Arizona Drought Monitoring Sensitivity and Verification Analyses

A Water Sustainability Institute,
Technology and Research Initiative Fund Project

Christopher L. Castro, Francina Dominguez, Stephen Bieda III,
Mike Crimmins and Gregg Garfin
University of Arizona

Andrew Ellis
Arizona State University

Arizona Department of Water Resources Seminar
Phoenix, Arizona

February 20, 2008

THE UNIVERSITY OF ARIZONA

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Presentation Outline

Motivation for a better physical understanding of drought in Arizona

Current state of Arizona drought monitoring

Methodological approach of the project

Preliminary results with respect to physical understanding aspects

Drought impacts data

Toward a seasonal climate forecasting and climate change projection capability for Arizona using a regional modeling approach

Concluding points

Motivation: Importance of Drought


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Scientists predict Southwest mega-drought

Climate models indicate region will be as dry as Dust Bowl for decades

A bleached "bathtub ring," the result of a six-year drought that has dramatically dropped the level of the reservoir, shows on red Navajo sandstone formations near Last Chance Bay at Lake Powell near Page, Ariz. Lake Powell and the next biggest Colorado River reservoir, the nearly 100-year-old Lake Mead, are at the lowest levels ever recorded.

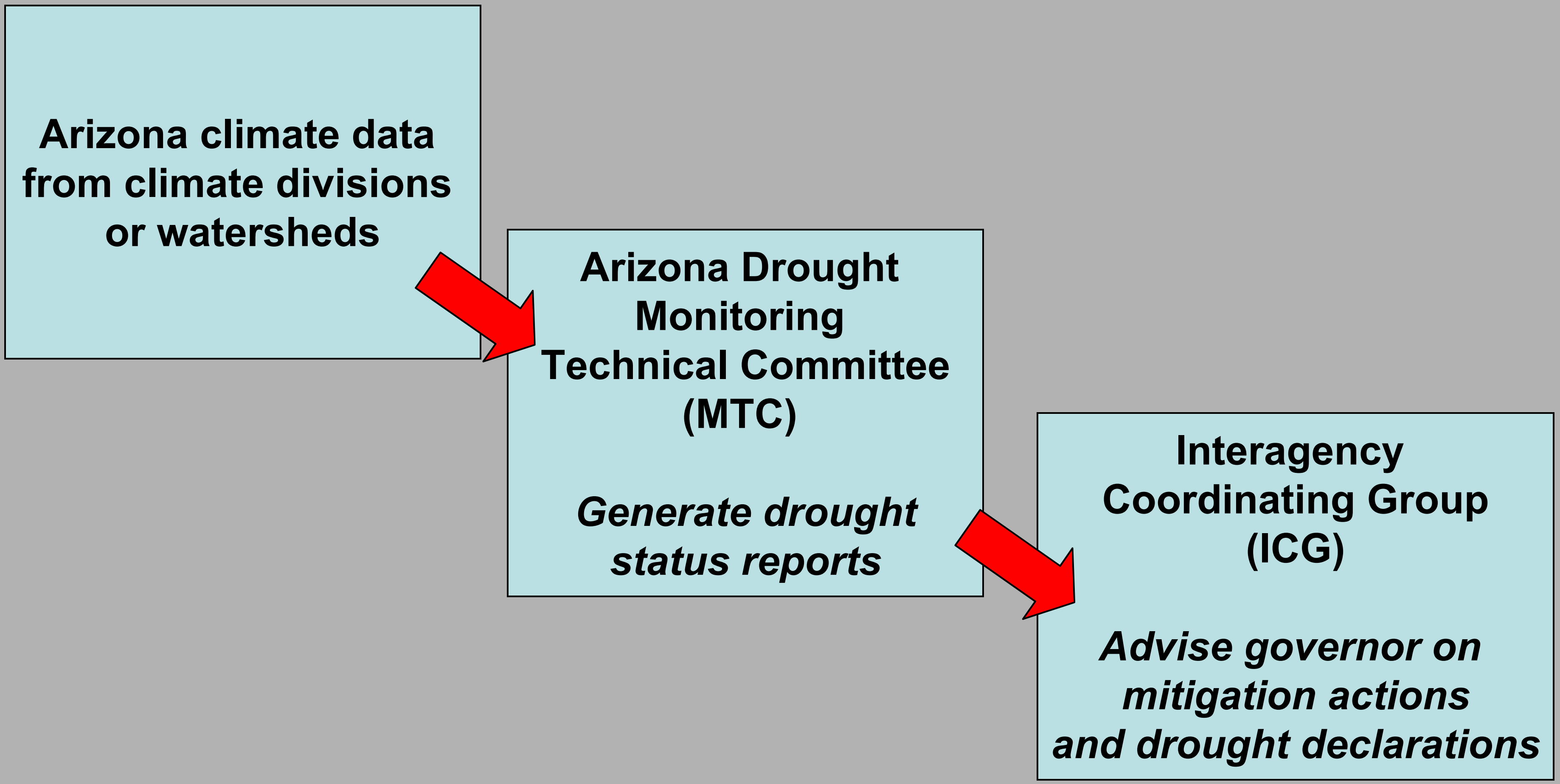
David Mcnew / Getty Images

MSNBC lead news story on April 5, 2007

Recent multi-year drought has awakened Arizona decision makers to the possibility of drought-induced water shortages

The sensitivity to drought will likely be exacerbated in the future due to anthropogenic climate change (i.e. global warming) and continued population growth, especially in the Southwest U.S.

Arizona Drought Monitoring and Response System



Current state of Arizona drought monitoring

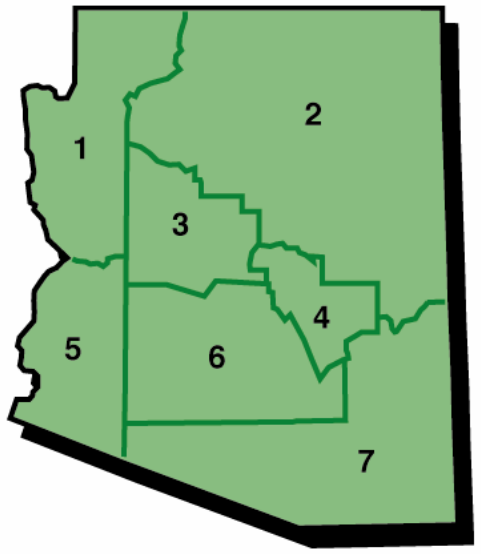


Figure 1. Arizona Climate Divisions.
http://www.ncdc.noaa.gov/img/onlineprod/drought/az.gif

(Garfin 2006)

Precipitation (SPI), streamflow, and reservoir data for Arizona climate divisions.

The climate divisions resolve drought quite coarsely because of their large variation in physiogeographic characteristics

Calculation of drought status

Status	Description	Indicator Percentiles
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 %

Table 1. Arizona Drought Trigger Levels.

Short-term drought status (≤ 1 year) is based on percentiles of 3-, 6-, and 12-month SPI (McKee et al.,1995). Long-term drought status (> 1 year) is based on percentiles of 24-, 36-, and 48-month SPI, streamflow from selected gages (personal communication, Chris Smith, USGS Arizona Water Science Center), and reservoir status (U.S. Bureau of Reclamation) for Arizona climate division 1, which has a tourism and recreation industry strongly affected by changes in reservoir levels.

(Garfin 2006)

Raw data are converted to drought status levels for each indicator, then averaged.

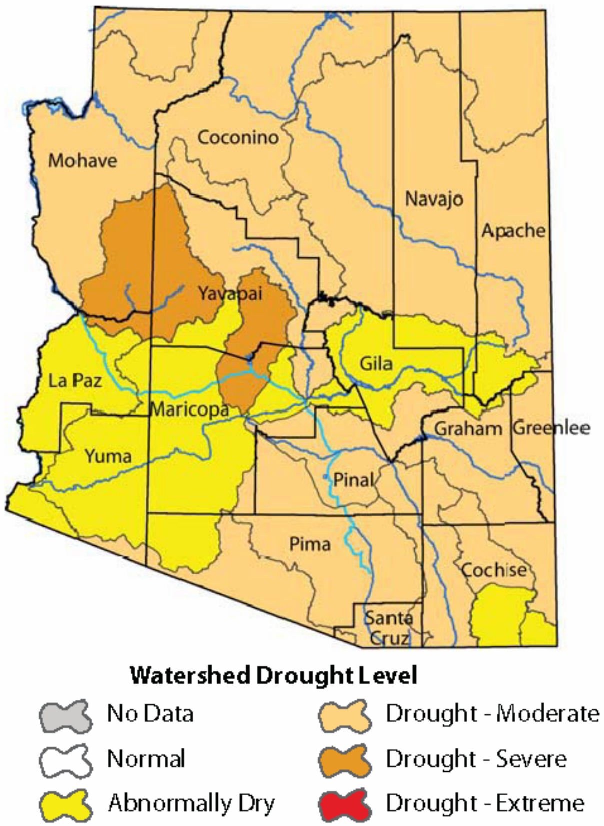
These levels are reported every month for short-term and long-term drought

To change categories, trends must be observed for several consecutive months.

A small cross-section of stakeholders and MTC (10) subjectively evaluated the method.

Adjustments to current drought status method since late 2004

Figure 4a. Arizona short-term drought status for December 2007.



(CLIMAS website)

More spatial detail and information by depiction of drought status at the watershed level and inclusion of individual indicators.

Recognition of differences between winter and summer seasons: "Fine-tuning" of drought status calculations, based on rapid changes in drought conditions during the monsoon.

Improved subjective evaluation by Interaction with a greater number of stakeholders (e.g. LDIGs) and extension agents.

Project Approach in relation to weaknesses in current drought status method

1. Create new retrospective drought indices (SPI) using monthly PRISM precipitation data. This is the most highly resolved U.S. precipitation product available at 4 km resolution from 1895-present.
   → High spatial resolution enables SPI linkage to detailed topographic characteristics of the region.

2. Evaluate relationship of PRISM-derived drought indices to climate indices which reflect Pacific SST variability.
   → Addresses precipitation differences between winter and summer season with respect to interannual variability.

Project Approach in relation to weaknesses in current drought status method (cont.)

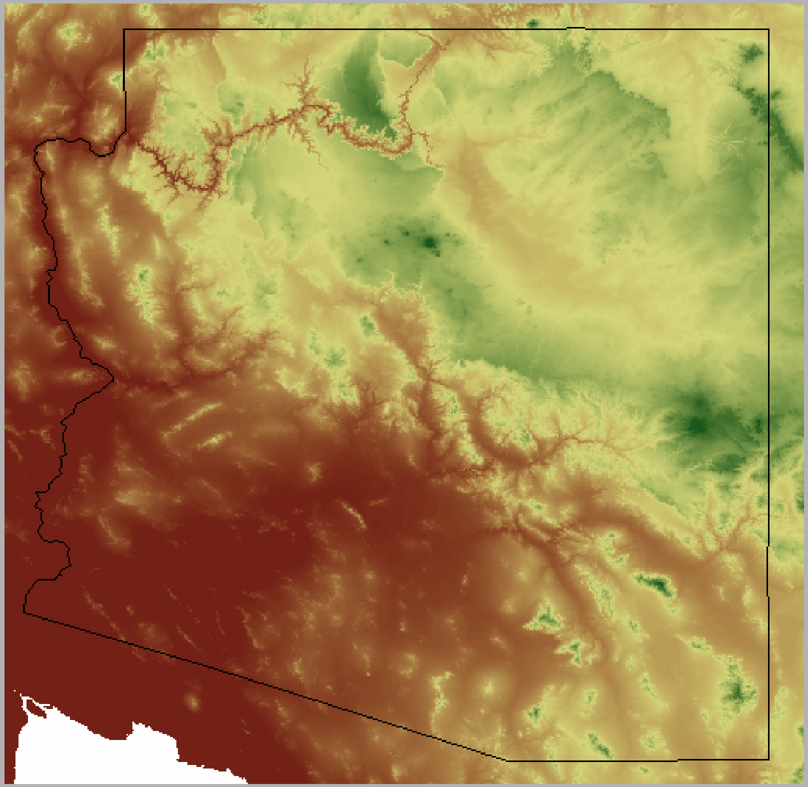
3. Quantitatively compare drought status depictions to stakeholder verification data collected primarily by government agencies and land surface indicators.
   → Eliminates the use of qualitative and subjective stakeholder information to characterize drought.

4. Use regional models to generate climate forecasts and projections
   → Generate forecast information at a regional scale, which is of much greater relevance to stakeholders.

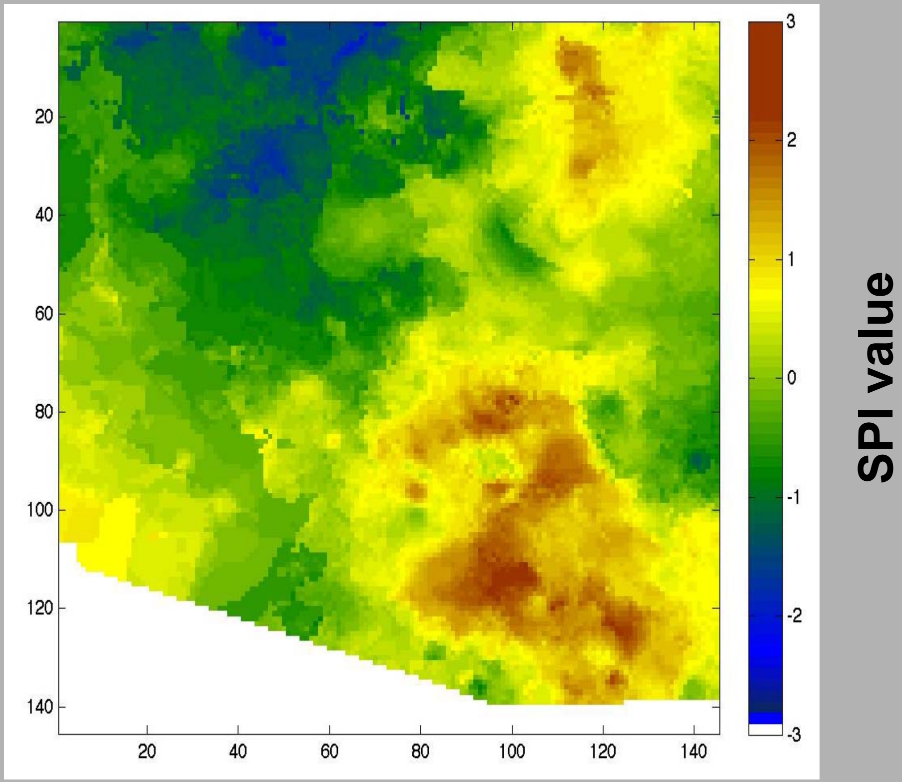
How do we improve our characterization and physical understanding of drought?

PRISM-based SPI: Preliminary evaluation

Topographic resolution



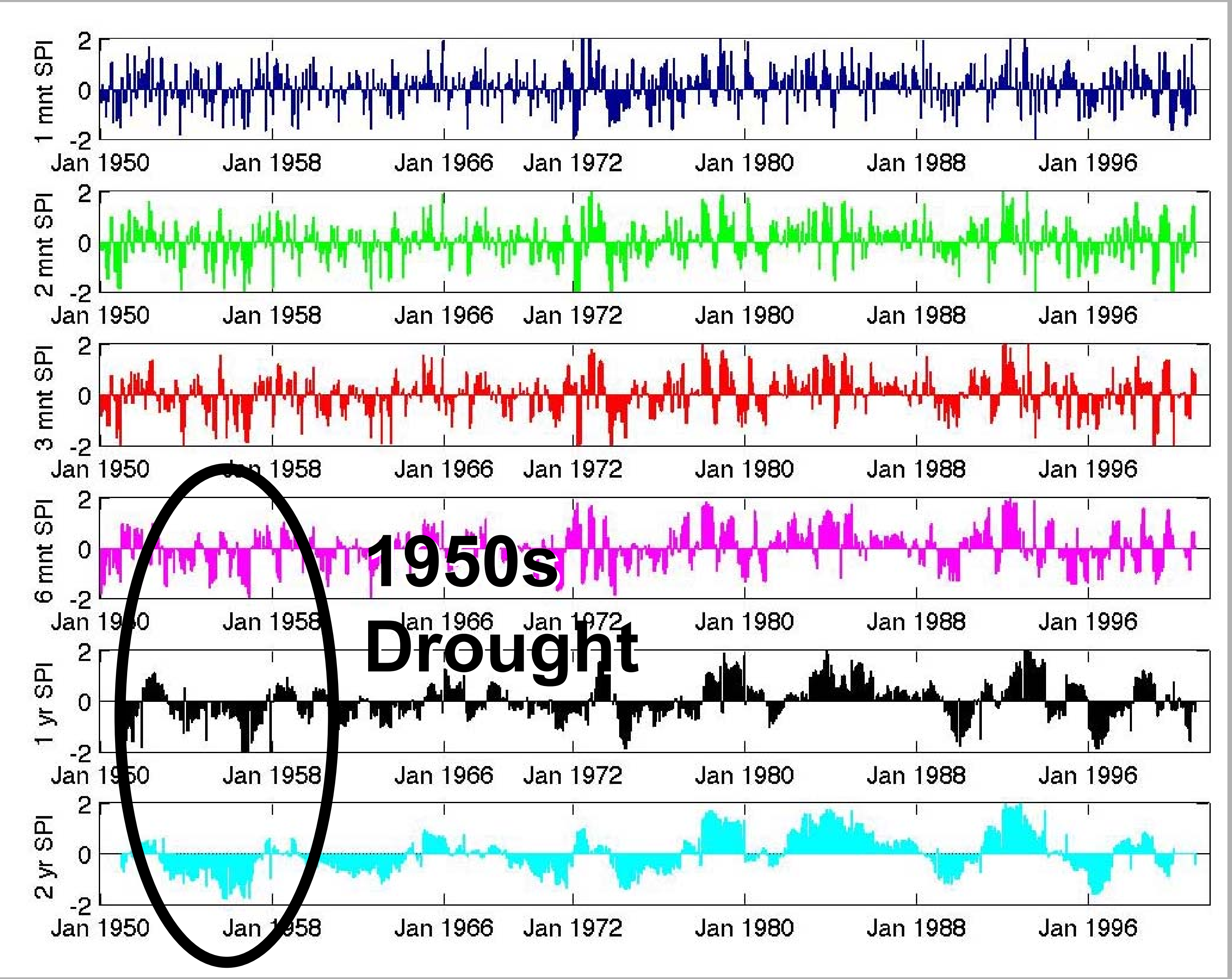
Arizona SPI at 4 km resolution

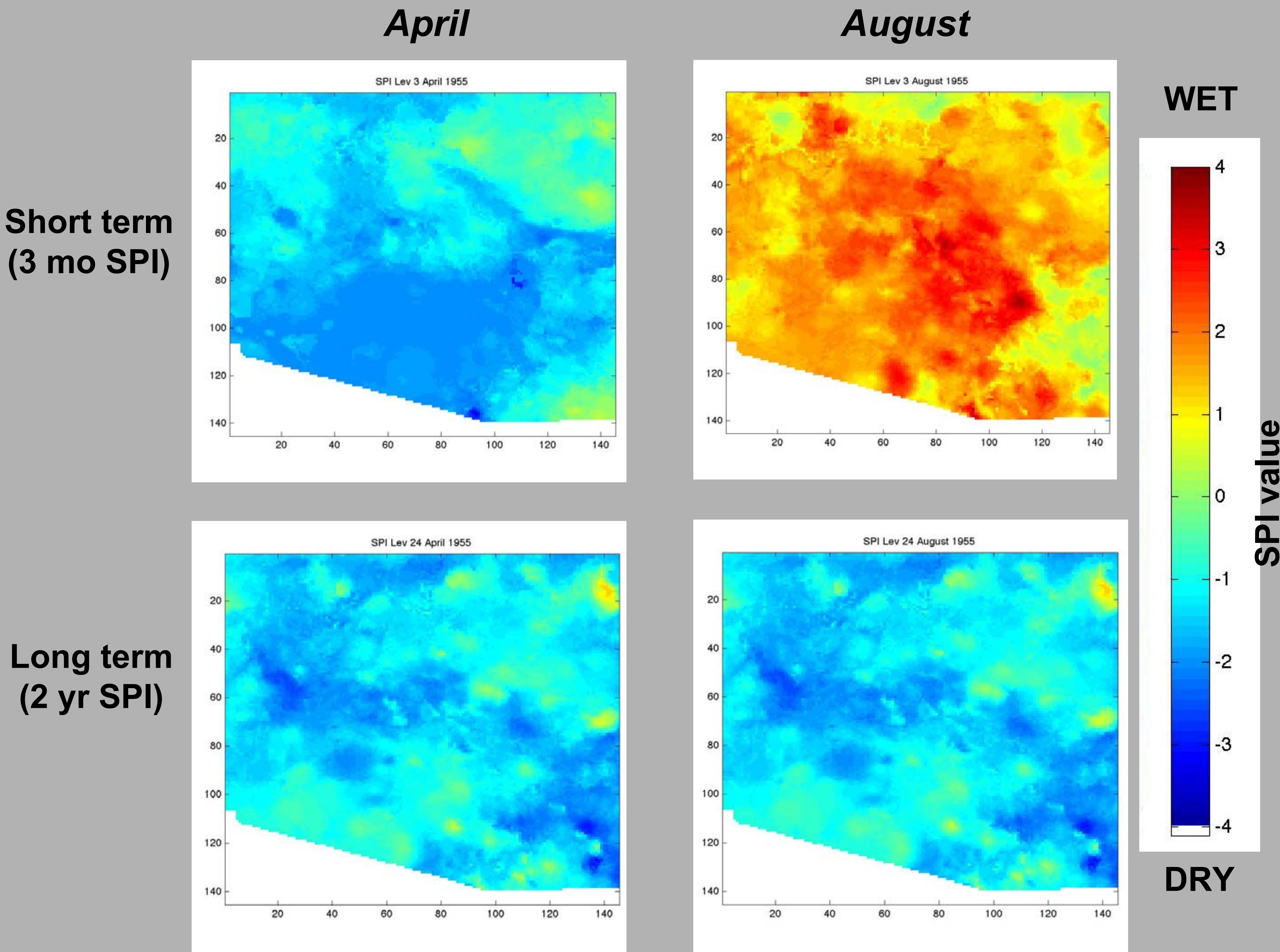


Arizona SPI from PRISM: 1950-2000

Short-term drought indicators

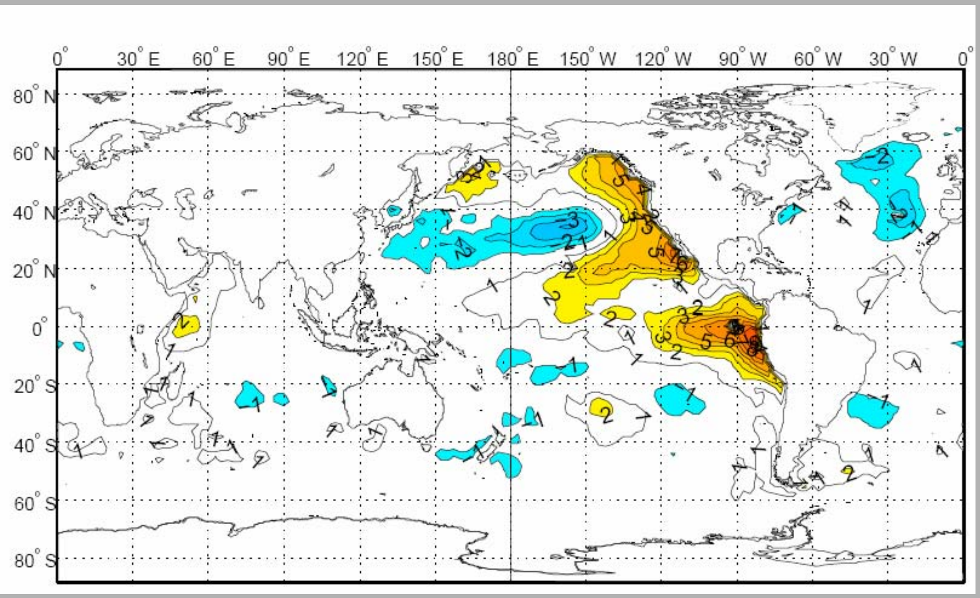
Long-term drought indictors



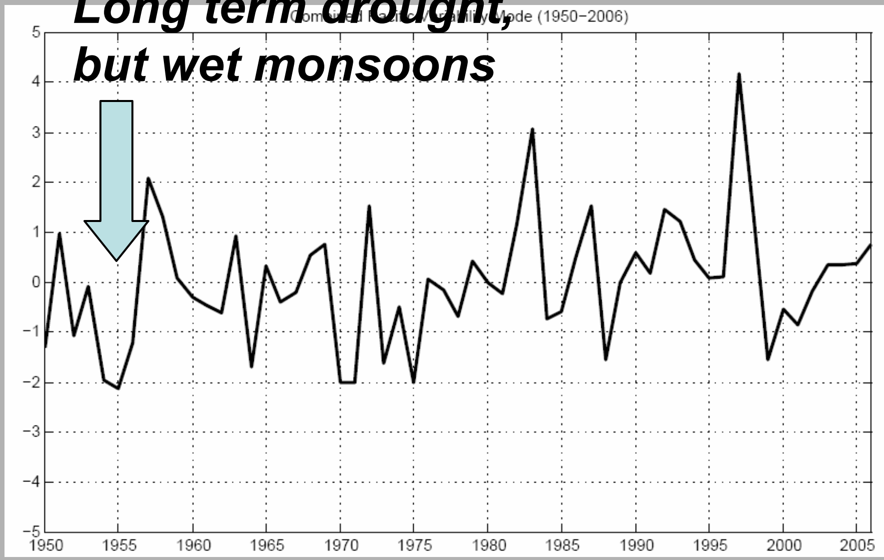


April
August
Short term
(3 mo SPI)
Long term
(2 yr SPI)
SPI Lev 3 April 1955
SPI Lev 3 August 1955
SPI Lev 24 April 1955
SPI Lev 24 August 1955
WET
DRY
SPI value
4
3
2
1
0
-1
-2
-3
-4

SST-based Climate Indices
Combined Pacific Variability mode (summer)



1950s:
Long term drought,
but wet monsoons

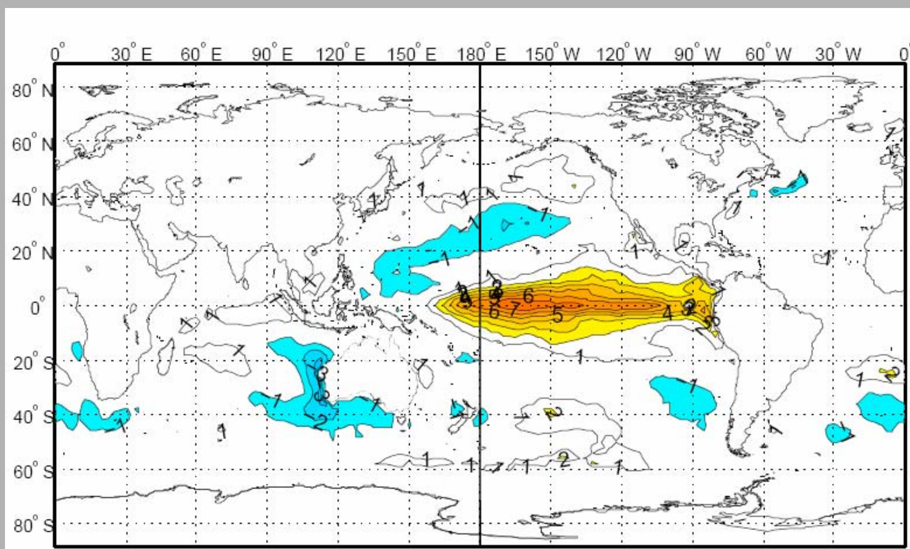


A combination of interannual and interdecadal variability in the Pacific.

These are the first order controls on natural climate variability in Arizona, with a strong response in BOTH winter and summer. The winter response is opposite from the summer response.

Wet winter → Dry and delayed monsoon
Dry winter → Wet and early monsoon

Combined Pacific Variability Mode (winter)



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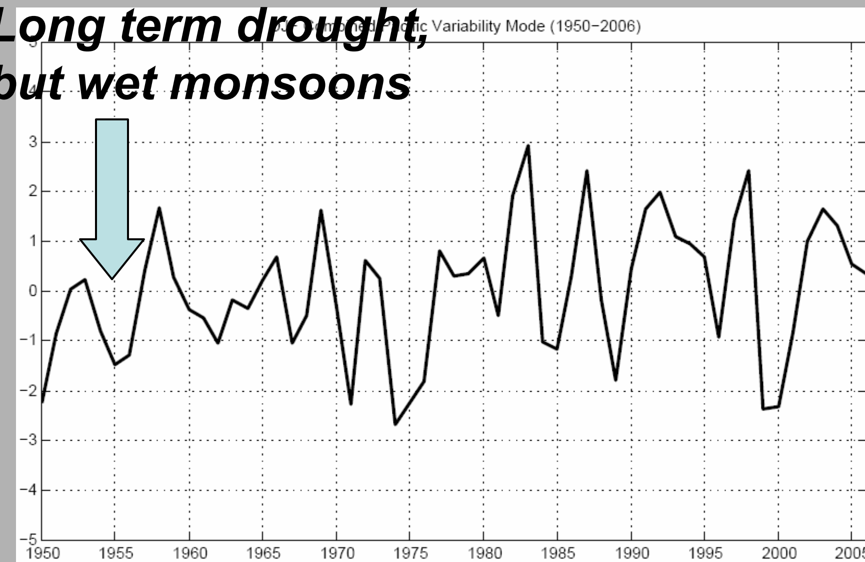
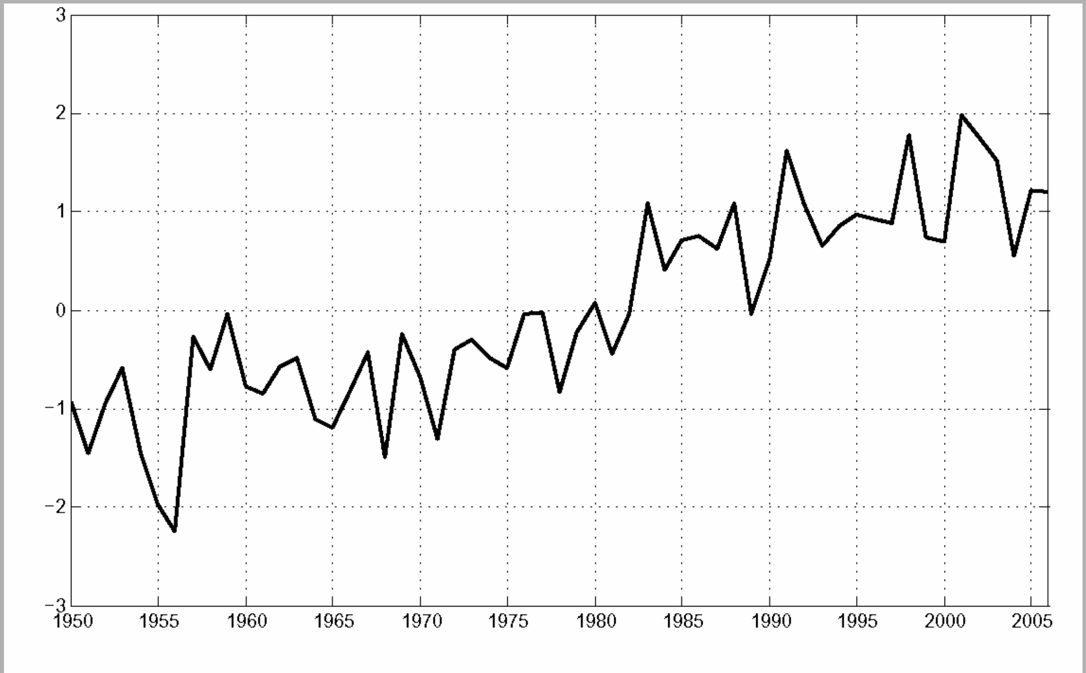


The SST signature is fairly persistent from the previous winter, so there is good potential for skillful drought forecasts based on statistical or regional model approaches!

Next step is to relate to PRISM-derived SPI data.

The "global warming" mode in global SSTs—which is becoming more dominant....



WHAT IS THE EFFECT OF GLOBAL WARMING ON HOW ARIZONA'S CLIMATE IS CURRENTLY CHANGING?

Please note the use of the present—and NOT future tense—in this statement.

There's a long enough observational record to give some quantitative insights.

How do we relate drought information to impacts data that reflects stakeholder needs?

Drought Impacts

<u>**First-order**</u>

Reduced streamflow, lake levels, increased forest fire frequency, soil moisture deficits

<u>**Second-order**</u>

Decreased agricultural yields, reduced park visitation, water hauling

<u>**Third-order**</u>

Lost business or income potential, conflicts over water allocation and management

Drought Impacts Data: First Order

USGS streamflow

USDA-NRCS reservoir levels

USDA-NRCS snow water equivalent, depth

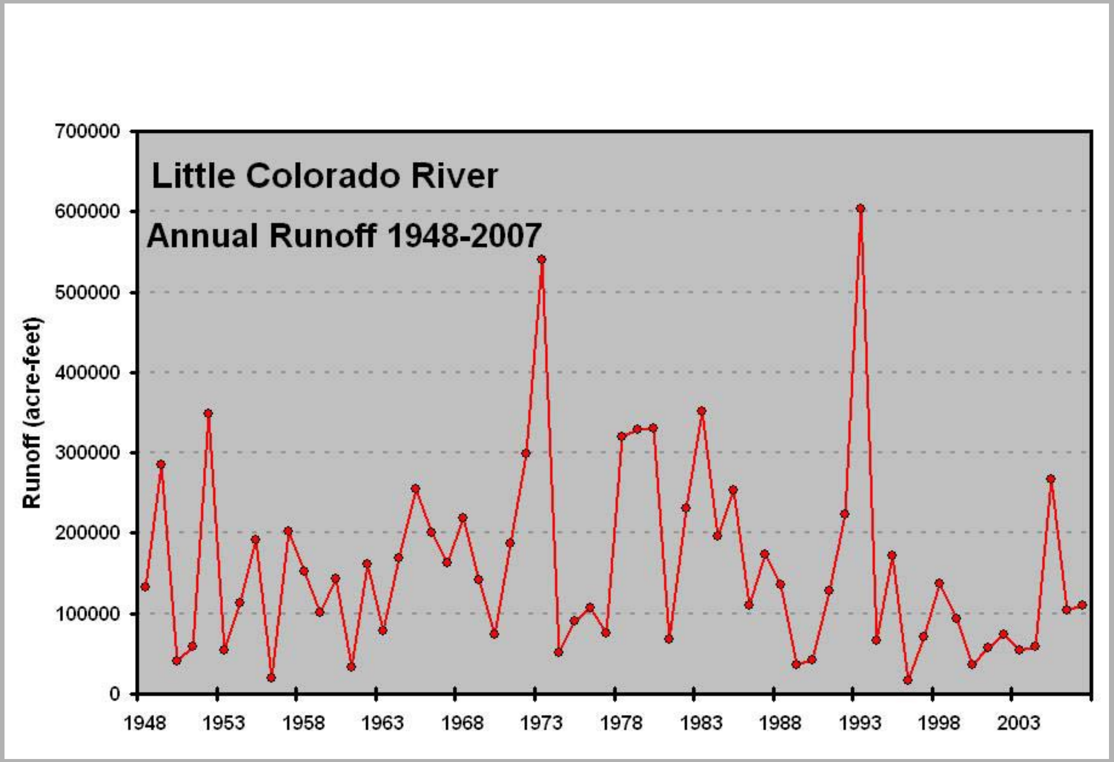
Fire frequency and acres burned (multi-agency)

NOAA/NASA vegetation health indices (NDVI)

Range and pasture condition (Cooperative Extension)
    Case studies only

Groundwater (ADWR, USGS)

USGS Streamflow Data Example



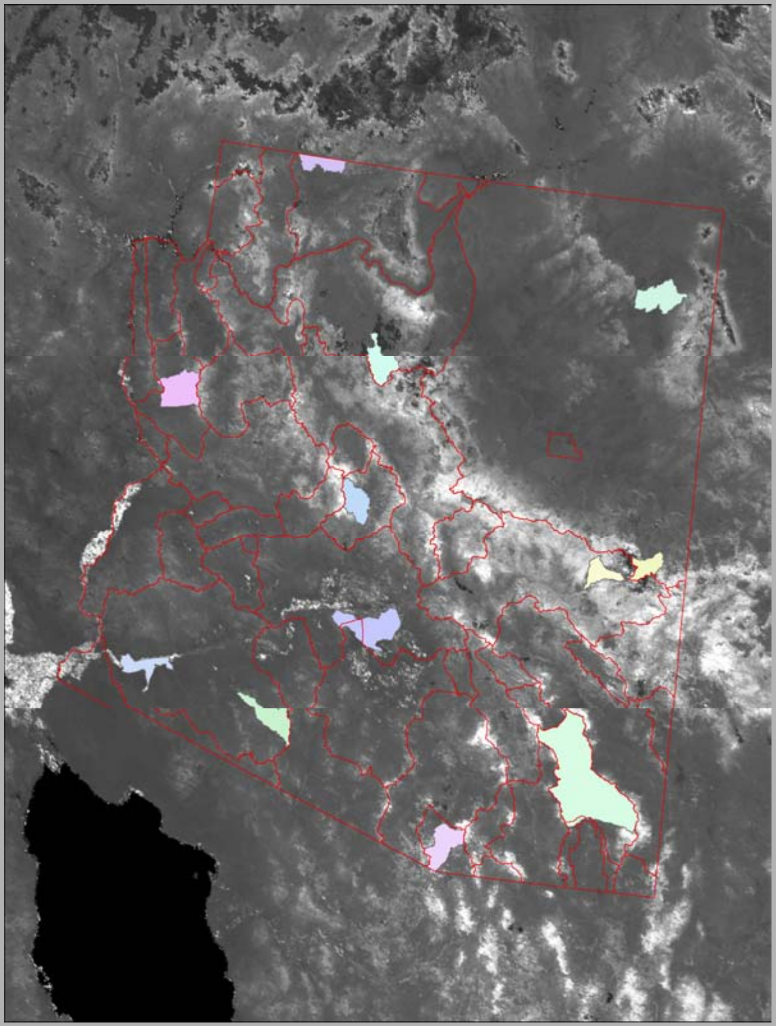
These data give streamflow within a given basin, matched to PRISM grid points.

Such data can be then be directly compared to PRISM-derived SPI.

High resolution satellite-derived vegetation greenness index (NDVI)

These data exist for last twenty years

Preliminary analysis shows this is strongly influenced by summer monsoon rainfall.



Example of NDVI data with Arizona watershed regions superimposed

Drought Impacts Data: Second and Third order

Tourism sector

Visitation, spending in state and national parks and forests
Forest closure and restrictions

Agriculture sector (USDA)

Crop yields
Livestock and cattle
Insurance claims

Water sector

Water hauling (ADWR)
Decreased irrigation allocations (Irrigation Districts)

Wildlife sector (Arizona G&F, US F&WS)

Large ungulates (e.g. Deer, elk)
Hunting permits

Can we make a local effort to improve drought prediction and climate change projection in Arizona?

Use of Regional Atmospheric Modeling to Improve Short and Long-term forecast capability of the North American Monsoon System

A Pending University of Arizona NSF Proposal
PIs: Christopher Castro and Francina Dominguez

Would use Weather Research and Forecasting Model to investigate potential utility of long-range climate forecasts and projections.

Downscale coarser model data from NCEP seasonal forecast model and IPCC scenarios.

Regional model should add substantial value for the warm season.

Would eventually lead to locally-generated, high resolution seasonal climate forecasts

Concluding points

The weakness of current MTC method for drought status monitoring which this project addresses are: 1) coarse spatial resolution, 2) failure to recognize the differences between winter and the summer monsoon, 3) subjective determination of drought indicators, and 4) ability to forecast drought on a seasonal and longer timescale.

More spatially resolved drought indices are developed using PRISM data. These can show marked differences in characterization of drought with respect to timescale and geographic location.

Arizona's climate variability is driven, to a first order, by Pacific SST variability, so there is good potential for skillful seasonal prediction using statistical methods or regional models. Global warming is also an important consideration—and has probably changed Arizona's climate over the last 20 years.

Quantitative drought impacts data in Arizona do exist. We have obtained some of these and are currently working on obtaining others. Ultimately we will statistically relate these to the more spatially detailed climate data.