008 as a percent of capacity. The map also depicts the average level and last year's storage for each reservoir. The table also lists current and maximum storage levels, and change in storage since last month.



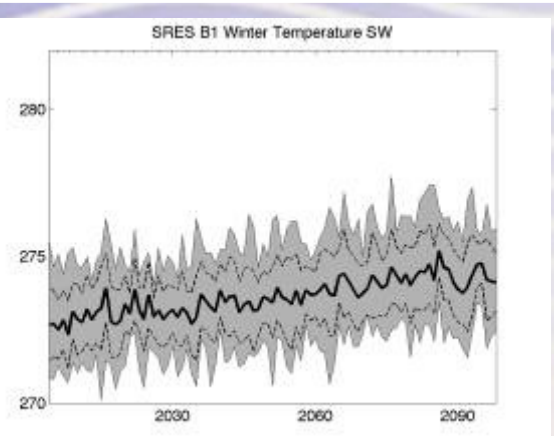
size of cups is representational of reservoir size, but not to scale

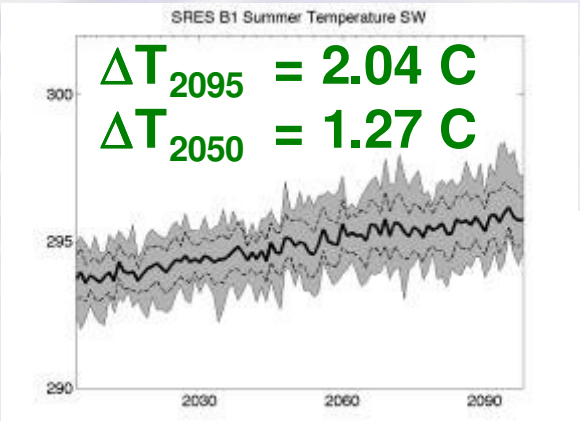


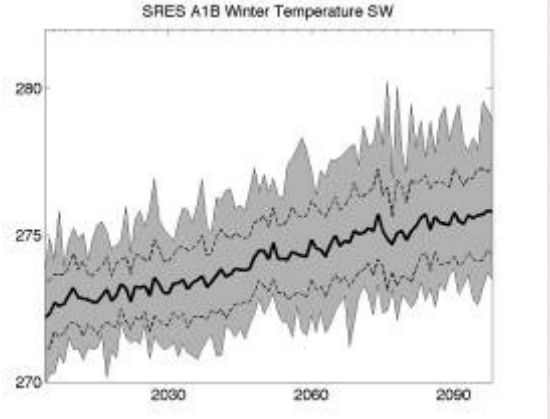
Reservoir Name	Capacity Level	Current Storage*	Max Storage*	Change in Storage*
1. Lake Powell	53%	12,812.0	24,322.0	1617.0
2. Lake Mead	46%	12,132.0	26,159.0	-331.0
3. Lake Mohave	100%	1,724.8	1,810.0	1075.0
4. Lake Havasu	96%	596.3	619.0	30.5
5. Lyman Reservoir	62%	18.7	30.0	3.1
6. San Carlos	35%	305.3	875.0	-27.9
7. Verde River System	86%	247.7	287.4	-31.0
8. Salt River System	97%	1,972.8	2,025.8	-9.8

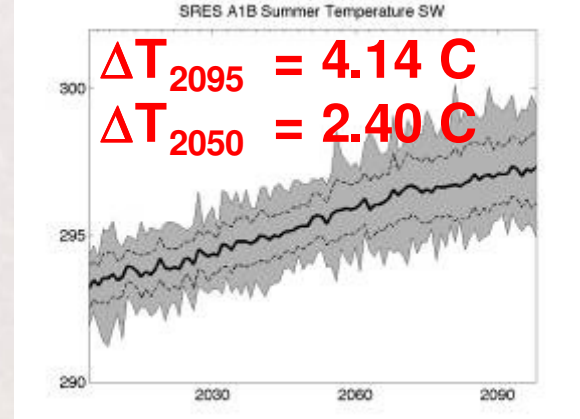
* thousands of acre-feet

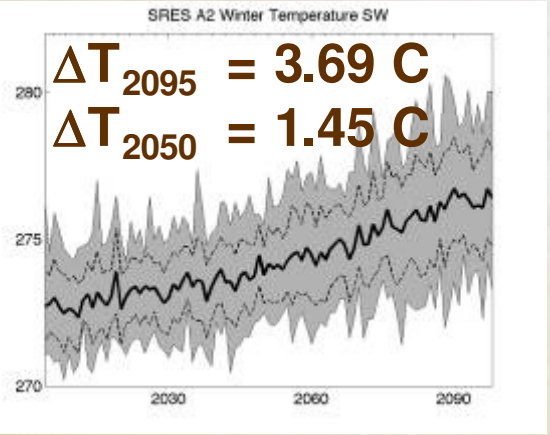
CLIMAS Southwest Outlook, June 2008

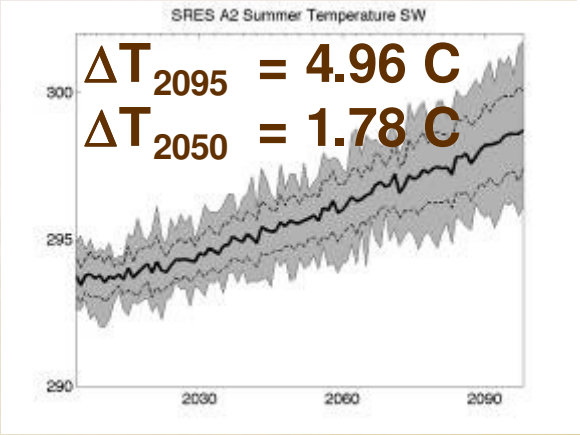


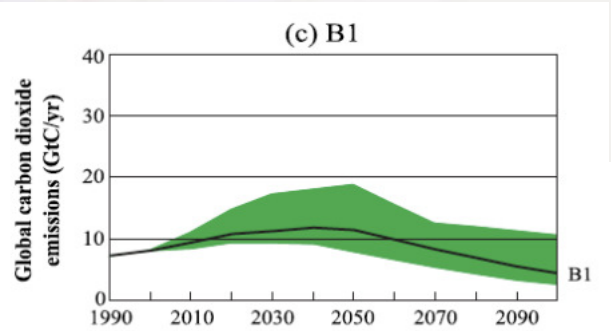


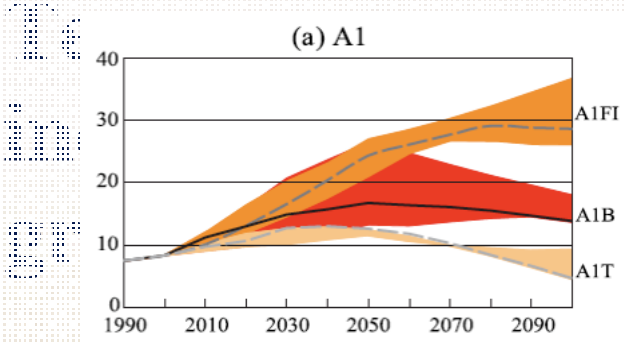


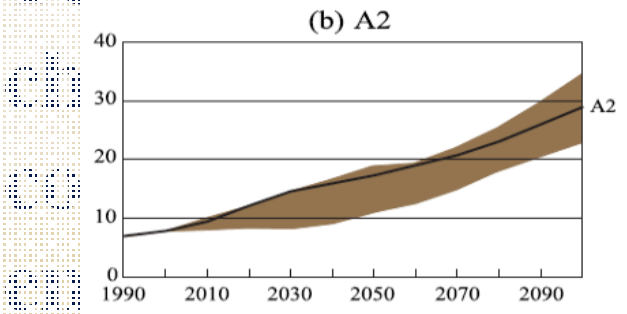




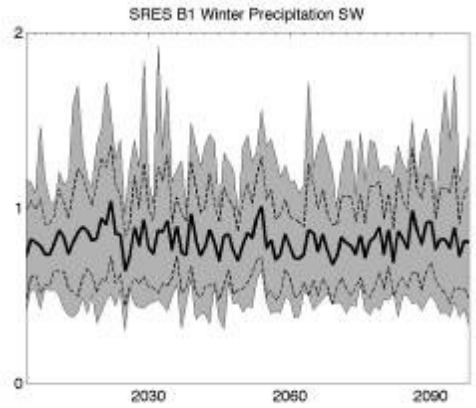


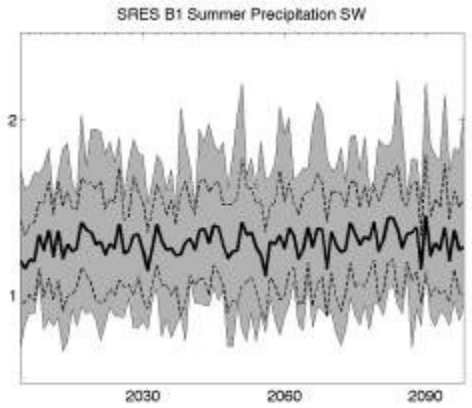


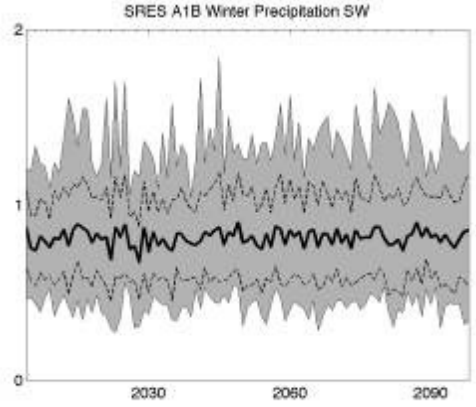


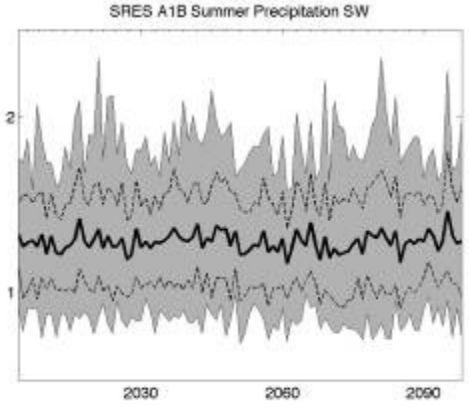


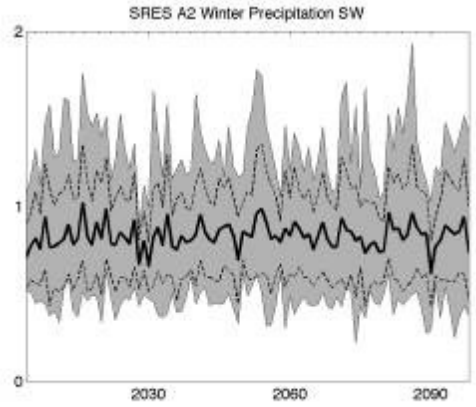
From: Dominguez et al., 2007

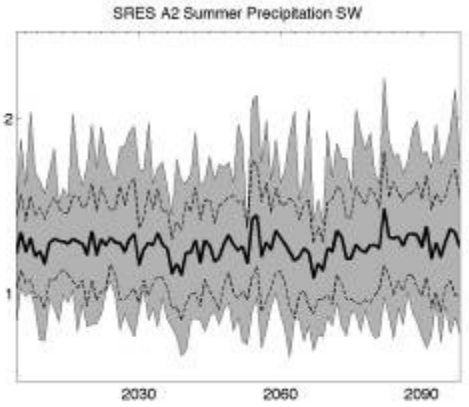








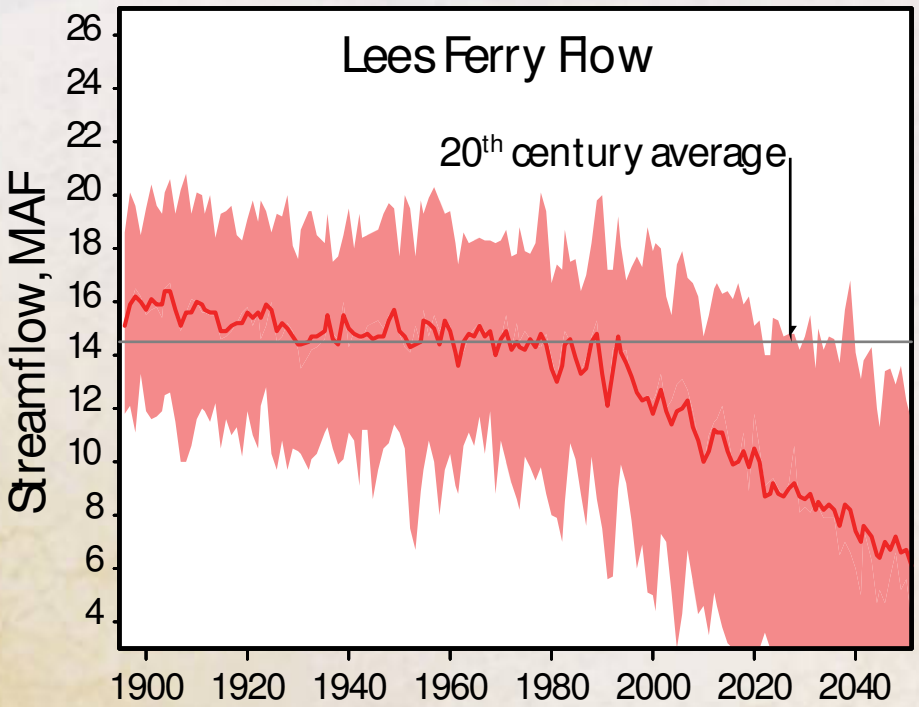


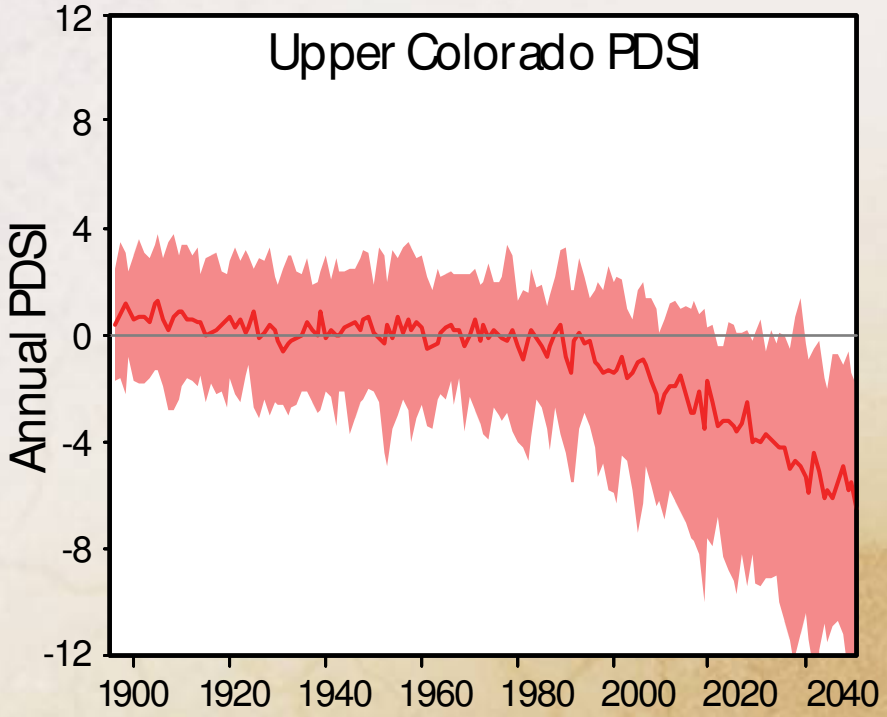


There are no significant changes in precipitation in winter or summer.

From: Dominguez et al, 2007

Climate change impacts on U.S. Southwest water resources



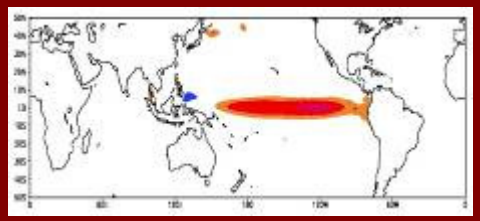


Source: "Past Peak Water in the Southwest"
Hoerling & Eischeid
Southwest Hydrology, Jan/Feb 2007, p. 35

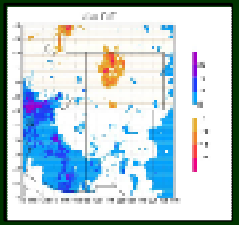
Goal: generate high-resolution SW climate data that account for ENSO-related variability.

Evaluation of coupled climate models over the Southwestern US.

ENSO and its climate teleconnections in selected coupled climate models.

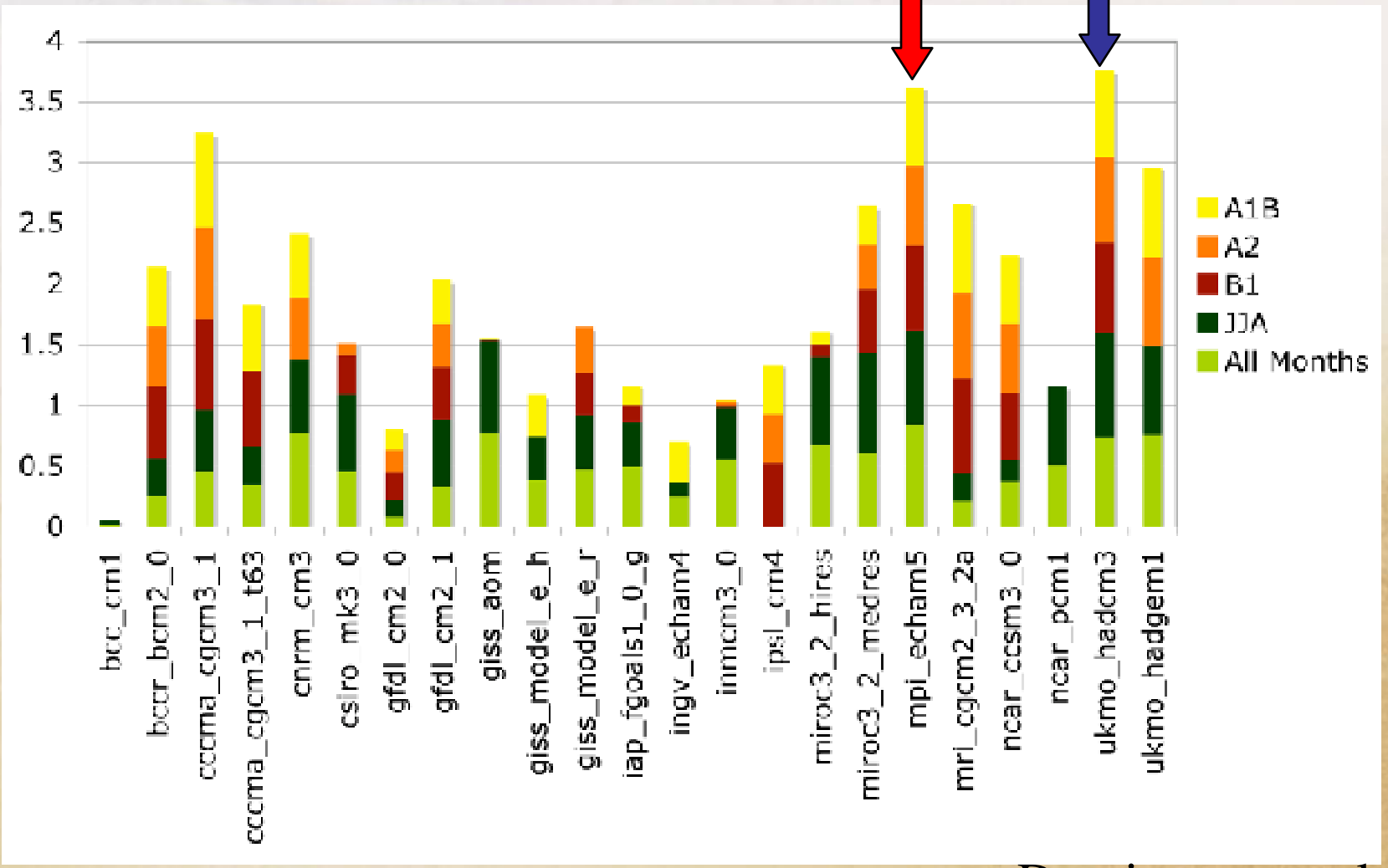


Downscaling of climate model data using ENSO projections.



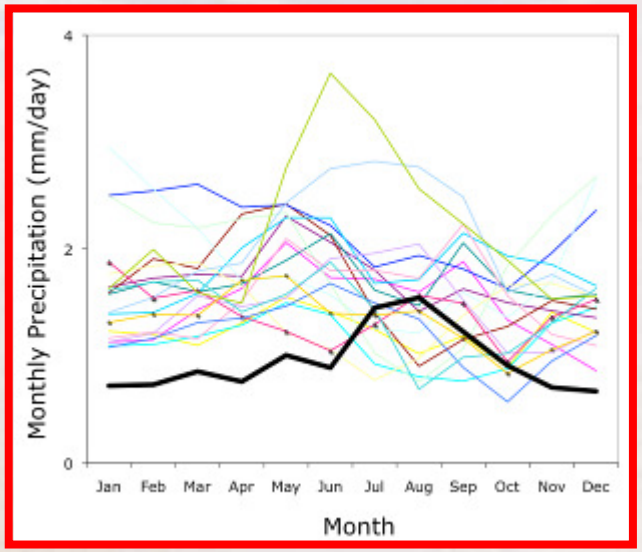
From: Dominguez et al, 2007

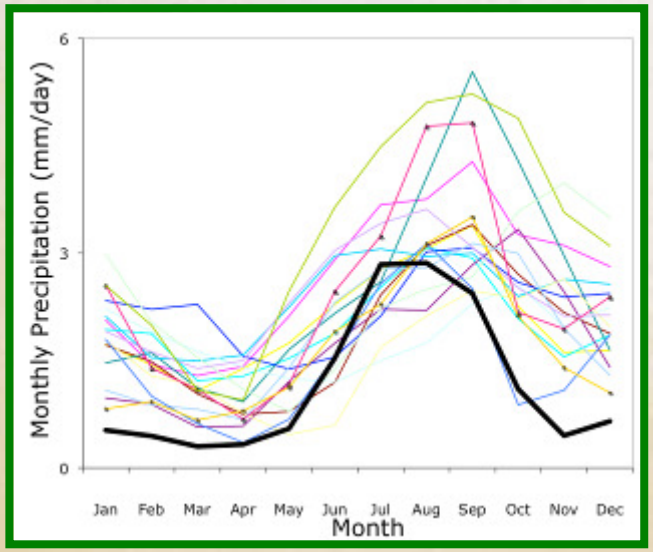
The Max Plank Institute and the UK. Met. Office models perform the best in the U.S. Southwest.



Dominguez et al, 2008

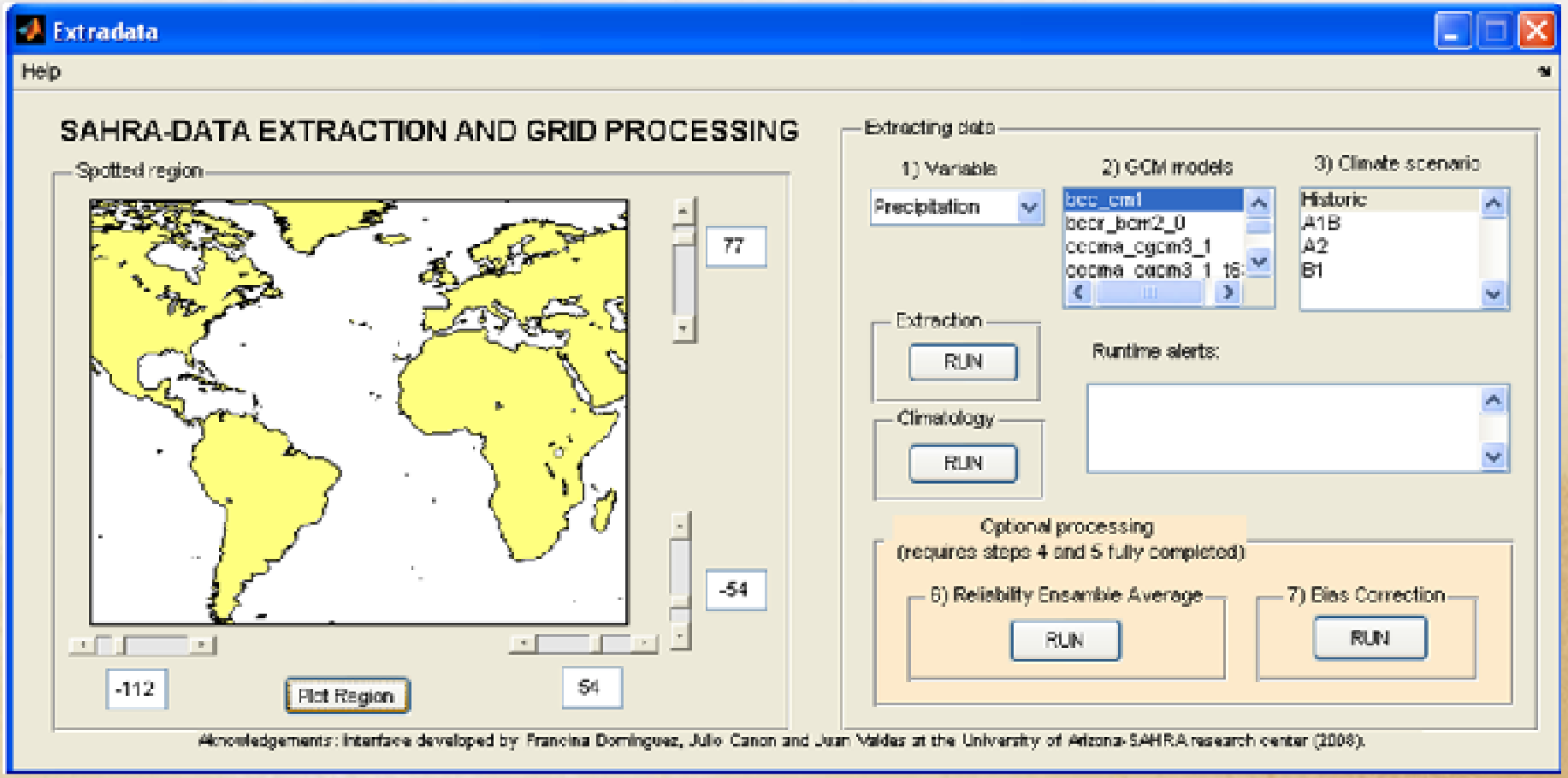
GCMs still have problems capturing the seasonal cycle of precipitation, especially in the Southwest





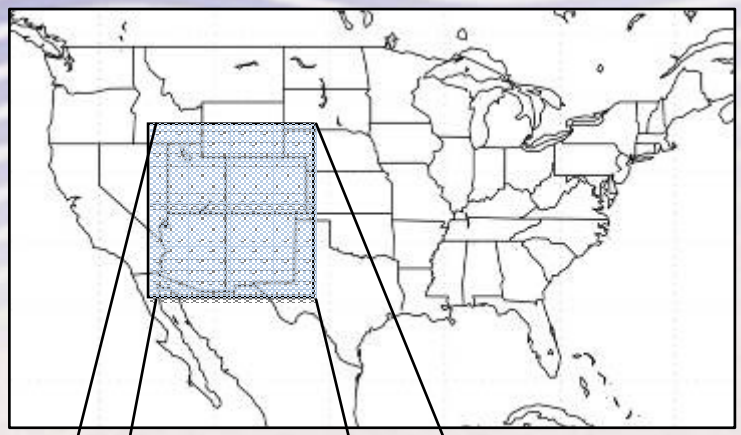
IPCC average historical modeled precipitation (mm/day),1970-2000 (colored lines) and **observations** (black bold line) (Dominguez et al., 2008)

Software facilitates data extraction, bias correction and GCM model selection



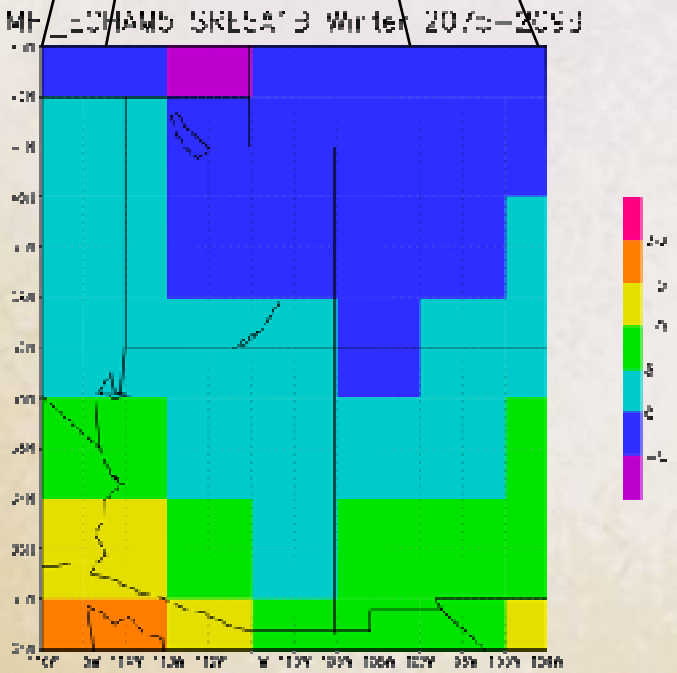
Cañón et al, 2008

SAHRA



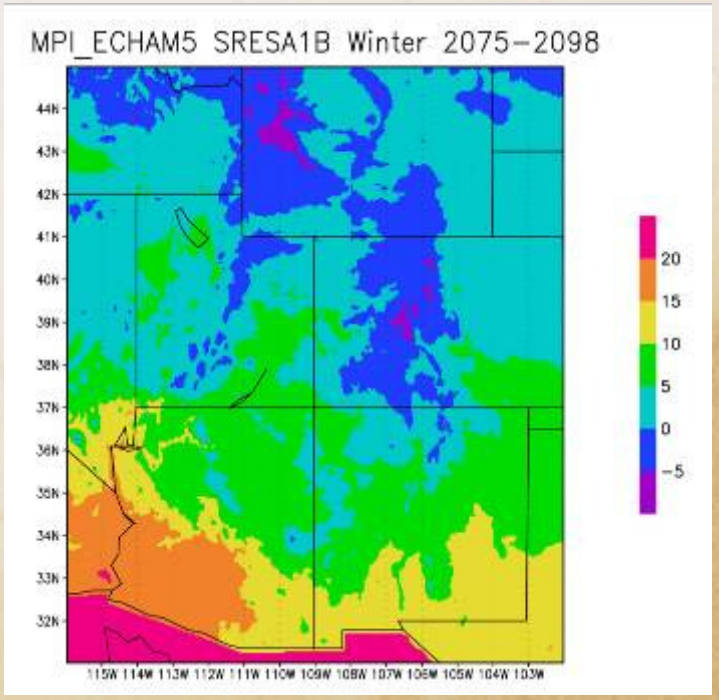
New statistical downscaling technique improves GCM data resolution from 200km to 4km. Topographical effects are now clearly visible.

GCM DATA



Applying new statistical downscaling technique

DOWNSCALED DATA



Cañón et al., 2008

SAHRA

Impacts on the Colorado Basin

- April 1 SWE: 75% of average by 2040-2069
- Releases to Lower Basin: drop below current annual releases 28-44% of years
- Delivery shortages: 21-38% of the time
- Average deliveries to Mexico: 85% to 94% of treaty agreement
- Power output: 80% of 1950-1999 average

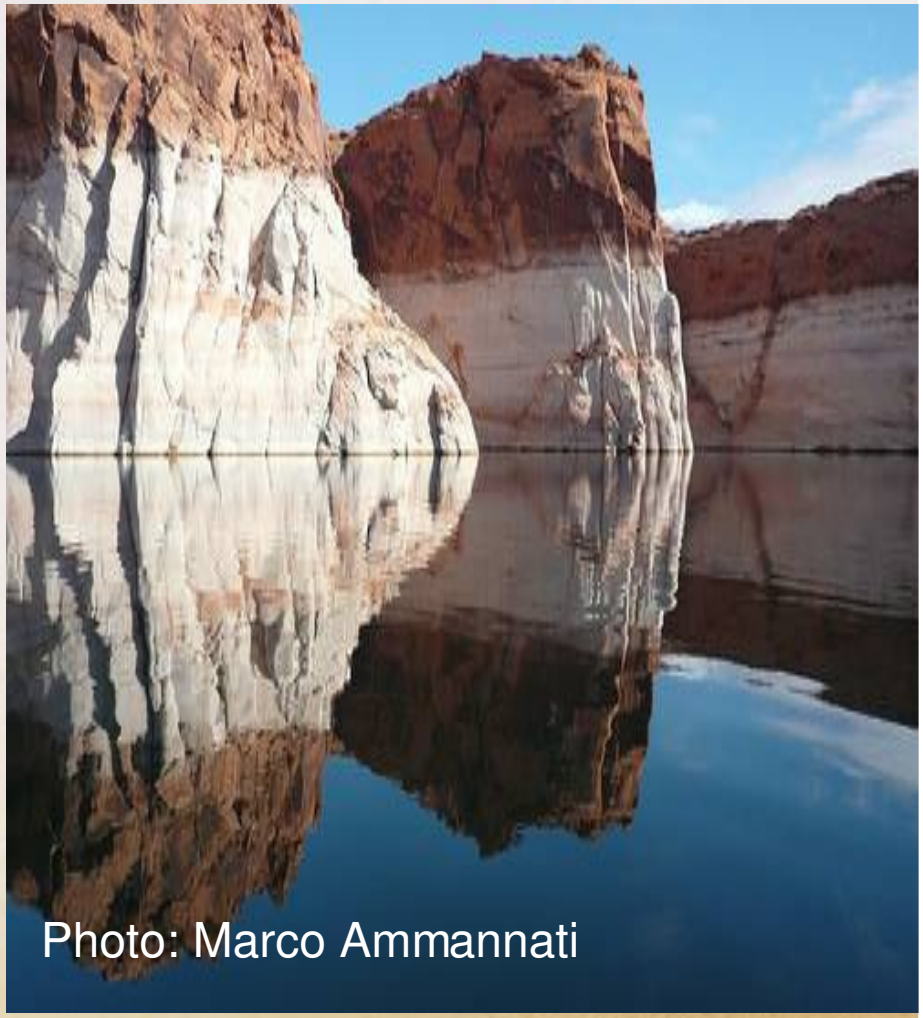


Photo: Marco Ammannati

Is there any hope?

- Increased emphasis in conservation measures in the Southwest. *"Conservation … is a positive exercise of skill and insight, not merely a negative exercise of abstinence or caution."*
- Signif
- Impro
- Signif

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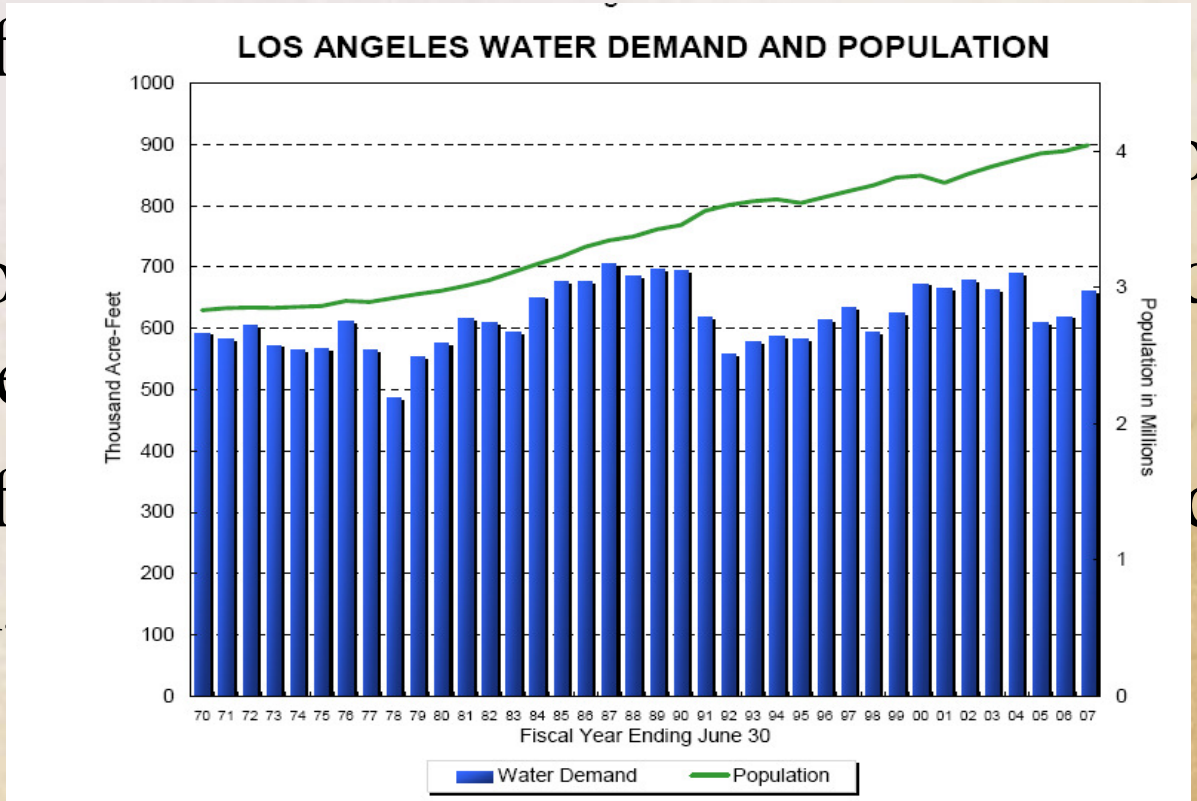
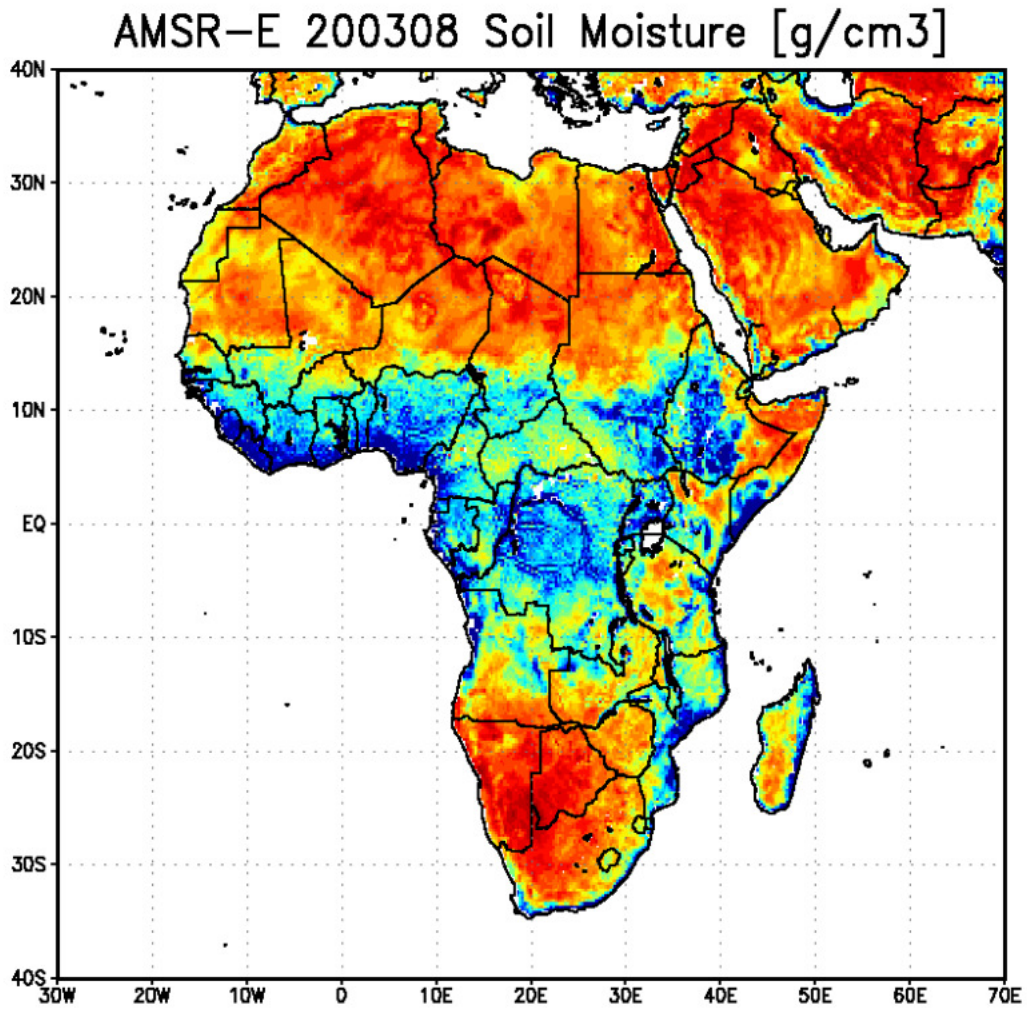


Satellites fill critical soil moisture data gaps



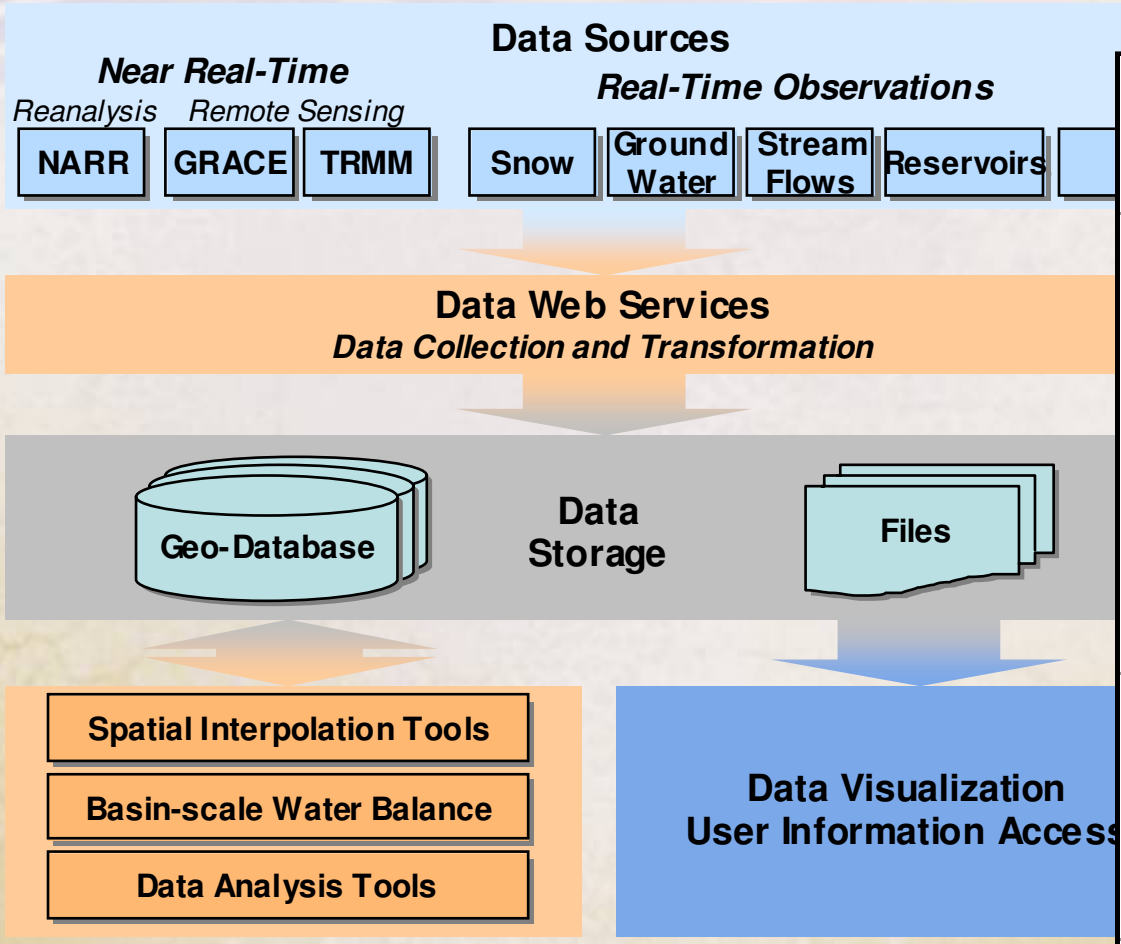
Soil moisture is a key factor for:

- predicting runoff and floods
- monitoring and early warning of droughts
- forecasting weather and climate

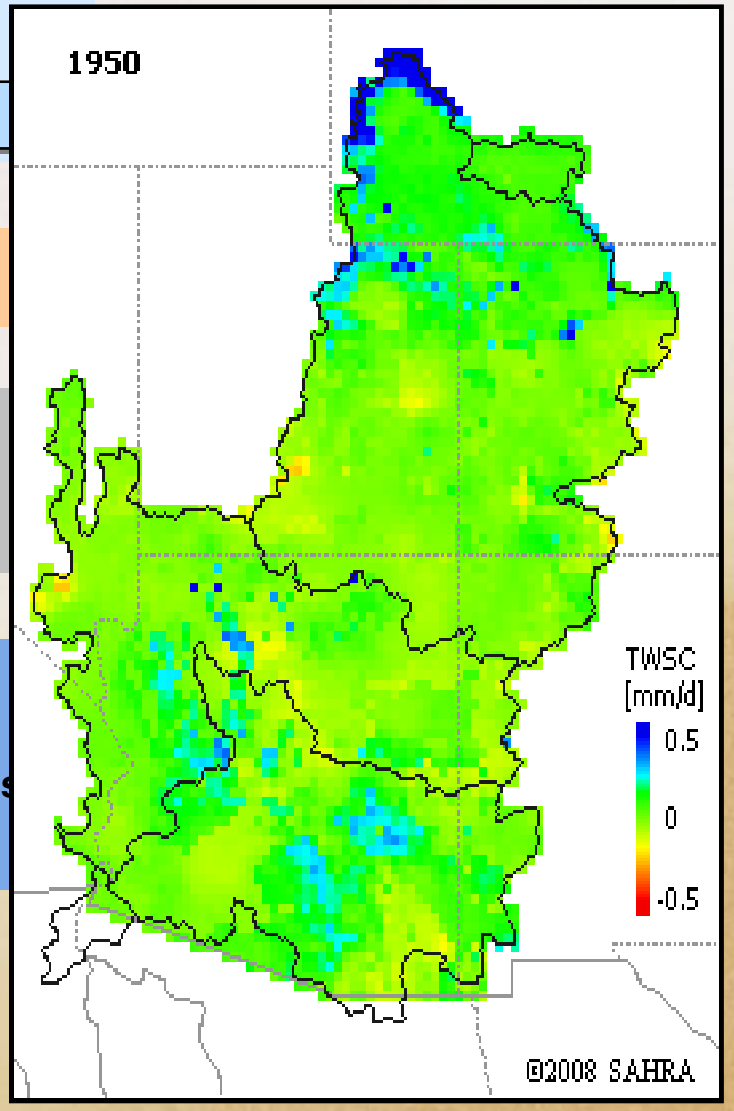
But ground-based measurements of soil moisture are difficult and costly.

Data source: AMSR-E (NASA & Japan)

Modeling real-time changes in terrestrial water storage in the Colorado Basin

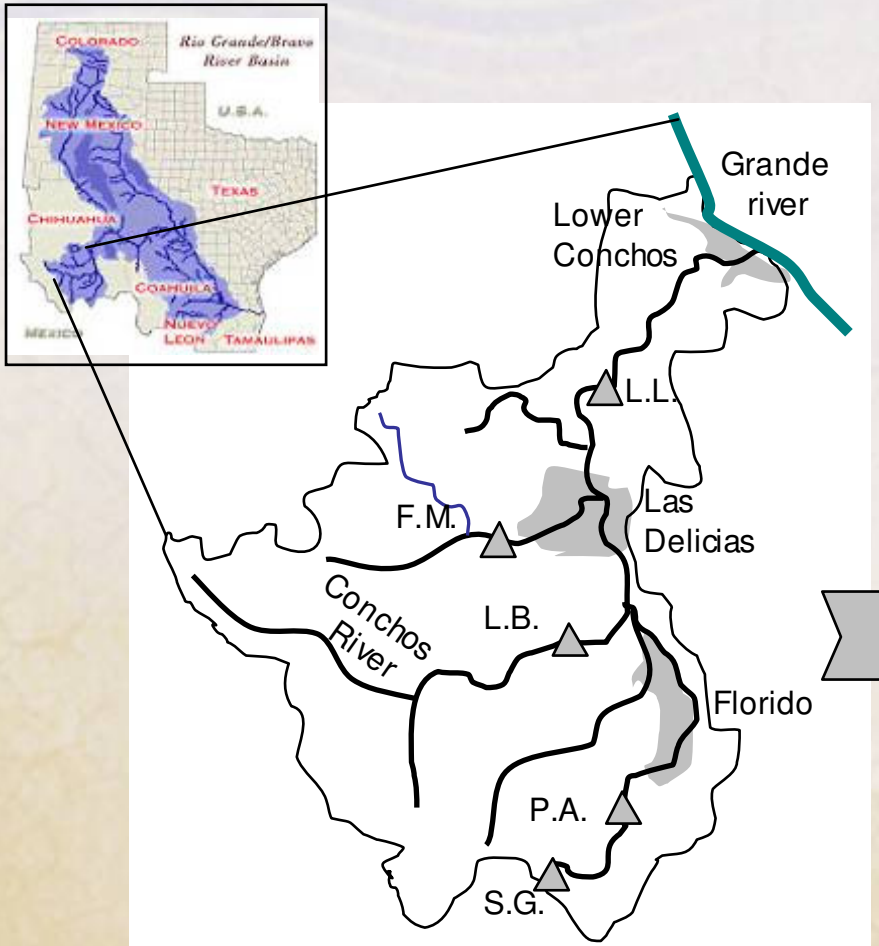


Troch et al., 2007

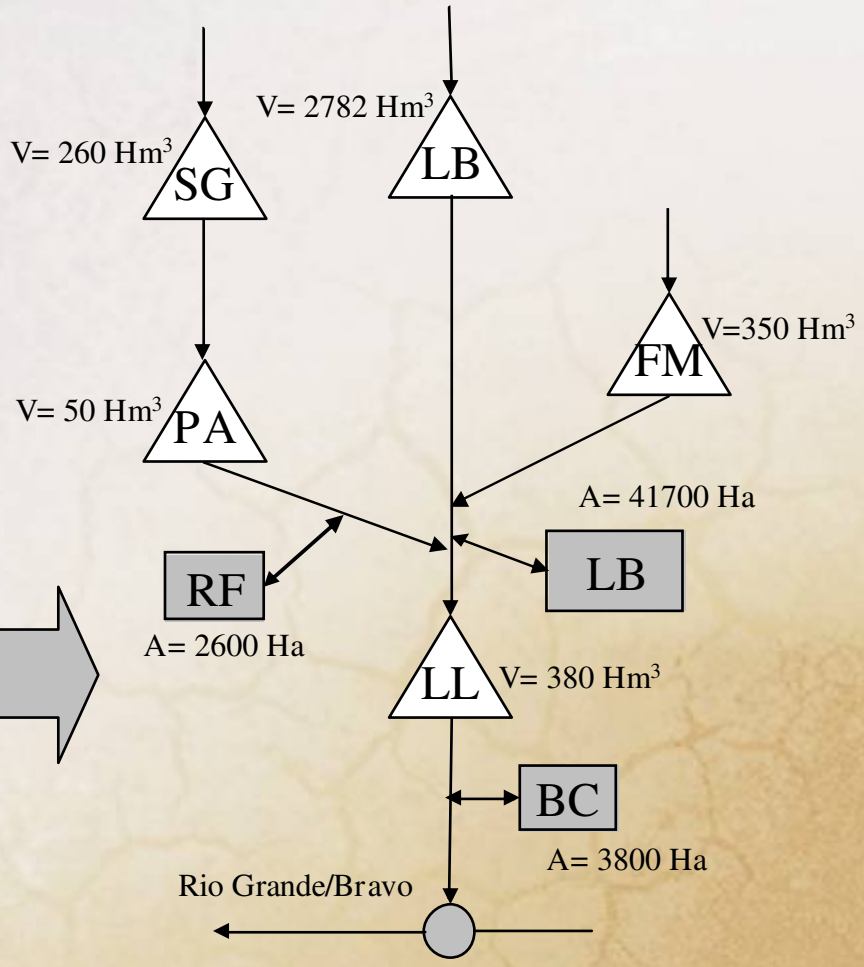


Changes in terrestrial water storage, 1950-2005

Drought Frequency Index (DFI) & Reservoir Operation: Conchos Basin

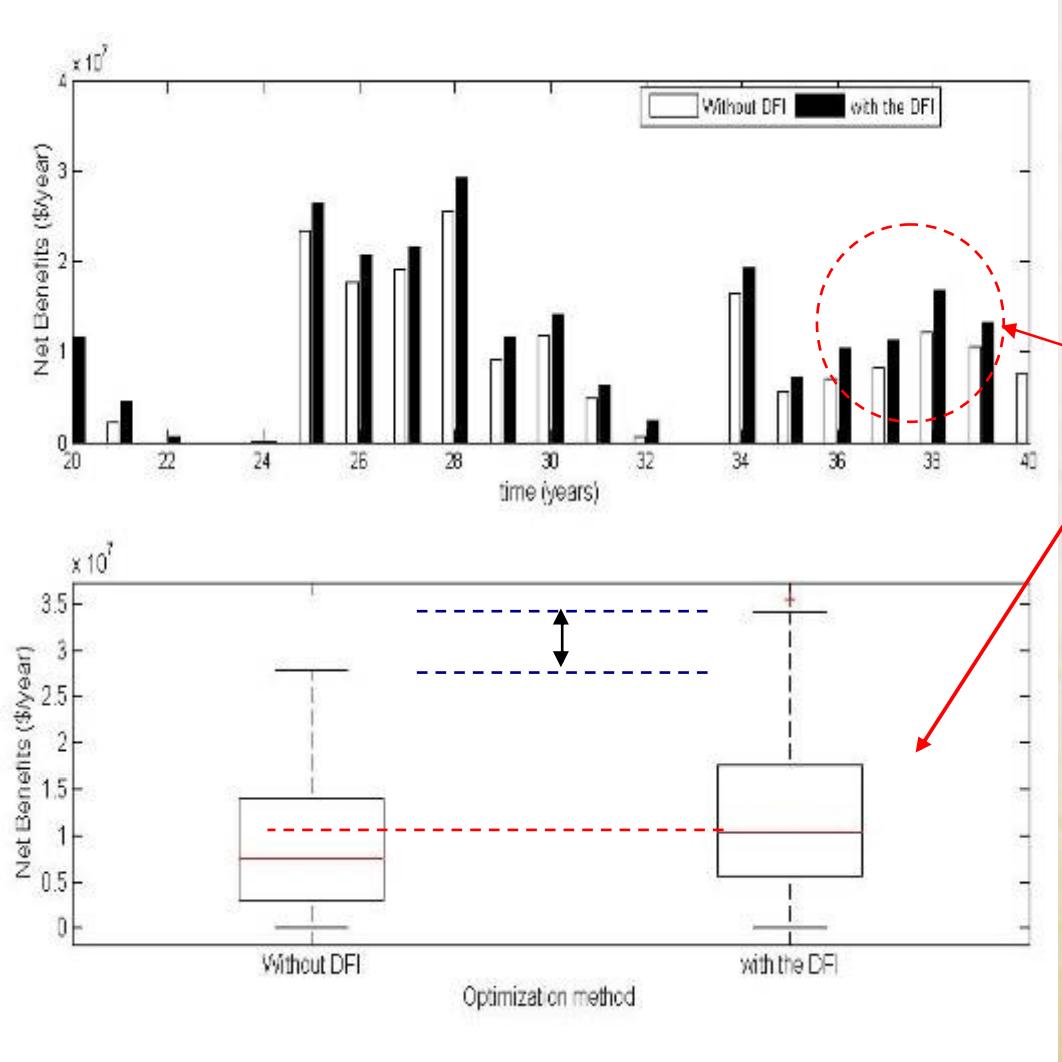


Conchos Basin

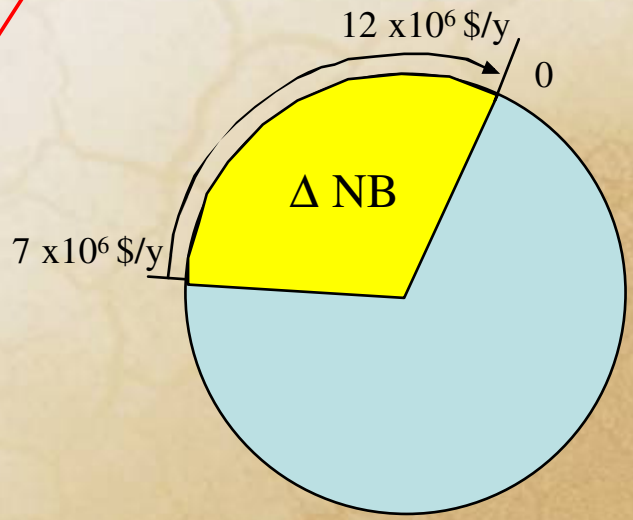


Operative Scheme

DFI: net benefits during drought periods



Better yields and net benefits are obtained during periods of drought when reservoir operations are based on the DFI.



Cañón et al., 2008

Final Comments

Increasing drought conditions are creating severe challenges for water resource managers.

Improvements in data gathering, integration, modeling and decision support systems allows us to develop management strategies that:

- are proactive and adaptive;
- allow greater efficiencies and resilience; and
- integrate top-down planning and governance with bottom-up local level management


Questions?
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Photo: J. Overpeck

Drought Trends Projections

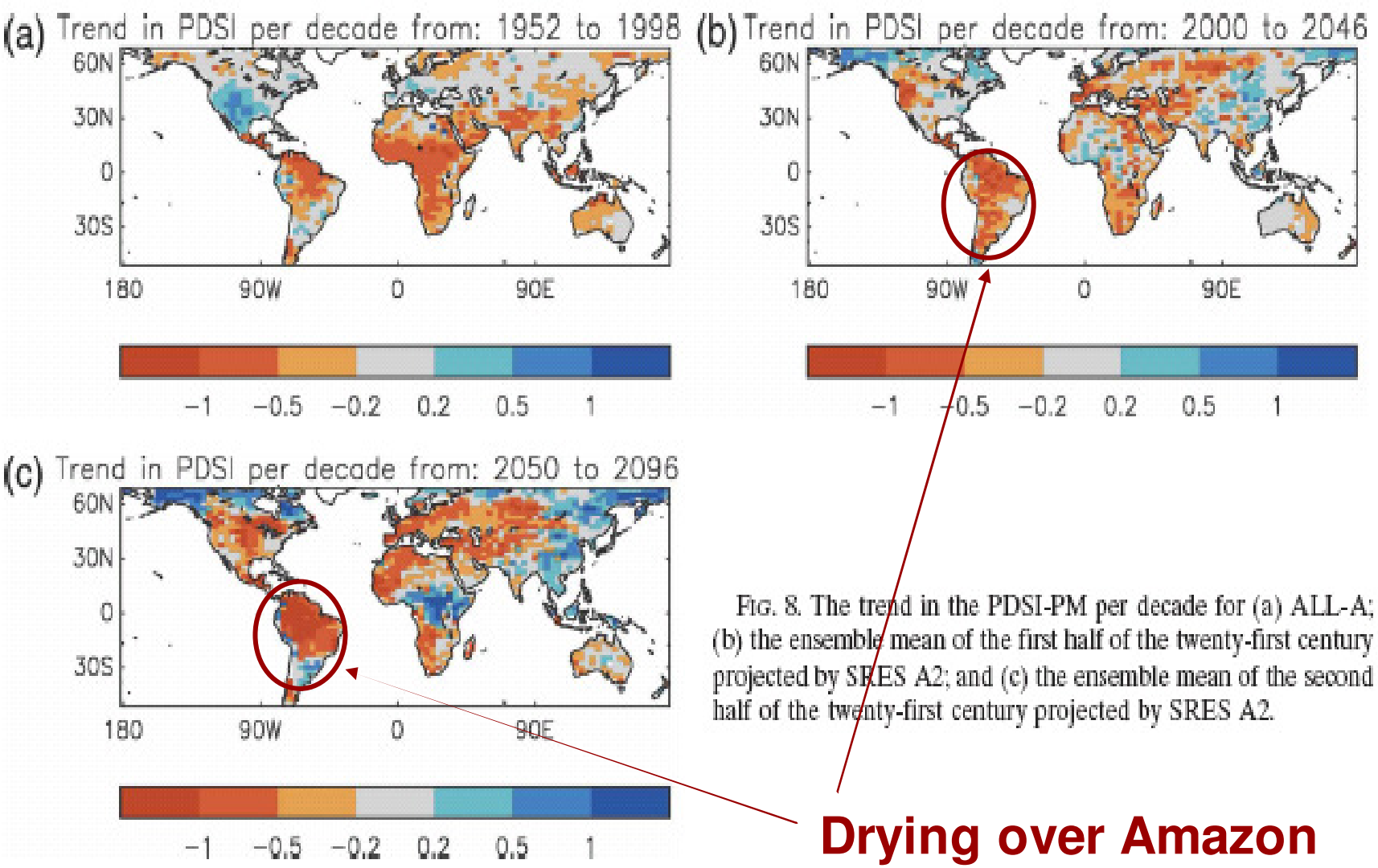
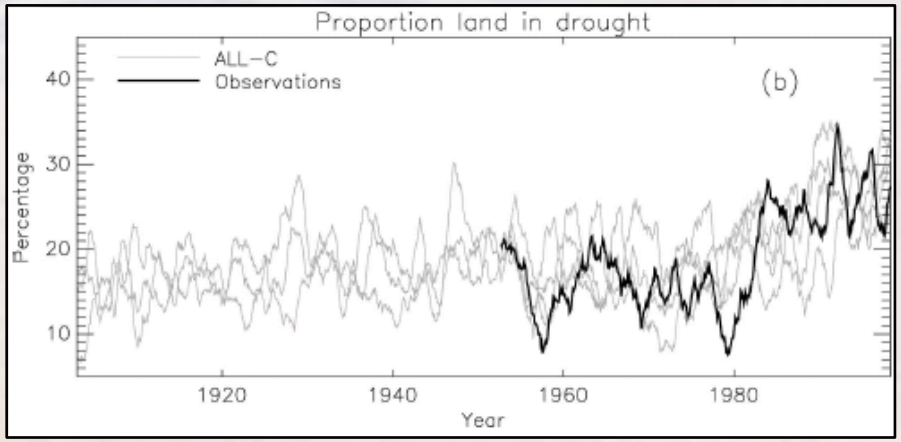


FIG. 8. The trend in the PDSI-PM per decade for (a) ALL-A; (b) the ensemble mean of the first half of the twenty-first century projected by SRES A2; and (c) the ensemble mean of the second half of the twenty-first century projected by SRES A2.

Drying over Amazon

Source: Burke et al, 2006. J of Hydrometeorology

Proportion of land in drought

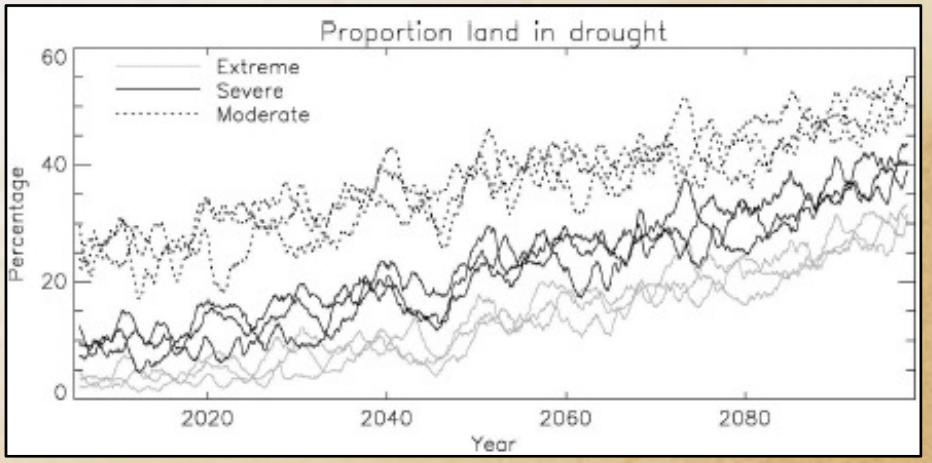


Observed Proportion land in drought (1900-2000)

Drought is defined as the 20th percentile of the entire PDSI time series

Proportion of land in drought under A2 emissions scenario

- extreme: 1% of land
- severe 5%
- moderate 20%



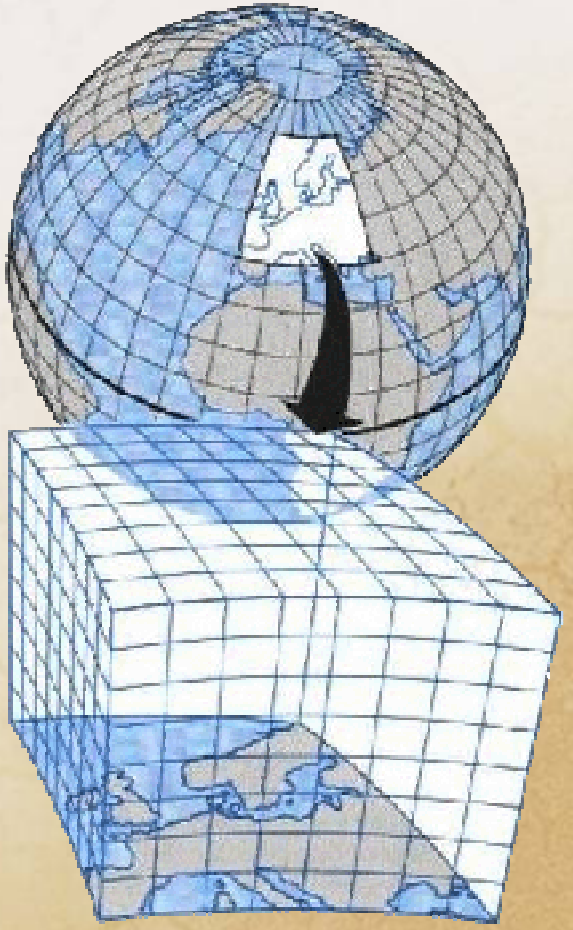
Source: Burke et al, 2006. J of Hydrometeorology

GCMs provide critical inputs for predicting climate changes

Global Climate Models (GCMs) model the dynamics of:

- atmosphere
- ocean
- land surface
- vegetation

Understanding the energy exchange is important in simulating past and predicting future climate.



www.uib.no/People/gbsag/bcm.html