Trends in U.S. Climate & Weather

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OSU Extension | Byrd Polar and Climate Research Center

State Climate Office of Ohio

2019 Summer Agricultural Outlook Conference

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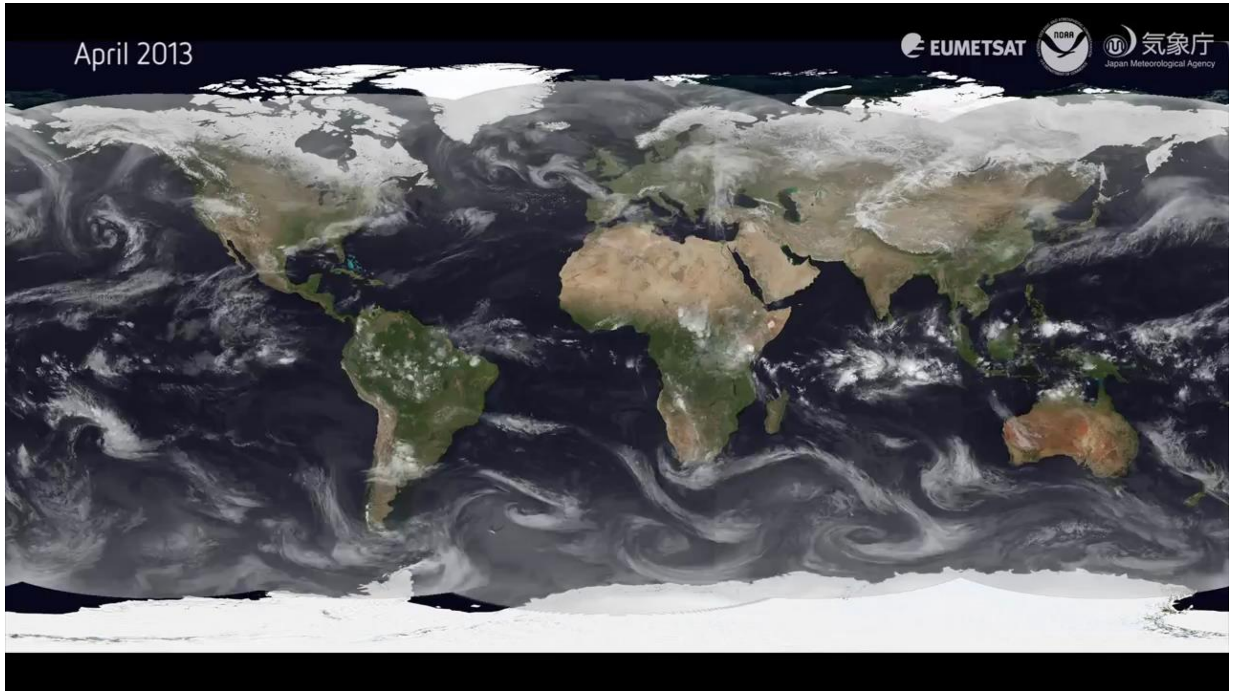
THE OHIO STATE UNIVERSITY

COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

Weather and Climate



Weather: High-frequency changes in temperature, wind speed, etc; Caused by imbalance of energy across the globe.

Climate: Slower-varying aspects; Averages over longer periods.

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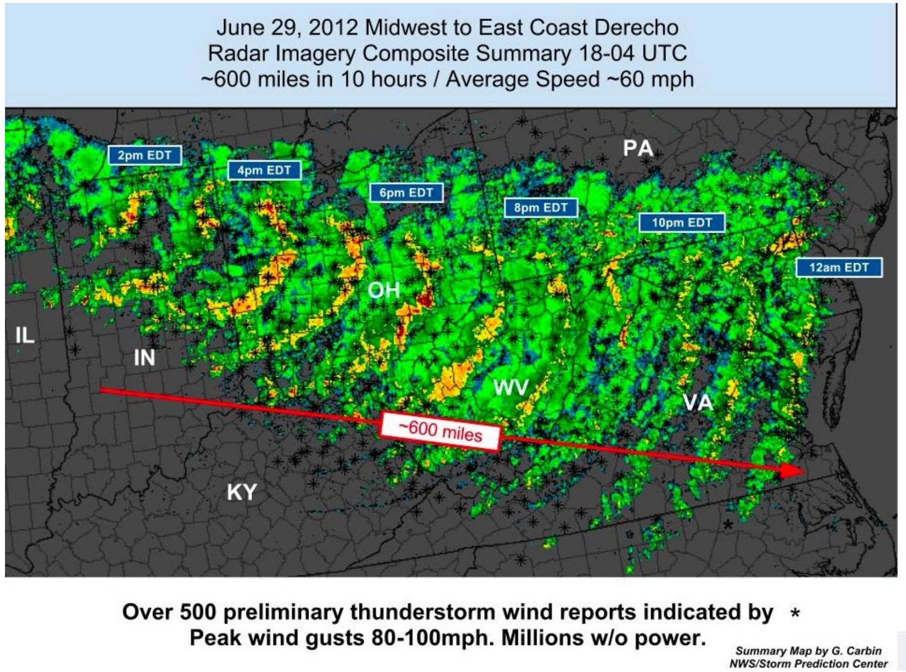
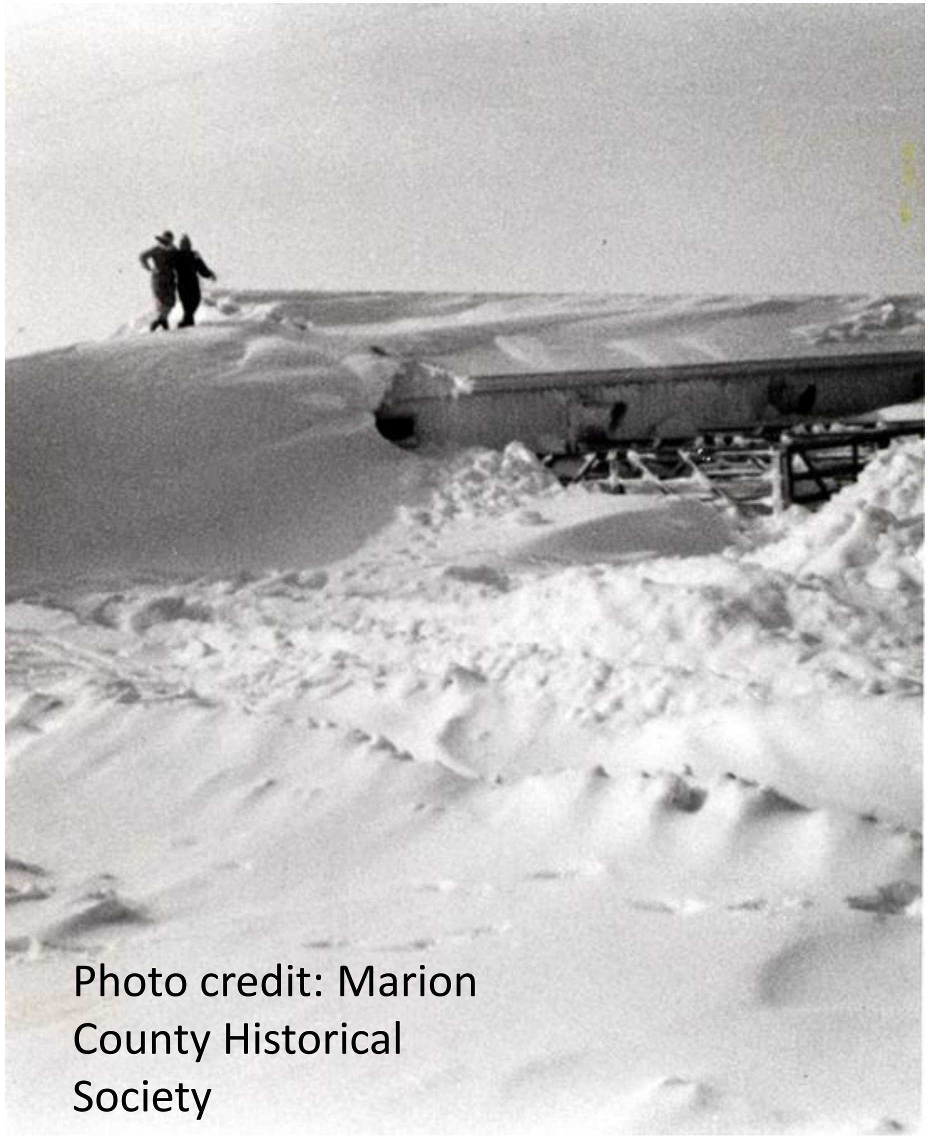
The Power of Weather





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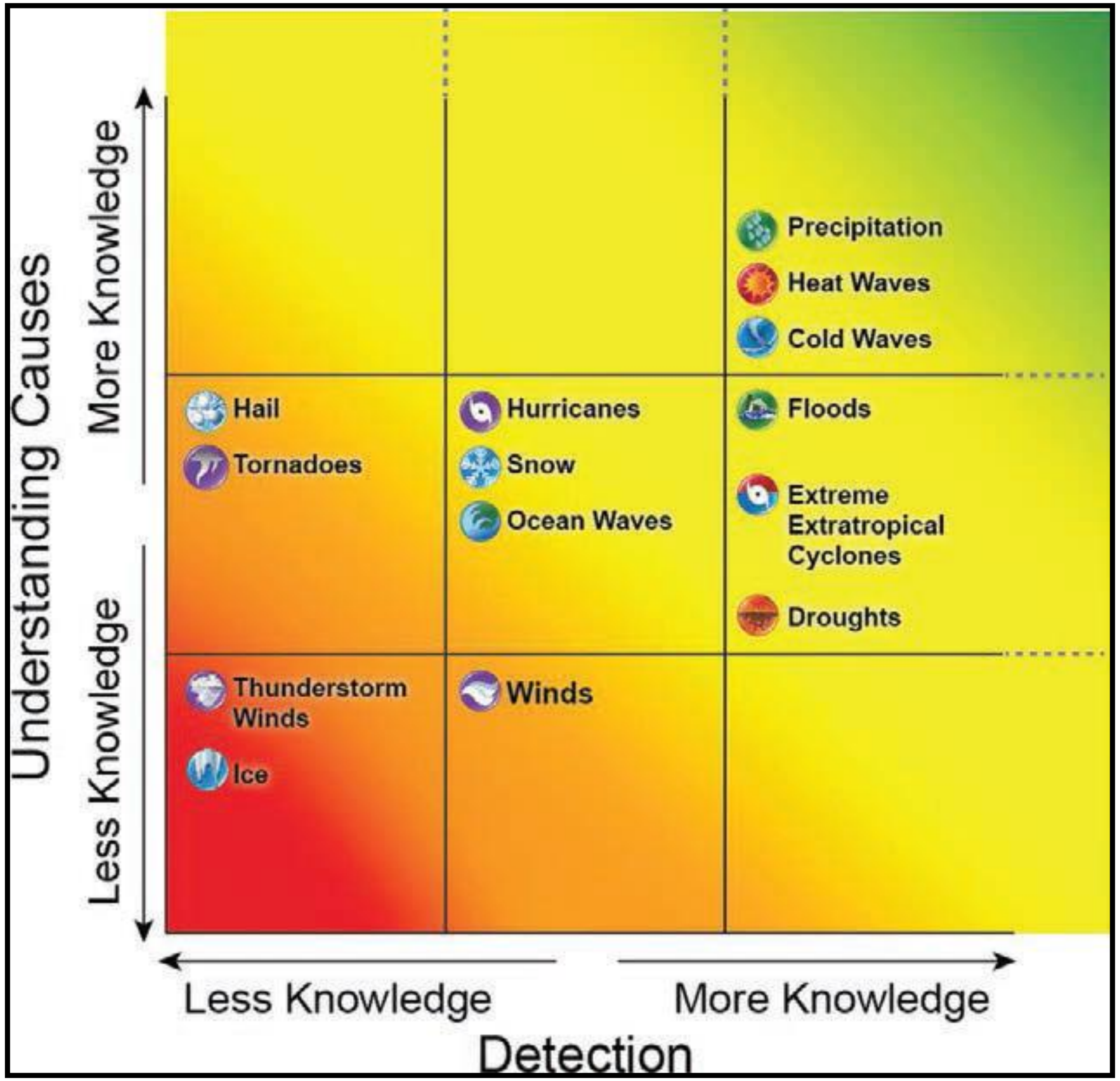
Detecting Weather Extremes



D Wuebbles et al. , 2014: CMIP5 Climate Model Analyses: Climate Extremes in the United States. *Bull. Amer. Meteor. Soc.*, **95**, 571–583, doi: 10.1175/BAMS-D-12-00172.1

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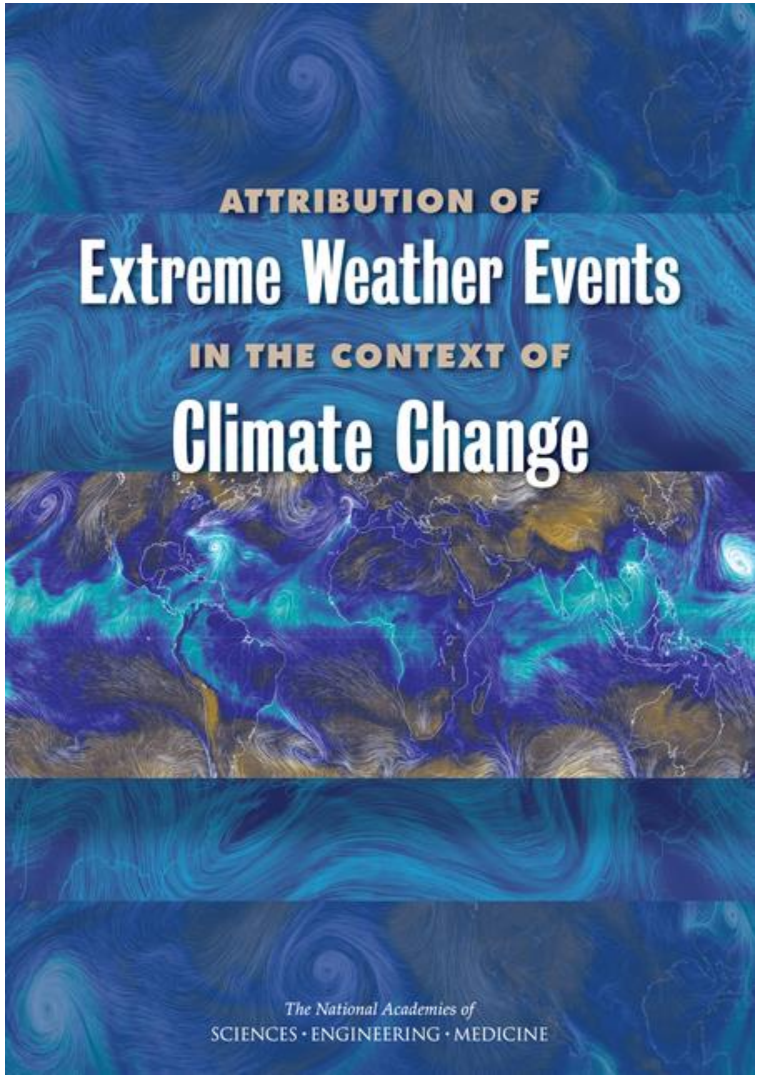
Have to Ask the Right Questions!

"Did climate change cause a particular event to occur?"

Bad Question!

"Are events of this severity becoming more or less likely because of climate change?"

"To what extent was the storm intensified or weakened, or its precipitation increased or decreased, because of climate change?"



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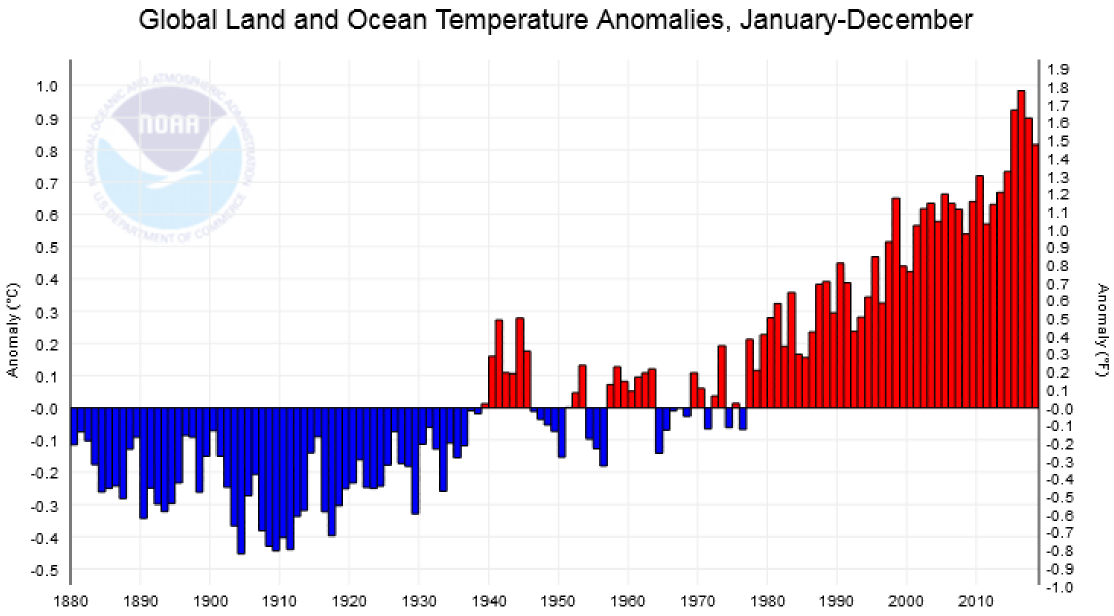
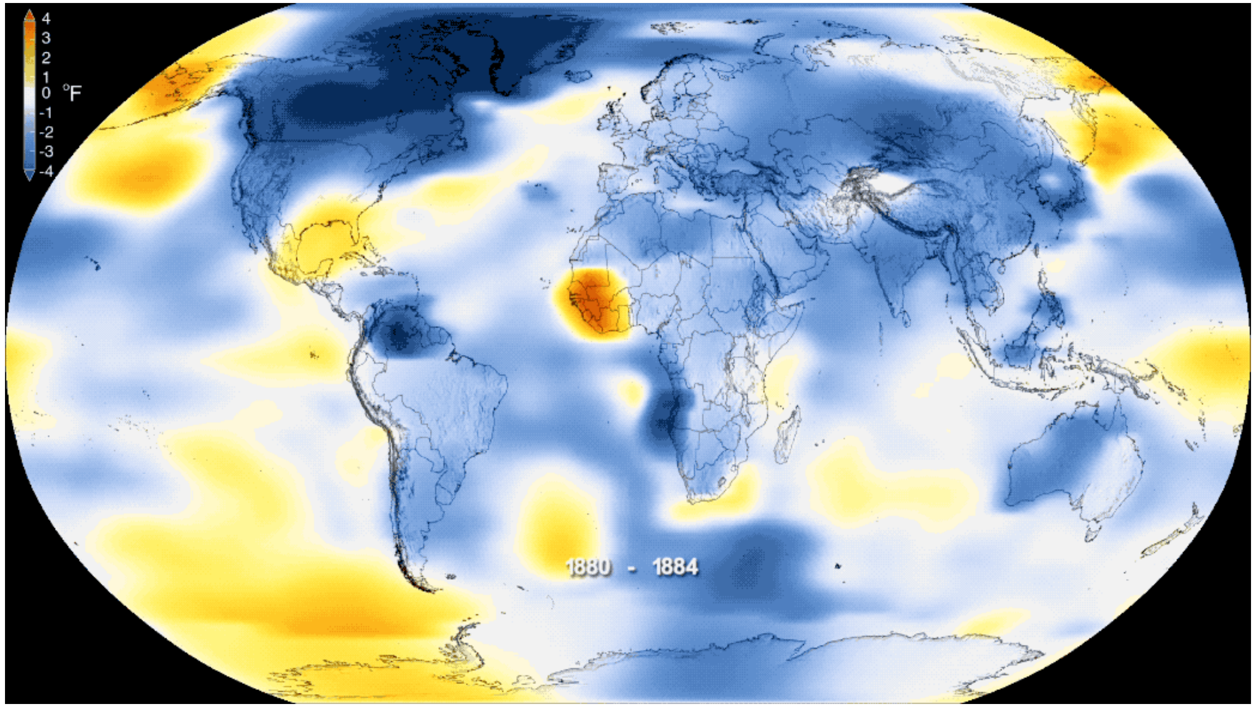
Global Temperatures Have Warmed





- 2018 Ranks as the 4th Warmest since 1880
- 9 out of the top 10 warmest years have occurred since 2005

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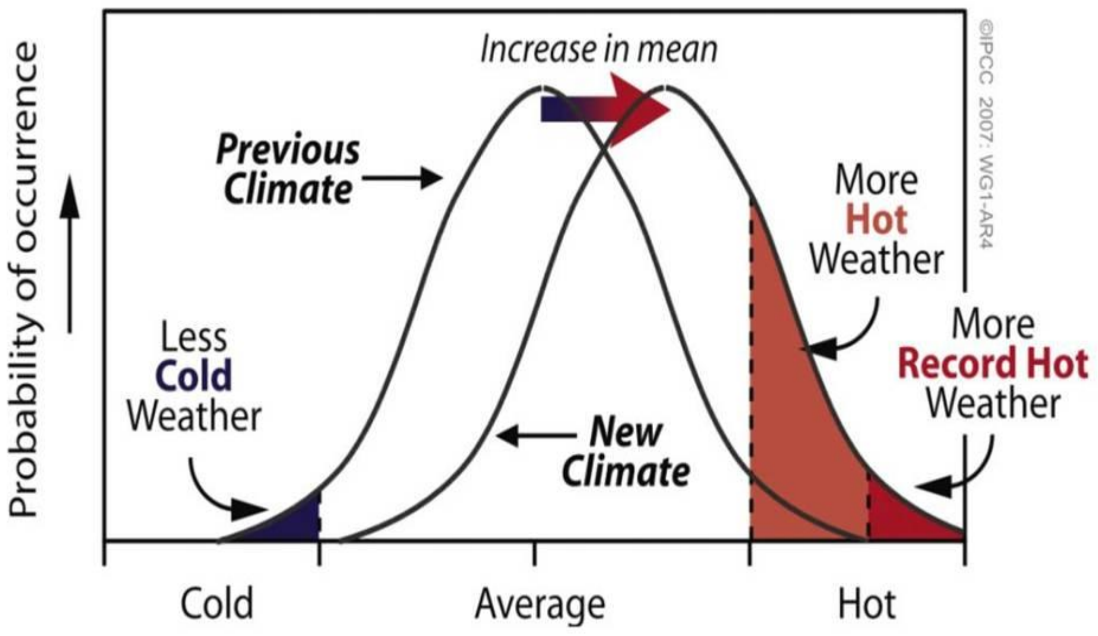
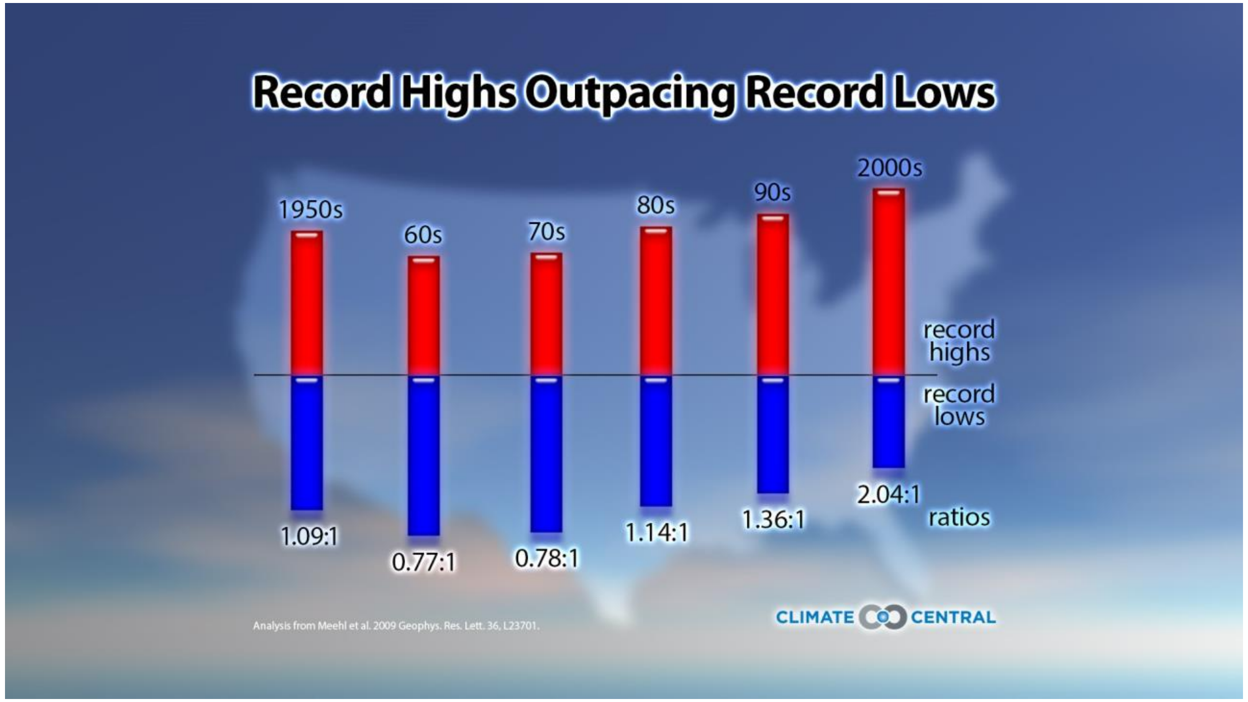
Impact: Record Warmth





Period	High Max	High Min	Low Max	Low Min
Last 7 Days	179	581	83	29
Last 30 Days	731	2585	583	1005
Last 365 Days	12814	27174	23028	12819

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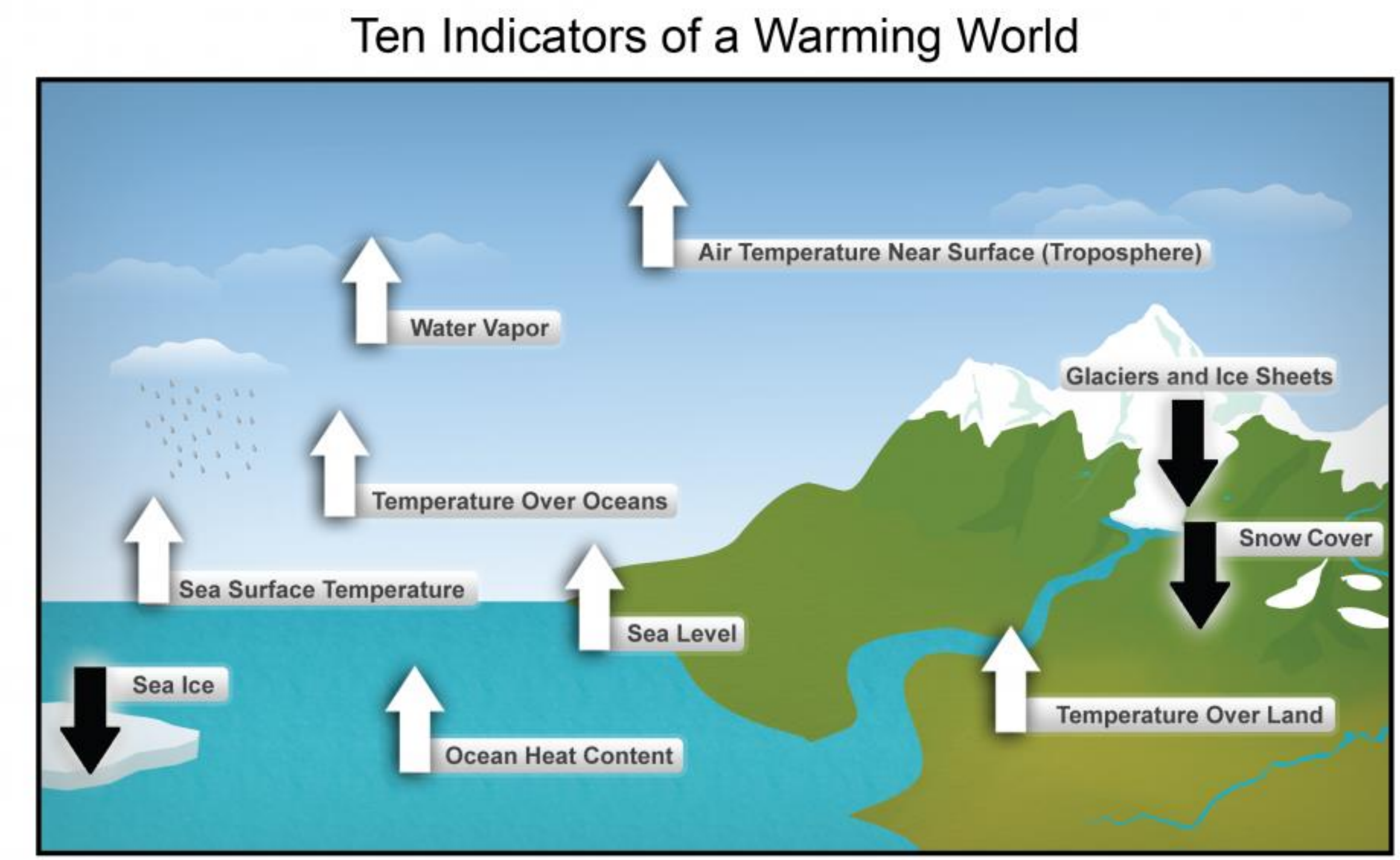
Warming Temperatures Have Feedbacks



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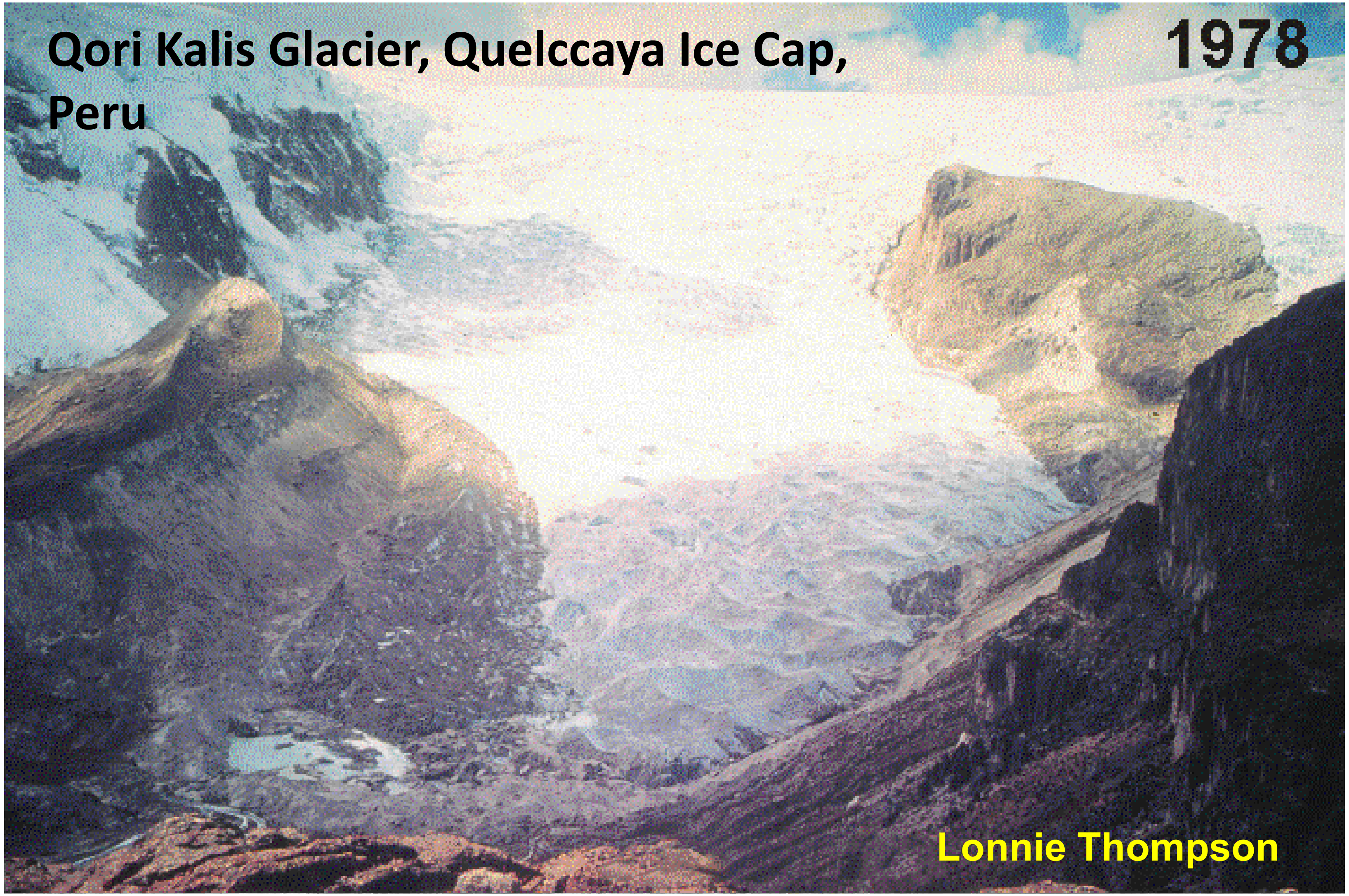
Global Evidence: The Loss of Glaciers



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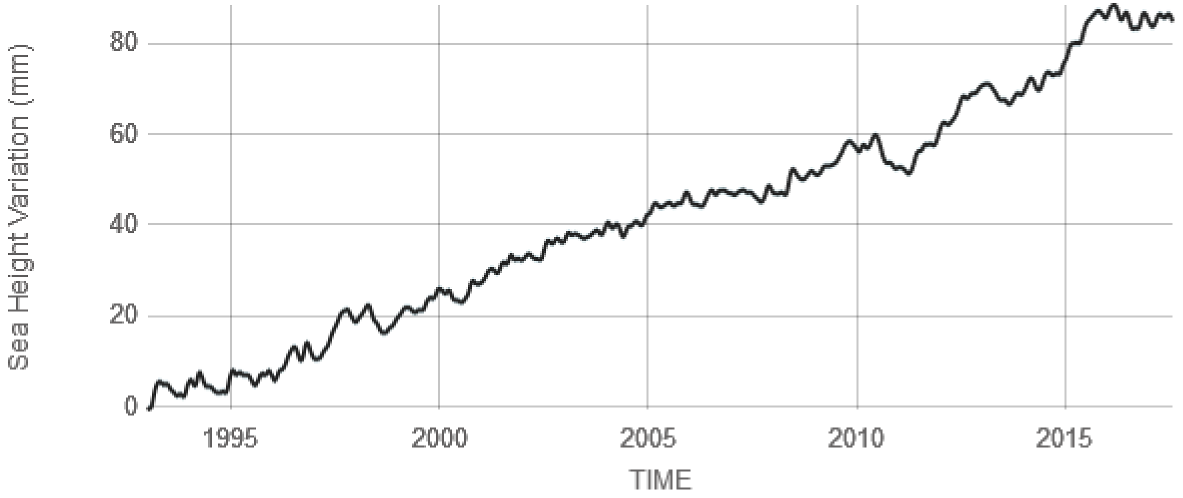
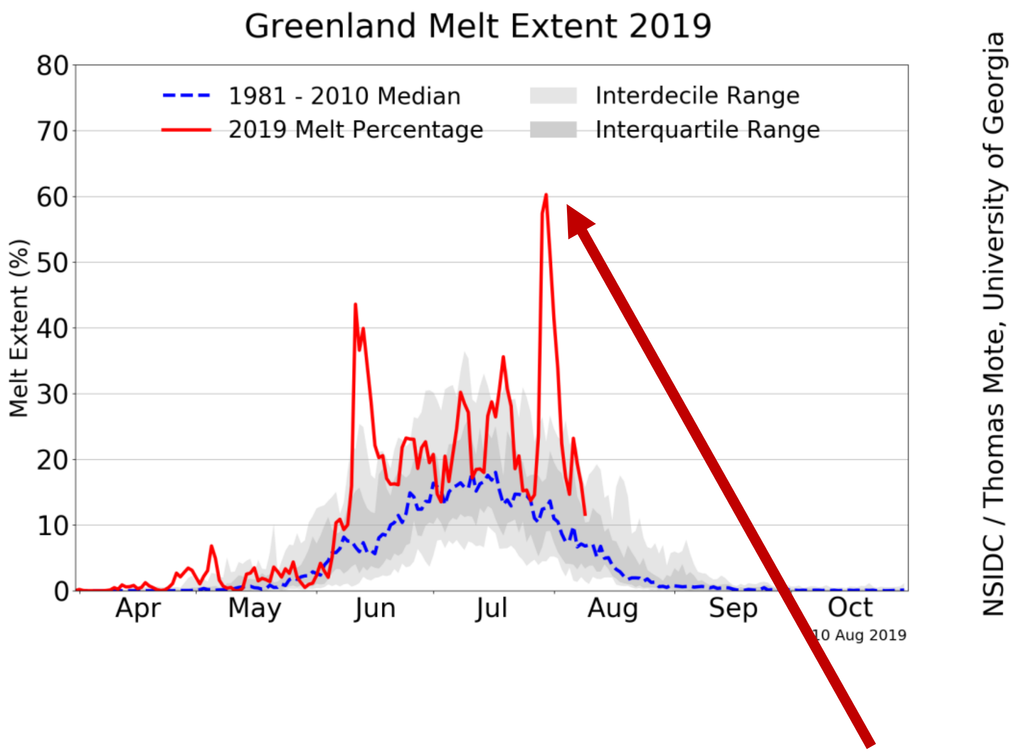
Global Evidence: Sea Level Rise

https://climate.nasa.gov/vital-signs/sea-level/



Source: climate.nasa.gov

Credit: NOAA



4.4 Million Olympic-sized swimming pools!

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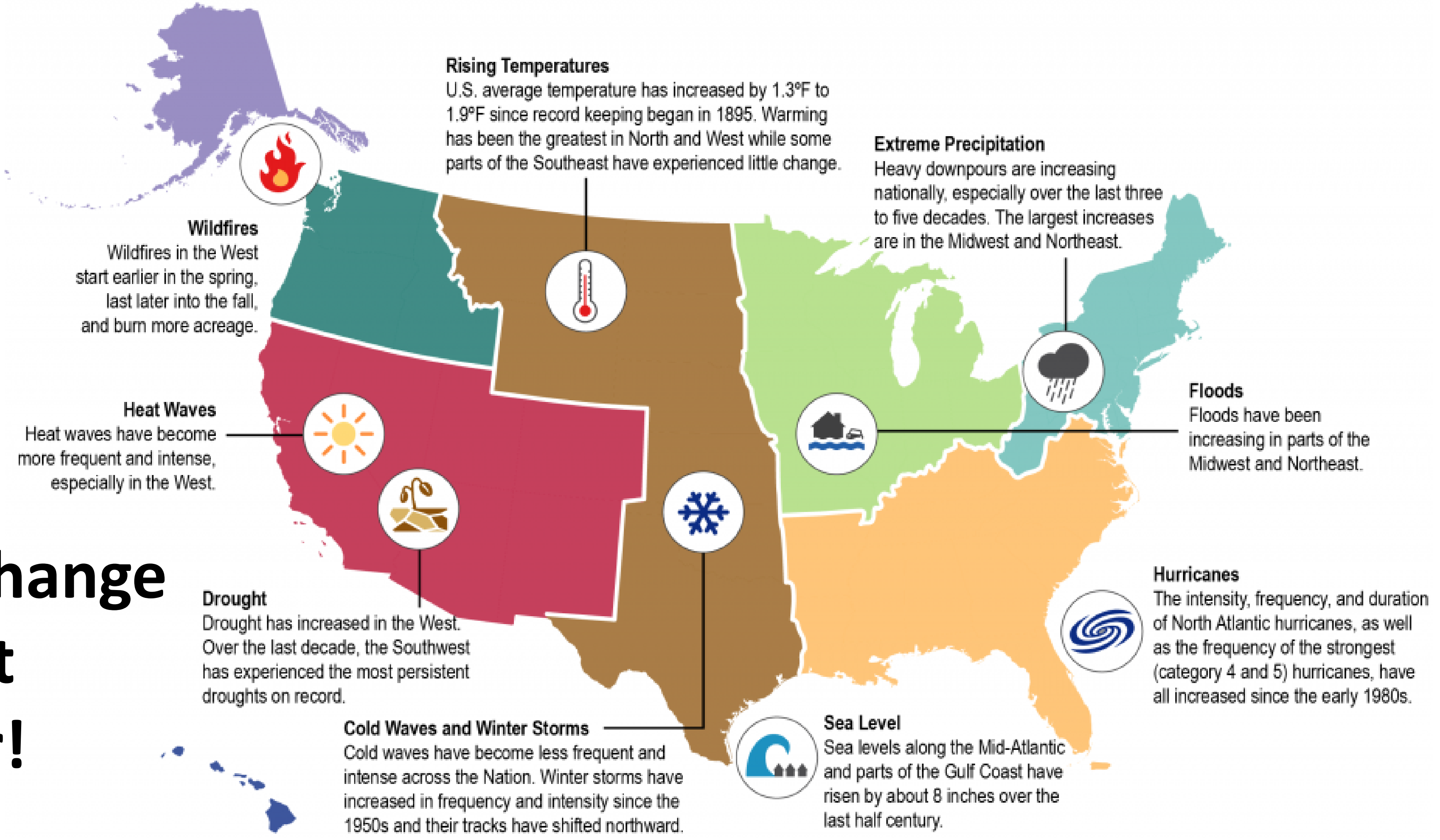
U.S. Regional Climate Trend Impacts



Climate Change is a Threat Multiplier!

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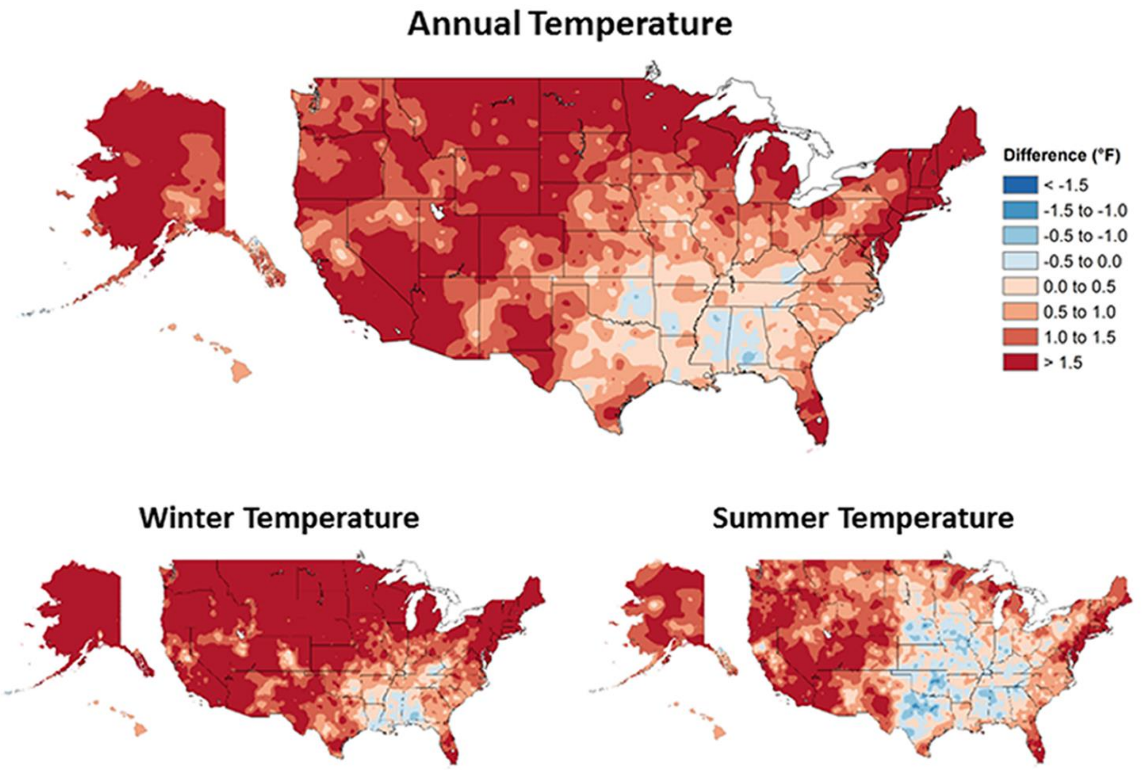
https://health2016.globalchange.gov/climate-change-and-human-health

Annual/Seasonal Temperature Trends



- More than 95% of the land surface demonstrated an increase in annual average temperature
- Paleoclimate records suggest recent period the warmest in at least the past 1,500 years
- Greatest and most widespread in winter

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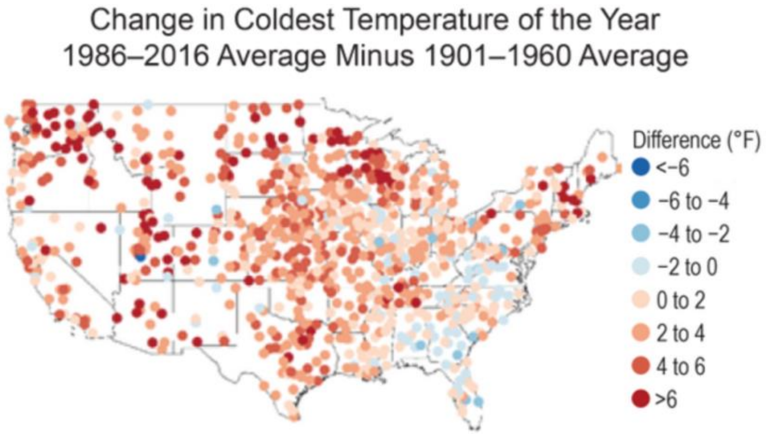
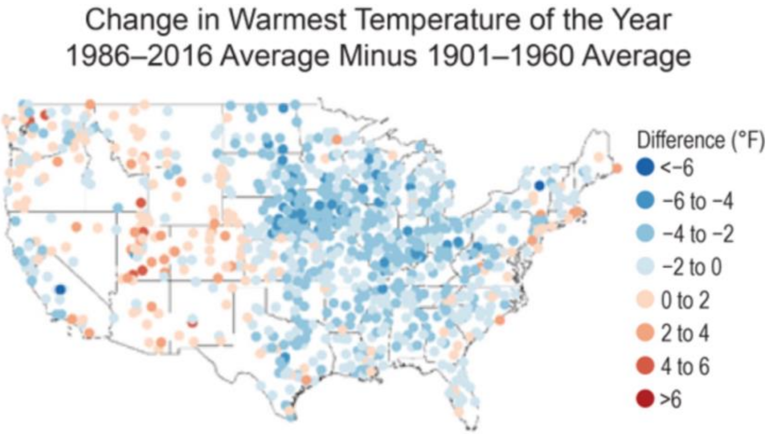
Annual average temperature over the contiguous United States has increased by 1.2°F (0.7°C) for the period 1986–2016 relative to 1901–1960 and by 1.8°F (1.0°C) based on a linear regression for the period 1895–2016: National Climate Assessment CCSR: https://science2017.globalchange.gov/

Are Summers Getting Cooler?

- The 1930s Dust Bowl era
- Agricultural intensification may have suppressed the hottest extremes in the Midwest. (Muller et al, 2016: Nature Climate Change; Science http://www.sciencemag.org/news/2018/02/america-s-corn-belt-making-its-own-weather)





https://science2017.globalchange.gov/chapter/6/

Maximum (maxT) and minimum (minT) temperature records set in 2018

Location	highest maxT	lowest maxT	Ratio	highest minT	lowest minT	Ratio
Cincinnati	4	2	2.00	6	2	3.00
Cleveland	6	0	> 6.00	11	0	> 11.00
Columbus	1	3	0.33	12	0	> 12.00
Toledo	5	1	5.00	7	0	> 7.00
Youngstown	6	4	1.50	9	2	4.50

Thanks to Jim DeGrand

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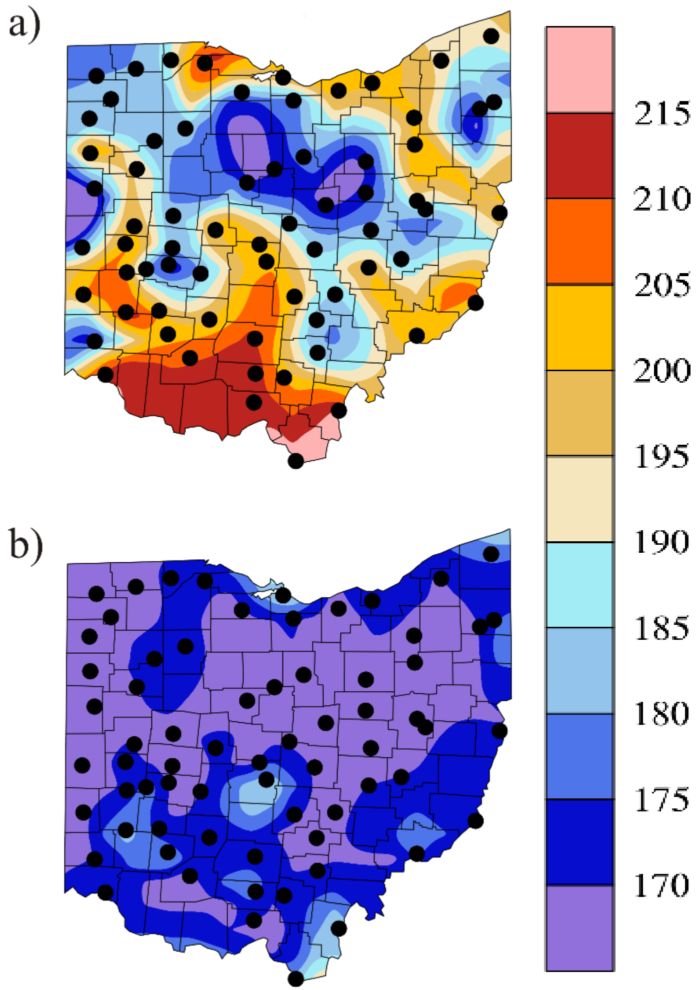
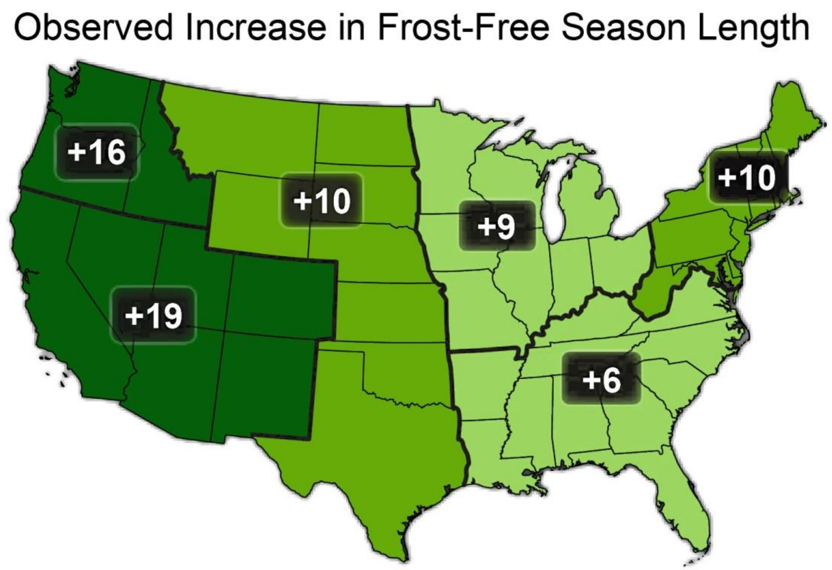
Growing Season Overview: Season Length



- Last frost date (32°F): Apr 21 and May 1
- First frost date (32°F):Oct 16 and 25
- Spatially, the patterns are consistent with the topography and infrastructure of Ohio.
- Growing season length approximately 10 days longer than the long-term median and is consistent with the climate trends



Growing season length defined by the number of days between minimum temperature observations of a) 28°F and b) 32°F. Black dots represent station locations used to spatially interpolate across the state.

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Temperature Impacts

- Additional (sustained) stress on humans and livestock; Increased need for adequate cooling
- Pollination and grain, fiber, or fruit production sensitive to high temperatures – lower productivity and reduced quality
- Shifting growing zones (subtropical vs temperature varieties)
- Increased weed pressure, insects, and potential disease
- Increased extremes elevate potential risk to crop failure

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Other Concerns

- Higher average temperatures and shifting precipitation patterns are causing plants to bloom earlier, creating unpredictable growing seasons.
- Invasive, non-native plants and animals' ranges are expanding and making them more apt to take advantage of weakened ecosystems and outcompete native species. (e.g., kudzu, garlic mustard, and purple loosestrife).
- Native and iconic plants may no longer be able to survive in portions of their historic range. (e.g., Ohio without the Ohio buckeye)
- Important connections between pollinators, breeding birds, insects, and other wildlife and the plants they depend on will be disrupted. Pollinators such as hummingbirds and bees may arrive either too early or too late to feed on the flowers on which they normally rely.

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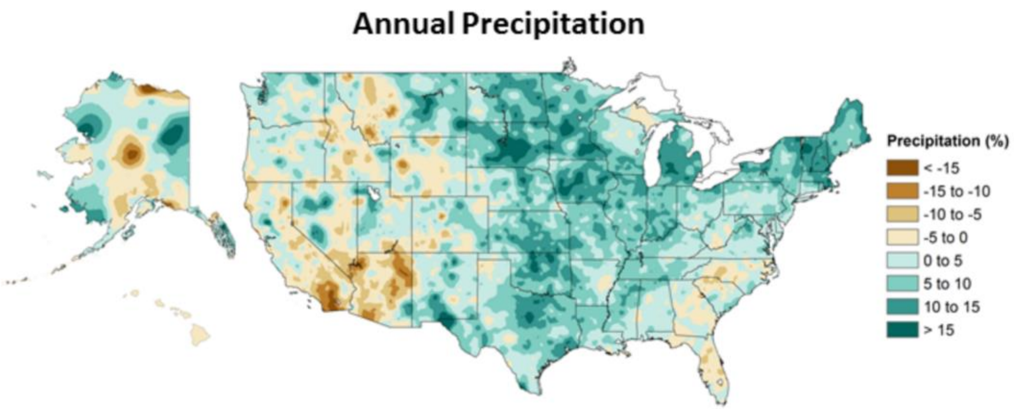
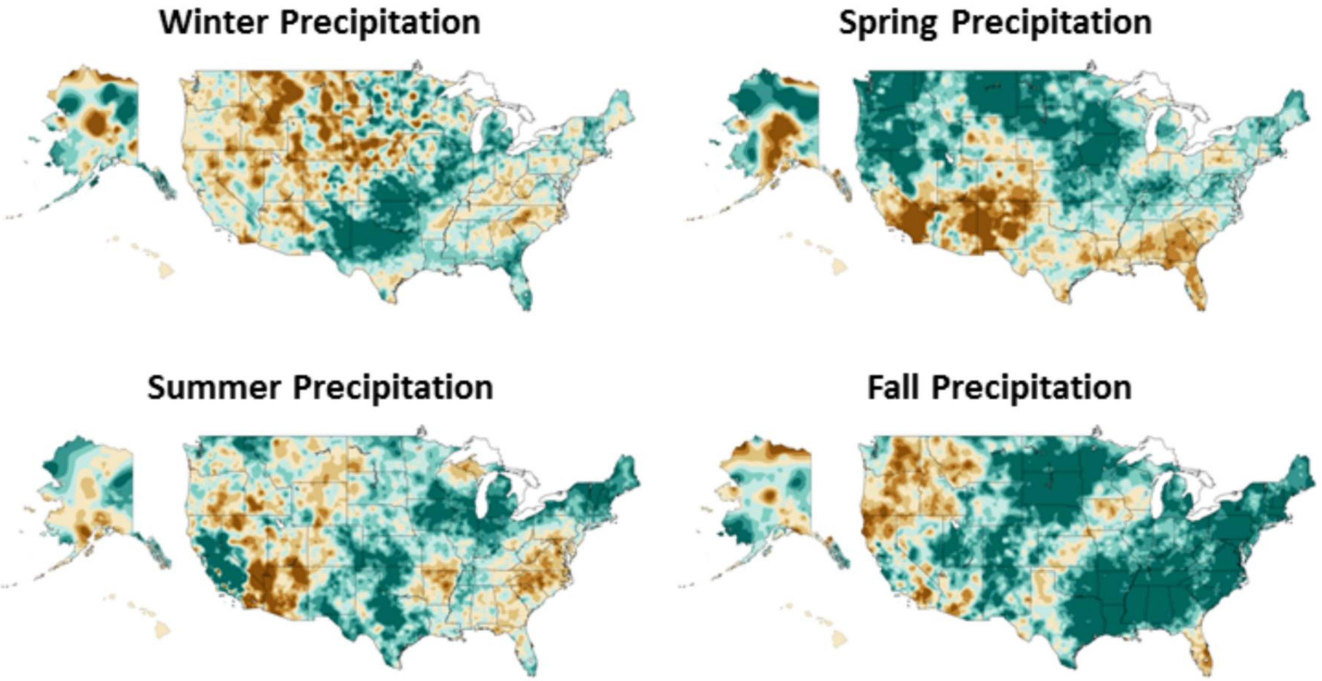
NWF: https://www.nwf.org/Our-Work/Environmental-Threats/Climate-Change/Greenhouse-Gases/Gardening-for-Climate-Change

Precipitation Trends: Annual and Seasonal





National Climate Assessment CCSR:
https://science2017.globalchange.gov/

- National average increase of 4% in annual precipitation since 1901: Ohio: 5-15%
- Driven strongly by fall trends (10-15% in some locations)
  - Regional Spring, Summer, and Fall Trends across Ohio
  - Increased Intensity of rainfall events

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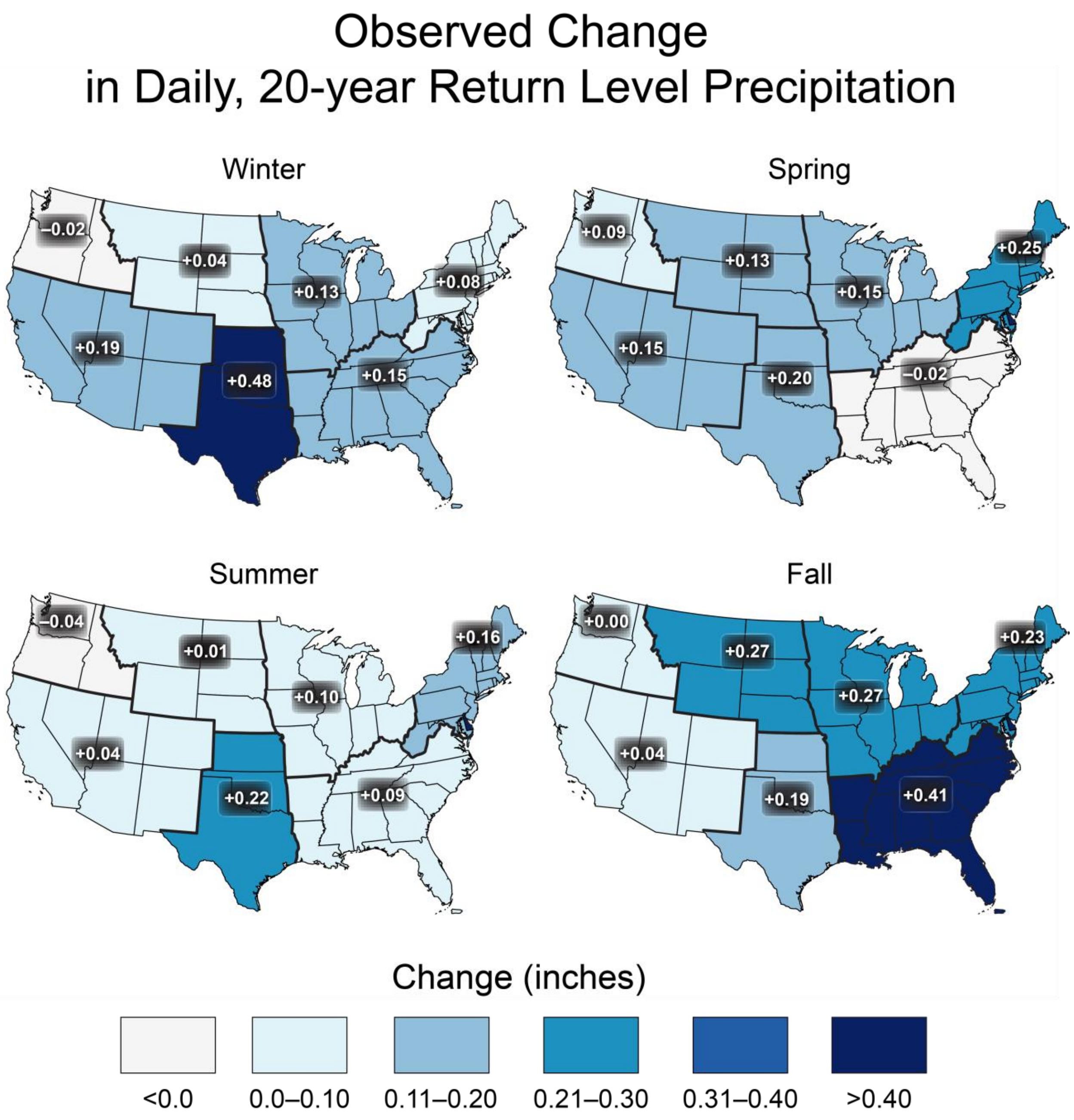
Observed changes in extreme precipitation

- Extreme precipitation events are generally observed to increase in intensity by about 6% to 7% for each degree Celsius of temperature increase.

- Change in seasonal maximum 1-day precipitation (1948-2015)



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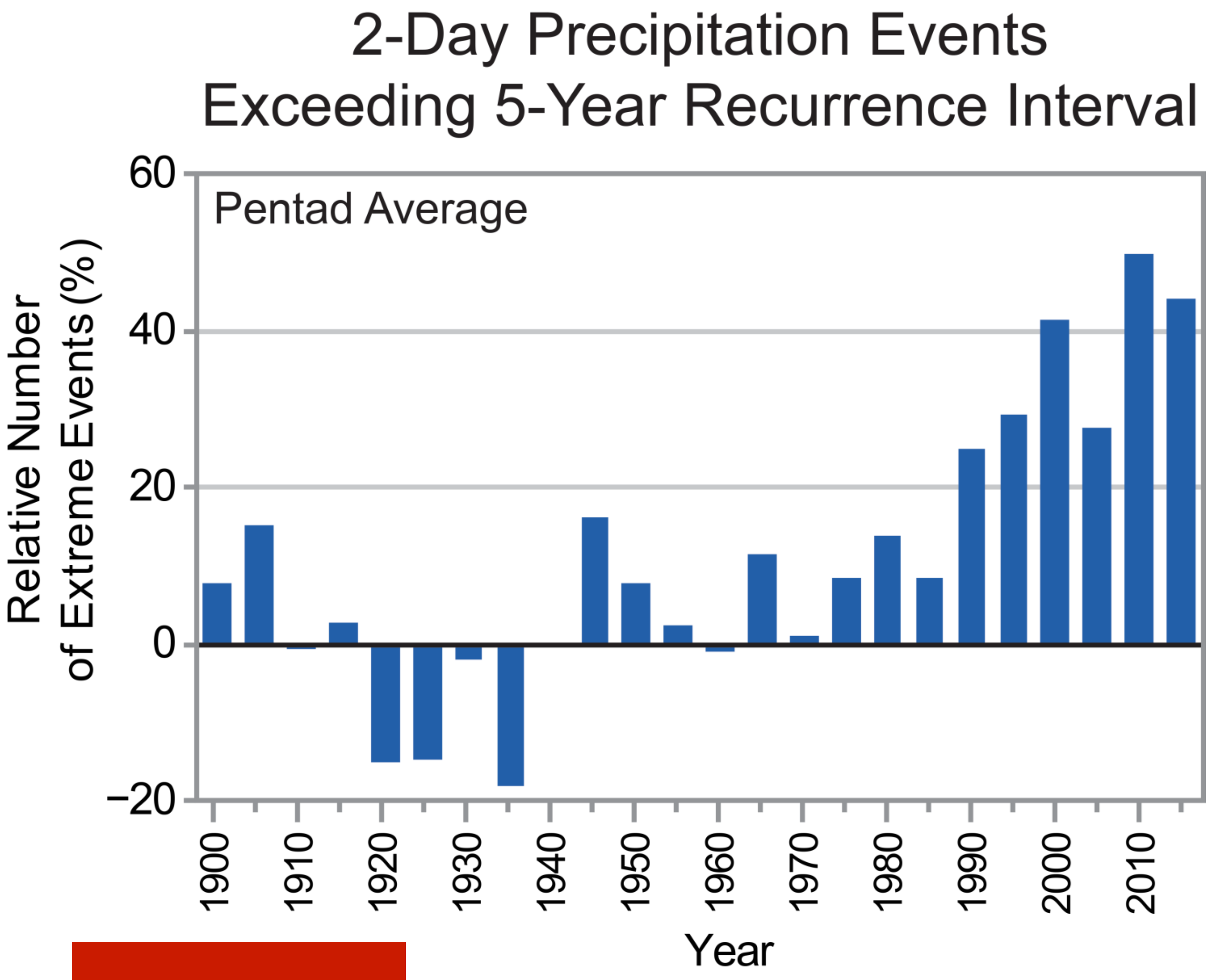
Multiday Events



- Number of 2-day precipitation events exceeding the threshold for a 5-year recurrence
- Well above average for the last 3 decades
- 2012 Drought Impact
- Index value for 2015 was 80% above the 1901–1960 reference period average (3rd highest value after 1998 and 2008).

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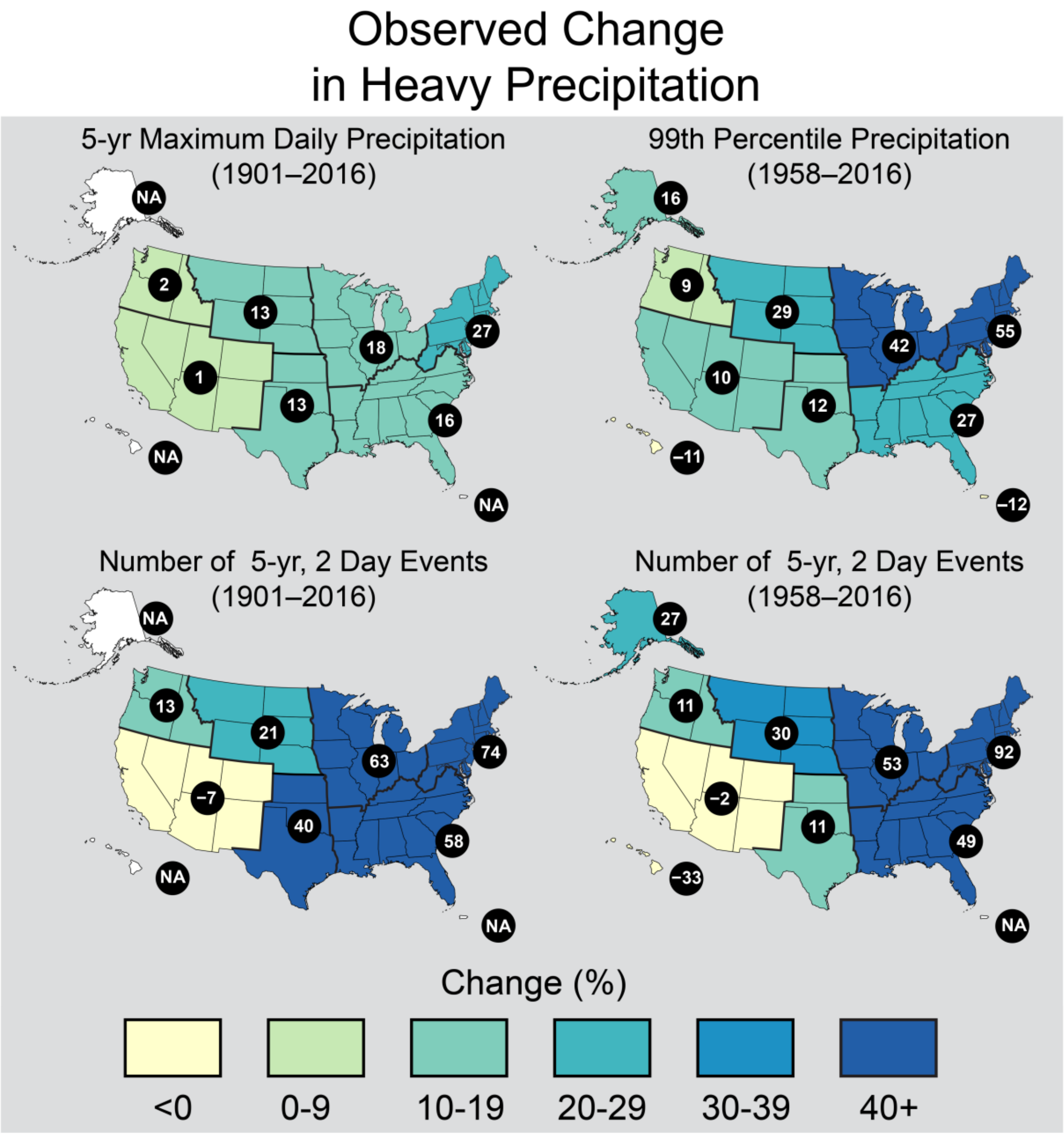
Other Heavy Precipitation Metrics

- Maximum daily precipitation totals were calculated for consecutive 5-year blocks from 1901

- The total precipitation falling in the top 1% of all days with precipitation



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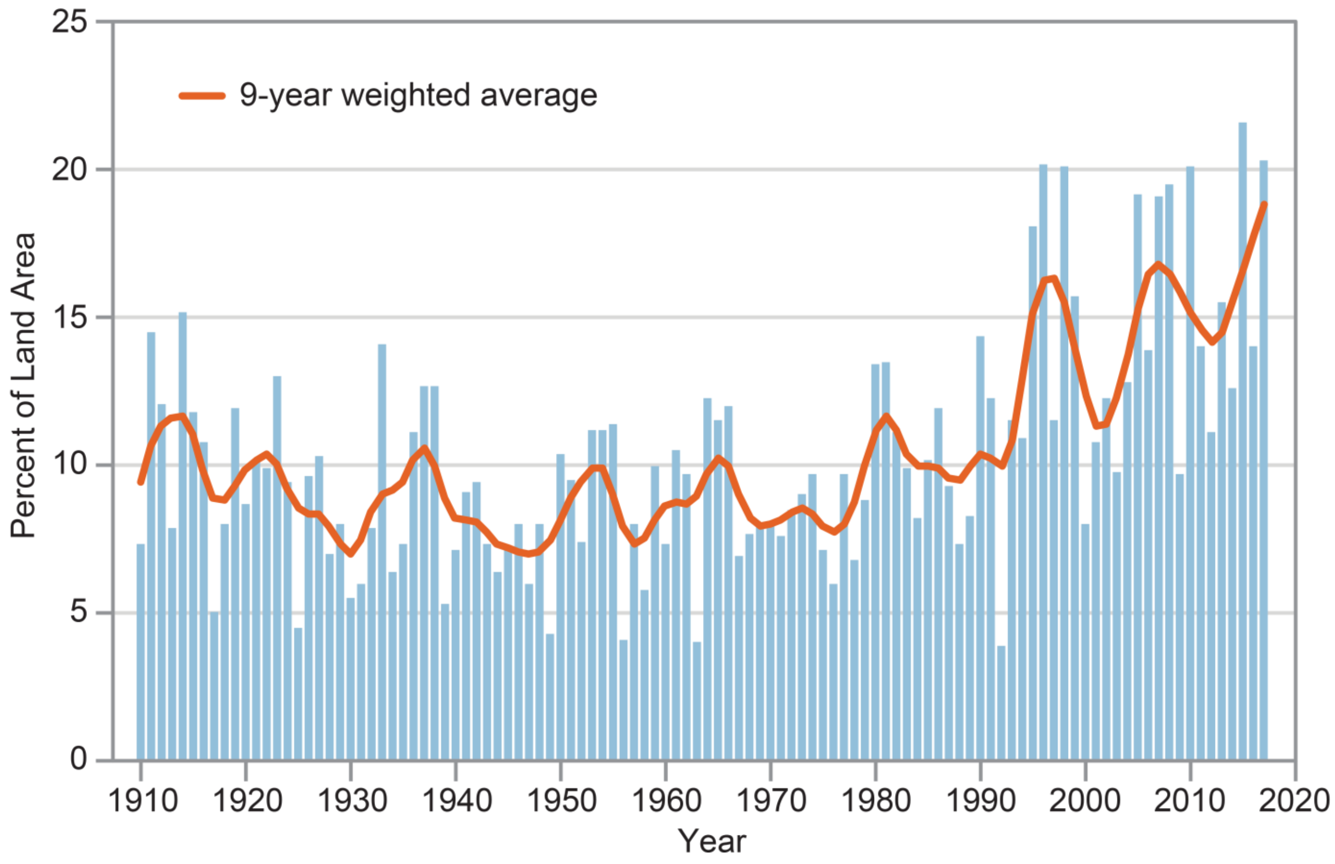
Extreme Precipitation

The figure shows the percent of land area in the contiguous 48 states experiencing extreme one-day precipitation events between 1910 and 2017. These extreme events pose erosion and water quality risks that have increased in recent decades. The bars represent individual years, and the orange line is a nine-year weighted average. Source: adapted from EPA 2016.

https://nca2018.globalchange.gov/chapter/10/



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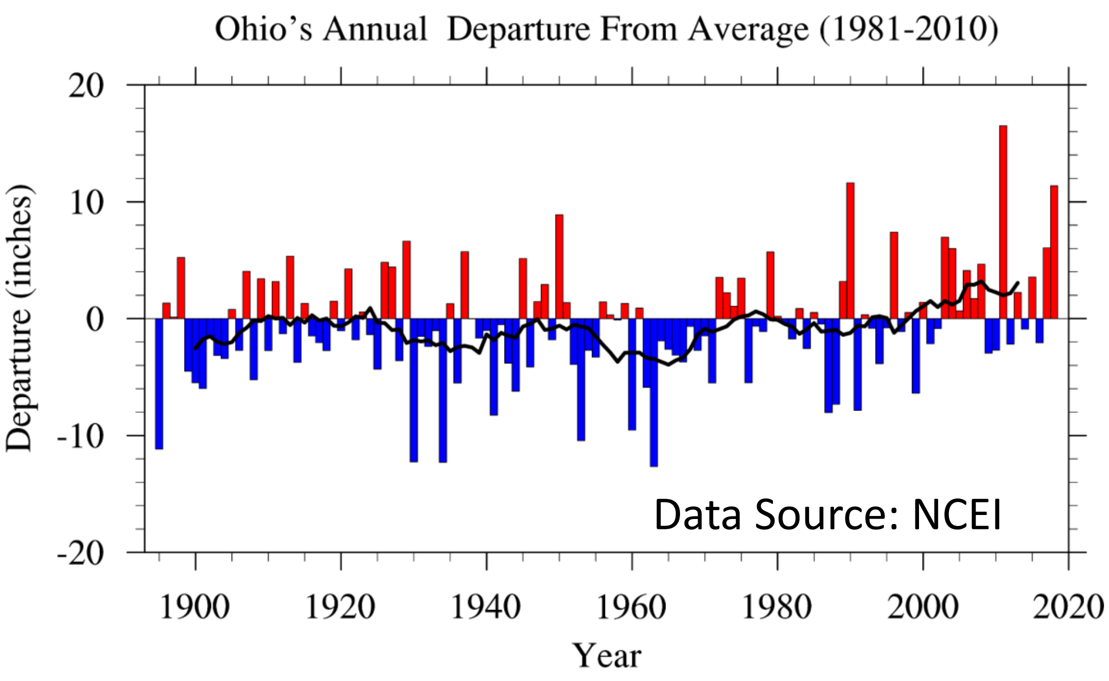
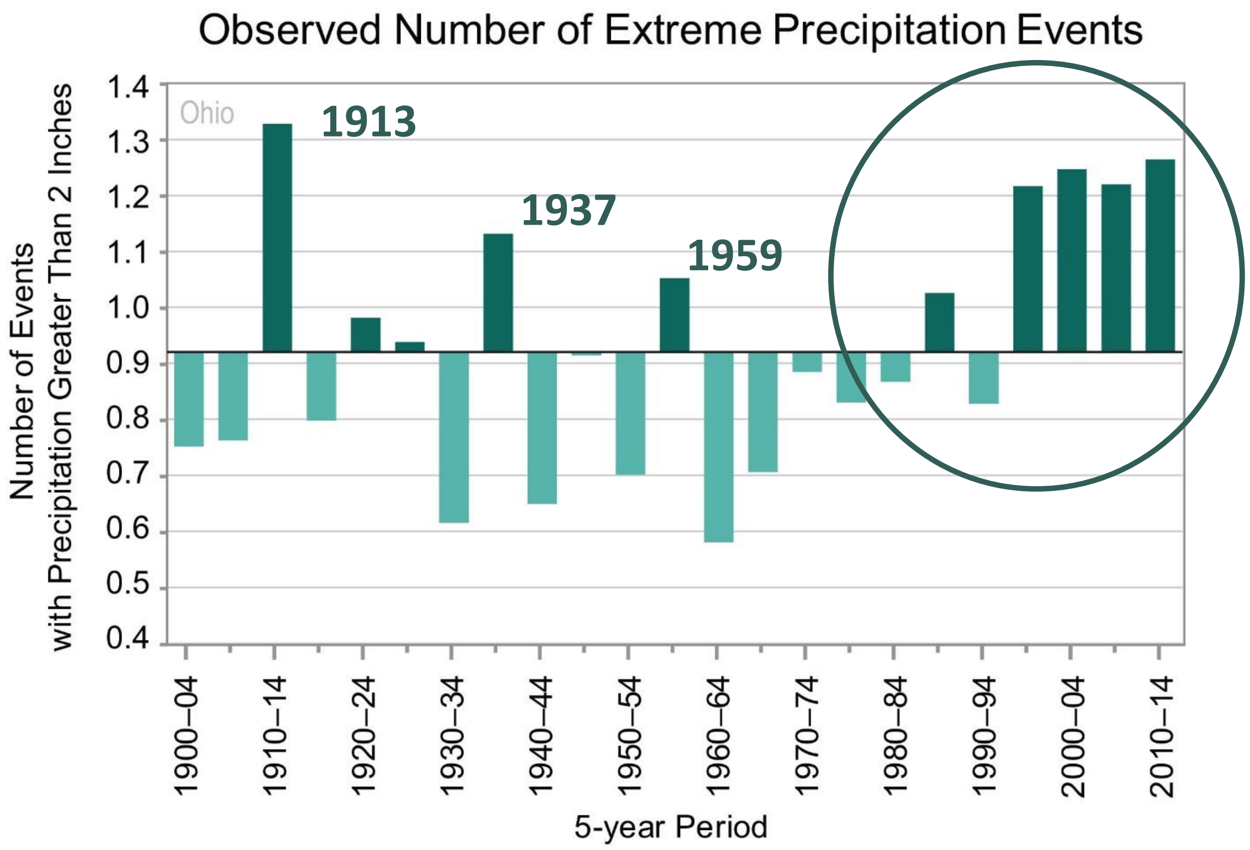
Long-term Precipitation Trends





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NOAA

https://statesummaries.ncics.org/oh

"the degradation of critical soil and water resources will expand as extreme precipitation events increase across agricultural landscapes. Sustainable crop production is threatened by excessive runoff, leaching and flooding, which will result in soil erosion, degraded water quality in lakes and streams, and damage to rural community infrastructure. These predicted impacts are already happening today. Thunderstorms are often much heavier, droughts often last longer, false springs threaten orchards, and abnormal weather events and climatic conditions are forcing farmers to adapt to challenges that are affecting their productivity and waterways."

-Fourth National Climate Assessment

https://nca2018.globalchange.gov/

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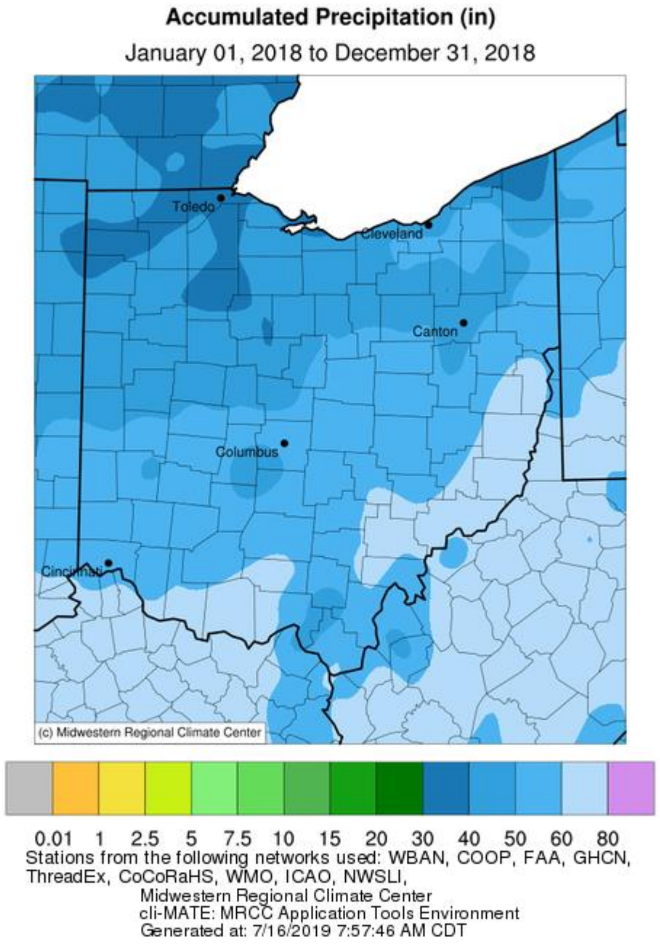
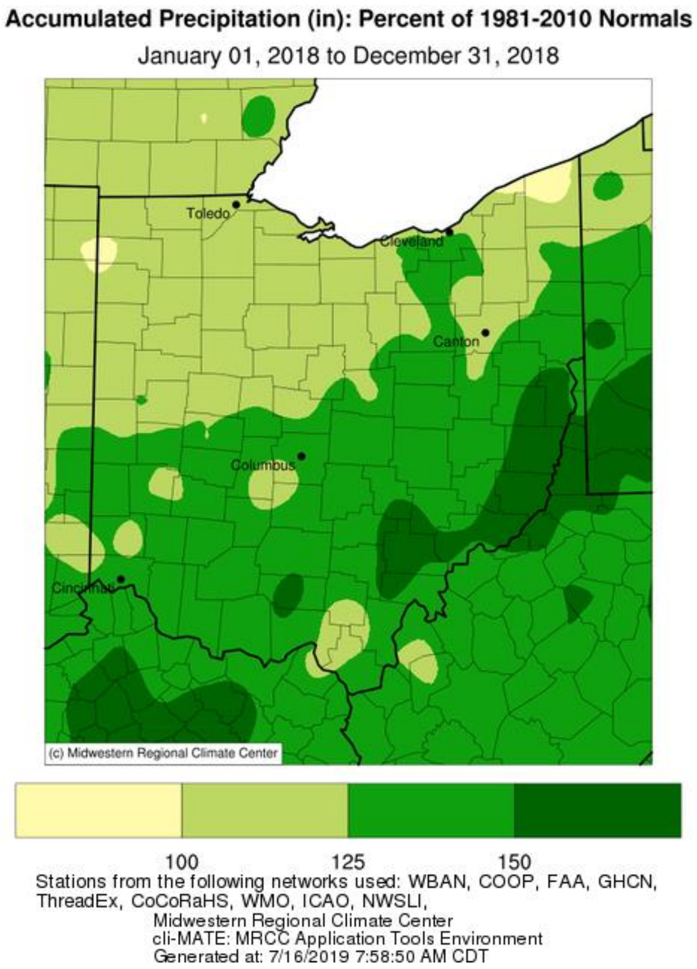
2018 for the State of Ohio





RANK	YEAR	AVERAGE	DIFFERENCE
1	2011	55.95	16.50
2	1990	51.07	11.62
3	2018	50.83	11.38
4	1950	48.34	8.89
5	1996	46.85	7.40
6	2003	46.42	6.97
7	1929	46.42	6.62
8	2017	45.51	6.06
9	2004	45.45	6.00
10	1937	45.18	5.73

- 19^{th} Warmest
- 3^{rd} Wettest
- Modern Period (1895 – 2018)

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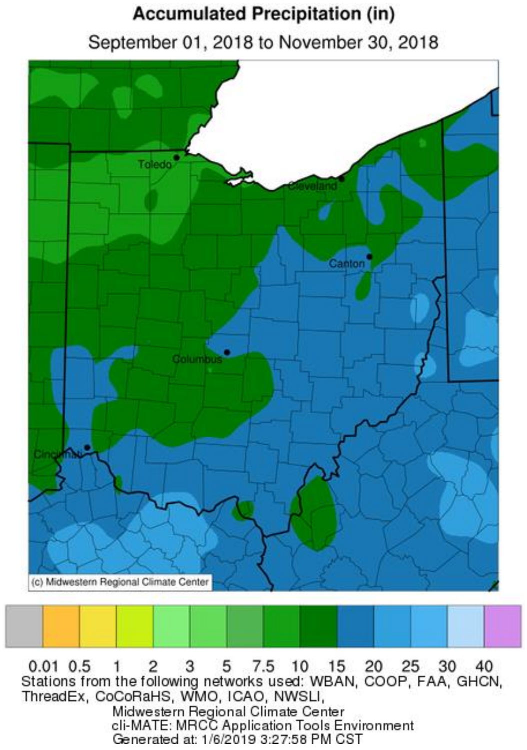
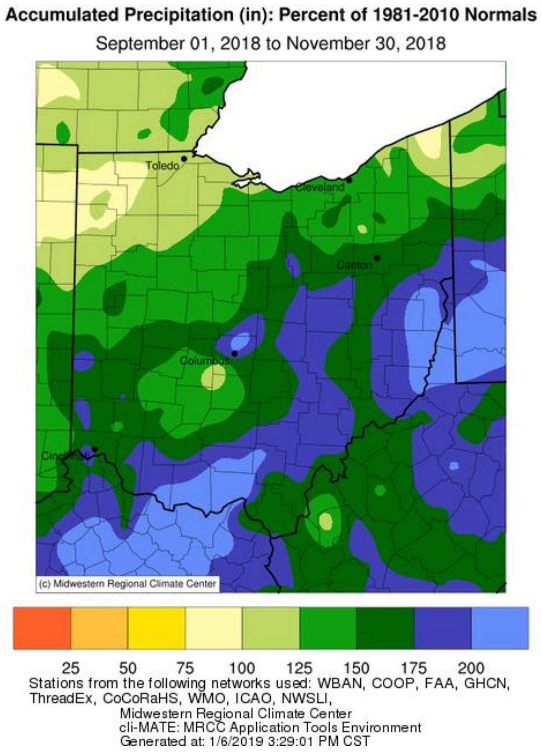
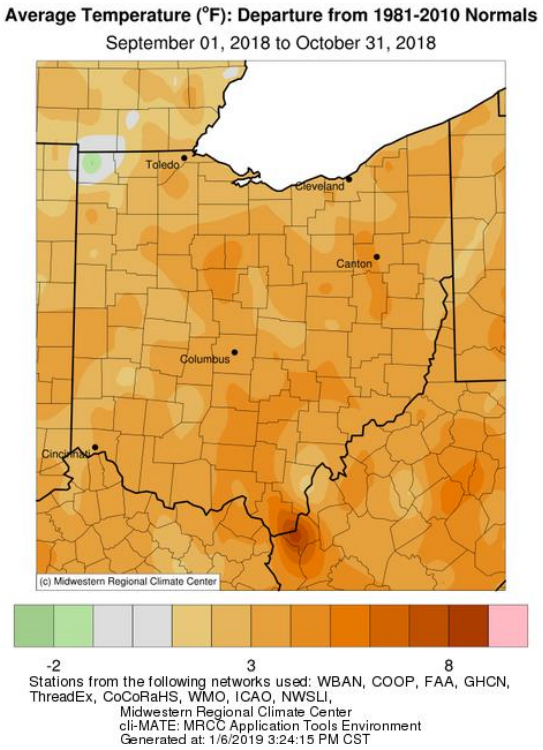
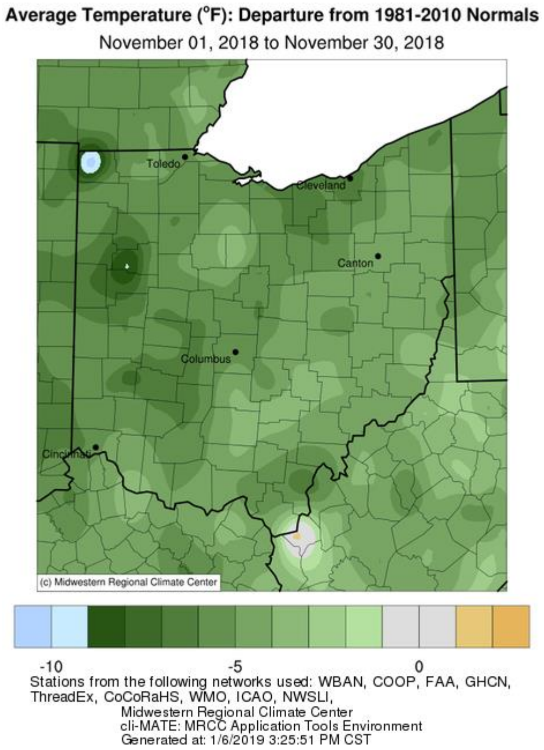
A Crazy Fall in Ohio



Fall 2018: Extreme Variability







- 3rd wettest on record since 1895.
- Sep. 2018 ranks as 2nd wettest.
- Driven largely by tropical activity

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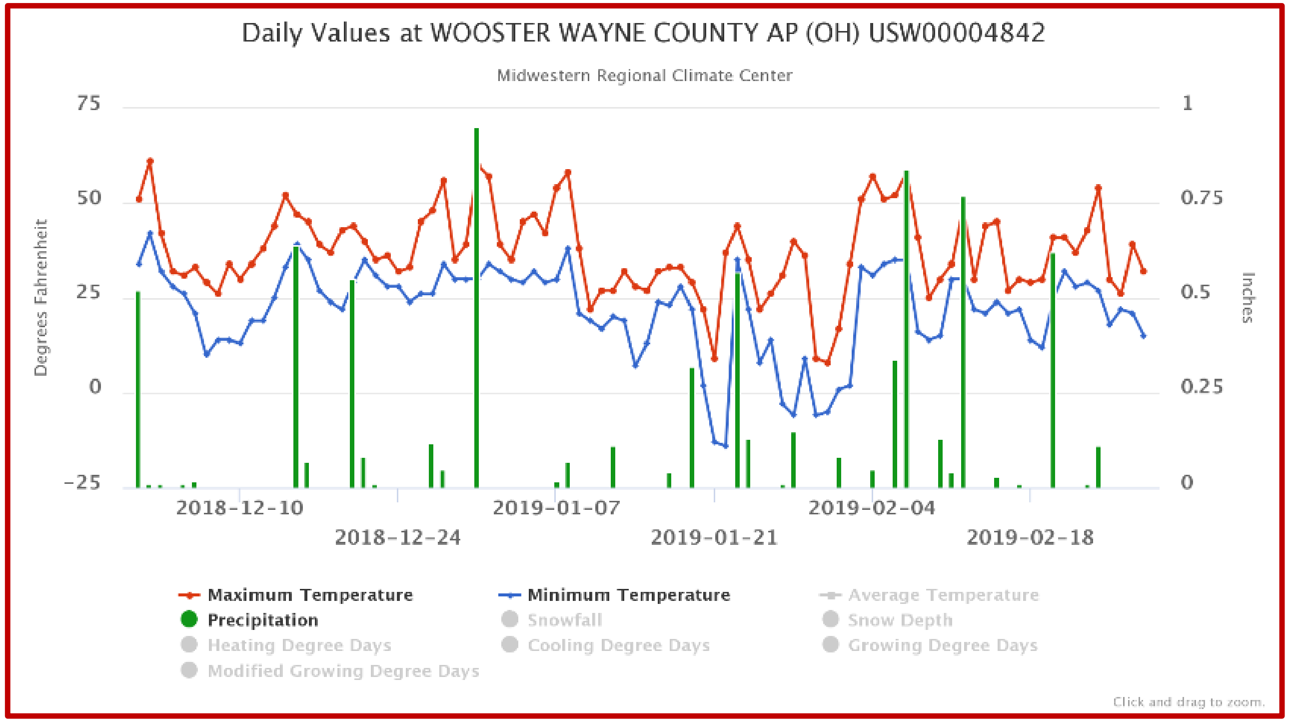
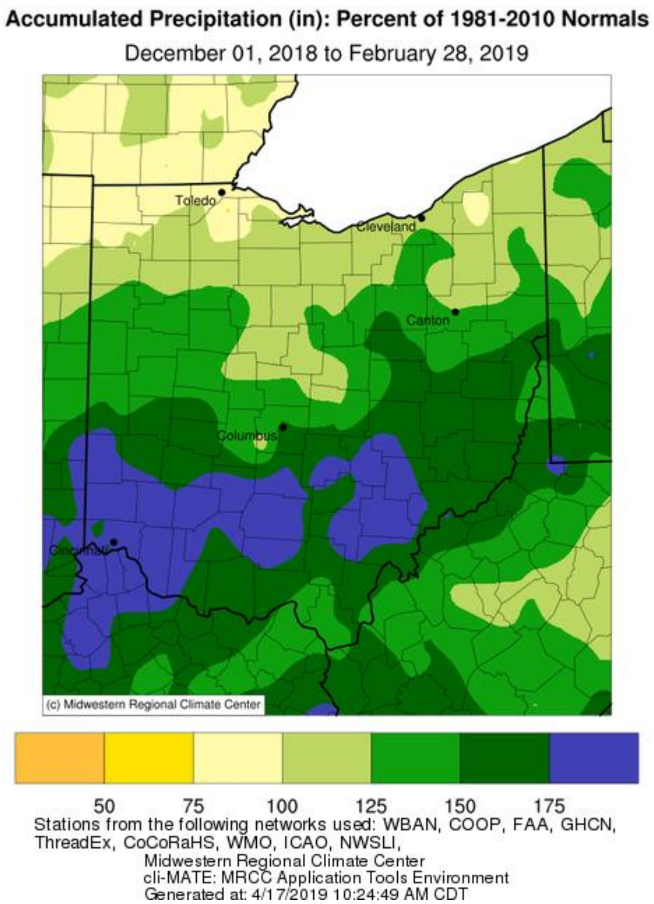
No Relief During Winter





- Winter 2019 ranks as the 11th wettest on record for Ohio, with precipitation 150-200% above average along and south of about I-70.

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- A short period of intense cold occurred during January, with frequent freeze-thaw cycles led to extreme heaving.

Spring: Rinse & Repeat

- March-May 2019 rank as the 36th warmest and 32nd wettest for the state
- West-central and northwest Ohio ranked 7th and 3rd wettest on record, respectively.
- St. Marys, Ohio (Auglaize County), CoCoRaHS observer reported over 20 inches of precipitation between March 1 and May 31 - ***that's over half of their normal yearly rainfall in just three months.***
- Multiple observers in excess of 15 inches
- Reports of 20-26 days of at least a trace of precipitation during the month of May
- Only 7 days suitable for fieldwork during May


Photo Credit: Greg McGlinch


Photo Credit: Amanda Douridas

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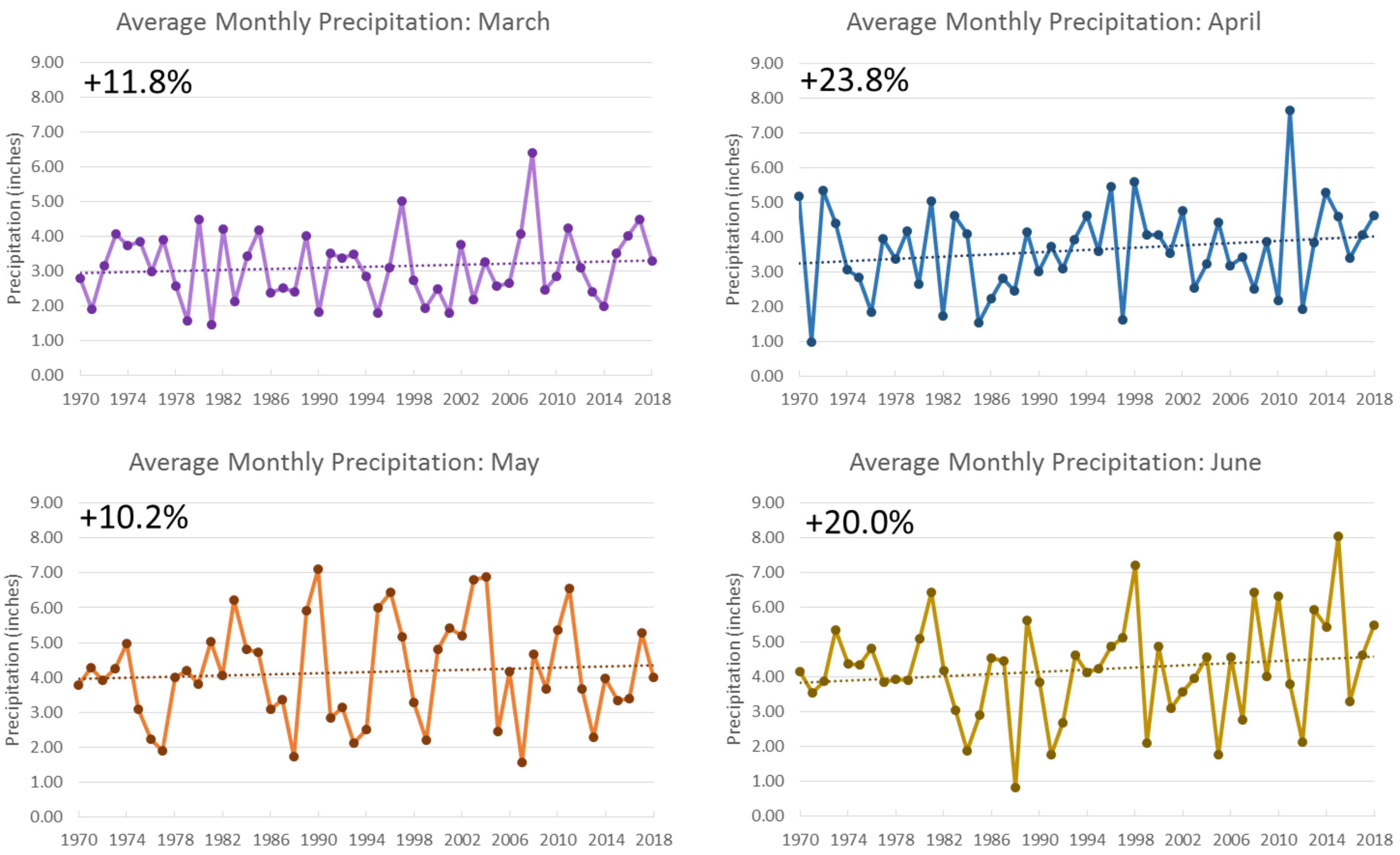
Ohio Spring Precipitation Changes

- Frequency: Up 3-11% for April-June
- Spring (AMJ) precipitation has increased 15-17% (1.5-2”) since 1970.
- April has seen the largest increase at nearly 24%.
- Events greater than 0.5” and 1.0” have increased for all months. (Largest increase in April).



Data Source: NCEI

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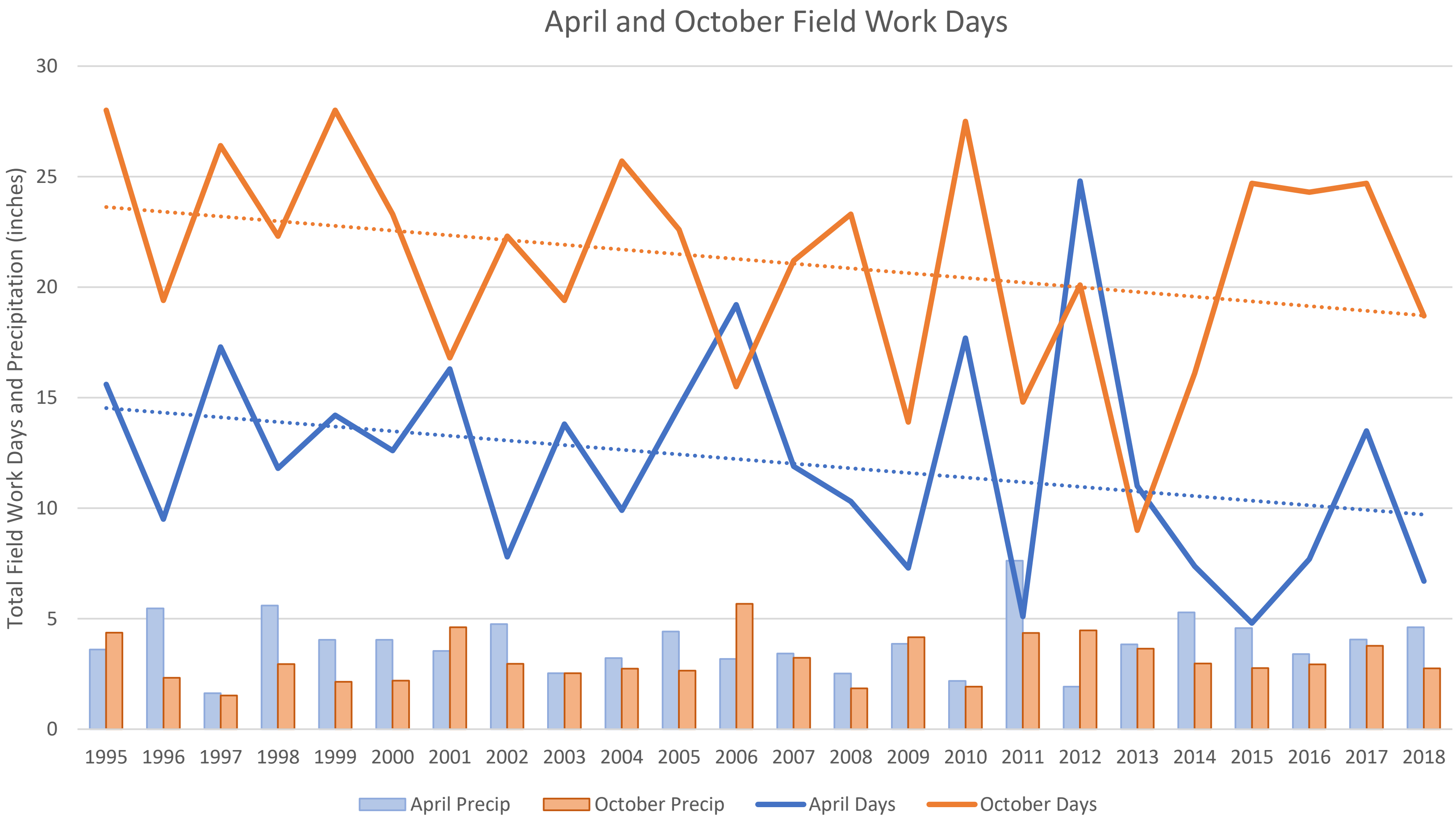
Fieldwork Days for Ohio

~5 fewer days on average in April and October



Data Source: NASS and NECI

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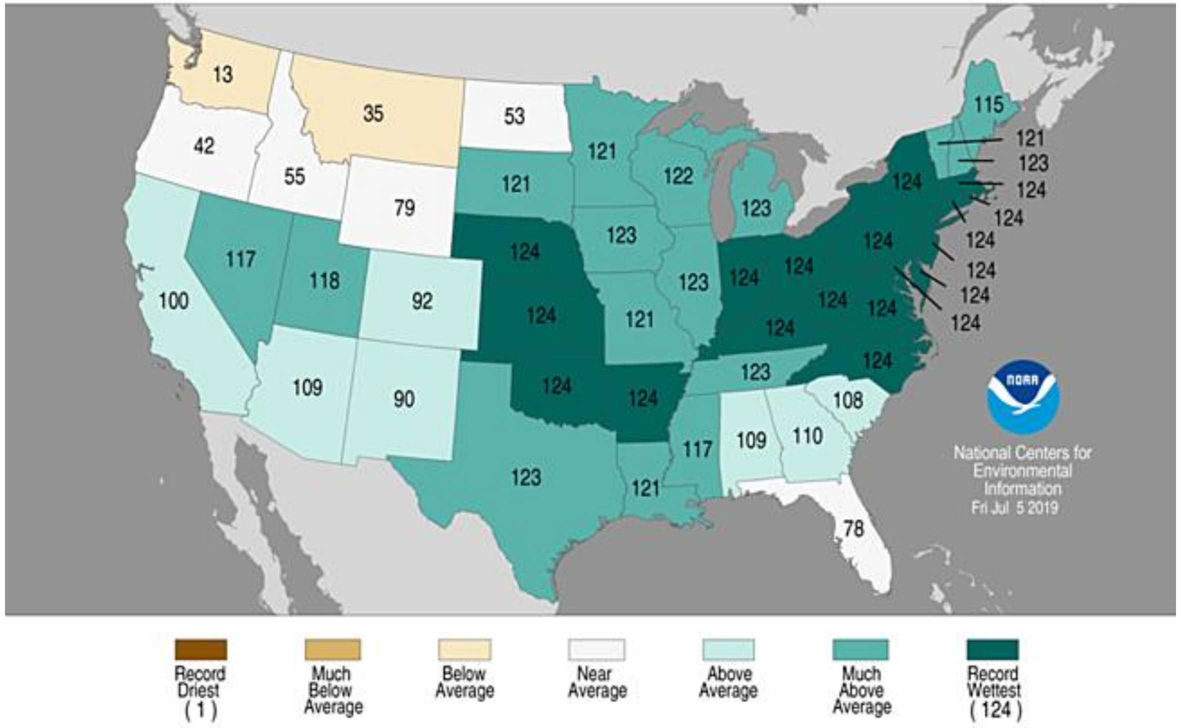
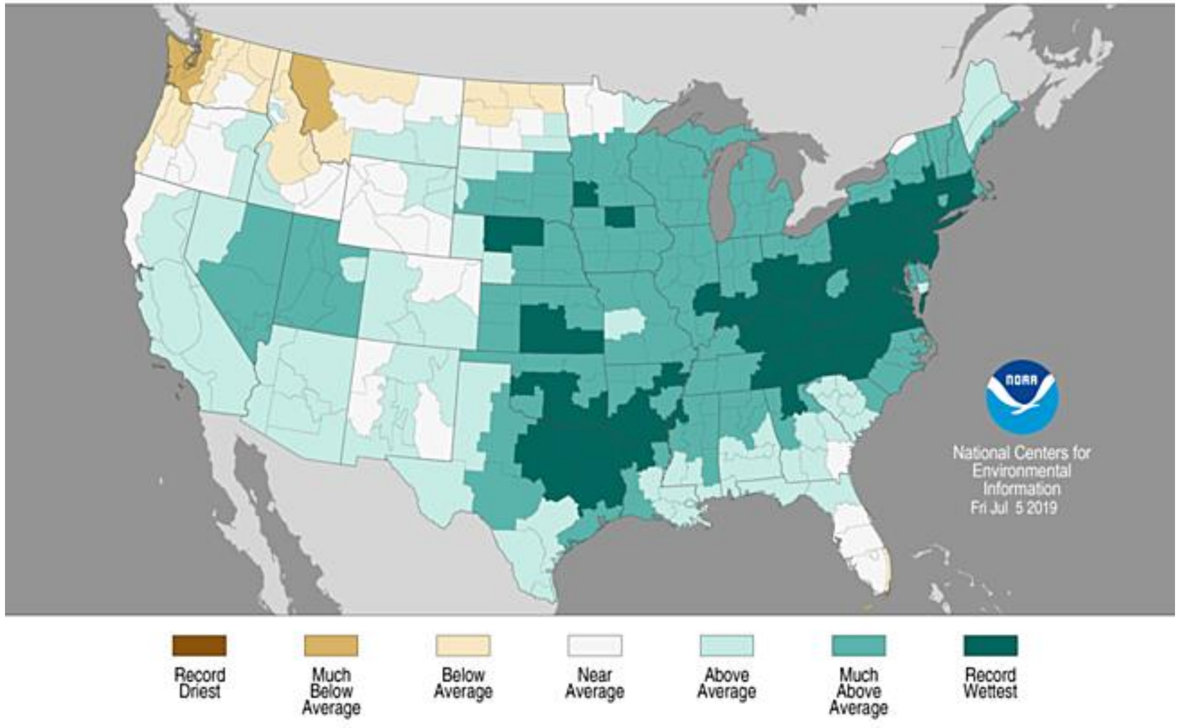
It’s Been a VERY Wet Year!

Statewide Precipitation Ranks
July 2018–June 2019
Period: 1895–2019



Divisional Precipitation Ranks
July 2018–June 2019
Period: 1895–2019



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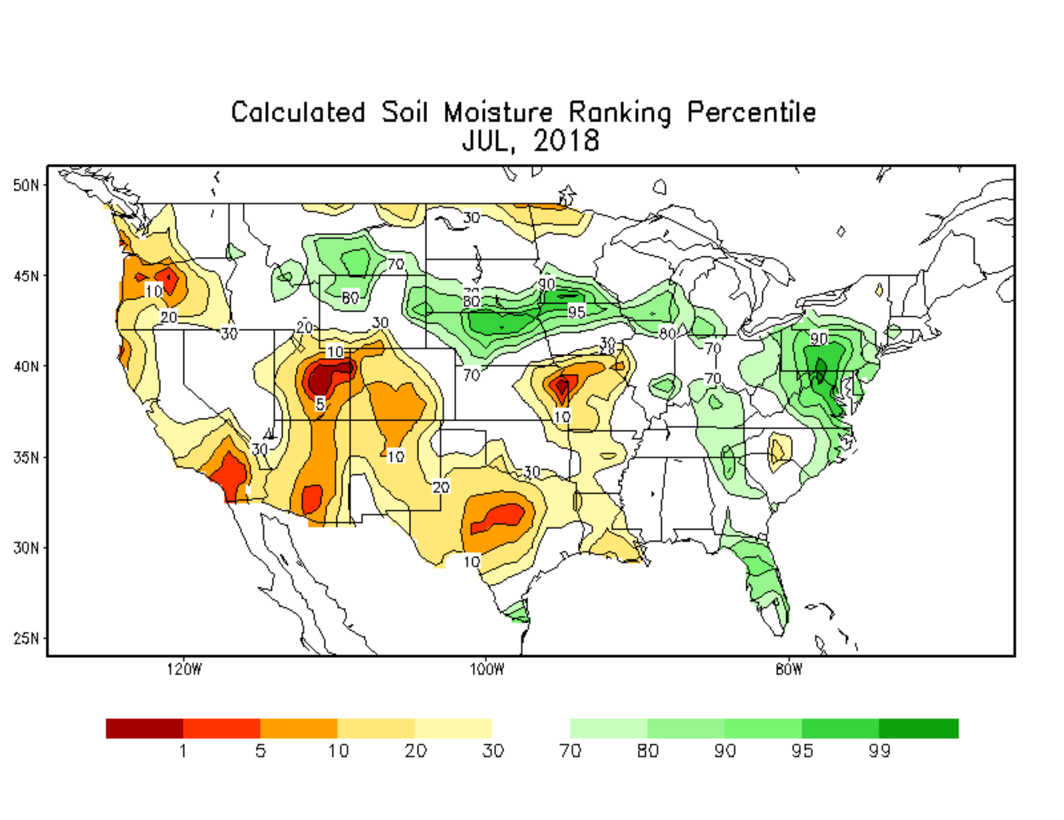
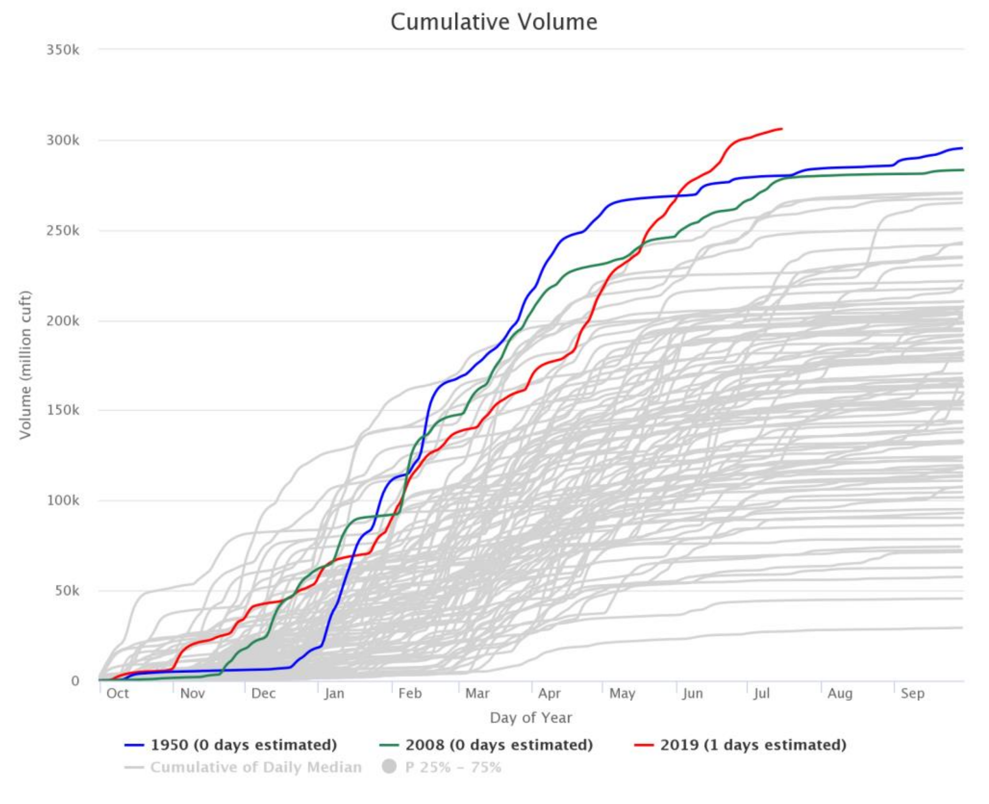
Consequences of All That Water



https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/Soilmst/Soilmst.shtml



Maumee River at Waterville

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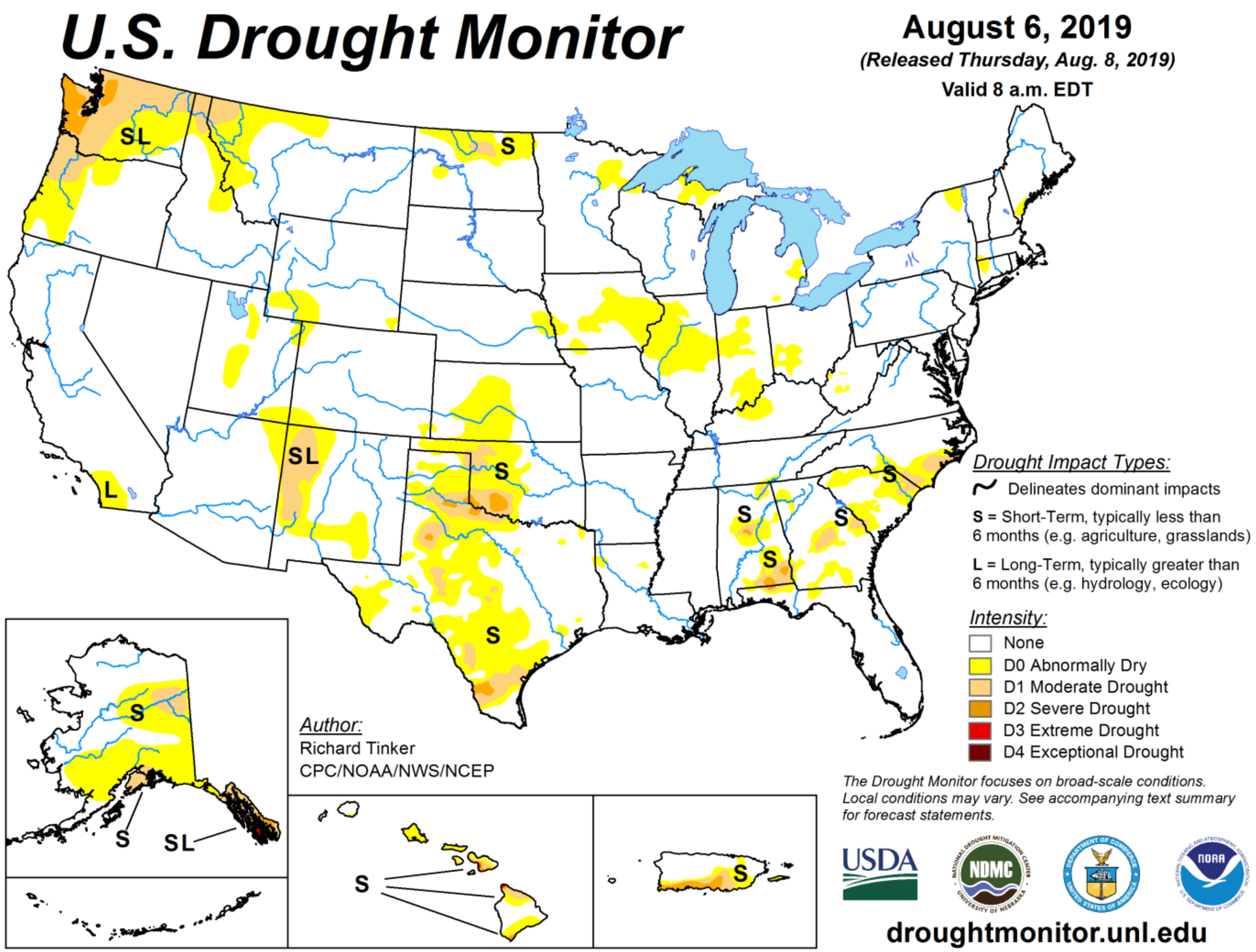
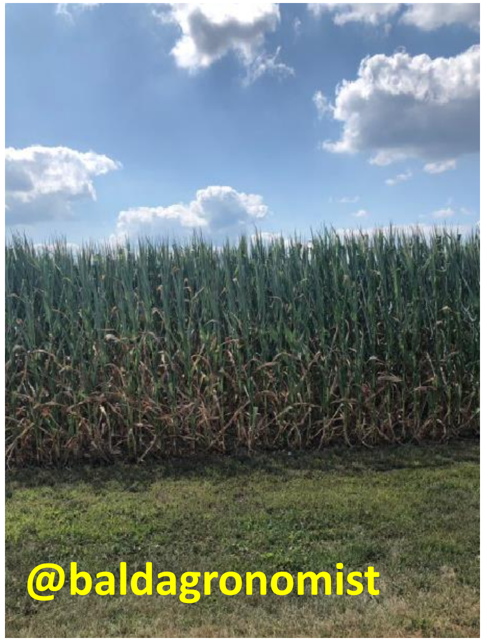
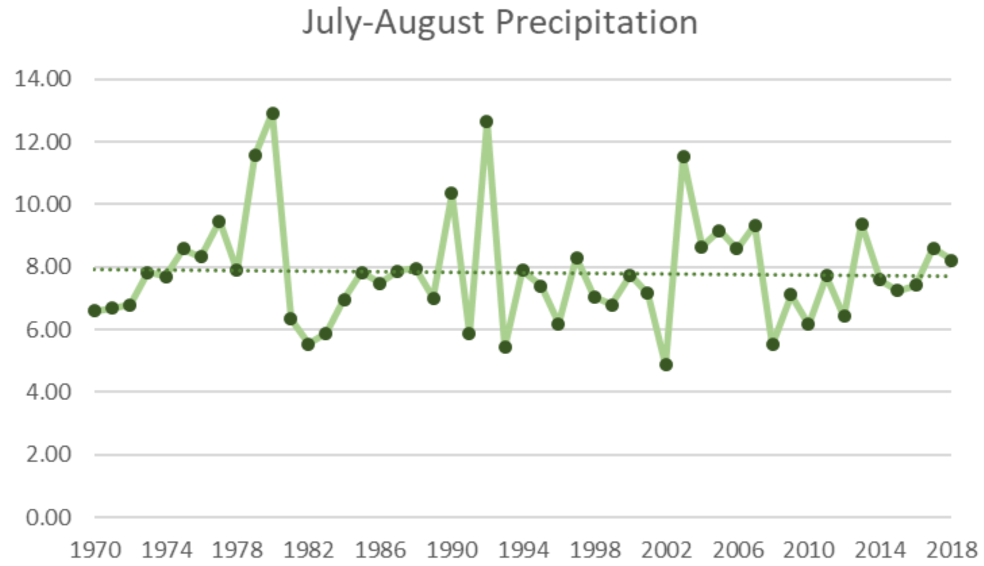
How can it be so dry, when it's been so wet?







Images of the Challenges

Assessing the Past Year

- Late planted small grains in the fall, followed by winter injury and water damage
- Lack of forages across the state due to poor stands and heaving
- Late or no planting of corn and soybeans this spring
- Impacts on fruits and vegetables (cold, wetness duration)
- Disruption to the agricultural production cycle including planting, spraying, and eventually harvesting
- Difficult crop insurance and field management questions

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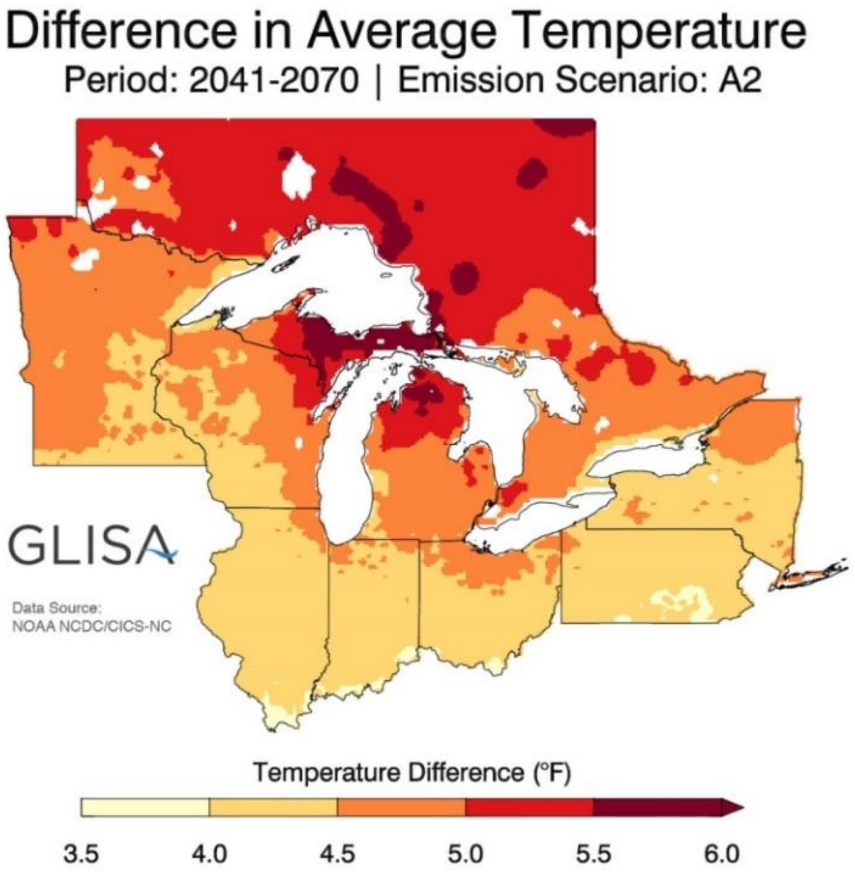
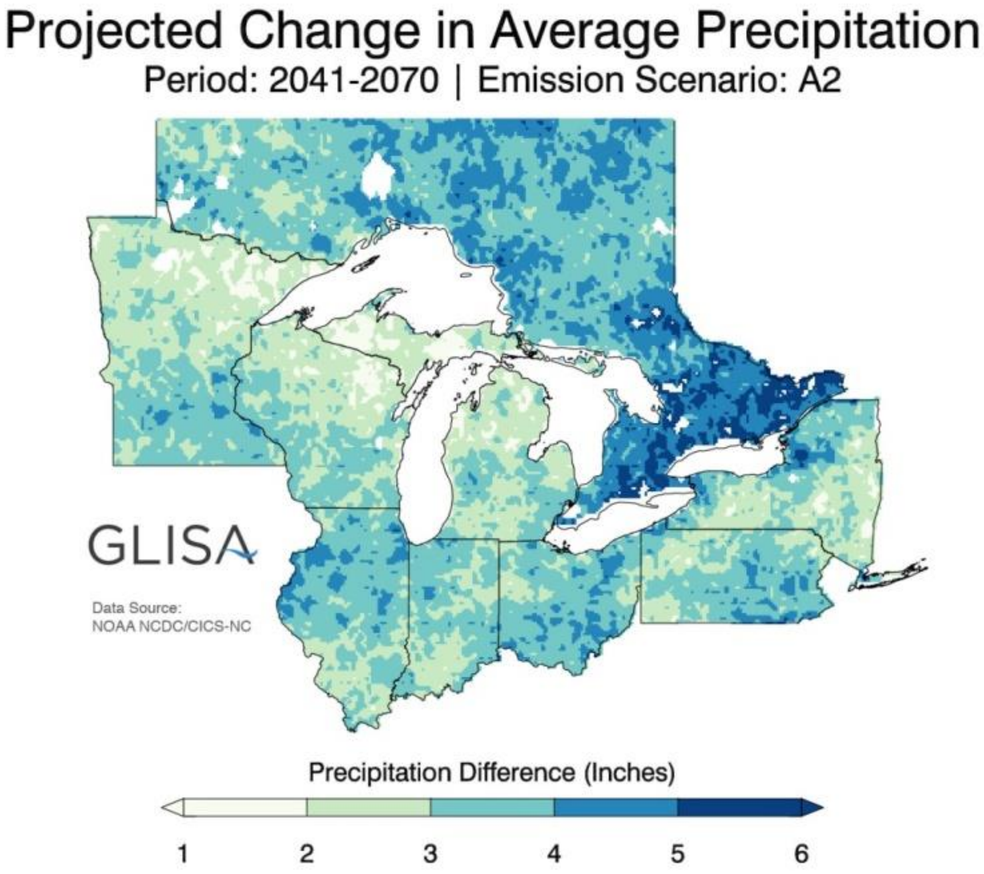
Future Climate





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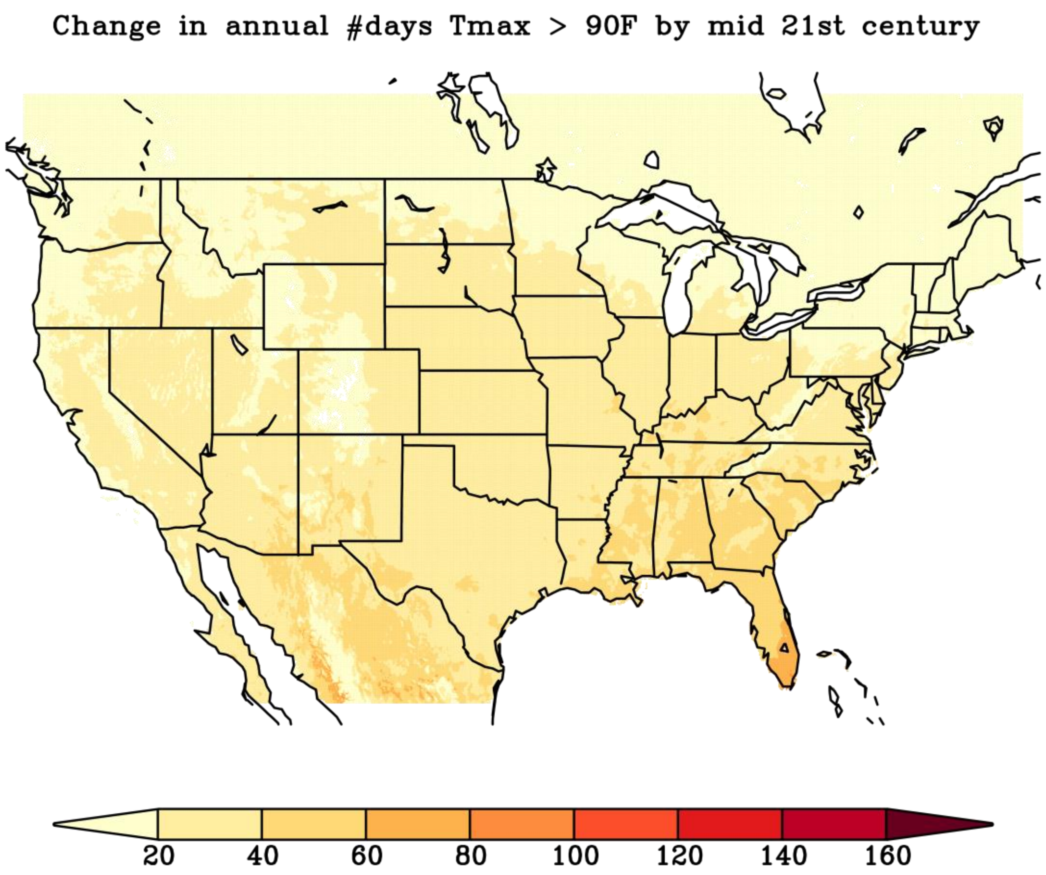
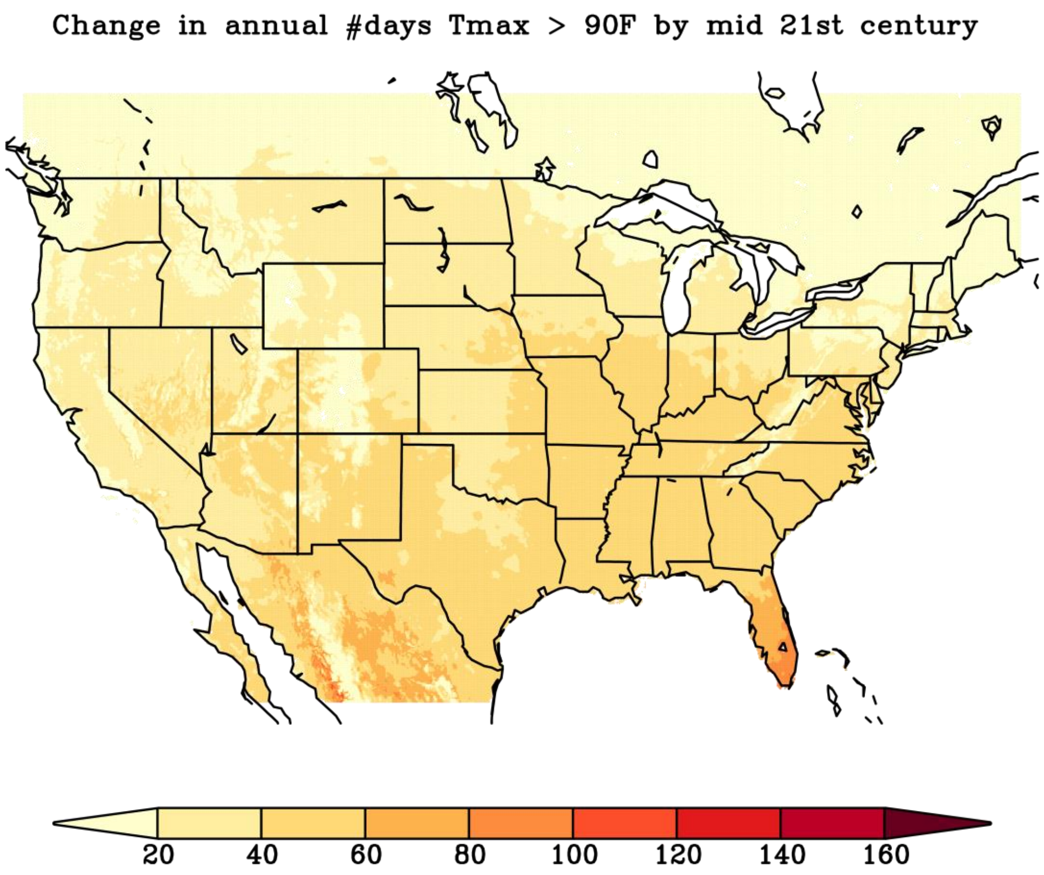
Change in Annual Number of Days > 90°F

Lower Emissions



Higher Emissions



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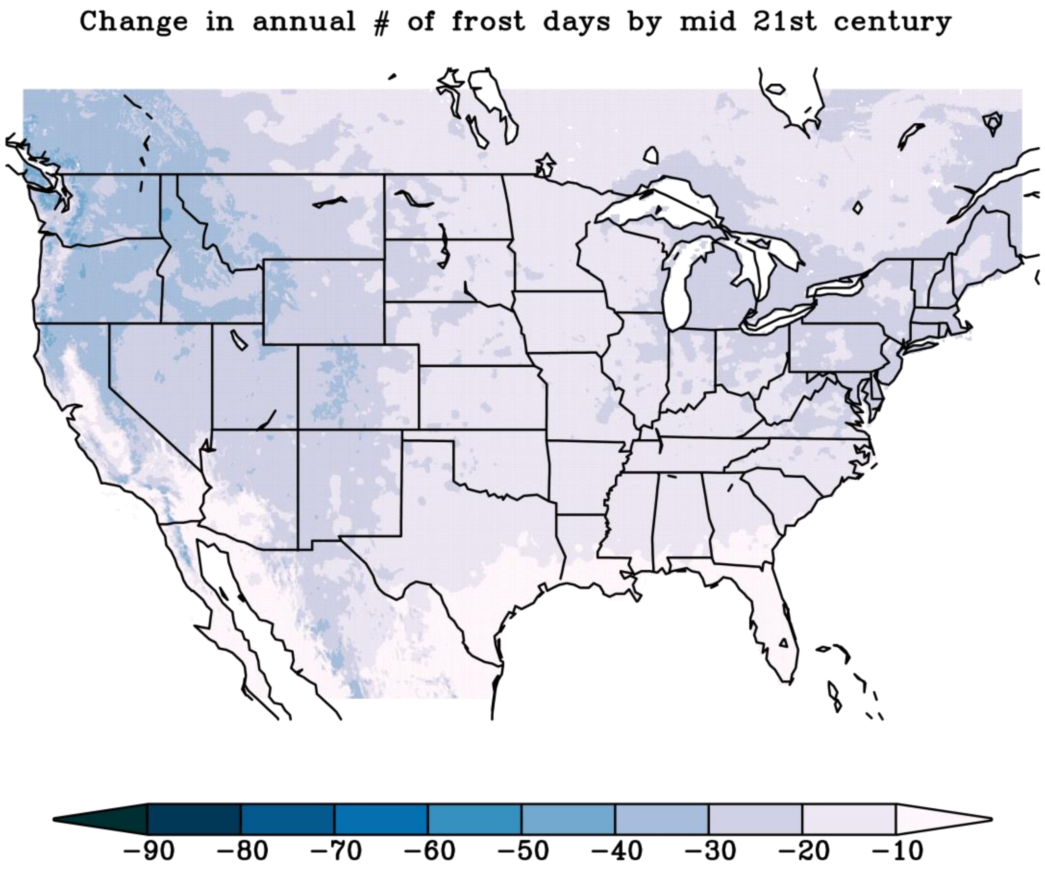
(1976-2005): 20-40 days per year

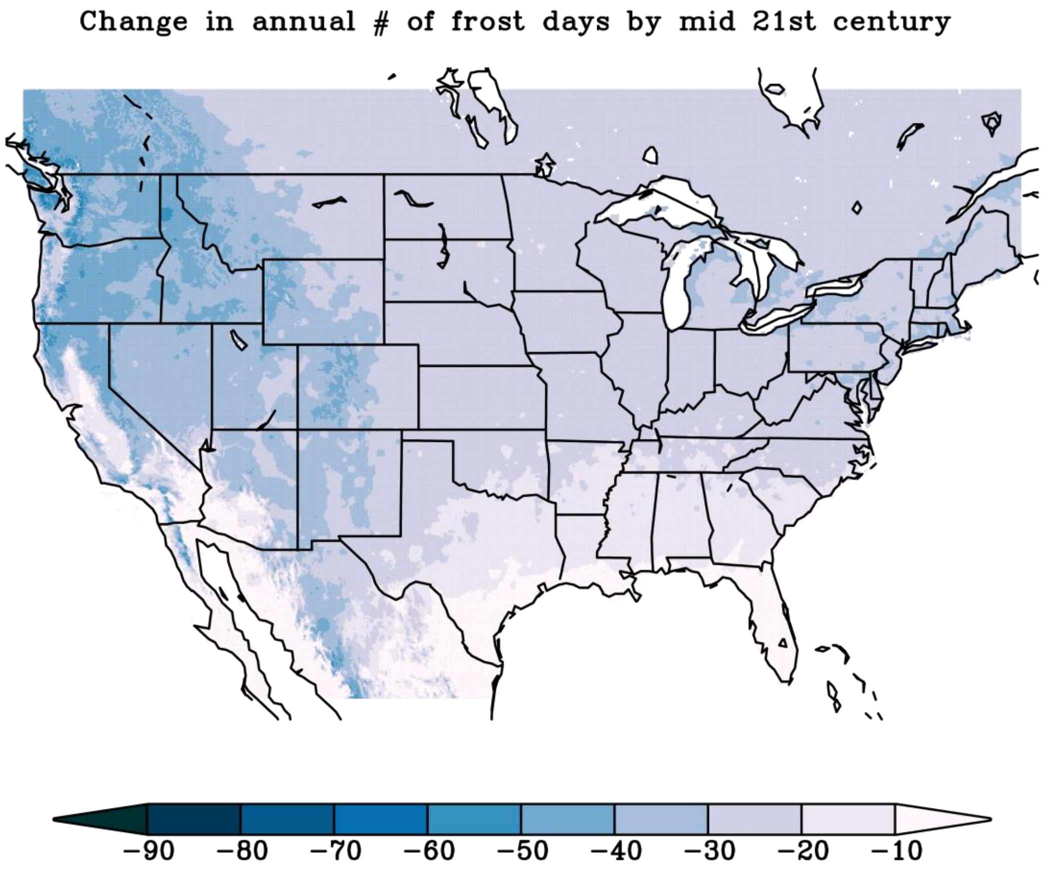
https://scenarios.globalchange.gov/loca-viewer/

Change in Annual Number of Days < 32°F

Lower Emissions



Higher Emissions



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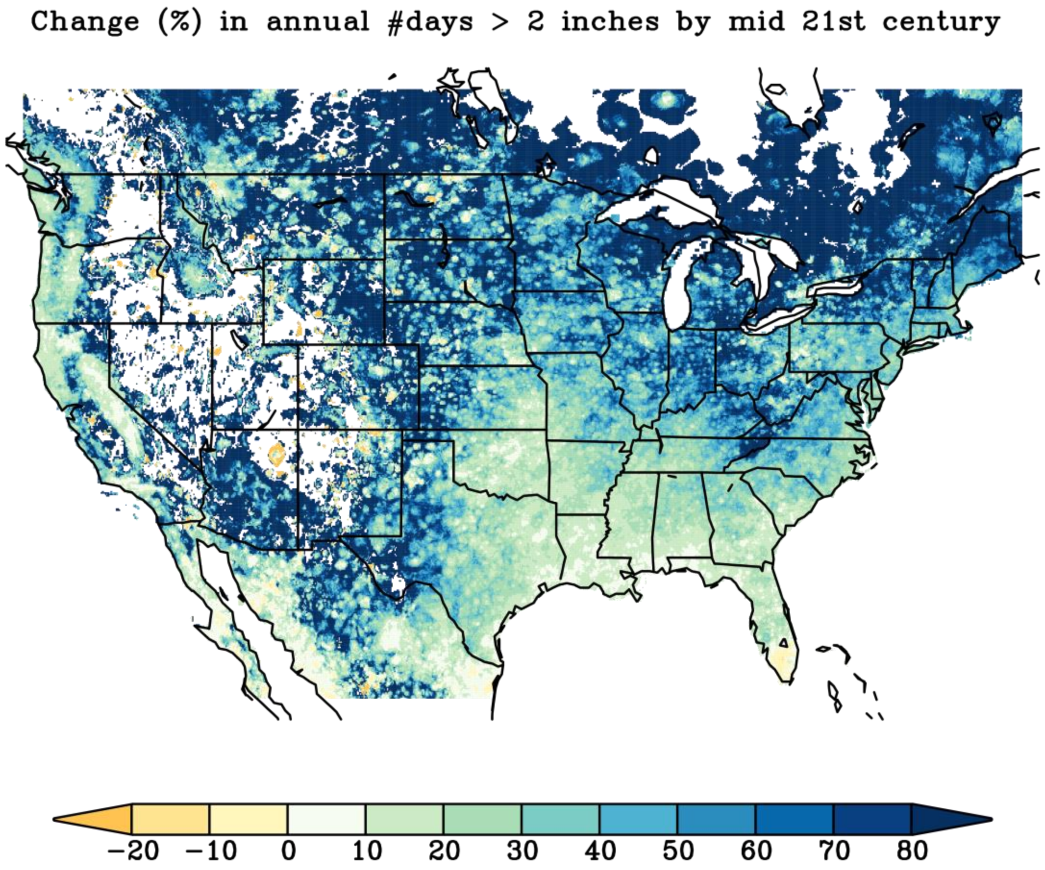
Ohio (1976-2005): 80-160 days per year

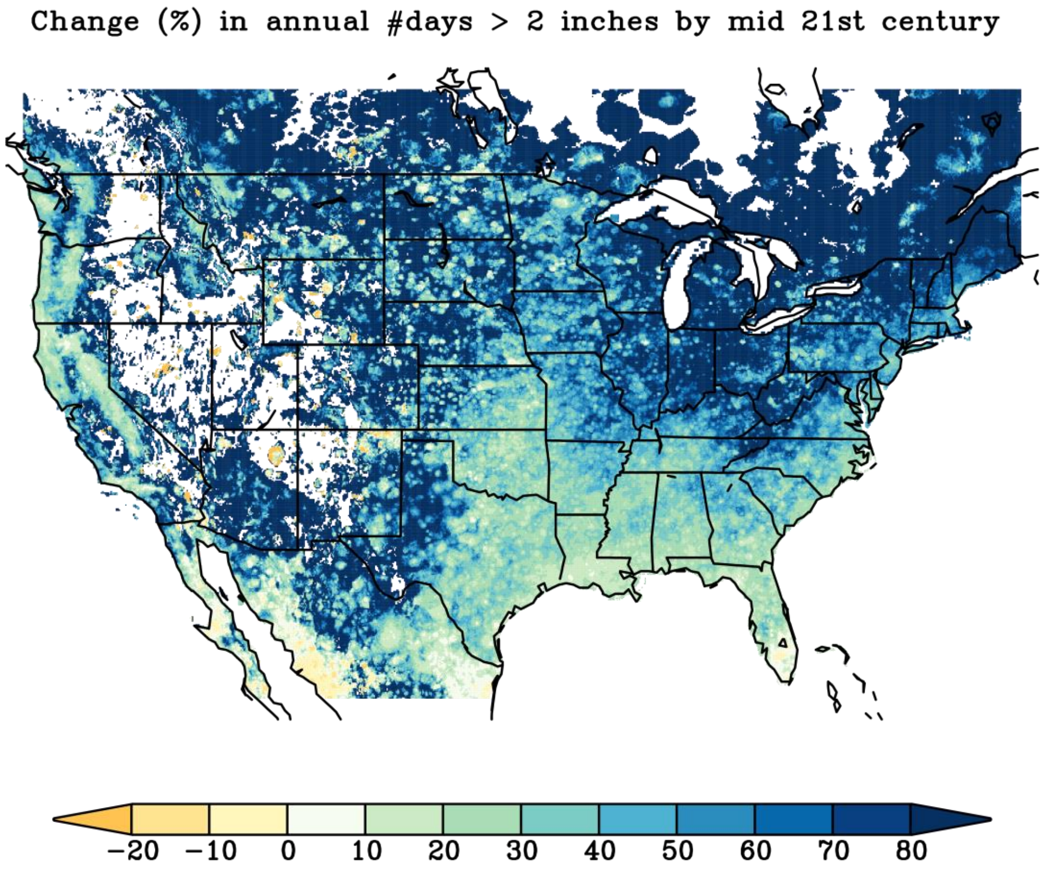
https://scenarios.globalchange.gov/loca-viewer/

Change in Mean Annual Days with Precipitation > 2”

Lower Emissions



Higher Emissions



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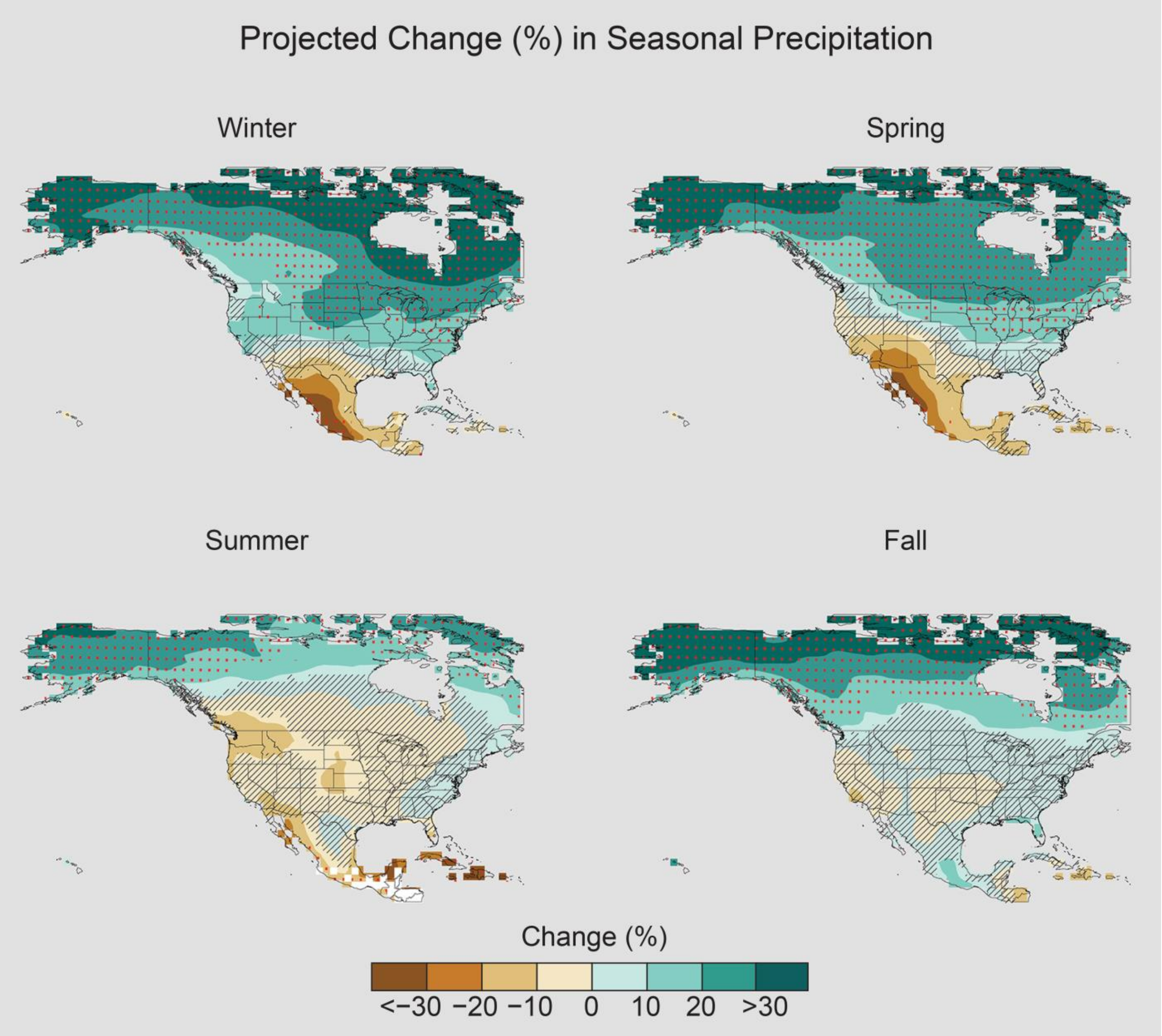
(1976-2005): < 1 day

https://scenarios.globalchange.gov/loca-viewer/

Seasonal Redistribution of Precipitation



-Fourth National Climate Assessment

https://nca2018.globalchange.gov/

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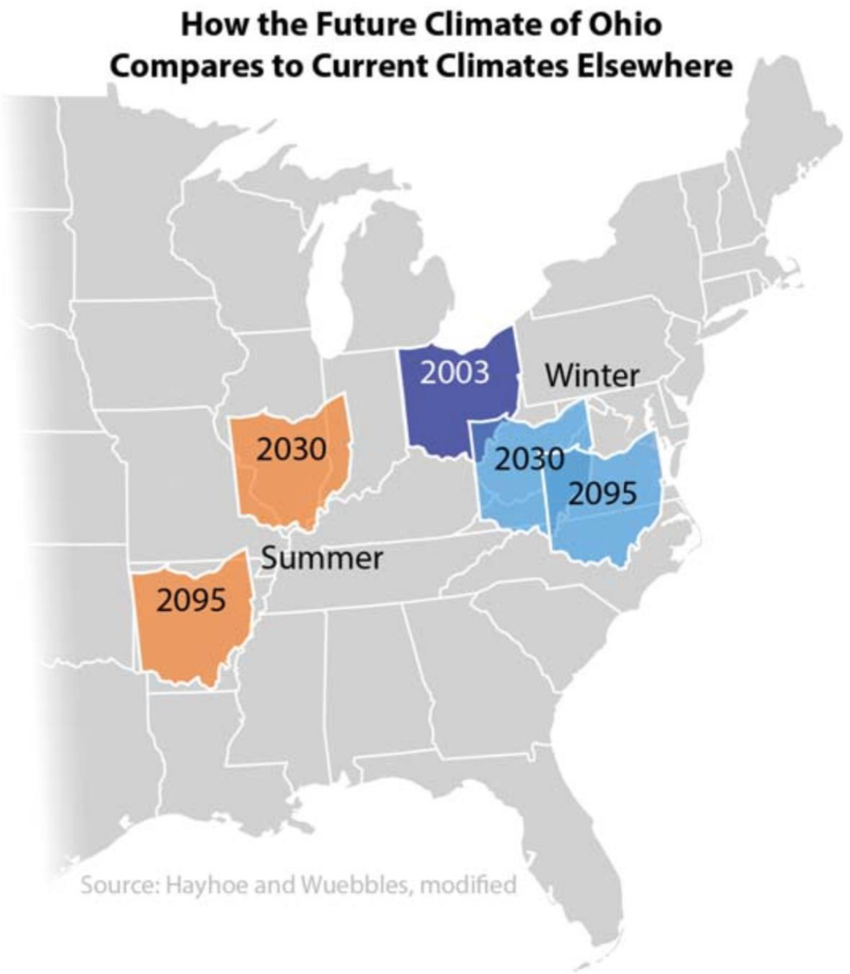
So what if I told you THIS is our new normal?

- ✓Longer Growing Season
- ✓Warmer Temperatures (Winter and at Night)
- ✓Higher Humidity
- ✓More Rainfall
- ✓More Intense Rainfall Events
- ✓More Autumn Precipitation



Based on temperature, humidity, and precipitation, future summers in Ohio might resemble those in Arkansas, and winters may become similar to those in Virginia.

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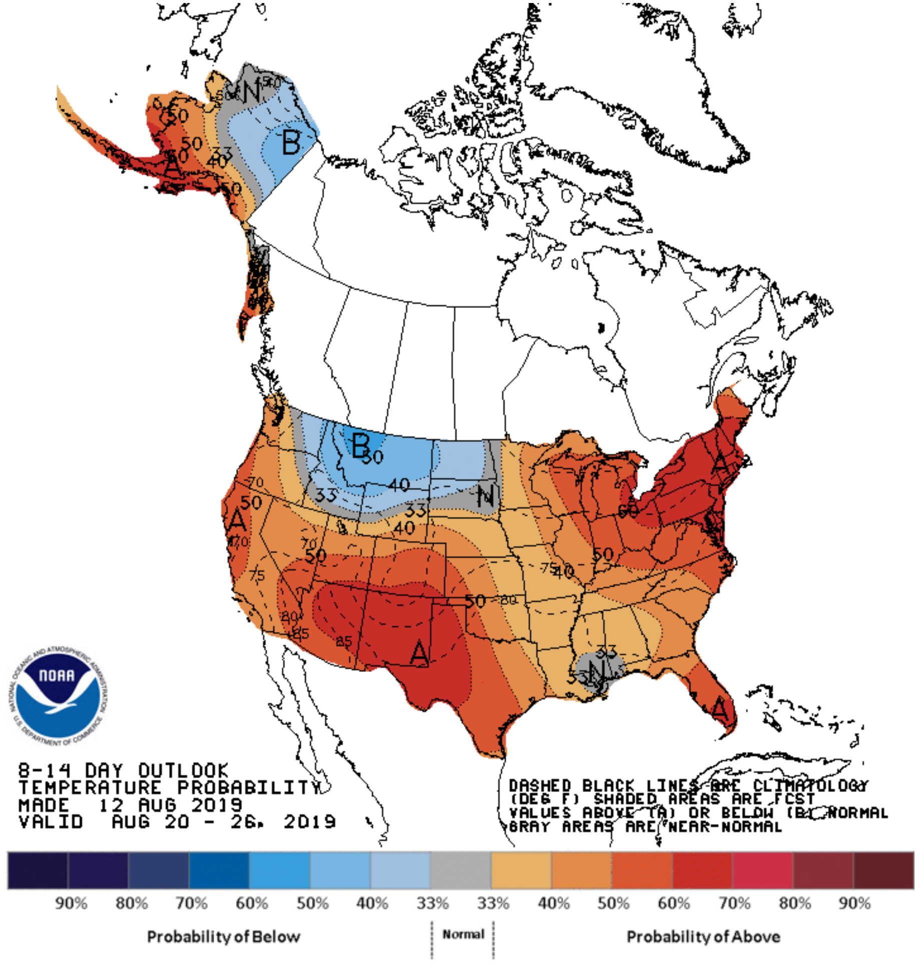
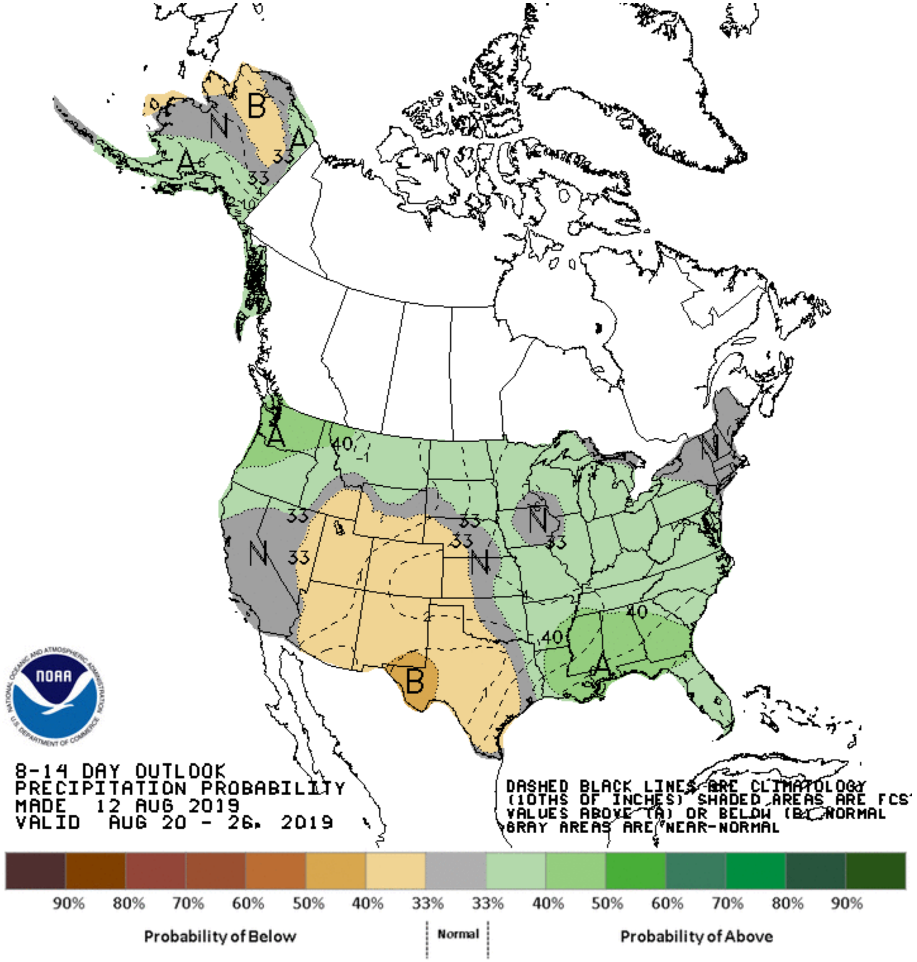
8-14 Day Outlook





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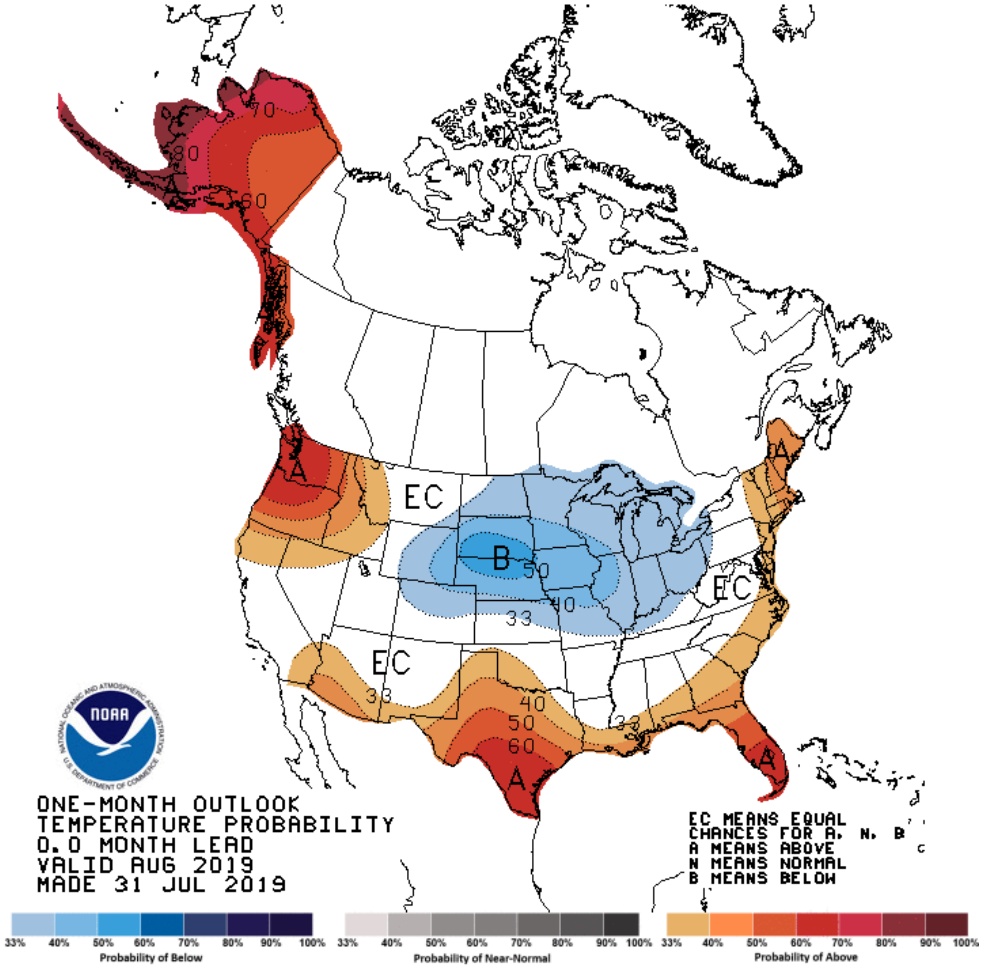
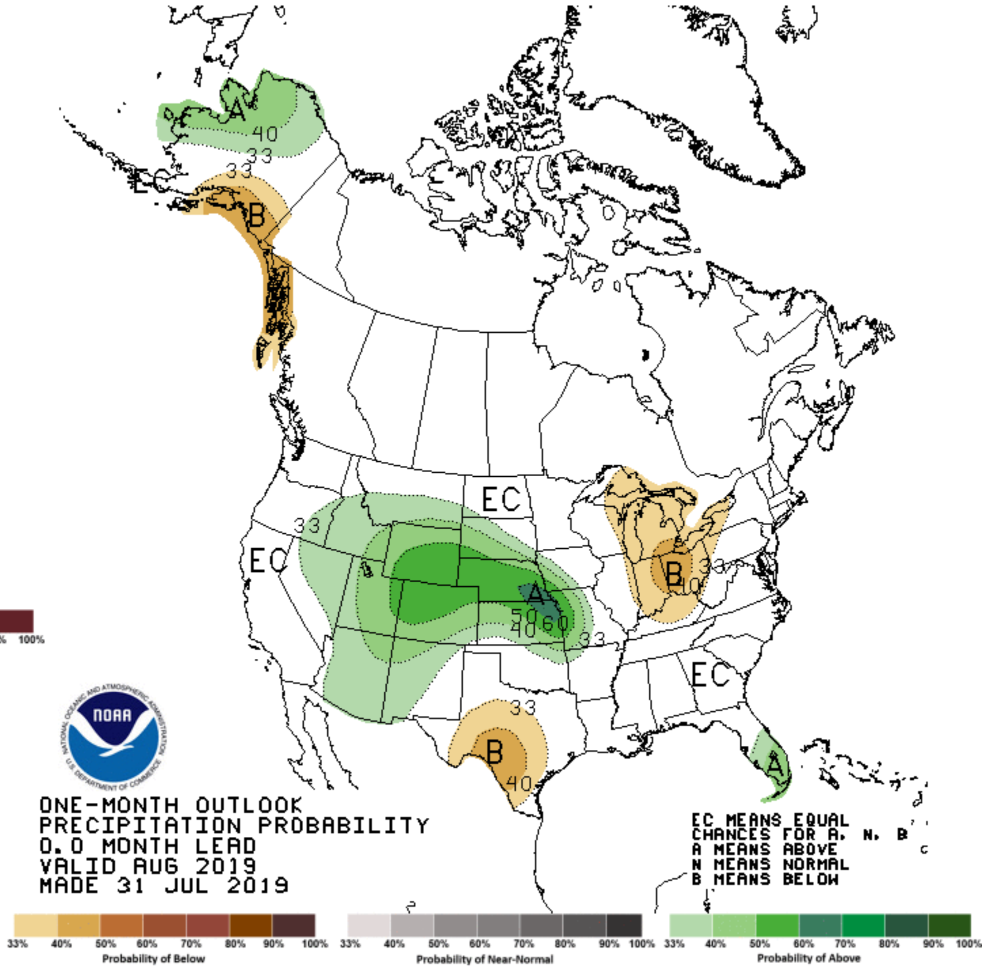
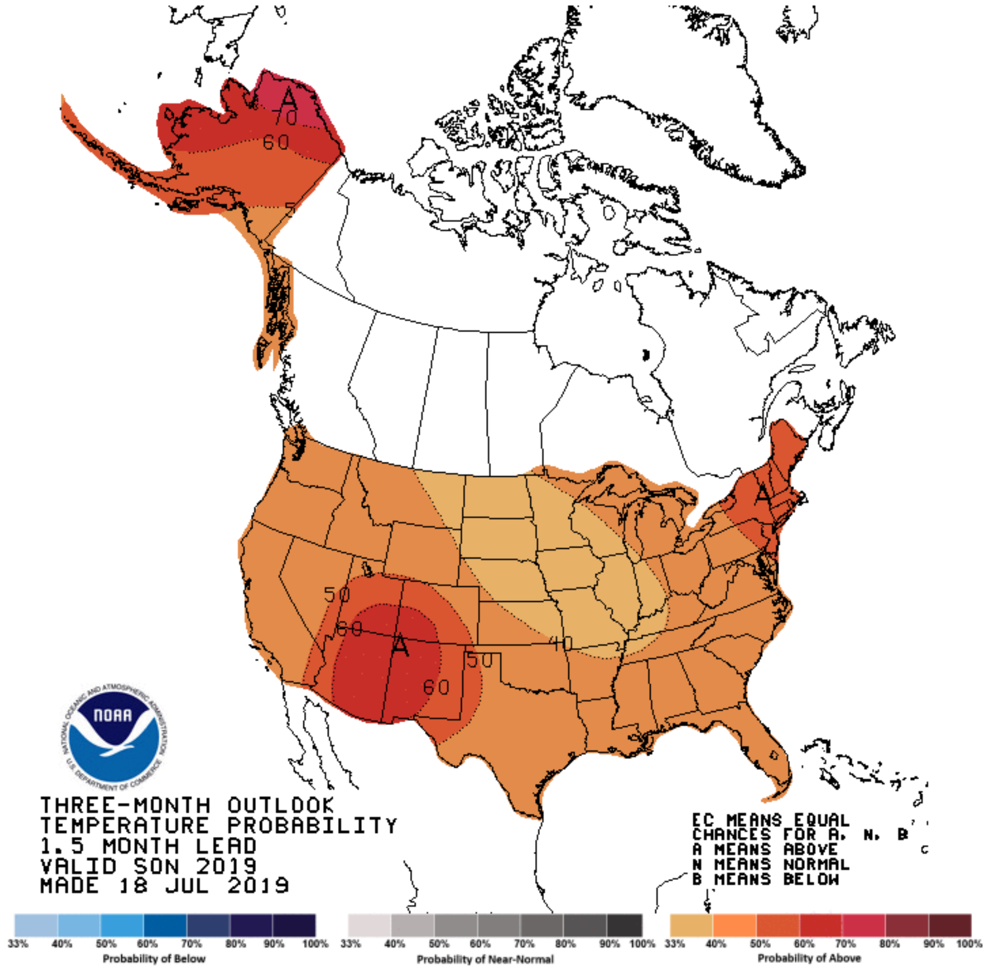
August





CFAES

Sept-Nov



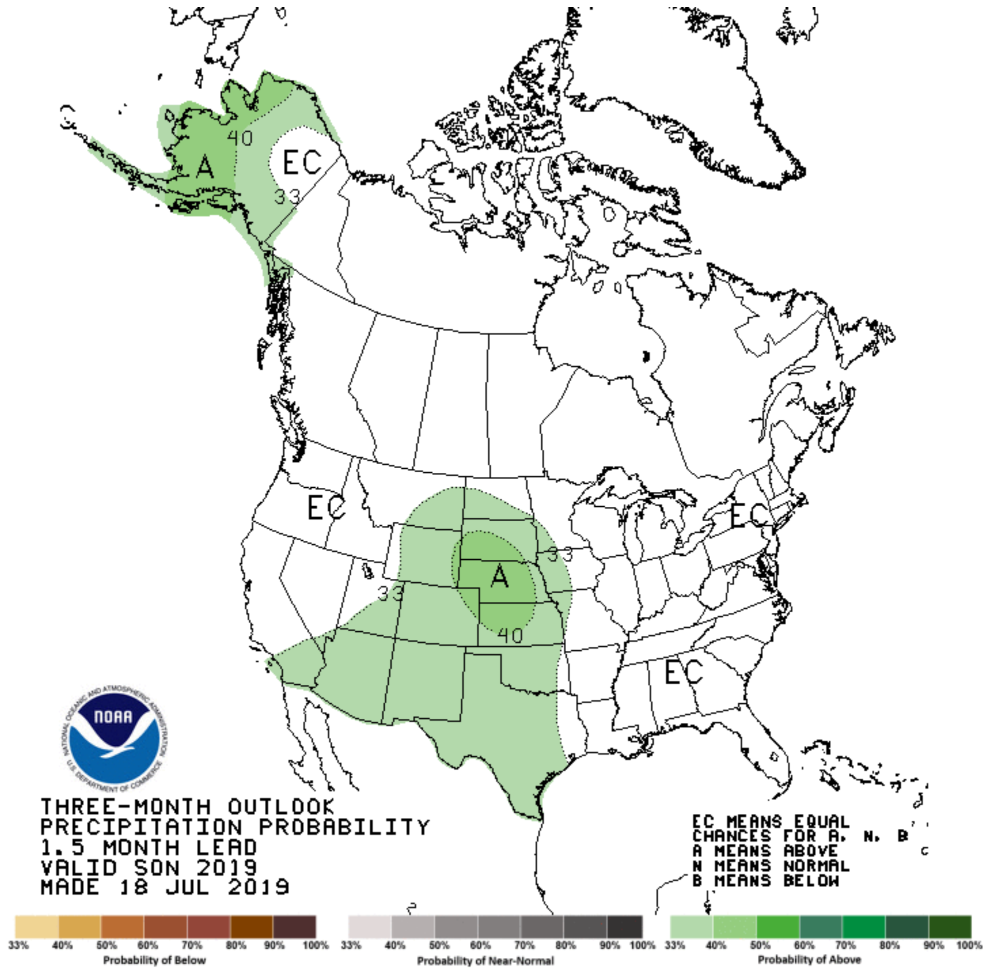


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Photo Credit: Amanda Douridas

Extra Slides

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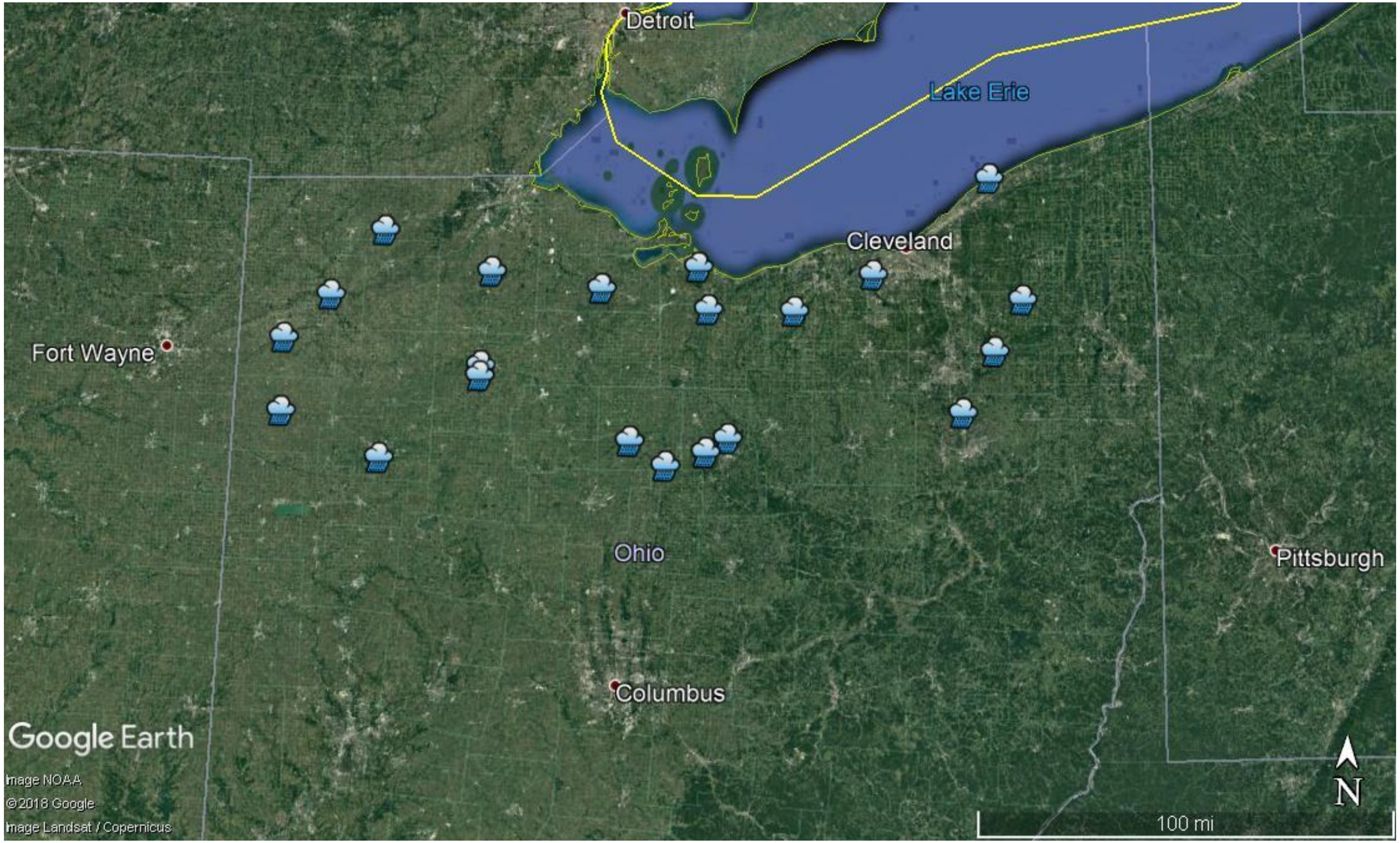
Lake Erie Basin Rainfall (1950-2014)



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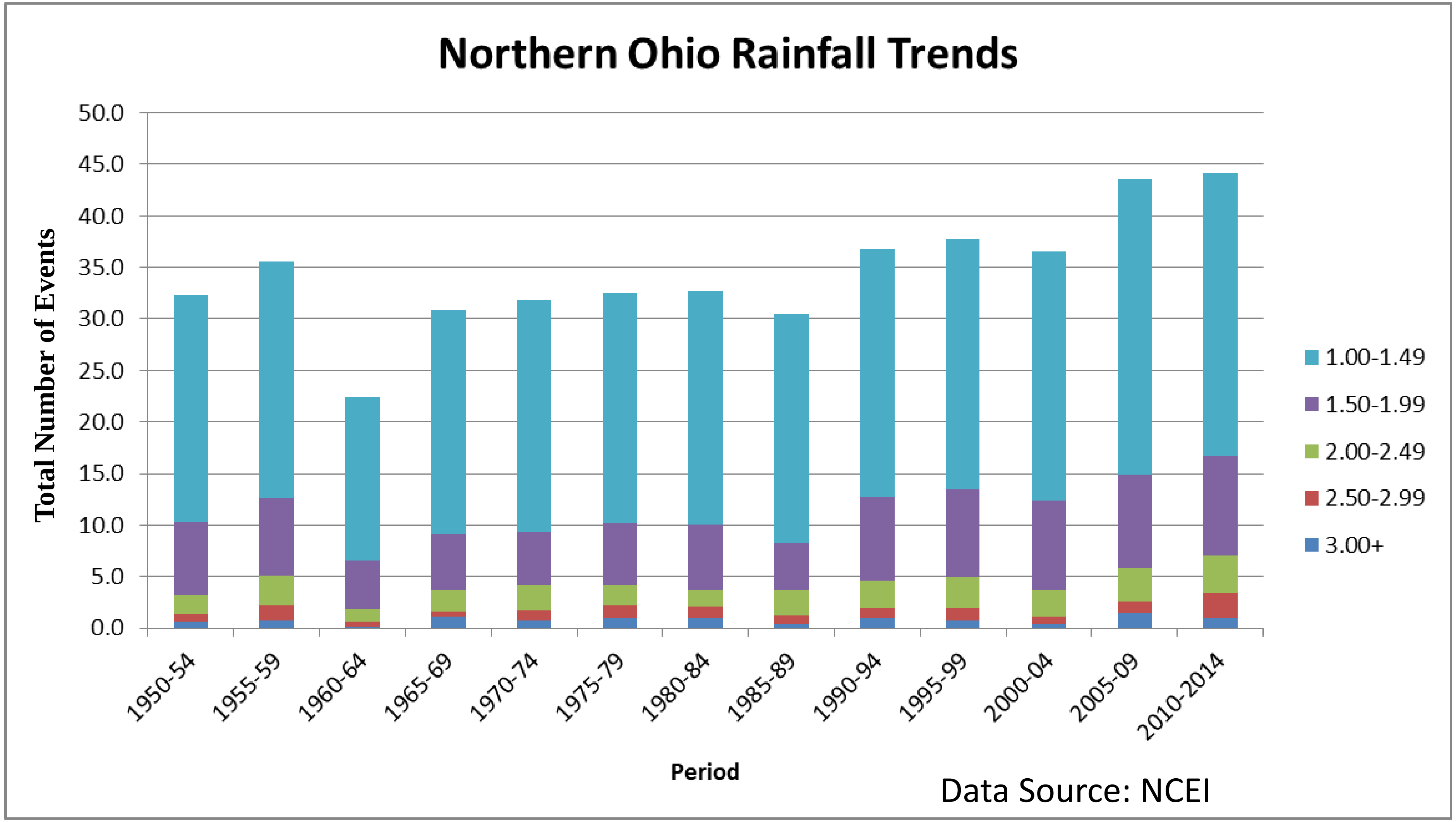
Daily Rainfall Frequencies



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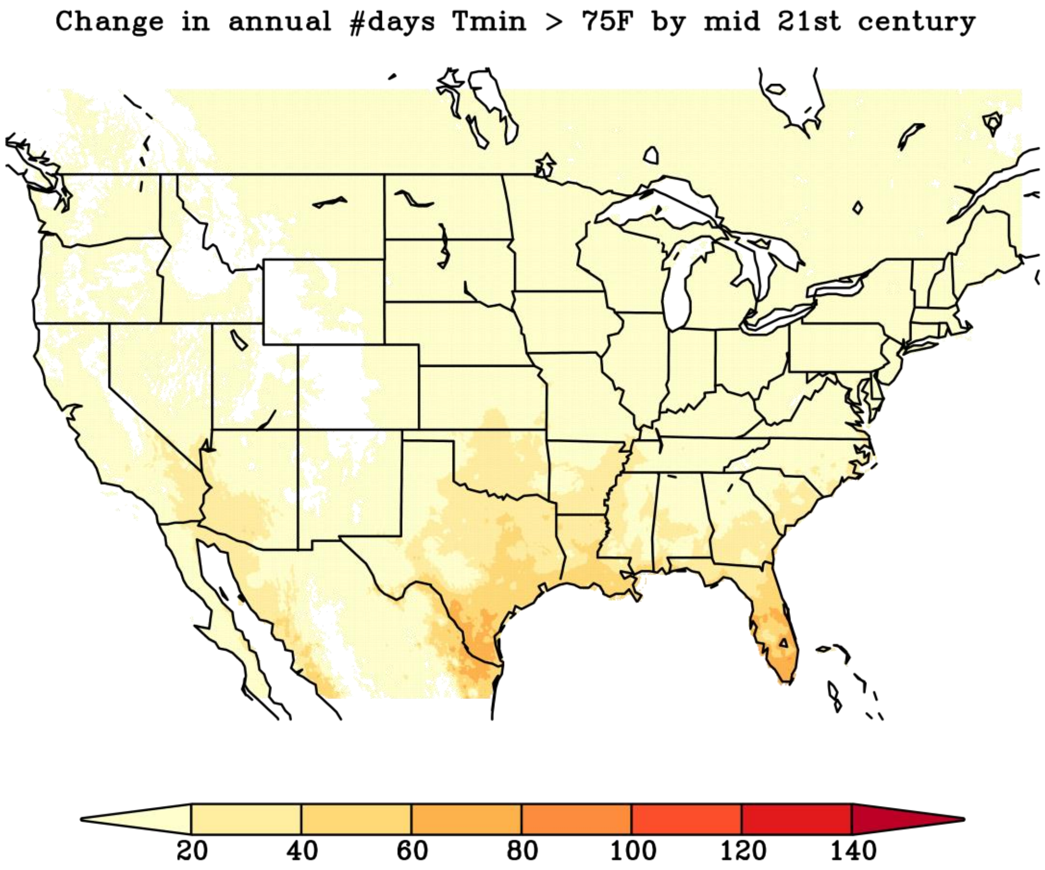
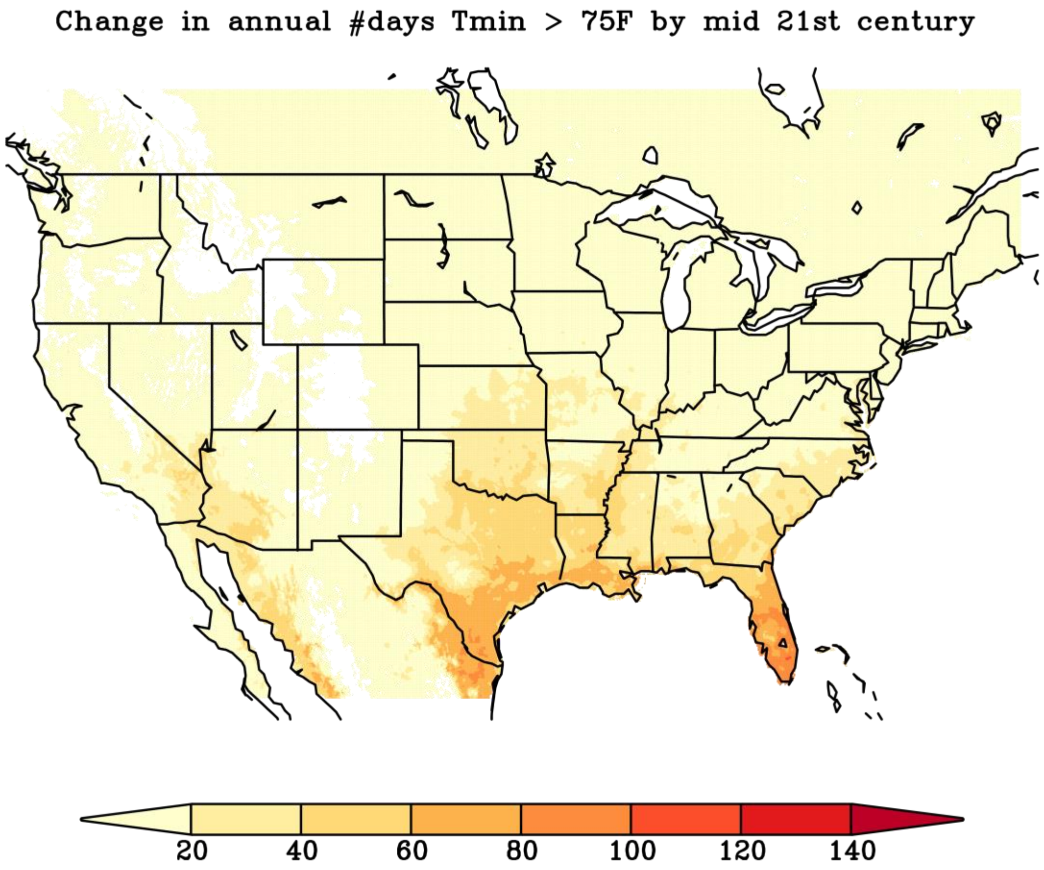
Change in Annual Number of Nights > 75°F

Lower Emissions



Higher Emissions



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(1976-2005): <10 days per year

https://scenarios.globalchange.gov/loca-viewer/

Impacts on Soil Processes

Pareek N (2017) Climate Change Impact on Soils: Adaptation and Mitigation. MOJ Eco Environ Sci 2(3): 00026. DOI: 10.15406/mojes.2017.02.00026

Increasing Temperature	Loss of soil organic matter Reduction in labile pool of SOM Reduction in moisture content Increase in mineralization rate Loss of soil structure Increase in soil respiration rate
Increasing CO2 Concentration	Increase in soil organic matter Increase in water use efficiency More availability of carbon to soil microorganisms Accelerated nutrient cycling.
Increasing Rainfall	Increase in soil moisture or soil wetness Enhanced surface runoff and erosion Increase in soil organic matter Nutrient leaching Increased reduction of Fe and nitrates Increased volatilization loss of nitrogen Increase in productivity in arid regions
Reduction in Rainfall	Reduction in soil organic matter Soil salinization Reduction in nutrient availability

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Soil & Water Health

- Seasonal precipitation changes and impacts on water availability for crop production

- Healthy soils impacted by erosion, compaction, and loss of organic matter.
  - Organic material impacted by soil temperature & water availability
  - Increased erosion from intense extreme rainfall events
  - Increased potential for associated, off-site, non-point-source pollution.
  - Tillage intensity, crop selection, as well as planting and harvest dates can significantly affect runoff and soil loss.

- Surface and groundwater systems impacted over time through changes in evapotranspiration and recharge)

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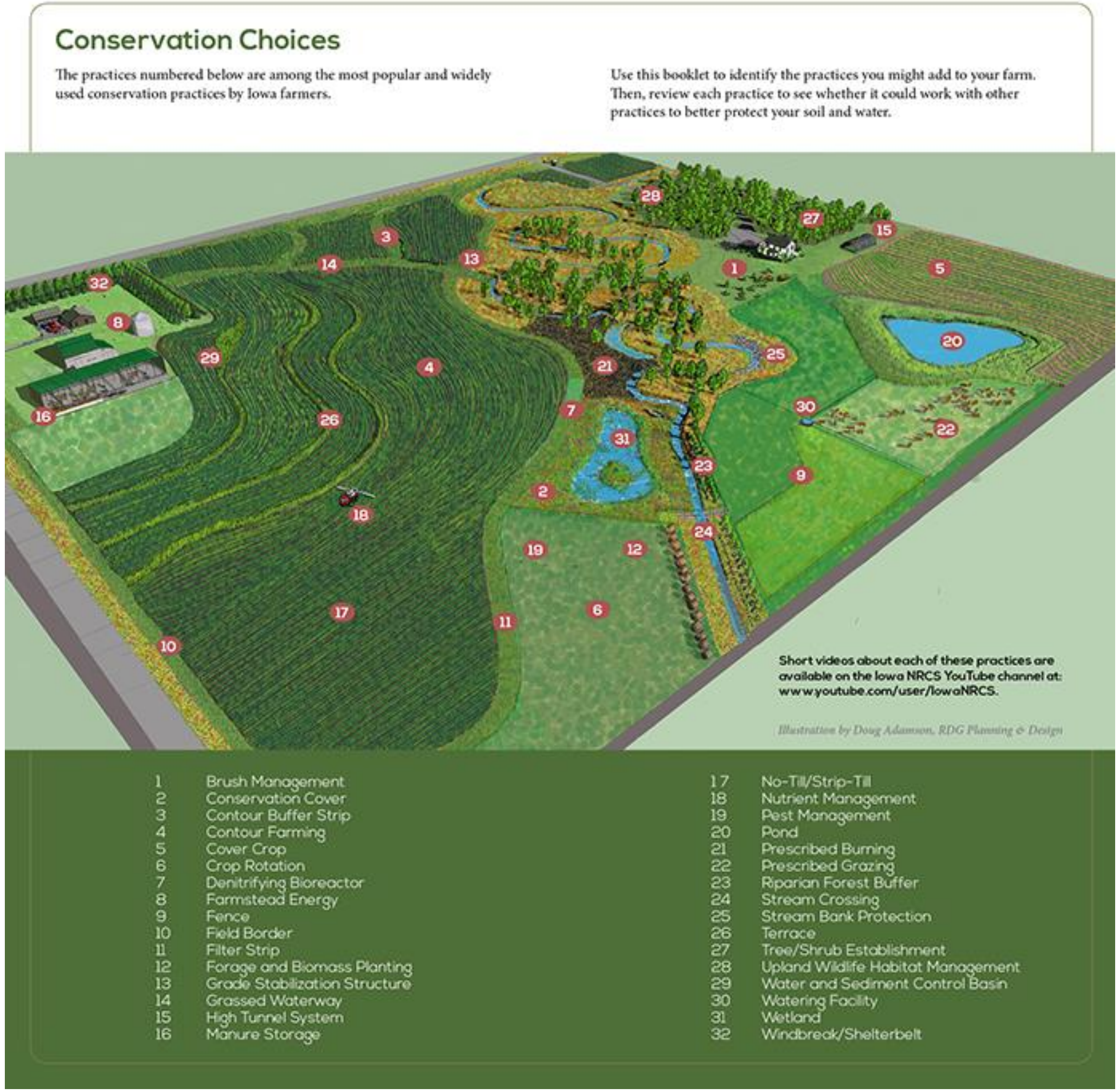
Conservation Practices for Discussion

- What strategies slow the progress of water from fields to streams?

- What strategies improve the quality of the soil, thereby improving plant health and water storage capacity?



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Other Crop and Water Management Strategies

Manage higher temperatures

•crop regulation and canopy management, such as using temperature data loggers to optimize temperatures; greenhouse modifications

•using irrigation to ameliorate temperature extremes; sprinkler irrigation can reduce canopy temperatures.

•Vegetable/Fruit hybrids with greater heat tolerance

https://www.agric.wa.gov.au/climate-change/climate-change-and-horticulture

Improve water harvesting and storage

- dams and catchments to cope with projected rainfall and evaporation rates
- use in-row water harvesting for grapes and tree crops
- harvest water run-off from greenhouses
- increase investment in tanks and dam storages.

Improve irrigation efficiency

- watering at night; drip irrigation; subsurface drip irrigation
- reduced evaporation of soil water through mulching with organic materials, mulching with plastic, rapid crop canopy development/closure
- reducing run-off by using appropriate irrigation rates, mulches, contour sowing, minimum tillage, claying.

Grow crops under shelters or greenhouses

- use netting to provide shade (reduced canopy temperature and evaporation) and reduce risk of hail and bird damage
- grow crops in greenhouses to increase productivity by using plastic tunnels, plastic structures with computerized temperature control and shading systems; glass structures with computerized temperature control and shading systems

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Climate Smart: Ag and Mitigation

Food and Agriculture Organization of the United Nations: "It is estimated that soils can sequester around 20 Pg C in 25 years, more than 10 % of the anthropogenic emissions."

http://www.fao.org/home/en/

1 Pg = 1 trillion kg

Rattan Lal: https://senr.osu.edu/our-people/rattan-lal

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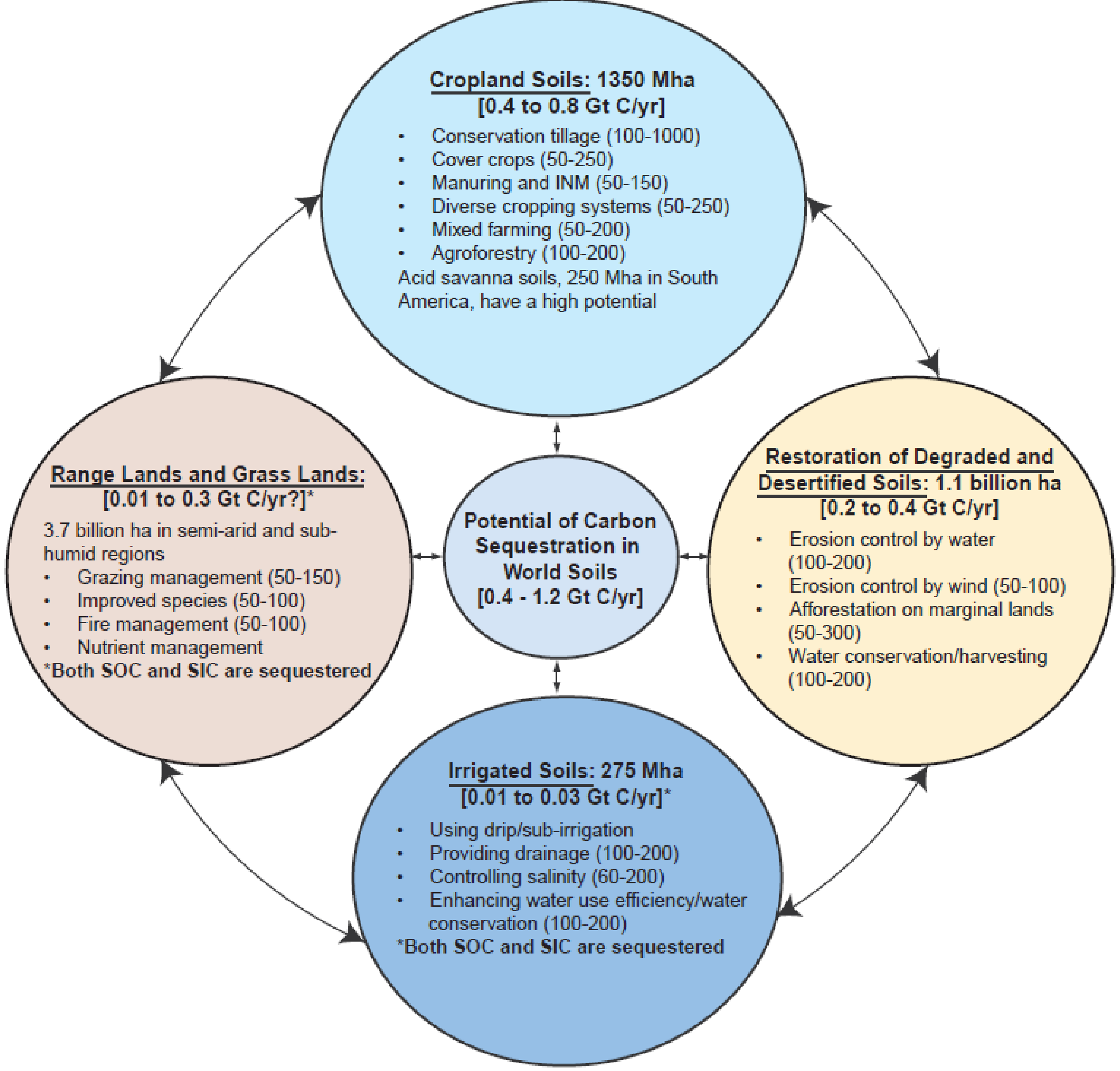
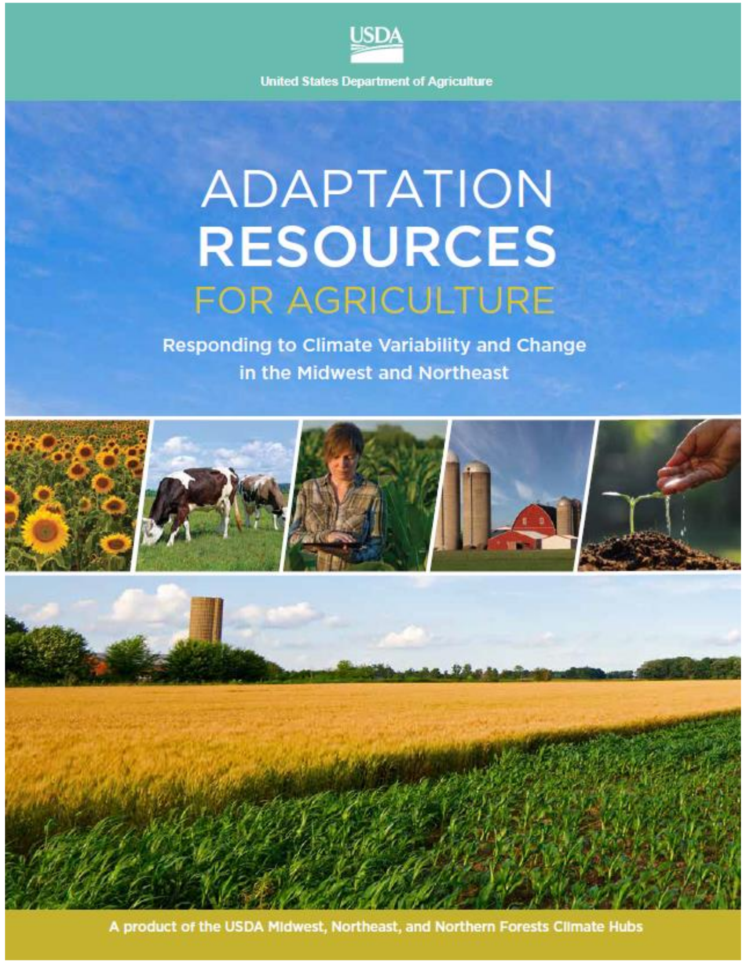


Fig. 2. Ecosystems with a high and attainable soil C sequestration potential are cropland, grazing/range land, degraded/desertified lands, and irrigated soils. Forest soils are included under afforestation of agriculturally marginal and otherwise degraded/desertified soils. Reforestation of previously forested sites have small additional soil C sequestration. The potential of C sequestration of range lands/grassland is not included in the global total because part of it is covered under other ecosystems, and there are large uncertainties. Rates of C sequestration given in parentheses are in kg C/ha per year, are not additive, and are low under on-farm conditions. [Rates are cited from (*2–9, 15, 25, 37–39*) and other references cited in the supporting material.]

Adaptation Resources



Strategy 1: Sustain fundamental functions of soil and water.

Strategy 2: Reduce existing stressors of crops and livestock.

Strategy 3: Reduce risks from warmer and drier conditions.

Strategy 4: Reduce the risk and long-term impacts of extreme weather.

Strategy 5: Manage farms and fields as part of a larger landscape.

Strategy 6: Alter management to accommodate expected future conditions.

Strategy 7: Alter agricultural systems or lands to new climate conditions.

Strategy 8: Alter infrastructure to match new and expected conditions.

https://www.climatehubs.oce.usda.gov/sites/default/files/AdaptationResourcesForAgriculture.pdf

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Janowiak, M., D. Dostie, M. Wilson, M. Kucera, R. Howard Skinner, J. Hatfield, D. Hollinger, and C. Swanston. 2016. Adaptation Resources for Agriculture: Responding to Climate Variability and Change in the Midwest and Northeast. Technical Bulletin 1944. Washington, DC: U.S. Department of Agriculture.