Projections of Midwest Warm-Season Rainfall Extremes from Dynamical Downscaling

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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

JJA North Central Percent of Precipitation Events

Most GCMs cannot accurately simulate extreme events

Harding et al. (2013) JGR-Atmos
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

<table>
<thead>
<tr>
<th>Climate Scenarios</th>
<th>Time Period</th>
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<tbody>
<tr>
<td>Historical</td>
<td>1990-1999</td>
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<tr>
<td>Medium Range, Moderate Emissions (RCP4.5)</td>
<td>2040-2049</td>
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<tr>
<td>Long Range, Moderate Emissions (RCP4.5)</td>
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<tr>
<td>Long Range, High Emissions (RCP8.5)</td>
<td>2090-2099</td>
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</tbody>
</table>
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

- 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
(40°-50°N, 105°-90°W)

South Central
(30°-40°N, 105°-90°W)
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

(40°-50°N, 105°-90°W)
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
(40°-50°N, 105°-90°W)

South Central
(30°-40°N, 105°-90°W)
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

![Maps showing change in average maximum number of consecutive dry days for different scenarios.](image-url)
Seasonality of changes

Seasonal Cycle of North Central U.S. Precipitation Changes

(a) Total Precipitation
(b) Maximum 1-day Rainfall
(c) Consecutive Dry Days

CPC 1961-2012 Trends
WRF Simulations

Difference from 1990-99 (mm)

Observed and projected extreme rainfall events increase most in April-July
(40°-50°N, 105°-90°W)

Observed late-summer drying projected to intensify in future simulations
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


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