Arizona Drought Monitoring Sensitivity and Verification Analyses

Project Results and Future Directions

A Water Sustainability Institute,
Technology and Research Initiative Fund Project

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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

Relationship of Arizona climate to larger-scale forcing

Relationship of precipitation to some first-order stakeholder impacts data

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

Concluding points and action recommendations

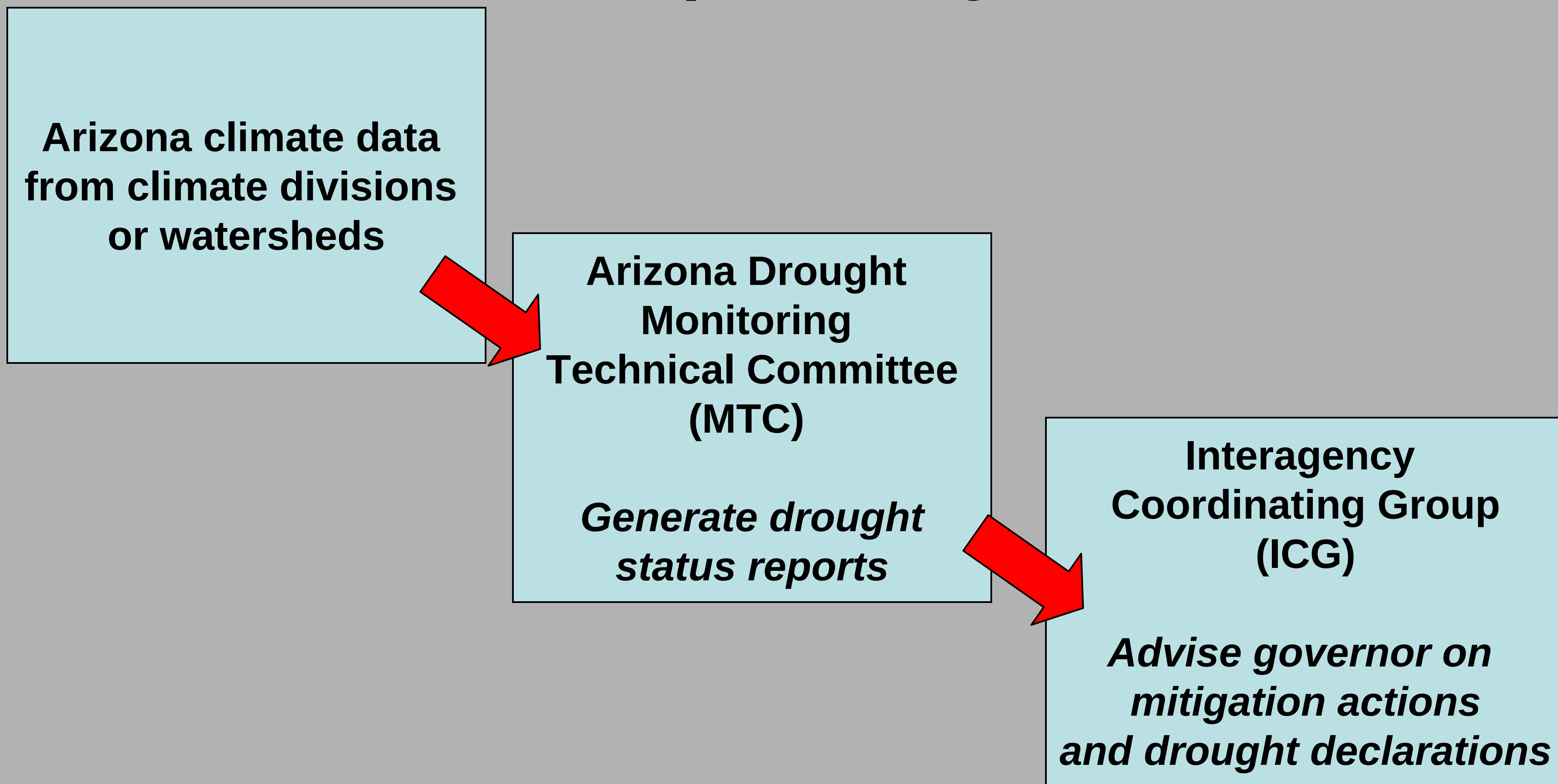
Motivation: Importance of Drought

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

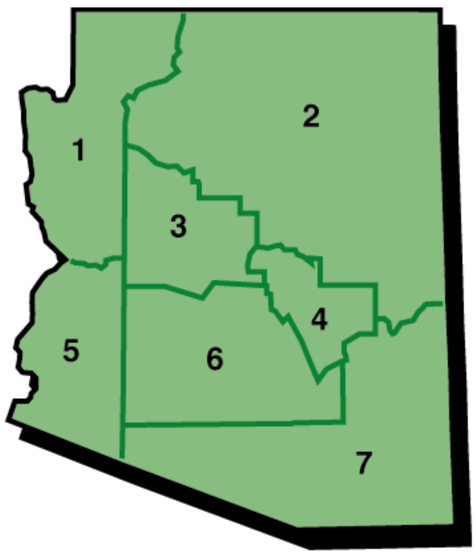


Figure 1. Arizona Climate Divisions.
http://www.ncdc.noaa.gov/img/onlineprod/drought/az.gif

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.

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

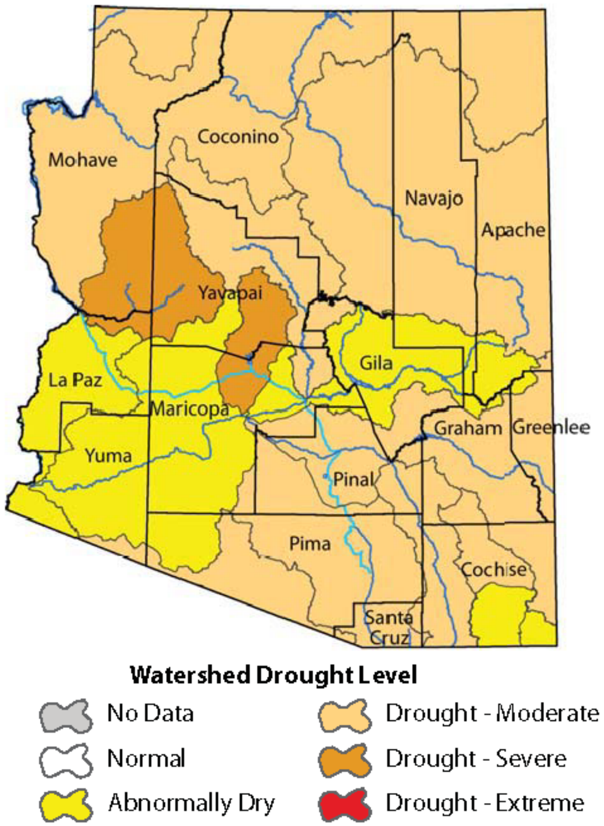
These levels are reported every month for short-term and long-term drought

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.



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.**

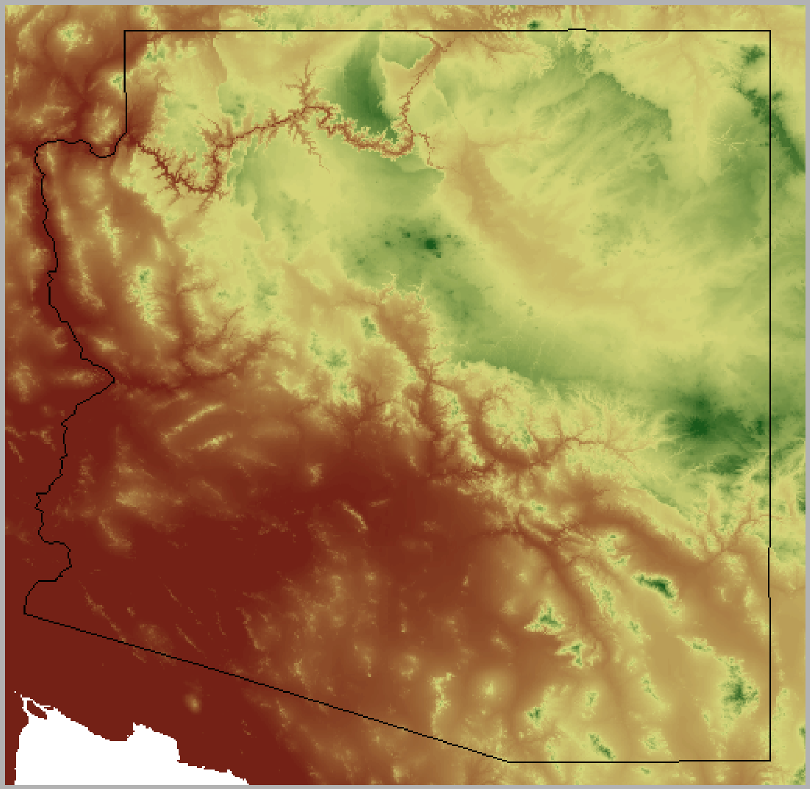
Project Approach in relation to weaknesses in current drought status method (cont.)

3. Quantitatively compare drought status depictions to stakeholder verification data collected primarily by government agencies and land surface indicators.
   → **Better relationship of stakeholder information to drought characterization.**

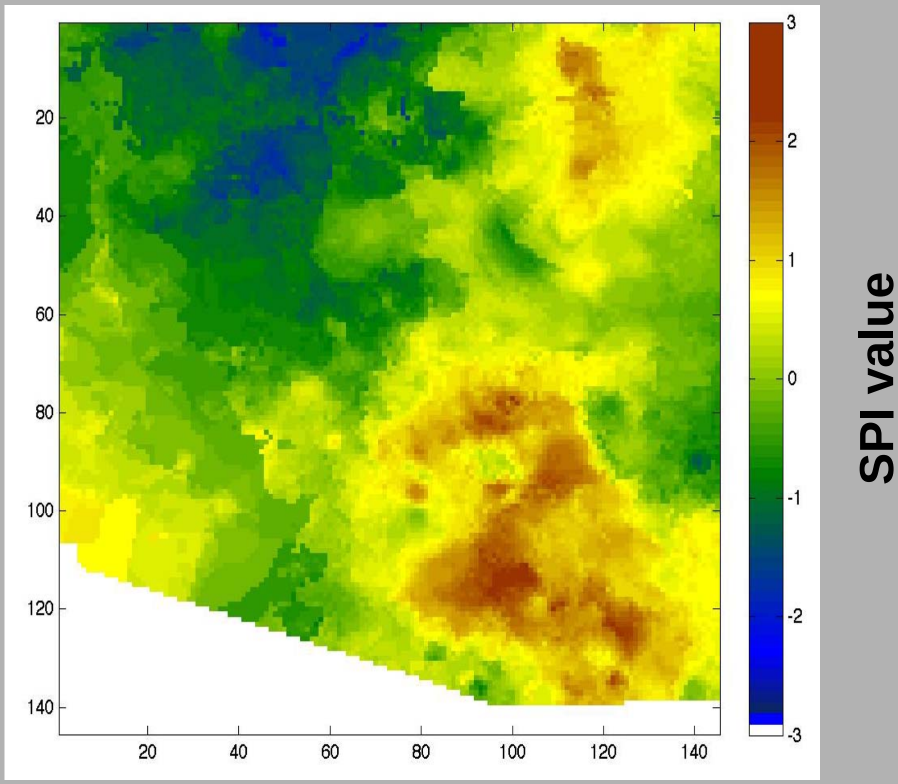
4. Use regional models to generate climate forecasts and projections
   → **Generate forecast information at a regional scale, which is of much greater relevance to stakeholders.**

PRISM-based SPI

Topographic resolution



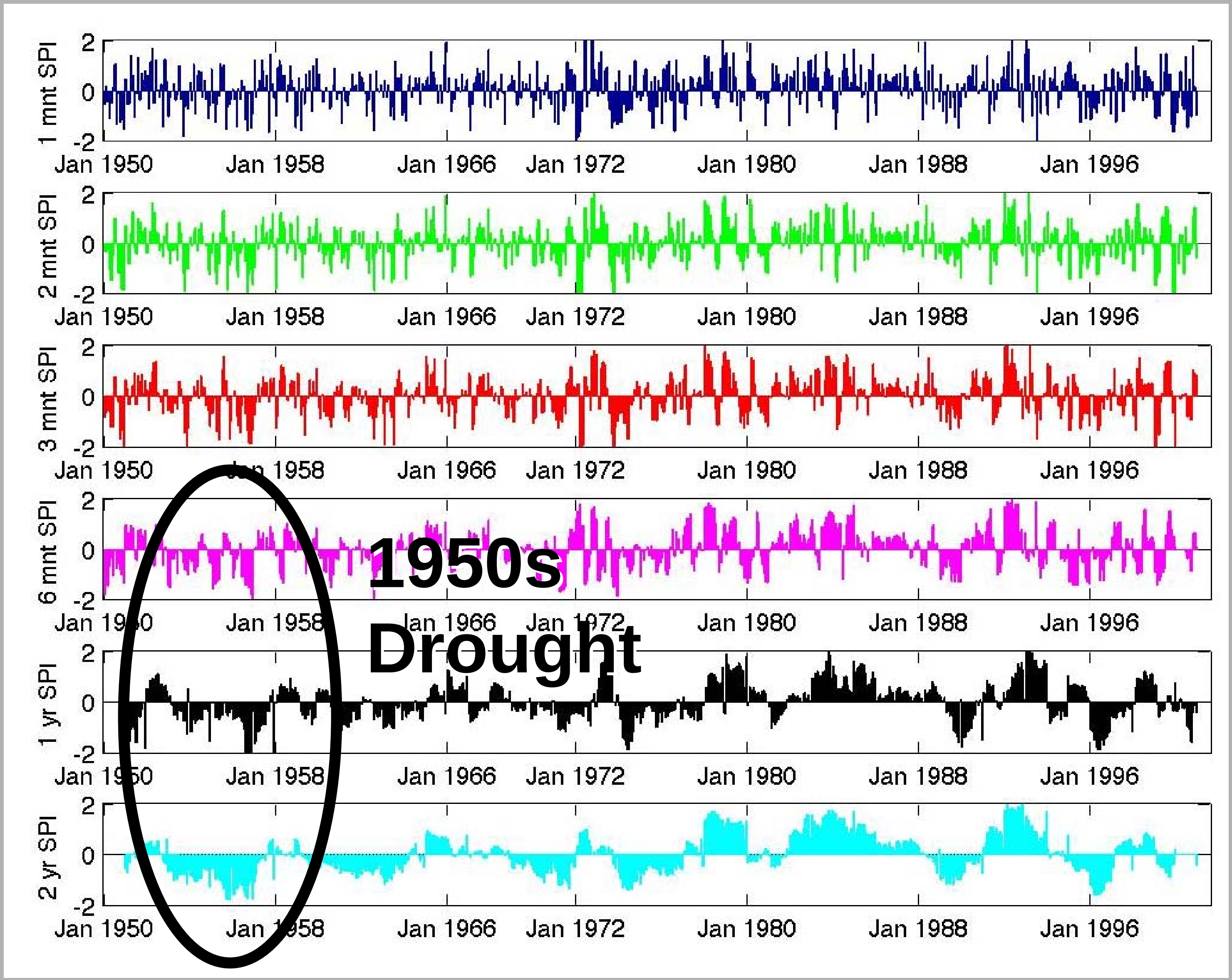
Arizona SPI at 4 km resolution



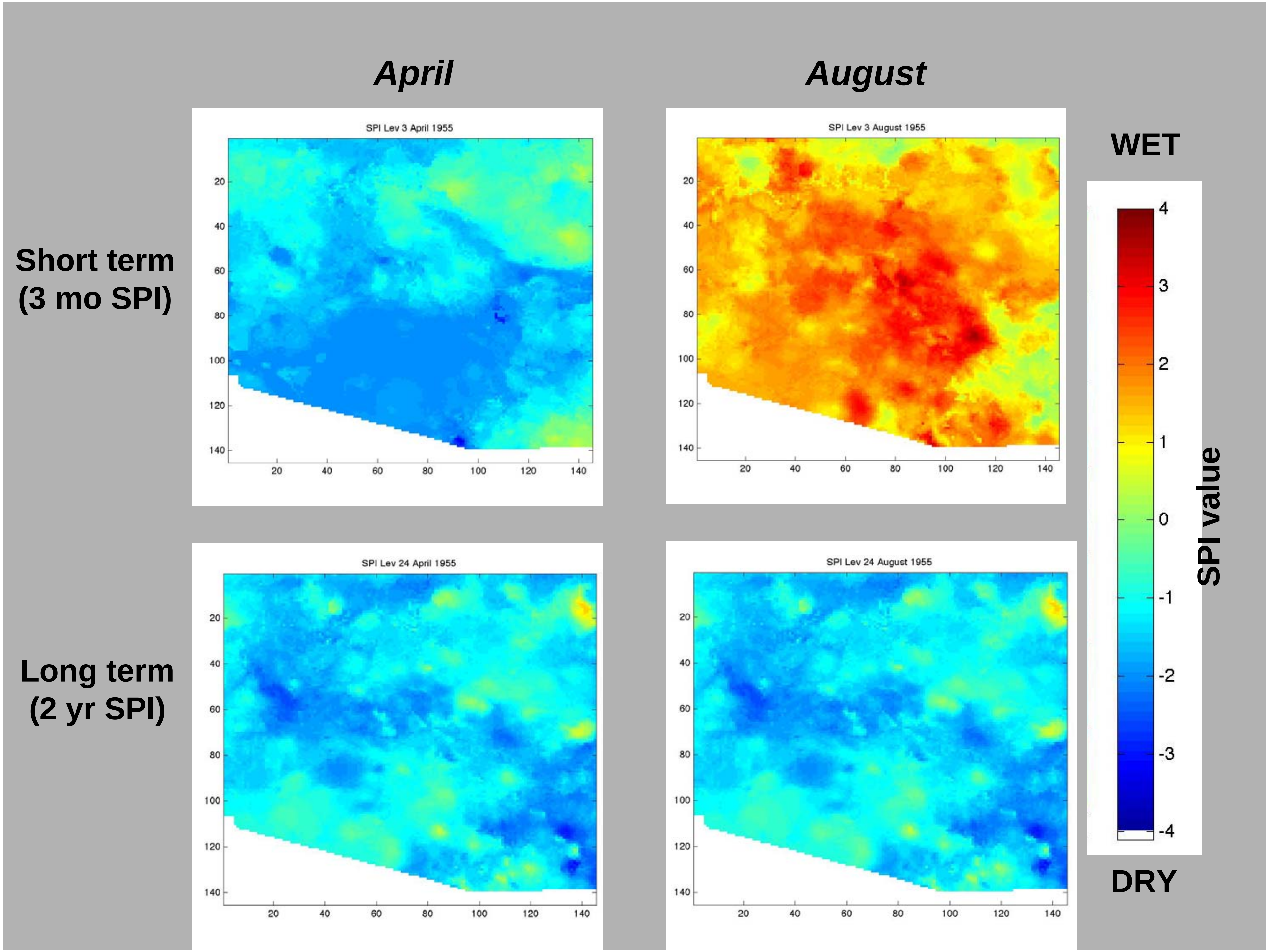
Arizona climate variability and larger-scale forcing

Arizona SPI from PRISM: 1950-2000

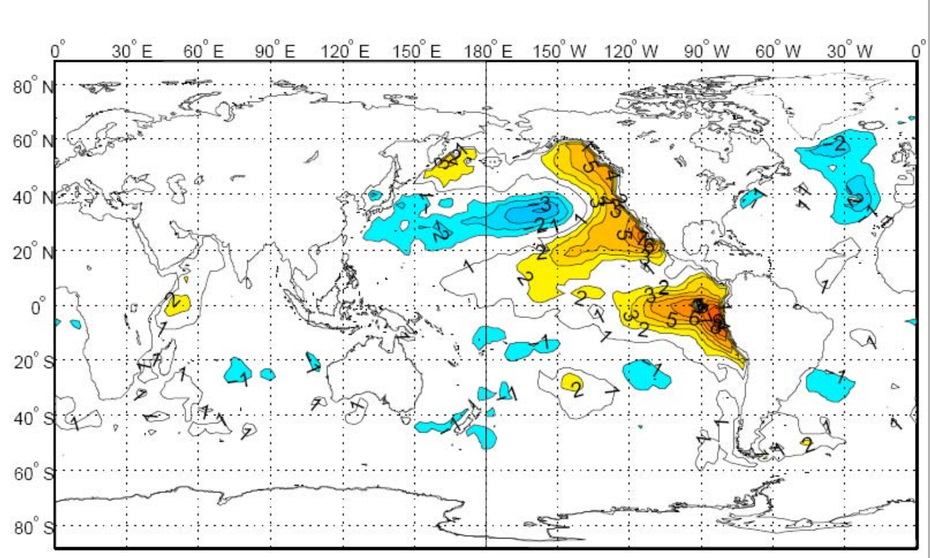
Short-term drought indicators

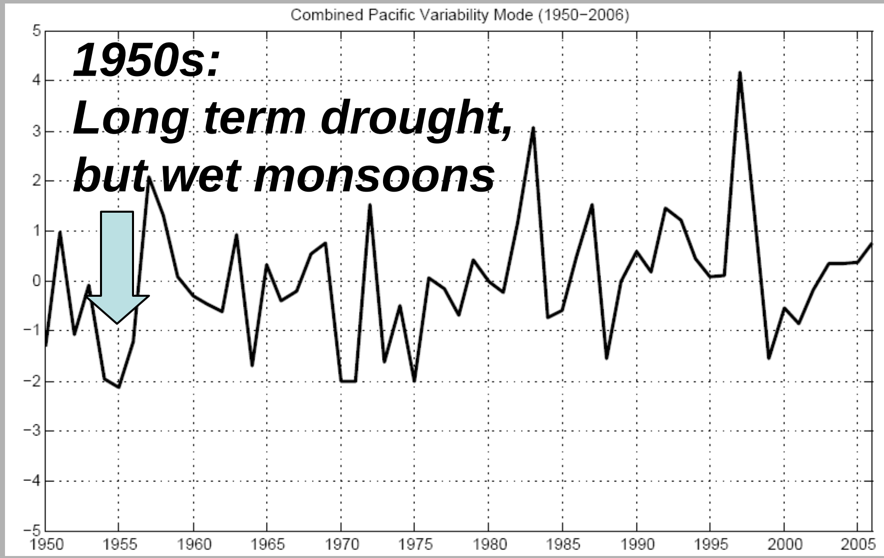


Long-term drought indictors


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)





A combination of interannual and interdecadal variability in the Pacific.

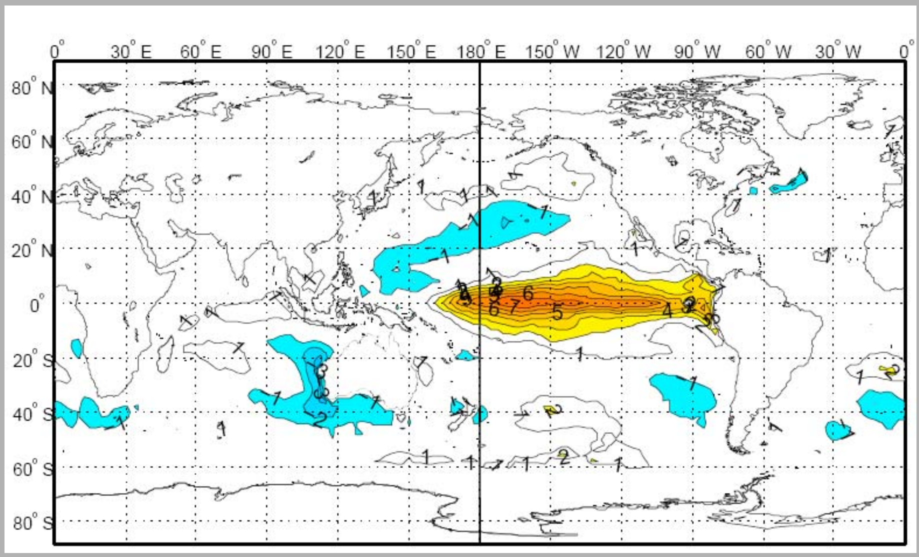
These are the first order controls on natural climate variability in Arizona, with a strong response in BOTH winter and summer. The winter response is opposite from the summer response.

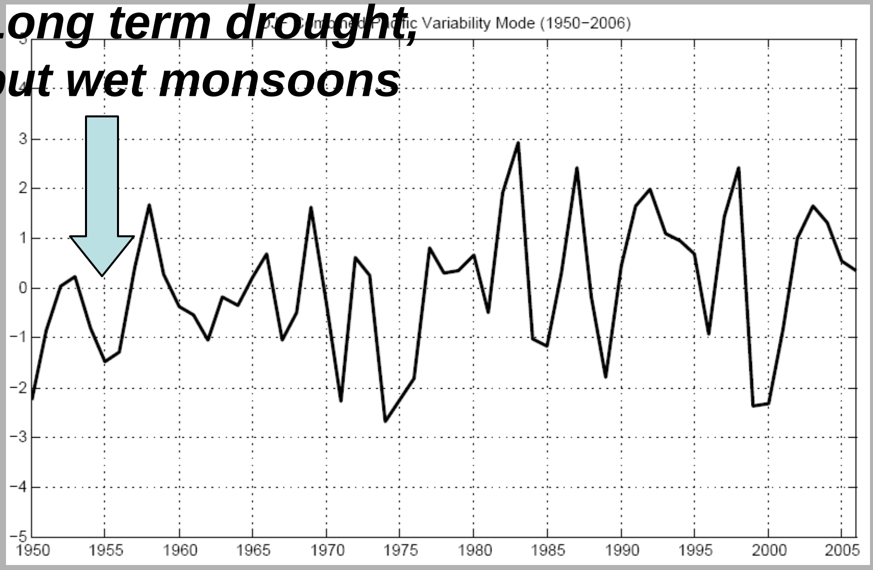
Wet winter → Dry and delayed monsoon

Dry winter → Wet and early monsoon

Combined Pacific Variability Mode (winter)

1950s:
Long term drought,
but wet monsoons

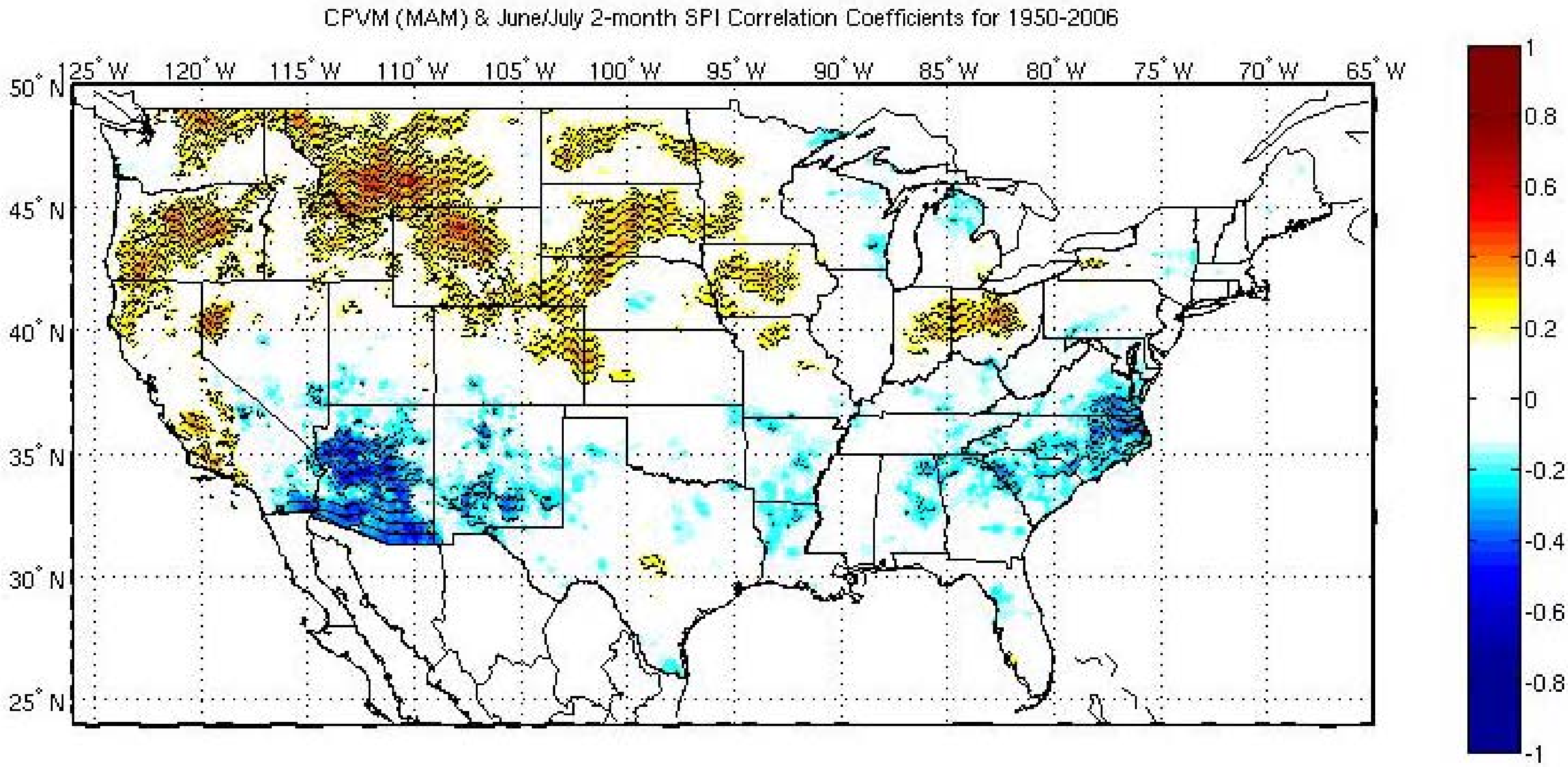




The SST signature is fairly persistent from the previous winter, so there is good potential for skillful drought forecasts based on statistical or regional model approaches!

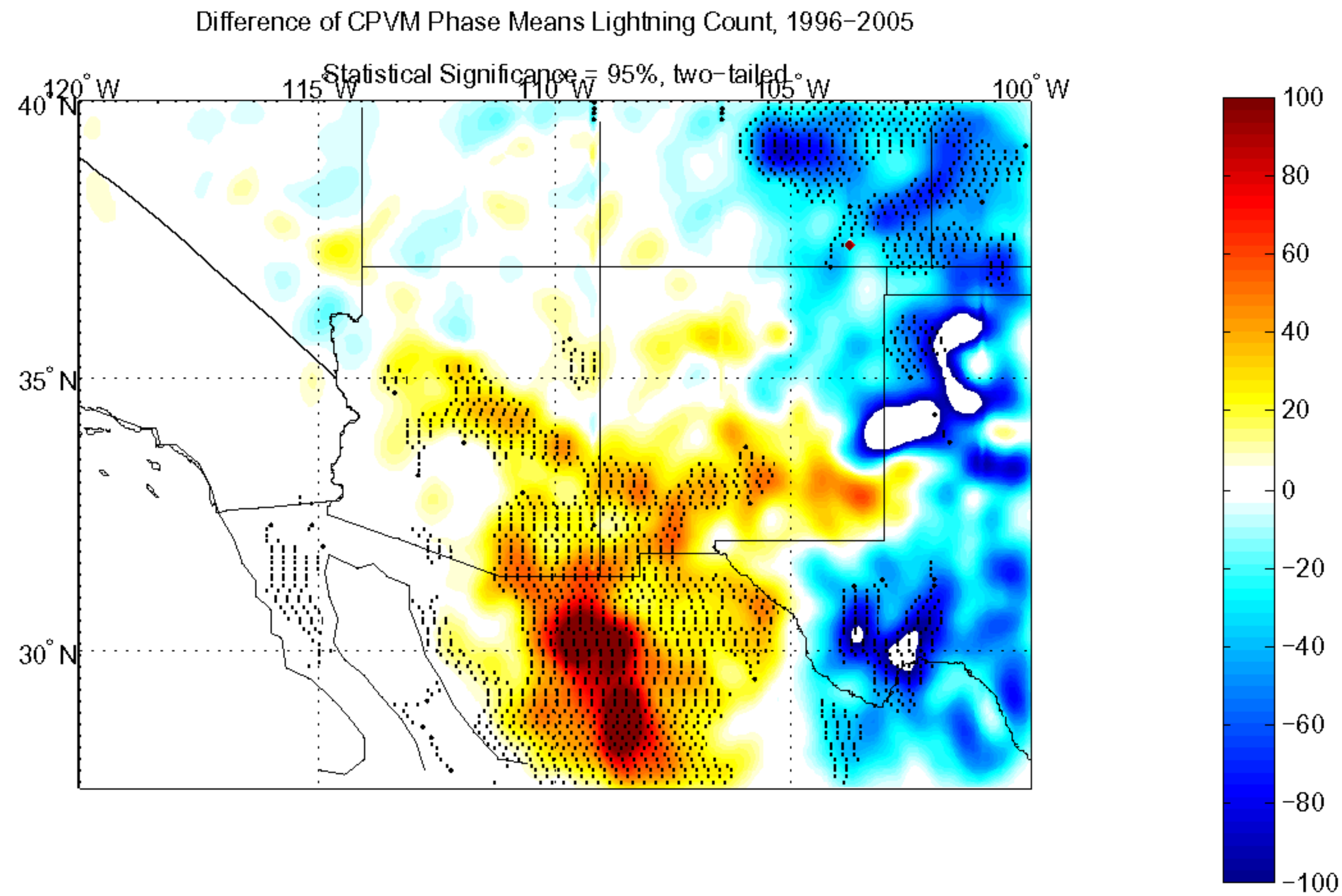
What is the relationship with PRISM-derived SPI data?

Correlation of antecedent spring CPVM with JJ 2 mo. SPI (monsoon onset)



This research was a basis, in part, for a correct monsoon seasonal forecast given in June 2008 (CLIMAS web briefing).

Difference in lightning counts associated with CPVM in June (low – high years)



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

Drought Impacts Data: First Order

USGS streamflow

USDA-NRCS reservoir levels

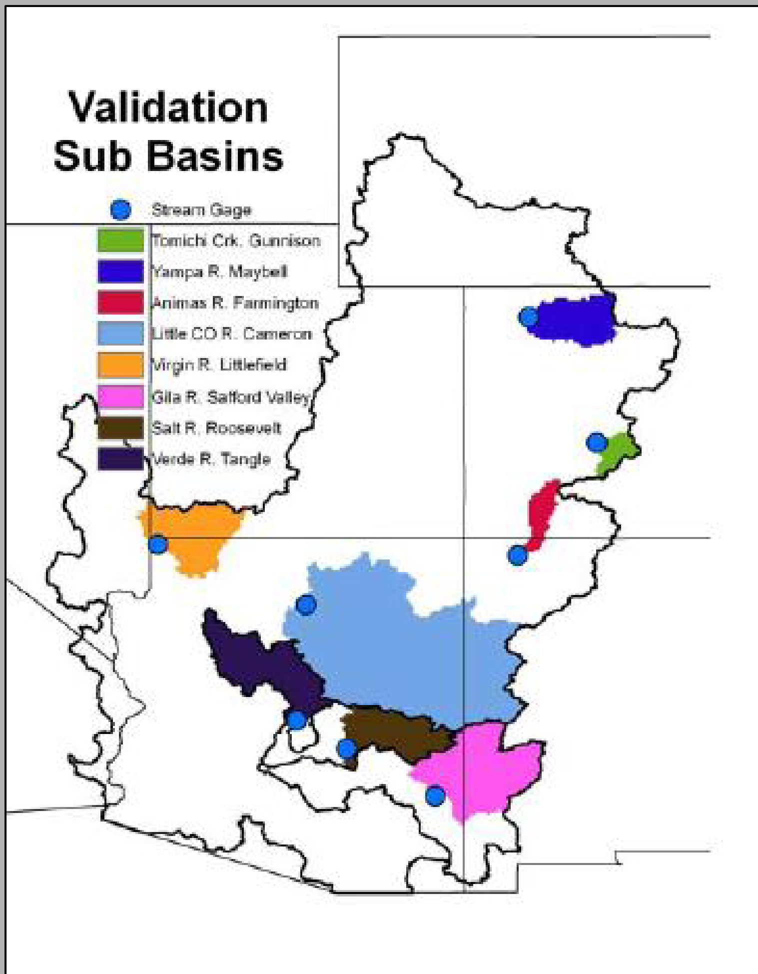
USDA-NRCS snow water equivalent, depth

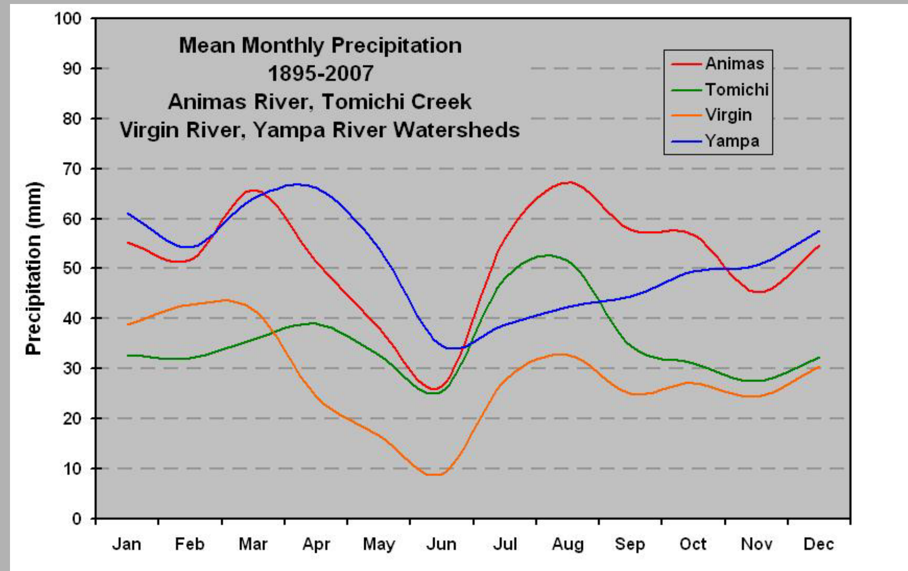
Fire frequency and acres burned (multi-agency)

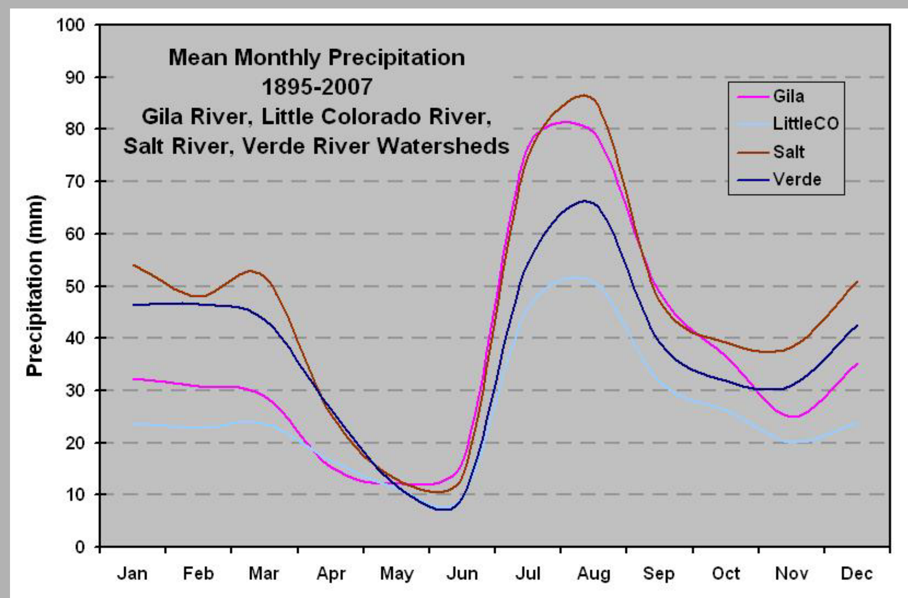
NOAA/NASA vegetation health indices (NDVI)

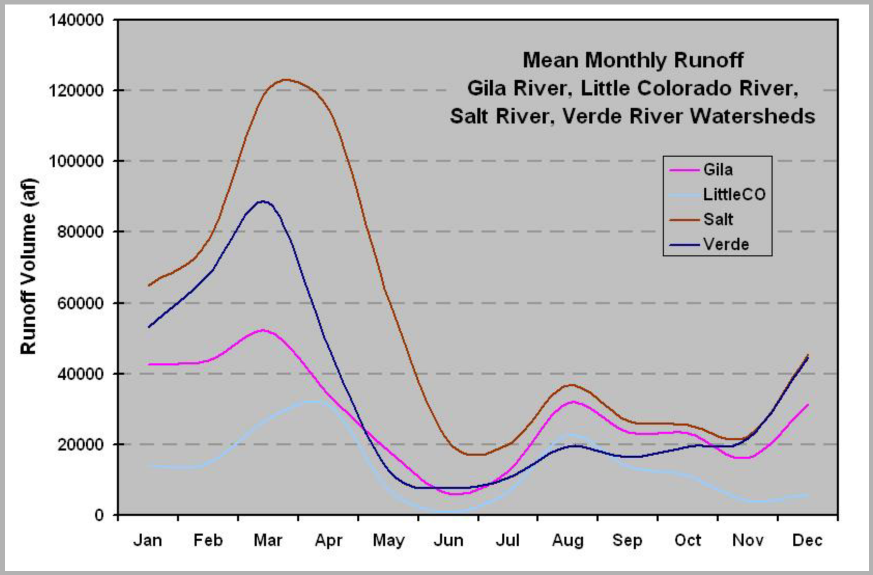
Range and pasture condition (Cooperative Extension)
Case studies only

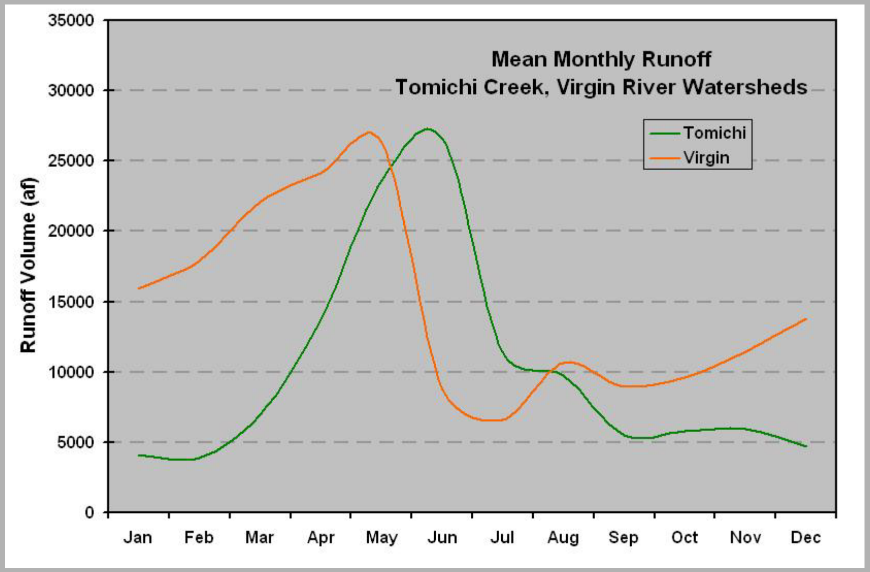
Groundwater (ADWR, USGS)

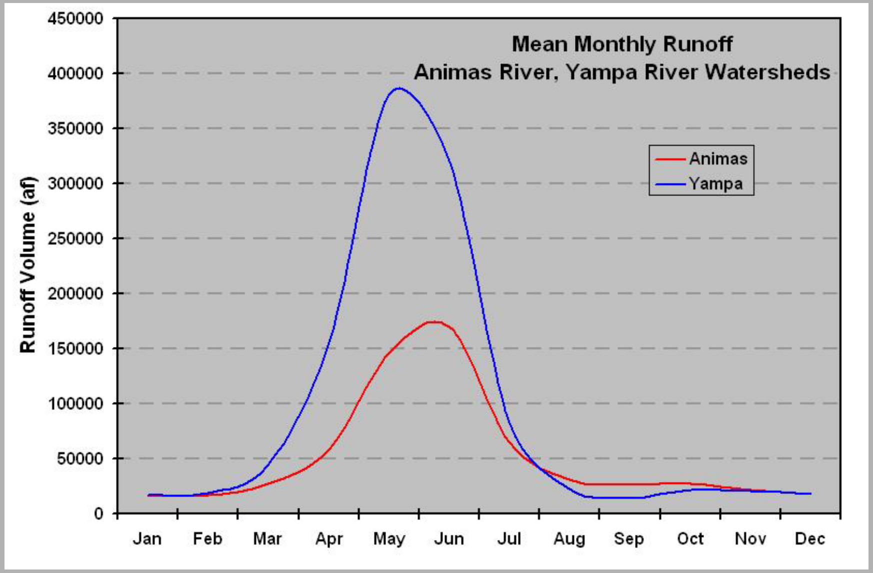

Validation
Sub Basins
Stream Gage
Tomichi Crk. Gunnison
Yampa R. Maybell
Animas R. Farmington
Little CO R. Cameron
Virgin R. Littlefield
Gila R. Safford Valley
Salt R. Roosevelt
Verde R. Tangle


Mean Monthly Precipitation
1895-2007
Animas River, Tomichi Creek
Virgin River, Yampa River Watersheds
Animas
Tomichi
Virgin
Yampa
Precipitation (mm)
0
10
20
30
40
50
60
70
80
90
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

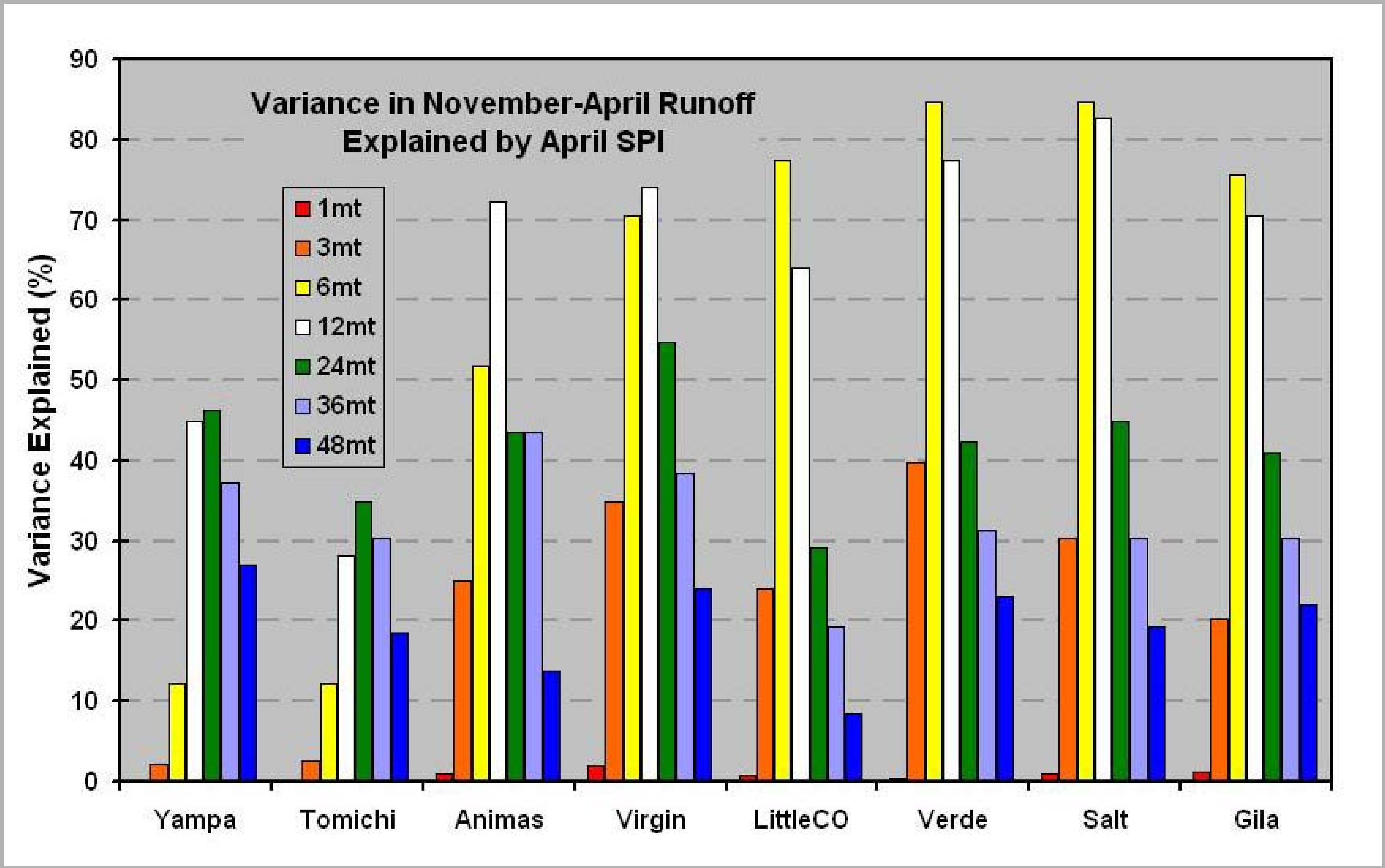

Mean Monthly Precipitation
1895-2007
Gila River, Little Colorado River,
Salt River, Verde River Watersheds
Gila
LittleCO
Salt
Verde
Precipitation (mm)
0
10
20
30
40
50
60
70
80
90
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Mean Monthly Runoff
Gila River, Little Colorado River, Salt River, Verde River Watersheds
Gila
LittleCO
Salt
Verde
Runoff Volume (af)
140000
120000
100000
80000
60000
40000
20000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Mean Monthly Runoff
Tomichi Creek, Virgin River Watersheds
Tomichi
Virgin
Runoff Volume (af)
35000
30000
25000
20000
15000
10000
5000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

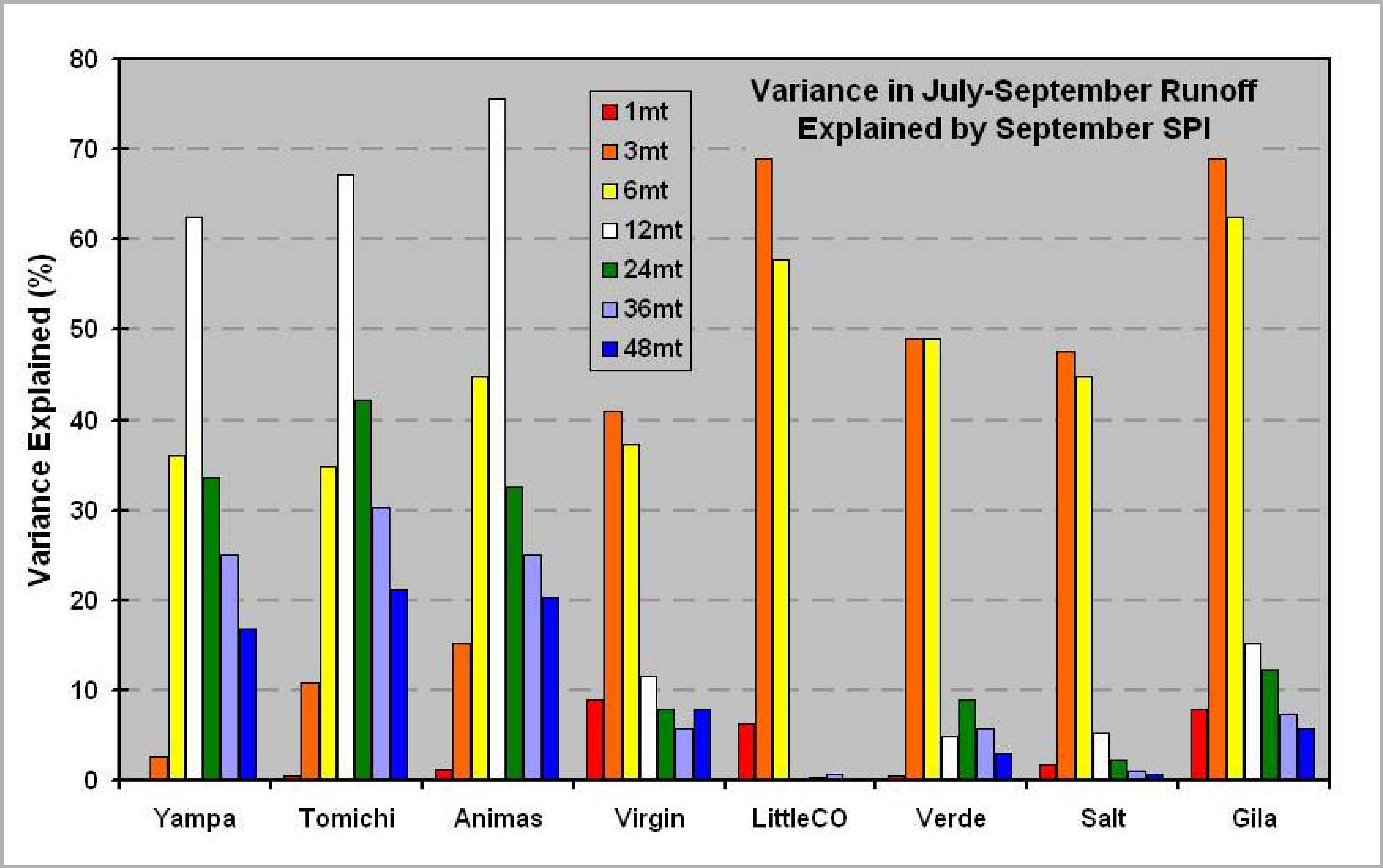

Mean Monthly Runoff
Animas River, Yampa River Watersheds
Animas
Yampa
Runoff Volume (af)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Cool Season Runoff Relationship to SPI



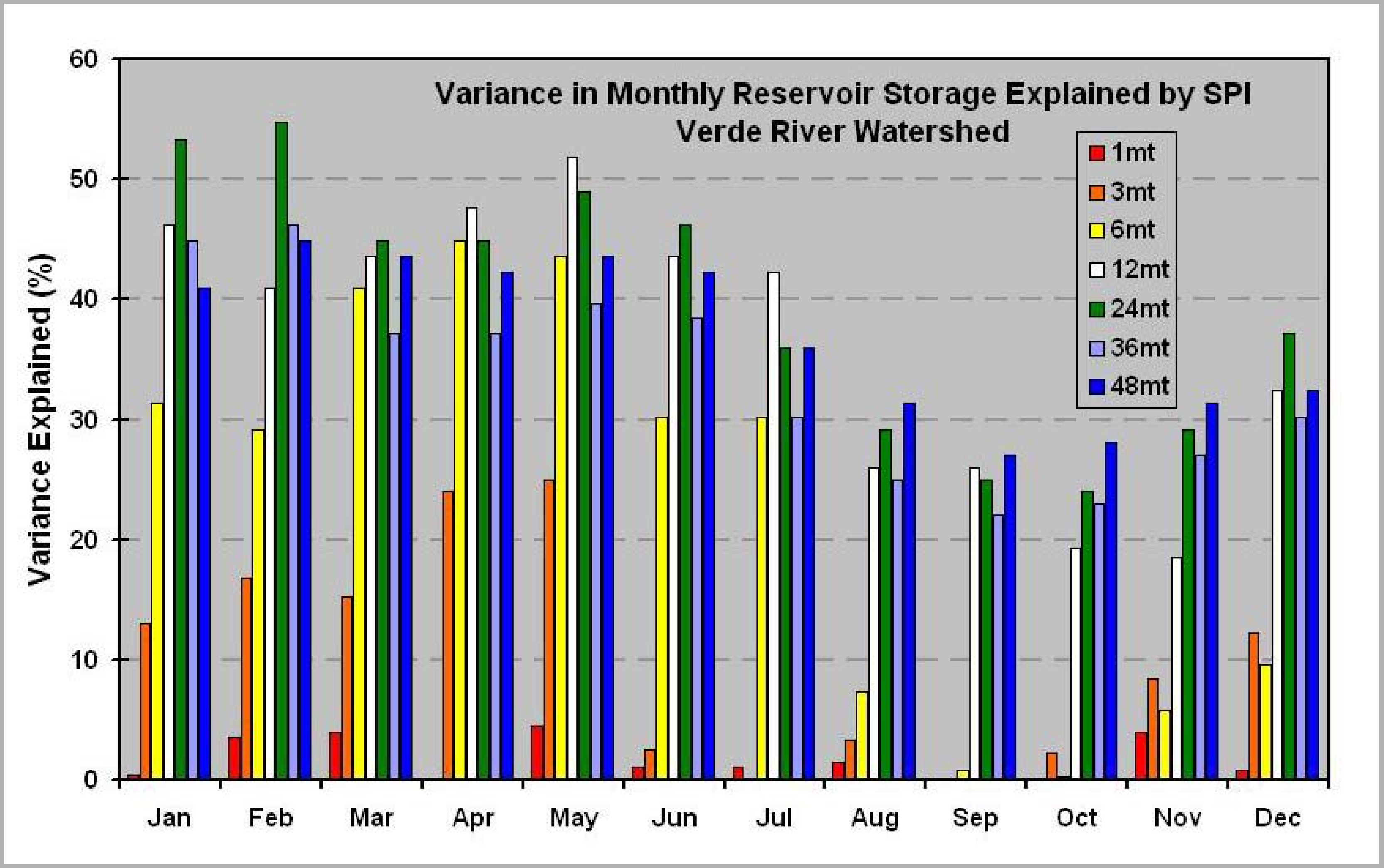
Winter signal for Arizona sub-basins 6-12 month SPI is best

Warm season runoff relationship to SPI

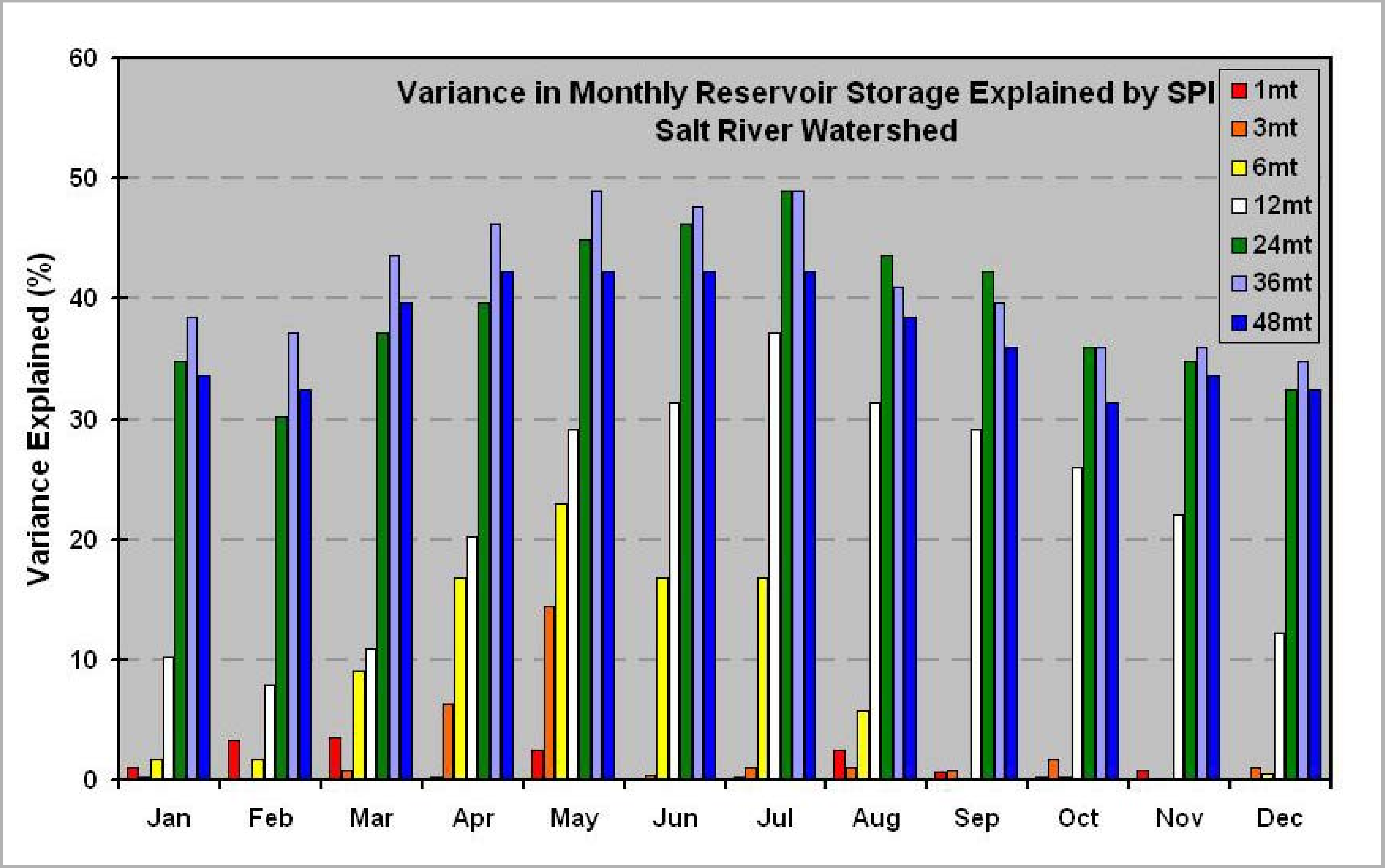


Monsoon signal: Stronger for Arizona sub-basins, 3-6 month SPI best

Relationship of Reservoir Storage to SPI
Verde River Watershed

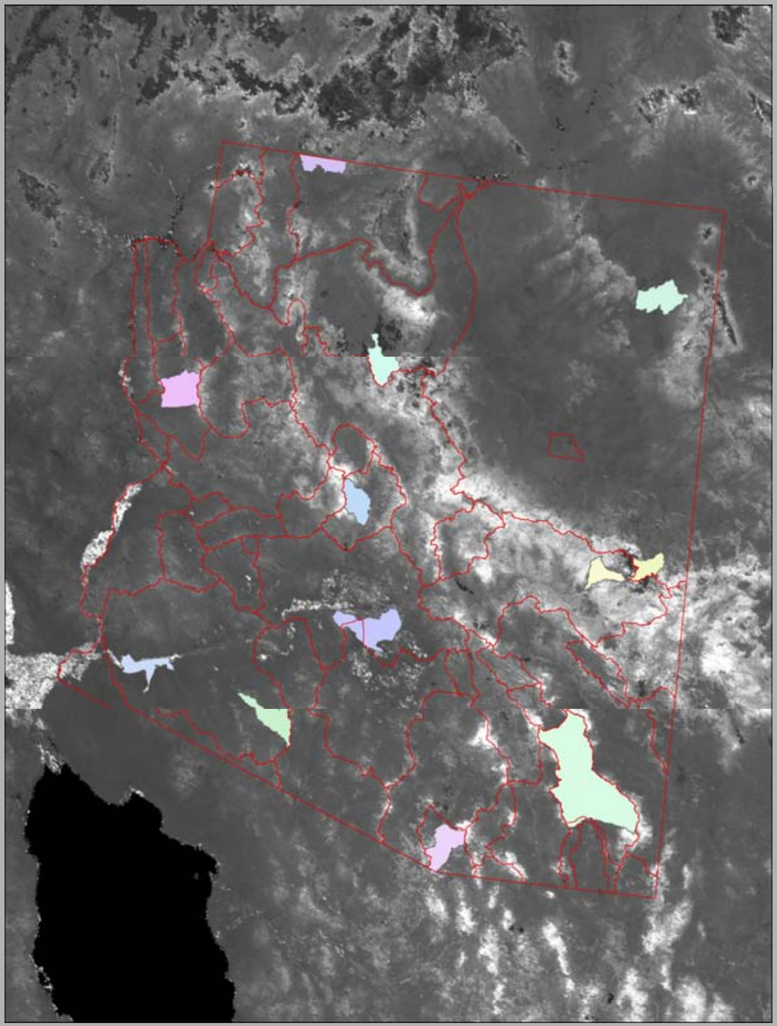


Relationship of Reservoir Storage to SPI
Salt River Watershed



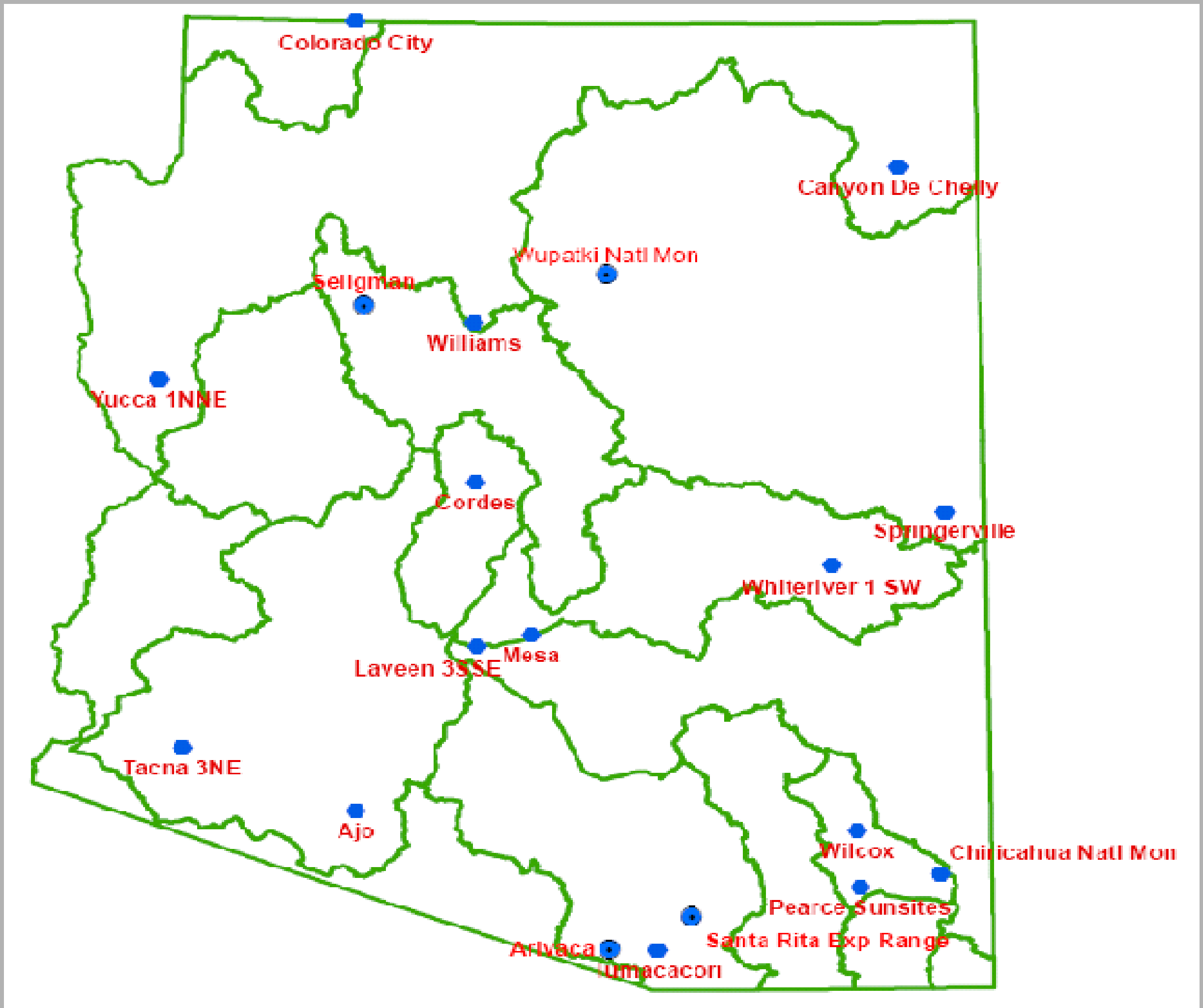
High resolution satellite-derived vegetation greenness index (NDVI)

These data exist for last twenty years



Example of NDVI data with Arizona watershed regions superimposed

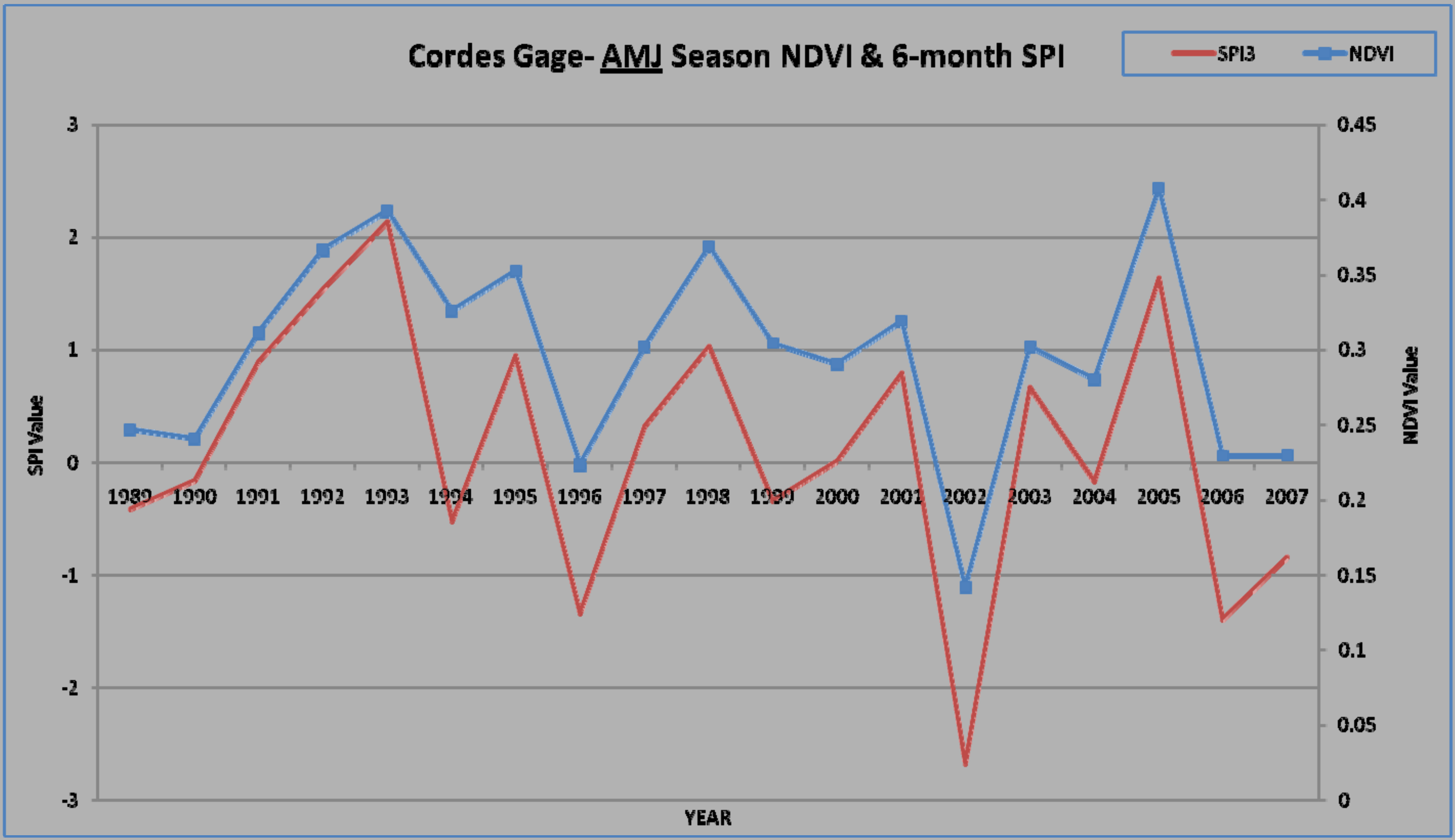
Sites selected for SPI-NDVI Analysis



				SPI - 3month			
Station		**elevation (ft)**	**dominant LC**	***DJFM***	***AMJ***	***JAS***	***ON***
ajo		1800	shrub/scrub	0.15	0.43	0.30	-0.16
cdchelly		5610	barren	-0.018	0.57	0.41	0.09
Chrichua		5300	evergreen forest	-0.43	0.21	0.54	0.30
Colocity		5003	shrub/scrub	0.12	0.54	0.25	0.17
Cordes		3771	shrub/scrub	0.45	0.43	0.23	0.61
demetrie/santa rita		4300	mixed: shrub/evergreen	-0.27	0.41	0.42	0.31
laveen		1135	shrub/scrub	0.47	0.40	0.38	0.20
pearce		4350	shrub/scrub	0.12	0.28	0.62	-0.23
sprville		6998	grassland/herbaceous	-0.02	0.25	0.55	0.00
tacna		324	shrub/scrub	0.39	0.13	0.19	-0.25
tucacori		3267	shrub/scrub	-0.02	0.27	0.63	0.36
upchino/seligman		5250	evergreen forest	-0.01	0.73	0.23	0.40
willcox		4175	shrub/scrub	0.12	0.53	0.59	-0.11
williams		6750	evergreen forest	-0.41	0.16	0.19	0.15
wriver		5120	shrub/scrub	-0.32	0.22	0.11	0.30
wupatki		4908	grassland/herbaceous	-0.02	0.38	0.32	0.43
yucca		1950	shrub/scrub	0.34	0.30	0.22	0.05

Stations highlighted in red have a fairly strong monsoon precipitation signal

				SPI - 6month			
Station		**elevation (ft)**	**dominant LC**	***DJFM****	***AMJ****	***JAS****	***ON****
ajo		**1800**	**shrub/scrub**	0.15	0.40	0.34	0.37
cdchelly		**5610**	**barren**	0.01	0.59	0.45	0.49
chrichua		**5300**	**evergreen forest**	-0.47	0.56	0.64	0.60
colocity		**5003**	**shrub/scrub**	0.15	0.55	0.45	0.57
cordes		**3771**	**shrub/scrub**	0.54	0.92	0.35	0.63
demetrie/santa rita		**4300**	**mixed: shrub/evergreen**	-0.21	0.66	0.50	0.20
laveen		**1135**	**shrub/scrub**	0.61	0.68	0.40	0.53
pearce		**4350**	**shrub/scrub**	0.17	0.67	0.60	0.25
sprville		**6998**	**grassland/herbaceous**	-0.30	0.48	0.57	0.18
tacna		**324**	**shrub/scrub**	0.49	0.39	0.24	-0.26
tucacori		**3267**	**shrub/scrub**	0.09	0.64	0.64	0.59
upchino/seligman		**5250**	**evergreen forest**	-0.05	0.86	0.37	0.59
willcox		**4175**	**shrub/scrub**	0.11	0.85	0.62	0.45
williams		**6750**	**evergreen forest**	-0.49	0.17	0.32	0.17
wriver		**5120**	**shrub/scrub**	-0.29	0.69	0.14	0.35
wupatki		**4908**	**grassland/herbaceous**	0.00	0.64	0.45	0.66
yucca		**1950**	**shrub/scrub**	0.36	0.79	0.23	0.29



Correlation = 0.92

Use of Regional Atmospheric Modeling to Improve Seasonal Forecasting

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

An funded University of Arizona NSF Proposal
PIs: Christopher Castro and Francina Dominguez

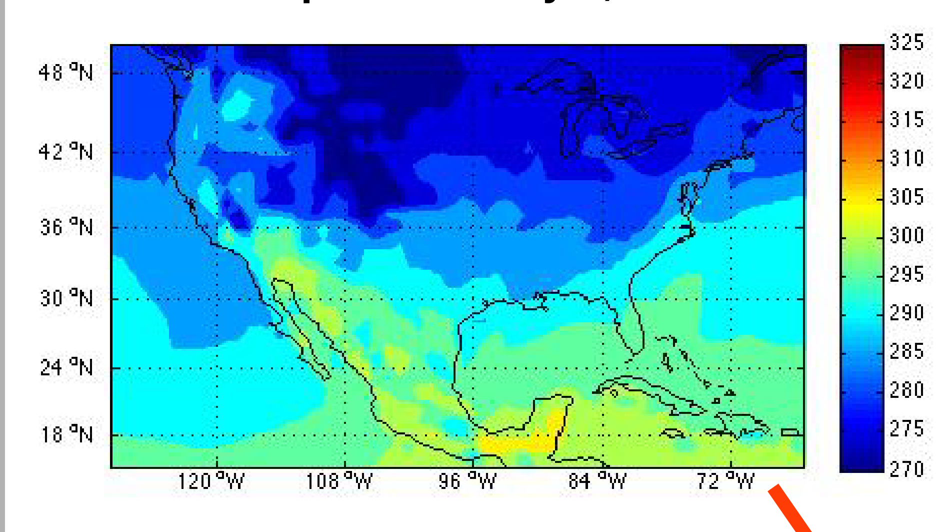
Would use Weather Research and Forecasting Model to investigate potential utility of long-range climate forecasts and projections.

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

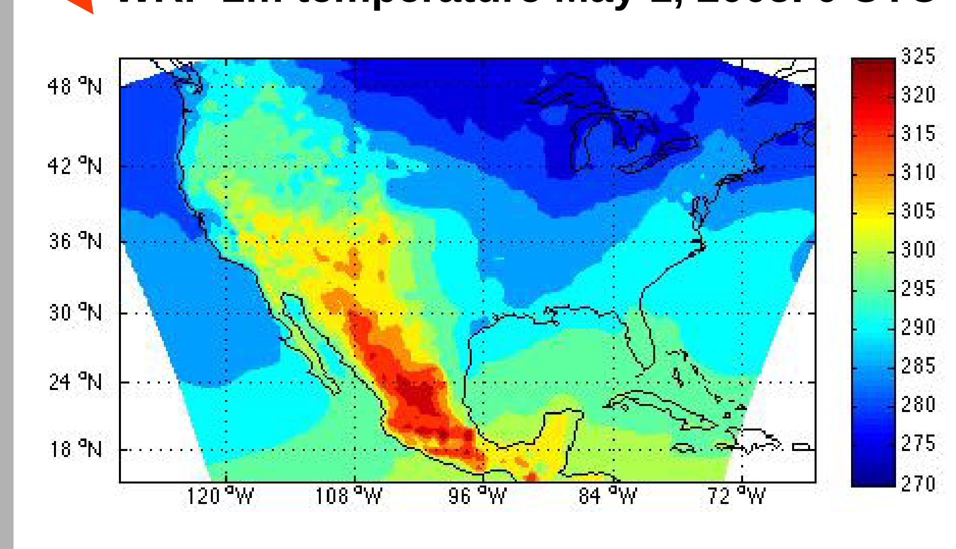
FNL 2m temperature May 1, 2005. 0 UTC



The original large-scale forcing data FNL (Final Global Analyses) has a resolution of 1º x 1º

WRF Dynamical Downscaling

WRF 2m temperature May 1, 2005. 0 UTC



Dynamical downscaling using WRF brings the resolution to 32km.

Concluding Points

SPI is a robust measure of drought at multiple timescales and relates very well to the first order stakeholder indices.

Short-term SPI best captures the monsoon signal and the transition in SPI associated with the monsoon can be quite rapid.

It is important to effectively separate summer monsoon precipitation vs. winter precipitation in characterizing drought impacts because each season varies differently with respect to larger-scale forcing (i.e. Pacific SSTs)

Concluding points (cont.)

Long-term SPI is driven by winter precipitation and that best relates to cool season streamflow and reservoir storage in the Salt and Verde basins. Short-term SPI is important for streamflow in the warm season, though.

Vegetation health throughout most of the state is best related to winter and spring precipitation. The monsoon also plays some role in areas where it contributes more to the annual rainfall, such as in southeastern Arizona.

Improved seasonal forecasts of the monsoon with regional climate models are on their way!

Recommendations to the Arizona Drought MTC

Real time display and archival of 4km SPI information once a real-time PRISM-like product comes online from NCDC. We're willing to share our data and codes for this.

Highlight gridded SPI analyses in the monthly drought status report?

An experimental summer/winter split approach corresponding to specific conditions (e.g. streamflow, vegetation)

Collaboration with the MTC on future outlook products and seasonal forecasts using regional atmospheric models? These may offer potential seasonal SPI forecasts in the near future.

Other suggestions?