# The Moisture Balance Drought Index and Efforts to Improve Drought Indicator Reporting

U.S. Drought Monitor Forum
October 8, 2009

**Gregg Garfin and Melanie Lenart**

Institute of the Environment

CLIMAS
Climate Assessment Project for the Southwest

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

**Andrew Ellis and Kevin Murphy**

ASU School of Geographical Sciences & Urban Planning
Arizona State University

Global Institute of Sustainability
Arizona State University

Decision Center for a Desert City
DCDC

# Outline

- MBDI methods and validation
- Website and sustainability
- AZ DroughtWatch
- CHANGE

**Lake Powell's decline**
J. Dohrenwend, USGS

**Wildland Fire**
Courtesy of Ron Smallwood

**Southwest U.S. forest die-off**
T. Degomez, UA Cooperative Extension

**2002**
**Soil desiccation**
*Arizona Daily Star*

# Moisture Balance Drought Index: MBDI

**P** (supply) – **PE** (demand)

$$PE = 13.97 dD^2 W_t$$

d = days in month
D = mean monthly daylight hours
$W_t$ = saturated water vapor density

$$W_t = \frac{4.95e^{0.062T}}{100}$$

T = mean monthly temperature (°C)
*e* = natural log

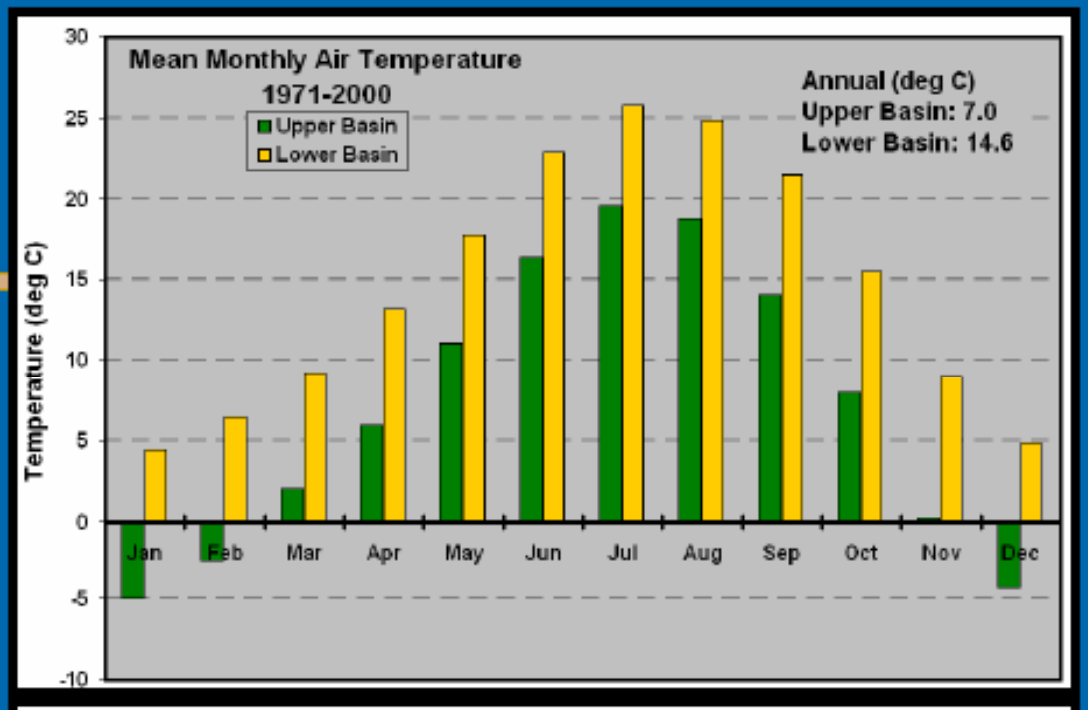
# Moisture Balance Drought Index: MBDI

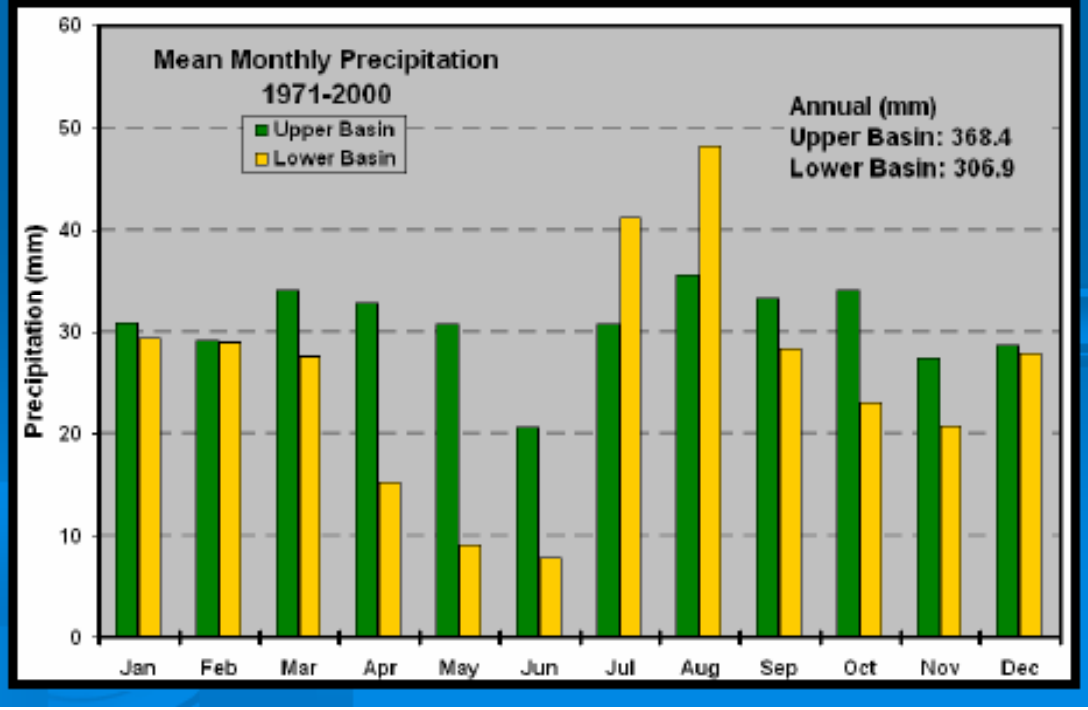
- Input data: PRISM
- Multiple time scales
  - 1- 3- 6- 12- 24- 36- and 48-month periods
- Historic perspective
  - **translated to percentiles**

# Basin Climatology

Lower Basin 2Xs warmer than Upper Basin – pronounced in cool season

Upper Basin wetter in fall and spring; Lower Basin wetter during monsoon season



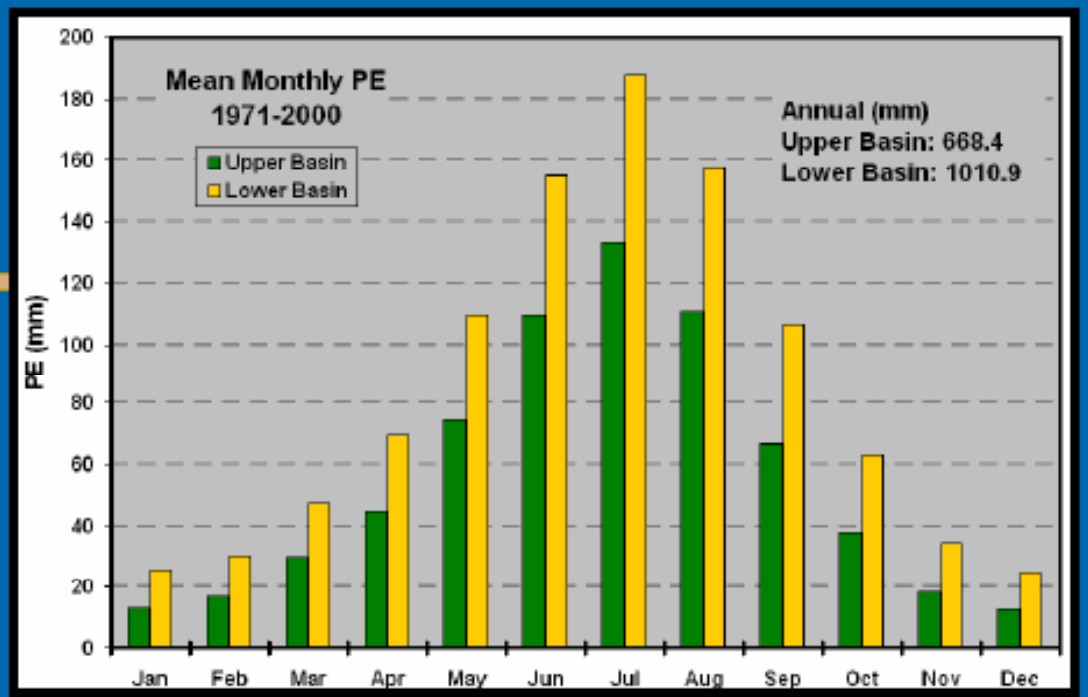
# Basin Climatology

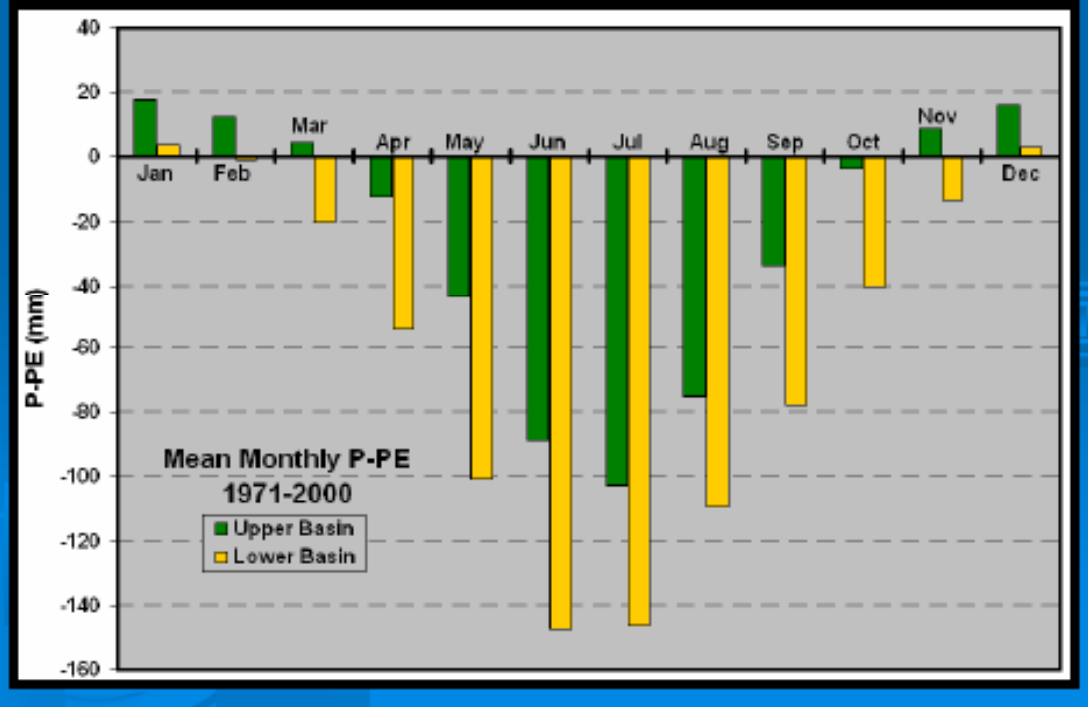
Lower Basin 1.5Xs the PE of the Upper Basin

P > PE

Nov-Mar on Upper Basin

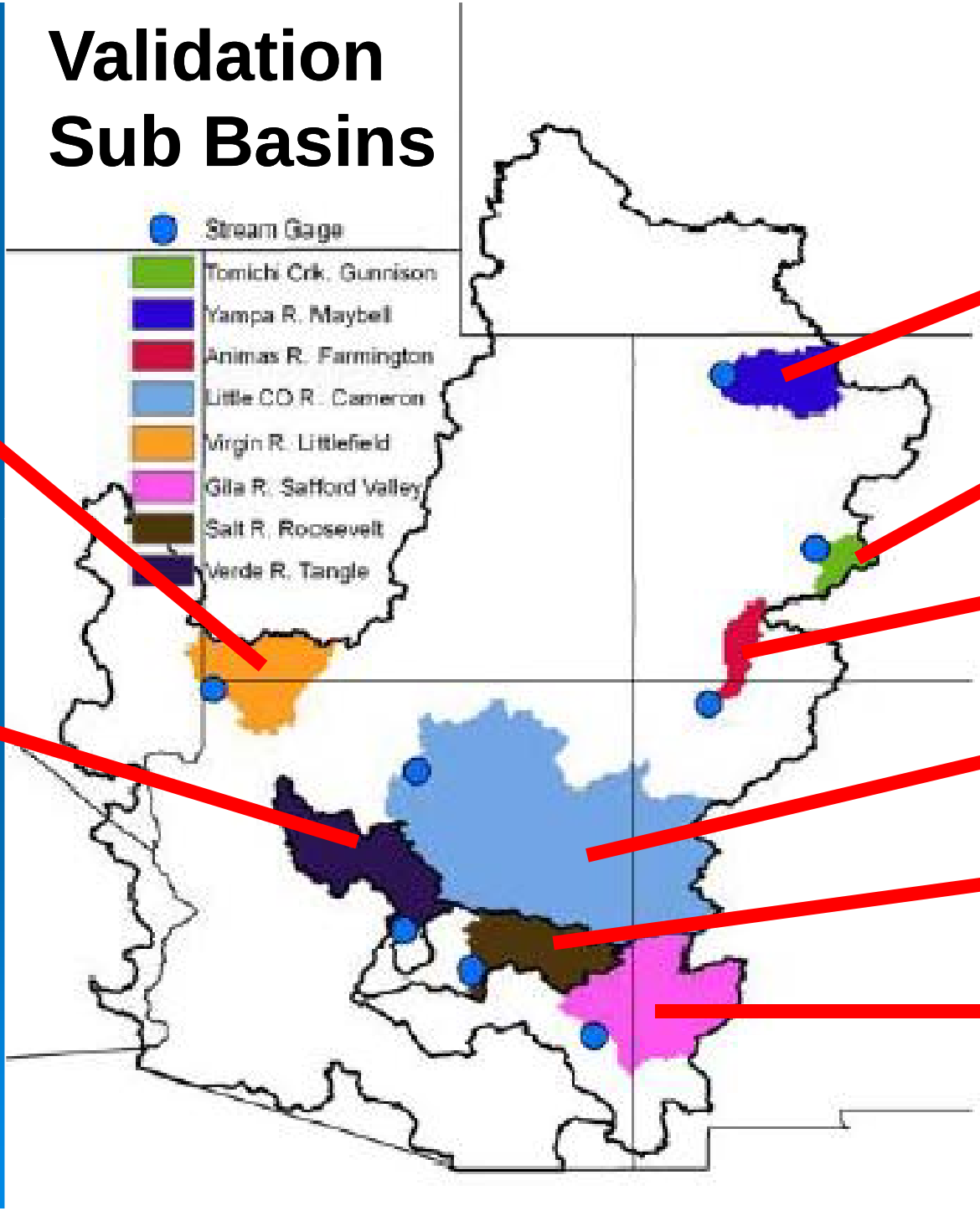
Dec-Jan on Lower Basin



# Validating MBDI

# Validation Sub Basins




Yampa

Tomichi

Animas

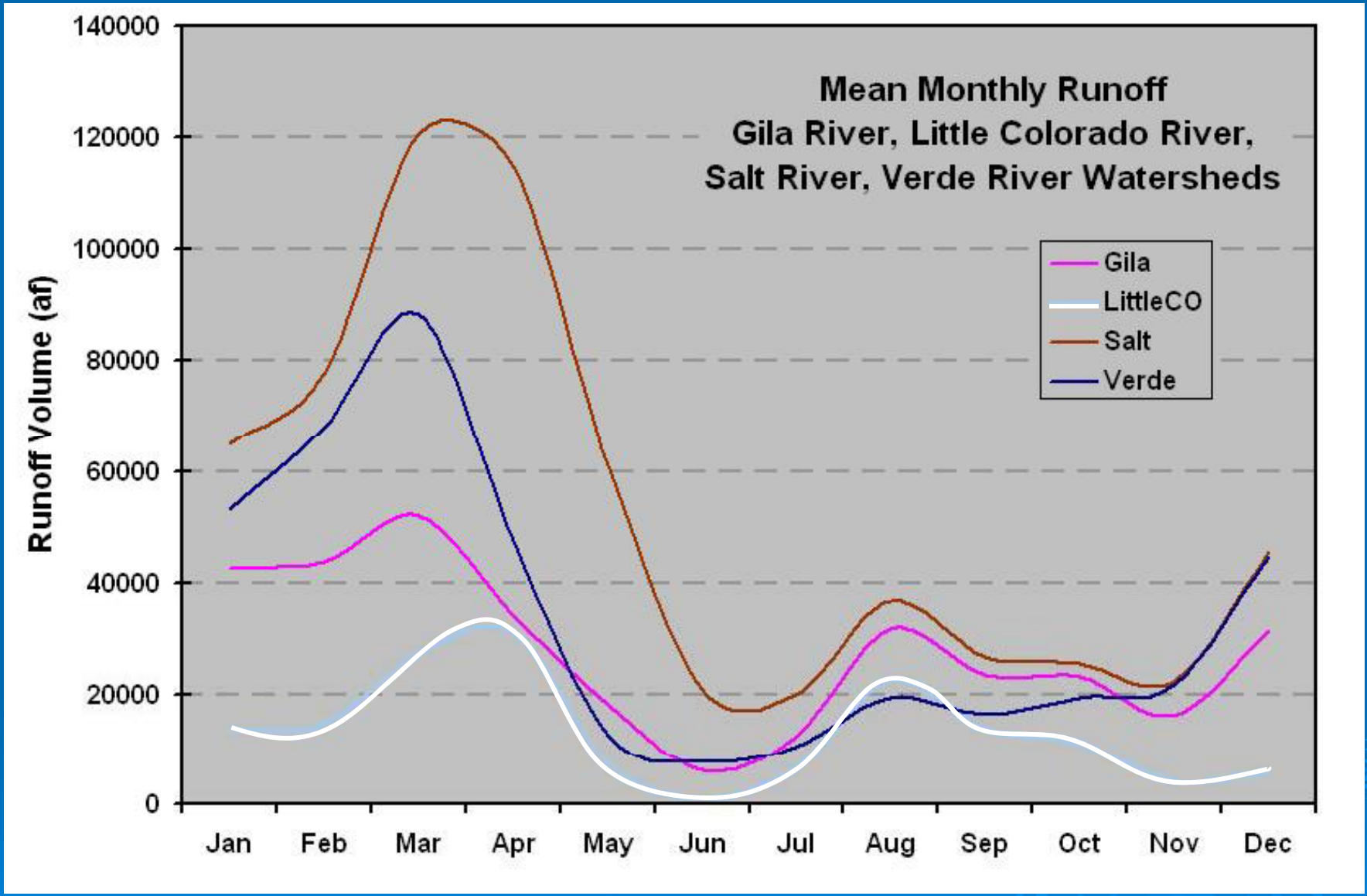
Little Colorado

Salt

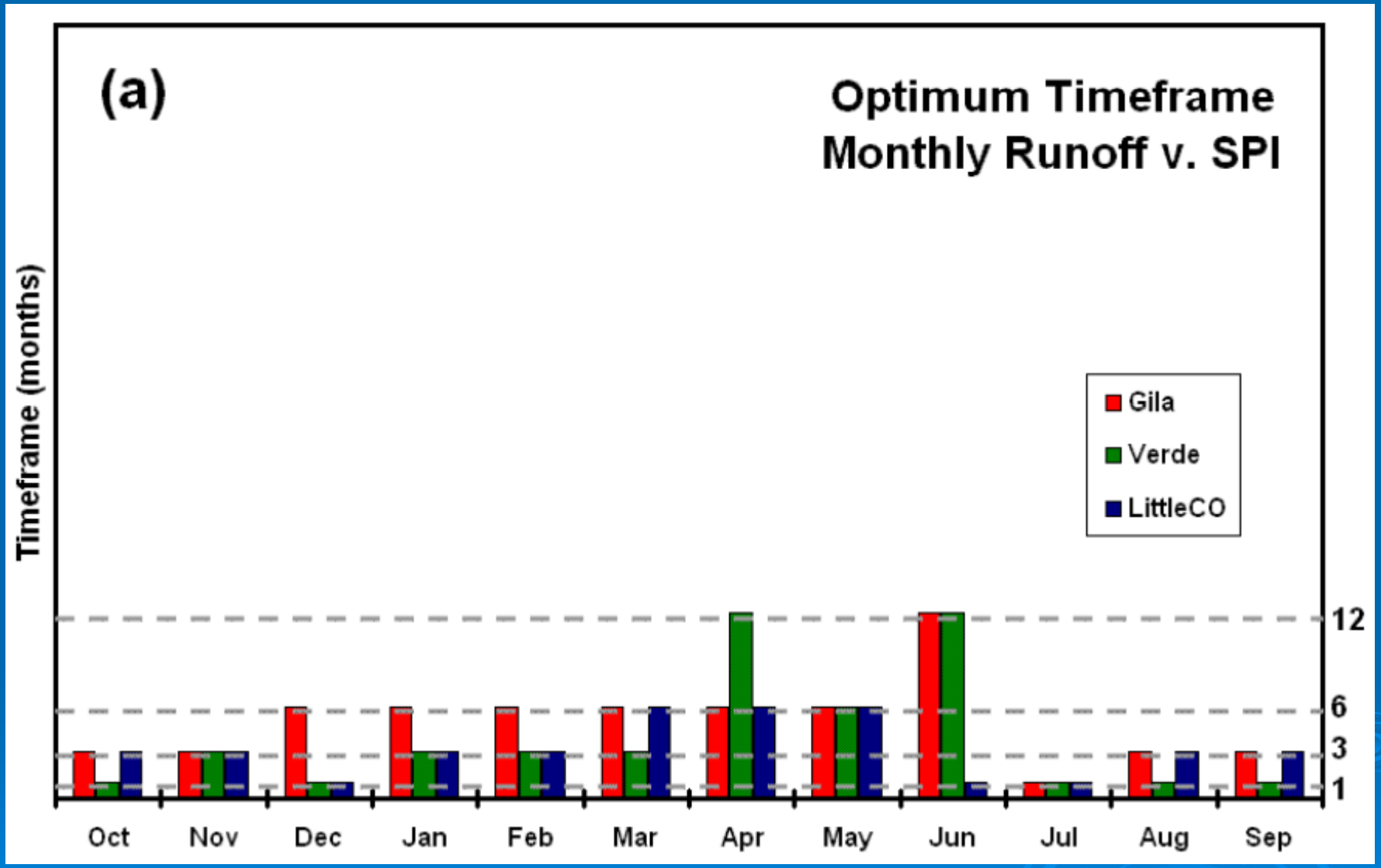
Gila

Virgin

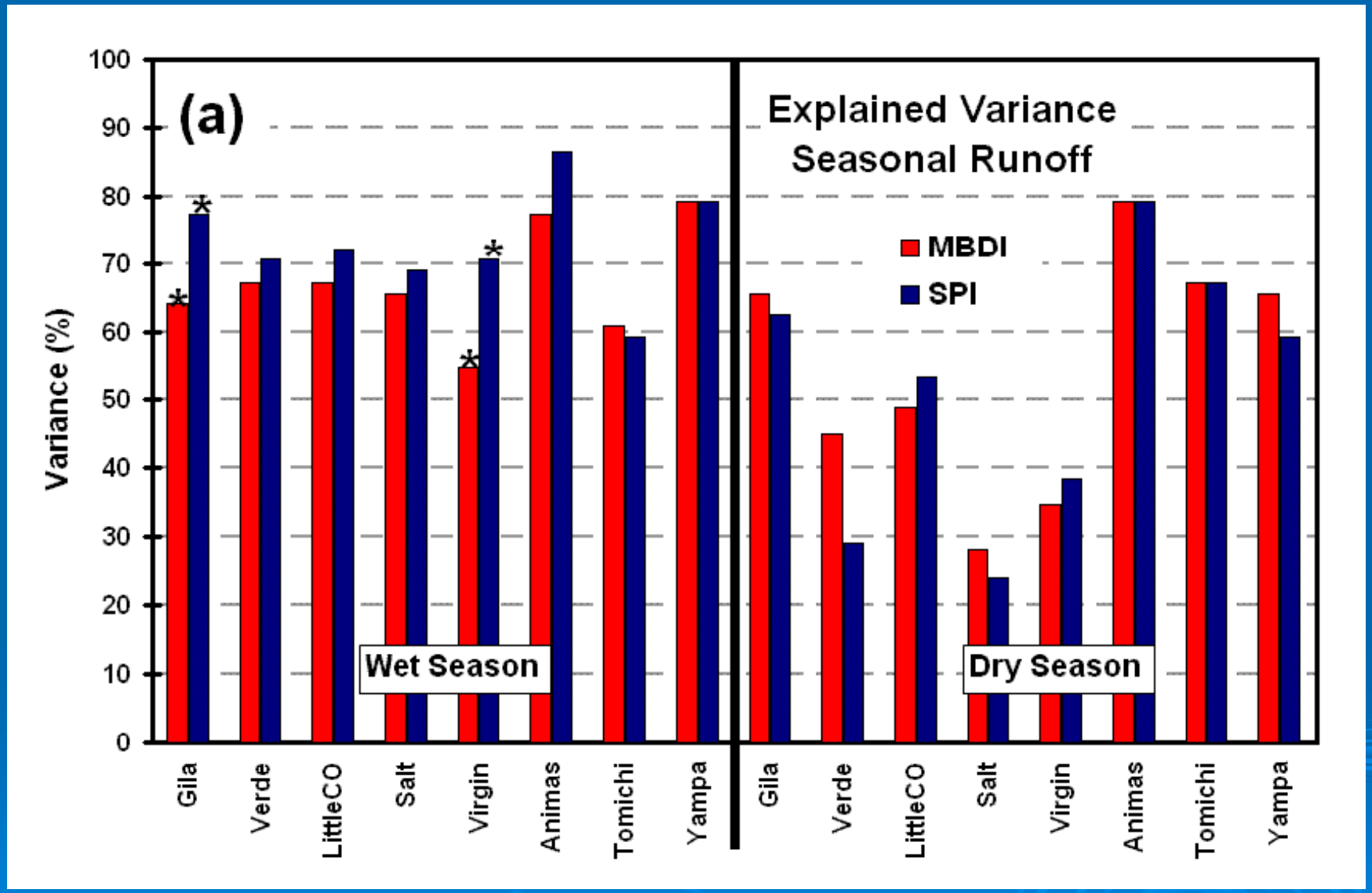
Verde




Chris Castro, University of Arizona

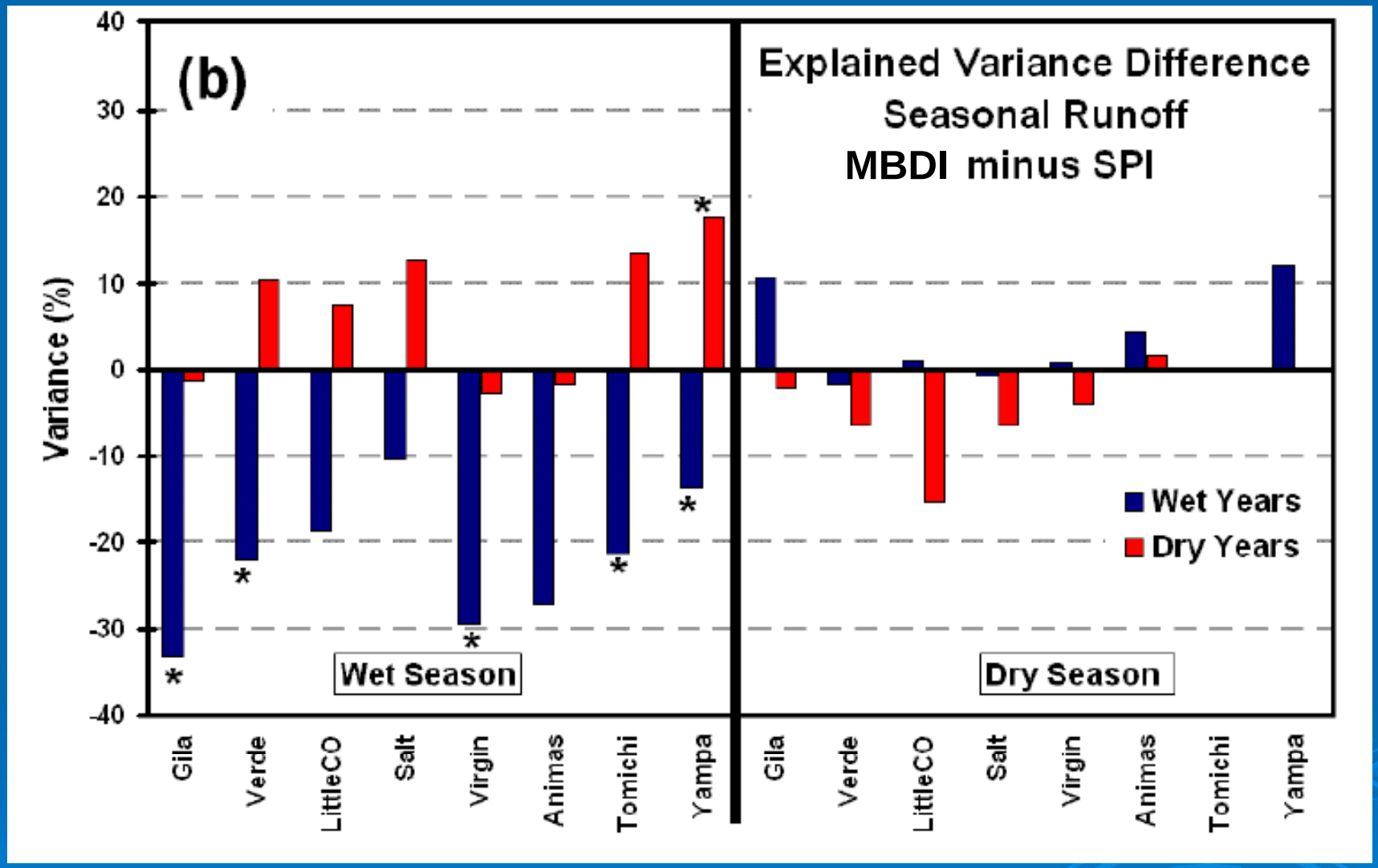

(a)
Optimum Timeframe
Monthly Runoff v. SPI
Timeframe (months)
Gila
Verde
LittleCO
12
6
3
1
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

WET SEASON DRY SEASON



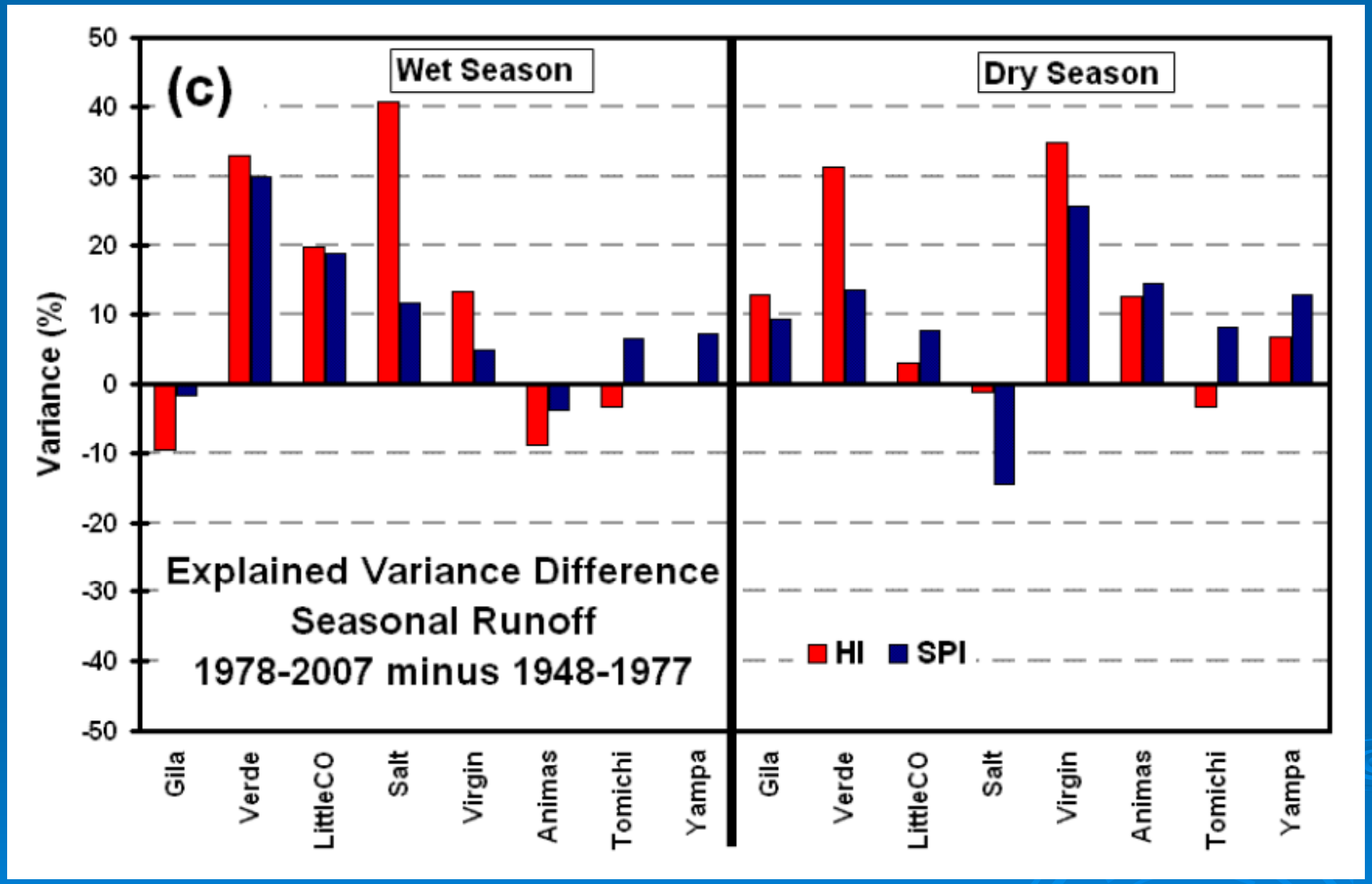

October-April, May May, June-September

WET SEASON DRY SEASON

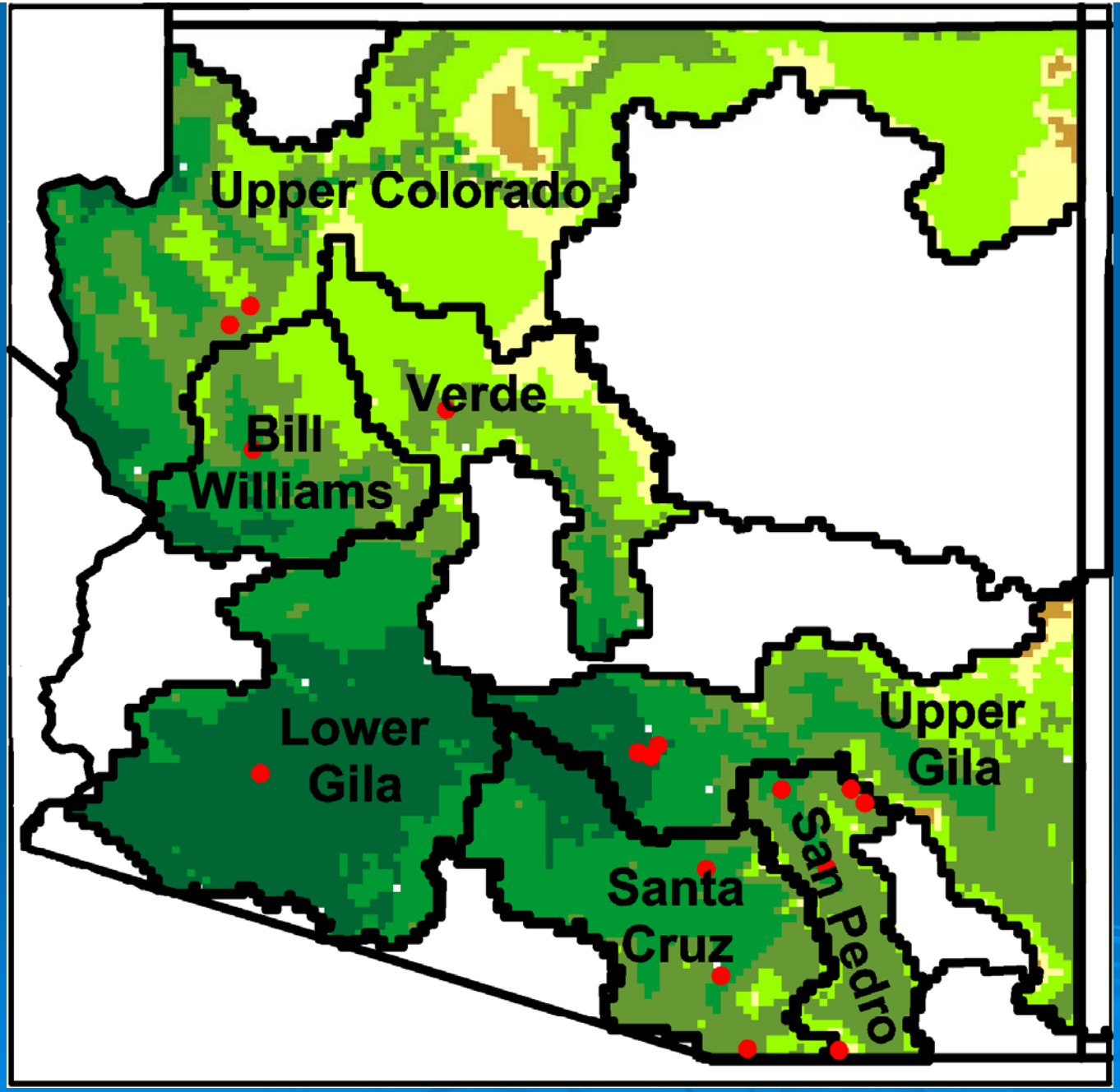



October-April, May May, June-September

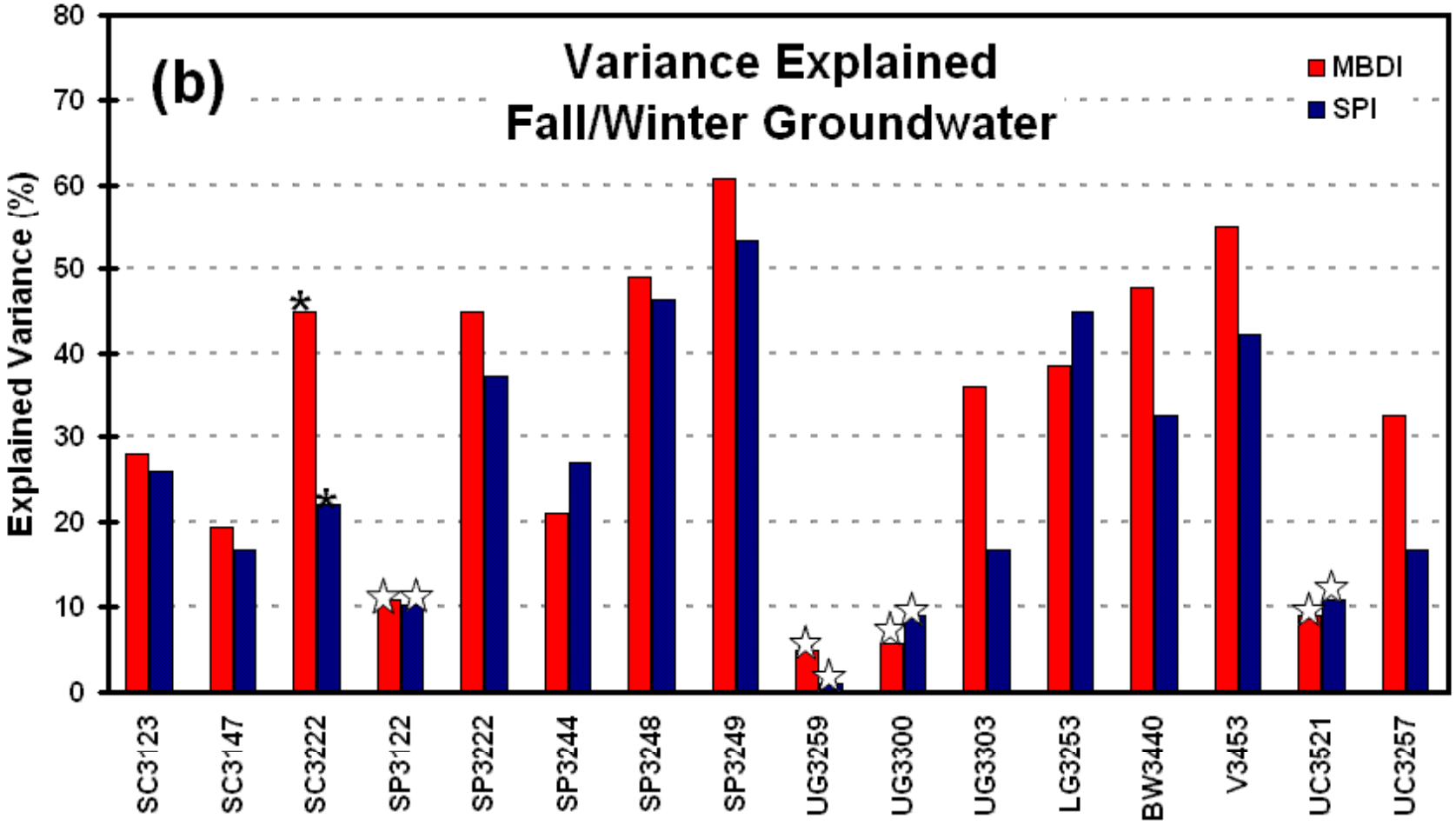
WET SEASON DRY SEASON




October-April, May May, June-September




Teri Davis, ADWR and Nancy Selover, Arizona State University



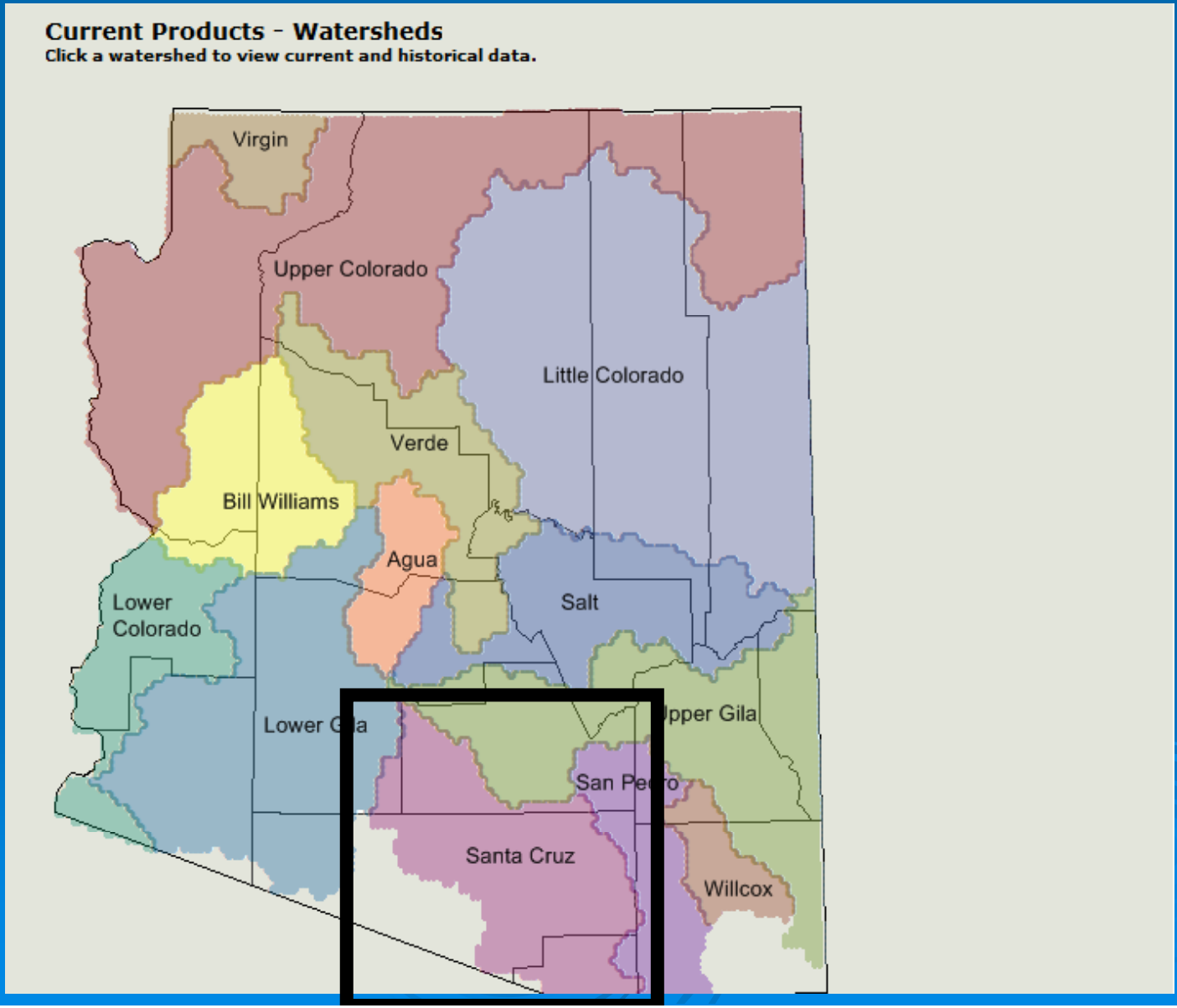

Santa Cruz | San Pedro | Upper Gila | Bill Williams | Upper Colorado

Optimum time frame 3-7 years

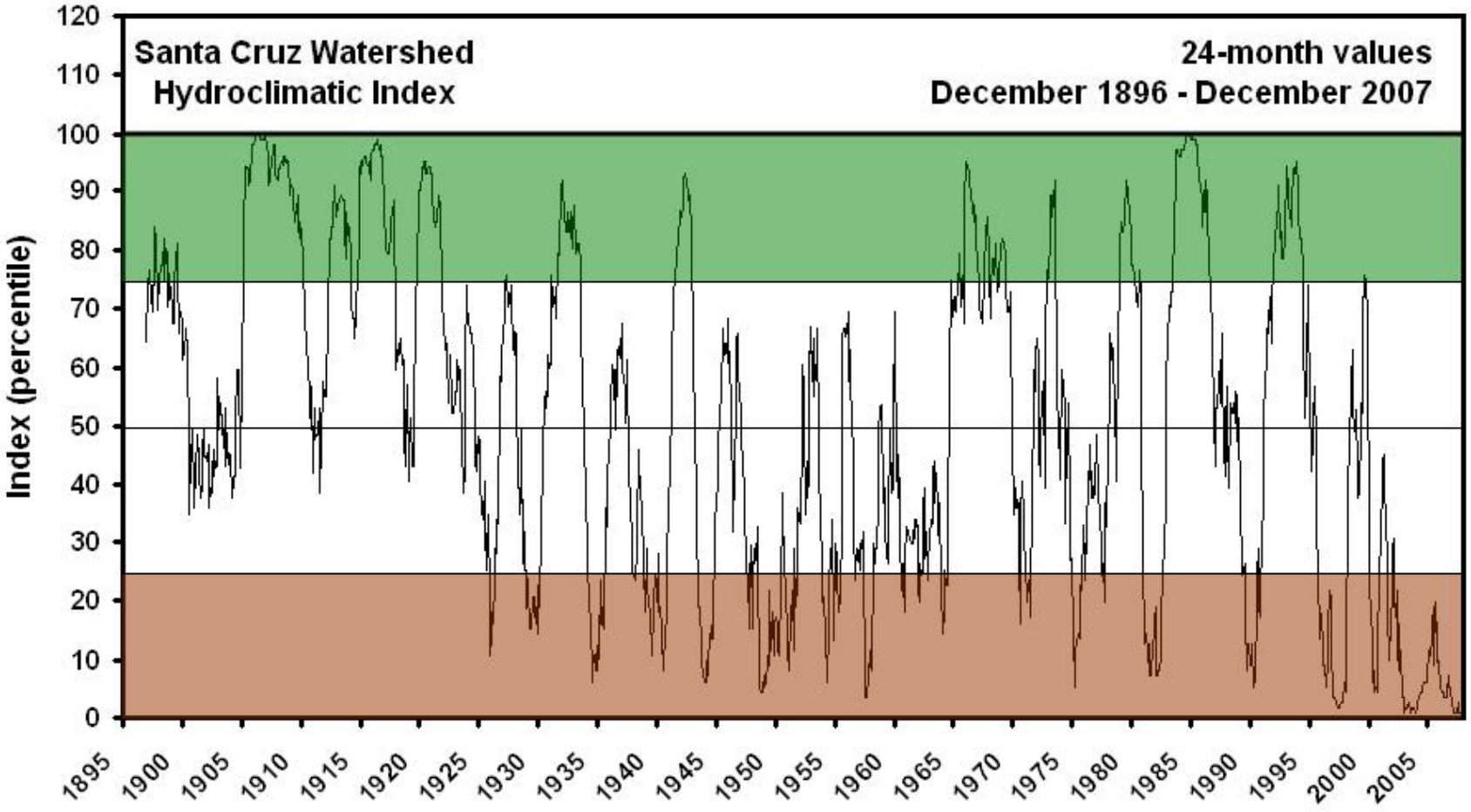
# Validation Summary

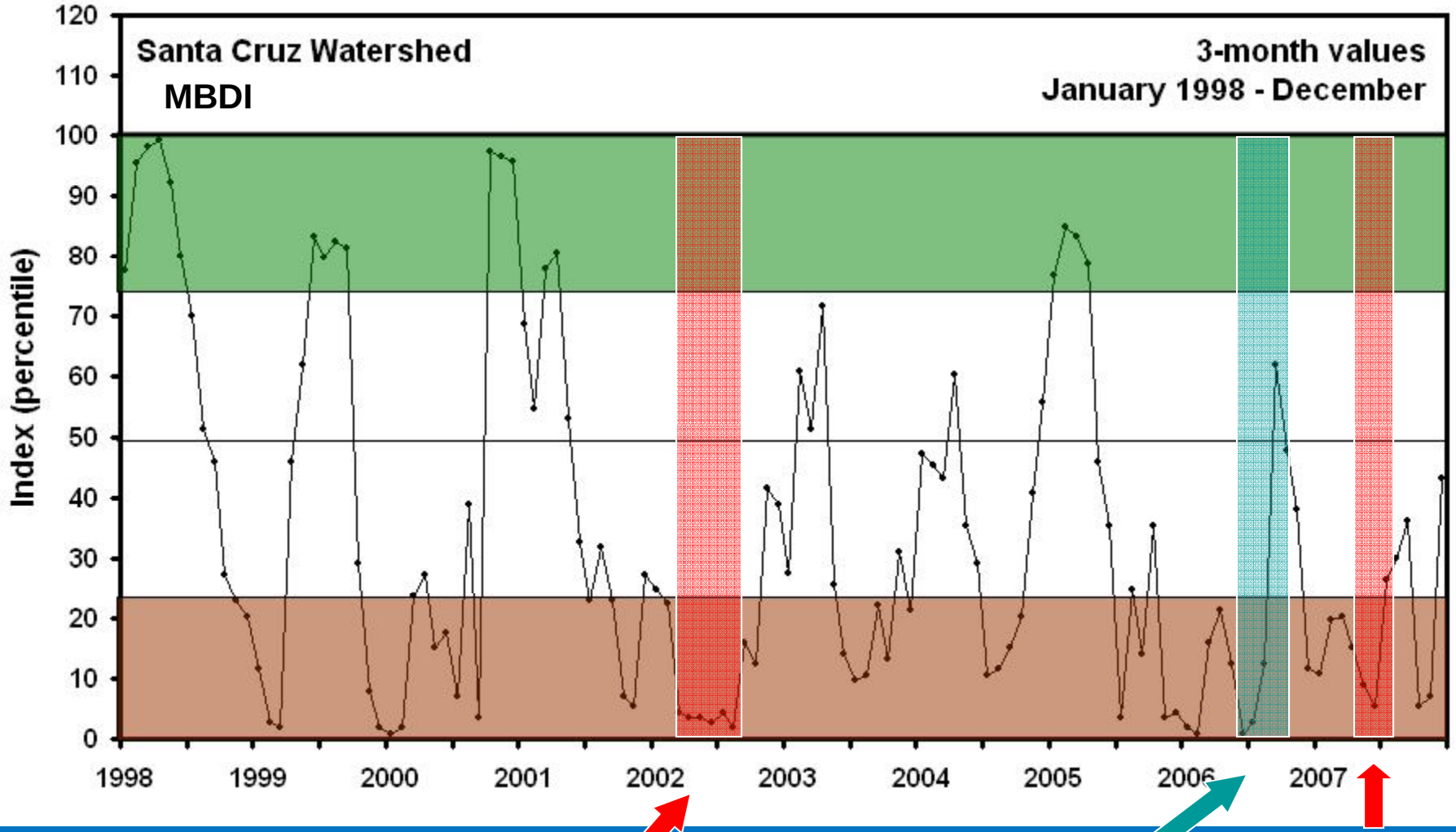
- MBDI, SPI: comparable
- MBDI slightly better for dry side
  - Dry years in wet season
  - Dry season runoff
- MBDI better for groundwater
- MBDI better for warmer part of record
- MBDI worse for wet season runoff
- MBDI worse for reservoir storage

# Time series for Santa Cruz



# 100+ Years of MBDI – Santa Cruz Watershed



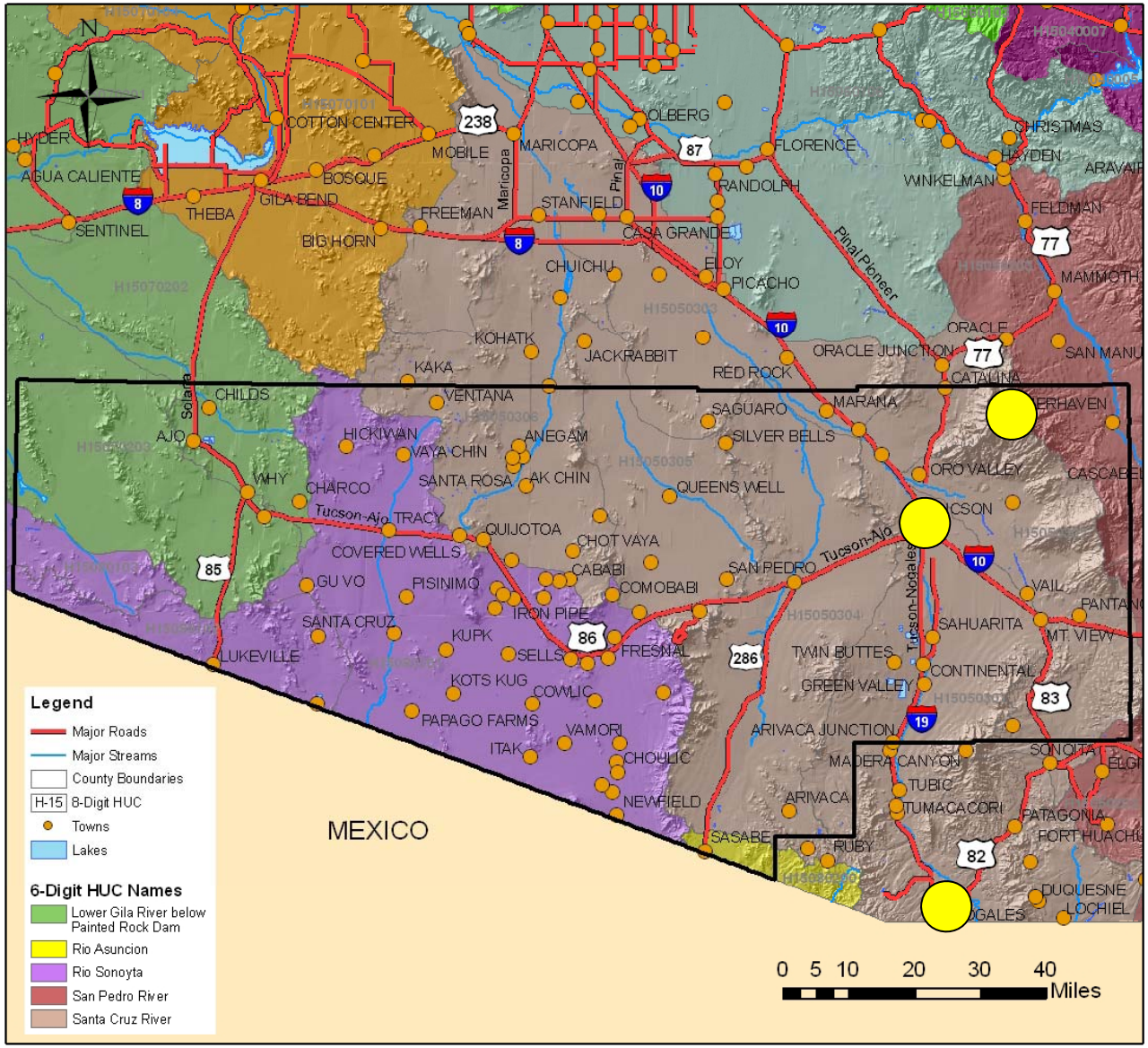



Bullock fire

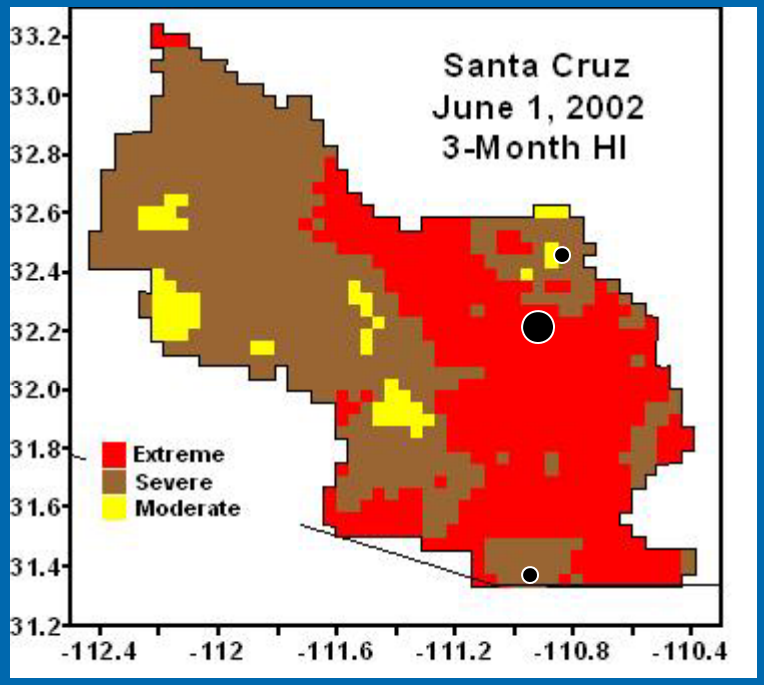
Santa Cruz, Rillito floods

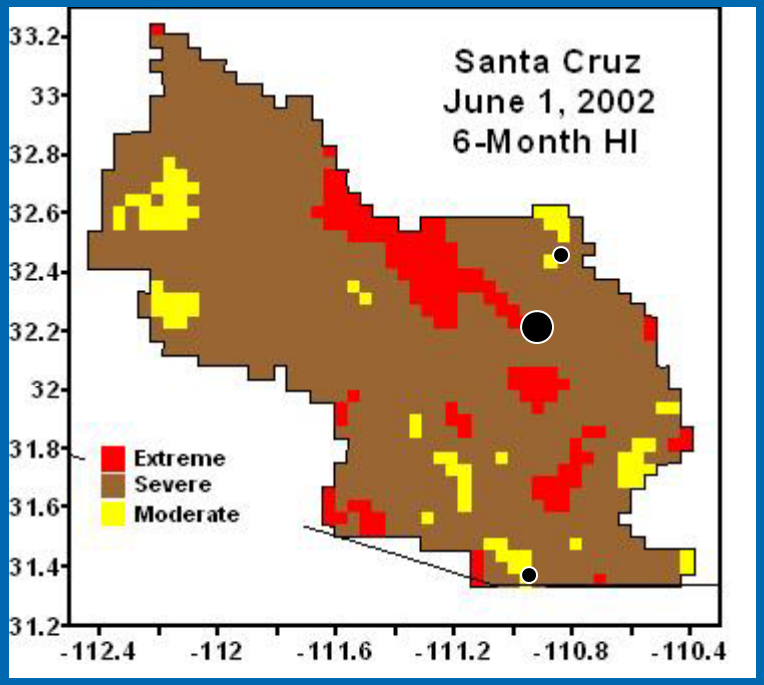
Stage 1 Drought

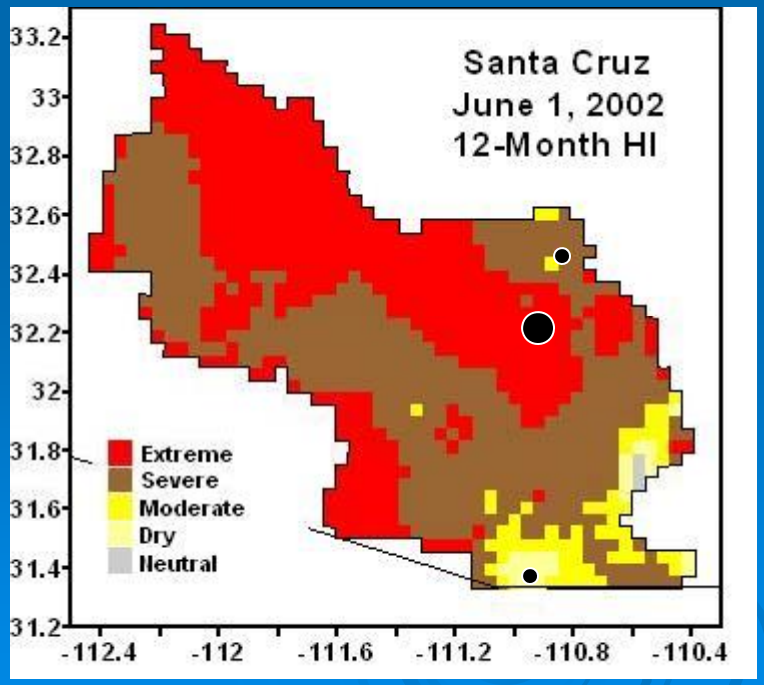
# Pima County Watersheds

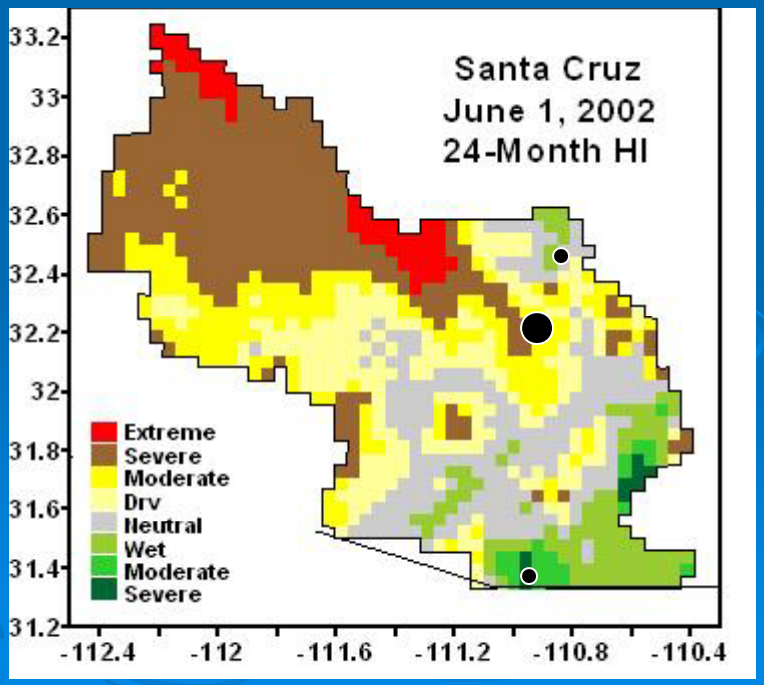


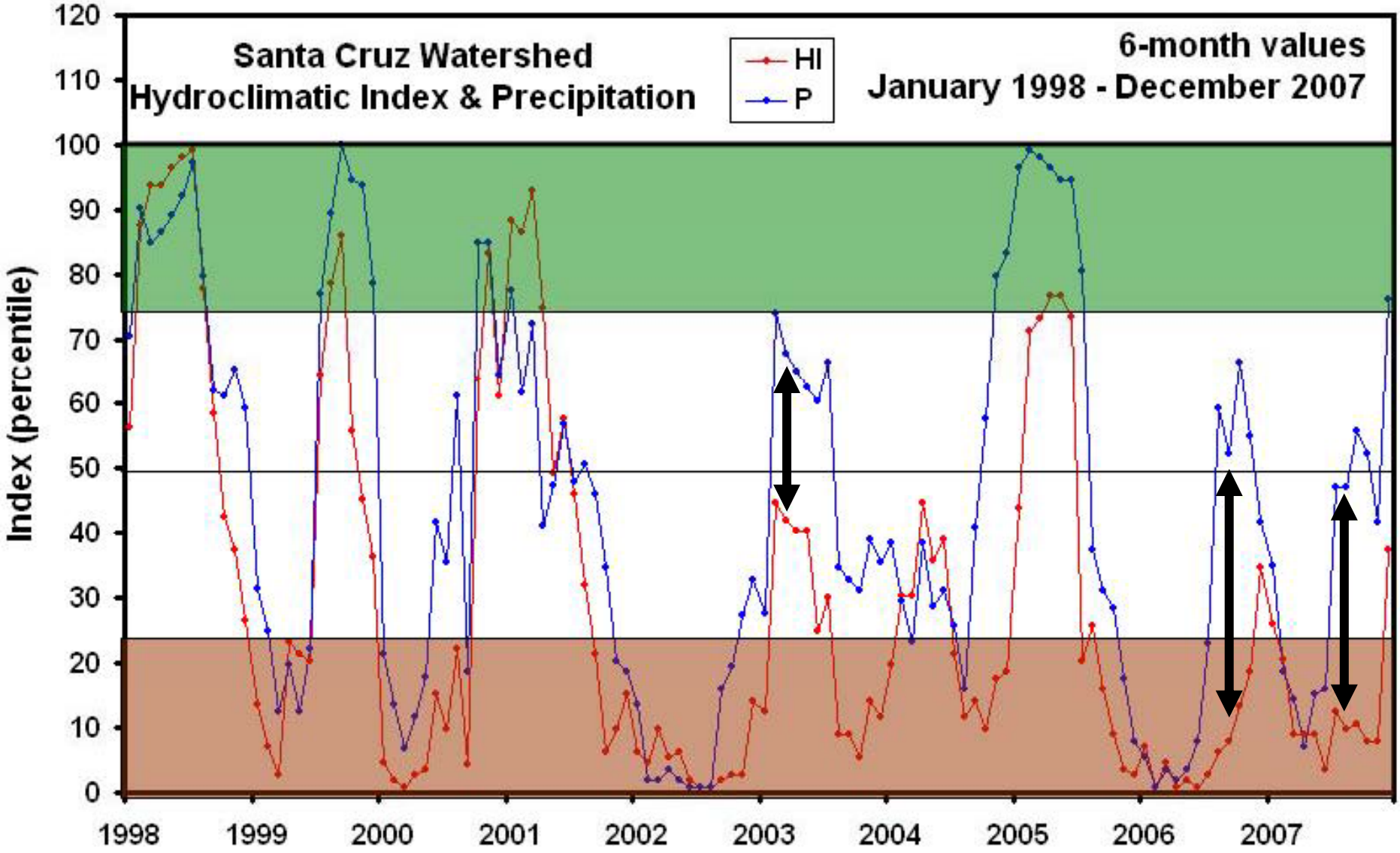
2002
Bullock Fire



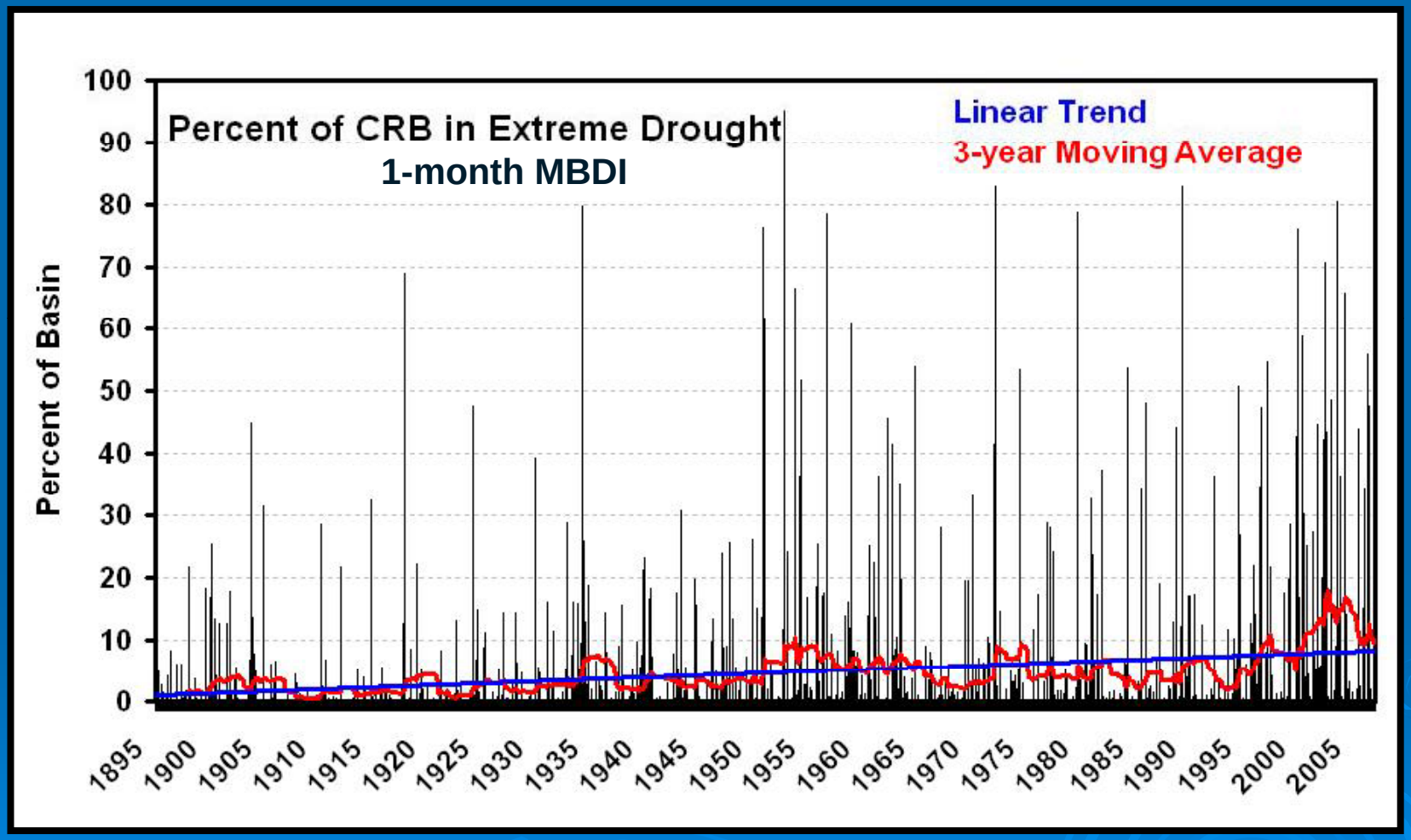




Santa Cruz Watershed
Hydroclimatic Index & Precipitation
HI
P
6-month values
January 1998 - December 2007
Index (percentile)
120
110
100
90
80
70
60
50
40
30
20
10
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

# Extreme Drought, 1895-2006



Ellis et al., 2009.
*International Journal of Climatology*
DOI: 10.1002/joc.1882

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*Int. J. Climatol.* (2009)
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# A hydroclimatic index for examining patterns of drought in the Colorado River Basin

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[c] *Institute for the Study of Planet Earth, University of Arizona, Tucson, Arizona, USA*

ABSTRACT: To better understand drought occurrence in the Colorado River Basin (CRB) of the southwestern United States we used a hydroclimatic index to create a historical record of drought coverage and analyzed the linear trend and relationships with key climate teleconnections. The past century was characterized by an increase in drought coverage during the warm portion of the year almost exclusively as a result of climatic warming. In recent decades, a significant increase in the drought coverage occurred earlier in the year, during the spring season, primarily as a function of warming, but in combination with a decline in precipitation for a significant portion of the basin. The El Niño (La Niña) phase of the El Niño-Southern Oscillation (ENSO) phenomenon is associated with a smaller (larger) area of drought during fall and winter, and the ENSO phase during the preceding six months is a significant predictor. The area of drought within the CRB is larger (smaller) during the warm (cold) phases of the Atlantic Multi-decadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO), although the relationship with the PDO is weak. Monthly AMO values for the two years preceding drought provide minor predictability. Decadal averages of drought coverage closely follow those of both the AMO and PDO index. However, the nature of the PDO-drought relationship is reversed over the two halves of the historical record, possibly indicating a dominance of the AMO over the PDO in influencing drought in the region. Teleconnection-drought relationships are stronger for the southern portion of the basin. Trends in drought coverage, the current phases of the AMO and PDO, climate change projections of regional warming, and the likelihood of continued rapid population growth could result in significant water resource problems within the CRB. Copyright © 2009 Royal Meteorological Society

KEY WORDS drought; Colorado River Basin; trends; teleconnection

*Received 28 July 2008; Revised 24 January 2009; Accepted 24 January 2009*

## 1. Introduction

### 1.1. Drought and the Colorado River Basin

Drought causes greater economic impact than any other natural hazard, with an estimated $6–8 billion in annual losses in the United States alone (Willhite *et al.*, 2005). Since 2000, southwestern states have exhibited a variety of drought impacts, including over 2.6 million acres of Arizona and New Mexico conifer damaged from a combination of severe drought stress and enhanced insect pest outbreaks (USDA Forest Service, 2004; Breshears *et al.*, 2005), substantial increases in acres burned in the Colorado River Basin (CRB) states, water restrictions in major metropolitan areas such as Las Vegas and Denver (e.g. Kenney *et al.*, 2004), water shortages in vulnerable rural regions and on tribal lands, and substantial livestock losses. The rapidly growing population of the southwestern United States is particularly sensitive to drought because of the reliance on water from the relatively arid CRB and over-allocated Colorado River. Since 2000, prolonged declines in Colorado River reservoir storage have sensitized regional water managers to the increasingly likely possibility of drought-related shortages (McCabe and Wolock, 2007; Garrick *et al.*, 2008). Regional cities and states had been engaged in unprecedented drought planning, and the seven CRB states developed the first-ever shortage criteria for reservoir operations (USDOI, 2007).

The CRB encompasses an area of approximately 634 550 km$^2$ that stretches across the southwestern United States (626 780 km$^2$ of the CRB) and northwestern Mexico (7770 km$^2$), and is drained by the Colorado River and its tributaries. Originating in the high elevations of Colorado and flowing southwestward for 2366 km to the Gulf of California, the Colorado River drains parts of seven states (Figure 1). The 1922 Colorado River Compact divided the river into an upper basin (UB) and lower basin (LB) that approximate two halves of the CRB, with the LB slightly larger at around 55% of the area. Positioned at a lower mean latitude and elevation, the LB is much warmer than the UB annually, with the greatest difference during the cool season (Figure 4(a)). Nearly 60% of the area of the UB is at an elevation greater than 2 km compared to only about 16% of the LB. Annual precipitation for the two

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Index - Mozilla Firefox

# http://azclimate.asu.edu/mbdi/index.php

ght Index

Home | Current Products | About The Index | Contact

## Moisture Balance Drought Index

Soil moisture is the focus of many drought indices, but the Moisture Balance Drought Index (MBDI) stops short of representing soil moisture in its characterization of the hydroclimatic condition. Only a few operational soil moisture sensors exist in the CRB, and the alternative of simulating soil moisture through time is difficult, as climate conditions, land surface characteristics (soil type, vegetation type, topography) and the amount of moisture relative to the soil's capacity combine to control soil moisture. The MBDI simply represents the difference between precipitation (P) and potential evapotranspiration (PE) (P-PE) through time at a given location. PE is the climatic demand for water, or that amount of evapotranspiration that would occur from a grass-covered soil for which the water content is maintained at capacity. Negative P-PE values indicate the amount by which the climatic demand for water can not be met by precipitation and actual soil moisture would decline if not irrigated. Positive values represent the amount of excess water from precipitation that would recharge soil moisture, percolate to ground water, or run to streams and reservoirs through overland flow or interflow.

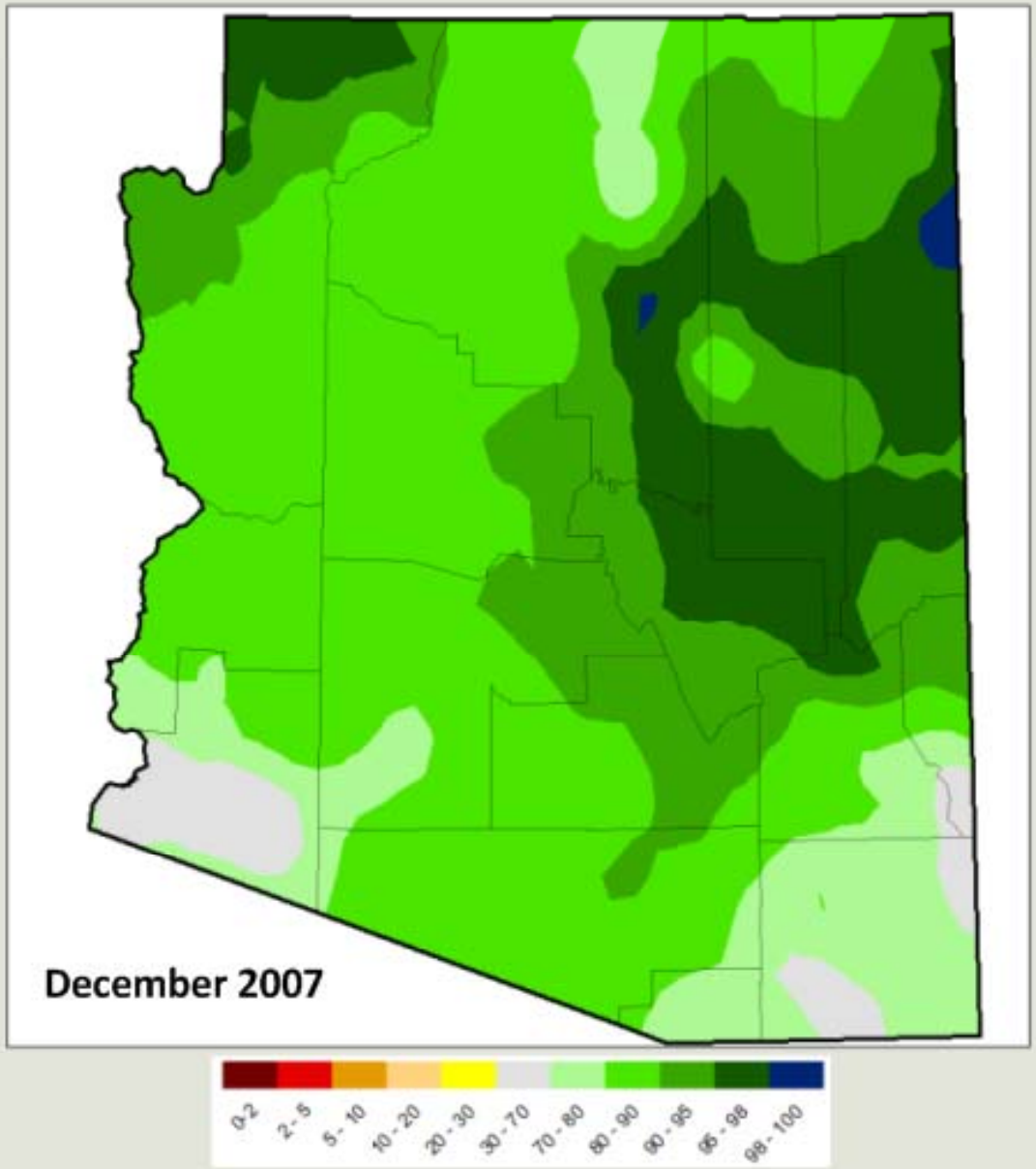
Aggregates of P-PE are constructed for periods that represent short-term conditions (1-, 3-month), intermediate conditions (6-, 12-month), and long-term conditions (24-, 36-, 48-month), and the aggregate values are converted to percentiles to form the MBDI. The MBDI can then be stratified into drought categories that represent levels of drought intensity.

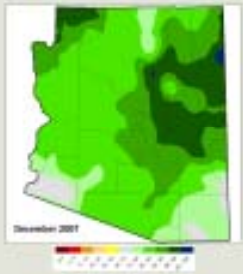
Decision Center for a Desert City Arizona State University

Institute for the Study of Planet Earth University of Arizona

Bureau of Reclamation

## Current Products - Arizona Drought Map

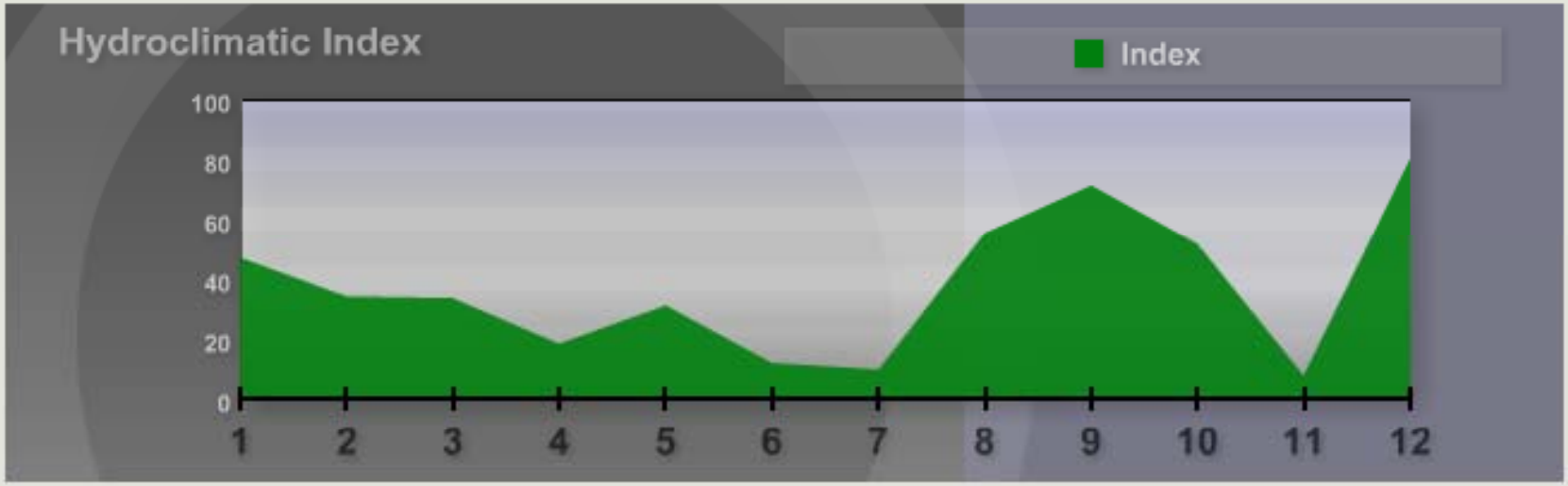


## Watershed - Little Colorado

Currently Viewing:
Year: 2007

**View Different Year (1895-2007):** Submit




**No drought - 30.01+**
**Abnormally Dry - 20.01-30**
**Moderate Drought - 10.01-20**
**Severe Drought - 5.01-10**
**Extreme Drought - 2.01-5**
**Exceptional Drought - 0-2**

No drought - 30.01+
Abnormally Dry - 20.01-30
Moderate Drought - 10.01-20
Severe Drought - 5.01-10
Extreme Drought - 2.01-5
Exceptional Drought - 0-2

| Year | Month | Index |
|---|---|---|
| 2007 | 1 | 47.18 |
| 2007 | 2 | 34.19 |
| 2007 | 3 | 33.59 |
| 2007 | 4 | 18.41 |
| 2007 | 5 | 31.19 |
| 2007 | 6 | 12.00 |
| 2007 | 7 | 9.74 |
| 2007 | 8 | 55.34 |
| 2007 | 9 | 71.30 |
| 2007 | 10 | 51.77 |
| 2007 | 11 | 7.84 |
| 2007 | 12 | 80.42 |

# What's Ahead?

- Verification case studies
  - Fire, NDVI, Audubon bird counts
- MBDI on the Internet
  - Data
  - Maps
  - Time series
  - Instructions
  - Comparisons
- Usability testing and online survey

# Acknowledgments

CLIMATE PROGRAM OFFICE
Understanding climate variability and change to enhance society's ability to plan and respond

RECLAMATION
Managing Water in the West

# AZ DroughtWatch

## Arizona's Drought Impact Reporting System

*AZ DroughtWatch beta release*

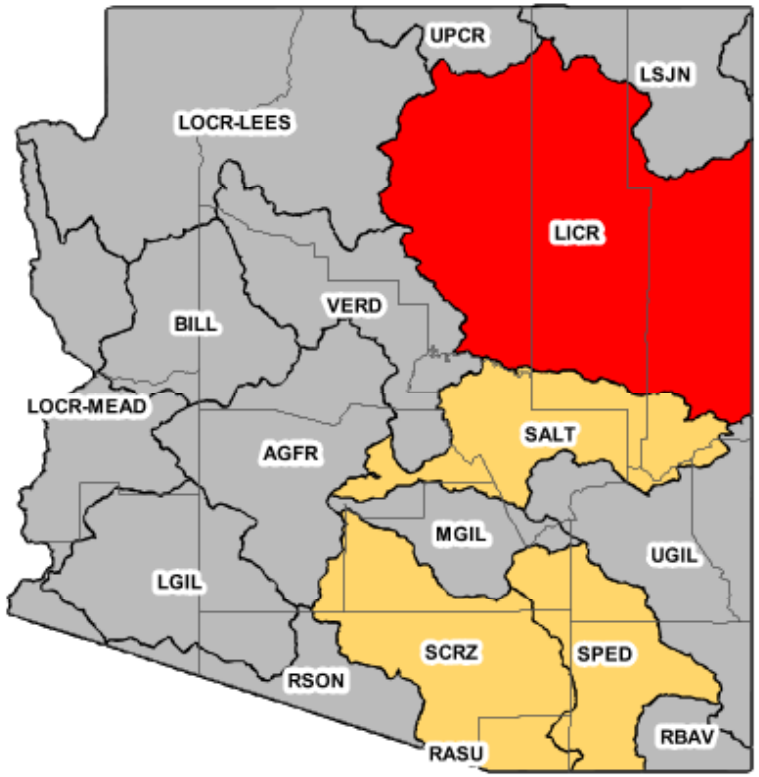
Home | My DroughtWatch | User Guide | Register | Latest News | About AZ DroughtWatch

## Summary Report for August, 2009

*<-- Previous Month* *Next Month -->*

Binary | **Diversity**

**HUC6** | HUC8 | HUC10 | County




**Show Only Reports From...**

Users Reporting to: no filter

Observer Type: no filter | Filter

**Impacts Reported**

- in 0 of 6 categories
- in 1 of 6 categories
- in 2 of 6 categories
- in 3 of 6 categories
- in 4 of 6 categories
- in 5 of 6 categories
- in 6 of 6 categories
- No reports made

**Categories**

- Water
- Agriculture
- Livestock
- Society
- Tourism
- Ecology

**Watershed Abbreviations**

| | |
|---|---|
| AGFR | Agua Fria River-Lower Gila River |
| BILL | Bill Williams River |
| LGIL | Lower Gila River below Painted Rock Dam |
| LICR | Little Colorado River |
| LOCR-LEES | Lower Colorado River, Lees Ferry to Lake Mead |
| LOCR-MEAD | Lower Colorado River below Lake Mead |
| LSJN | Lower San Juan River |
| MGIL | Middle Gila River (Local Drainage) |
| RASU | Rio Asuncion |
| RBAV | Rio Bavispe |
| RSON | Rio Sonoyta |
| SALT | Salt River |
| SCRZ | Santa Cruz River |
| SPED | San Pedro River |
| UGIL | Upper Gila River |
| UPCR | Upper Colorado River of Lake Powel Area |
| USJN | Upper San Juan River |
| VERD | Verde River |

### Monthly Summary Report

The impact summary tables displayed on this page provide a quick look of drought conditions across Arizona. Impacts reports are tabulated by large watershed in the top table and by county in the bottom table. The first six columns in each table represent the total number of impacts reported in each of the main categories. The seventh column show the number of surveys from which the impacts were totaled and the last column shows the number of unique observers.

### Interpreting the summary tables

- Many impacts across multiple categories may indicate more widespread drought conditions versus many impacts in one category alone.
- A large number of surveys indicates that impacts are distributed across many geographic locations.
- A large number of unique observers indicates that surveys are being made by different people rather many surveys submitted by one observer.
- Use the 'Observer Type' filter at the top of the page to examine potential relationships between observer type and impact totals in each category

**Mike Crimmins, University of Arizona**

**Huc 6: San Pedro River**

**Huc 8: Willcox Playa**

**Huc 10: Willcox Playa**

## Individual Watershed Report

Report name: Report Name: Turkey Creek - Proxy Report
User: Username: crimmins (Mike Crimmins) [Cloak]

Observer Type: University Researcher
Observation Frequency: 2-5 days

### Surface Water Impacts

| | | |
|---|---|---|
| Unusually low flows in streams, rivers, and springs | *A 97 year old lady in the Turkey creek area of the Chiricahua Mountains (Cochise County) reports that the creek was dry this past month. She has lived there since 1932 and every year but this year Turkey creek has run through their ranch in the month of August. (Reported by local agricultural producer and LDIG member)* | (Falling) |

## Individual Watershed Report

Report name: Report Name: High Creek - Proxy Report
User: Username: crimmins (Mike Crimmins) [Cloak]

Observer Type: University Researcher
Observation Frequency: 2-5 days

### Surface Water Impacts

| | | |
|---|---|---|
| Unusually low flows in streams, rivers, and springs | *Rancher in Galiuro Mountains (northeastern Cochise County) pipes water down from High Creek. Reported that it is almost dry, first time that he knows of. He has lived there since 1975 and he did not think the old timers ever saw it dry up. (Reported by local agricultural producer and LDIG member)* | (Falling) |

### Forage/Vegetation Impacts

| | | |
|---|---|---|
| Poor forage nutritional quality/increased toxicity of forage | *Cochise County rancher lost 18 head of cattle from ingesting burro weed, according to local veterinarian it was due to the drought. When conditions are just right the cattle will eat the budding tips of the burro weed which contain a toxin that causes the central nervous system to break down and can kill cattle.* | (Worsening) |

# Mike Crimmins, University of Arizona

# International Workshop for CHANGE

(**C**limate and **H**ydrology **A**cademic **N**etwork for **G**overnance and the **E**nvironment)
March 5-6, 2009
México City, D.F., México

**Project Report**
Prepared for:
**Foreign Affairs and International Trade Canada (DFAIT)**

Authors:
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Victor Magaña, Universidad Autónoma de México
Ronald Stewart, University of Manitoba
Jamie McEvoy, University of Arizona

http://www.environment.arizona.edu/change

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Institute of the Environment
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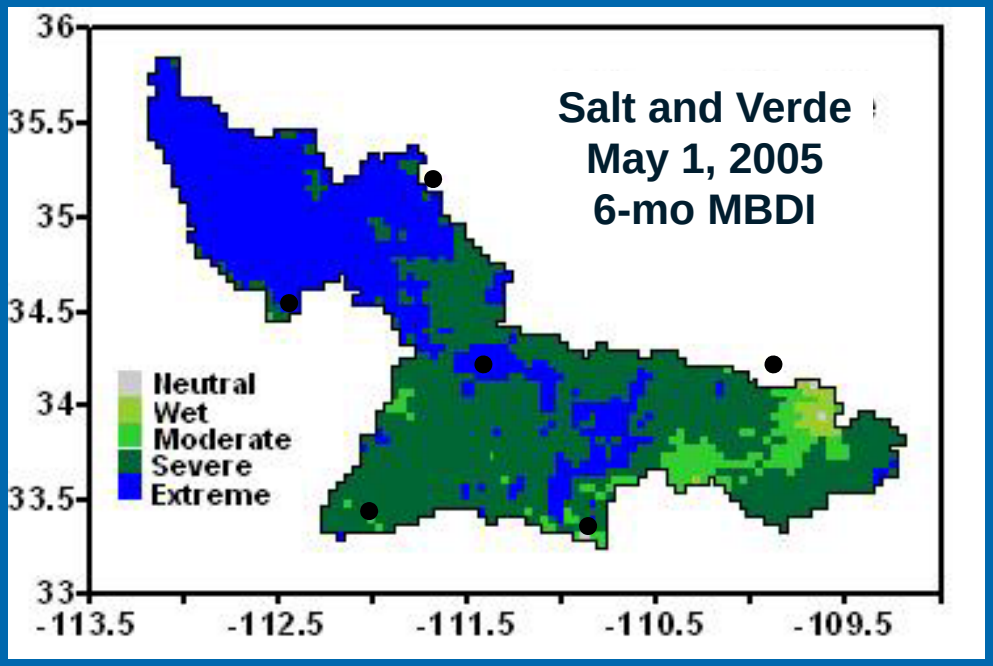
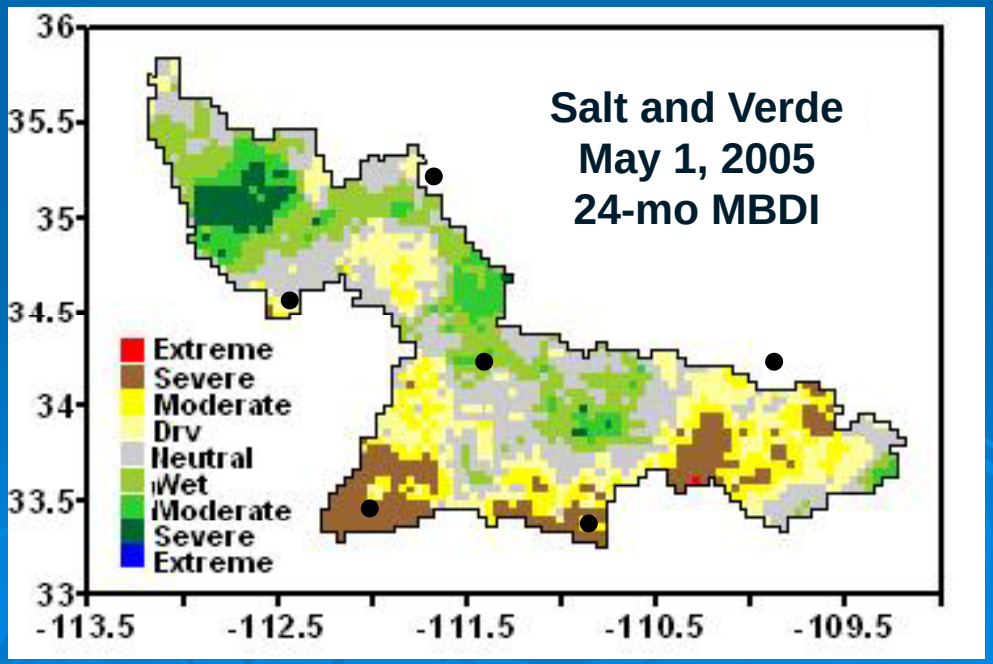
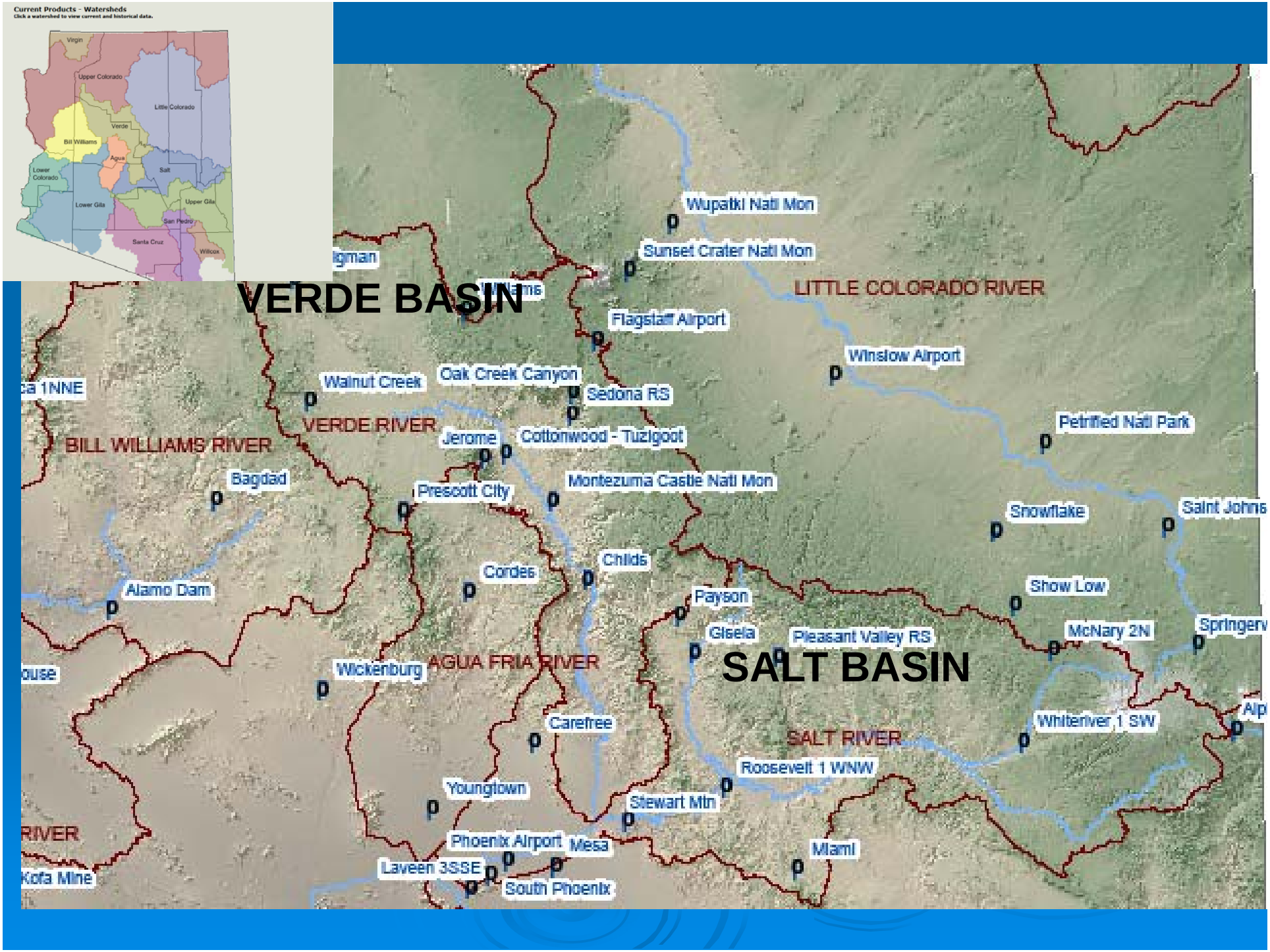
520-626-4372
http://www.environment.edu

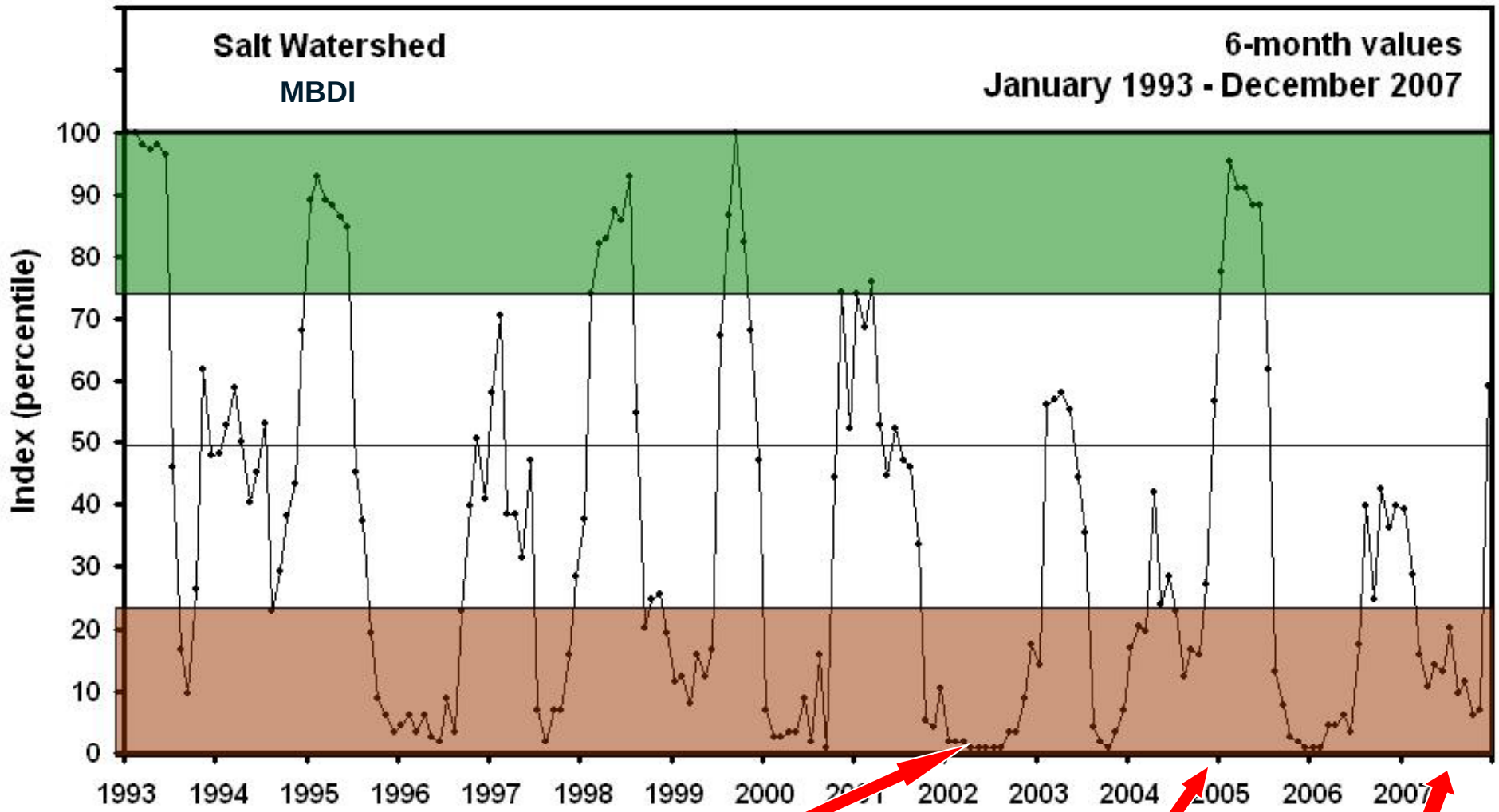
# 2005
# Wet winter
# Salt and Verde
# Reservoirs
# Refill



# Examples for Salt & Upper Colorado


Current Products - Watersheds
Click a watershed to view current and historical data.
Virgin
Upper Colorado
Little Colorado
Verde
Bill Williams
Agua
Salt
Lower Colorado
Lower Gila
Upper Gila
San Pedro
Santa Cruz
Wilcox
VERDE BASIN
SALT BASIN
LITTLE COLORADO RIVER
VERDE RIVER
BILL WILLIAMS RIVER
AGUA FRIA RIVER
SALT RIVER
Wupatki Natl Mon
Sunset Crater Natl Mon
Flagstaff Airport
Winslow Airport
Walnut Creek
Oak Creek Canyon
Sedona RS
Cottonwood - Tuzigoot
Jerome
Petrified Natl Park
Bagdad
Prescott City
Montezuma Castle Natl Mon
Snowflake
Childs
Cordes
Alamo Dam
Payson
Show Low
Gisela
Pleasant Valley RS
McNary 2N
Wickenburg
Carefree
Whiteriver 1 SW
Roosevelt 1 WNW
Youngtown
Stewart Mtn
Phoenix Airport
Mesa
Miami
Laveen 3SSE
South Phoenix
Kofa Mine

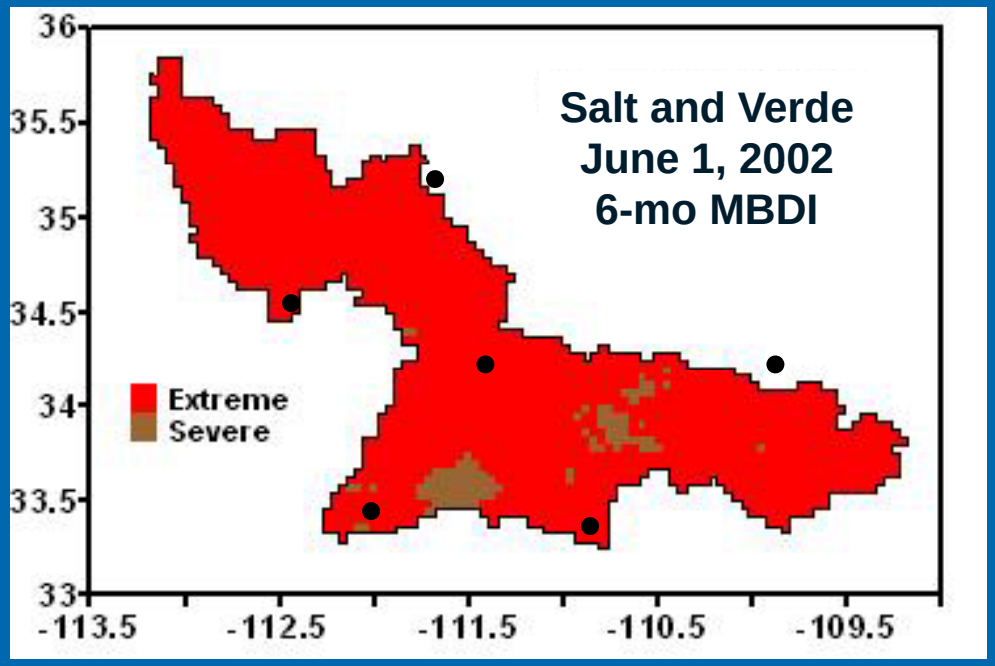


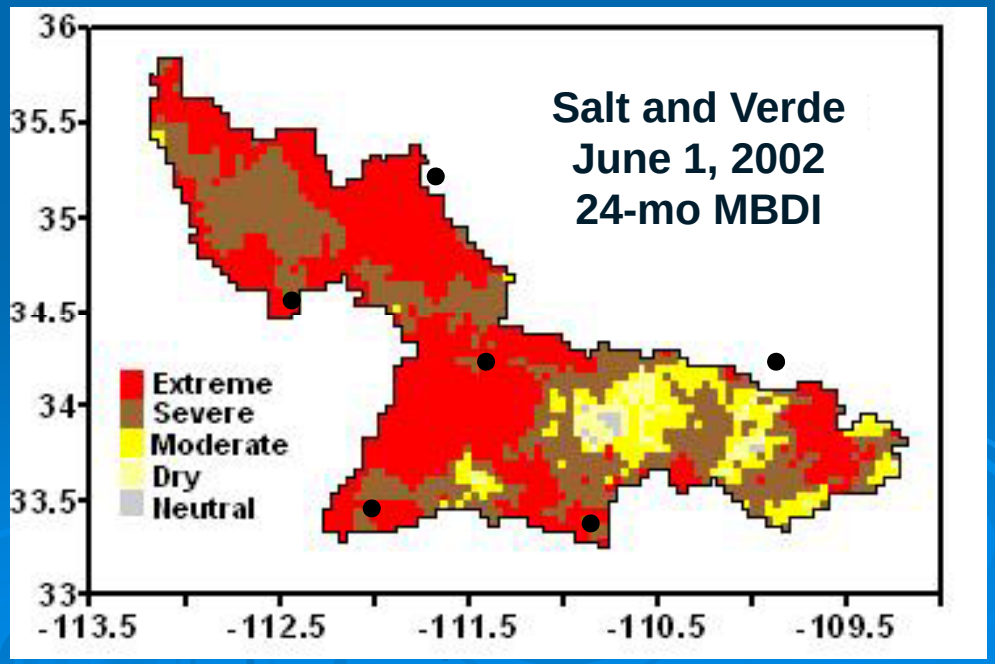

Rodeo-Chediski fire

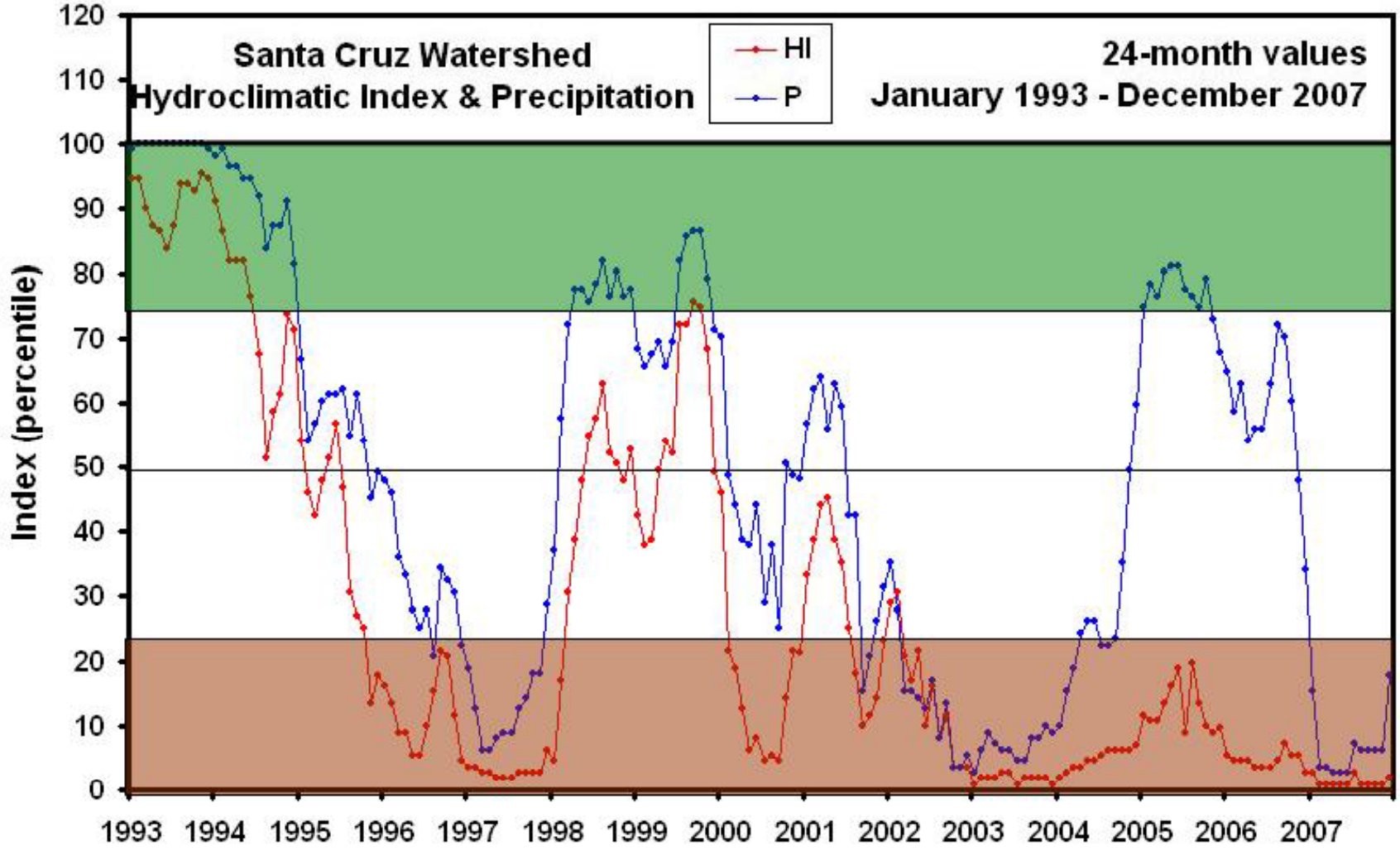
Salt-Verde reservoirs refill

Dry winter

# 2002 Rodeo-Chediski Fire




Santa Cruz Watershed
Hydroclimatic Index & Precipitation
HI
P
24-month values
January 1993 - December 2007
Index (percentile)
120
110
100
90
80
70
60
50
40
30
20
10
0
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007