CPASW March 23, 2006

Incorporating Climate Variability Uncertainty in Water Resources Planning for the Upper Santa Cruz River.

Eylon Shamir

Hydrologic Research Center

12780 High Bluff Drive suite 250

San Diego, CA 92130

Tel: (858) 794 2726

www.hrc-web.org

Project

- **Researchers:**
- Konstantine Georgakakos, HRC Director
- Eylon Shamir, HRC
- Nicholas Graham, HRC
- Jianzhong Wang, HRC
- David Meko, The Tree-Ring Research Laboratory, The University of Arizona

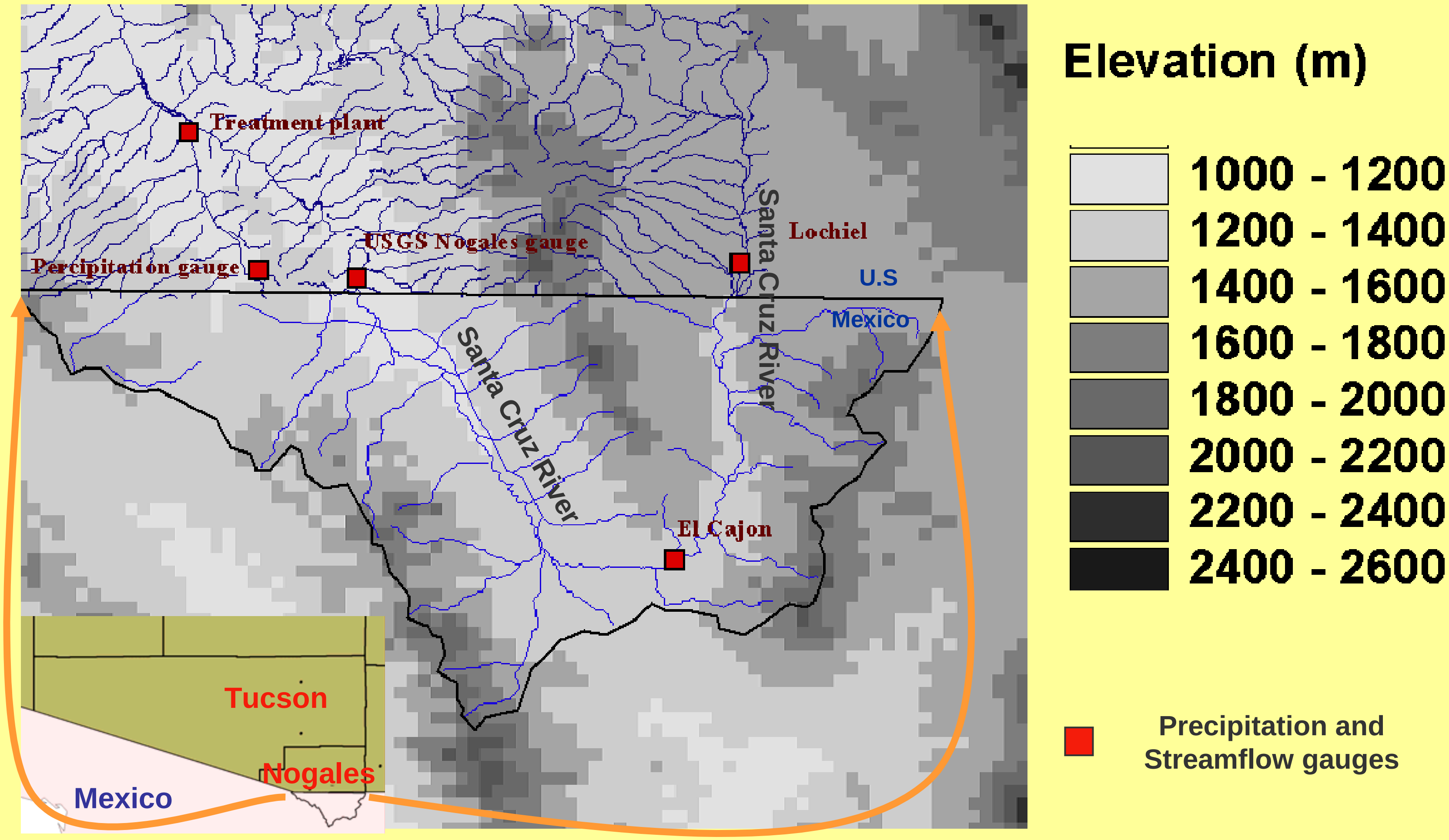
In cooperation with Arizona Department of Water Resources:

- Frank Corkhill, Alejandro Barcenas, Frank Putman, Gretchen Erwin and Keith Nelson.

- Sponsored by,

Arizona Department of Water Resources Contract No. 2005-2568

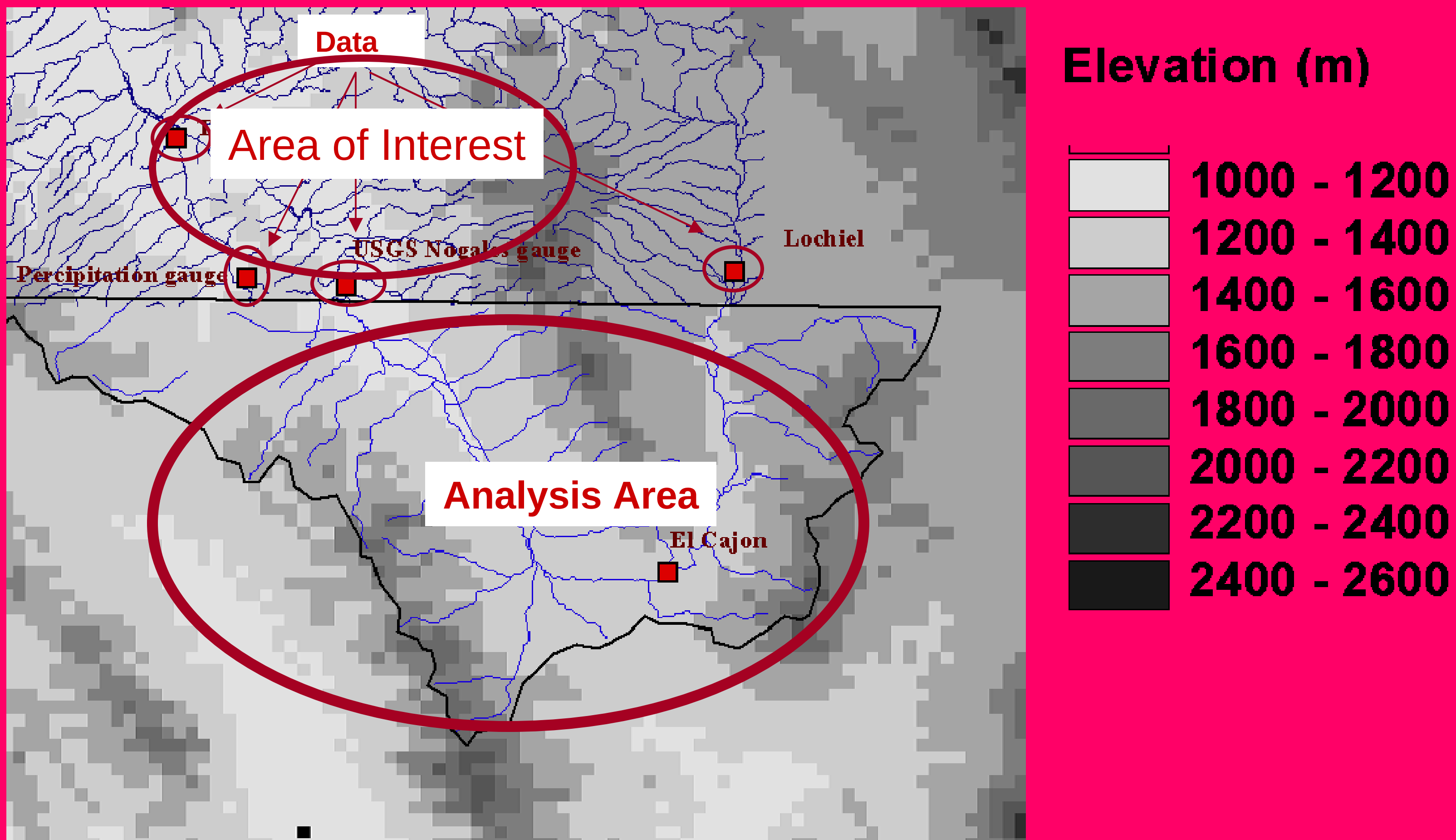
Santa Cruz Headwater



The Study Objectives

- Develop a modeling system that produces likely future streamflow scenarios at the Nogales USGS Gauge site.
- Integrate the future streamflow scenarios with a groundwater model
- Evaluate the future streamflow – groundwater response in various schemes of water consumptions.

Zoom into the study area



Landscape

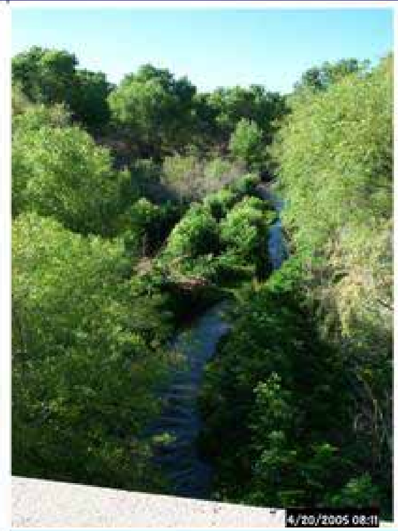
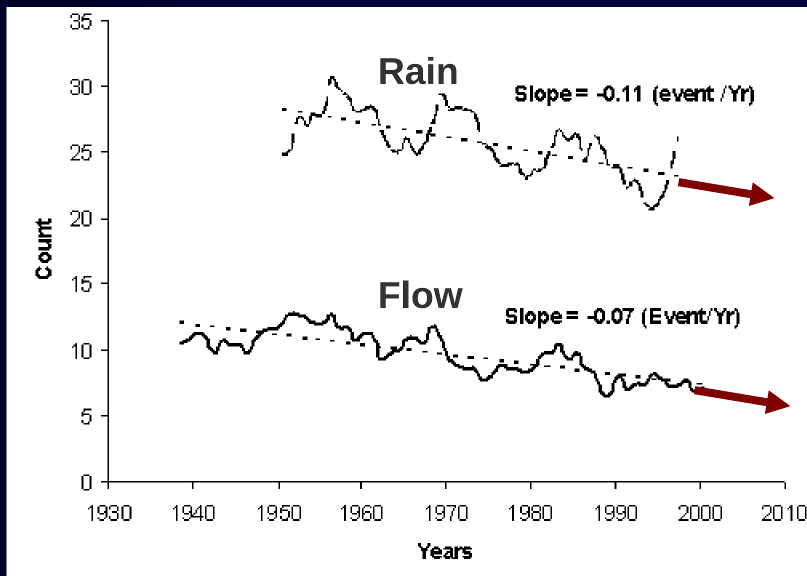
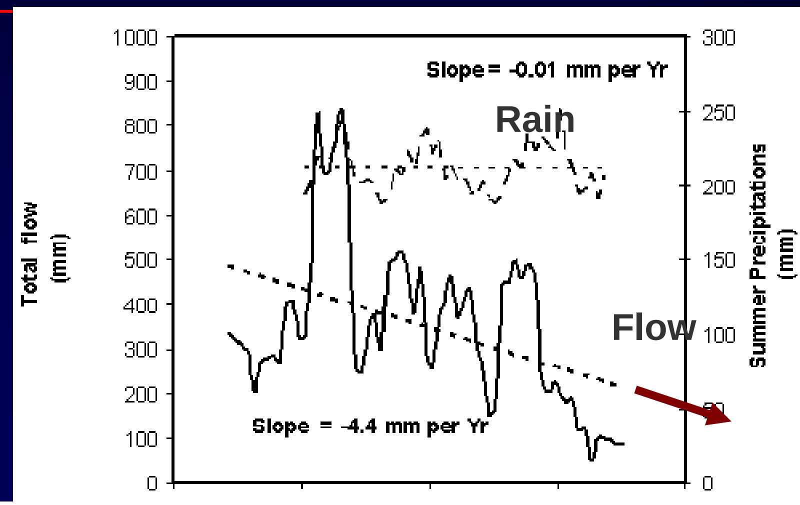
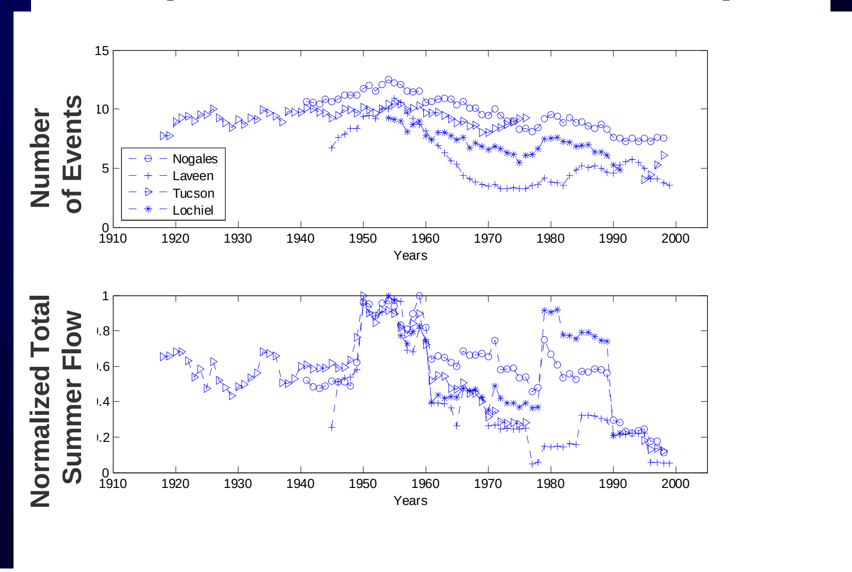


Figure 4 The USGS Nogales streamflow gauge -looking northwest accross the Santa Cruz

Trends in summer (Jul-Aug) flow





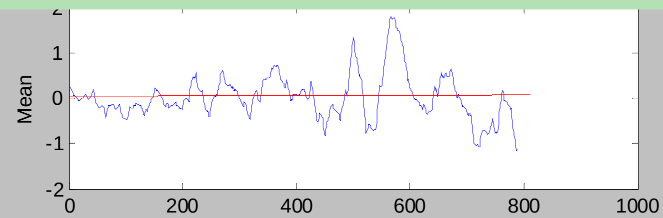


Pool and Coes (1999) found similar trend in Charleston gauge –San Pedro

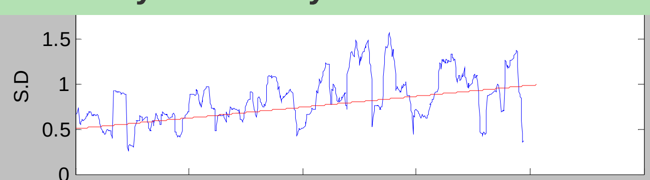
Variability in Monthly Flow

- **Change in monthly flow variability since the 1970s**

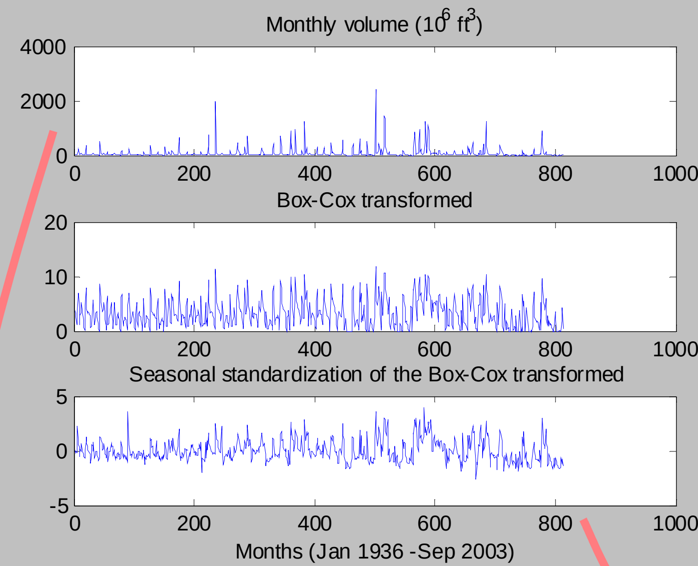
Average monthly flow as a function of time



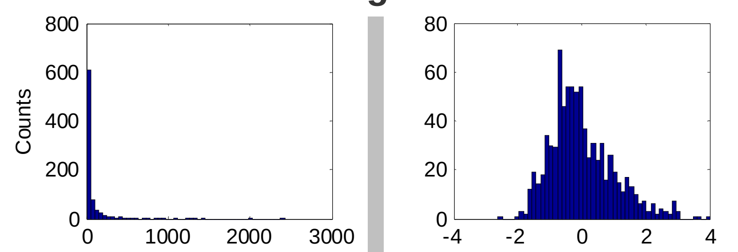
Variability of monthly flow as a function of time



1936 Years 2003



Histograms

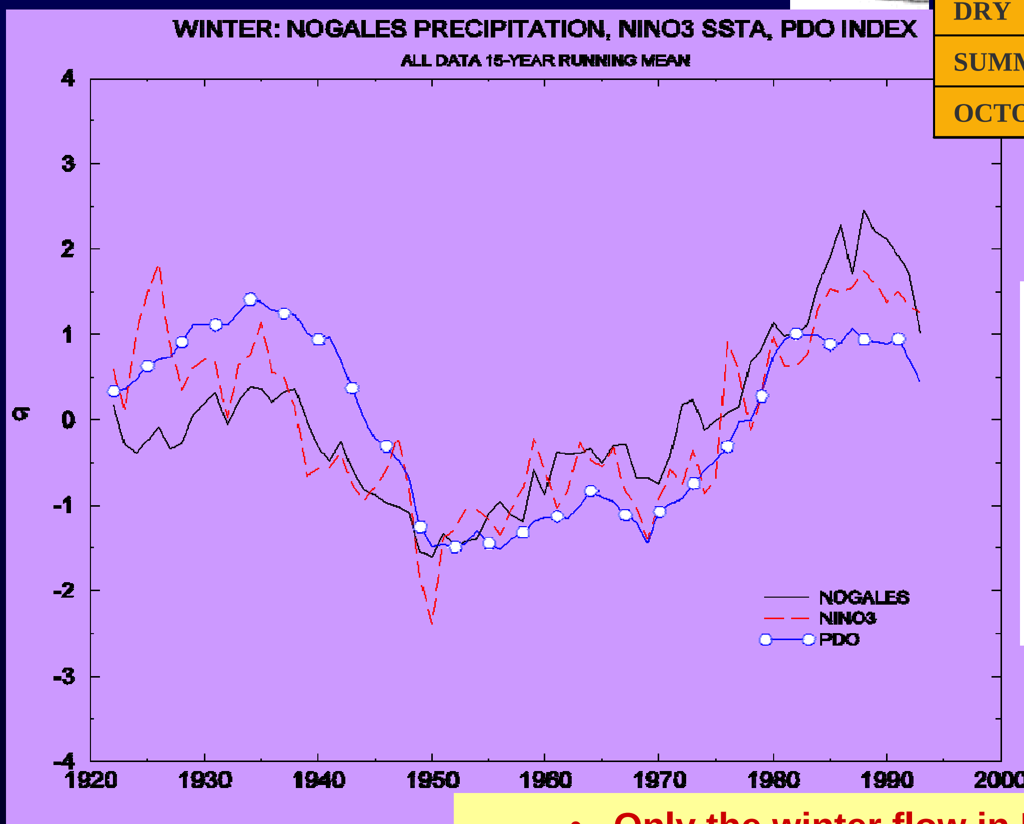


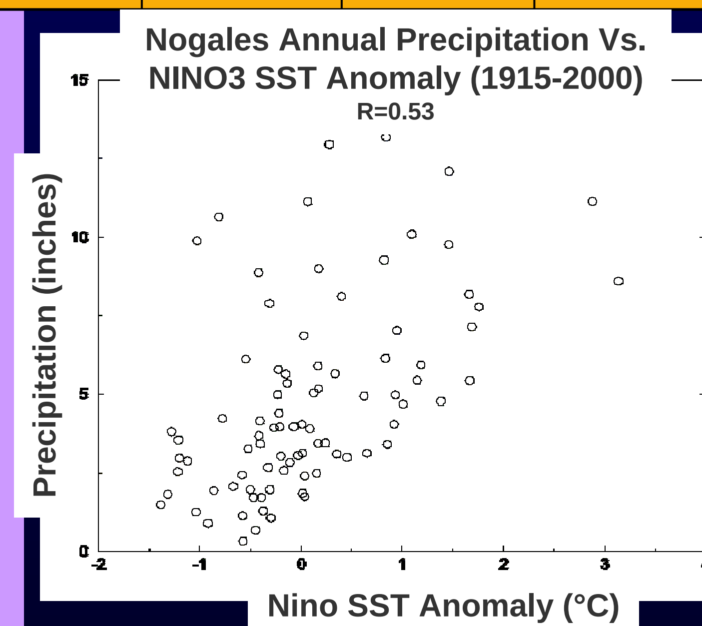
Nogales precipitation Vs. climatic indices

Climate Divisions

Correlations with Nogales precipitation (1915-2000).

	NINO3	PDO	ARIZ. DIV. 7
WINTER	0.53	0.27	0.94
DRY	0.11	0.22	0.70
SUMMER	-0.06	0.09	0.53
OCTOBER	-0.03	-0.09	0.87





- Only the winter flow in Nogales is correlated with El–Niño

Simulation of Precipitation Vs. Streamflow

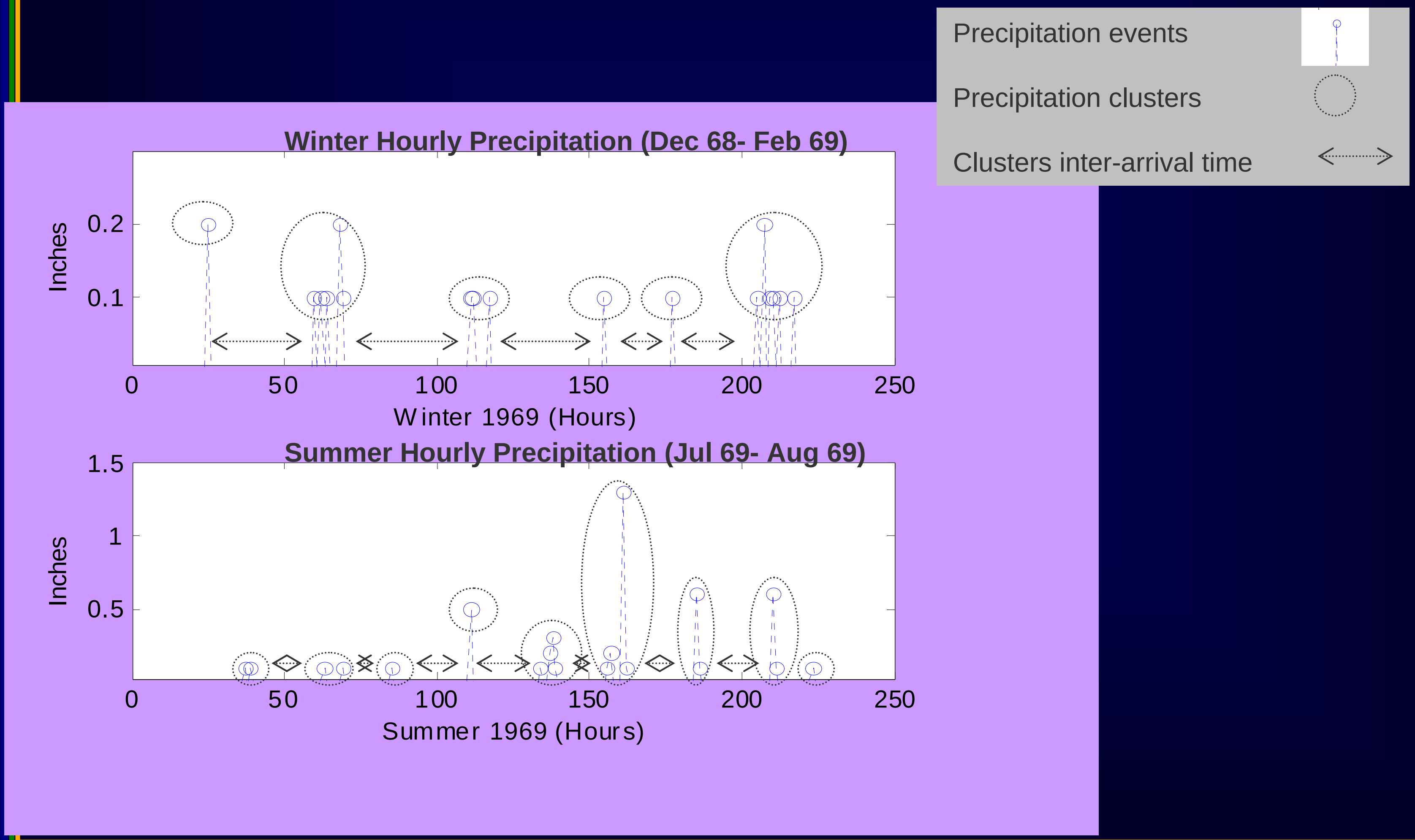
- Precipitation (Pros)
  - Better linked to climatic forcing and global circulation
  - Less affected by geomorphological changes and human activity in regional scale.
  - Independent of the basin antecedent condition

Precipitation (Cons)

- Point measurement rather than areal measurement that contributes to the flow.
- Requires a model to transform into streamflow

EShamir@hrc-lab.org

Stochastic Precipitation model components



The Modeling Scheme

Stochastic hourly precipitation over the basin drainage area

↓

Daily streamflow transformation model for the basin outlet

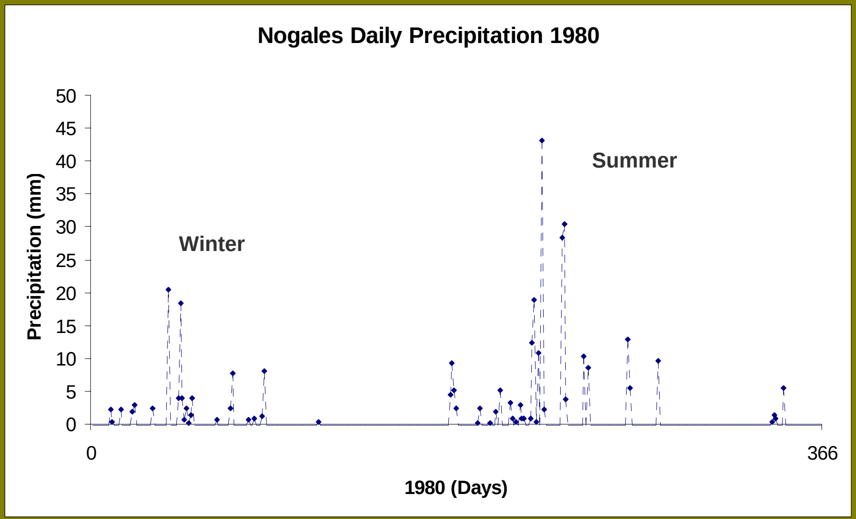
↓

Groundwater storage changes in the downstream aquifers

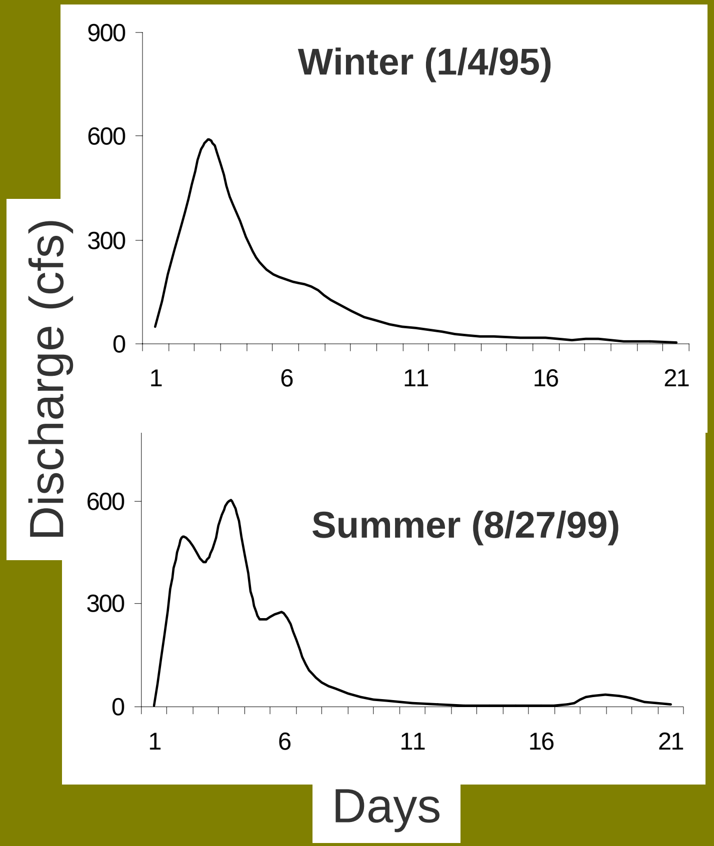
↓

Long term risk assessment for a variety of management schemes

Summer and winter properties



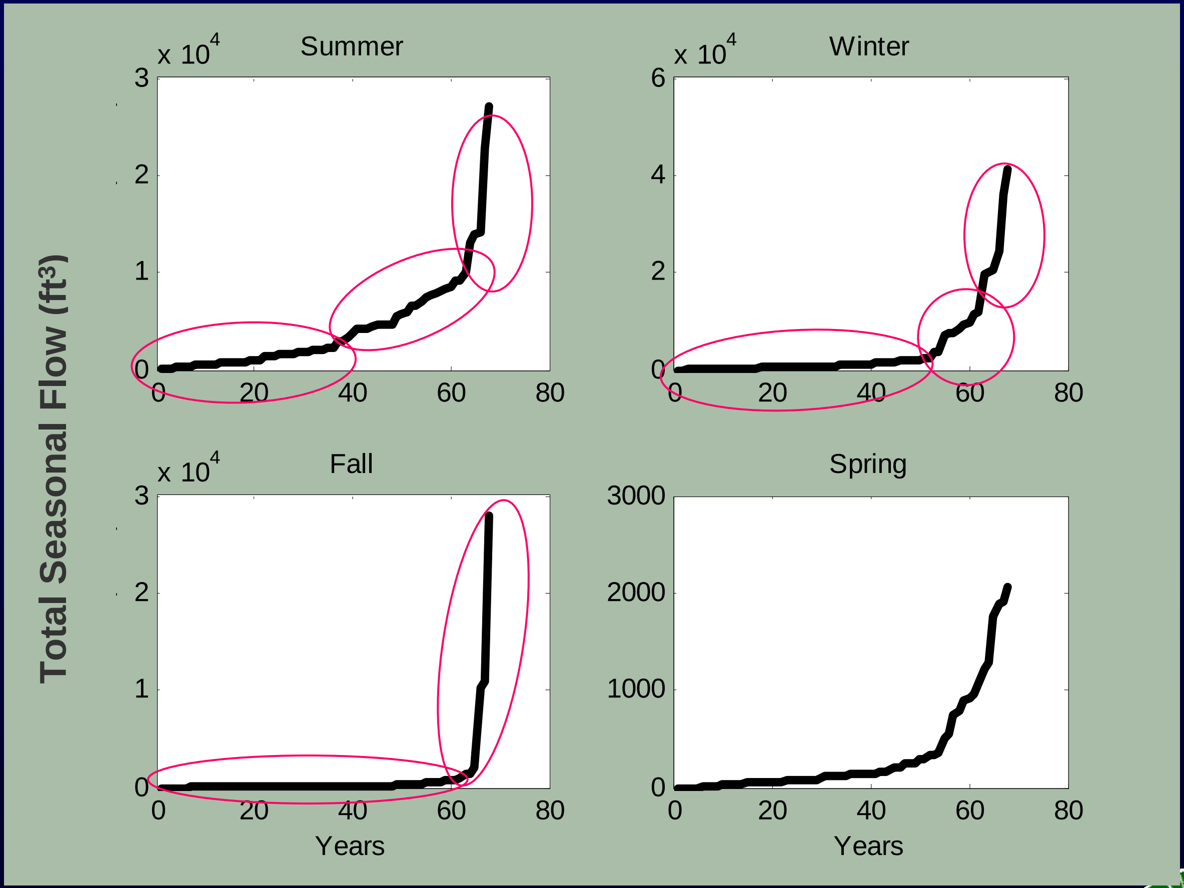
Model of the watershed



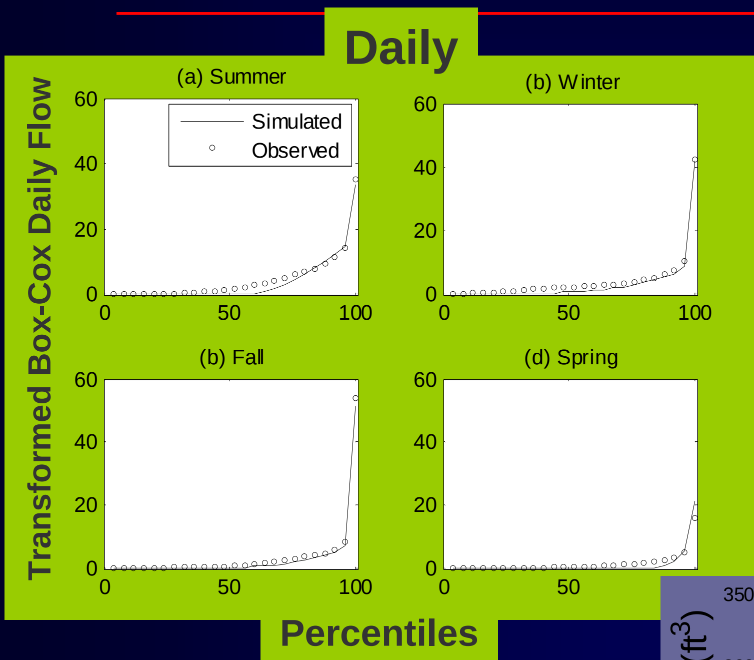
- The model should maintain the special characteristics of the seasons

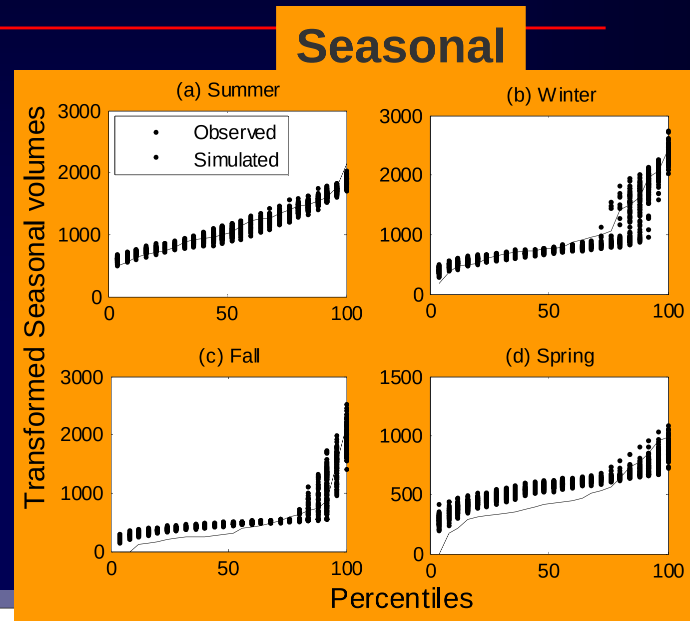
Total Seasonal Flow

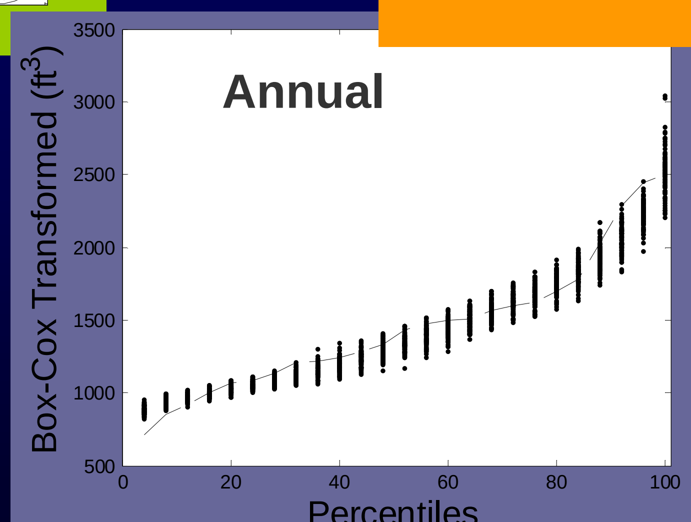
<u>Seasonal division:</u>
Winter: November-March
Spring: April–June
Summer: July-September
Fall: October



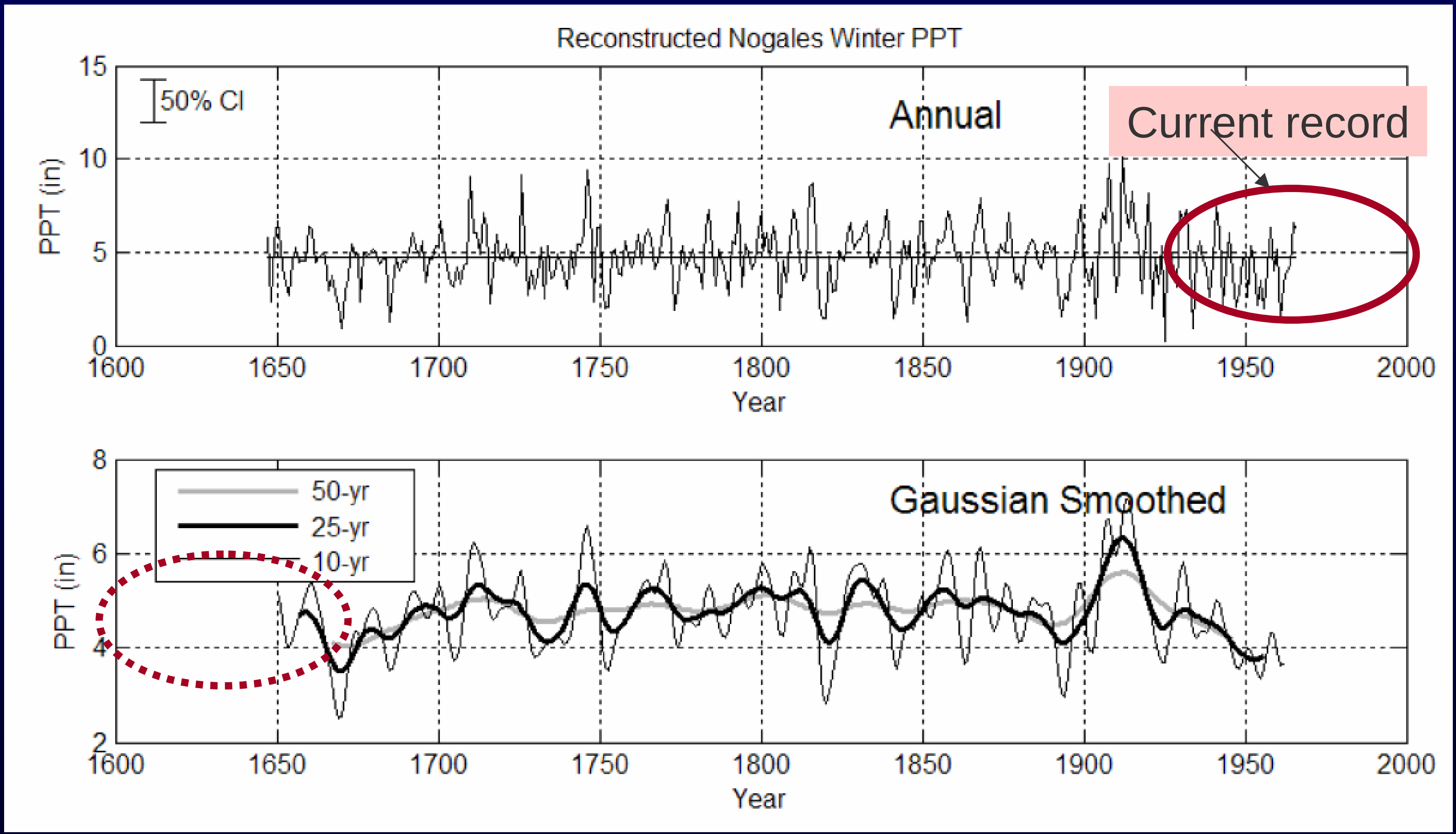
Evaluation of the simulated streamflow





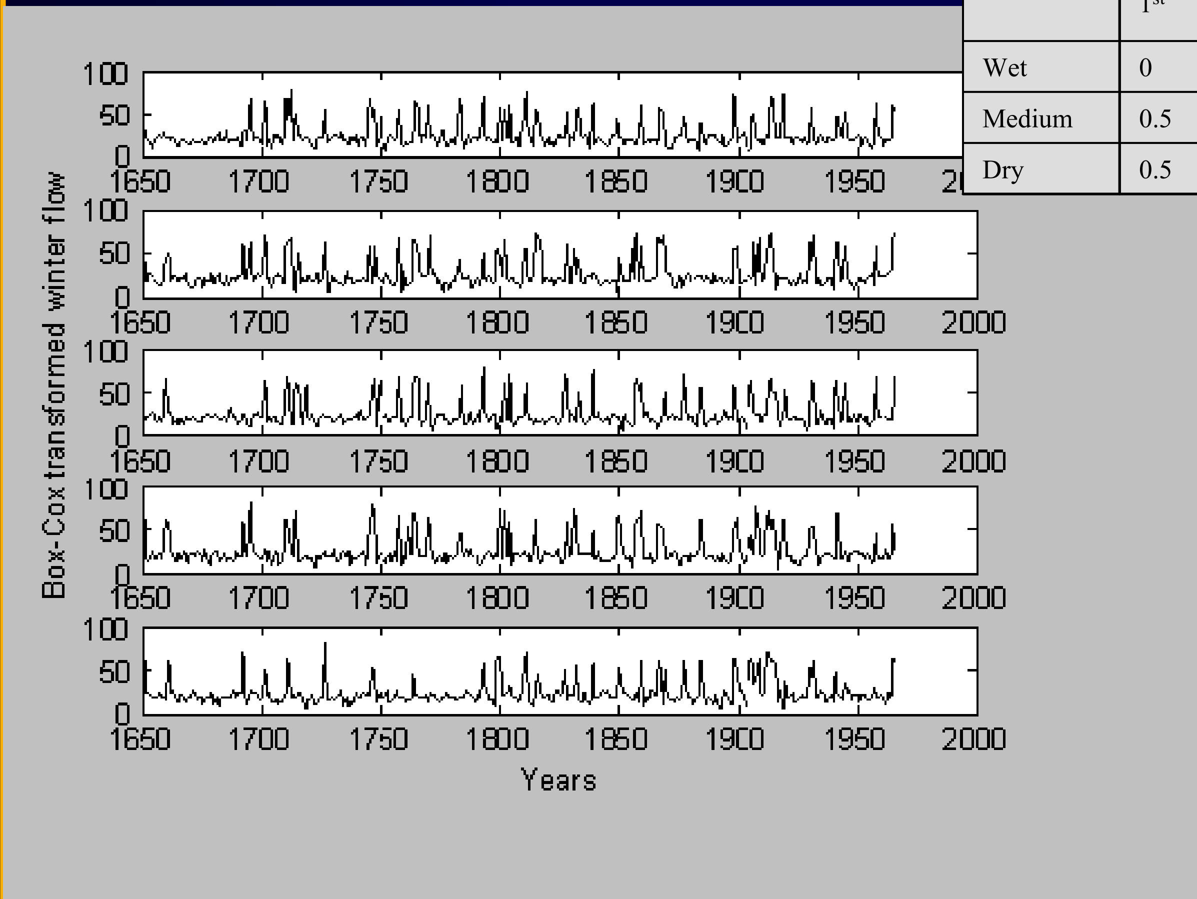


Precipitation estimates from tree-rings



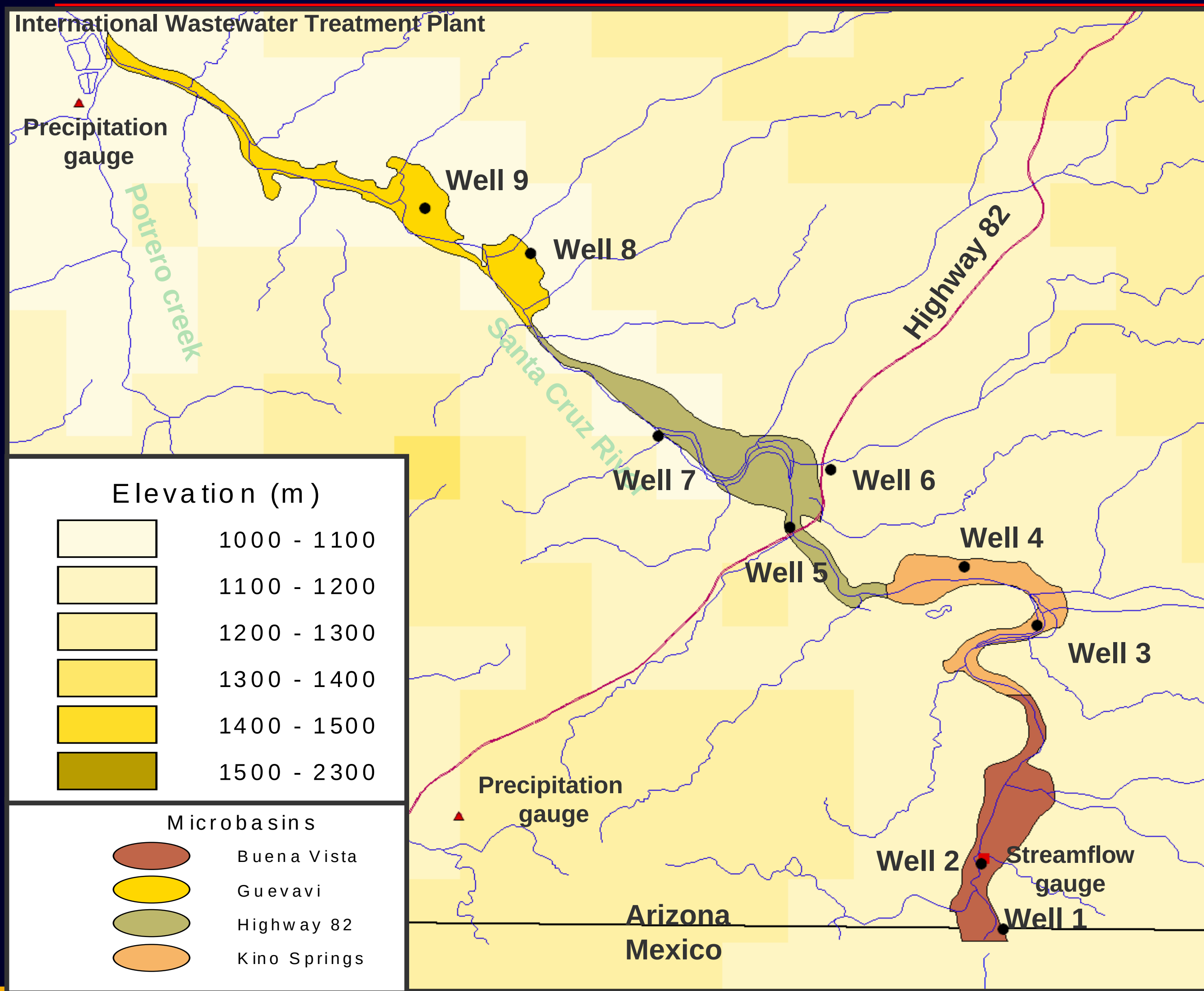
Reconstructed by, David Meko, The Tree-Ring Research Laboratory, The University of Arizona

Streamflow scenarios forced by the tree-ring reconstructed precipitations

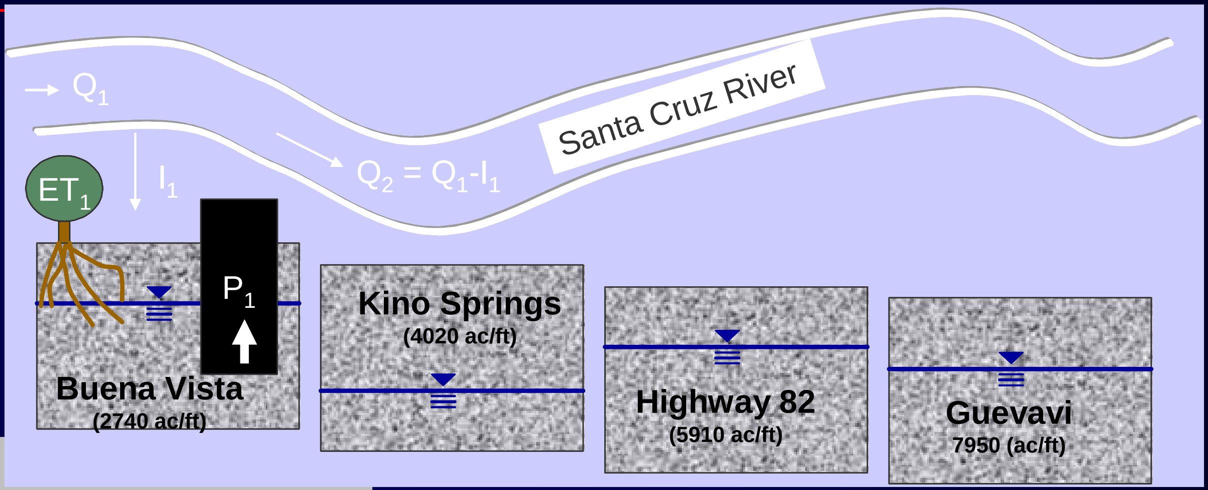


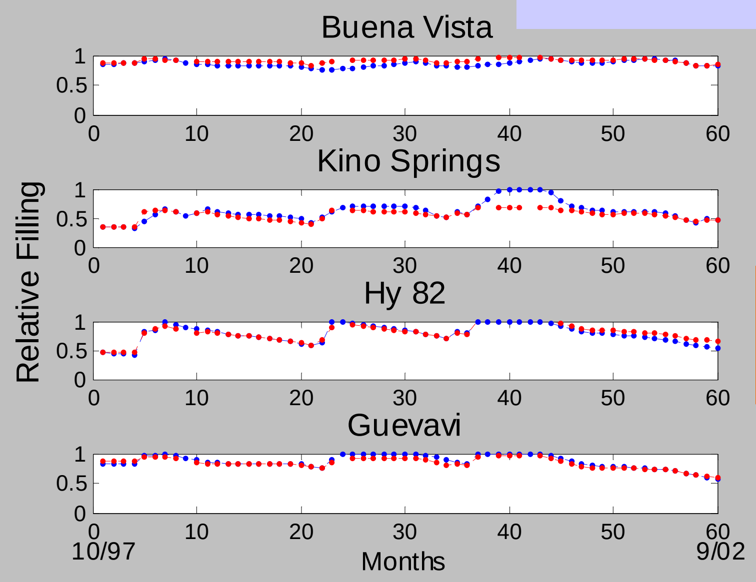
Winter flow categories	Precipitations quartiles of the tree rings			
	1st	2nd	3rd	4th
Wet	0	0	0	0.625
Medium	0.5	0.69	0.75	0.375
Dry	0.5	0.31	0.25	0

Groundwater Microbasins



Groundwater Model Development

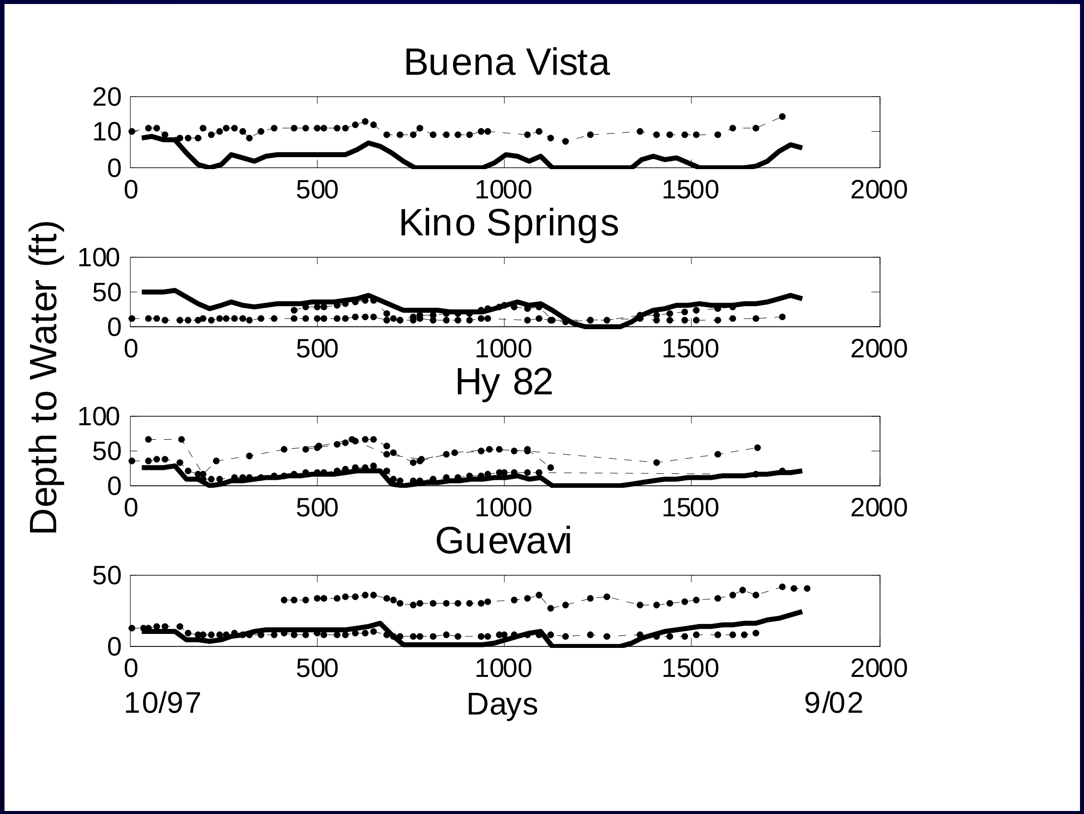




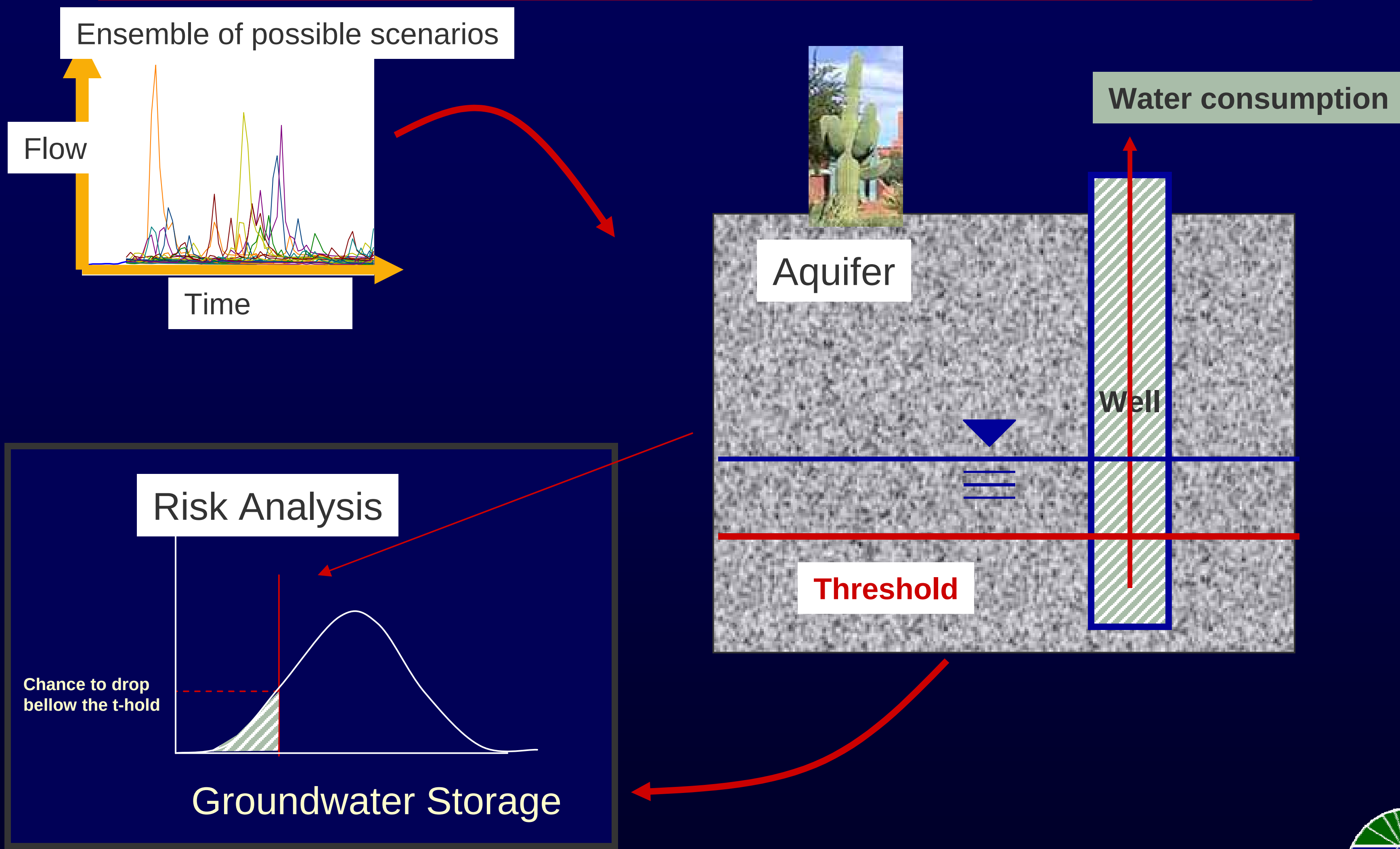
Red –AZDWR MODFLOW MODEL
Blue- HRC Simplified model

Model Comparison with index-wells

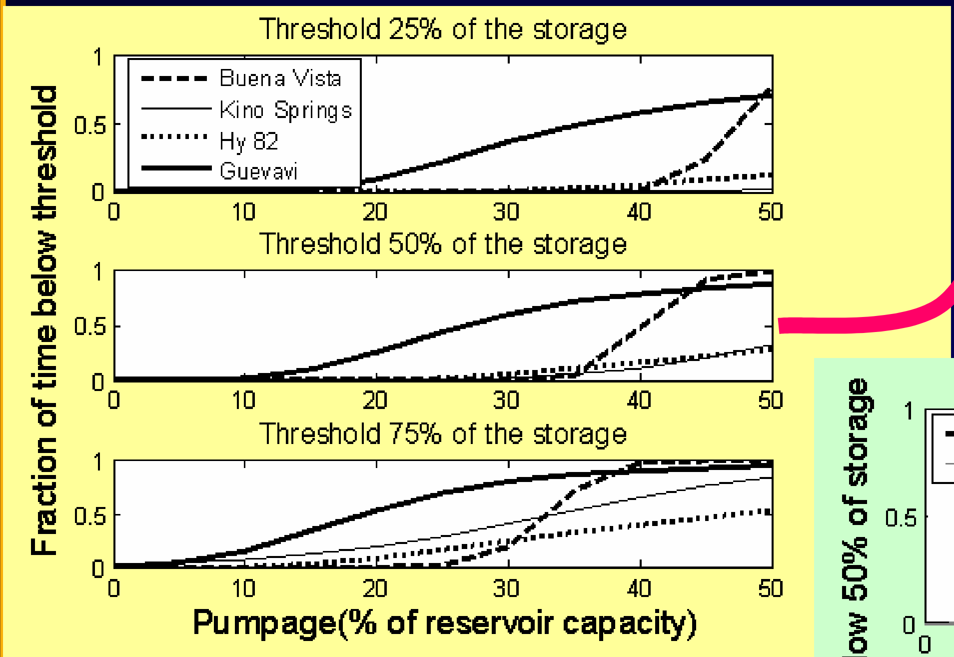
Point to area

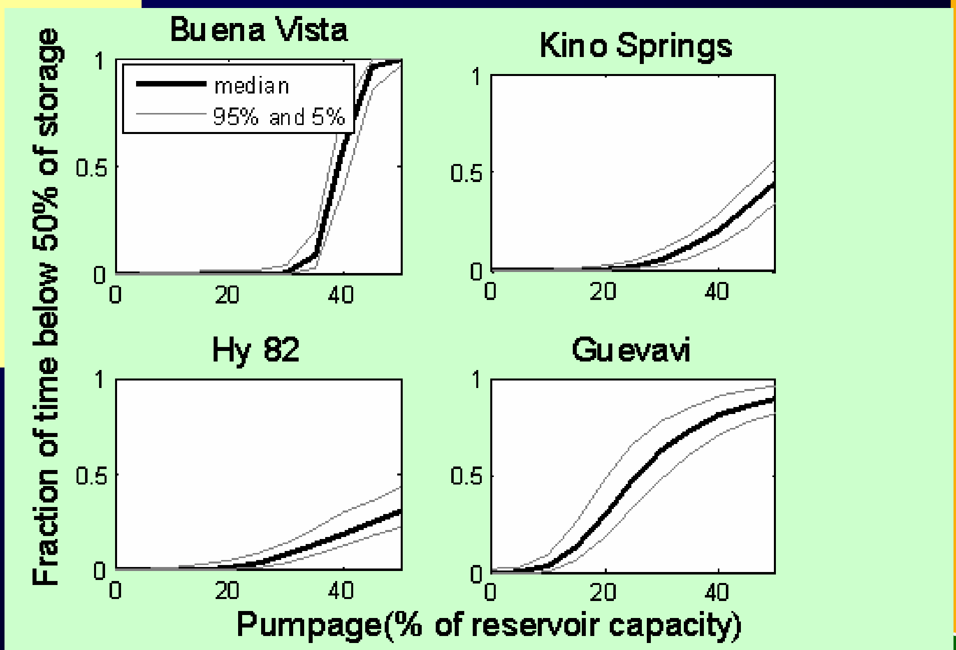


How can the model output be used?



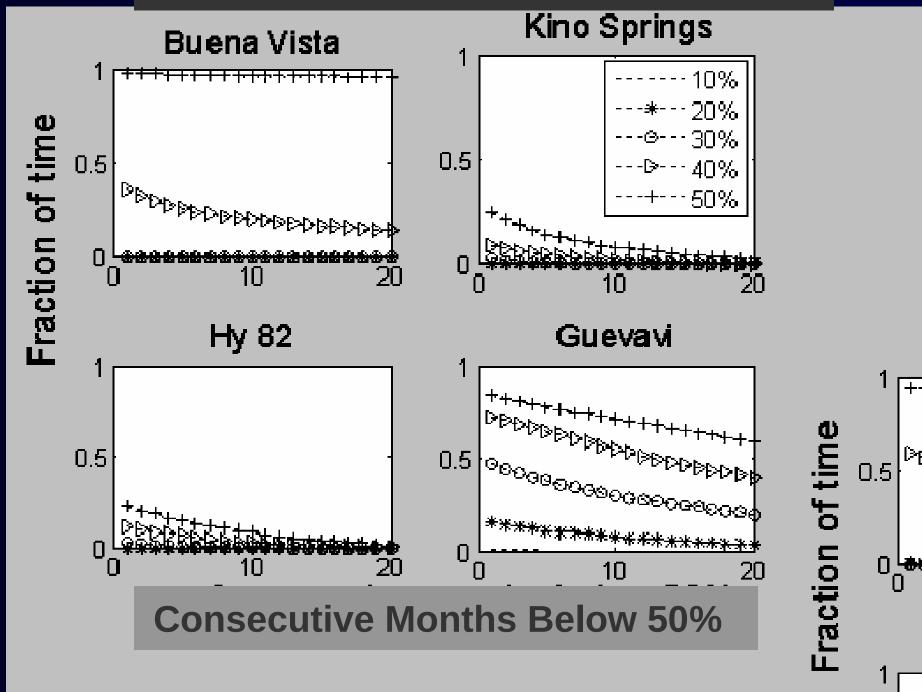
Various water consumption scenarios



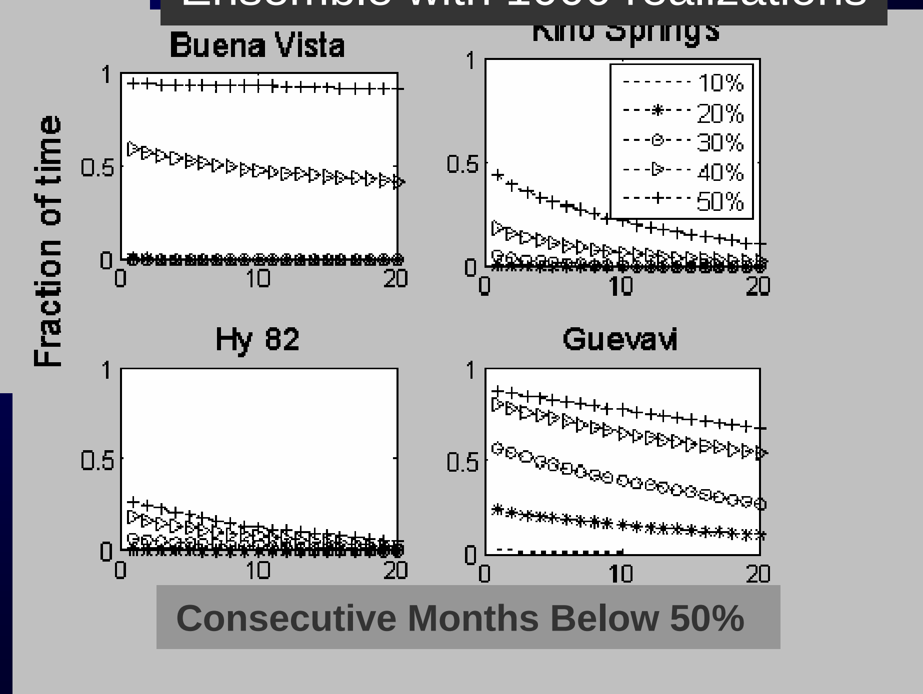


Consecutive monthly stress

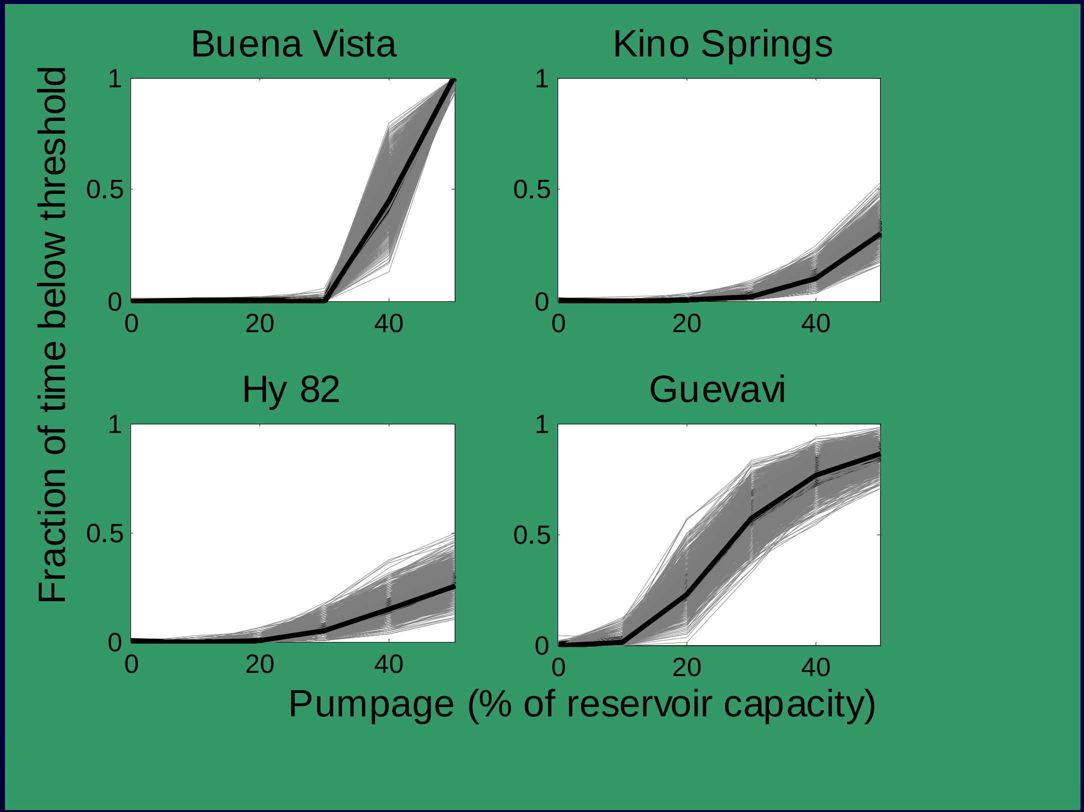
Ensemble with 100 realizations



Ensemble with 1000 realizations



Risk Assessment Using Tree Ring Winter Precipitation Estimate



Future Challenges

- The use of risk analysis as exemplified in this work in collaboration with regional officials and agencies to establish policy regarding regional development.

- Incorporation of climate change scenarios to possibly improve the generation of future streamflow ensembles.

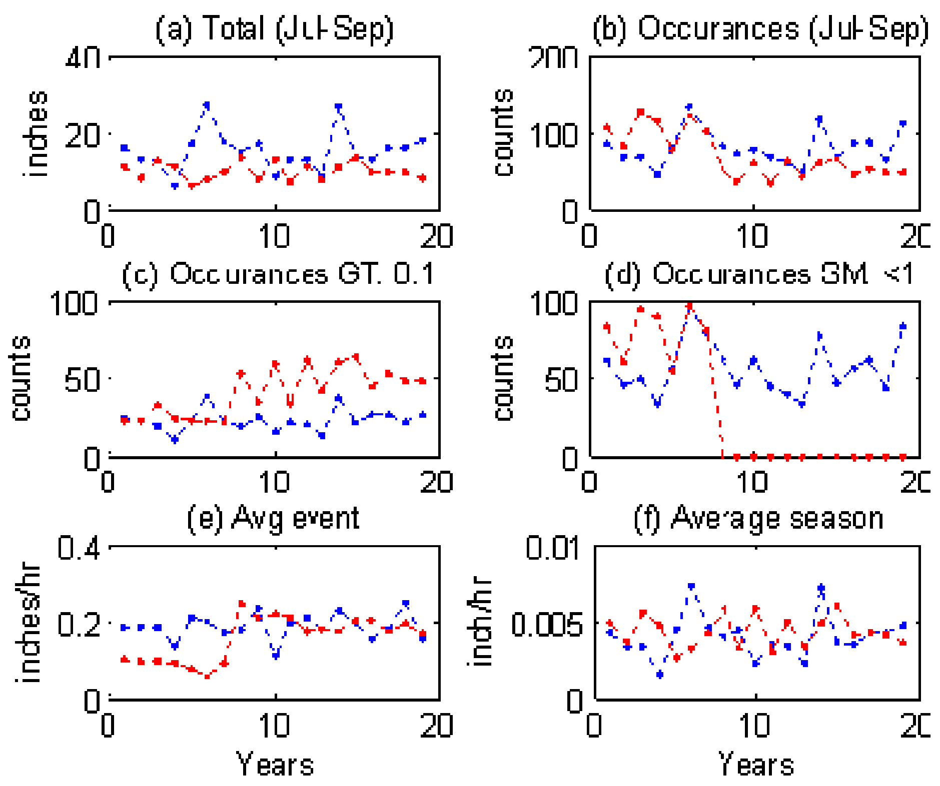
- Application in other semi-arid or arid regions

➢Project Report:

http://www.hrc-lab.org/projects/dsp_projectSubPage.php?subpage=santacruz

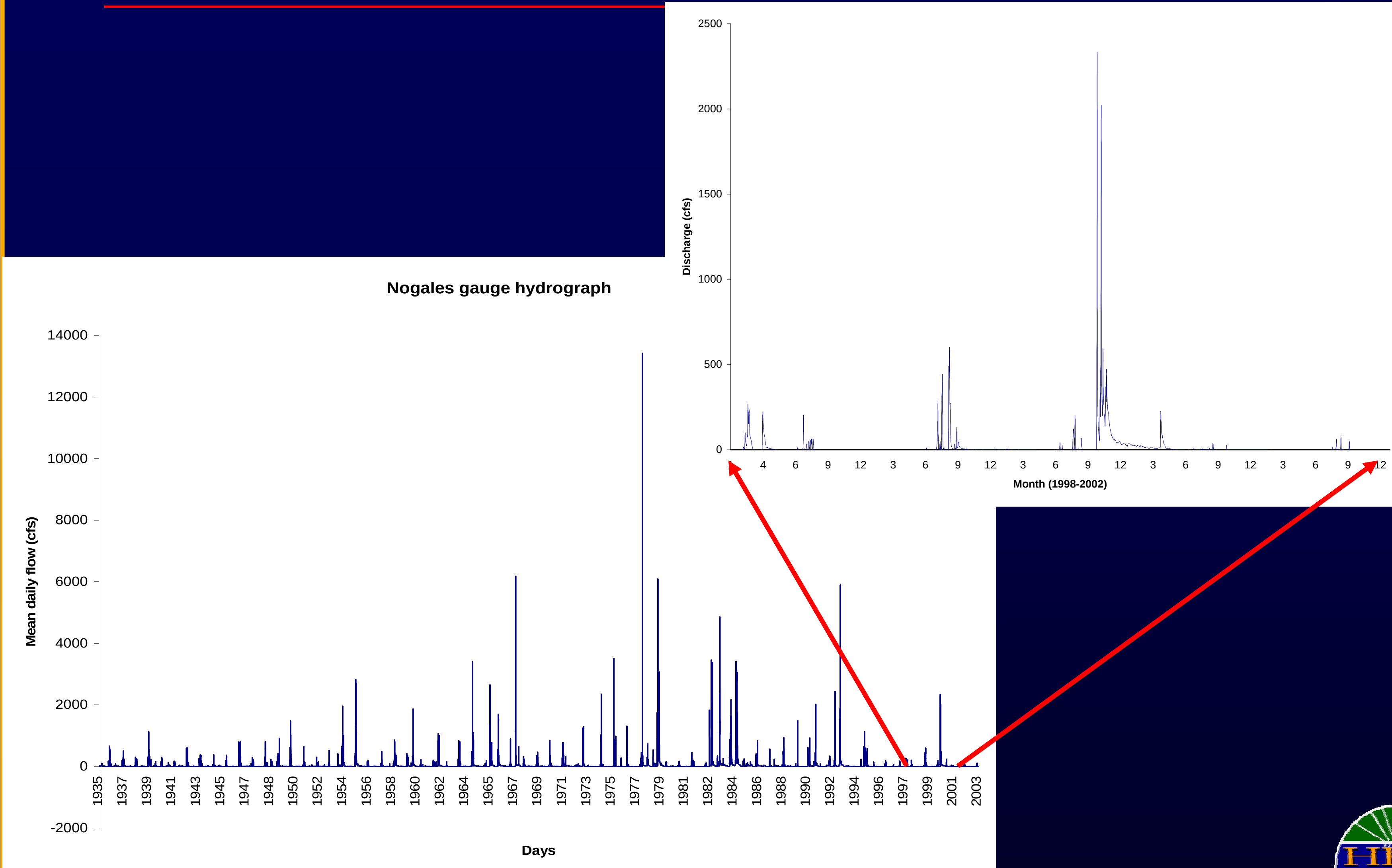
Precipitation Evaluation

Red –Observed
Blue -Simulated

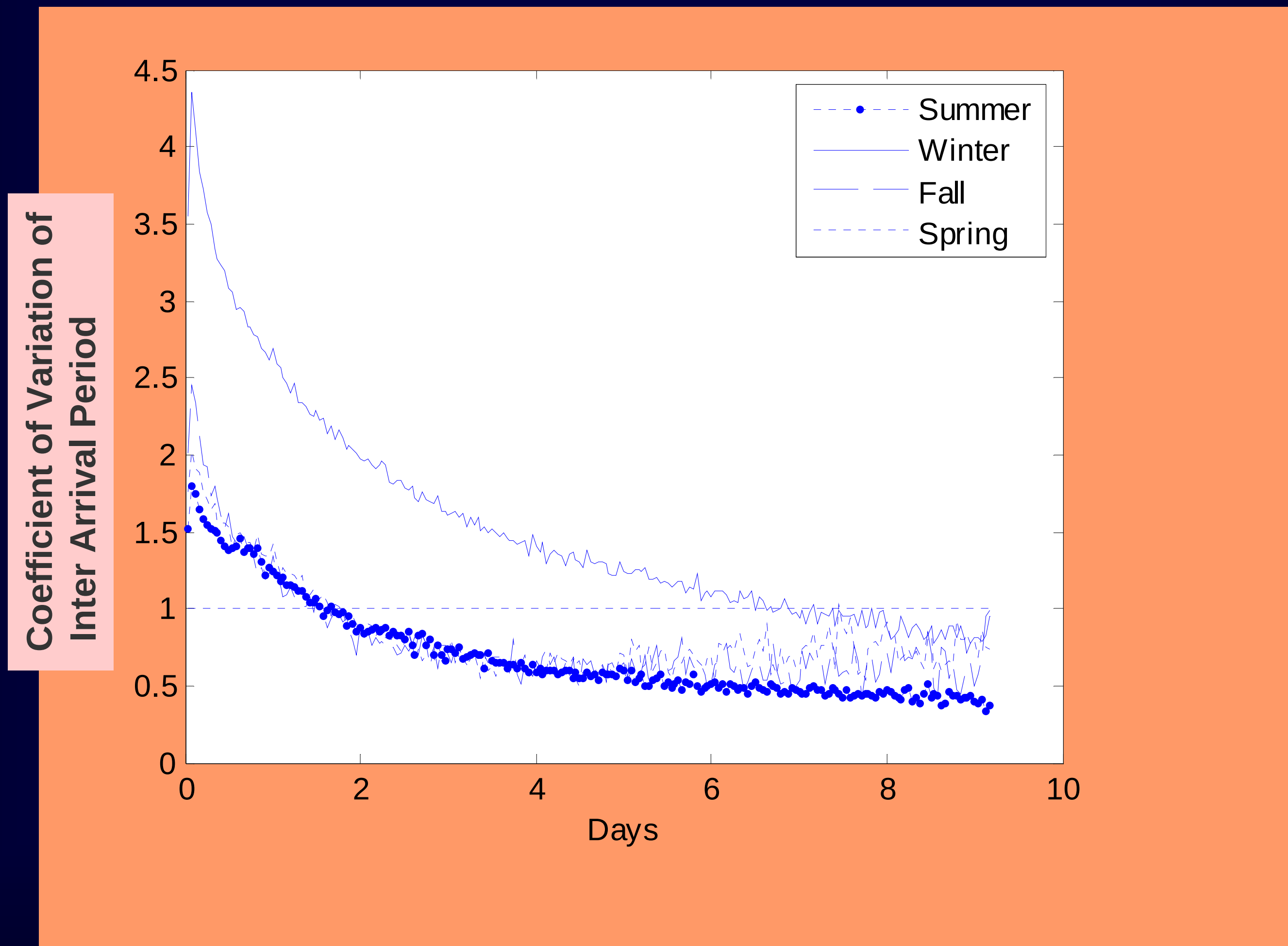


Medium Summer

Nogales Gauge



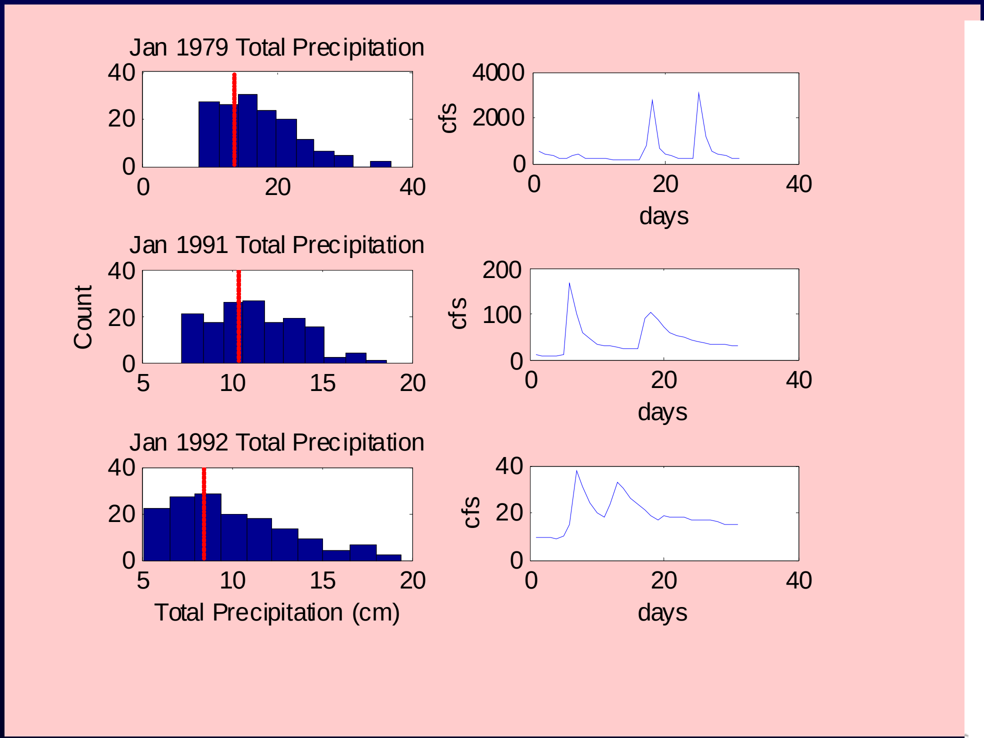
Minimum Cluster Inter-Arrival Time

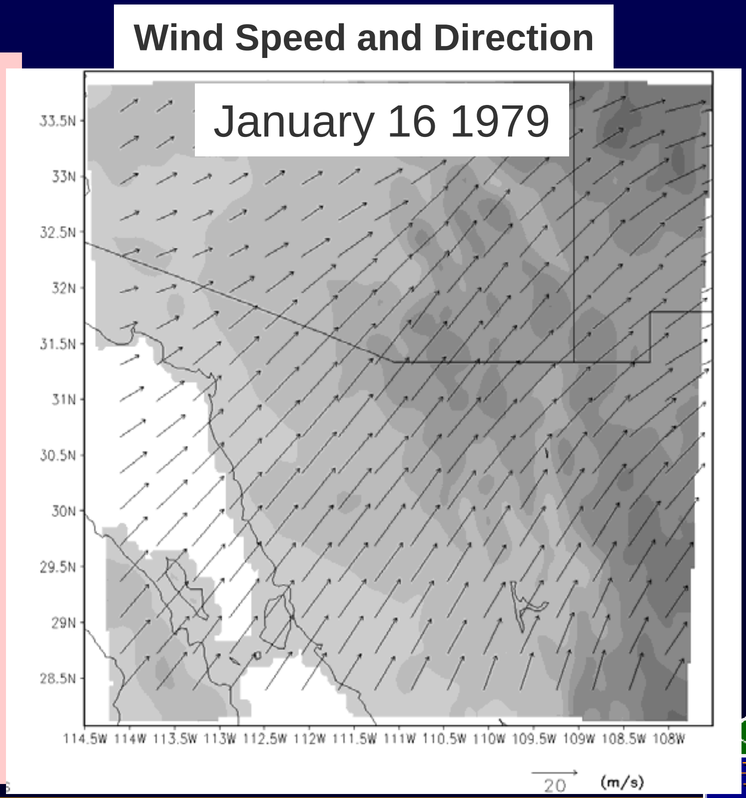


Restrepo-Posada and Eagleson (1982)

Precipitation distribution from regional atmospheric modeling

- **Regional simulation using mm5 atmospheric model**
- **6X6 km, 20 second (output at 1 hour) for January 1979, 1991, and 1992**
- **Lateral Boundary layers are from the NCEP ETA re-analysis data   32X32 km 3 hour**





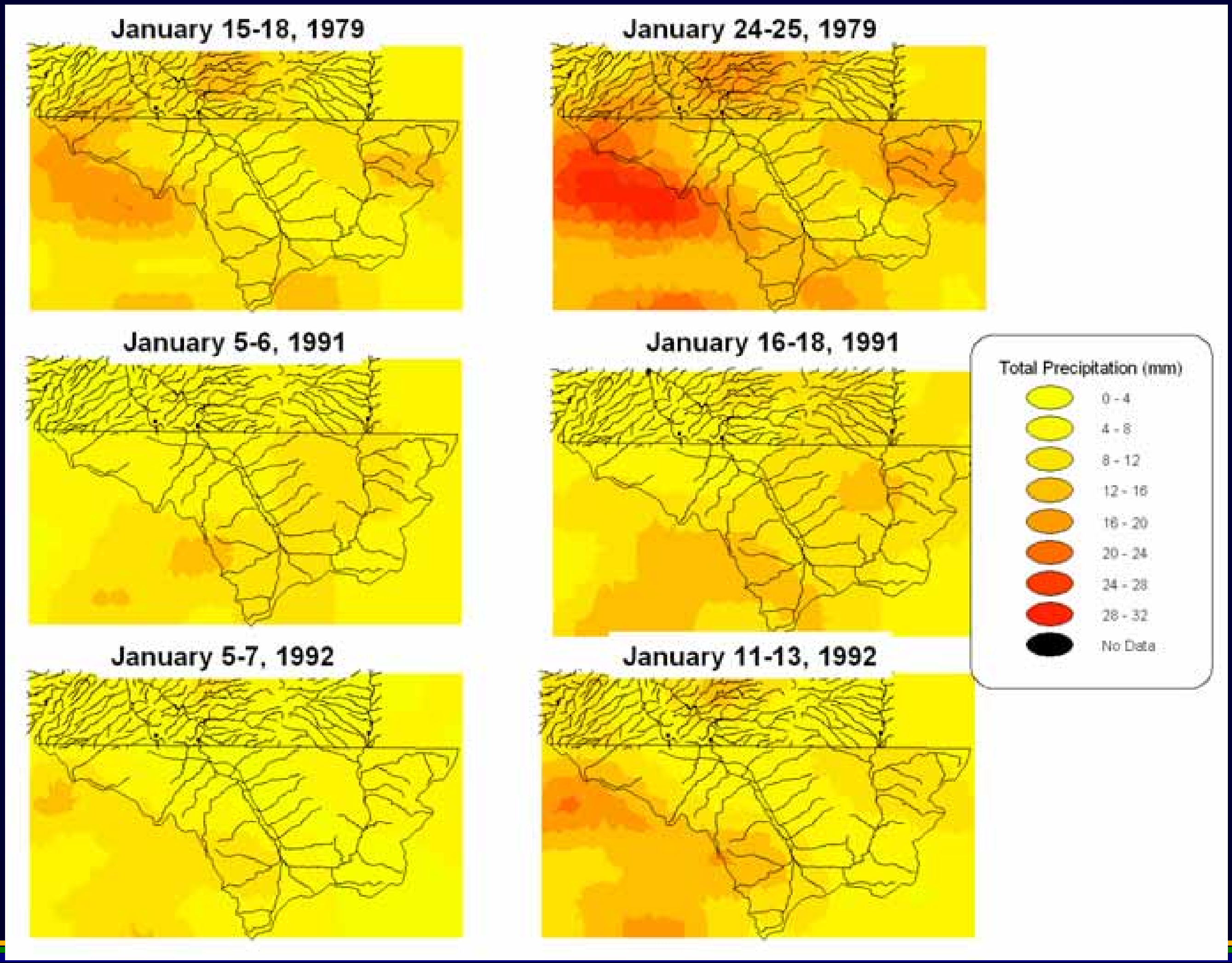
Precipitation areal distribution

- **How is precipitation distributed over the area?**

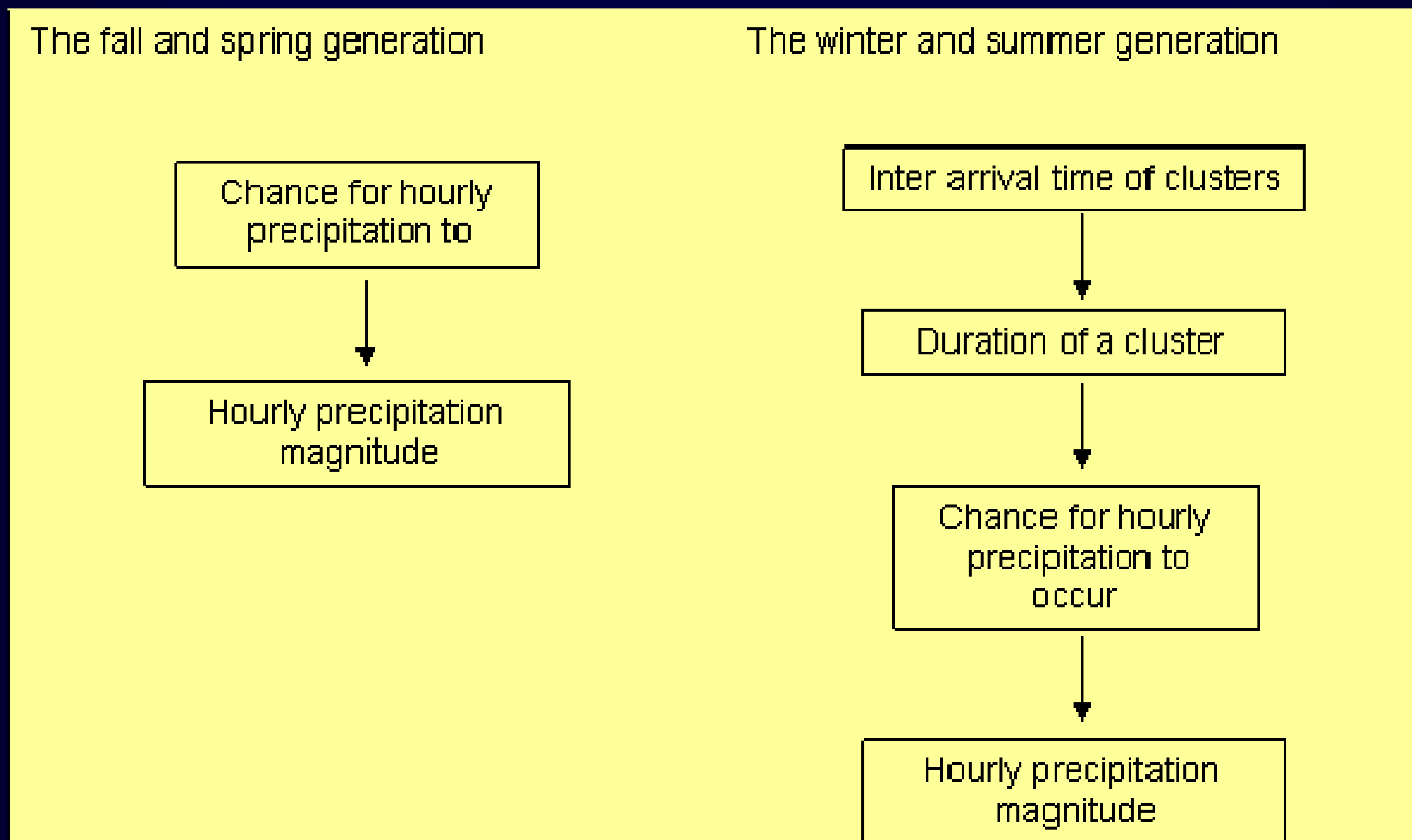
With the lack of dense raingauges, we used:

- Regional atmospheric model with high spatial resolution
  - Analysis was done for 6 historical winter storms

Areal distribution of precipitation for 6 winter storms from regional atmospheric model



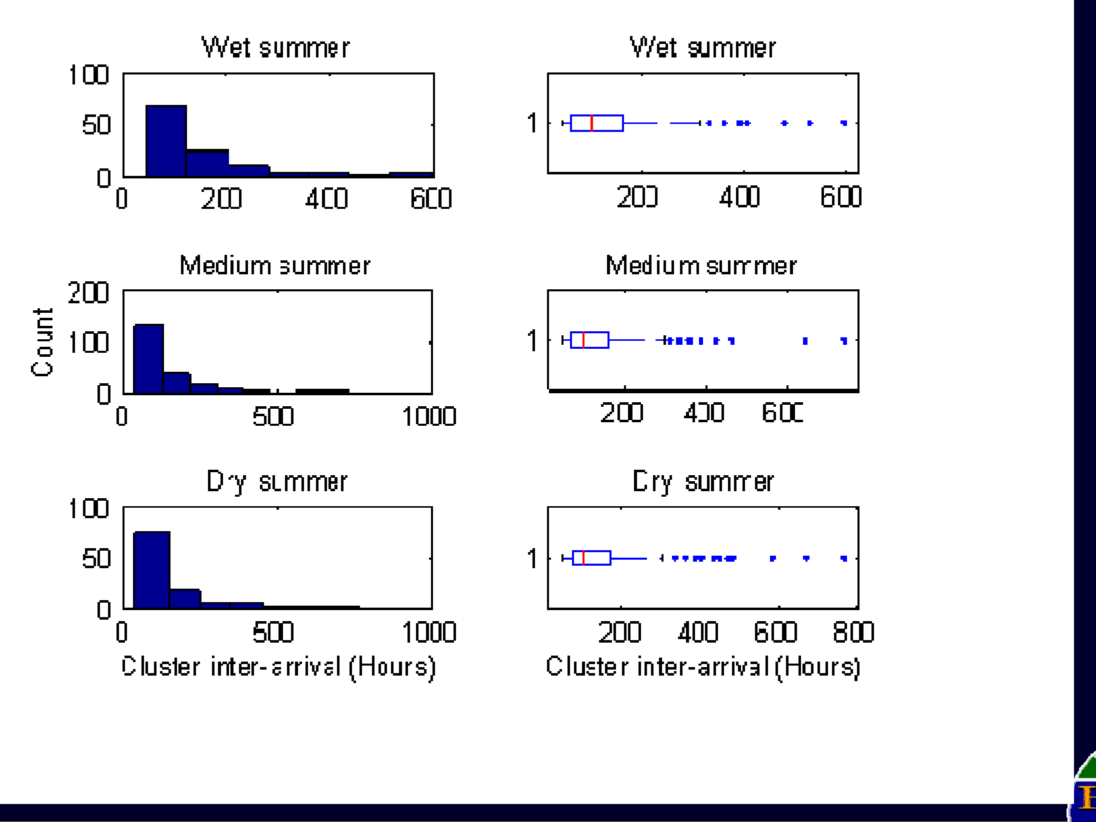
Stochastic Hourly Precipitation Model



Exponential Distribution

Exponential Distribution

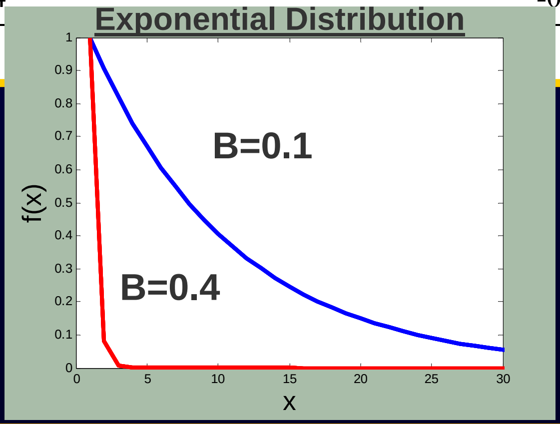
$$f_x = B^{-1} e^{\frac{(A-x)}{B}}$$, A ≤ x, and B > 0



Exponential Distribution cont.

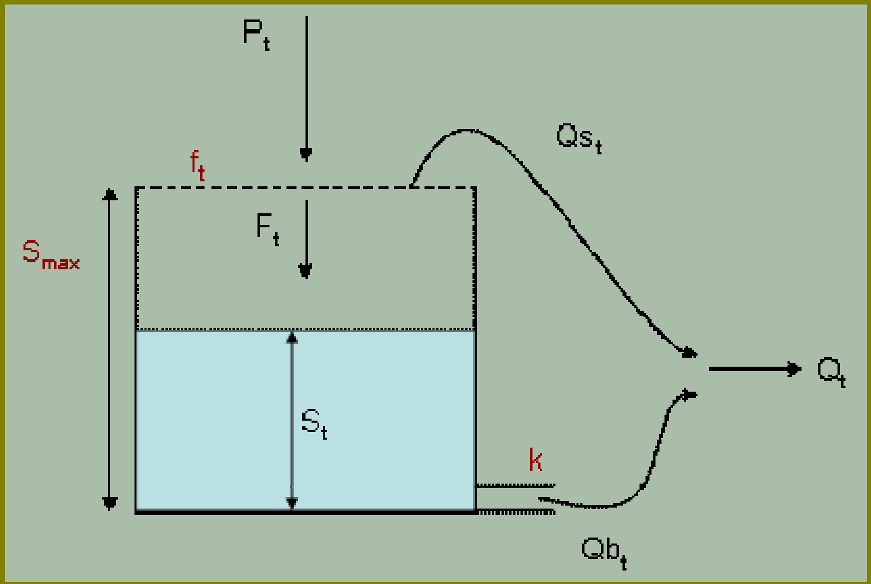
Table B-2: Parameter values of the exponential distributions that are used to simulate the hourly precipitation at Nogales. In parenthesis are the fitted parameters that are used to match the flow.

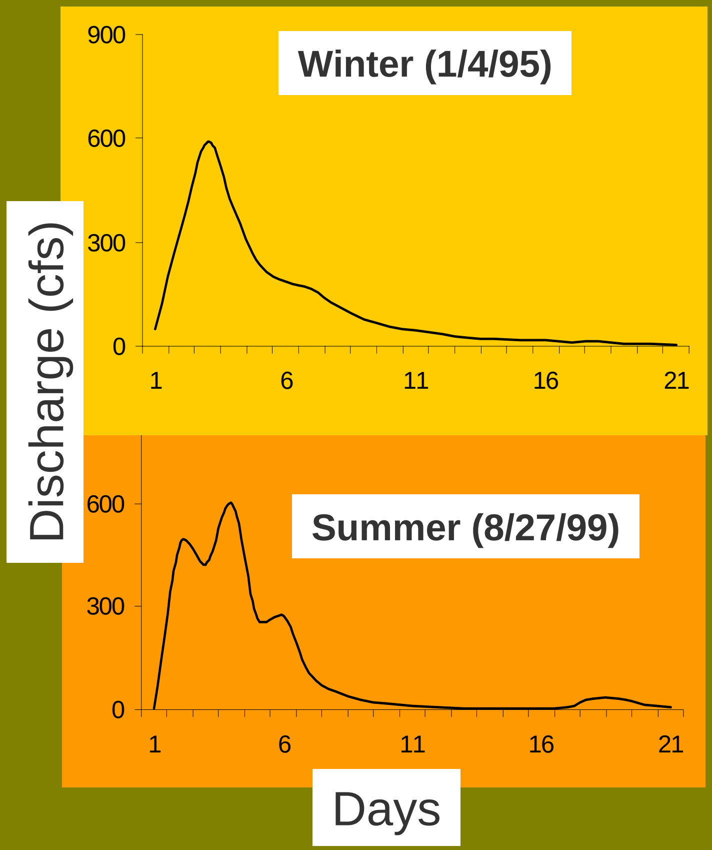
	Cluster inter arrival period		Duration of cluster		Hourly precipitation magnitude	
	A	B	A	B	A	B
Winter: Wet	0.06	0.17	0.02	0.26	0.02	0.1 (0.5)
Medium	0.11	0.4	-0.05	0.1	0.008	0.14
Dry	0.12	0.3	-0.04	0.1	0.08	0.12
Summer: Wet	0.06	0.4 (0.1)	0.02	0.17	-0.04	0.13 (0.5)
Medium	0.04	0.5 (0.15)	-0.01	0.3 (0.2)	-0.03	0.1
Dry	0.02	0.45 (0.4)	-0.015	0.2	-0.04	0.15 (0.1)
	Hourly precipitation chance				Magnitude	
Fall	-0.03	0.2 (0.05)			-.009	0.04 (0.015)
Spring	0.04	0.24			-0.01	0.087 (0.01)



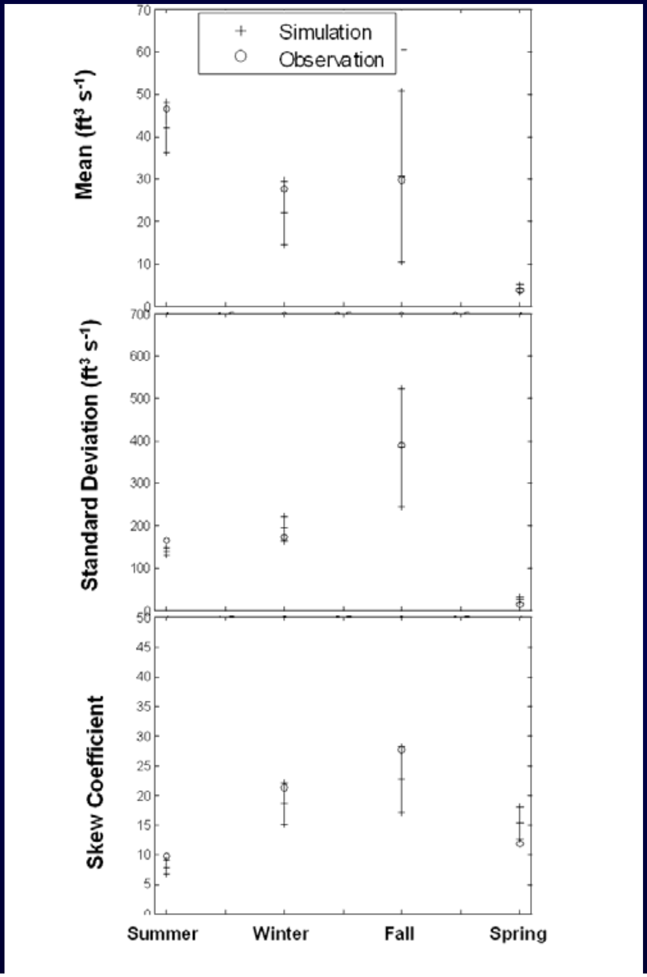
Hourly precipitation to mean daily flow

Processes-based Conceptual Model





Seasonal Daily flow of the three moments



simulations are from 100 realizations 100 year each. (mean and the standard deviation of the moments from the 100 realizations).

Ensemble of 100 realizations using the tree ring reconstruction of precipitation