Building Resilience to a Changing Climate:

A Technical Training in Water Sector
Utility Decision Support

WUCA
Water Utility Climate Alliance

Climate Science for Water Professionals: What Do We Know About How the South Central's Climate Will Change?

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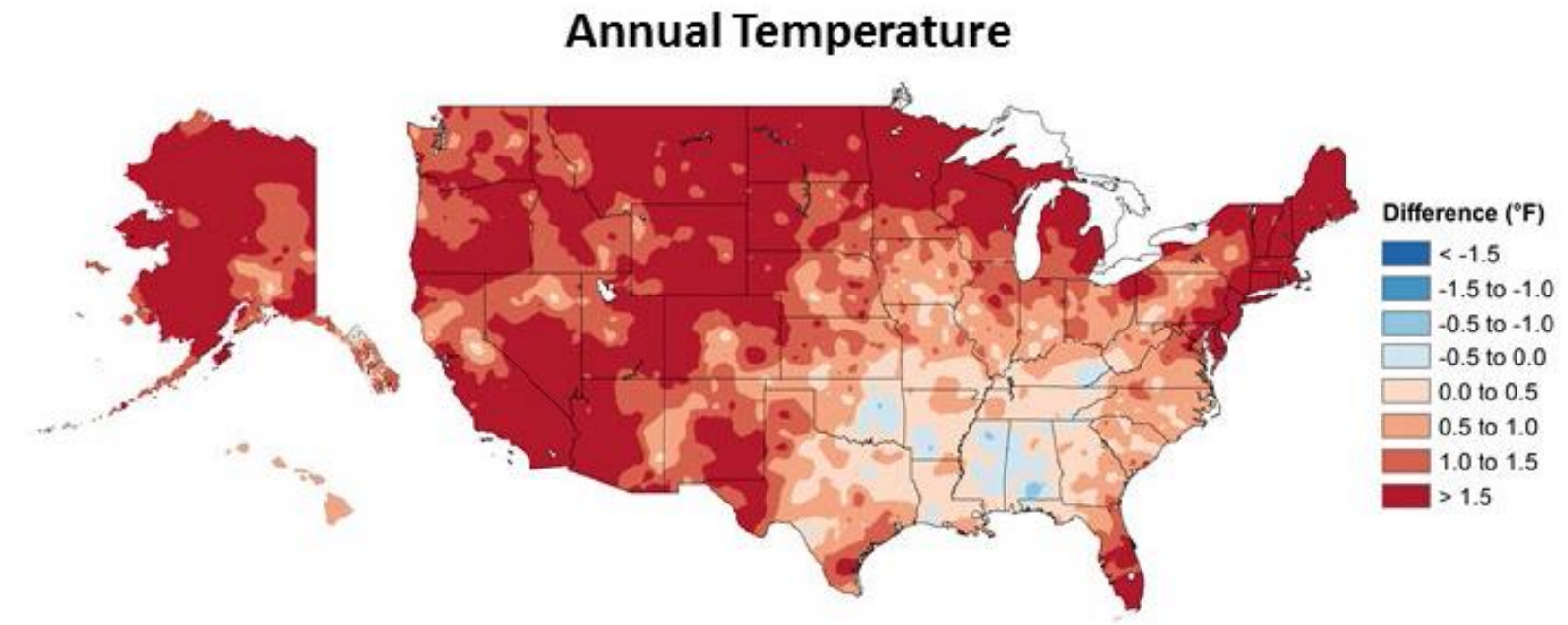
This Session Will Cover:

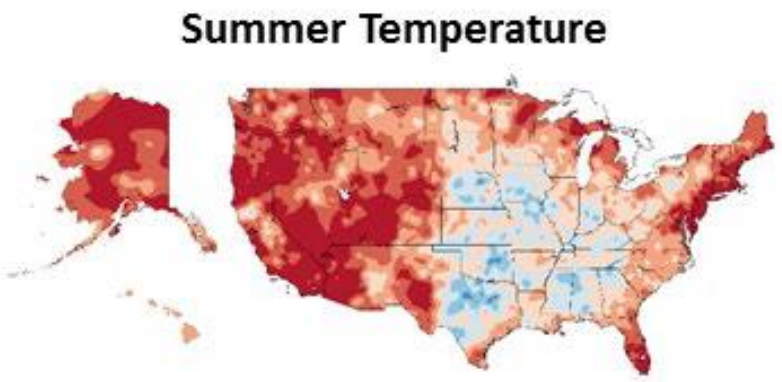
- Observed changes in climate of the south central region of the U.S.
- What do we know about how the future climate may change
  - Projections about the future
  - Key sources of uncertainty about projections of change in climate

Key Takeaways

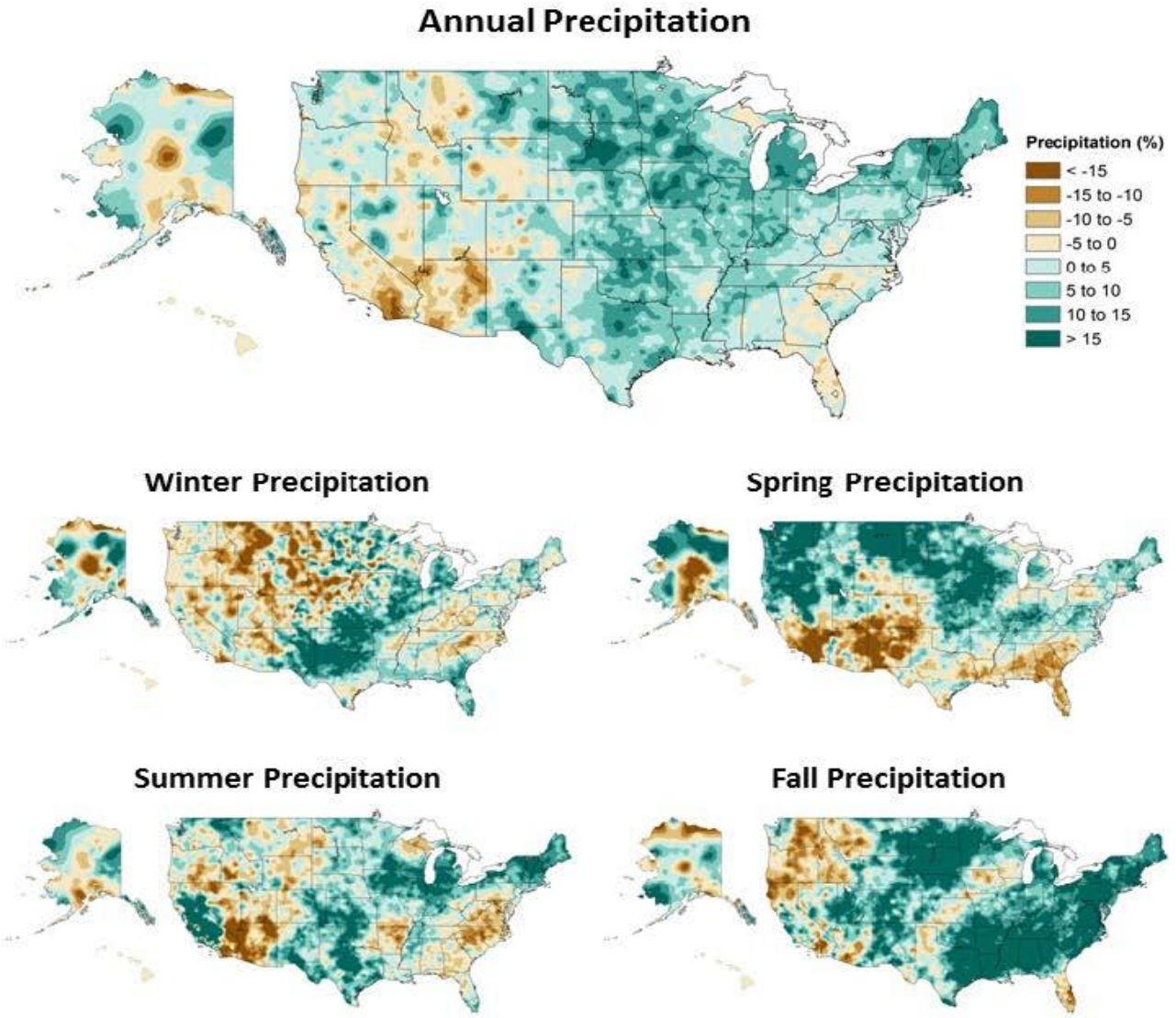
- Temperatures are rising – the climate is changing
- We expect more warming in the future
  - Timing and magnitude are uncertain
- We can *project* potential changes in climate, but can't *predict* them
- There are many sources of uncertainty including uncertainty about future emissions and exactly how the climate will change
- We expect some sources of uncertainty to not go away

Observed Temperature Changes: 1901-1960 to 1986-2015





Observed Precipitation Changes: 1901-1960 to 1986-2015



Data Provided by Dr. Ken Kunkel, NOAA

Climate Change Terminology

- A *Projection*
  - A plausible future condition
  - May be conditional, for example, based on a specific Representative Concentration Pathway (RCP)
  - Individual model estimates of future climate conditions are considered "projections"
  - Do not have probabilities assigned to projections
- A *Prediction* or *Forecast*
  - A "most likely" outcome
  - A precise statement about the future, for example:
    - "There is a 70% chance of rain tomorrow."
    - "Global mean temperatures will rise 4 to 11ºF by 2100 over 1990."

Future: More vs. Less Confidence

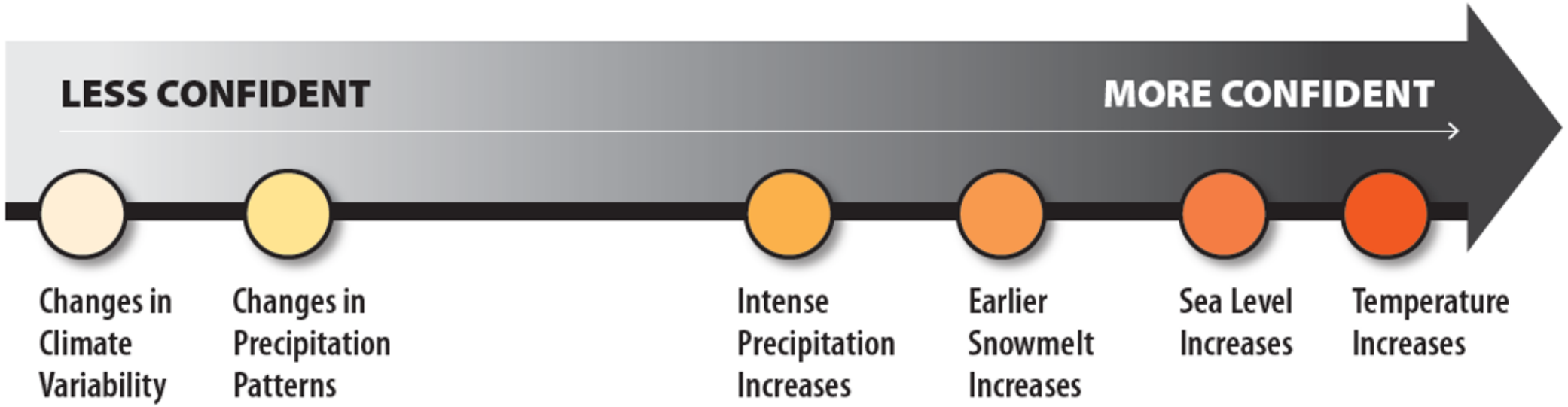
More Confidence

- Global and continental scale projections
- Averages
- Direction of change
- Temperature is dominant process

Less Confidence

- Regional and local projections
- Extremes
- Magnitude of change
- Other physical processes govern

Future: Continuum of Certainty in Direction of Change



Key Sources of Uncertainty in Predicting Future Climate

1. Human activity – Future emissions

2. The physical response of the climate system
   - Climate sensitivity
   - Regional patterns and timing of change

3. Natural climate variability

4. An additional source of uncertainty are climate models
   - Translation through downscaling, hydrologic modeling, etc.
   - More on that later….

1. Human Activity: Future Emissions

Photo Credit: Greg Goebel/flickr

Uncertainty in amounts of:

- GHG emissions
  - Carbon dioxide (CO_2)
  - Methane (CH_4)
  - Others
- Aerosols
  - Soot
  - Dust
- Land use

Estimating Future Emissions

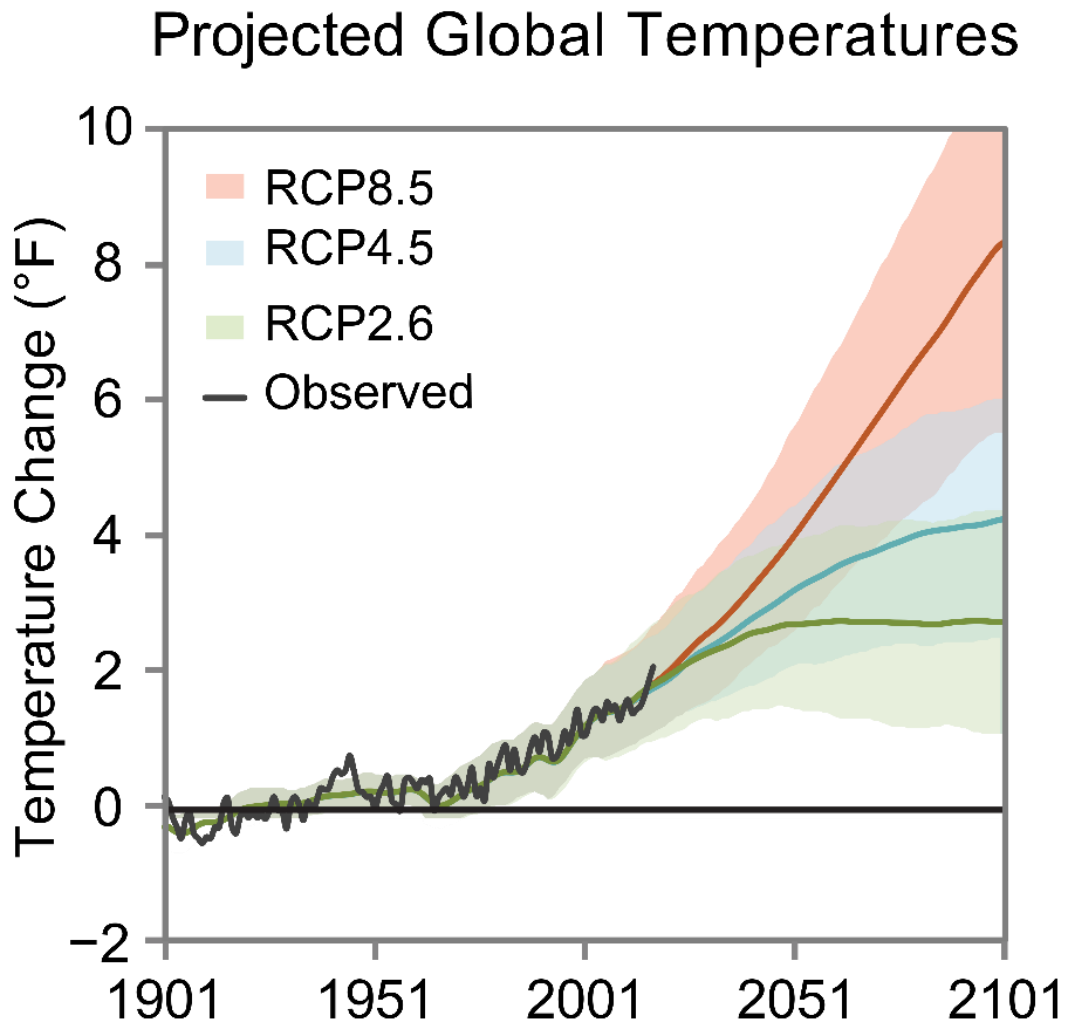
- IPCC is using “RCPs”
  - IPCC is Intergovernmental Panel on Climate Change
  - RCPs are “Representative Concentration Pathways”
    - We measure how much additional energy is being trapped by GHGs
    - Expressed in units of radiative forcing watts/square meter (w/m^2)
  - We get about 300 w/m^2 from the sun
  - Doubling of CO_2 concentrations will trap another 4.5 w/m^2
  - We are currently about 2.8 w/m^2 above preindustrial levels

The Main RCPs

- These are scenarios
  - No likelihoods assigned
- Baseline scenarios
  - RCP 8.5
    - ~ 1000 ppm of CO_2 by 2100
    - Global population 12 billion
    - CO_2 emissions triple
      - Large increase in coal use
  - RCP 6.0
    - 600-700 ppm of CO_2 Carbon emissions peak in mid-century
- Stabilization scenarios
  - RCP 4.5
    - CO_2 doubling scenario – around 500-600 ppm of CO_2
  - RCP 2.6
    - Might limit warming to 2^{o}C (3.6^{o}F) above pre-industrial
  - RCP 1.9
    - Might limit warming to 1.5^{o}C (2.7^{o}F) above pre-industrial

Which RCP should be used as “Baseline?”

- Baseline Scenarios:
  - 8.5 and 6.0
- Credible estimates of likelihoods of RCPs do not exist
- Many assessments, for example, NCA, use 8.5 as high or BAU
- CMIP6 is adding RCP 7.0



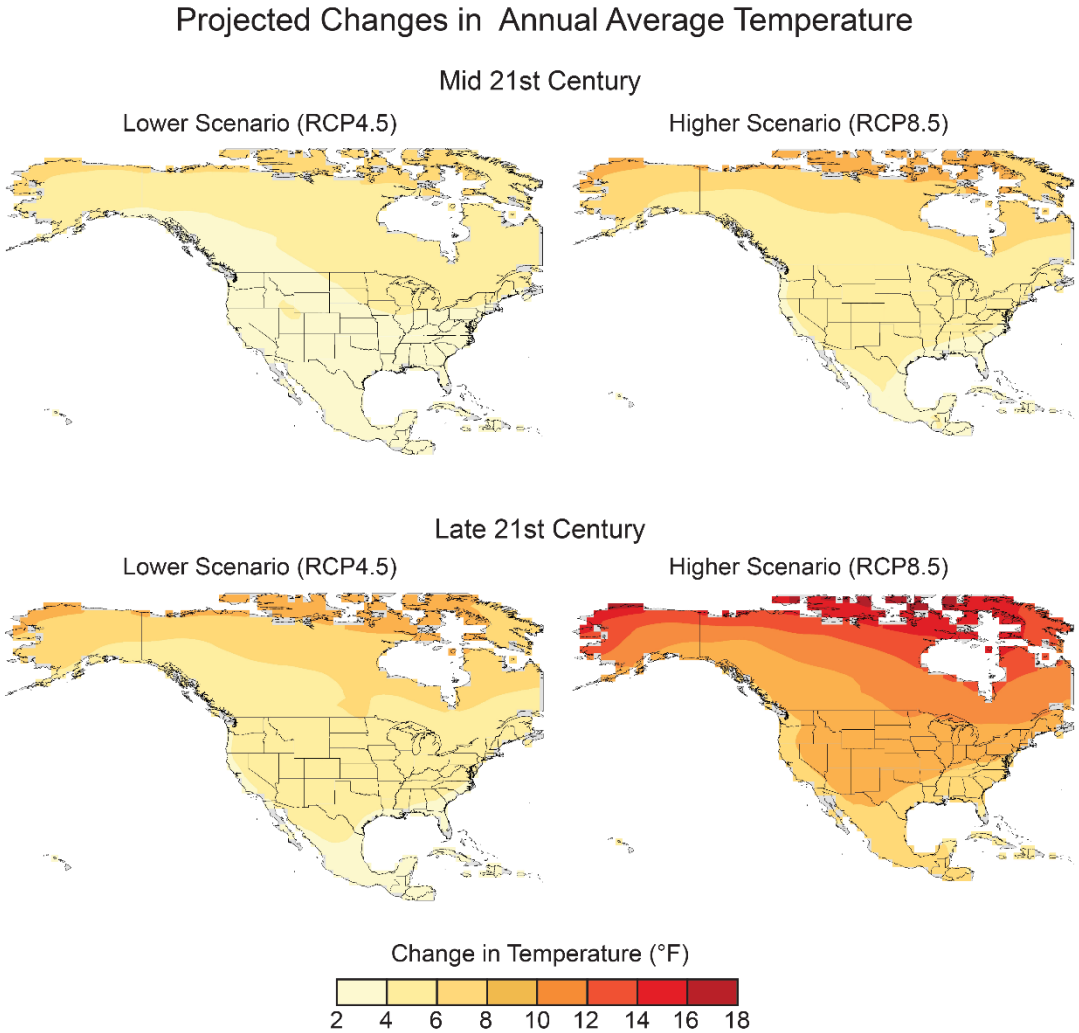
Source: U.S. National Climate Assessment, 2017

2a. Physical Response: Climate Sensitivity

- How much does the Earth's atmosphere eventually warm with a CO_2 doubling?

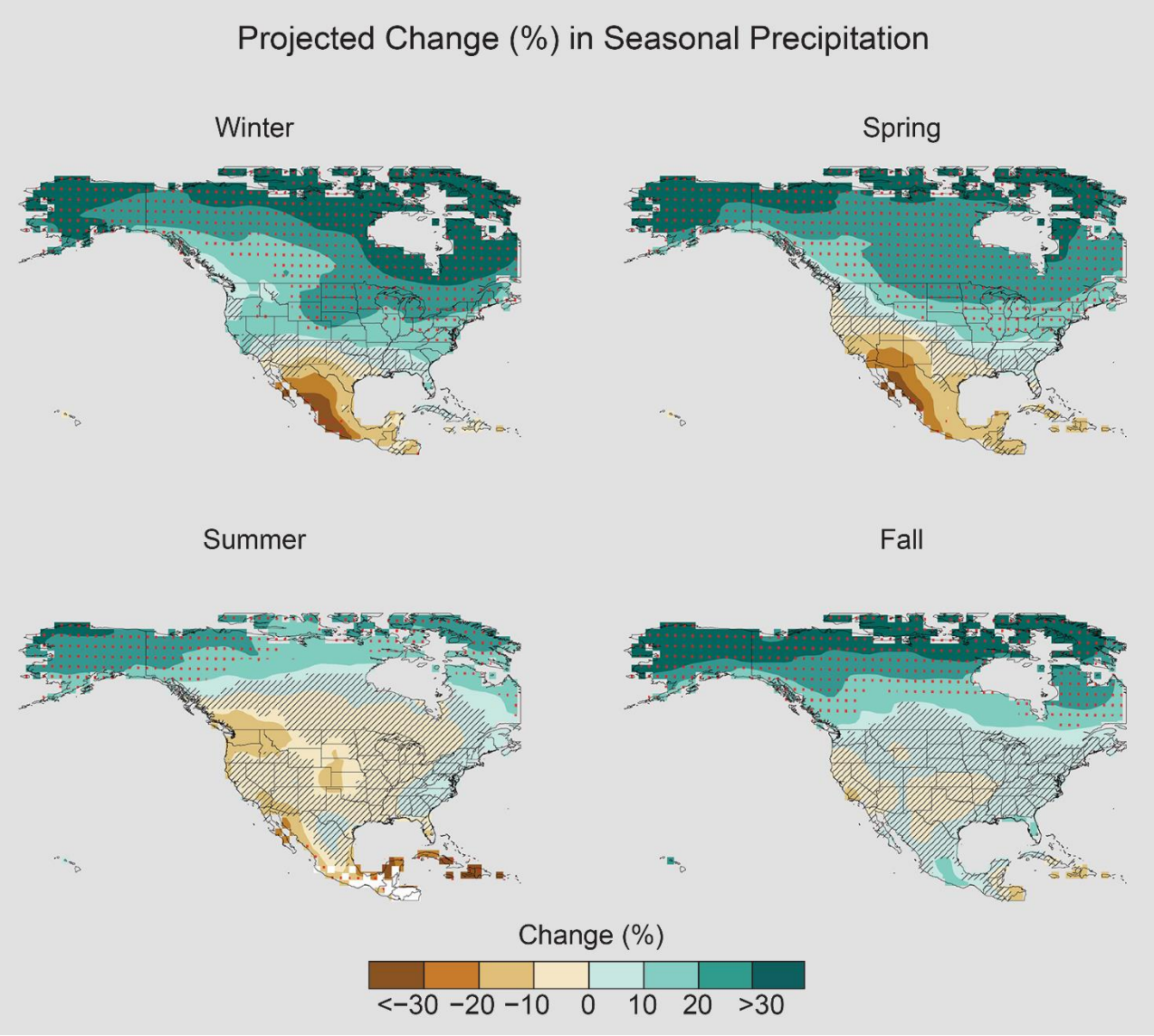
- What is the magnitude of warming
  - Most likely between 2 (3.6ºF) and 4.5ºC (8ºF)
  - Very unlikely below 1 (1.8ºF) or above 6ºC (11ºF)

2b. Physical Response: Regional Pattern and Timing of Change



Source: U.S. National Climate Assessment, 2017

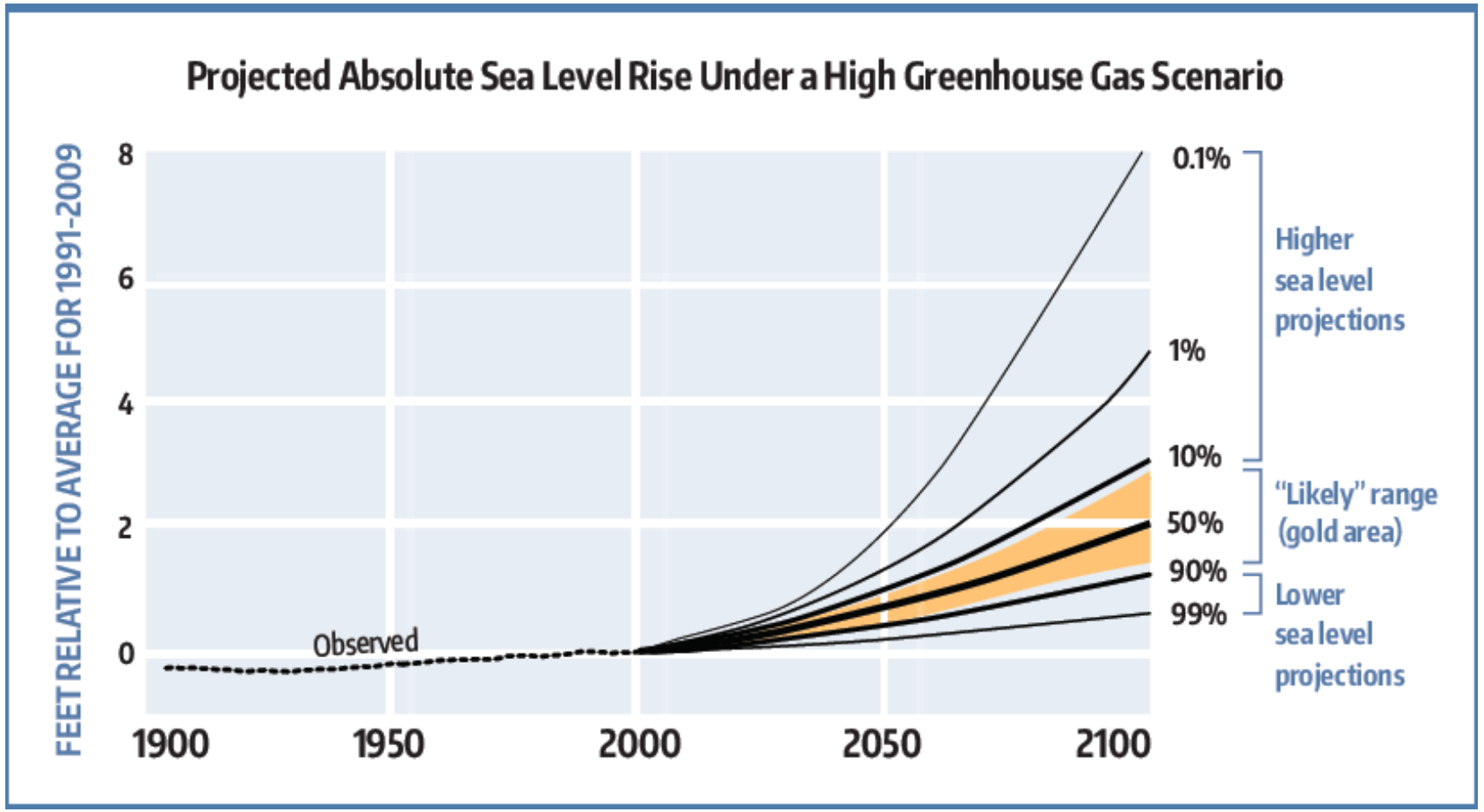
Seasonal Precipitation Patterns Can Change



Graphs Show RCP 8.5

Source: U.S. National Climate Assessment, 2017

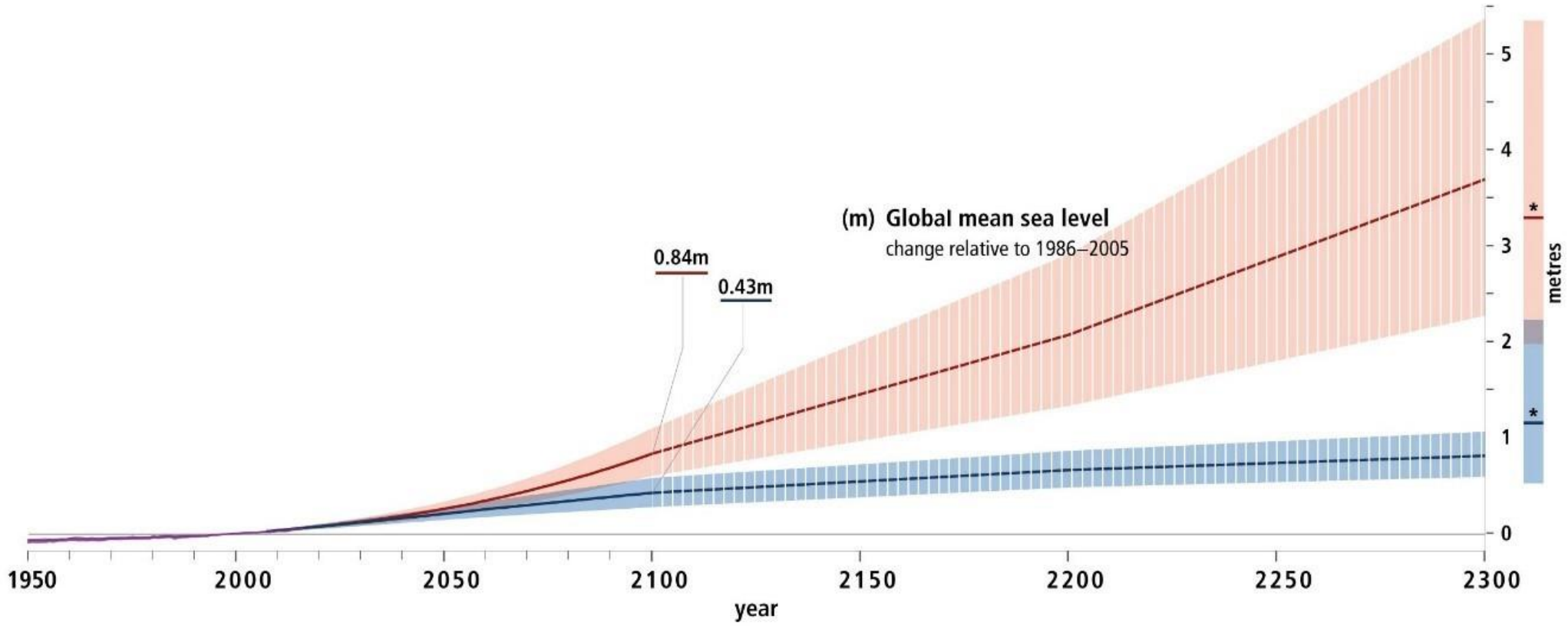
Sea Level Rise



- Sea level rise of 3 feet or less seems most likely
- Possibility of much more SLR by 2100

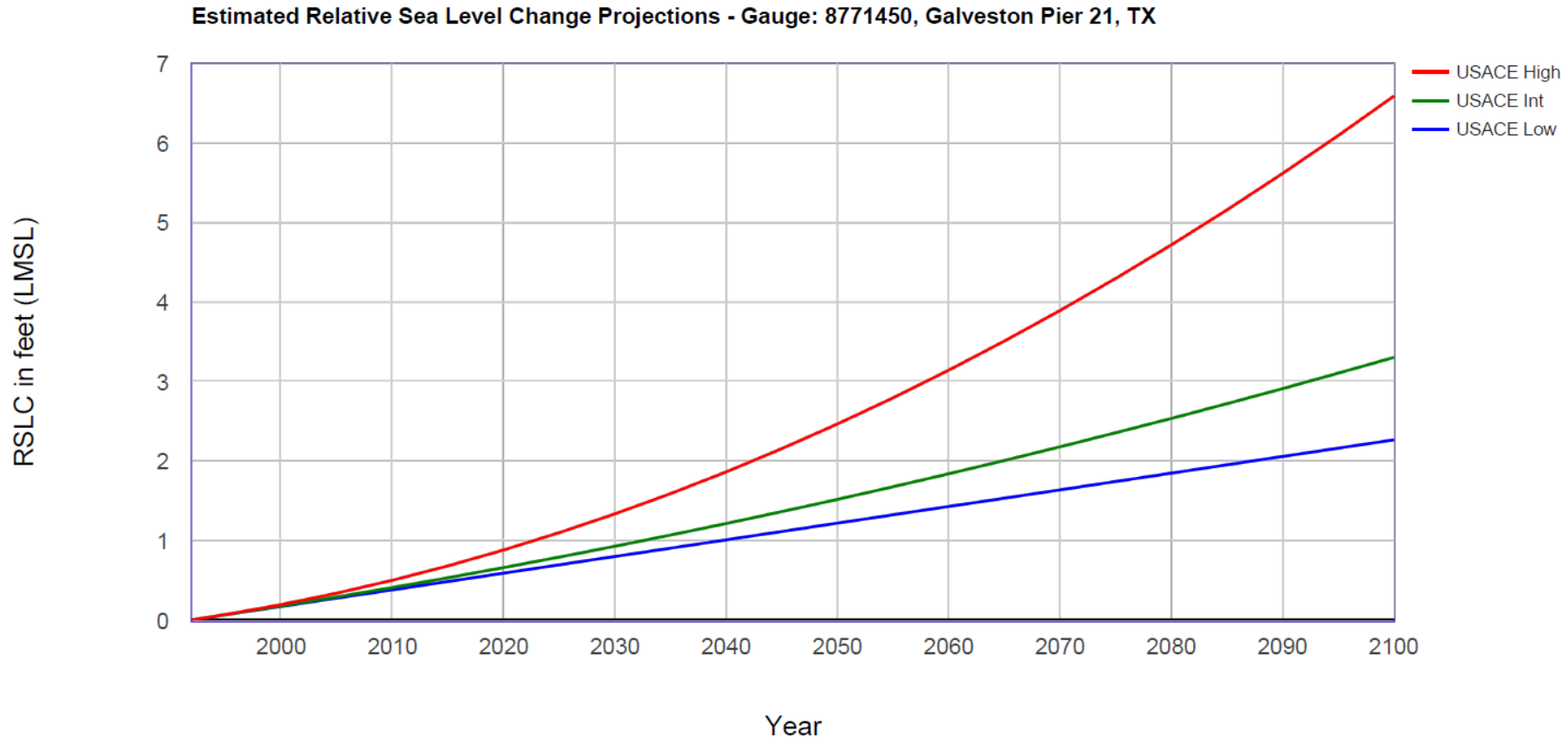
Source: Projected Sea Level Rise for Washington State, Miller et al., 2018

Long Term Sea Level Rise



IPCC, 2019. Special Report on Oceans and Cryosphere

Relative Sea Level Rise Varies by Location

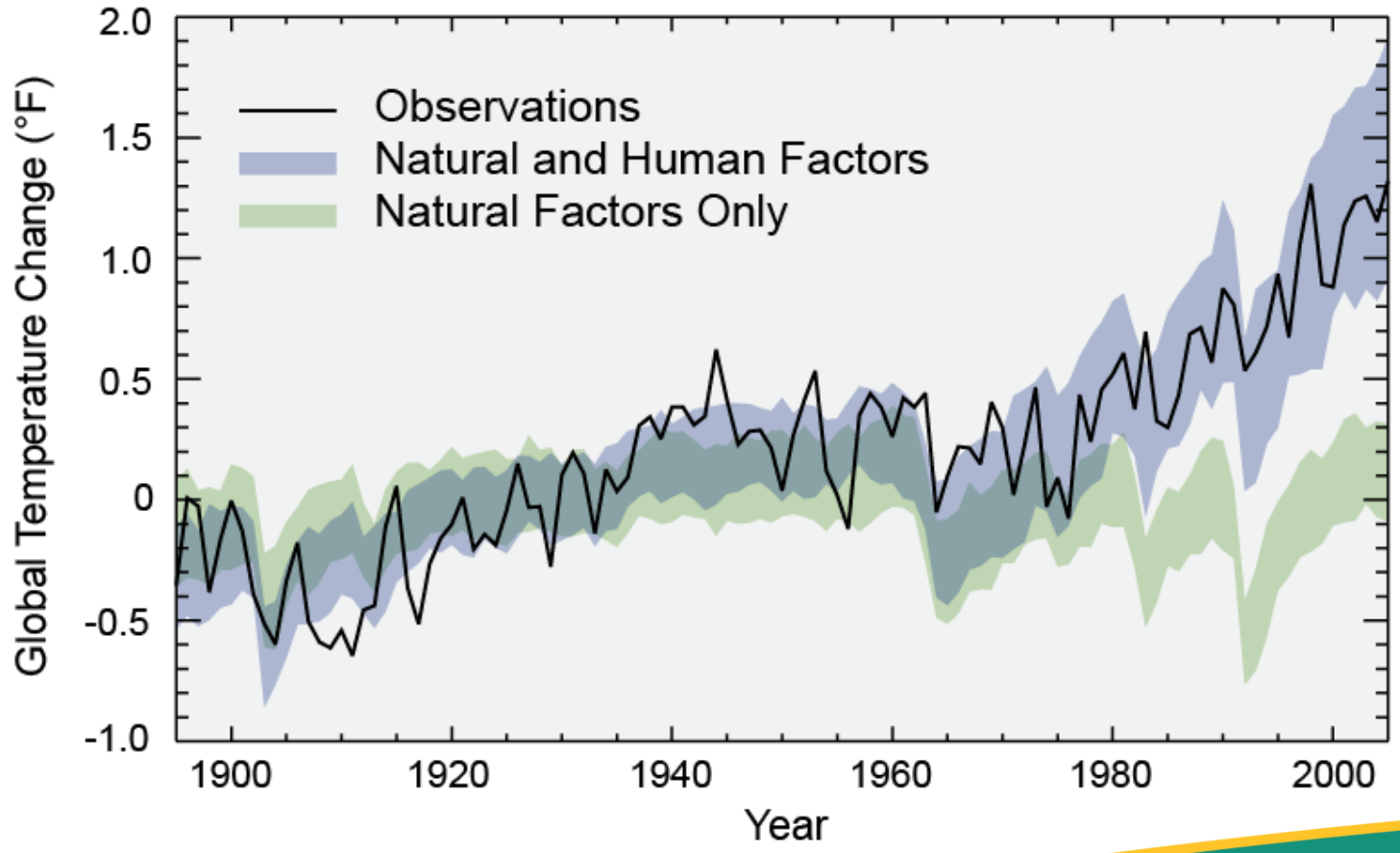


Source: U.S. Army Corps of Engineers Sea-Level Change Curve Calculator. http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html

3. Natural Climate Variability

- Noise from year-to-year natural variability
  - Often greater than the climate change signal
- Multi-year and multi-decadal events
  - El Nino Southern Oscillation (ENSO)
  - Atlantic Multi-decadal Oscillation (AMO)
  - Pacific Decadal Oscillation (PDO)
- How these will be affected by and will affect climate change is not clear

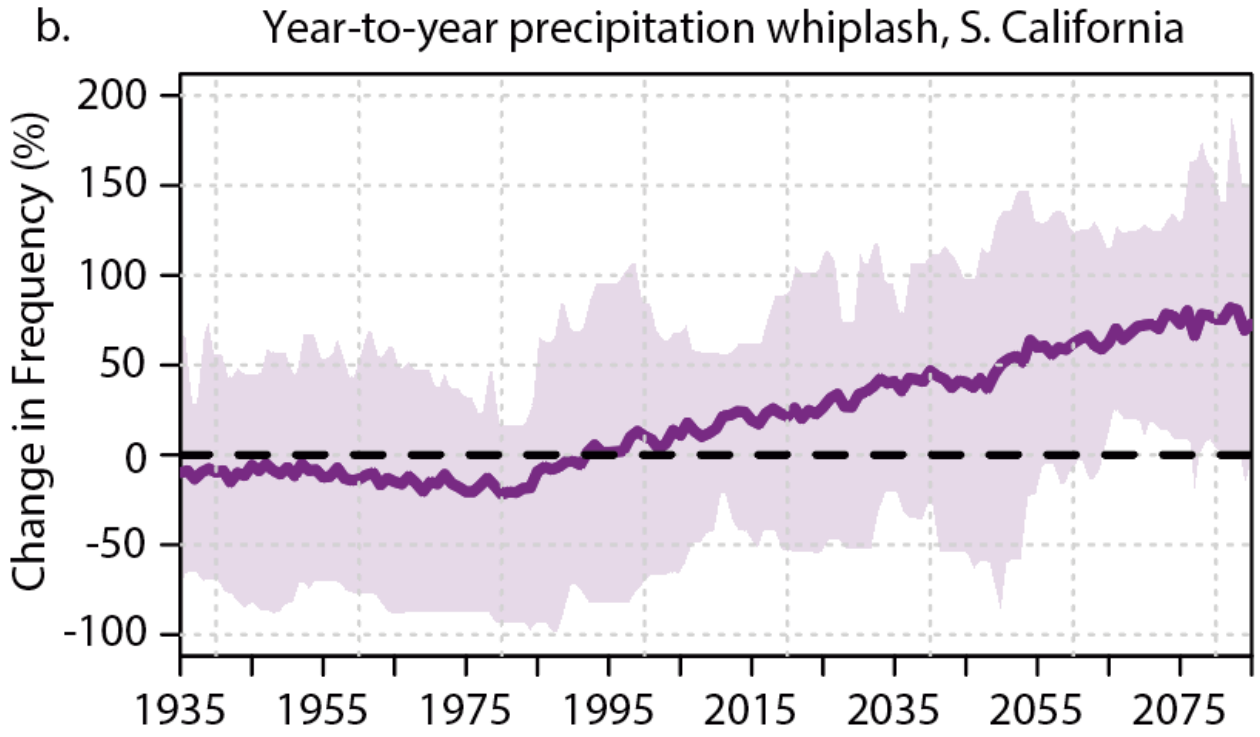
Role of Natural Variability vs. Human Forcing of Climate



Source: U.S. National Climate Assessment, 2014

Potential Changes in Climate Variability

- Variability may be changing
- Patterns of heat waves (Raymond et al., 2019)
- Inter-annual and seasonal precipitation patterns (Swain et al., 2018)



Source: Swain et al., 2018

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A Final Thought

We probably all know the saying:

“God grant us the serenity to **accept** the things we cannot **change**, the courage to **change** the things we **can**, and the **wisdom** to **know** the difference.”

An Update for We Who Wrestle With a Changing Climate

Grant us the serenity to accept the uncertainties that cannot be reduced; the will, patience, and resources to reduce those that can; and the wisdom to know the difference.