Arizona Drought Monitoring

North American Drought Monitor Workshop

October, 2006

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CLIMAS/ISPE
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Institute for the Study of Planet Earth

CLIMAS
Climate Assessment Project for the Southwest

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Goals of Presentation

- **Introduction to Arizona drought monitoring**
- **Discussion of methods**
- **Local drought impact group program**
- **Plans for the future**

- Acknowledgements: Thanks to the Arizona Drought Monitoring Technical Committee, Statewide Drought Program, Arizona Cooperative Extension, and the SAHRA NSF center for some of the material presented here. Special Thanks to Andrea Ray (NOAA) for delivering the presentation at the NADM Workshop.

Arizona Drought Monitoring Technical Committee – "**MTC**"

- **State, Federal, University, and Private agency experts**
- **Meet monthly**
  - Report to Director of Arizona Department of Water Resources
  - Reports are published on website: http://www.azwater.gov/dwr/drought/MTC.html
  - Discuss drought issues, improvements to methods and communication

Arizona Drought Monitoring Technical Committee – "**MTC**"

NRCS Natural Resources Conservation Service

Securing Arizona's Water Future
Arizona Department of Water Resources

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USGS
science for a changing world
Water Resources of ARIZONA

OFFICE OF THE ARIZONA STATE CLIMATOLOGIST

MTC Monitoring

- Much of our indicator/trigger method is based on work by Anne Steinemann (Univ. Washington) and can be found in the publication:

Steinemann, A.C., and L.F.N. Cavalcanti, 2006: Developing Multiple Indicators and Triggers for Drought Plans. *Journal of Water Resources Planning and Management*, **132(3):** 164-174.

DOI: 10.1061/(ASCE)0733-9496(2206)132:3(164)

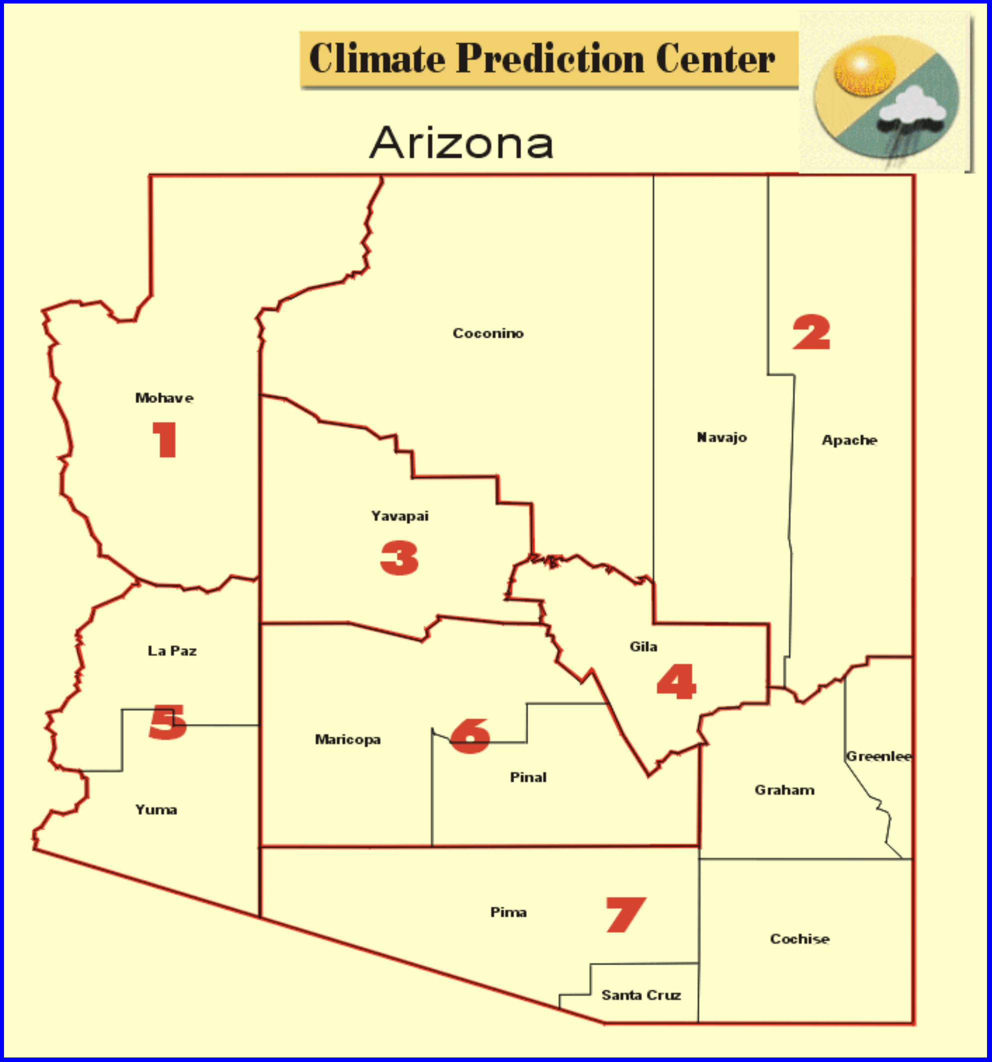
MTC Monitoring Philosophy

- We monitor drought at a regional level – to get the initial “big picture”
- We calculate and display drought status for two time periods:
  - Short-term (< 12 months)
  - Long-term (12-48 months)

MTC Monitoring Philosophy

- We use precipitation (SPI) and streamflow data as drought indicators, from 1975-present
  - Because this time period gives us the most stations and gages with the fewest missing data
  - But, we consult other indicators to add spatial detail and to corroborate SPI and streamflow
  - These other indicators are included in our monthly reports
    - Reservoir levels, vegetation health, snow, etc.

Spatial Resolution 2004-2005

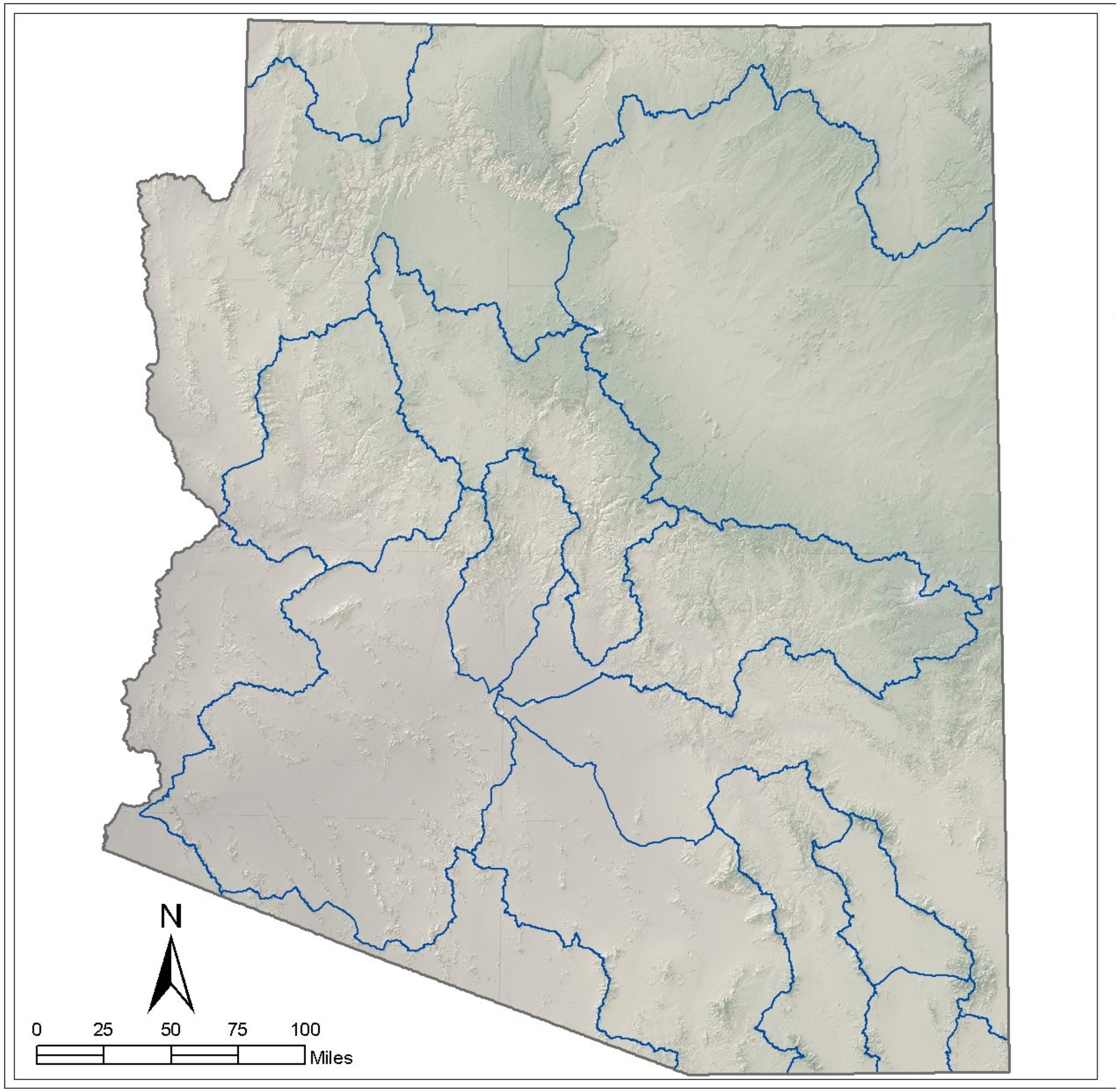


We used to use NOAA climate division data

- Easy to access and use
- Divisions follow ***political boundaries***
- Universally disliked by stakeholders

Map: NOAA Climate Prediction Center

Spatial Resolution 2006



Map: AZ Dept. of Water Resources

Now we use surface watersheds

- Still large regions
- Still plenty of data gaps (northeastern Arizona)
- Watersheds add credibility compared to political boundaries
- The jury is out on whether this is really an improvement

AZ 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

USDM Drought Triggers

Level	Description	Percentile
0	No Drought	31-100%
1	Abnormally Dry	21-30%
2	Moderate Drought	11-20%
3	Severe Drought	6-10%
4	Extreme Drought	3-5%
5	Exceptional Drought	1-2%

The monitoring committee recommended using the USDM levels, but the Drought Task Force thought there were too many levels, and that it would be too confusing to the public.

Drought Trigger Goals

- We are monitoring for drought management, so our approach is conservative
- We want rapid detection going into drought (no lags)
- But we are cautious coming out of drought – we don’t want status to jump rapidly, based on short-term anomalies
  - Drought amelioration criteria – requirement that drought status move in a positive direction for multiple months before decreasing drought status

Drought Trigger Goals

- We strive for consistency with historical impacts
  - In 2004, we checked this in two ways
    - Through a stakeholder assessment, based on their operations
    - Through subjective assessment by the MTC

Drought Trigger Steps

- Rank raw data = “percentiles”
- Assign each indicator a status level, based on the match between indicator percentile and trigger intervals
- Average the drought status levels and round up
- Apply amelioration criteria, if necessary

Indicators and Triggers Example: Southeastern AZ

Short-Term				
Date	SPI_3_In	SPI_6_In	SPI_12_In	Final Drought Level
Jul-03	2	1	2	2
Aug-03	2	1	2	2
Sep-03	2	3	2	3
Oct-03	2	3	2	3
Nov-03	1	2	2	2
Dec-03	1	2	2	2
Jan-04	1	2	2	2
Feb-04	1	1	2	2
Mar-04	1	1	2	2
Apr-04	0	1	2	1
May-04	0	0	1	1
Jun-04	0	0	1	1

Note: Example is from 2004

SPI 3, 6, 12 month averaged to get final short-term level

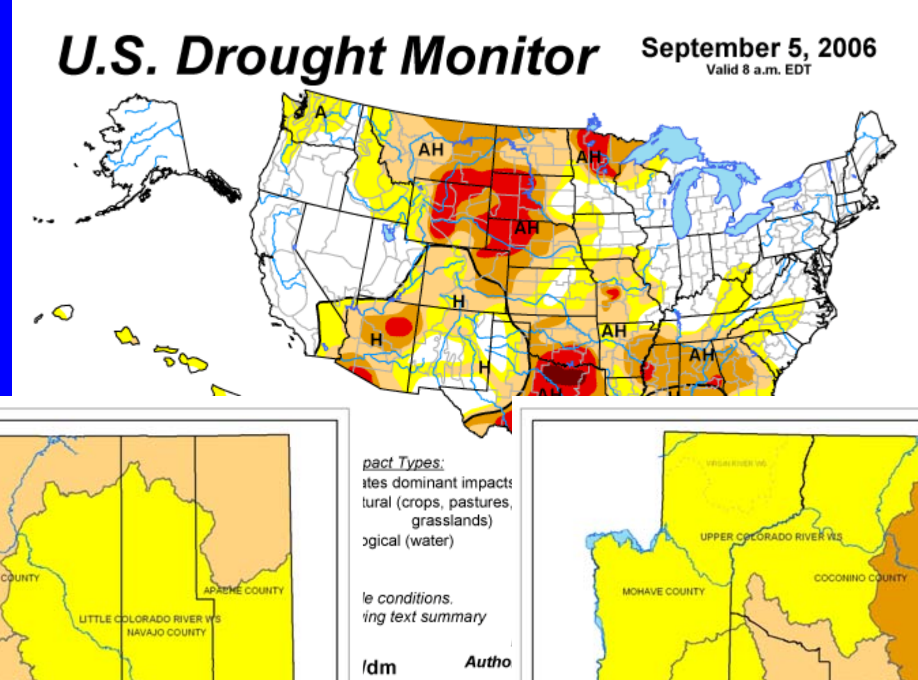
Indicators and Triggers Example: Southeastern AZ

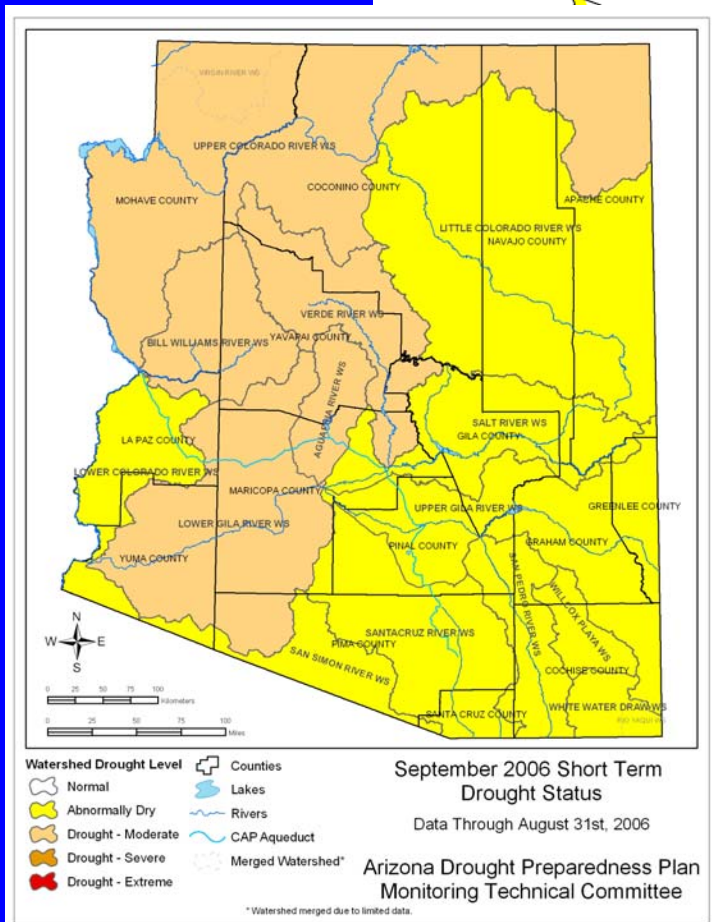
Note: Example is from 2004

Long-Term												
Date	**SPI_24_ln**	**SPI_36_ln**	**SPI_48_ln**	**Blue R. nr. Clifton**	**SF R. nr. Clifton**	**Gila R. nr. Solomon**	**San Pedro Palominas**	**San Pedro Charleston**	**Aravaipa Ck. Mammo**	**Santa Cruz Lochiel**	**Leslie Ck. McNeal**	Final Drought Level
Jul-03	4	1	2	2	2	1	2	3	2	2	2	3
Aug-03	4	1	2	2	4	4	1	2	2	4	2	3
Sep-03	4	2	3	2	4	4	1	2	2	4	3	3
Oct-03	4	2	3	2	2	3	3	2	2	3	3	3
Nov-03	4	3	3	2	2	3	3	3	2	3	3	3
Dec-03	3	3	2	2	2	2	3	4	2	3	3	3
Jan-04	3	3	2	2	2	2	3	4	2	3	3	3
Feb-04	3	3	2	2	1	1	3	4	2	3	3	3
Mar-04	3	3	2	2	1	1	2	4	2	2	3	3
Apr-04	3	3	2	0	0	0	2	3	2	2	3	2
May-04	2	3	1	0	0	0	1	3	2	2	3	2
Jun-04	2	3	1	1	1	0	1	3	4	2	3	2

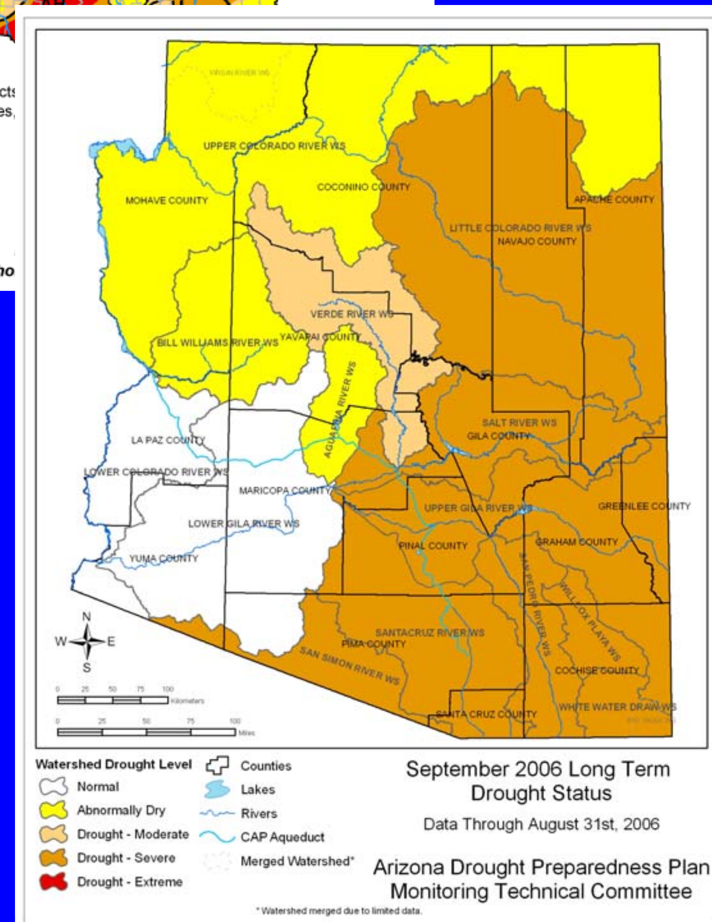
SPI 24, 36, 48 month + various unregulated streams averaged to get final long-term level

September 2006 (data through August 31, 2006)





Short-term Drought Status



Long-term Drought Status

Corroborative Data

We always use a two-step process

- We examine the calculated drought status
- Then we consult additional data sources, in order to corroborate drought status and add spatial precision

Examples:

- Snowpack reports
- Range and pasture status reports
- Satellite vegetation health

LDIGs: Local Drought Impact Groups

- Volunteer groups, coordinated by county cooperative extension and county emergency management to:
- They identify local drought-related impacts
  - Provide drought impact data to MTC
- Define and assess
  - societal impacts, severity, associated costs
- Identify response options and needs
- Identify and facilitate efforts to mitigate impacts

Partnership

Securing Arizona's Water Future
Arizona Department of Water Resources

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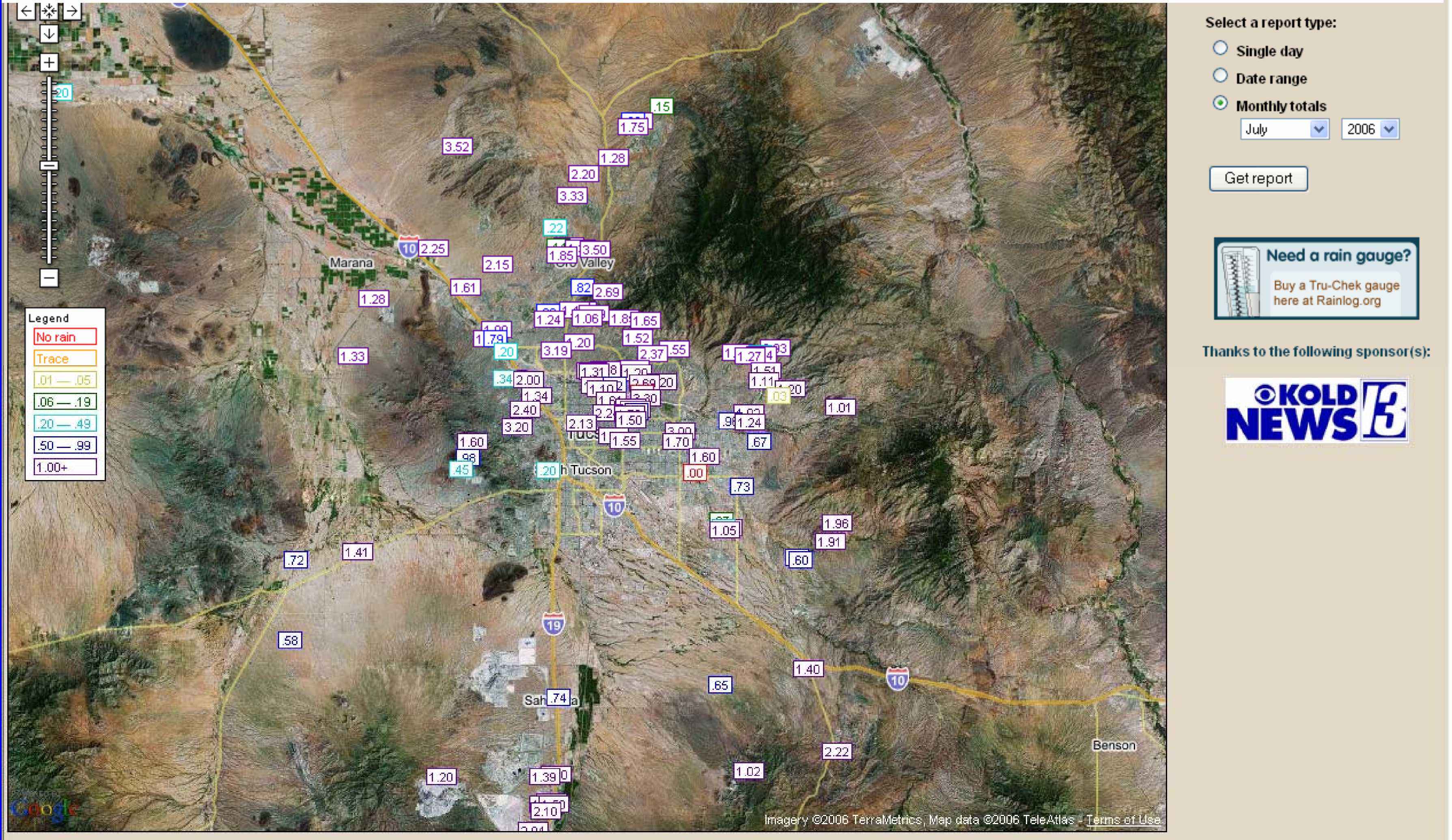
LDIGs & Drought Monitoring

The link between numbers that the experts look at and impacts that people experience

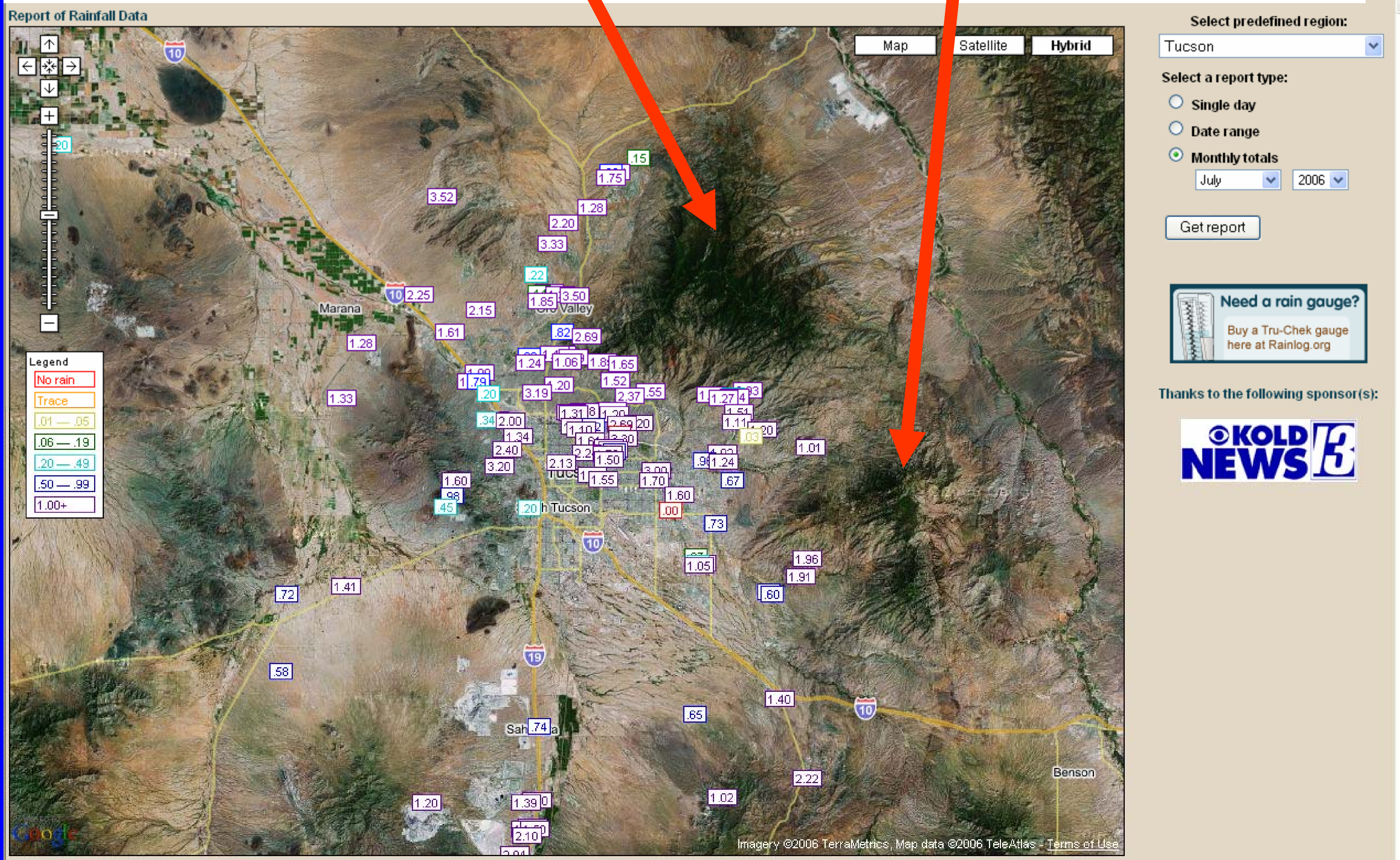
- MTC gets information on
  - Instantaneous conditions (our reports usually lag current conditions by 15-20 day)
  - Local impacts
  - Quantitative precipitation totals through volunteer rain log networks
    - Improved spatial information
  - Verification of calculated drought status

Rainlog.org (created by SAHRA and Arizona Cooperative Extension)



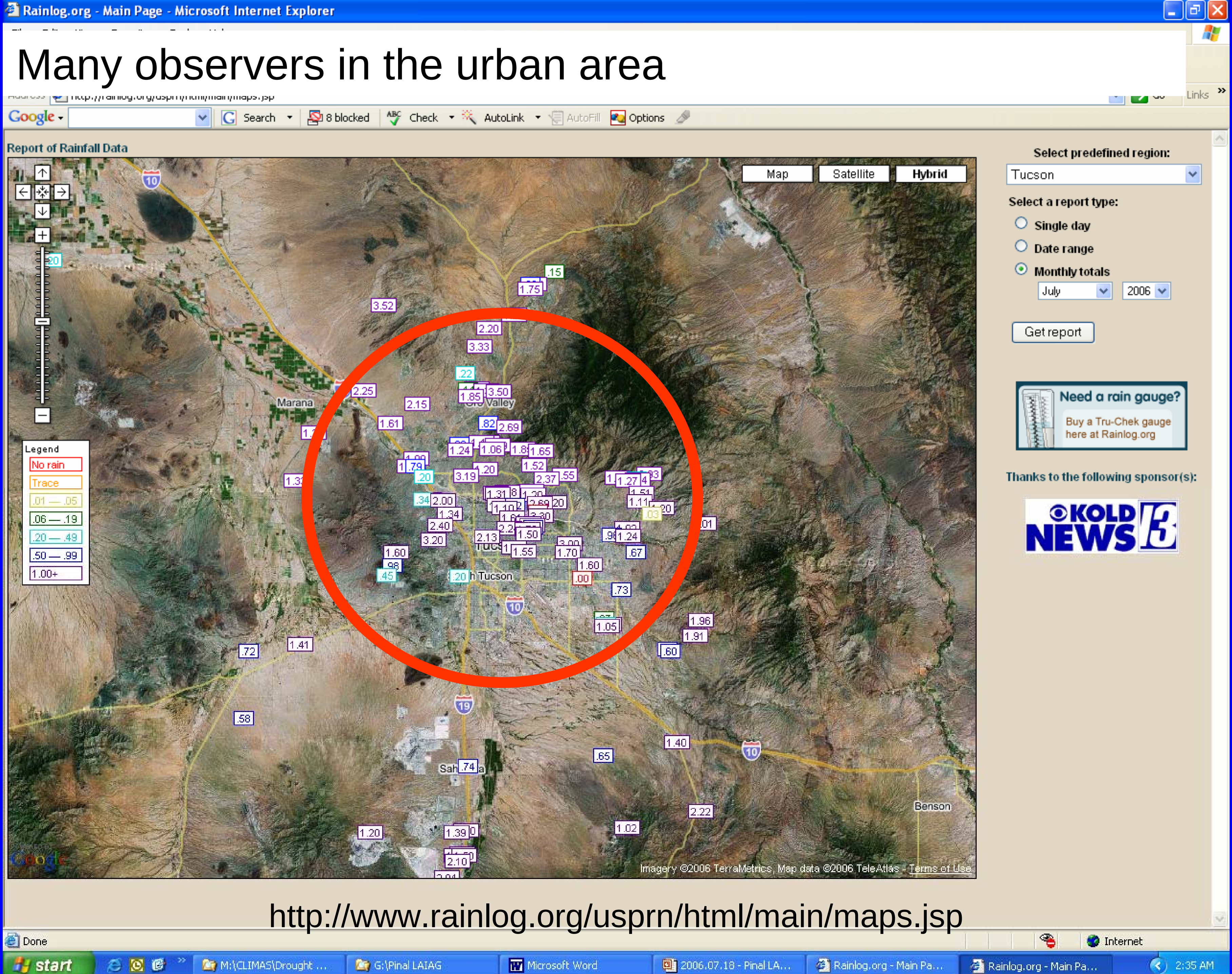
http://www.rainlog.org/usprn/html/main/maps.jsp

This is the Tucson region
with the Santa Catalina Mountains, Rincon Mountains

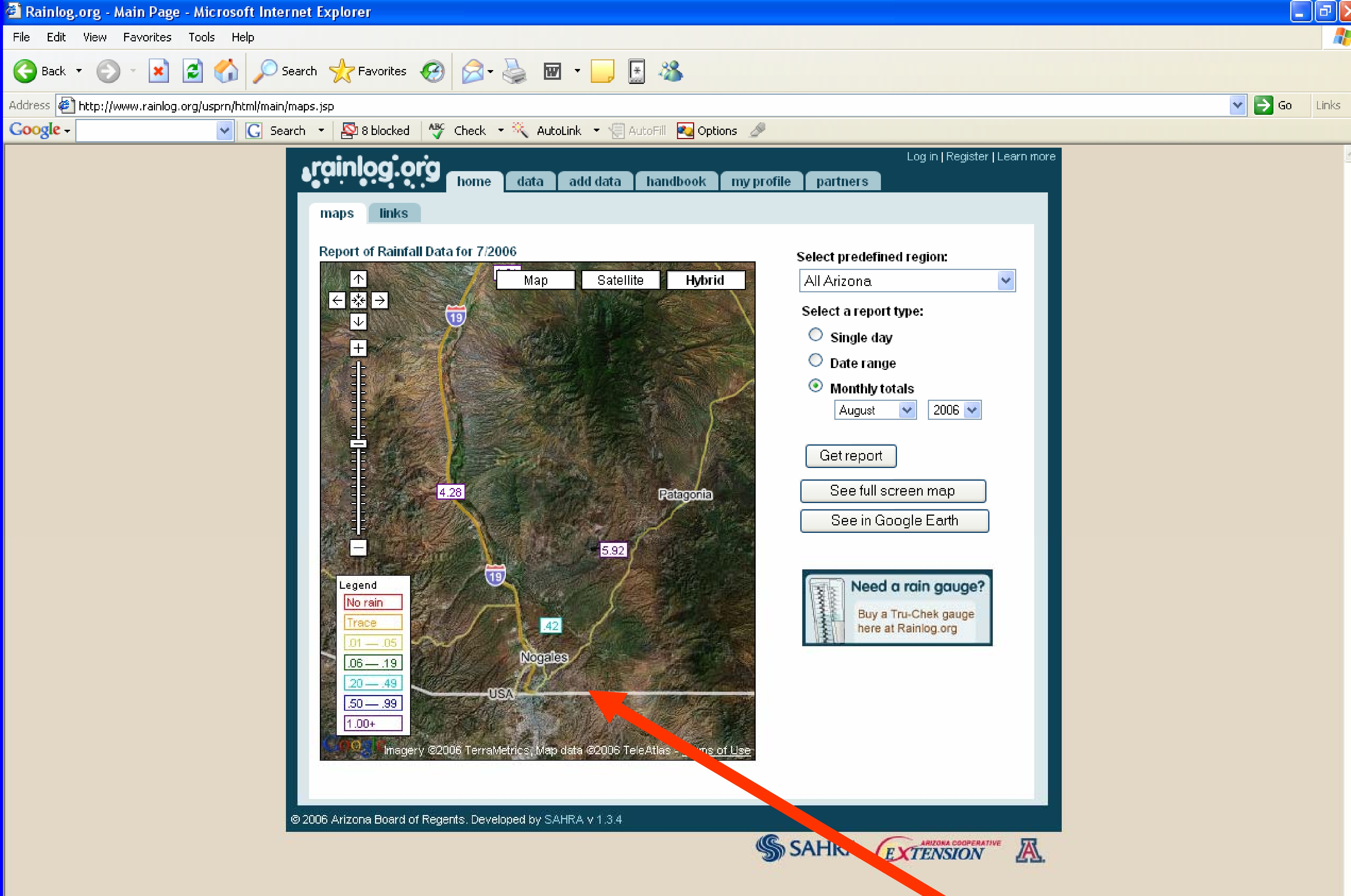


http://www.rainlog.org/usprn/html/main/maps.jsp

Many observers in the urban area

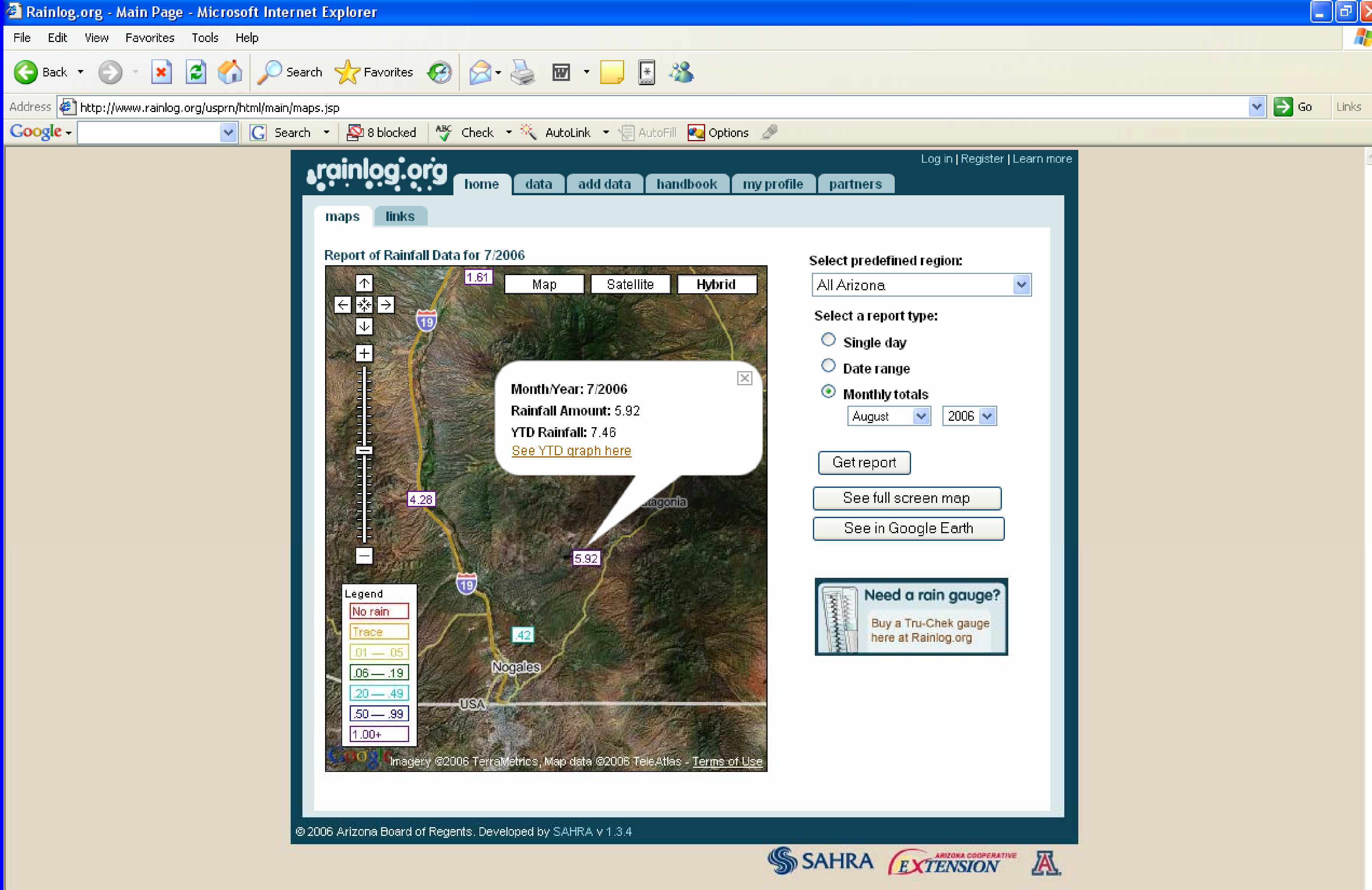


http://www.rainlog.org/usprn/html/main/maps.jsp

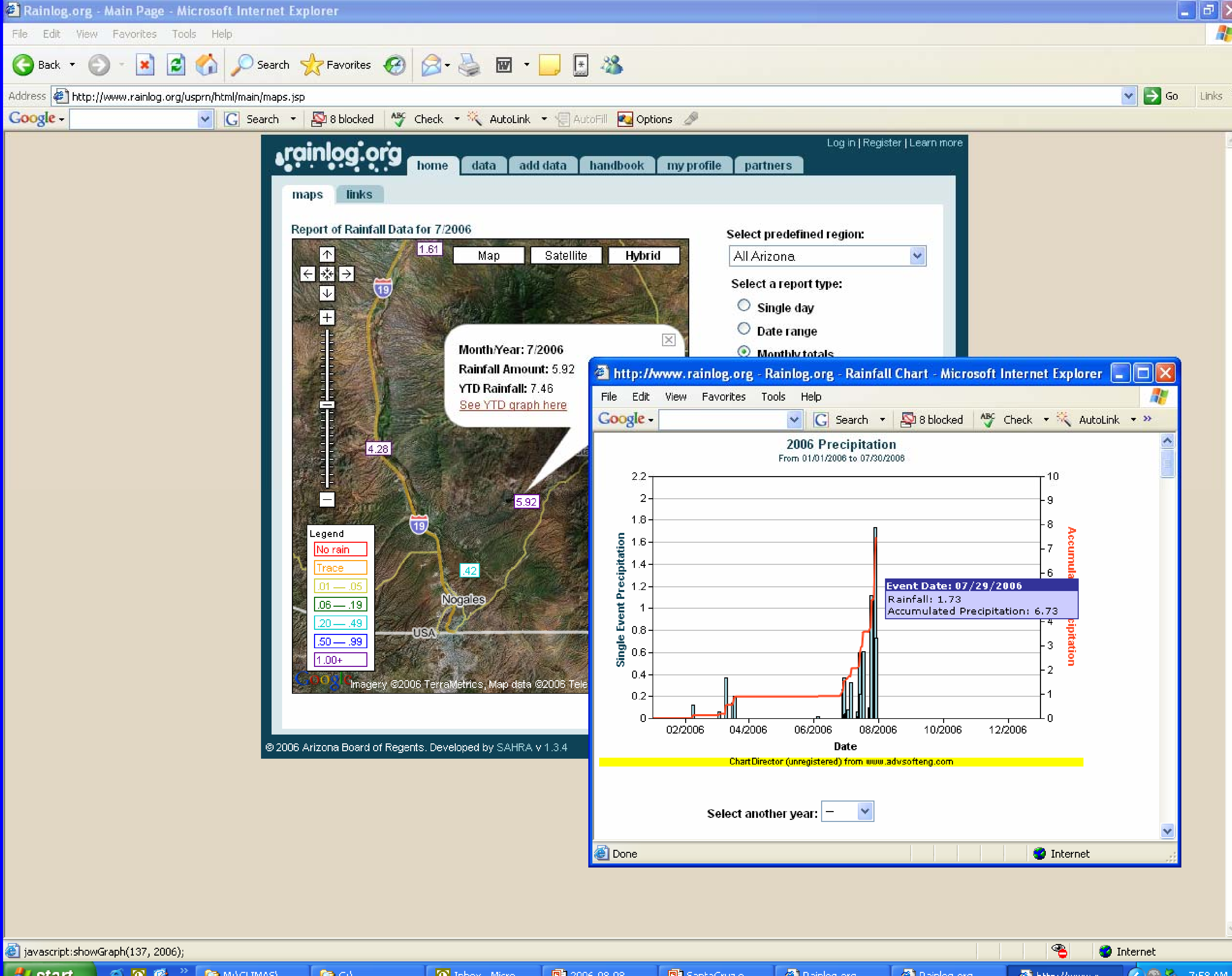


This is the Nogales region with the U.S.-Mexico border

We are now recruiting more rural observers



Each rainlog observer reports precipitation values.
By clicking on an observer’s site, you can get year-to-date precipitation.


Rainlog.org - Main Page - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Address http://www.rainlog.org/usprn/html/main/maps.jsp
Log in | Register | Learn more
rainlog.org
home
data
add data
handbook
my profile
partners
maps
links
Report of Rainfall Data for 7/2006
Map
Satellite
Hybrid
1.61
4.28
5.92
.42
Month/Year: 7/2006
Rainfall Amount: 5.92
YTD Rainfall: 7.46
See YTD graph here
Legend
No rain
Trace
.01 — .05
.06 — .19
.20 — .49
.50 — .99
1.00+
Nogales
USA
Imagery ©2006 TerraMetrics, Map data ©2006 Tele
Select predefined region:
All Arizona
Select a report type:
Single day
Date range
Monthly totals
© 2006 Arizona Board of Regents. Developed by SAHRA v 1.3.4
http://www.rainlog.org - Rainlog.org - Rainfall Chart - Microsoft Internet Explorer
2006 Precipitation
From 01/01/2006 to 07/30/2006
Single Event Precipitation
Event Date: 07/29/2006
Rainfall: 1.73
Accumulated Precipitation: 6.73
Date
02/2006
04/2006
06/2006
08/2006
10/2006
12/2006
ChartDirector (unregistered) from www.advsofteng.com
Select another year:
Done
Internet
javascript:showGraph(137, 2006);

LAIAGs & Drought Monitoring

Drought impact monitoring strategy

- Systematic qualitative monitoring of selected locations

LAIAGs & Drought Monitoring

Drought impacts monitoring variables

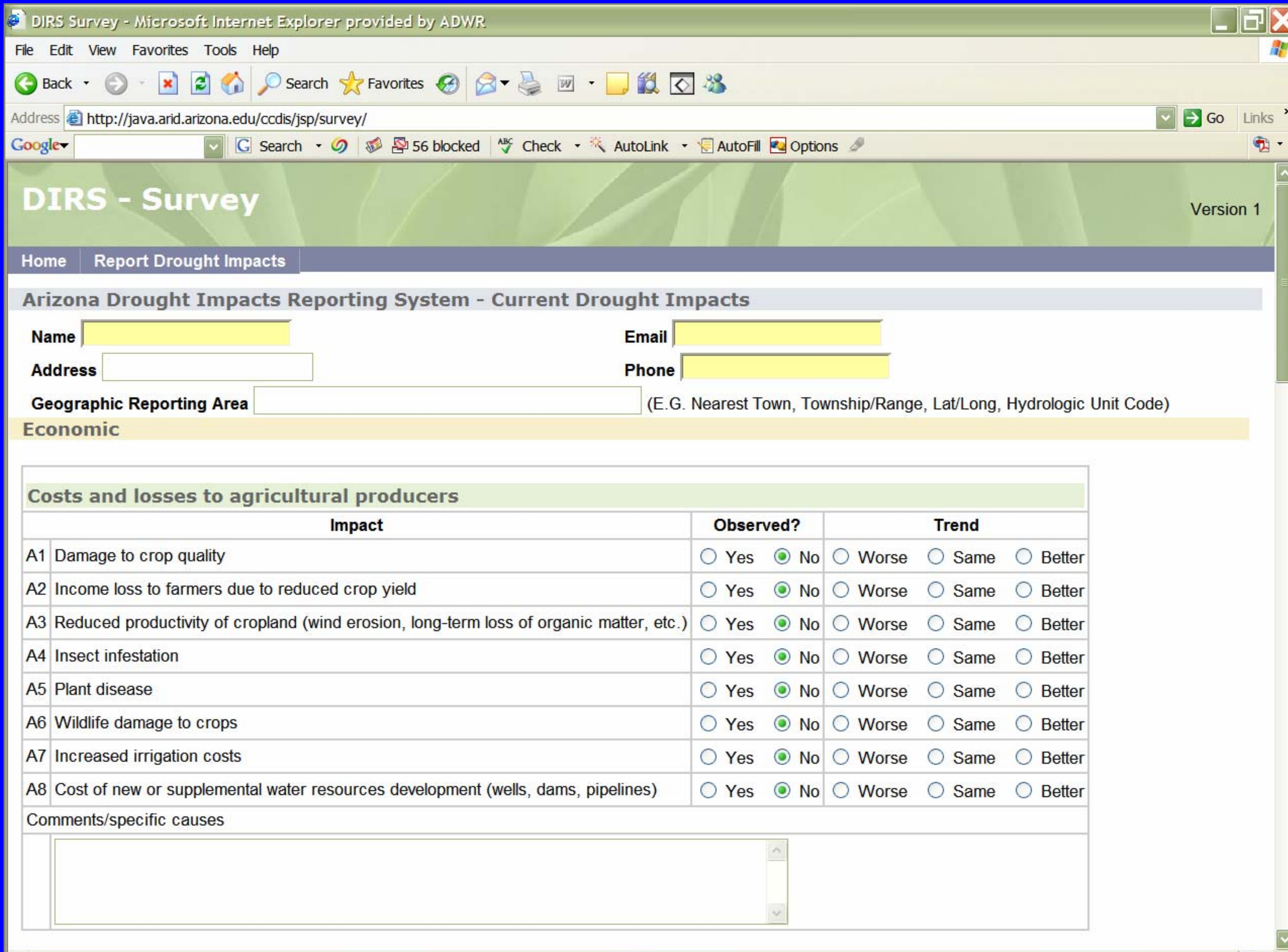
- Hauling water, water conveyance issues
  - Seeps, springs, stock ponds
  - Soil conditions
  - Range impacts

LAIAGs & Drought Monitoring

Drought impacts monitoring variables

- Vegetation condition
  - Indicator species
- Water table declines
- Wildlife
- Subsidence

Drought Impact Report System



DIRS Survey - Microsoft Internet Explorer provided by ADWR

File Edit View Favorites Tools Help

Address http://java.arid.arizona.edu/ccdis/jsp/survey/

DIRS - Survey

Version 1

Home | Report Drought Impacts

Arizona Drought Impacts Reporting System - Current Drought Impacts

Name

Email

Address

Phone

Geographic Reporting Area (E.G. Nearest Town, Township/Range, Lat/Long, Hydrologic Unit Code)

Economic

Costs and losses to agricultural producers

	Impact	Observed?		Trend		
A1	Damage to crop quality	Yes	No	Worse	Same	Better
A2	Income loss to farmers due to reduced crop yield	Yes	No	Worse	Same	Better
A3	Reduced productivity of cropland (wind erosion, long-term loss of organic matter, etc.)	Yes	No	Worse	Same	Better
A4	Insect infestation	Yes	No	Worse	Same	Better
A5	Plant disease	Yes	No	Worse	Same	Better
A6	Wildlife damage to crops	Yes	No	Worse	Same	Better
A7	Increased irrigation costs	Yes	No	Worse	Same	Better
A8	Cost of new or supplemental water resources development (wells, dams, pipelines)	Yes	No	Worse	Same	Better

Comments/specific causes

Website: Arizona Cooperative Extension

LDIGs & Drought Monitoring

We also conduct **drought "capacity building" workshops** with the LDIGs

- We discuss drought history with them
- Examine tree-ring drought reconstructions
- Discuss ocean-atmosphere causes of drought
- Introduce them to online drought resources
- USDM, NCDC climate monitoring, Local NWS resources, NRCS SNOTEL, etc.

Participants include ranchers, farmers, water providers, land managers, interested citizens

Plans for the Future

- Sensitivity analysis of indicator/trigger system
  - Which stream gages should be short-term drought indicators? – In progress through USGS
  - Can we reduce redundancy in 24-, 36-, 48-month SPI for long-term drought?

Plans for the Future

- Implement South Carolina drought tools – in progress – (through CLIMAS, ADWR, NWS)
    - Allows users to see status of their favorite drought indicator(s), at various spatial scales and groupings (such as county, watershed, climate division)

Plans for the Future

- Provide longer-term perspectives on drought
    - Contrast current drought status with status for stations with longer records and with tree-ring records of winter precipitation
- Add groundwater indicators – in progress (through the efforts of Arizona Department of Water Resources)

Plans for the Future

- Merge drought and flood warning websites – in progress – (ADWR and NWS Phoenix are leaders)
- Work more closely with Native Nations
    - Proposal submitted to assess Navajo Nation hydromet system – opportunities for data sharing
    - Leaders: CLIMAS, State Climate Office, Northern Arizona University

Sample of Arizona MTC Monthly Drought Report

Arizona Drought Monitor Report
September 2006

Produced by the Monitoring Technical Committee

Mike Crimmins, Extension Specialist, U of A Cooperative Extension

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Gregg Garfin, University of Arizona – CLIMAS

Tony Haffer, National Weather Service

Larry Martinez, Natural Resources Conservation Service

Ron Ridgway, Arizona Division of Emergency Management

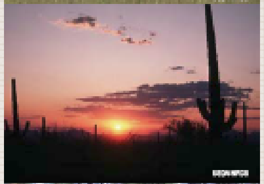
Nancy Selover, Asst. State Climatologist Arizona State University

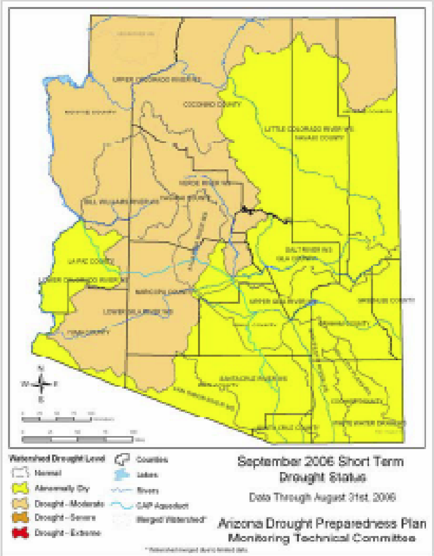
Chris Smith, U.S. Geological Survey

Coordinator: Susan Craig, Arizona Department of Water Resources

Computer Support: Andy Fisher, Arizona Department of Water Resources

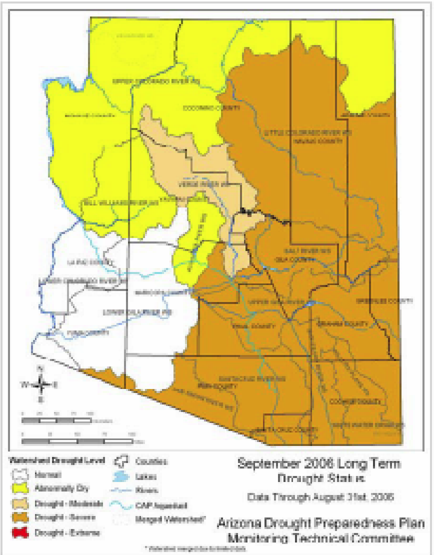
Arizona Department of Water Resources





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.

Reservoir Storage

Arizona Reservoir Status

The abundant rainfall brought by this year's monsoon season has helped to raise water storage levels in several Arizona reservoirs, an event most often caused by winter precipitation rather than summer rains. According to the Tucson *Citizen*, officials at the Salt River Project said that runoff from the summer precipitation this year has exceeded winter runoff for only the ninth time since record-keeping began just over a century ago.

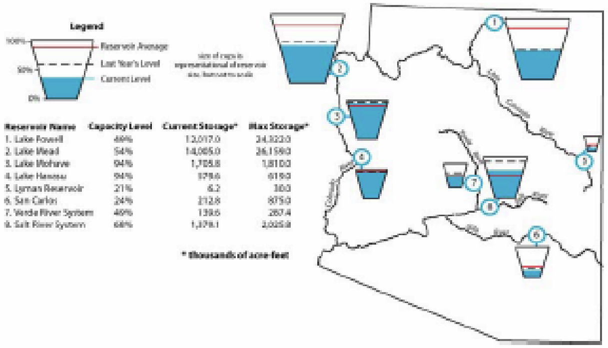
Storage in the Salt River system increased by about three percent of capacity, and the Verde system gained five percent. Reservoir managers had feared that the San Carlos Reservoir could dry up by the end of the summer, leaving farmers in the area without a dependable source of water, according to the Tucson *Citizen*. However, storage has more than tripled in the San Carlos Reservoir on the Gila River, which had been down to eight percent last month, and has now filled to more than 24 percent of its capacity.

On the Colorado River, Lake Powell declined by less than two percent, while Lake Mead rose slightly by less than one percent. The total Colorado River storage is at about 53.5 percent of capacity, declining by less than one percent since last month. Storage on the Colorado River remains only slightly less than one year ago, when it was at 57 percent of capacity.

The monsoon rains, while raising water levels in many reservoirs, were still not enough to counter the significant depletion of in-state water storage resulting from the almost complete lack of rain and snowpack over the past winter. Total in-state storage (San Carlos, Salt River system, and Verde River system reservoirs) stands at 54 percent of capacity, though this is an increase from 48% last month.

(Data provided by USDA-NRCS)

Arizona reservoir levels for August 2006 as a percent of capacity. The map depicts the average level and last year's storage for each reservoir, while the table also lists current and maximum storage levels.

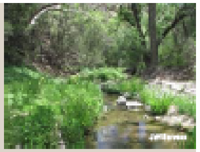


Reservoir Name	Capacity Level	Current Storage*	Max Storage*
1. Lake Powell	49%	12,017.0	24,322.0
2. Lake Mead	54%	14,085.0	26,159.0
3. Lake Mohave	94%	1,705.8	1,810.0
4. Lake Havasu	94%	579.6	619.0
5. Lyman Reservoir	21%	6.2	30.0
6. San Carlos	24%	212.8	875.0
7. Verde River System	49%	139.6	287.4
8. Salt River System	68%	1,379.1	2,025.8

* thousands of acre-feet

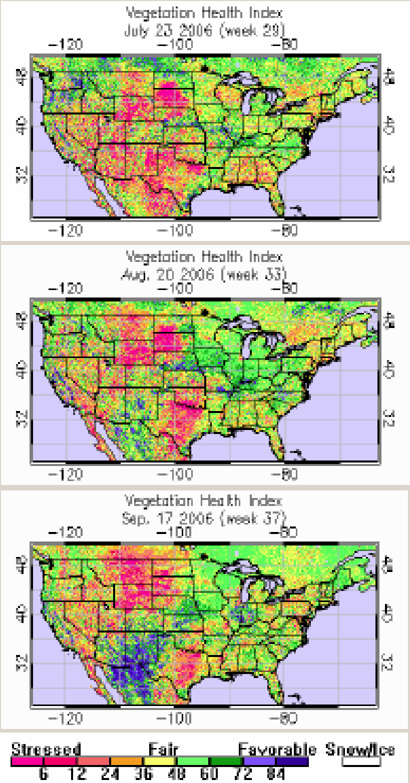
Data provided by USDA-NRCS, graphic provided by University of Arizona - CLIMAS (Climate Assessment for the Southwest)

Vegetation Health



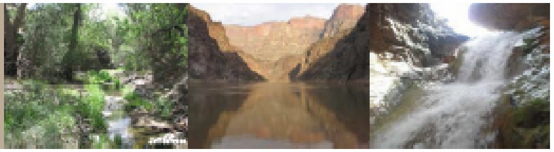
Conditions in Arizona have continued to improve due to above-average monsoon precipitation, particularly in eastern Arizona and at higher elevations along the Mogollon Rim. Portions of southwestern and northern Arizona still show stressed vegetation. Observed improvements in vegetation health often lag several weeks behind precipitation events, so continued improvements are possible even though future monsoon precipitation is unlikely.

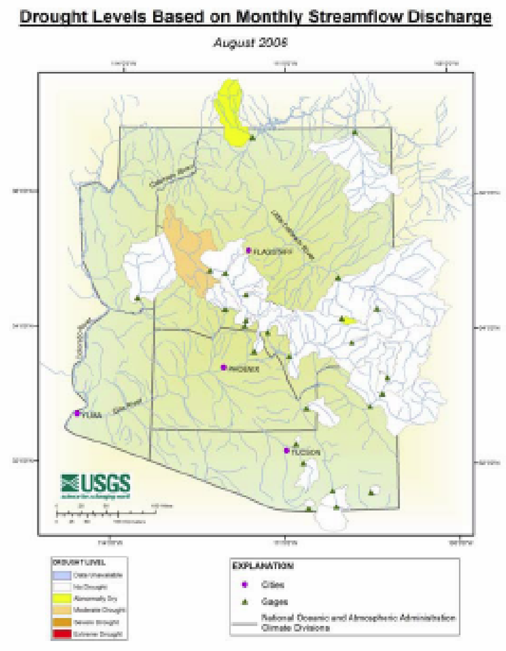
The satellite-derived images below were taken on July 23, (top figure), August 20 (middle), and September 17, 2006.



(Images taken by the National Oceanic and Atmospheric Administration's National Environmental Satellite, Data and Information Service (NESDIS))

Mountain Streamflow and Precipitation





August Streamflow

Following an extremely dry winter, an exceptionally active monsoon produced a very unusual summer hydrologic response. In that regard, heavy rainfall in August produced huge volumes of runoff in the Salt and Gila Rivers, and flows increased significantly in the other basins as well (see table below). In fact, total inflow for August alone into the combined Salt River Project (SRP) reservoir system was greater than the accumulated winter runoff of 121,400 acre-feet for the snowmelt runoff period of January through May 2006. Despite the encouraging August flows into the SRP reservoir system, the year-to-date runoff is only 44 percent of median at 336,889 acre-feet, as the result of the dry winter of 2006.

August Streamflow Observed (compiled by NRCS from USGS data)

Water body	August Runoff in Acre Feet	% of Median
Salt River near Roosevelt	146,835	616%
Tonto Creek	5,936	341%
Verde River at Horseshoe Dam	14,436	108%
Combined Inflow to Salt River Project (SRP) reservoir system	167,207	416%
Little Colorado River above Lyman Lake	2,740	391%
Gila River to San Carlos Reservoir	159,600	2660%

Mountain Precipitation

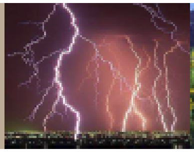
August Precipitation

August was dominated by monsoon thunderstorm activity, with 4-8 inches of precipitation recorded at high elevation SNOTEL sites. Precipitation catch in August was 146 percent of average over the Salt River basin, 106 percent of average over the Verde River basin, and 186 percent of average over the San Francisco-Upper Gila River basin. The Little Colorado River basin received 144 percent of average precipitation in August.

Water Year Precipitation by River Basin

For the water year, SNOTEL data shows that mountain precipitation is below average in all basins, ranging from 65 to 91 percent of average (see table).

Watershed	Percent (%) of 30-Yr. Average Water Year Precipitation October 1 – August 31
Salt River Basin	73%
Verde River Basin	58%
Little Colorado River Basin	65%
San Francisco-Upper Gila River Basin	91%
Central Mogollon Rim	56%



Temperature and Precipitation

Update

August brought above-average monsoon rainfall for much of the state, particularly the southeast, where a few extreme rainfall events caused widespread flooding on the Santa Cruz River. The high runoff in the Salt River basin caused the level in Roosevelt Lake to rise during August. Although the one-month rainfall does not end the drought, it does improve rangeland conditions and provide short-term relief. The rainfall and associated humidity also brought significantly cooler temperatures to the southeast and northwest parts of the state. However, the temperatures in the northeast and southwest continued to be well above average in August.

Three-month period - Precipitation totals for the summer months were near or above average for all basins except Bill Williams and the Virgin River in the northwest. Temperatures were above the 85th percentile everywhere except the northeast plateau.

Six-month period - Precipitation totals in the Bill Williams basin fell below the 25th percentile, while all other areas of the state were near or above normal. Temperatures statewide continued to be well above average for the six-month period.

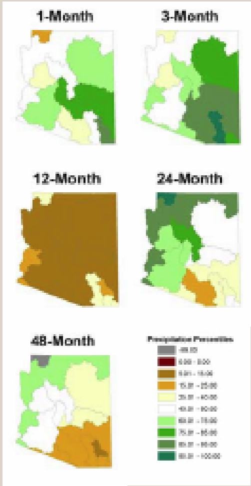
12-month period - The 12-month period includes the wetter than normal monsoon season and the much drier than normal winter season. Most of the watersheds remain below the 15th percentile for 12-month precipitation, while the Virgin basin dropped below the 40th percentile and the Lower Colorado River basin dropped below the 25th percentile. The corresponding temperatures for the one-year period have been extremely high: above the 85th percentile everywhere except the northeast corner of the state, which is above the 75th percentile.

Two-year period - The two-year period combines the wet winter of 2005 and wet summer of 2006 with the dry winter of 2006 and dry summer of 2005. Taken together, there is very little evidence of dryness across the western and west central portions of the state, with precipitation totals above normal. However, precipitation totals in the Little Colorado and the southeastern watersheds are below the 35th percentile, with the driest watersheds being the San Pedro and Willcox Playa. Except for areas along the lower Colorado River, temperatures for the two-year period were all at or above the 80th percentile.

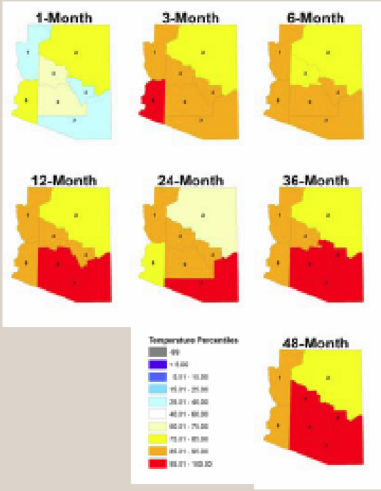
Three-year period - Precipitation totals remain above average in the northern third of the state, below average in the southern half of the state, and well below the three-year average in the southeastern watersheds. The entire state is still well above average for temperature, with the southeast and south central portions of the state above the 95th percentile.

Four-year period—The northern and western watersheds have had near or above normal precipitation during the four-year period, while the eastern and southeastern watersheds are still well below the 25th percentile. Along with the dryness has been excessive heat, particularly in the southeast.

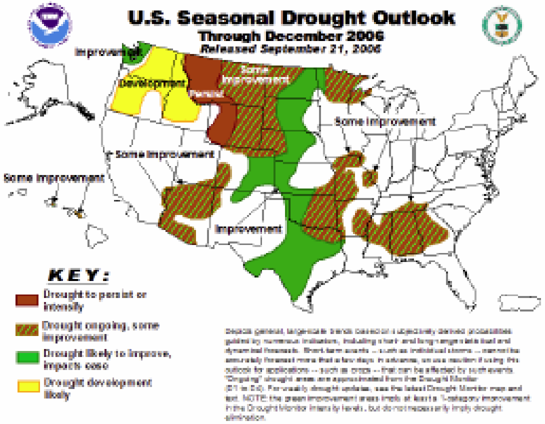
Precipitation Percentiles by Watershed



Temperature Percentiles by Climate Division



Weather Outlook



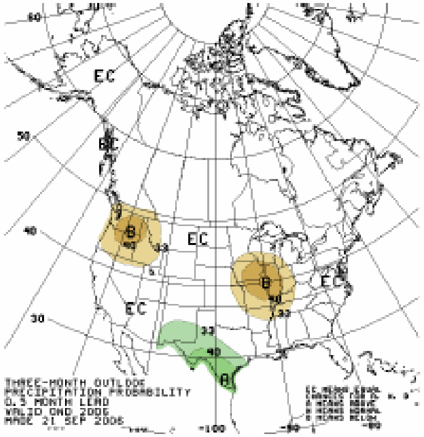
Drought Outlook

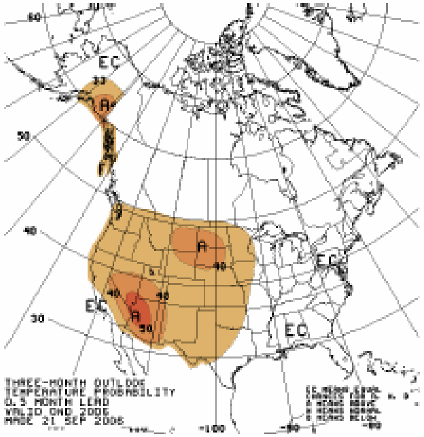
The NOAA Climate Prediction indicates most of the state will see some improvement in drought conditions, with a lessening of some of the drought impacts by January 2007. Worthy of note is the evolution of a weak *El Nino* event in the eastern Pacific Ocean. While it is too early to tell what impact this will have on Arizona's winter, history shows that in similar situations, precipitation in Arizona showed a tendency to be above normal, especially after January 1st.

Also see the most current Southwest Climate Outlook -
www.ispe.arizona.edu/climas/forecasts/swoutlook.html

For additional weather information from the Office of the State Climatologist for Arizona -
http://geography.asu.edu/azclimate

October to December Weather Outlooks





Precipitation

Equal chances for above average, average, and below average precipitation across the state.

Temperature

High confidence level that temperatures will be above average.

NOAA's CPC Outlooks are 3-category forecasts. As a starting point, the 1971–2000 climate record is divided into 3 categories, each with a 33.3 percent chance of occuring (i.e., equal chances, EC). The forecast indicates the likelihood of one of the extremes—above-average (A) or below-average (B)—with a corresponding adjustment to the other extreme category; the "average" category is preserved at 33.3 likelihood, unless the forecast is very strong. Thus, using the NOAA-CPC temperature (precipitation) outlooks, areas with light brown (green) shading display a 33.3–39.9 percent chance of above-average, a 33.3 percent chance of average, and a 26.7–33.3 percent chance of below-average temperature (precipitation). A shade darker indicates a higher than 40.0 percent chance of above-average, a 33.3 percent chance of average, and a further reduced chance of below-average temperature, and so on. Equal Chances (EC) indicates areas with an equal likelihood of above-average, average, or below-average conditions; it is used by forecasters when the forecast tools do not indicate a strong "signal" that conditions during a given period will be in any one of the three categories.