Historical and Projected Future Climatic Changes in the Great Lakes Region

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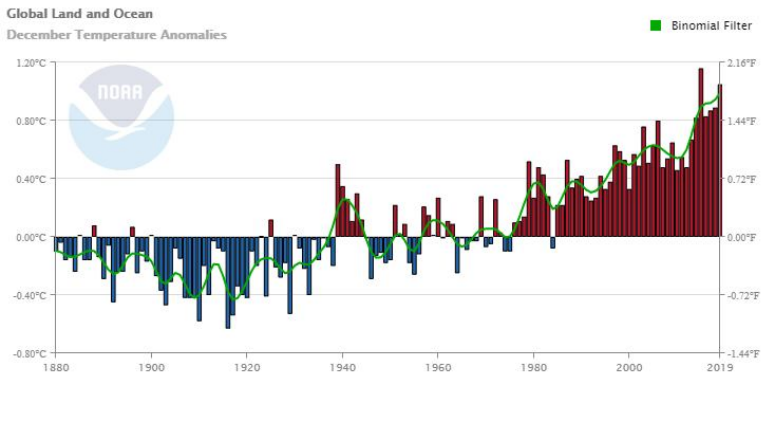
Outline

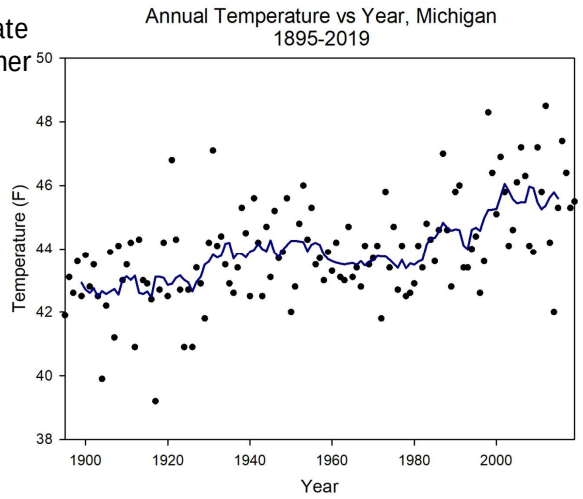
- Historical Trends
- Climatic Variability/Extreme Events
- Future Projections

Global Land and Ocean Temperature Anomalies

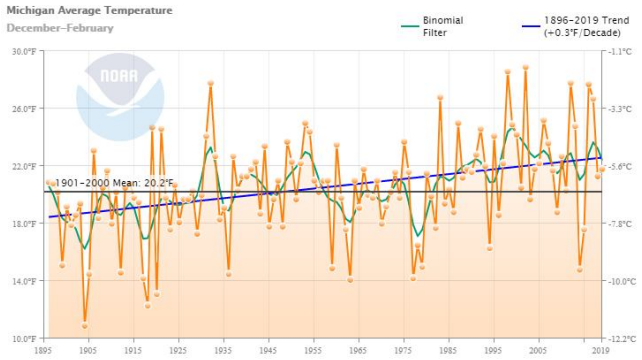
1880-2019

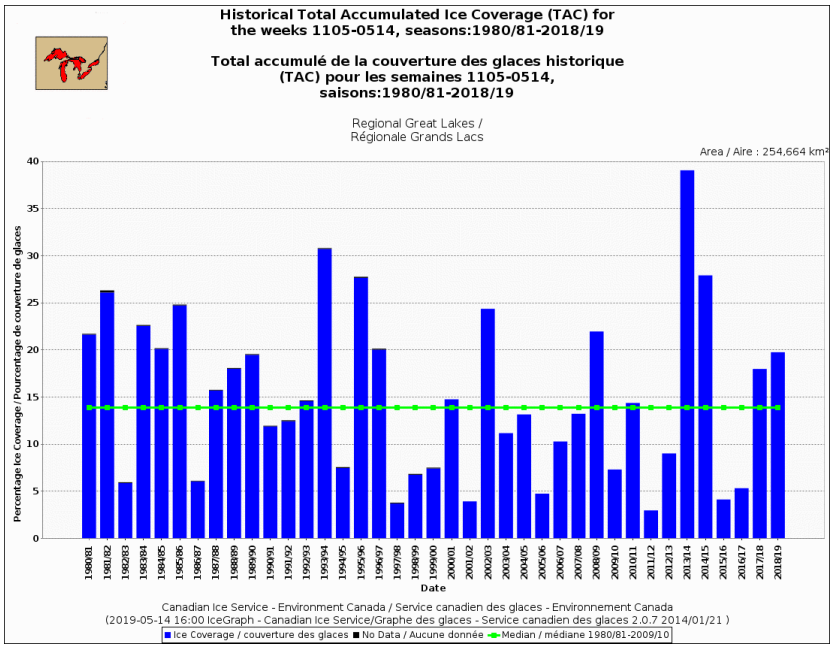


Regional climate trending warmer

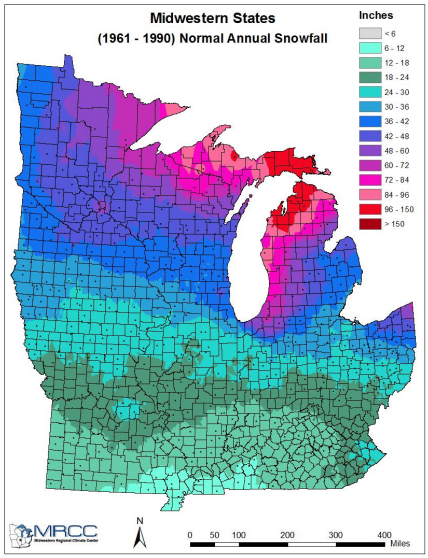


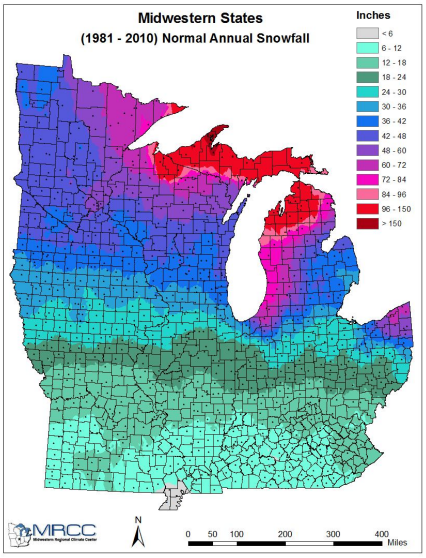
Annual Mean Winter Temperatures vs. Year, Michigan
1895-2019





https://ice-glaces.ec.gc.ca/prods/CVCHACTGL/20190513180000_CVCHACTGL_0010581627.gif

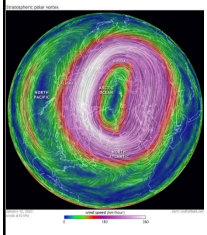




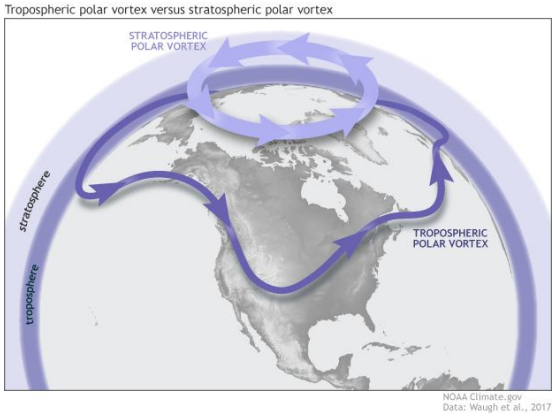
Mean seasonal total snowfall (inches)

(Midwestern Regional Climate Center)

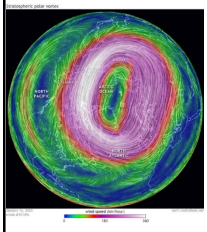
Role of the Polar Vortex?

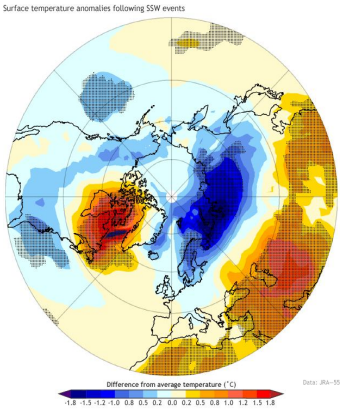


Tropospheric polar vortex versus stratospheric polar vortex



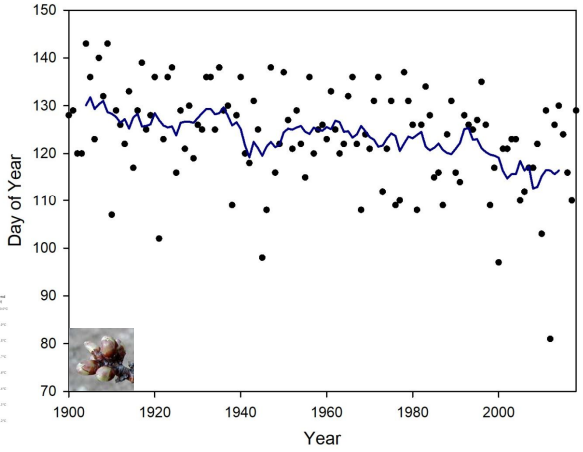
Role of the Polar Vortex?

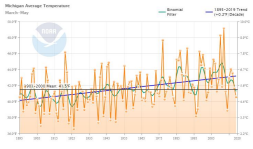




Date of Tart Cherry Side Green Stage

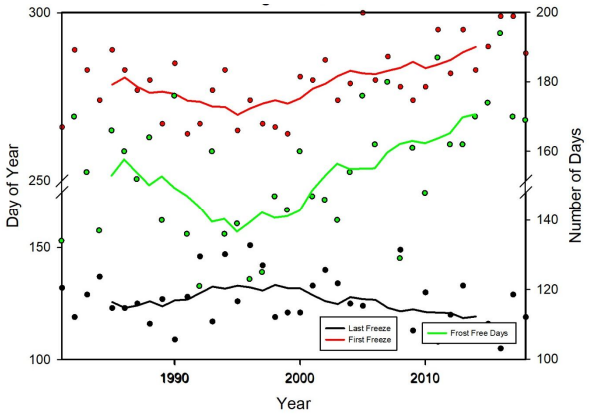
Traverse City, MI, 1900 - 2018



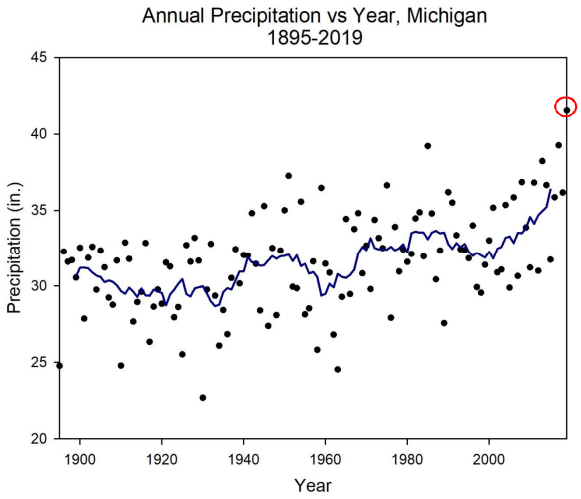


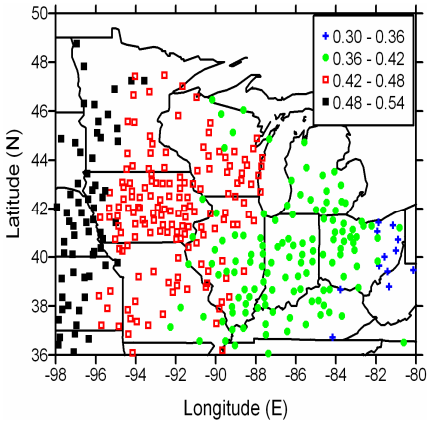
First, Last Freezes and Frost-Free Season Length

Lansing, MI, 1981-2018

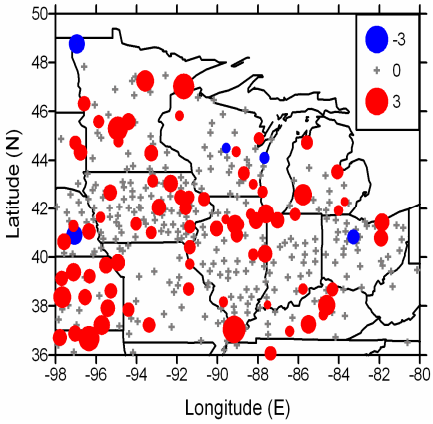


Regional climate trending wetter





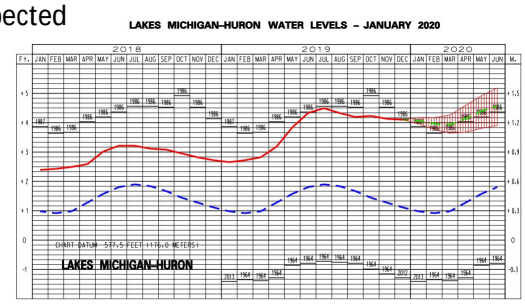
Mean fraction of annual precipitation derived from10 wettest days
1971-2000

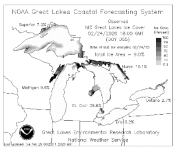


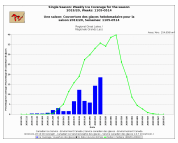
Trend in sum of the top-10 wettest days in a year (%/decade)
1901-2000

(Pryor et al., 2009)

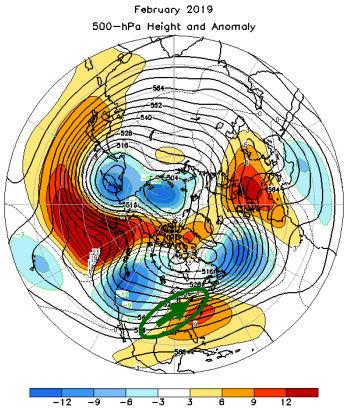
Record High Lake Water Levels Expected To Continue into the Summer







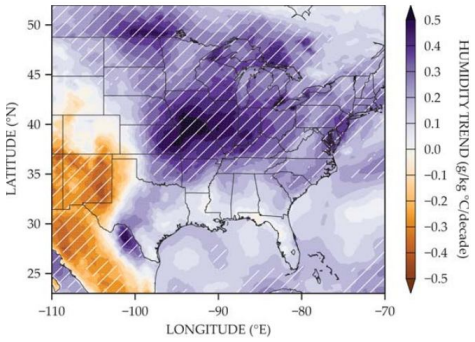
Climatic trends tend to be associated with certain upper air patterns



(Zhang et al., 2019)

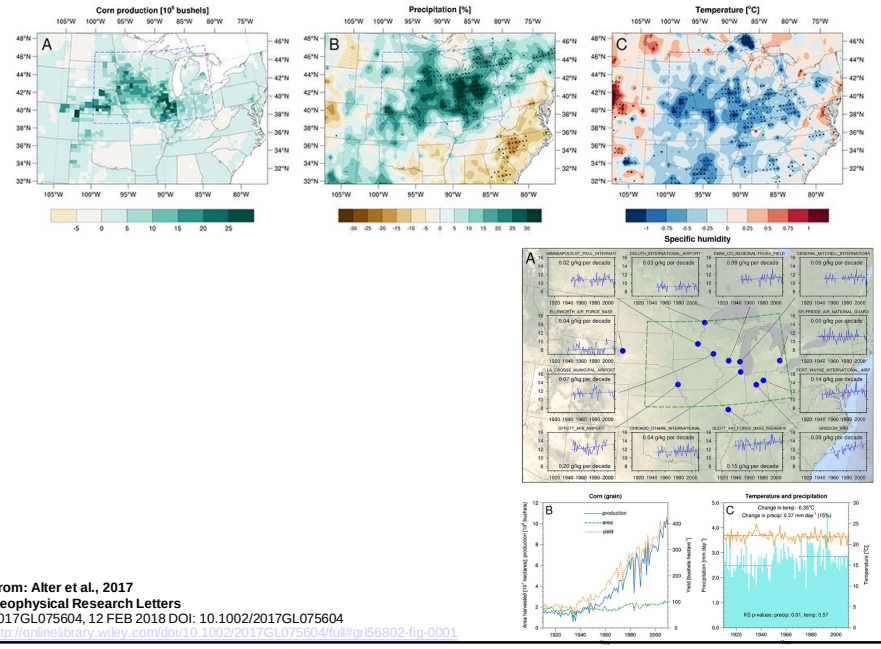
Changes in Absolute Humidity

APR-JUN, 1979-2014



(Feng et al., 2016)

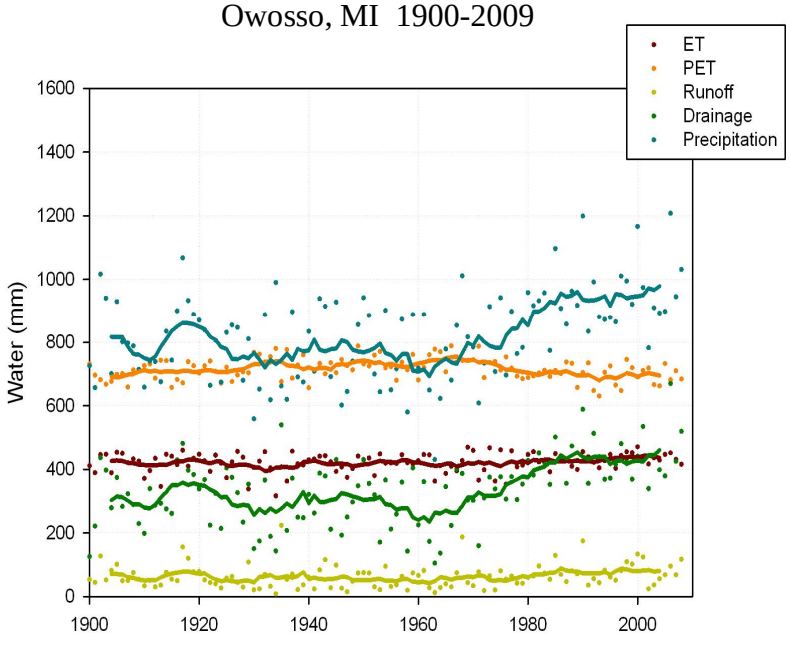
Twentieth Century Regional Climate Change During the Summer in the Central United States Attributed to Agricultural Intensification



From: Alter et al., 2017
Geophysical Research Letters
2017GL075604, 12 FEB 2018 DOI: 10.1002/2017GL075604
http://onlinelibrary.wiley.com/doi/10.1002/2017GL075604/full#grl56802-fig-0001

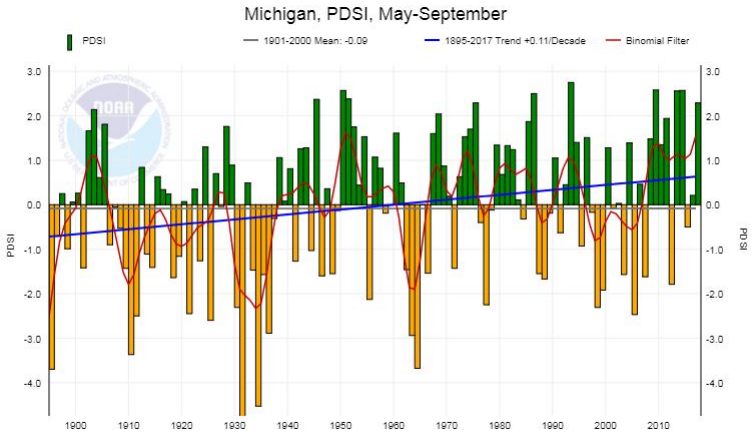
Hydrologic Variables vs. Year

Owosso, MI 1900-2009



Growing Season Drought Severity

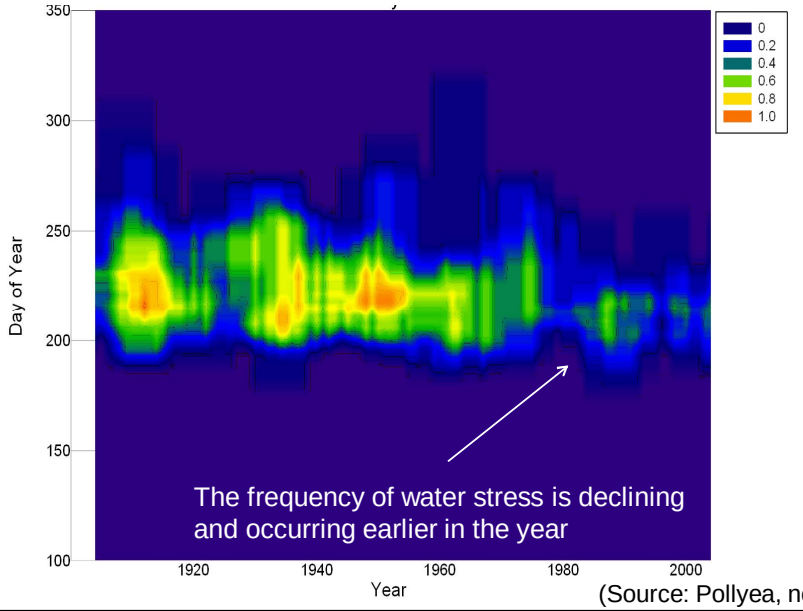
Michigan, 1895-2017



(Source: NOAA/NCEI, 2018)

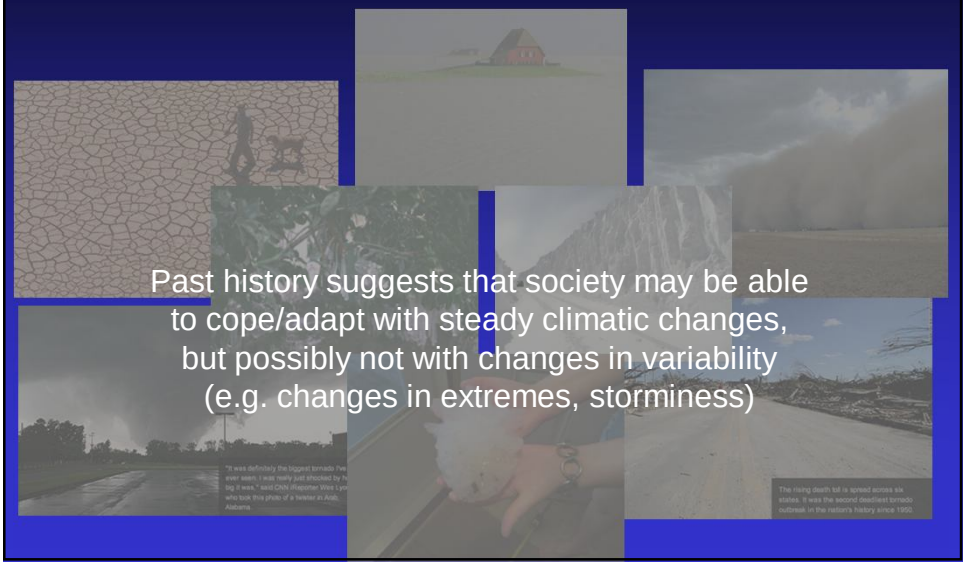
Frequency of Days PAW_{150} < 0.50 Potential PAW_{150}

Ann Arbor, MI, Silt Loam, 1900-2009

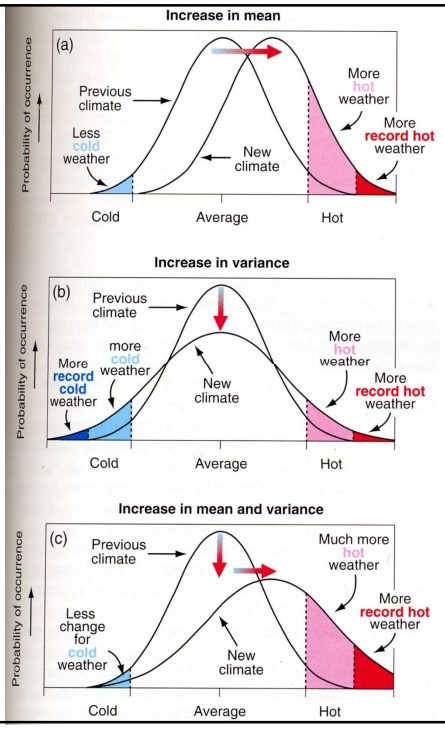


(Source: Pollyea, no date)

Impacts of Climatic Variability



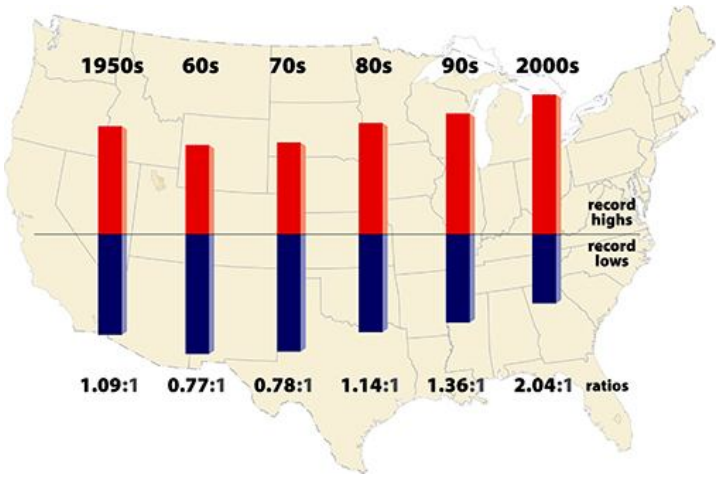
Past history suggests that society may be able to cope/adapt with steady climatic changes, but possibly not with changes in variability (e.g. changes in extremes, storminess)



Climatic changes and trends can occur as changes in:

1) the mean state
2) variability
3) both

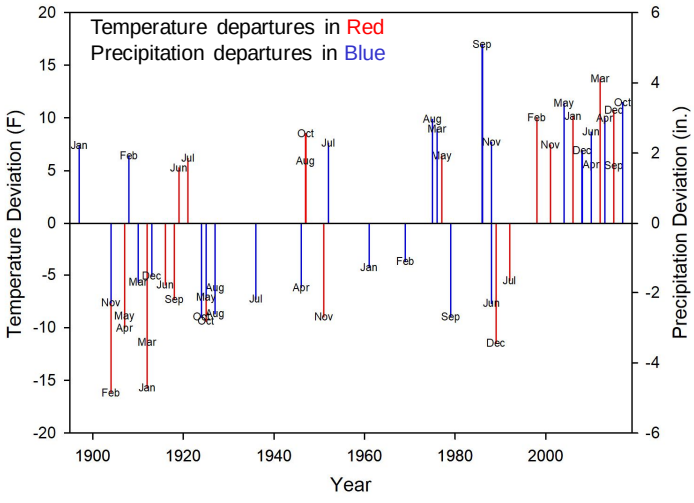
Decadal Ratios of Record Highs, Lows

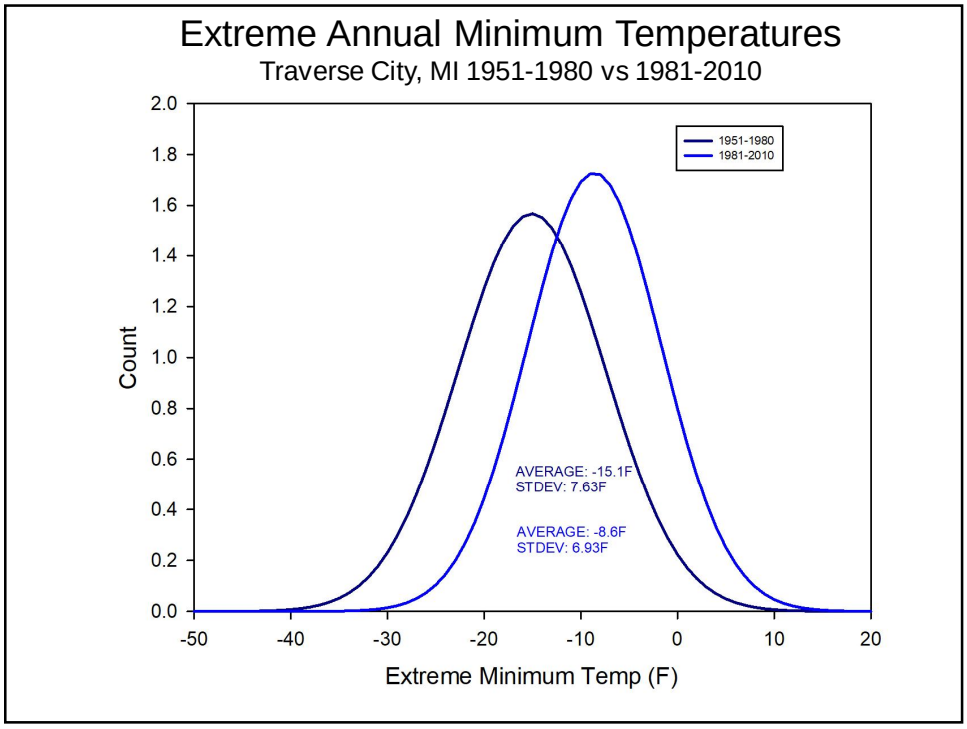


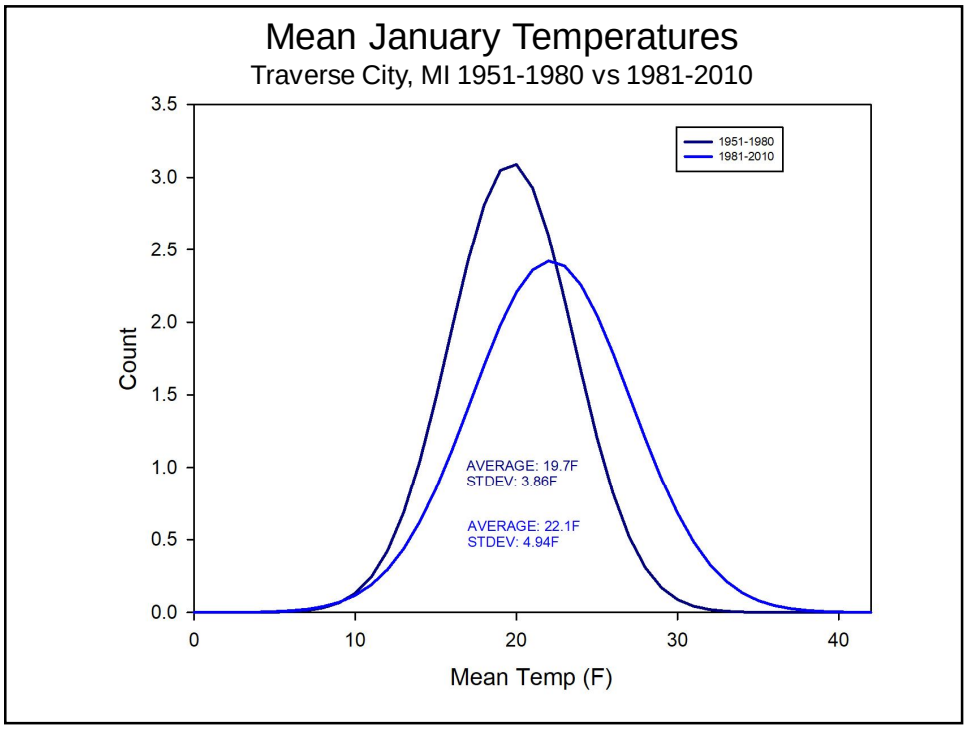
(From Meehl et al, 2009)

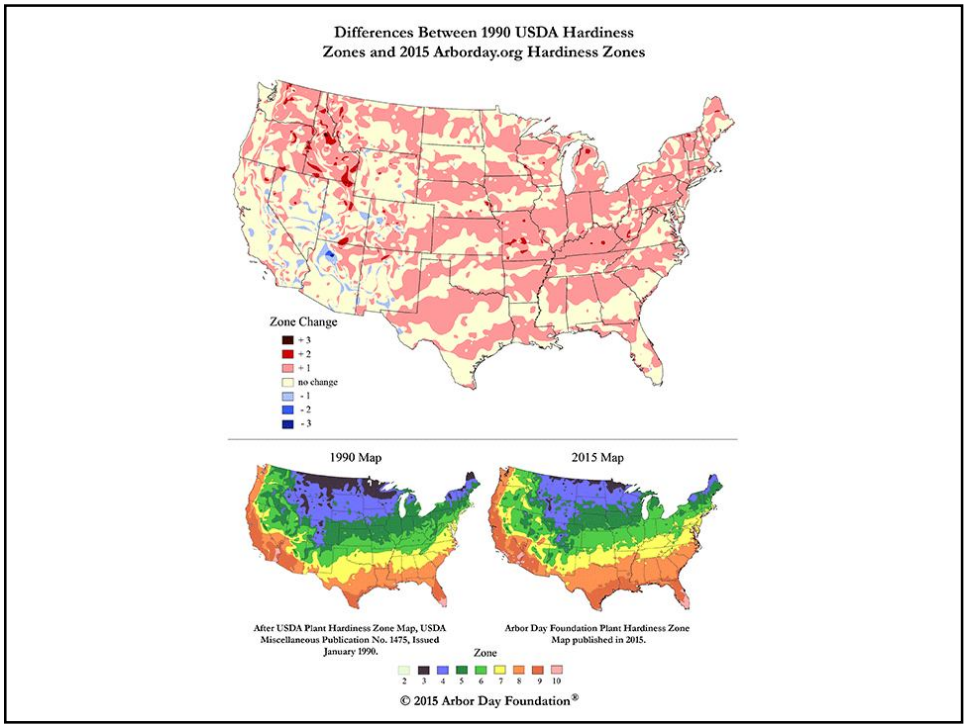
Monthly Mean Temperature and Precipitation Departure Extremes

Michigan, 1895-2019

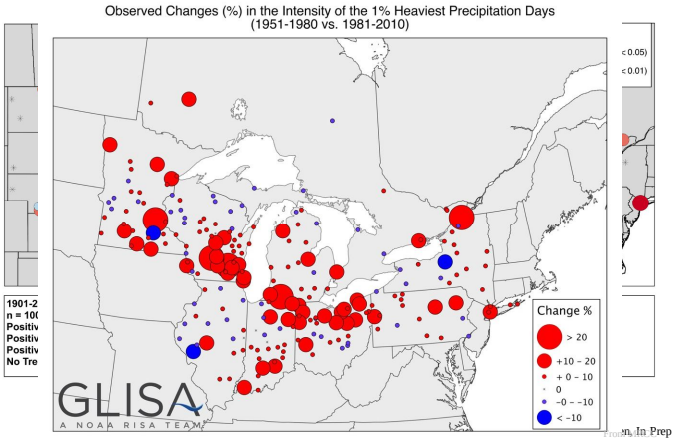



Extreme Annual Minimum Temperatures
Traverse City, MI 1951-1980 vs 1981-2010
1951-1980
1981-2010
AVERAGE: -15.1F
STDEV: 7.63F
AVERAGE: -8.6F
STDEV: 6.93F
Count
Extreme Minimum Temp (F)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-50
-40
-30
-20
-10
0
10
20


Mean January Temperatures
Traverse City, MI 1951-1980 vs 1981-2010
1951-1980
1981-2010
AVERAGE: 19.7F
STDEV: 3.86F
AVERAGE: 22.1F
STDEV: 4.94F
Count
Mean Temp (F)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40



More Heavy Precipitation



24-Hour Precipitation Totals (inches) for 2-100 Year Recurrence Intervals
Lansing, MI

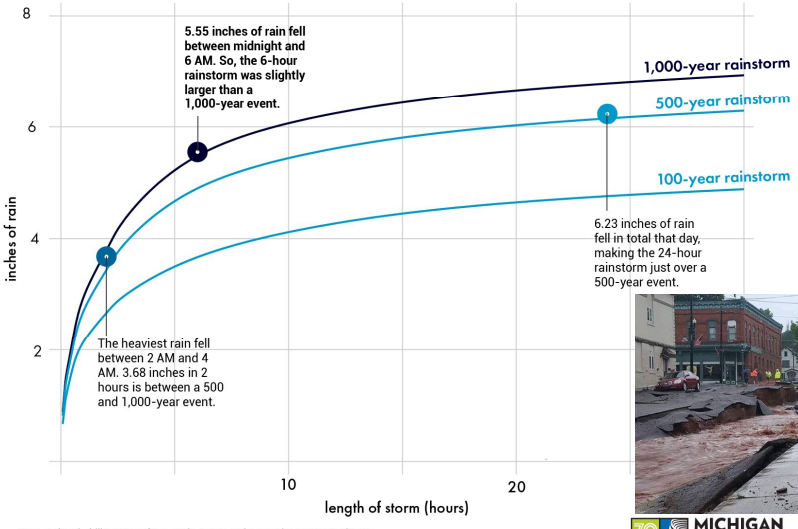
	Recurrence Interval			
	2 Year	10 Year	50 Year	100 Year
TP 40 (1938-1957)	2.35	3.70	4.45	4.80
Huff and Angel (1948-1991)	2.35	3.25	4.45	5.25
NOAA Atlas 14 Vol. 8 (POR, 2013)	2.43	3.42	4.80	5.50

How unusual was the rain during the Upper Peninsula Father's Day Floods?

The graph shows the combined rainstorm intensities and durations expected during a 100, 500, or 1,000-year rainstorm. These rainstorm probabilities are calculated using historical rainfall data.

A 1,000-year rainstorm has a 1 in 1,000 chance of occurring each year.

The circles show rainfall at the Houghton County Airport on June 17th, 2018.

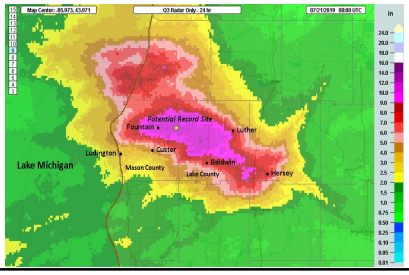


Data and probability curves from a rain gauge at the Houghton County Airport.
Source: Weather Underground and the National Oceanic and Atmospheric Administration's National Weather Service.

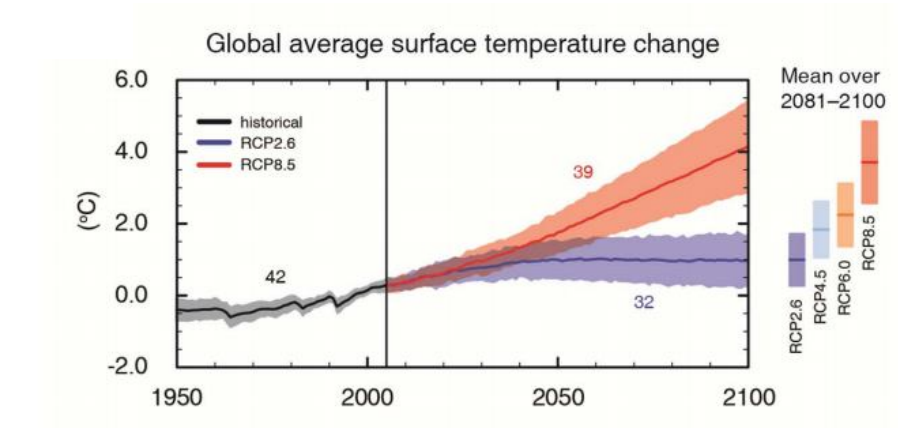
70 YEARS MICHIGAN RADIO

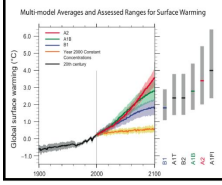
New All-Time MI 24Hr Precipitation Record

- Several rounds of training thunderstorms impacted west central Lower Michigan during the morning, afternoon, and early evening hours of July 20, 2019 with rainfall rates of 1”-3” per hour.
- The greatest observed total was 12.95” at Fountain, MI (9 mi E)
- Old Record 9.78”, August 31st, 1914 at Bloomingdale, MI

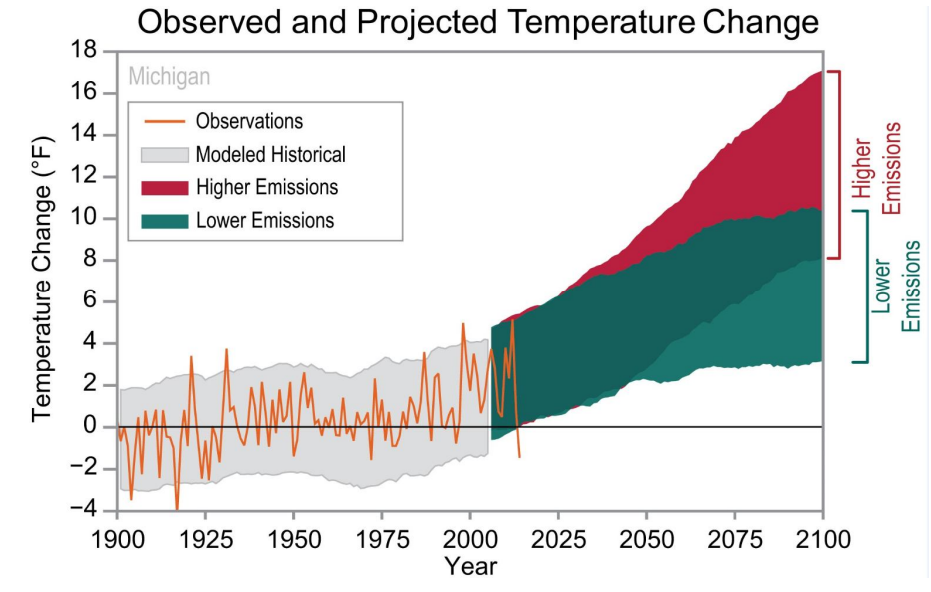


Projecting the Future: Global Climate Models (GCMs)



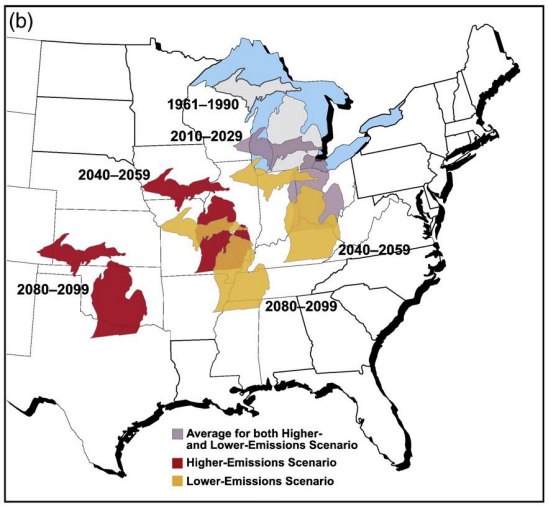


(IPCC, 2013)



(NCICS, 2017)

Projected Temperature Changes

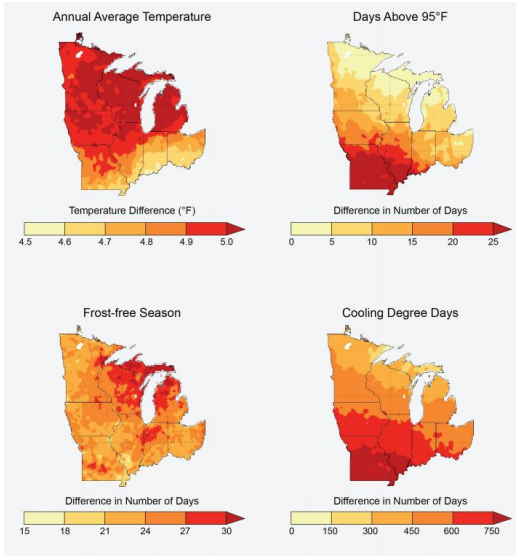


Hayhoe et al (2010)

GLISA

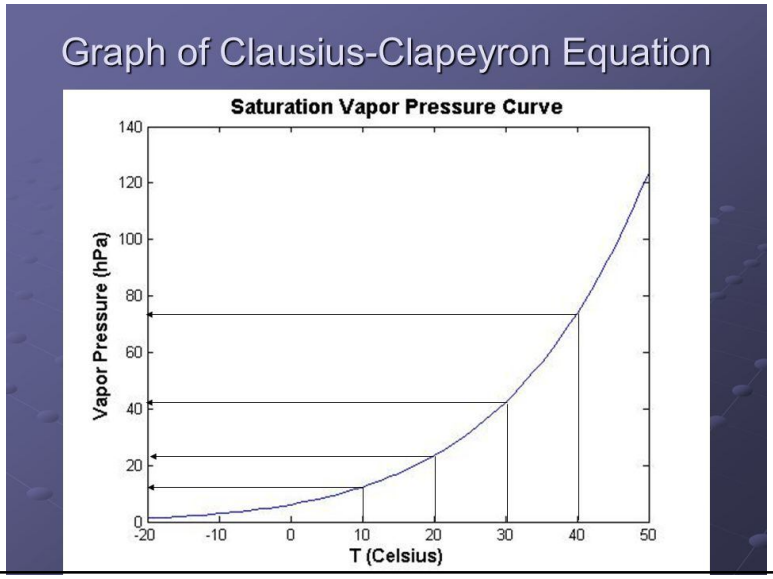
Projected Temperature-Related Changes

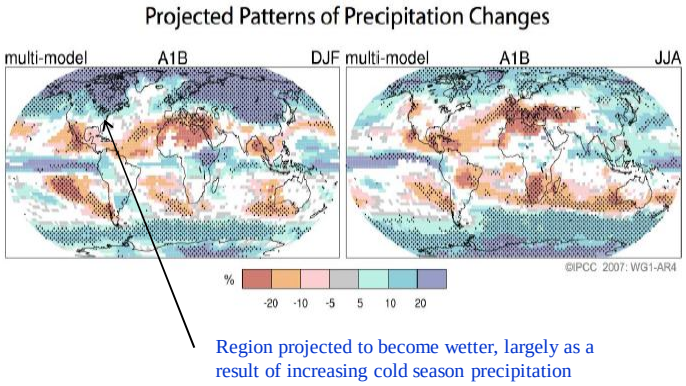
2041-2070 vs. 1971-2000



(Pryor and Scavia, 2013)

The warmer the temperature of air, the more water vapor it can potentially hold…

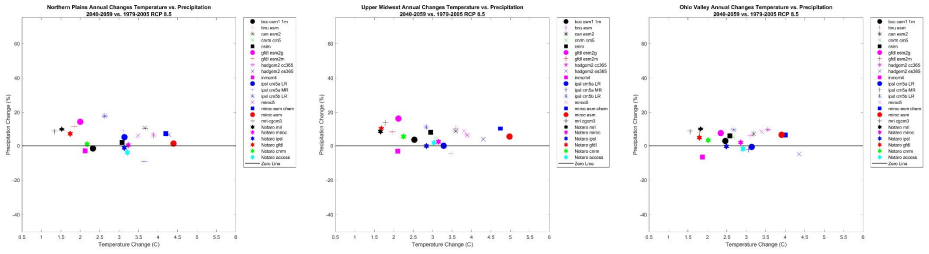




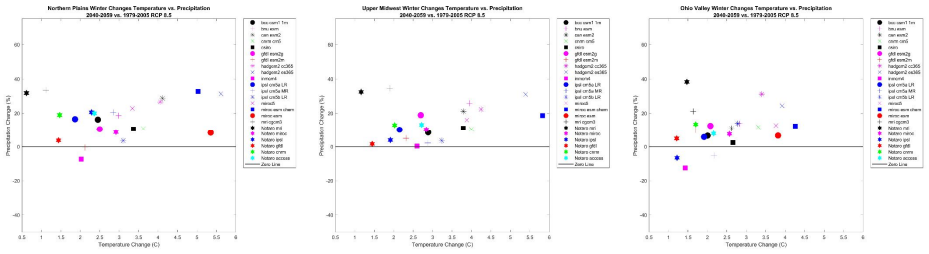
Region projected to become wetter, largely as a result of increasing cold season precipitation

Source: (IPCC, 2007)

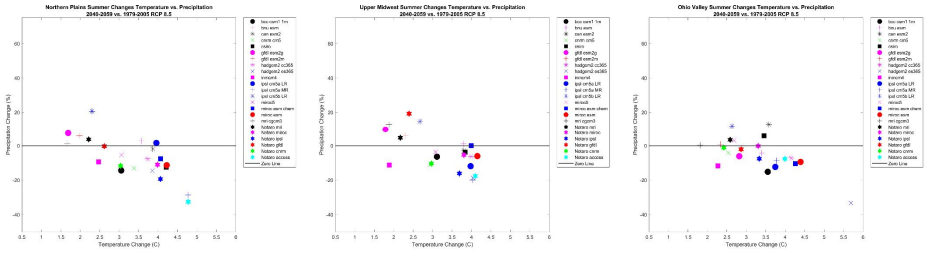
Annual



Winter



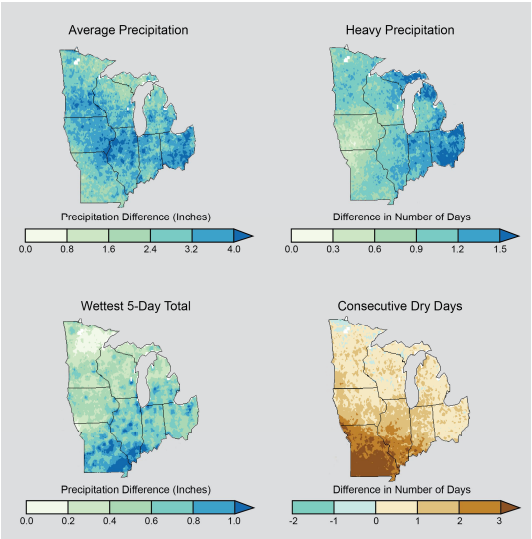
Summer



Projected Preciptation-Related Changes

2041-2070 vs. 1971-2000

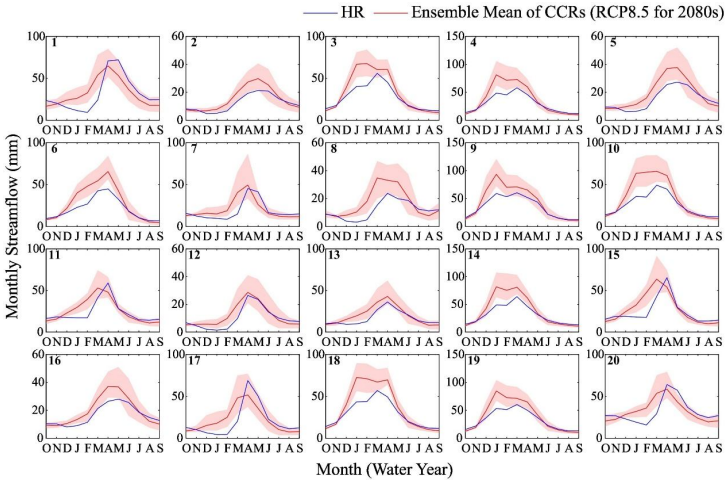
While possibly heavier, precipitation becomes more extreme and erratic



(Pryor and Scavia, 2013)

Projected Future Changes in Monthly Streamflow

Great Lakes Basin, 2071-2100 vs. Historical

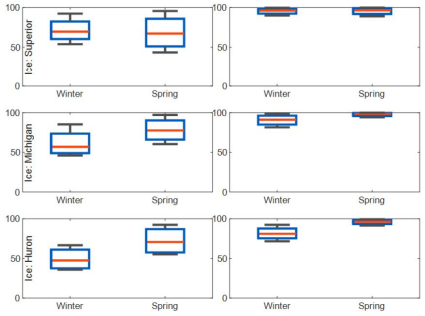


(Byun et al., 2019)

Ice cover (% loss)

All simulations for RCP8.5 (SUP, MIC, HUR)

2050 time slice 2090 time slice



(Denghan et al., 2018)

Summary

- Overall, mean average temperatures in Michigan rose approximately 1.0ºF during the past century. Warming of about 2.0ºF has occurred between 1980 and the present.
- Milder winter temperatures have led to less ice cover on the Great Lakes and the seasonal spring warm-up is occurring earlier than in the past.
- Annual precipitation rates increased from the 1930's through the present, due both to more wet days and more extreme events.
- Most recent GCM simulations of the Great Lakes region suggest a warmer and wetter climate in the distant future, with much of the additional precipitation coming during the cold season months.
- Projections of future climate change in Michigan suggest a mix of beneficial and adverse impacts. Peak daily streamflow is projected to increase with shifts towards earlier peak flow timing. Extreme low soil moisture increases by mid-century, but decreases by late century.
- Given the projected rate of climate change, adaptive planning strategies should be dynamic in nature.