

# Scientific Challenges for NOAA Atlas 15 Projections of Heavy Rainfall Design Values

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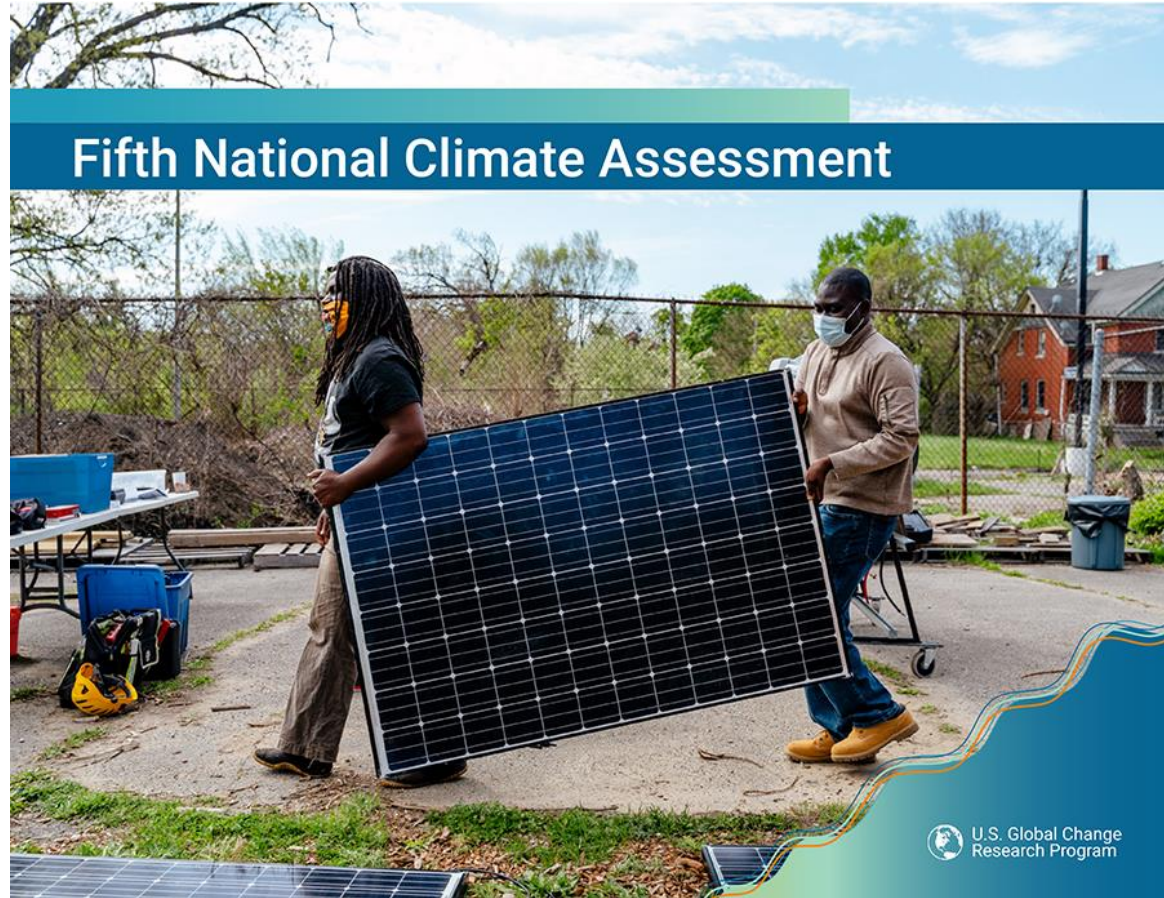


OWP

OFFICE OF  
WATER  
PREDICTION

# The Basics

The six Assessment Reports of the Intergovernmental Panel on Climate Change and the 5 U.S. National Climate Assessment Reports have been uniform in projecting increases in extreme precipitation if the globe continues to warm



# The Basics

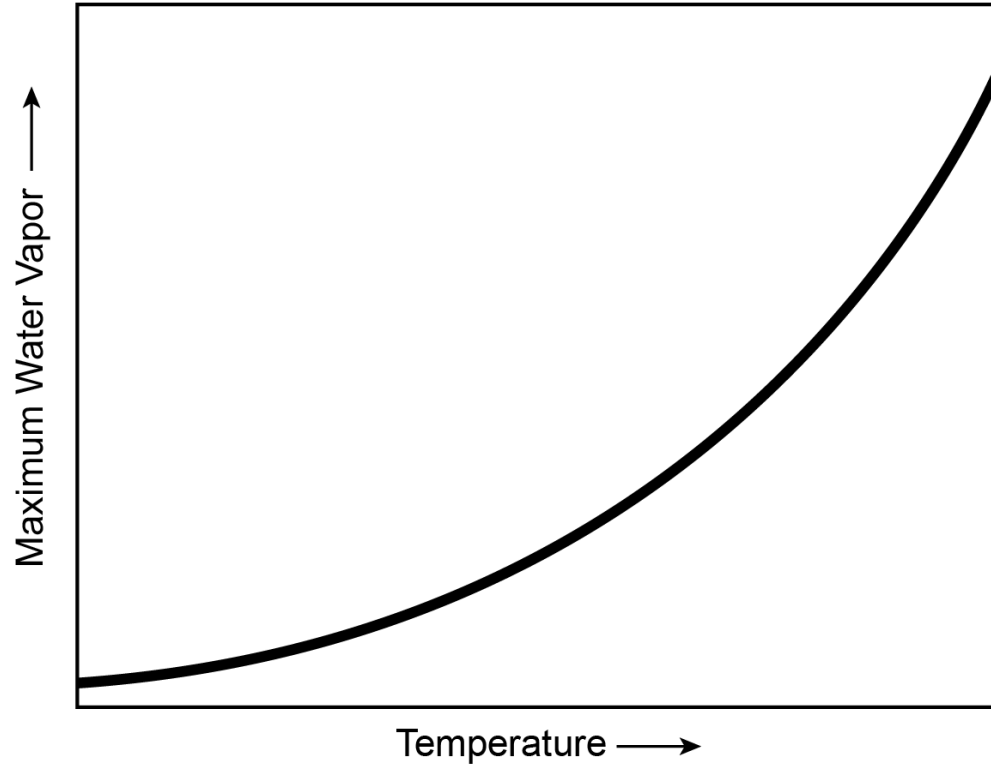
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- Why?
  - The potential for increased atmospheric moisture content due to the Clausius-Clapeyron relationship



# Warmer -> (Potentially) Moister

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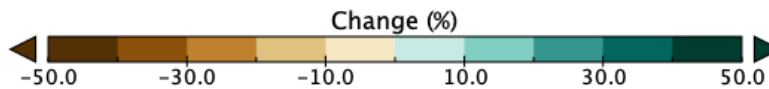
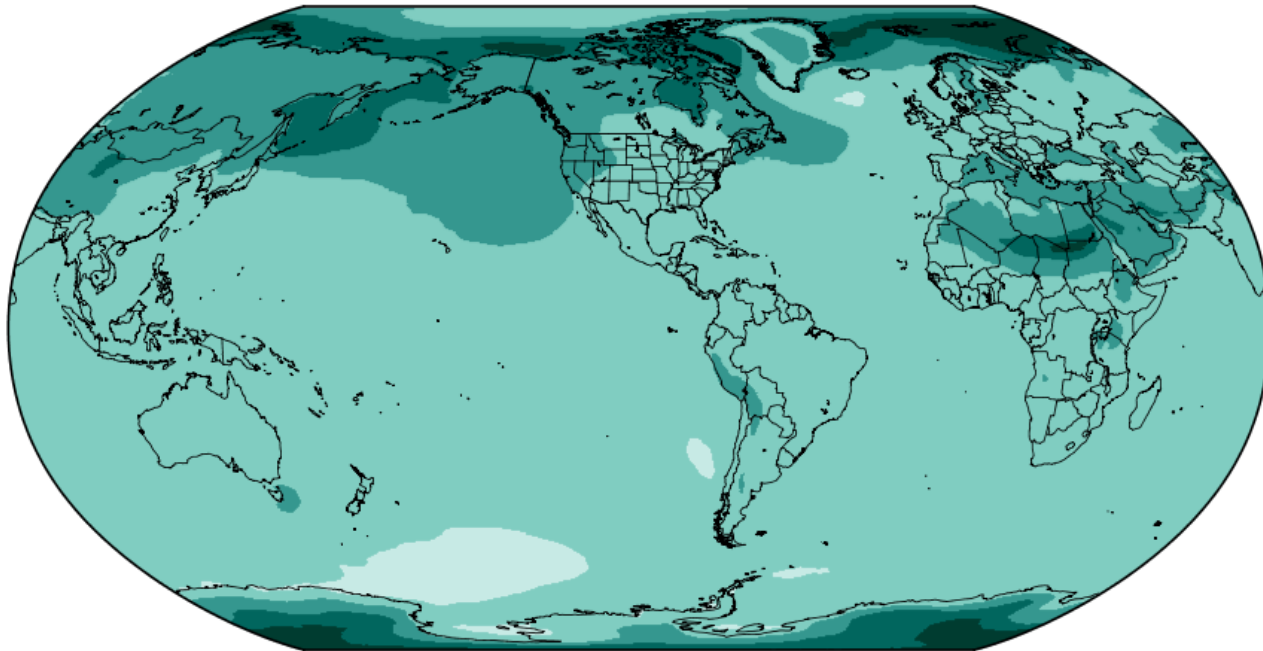


Clausius-Clapeyron relationship: Maximum (saturation) water vapor increases by about 7% per °C



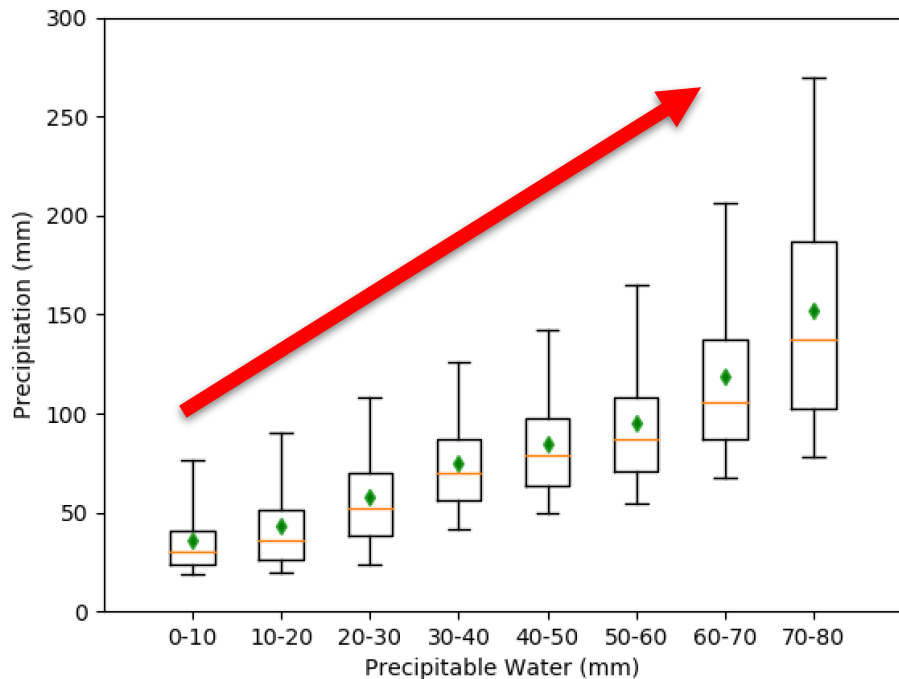
# CMIP6 Projections

CMIP6 Projected Change [(2070–2099)] minus (1985–2014)], SSP3–7.0  
Annual Maximum Daily 2m Specific Humidity



Data Min = 6.5, Max = 54.0, Mean = 17.8

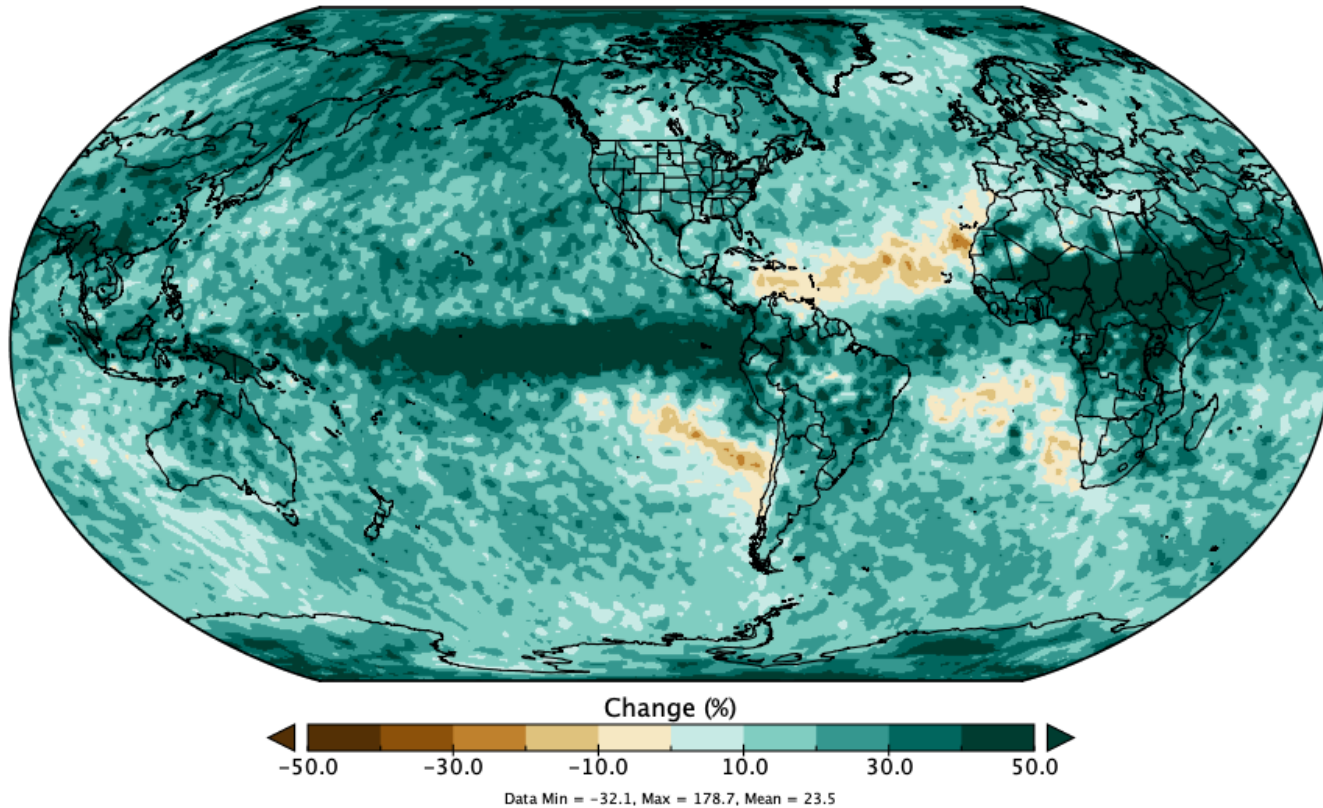
# Extreme Precipitation Amounts vs Water Vapor



**Over CONUS, heavy precipitation amounts on average increased monotonically with precipitable water**

# CMIP6 Projections

CMIP6 Projected Change [(2070–2099)] minus (1985–2014)], SSP3–7.0  
30-yr Extreme Daily Precipitation





## Magnitude of Increases

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- An exact scaling of extreme precipitation based on the C-C relationship is unlikely everywhere for at least 2 reasons:
  - Vertical uplift in convective storms may be enhanced because of increased latent heat release
  - Changes in frequency and/or intensity of weather systems that cause extreme precipitation may occur



A dynamic, high-speed photograph of a blue liquid splash, likely water, creating a sense of movement and energy. The splash is composed of various droplets and bubbles, with some larger, more defined shapes and many smaller, more diffuse ones. The overall color is a vibrant blue, with lighter and darker shades creating depth and texture. The text 'The Challenge' is overlaid on the left side of the image, underlined.

# The Challenge

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# The Challenge

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- Durations (19)
  - 5 minutes up to 60 days
- Annual Exceedance Probabilities (10)
  - 63% down to 0.1%





## Where to turn for answers?

- Climate Model Simulations are a prime source
- We would like lengthy (multi-decadal) simulations from multiple models for multiple future emissions pathways
  - High spatial resolution
  - Data storage at sub-hourly time resolution
- But, **we do not have this**

## **NOAA Atlas 15-Volume 2**

**So, what do we have?**

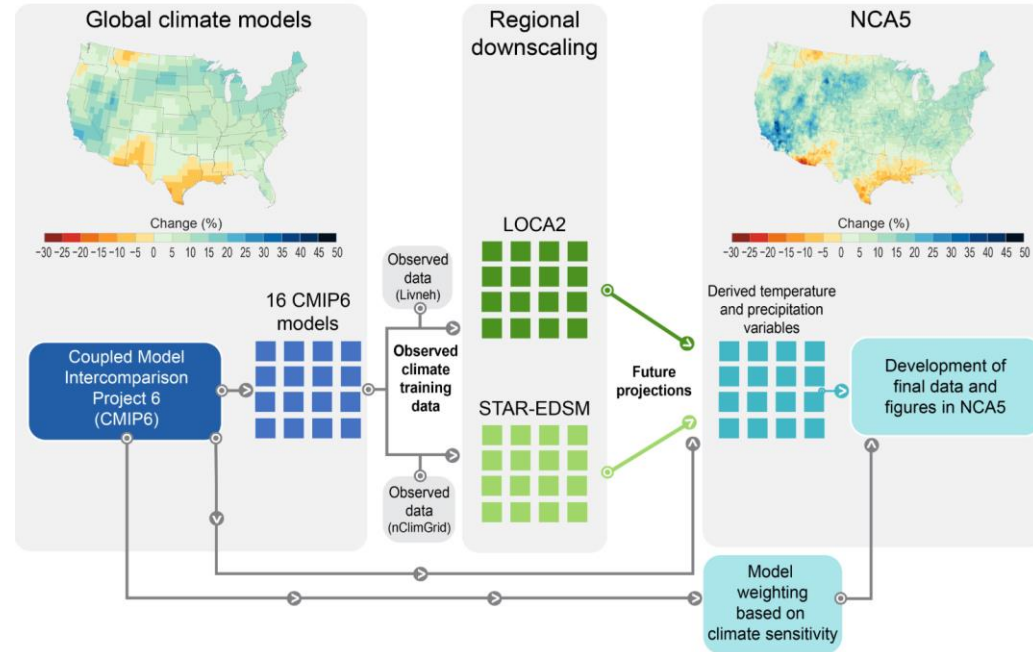


# NA15-Vol.2 Science Tasks/Challenges

- Downscaled Climate Model Datasets (at this point in time)
  - LOCA2 (1/16<sup>th</sup> degree resolution)
  - STAR (1/24<sup>th</sup> degree resolution)
  - UWPD (1/10<sup>th</sup> degree resolution)

Used in 5<sup>th</sup> National Climate Assessment

Downscaling Global Climate Model Data for NCA5



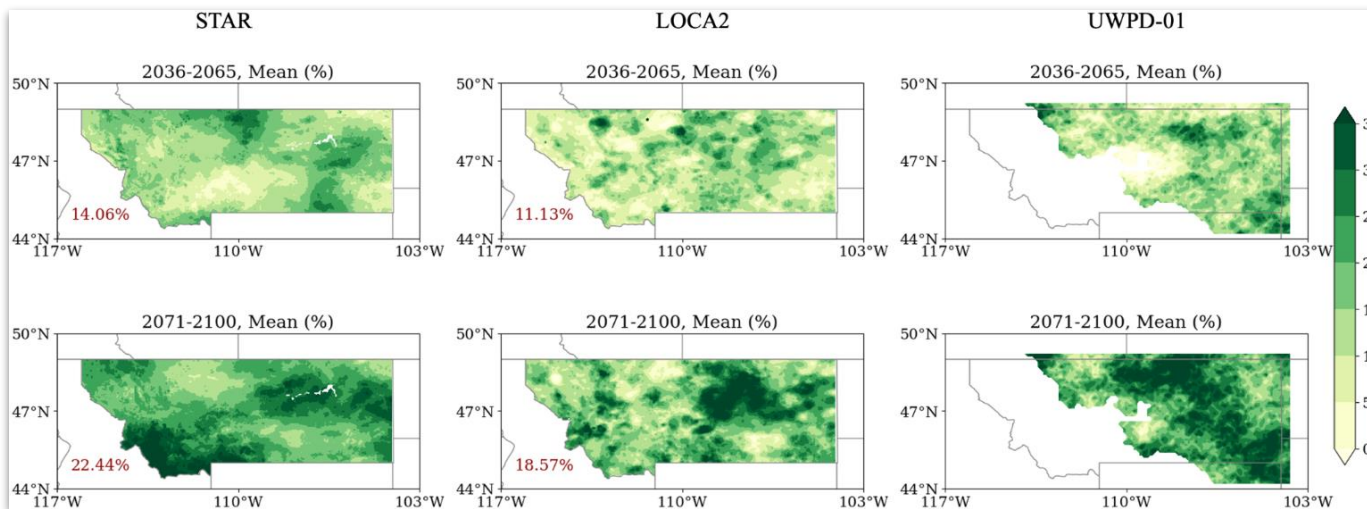


## **NA15-Vol.2 Science Tasks/Challenges**

- Downscaled Climate Model Datasets
  - LOCA2, STAR, UWPD (daily precipitation)
  - Provides information for 24-hr and longer durations, maybe down to the 1-2% AEP range

# Preliminary Results of Downscaled Data Analysis

- Comparison of 5% AEP, daily values among the 3 downscaled datasets
- Overall changes are similar, but lots of spatial variability
- **Our conclusion:** Adjustment factors should be averaged over large areas and multiple models



*Estimated daily, 20-yr values under SSP5-8.5 for mid-Century (top) and end of Century (bottom)*



## NA15-Vol.2 Science Tasks/Challenges

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- Downscaled Climate Model Datasets
  - LOCA2, STAR, UWPD (daily precipitation)
  - Provides information for 24-hr and longer durations, maybe down to the 1-2% AEP range
- Limitations
  - Statistically downscaled data typically available only at daily resolution
  - Limited CMIP6 data availability at sub-daily resolutions





**So, what about sub-  
daily durations?**



## **NA15-Vol.2 Science Tasks/Challenges**

- As duration shortens, localized convection may play a more important role in extreme events
- Convection-resolving Climate Models
  - Sidesteps uncertainties in cumulus parameterization schemes



## Sub-daily durations

- Convection-resolving Climate Models (CRCMs)
  - National Center for Atmospheric Research simulations (CONUS404)
    - 4 km spatial resolution, 15 min time resolution
    - Historical simulation (1979-2022) completed
    - Future simulation possibly available in spring 2024

Rasmussen, R.M., Chen, F., Liu, C.H., Ikeda, K., Prein, A., Kim, J., Schneider, T., Dai, A., Gochis, D., Dugger, A. and Zhang, Y., 2023. CONUS404: The NCAR-USGS 4-km Long-Term Regional Hydroclimate Reanalysis over the CONUS. *Bulletin of the American Meteorological Society*, 104(8), pp.E1382-E1408.

## Sub-daily durations

- Convection-resolving Climate Models (CRCMs)
  - Northern Illinois University
    - 3.75 km spatial resolution, 15-min time resolution
    - Historical and future 15-yr simulations



## Sub-daily durations

- Other model resources
  - NA-CORDEX
    - 25 km spatial resolution, 1-hr time resolution precip data
    - 1950s/1970s-2100

## Sub-daily durations

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- Other high resolution simulations may become available during the project

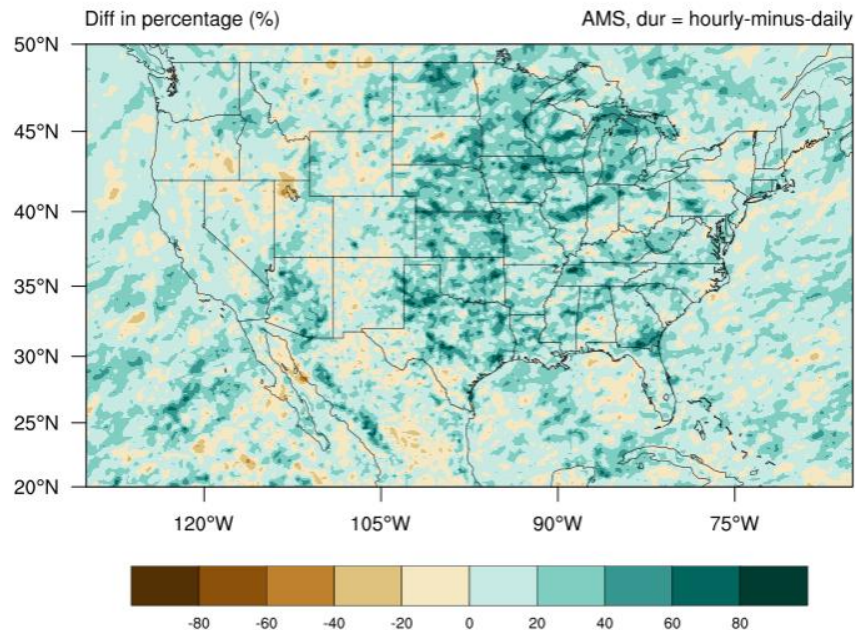


## Sub-daily durations

- Sub-daily climate model simulation data
  - Null hypothesis: the relative adjustment  $[(\text{future-historical})/\text{historical}]$  is the same for durations from 5 minutes to 24-hr
  - Will the CRCM simulations provide robust evidence that this is not the case?

# Preliminary Results of NA-CORDEX hourly data

- Comparison of Annual Maximum Series (AMS) average values for late 21<sup>st</sup> Century relative to late 20<sup>th</sup> Century
- Hourly AMS minus 24-hr AMS
- **Our conclusion:** Adjustment factors for hourly duration may be higher than 24-yr over central U.S



*Difference (%) in average AMS between hourly and daily durations*





# What about small AEPs?



## **NA15-Vol.2 Science Tasks/Challenges**

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- Small Annual Exceedance Probabilities (AEPs)
  - How to reliably estimate
    - With only about 100 years of high quality historical data
    - From future projections from single model simulations extending to 2100
- Pooling of climate model data one possible research approach

## Small AEPs

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- Large single GCM ensembles
  - NOAA SPEAR
    - 50 km resolution
    - 30 members (1920-2100) completed
  - CESM LENS
    - ~100 km resolution
    - 40 members (1920-2100)

## Small AEPs

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- CMIP6 multi-model ensembles
  - ~40 models with daily precipitation for historical and scenarioMIP experiments
  - Pooling of data is more challenging than with single model large ensembles

## Small AEPs

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- Large ensembles analysis
  - Null hypothesis: the relative adjustment  $[(\text{future-historical})/\text{historical}]$  is the same for AEPs from 2% down to 0.1%
  - Will the large ensemble simulations provide robust evidence that this is not the case?



# Questions?

## Acknowledgements

- Technical assistance provided by Xia Sun and Liqiang Sun
- Funding for my effort on this project provided by NOAA through CIROH in cooperation with RTI