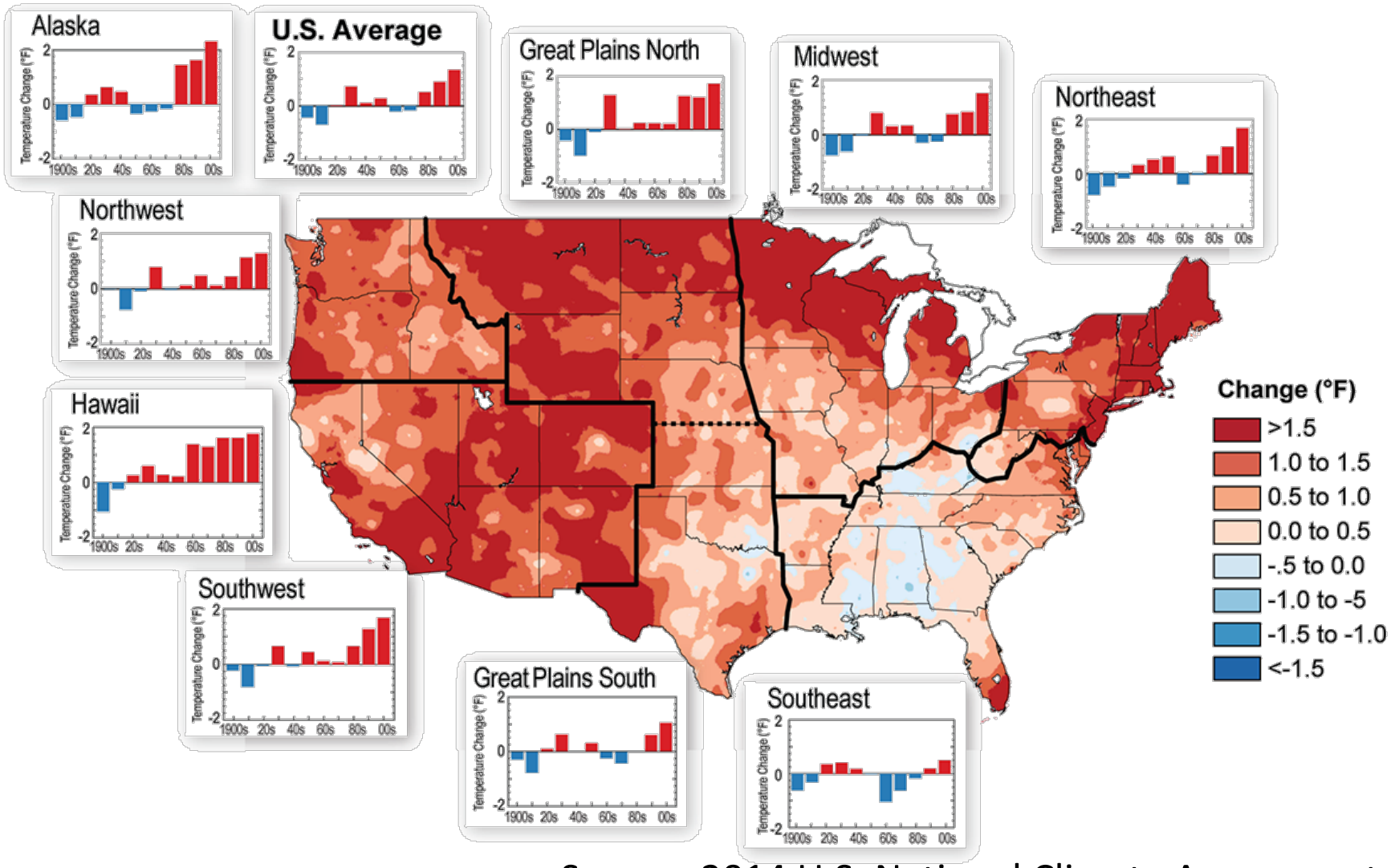
Application Examples of Downscaled Output

ANNE STONER, PhD

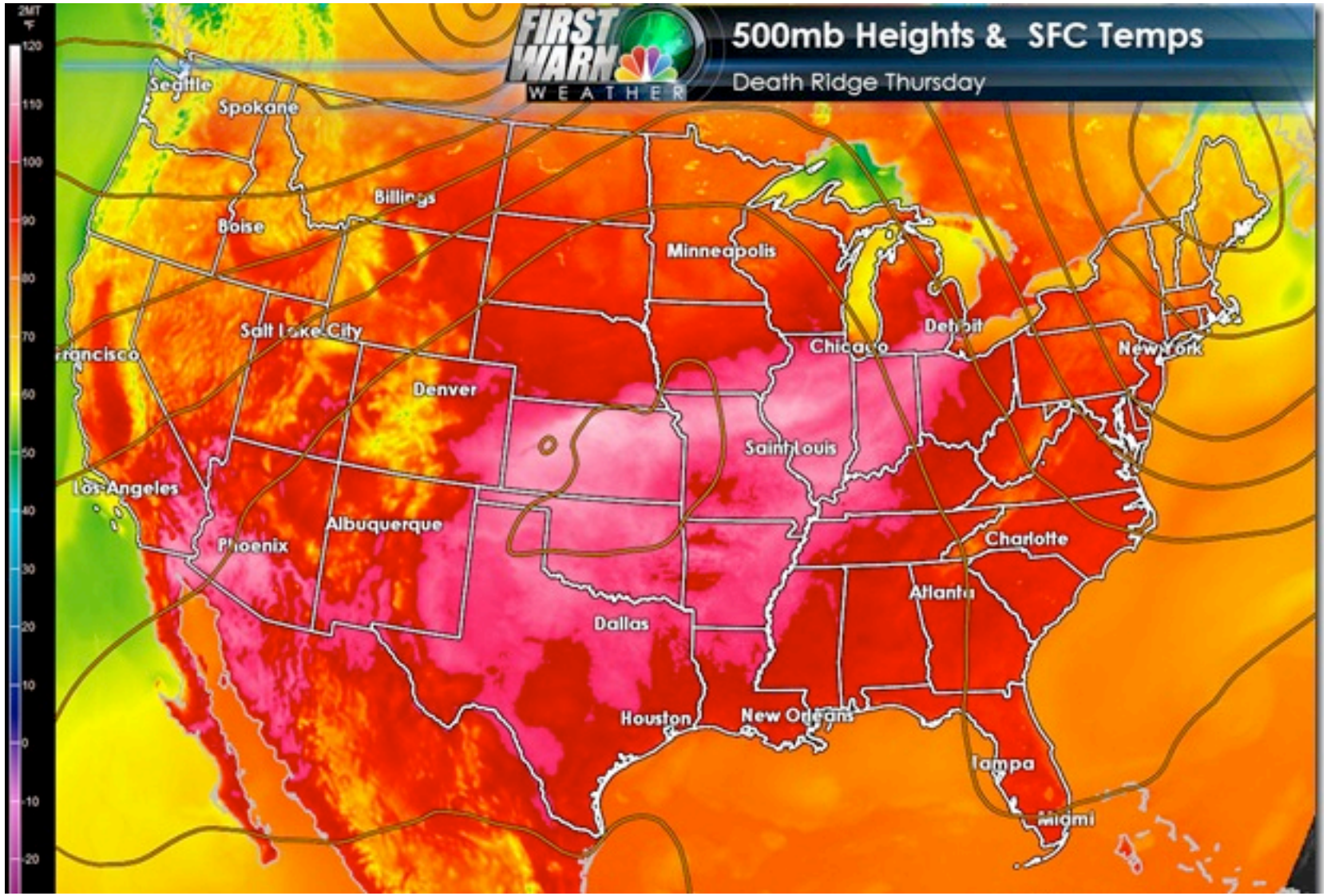
TEXAS TECH UNIVERSITY.

The U.S. is getting warmer

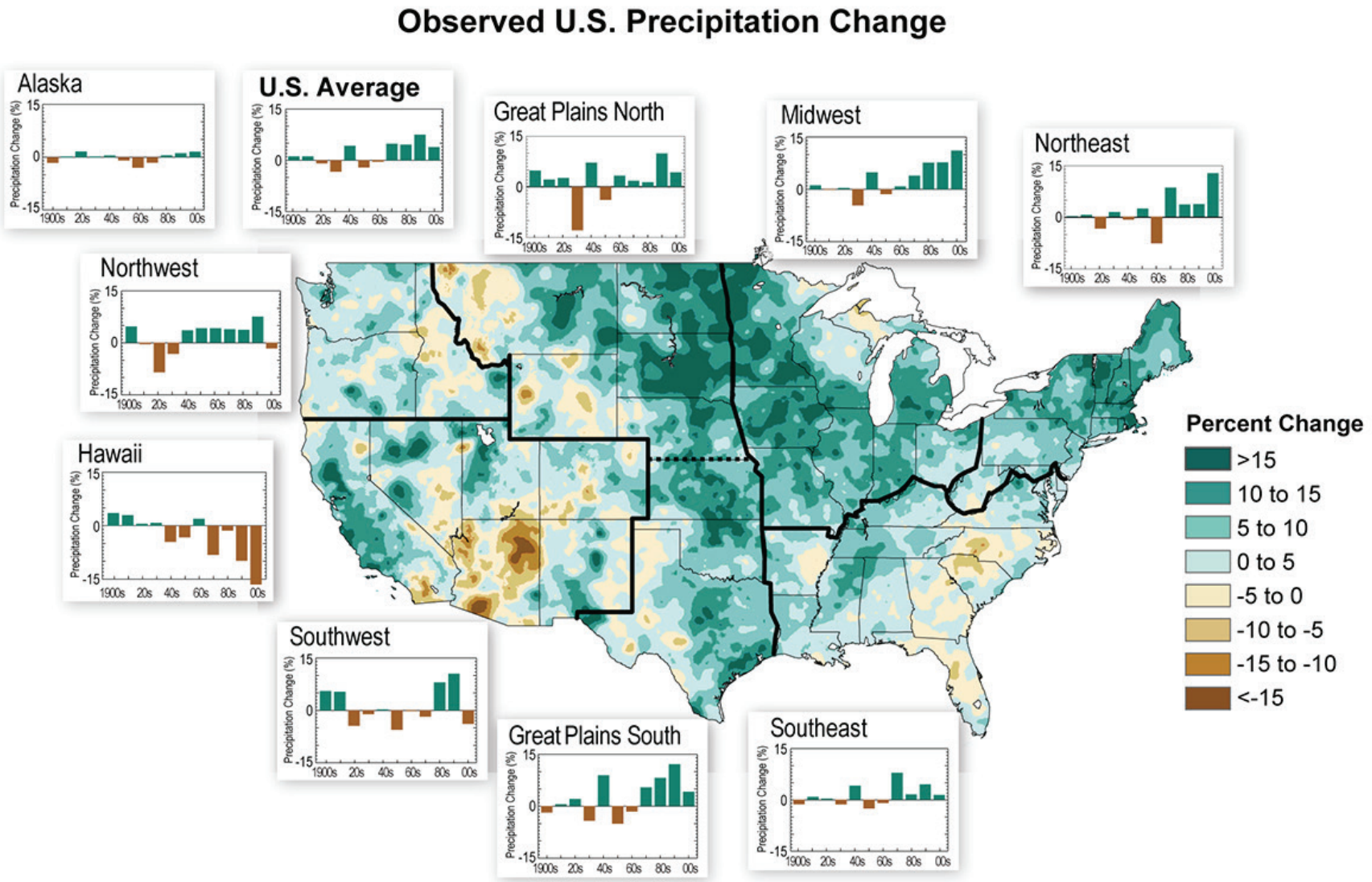


Source: 2014 U.S. National Climate Assessment

Heat waves are stronger and more frequent



Regional precipitation patterns have shifted



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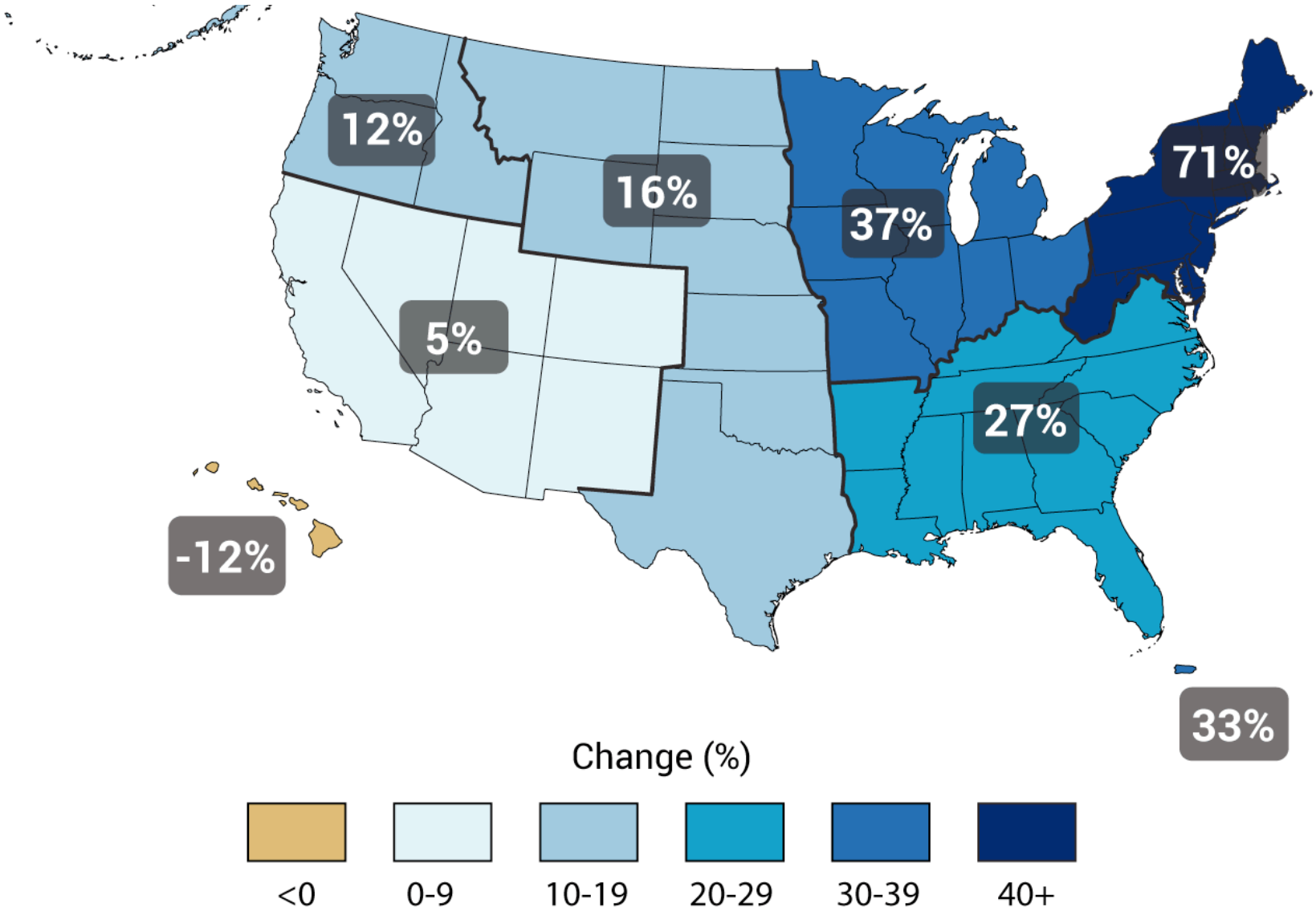
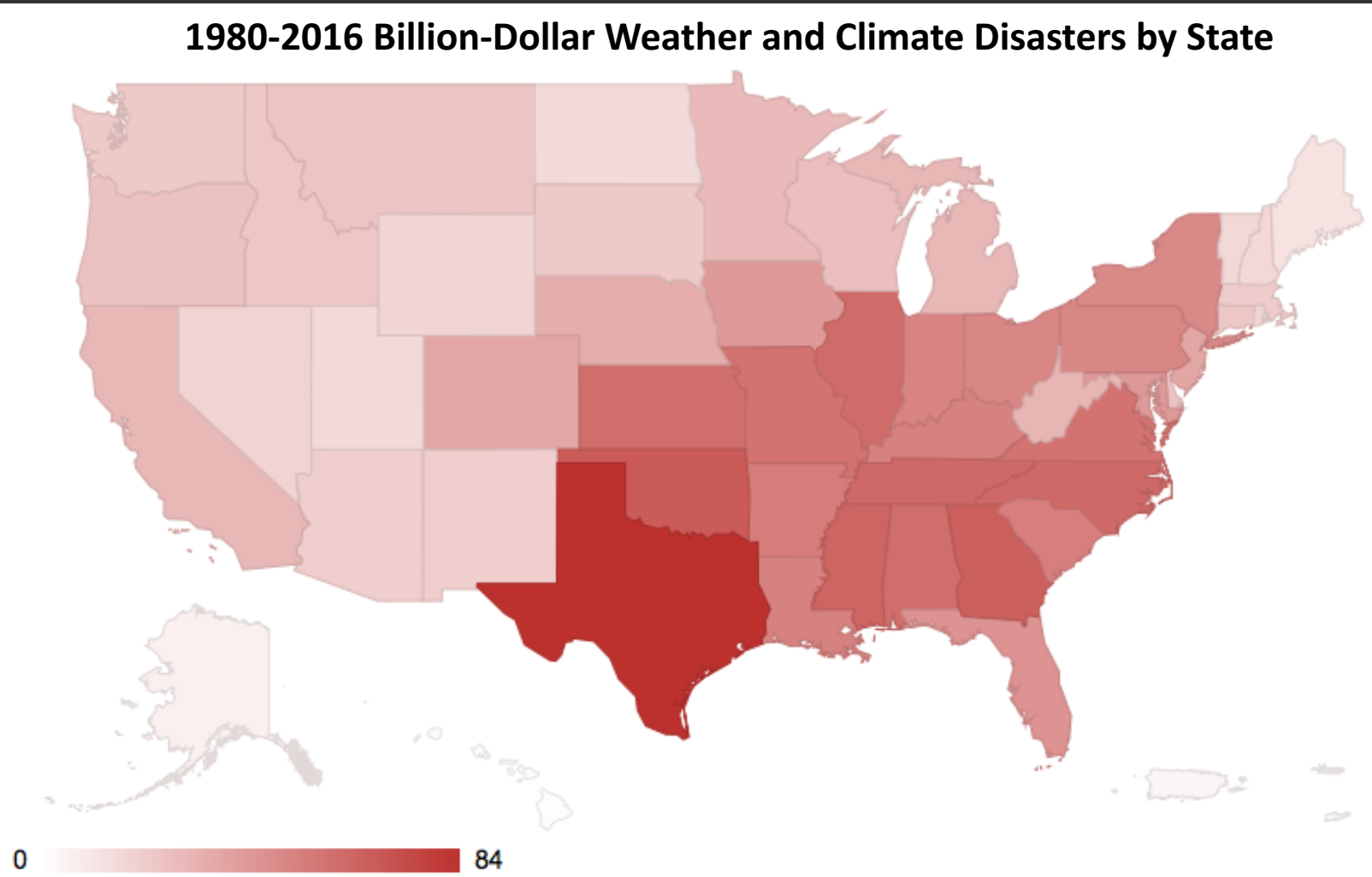
Heavy precipitation becoming more frequent



Billion dollar disasters are on the rise



Source: NOAA National Centers for Environmental Information (2017)

What types of weather events cause these?

Wildfire

Rapid Snowmelt

Hurricanes

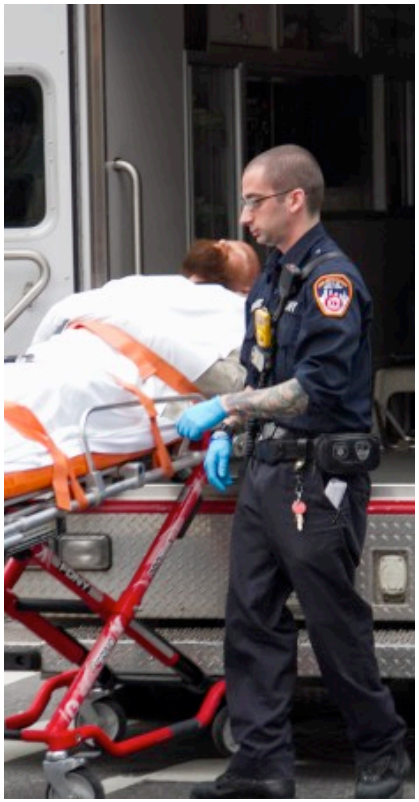
Heatwaves

1. How does climate and weather affect our interests?

The first and most important step in any climate impact assessment is to mine available information and knowledge, which includes both existing vulnerabilities and historical events.

Infrastructure Maintenance

Tourism



Public Health

Agriculture

2. What can climate science reliably tell us?

The second step in any climate impact assessment is to consider the extent to which robust quantitative projections can be developed.

Specifically:

- Is the relationship between climate indicators and relevant infrastructure or other impacts clear?
- Are there historical trends in these indicators?
- Are climate models able to reproduce the observed historical trend?
- Can future trends be quantified, or does the noise outweigh the signal?

3. Data, Model Output, and Methods

To answer the questions posed in the second step, we need to simultaneously complete a third step: assembling available data and information. This includes:

1. Daily temperature, precipitation, and humidity (dewpoint) observations for **several weather stations**

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3. Use at least a higher and lower future scenario to cover the range in projected climate
4. Use an **empirical statistical downscaling model** capable of resolving changes in mean and extreme values or use output from a **regional climate model** if available

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5. Calculate relevant **climate indices** or apply an **impact model**

Urban planning for Washington D.C.

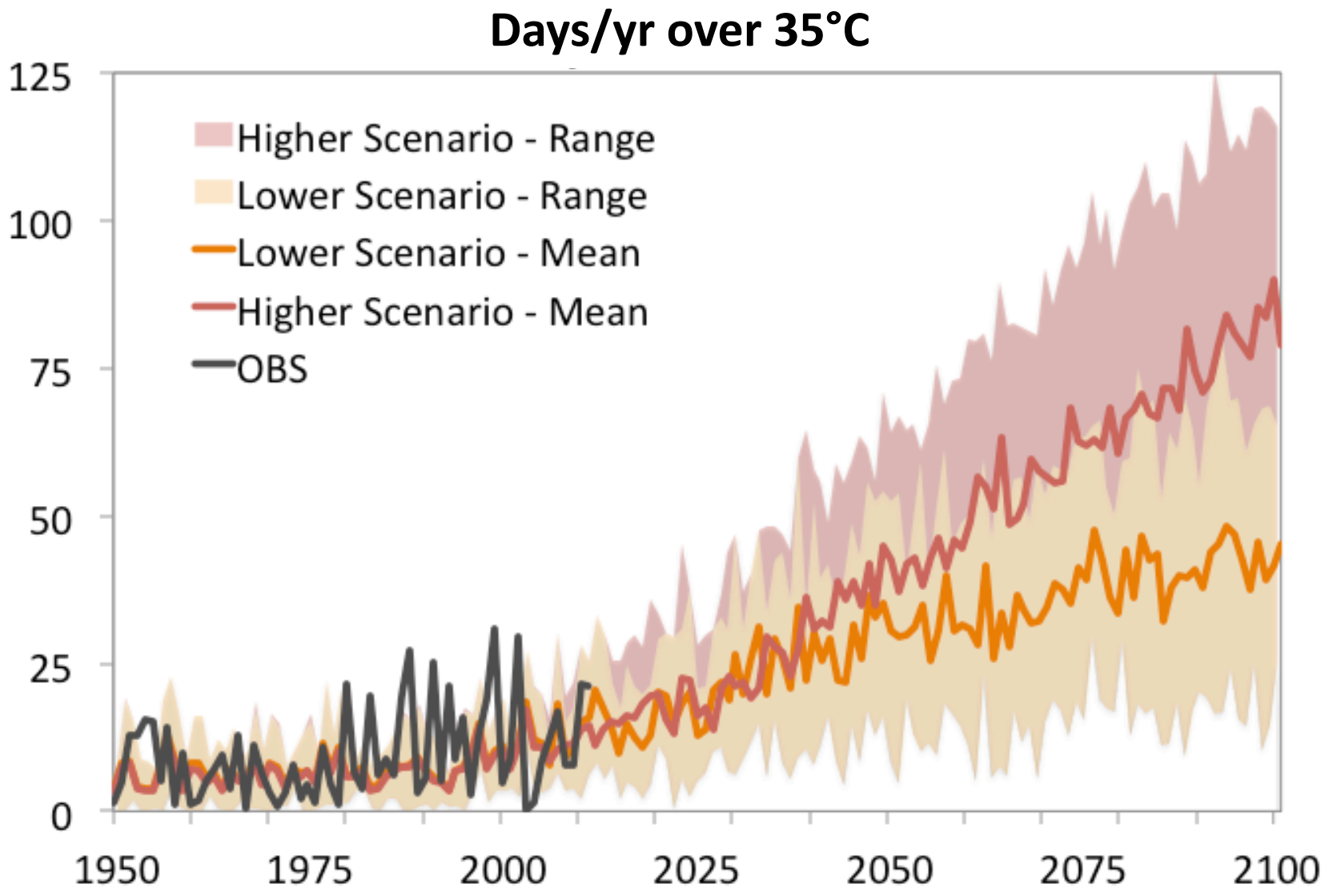
City planners and officials in Washington D.C. are worried about the recurrence of the 2012 heat wave

- 11 consecutive days with Tmax > 35°C
- 1 day with Tmax > 40°C

Procedure

- Downscaled 9 CMIP5 GCMs
- 3 local weather stations for 1950-2100
- 2 future scenarios (RCP4.5, RCP8.5)
- 4 daily variables (min/max temperature, precipitation, humidity)
- Calculated suite of climate indicators tailored to concerns

Will the 2012 heat wave recur?



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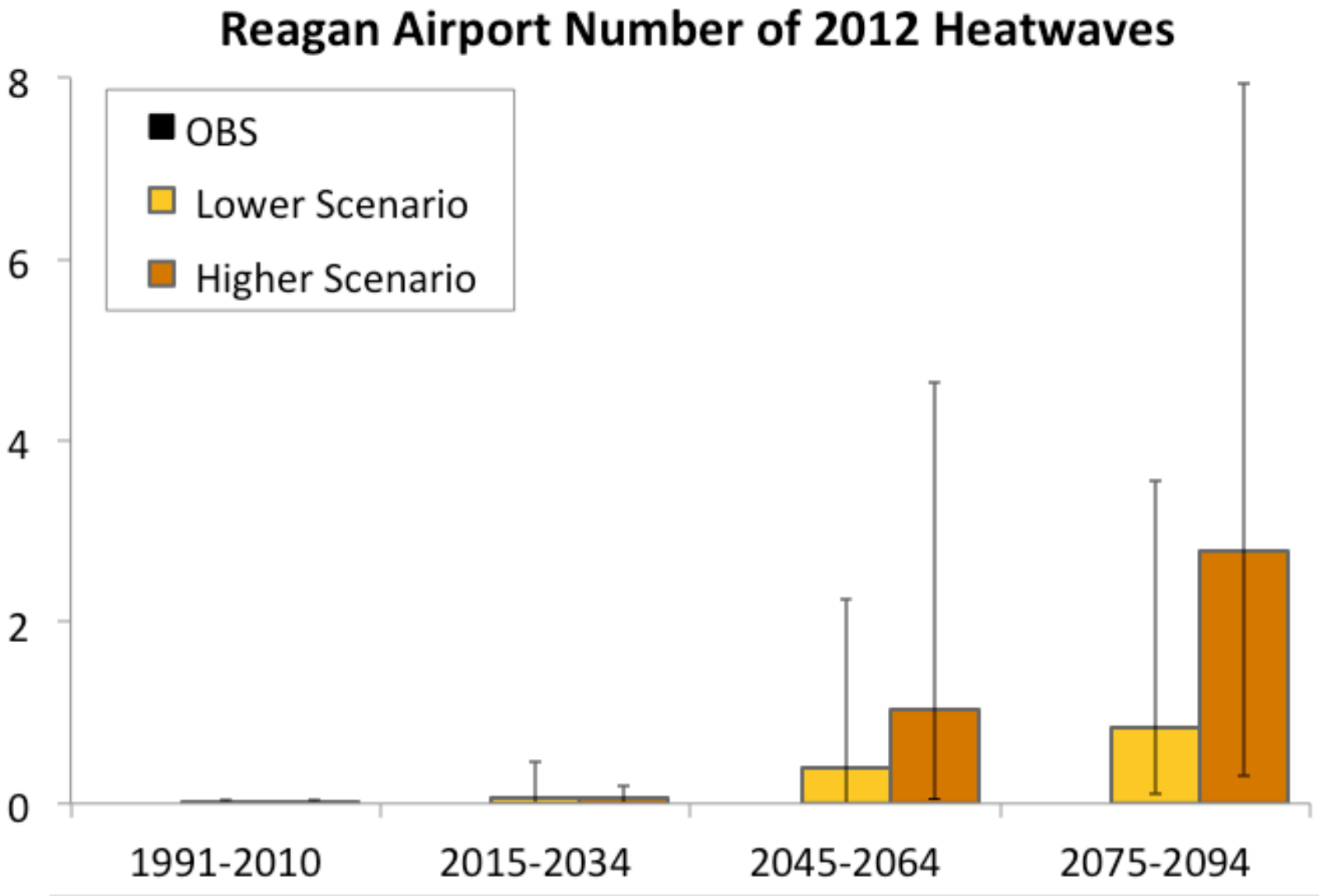

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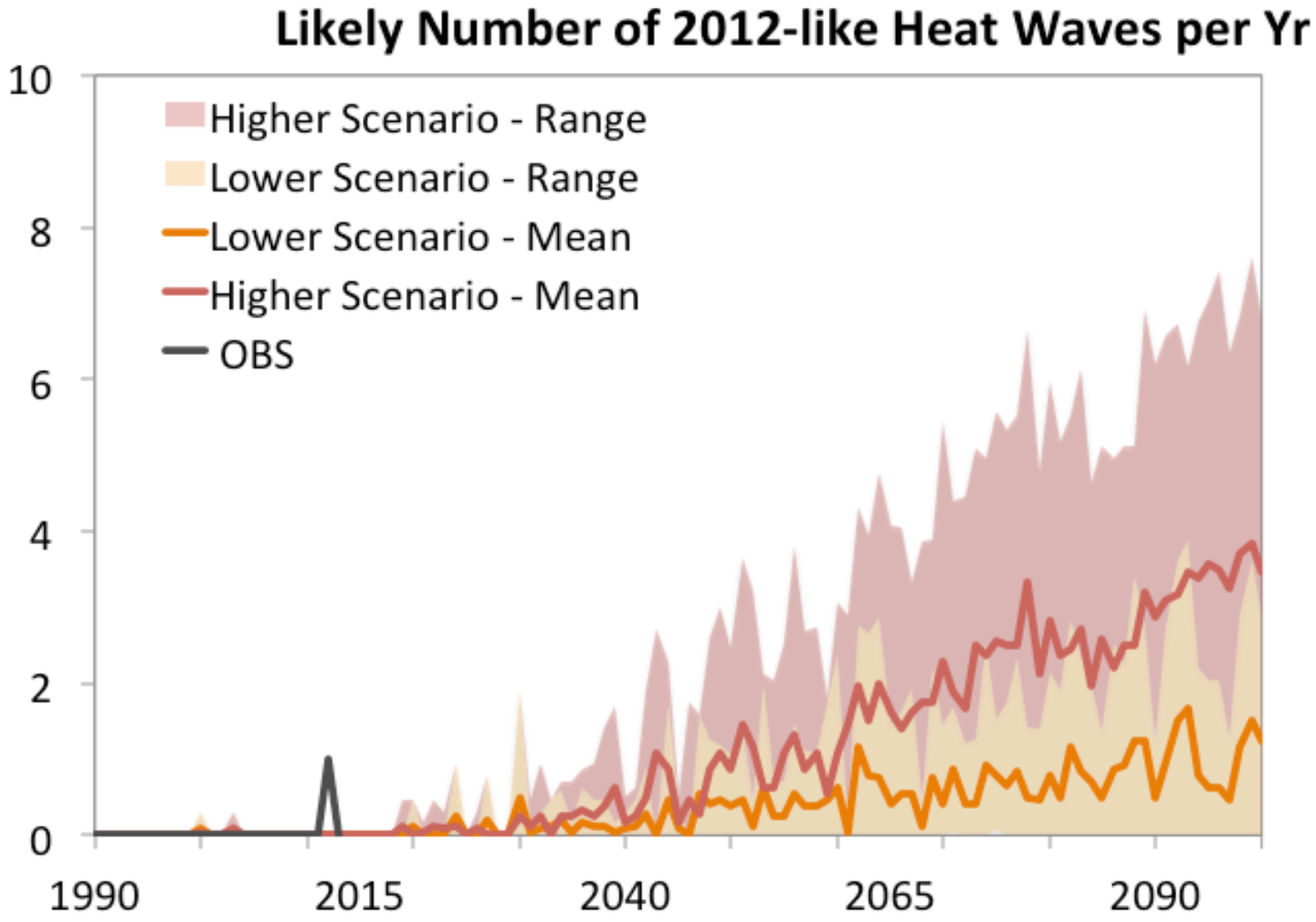
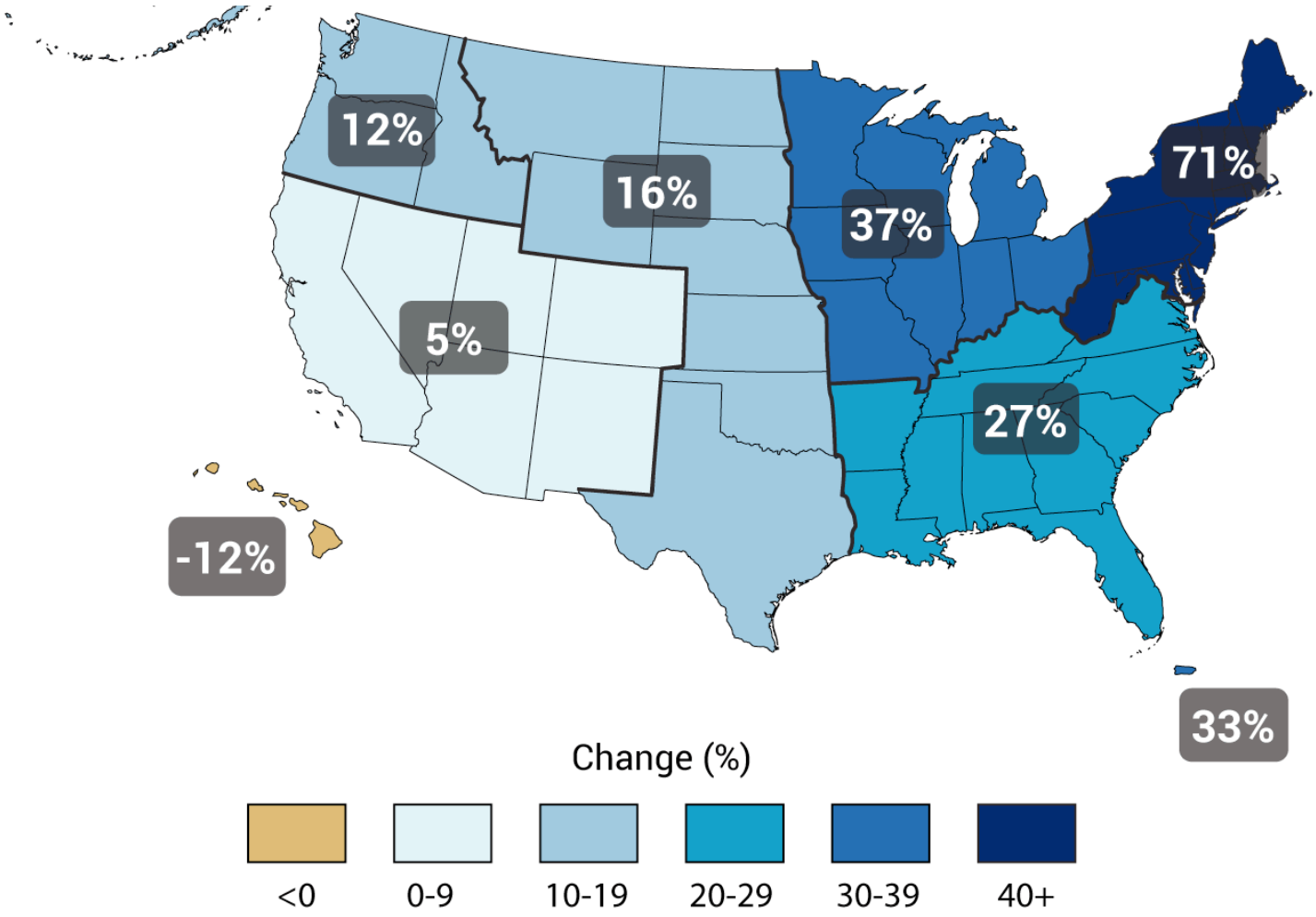


Heat wave prevention

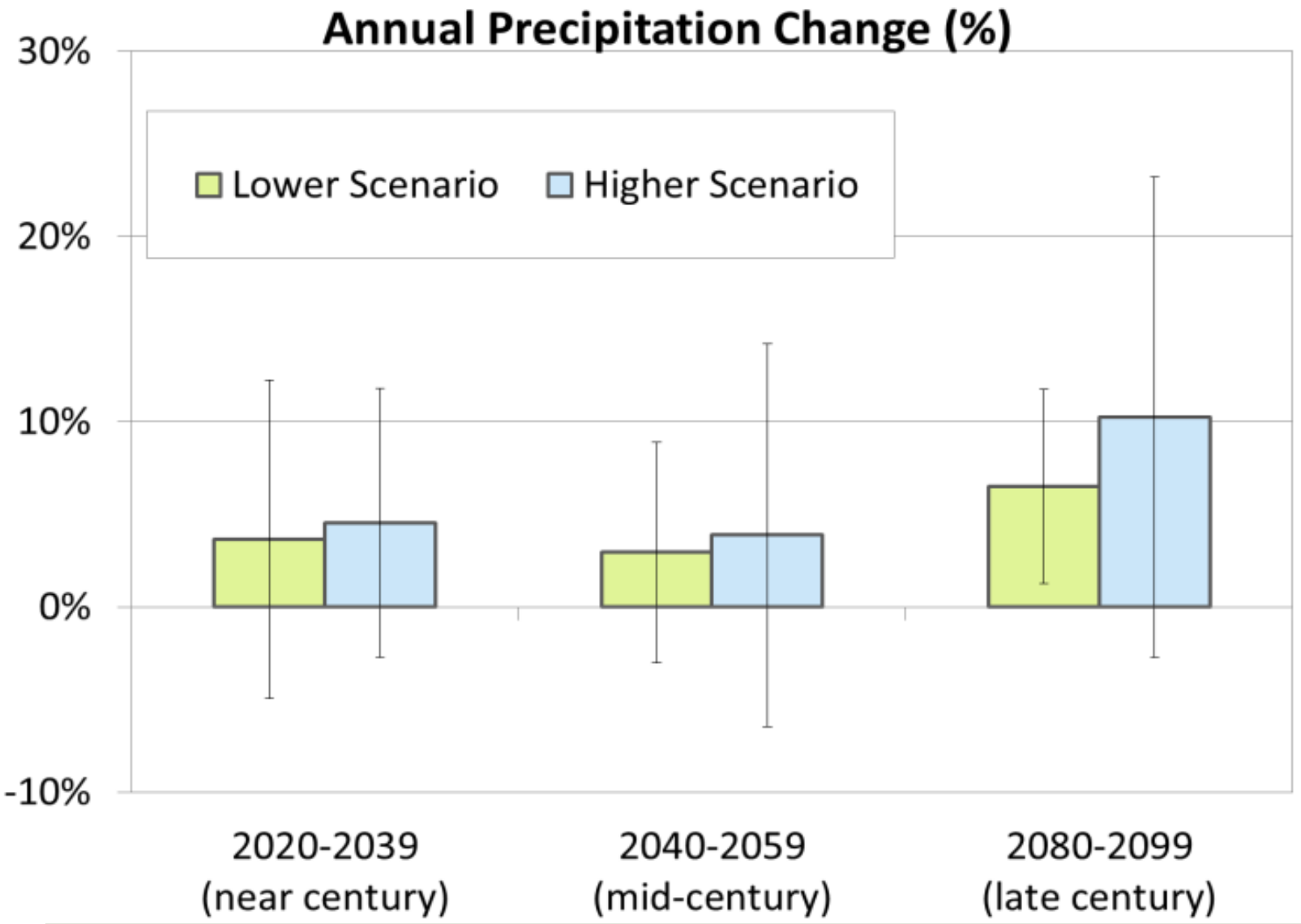
Delaware

Officials in Delaware are worried about flooding events

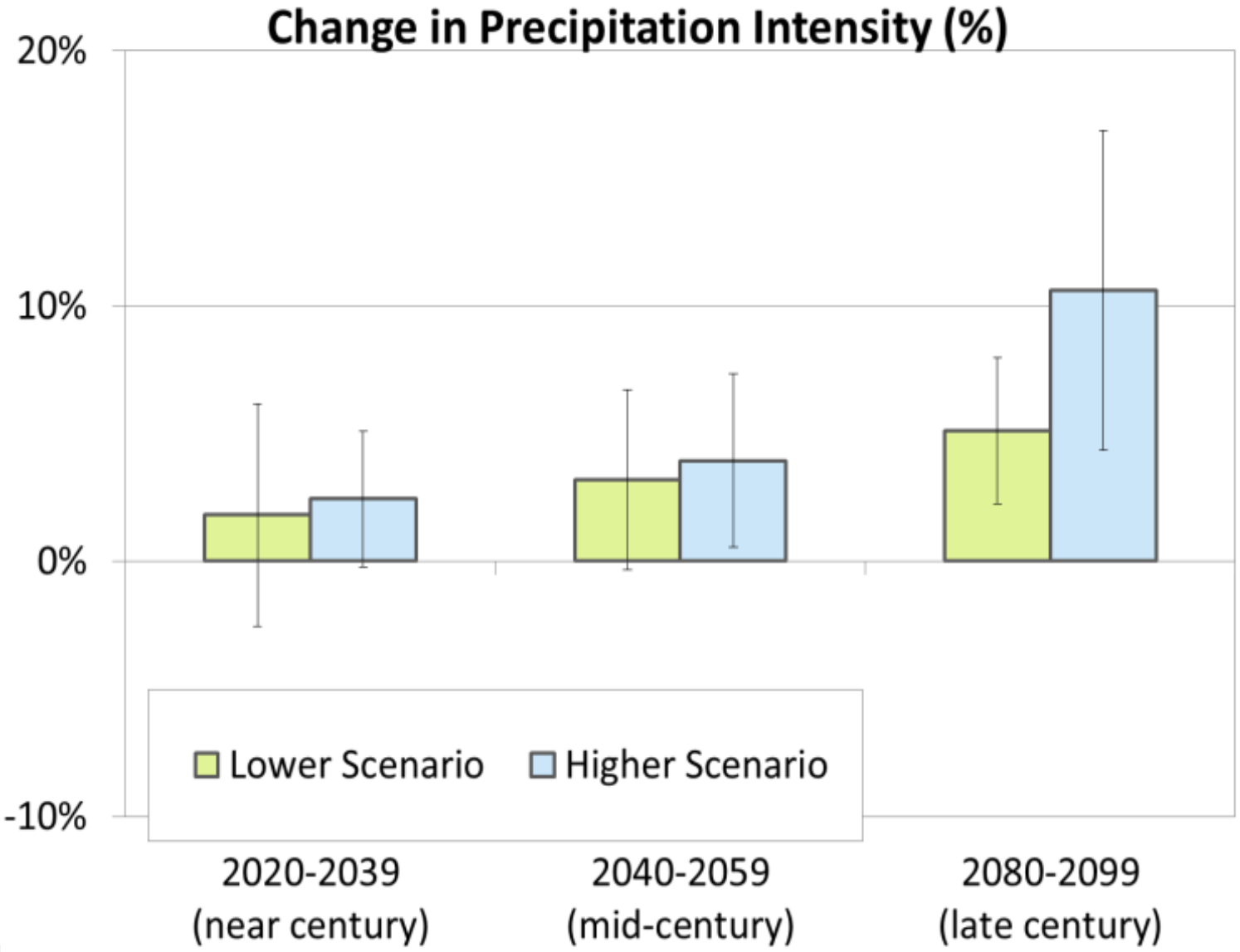
Heavy precipitation becoming more frequent



Annual precipitation projected to increase

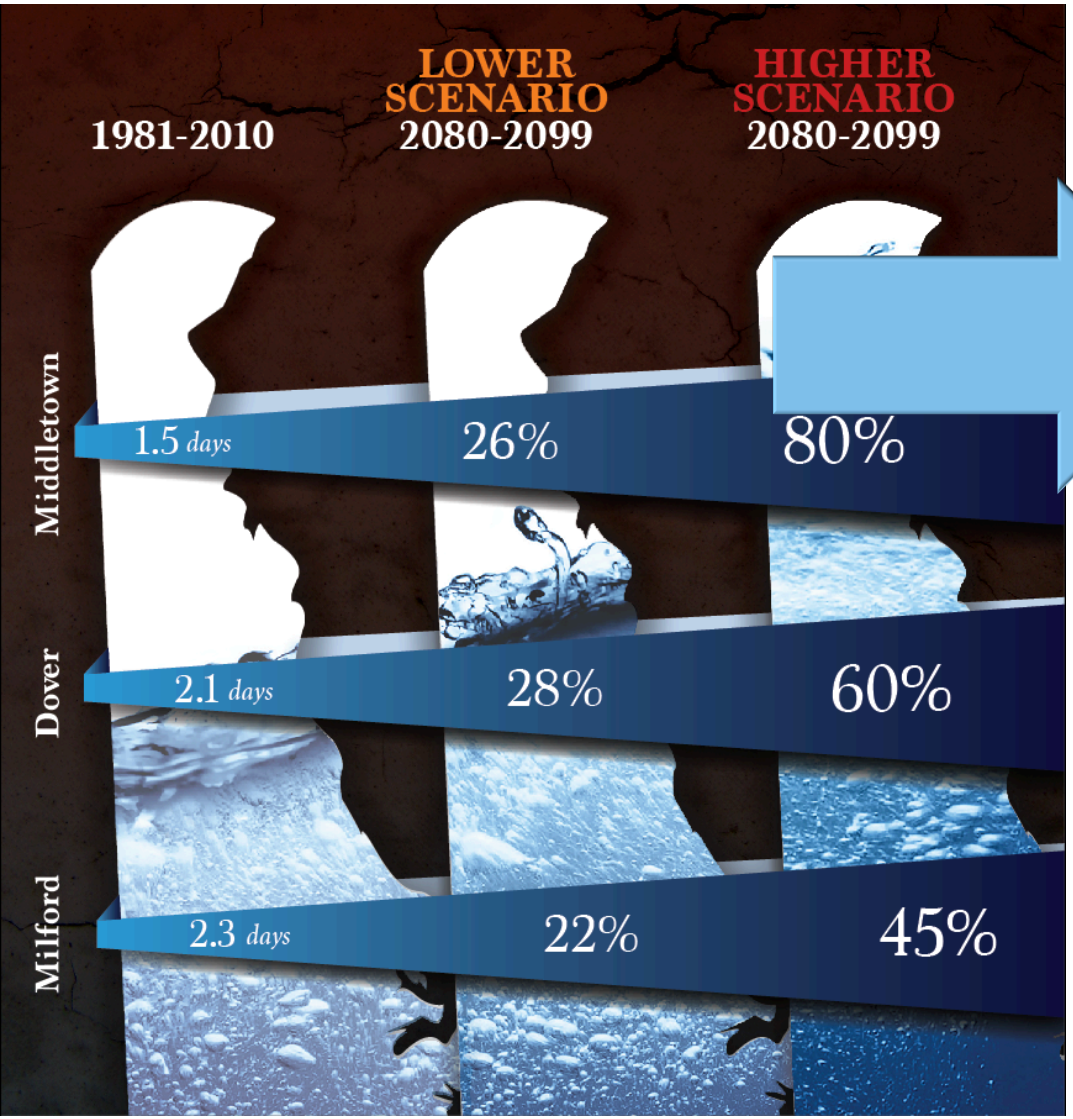


Precipitation becomes more intense



Flood prevention management

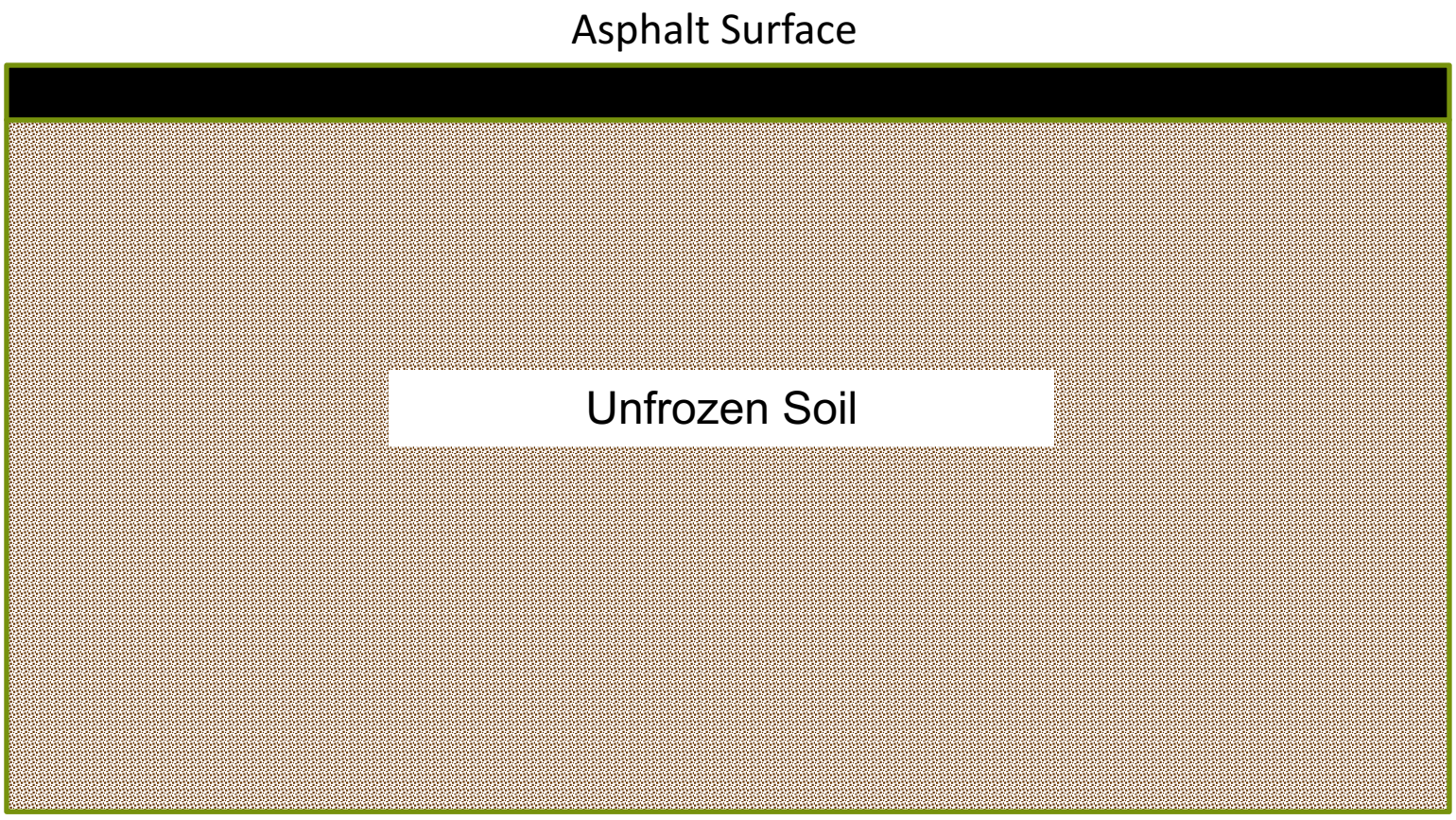
More frequent extreme precipitation



Infrastructure in the Northeast US

Engineers in the Northeast US are worried about climate change affecting the freeze-thaw cycles in roadways, which has implications for the logging business

Roadway sub-surface



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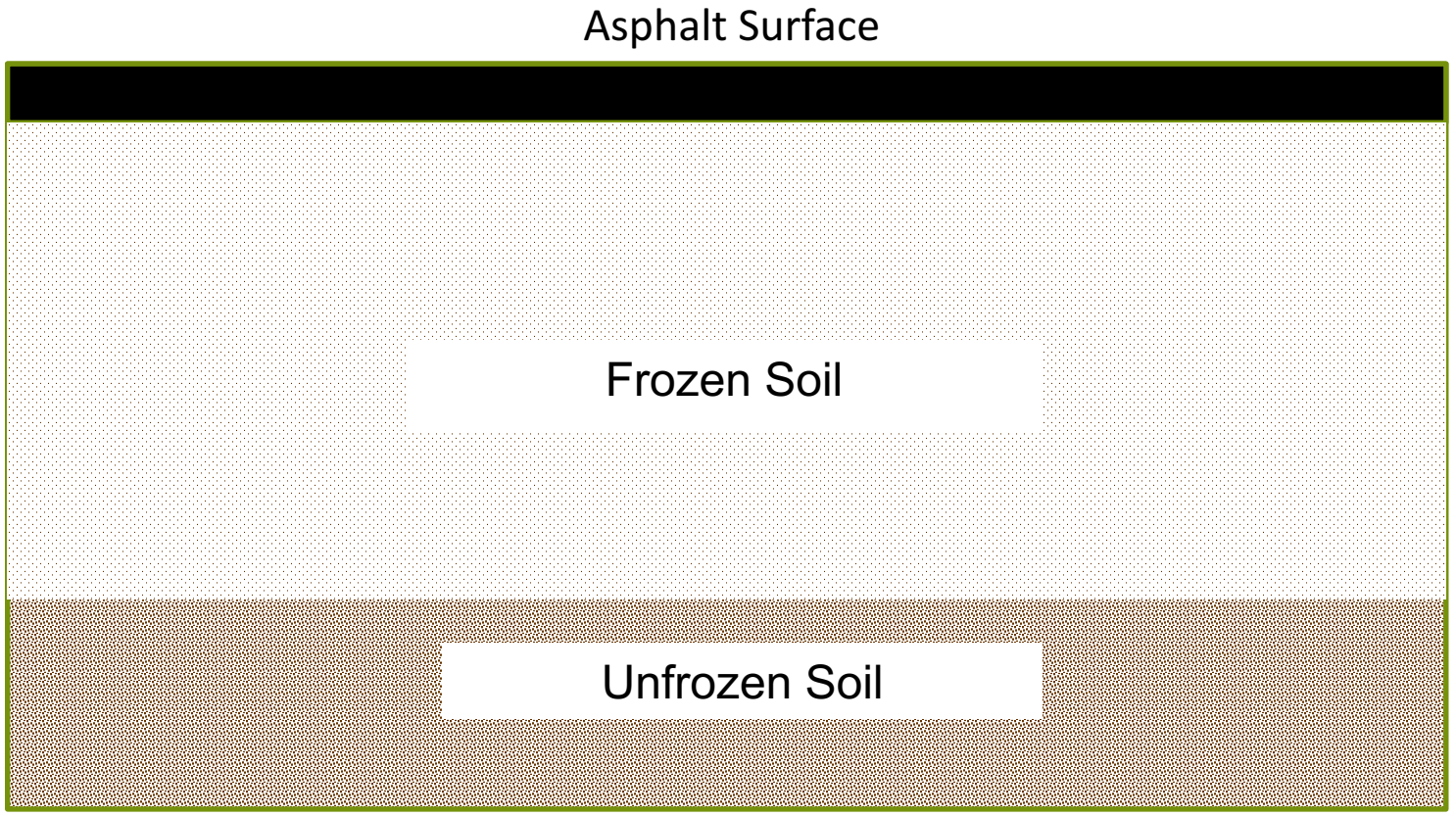
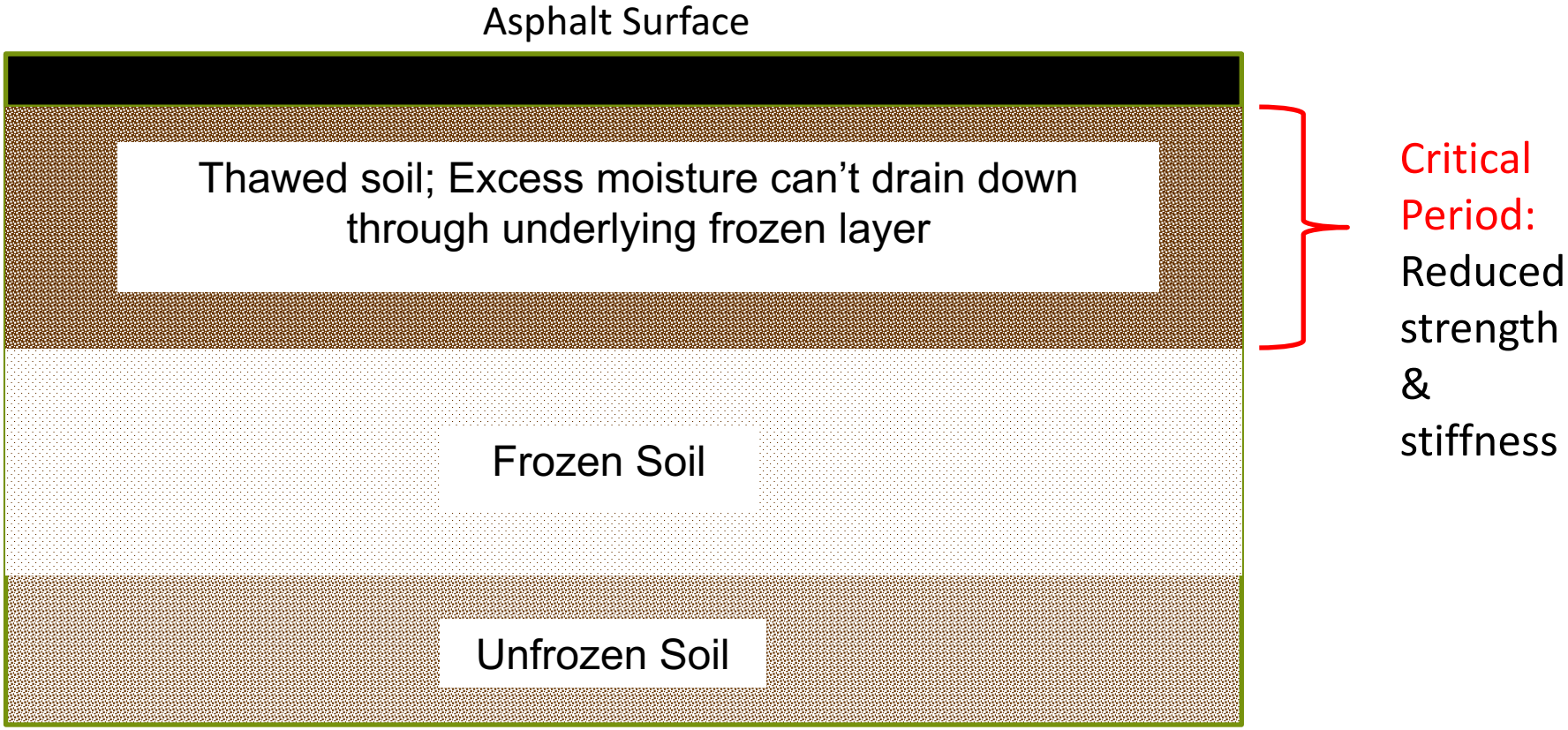


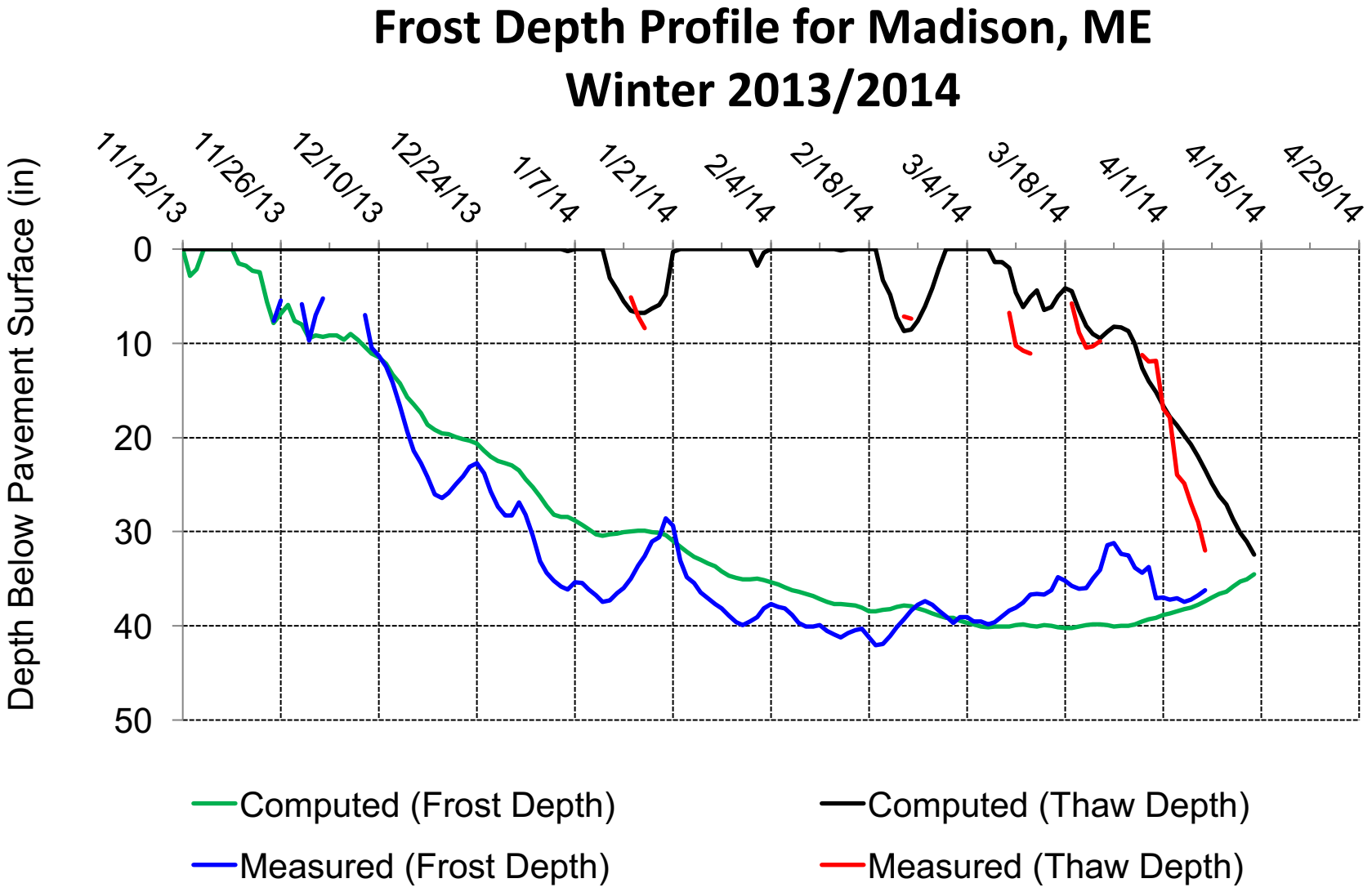
Winter weight premiums are applied

Roadway sub-surface

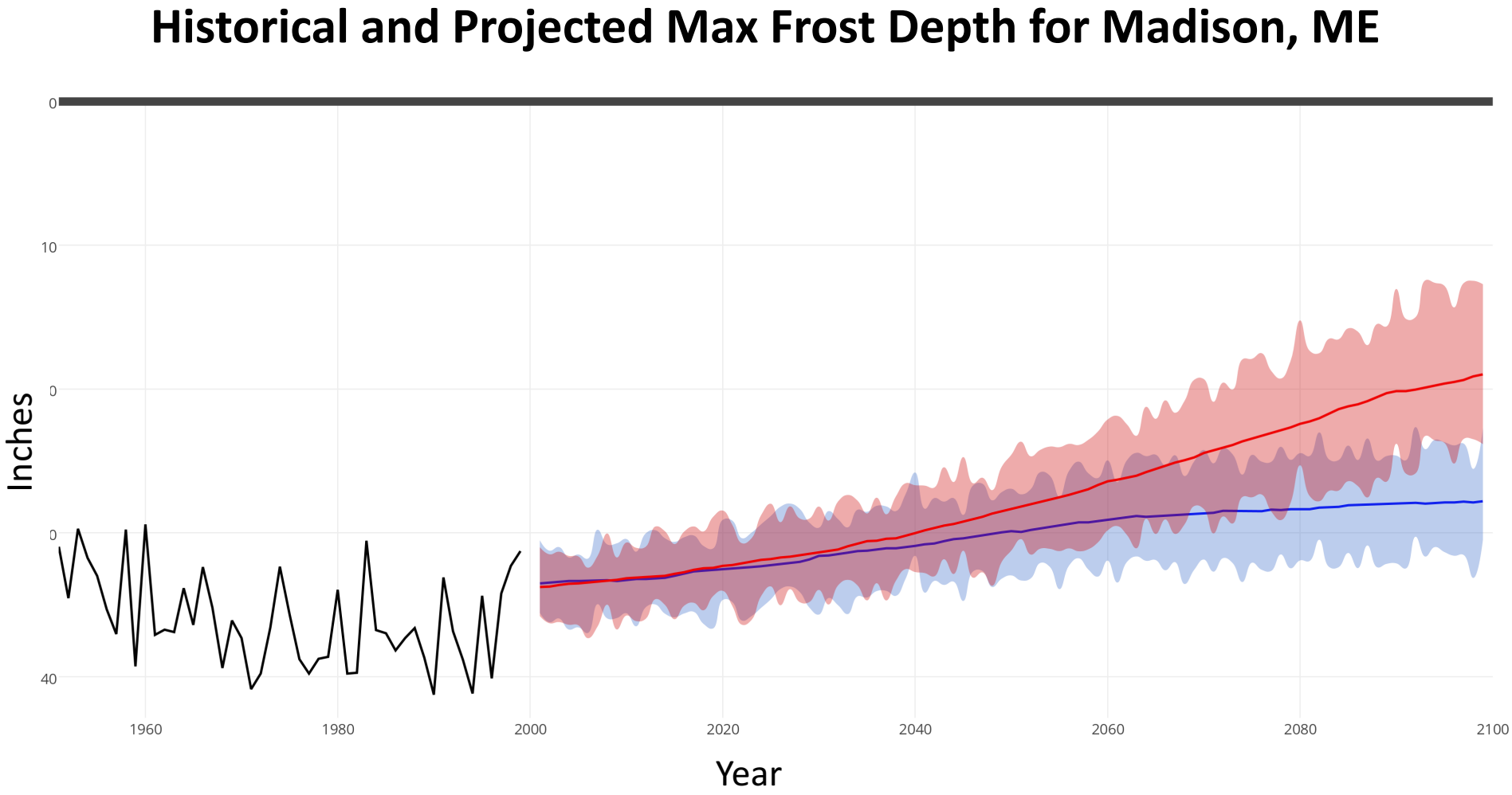


Spring load restrictions are applied

Roadway sub-surface frost depth profile



Projected Frost Depth



Freezing and Thawing Index

- Cumulative Freezing Index (CFI)
  - When CFI reaches specific level winter weight premiums are applied

$$FI_i = T_{ref} - T_{avg,i}$$

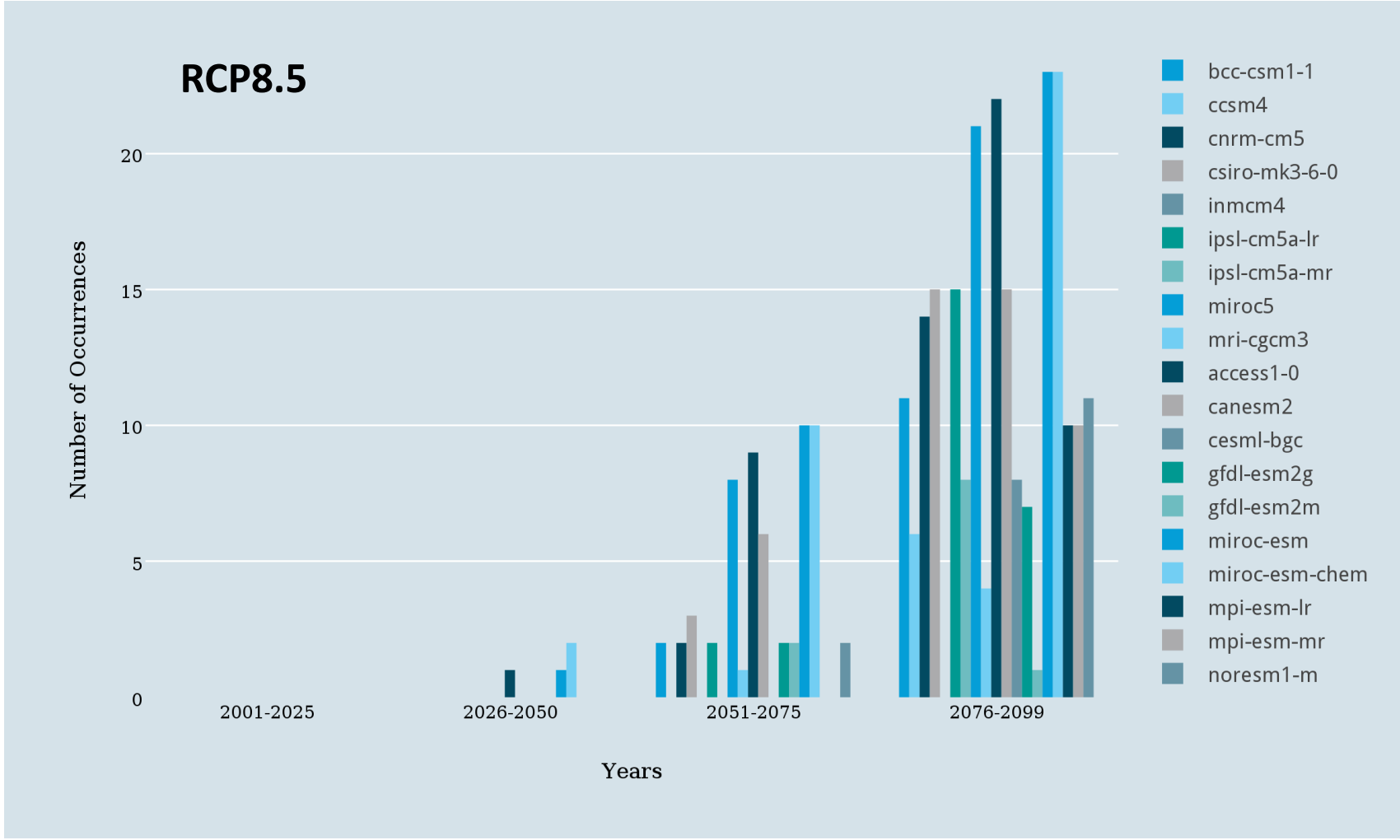
$$CFI_n = \sum_{i=1}^{n} FI_i$$

- Cumulative Thawing Index (CTI)
  - When CTI reaches specific level spring load restrictions are applied

$$TI_i = T_{avg,i} - T_{ref}$$

$$CTI_n = \sum_{i=1}^{n} \left(\text{Daily Thawing Index} - 0.5 \times \text{Daily Freezing Index} \right)$$

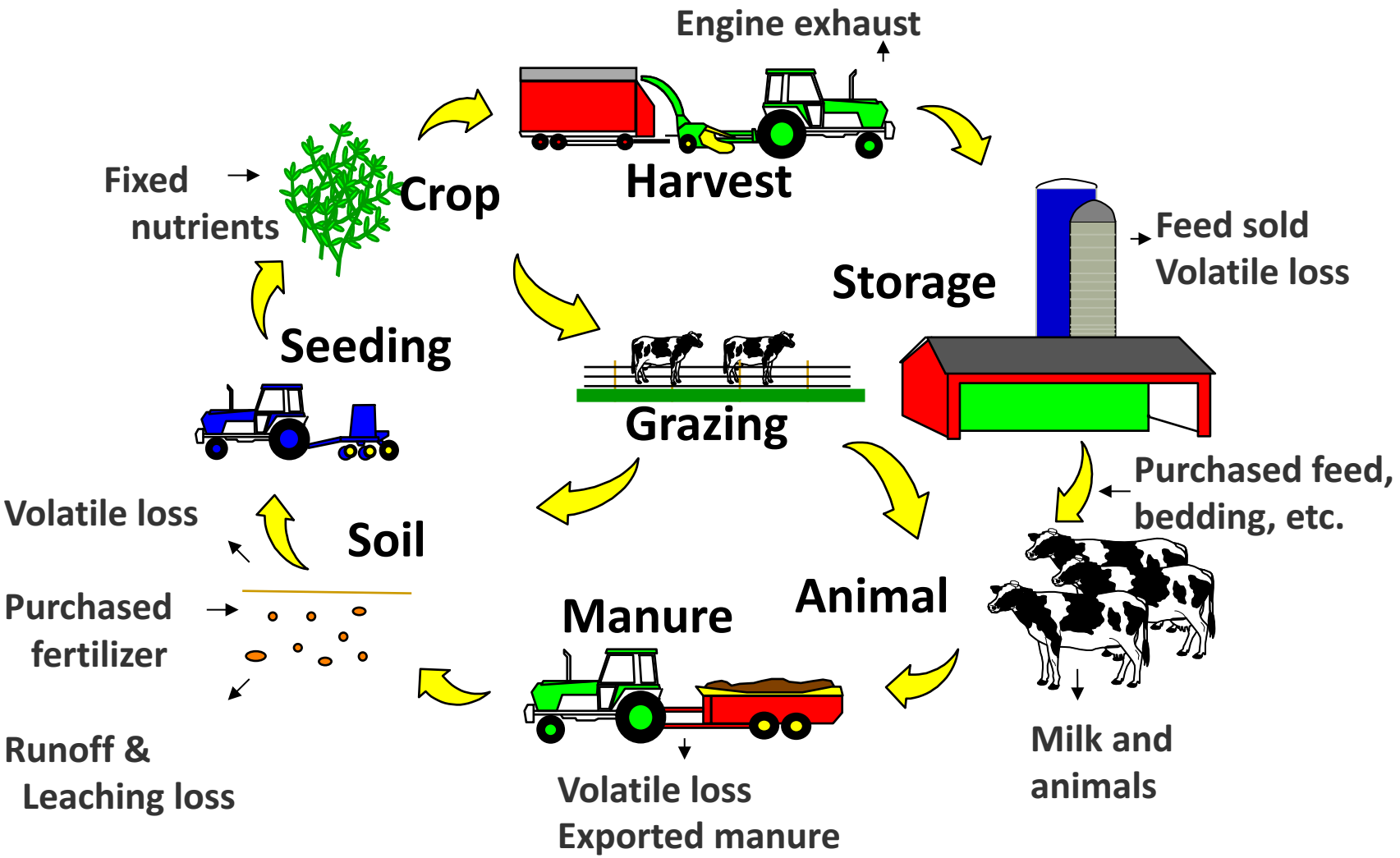
Historical and Projected times CFI threshold is not exceeded for Madison, ME



Adapting Dairy Farms to Climate Change

People in agriculture are concerned about impacts such as crop yields and quality, animal stress and performance, production costs and profit, and emissions to the environment

Farm System Model



Farm System Model Output

- Crop yields and quality
- Milk produced
- Resources used (labor, fuel, equipment)
- Production costs and profit
- Gaseous emissions
- Nutrient losses in runoff and leaching

Environmental Footprint

- Carbon emissions
- Energy use
- Water use
- Reactive nitrogen loss

Dairy Farms

- Syracuse, NY 1,000 cows, 930 ha
- Lancaster, PA 100 cows, 100 ha
- Madison, WI 300 cows, 240 ha
- Jerome, ID 10,000 cows, 3000 ha
- Sacramento, CA 2,000 cows, 320 ha
- Stephenville, TX 1,000 cows, 800 ha

Soils and crops were representative of those at each location

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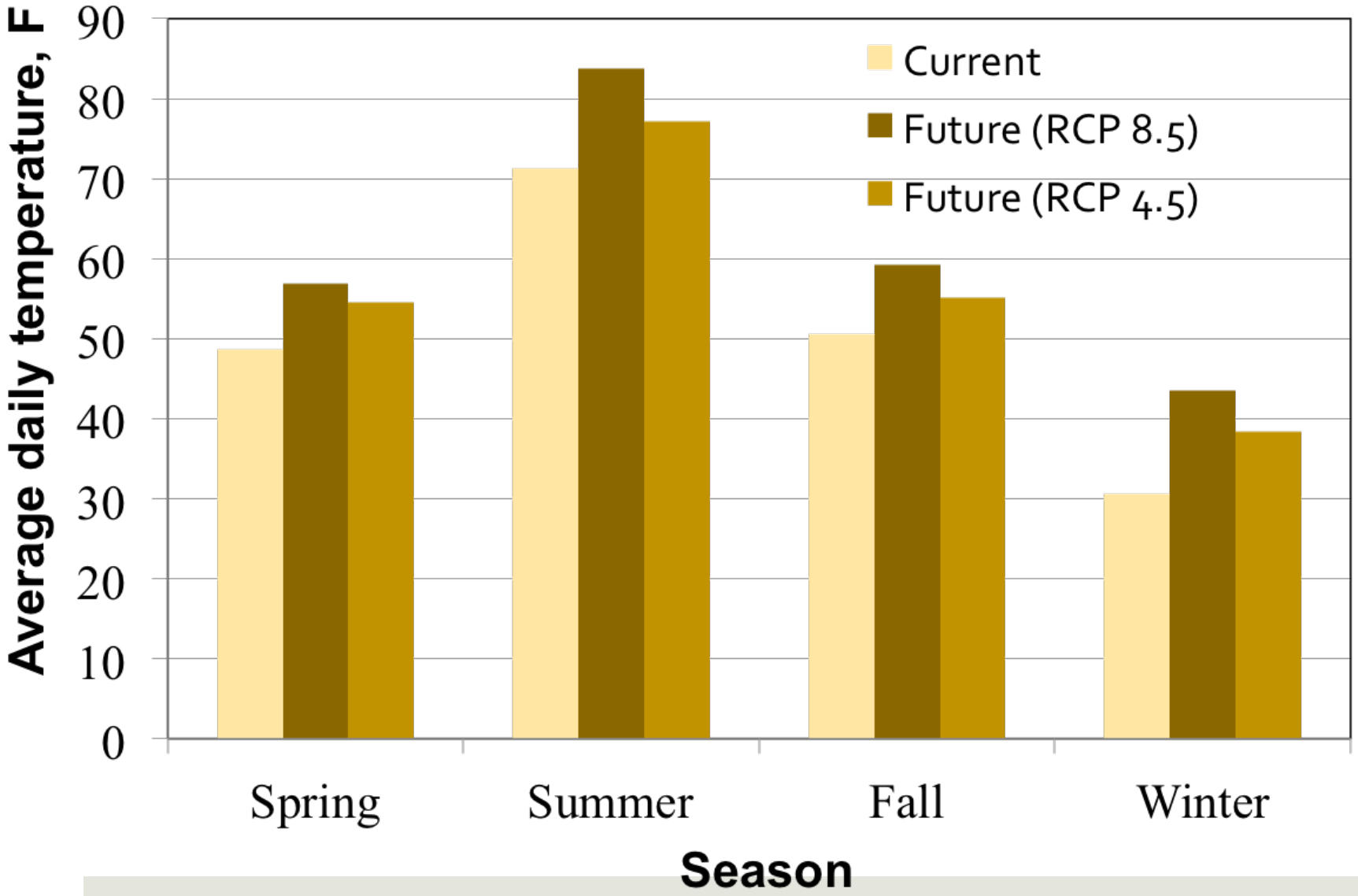
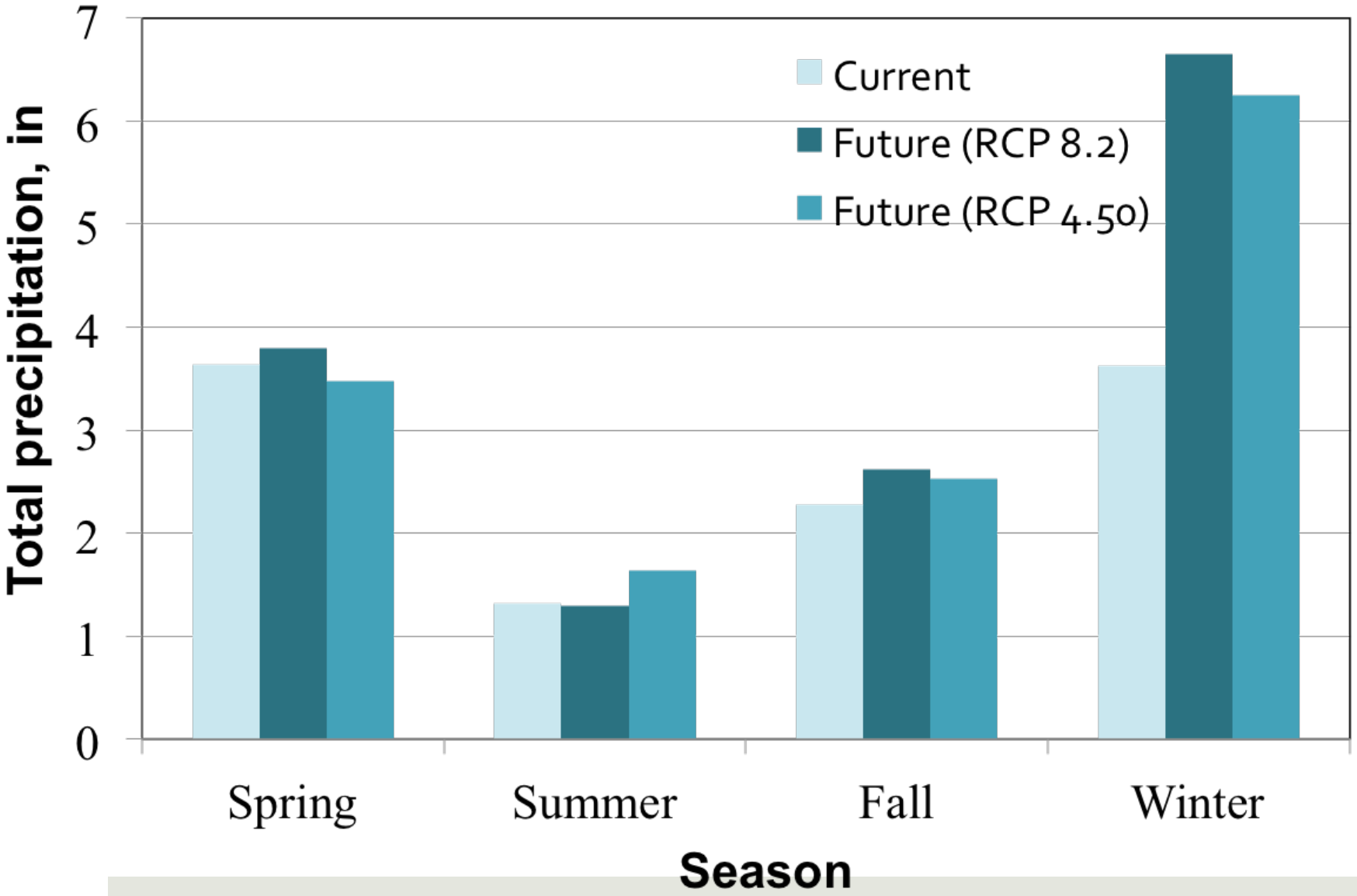
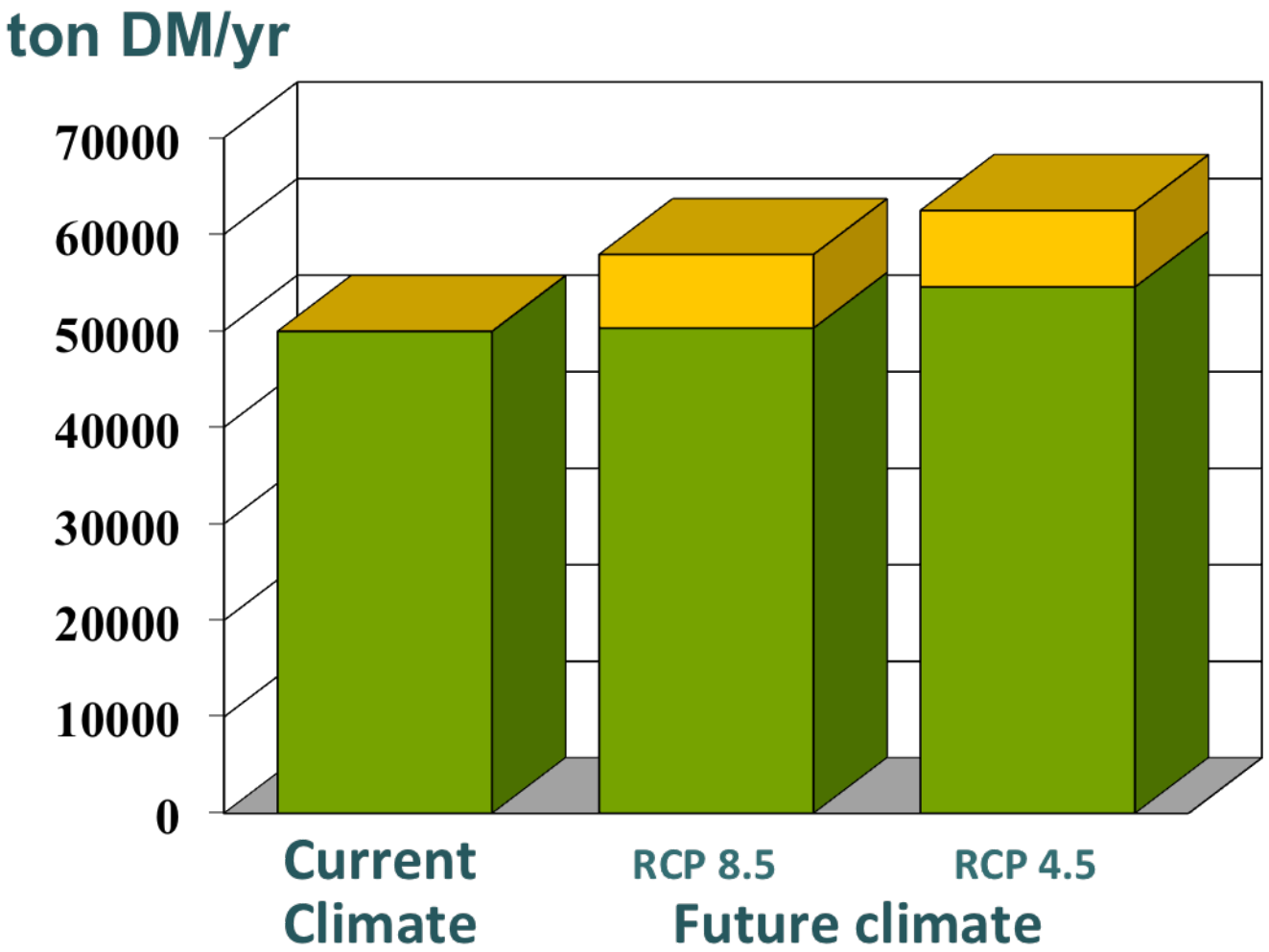
Jerome, ID – Temperature



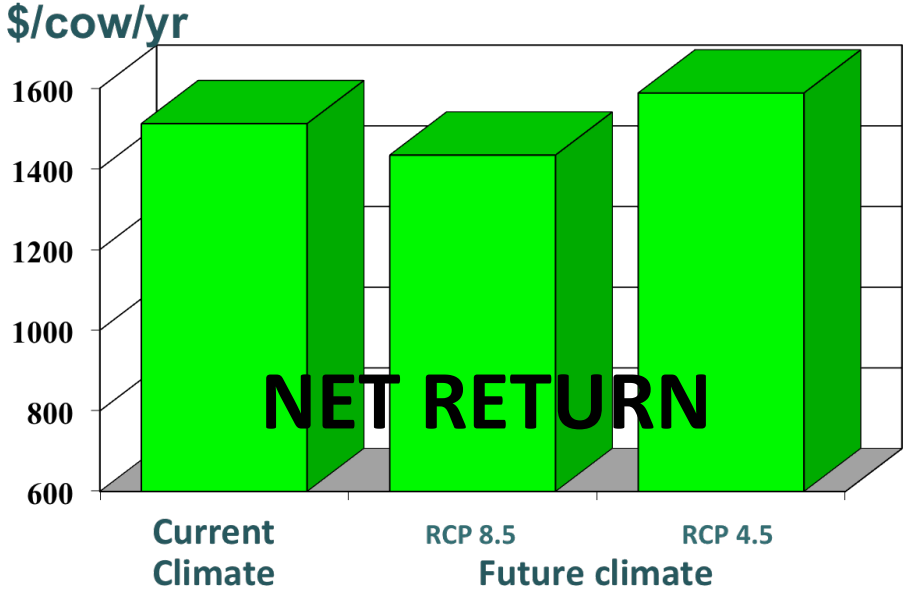
Jerome, ID – Precipitation

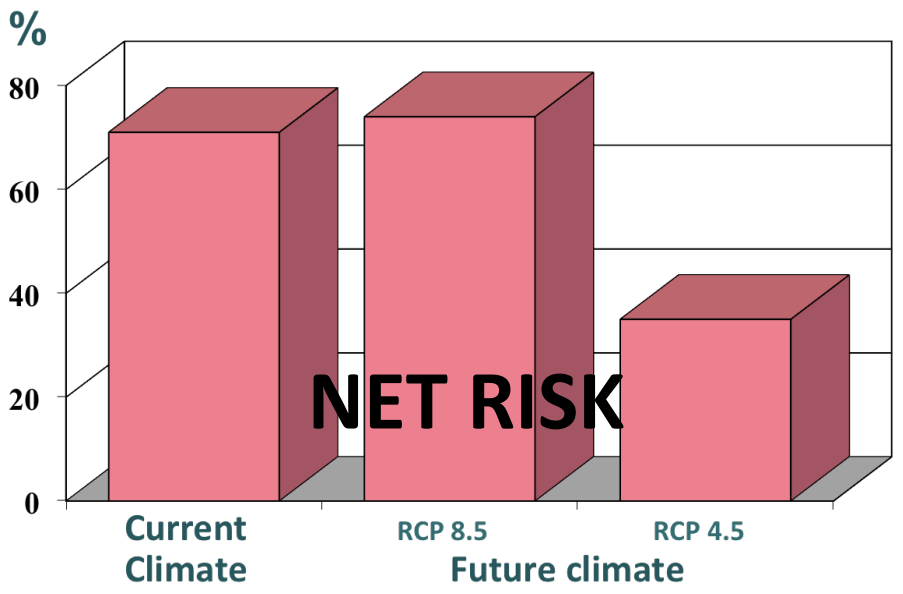


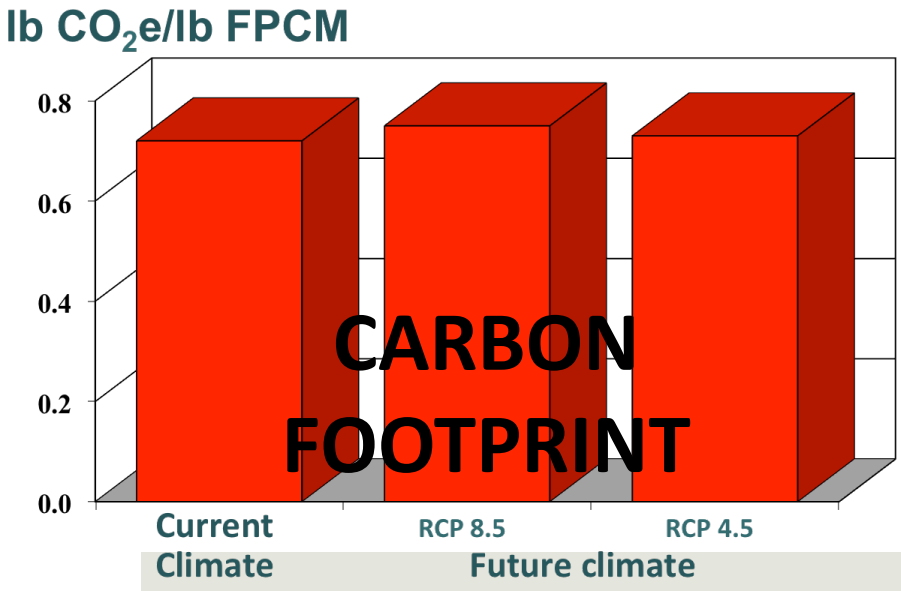
Jerome, ID – Feed Production

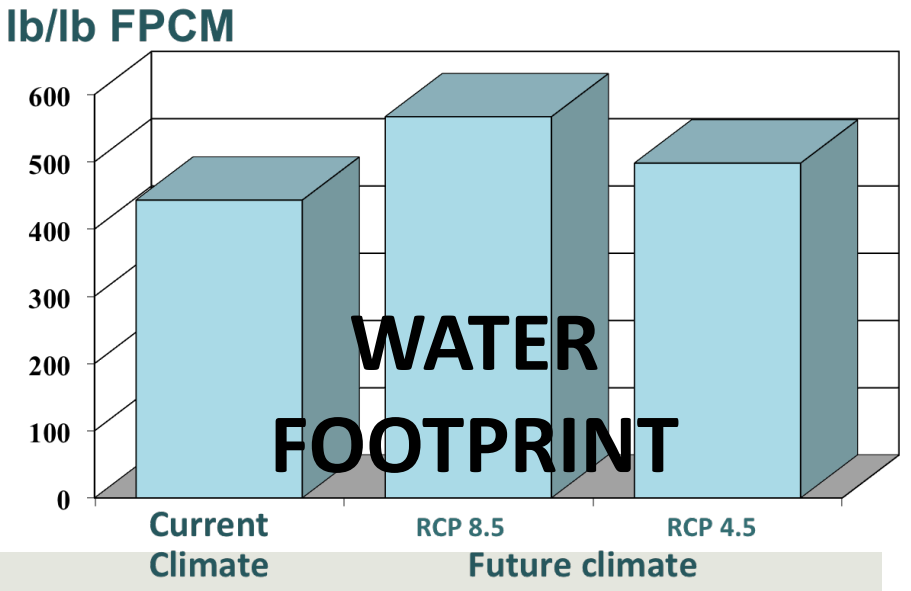


Jerome, ID – Results









Farm Simulation – Overall Results

- Forage production may benefit from climate change as long as adequate water is available
- Higher temperatures and changes in precipitation patterns will increase gaseous emissions and nutrient losses
- Adaptations in management can often maintain farm profitability

CONCLUSIONS

- Local climate studies and assessments can provide crucial information in building resilience, preparing to adapt, and even mitigating future emissions.
- In many sectors, downscaled climate projections can be used to assess quantifiable local impacts of climate change
  - Here I showed examples from infrastructure and agriculture
  - But the possibilities are many

KEY INFORMATION TO TAKE AWAY

Regional and sectoral impact assessments can be based on this step-by-step procedure:

1. Understand and quantify historical and current vulnerabilities to climate and weather risks
2. Assess the extent to which quantitative projections can be developed to inform how this risk may change in the future
3. Assemble data and information (historical events, future projections)
4. Calculate indices or use projections as input to an impact or risk assessment model that is already being used in this area (e.g. a water availability model, a crop yield production model, etc.)

THANK YOU!

Collaborators:

- Katharine Hayhoe, TTU
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- Jo Daniel, UNH
- Al Rotz, USDA
- Howard Skinner, USDA