CLIMATE MODEL DOWNSCALING:

HOW DOES IT WORK AND WHAT DOES IT TELL YOU?

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Northeast Monthly Climate Update

- Long-term observations are among the most consistent and widespread evidences of a changing climate

- Climate changes have profound effects on energy use, water resources, infrastructure, natural ecosystems, and many essential aspects of the society

- Unfortunately, observations are not available for future

- Climate model outputs are increasingly used by industrial sectors, regulatory agencies and policy makers in their decision making processes for future projection

How do the climate models work? What do they produce? Are they fit for the intended purposes?

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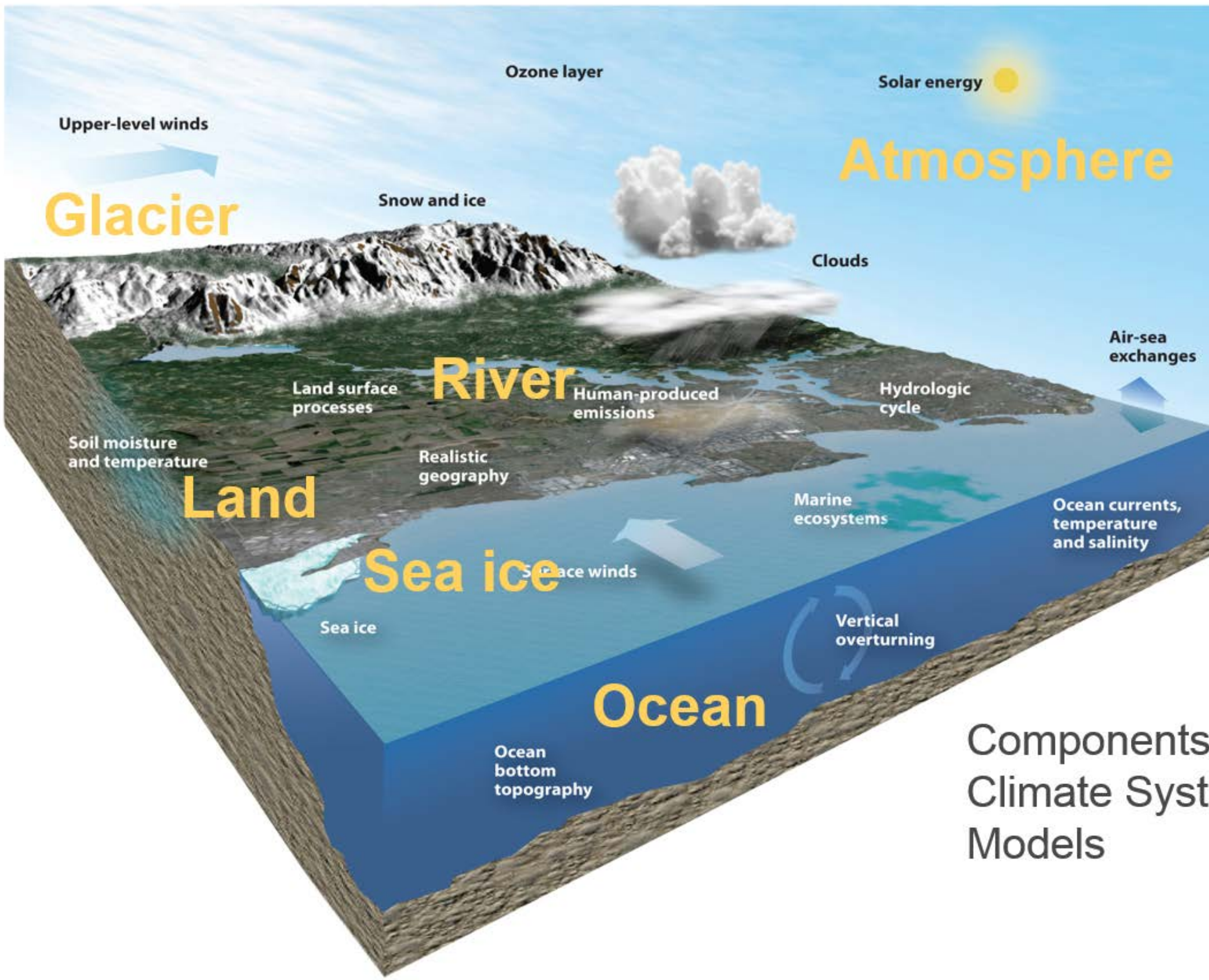
CLIMATE MODELS ARE MATHEMATICAL REPRESENTATIONS OF THE CLIMATE SYSTEM BASED ON PHYSICAL LAWS AND UNDERSTANDING OF PROCESSES



Source: UCAR

- Winds
- Temperature
- Humidity
- Rainfall

Components of Climate System Models

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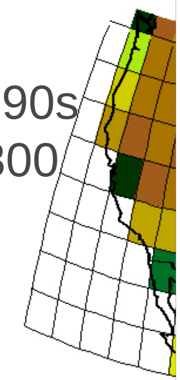
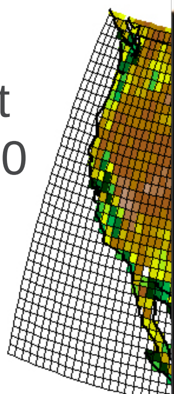
IN GLOBAL CLIMATE MODELS, THE ATMOSPHERE IS DIVIDED INTO A 3-DIMENSIONAL GRID SYSTEM MADE OF SEVERAL MILLION GRID CELLS

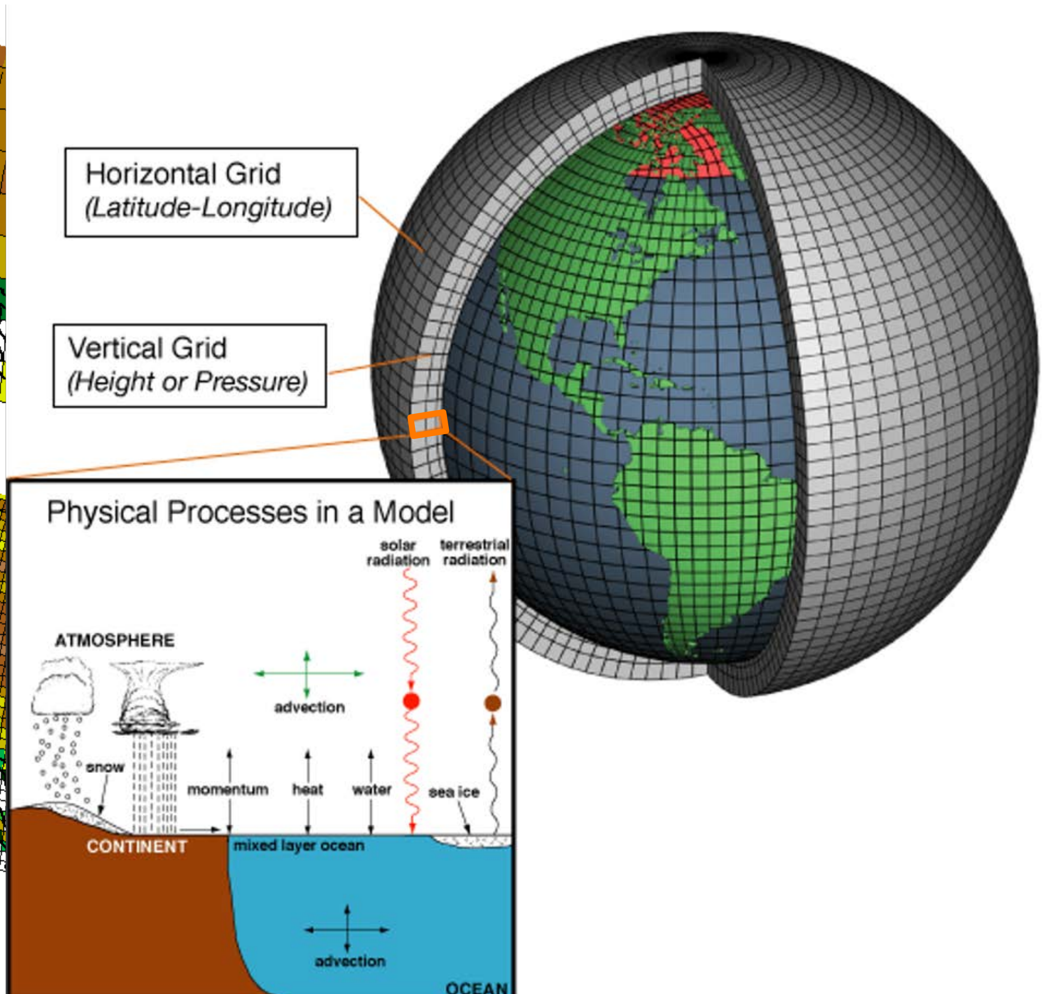
Model resolution or granularity

Mid-1990s (200~300 kms)

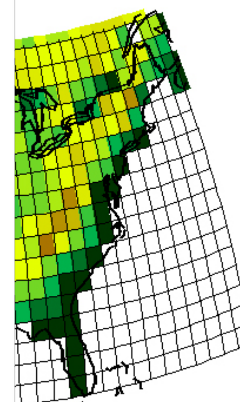


Current (50~100 kms)





2007ish (100~150 kms)



Future (25~40 kms)

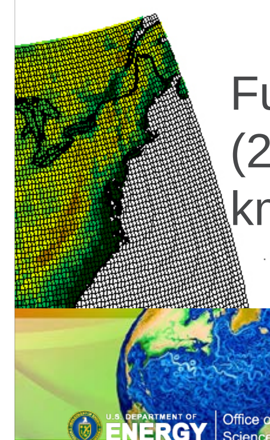
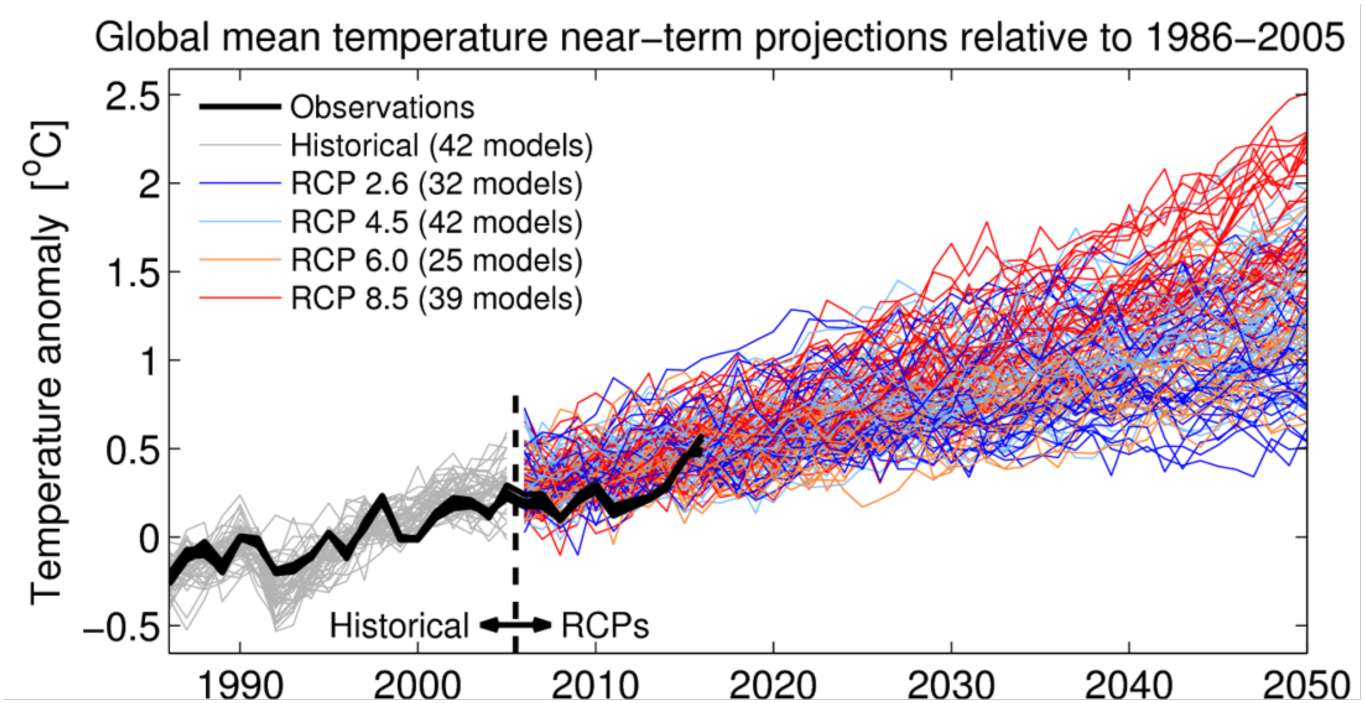


Image source: NOAA

GLOBAL CLIMATE MODELS ARE IMPORTANT TOOLS TO UNDERSTAND THE CLIMATE SYSTEM



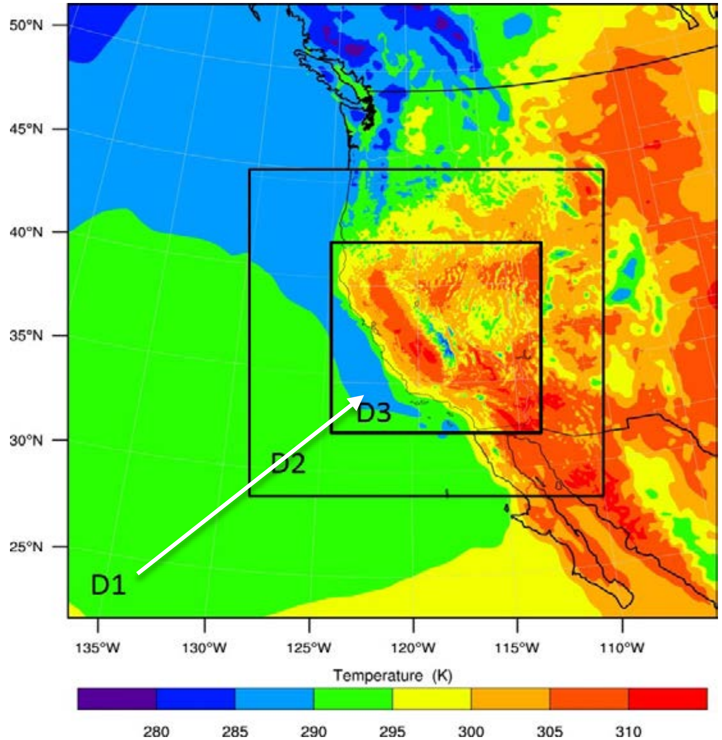
Updated version of IPCC AR5 (2013). The black lines represent observational datasets (HadCRUT4.5, Cowtan & Way, NASA GISTEMP, NOAA GlobalTemp).

Source: https://www.climate-lab-book.ac.uk/comparing-cmip5-observations/

Decadal and large-scale signals

THERE ARE EMERGING NEEDS FOR CLIMATE MODEL DOWNSCALING DATA AT FINER SCALES

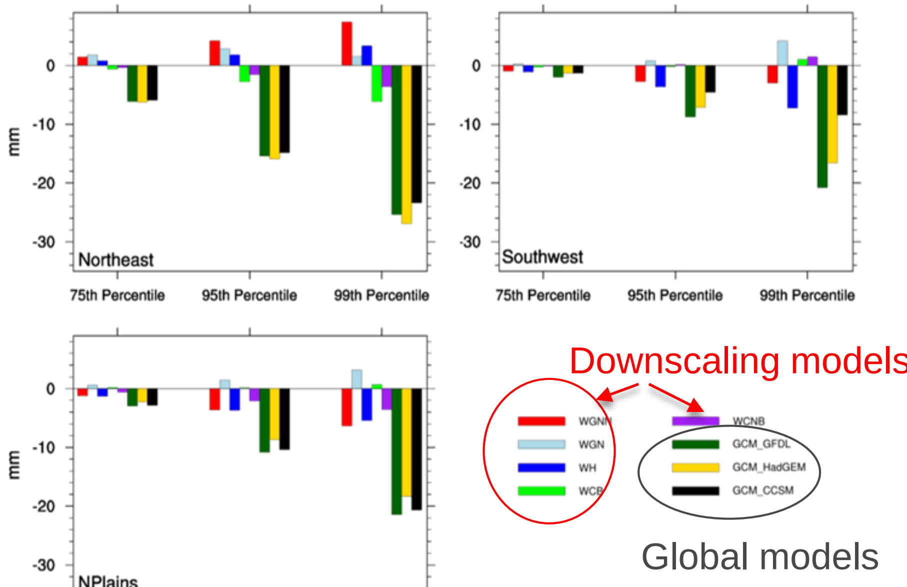
Surface air temperature predictions from the regional climate model (WRF)



The outer domain (D1): resolution =18 km → Mid-domain (D2): resolution = 6 km → The inner domain (D3): resolution = 2 km

Finer-scale and detail features

Differences between model and observed precipitation over three regions in US



Zobel et al. (2017)

- The lengths of the bars indicate the model deviations from the observations.

The global model outputs have larger systematical errors than regional downscaling results

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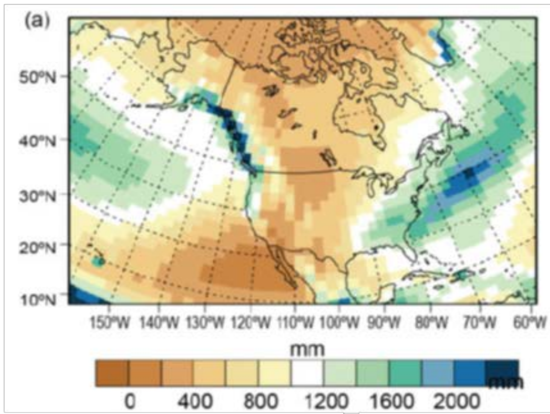
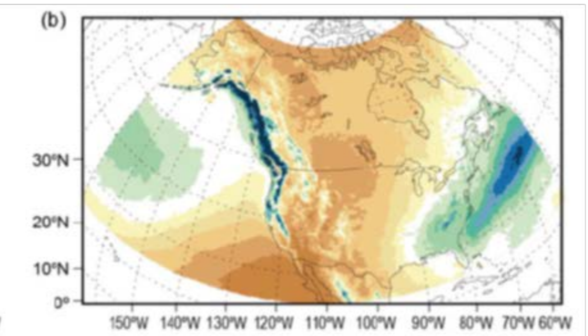
TWO BROAD TYPES OF DOWNSCALING APPROACHES

Dynamical Downscaling

Global Model Outputs or Data
resolution ~100km

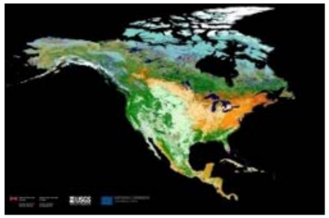


Regional Climate Model
resolution ~ 25 km or less



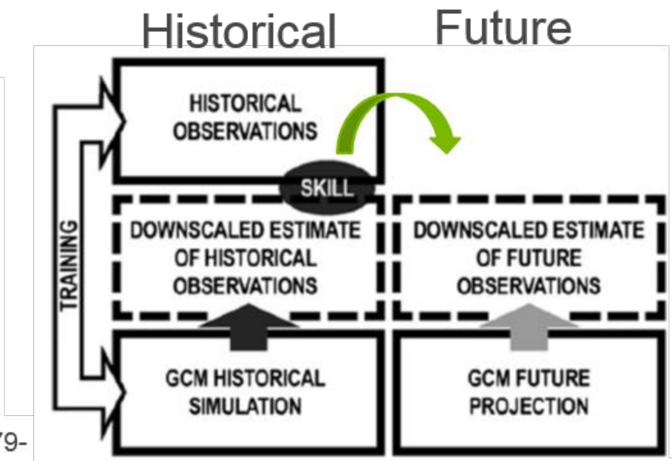
Annual mean rainfall (millimeters) for years 1979-2008 (Adapted from Dixon et al., 2016)

- Initial and boundary conditions (Temperature, soil moisture, etc)
- High-res topography



- Use of regional model to dynamically extrapolate the large-scale simulations
- *Pro: higher resolution; better represented physics*
- *Con: computer resources*

Statistical Downscaling



(Dixon et al., 2016)

- 'Training': use of statistical techniques to determine relationships between large-scale climate patterns resolved by global climate models and local observations
- *Pro: computationally efficient*
- *Con: stationarity ?*

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INFORMATION ON USE OF CLIMATE MODEL DATA

Dynamical model downscaling products in US (examples):

- NARCCAP (http://www.narccap.ucar.edu/) – 50km
- North American CORDEX program (https://na-cordex.org/) – 25~50km
- Argonne climate model archive (12km, 4km or finer upon requests)

Global (and regional) climate model outputs:

- Intergovernmental Panel on Climate Change (IPCC) Data Distribution Center;
- Earth System Grid Federation (ESGF) Data Download

Some questions to think about before use of climate model data

Observation/Model

Purpose
Historical? Future projection?

→

Global/Downscaling

Spatial Resolution
Global? Regional? 1~100km?

→

Dynamical/Statistical Downscaling

Temporal Resolution
Yearly or seasonal or daily mean? Or decadal or daily extremes? Hazards?

No simple one-size-fits-all guidance on use of climate data
(Lanzante et al., 2017; Kotamarthi et al., 2016)

FROM CLIMATE MODEL OUTPUT TO ACTIONABLE INFORMATION

What questions do I need to ask to pursue climate model projection information for business, planning, or design purposes?

1. What is the timeframe of concern for my current planning effort?

2. What are the climate variables that I need to inform my current planning effort?

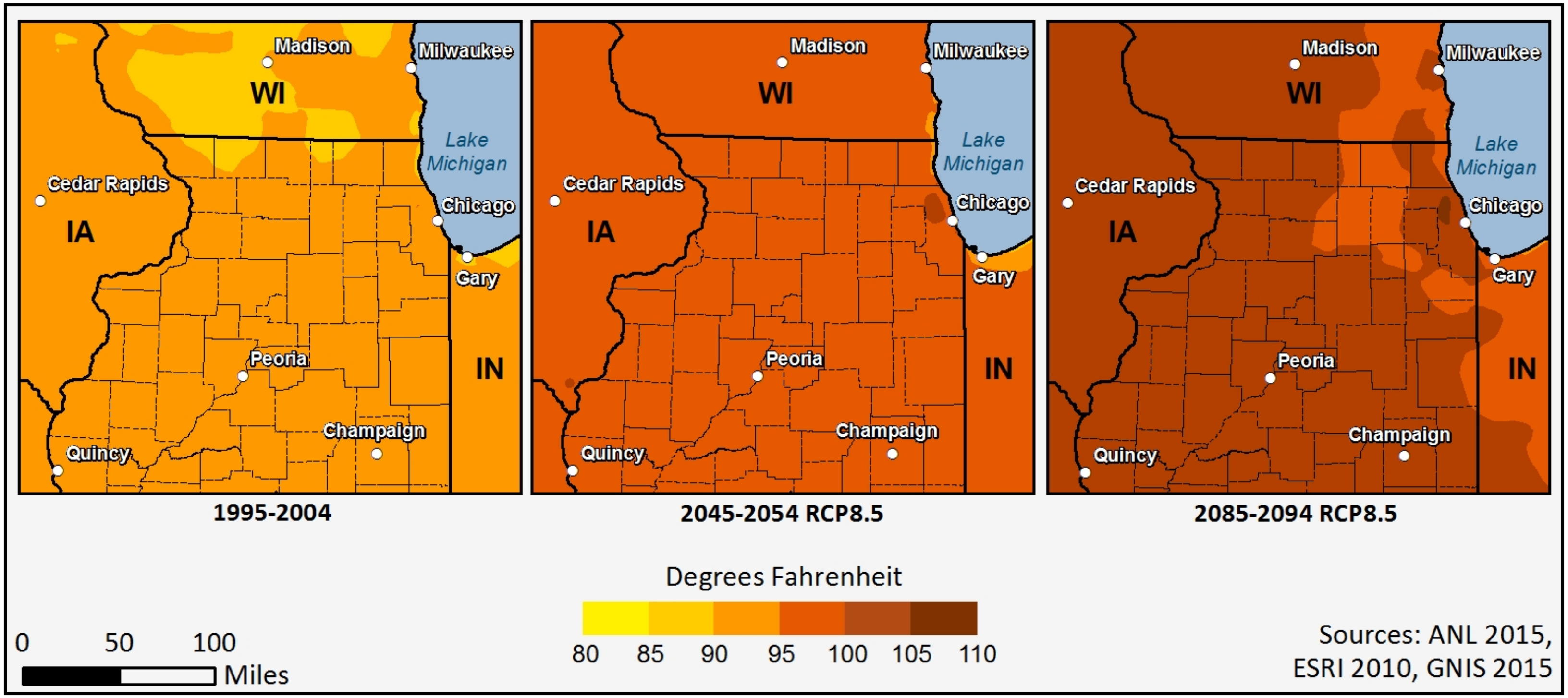
3. What is an acceptable level of uncertainty – do I plan for the best, the worst, or something else?

PLANNING TIMEFRAME

Why mid-century vs. end-of-century?
Why are climate impacts always projected for a future time range?

Because the climate is non-stationary, we examine multiple future timeframes – and align our specific planning context and location with a future timeframes to determine how much the climate is projected to change

Average Annual Maximum Temperature



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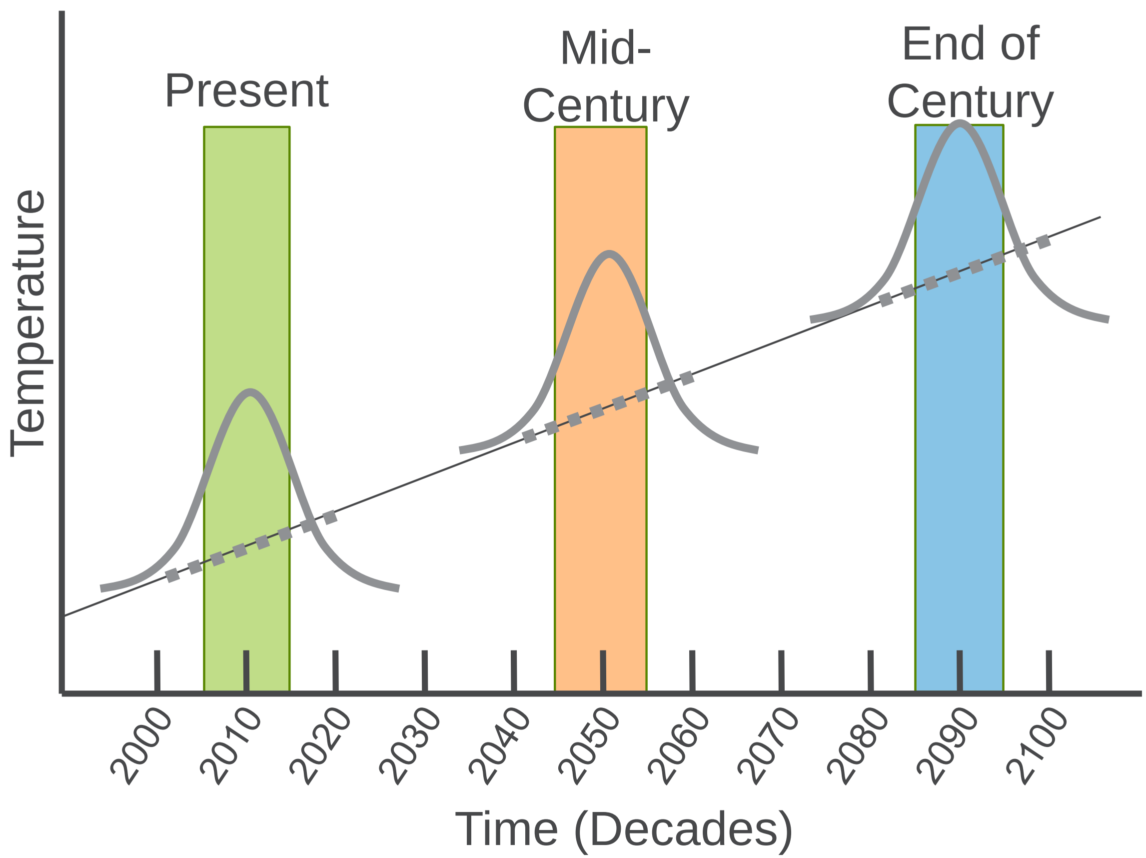
PLANNING TIMEFRAME

Why mid-century vs. end-of-century?
Why are climate impacts always projected for a future time range?

To calculate meaningful values from projected “records,” we have to examine them in smaller future timeframes



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CLIMATE VARIABLES

Some climate impact variables can come directly out of the global or regional climate models…

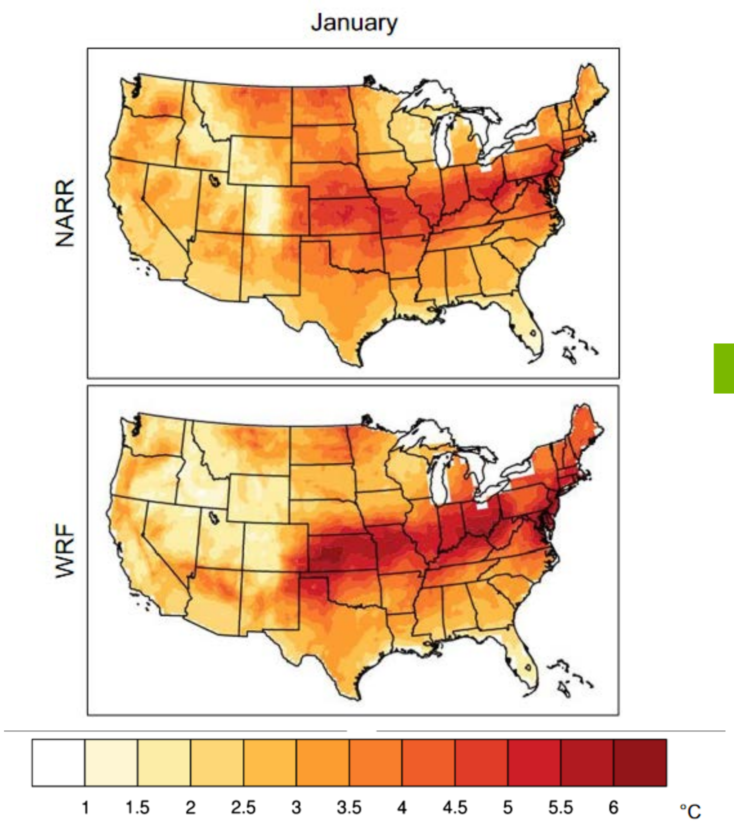
Precipitation	Total Soil Moisture Content
Near-Surface Air Temperature	Surface Air Pressure
Daily Maximum Near-Surface Air Temperature	Sea Level Pressure
Daily Minimum Near-Surface Air Temperature	Near-Surface Wind Speed
Near-Surface Relative Humidity	Surface Snow Melt
Daily Maximum Hourly Precipitation Rate	Snow Amount
Surface Downwelling Shortwave Radiation	Atmosphere Grid-Cell Area
Eastward Near-Surface Wind Velocity	Capacity of Soil to Store Water
Northward Near-Surface Wind Velocity	Maximum Root Depth
Surface Altitude	Fraction of Grid Cell Covered with Glacier
Land Area Fraction	Total Cloud Fraction
Evaporation	Total Runoff
Potential Evapotranspiration	Surface Upwelling Shortwave Radiation
Near-Surface Specific Humidity	Snow Area Fraction
Surface Runoff	Duration Of Sunshine

Source: https://na-cordex.org/variable-list

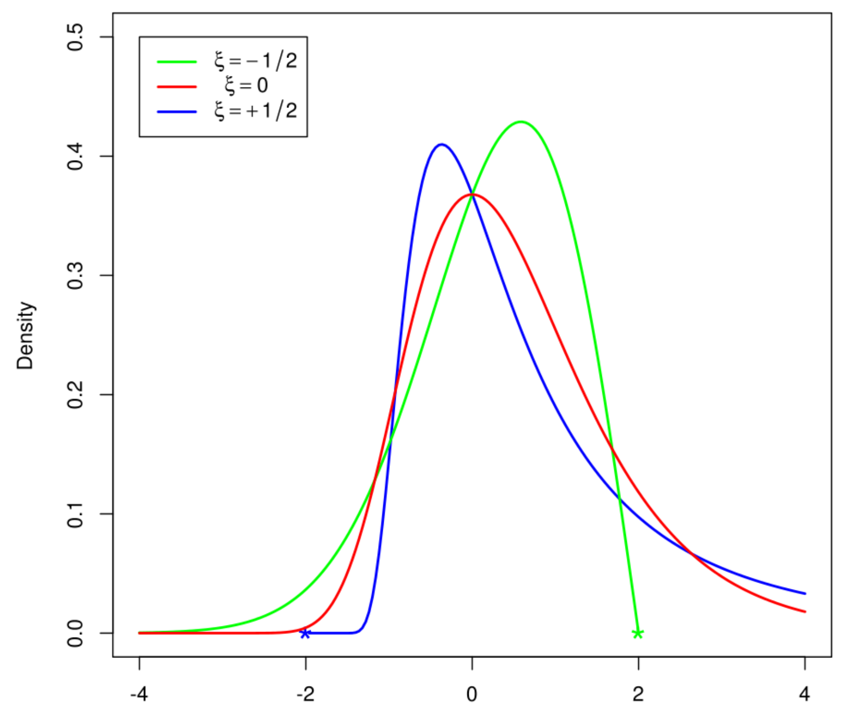
CLIMATE VARIABLES

…some climate impact variables require additional analysis or modeling

Example: Extreme temperature projections (e.g., heat waves) require statistical analysis to identify events that occur in the “tails” of the distribution



Source: Wang et al. 2016



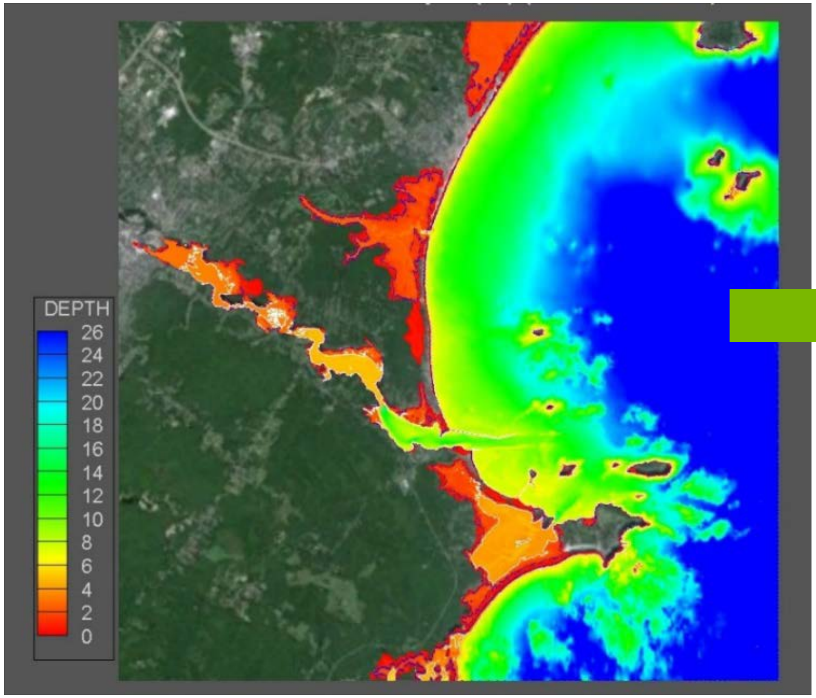
Source: Wikipedia.org

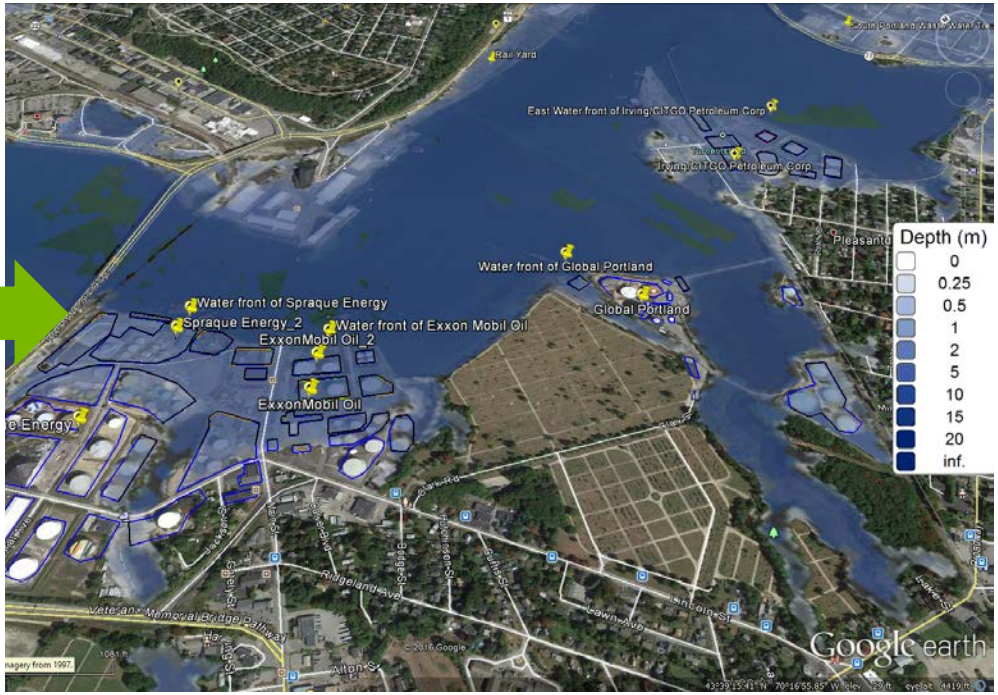
CLIMATE VARIABLES

Some climate impact variables require additional analysis or modeling

Example: Coastal inundation due to hurricane storm surges occurring on top of risen sea levels.

- Regional sea level rise projections + AdCirc Coastal Surge Modeling
- Examine multiple SLR and Hurricane Category scenarios





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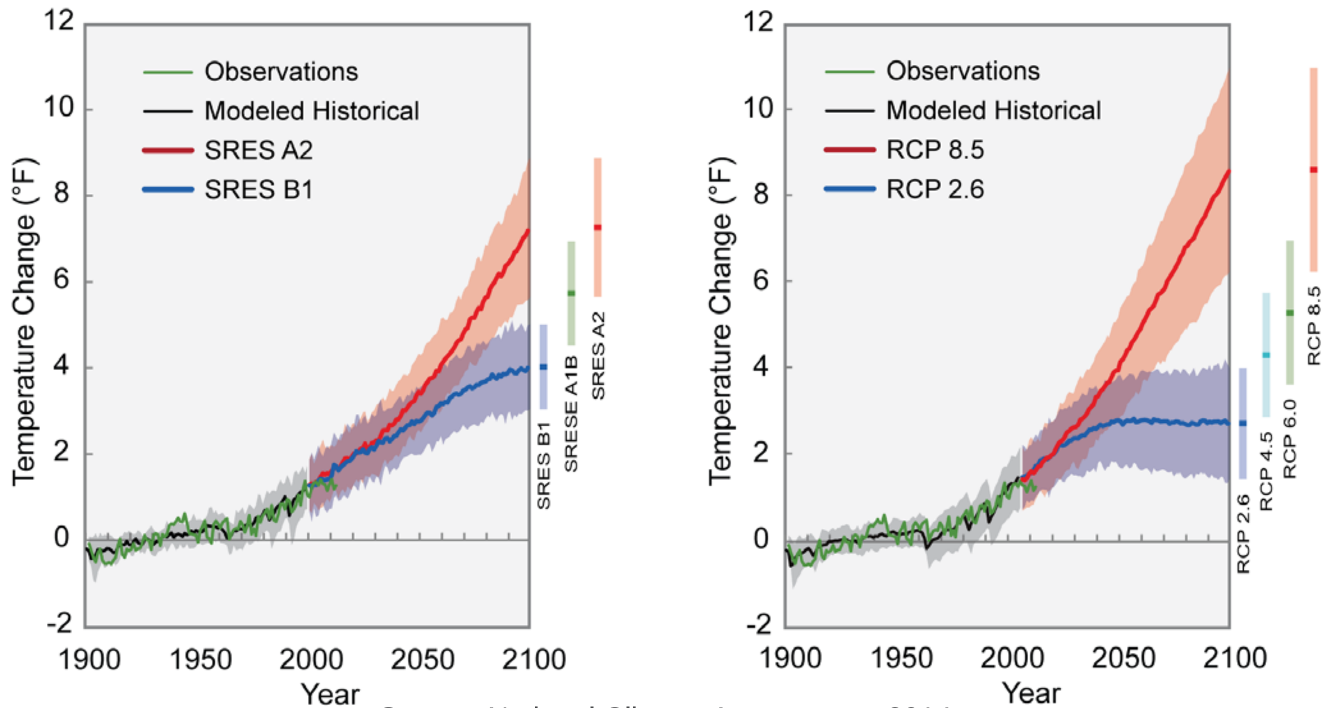
ACCEPTABLE LEVELS OF UNCERTAINTY

Do I plan for the best, the worst, or something else?

Emission Scenarios:

- SRES (Older): Special Report on Emission Scenarios (Nakicenovic et al, 2000)
- RCP (Newer): Representative Concentration Pathways (van Vuuren et al, 2011)

Emissions Levels Determine Temperature Rises

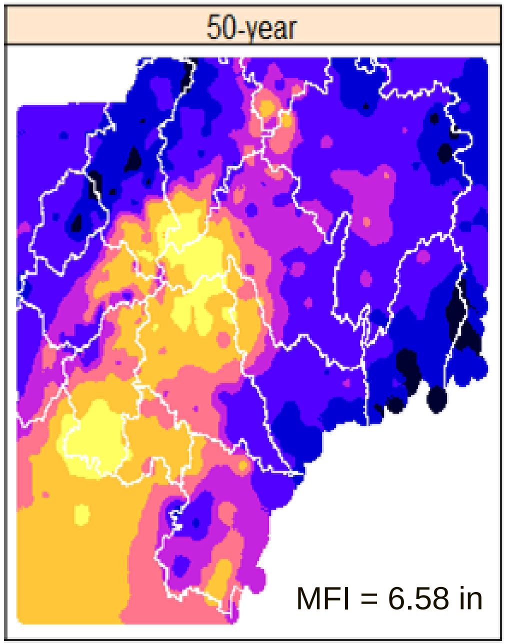


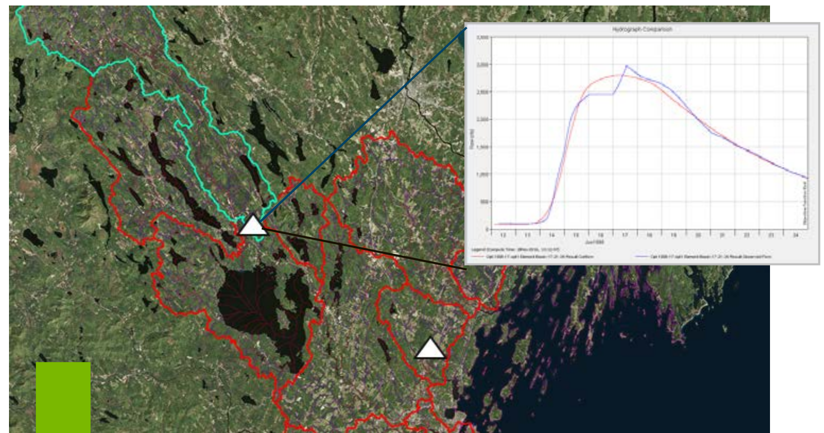
Source: National Climate Assessment, 2014

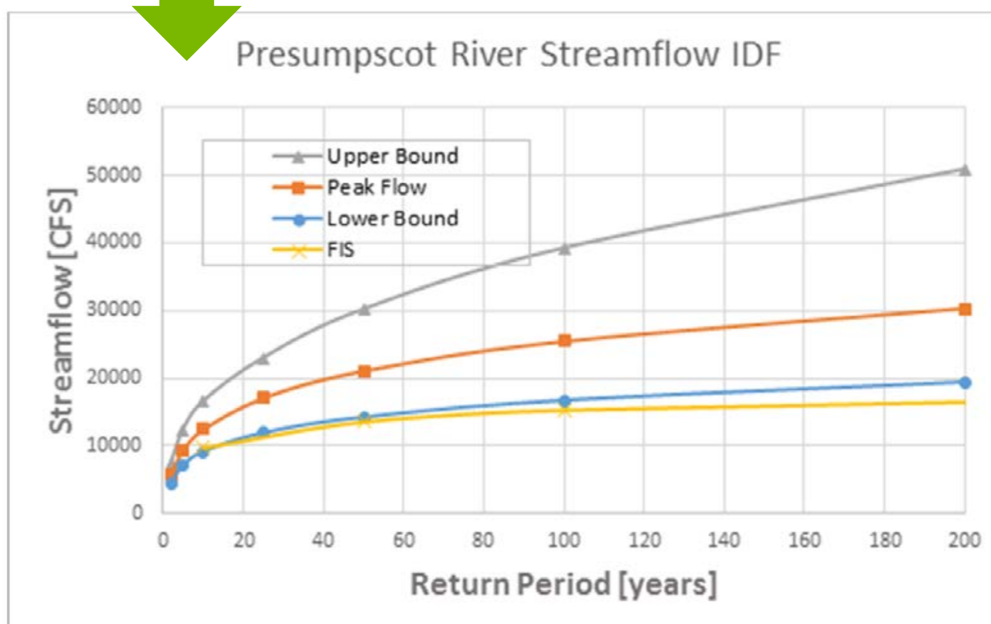
ACCEPTABLE LEVELS OF UNCERTAINTY

Do I plan for the best, the worst, or something else?

- Precipitation → Flood Event







For summary of decision-making methods:

Willows, R., and R. Connell. Climate Adaptation: Risk, Uncertainty and Decision-Making. UKCIP Technical Report, UKCIP, Oxford, U.K., 2003

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FROM CLIMATE MODEL OUTPUT TO ACTIONABLE INFORMATION

Questions

1. What is the timeframe of concern for my current planning effort?
2. What are the climate variables that I need to inform my current planning effort?
3. What is an acceptable level of uncertainty – do I plan for the best, the worst, or something else?

Seek partnerships with state climatologists, universities, national laboratories, regional government offices (e.g., NOAA), consulting firms, etc.

- People who can act as "climate interpreter" (L.O. Mearns, NCAR)
- They know what data is available and where to find it
- They can help to answer the key questions at the outset of planning

THANK YOU!

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