What I Learned When I Stopped Worrying and Embraced Future Uncertainty

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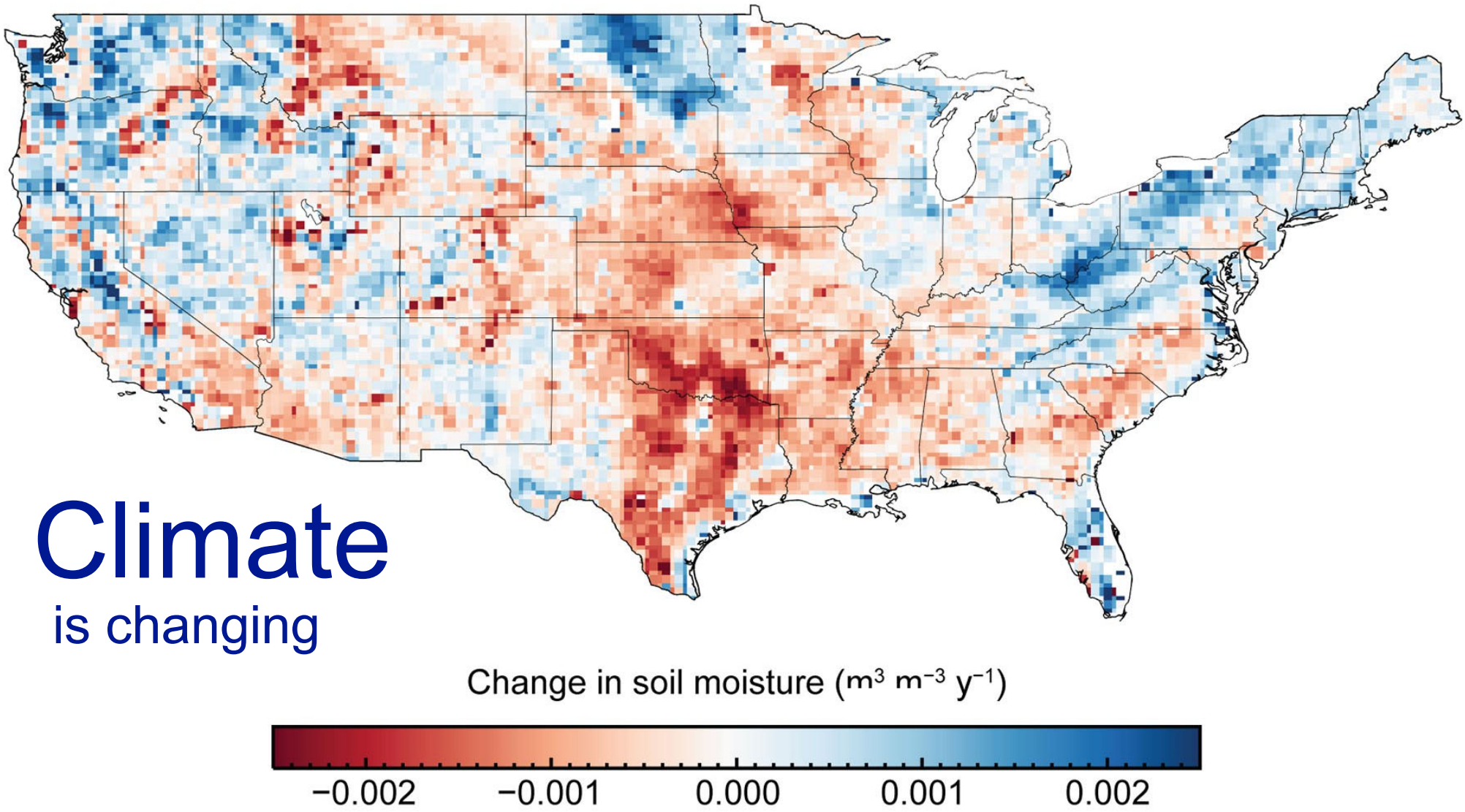
Outline

- Why worry?
- What can we expect from climate change?
- How can we make good adaptation decisions?
- Example: WRF Study – Long Term Vulnerability Assessment for SF Water

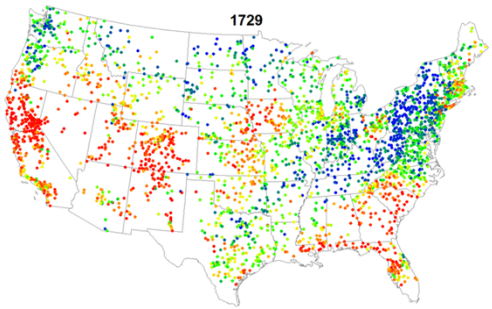


Climate

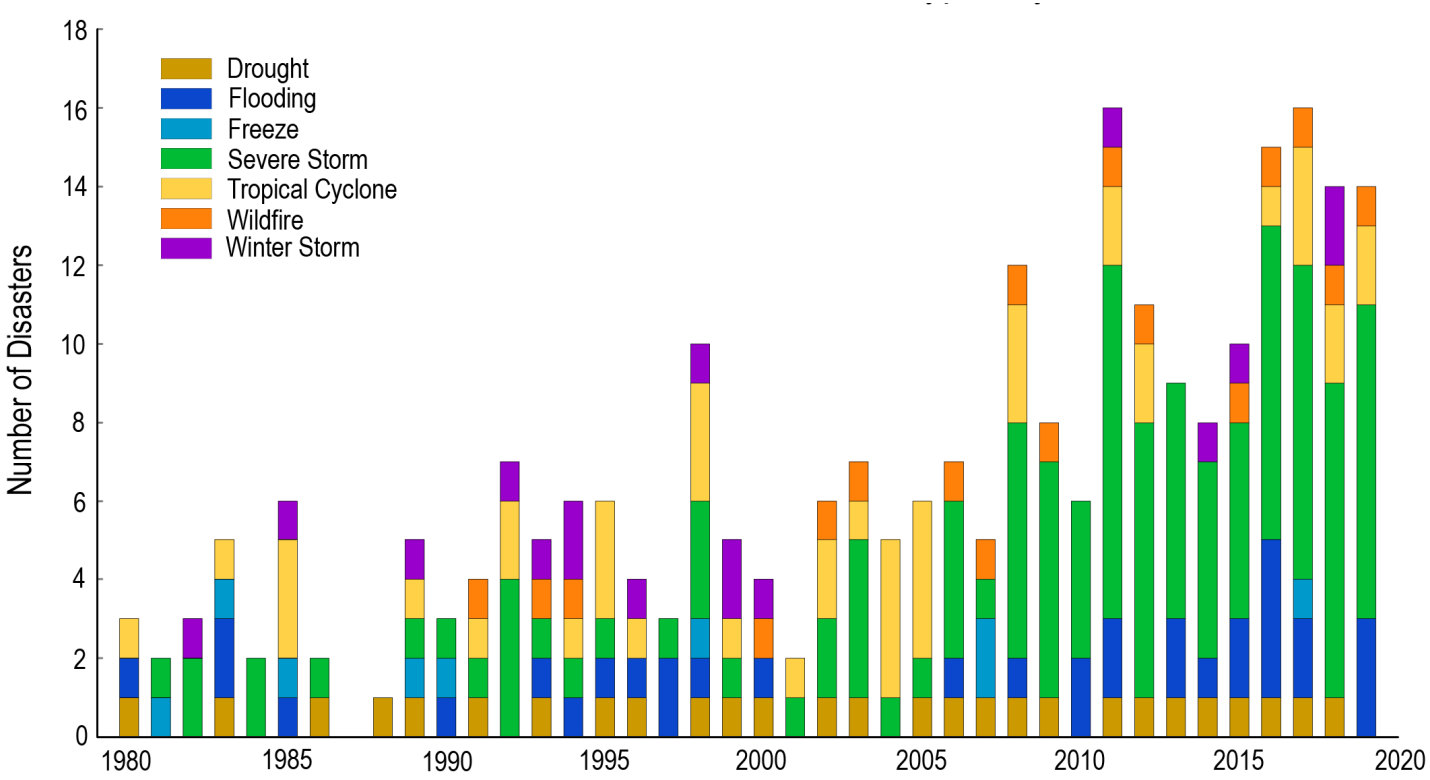
is changing

$450 Billion

Projected Per year water damages



U.S. Billion-Dollar Disaster Events Types by Year




$3 Trillion
investment
needed

Society is exposed

Cloud-based Vulnerability Self-Assessment

Convergence Accelerator
TRACK D | 613

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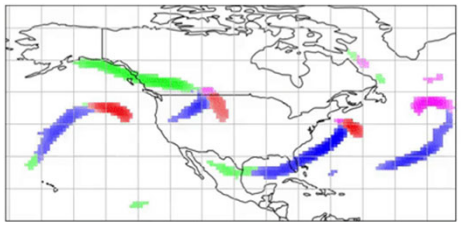
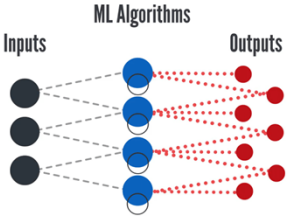
Ken Kunkel
North Carolina State University

Scott Steinschneider
Cornell University

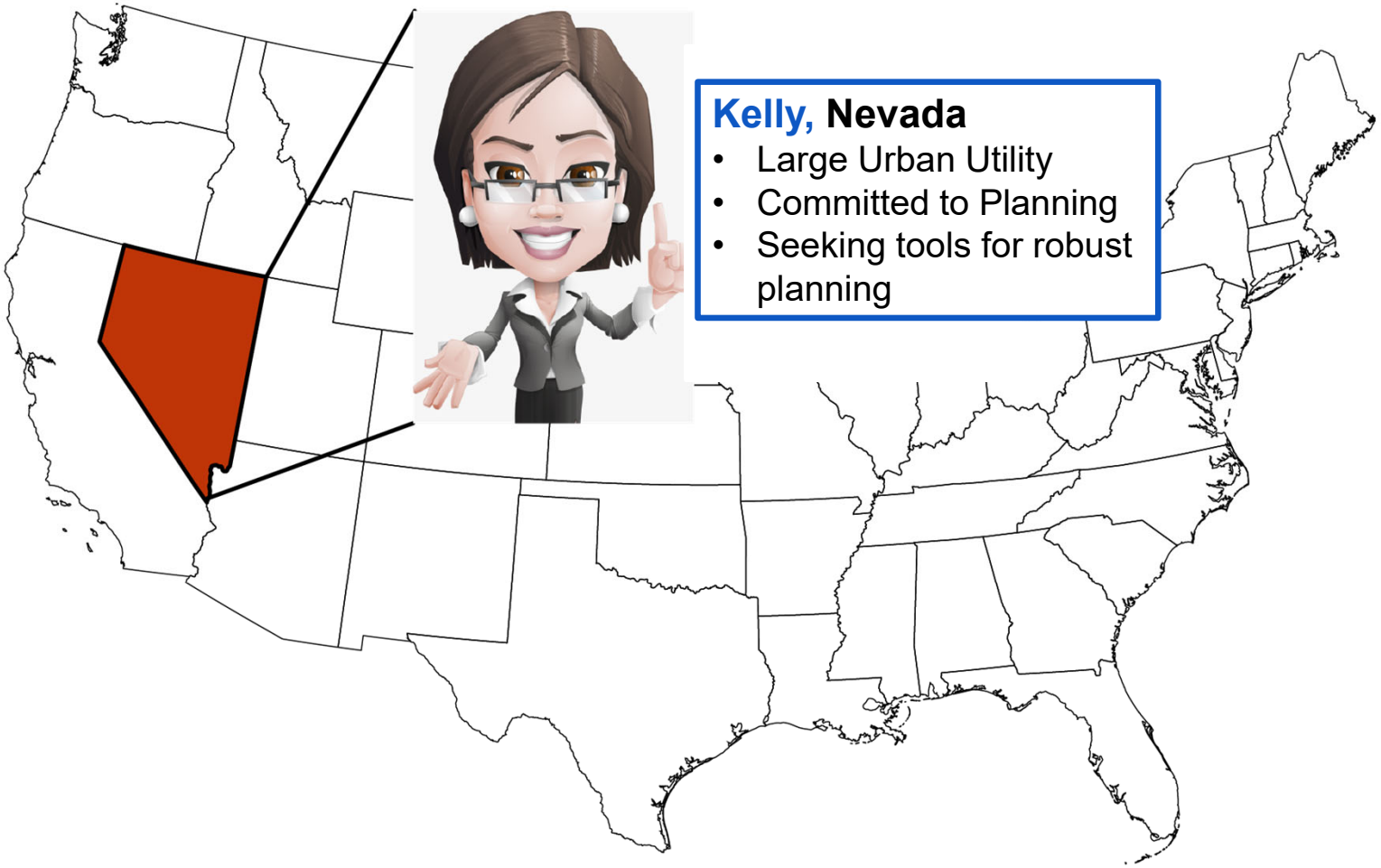
Climate Forecasts
Space-Time Machine Learning



Hydrologic Simulation
LSTM Artificial Intelligence Model

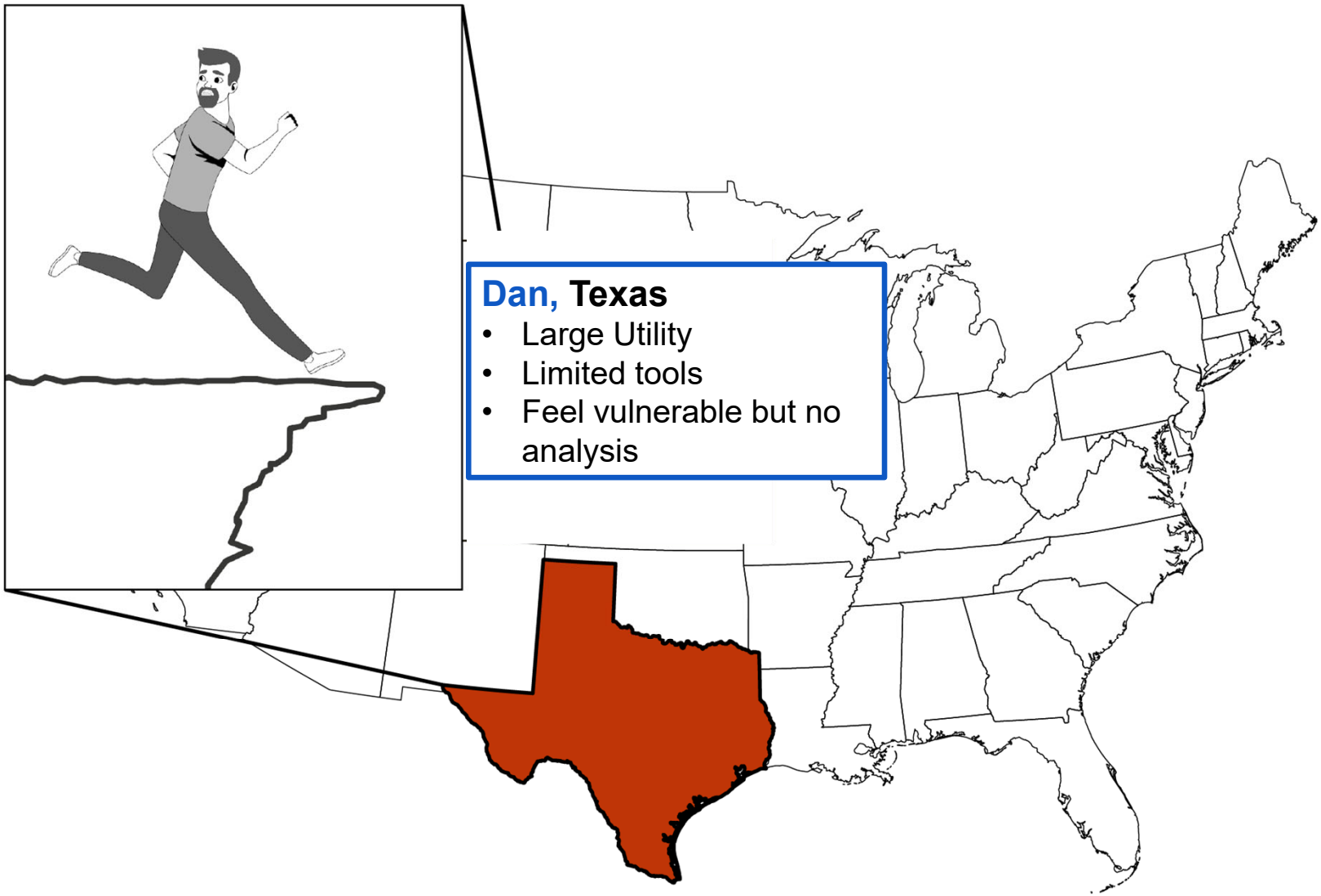


Water System Model
Emulator/Synthetic Data Training



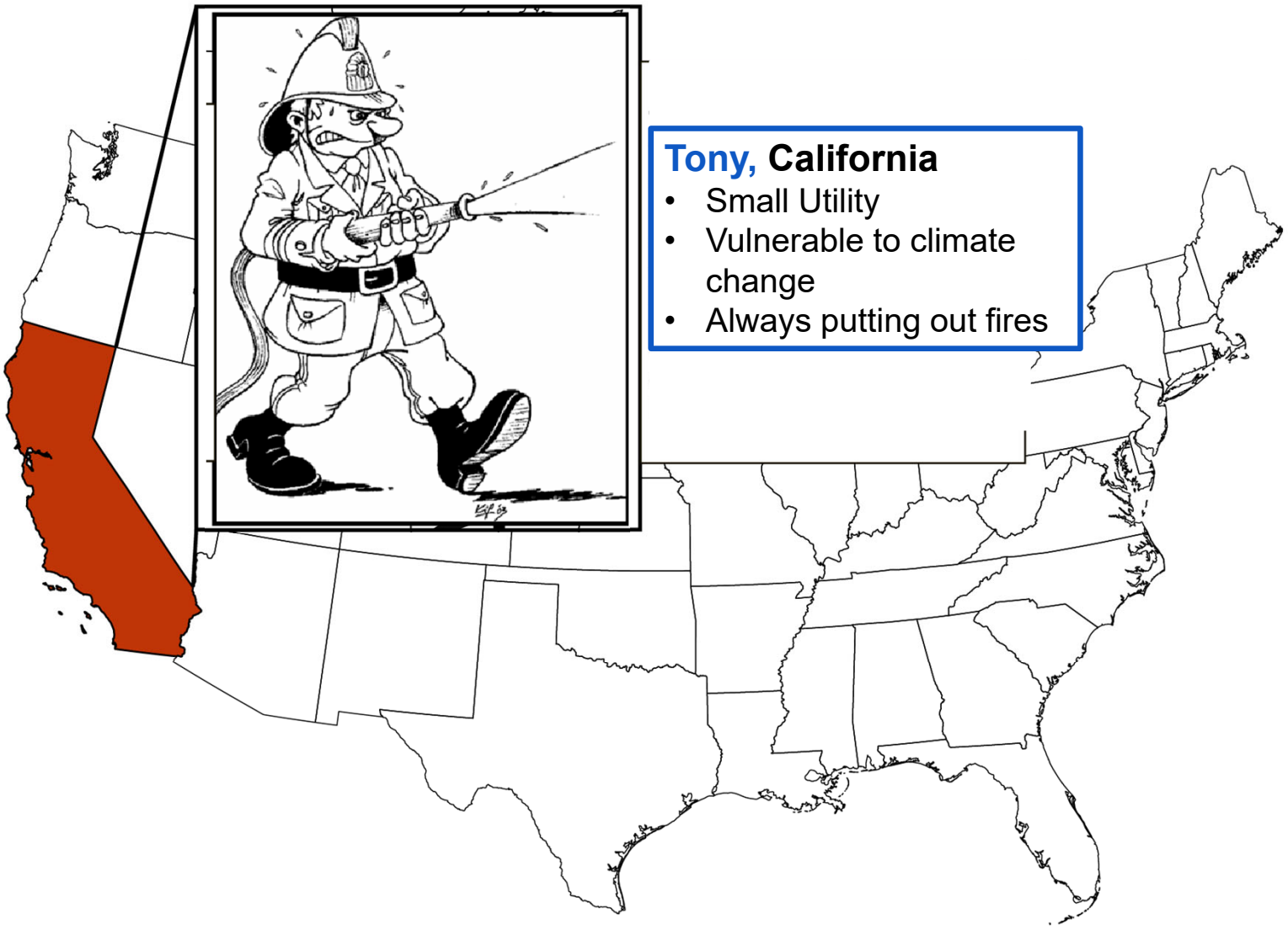
Kelly, Nevada

- Large Urban Utility
- Committed to Planning
- Seeking tools for robust planning



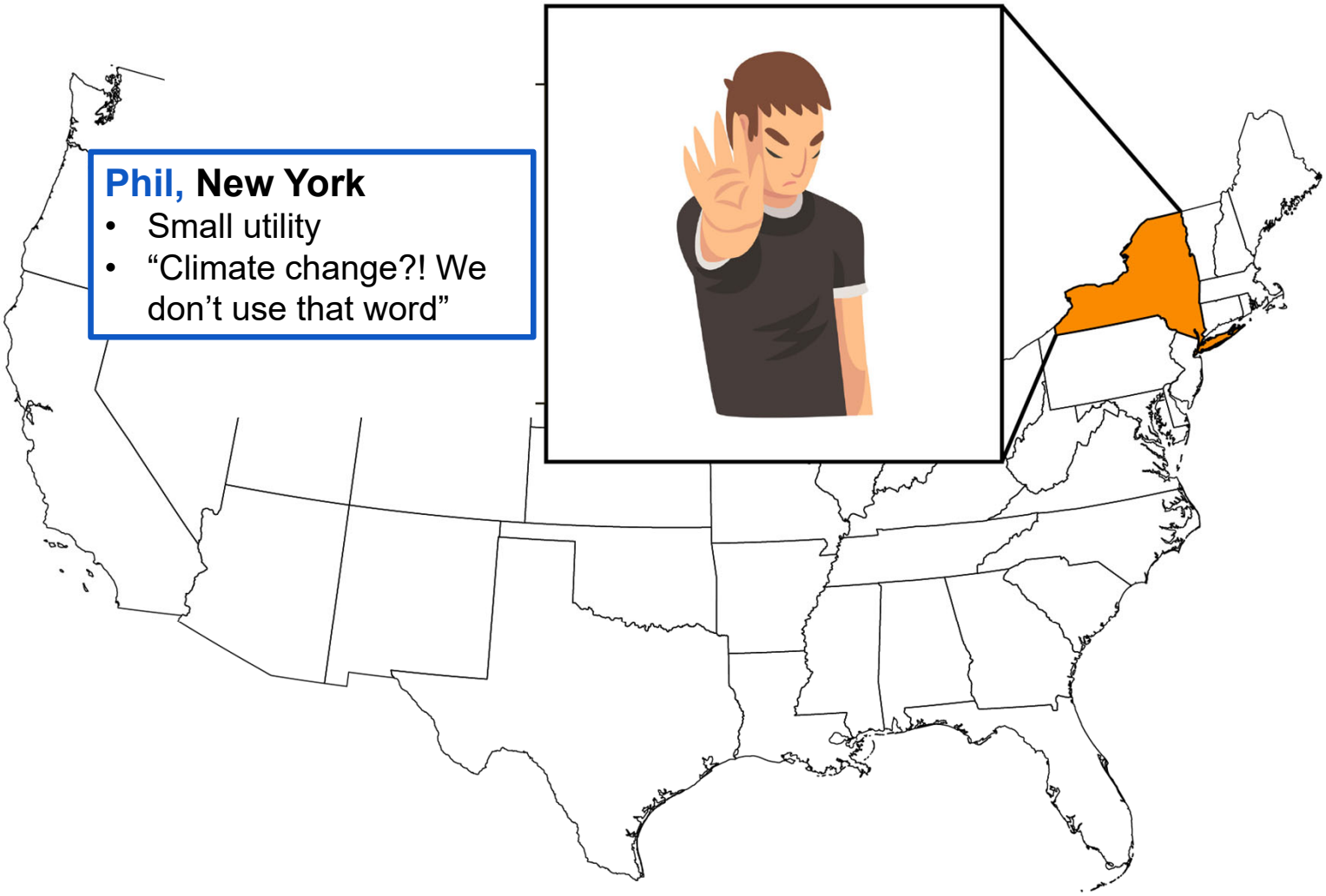
Dan, Texas

- Large Utility
- Limited tools
- Feel vulnerable but no analysis



Tony, California

- Small Utility
- Vulnerable to climate change
- Always putting out fires


Phil, New York
• Small utility
• “Climate change?! We don’t use that word”

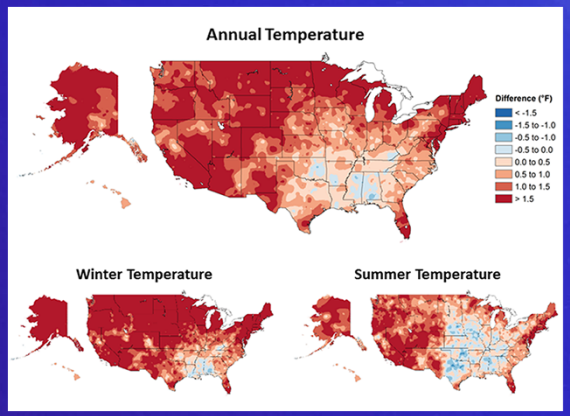
Vince, Alabama

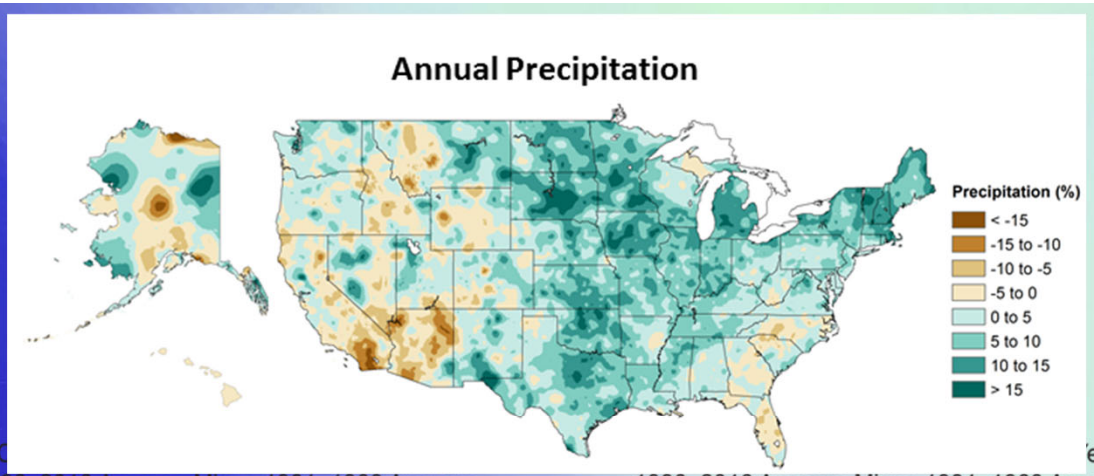
- Medium utility
- "Running a water utility is like playing whack-a-mole"

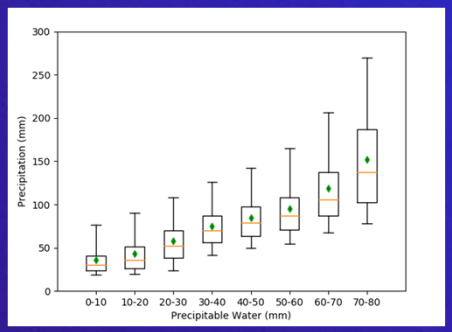
Planning. Digital. People.

- Planning is often undervalued or non-existent
- Limited data analysis and use of “digital twins”
- People. People. People.
  - Reliance on consultants
  - Silos and impediments to innovation
  - Retirement

What can we expect for climate change?

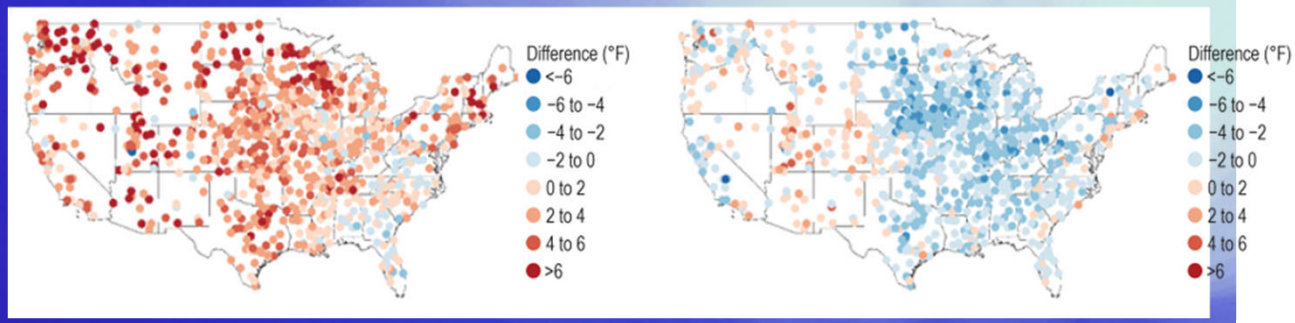






1986–2016 Average Minus 1901–1960 Average

1986–2016 Average Minus 1901–1960 Average



Summary of Robust Climate Changes

[Observations + Theory + Projections = Robust]

TEMPERATURES ARE INCREASING

PRECIPITATION INTENSITY INCREASING

LESS SNOW

How do you make good adaptation decisions?

Making Good Adaptation Decisions

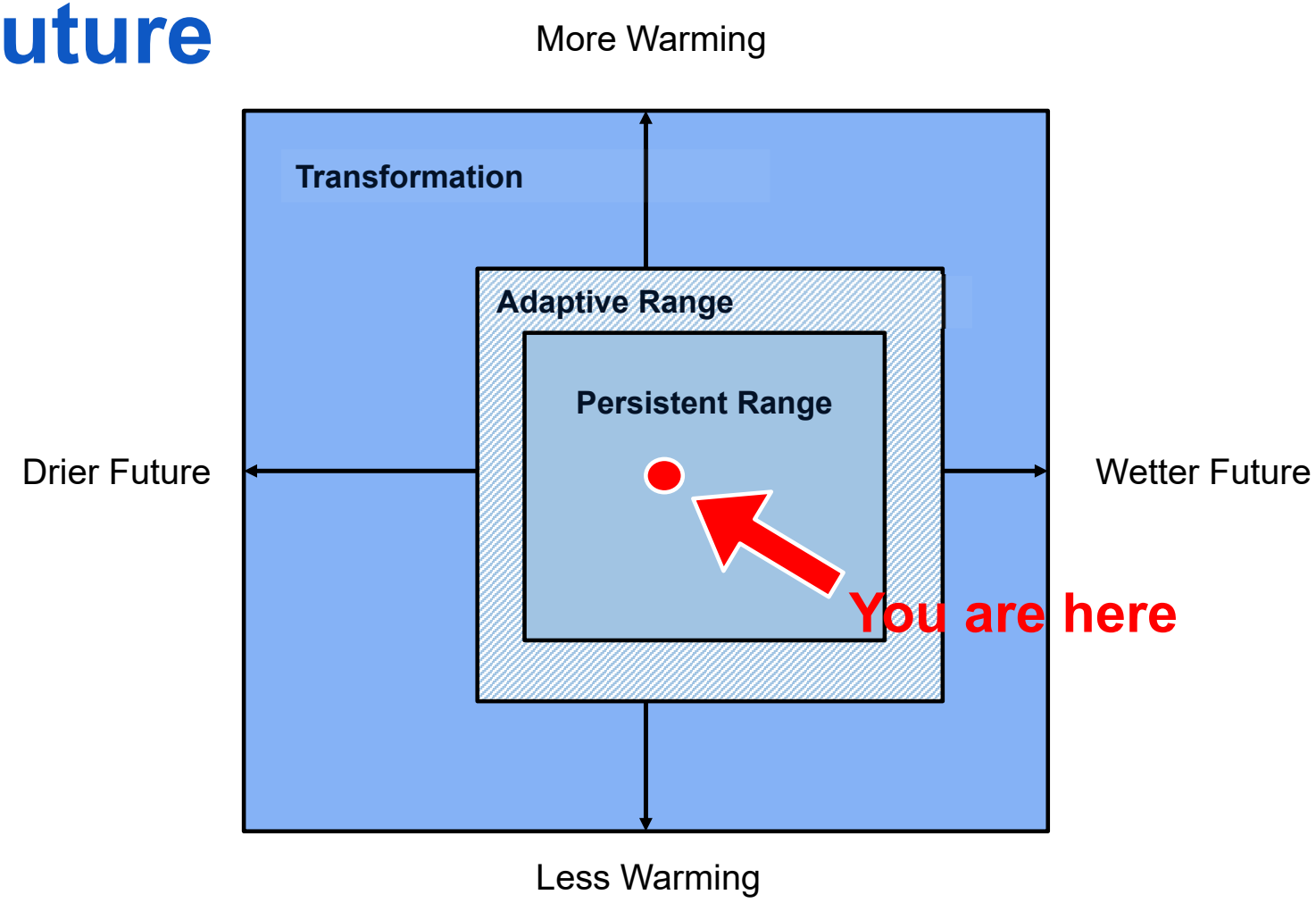
Become financially robust

Evaluate performance over many possible futures

Understand your vulnerabilities

More resilient with every decision

Your Future


More Warming
Transformation
Adaptive Range
Persistent Range
Drier Future
Wetter Future
You are here
Less Warming

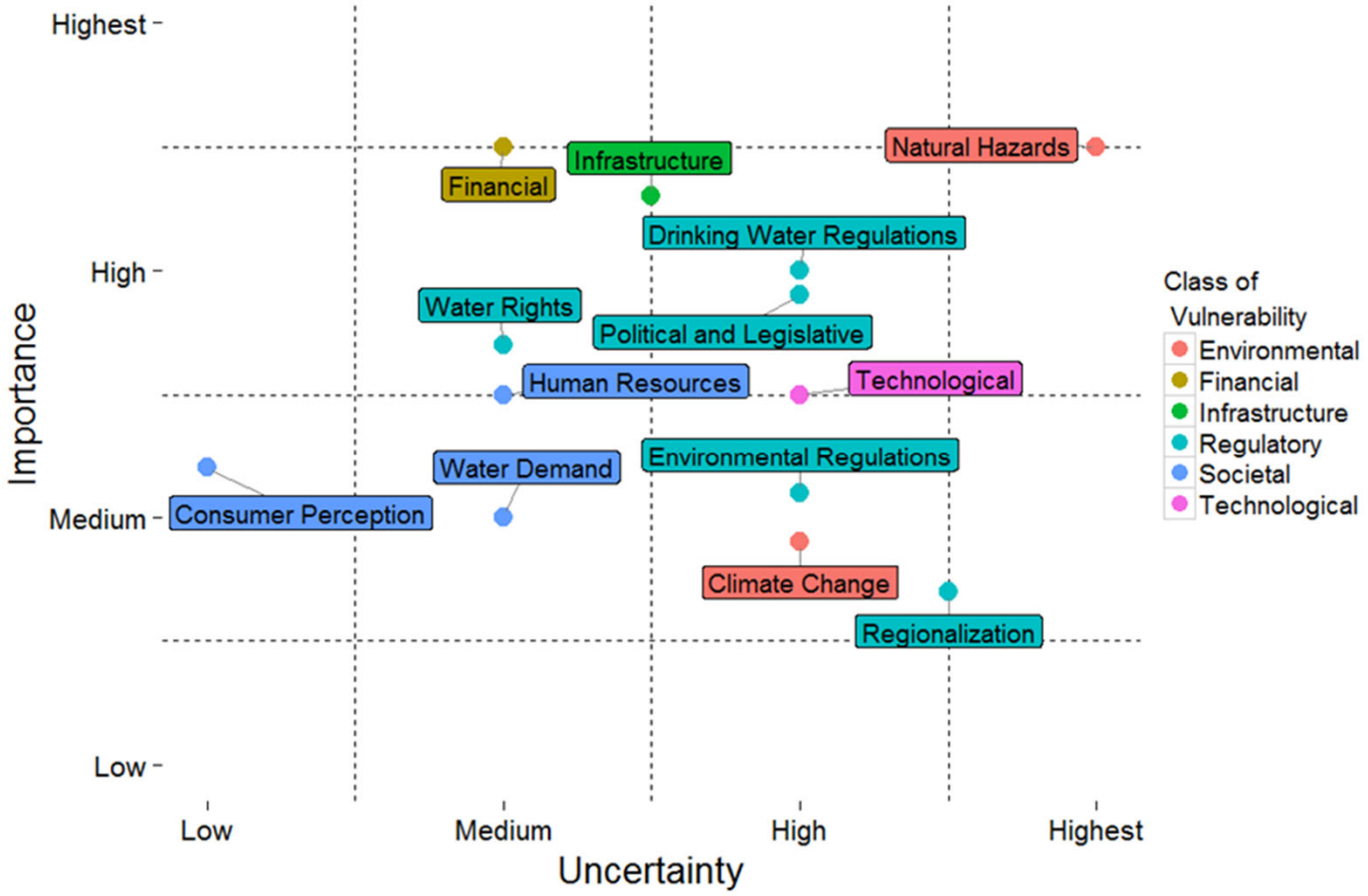
THE Water Research FOUNDATION

PROJECT NO.
4703

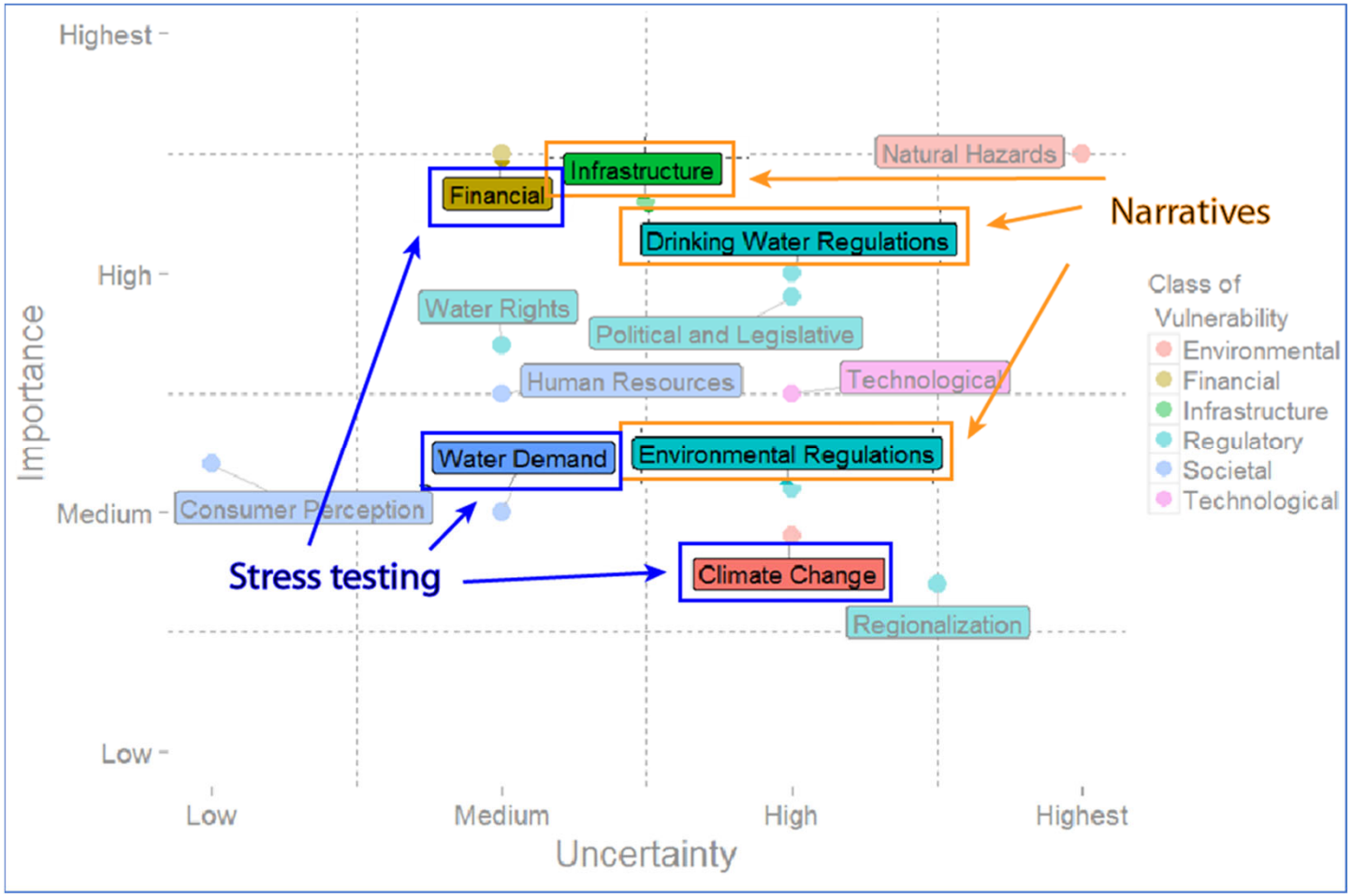
Long Term Vulnerability Assessment and Adaptation Plan for the San Francisco Public Utilities Commission Water Enterprise - Phase I

San Francisco Water Power Sewer

Selecting the Key Uncertainties



What are the most important sources of vulnerability?



Why is future climate uncertain?

- Unknown future Green House Gas (GHG) emissions

  →Less influential at local scale

- Unknown response of the climate system to GHG emissions

  →Test scenarios of warming and precipitation change

- Natural climate variability

  → Test scenarios of variability

How does climate change affect water supply?

- Changing runoff

  → Hydrology model

- Capability of the system to manage runoff changes

  → Water System model

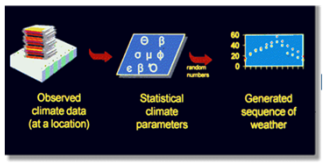
- Other factors (e.g., water rights, water demand, water supply augmentation)

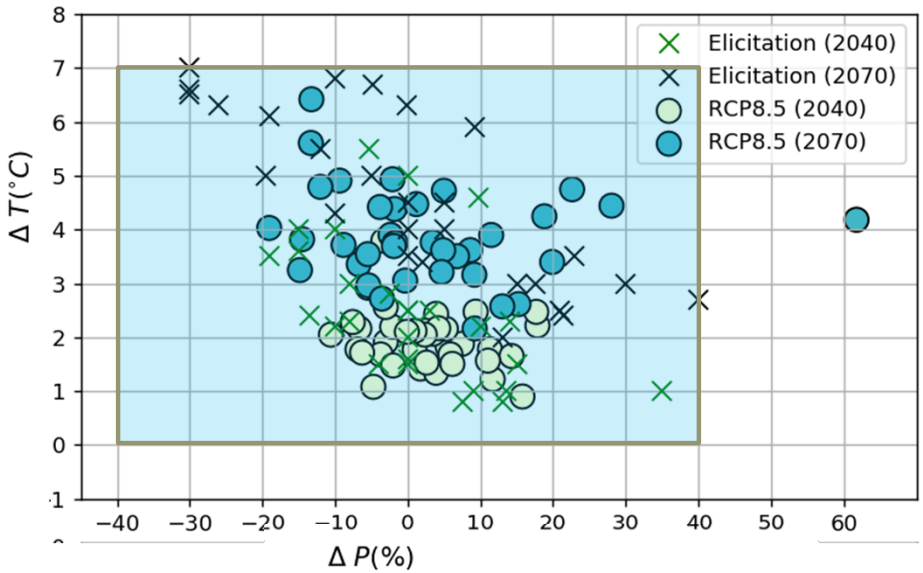
  → Water System model

Hetch Hetchy Regional Water System

Climate Stress Test Scenarios

Climate/Weather Generator

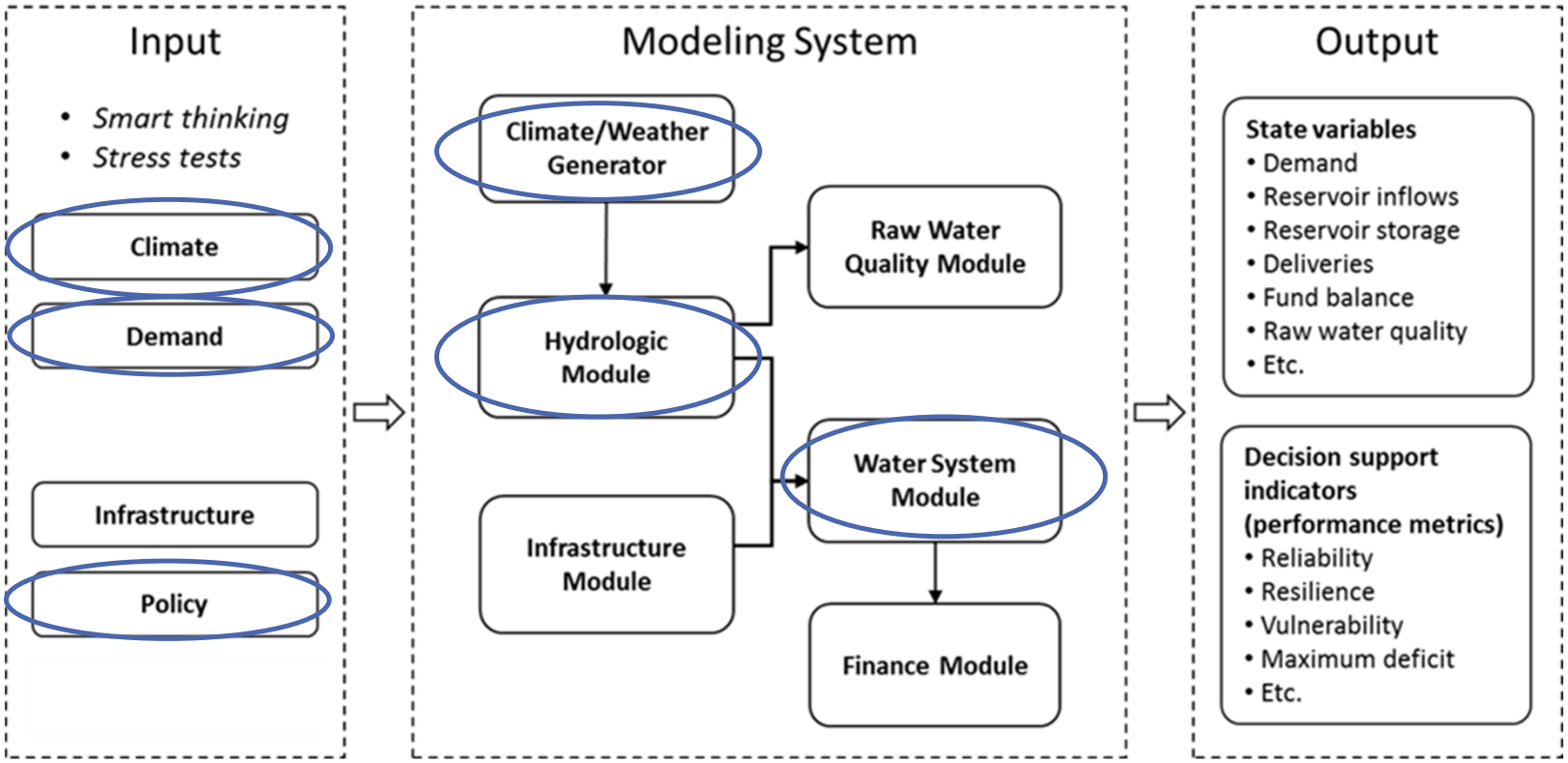




Future Climate Scenarios

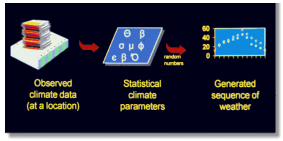
Type of uncertainty	Sampling range	Sample size
Natural climate variability	Stochastic realizations	10 realizations
Changes in mean annual precipitation (%)	-40 % to 40 % with 5% increments	17 change factors
Changes in mean annual temperature (°C)	0 to 7°C with 1°C increments	8 change factors
TOTAL		**1360 climate scenarios**

Our approach for assessing vulnerability



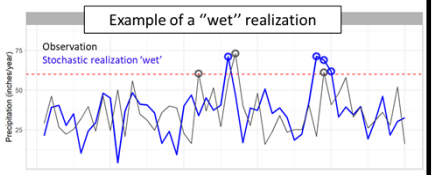
Climate Stress Test Components

Climate/Weather Generator

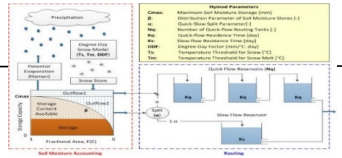


9 realizations

- 9 stochastic weather realizations (50 yrs)



Hydrologic Model

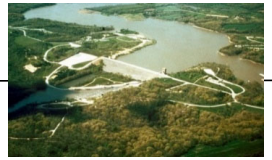


918 weather scenarios

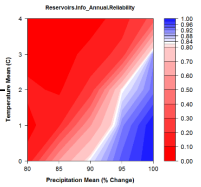
- 6 temperature change scenarios from 0 to +5ºC (1 ºC step)
- 17 precipitation change scenarios from -40% to +40% (5% step)

9x6x17 flow realizations

System Model



9x6x17x9 perf metrics

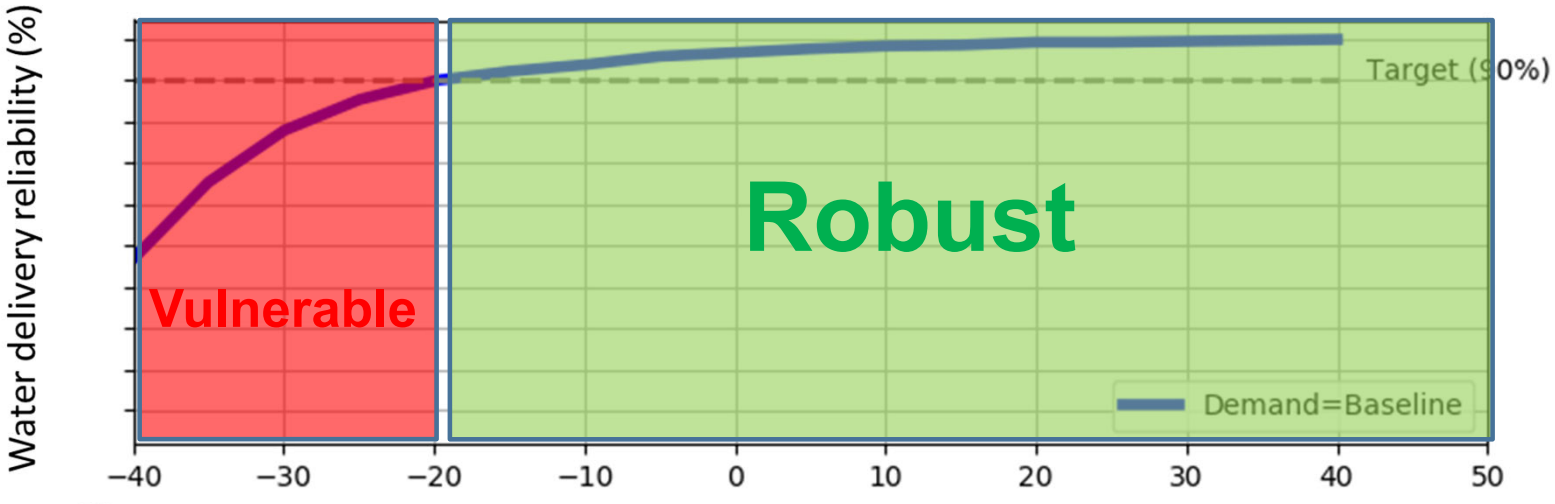


Performance metrics

8,262 scenarios

- 9 scenarios of change in urban water demand from -15% to +105% (15% step) (Bruce et al. in prep)

Water Supply Reliability under Precipitation Change

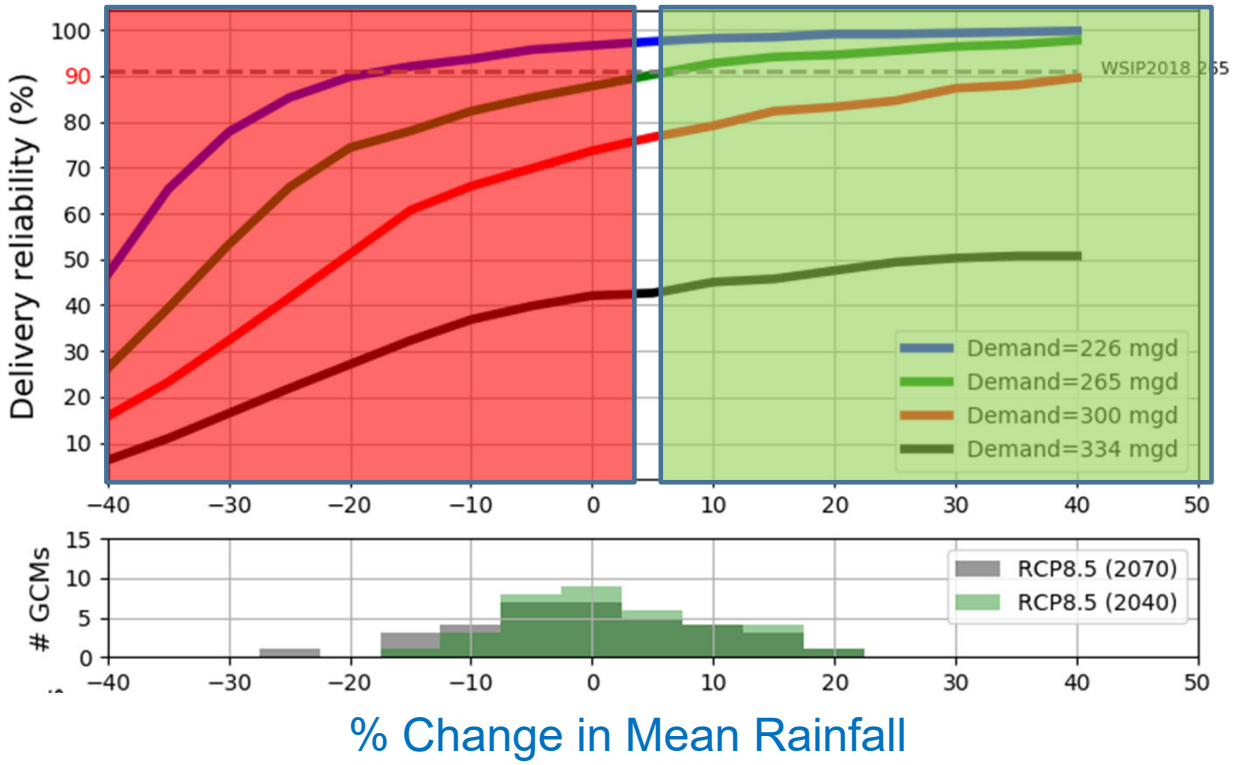


% Change in Mean Rainfall

Vulnerable if precipitation decreases by more than 20%

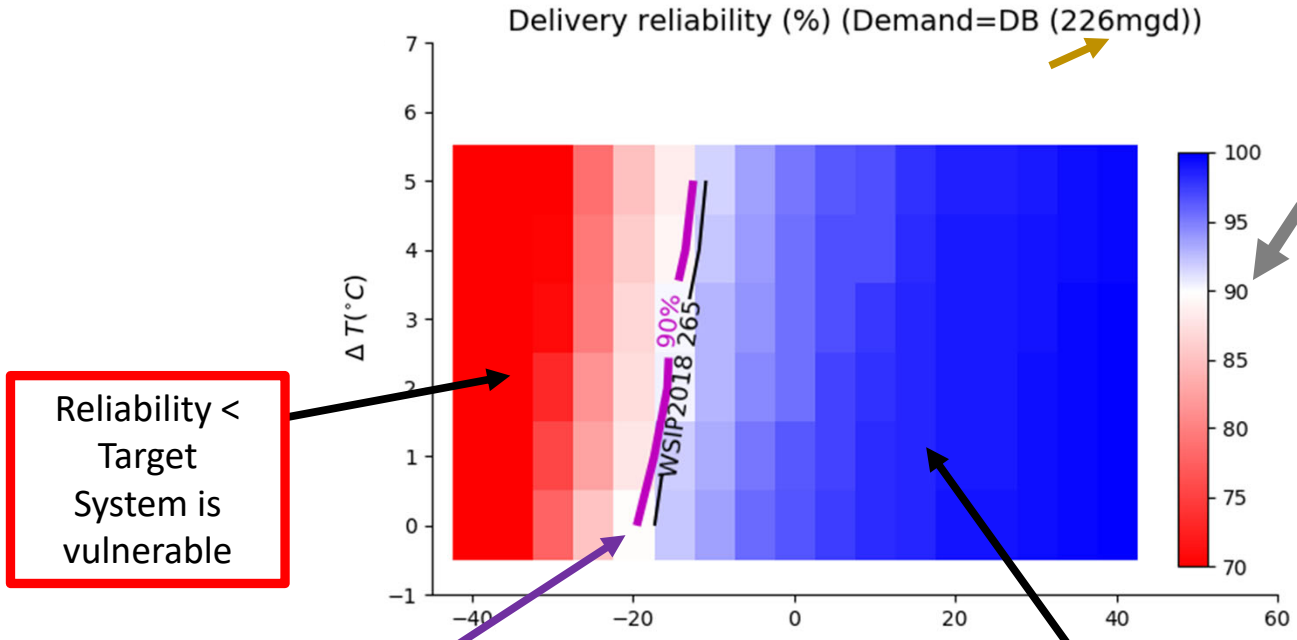
Effect of Precipitation and Demand Change

Increased Demand causes vulnerability unless Precipitation increases!



Demand increase causes climate vulnerability

Temperature and Precipitation Climate Vulnerability



Reliability < Target System is vulnerable

The colormap shows the reliability metric (%) for a large range of change in precipitation (ΔP, %) and temperature (ΔT, degC).

Target reliability=90%

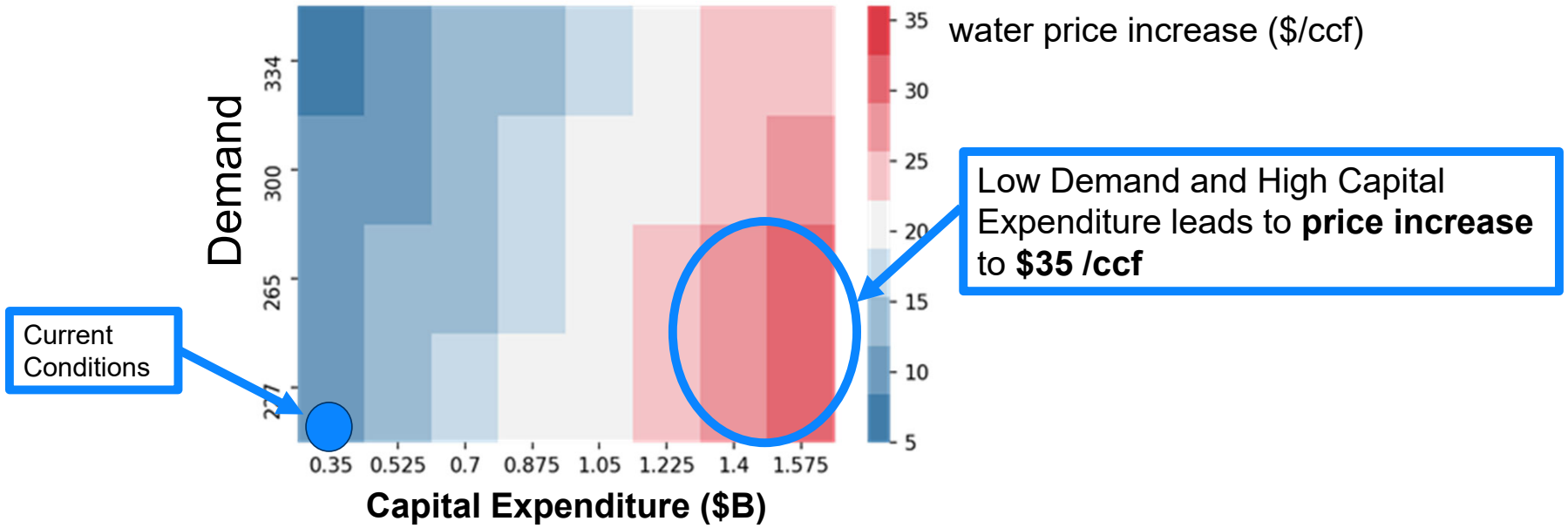
Reliability > Target System is NOT vulnerable

Climate Vulnerable: > +2C and -15% Precip

Hetch Hetchy Regional Water System

Climate Change and Finance

- If major capital investment is needed, **substantial increases in the price** of water are required



Color indicates Price Increase ($/ccf) for Demand and Capital Expenditure changes

Lindy Effect – Perishable or Non-

What if … ?

Your history did not predict your future

Your planning horizon was 1000 years

Every decision made you more robust to change

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Acknowledgments

Thanks to all our collaborators and funders, especially those featured in this talk:

Erica Brown	AMWA
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Andrew Schwarz	Delta Stewardship Council nee DWR
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Patrick Ray	Univ of Cincinnati

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Climate Analysis Results

- Understanding of the conditions that make the system vulnerable

  - (What climate changes make us vulnerable?)

- The level of concern associated with vulnerabilities

  - (How much should we worry?)

- The ability of proposed alternatives to reduce vulnerability

  - (What action should we take?)

Summary - Making Good Adaptation Decisions

Become financially robust

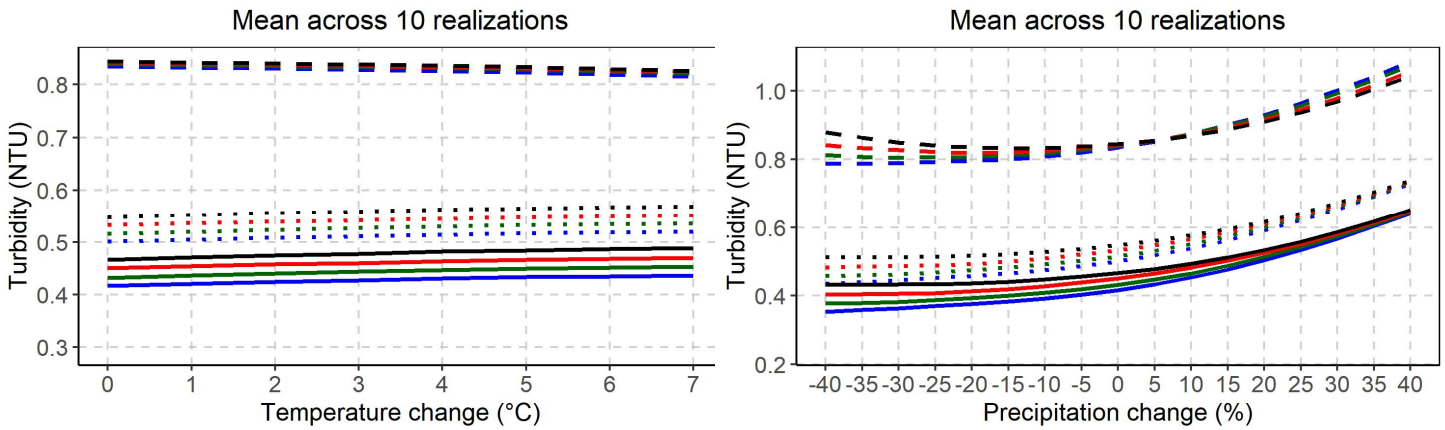
Evaluate performance over many possible futures

Understand your vulnerabilities

More resilient with every decision

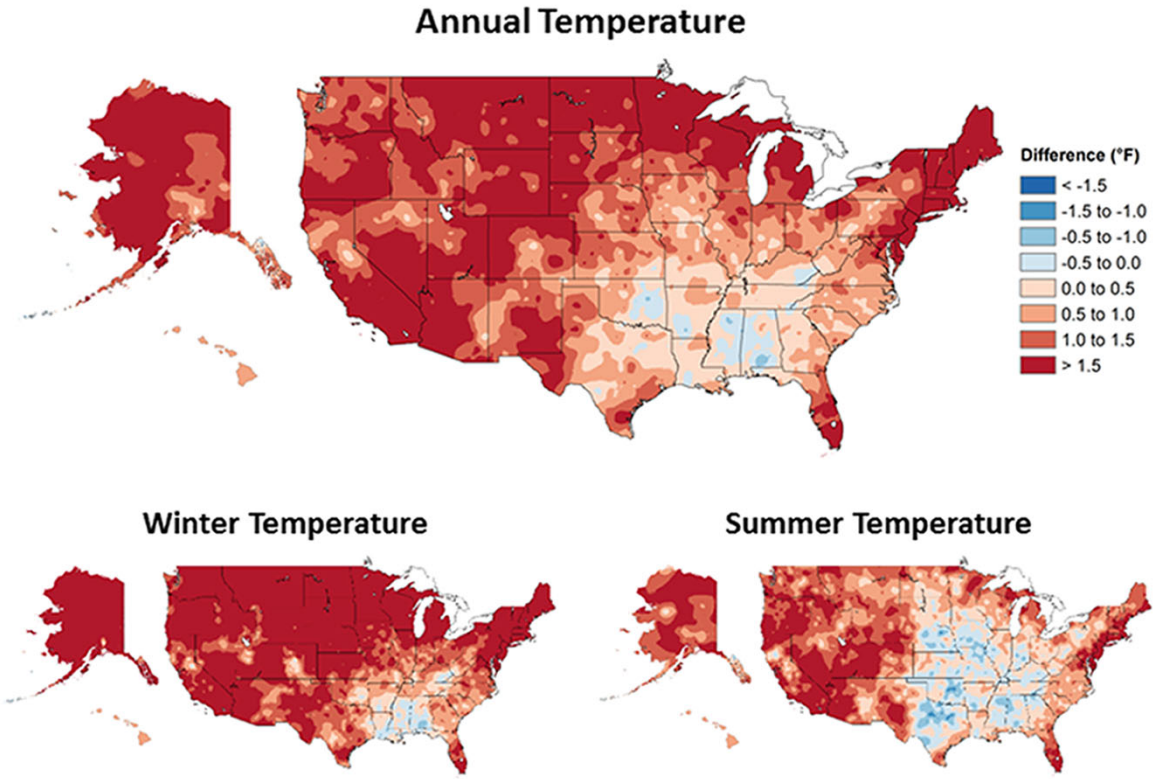
Raw Water Quality –
Turbidity and Total Organic Carbon (TOC)

- Overall, raw water quality deterioration in turbidity or TOC **does not appear to be a major concern**

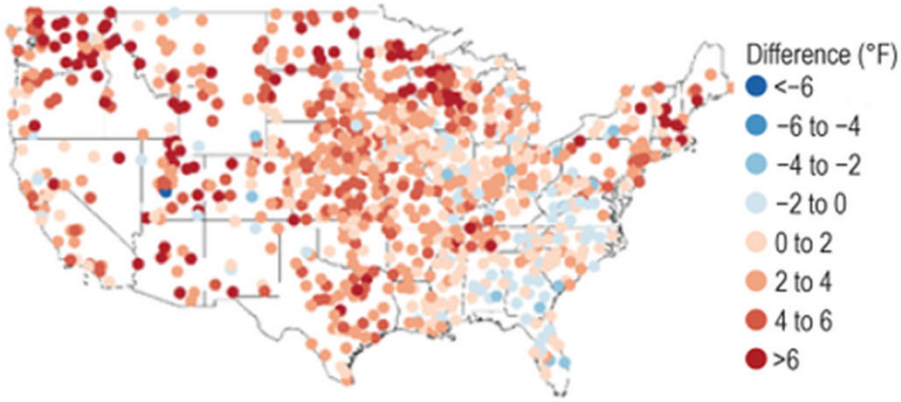


Hetch Hetchy Regional Water System

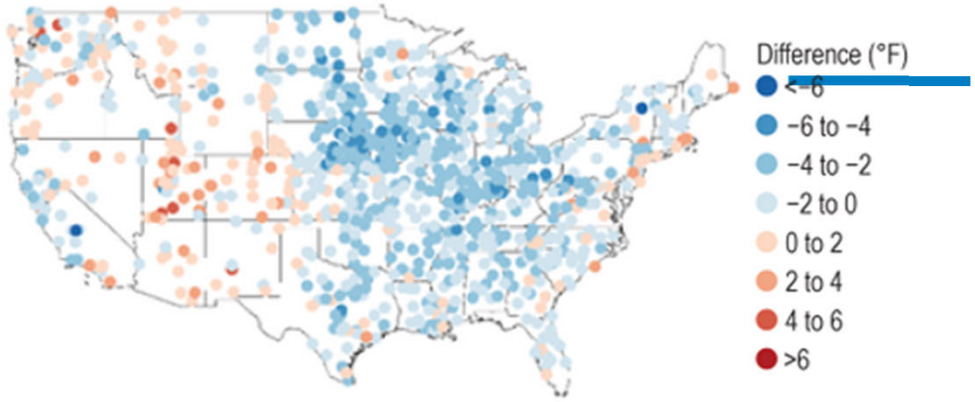
Recent Temperature Changes

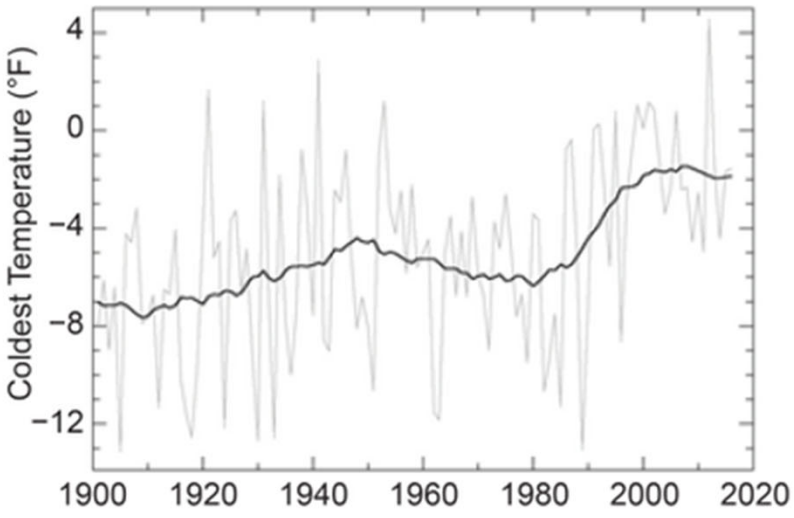


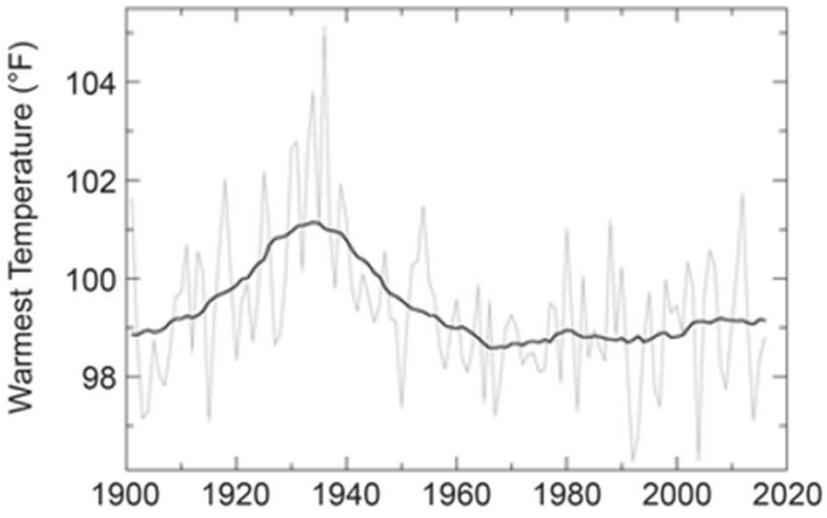
Change in Coldest Temperature of the Year
1986–2016 Average Minus 1901–1960 Average



Change in Warmest Temperature of the Year
1986–2016 Average Minus 1901–1960 Average

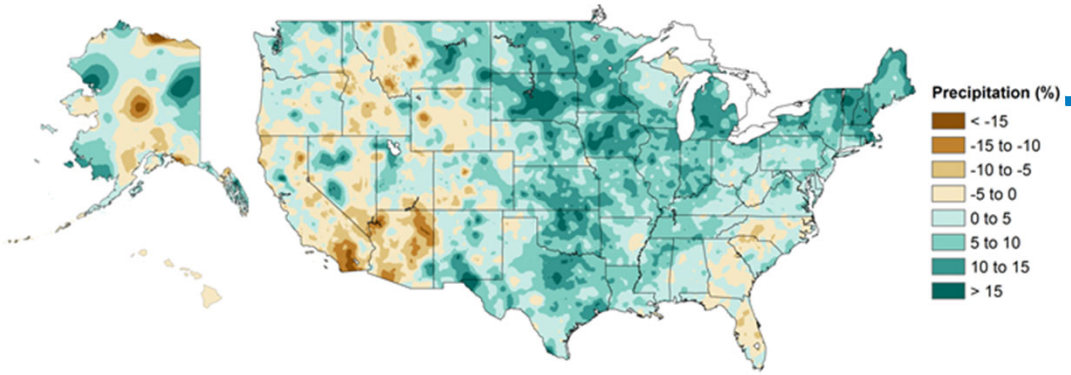




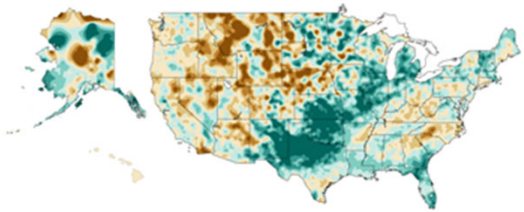


Hetch Hetchy
Regional
Water
System

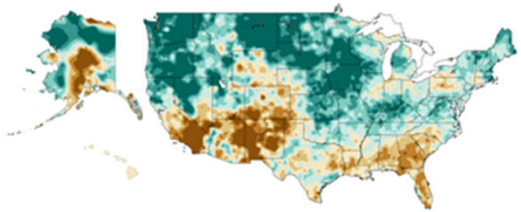
Annual Precipitation



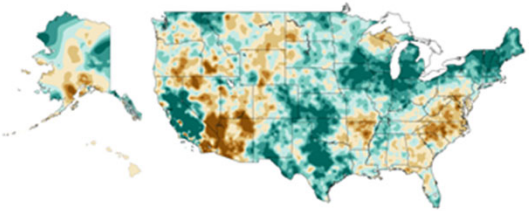
Winter Precipitation



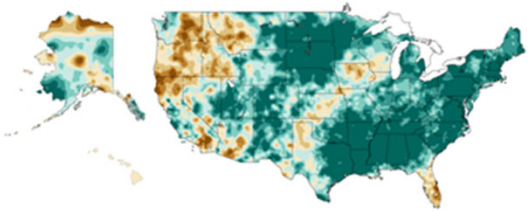
Spring Precipitation



Summer Precipitation

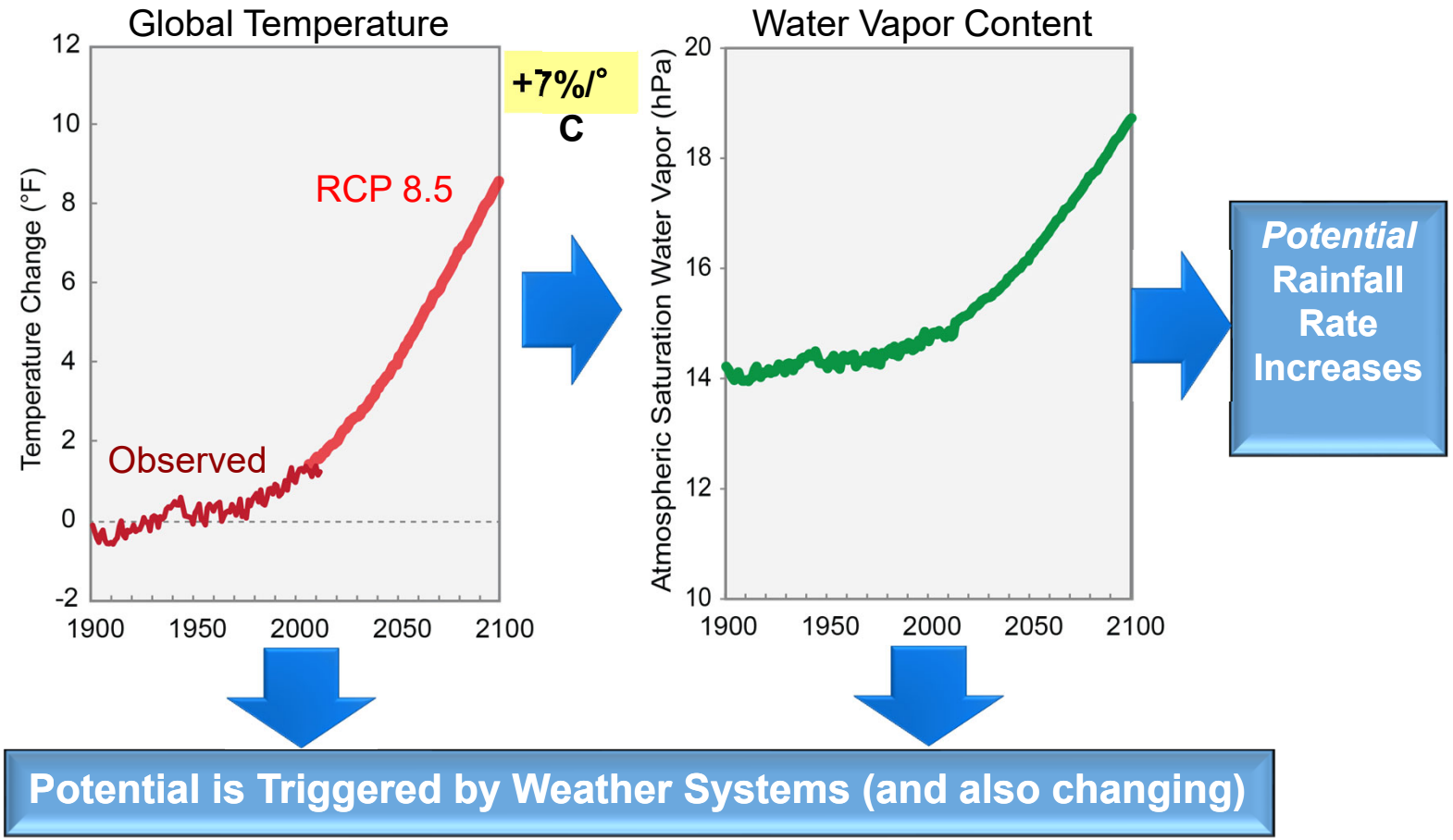


Fall Precipitation

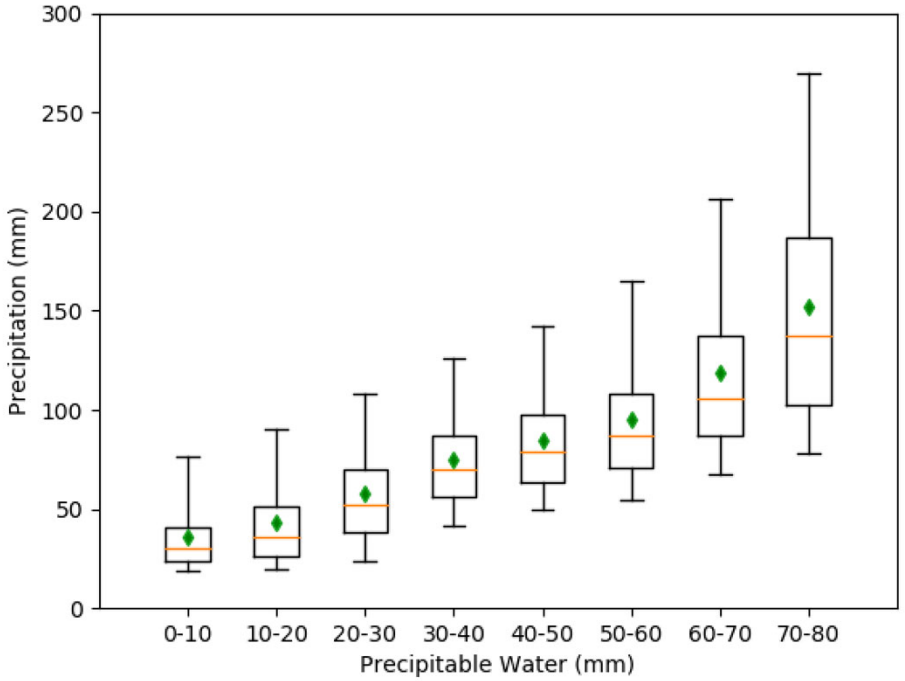


Kunkel Approach

Global Warming->Saturation Water Vapor Increases



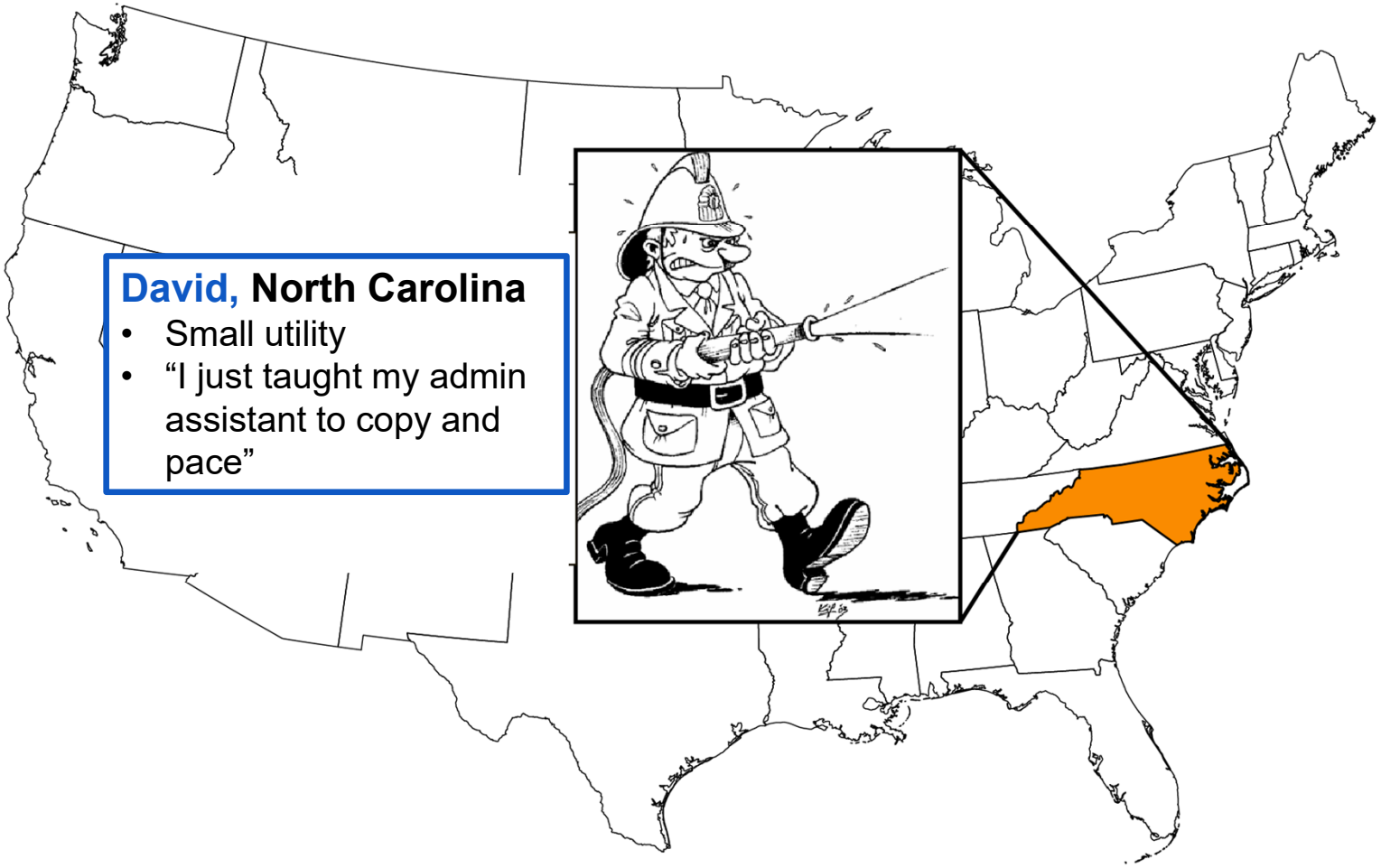
Annual Maximum Precip Increases with Temp



Statistically significant positive correlations: 1178 stations (out of 3018 stations)
Statistically significant negative correlations: 4 station

David, North Carolina

- Small utility
- “I just taught my admin assistant to copy and pace”


David, North Carolina
• Small utility
• “I just taught my admin assistant to copy and pace”

Motivate younger employees by creating a clear company vision and emphasizing job flexibility and collaboration.

smarp

3 Things Millennials Want in the Workplace

Interact with their colleagues

Millennials want to interact with their colleagues through their favorite channels

Share new ideas

Millennials want to be able to share their ideas with their colleagues

Be heard

Millennials want to be listened to and make an impact on the business