Climate Stress Testing to Reveal Vulnerabilities

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Planning under Uncertainty

• "When we try to pick out anything by itself we find that it is bound fast by a thousand invisible cords that cannot be broken, to everything in the universe." *Muir* (1869)

• “All solutions are provisional and local.” *Briscoe* (2014)

• “Everyone has a plan until they get punched in the face” *Mike Tyson* (US Heavy Weight Boxer) via Briscoe.
What is a Water Planner to do?

• The statistics used to design and operate the water supply system may not be indicative of future climate

• Future drought risks may be greater than historical, or not

• Substantial possible regrets for any decision taken

• Unclear how to use climate information to aid decisions
Why is climate change assessment different?

• How does 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 …
Now What?
Emission Scenarios

General Circulation Models (GCMs)

Schematic for Global Atmospheric Model

Horizontal Grid (Latitude-Longitude)

Vertical Grid (Height or Pressure)

Downscaling

Water System Performance Under Future Climate Scenarios

Hydrologic Model

Greene County, PA Department of Econ. Development

Water Resources System Model

Wisconsin Valley Improvement Company
Natural Variability may dominate

Source of Future Uncertainty in Performance
Family Tree of GCMs

Knutti et al., 2013
Uncertainty: Pigs, Ducks, Skunks

Kunk

= a known unknown

Unkunk

= an unknown unknown
related: surprises; black swans

Skunk

= a known that stinks

(Klemes, 2002)

(Taleb, 2007)
Q. What do you learn from a climate projection led analysis?

A. Whether your system is vulnerable to the projections that happen to be used.

*Corollary 1: Better think carefully about the projections you use! But how to decide …*

*Corollary 2: Will these projections really explore all the climate risks you face …*
Q. What do you learn from a decision scaling analysis?

A1. What climate conditions cause your system to break (the “climate stress test”).
   - mean climate changes
   - variability conditions
   - other factors
A2. How robust your system is to climate change.
A3. The additional robustness gained from an adaptation.
A4. Climate risks in context of other risks
A5. The weather/climate mechanisms that cause failure
   - Inverse analysis to assess change of mechanisms
Summary

• Climate projections have strong biases, especially in the events we care most about

• The fully address the uncertainty, must use multi-GCM, multi-run ensemble
  • Difficult!

• Natural variability and other uncertainties will probably dominate project performance in next 30 years

• Better to focus on understanding the project and its vulnerabilities
Decision-centric Climate Science

“Decision Scaling”, Brown, 2012

1. Stakeholder defined Risks

2. Identify Climate Hazards “Stress Test”

3. Evaluate climate informed risk scenarios

GCM Projections

How do investments respond to changing climate conditions? What are non-climate factors that are also important? At what level of change makes an investment fail?
The Decision Tree for Climate Risk

- Guidance for conducting Climate Risk Assessment for water infrastructure

- Designed to **screen first** and increase analysis *only if required*

- Bottom up = Project focused
The Decision Tree

Phase 1: Project Screening

Phase 2: Initial Analysis

Phase 3: Climate Stress Test

Phase 4: Climate Risk Management
Decision Tree Step 4: Climate Risk Management

- Stakeholder Engagement
- Trade-off Analysis
- Adaptation Alternatives
- Model and Data Preparation
- Stress Test
- Climate Vulnerability Report

Climate Risk Management Strategy
Detail: Climate Stress Test

- Prepare Project Modeling Environment (e.g., WEAP)
- Design Climate Stress Tester
- Vulnerability Map
- Climate Risk Assessment
- Historical data
- GCM Projections
Climate Stress Test

Climate/Weather Generator

Hydrologic Model

Wat. Res. Model

Climate Vulnerability

Robust
Stress Test Results

Performance metric: water supply reliability

![Graph showing precipitation change (%) against temperature change (°C)]
Stress Test Results

Performance metric: water supply reliability
Stress Test Results

Reliability Threshold (Y) = 0.95
COLORADO SPRINGS

Current and Build-out Conditions
Monte Carlo to Sample Uncertainties

- Climate Trends
- Internal Climate Variability
- Hydrologic Model

Stochastic Climate Model

WEAP Hydrologic and Systems Model

MODSIM Systems Model (All Alternatives)
Targeted Variability Sampling
Select 5 trials from 40

CSU Storage Timeseries Results

Year of Date

Total System Capacity

Total Priority Reservoir Capacity

Avg. Total Storage (acre-ft)

Avg. High Priority Storage (acre-ft)

Ensemble Number

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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

Climate Stress Test – Prescribed Climate Changes

**Daily Variability**

Unadjusted Precipitation Time Series

**Theoretical CDF (Gamma Distribution)**

January Precip

Empirical CDF

January Precip

Adjusted Precipitation Time Series

**Interannual**

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

Hyon-Han Kwon · Umapama Lal · Jayantha Obeysekera
Colorado Springs (USAFA): CURRENT CONDITIONS
Colorado Springs (USAFA): Future Conditions
Non-independent models implies greater risk!

Early results!
Conclusion

- There is no reduction of climate uncertainty in sight
- The best adaptation is to address climate variability
- Climate change assessments should use bottom-up approaches and include non-climate uncertainties
- The objective is to identify climate vulnerabilities of potential projects and identify robust alternatives

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EVALUATING ADAPTATION ALTERNATIVES
Further Reading


Thanks! Questions: casey@umass.edu

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