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Regional Climate Change Projections - Potential Impacts to Nuclear Facilities

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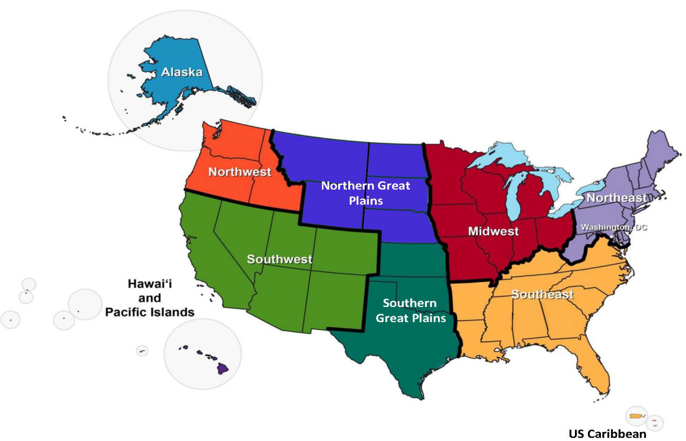
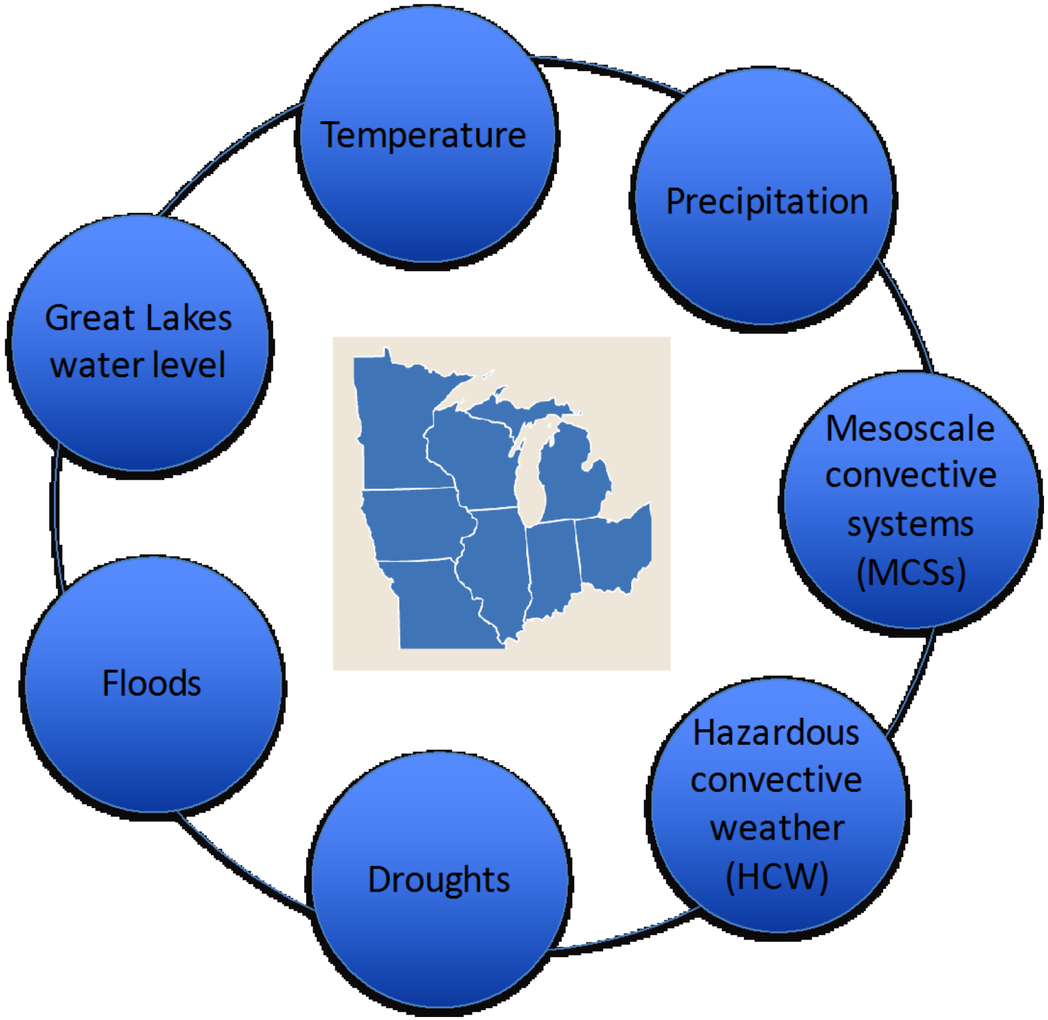
The Midwest region

- **Midwest Region in NCA3 and NCA4**: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin
- All states in the Midwest Region except for Indiana, have operating nuclear power plants



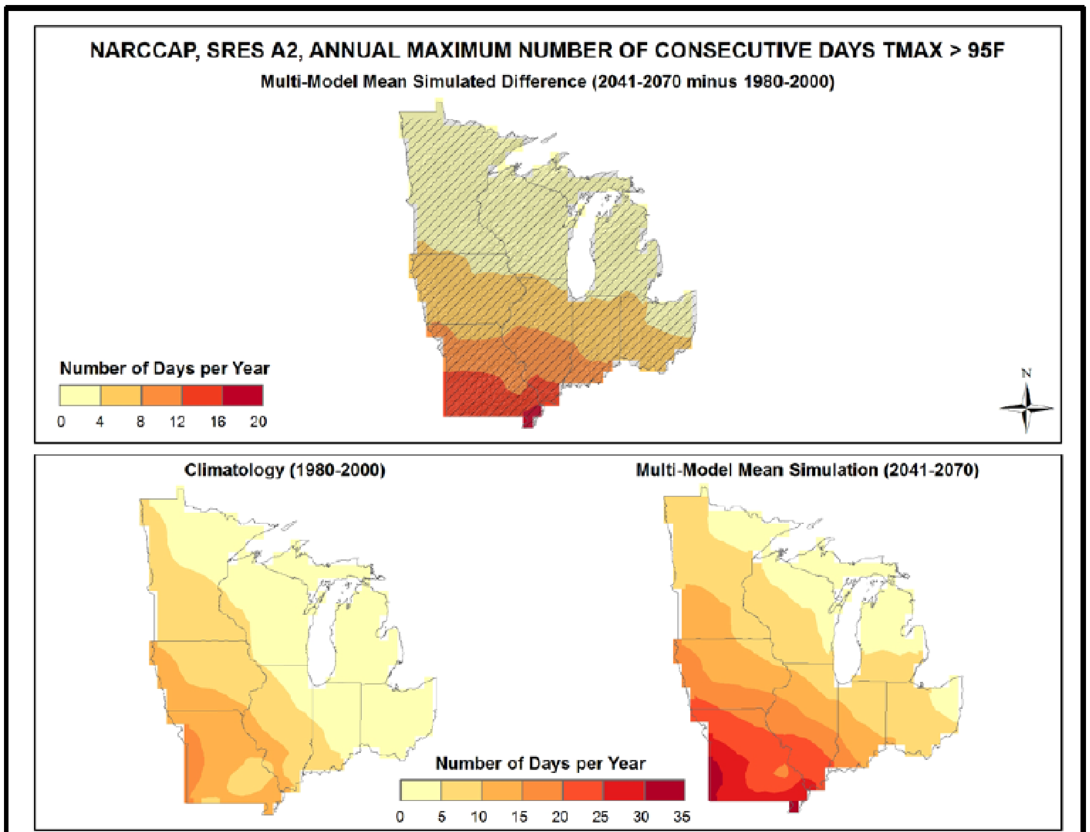
NCA4 regions



Changes in hot days

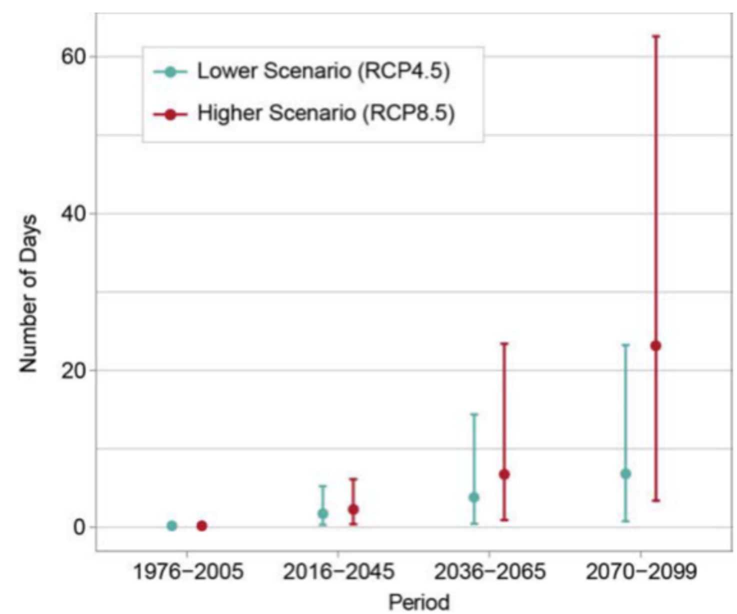
- Increase in heat extremes can pose challenges to infrastructure (e.g., material stress) and rising stream temperature may affect power plant operations

Consecutive days with Tmax > 95F



NCA3 report

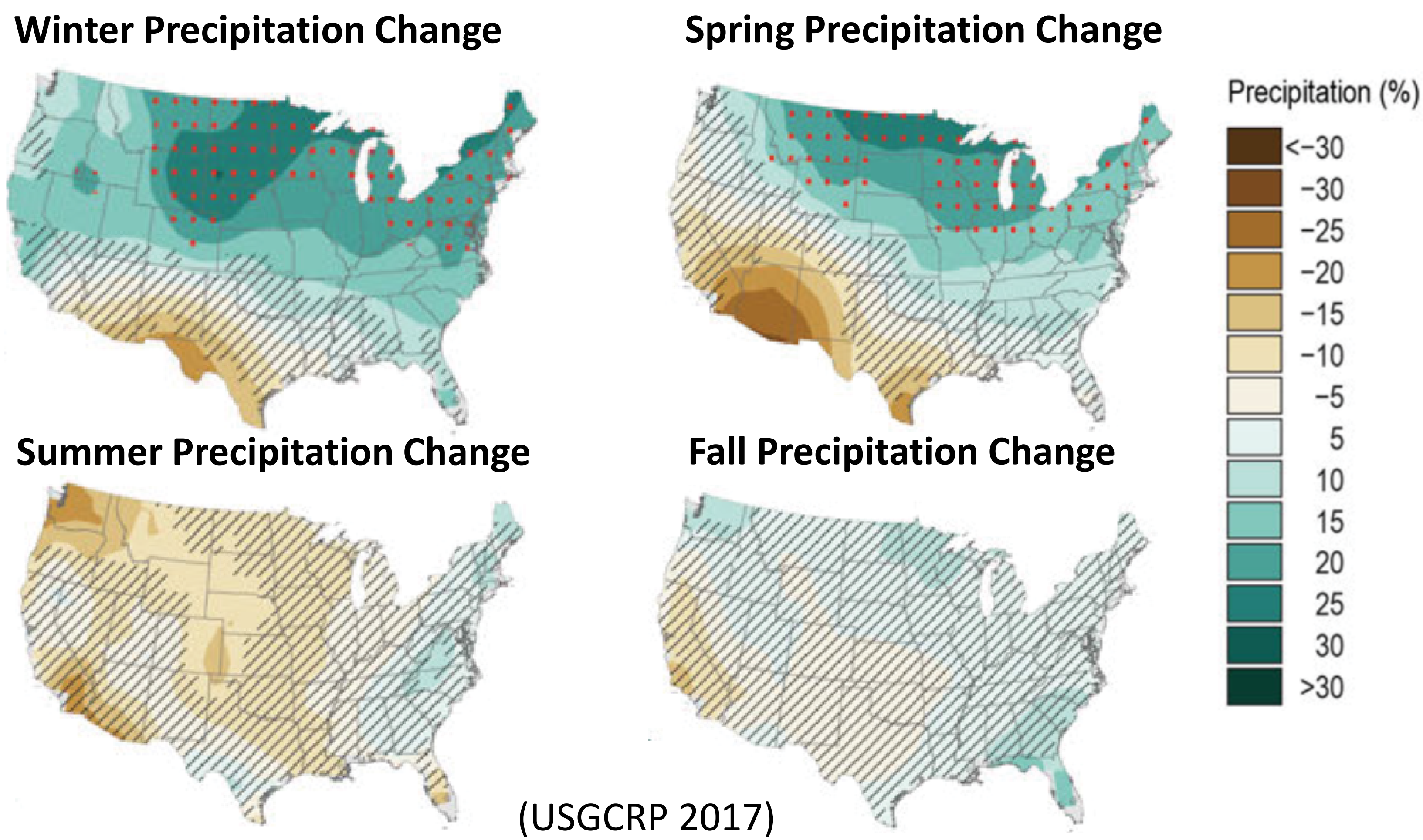
Projected number of days > 100F for Chicago



NCA4 report

Seasonal precipitation changes

- Annual precipitation in the Midwest has increased by 5% to 15%from 1901–1960 compared to 1986–2015
- Increase in cold season precipitation due to poleward shift of storm tracks



(USGCRP 2017)

Changes in extreme precipitation

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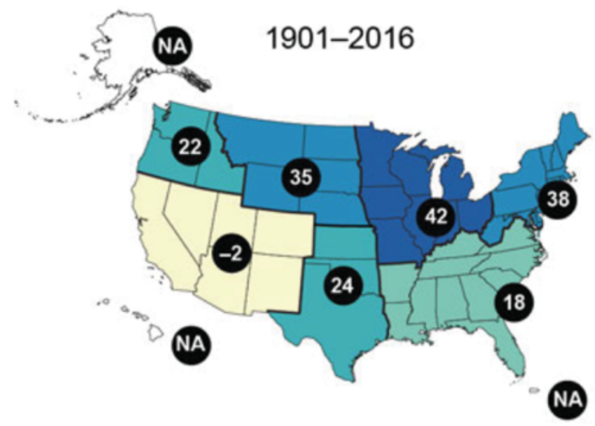
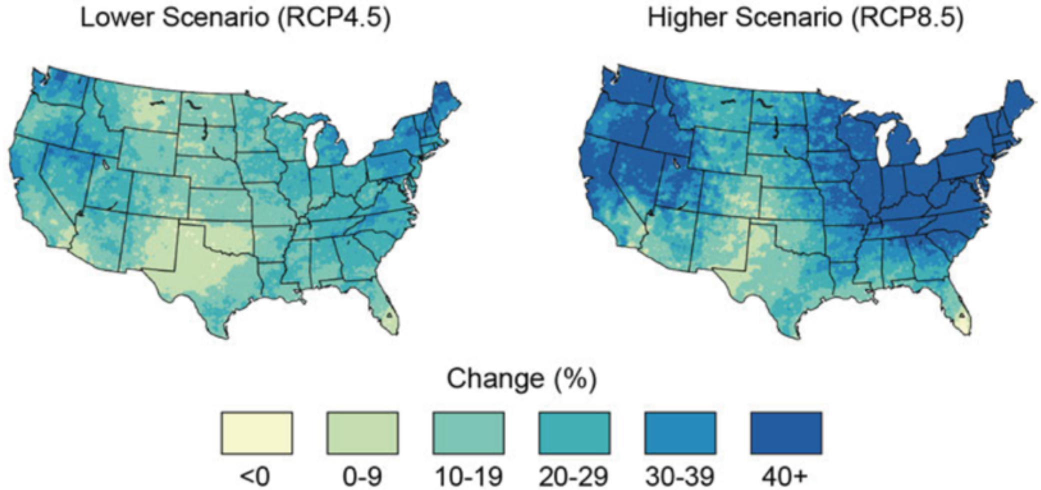
- Observed changes are largest over the Midwest
- Projected changes are largest over the Midwest and western U.S.

Observed Change in Total Annual Precipitation Above the 99th Percentile

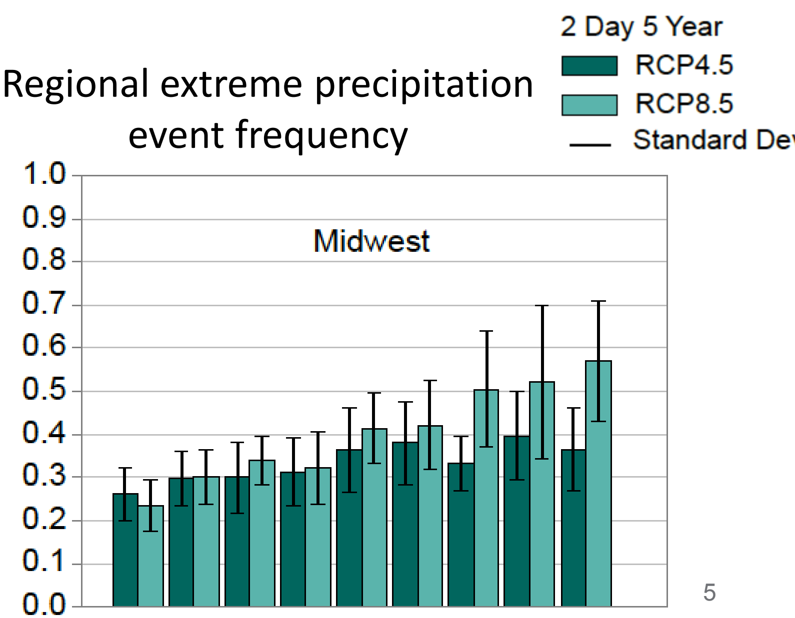


Projected Change in Total Annual Precipitation Above the 99th Percentile by Late 21st Century



(USGCRP 2017)

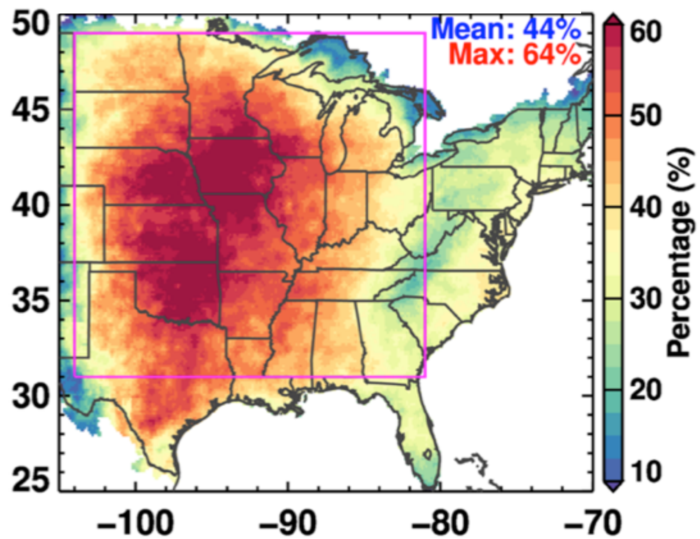
Regional extreme precipitation event frequency



Contribution of MCS to mean and extreme precipitation

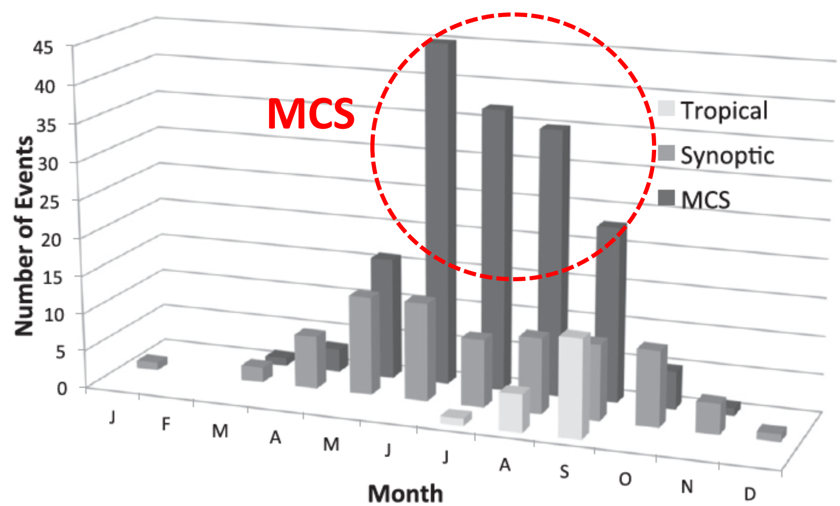
- Mesoscale convective systems (MCSs) play a critical role in producing heavy rainfall in the tropics and mid-latitudes during warm seasons
- In Midwest, MCSs contribute 30%-60% of the total warm-season rainfall
- Most of 100-yr, 24-h extreme rainfall events east of the Rocky Mountains were caused by MCSs in the warm season (Stevenson & Schumacher 2014)

15-year MCS precipitation climatology



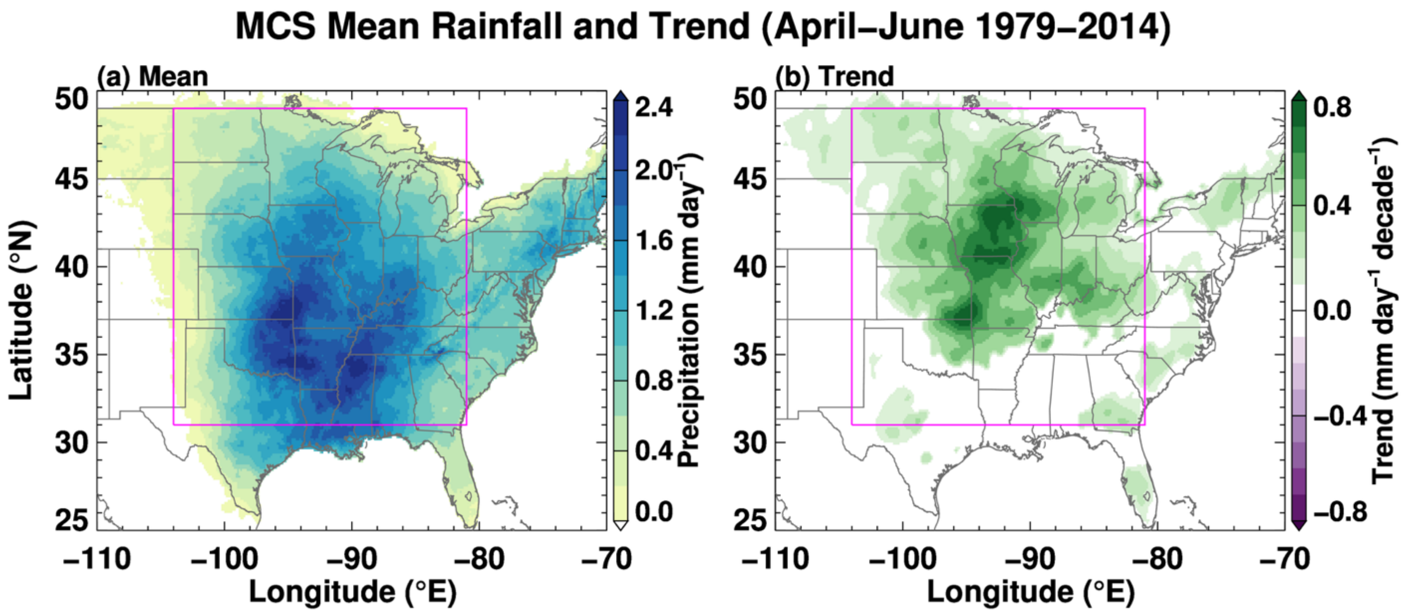
(Feng et al. (2016) Nature Commun.)

Extreme Event Types

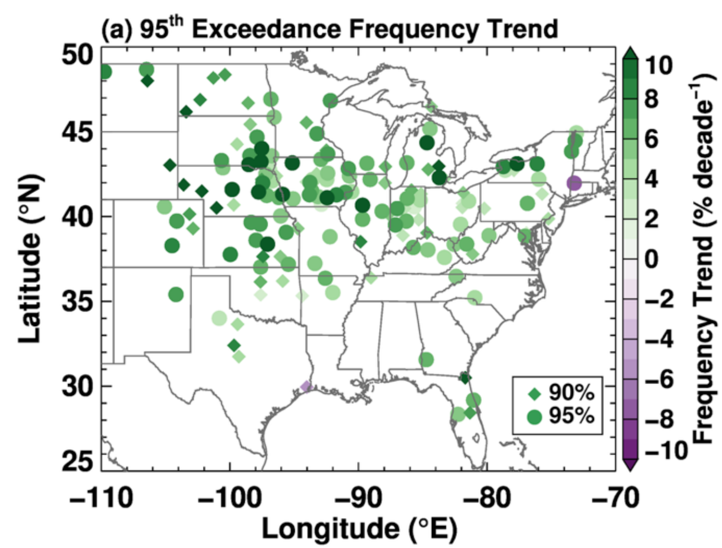


(Stevenson & Schumacher 2014 MWR)

MCS rainfall increased in the past



- Some regions in Midwest experienced 0.4-0.8 mm day^{-1} (20-40%) increase in MCS precipitation
- 95th percentile MCS hourly rain-rate increased consistent with mean MCS precipitation increase



(Feng et al. 2016 Nature Commun.)

Changes in large-scale environment

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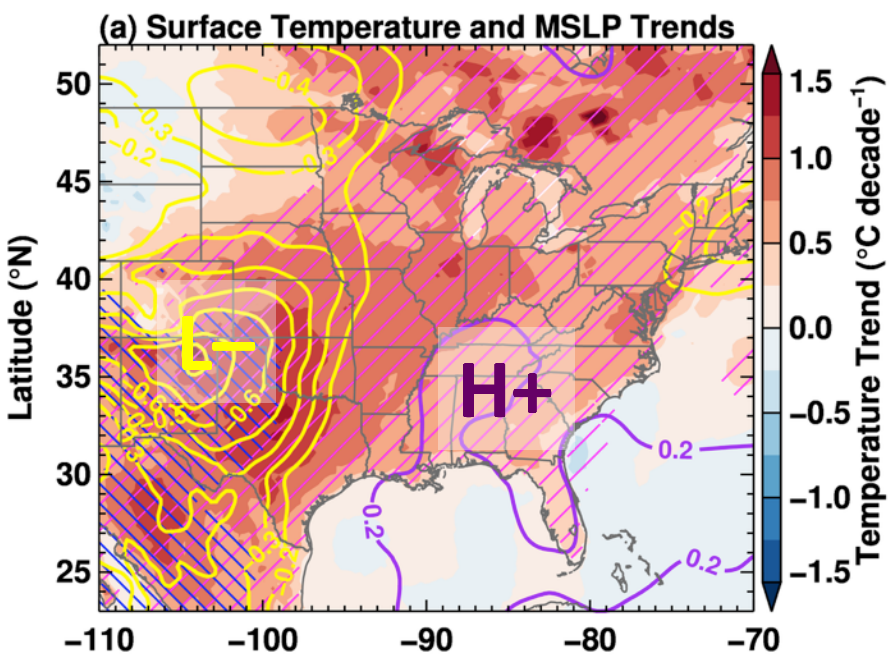
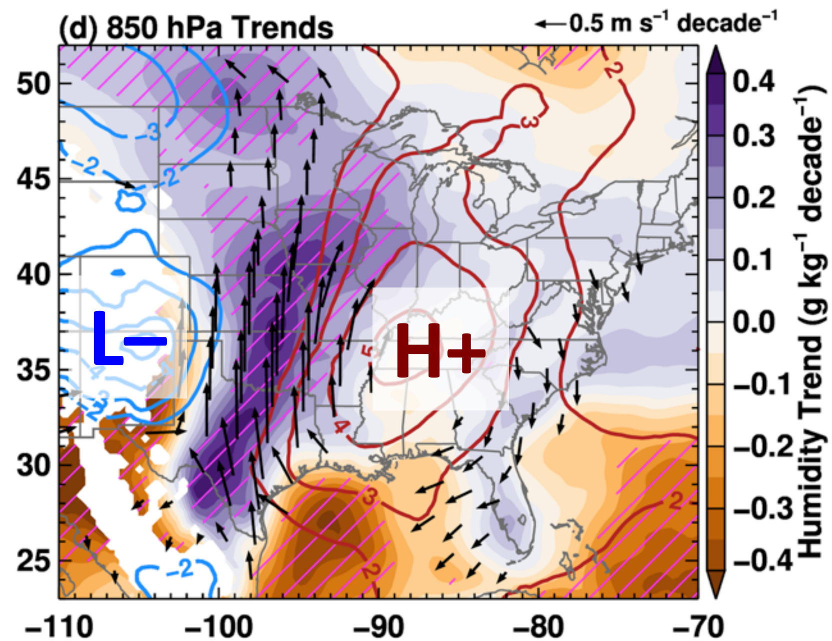
Surface trend



850 hPa trend



- Surface warming over land and lack of warming in surrounding oceans increase pressure gradient across central US
- Low-level moistening associated with enhanced GPLLJ moisture transport facilitates more intense MCS precipitation

(Feng et al. 2016 Nature Commun.)

Changes in hourly extreme precipitation from convection permitting simulations

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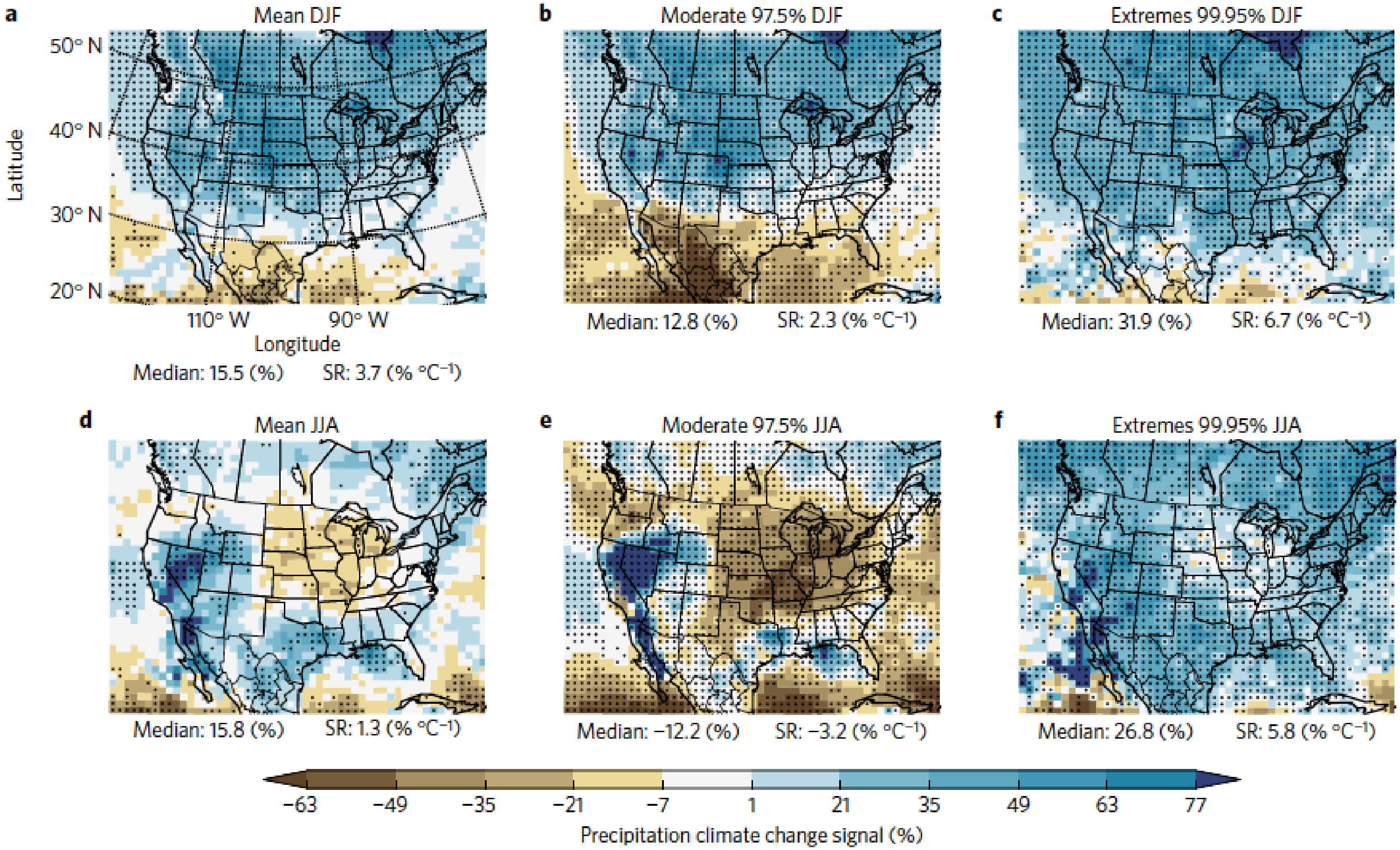
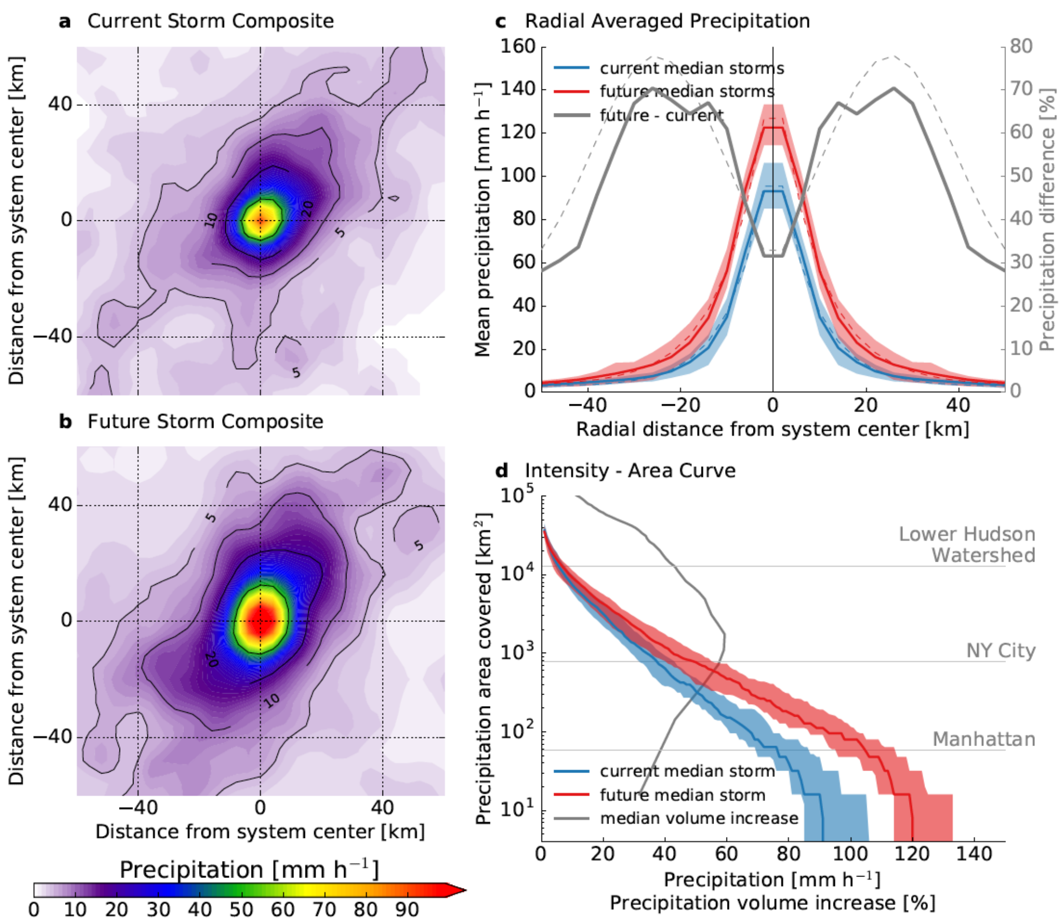
Precipitation change (%) for 2071-2100 relative to 1976-2005: increase in 99.95% hourly precipitation everywhere



(Prein et al. 2016 Nature Climate Change)

Changes in MCS precipitation

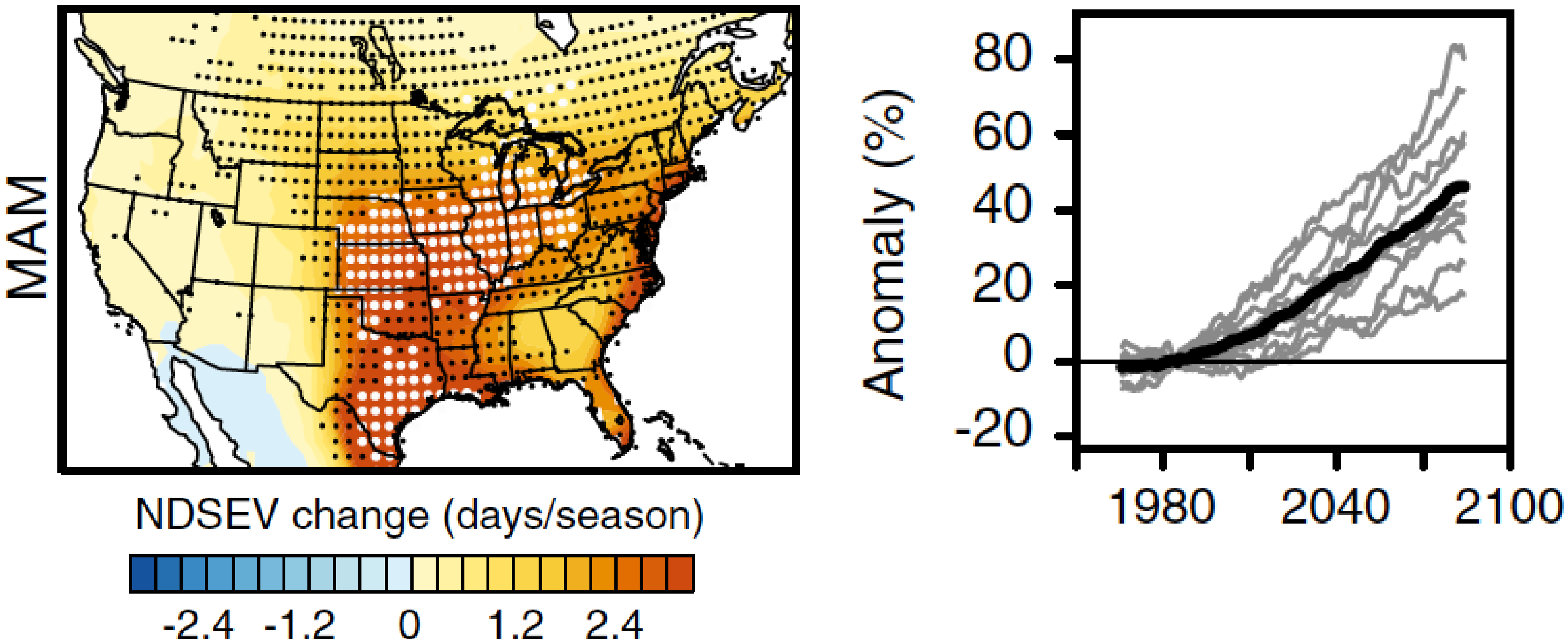
- Intense summertime MCS frequency will more than triple in North America
- MCSs that move slower than 20 kmh^{-1} reduce their speed by up to 20% in the Midwest, Mid-Atlantic, and Canada



(Prein et al. 2017 Nature Climate Change)

Changes in severe storm environment

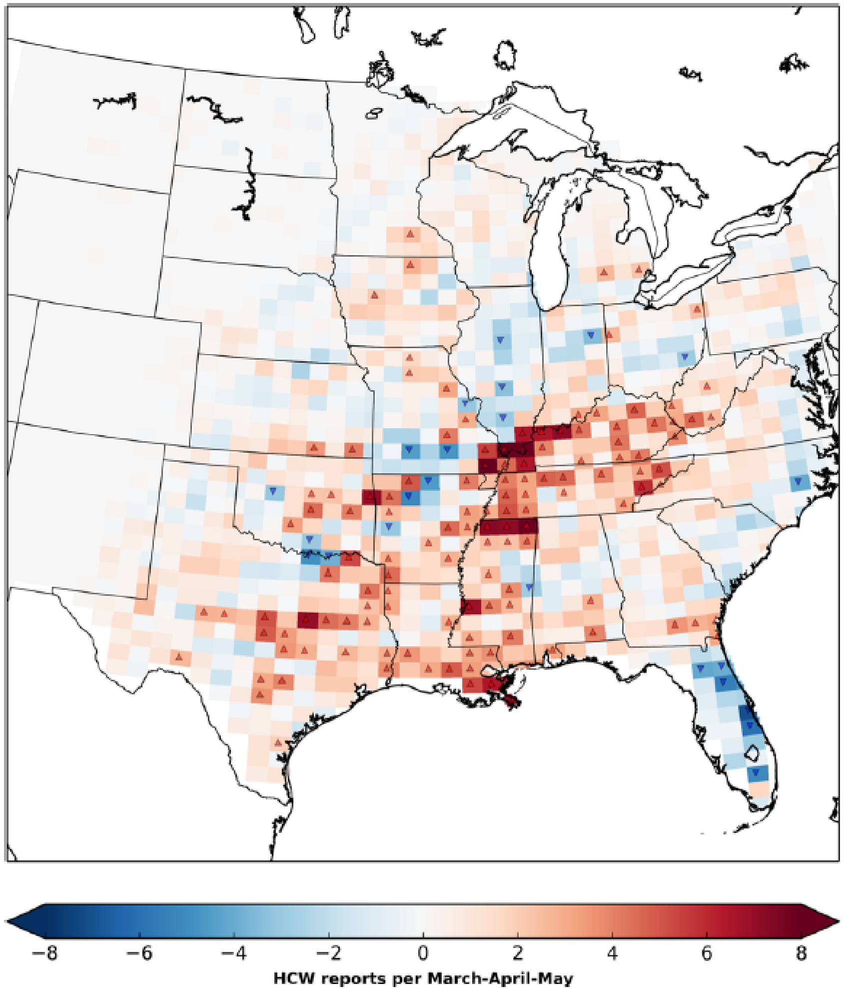
Changes in number of days with spring (March-April-May) severe thunderstorm environment (NDSEV) comparing 2070 to 2099 with 1970 to 1999 from CMIP5 models in the RCP8.5 scenario



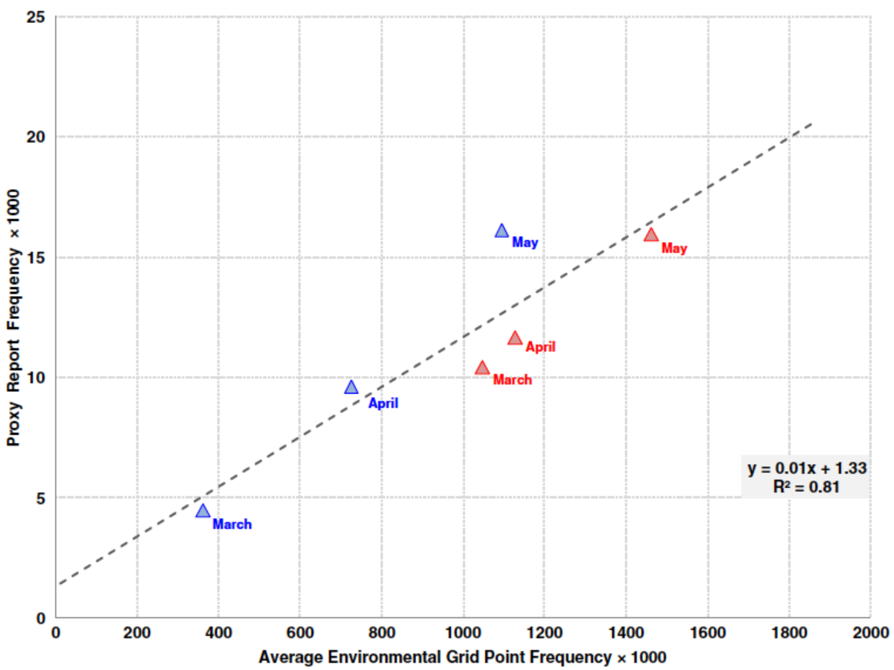
(Diffenbaugh et al. 2013 PNAS)

Simulating changes in HCW

Average difference between 2080–2090 and 1980–1990 modeled severe weather reports



Environmental conditions explain over 80% of the variance associated with modeled reports during March–May

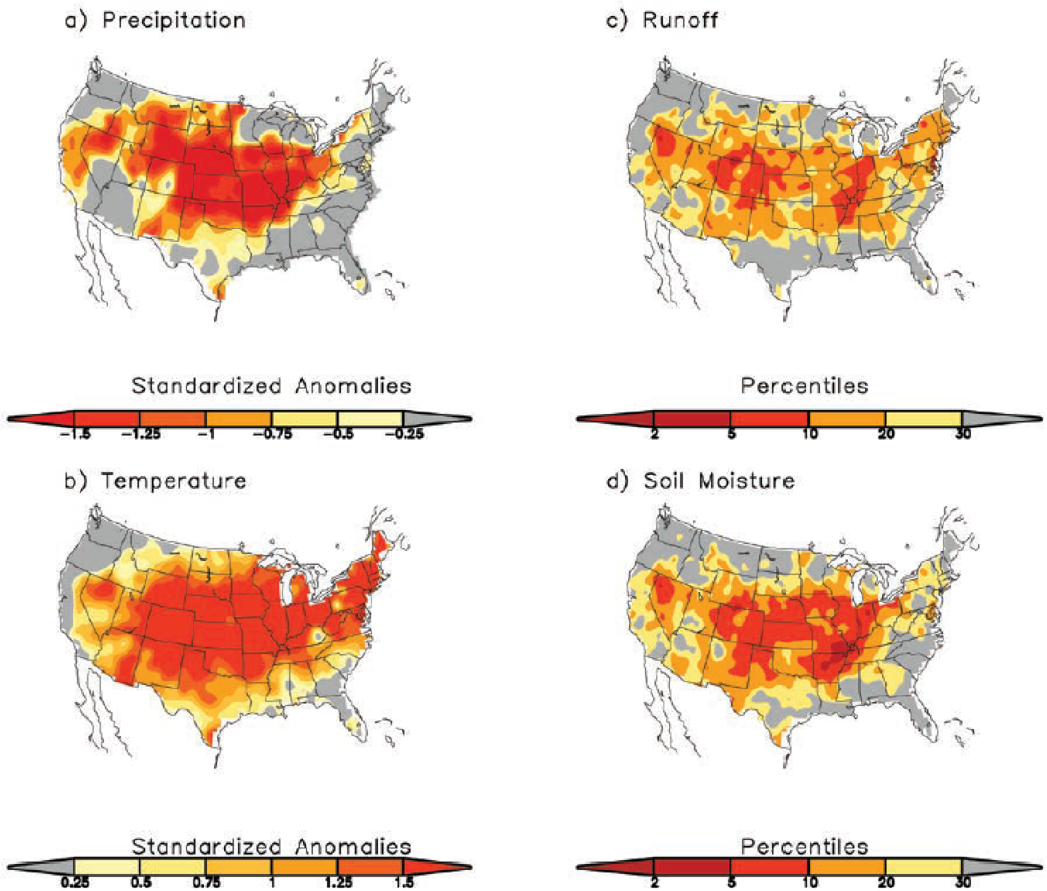


(Gensini and Mote 2015 Climatic Change)

Midwest droughts - historical

- Meteorological (precipitation deficit), Agricultural (soil moisture deficit), and Hydrological (runoff/streamflow deficit)
- 2012 Great Plains/Midwest drought, most severe observed meteorological drought - caused by large-scale meteorology reducing rain during summer (May-August, 2012)

Standardized anomalies over May – Aug 2012 relative to 1979-2011



(Hoerling et al., 2014 BAMS)

Midwest droughts - projected

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- Increases in temperatures in the future are expected to result in increases in evapotranspiration exceeding increases in precipitation, leading to increased soil moisture deficits and agricultural droughts

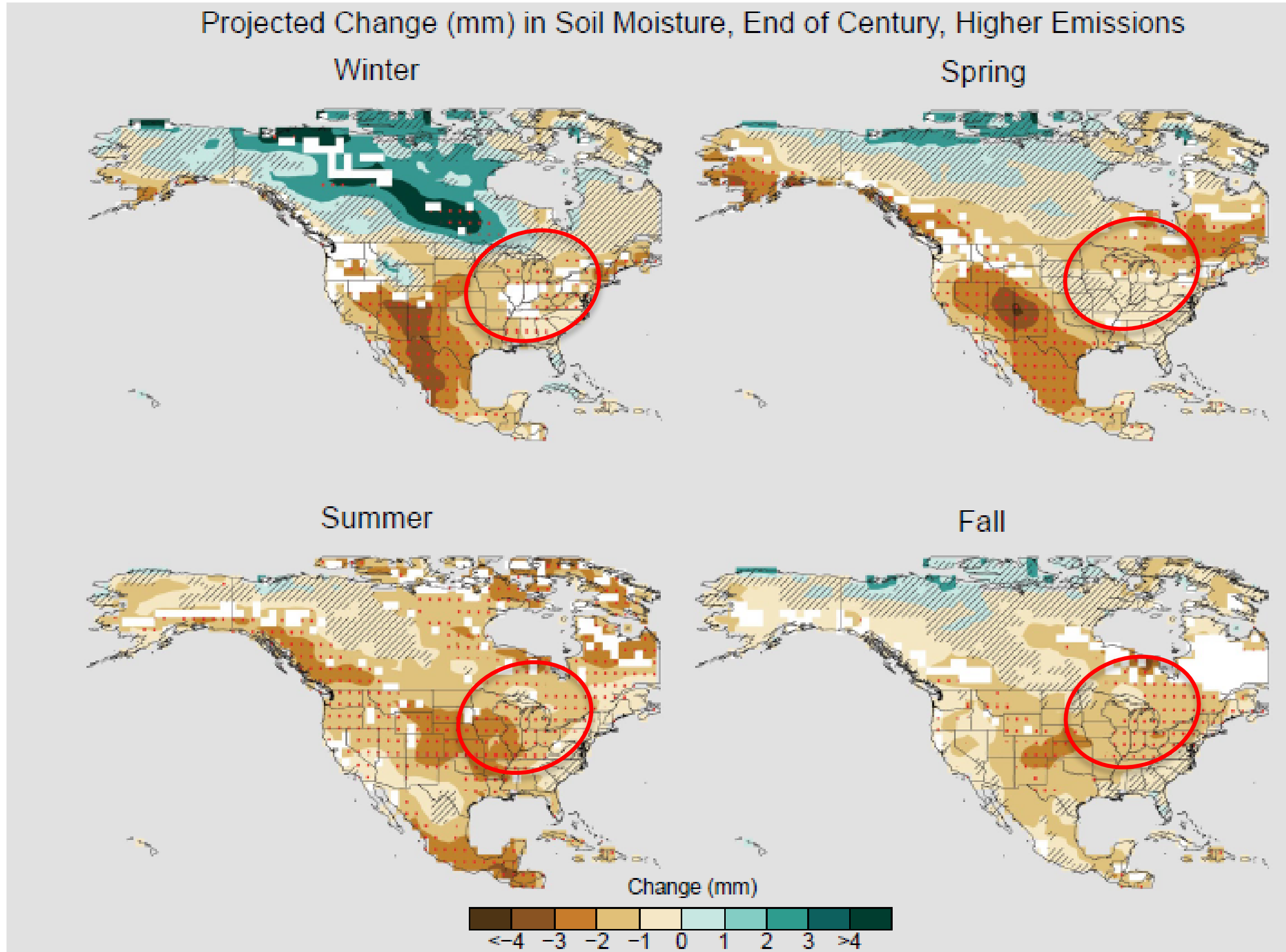
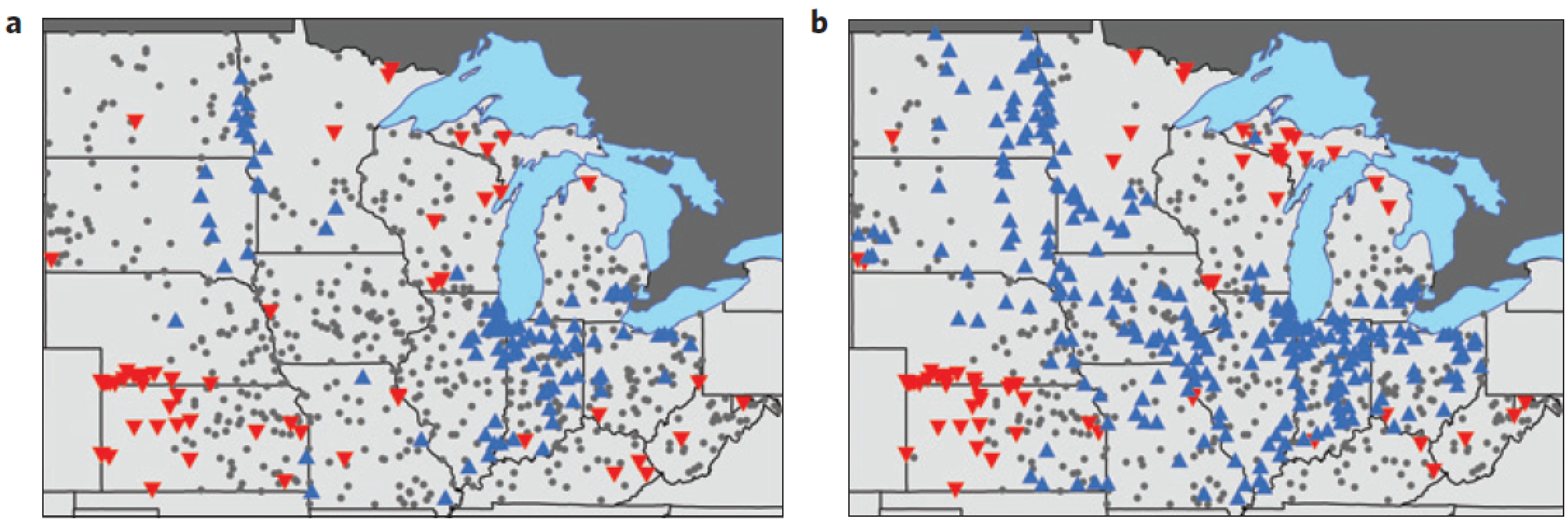


Figure 8.1: Projected end of the 21st century weighted CMIP5 multimodel average percent changes in near surface seasonal soil moisture (mrsos) under the higher scenario (RCP8.5). Stippling indicates that changes are assessed to be large compared to natural variations. Hashing indicates that changes are assessed to be small compared to natural variations. Blank regions (if any) are where projections are assessed to be inconclusive (Appendix B). (Figure source: NOAA NCEI and CICS-NC).

(USGCRP 2017)

Midwest floods - historical

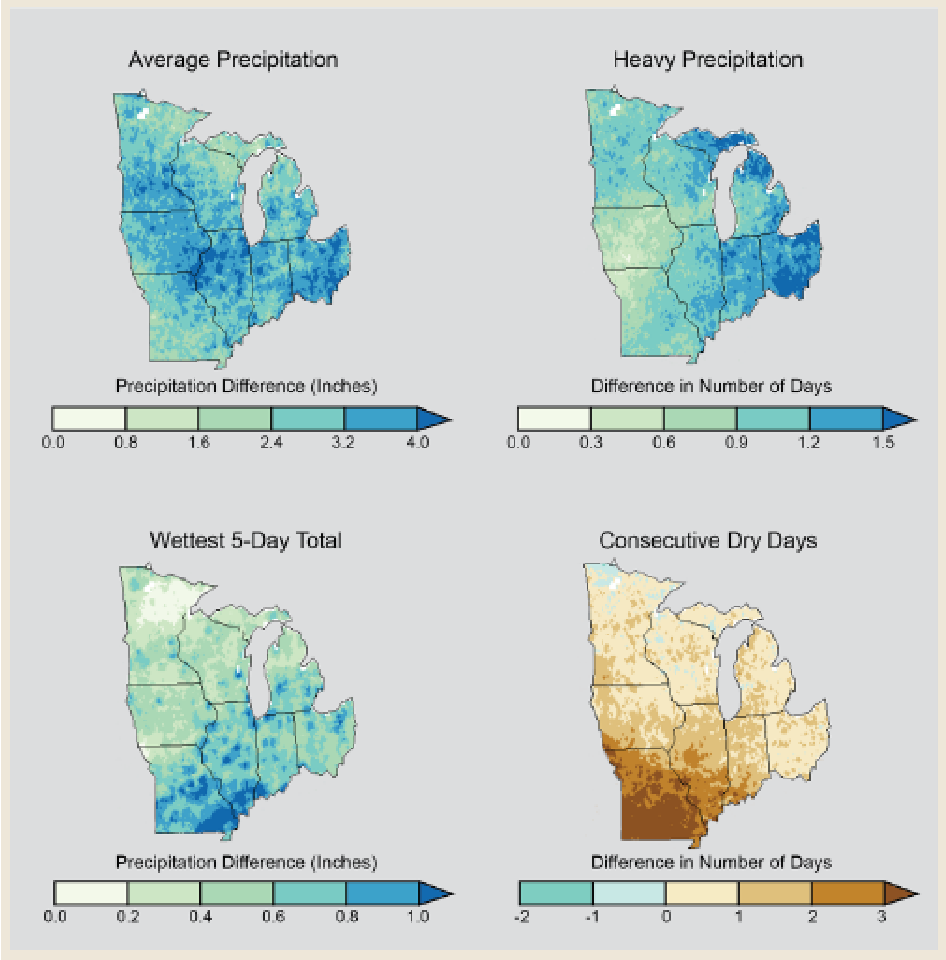
- 2008 floods (USGS Professional Paper 1775)
  - Above-average snowpack, record precipitation, saturated soils, remnants of two hurricanes
  - Separate flooding events in January through July, and September 2008
  - Affected all states in the Midwest Region except Ohio
- 2011 floods (USGS Professional Paper 1798-B)
  - Large snowpack, near-record spring rainfall, large releases from dams
  - Flooding from February through September 2011
- Mallakpour and Villarini, 2015, 2016



Magnitude ▲ Positive trend ▼ Negative trend Frequency

Midwest floods - projected

- Projected future floods
  - NCA3: Increases in rainfall and flooding are expected to continue in the future
    - Total amount of precipitation to increase
    - Number of days with top 2% of rainfalls to increase
    - Wettest 5 -day total precipitation to increase
    - Consecutive dry days to increase (related to droughts)
    - Warm-season precipitation to increase
  - NCA4:
    - Frequency and intensity of heavy precipitation events to increase (high confidence); based on physical reasoning local flooding in some catchments or regions would increase (medium confidence)



Midwest streamflow - historical

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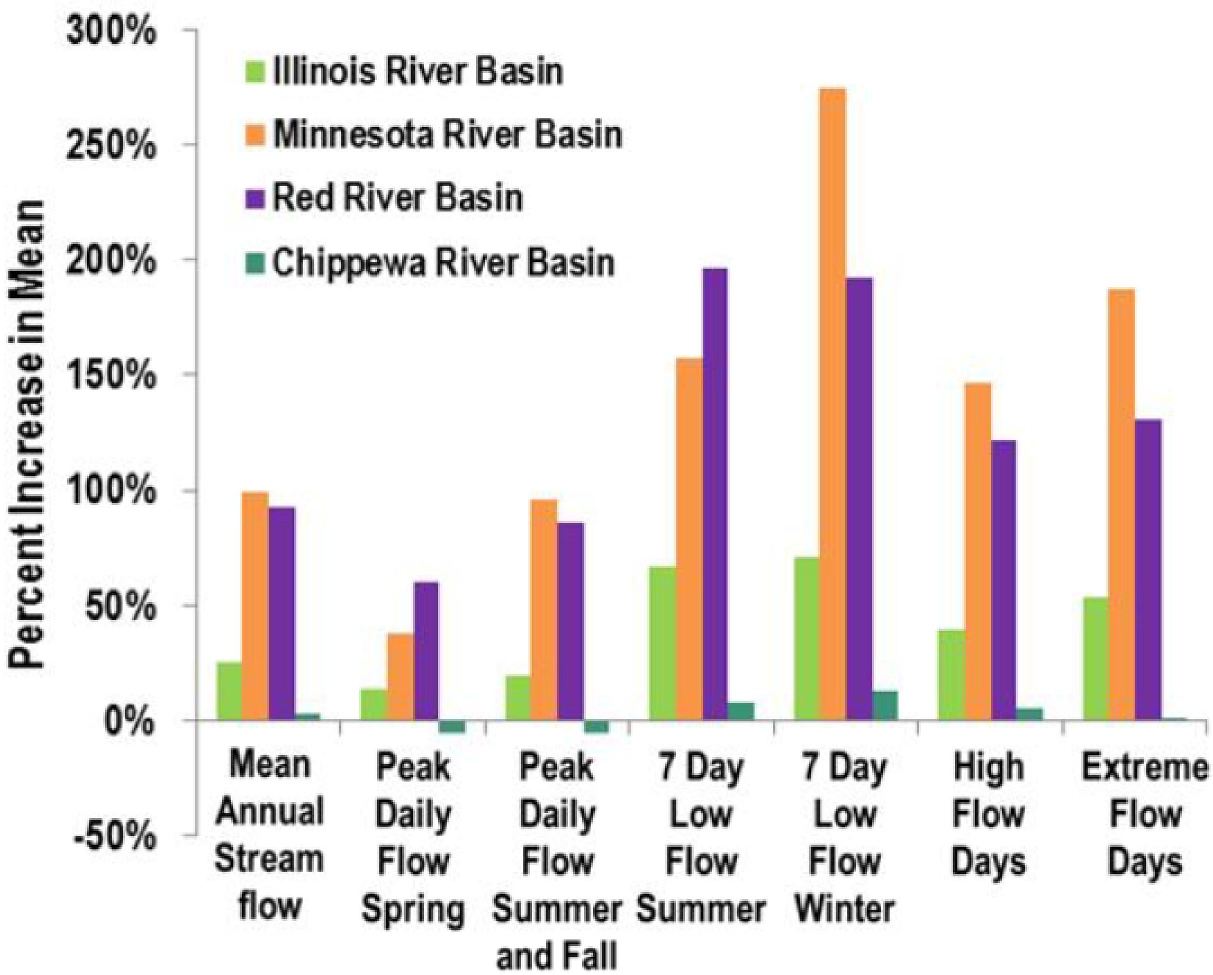
- EPA Climate Change Indicators, 2016
  - Mean annual streamflow
  - 3-day high streamflow
  - 7-day low streamflow
  - Timing of spring runoff
- Kelly et al., 2016; Gupta et al., 2015



Midwest streamflow - projected

- Projected future streamflow
  - Demaria et al., 2016
    Chien et al., 2013

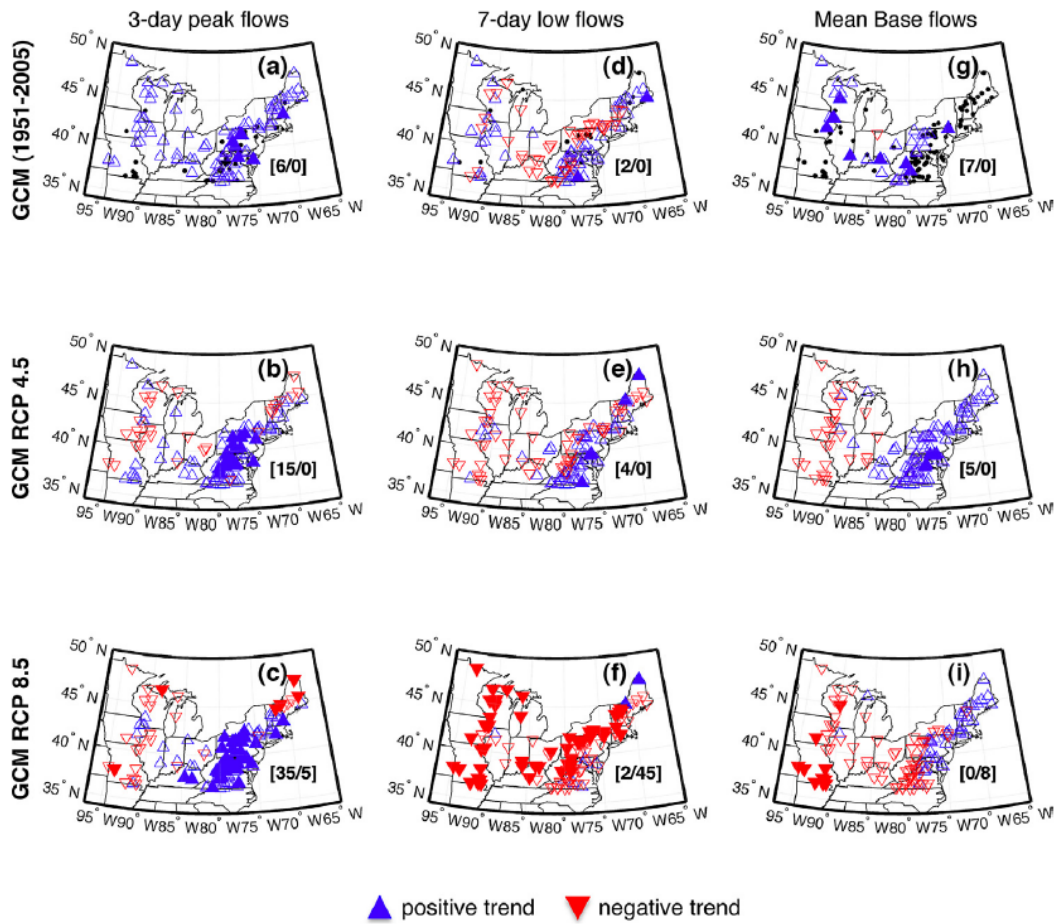


Fig. 5. Trends in GCM-driven simulations of 3-day peak flows (left column), 7-day low flows (middle column), and annual pre-whitened mean base flows (right column), during the historical (1951–2005) and future (2028–2082) periods. The black dot indicates the location of basins with statistically significant (α 0.05) point changes in the mean using the Pettitt test in Fig. 4. The numbers in the lower right corner indicate the percentage of basins with statistically significant trends.

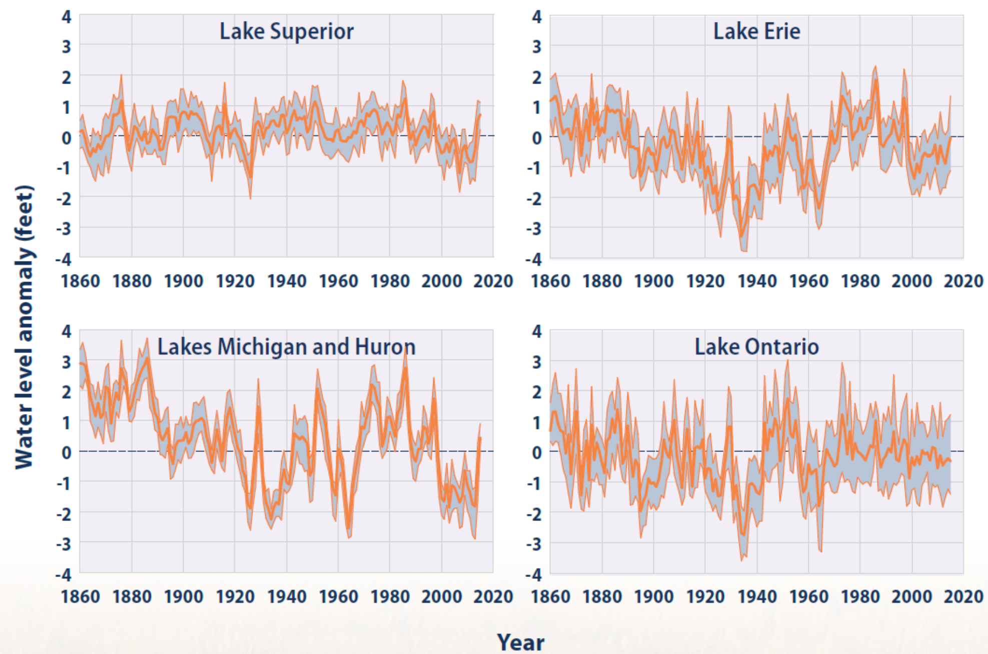
Great Lakes water levels - historical

- Historical water levels
  - EPA Climate Change Indicators 2016; International Upper Great Lakes Study, 2012

WHAT'S HAPPENING

- Water levels in the Great Lakes have fluctuated since 1860. Over the last few decades, they appear to have declined for most of the Great Lakes. The most recent levels are all within the range of historical variation, however.

Water Levels of the Great Lakes, 1860–2015



This figure displays how water levels in each of the Great Lakes have changed since 1860. For each year, the shaded band shows the range of monthly average water levels, and the line in the middle shows the annual average. The graph uses the 1981 to 2010 average as a baseline for depicting change. Choosing a different baseline period would not change the shape of the data over time. Lakes Michigan and Huron are shown together because they are connected at the same water level. Data source: NOAA, 2016[20]

Great Lakes water levels - projected

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- Projected future water levels
  - International Upper Great Lakes Study, 2012
  - NCA3: Angel and Kunkel, 2010; MacKay and Seglenieks, 2012

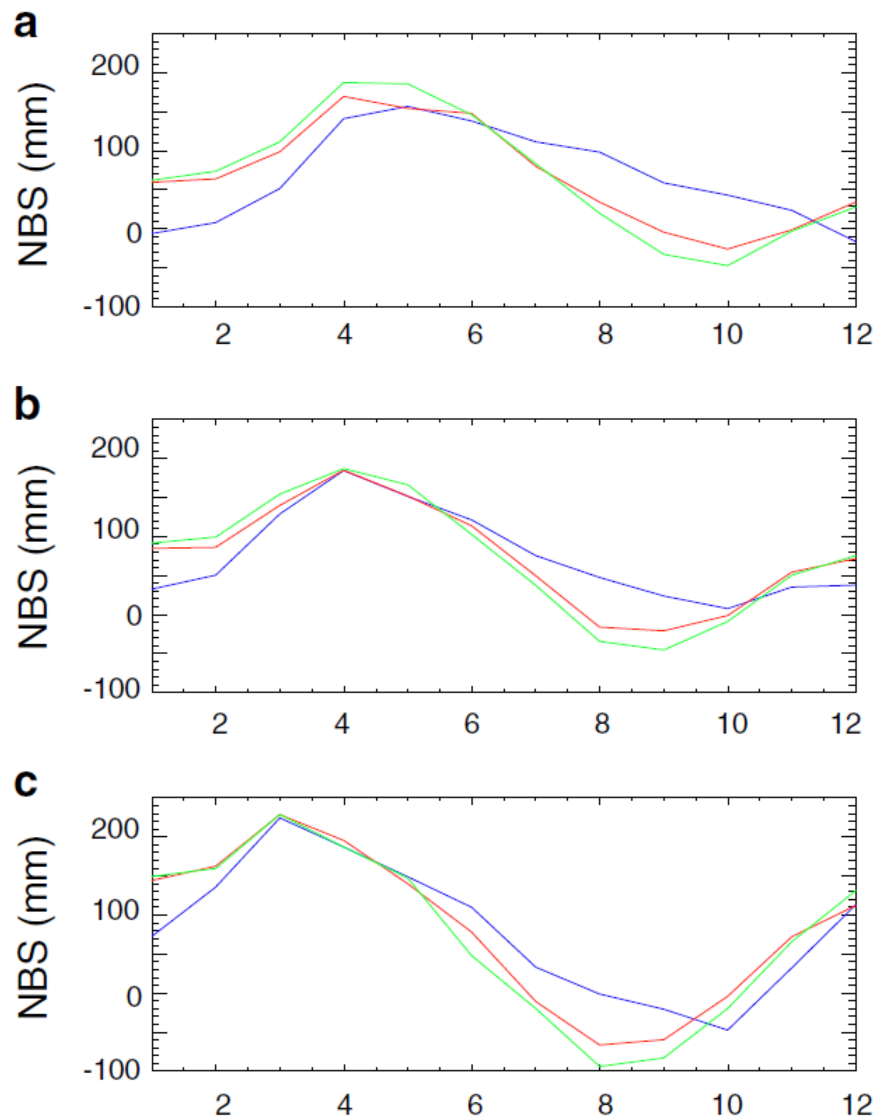

Fig. 3 NBS mean seasonal cycle for: **a** Lake Superior; **b** Lake Michigan – Huron; **c** Lake Erie. blue-observed (EC residual method); red-GLRCM 1962–1990; green-GLRCM 2021–2050. Units are mm over lake surface area

Summary

- The Midwest has seen warming in the past, with larger increase in precipitation compared to other US states
- Hot days and extreme precipitation are projected to increase in the future
- Convection permitting modeling is becoming viable for projecting changes in MCSs and HCW
  - MCS precipitation has increased in the past and is projected to increase in the future
  - HCW and its large-scale environment are projected to be more frequent in the future
- Soil moisture is projected to decrease due to increase in evapotranspiration, increasing the likelihood of drought
- Floods may increase as extreme precipitation increases
- Great Lakes water level may become lower in the future