Decision Scaling

Bottom-up Meets Top-down for Climate Risk Assessment

Casey Brown

Associate Professor of Civil and Environmental Engineering

University of Massachusetts

Goal: We want to assess the risk that climate change poses to our systems.

And we don't want to miss any risks.

Given the large degree of uncertainty about future climate,

our premise is that it is best to identify vulnerabilities first,

and then make judgments about whether vulnerabilities are likely or not.

Our Concern: GCM projections are used to sample uncertainty of future climate,

but their sampling is computationally expensive, inefficient and biased.

We're concerned that real vulnerabilities will be missed.

Can we design a vulnerability analysis that uses the strengths of available climate information (e.g., climate projections)

without being compromised by their weaknesses?

Our Approach: Design a vulnerability approach that is not dependent on or biased by

ex ante scenarios,

a proiri probabilities,

or particular GCM projections.

Our Approach: Design the analysis to systematically explore changes in

mean conditions and variability

(and be able to tell the difference).

Our Approach: Design the analysis to scale to the most credible signals that can be derived from GCM projections,

Changes in mean Precip and Temperature

Coarse spatial scales

Our Approach: Use the revealed vulnerabilities (ex post scenarios) as starting point for probabilistic assessment of risk.

Analysis designed results so vulnerabilities are defined in terms of climate changes we can investigate.

Challenge #1: want to design a "stress test" that varies climate in physically plausible ways to reveal vulnerabilities.

- Maintain everything that we don't want varied (e.g., spatial correlation, temporal statistics),

but allow us to vary everything we want to (mean climate, temporal statistics, etc.) in a controlled fashion.

Challenge #2: Design the stress test such that we can make inferences about the revealed vulnerabilities:

- At spatial and temporal scales that can be linked to available information, including projections
- As function of physical mechanisms that are credibly represented in climate model simulations (or that can be investigated)

Decision Frameworks for Climate Change

- How will the science improve decisions?

- Usual mode of engagement: Prediction - centric
  - Science reduces the uncertainty affecting the decision
  - E.g., Science: the most likely future condition is A
    - Decision – under Future A, Option 1 is my best choice

- Mode of engagement under climate change
  - Science characterizes uncertainty (*may increase*)
  - E.g., Science: here is a wide range of possible futures, and we’re not sure they delimit the true range
    - Decision – um …

Klemes (1974): "… by assuming nonstationarity we acknowledge nonexistence of preset limits and directions … unpredictability… and subscribe to philosophical indeterminism"

Use of Climate Information in Decisions

Precautionary Principle

Predict then Act

Uncertain but informative

Deep

Well Characterized

Uncertainty

No Probabilities

Decision-Scaling

Use Probabilities

Projection driven vs Decision Scaling

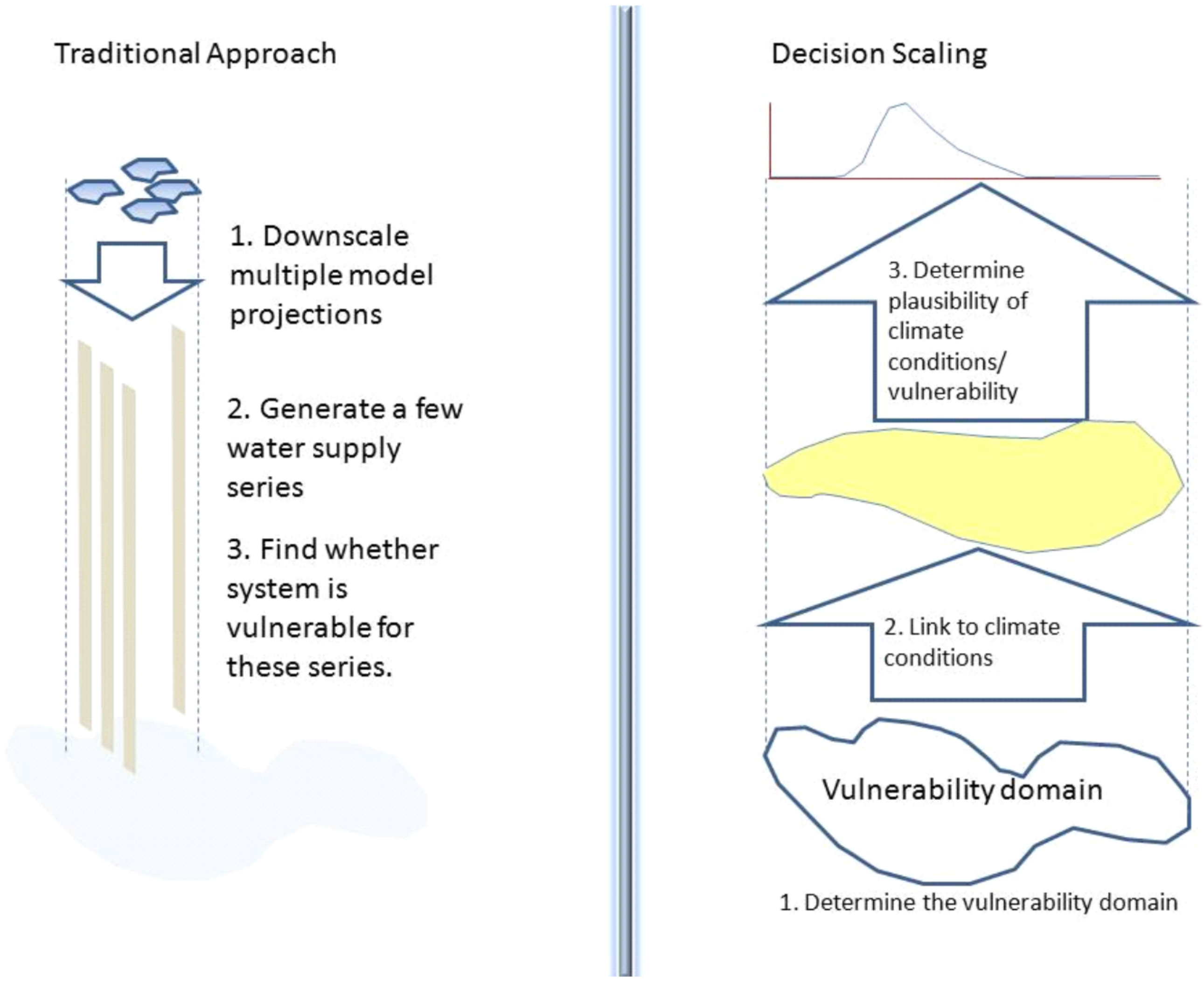
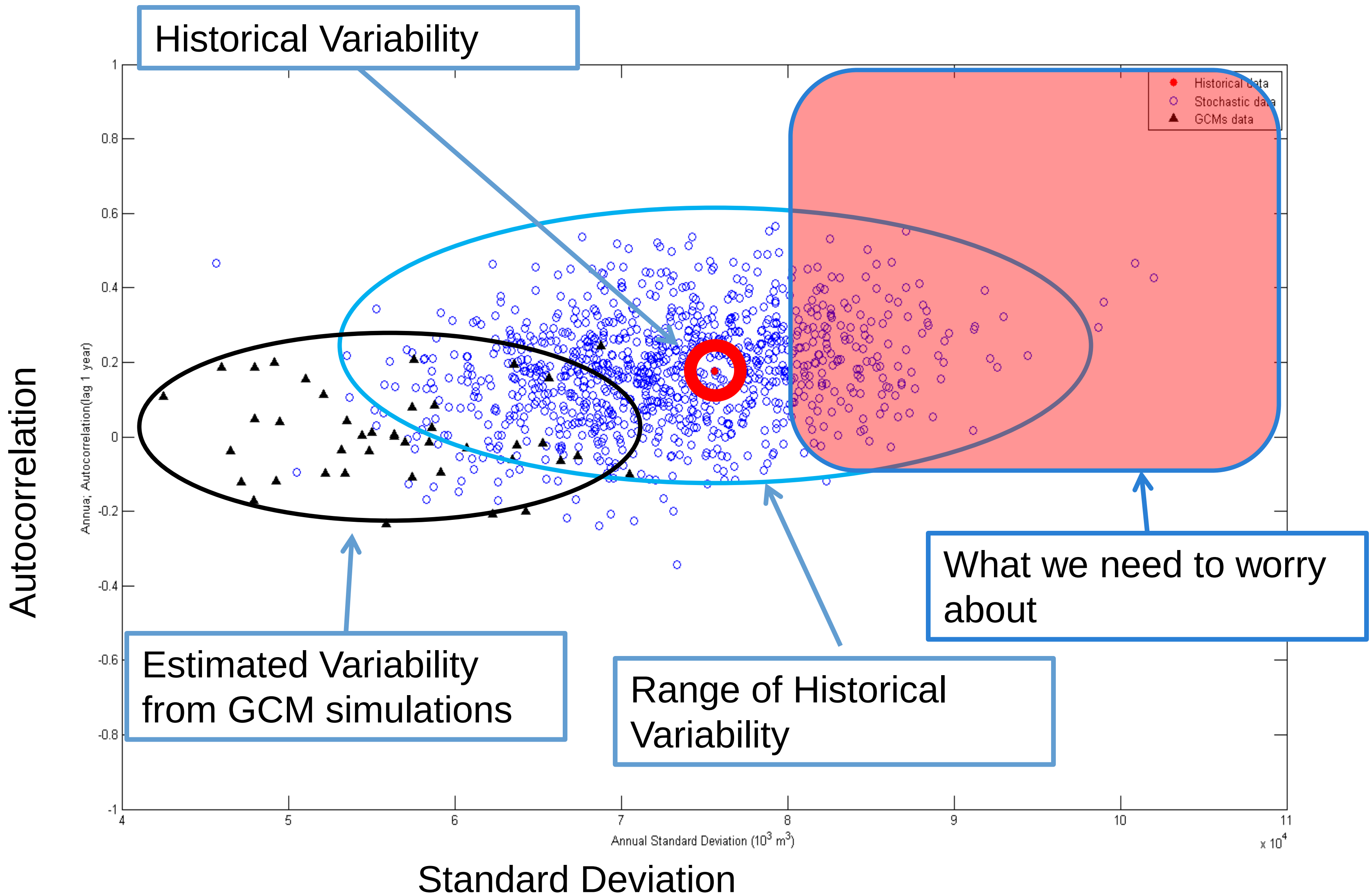


Figure 1 Steps in decision scaling vs. traditional approach

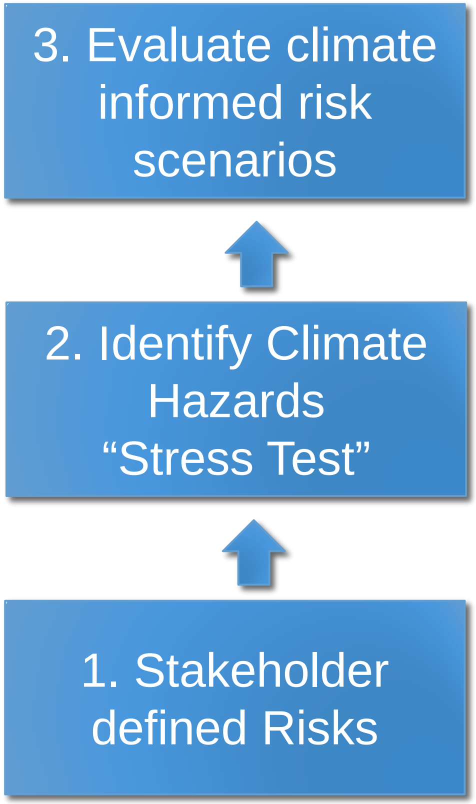
Brown et al., 2011 *JAWRA*

Underestimated Risk



Data Source: Base climate projections downscaled by Maurer, et al. (2007)
Santa Clara University.

Decision-Scaling



Systematic Sampling:

- *Changes in mean conditions*
- *Variability*
- *Seasonality*
- *Other factors (water demand, etc.)*

What level of performance is needed?
What are non-climate factors that are also important?
What are current climate/weather effects?

Decision-Scaling

GCM Projections

3. Evaluate climate informed risk scenarios

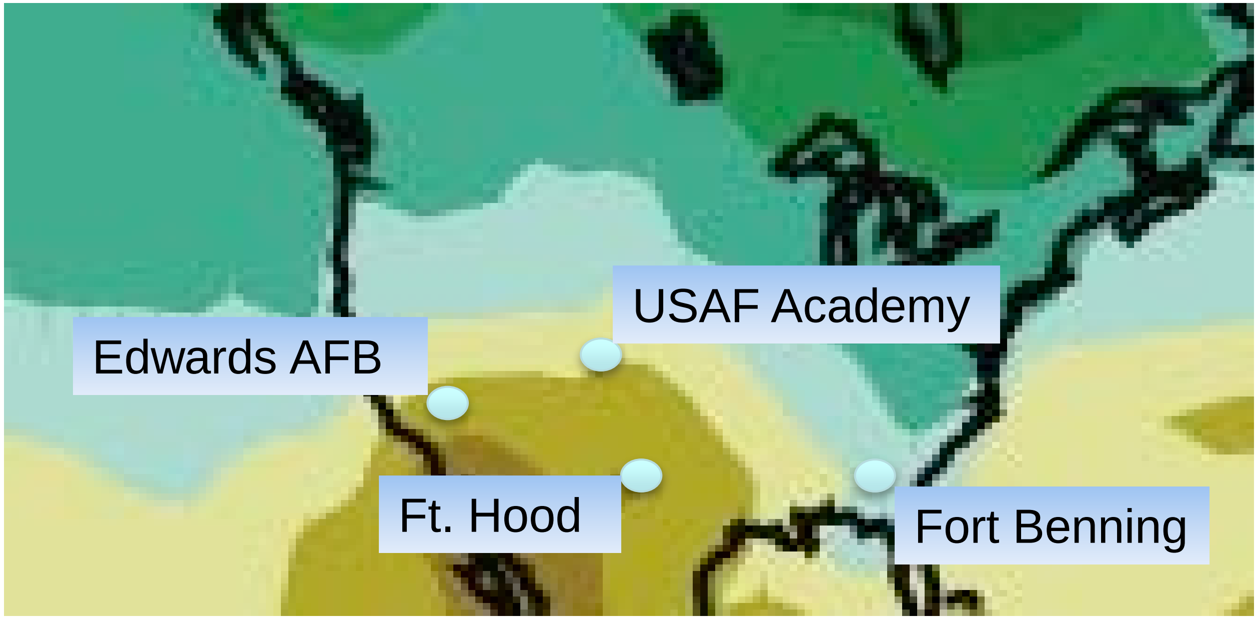
Do projections indicate these conditions are likely?
Are projections credible in simulating these conditions?
How robust is the system?
What are the relative effects of climate and non-climate factors?

2. Identify Climate Hazards "Stress Test"

1. Stakeholder defined Risks

What level of performance is needed?
What are non-climate factors that are also important?
What are current climate/weather effects?

SERDP Project Study Sites



- **Fort Hood (South Central) – Fire management; Training; Water**
- **Fort Benning (Southeast) – Fire management; Training; Energy**
- **USAF Academy (Mountain West) – Water; Training; Energy**
- **Edwards AFB (West) – Water; Energy**

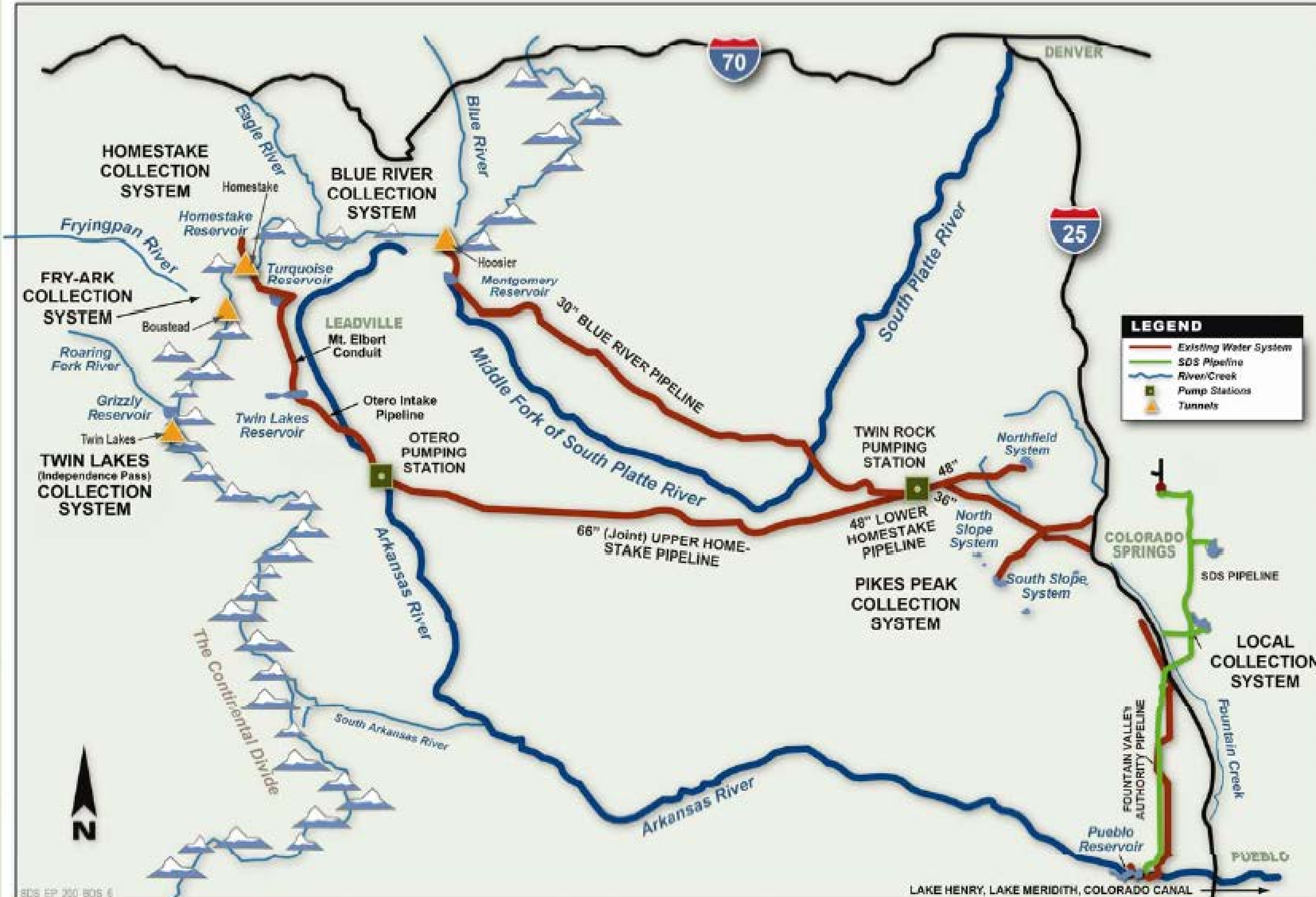
COLORADO SPRINGS

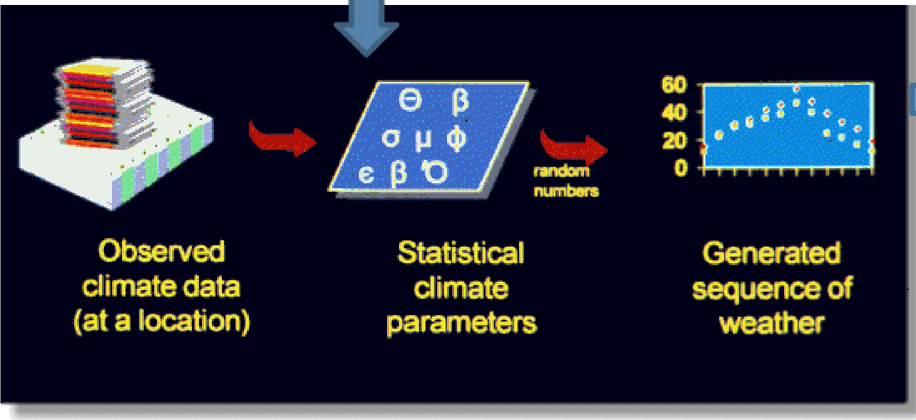
Current and Build-out Conditions

Colorado Springs Utilities
It's how we're all connected

MWH
BUILDING A BET

Colorado Springs' Water Supply System





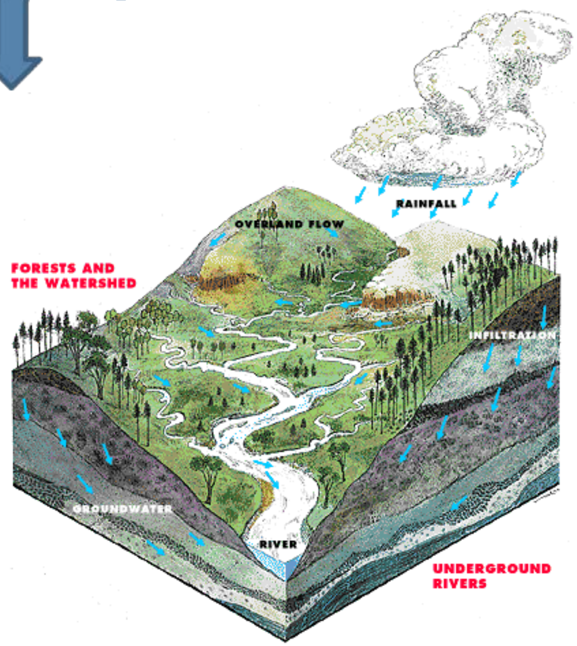
Stochastic Climate Model

Monte Carlo to Sample Uncertainties

-Climate Trends

-Internal Climate Variability

-Hydrologic Model



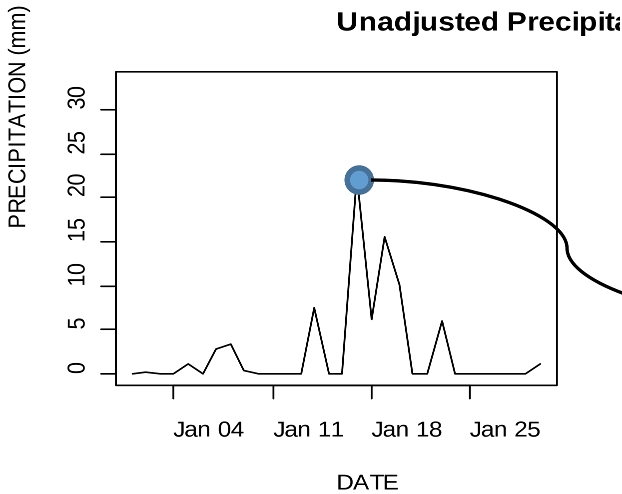
WEAP Hydrologic and Systems Model

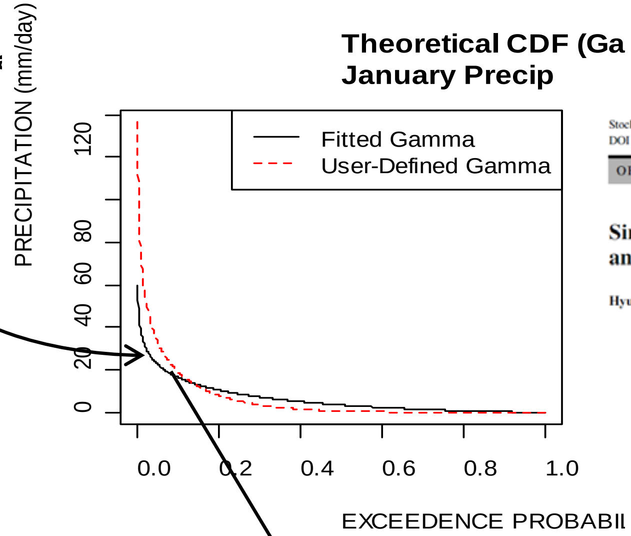
MODSIM Systems Model (All Alternatives)

Performance Metrics

Climate Stress Test – Prescribed Climate Changes

Daily Variability

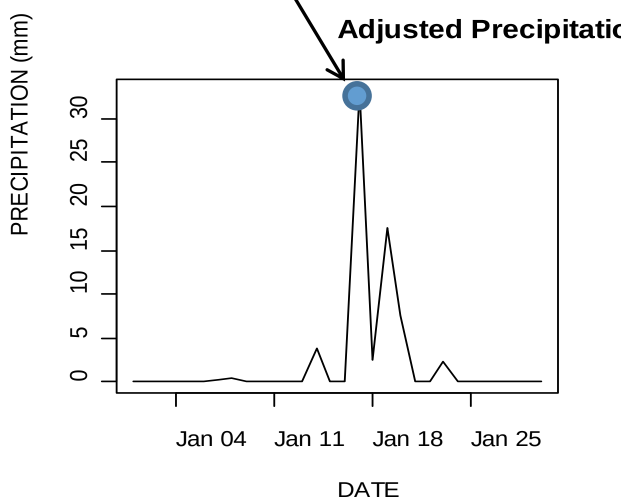




1.) Select a simulated non-zero precipitation event

2.) Map precipitation amount to quantile of fitted distribution

3.) Replace with precipitation amount drawn from user-defined distribution at same quantile



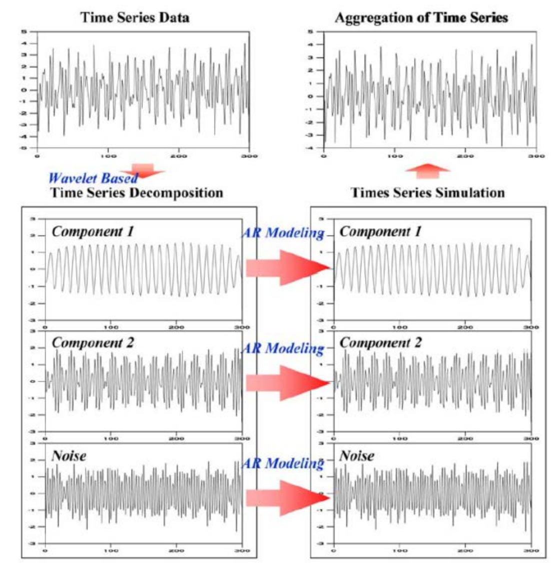
Interannual

Stoch Environ Res Risk Assess (2009) 23:879–896
DOI 10.1007/s00477-008-0270-2

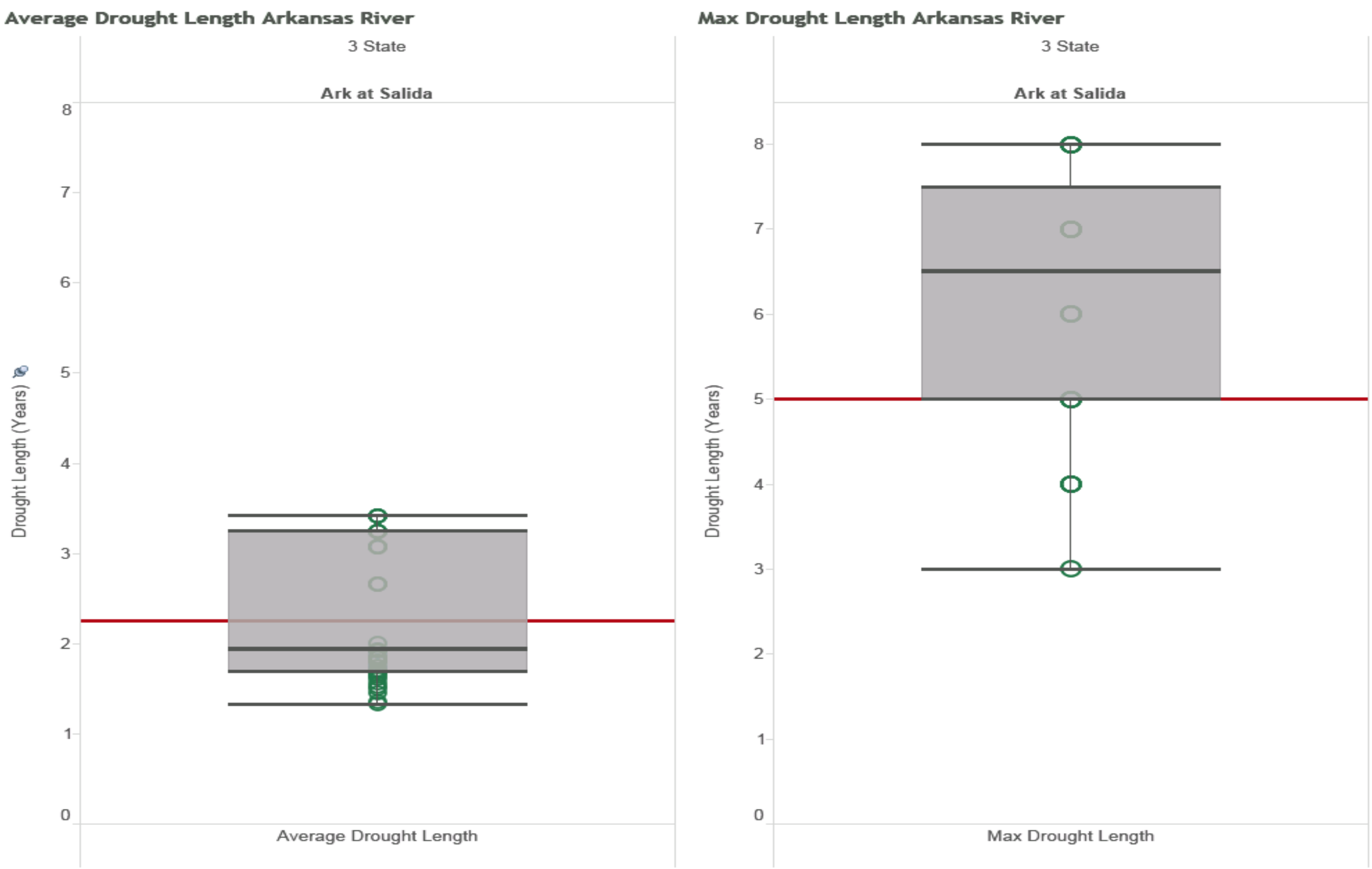
ORIGINAL PAPER

Simulation of daily rainfall scenarios with interannual and multidecadal climate cycles for South Florida

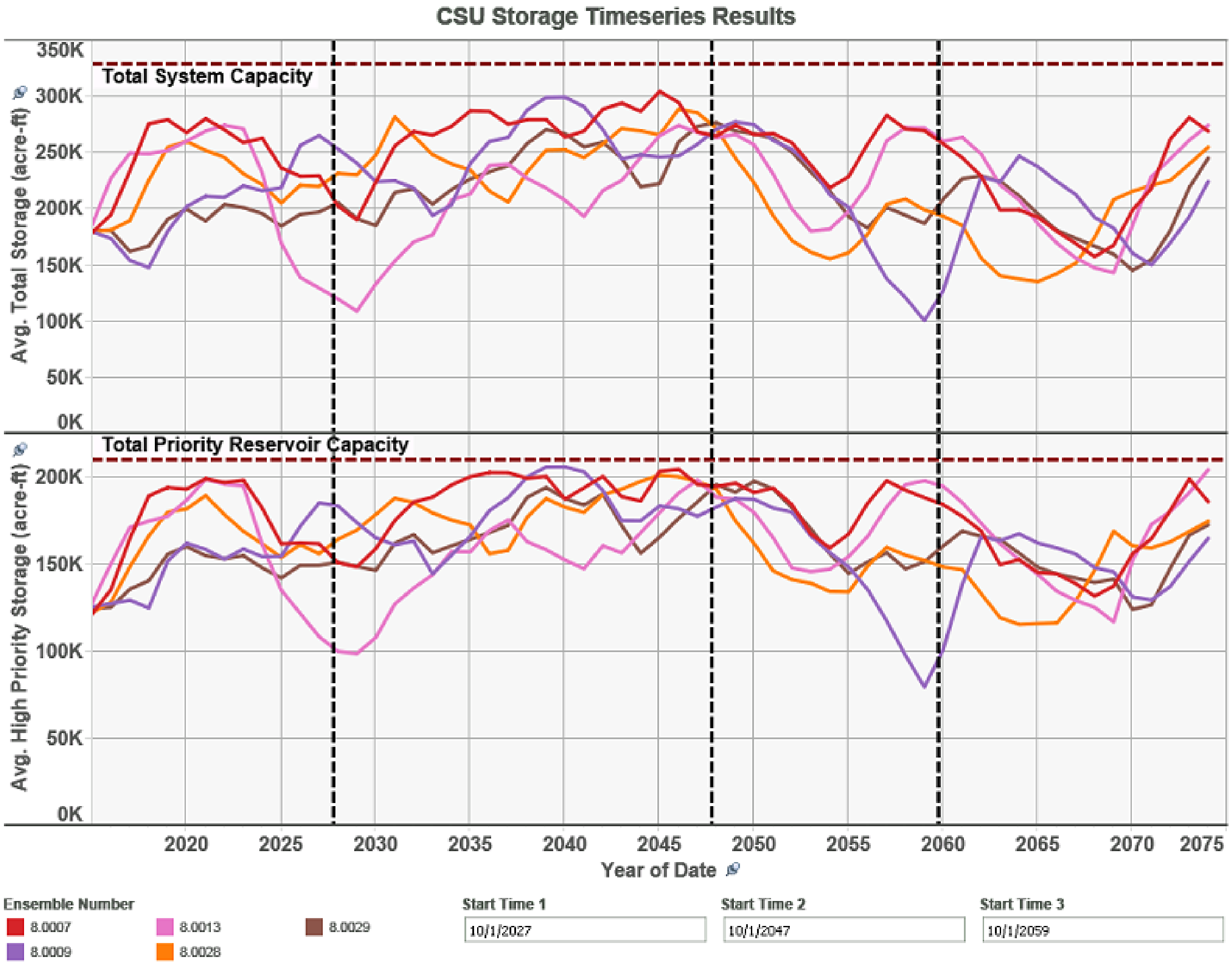
Hyun-Han Kwon · Upmanu Lall · Jayantha Obeysekera



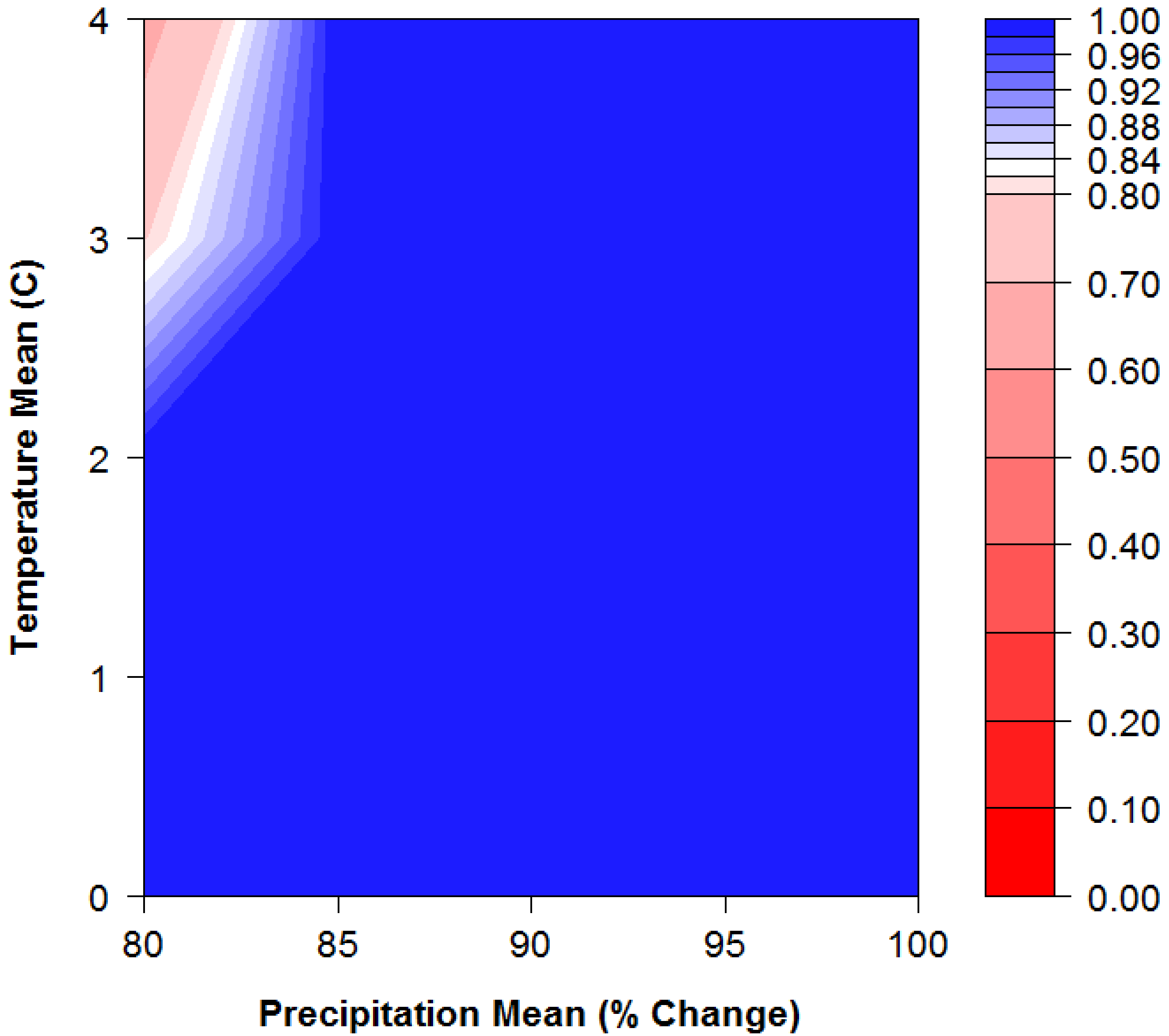
Selective Variability Sampling



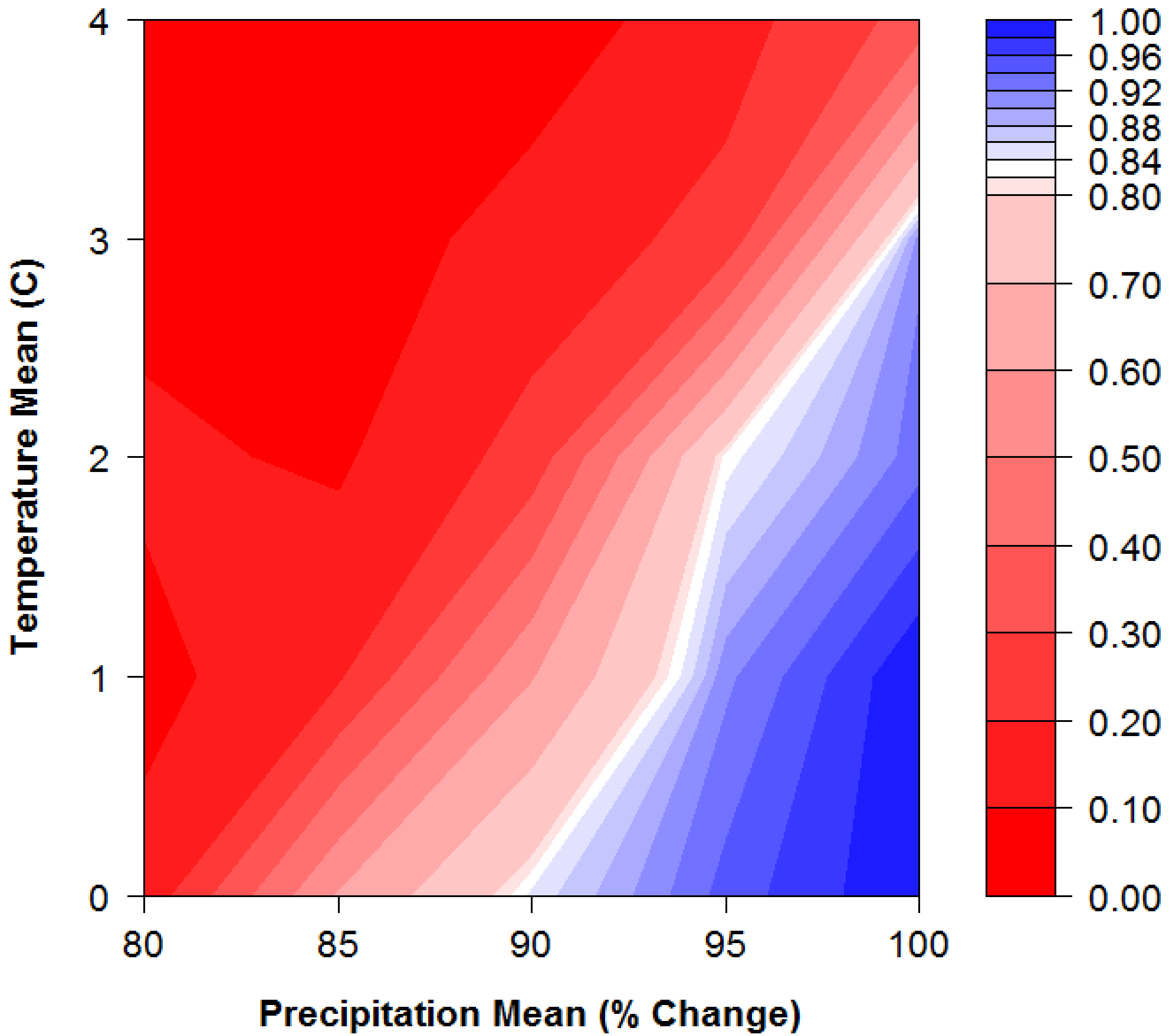
Select 5 trials from 40



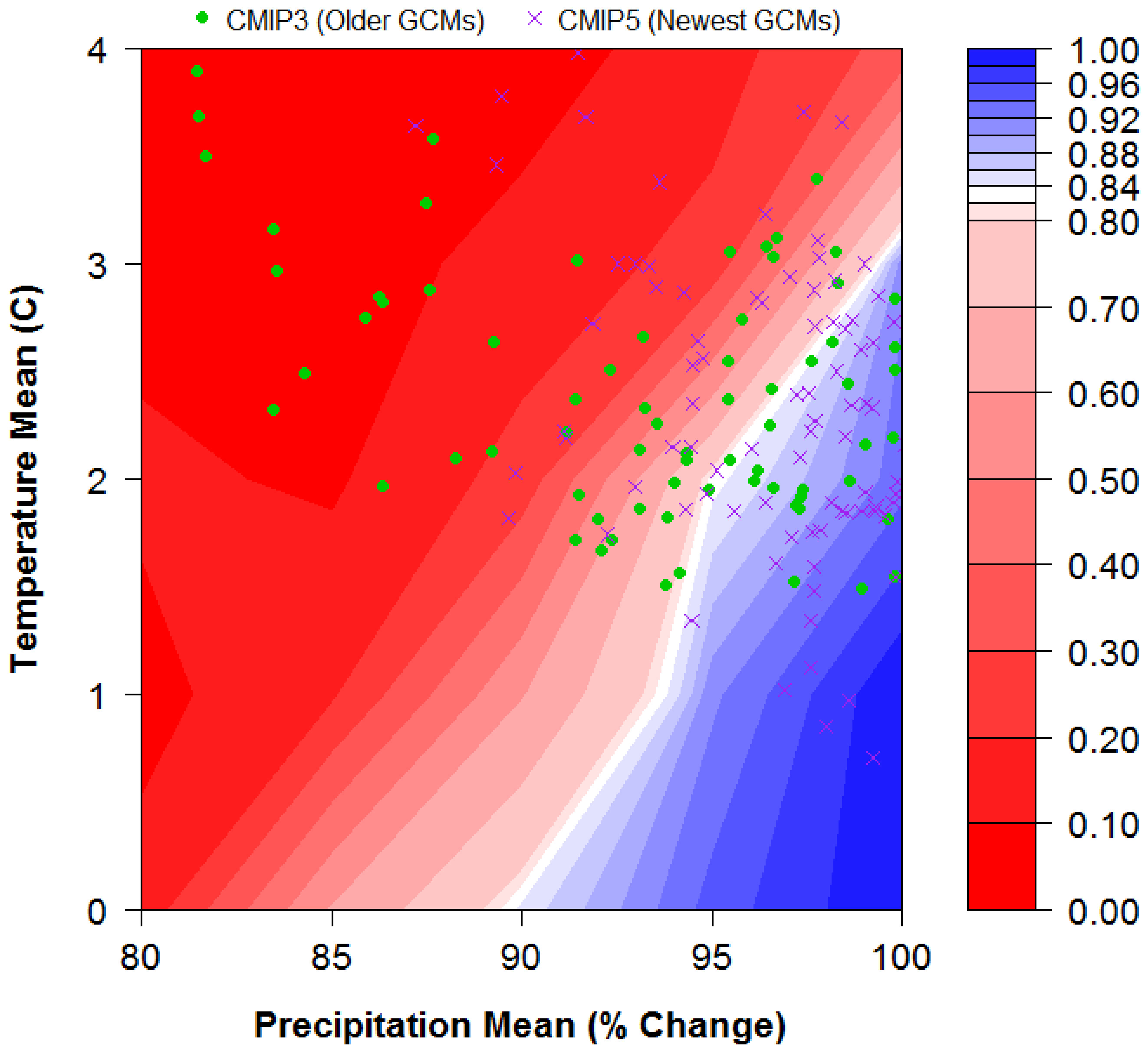
Colorado Springs (USAFA): CURRENT CONDITIONS



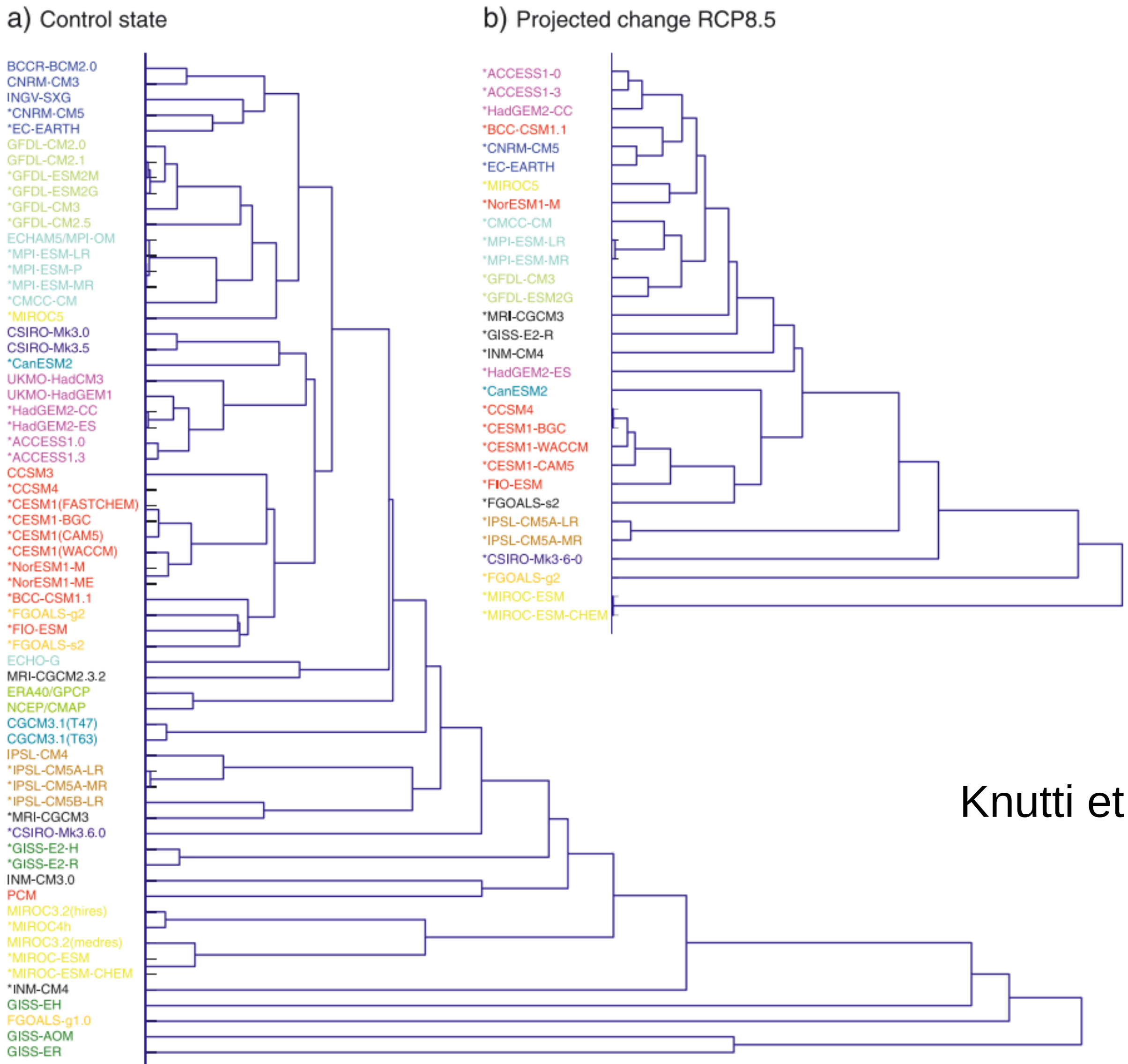
Colorado Springs (USAFA): Future Conditions



Colorado Springs (USAFA) Water Assessment

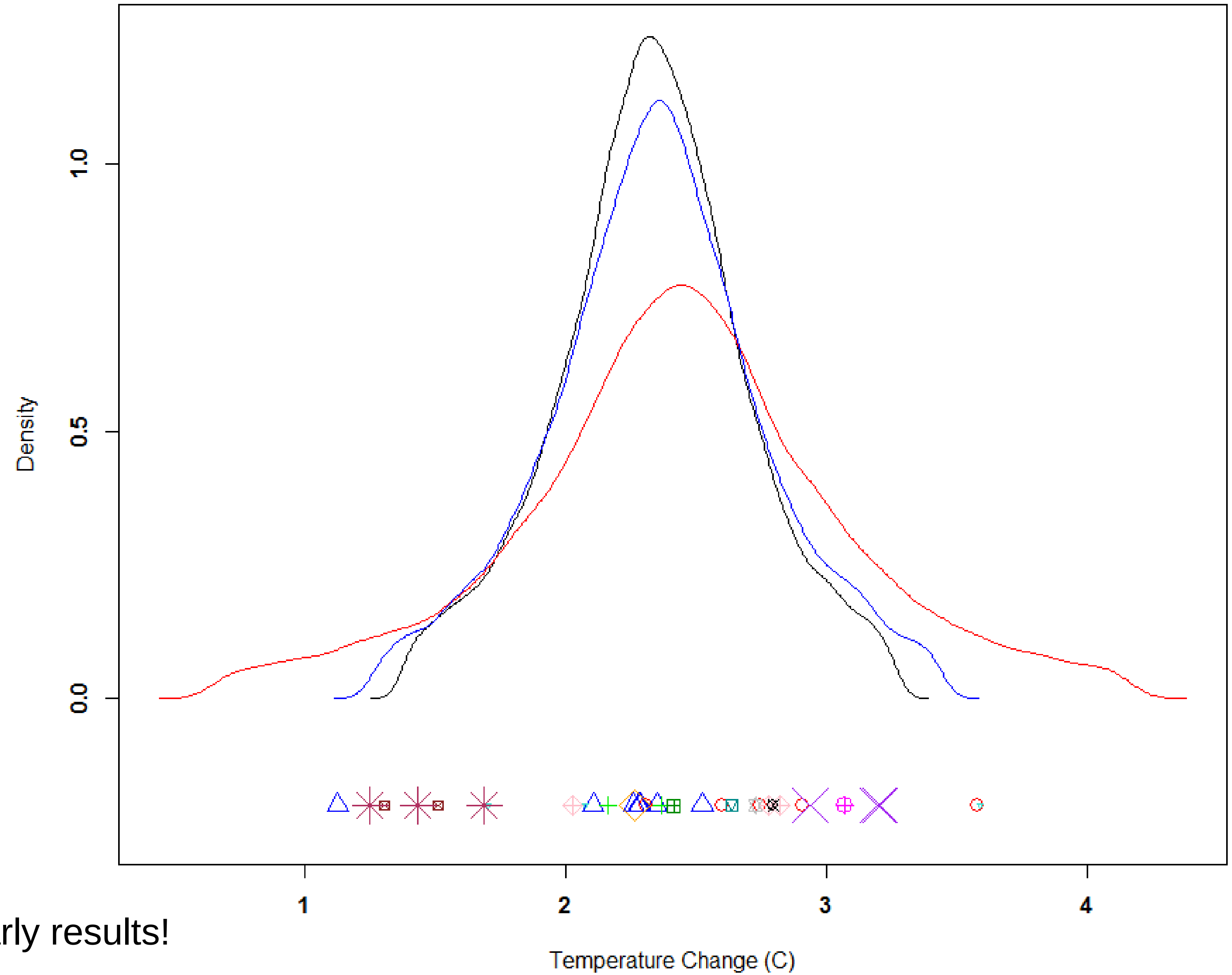


Family Tree of GCMs



Knutti et al., 2013

Non-independent models implies greater risk!



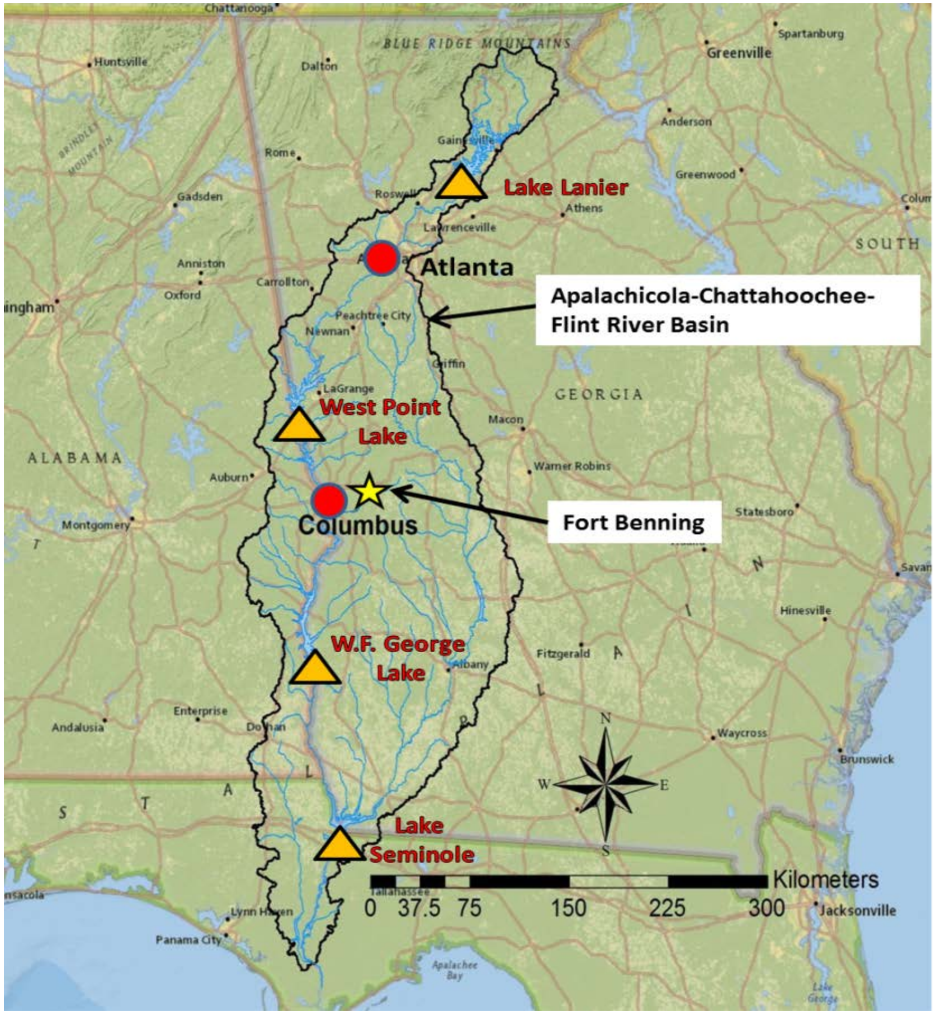
Early results!

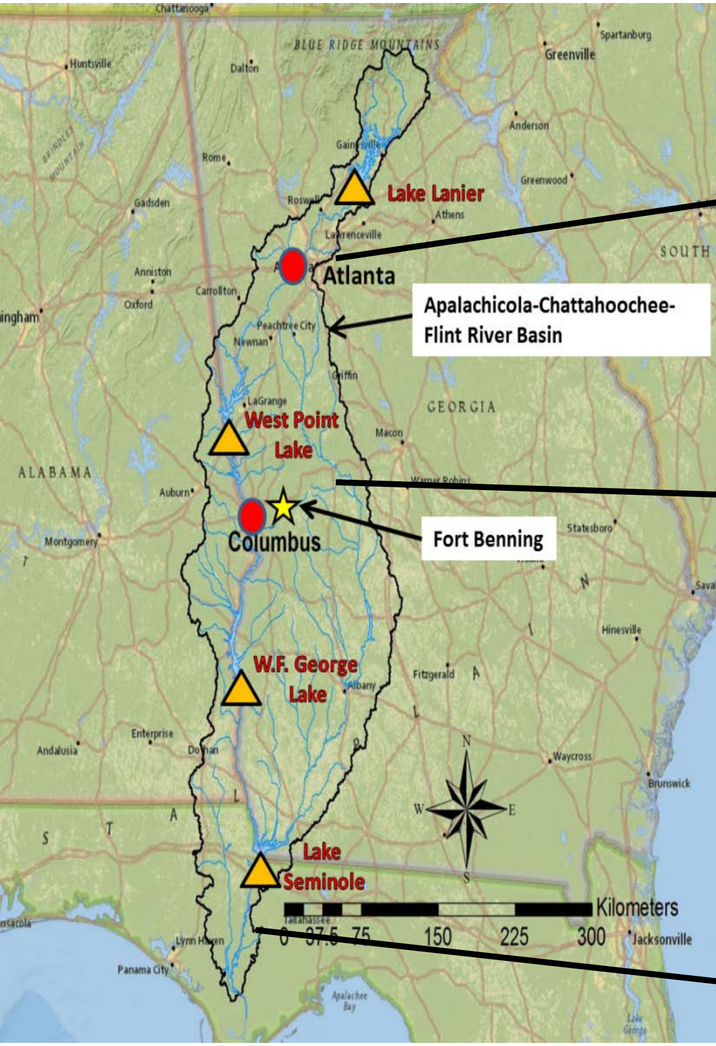
Water Supply for Ft. Benning, Georgia

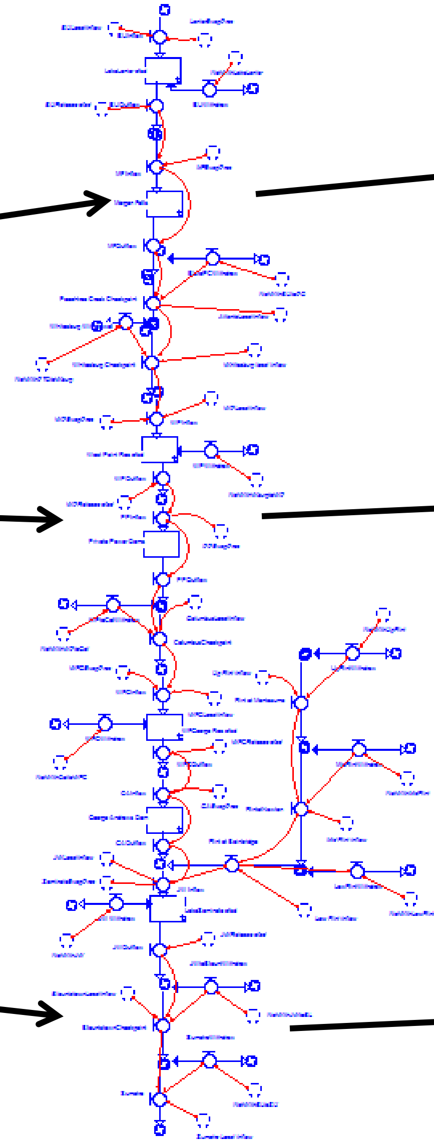
Major Facilities
(U.S. Army Corps of Engineers)
1. Lake Lanier
2. West Point Lake
3. W.F. George Lake
4. Lake Seminole

Objectives:
1. Water Supply
2. Flood Risk Reduction
3. Low Flow Augmentation

Serving Utility:
Columbus Water Works
(Lake Oliver)







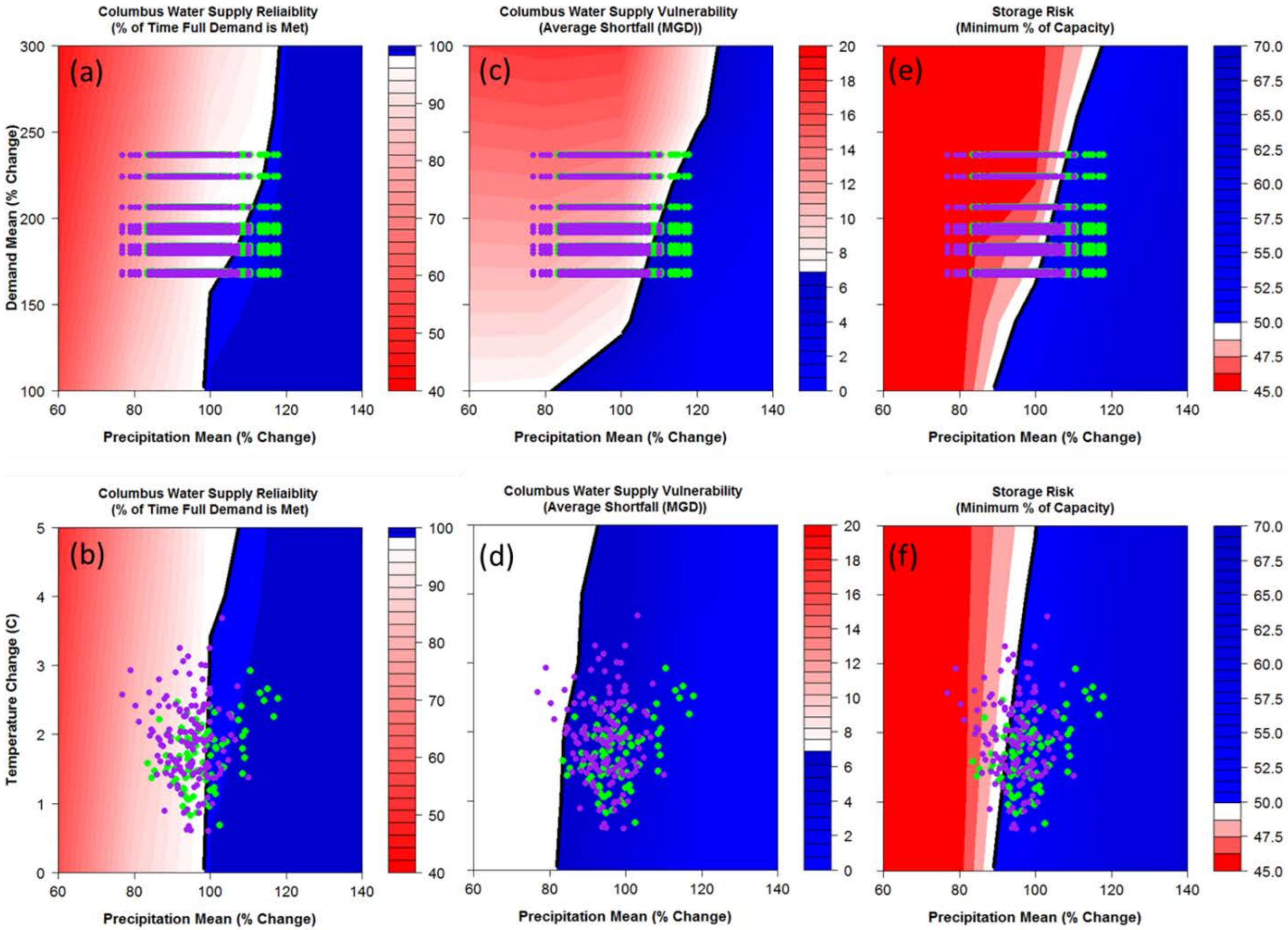
OBJECTIVES

Atlanta Water Supply

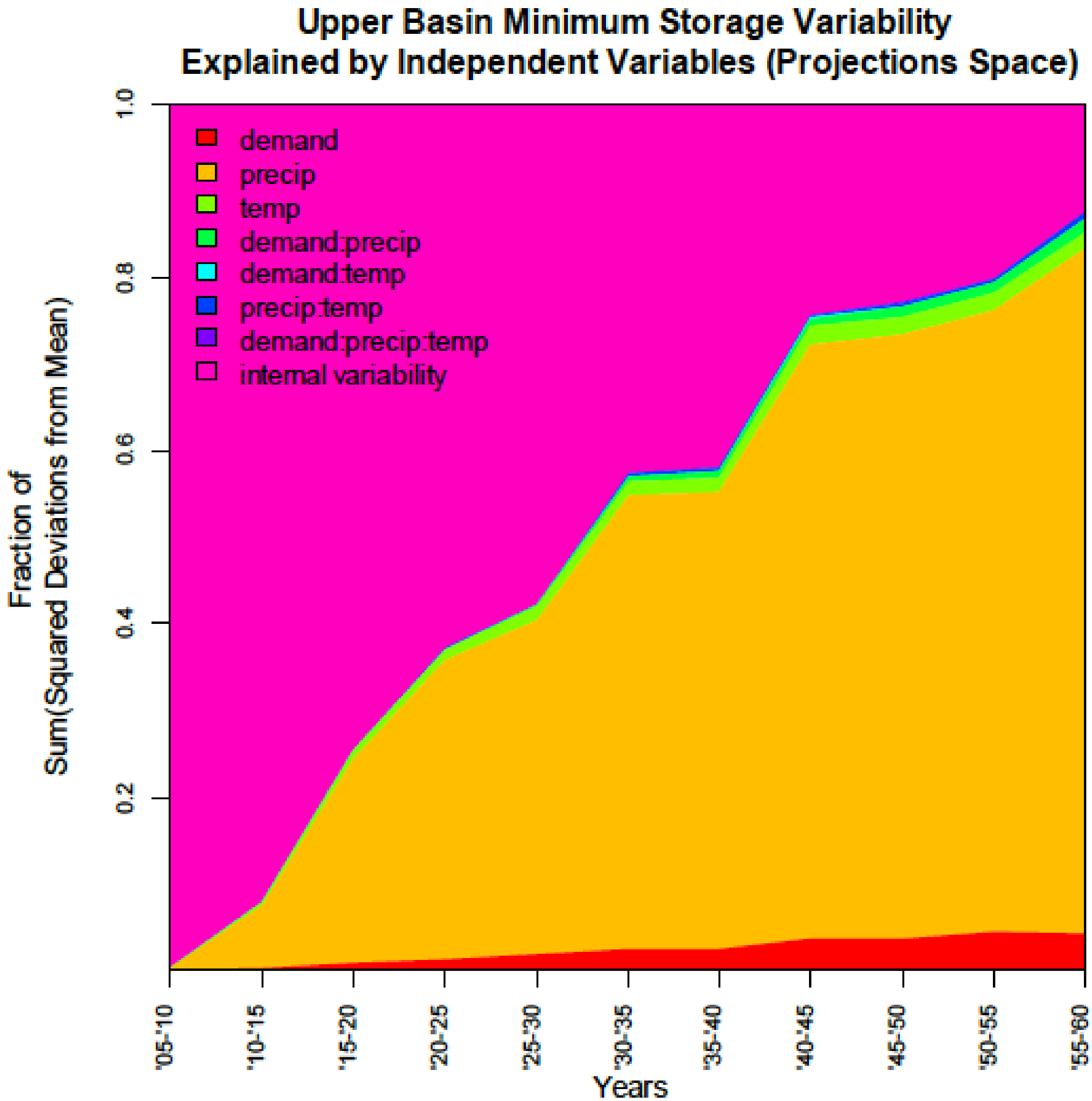
Columbus (Ft. Hood) Water Supply

Navigation/ Environmental Flows to Florida

ACF Climate Risk Assessment



Attribution of Risk/Uncertainty



EVALUATING ADAPTATION ALTERNATIVES

Fort Hood: Water Supply and Flood Risk

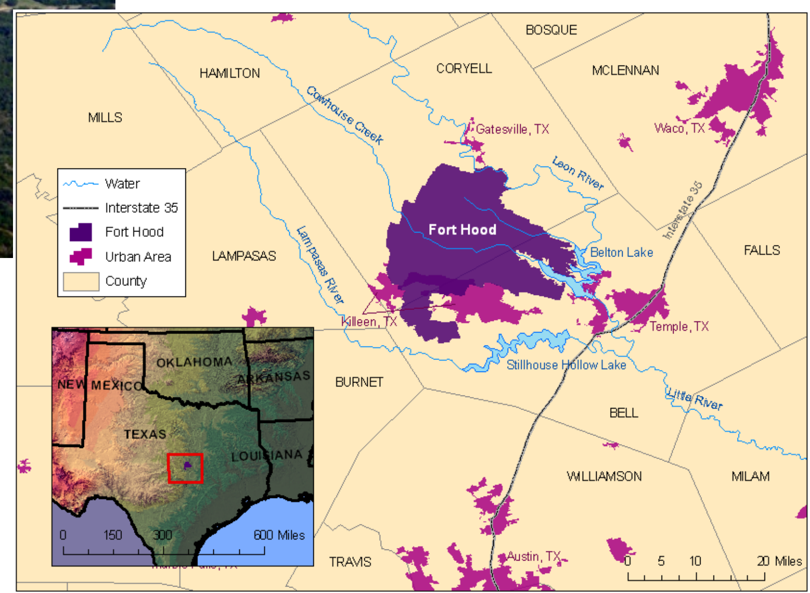
<u>Lake Belton Facts</u>

Capacity: 1,357 MCM

~60% Flood Storage

~40% Water Supply

Drainage: 9,220 km^2



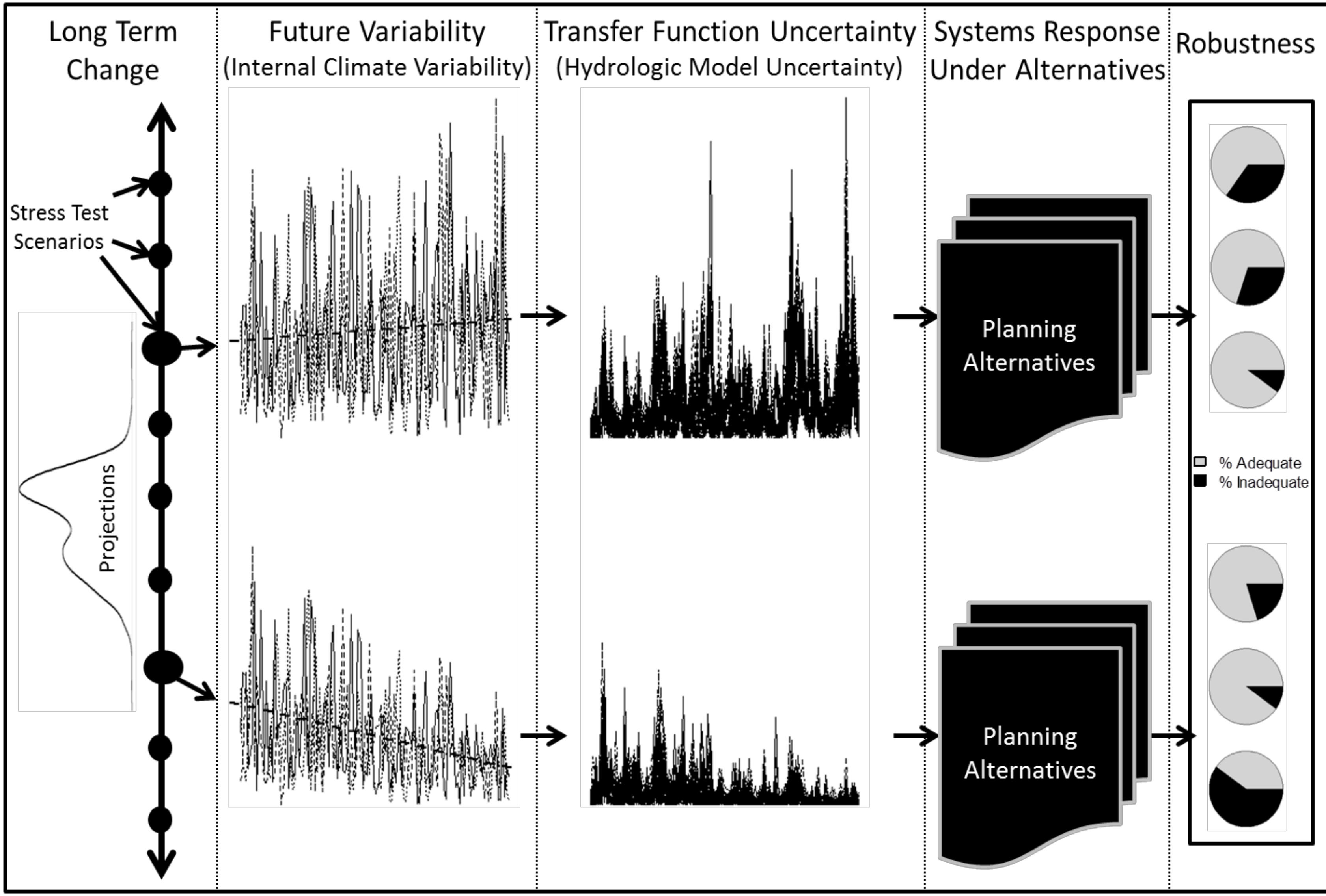
Performance Metrics

Objective	Metric	Threshold of Acceptable Performance	Threshold of Robustness Across Hydrologic Uncertainty and Internal Climate Variability
Flood Risk Reduction	**Frequency of Reservoir Spills**	**1 in every 50 years**	**90%**
Water Supply Security	**Frequency of Drought Warning**	**1 in every 10 years**	**90%**
	Minimum Storage	**Drought Emergency Storage (~175,000 af)**	**90%**

Low Regrets Adaptation: Storage Reallocation

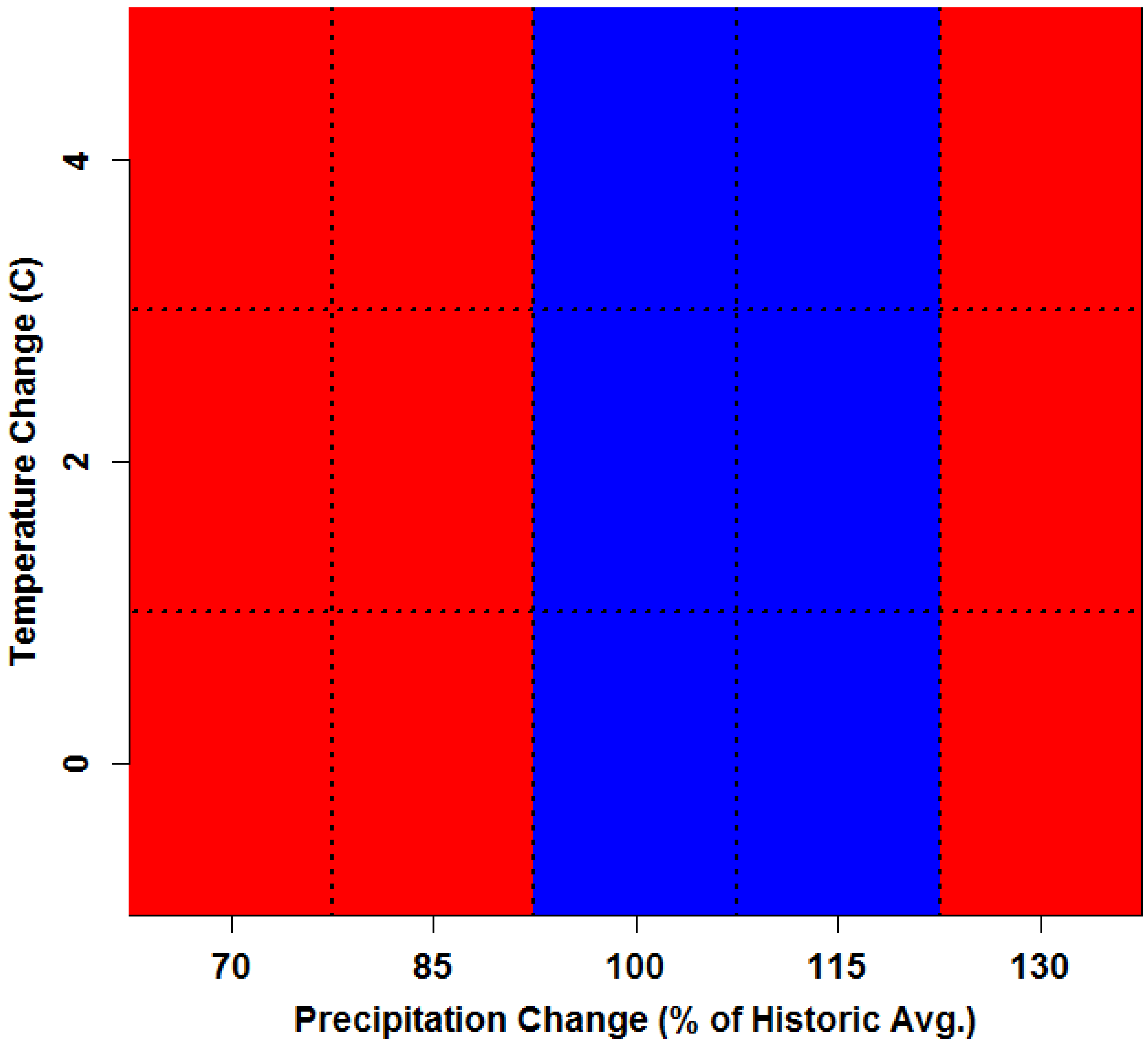
- *Can climate change impacts be mitigated by increasing the conservation pool?*

Alternative	Conservation Pool Elevation (meters above mean sea level)	Water Supply Storage (MCM)	Percent of Total Capacity (%)
Current	181.1	537	40
Alternative 1	181.7	568	42
Alternative 2	182.3	598	44
Alternative 3	182.6	615	45
Alternative 4	184.7	739	54

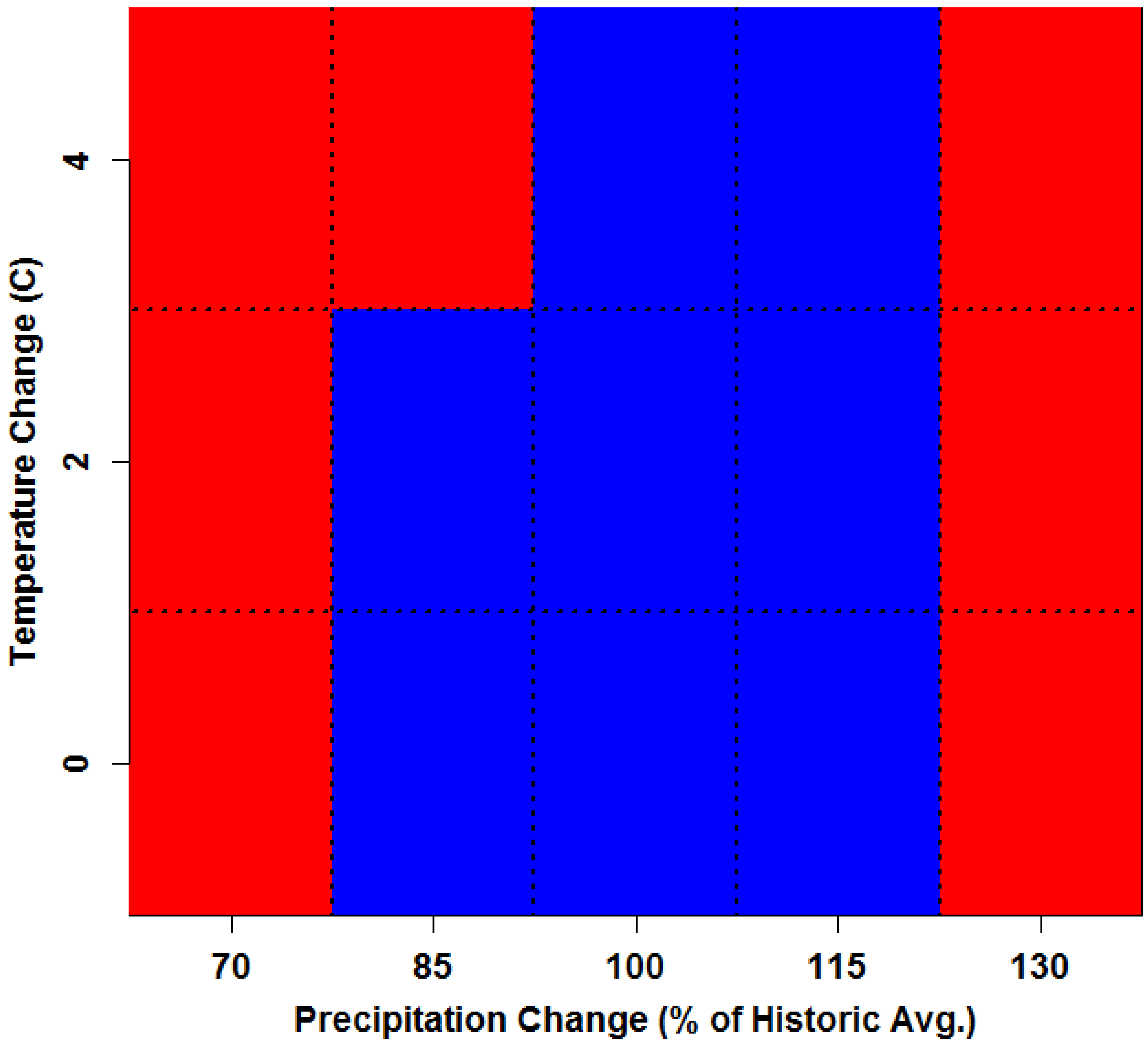


Long Term Change
Future Variability
(Internal Climate Variability)
Transfer Function Uncertainty
(Hydrologic Model Uncertainty)
Systems Response Under Alternatives
Robustness
Stress Test Scenarios
Projections
Planning Alternatives
Planning Alternatives
% Adequate
% Inadequate

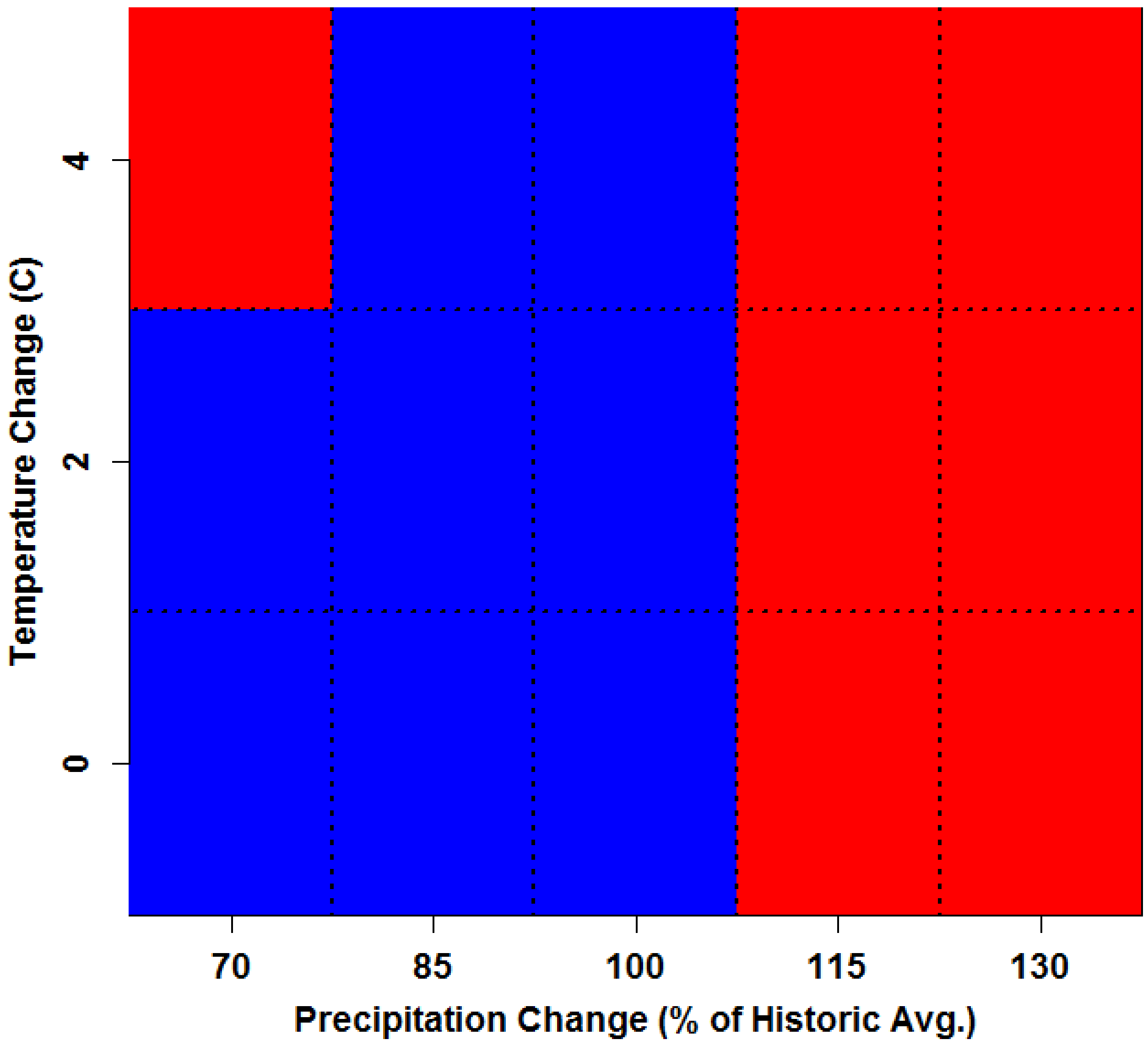
Existing Conservation Pool – Robust Performance



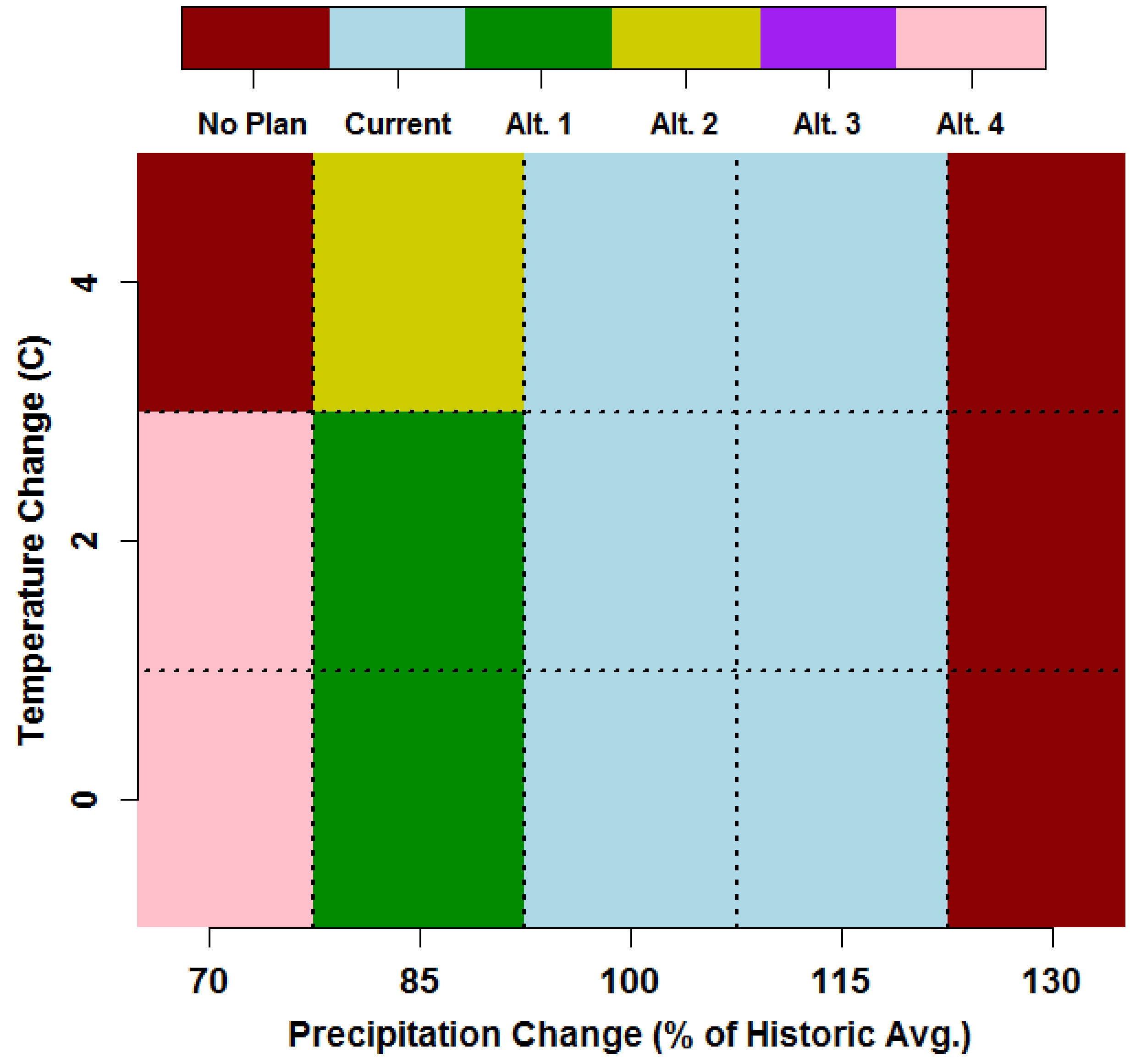
Alternative 1



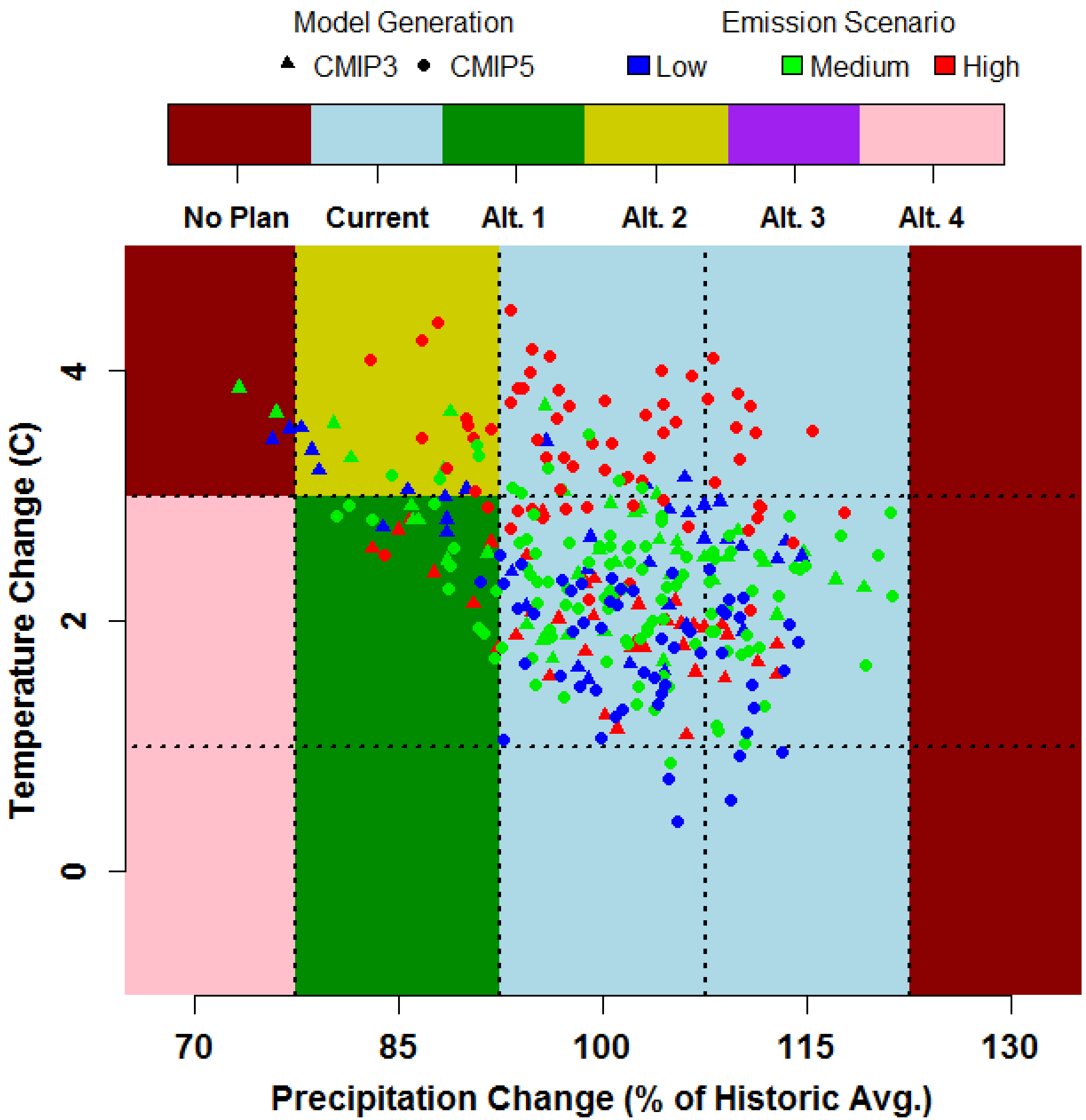
Alternative 4



Best Performing Alternatives for given climate change



Best Performing Alternatives for given climate change



Summary

- Inherent, irreducible uncertainties of climate system
  - Requires a shift of emphasis from “reduce uncertainty” to manage uncertainty
  - GCM projections are an inefficient tool for exploring vulnerability

- Decision-Scaling links bottom-up and top-down approaches
  - First, detects the climate vulnerabilities of the system through systematic sampling of plausible climate change space (projections not needed)
  - Incorporates stakeholder input and vulnerability thresholds
  - Reveals the key climate variables that the system is sensitive to, and the magnitude of climate changes that cause unacceptable outcomes
  - Allows the climate science investigation to focus on priorities revealed through the analysis

Further Reading

- Brown, C. and R. L. Wilby (2012), An alternate approach to assessing climate risks, *Eos Trans. AGU*, 93(41), 401, doi:10.1029/2012EO410001.
- Moody, P. and C. Brown (2012), Modeling stakeholder-defined climate risk on the Upper Great Lakes, *Water Resources Research*, 48, W10524, doi:10.1029/2012WR012497.
- Brown, C., Y. Ghile, M. A. Laverty, and K. Li (2012), Decision scaling: Linking bottom-up vulnerability analysis with climate projections in the water sector, *Water Resour. Res.*, doi:10.1029/2011WR011212.
- Brown, C., Werick, W., Fay, D., and Leger, W. (2011) "A Decision Analytic Approach to Managing Climate Risks - Application to the Upper Great Lakes" Journal of the American Water Resources Association, 47, 3, doi/10.1111/j.1752-1688.2011.00552.x.
- Hallegatte, S., Shah, A., Lempert, R., Brown, C., and S. Gill (2012) "Investment Decision Making under Deep Uncertainty: Application to Climate Change. World Bank Policy Research Working Paper #6193.
- Brown, C. (2011) "Decision-scaling for robust planning and policy under climate uncertainty." World Resources Report, Washington DC. Available online at http://www.worldresourcesreport.org