Drought Monitoring and Planning for Climate Change

Water Resources in Developing Countries:
Planning and Management in a Climate Change Scenario
27 April – 8 May 2009

Gregg Garfin
Deputy Director for Science Translation and Outreach

INSTITUTE FOR ENVIRONMENT AND SOCIETY
THE UNIVERSITY OF ARIZONA.

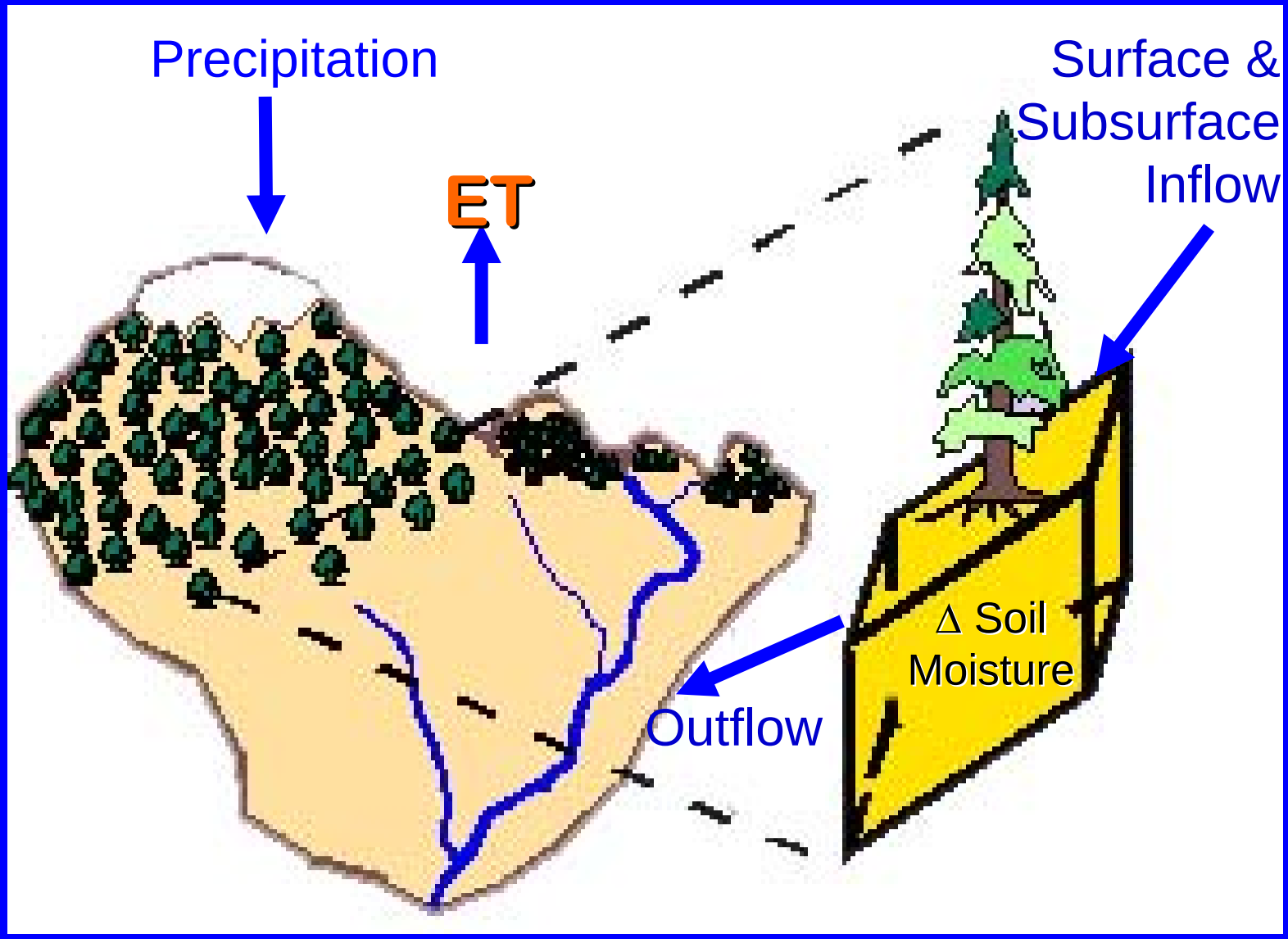
CLIMAS
Climate Assessment Project for the Southwest

RISA
Regional Integrated Sciences and Assessments
Building Bridges Between Climate Sciences and Society

The World's Shortest Primer to Tree-Ring Streamflow Reconstruction

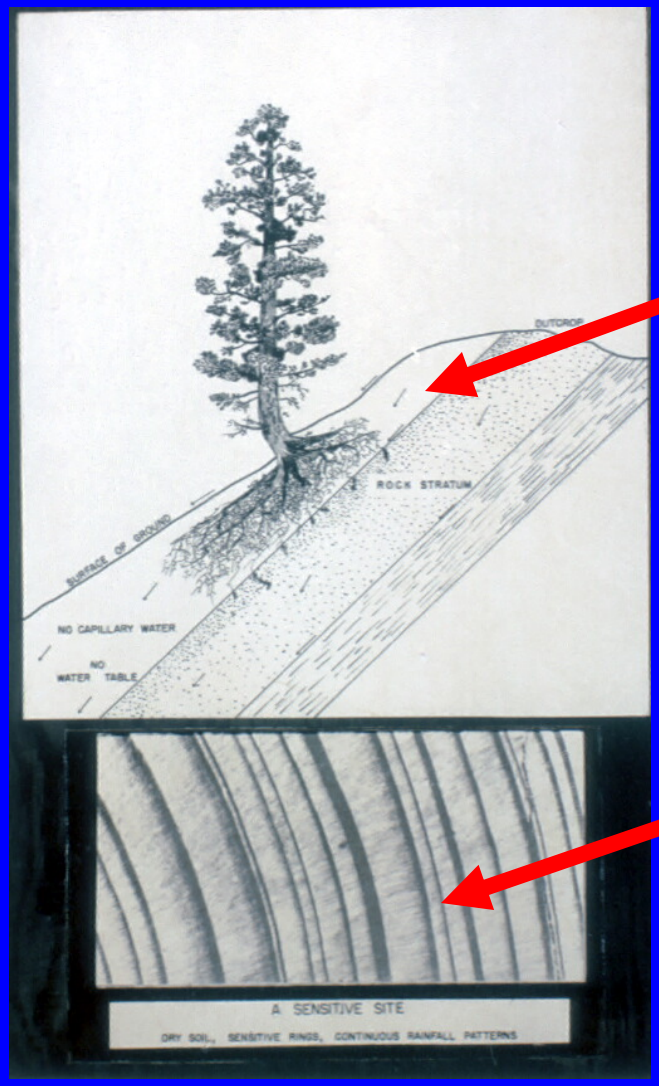
DENDROHYDROLOGY

Physical Basis for Dendrohydrology:



Courtesy of Katie Hirschboeck, UA-LTRR

Site Selection



Site selection: low soil moisture is likely to limit growth

Rings narrow **in** dry **years**, *wide* in *wet* **years**

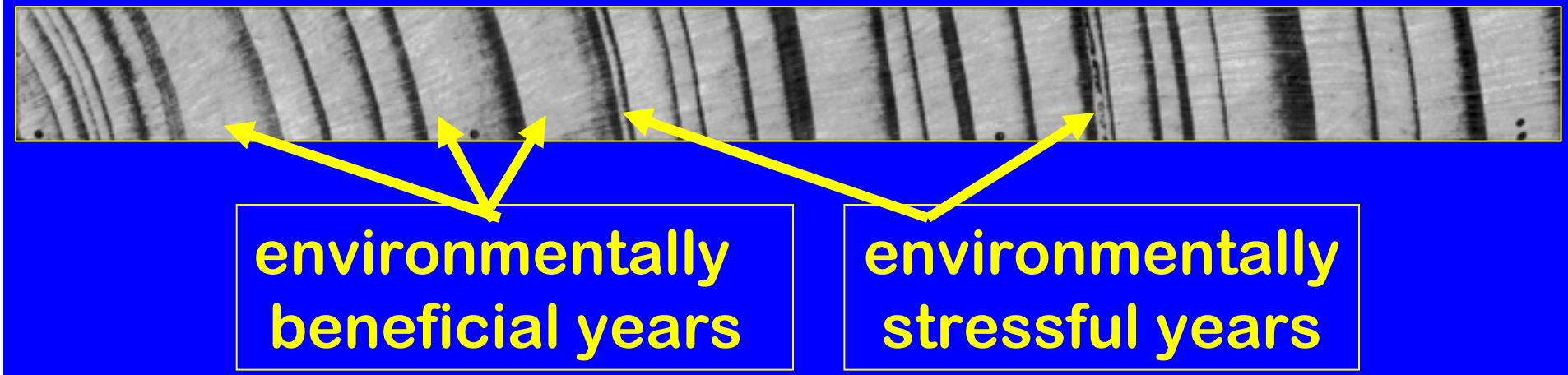
Courtesy of Dave Meko, UA-LTRR

Sensitive Site:
Western Juniper at Carson Pass, CA

Courtesy of Dave Meko, UA-LTRR

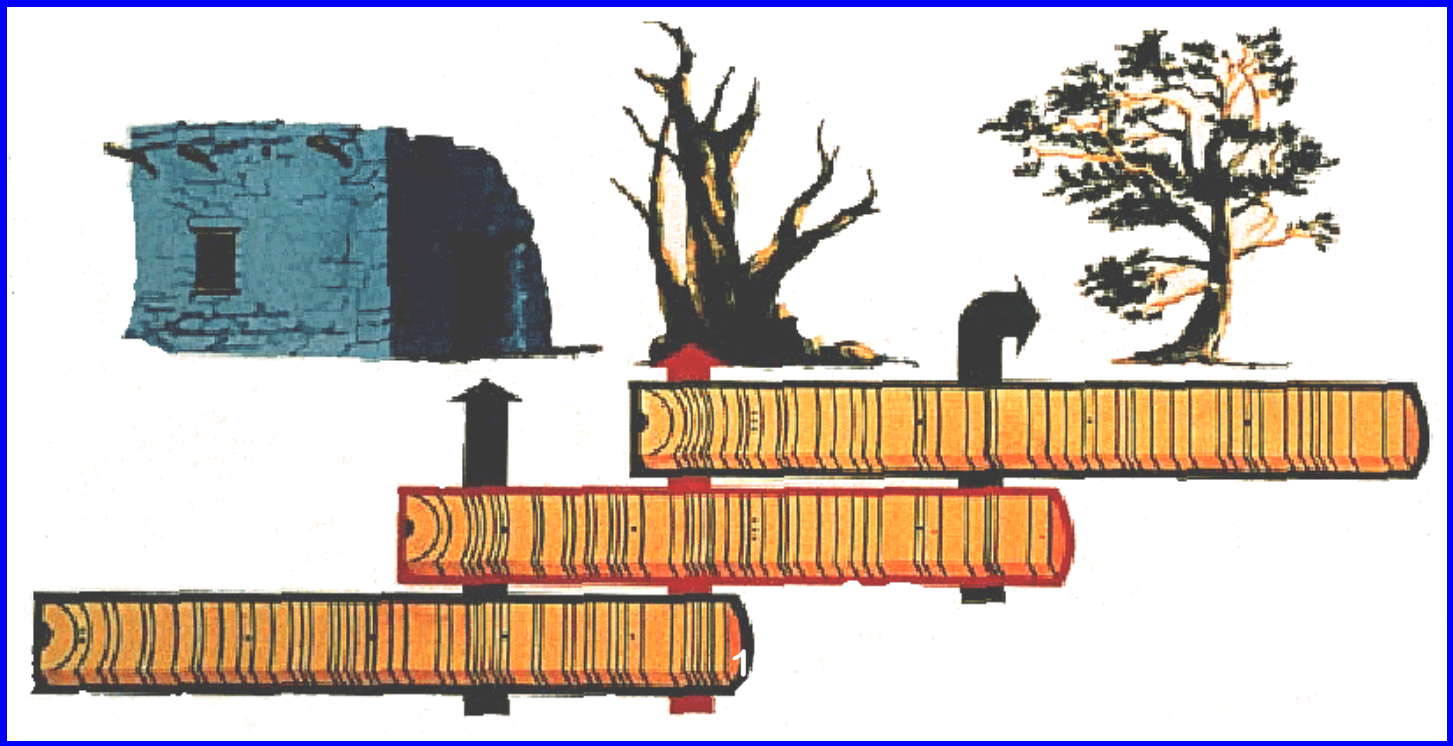
Dendrochronology: Dating Tree Ring Records

Courtesy of Katie Hirschboeck, UA-LTRR



Courtesy of Katie Hirschboeck, UA-LTRR

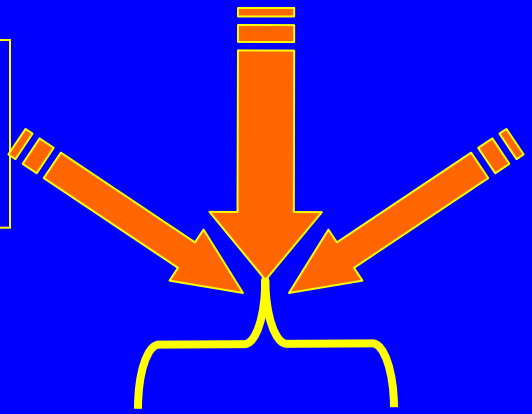
Crossdating and development of long chronologies



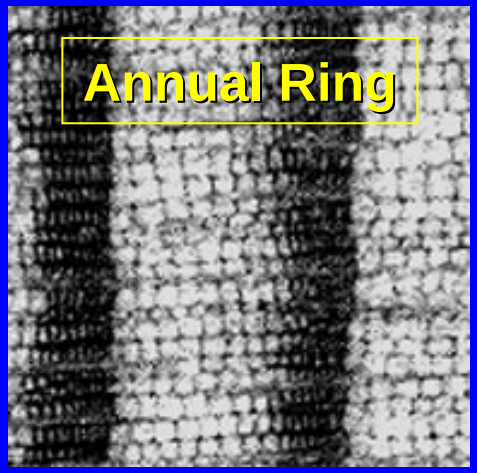
Relating Tree-Growth to Climate

Climate: Precipitation, temperature, snow...

Tree biology:
age, vigor, ...

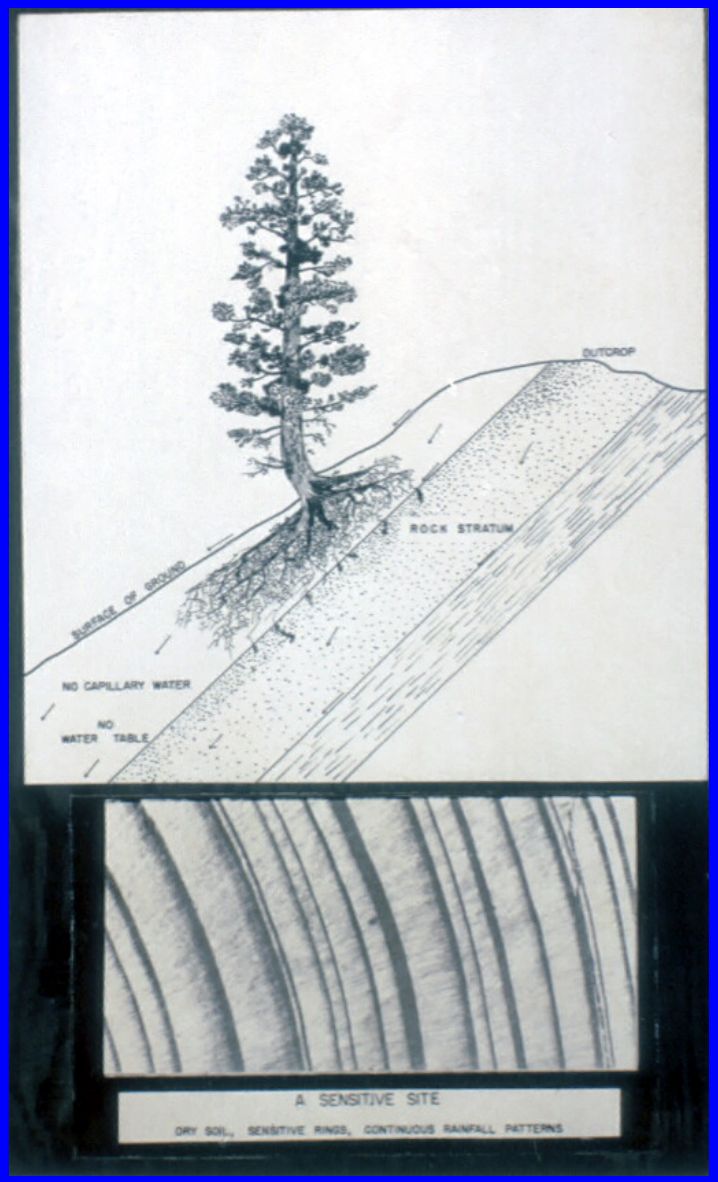


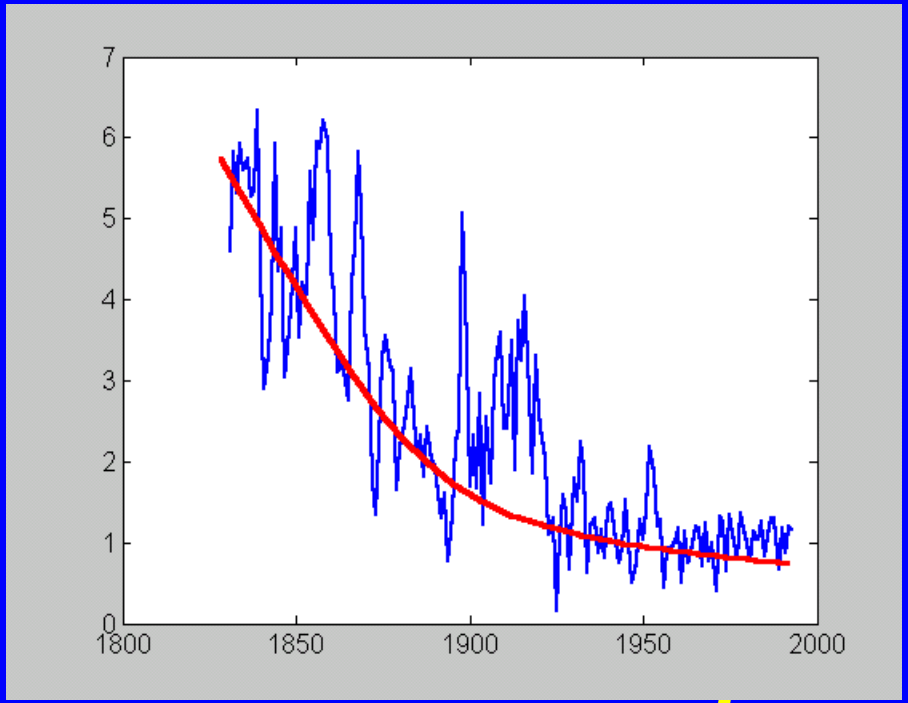
Site factors:
Substrate, exposure, competition



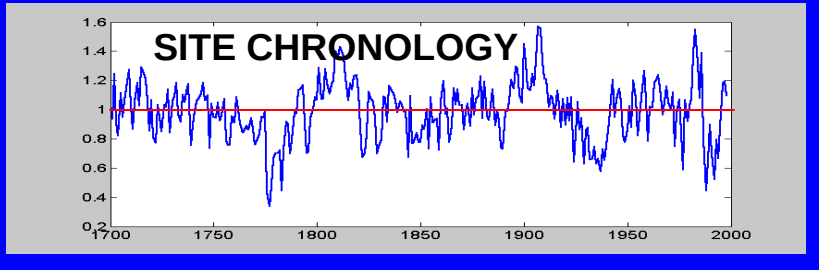
Courtesy of Kurt Kipfmueller, UA-LTRR

Chronology Development



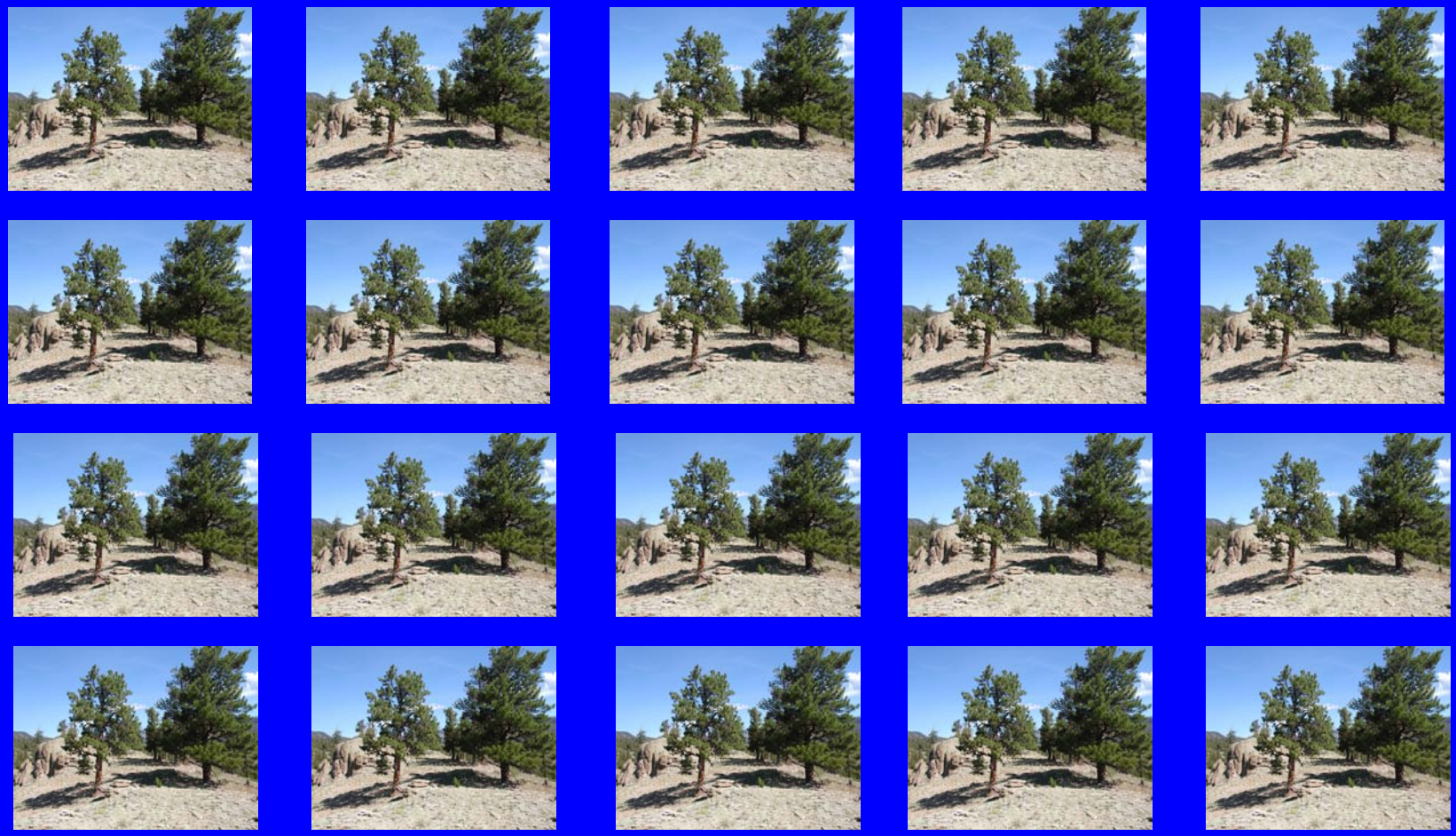


REPLICATE

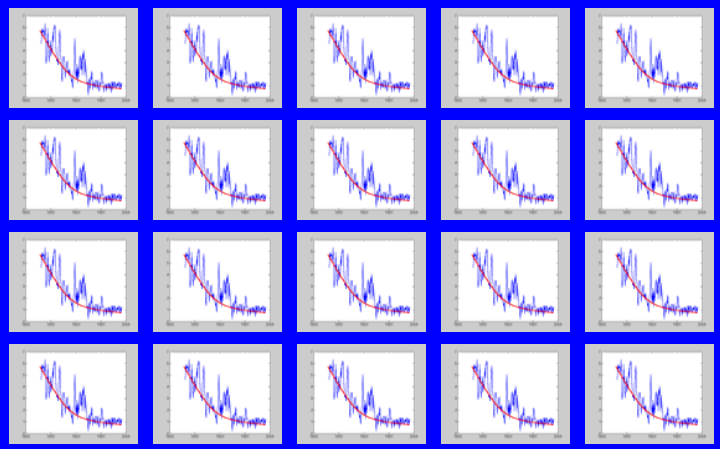


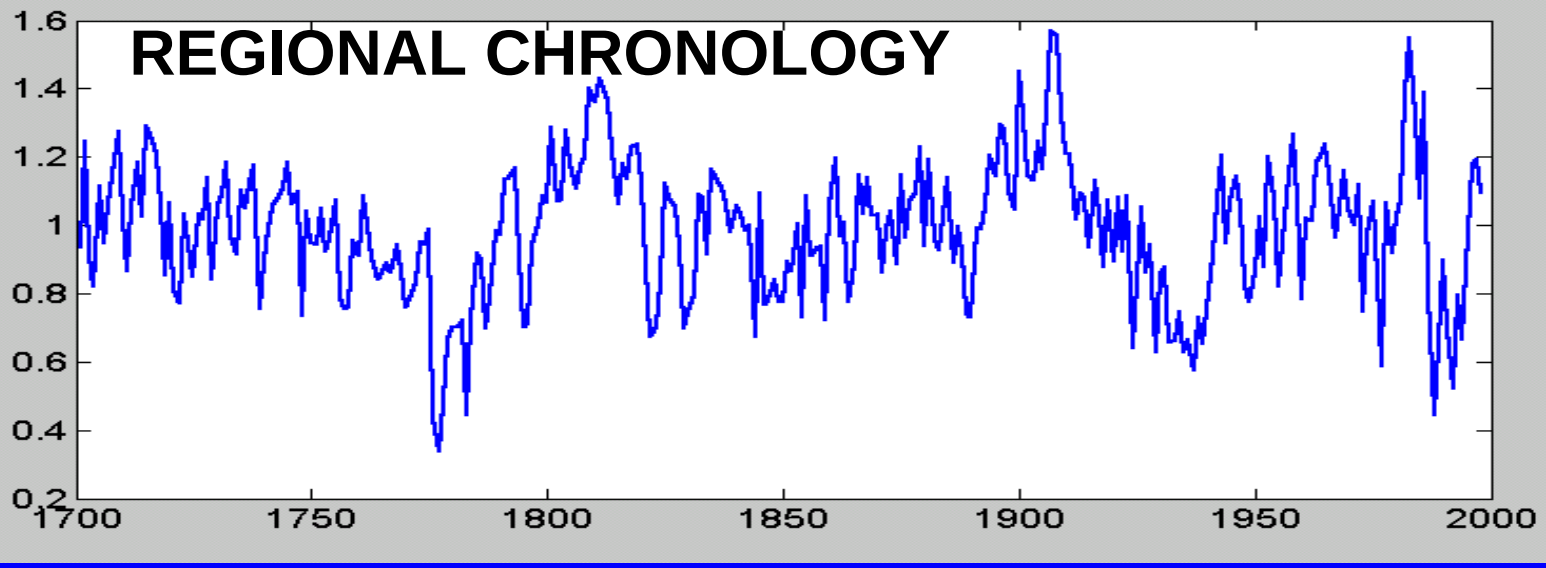
Replication

Replication

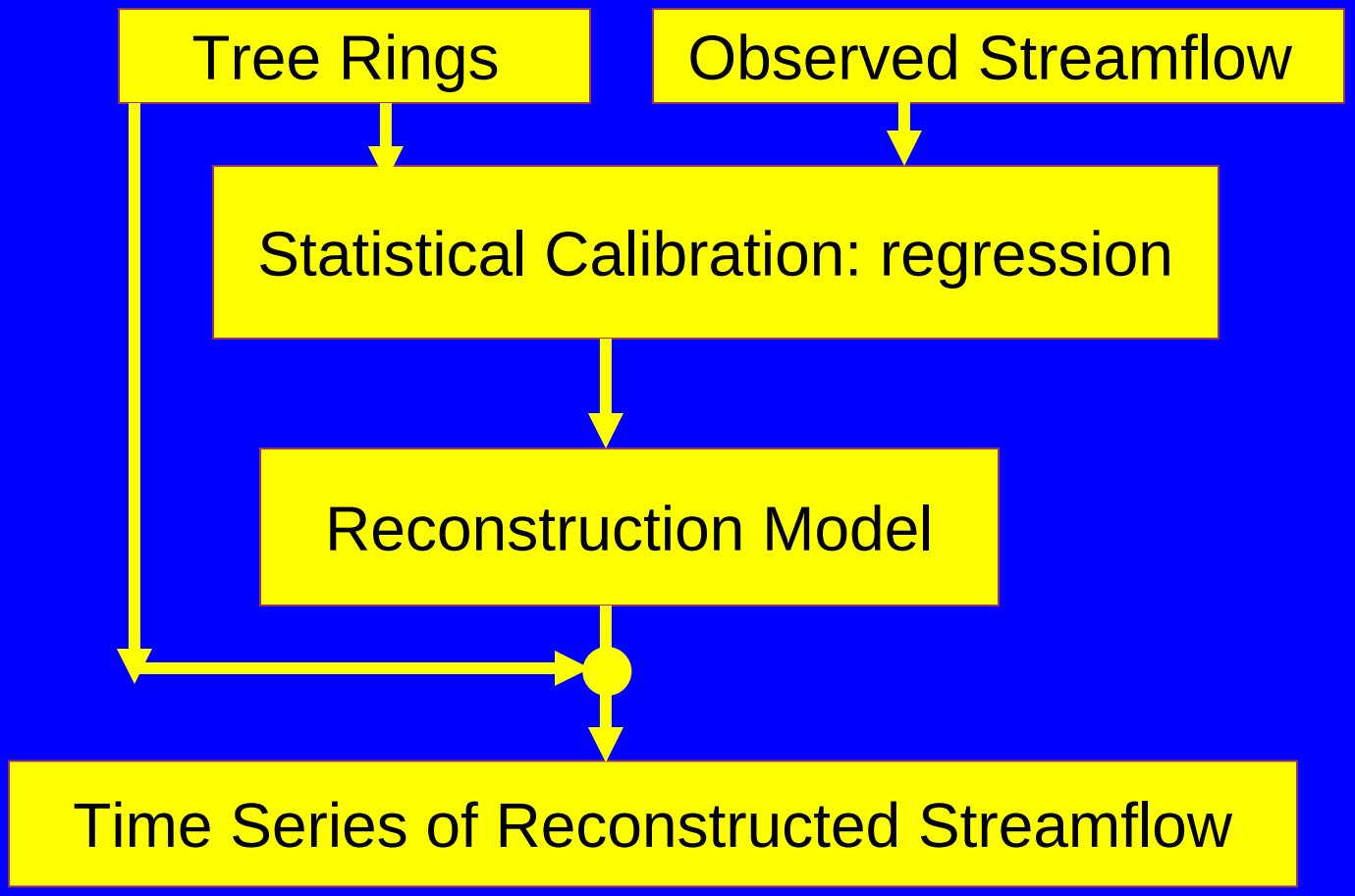


Replication



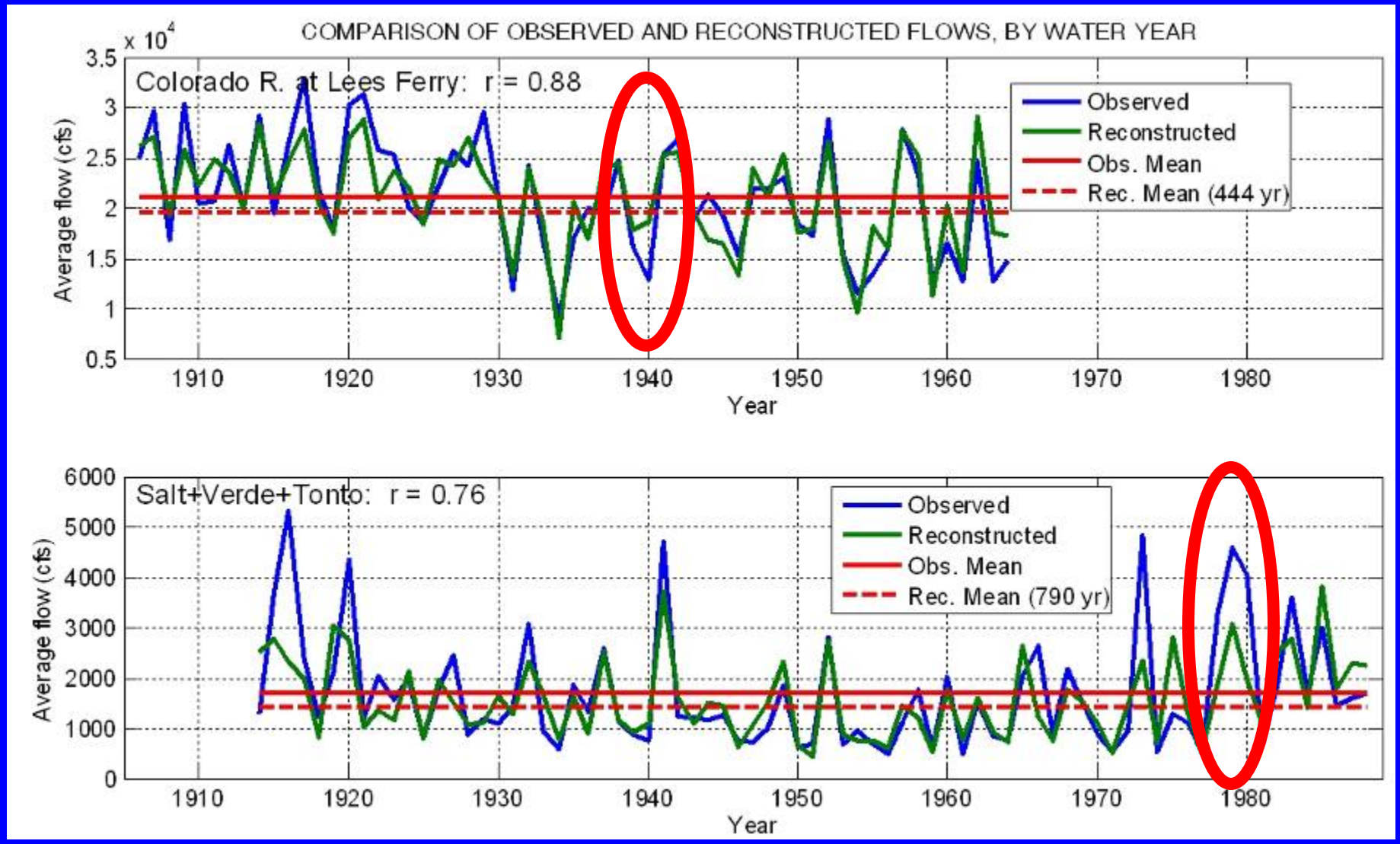


Reconstruction Model



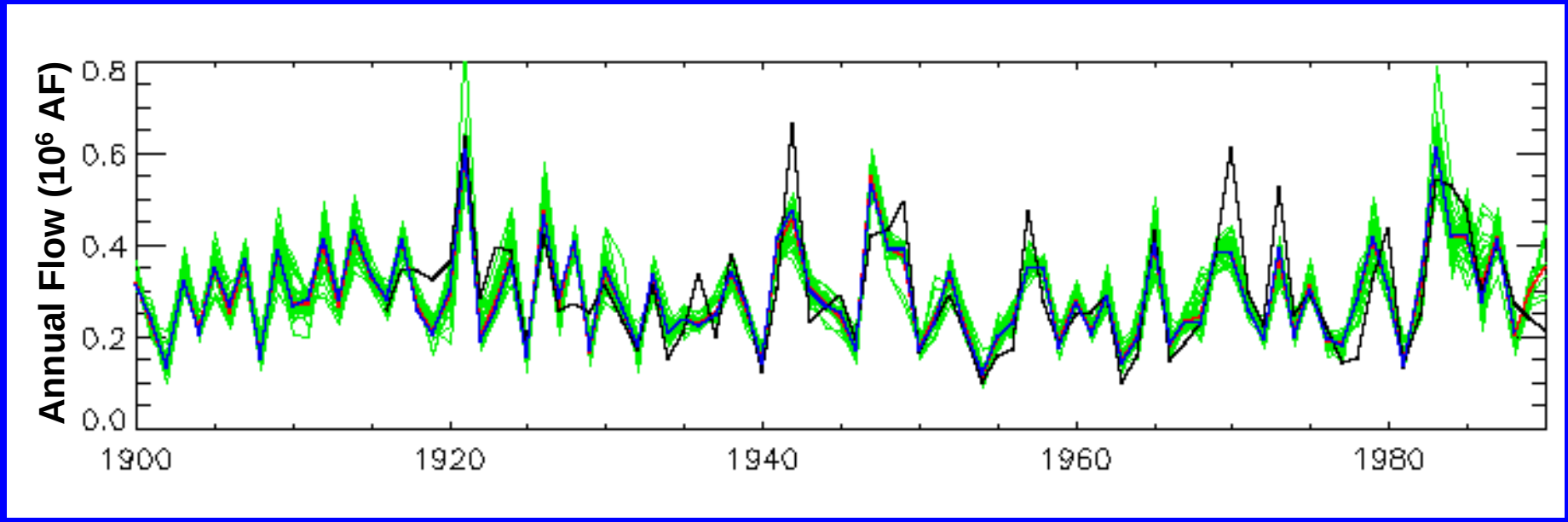
Courtesy of Dave Meko, UA-LTRR

Reconstruction Accuracy



Courtesy of Dave Meko & Katie Hirschboeck, UA-LTRR

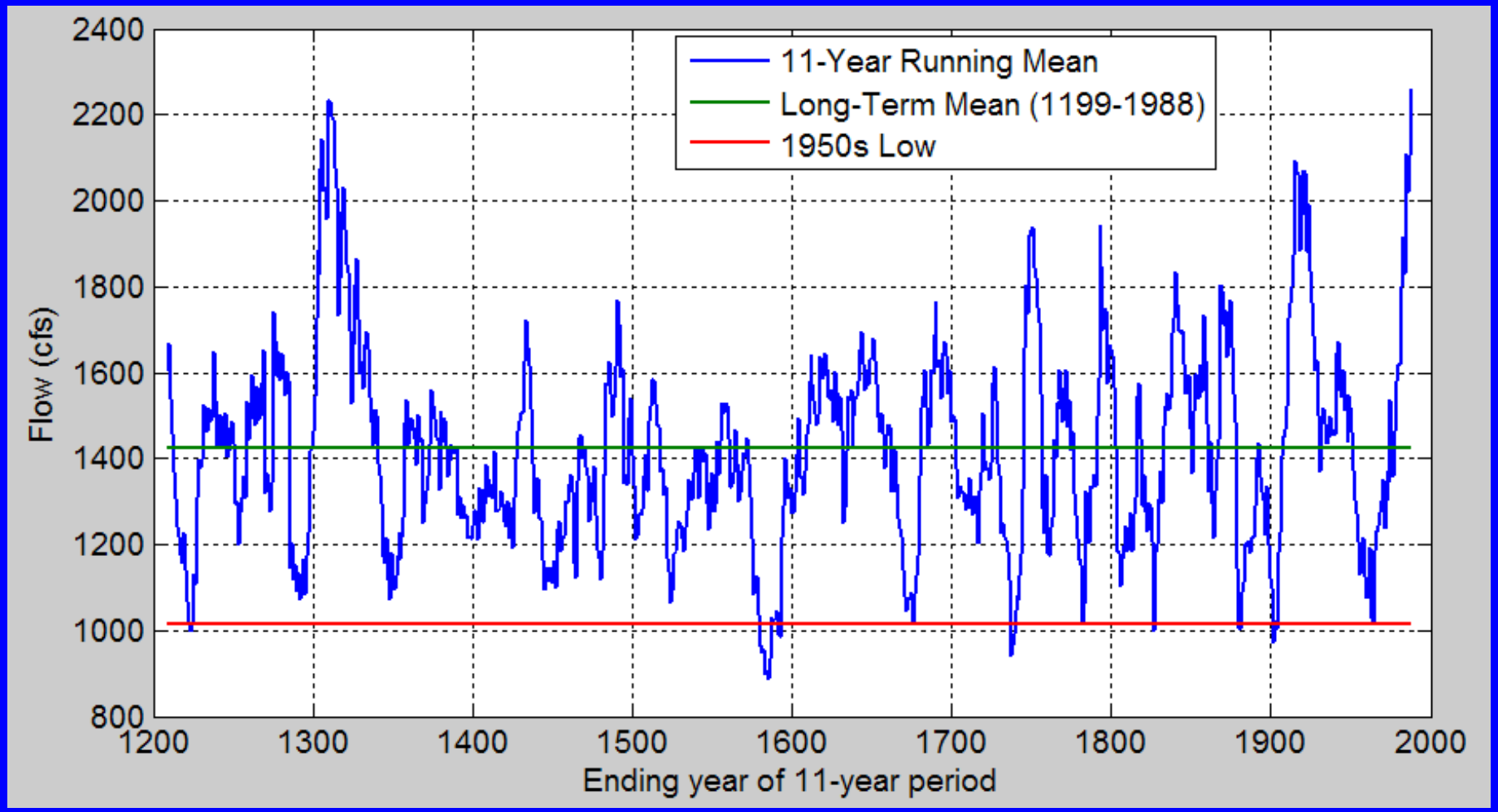
Tree Ring Ensemble Streamflow Reconstruction
South Platte at South Platte 20th Century



Calibration data ———
Best Model ———
Ensemble Mean ———
Ensemble Members ———

Courtesy of Robert S. Webb and Connie Woodhouse, NOAA

Long-Term Reconstruction

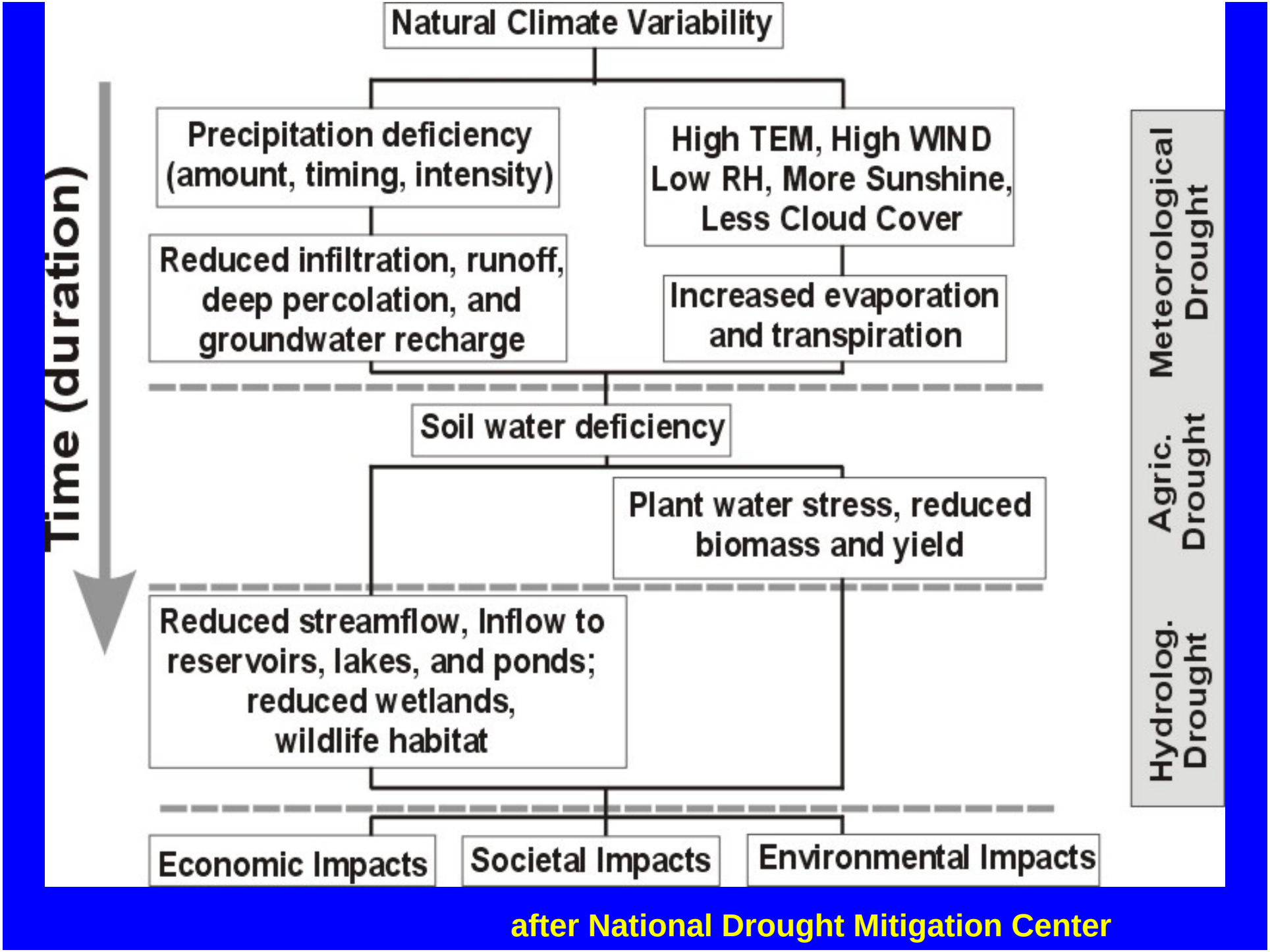


Courtesy of Dave Meko & Katie Hirschboeck, UA-LTRR

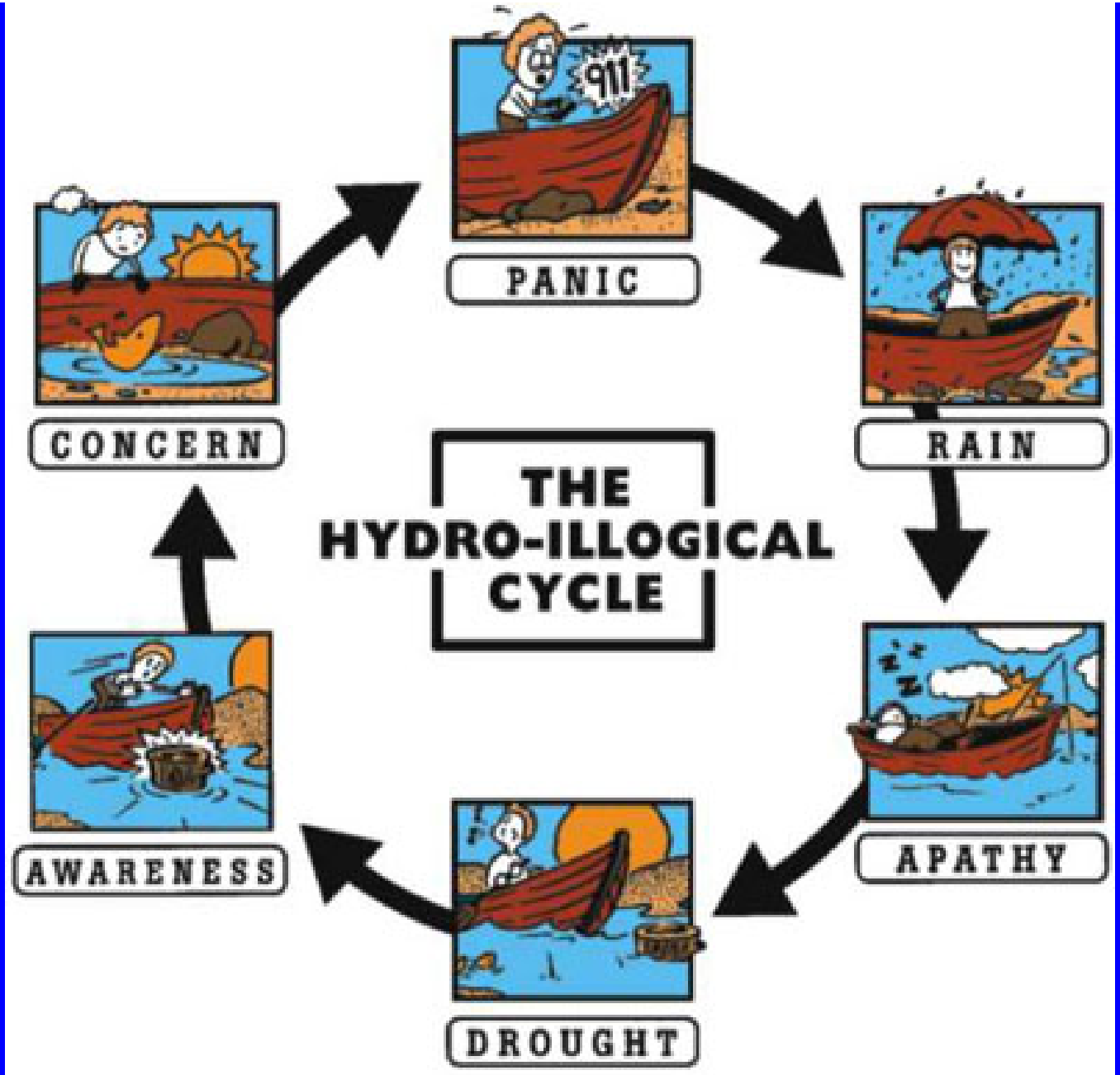
Back to our regularly scheduled program

Characteristics of Drought

- "Creeping"
  - Effects accumulate
  - Onset and termination unclear
  - Effects are nonstructural
  - Effects may linger
- No standard definition
- Multiple time scales
- Timing sensitive
- Interacts with management practices
- Interacts with societal vulnerability
- Often the last problem to gain attention



after National Drought Mitigation Center



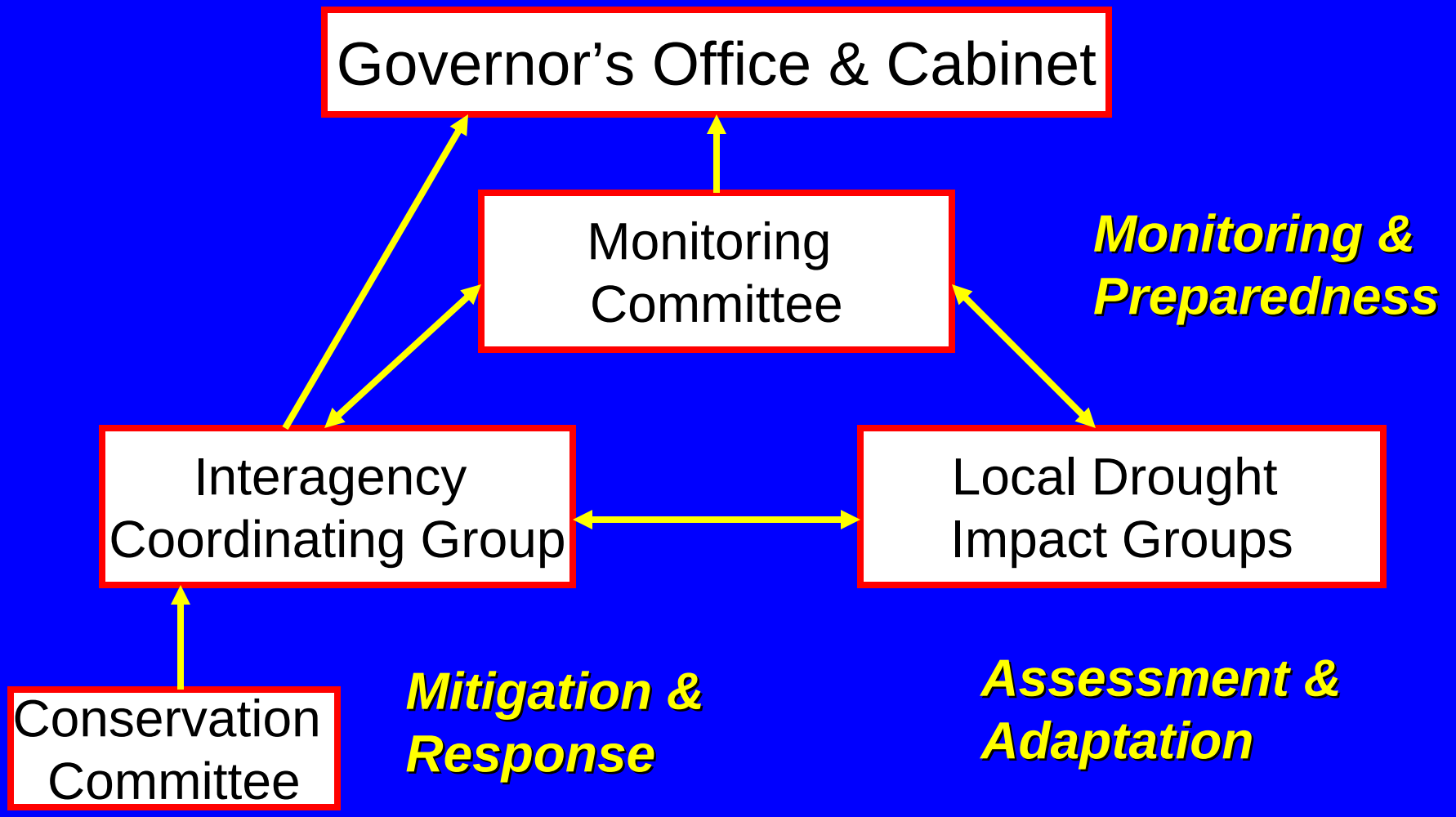
-National Drought Mitigation Center

What Goes Into a Drought Plan?

Drought Plan Goals

1. Identify the impacts of drought.
2. Define the sources of drought vulnerability.
3. Develop monitoring programs to alert water users and resource managers of the onset and severity of drought events.
4. Prepare drought response options mitigation strategies to reduce the impacts of drought.

State Drought Coordination



Drought Monitoring

- Ground-based observations
- Remotely-sensed observations
- Blended data
- Estimated data
  - Statistical, Modeled
- Indices
- Impacts -- reporting/perceptions can be motivated by non-climate factors

Drought Monitoring

- Long records
  - High quality
  - Undisturbed
- External and internal drivers
  - SSTs
- Causes and effects…**or not?**
- Inputs and outputs
  - Recharge, discharge
  - Supply, demand

MTC Indicators and Procedure

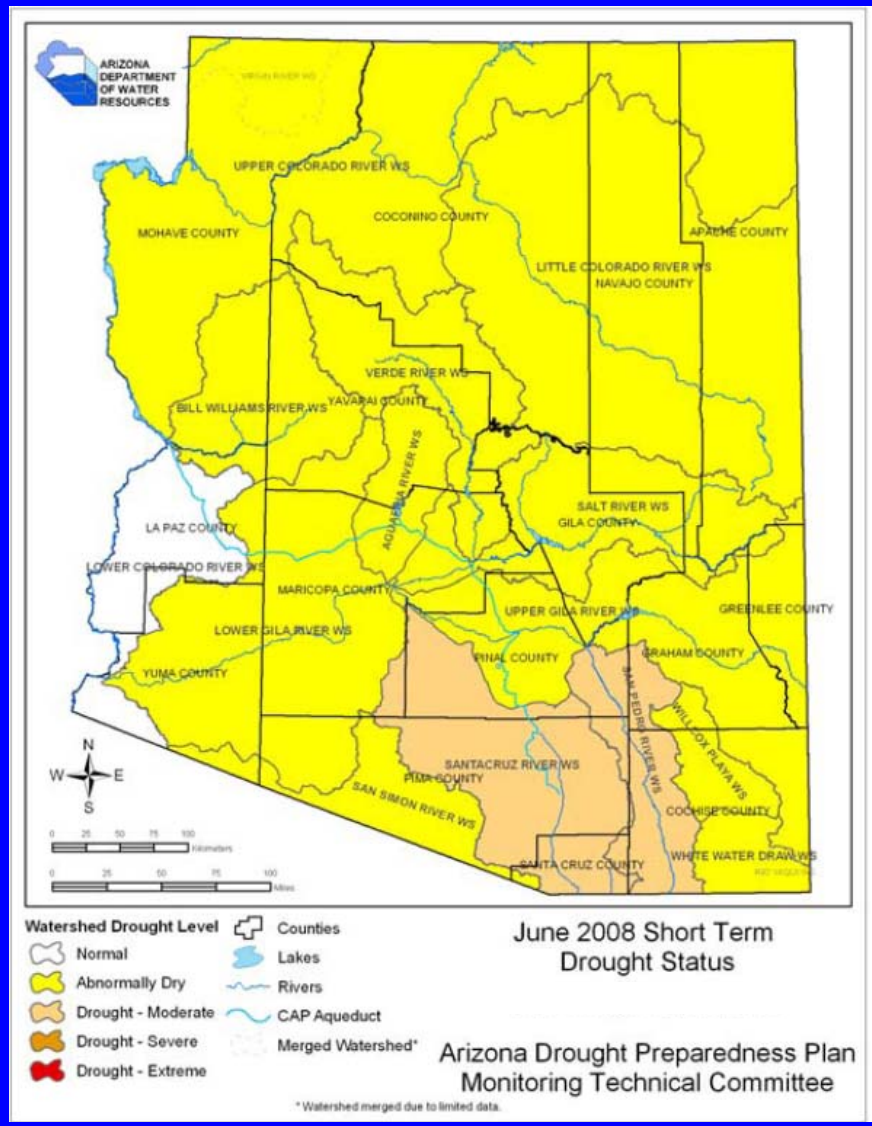
- Monitor drought at a regional level
- Calculate and display drought status for two time periods:
  - *Short-term (< 12 months)*
  - *Long-term (12-48 months)*
- Indicators: SPI, streamflow, reservoir levels
- Corroborate with other data:
  - *SNOTEL*
  - *Range and pasture status, vegetation health*
  - *Drought impacts information*

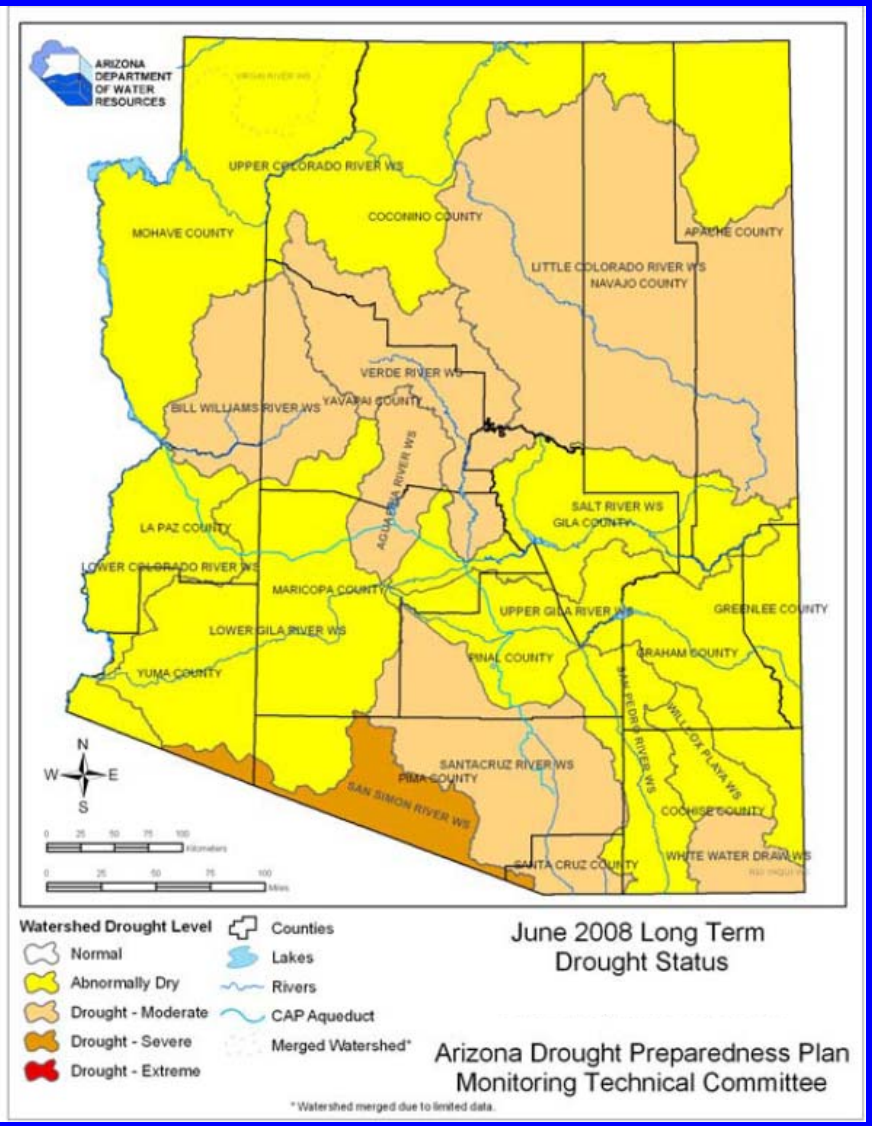
MTC Drought Triggers

Level	Description	Percentile
0	No Drought	40.1-100.0%
1	Abnormally Dry	25.1-40.0%
2	Moderate Drought	15.1-25.0%
3	Severe Drought	5.1-15.0%
4	Extreme Drought	0.0-5.0%

Triggers are specific values of the indicators that initiate and terminate drought status levels and management responses

June 2008 Status Maps





Arizona Drought Monitor Report
September 2006

Produced by the Monitoring Technical Committee

Mike Crimmins, Extension Specialist, U of A Cooperative Extension

Charlie Ester, Salt River Project

Gregg Garfin, University of Arizona – CLIMAS

Tony Haffer, National Weather Service

Larry Martinez, Natural Resources Conservation Service

Ron Ridgway, Arizona Division of Emergency Management

Nancy Selover, Asst. State Climatologist Arizona State University

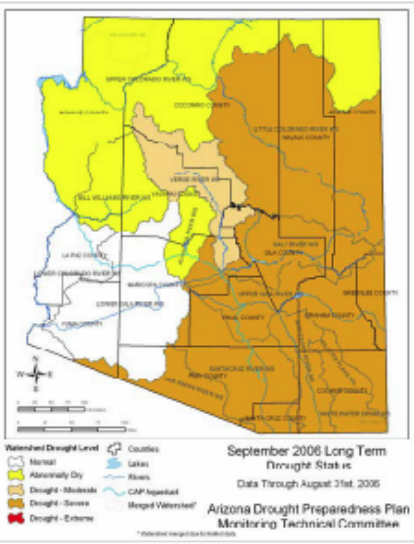
Chris Smith, U.S. Geological Survey

Coordinator: Susan Craig, Arizona Department of Water Resources
Computer Support: Andy Fisher, Arizona Department of Water Resources

Arizona Department of Water Resources

Short-term Drought Status

All areas of the state have continued to improve in the short-term to either abnormally dry or moderate drought status. Monsoon rains have improved soil moisture, refilled stock ponds, reinvigorated grass growth, and decreased the fire danger dramatically. Improvement was particularly dramatic in the southeastern portion of the state, which received the most extreme rainfall events. However, the state is still seeing lingering impacts from one of the driest winters on record. Wildlife continue to migrate from mountain areas into urban areas in search of food sources.

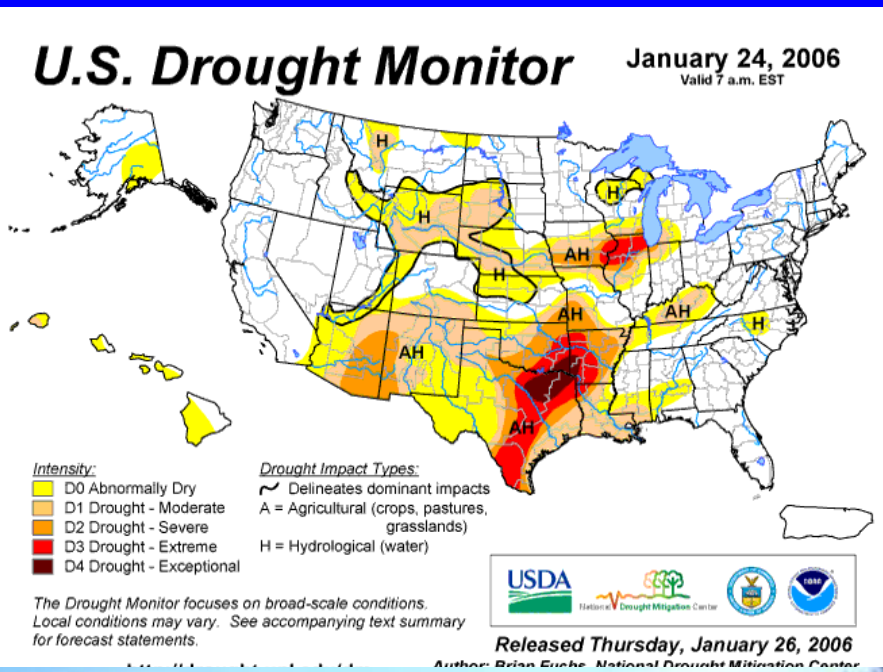


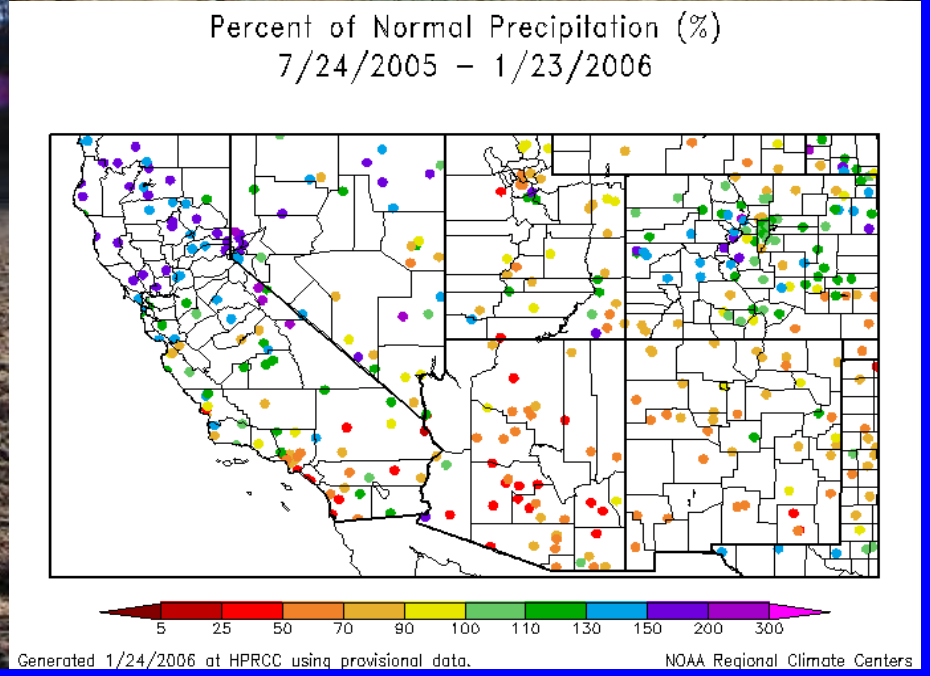
Long-term Drought Status

Although the short-term map has shown significant improvement, long-term drought conditions will be slower to recover. Only the San Pedro and Willcox Playa watersheds have improved since last month, from extreme to severe drought. Despite the monsoon rains, overall reservoir storage has decreased over the past year due to the extremely dry winter and lack of snowpack. Although grasses have benefited from the recent rain, other types of vegetation will take longer to recover. However, with the prospect of a weak to moderate El Niño, conditions are expected to continue to improve through the winter months.

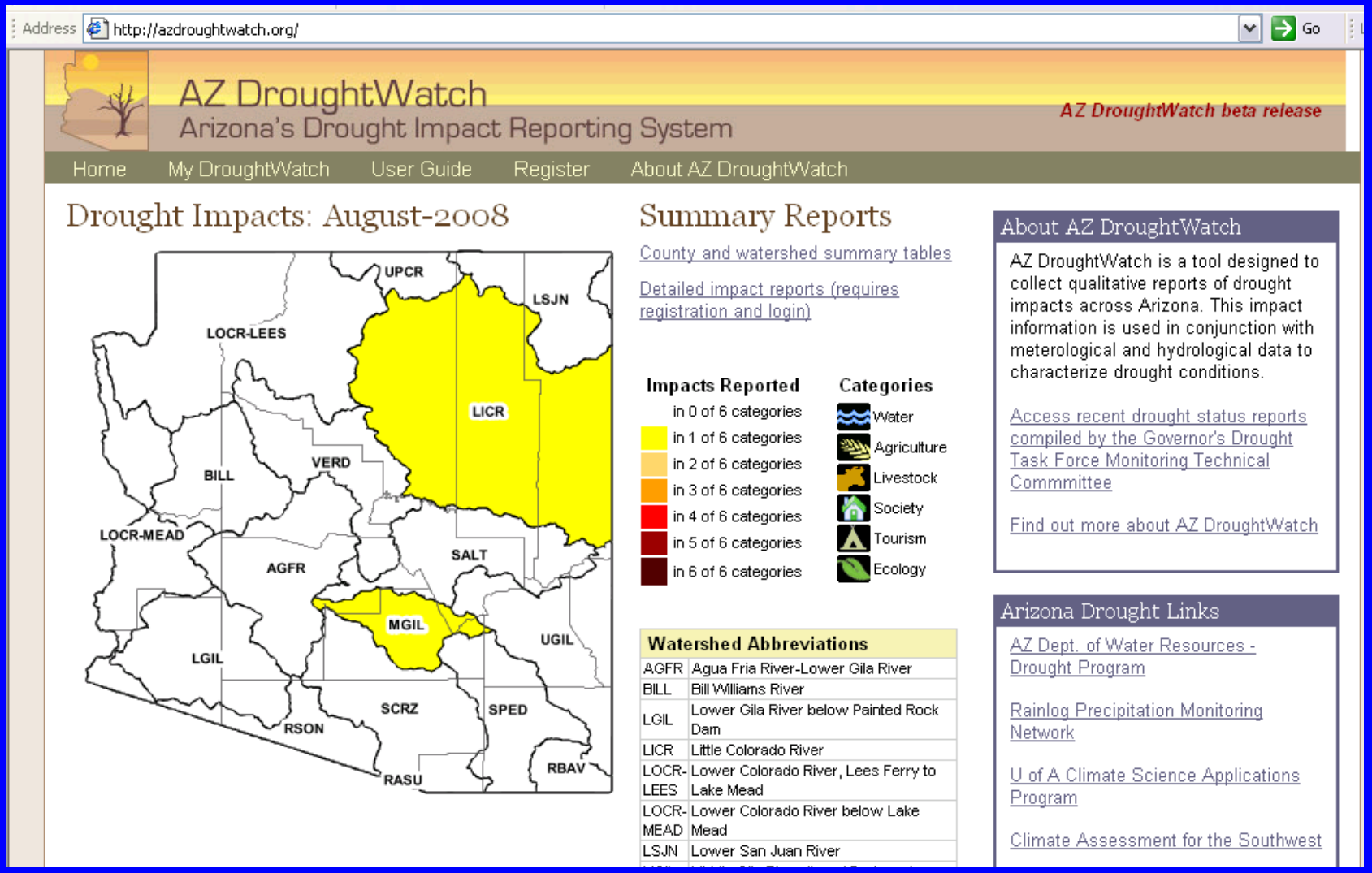
Lessons:

- Objective calculated drought status must be supplemented
- Local impacts information
- More study to connect status to impacts


U.S. Drought Monitor
January 24, 2006
Valid 7 a.m. EST
H
H
H
H
AH
AH
AH
AH
H
AH
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
USDA
Released Thursday, January 26, 2006


Percent of Normal Precipitation (%)
7/24/2005 - 1/23/2006
5
25
50
70
90
100
110
130
150
200
300
Generated 1/24/2006 at HPRCC using provisional data.
NOAA Regional Climate Centers

azdroughtwatch.org



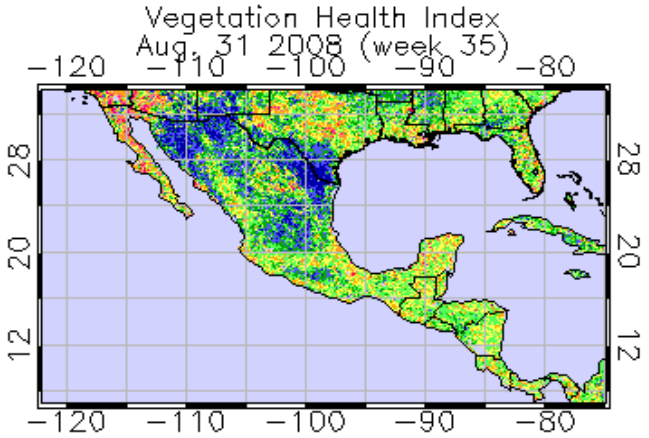
Mike Crimmins, UA Cooperative Extension

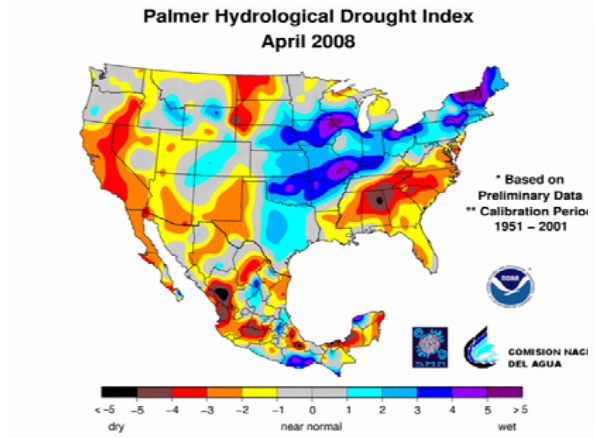
Geographical distribution of PRCP stations

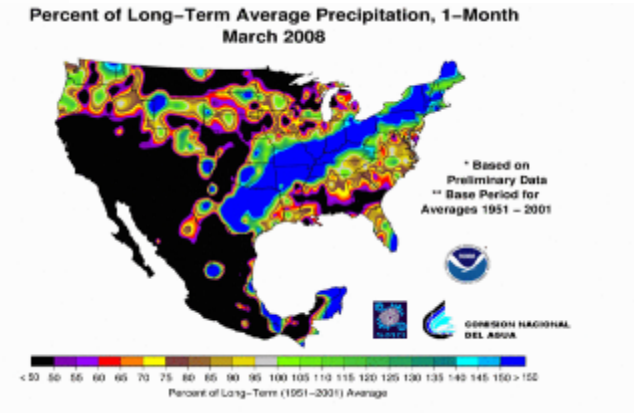
(NADM data base of 132 stations)

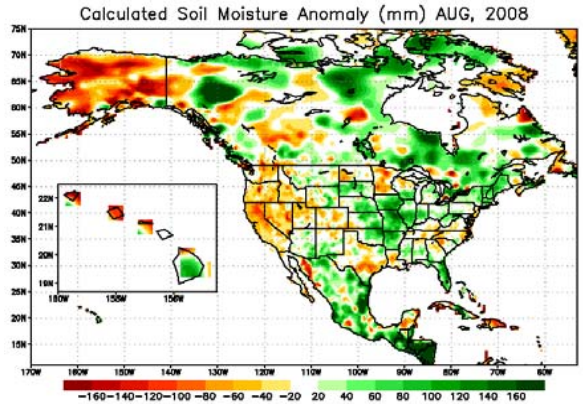
Davydova-Belitskaya and Cruz, 2009

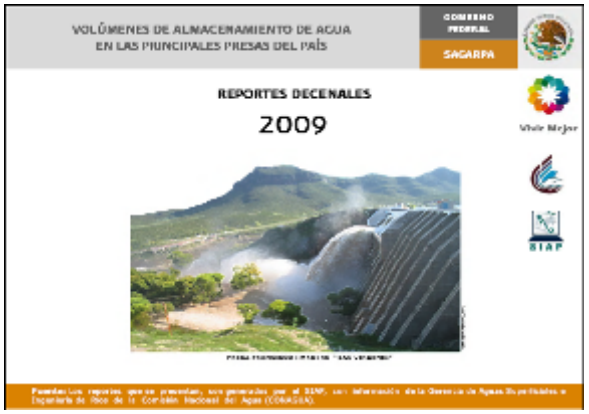
INDICADORES DE SEQUÍA / DROUGHT PARAMETERS

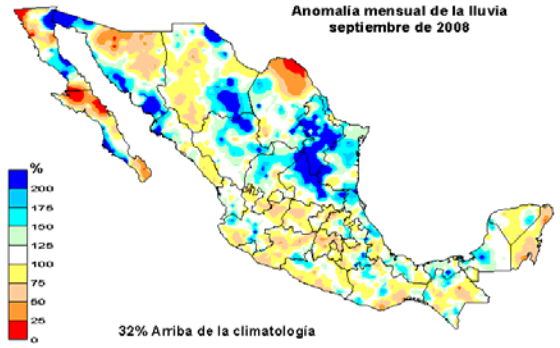


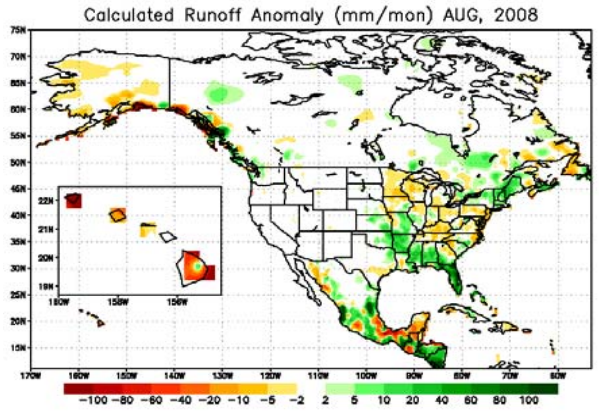


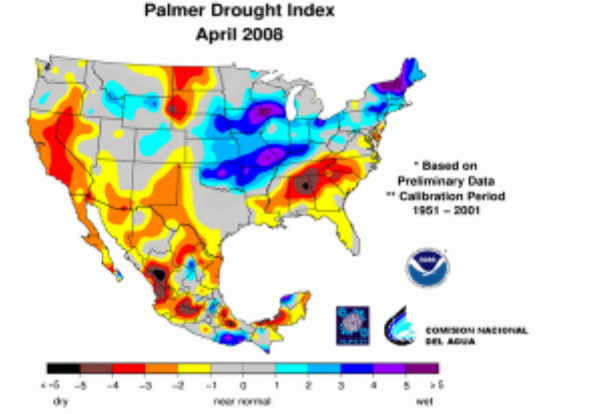












North American Drought Monitor

January 31, 2009

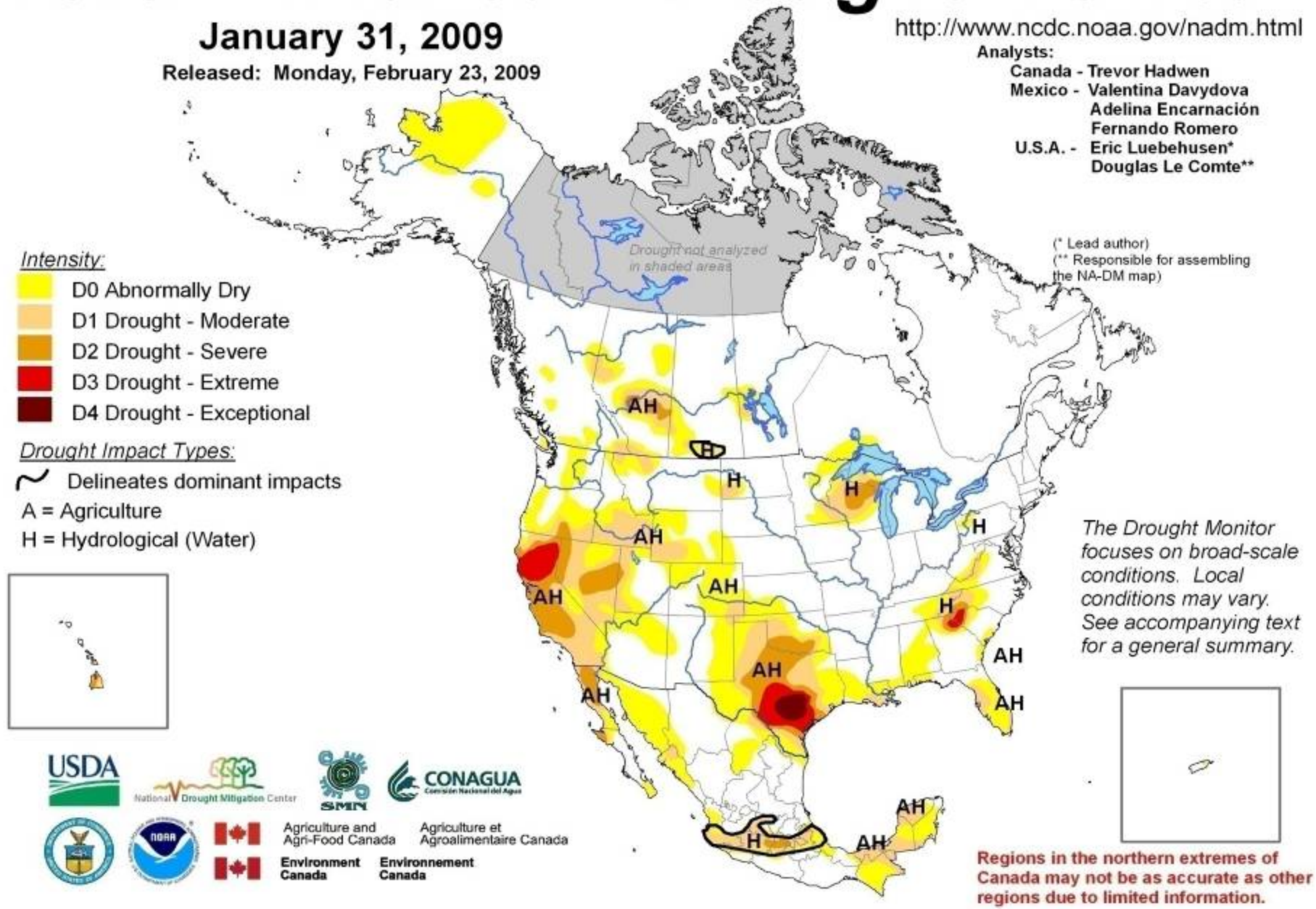
Released: Monday, February 23, 2009

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

Analysts:

Canada - Trevor Hadwen
Mexico - Valentina Davydova
Adelina Encarnación
Fernando Romero
U.S.A. - Eric Luebehusen*
Douglas Le Comte**

(* Lead author)
(** Responsible for assembling the NA-DM map)



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

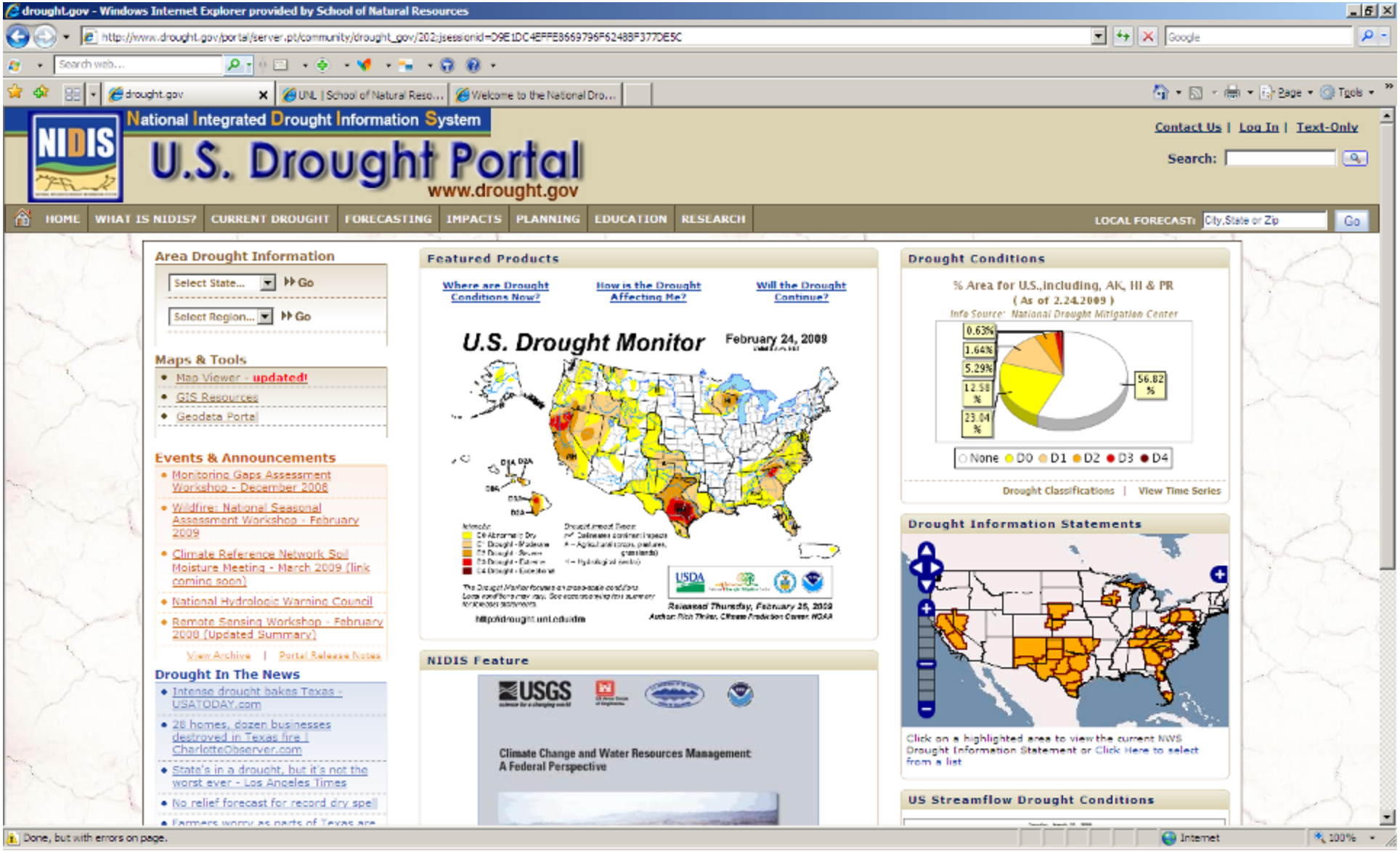
Drought Impact Types:

Delineates dominant impacts
A = Agriculture
H = Hydrological (Water)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text for a general summary.

Regions in the northern extremes of Canada may not be as accurate as other regions due to limited information.

USDA | National Drought Mitigation Center | SMN | CONAGUA Comisión Nacional del Agua | NOAA | Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada | Environment Canada / Environnement Canada


drought.gov - Windows Internet Explorer provided by School of Natural Resources
National Integrated Drought Information System
U.S. Drought Portal
www.drought.gov
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IMPACTS
PLANNING
EDUCATION
RESEARCH
LOCAL FORECAST:
City, State or Zip
Go
Area Drought Information
Select State...
Go
Select Region...
Go
Maps & Tools
Map Viewer - updated!
GIS Resources
Geodata Portal
Events & Announcements
Monitoring Gaps Assessment Workshop - December 2008
Wildfire: National Seasonal Assessment Workshop - February 2009
Climate Reference Network Soil Moisture Meeting - March 2009 (link coming soon)
National Hydrologic Warning Council
Remote Sensing Workshop - February 2008 (Updated Summary)
View Archive | Portal Release Notes
Drought In The News
Intense drought bakes Texas - USATODAY.com
28 homes, dozen businesses destroyed in Texas fire | CharlotteObserver.com
State's in a drought, but it's not the worst ever - Los Angeles Times
No relief forecast for record dry spell
Farmers worry as parts of Texas are
Featured Products
Where are Drought Conditions Now?
How is the Drought Affecting Me?
Will the Drought Continue?
U.S. Drought Monitor
February 24, 2009
Released Thursday, February 26, 2009
NIDIS Feature
USGS
Climate Change and Water Resources Management:
A Federal Perspective
Drought Conditions
% Area for U.S., including, AK, HI & PR
(As of 2.24.2009)
Info Source: National Drought Mitigation Center
0.63%
1.64%
5.29%
12.58 %
23.04 %
56.82 %
None D0 D1 D2 D3 D4
Drought Classifications | View Time Series
Drought Information Statements
Click on a highlighted area to view the current NWS Drought Information Statement or Click Here to select from a list
US Streamflow Drought Conditions
Done, but with errors on page.
Internet
100%

Drought.gov

Experimental Surface Water Monitor for the Continental U.S.

University of Washington

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Multimodel
Plots

Home

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NOAA Regional Climate Centers

Multimodel Surface Water Monitor

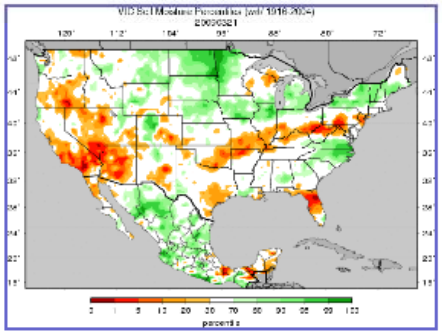
The plots below show the current percentiles for soil moisture, with respect to the climatological period (1916-2004 for CONUS and 1926-2004 for Mexico), for the following models:

- VIC (Variable Infiltration Capacity) version 4.0.6
- Noah (National Centers for Environmental Prediction/Oregon State University/Air Force/Hydrologic Research Lab) version 2.8
- SAC (Sacramento/Snow-17)
- CLM (Community Land Model) version 3.5
- Multimodel (average of the percentiles of VIC, Noah, SAC, and CLM)

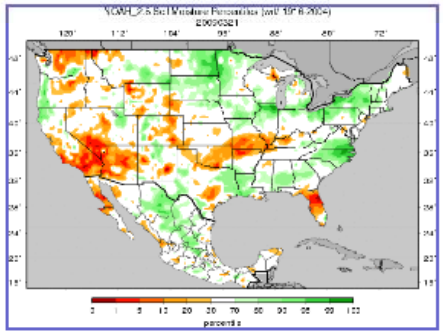
Note: percentiles are computed for current day with respect to grand distribution of values in the 5-day window centered on current day over the climatological period (1916-2004 for continental US and 1926-2004 for Mexico). This is also true of the multimodel ensemble average, i.e. first we compute the average of the percentiles of the individual models, then we compute the percentile of this average with respect to the historical distribution of the average.

(Click on thumbnails below for larger image)

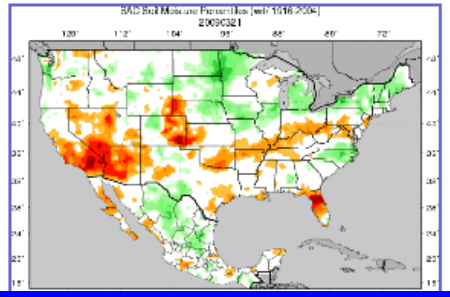
VIC



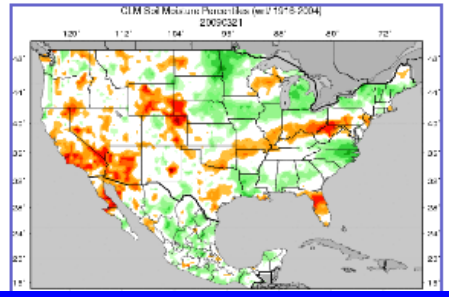
NOAH



SAC



CLM



http://www.hydro.washington.edu/forecast/monitor/curr/conus.mexico/main_sm.multimodel.shtml

UW West-Wide Seasonal Hydrologic Forecast System - Western U.S. Streamflow Forecasts - Mozilla Firefox

File Edit View History Bookmarks Tools Help

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http://www.hydro.washington.edu/forecast/westwide/sflow/

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Drought Indicators | UW West-Wide Seasonal Hydrolo...

- Summary statistics
- Ensemble Data
- Forecast Point Information

Spatial

- Initial Conditions
- Climate Forecast Inputs
- Hydrologic Forecasts

Daily West-wide Monitor

Archive

Research

Verification

Activity Log

Status Log

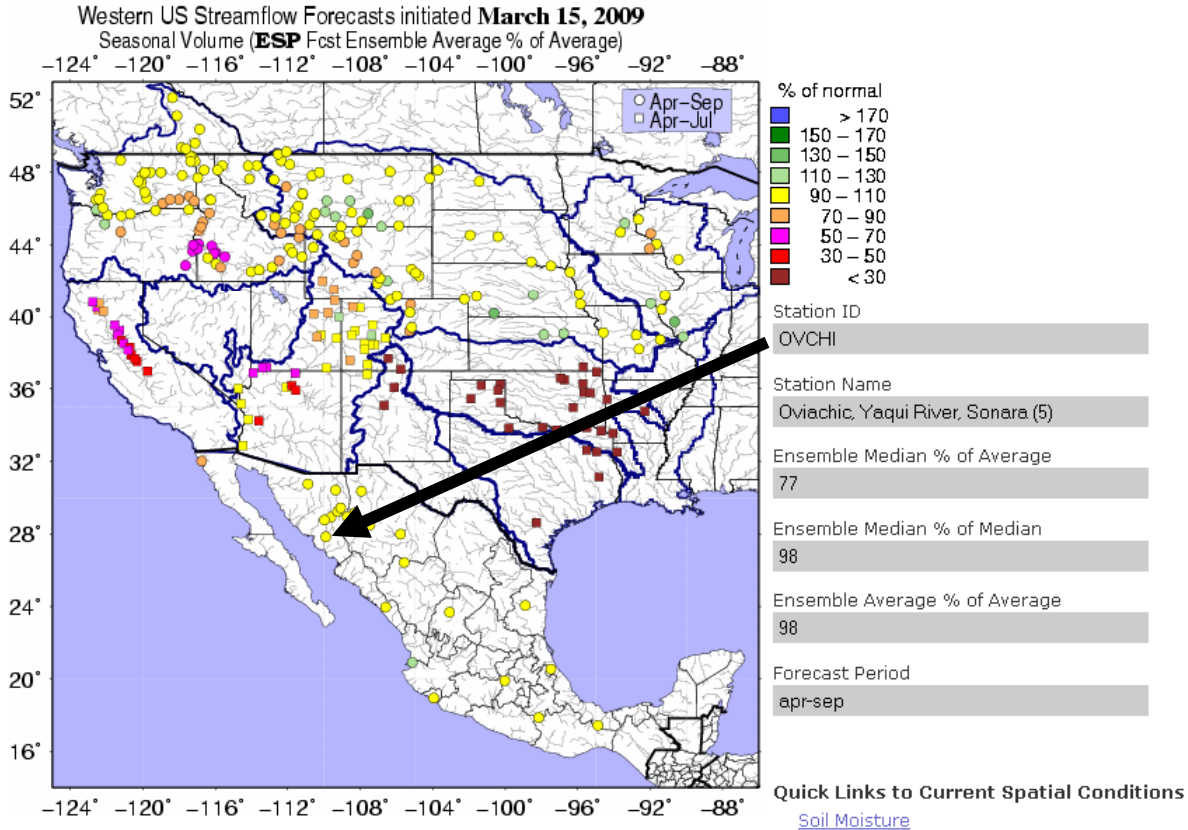
Powered by ACIS NOAA Regional Climate Centers

UNIVERSITY OF WASHINGTON

Seasonal Volume Forecasts

The clickable map below summarizes the current ESP/CPC volume forecasts for the streamflow simulation locations that are currently active. Clicking on a point launches a window showing the monthly streamflow hydrograph distributions for each type of forecast (e.g., ESP, CPC). NEW! **Below the hydrographs, the prior evolution of selected basin-averaged hydrometeorological variables is also shown.** Tabular results for all volume forecasts are available from links at the bottom of the page.

Summer Streamflow: ESP CPC Next 6 months Streamflow: ESP CPC NEW!



Station ID: OVCHI

Station Name: Oviachic, Yaqui River, Sonara (5)

Ensemble Median % of Average: 77

Ensemble Median % of Median: 98

Ensemble Average % of Average: 98

Forecast Period: apr-sep

Quick Links to Current Spatial Conditions

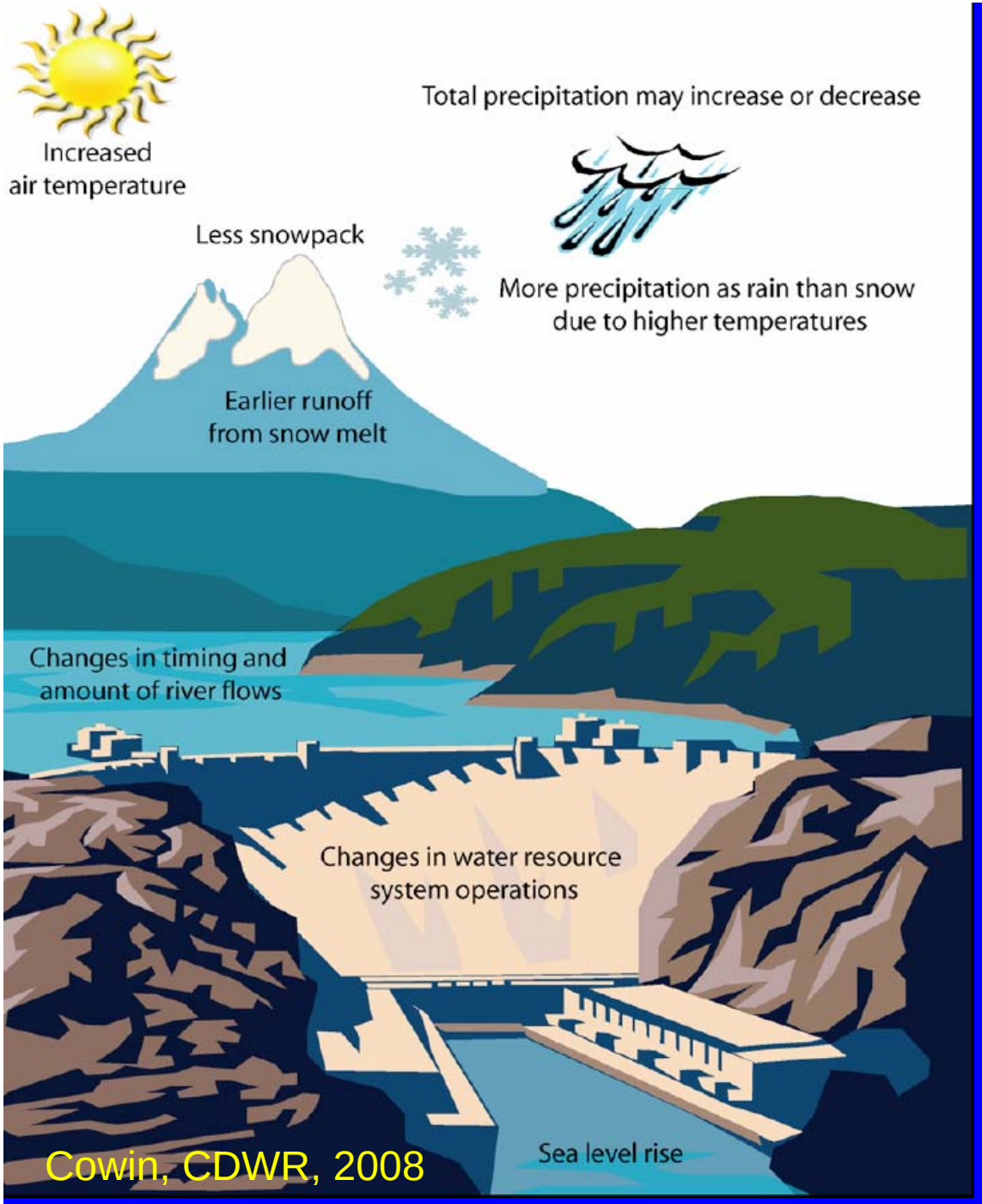
Soil Moisture

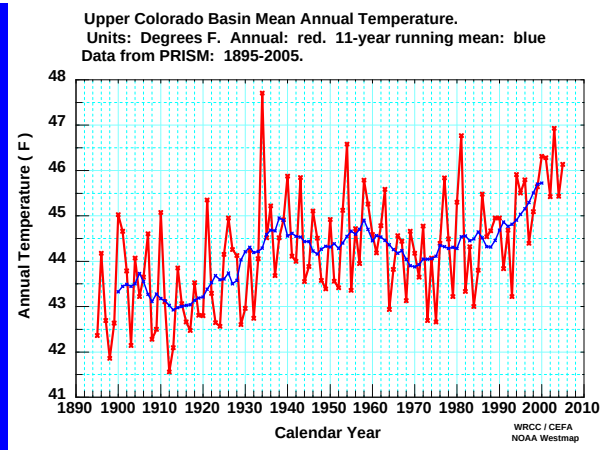
Snow Water Equivalent

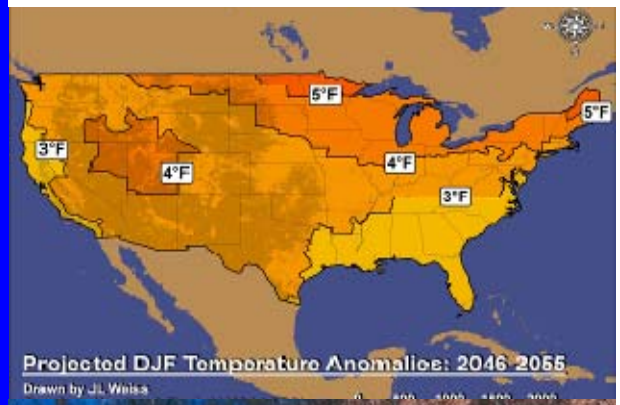
http://www.hydro.washington.edu/forecast/westwide/sflow/

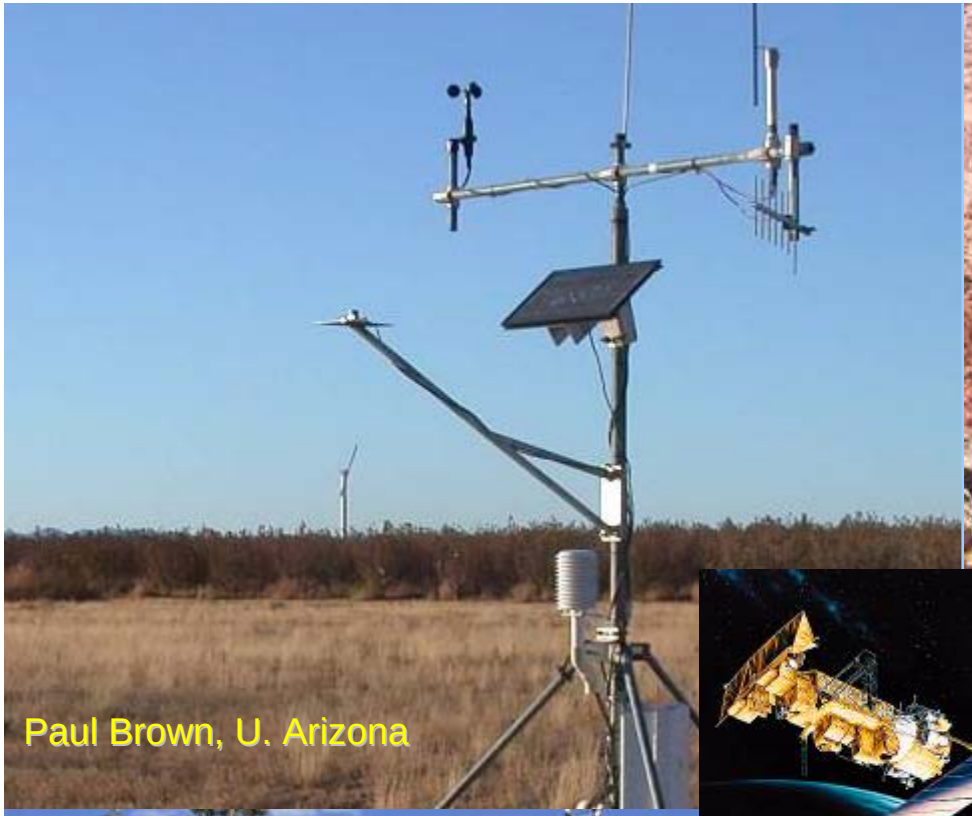
start | UW West-Wide Seas... | UW Experimental Su... | Downloads | Microsoft PowerPoin... | Binational | Desktop | Links | 8:10 PM

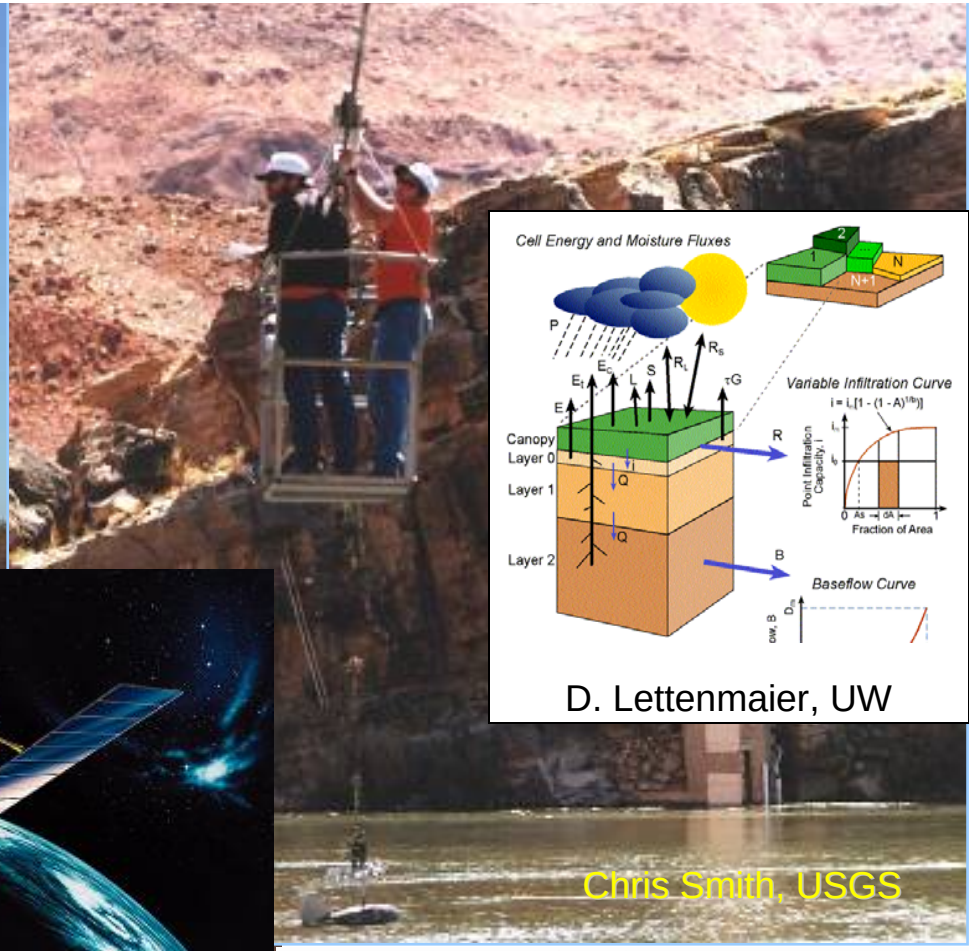
What Do We Need to Do Differently to Cope With Climate Change?


Increased
air temperature
Total precipitation may increase or decrease
Less snowpack
More precipitation as rain than snow
due to higher temperatures
Earlier runoff
from snow melt
Changes in timing and
amount of river flows
Changes in water resource
system operations
Sea level rise
Cowin, CDWR, 2008


Upper Colorado Basin Mean Annual Temperature.
Units: Degrees F. Annual: red. 11-year running mean: blue
Data from PRISM: 1895-2005.
Annual Temperature (F)
48
47
46
45
44
43
42
41
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
Calendar Year
WRCC / CEFA
NOAA Westmap


5°F
5°F
3°F
4°F
4°F
3°F
Projected DJF Temperature Anomalies: 2046-2055
Drawn by JL Weiss


Paul Brown, U. Arizona

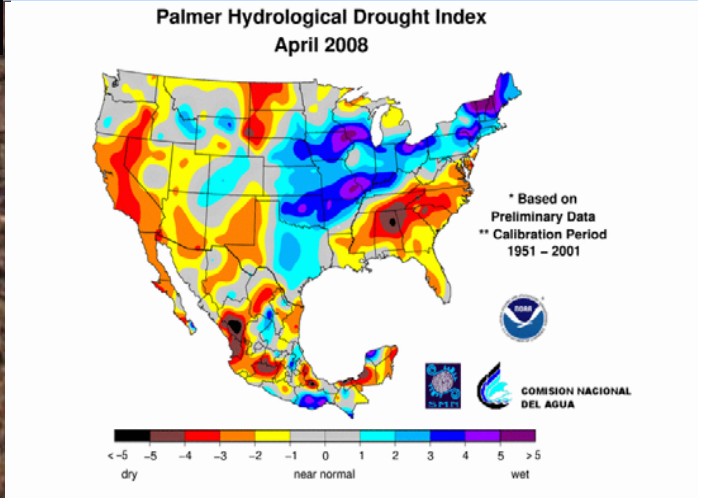


D. Lettenmaier, UW

Chris Smith, USGS


NOAA

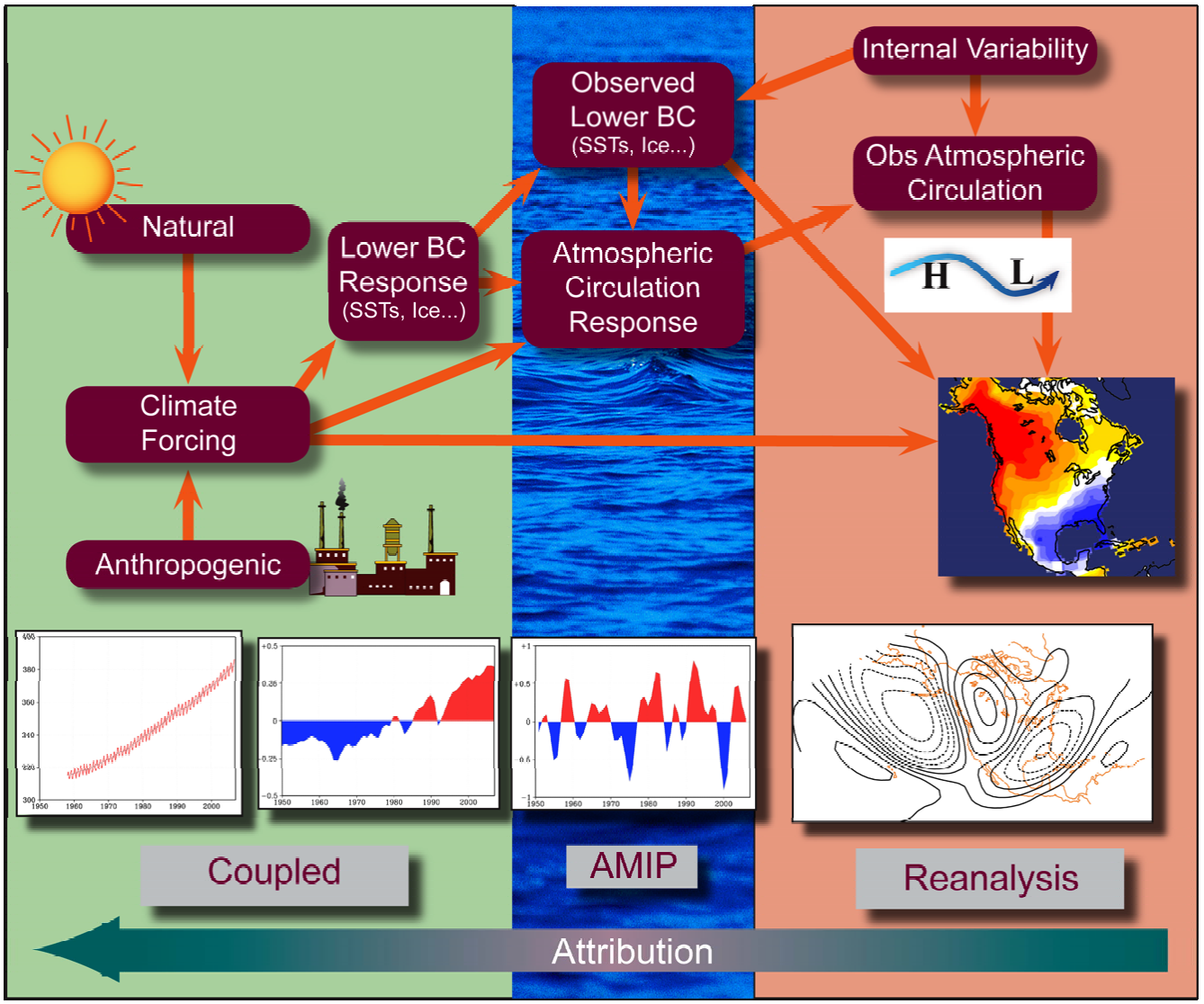

USDA-NRCS SNOTEL
Roger Bales, UC Merced



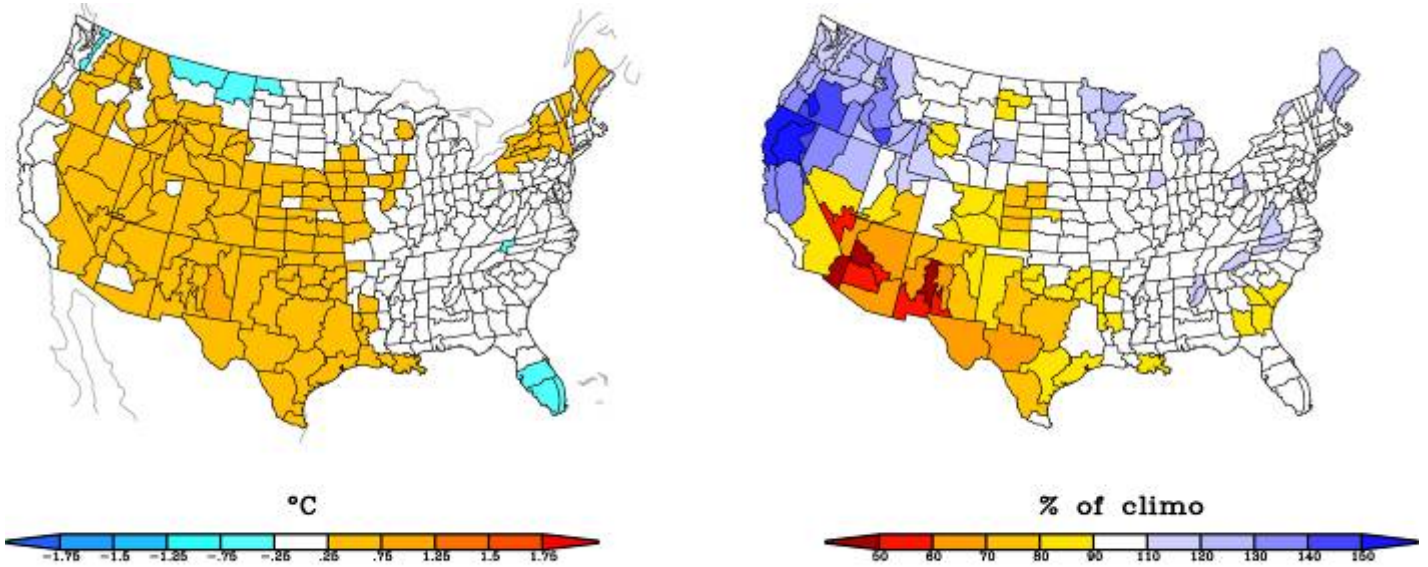
Drought Monitoring for Climate Change

- Seasonality
- Extremes - variability outside of historic ranges
- Temperature as a hydrologic variable
- Demand-side monitoring
  - ET, consumptive uses, groundwater pumping
- Trends
- **Monitoring for detection and attribution**

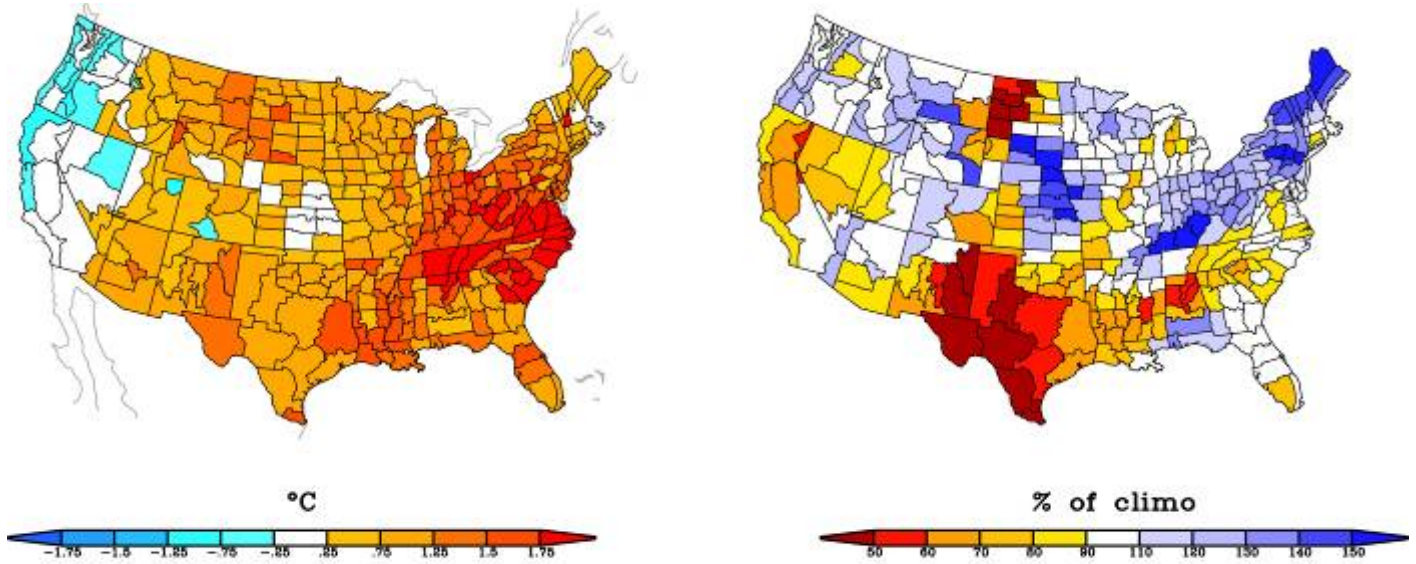
Establishing Attributable Cause



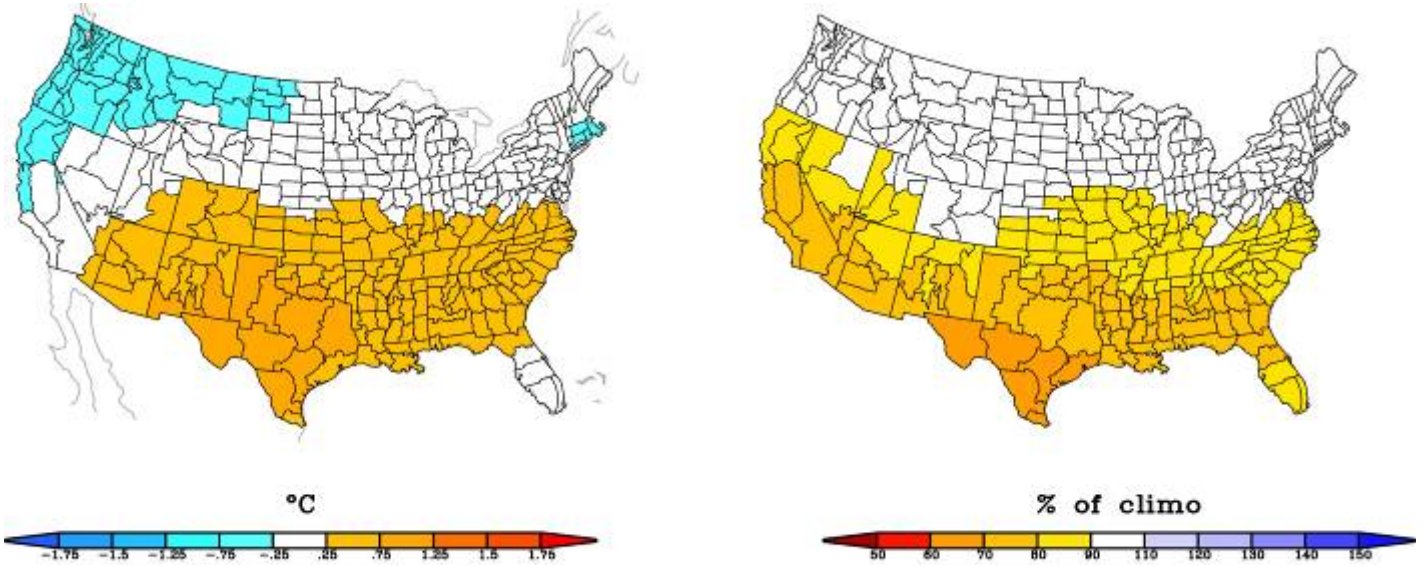
Martin Hoerling and Arun Kumar, NOAA



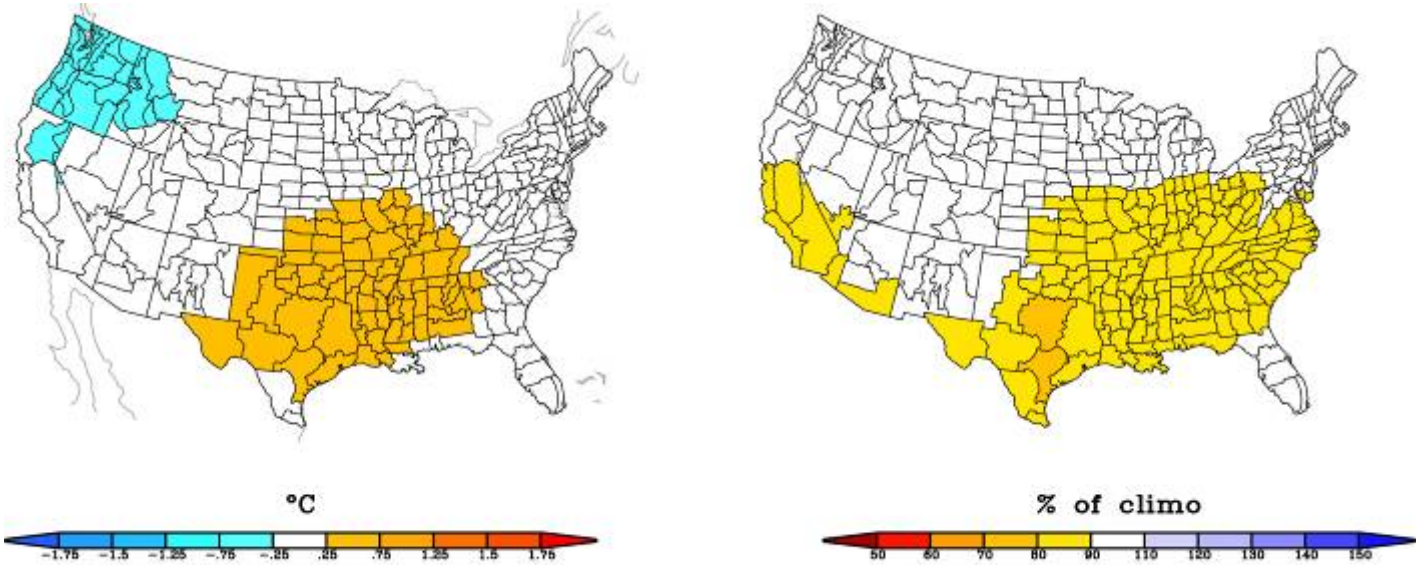
Observed La Nina OND Compostite



Observed OND 2007



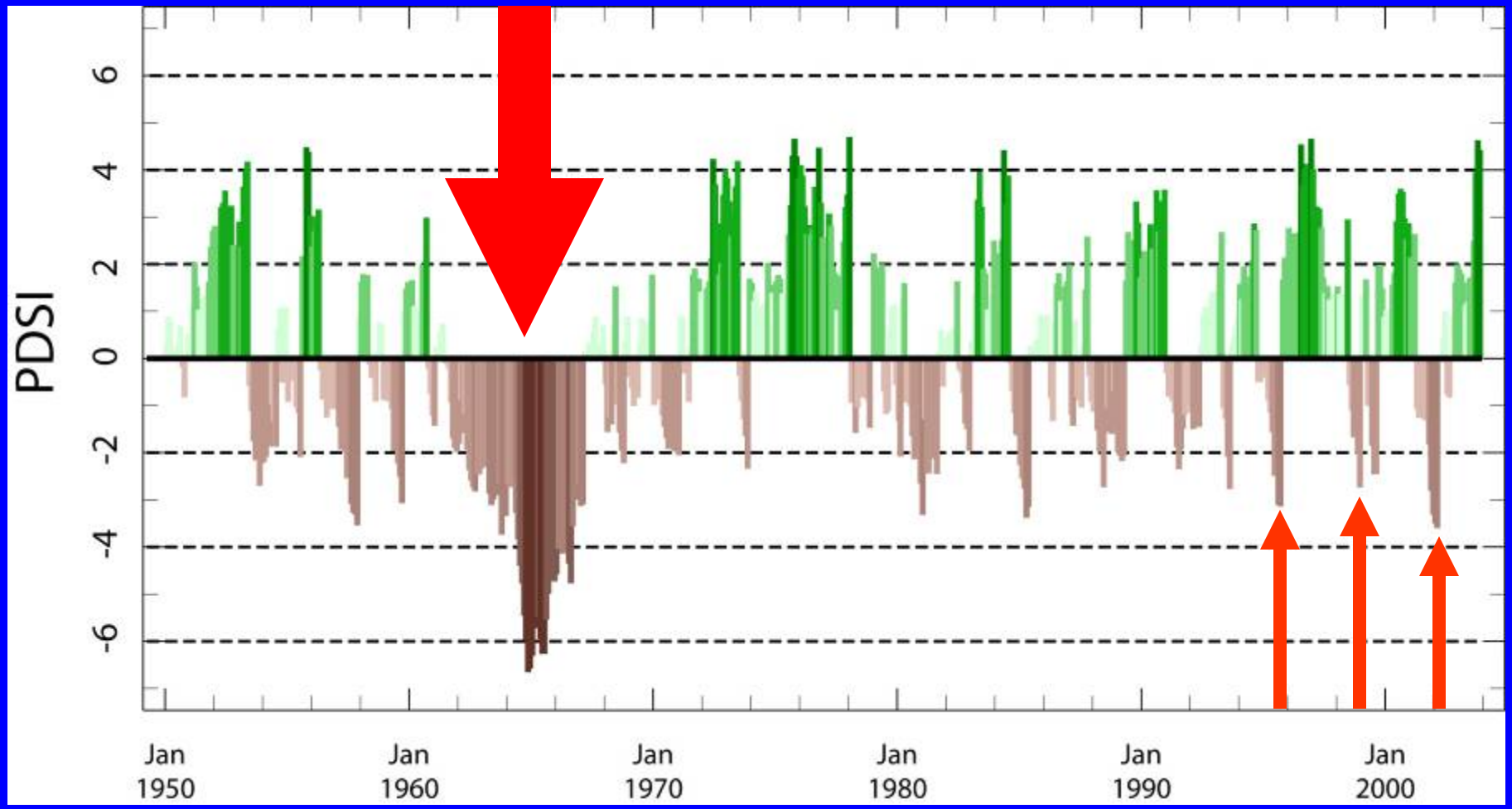
Global Simulated OND 2007



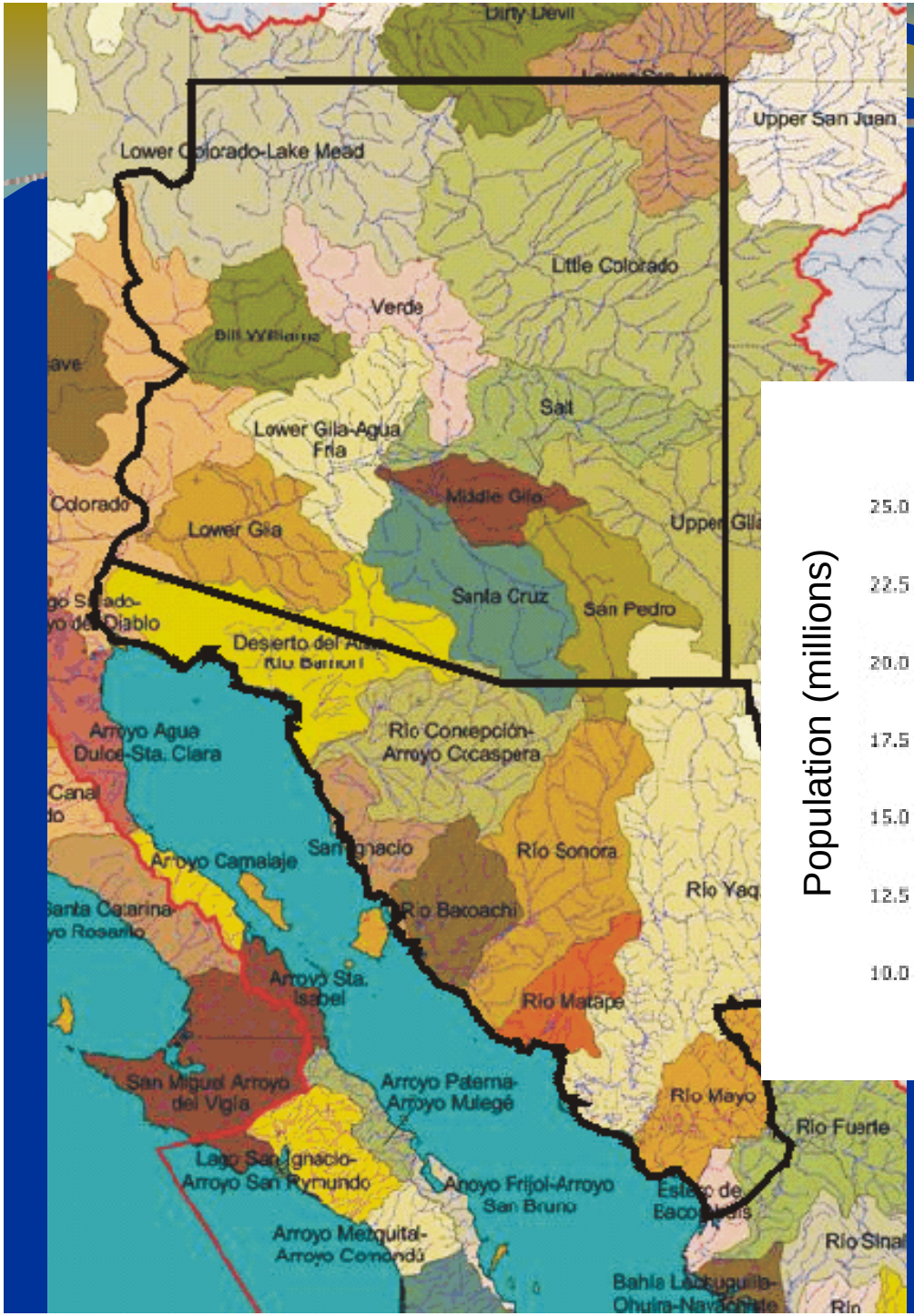
EPAC Simulated OND 2007

Suggestions to Improve Drought Plans for Climate Change

Hudson Valley, NY

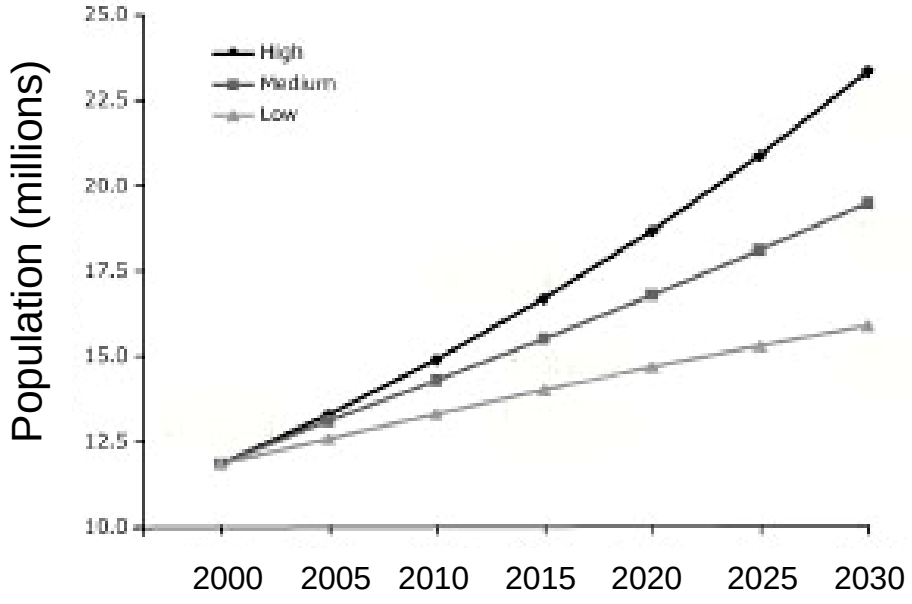


Brad Lyon, IRI/Columbia University



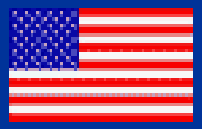
Water and Population

Population Projection:
U.S.-Mexico Border Region



Robert Varady
UA Udall Center for Studies in Public Policy

Context: Institutional



- Decentralized
- Easy data access
- Management continuity
- Strong regulation and enforcement
- Good access to funds for management and research

- Highly centralized
  - Consejos de Cuenca
- Limited data access
- Short-term water management appointments
- Gap between laws and enforcement
- Lack of funds

R. Varady, M. Wilder, R. Diaz, UA Udall Center + CLIMAS

Improved Vulnerability Assessments

- Hydrological vulnerability
- Vulnerable water supply and delivery systems
  - Improve security of surface water supplies
    - non-stationarity
    - decadal variation
    - climate signals propagating slowly in groundwater in arid areas
- Changes in energy supplies and costs

Improved Vulnerability Assessments

- Social, cultural and economic issues and perceptions affect vulnerability:
  - Response of indigenous communities to drought is often different from that of neighboring communities;
  - Long-term farmers may be less likely to diversify and survive economically;
  - Farming communities may object to fallowing programs on principle even if the economics are significantly in their favor

Integrated Planning

- **Integrate** long-term water management planning objectives with drought planning
- Reuse, desalination, surface-groundwater conjunctive managment, water banking
- Economic alternatives
  - Dry year trade-offs
  - Water markets
- Shifts in global agriculture production
- Iterative assessment – adaptive management

Metrics for Drought Planning Success

- Coordination and Structure
- Planning
- Communication and Awareness
- Infrastructure
- Preparedness
- Conservation Action
- Policy, Regulation, and Conflict Resolution

Gregg Garfin

Director for Science Translation and Outreach
Institute for Environment and Society
The University of Arizona

gmgarfin@email.arizona.edu
520-622-9016
www.ispe.arizona.edu

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THE UNIVERSITY OF ARIZONA.

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Climate Assessment Project for the Southwest

RISA
Regional Integrated Sciences and Assessments

Building Bridges Between Climate Sciences and Society