Extreme Climate Trends and Projections for the Southeast U.S.

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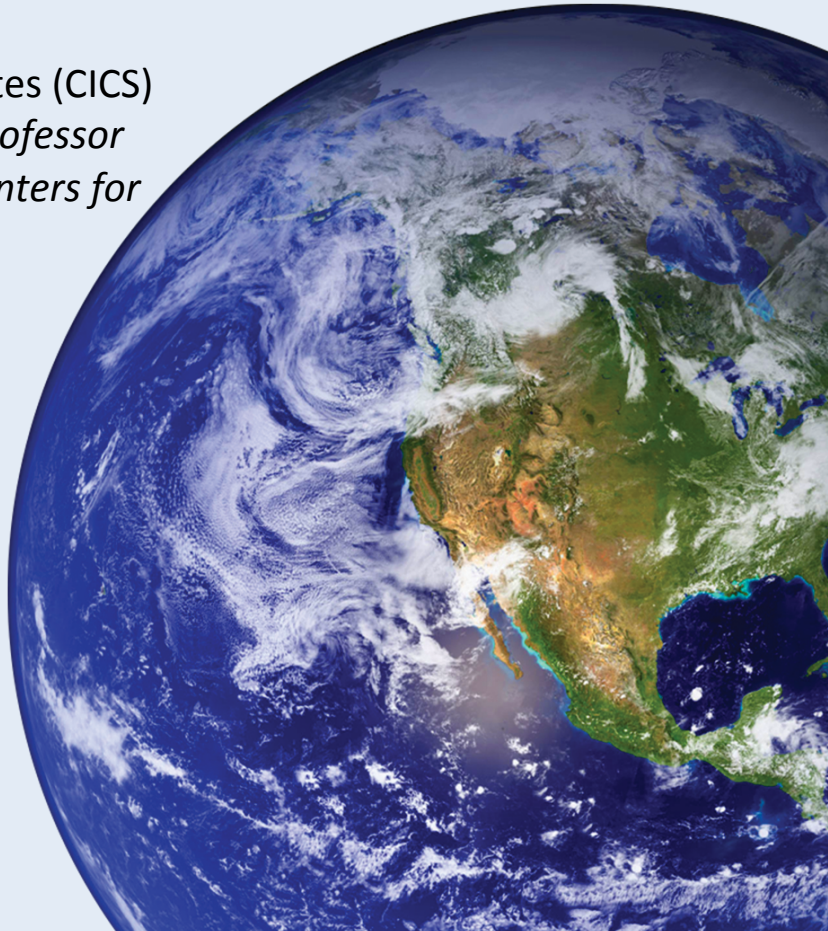
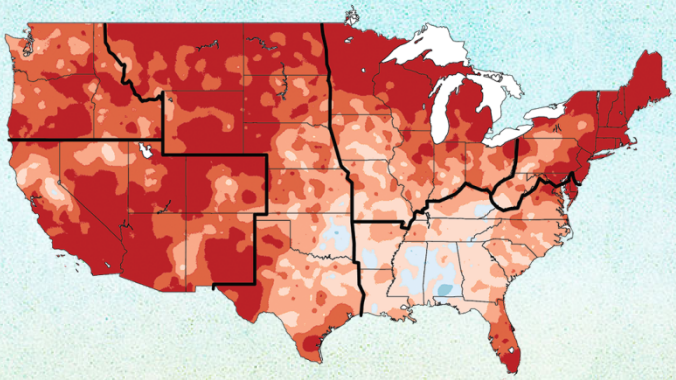
October 20, 2015



Third National Climate Assessment

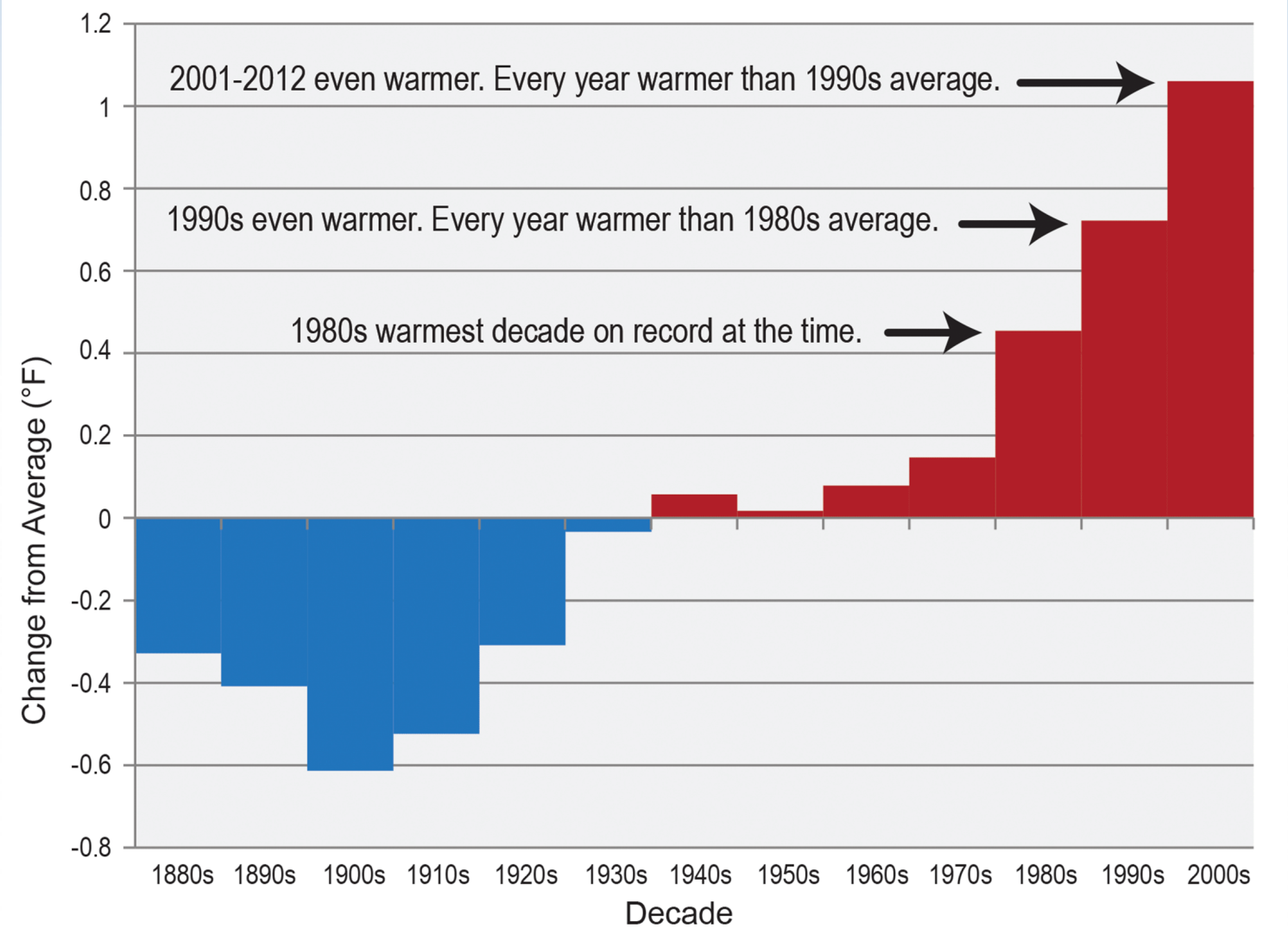
Climate Change Impacts in the United States



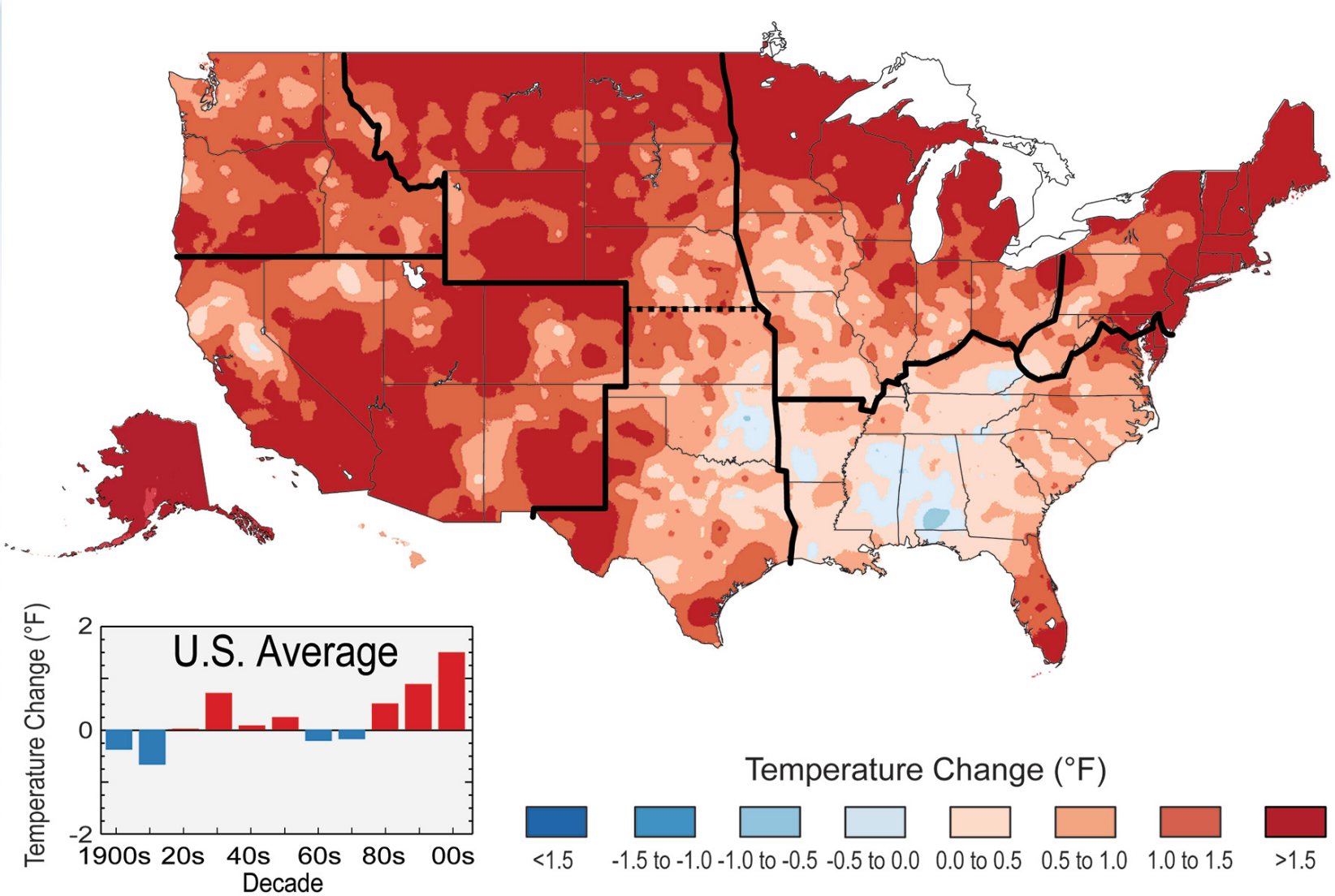
GlobalChange.gov
U.S. Global Change Research Program

Global and U.S. Trends
Temperature and Precipitation

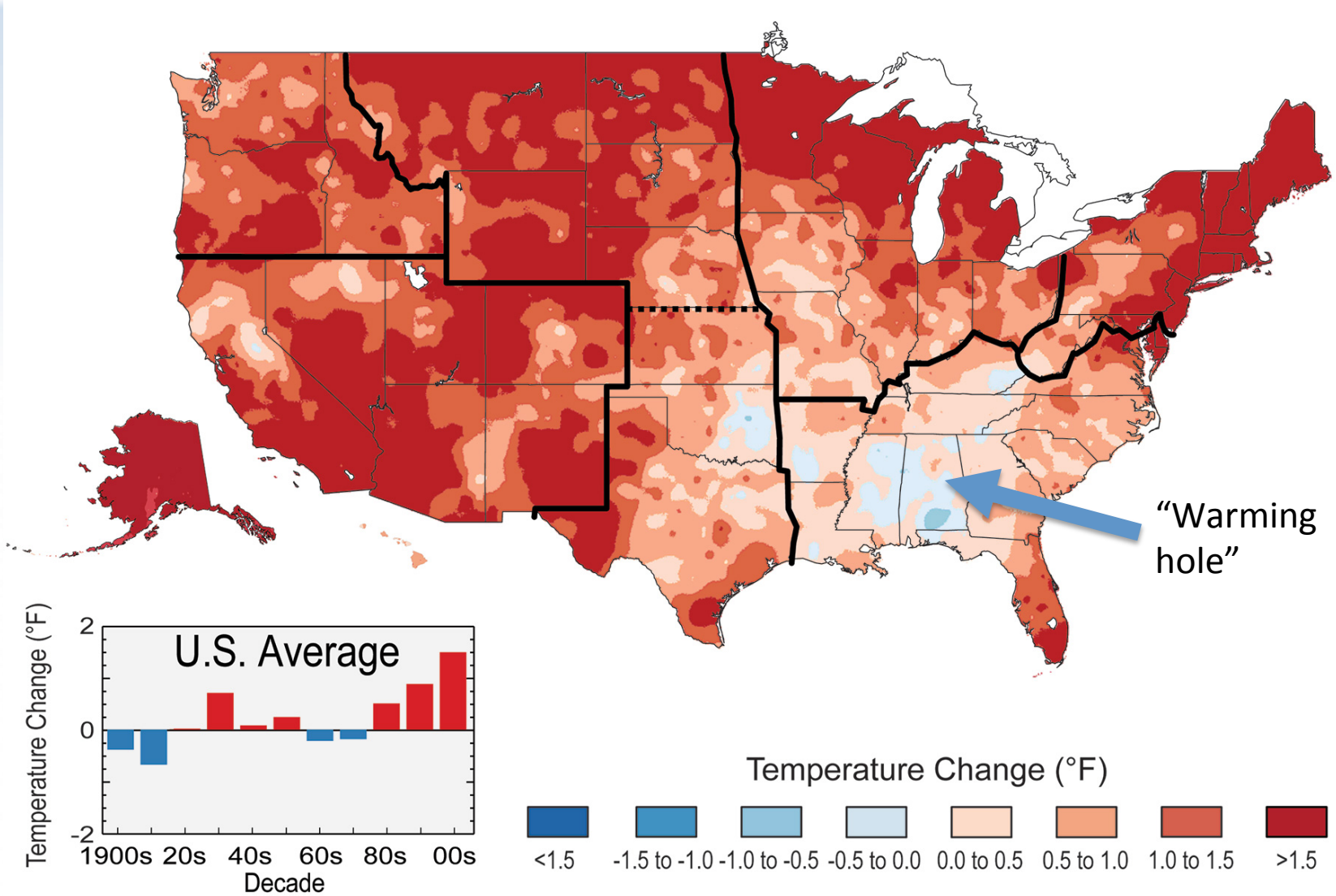
Global Temperature Change by Decade



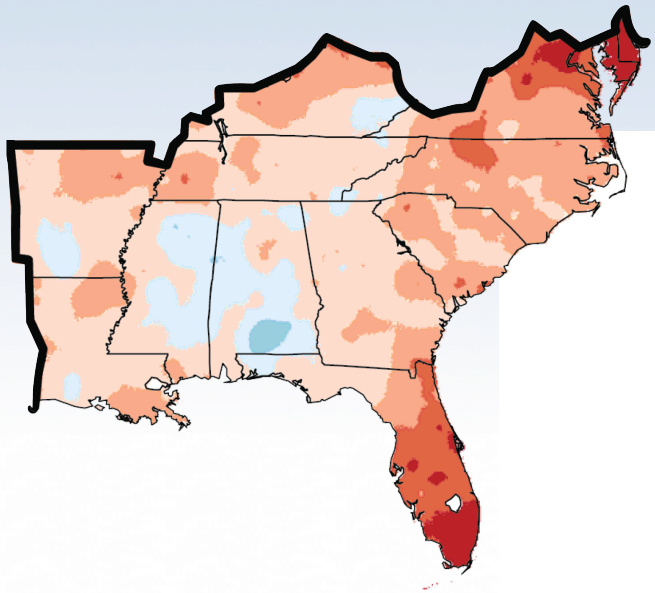
Observed U.S. Temperature Change

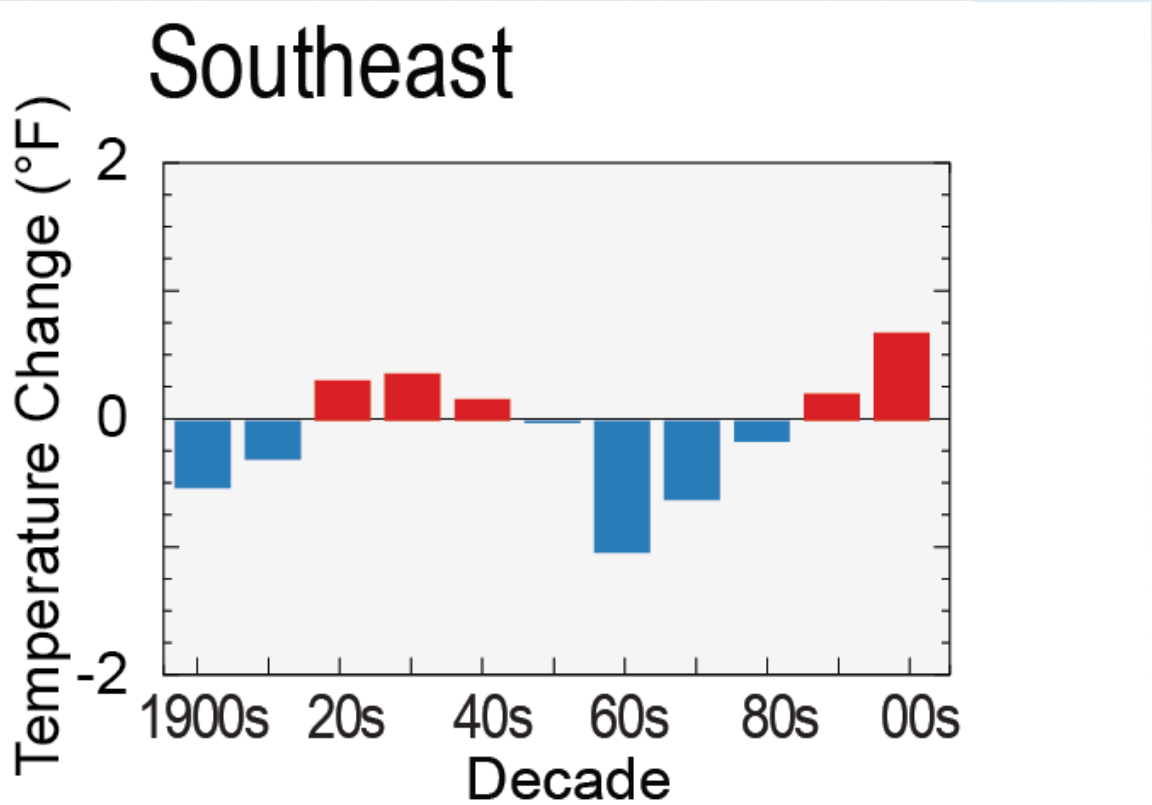


Observed U.S. Temperature Change



Observed Southeast Temperature Change

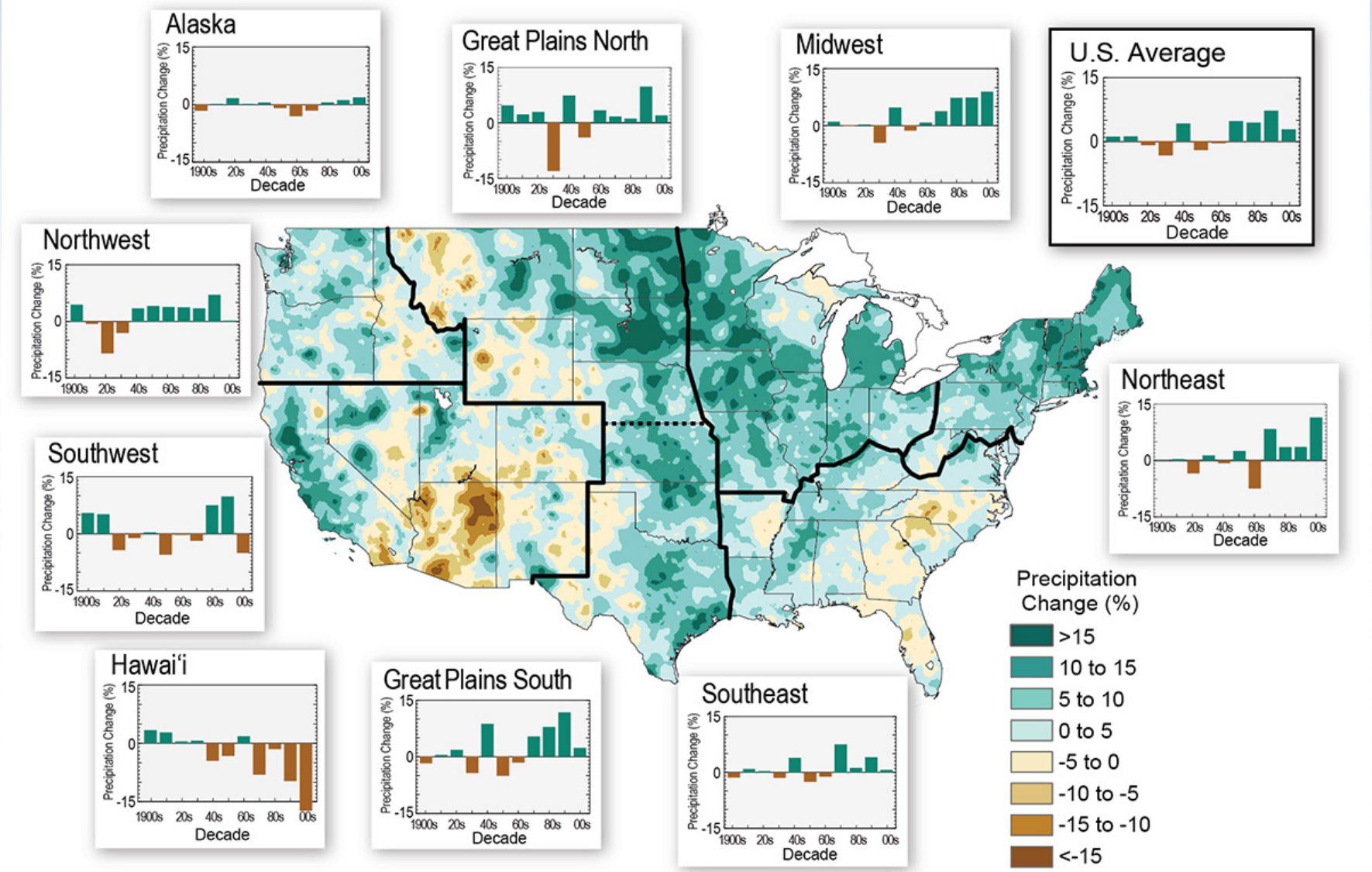




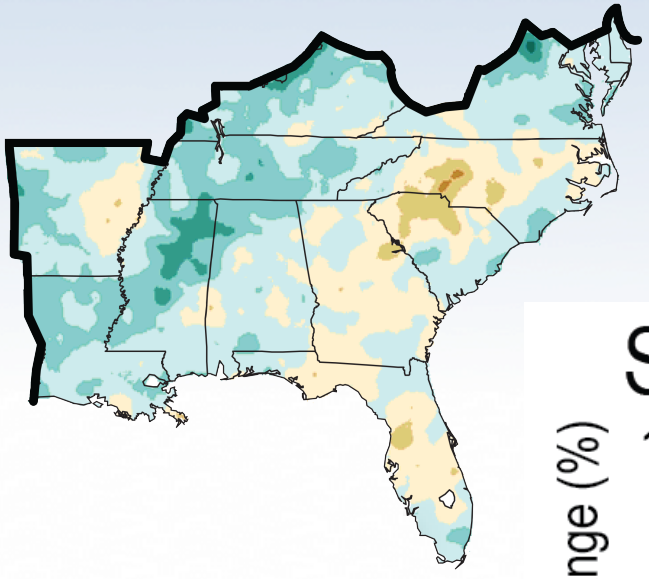
Temperature Change (°F)

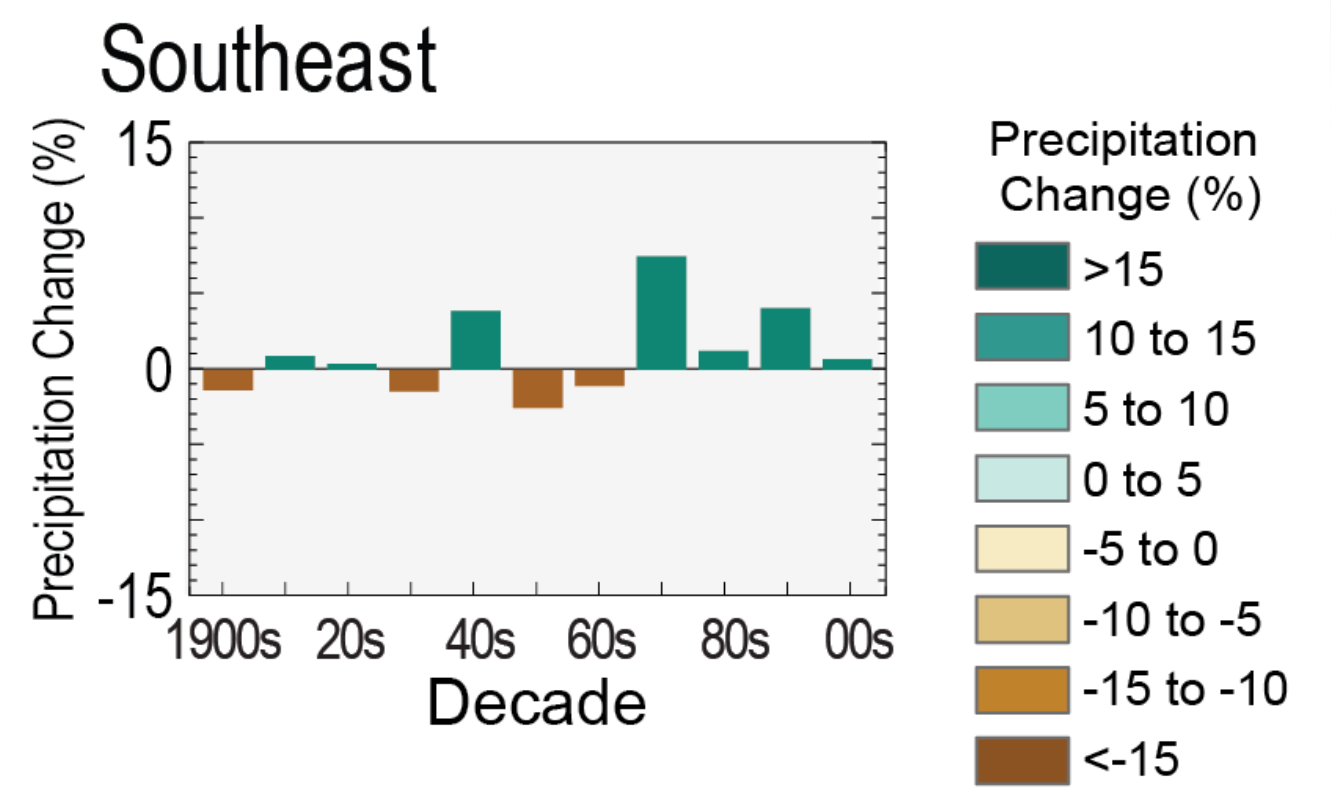
< -1.5 | -1.5 to -1.0 | -1.0 to -0.5 | -0.5 to 0.0 | 0.0 to 0.5 | 0.5 to 1.0 | 1.0 to 1.5 | >1.5

Observed US Precipitation Change

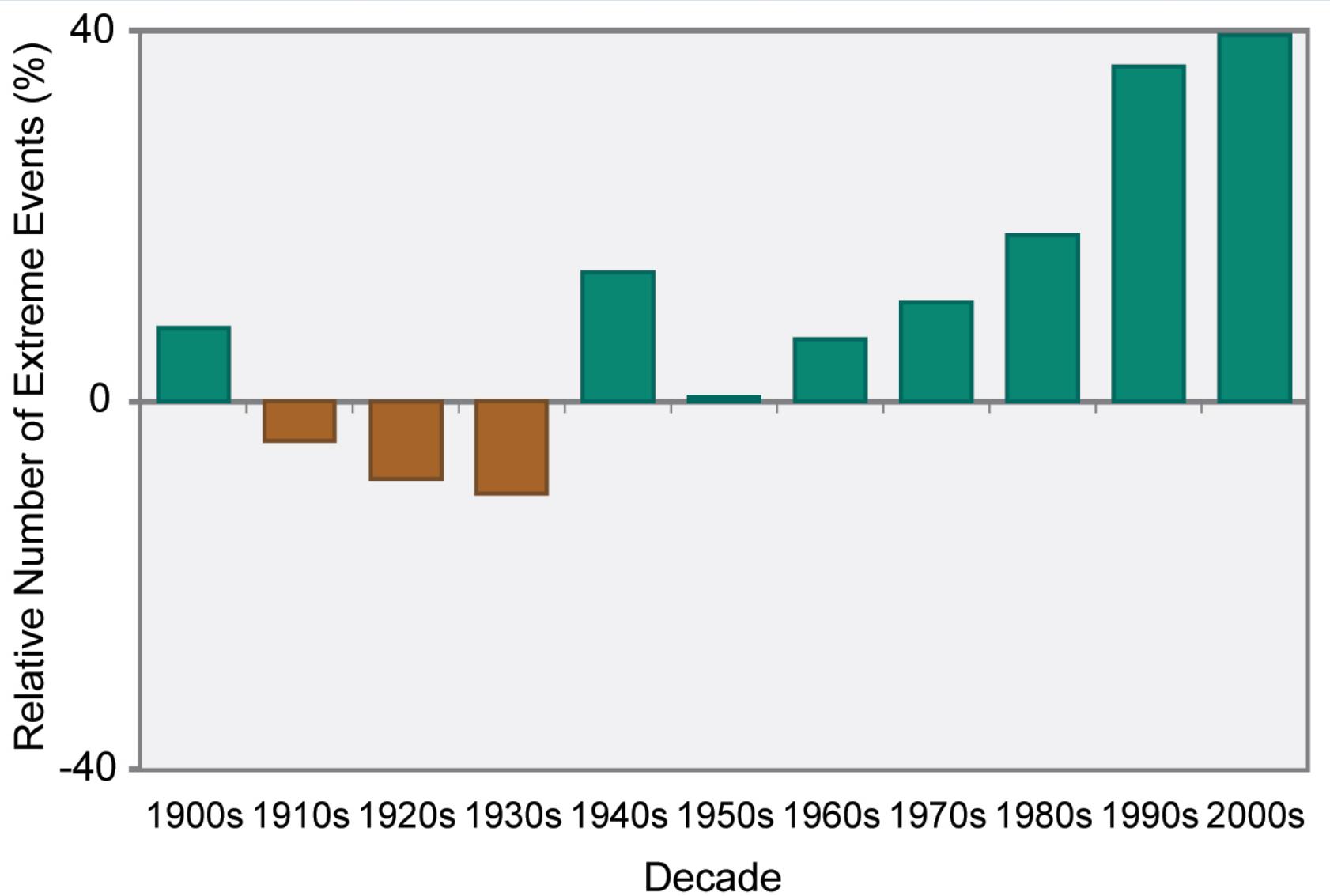


Observed Southeast Precipitation Change

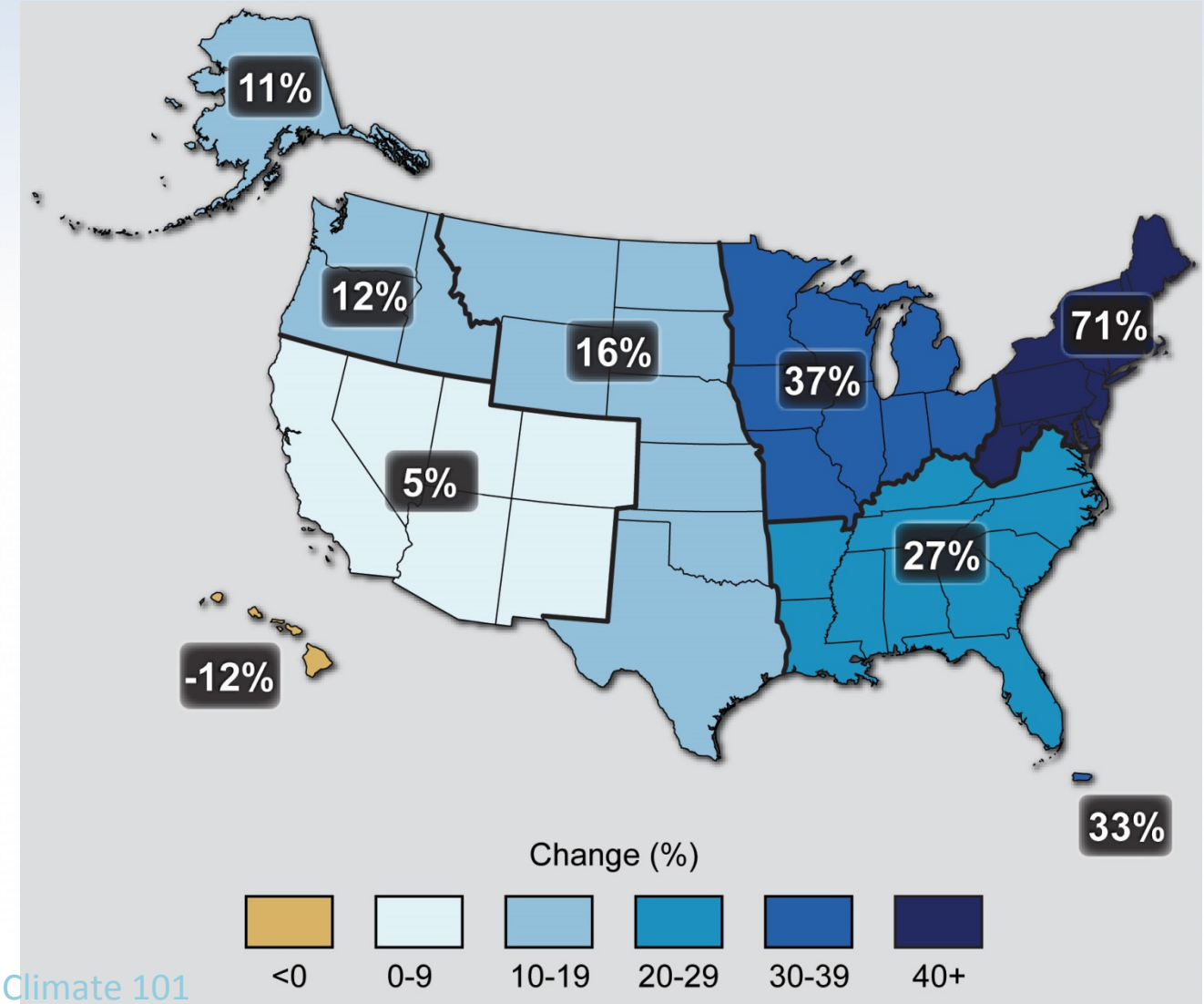




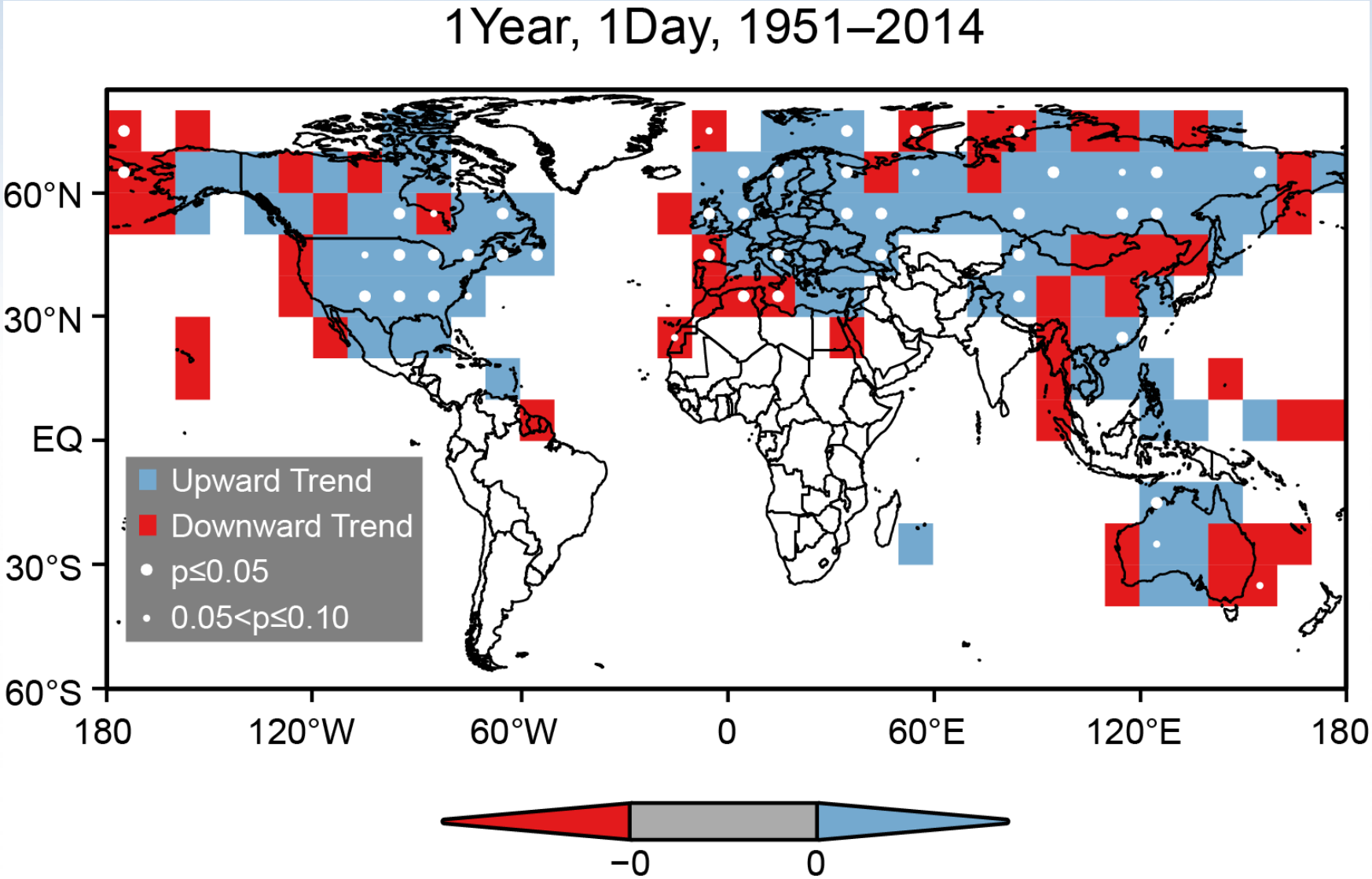
Observed U.S. Trends in Heavy Precipitation



Observed Change in Very Heavy Precipitation

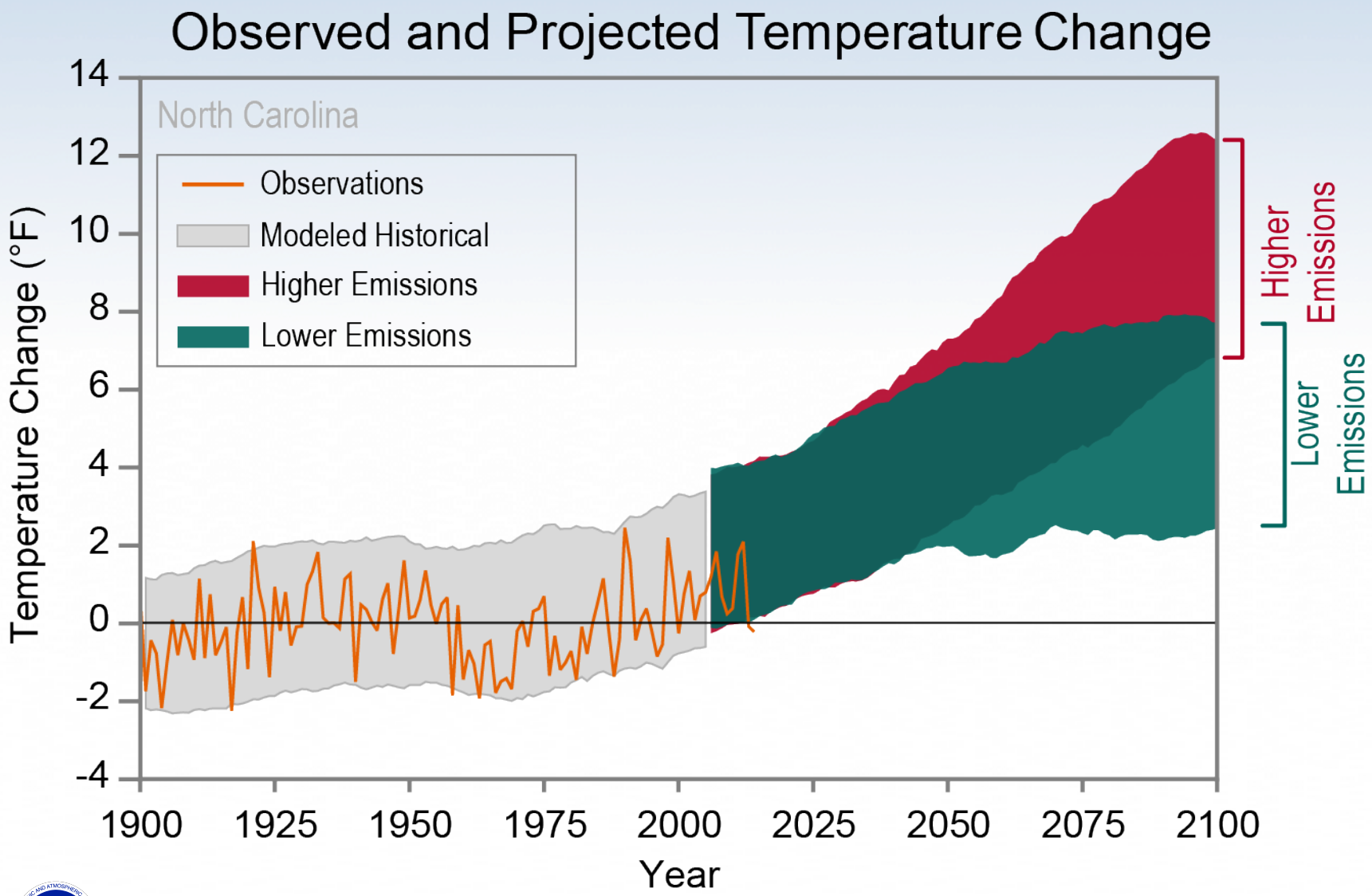


Global Extreme Precipitation Trends

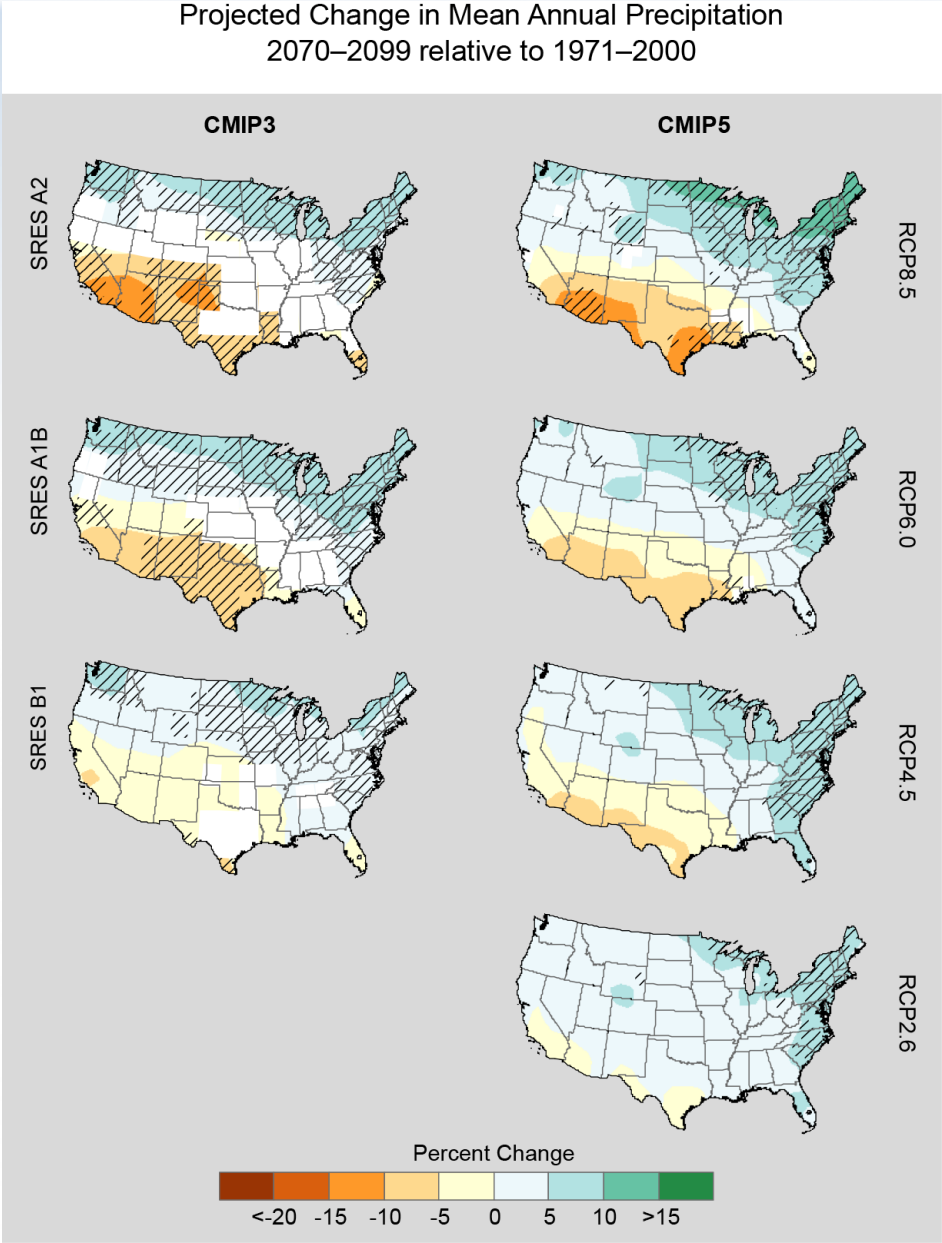


Future Projections
Temperature and Precipitation

North Carolina Temperature



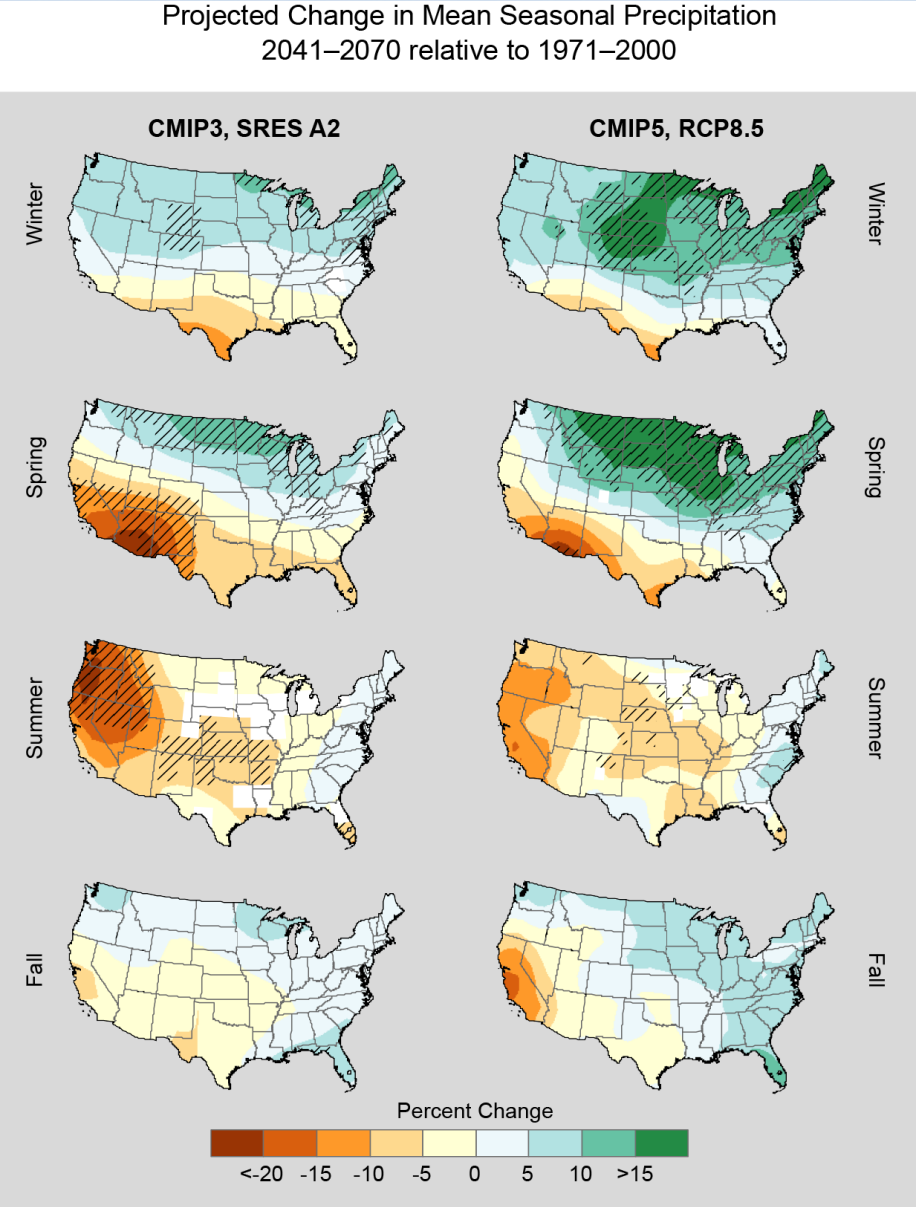
Projected Precipitation Change – End of Century



High Emissions

Low Emissions

Projected Precipitation Change – mid Century



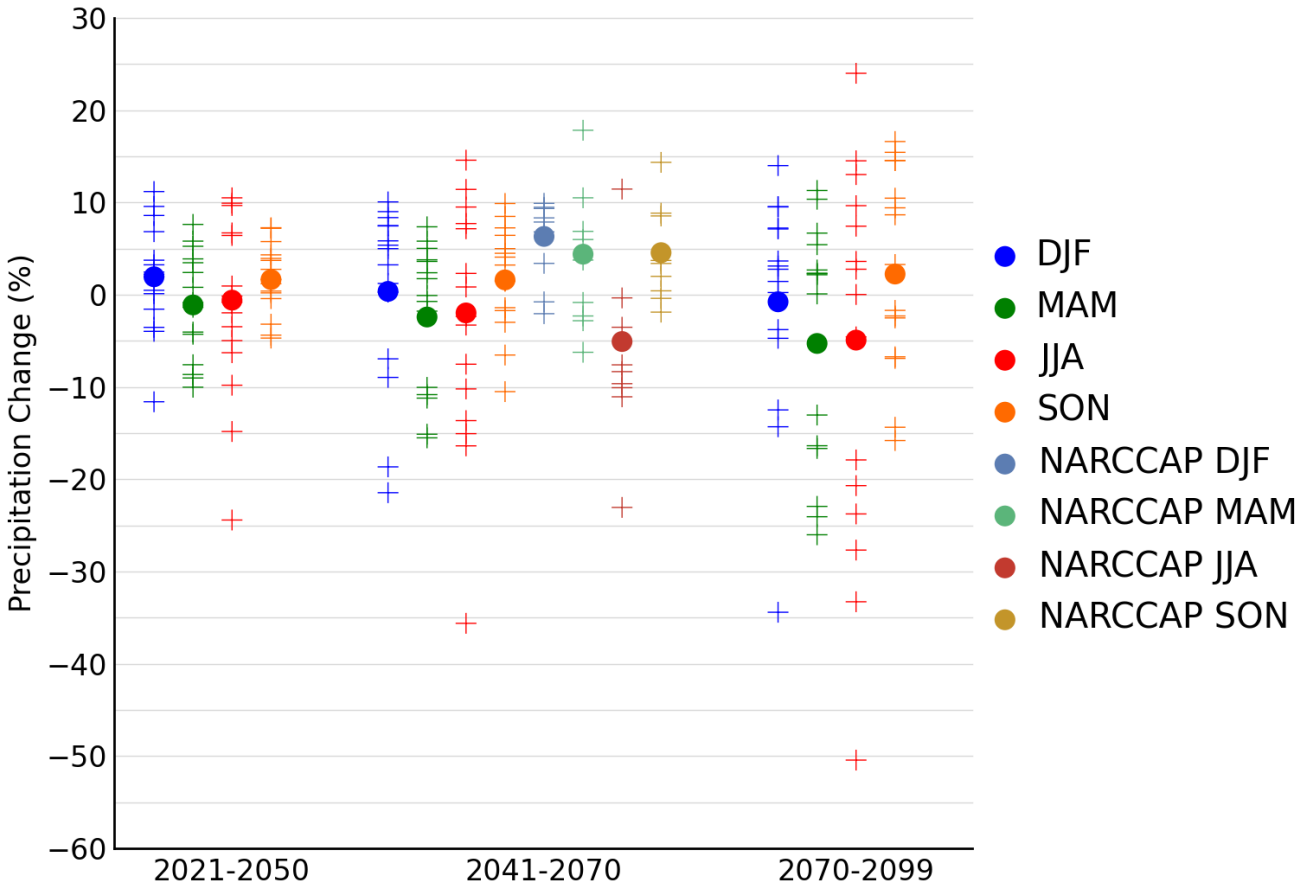
Winter

Spring

Summer

Fall

Southeast U.S. Precipitation Projections

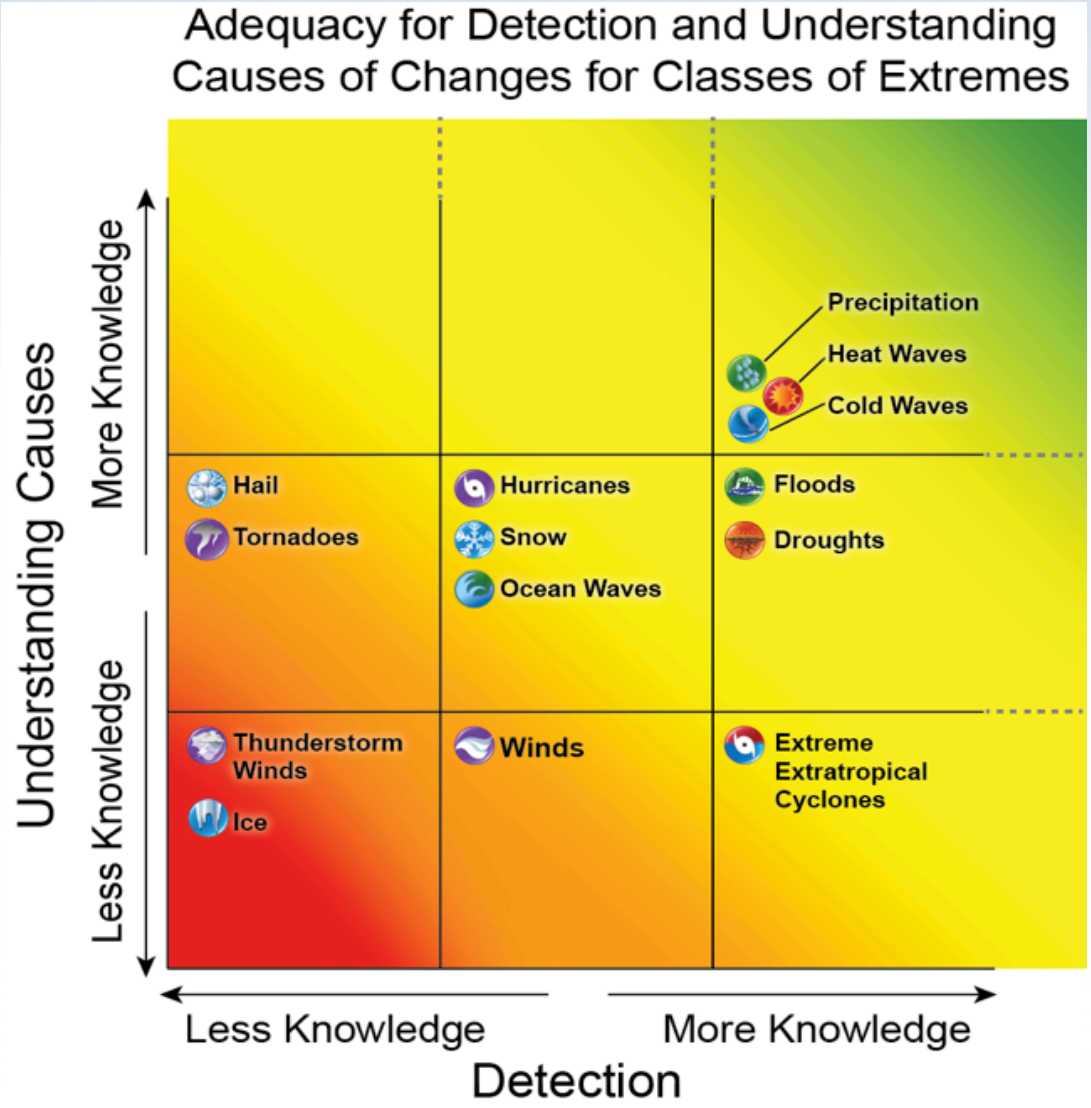


Extreme Events

Trends, projections and confidence:

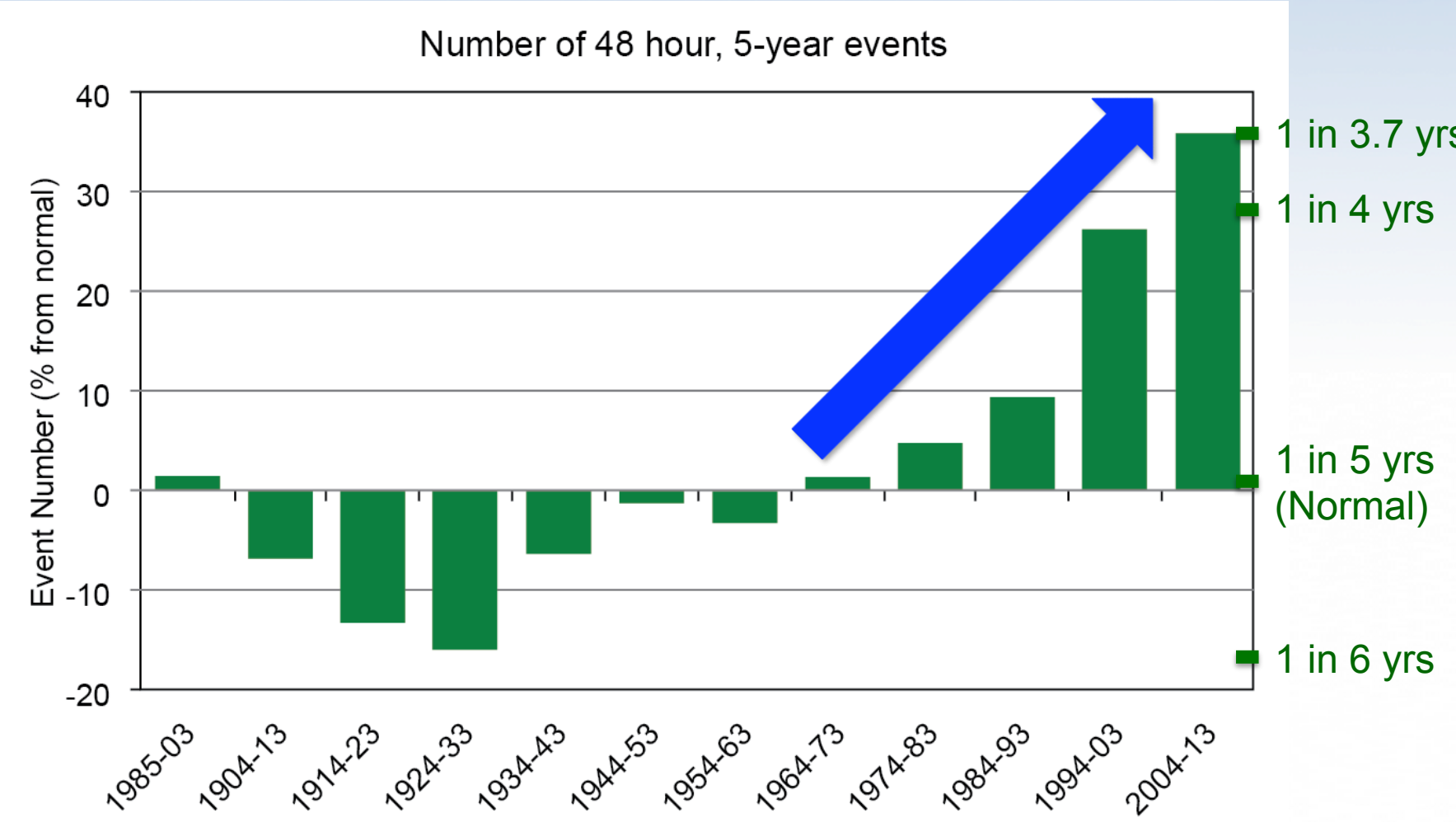
- ✓ Heavy precipitation
- ✓ Hurricanes
- ✓ Heat and cold waves
- ✓ Severe thunderstorms (tornadoes and hail)
- ✓ Winter Storms
- ✓ Drought

Attribution – State of Knowledge

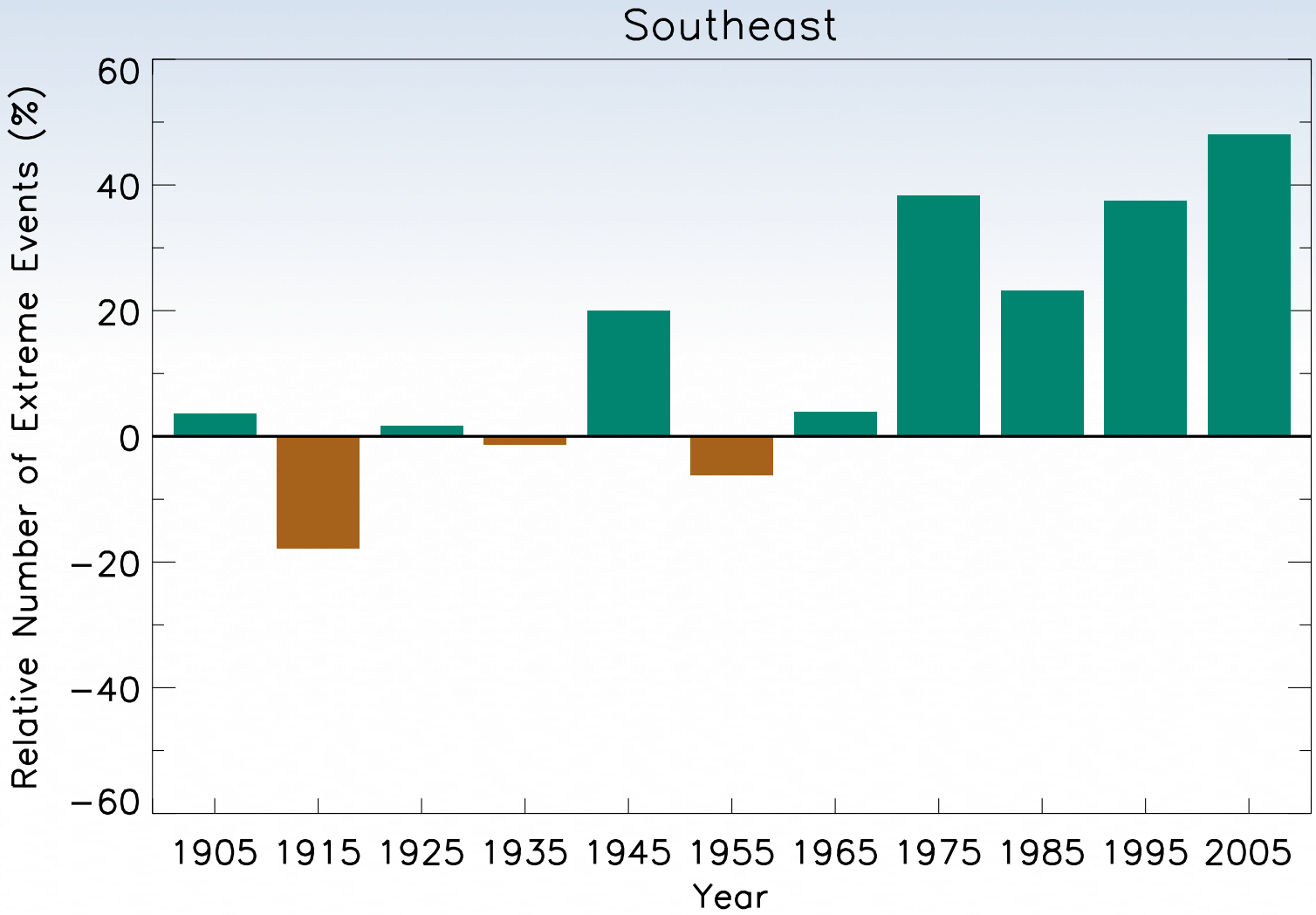


Heavy Precipitation

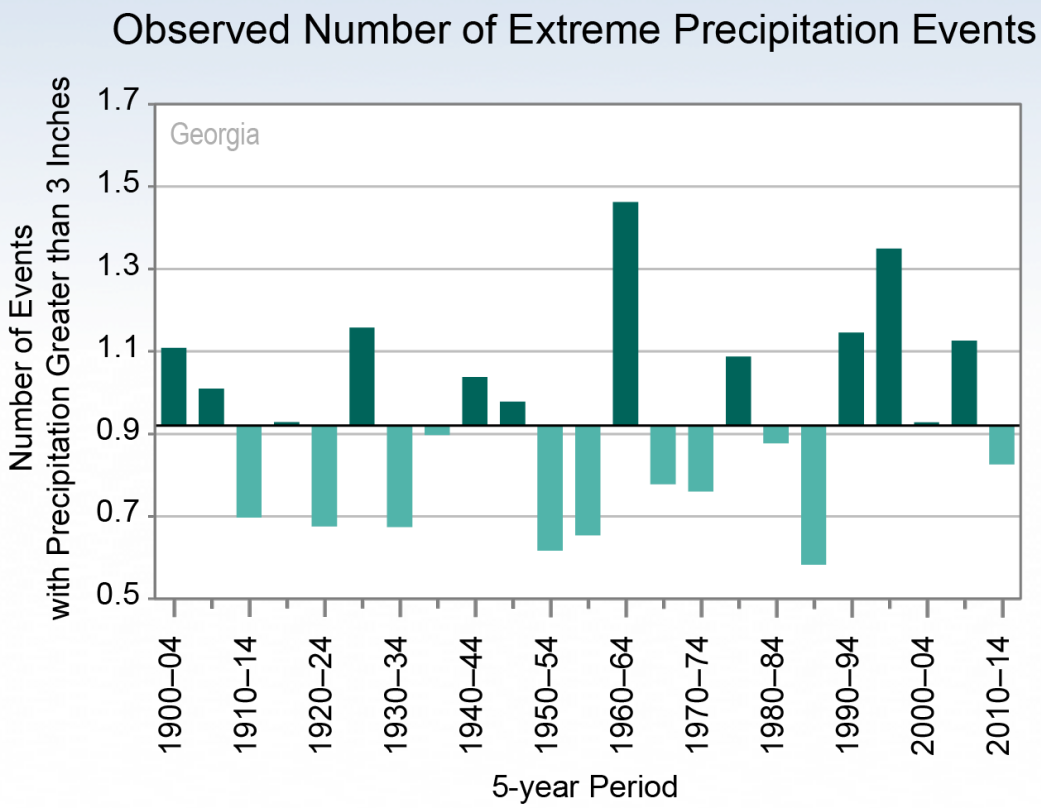
Upward U.S. Trends in Extreme Precipitation

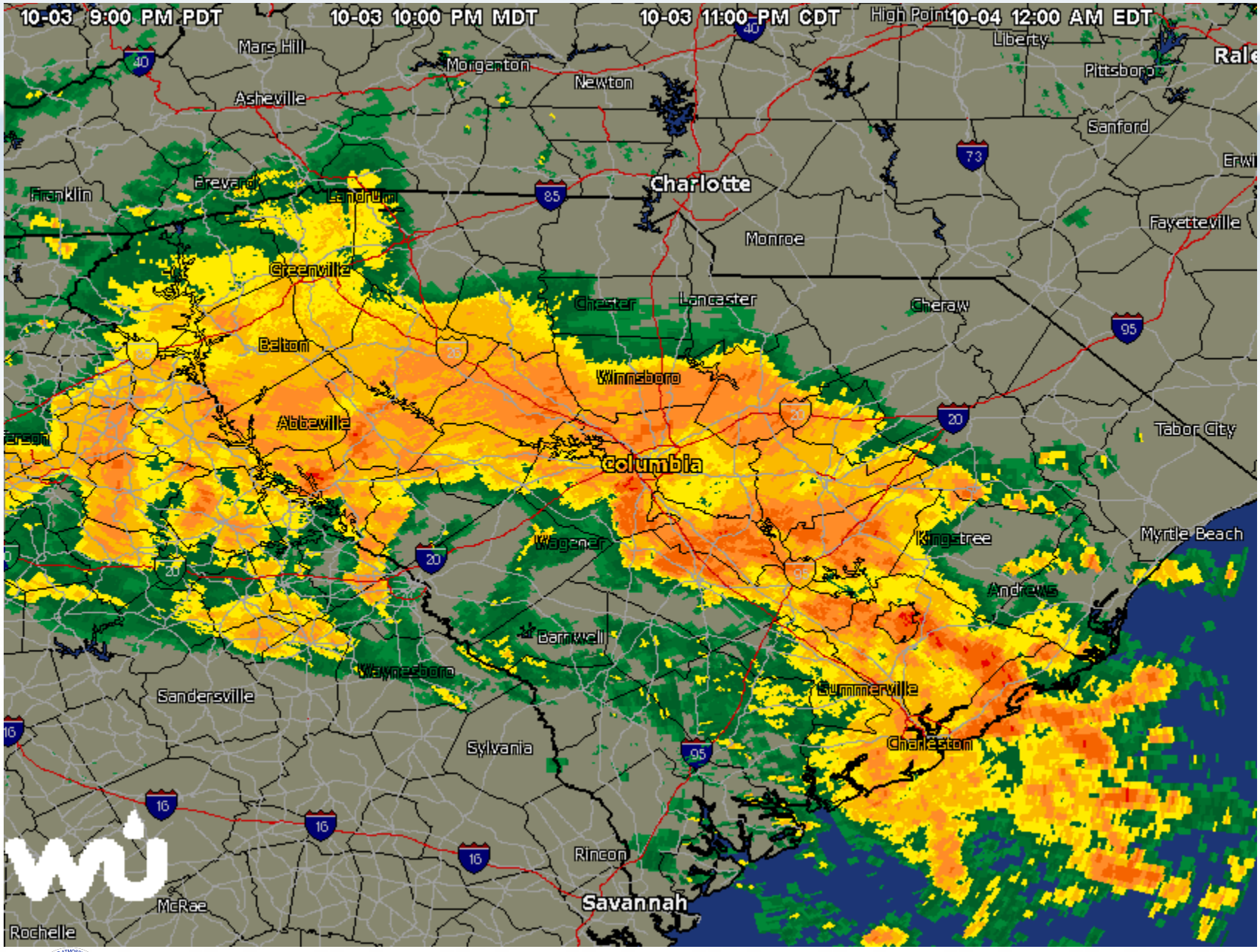


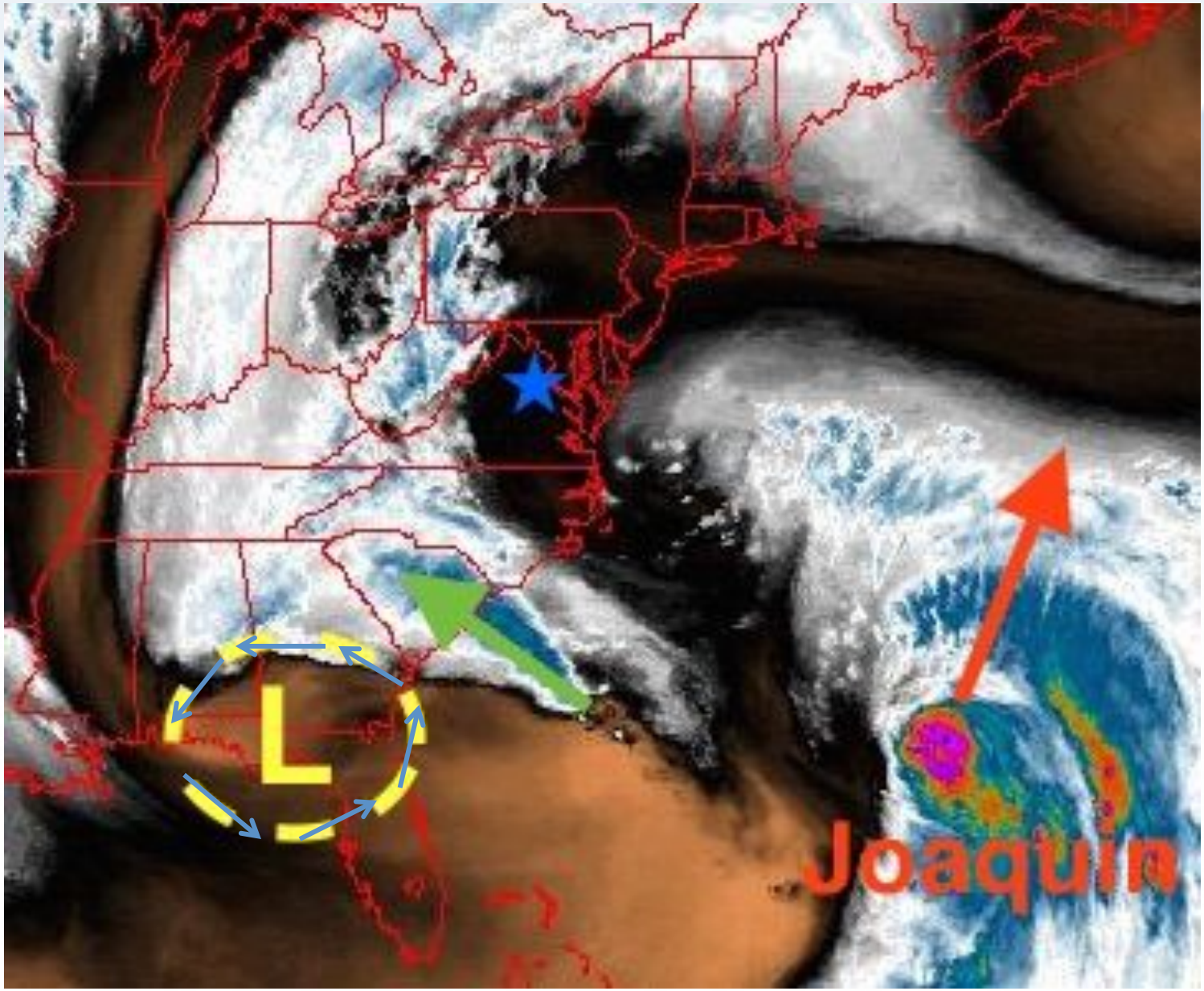
Southeast Extreme Precipitation Trends



Georgia Extreme Precipitation Trends




10-03 9:00 PM PDT
10-03 10:00 PM MDT
10-03 11:00 PM CDT
10-04 12:00 AM EDT
Mars Hill
Morganton
Newton
High Point
Liberty
Pittsboro
Asheville
Sanford
Franklin
Brevard
Landrum
Charlotte
Fayetteville
Monroe
Greenville
Chester
Lancaster
Cheraw
Belton
Winnsboro
Abbeville
Tabor City
Columbia
Wagener
Kingstree
Myrtle Beach
Andrews
Barnwell
Waynesboro
Sandersville
Summerville
Sylvania
Charleston
Rincon
Savannah
McRae
Rochelle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Joaquin

Projected Extreme Precipitation

- **Increases throughout U.S.**

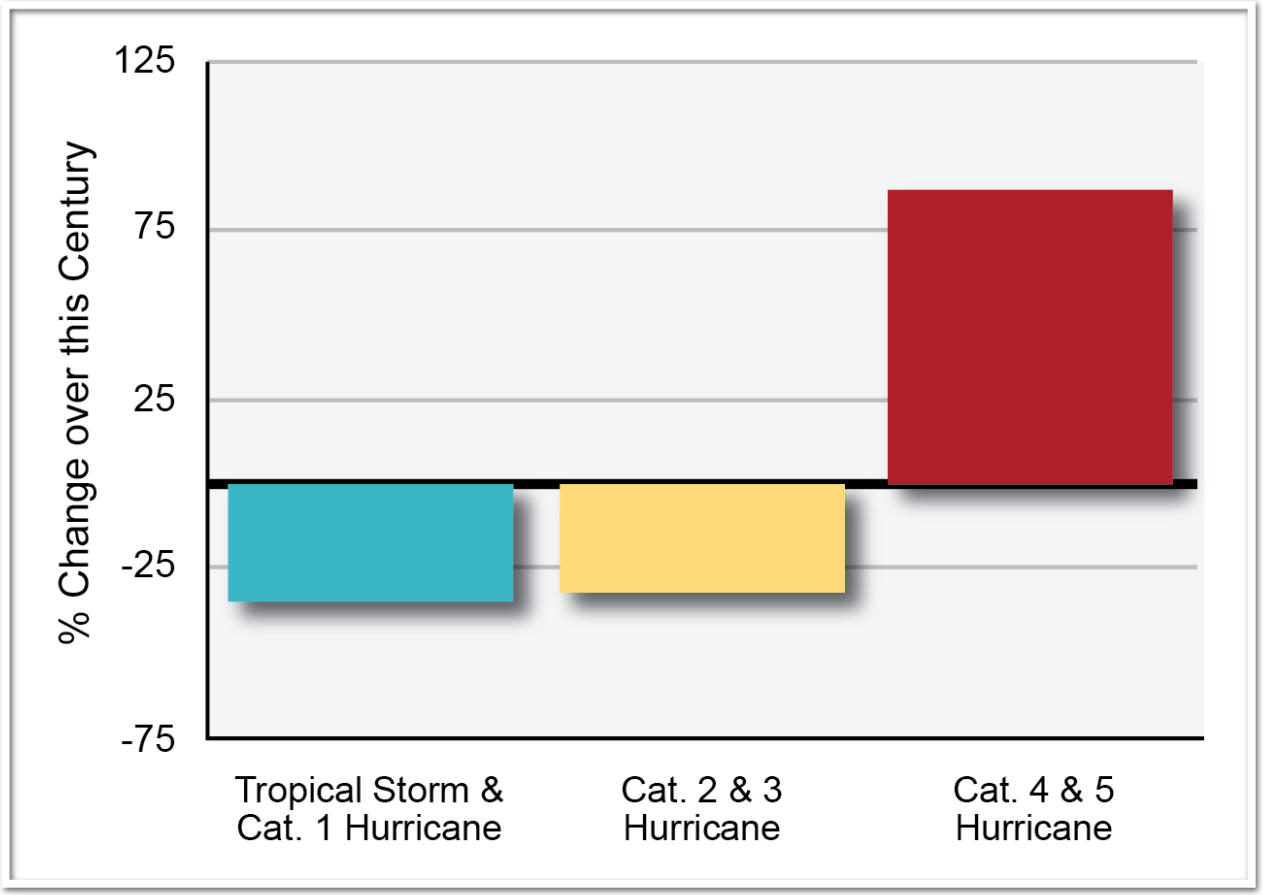
Confidence in Projected Extreme Precipitation

- **High**
- Why? Because there is a direct link between air temperature and the amount of water vapor in the atmosphere over the oceans. As **temperature increases**, the capacity of the atmosphere to hold **water vapor increases.**
- Climate model simulations show increases in the most extreme precipitation amounts as a direct consequence of increased water vapor

Hurricanes

Projections of Hurricanes

Projected Changes in Atlantic Hurricane Frequency by Category



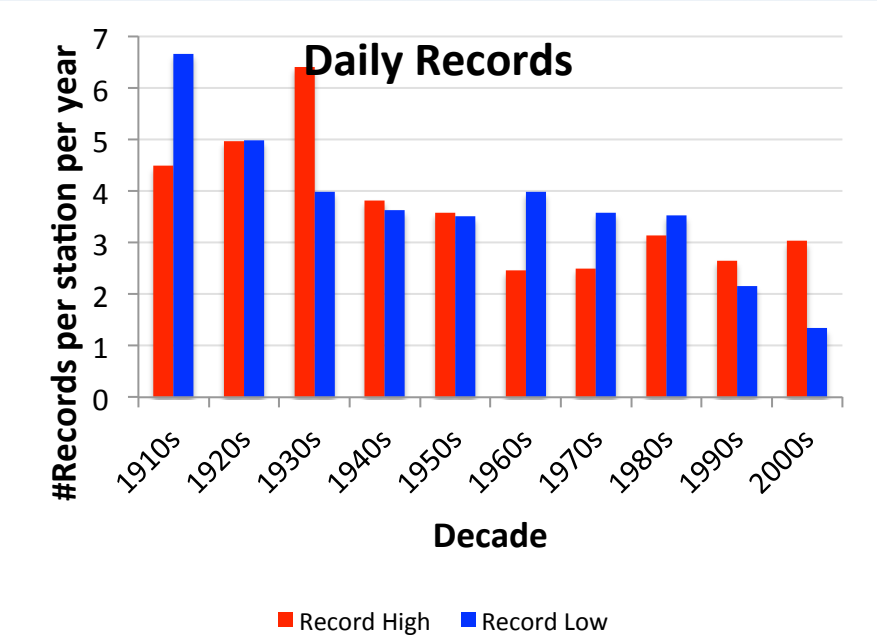
Confidence in Projected Hurricane Intensity

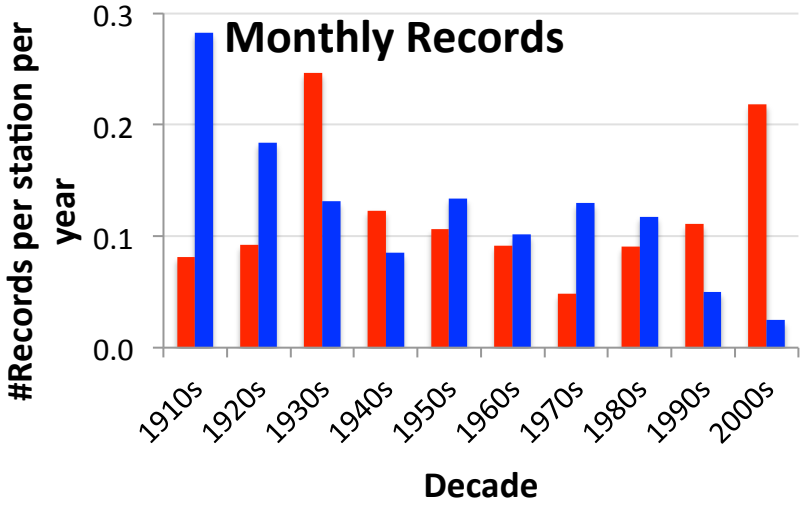
- **Medium**
- Why? Because hurricane development requires several conditions including (among others)
  - high sea surface temperatures (relative?)
  - Low vertical wind shear
  - Low pressure disturbances
- There is high confidence sea surface temperatures will **increase** in future but not so for relative changes
- There is lower confidence about changes in vertical wind shear and the number of low pressure disturbances

Heat and Cold Waves

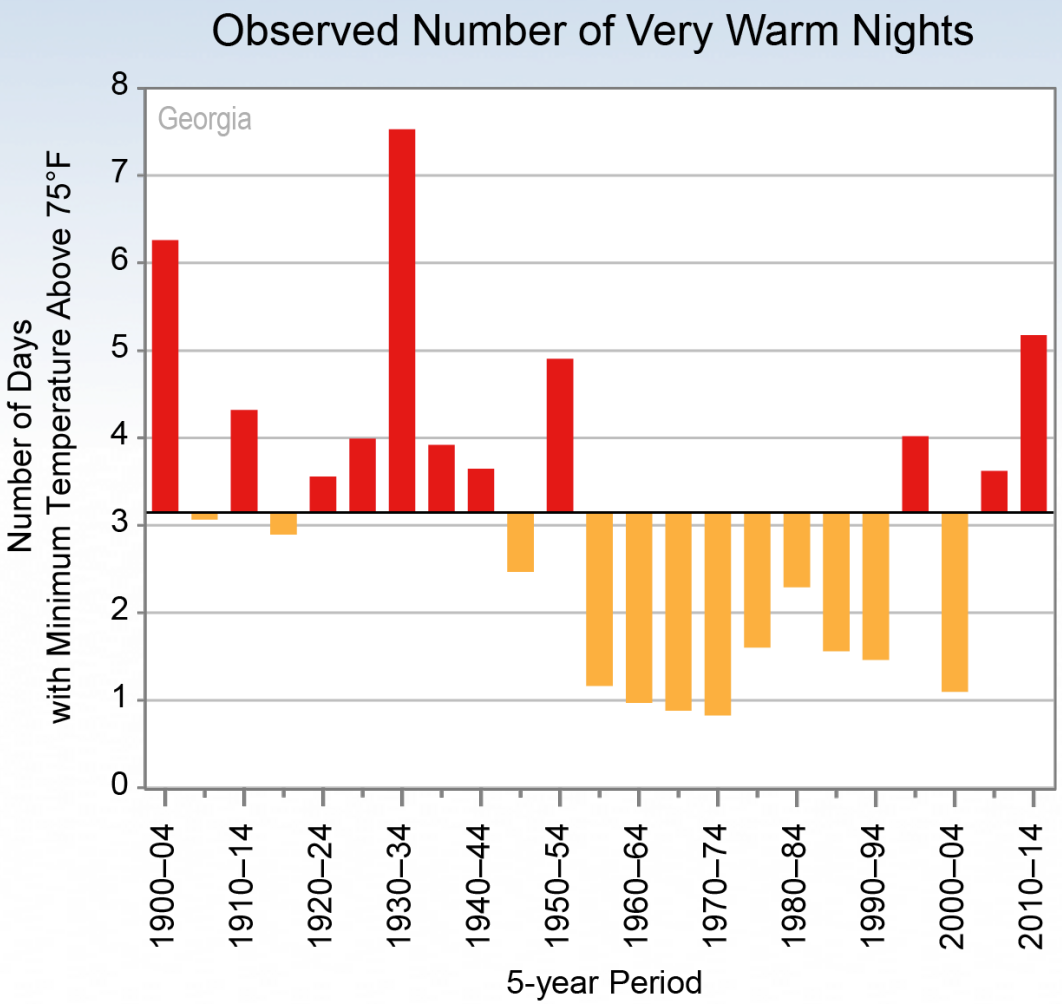
Extreme Temperature Episodes

- Record hot and cold temperatures
  - Daily records
  - Monthly temperature records

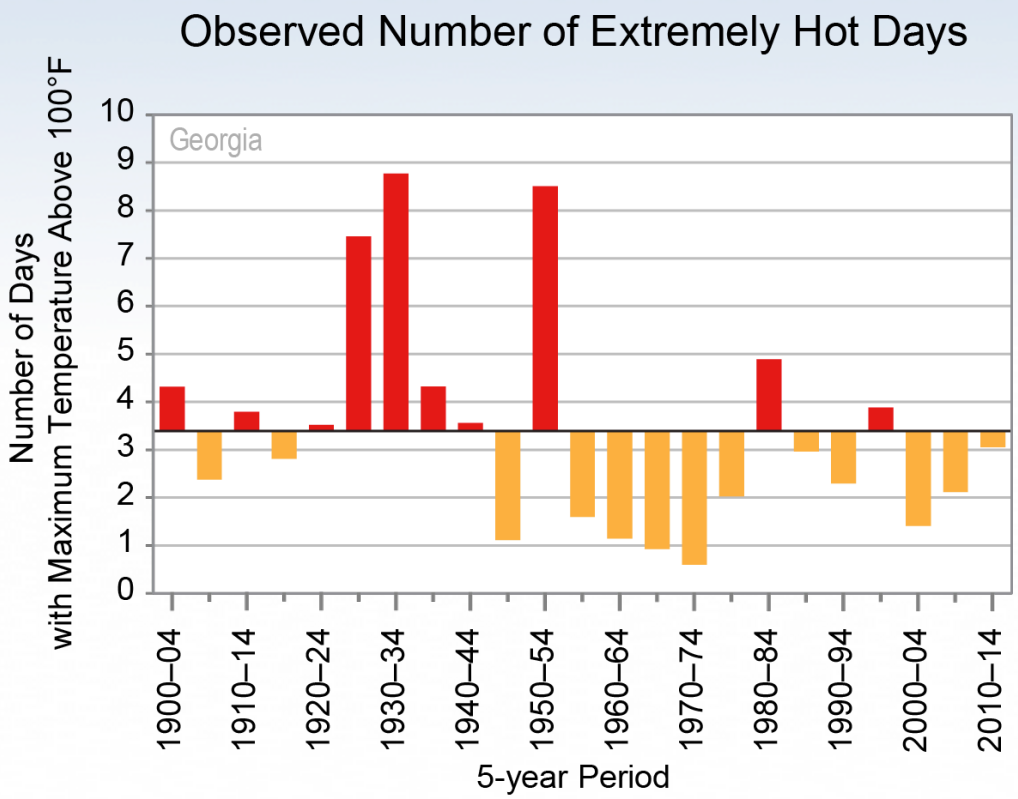




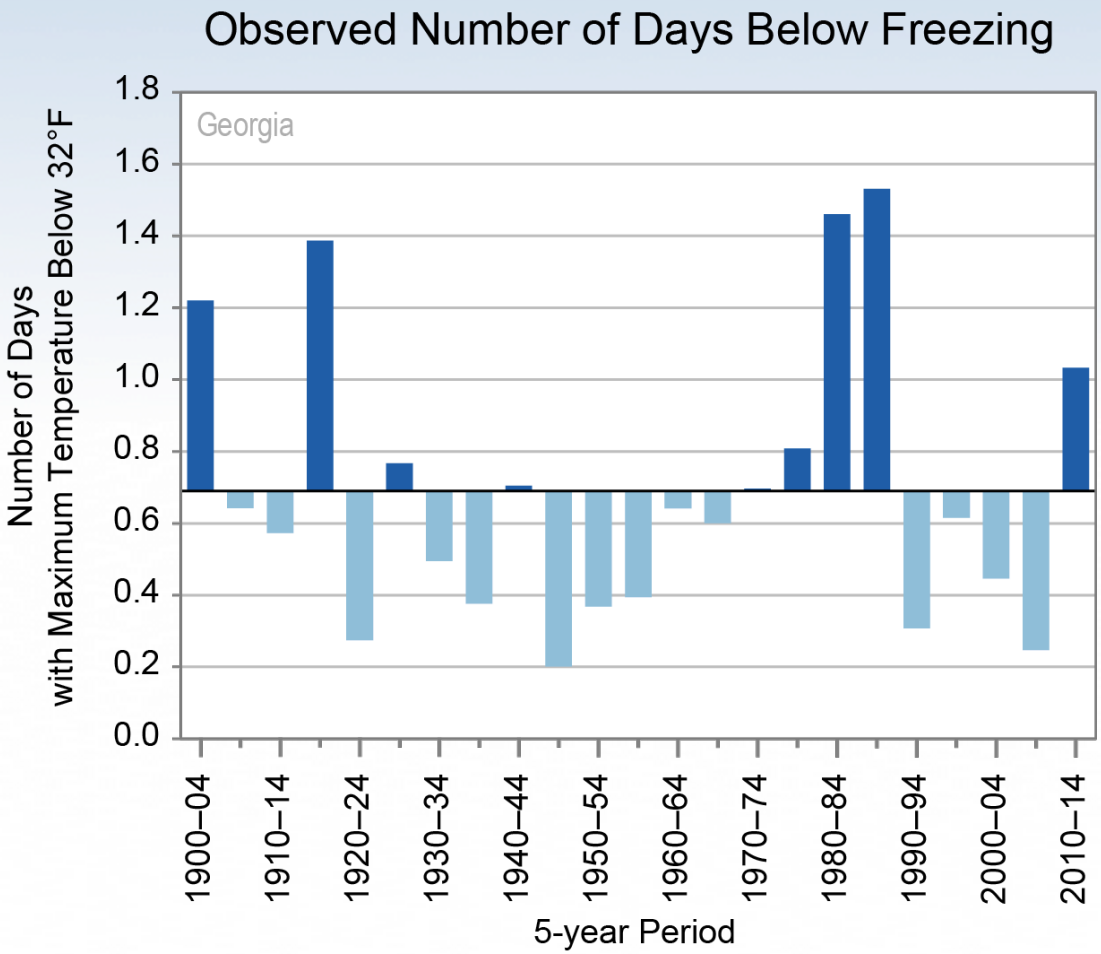
Southeast Extreme Precipitation Trends



Southeast Extreme Precipitation Trends

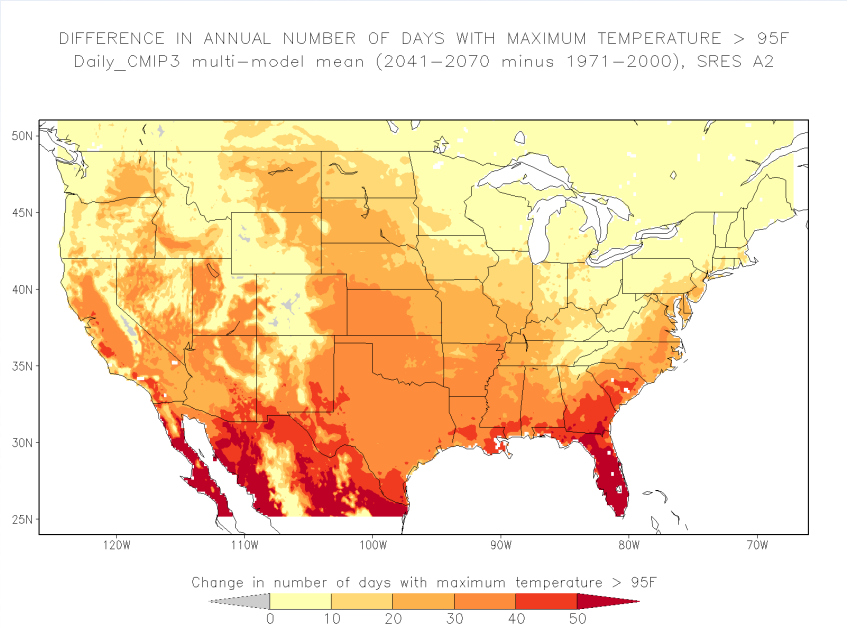


Southeast Extreme Precipitation Trends



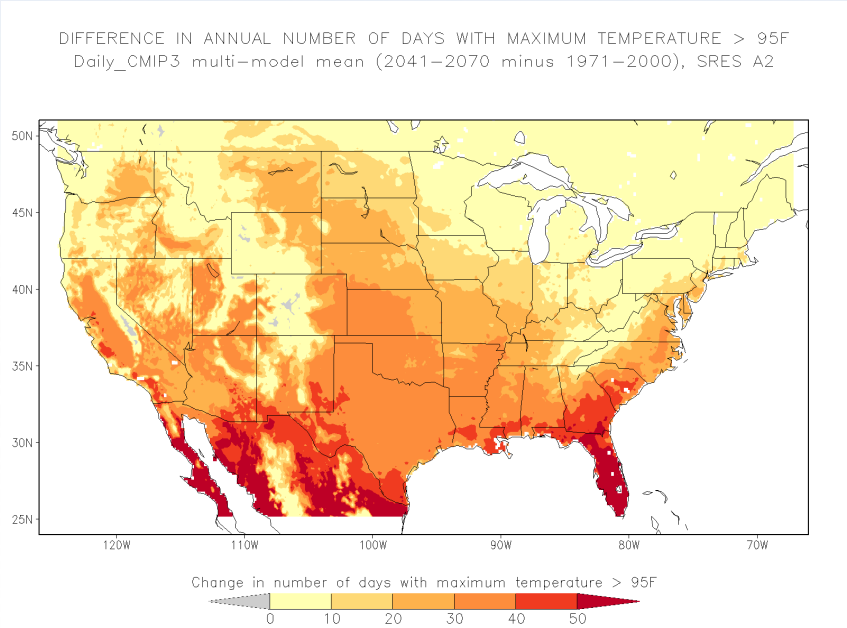
Projected Extreme Temperatures

- Hot Extremes projected to become more intense
- Cold extremes projected to become less intense



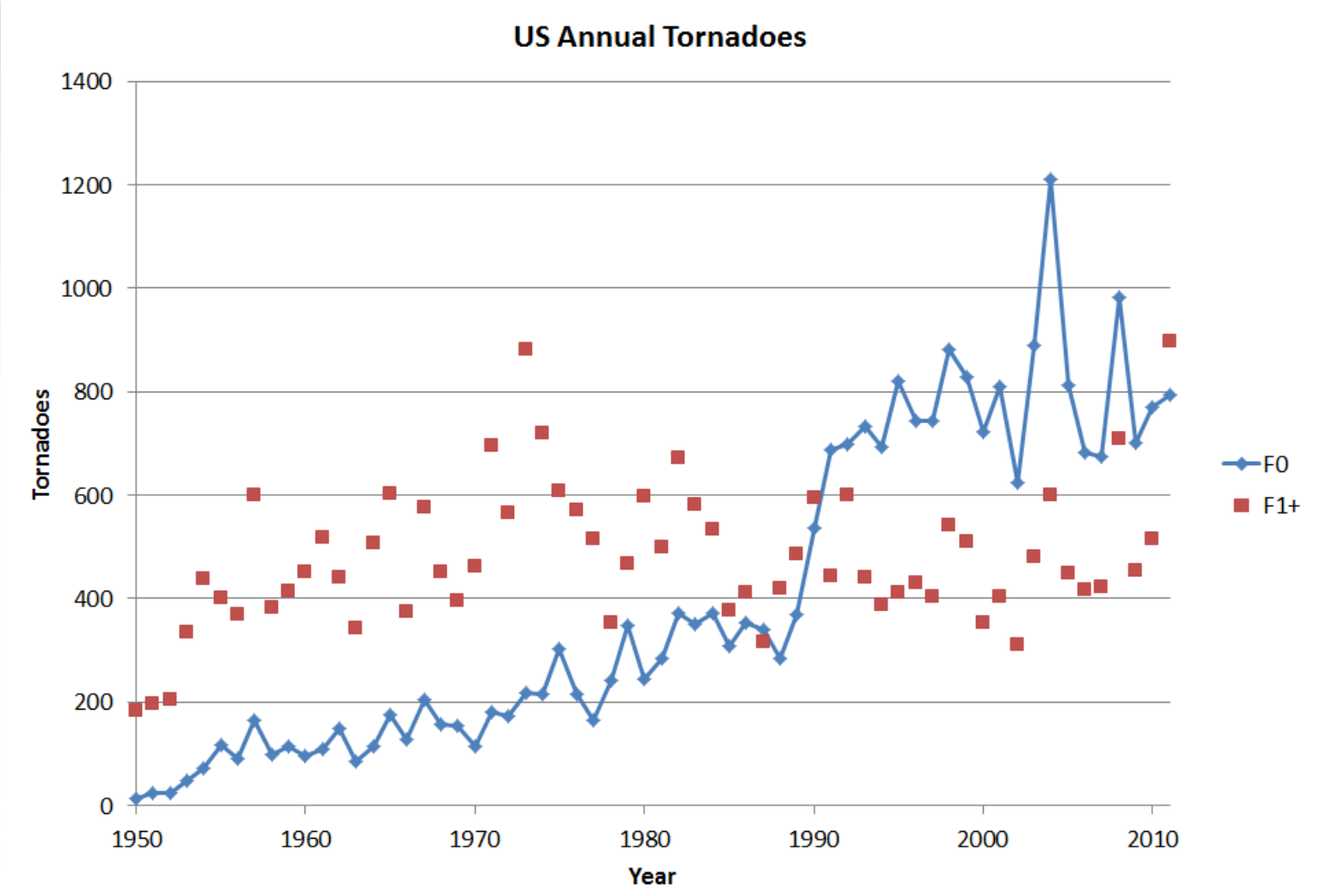
Confidence in Projected Extreme Temperatures

- **High**
- Why? Because there is high confidence about **increases in mean temperature** and to a first approximation climate models simulate similar changes in extreme temperatures
- Tempered by unknown causes of “warming hole”



Severe Thunderstorms Tornadoes and Hail

US Annual Tornadoes



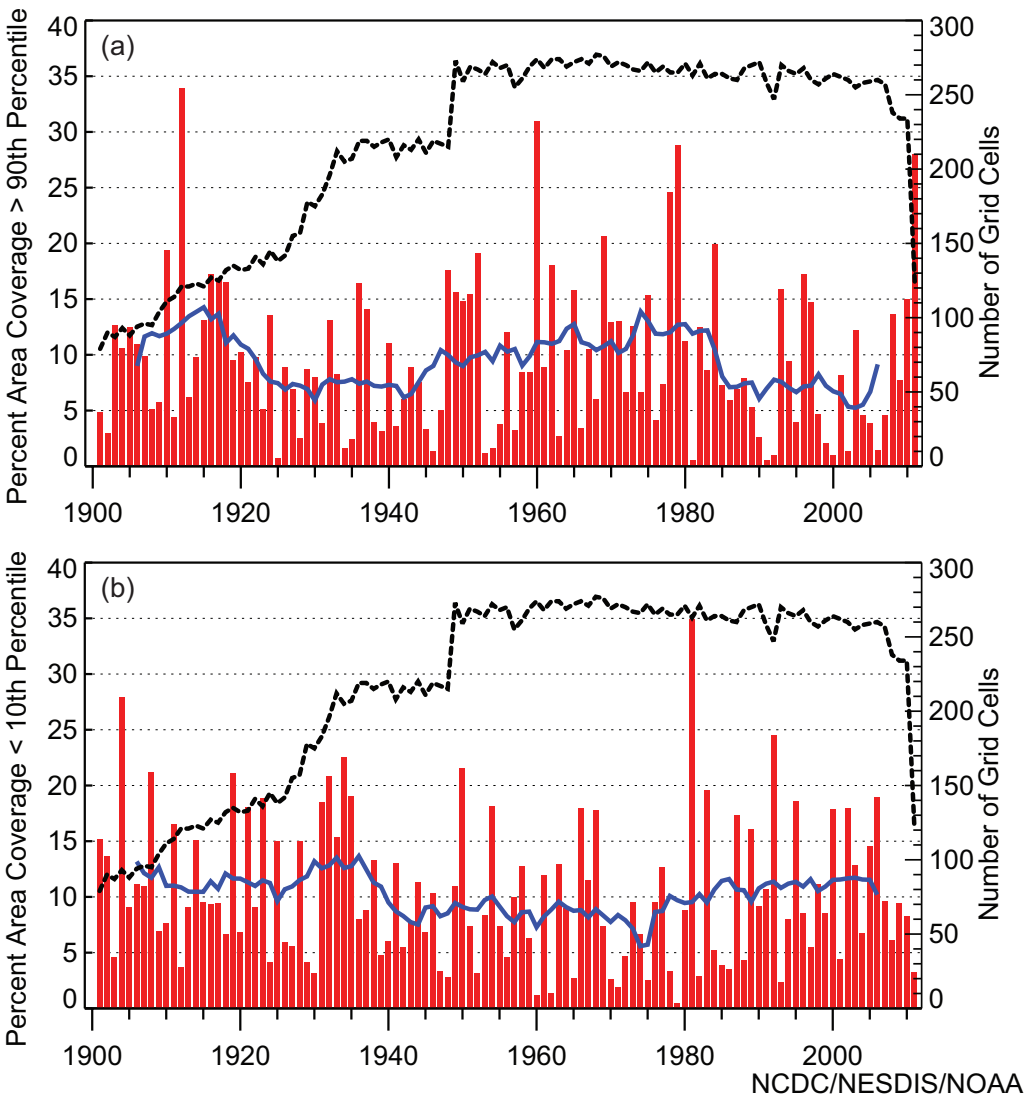
Confidence in Projected Severe Thunderstorms

- **Low**
- Why? Because the two key atmospheric conditions necessary for severe thunderstorms appear likely to change in opposite directions in response to global warming
- Recent research results point to increases in frequency of favorable conditions

Winter Storms

Winter Storms

- Percent area with seasonal snowfall above 90th percentile and below 10th percentile



Projections of Winter Storms

- Regionally variable
  - Higher moisture content would favor larger snowstorms in areas where it is cold enough to snow
  - Decreases on southern margins of climatologically snowy areas – becomes too warm to snow

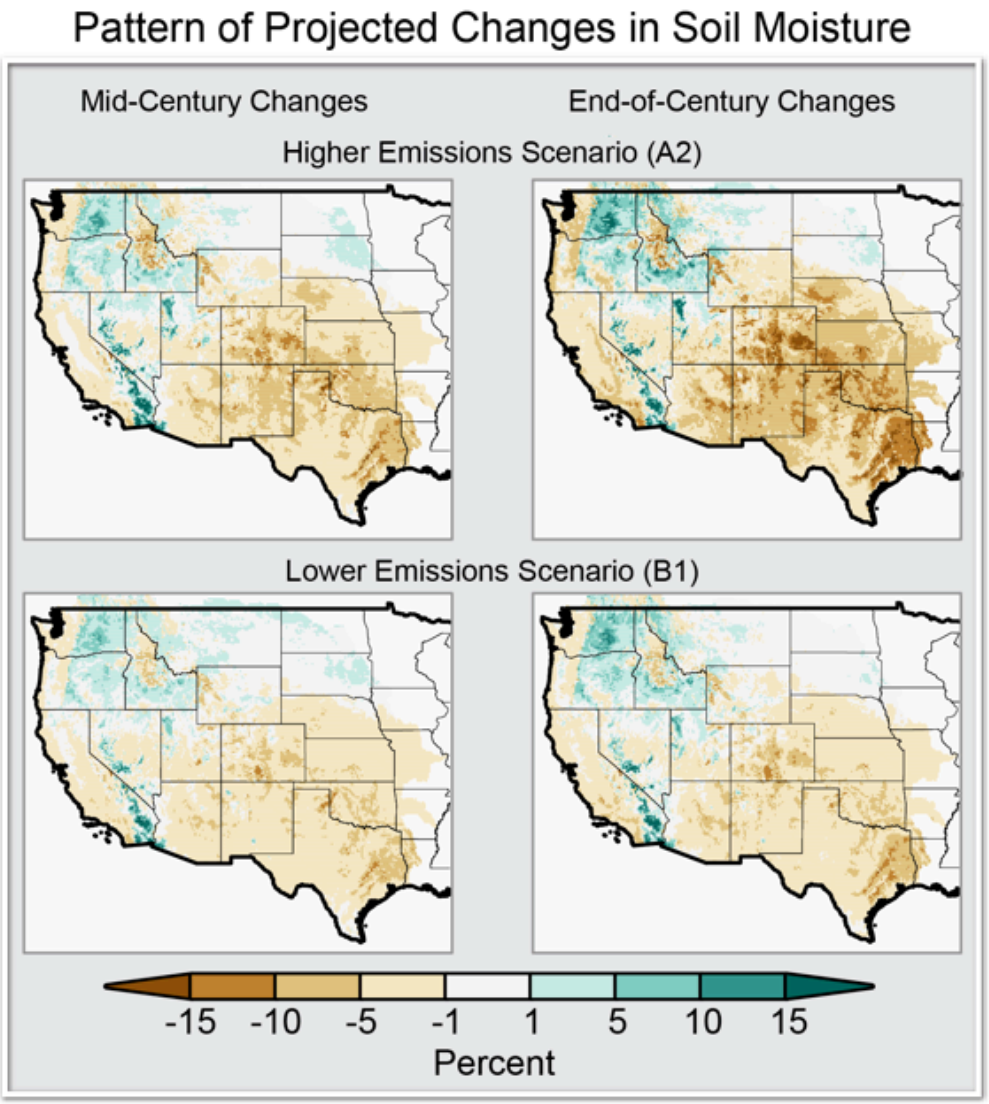
- **CONFIDENCE: Medium**

- Why? Because there is high confidence about **increases in temperature** and associated changes in where it can snow and in the amount of water vapor in the atmosphere but lower confidence in whether the **number and intensity of low pressure storms will change** over the U.S.

Drought

Drought

- Increased temperature leads to increased evaporation rates and tendency toward decreased soil moisture



Confidence in Projected Extreme Drought

- **Medium**
- Why? Because there is high confidence about **increases in mean temperature** and this will lead to increases in evaporation and **decreases in soil moisture**. But there is low confidence in changes in precipitation over much of U.S.

What Do We Know – Key Messages

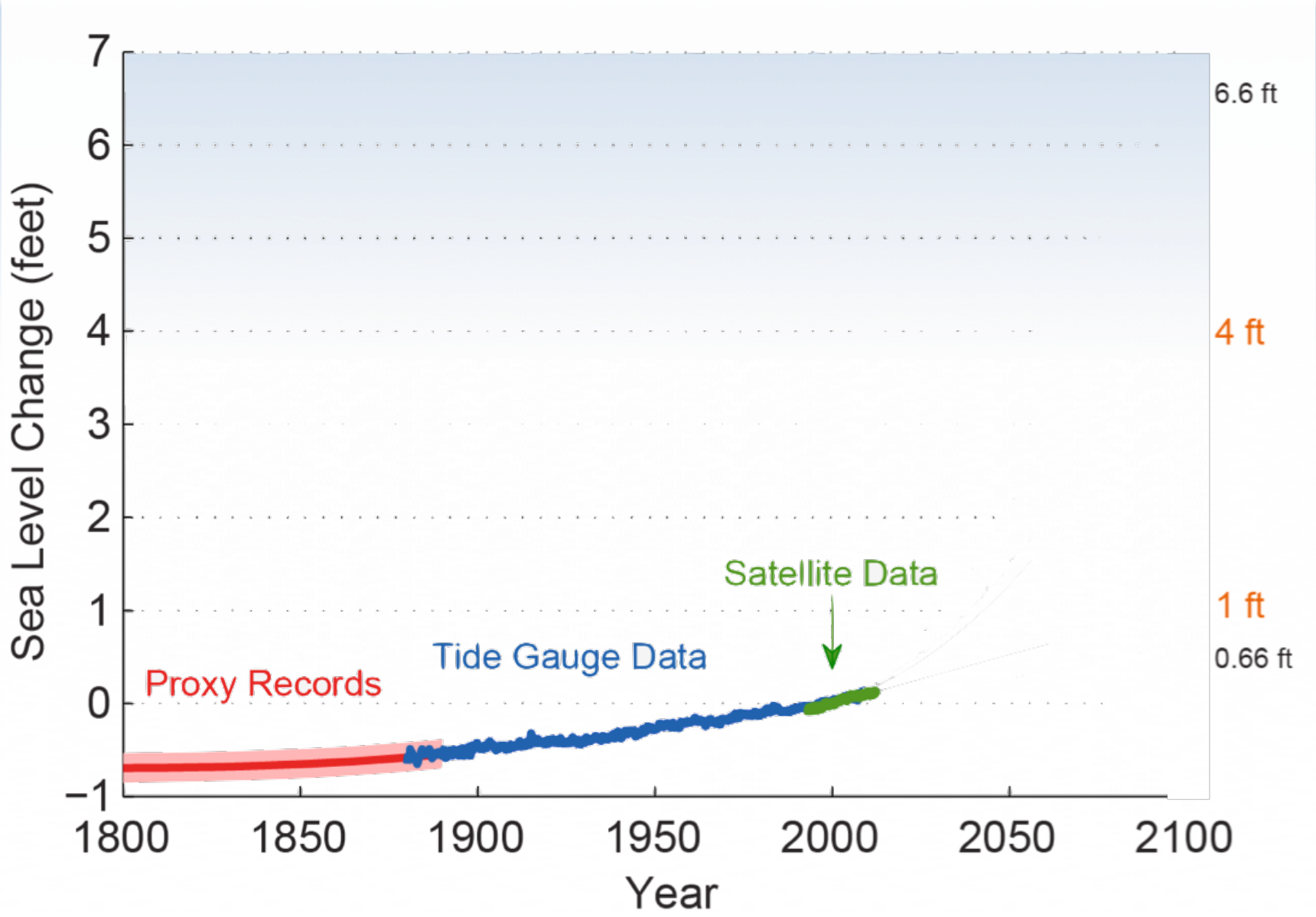
- **Observed changes in extremes**
  - Increase in extreme rainfall events
  - Data insufficient to determine trends in severe thunderstorms
  - Increase in number of intense hurricanes
  - No trends in winter storm severity
  - Increase in warm nights and decrease in unusual cold
- **Future projections**
  - Increases in hot extreme temperatures and precipitation extremes; decreases in cold extremes
  - Uncertainty about trends in certain types of extremes, most notably severe thunderstorms and tornadoes
  - Possible increase in intensity of most extreme hurricanes
  - Regional changes in winter storms

Confidence in Projections

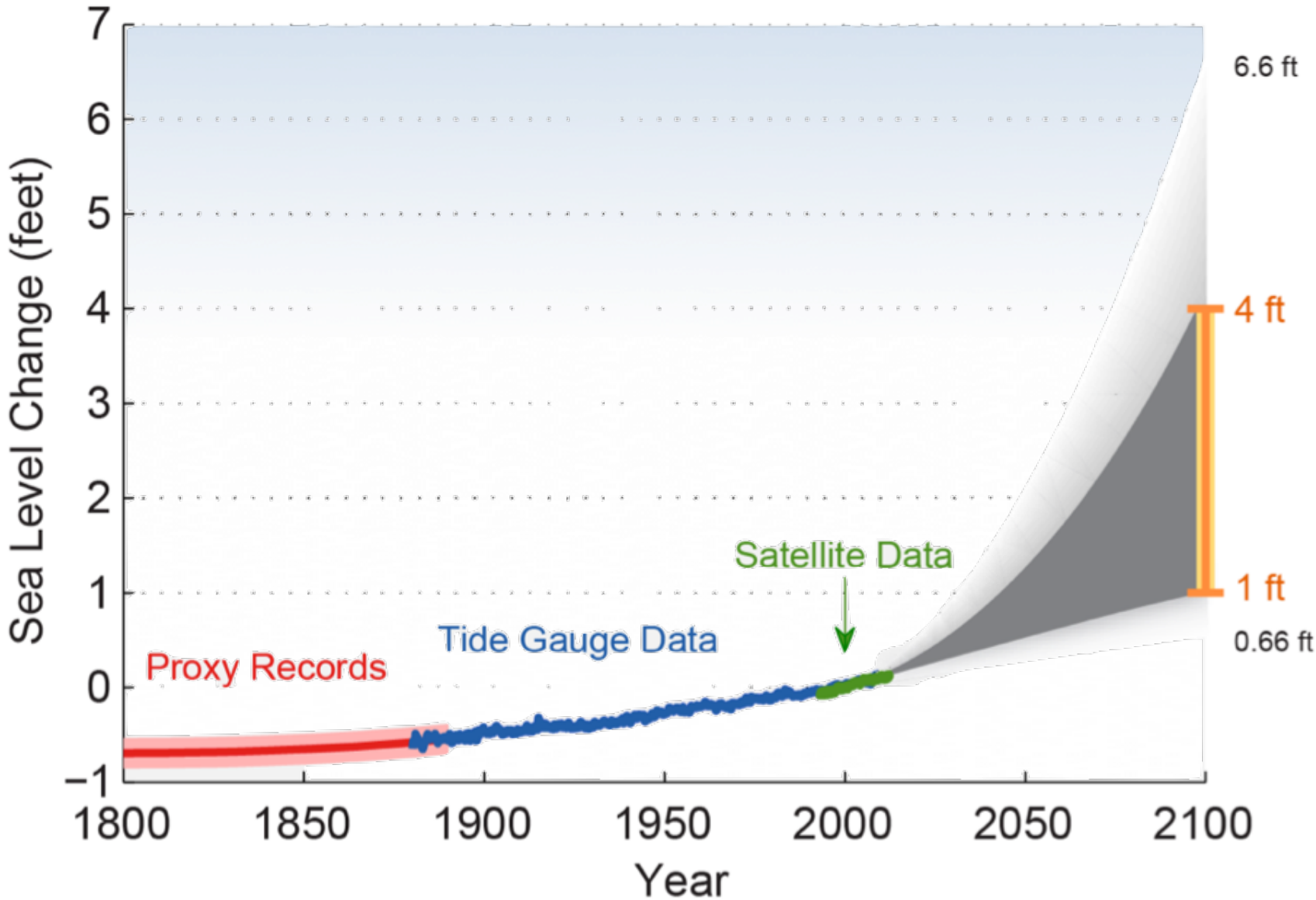
- **Highest confidence is for those extreme types that are directly correlated with temperature**
  - Heat waves and cold waves (follows mean temperature)
  - Extreme Precipitation (higher water vapor content)
  - Drought (higher evaporation)
  - Hurricanes (higher sea surface temperatures)
- **Lower confidence where the linkage to temperature is indirect or complex**
  - Severe thunderstorms (competing effects)
  - Winter storms (complex linkages)
  - Drought (weather system changes)

Sea Level Rise

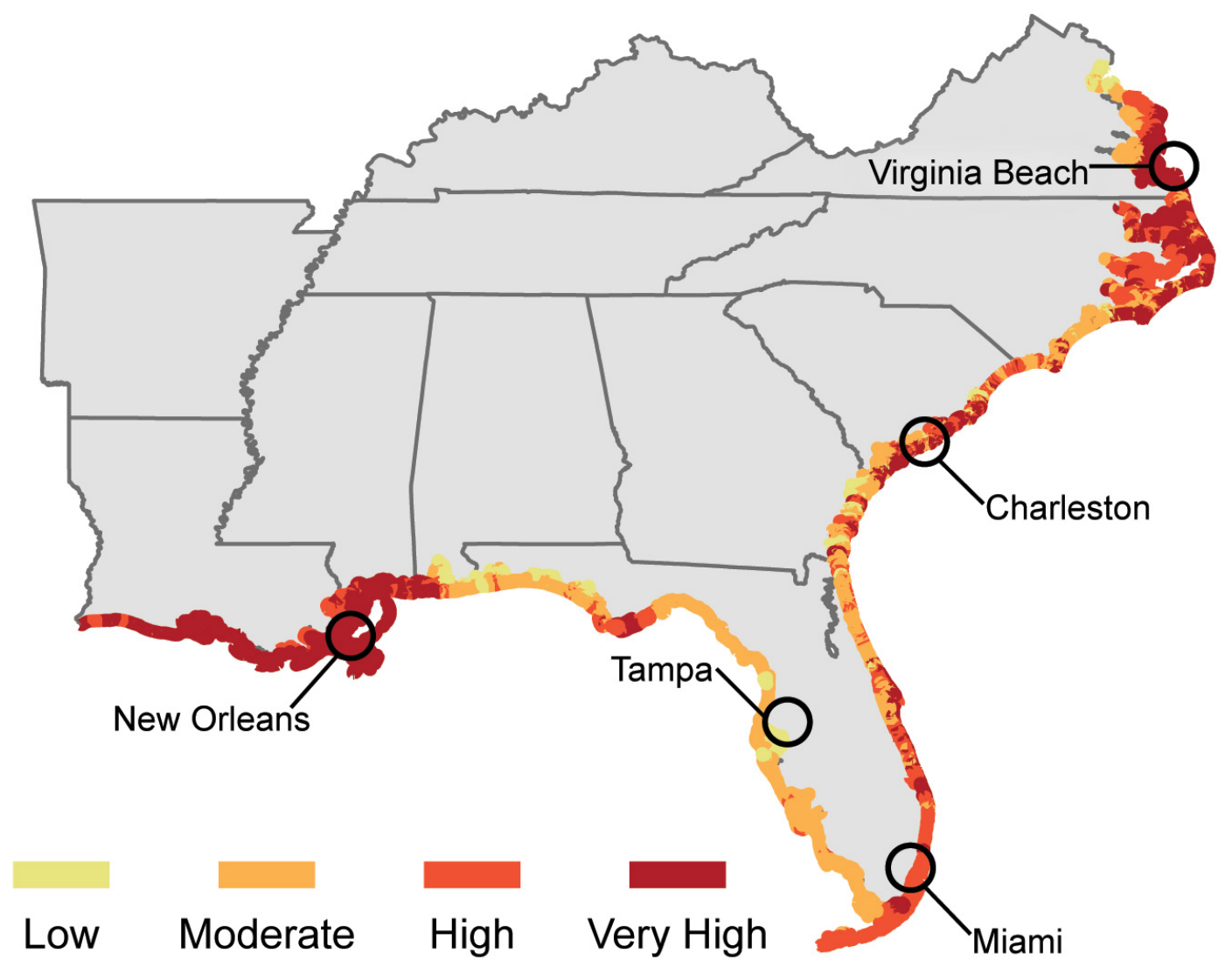
Past Changes Global Sea Level



Projected Changes Global Sea Level



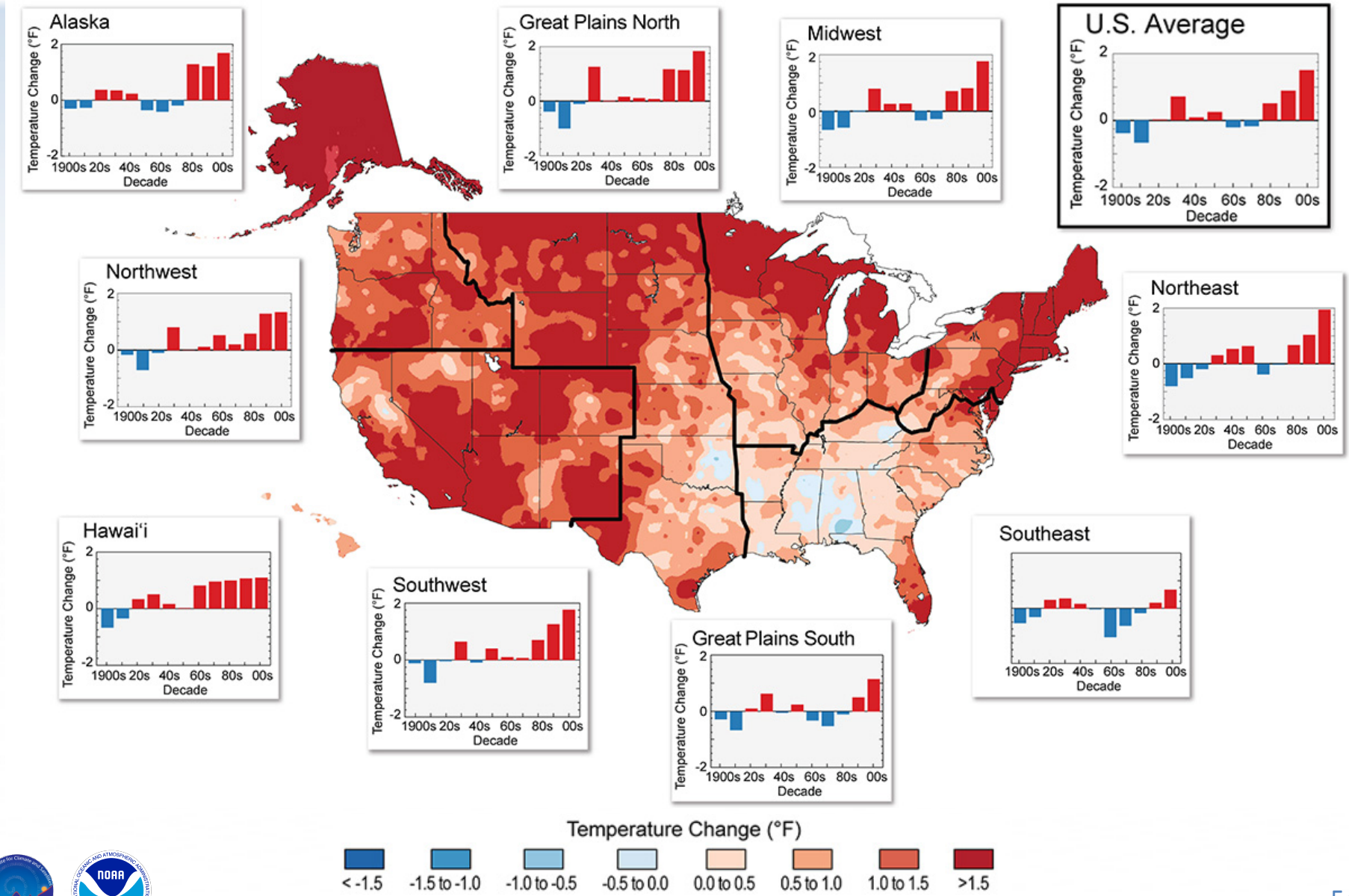
Vulnerability to Sea Level Rise



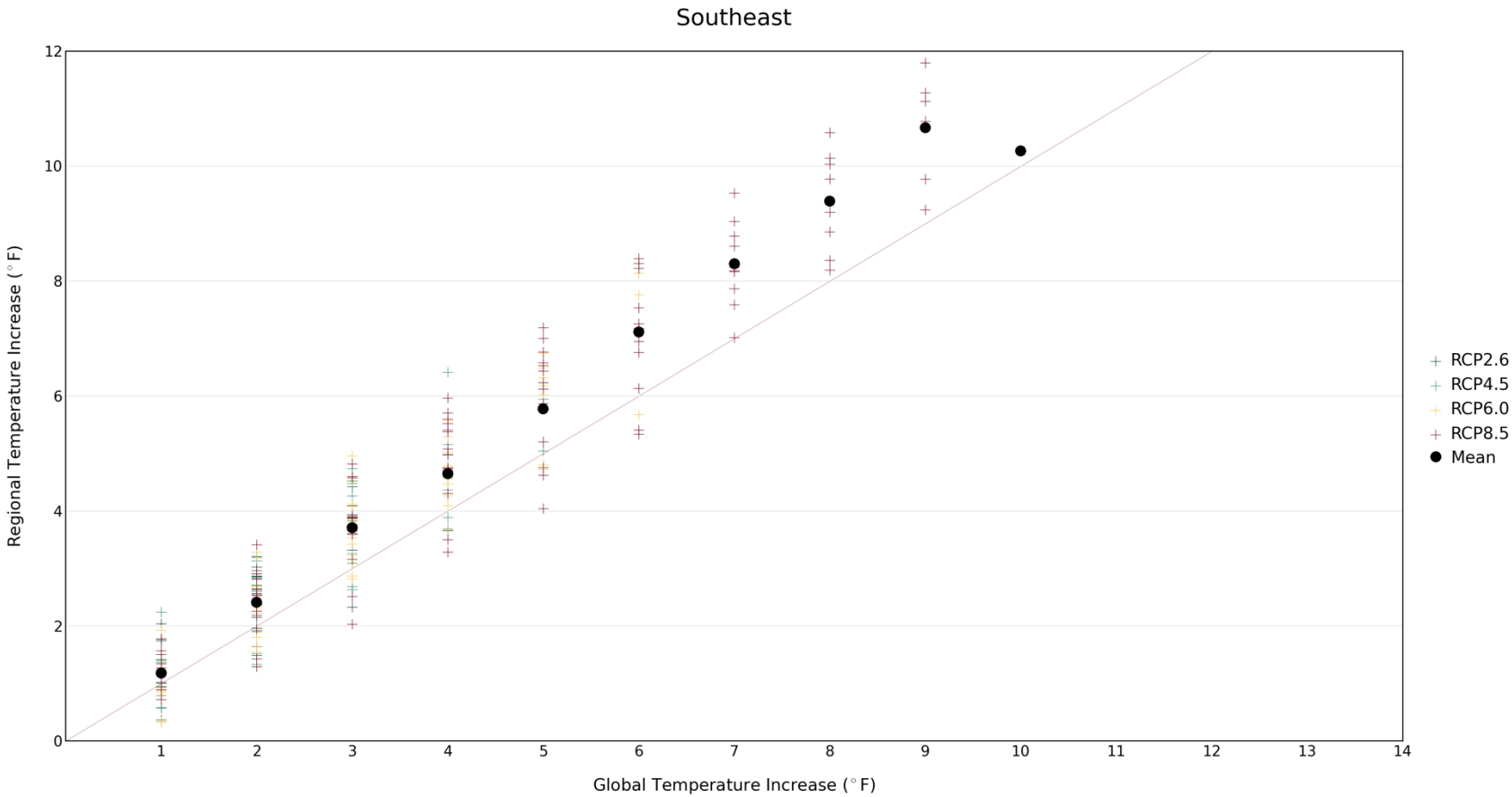
Concluding Thoughts

- "Extremes will become worse" has become a bit of a mantra
- But, projected changes in extremes are very much specific to extreme type
- Regional and temporal variations are likely to be substantial and superimposed on long-term global changes

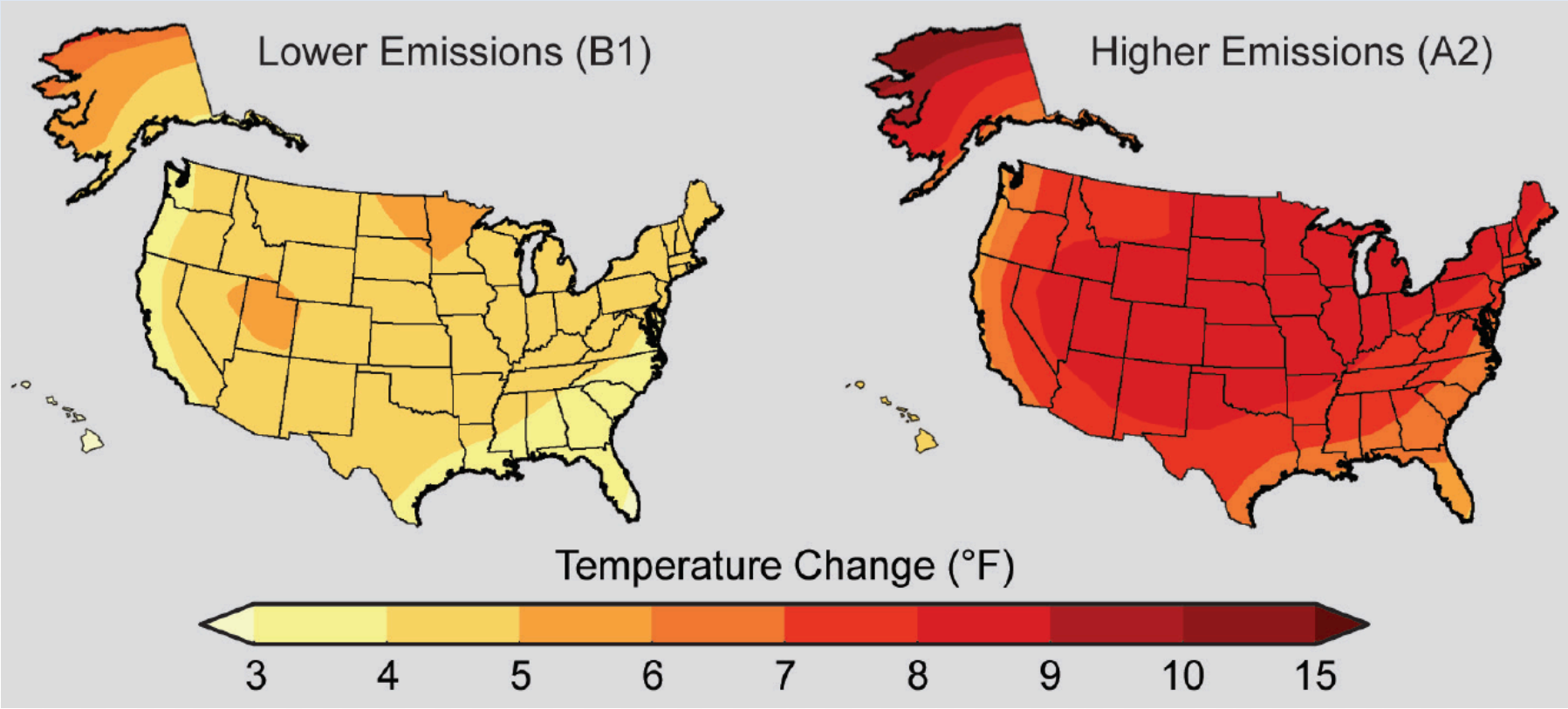
Observed US Temperature Change



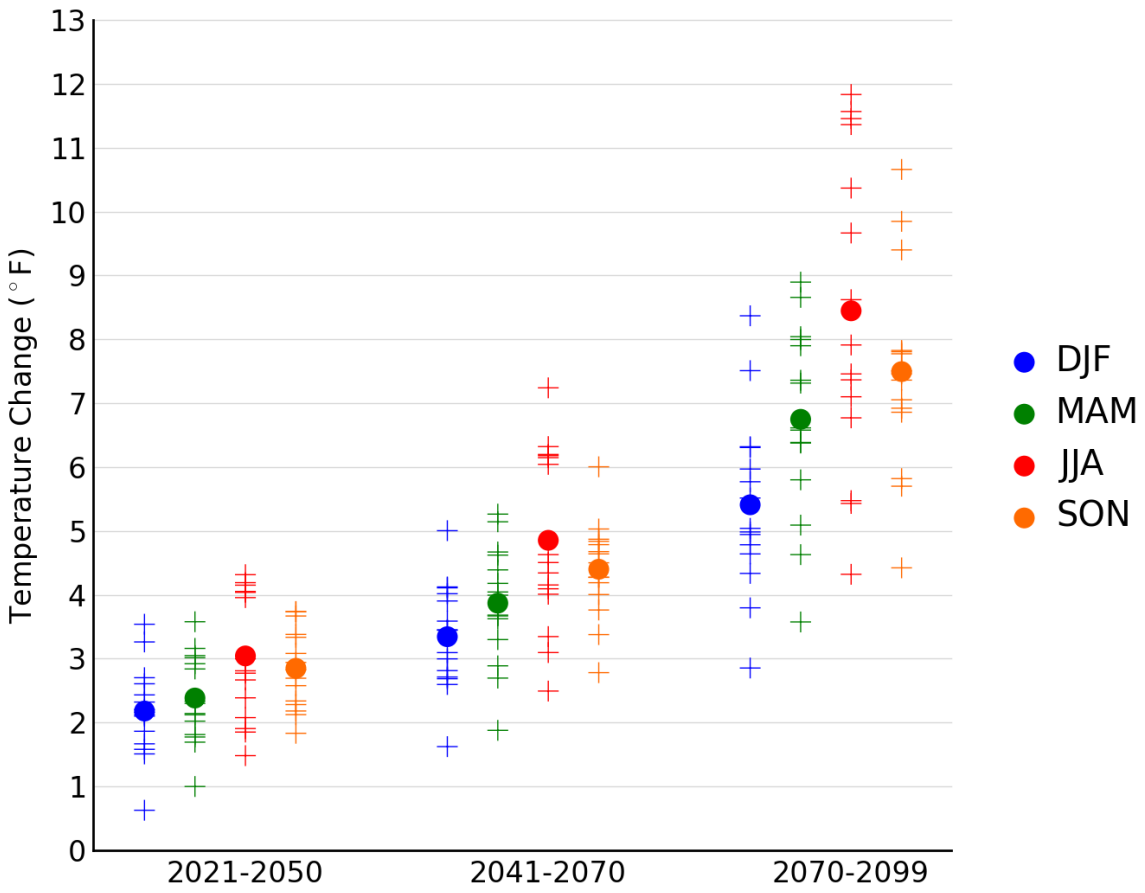
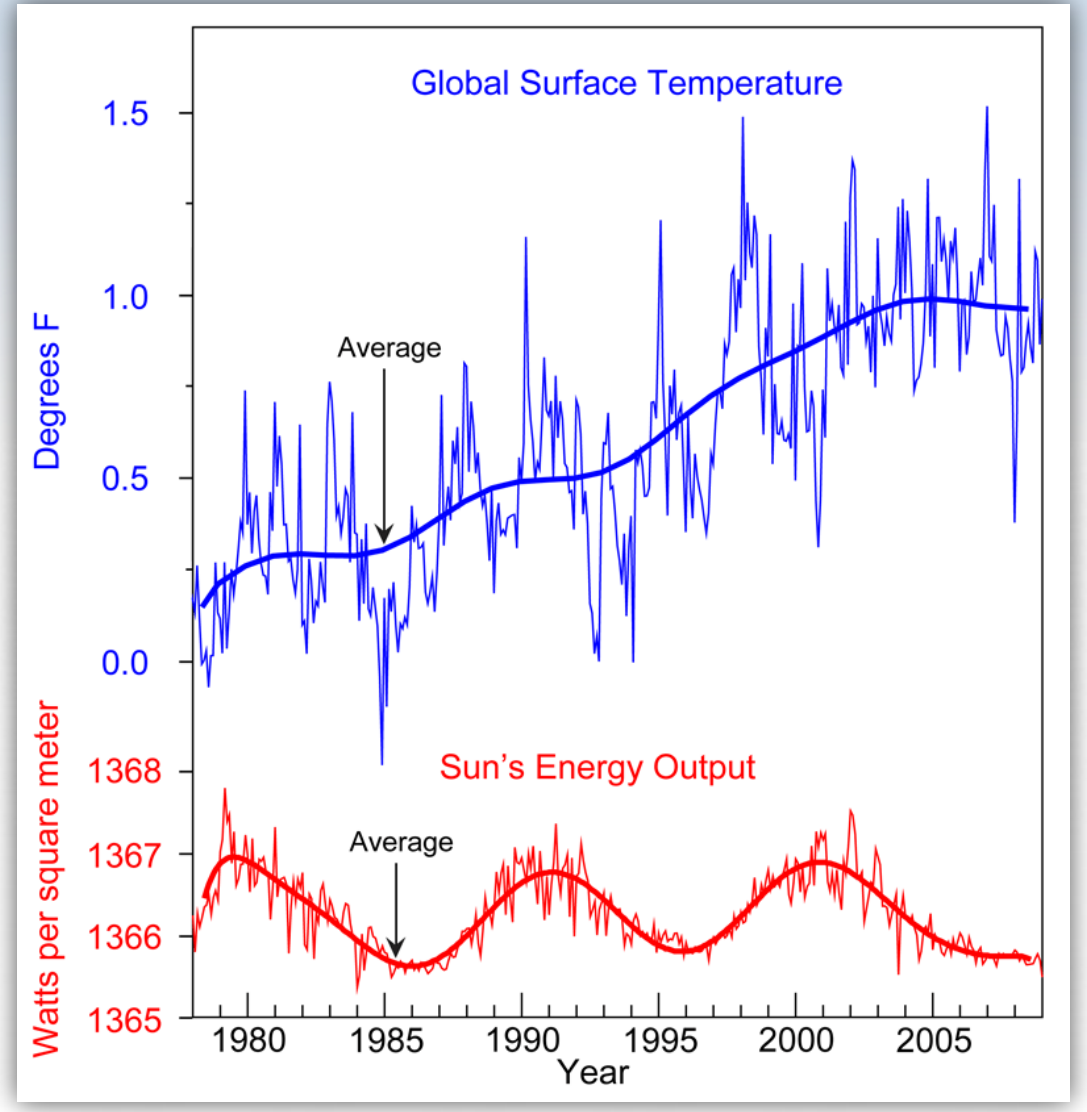
Southeast U.S. Temperature Projections



Projected Temperature Change



Southeast U.S. Temperature Projections



Temperature vs Sun's Energy Output