Considerations for the Design and Use of Scenarios that Inform Robust Decisions

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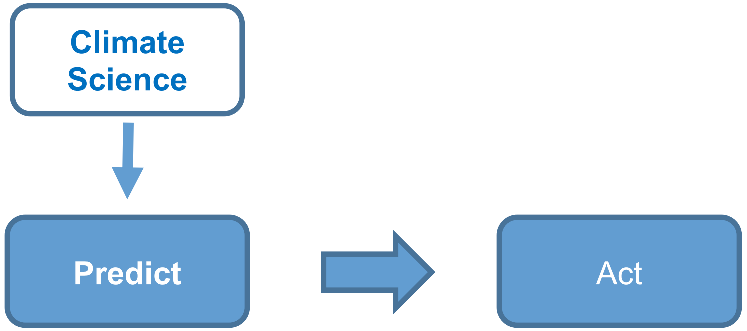
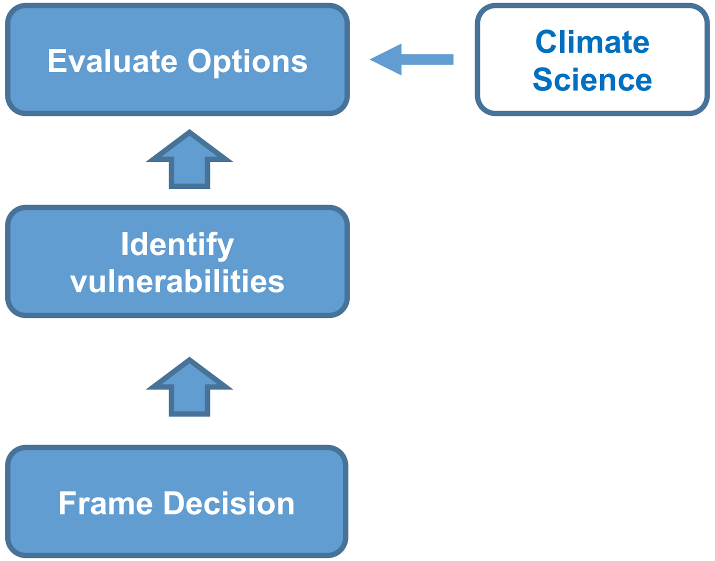
Photo: Salinas Valley, California

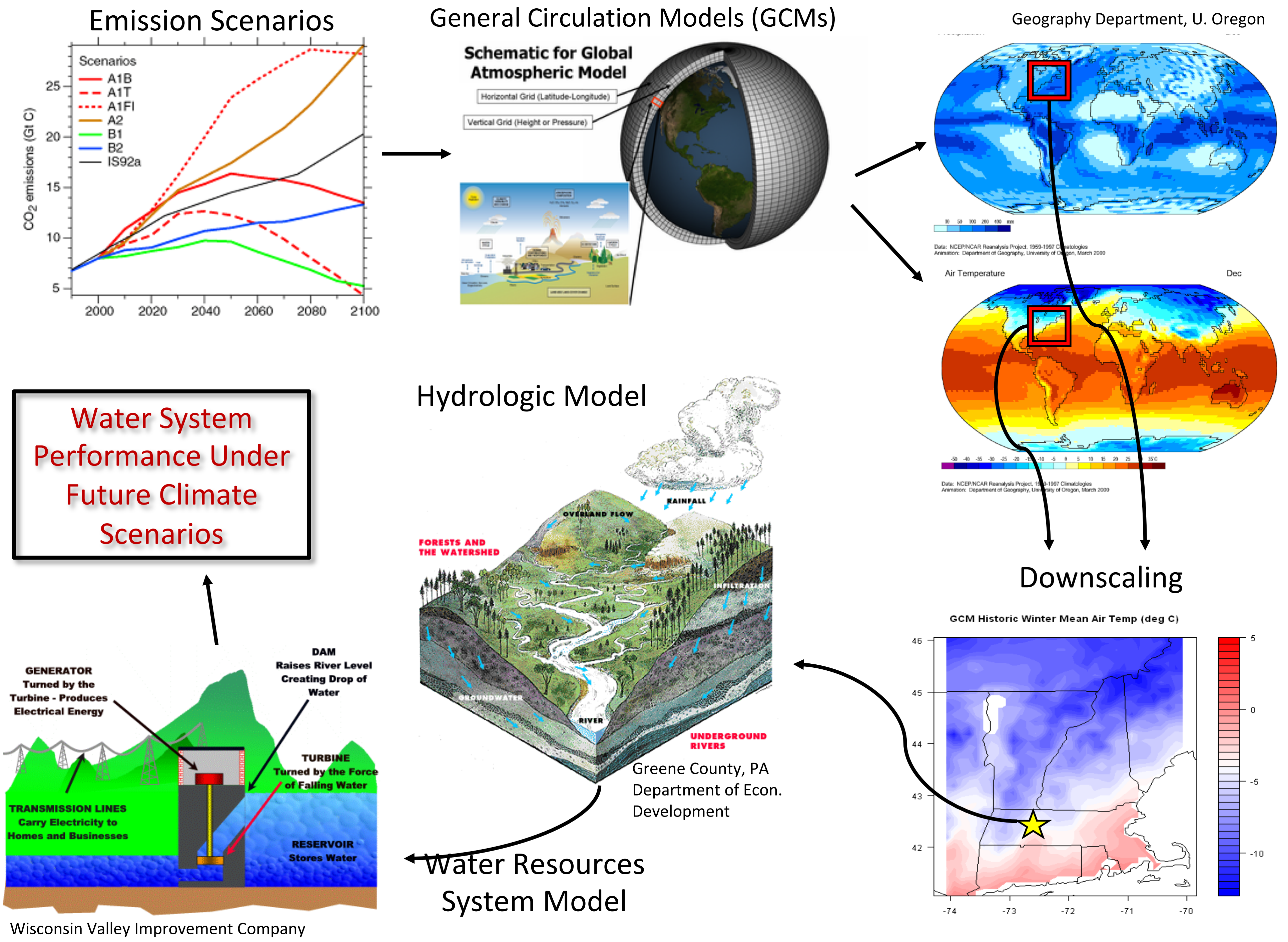
How does Climate Science Inform Decisions?

Common Decision Model



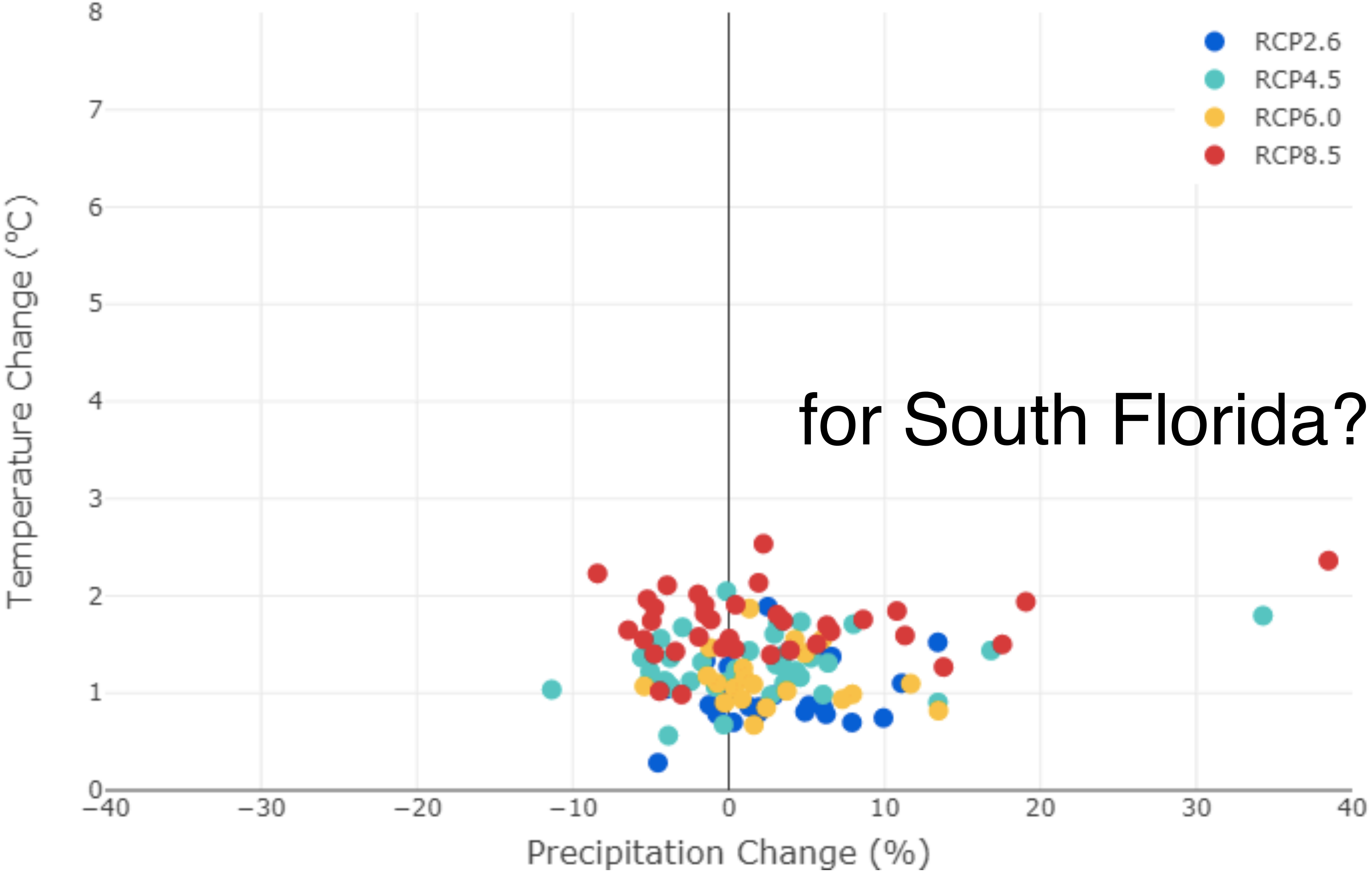
Decision Making under Deep Uncertainty





Emission Scenarios
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a
CO_2 emissions (Gt C)
25
20
15
10
5
2000
2020
2040
2060
2080
2100
General Circulation Models (GCMs)
Schematic for Global Atmospheric Model
Horizontal Grid (Latitude-Longitude)
Vertical Grid (Height or Pressure)
Geography Department, U. Oregon
Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000
Air Temperature
Dec
Downscaling
GCM Historic Winter Mean Air Temp (deg C)
Hydrologic Model
RAINFALL
OVERLAND FLOW
FORESTS AND THE WATERSHED
INFILTRATION
GROUNDWATER
RIVER
UNDERGROUND RIVERS
Greene County, PA Department of Econ. Development
Water System Performance Under Future Climate Scenarios
GENERATOR Turned by the Turbine - Produces Electrical Energy
DAM Raises River Level Creating Drop of Water
TURBINE Turned by the Force of Falling Water
TRANSMISSION LINES Carry Electricity to Homes and Businesses
RESERVOIR Stores Water
Wisconsin Valley Improvement Company
Water Resources System Model

How to Use GCM Projections



for South Florida?

The Climate Scenario Dilemma

- GCM scenarios explore forcing uncertainty; not designed to explore adaptation uncertainty
- Thus, GCM scenarios are neither true scenario analysis nor predictions
- How would you design a risk assessment process if you started from a blank slate?

Mitigation-oriented climate science

Meet

Adaptation Decision Making

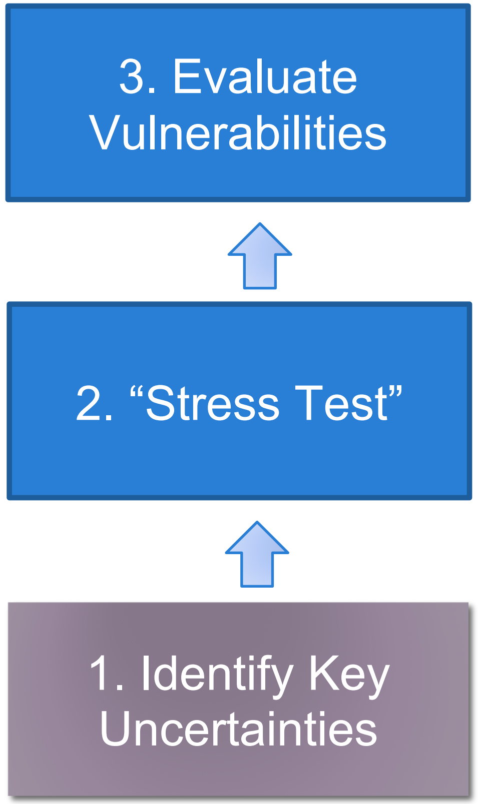
A Climate Informed Decision Analysis

To provide clear guidance for addressing climate change in planning and operations using the best available science and stakeholder inputs

Approach:

- ***Adopt "scenario neutral" approach within decision analytic framework***
- ***Stress test – multidimensional sensitivity analysis reveals vulnerabilities and comparative advantage of alternatives***
- ***Climate projections enters at end of analysis, to prioritize responses or evaluate best alternatives***

<u>*Decision Scaling*</u>



Define uncertain factors that can affect the system

Brown and Wilby, *EOS*, 2012; Brown et al., *WRR*, 2012, Poff et al., 2015 *Nature Climate Change*

Decision Scaling

3. Evaluate Vulnerabilities

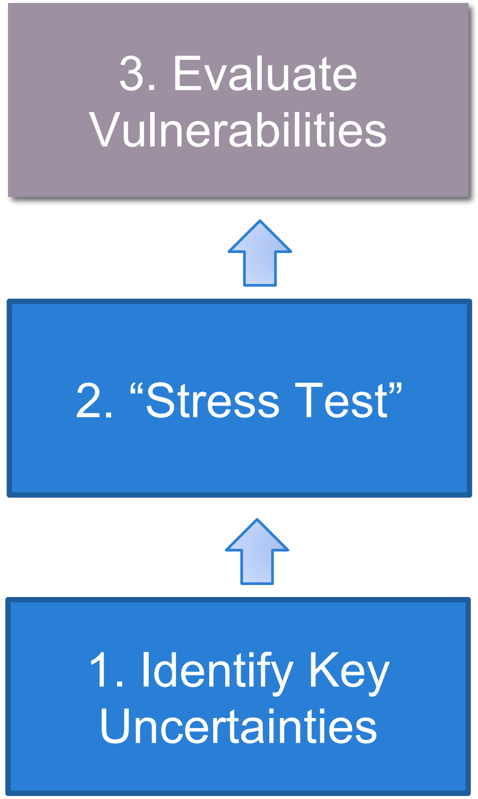
2. "Stress Test"

1. Identify Key Uncertainties

Systematic perturbation to characterize response of the system

Brown and Wilby, *EOS*, 2012; Brown et al., *WRR*, 2012, Poff et al., 2015 *Nature Climate Change*

Decision Scaling



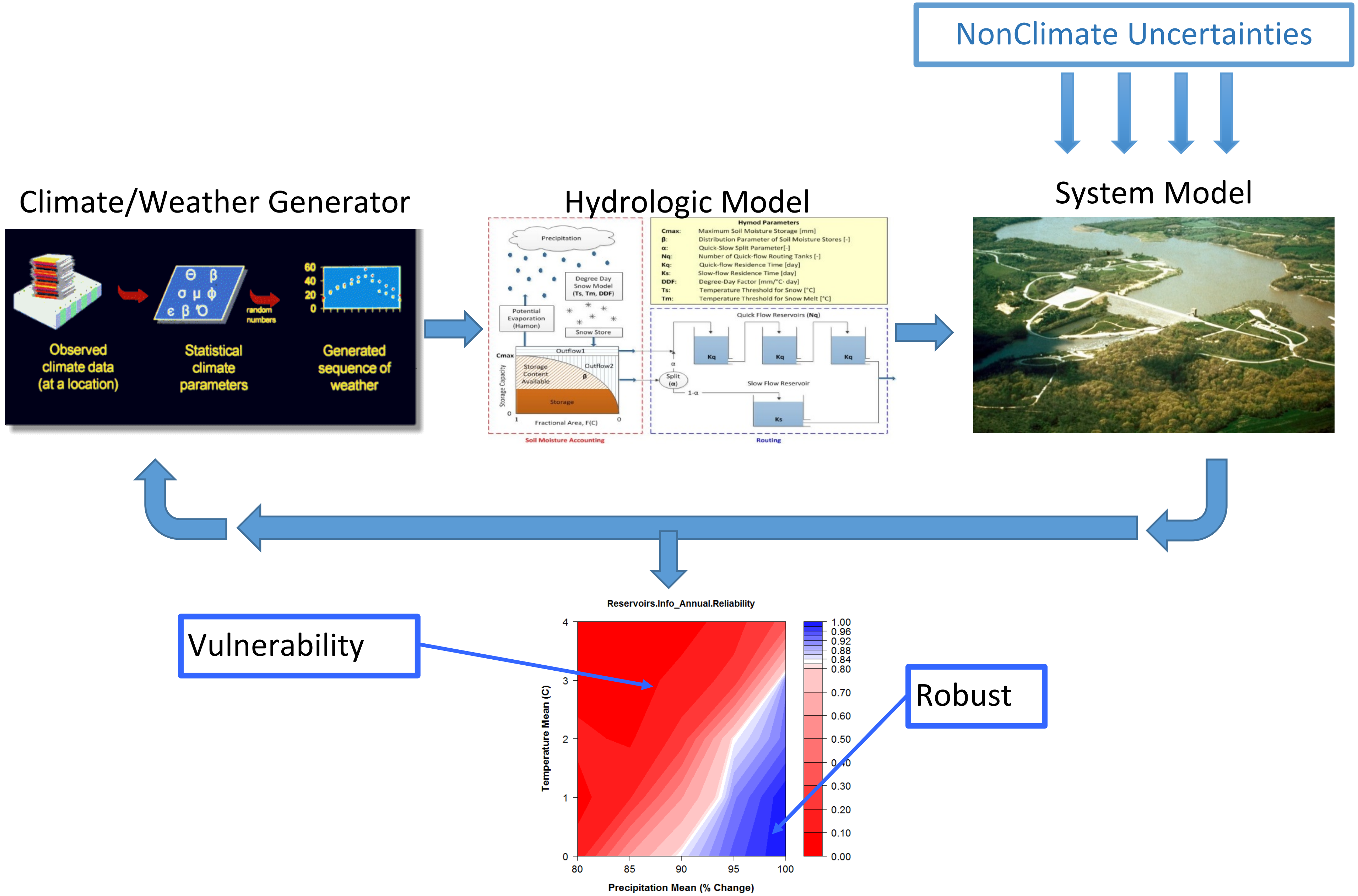
Data mining to extract scenarios for further analysis. Climate projections inform vulnerabilities

Brown and Wilby, *EOS*, 2012; Brown et al., *WRR*, 2012, Poff et al., 2015 *Nature Climate Change*

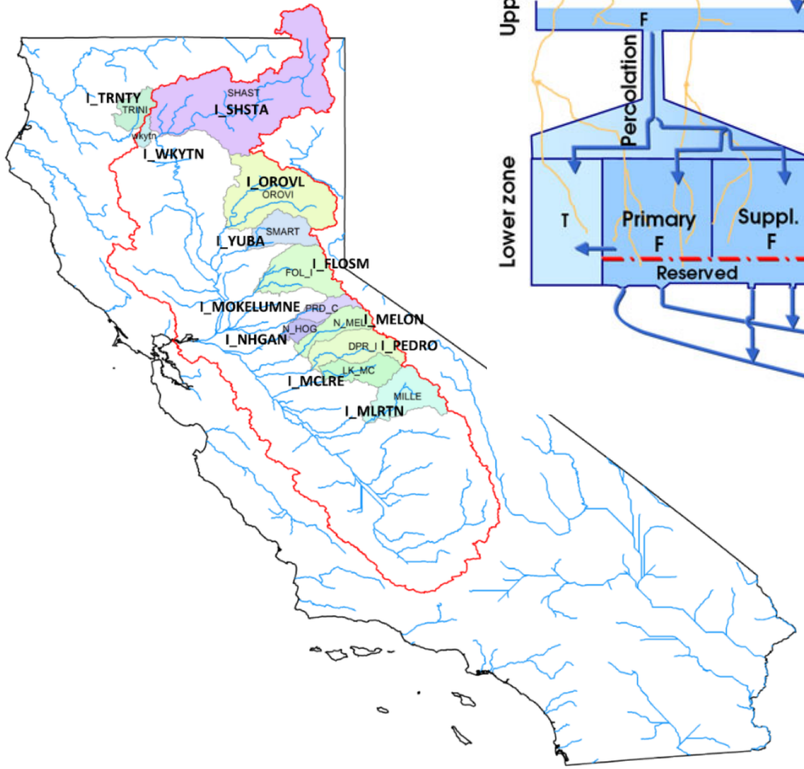
1. Frame the Analysis for Actionable Science

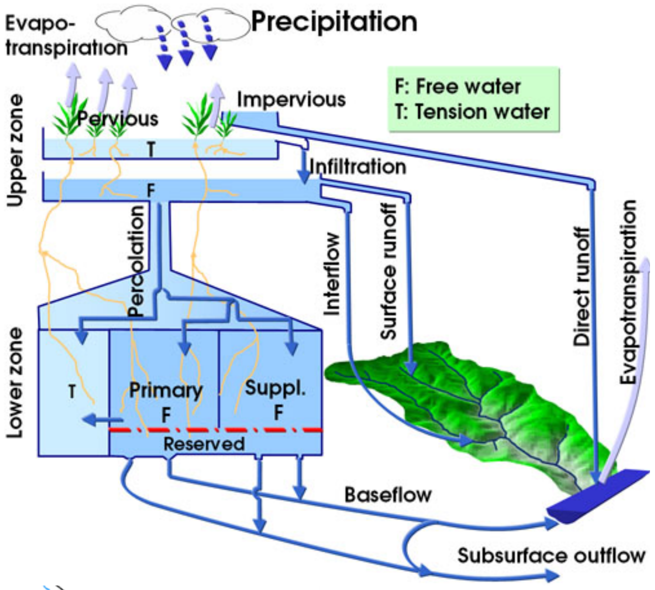
unCertainties Things that we cannot control but affect the ability to meet objectives	**Consequences** How we measure success and failure
Connections The definition of the system, formalized as a model	**Choices** Policies, infrastructure, social consciousness

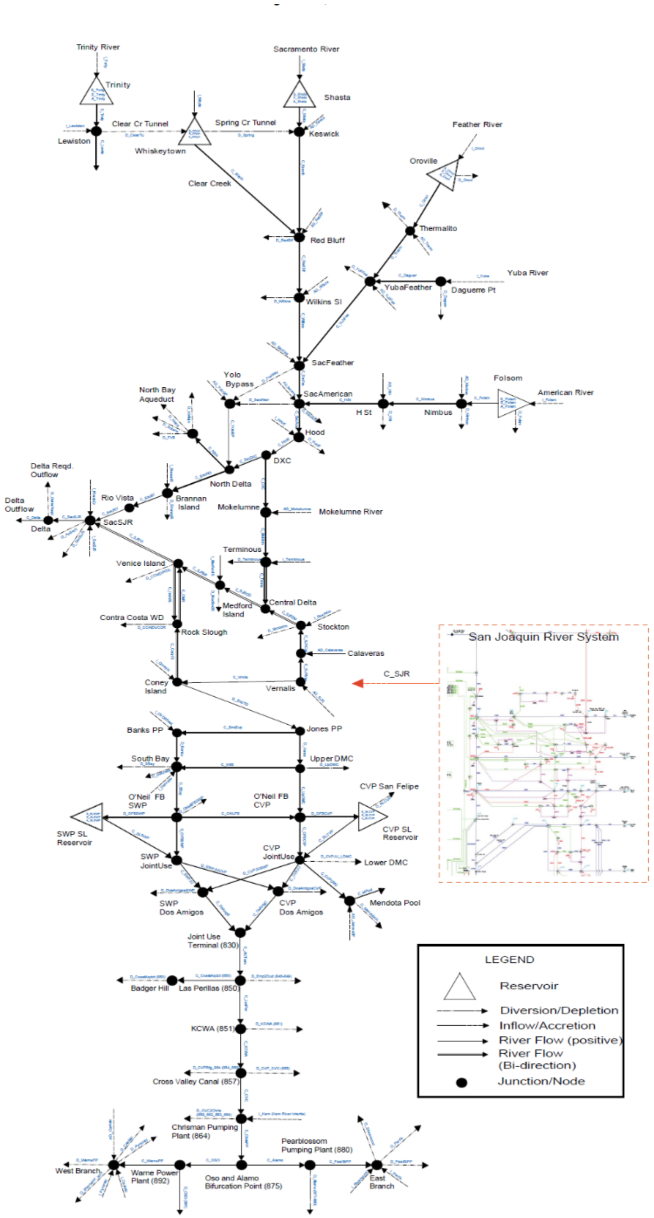
2. Stress Test to define system response

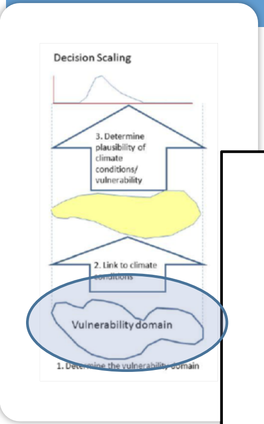


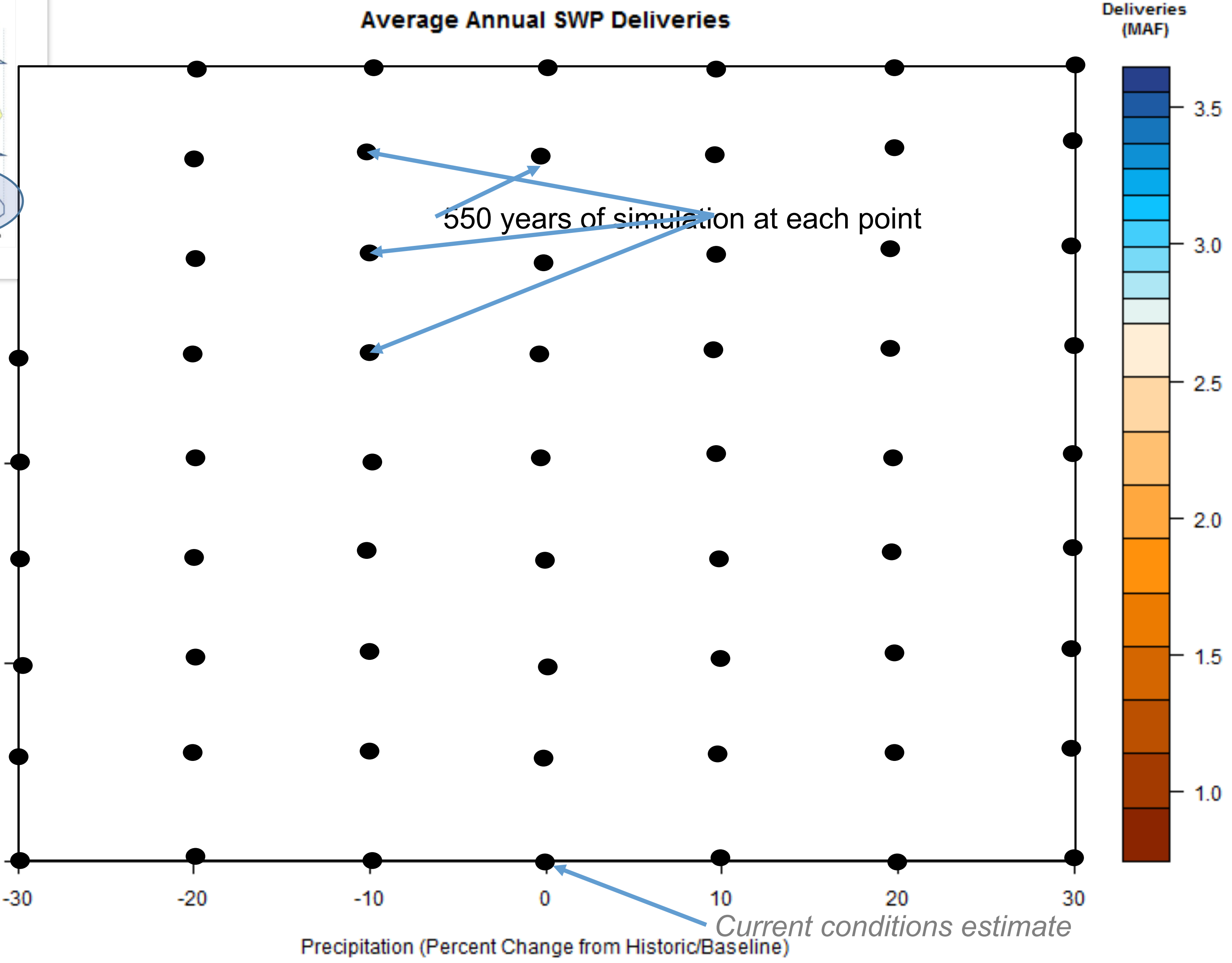
Climate Vulnerability Assessment:
California DWR



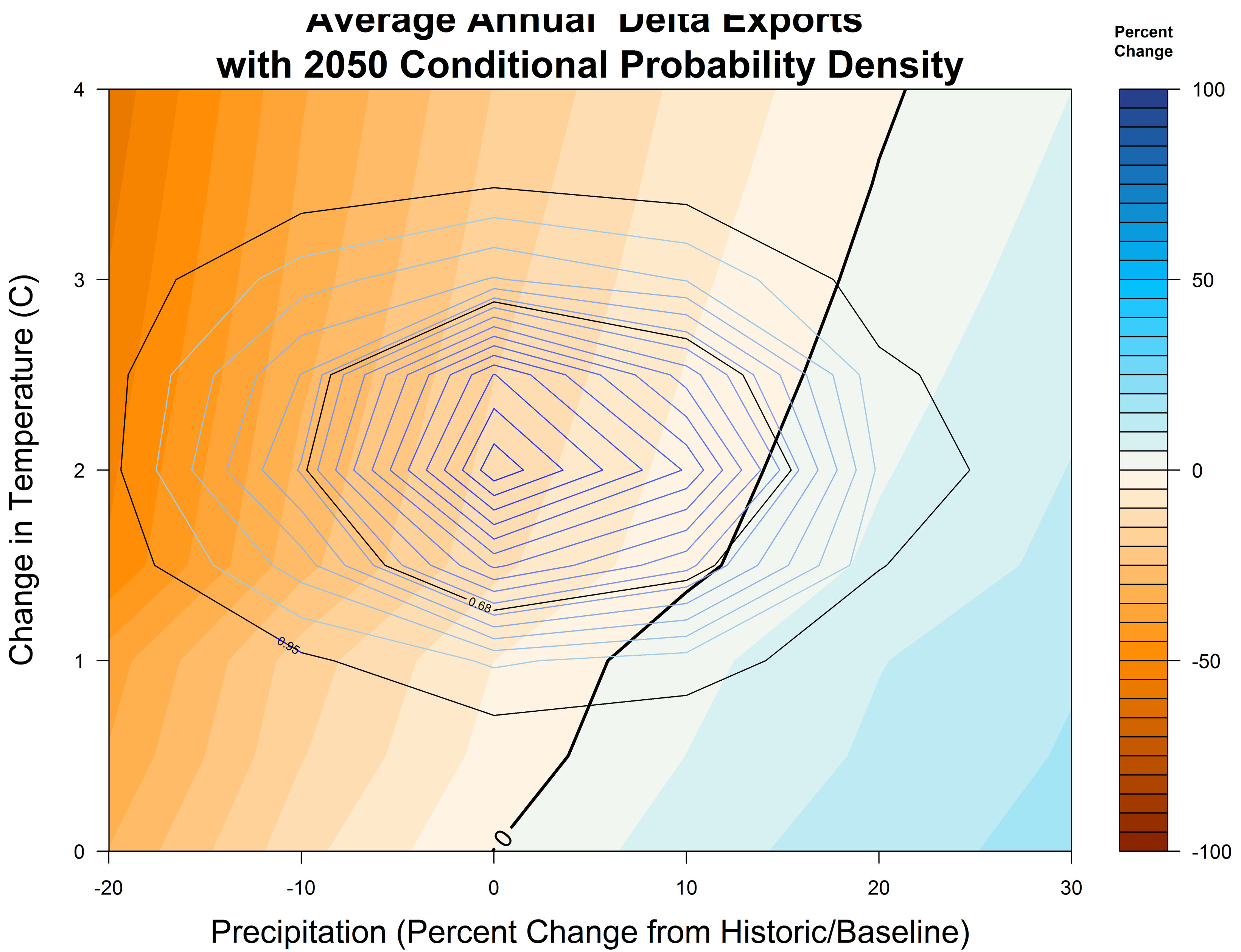




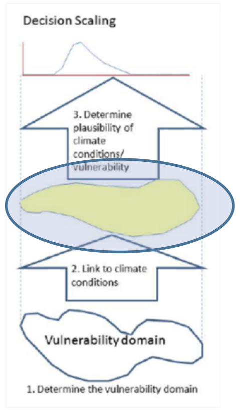

Decision Scaling
3. Determine plausibility of climate conditions/ vulnerability
2. Link to climate conditions
Vulnerability domain

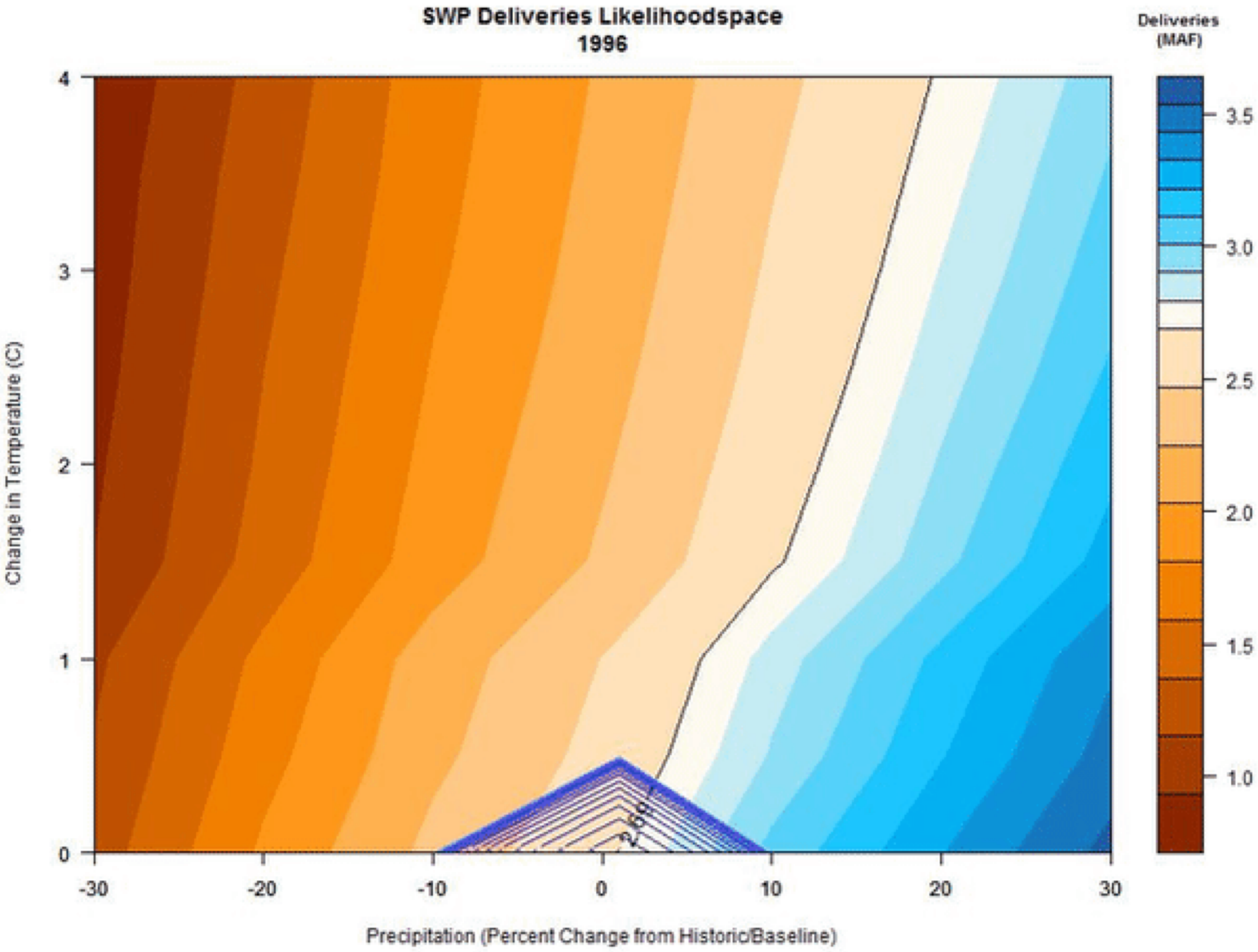

Average Annual SWP Deliveries
Deliveries (MAF)
550 years of simulation at each point
Change in Temperature (C)
Precipitation (Percent Change from Historic/Baseline)
Current conditions estimate
0
1
2
-30
-20
-10
0
10
20
30
3.5
3.0
2.5
2.0
1.5
1.0

3. Climate Projects define level of concern (risk)



Identify Vulnerability Space





Examples

Climate Change Guidance Framework

Informed Decision Making for Transboundary Waters

Alec Bernstein, Casey Brown

LCRR Climate Change Workshop

Montreal, QC

March 19, 2019

UMASS AMHERST

Hydrosystems Group

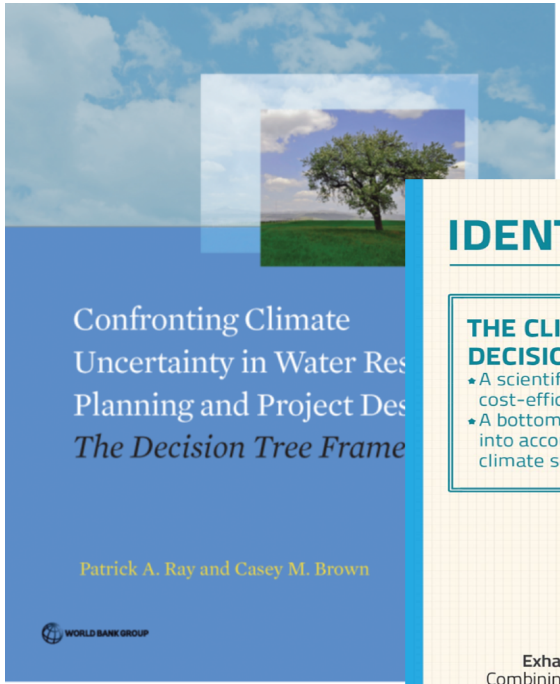
Decision Scaling Climate Vulnerability Assessment for the California Department of Water Resources Final Report

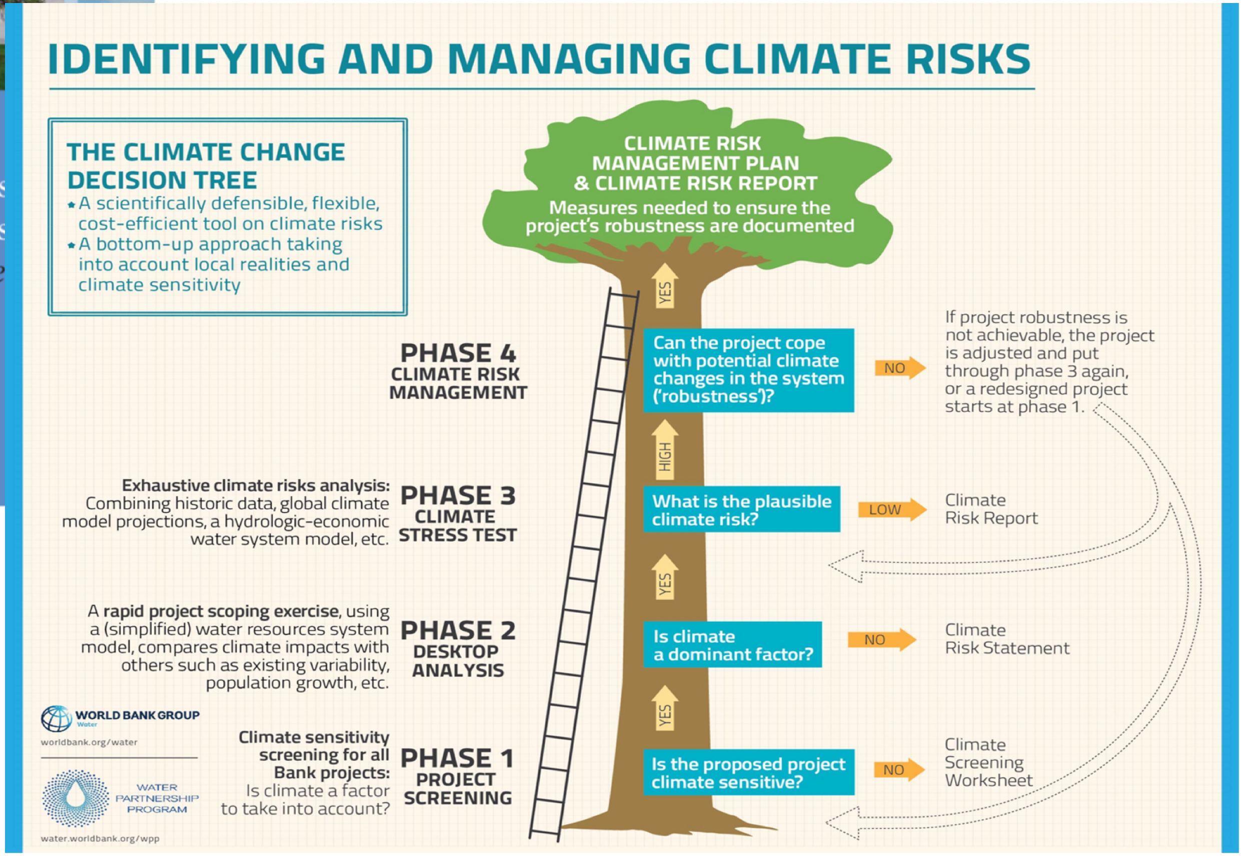
A Collaborative Study of the Hydrosystems Research Group, University of Massachusetts, Amherst and the California Department of Water Resources

"Snow White Mountains and Blue Watershed," Dr. Qinqin Liu, DWR Climate Change Program, 2017

May 2019

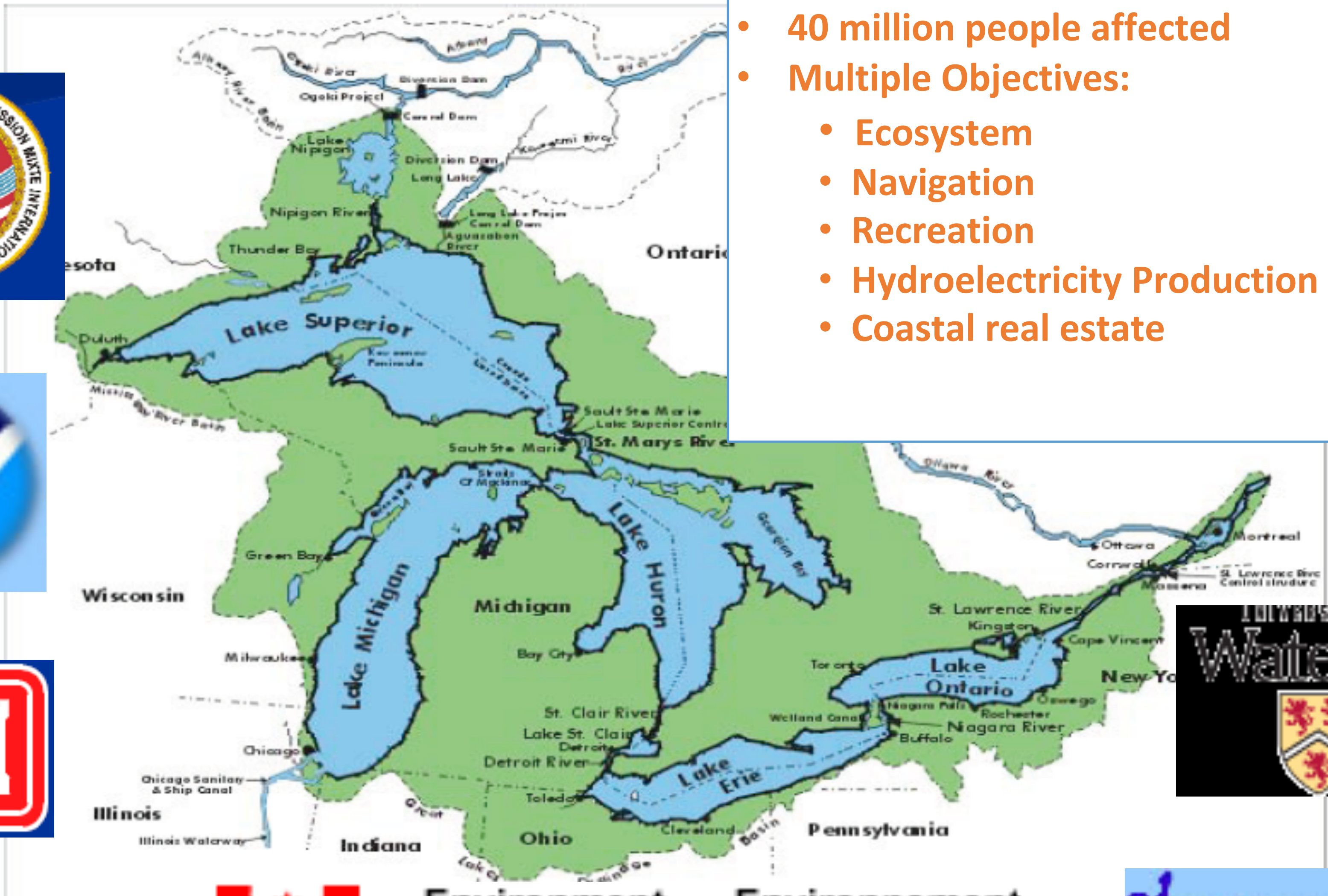
World Bank Water Global Practice





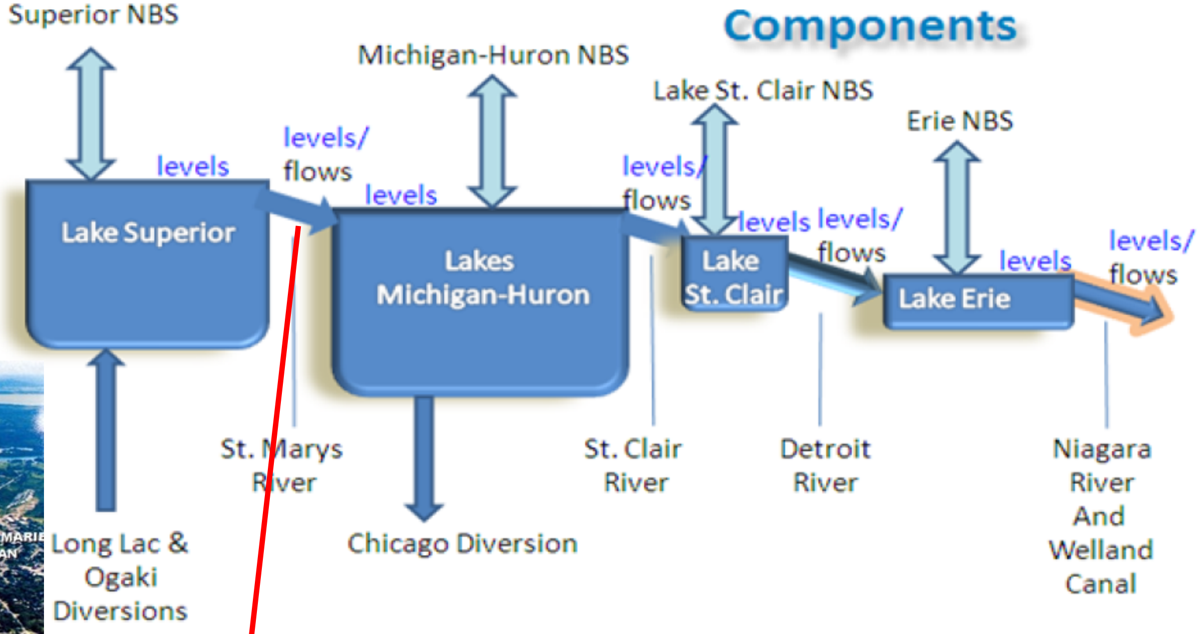
International Upper Great Lakes Study

- **20% of world's freshwater**
- **40 million people affected**
- **Multiple Objectives:**
  - **Ecosystem**
  - **Navigation**
  - **Recreation**
  - **Hydroelectricity Production**
  - **Coastal real estate**



Environment Canada
Environnement Canada

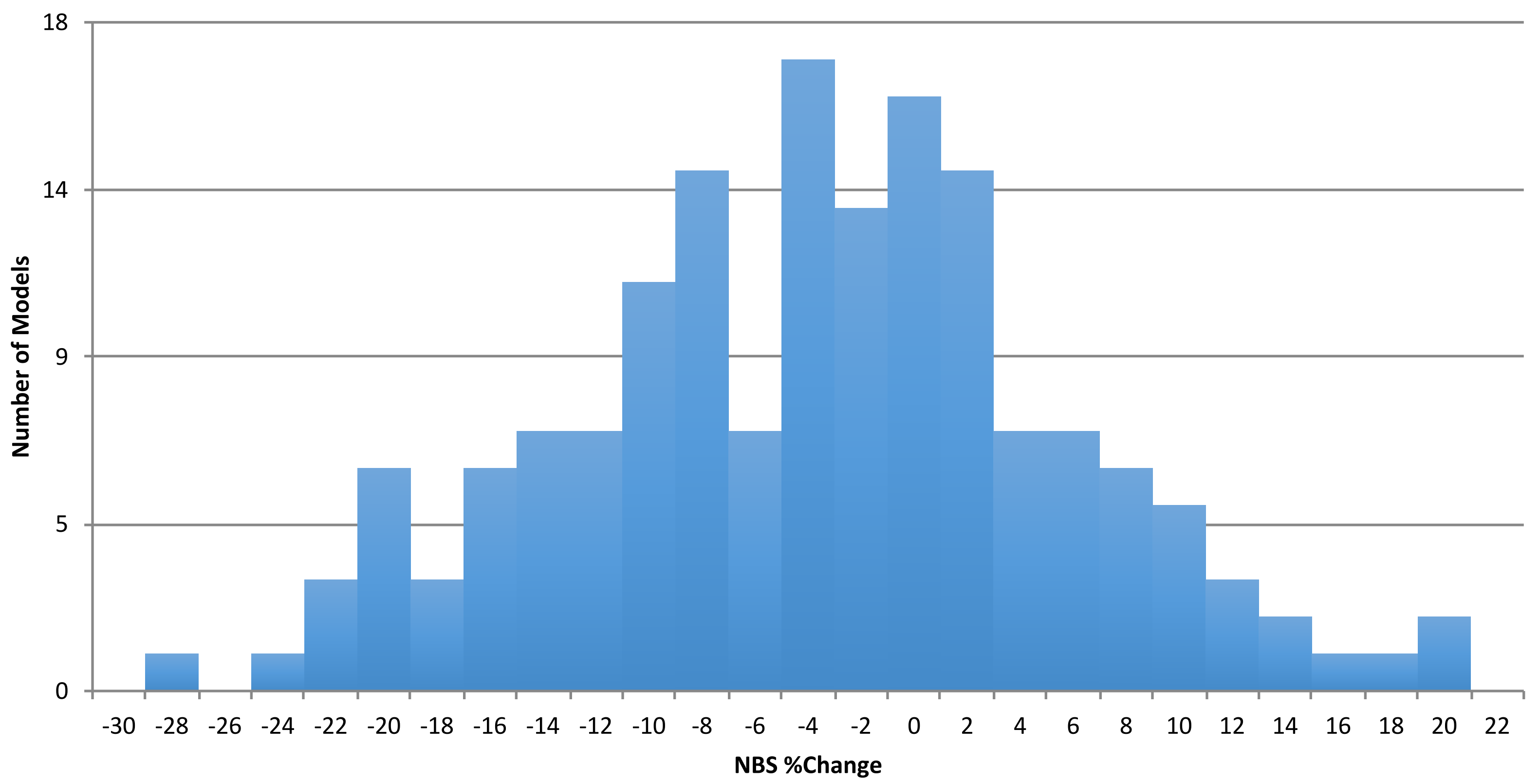
Great Lakes “System”



Overview of Soo Locks complex looking downbound toward Lake Huron.

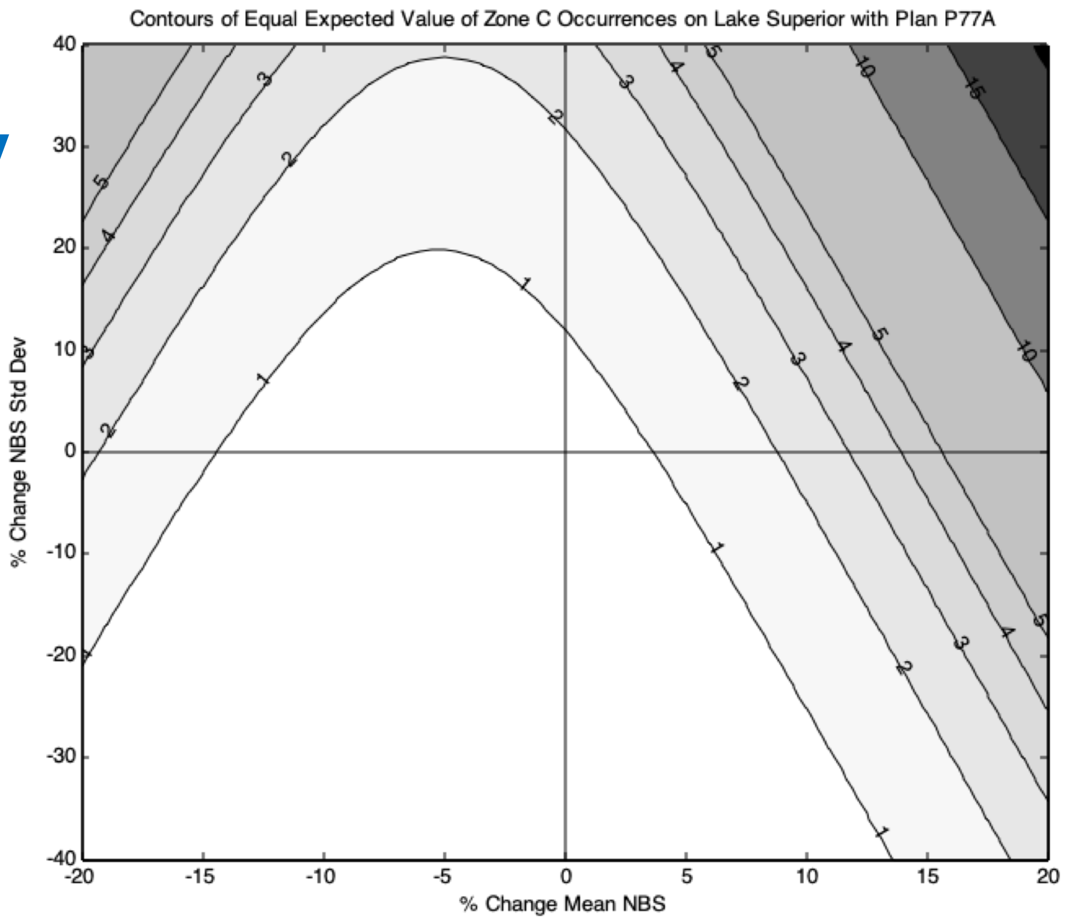
http://mff.dsisd.net

Climate Change Projections of Net Basin Supply - Lake Superior, 2050



Contours of "Robustness" to a Given Level of Hazard (Historical = 1)

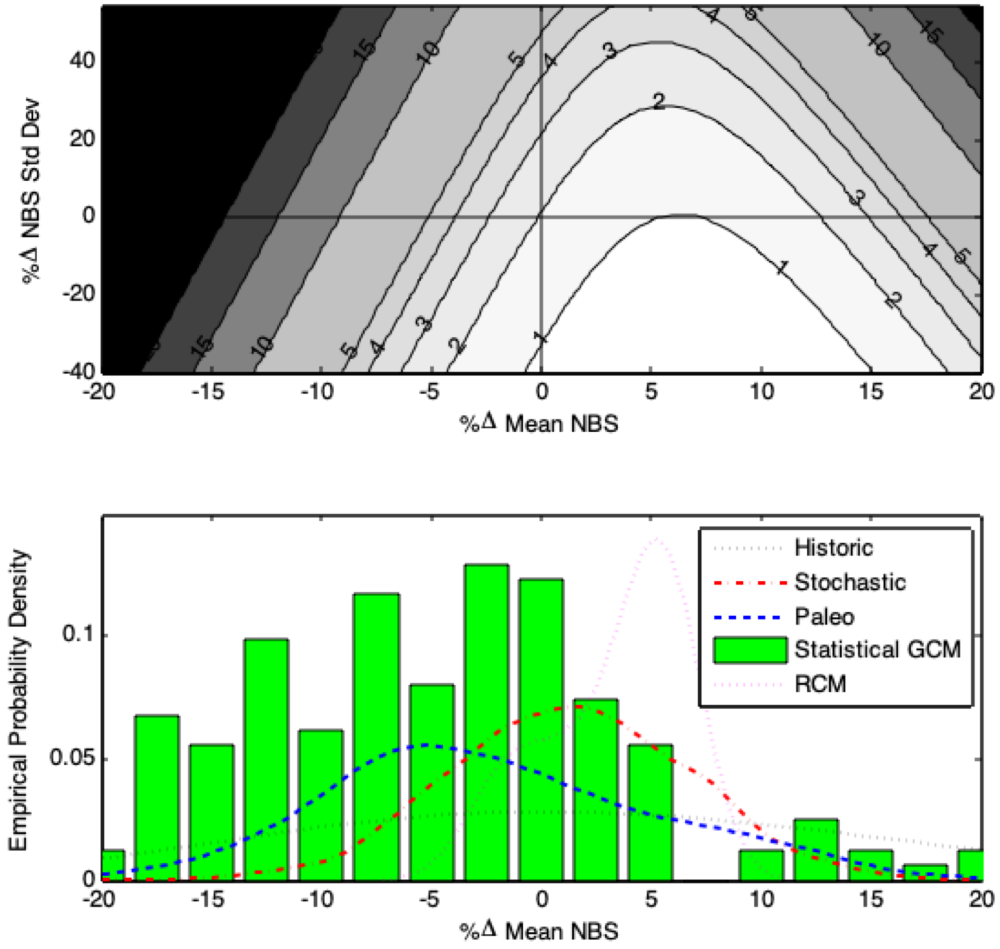
Robustness to Variability



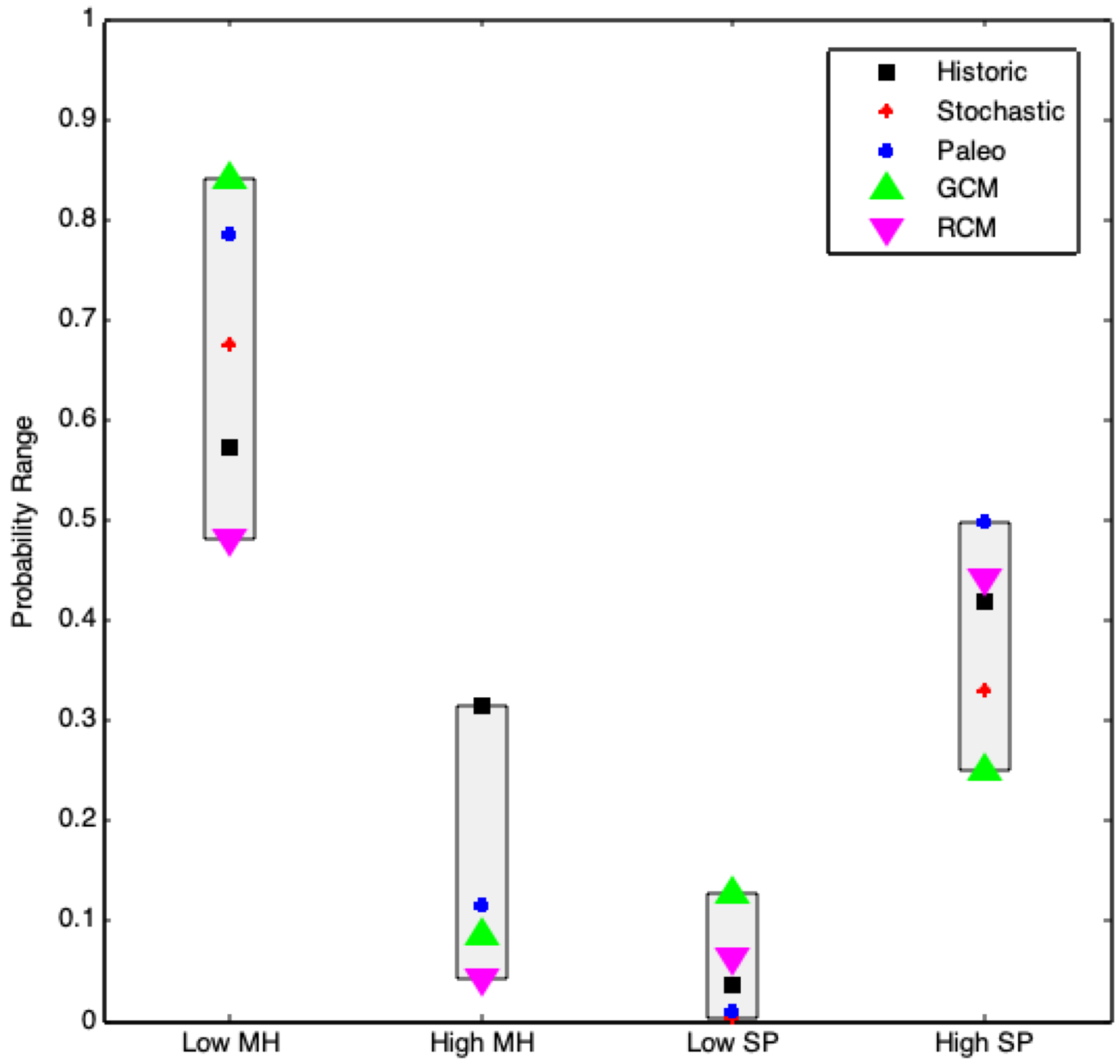
Robustness to Mean changes

Moody and Brown, WRR, 2012

Vulnerability and Climate Projections



Residual Risk according to Projections



Summary Thoughts

Scenario Definition?

- GCM derived scenarios are neither mutually exclusive nor collectively exhaustive
  - ➢ Climate Stress Test – systematic sampling to create mutually exclusive and collectively exhaustive scenarios
  - ➢ Carefully preserve connections to climate drivers to infer insights on change
  - ➢ Allows clear identification of vulnerabilities

Use of GCM Simulations?

- Forecasts of climate change considered unreliable but can be useful
  - ➢ Define sampling ranges
  - ➢ Used to assess level of concern of the vulnerabilities identified
  - ➢ Assign subjective probabilities to ex post scenarios when needed

Thank You

Questions: casey@umass.edu

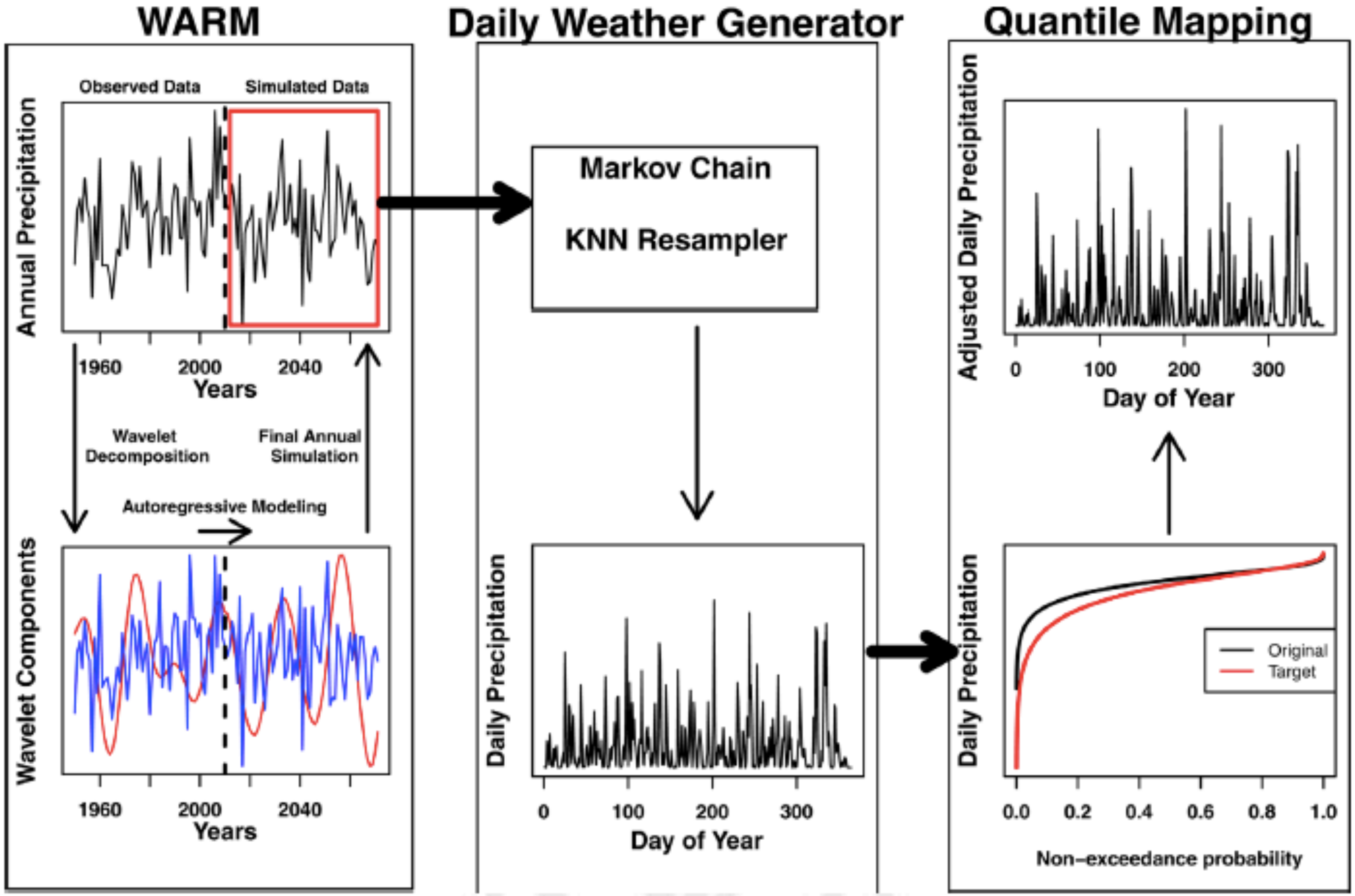
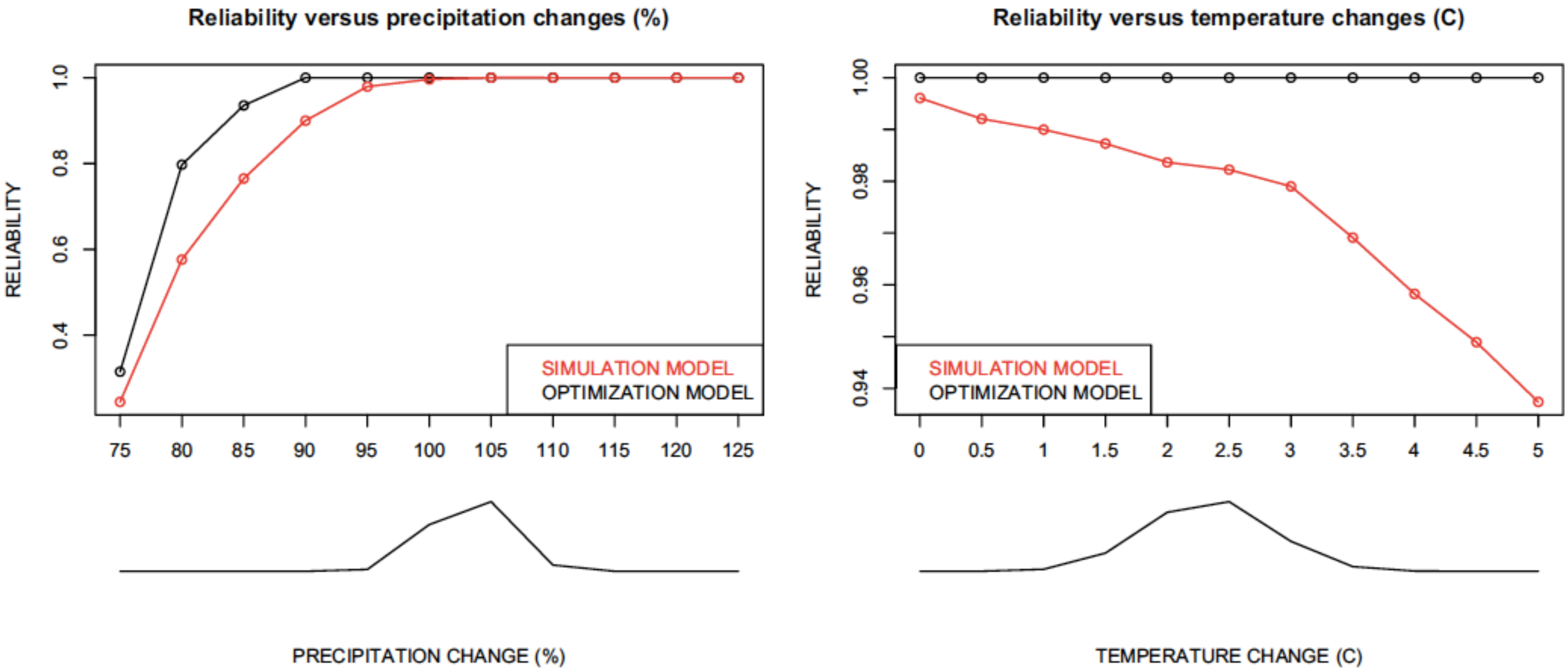


Figure 1. Schematic flowchart of the daily weather generation process conditional on annual simulations of climate and subject to postprocess distributional adjustments.

Adaptation via Operations?



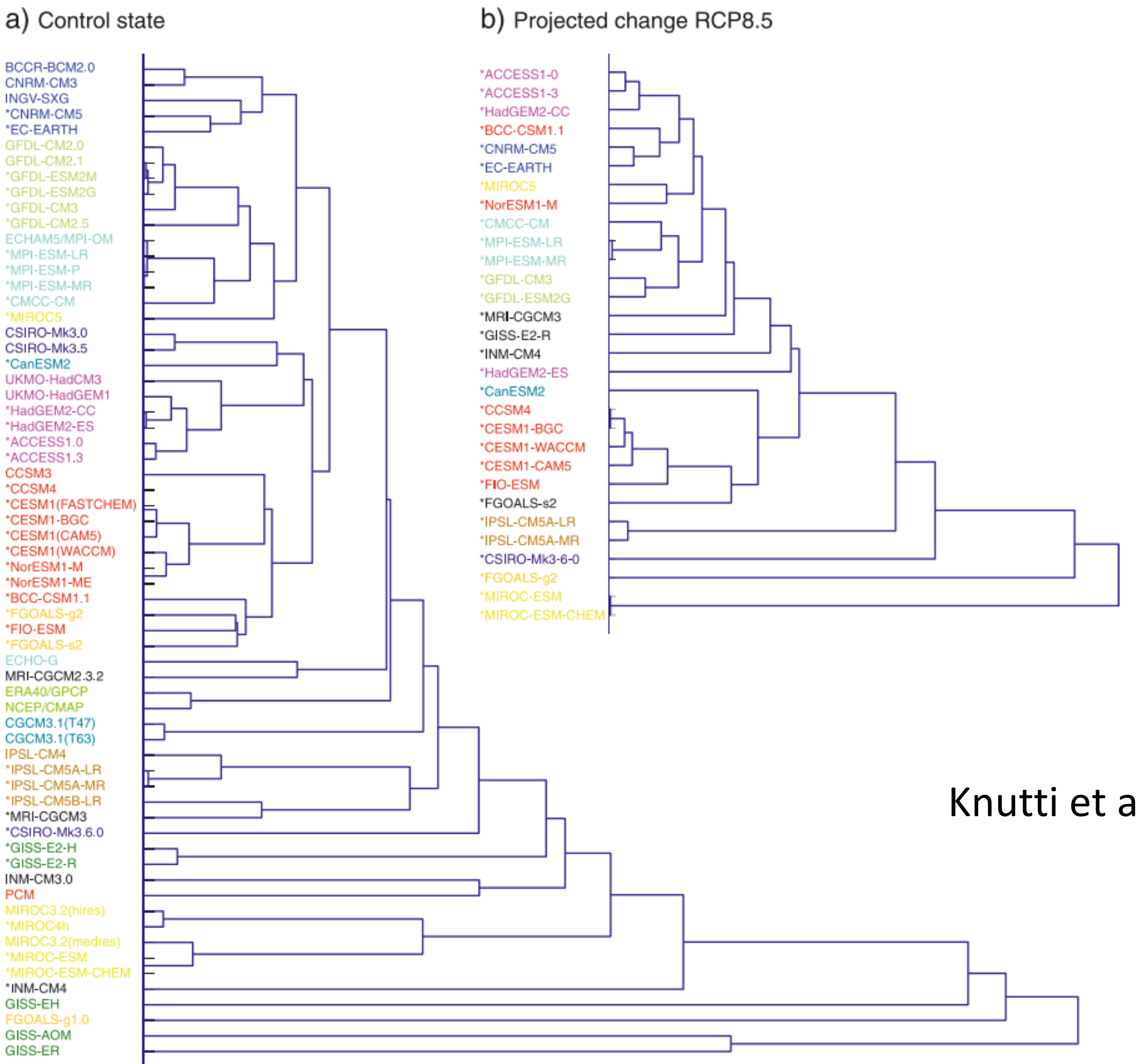
(Whateley et al., 2014)

Framing the Analysis for Actionable Science

Uncertainties	Investment and Policy Options
<u>Natural Uncertainties</u> Precipitation (intensity, duration, frequency, timing) Temperature (melt/evapotranspiration) Sedimentation Seismic risk and disasters <u>Nepal Future System and Operations</u> National markets; International agreements; Prices <u>Project Variables</u> Capital costs; Lifetime of the projects; Discount rate	<u>Upper Arun HP</u> 335 MW (Q70) – original design 750 MW (Q40) – possible alternative 2000 MW (Q25) – possible alternative
Metrics of Success	**Models and Data**
<u>Hydropower Performance</u> Net Present Value Power generation (Dry season; Wet season; Total Annual)	<u>Hydrological model</u> UMass Glacio-Hydrologic Model <u>Watershed System</u> Run of River Hydropower in R

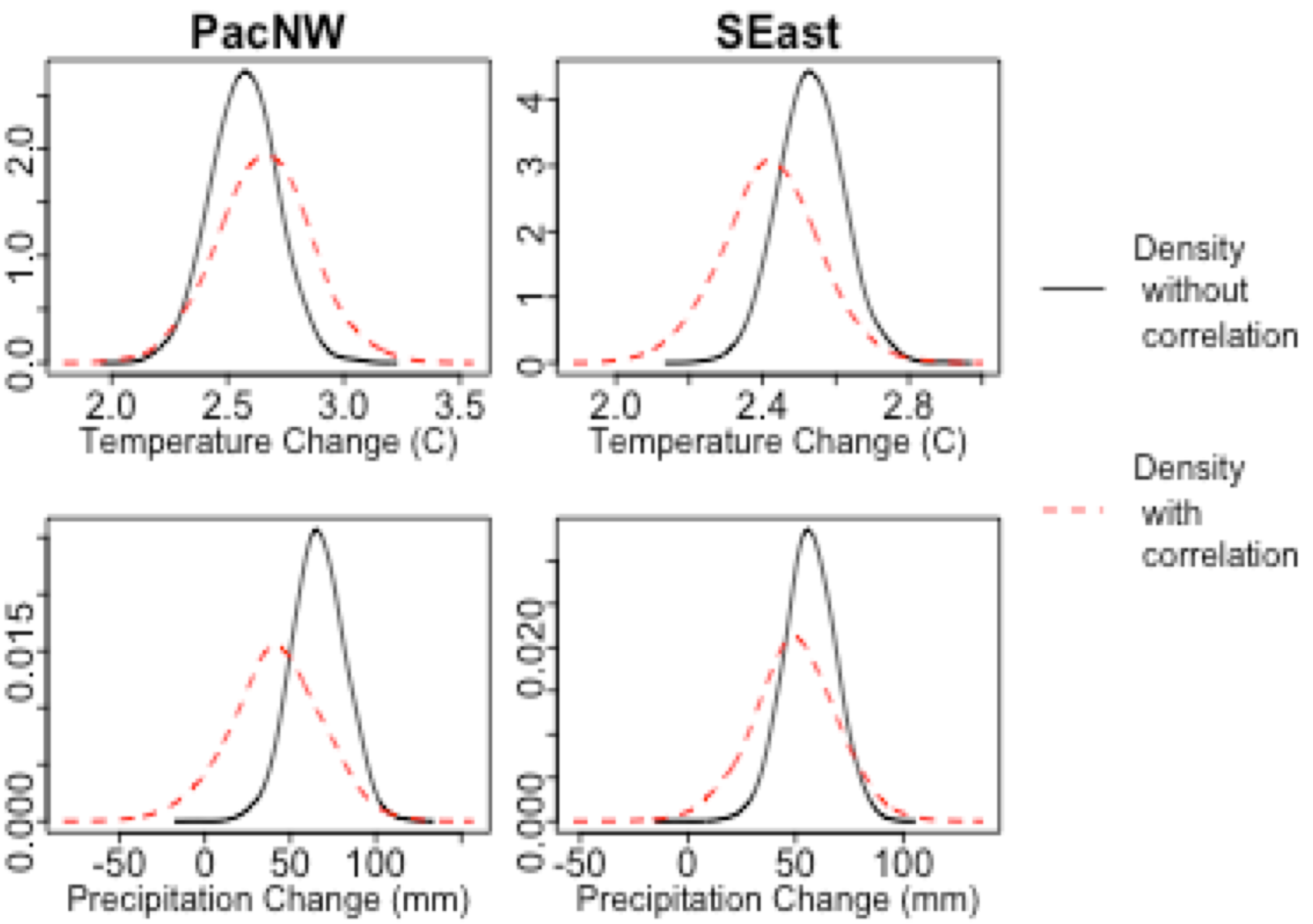
Nepal Hydroelectricity Project - Upper Arun

Family Tree of GCMs



Knutti et al., 2013

GCMs are not Independent and it Matters!



Steinschneider, Brown, Mearns, McCrary (GRL – 2015)

Thank you! Questions?