Projections of Midwest Warm-Season Rainfall Extremes from Dynamical Downscaling

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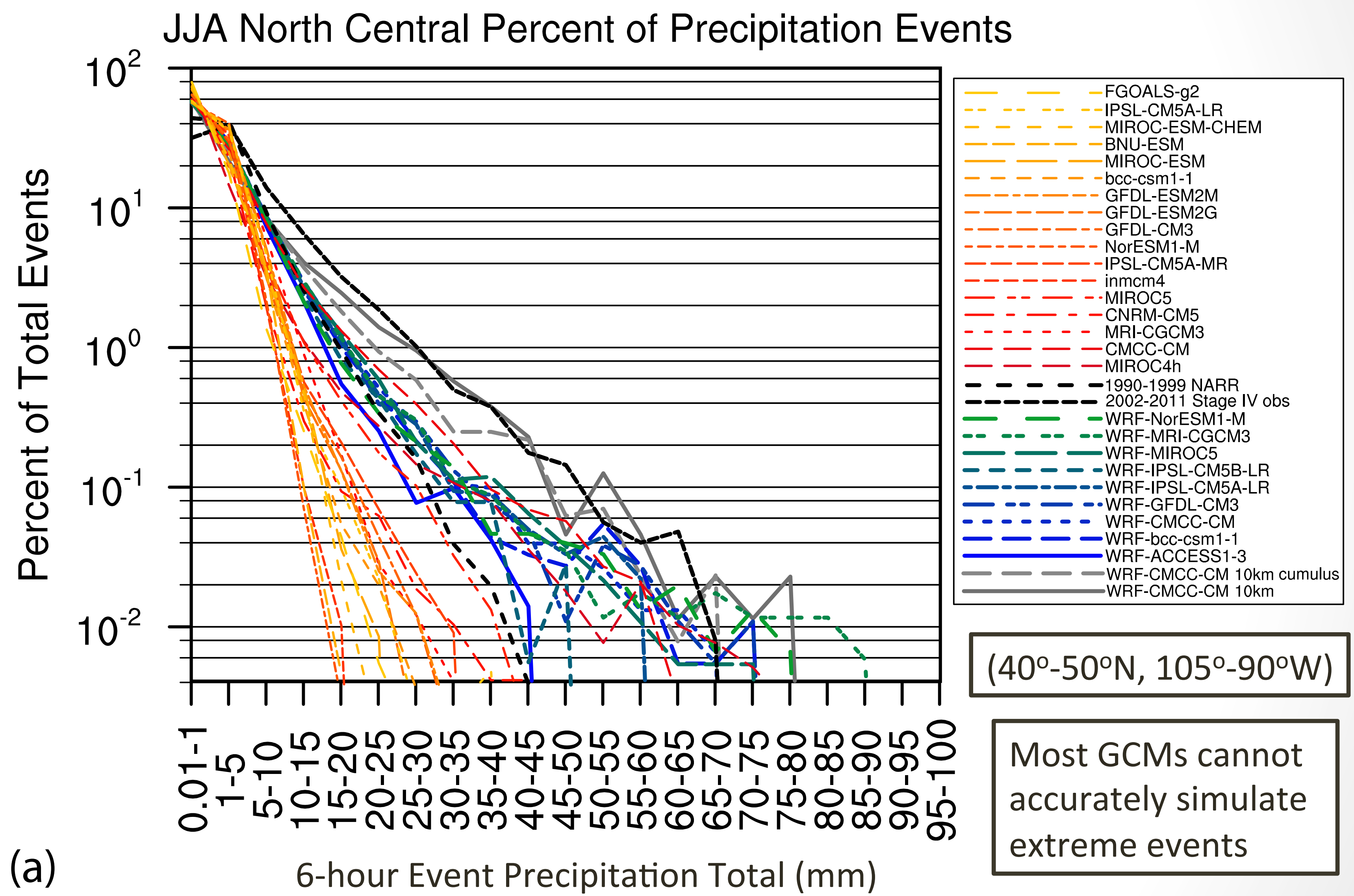
Harding and Snyder (2014), In Prep

Study Objectives

- Examine observed trends in Midwest rainfall extremes
- Accurately simulate historical characteristics of Midwest rainfall with dynamical downscaling
- Examine future trends in Midwest extreme rainfall with climate change
- Identify possible mechanisms responsible for changes in extreme rainfall events

Precipitation Frequency Distributions

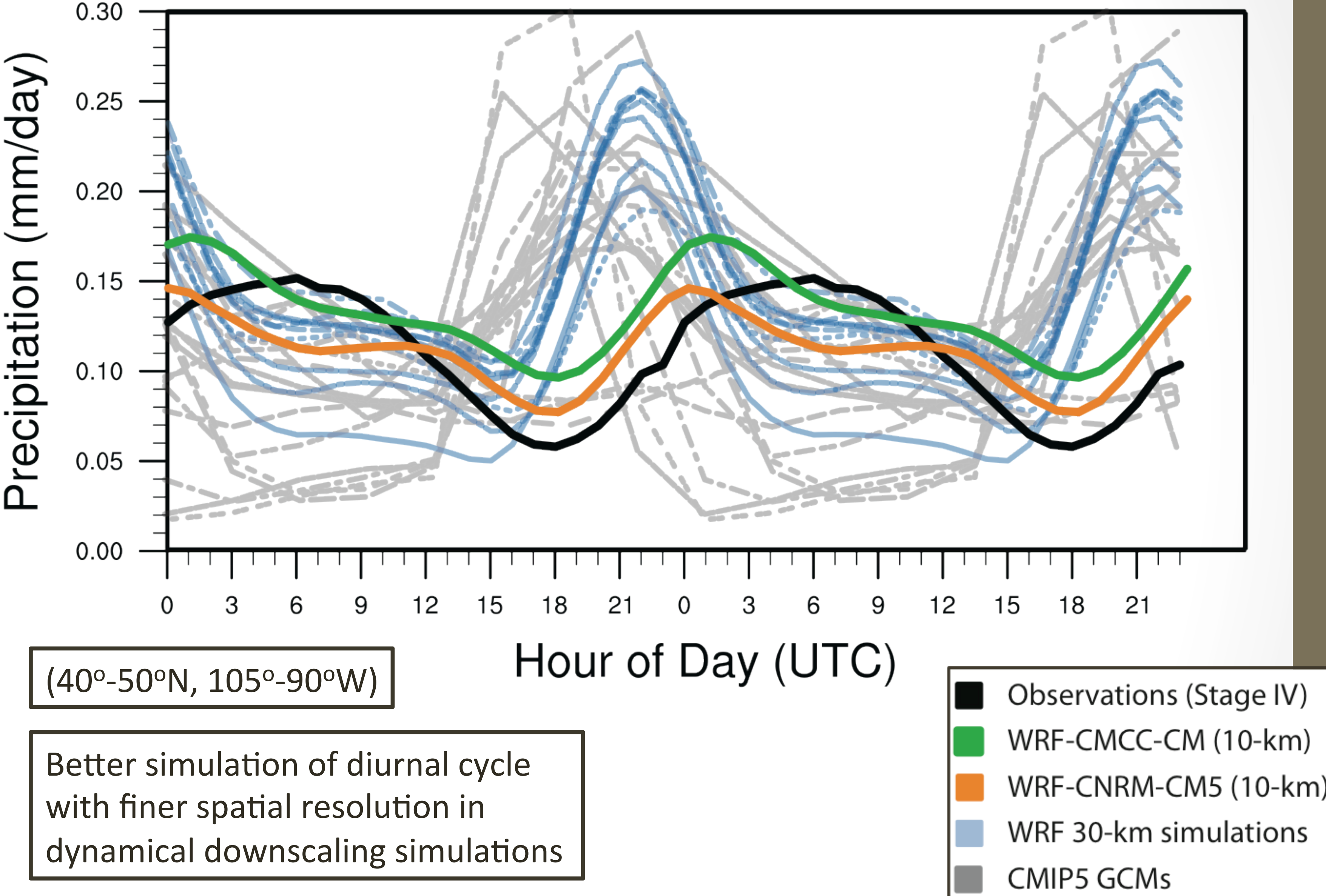


(40°-50°N, 105°-90°W)

Most GCMs cannot accurately simulate extreme events

Harding et al.(2013) *JGR-Atmos*

JJA North Central Diurnal Precipitation



(40º-50ºN, 105º-90ºW)

Better simulation of diurnal cycle with finer spatial resolution in dynamical downscaling simulations

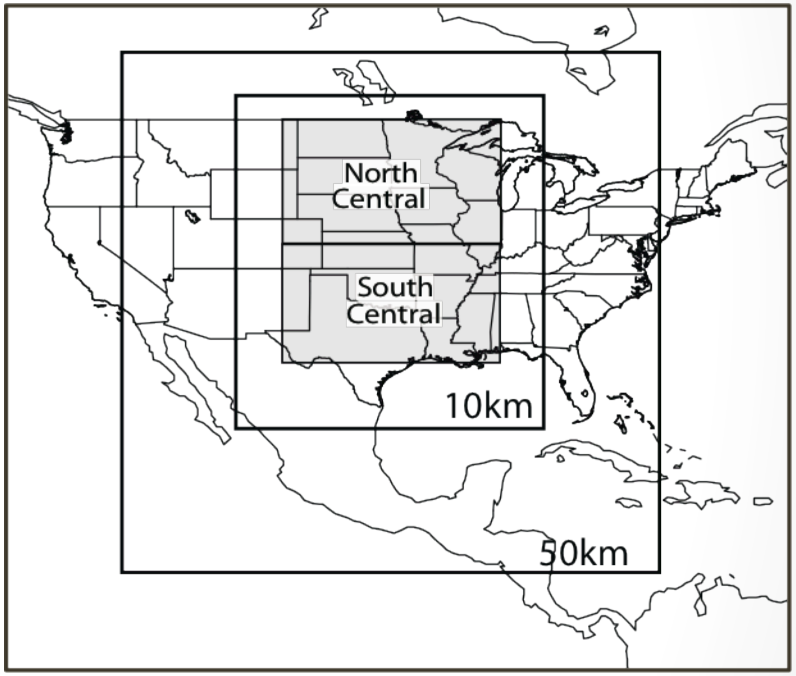
Experimental Design

- Dynamical downscaling of two GCMs in WRF
  - Must adequately simulate the Great Plains Low-Level Jet
    - Dominant driver of warm-season rainfall
  - Must reasonably simulate precipitation when downscaled
  - CMCC-CM and CNRM-CM5 models fit criteria
- Future climate scenarios

Climate Scenarios	Time Period
Historical	1990-1999
Medium Range, Moderate Emissions (RCP4.5)	2040-2049
Long Range, Moderate Emissions (RCP4.5)	2090-2099
Long Range, High Emissions (RCP8.5)	2090-2099

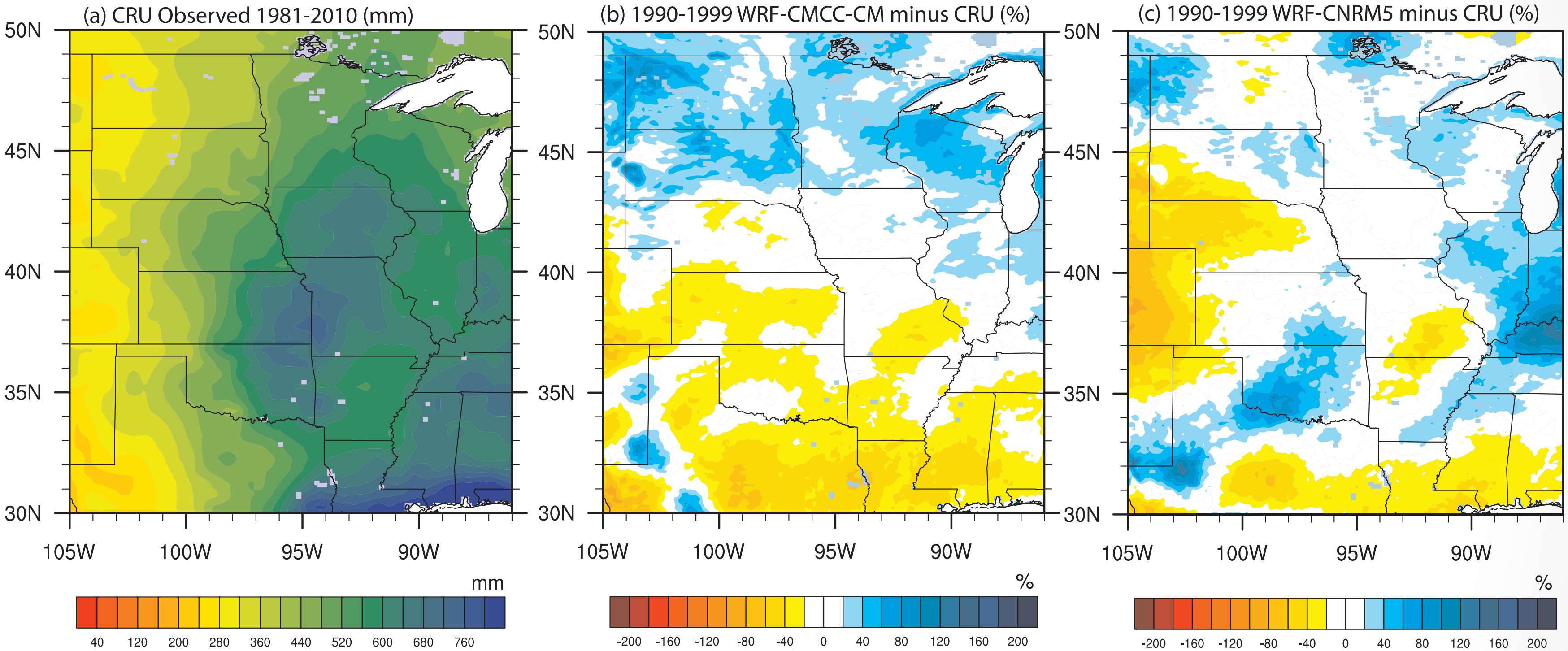
WRF Model Configuration

- Simulations from March 15 to October 1 for each year
- 50-km outer grid, 10-km inner grid with 35 vertical levels
- 30-second time step in inner domain
- No convective parameterization
- Nudging of moisture, temperature, and momentum
    - Reduced within inner domain
    - Reduced for moisture



Validation

April-September Precipitation



- Systematic but reasonable biases present in both models
- Generally realistic simulation of average precipitation

Validation

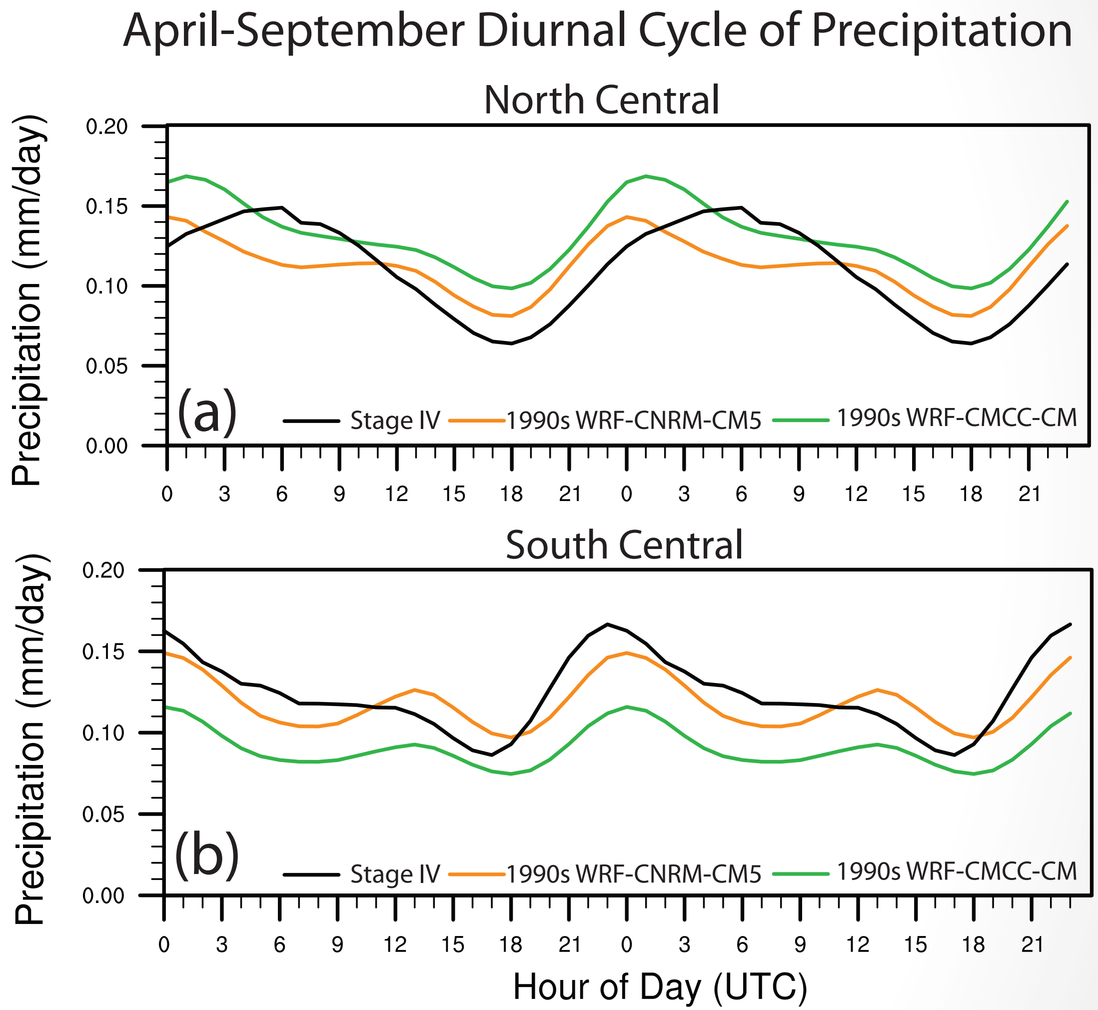
- Reasonably accurate diurnal cycle
- Significant nocturnal rainfall
- Dynamic forcing for convective precipitation represented

North Central

(40º-50ºN, 105º-90ºW)

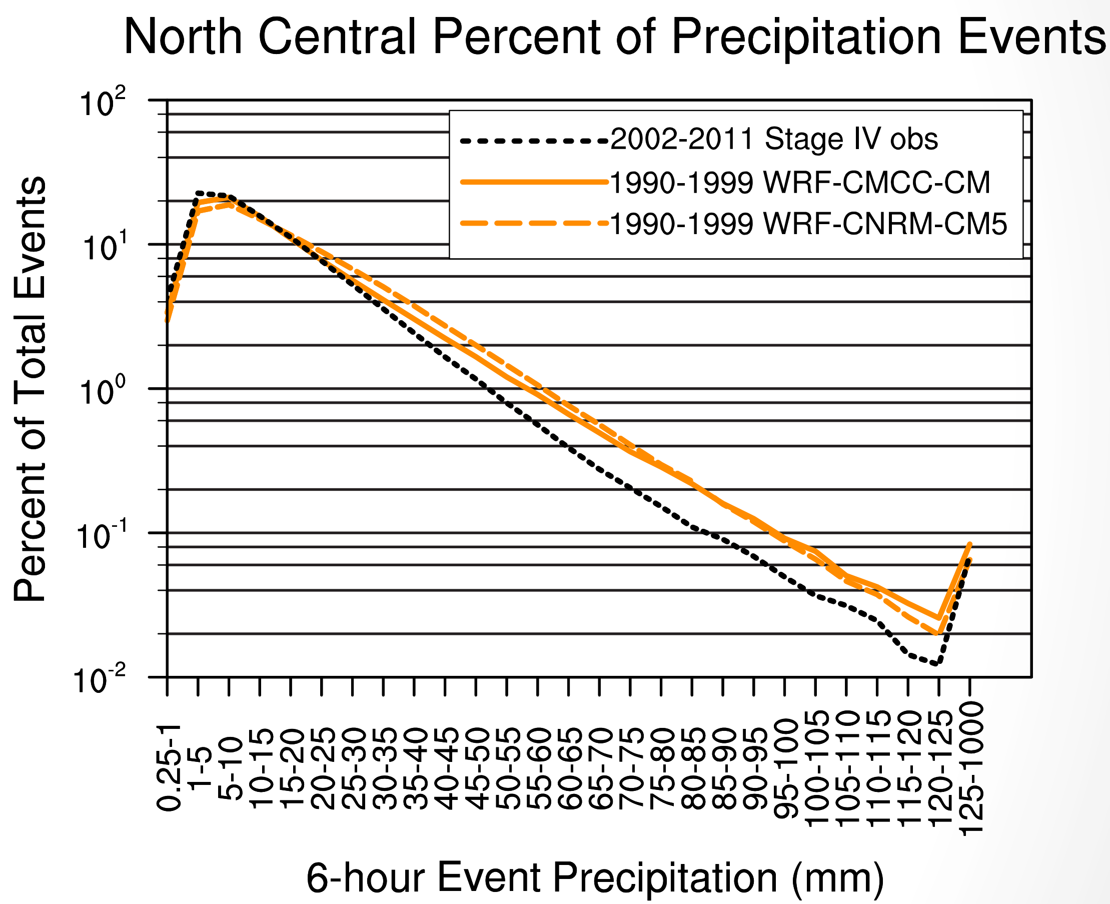
South Central

(30º-40ºN, 105º-90ºW)



Validation

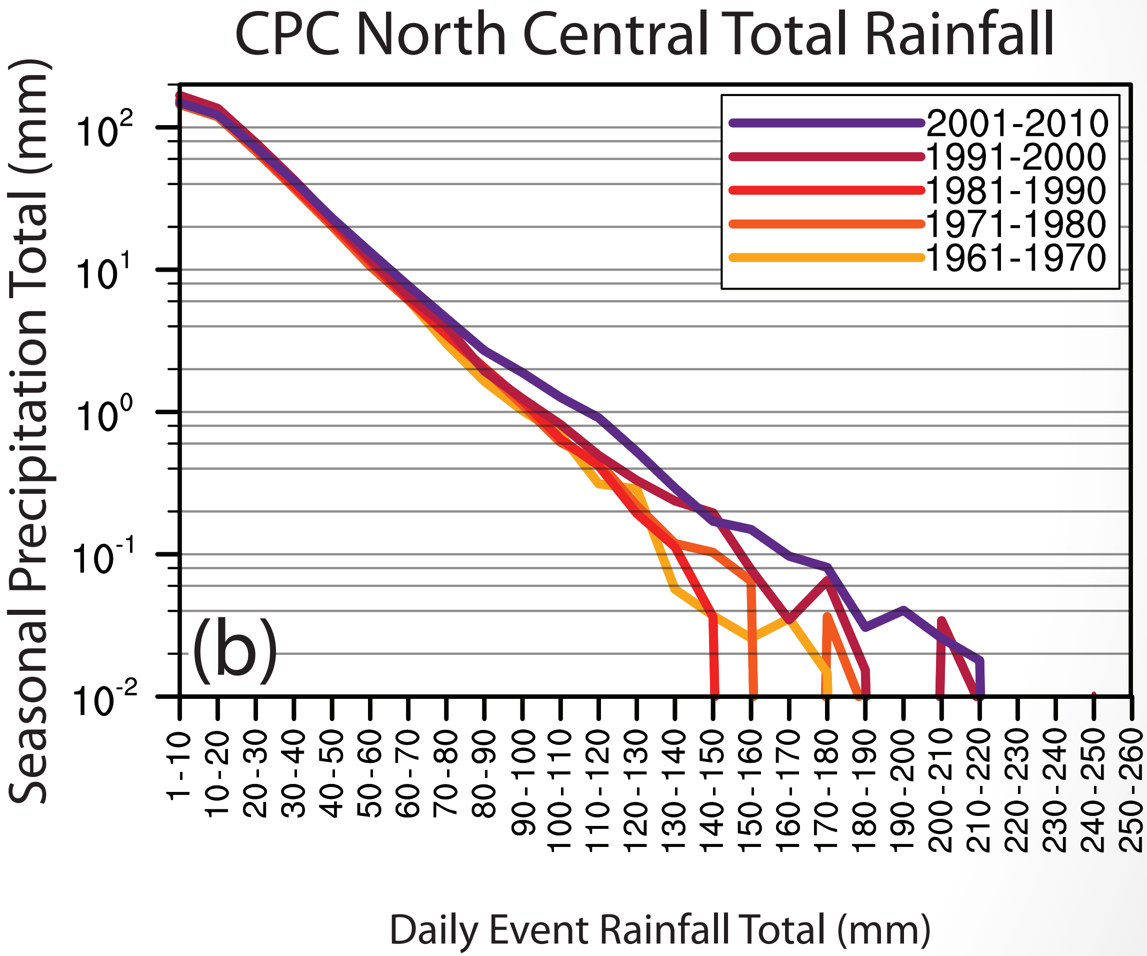
- Models can simulate the heaviest events
- Slight overestimation of heaviest events
- Accurate simulation of average rainfall intensity
- Accurate number of rainy days (≥ 1 mm)



(40°-50°N, 105°-90°W)

Observed change in precipitation intensity

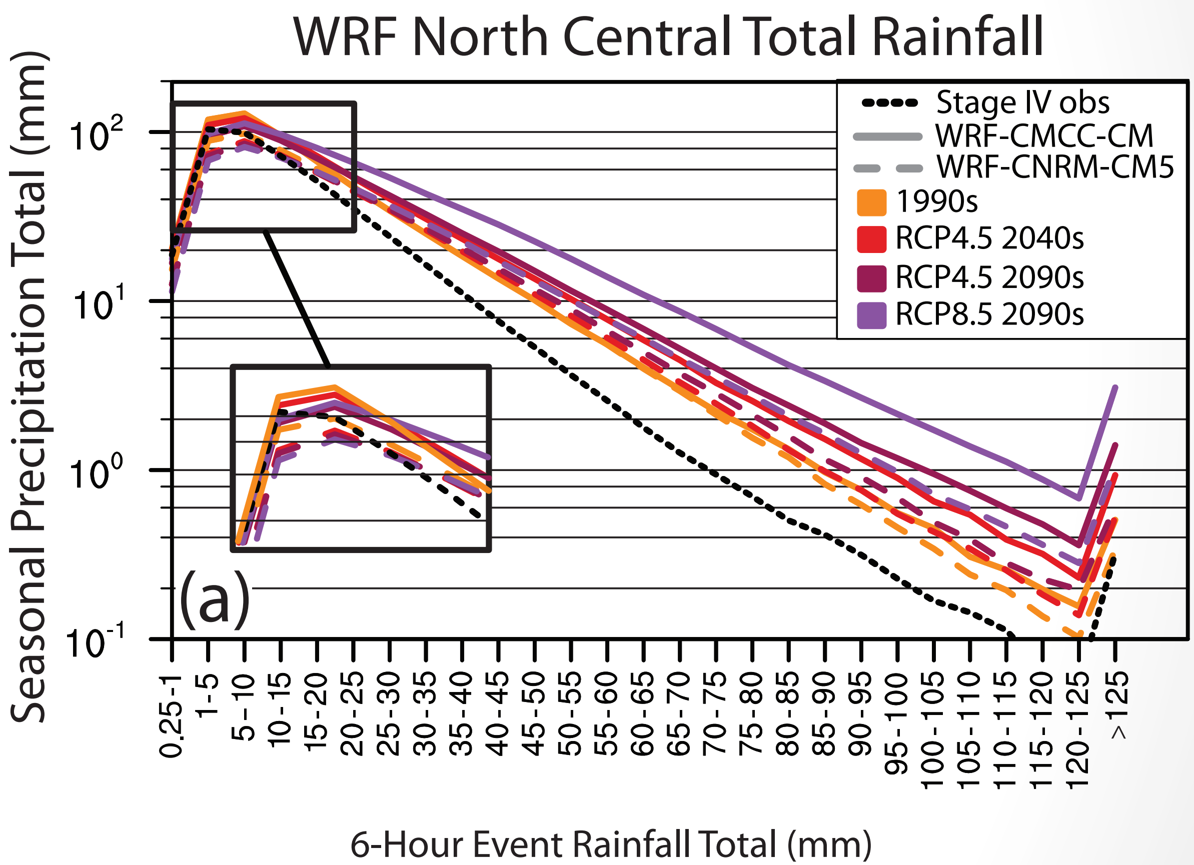
- More precipitation from heavy rainfall events
- No significant change in rainfall from lighter events
- Increased precipitation intensity observed



(40º-50ºN, 105º-90ºW)

Simulated Changes

- Rightward shift in precipitation frequency distribution
- More heavy events at expense of lighter events
- Fewer rainy days (-10% in RCP8.5)
- Increased rainfall intensity (19% in RCP8.5)
- Greater change with stronger climate forcing as expected



(40°-50°N, 105°-90°W)

Observed Changes in Heavy Rainfall Events

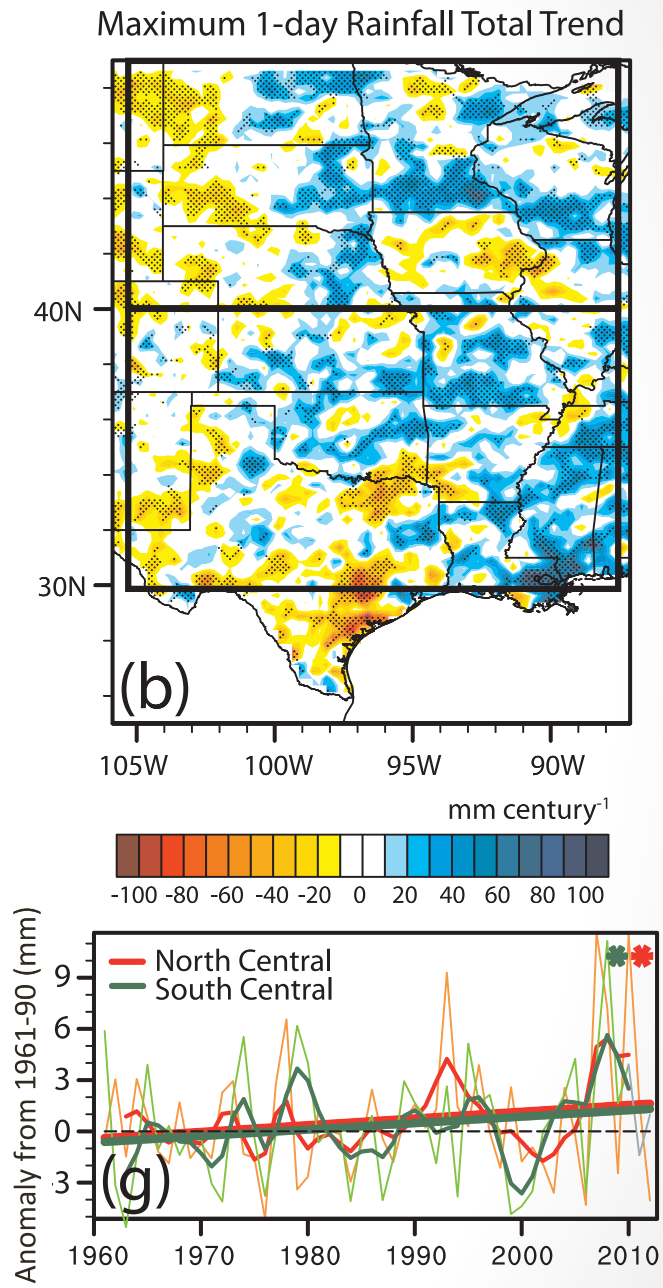
- Widespread increases in annual maximum 1-day rainfall totals
- Positive trend of 3.93 mm/century (+9.0%, $p < 0.05$) over North Central
- Increase in heavy events likely responsible for observed increase in precipitation

North Central

(40º-50ºN, 105º-90ºW)

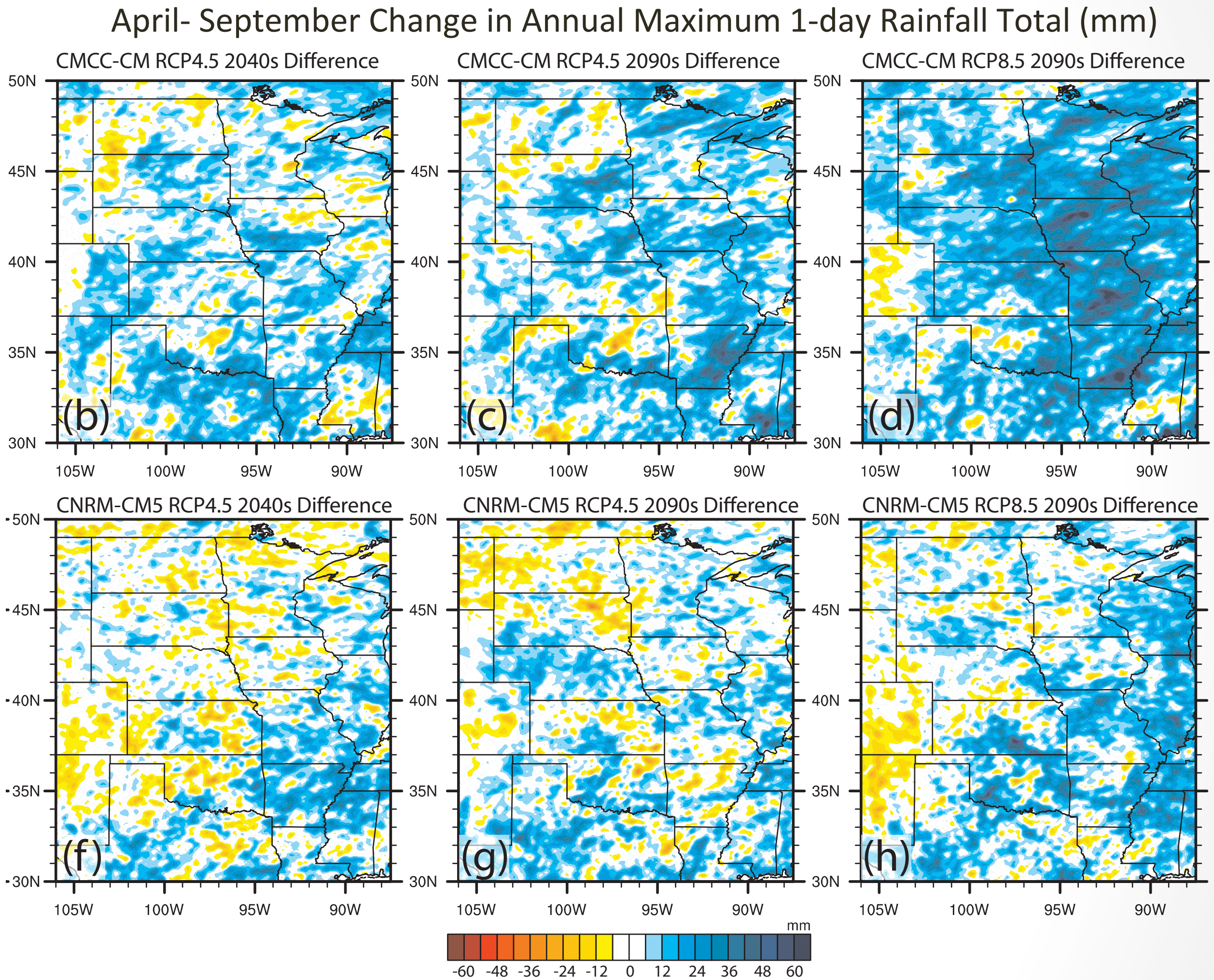
South Central

(30º-40ºN, 105º-90ºW)



Simulated Changes in Extreme Precipitation Events

- 20.1% increase in maximum 1-day rainfall in RCP8.5 2090s
- Smaller changes in RCP4.5
- Larger changes in WRF-CMCC-CM



Stronger climate forcing

Observed changes in drought

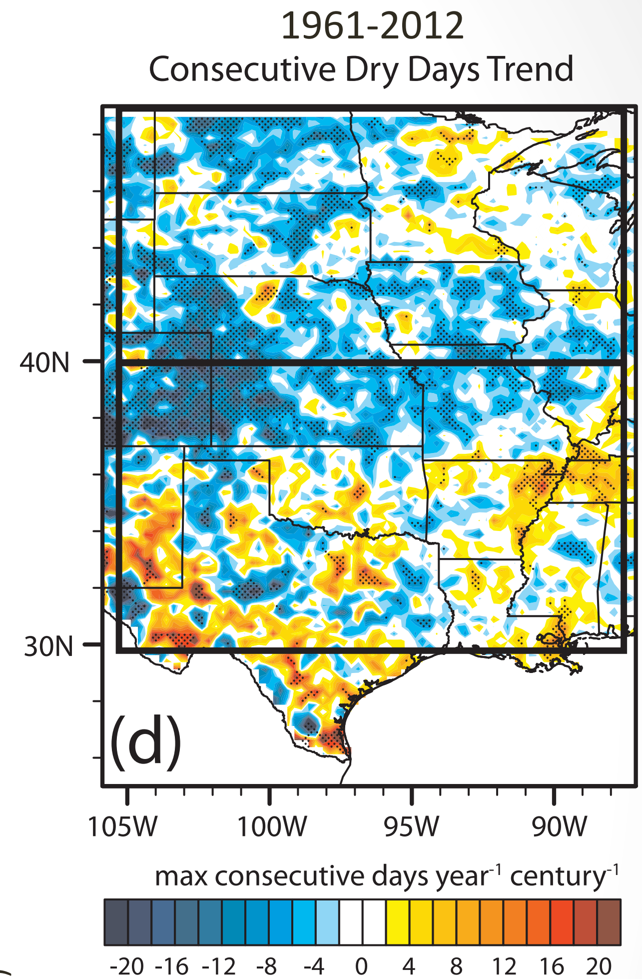
- Trend in the annual maximum number of consecutive days < 1 mm
- Statistically significant decline in the number of consecutive dry days in North Central U.S. from 1961-2012
- Increase in number of rainy days ($p < 0.05$)
- Observations show a decline in North Central U.S. meteorological drought

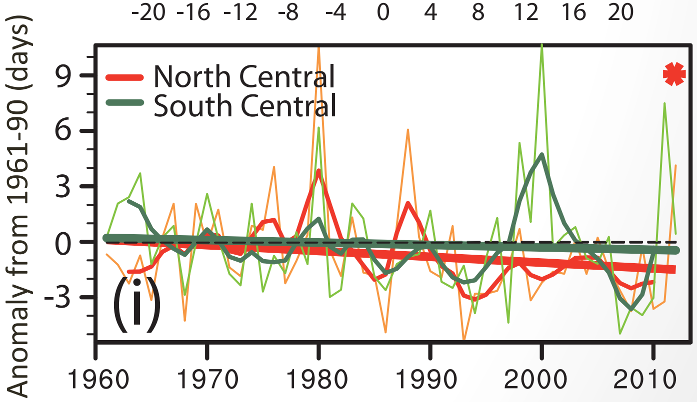
North Central

(40°-50°N, 105°-90°W)

South Central

(30°-40°N, 105°-90°W)

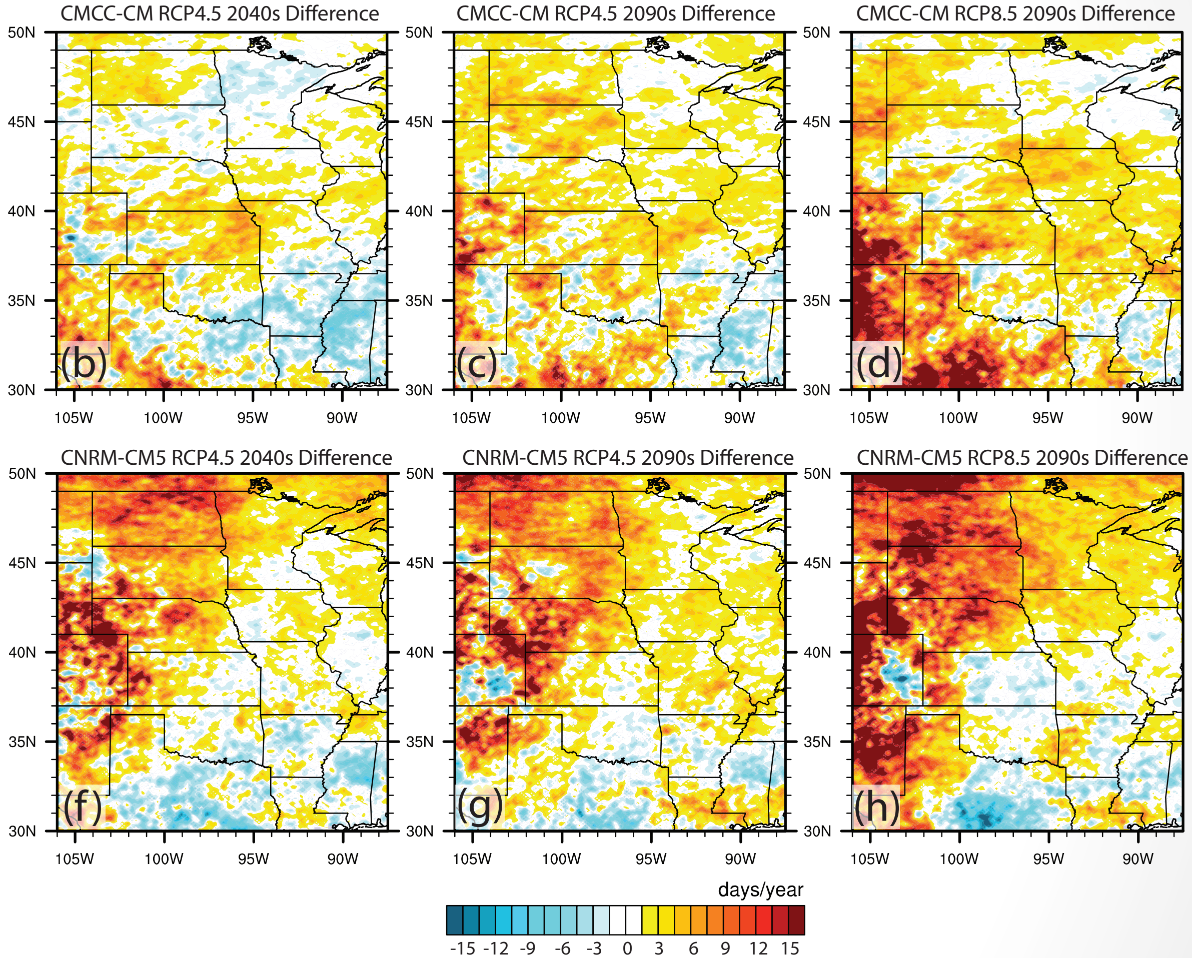




Drought Projections

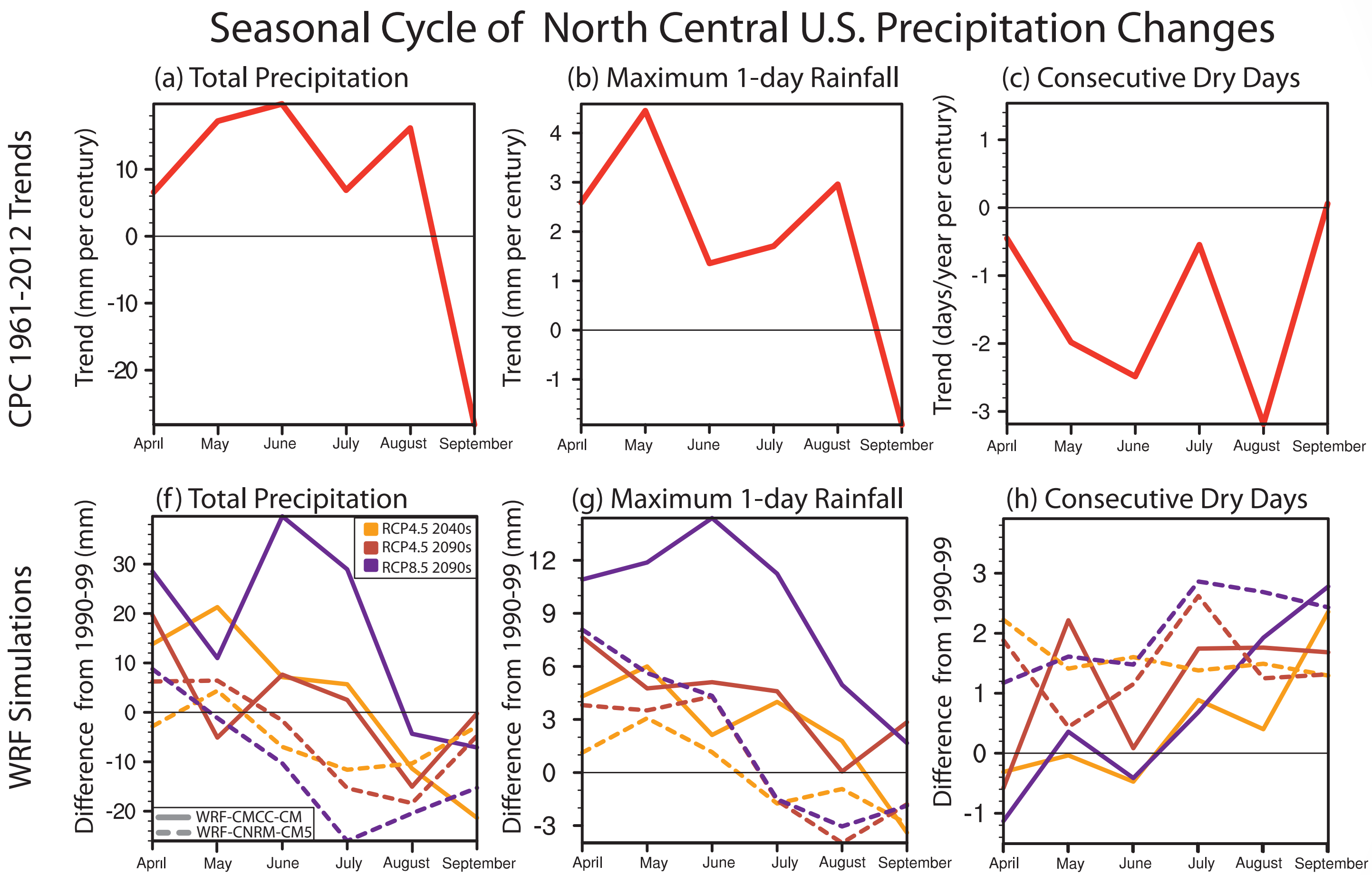
- Widespread increase in meteorological drought
- Greatest in western Plains
- Largest in RCP8.5 scenario
- Decrease in number of rainy days (≥ 1 mm)

Change in Average Maximum Number of Consecutive Dry Days



Stronger climate forcing

Seasonality of changes



Observed and projected extreme rainfall events increase most in April-July

Observed late-summer drying projected to intensify in future simulations

(40°-50°N, 105°-90°W)

Summary

- Observed increase in rainfall intensity and extreme rainfall events
- Future projections indicate less frequent but more intense rainfall
  - More heavy events at expense of light events
- Observed and simulated increases in North Central heavy rainfall events greatest in April-July
- Late summer drying observed and projected in North Central U.S.
- No clear future change in total summer rainfall
  - Timing, frequency, and intensity more important
- Simulated changes in extreme events smaller than predicted by Clausius-Clapeyron

References

- Harding, K. J., P. K. Snyder, and S. Liess, 2013: Use of Dynamical Downscaling to Improve the Simulation of Central U.S. Warm-Season Precipitation in CMIP5 Models. *JGR-Atmospheres*. doi: 10.1002/2013JD019994
- Harding, K. J., and P. K. Snyder, 2014: Examining future changes in the character of Midwestern warm-season precipitation using dynamical downscaling. *Journal of Climate. Under Review.*

Acknowledgments

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