CFAES

The Effects of Climate Change on Water and Wastewater Utilities

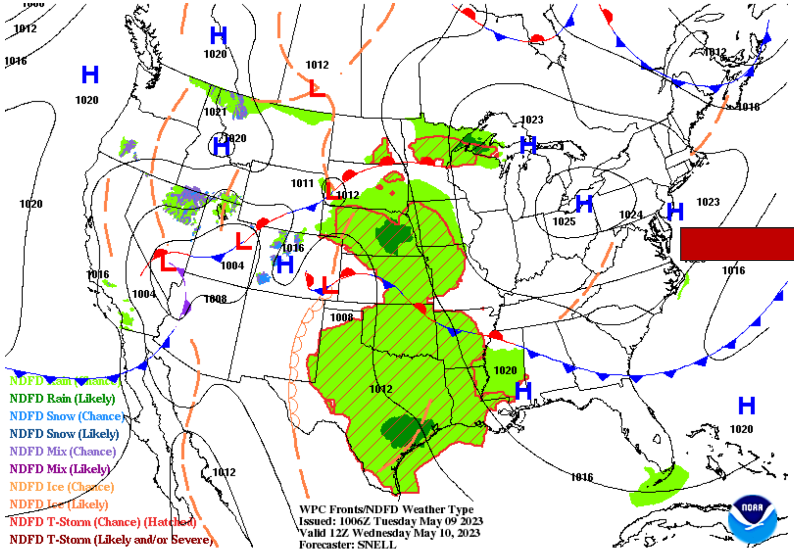
Operator Training of Ohio

Aaron B. Wilson | Assistant Professor – Ag Weather & Climate Field Specialist, Department of Extension – CFAES; Byrd Polar and Climate Center; State Climatologist - The Ohio State University

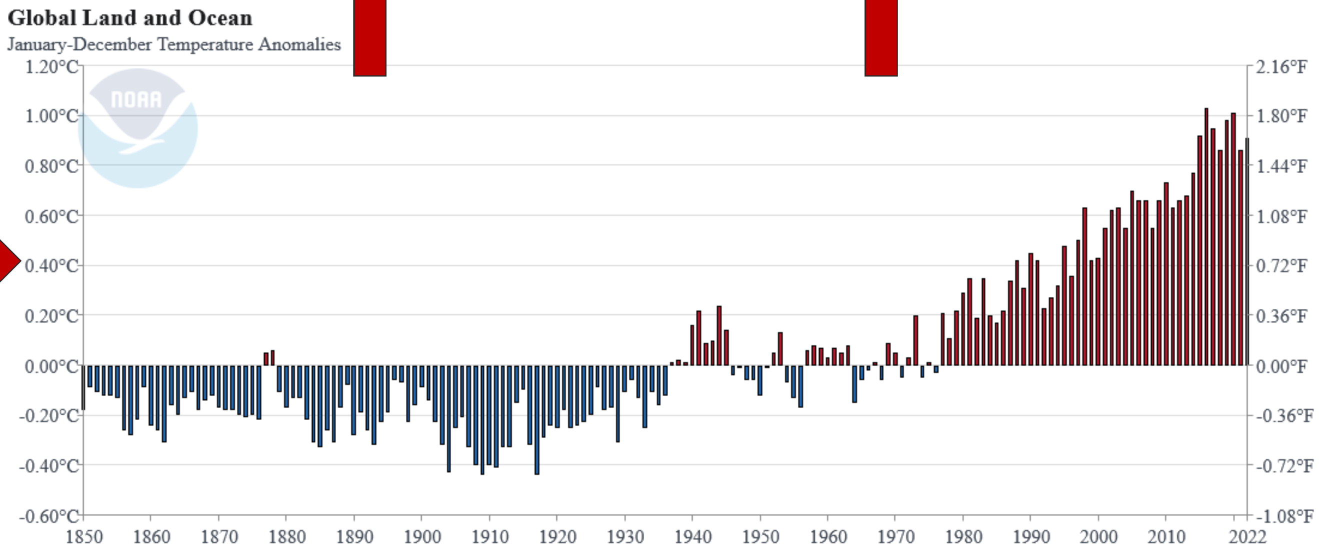
9 August 2023

The Ohio State University

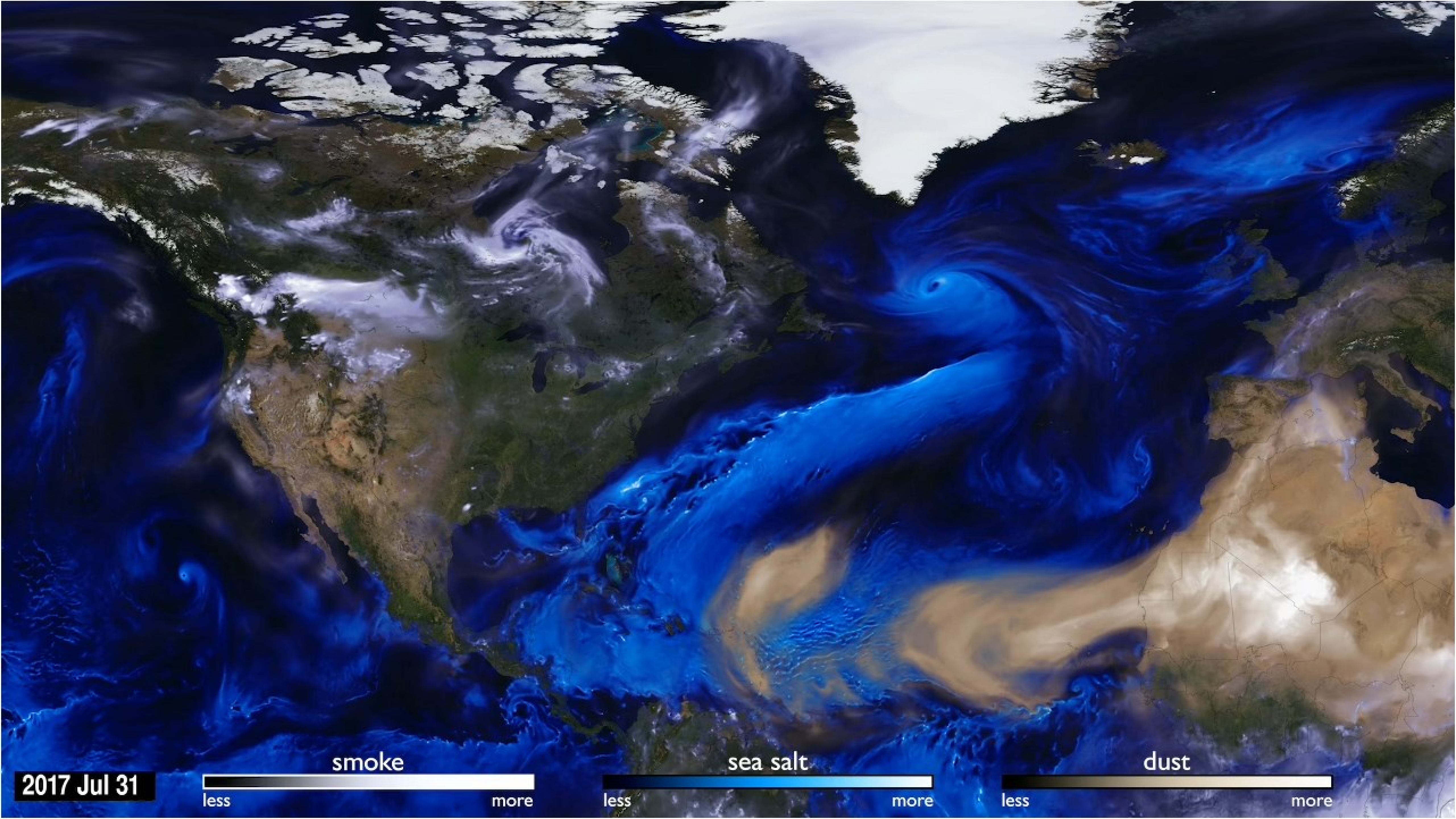
College of Food, Agricultural, and Environmental Sciences

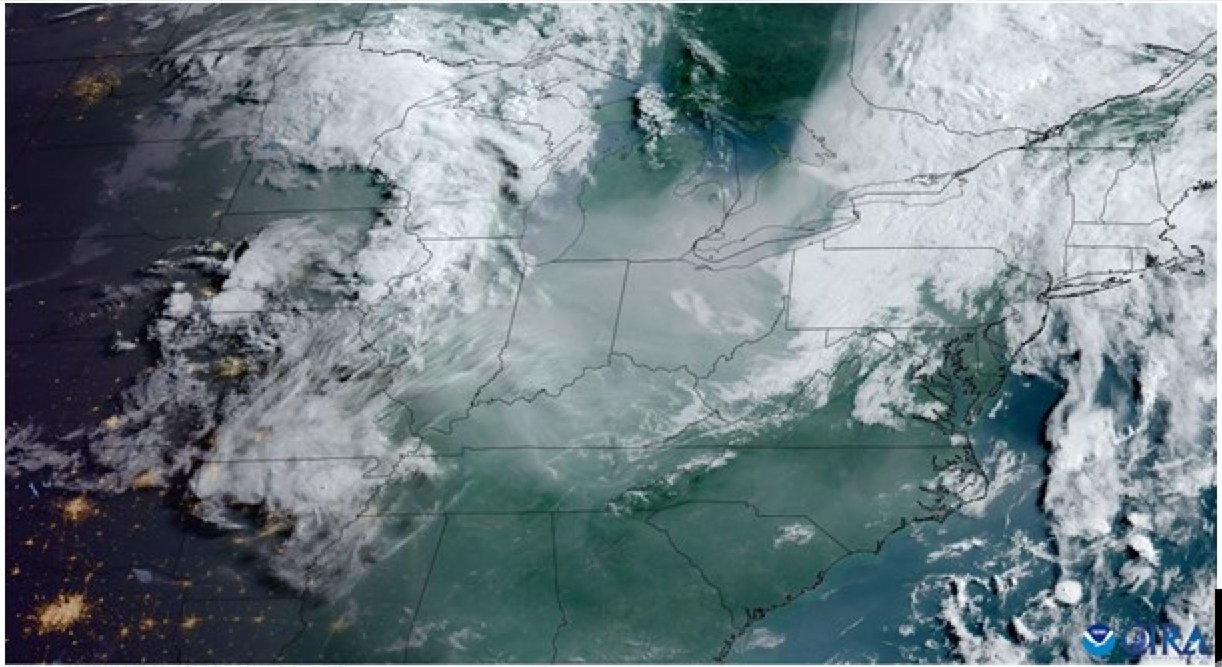


NDFD Rain (Likely)
NDFD Snow (Chance)
NDFD Snow (Likely)
NDFD Mix (Chance)
NDFD Mix (Likely)
NDFD Ice (Chance)
NDFD T-Storm (Chance) (Hatched)
NDFD T-Storm (Likely and/or Severe)
WPC Fronts/NDFD Weather Type
Issued: 1006Z Tuesday May 09 2023
Valid 12Z Wednesday May 10, 2023
Forecaster: SNELL



Global Land and Ocean
January-December Temperature Anomalies
1.20°C
1.00°C
0.80°C
0.60°C
0.40°C
0.20°C
0.00°C
-0.20°C
-0.40°C
-0.60°C
2.16°F
1.80°F
1.44°F
1.08°F
0.72°F
0.36°F
0.00°F
-0.36°F
-0.72°F
-1.08°F
1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2022


2017 Jul 31
smoke
less
more
sea salt
less
more
dust
less
more


06-28-2023 | 12:01:17 UTC | GOES-16 | GeoColor

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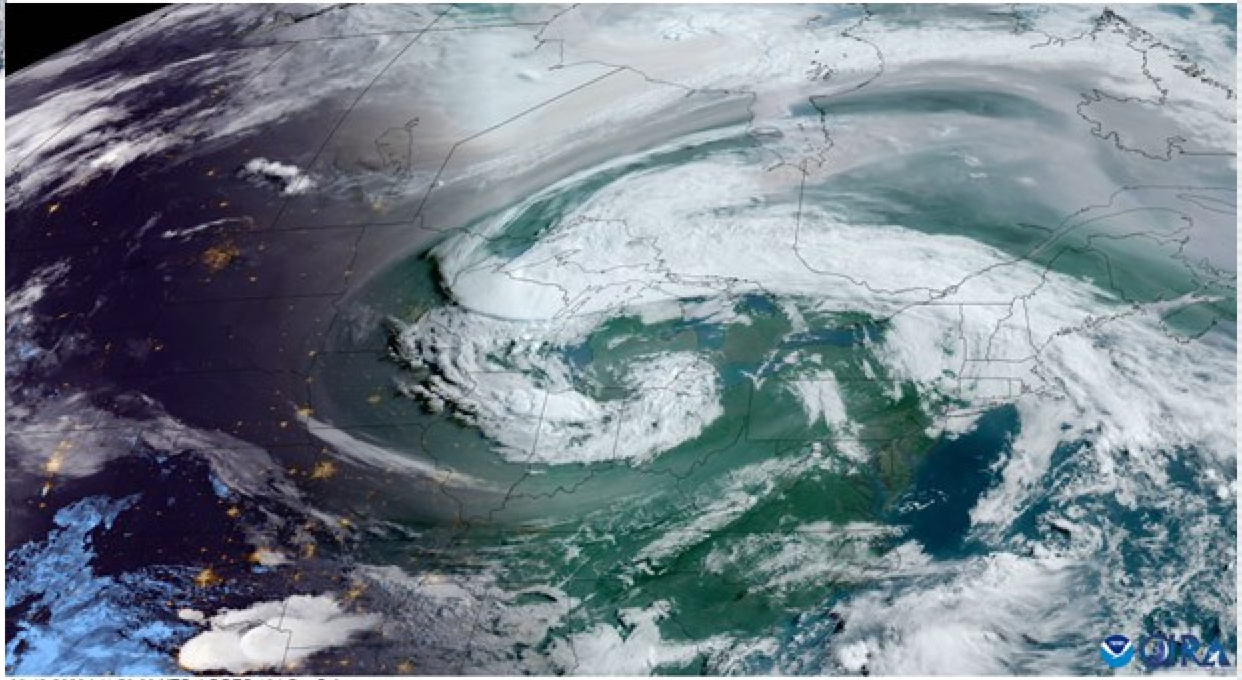
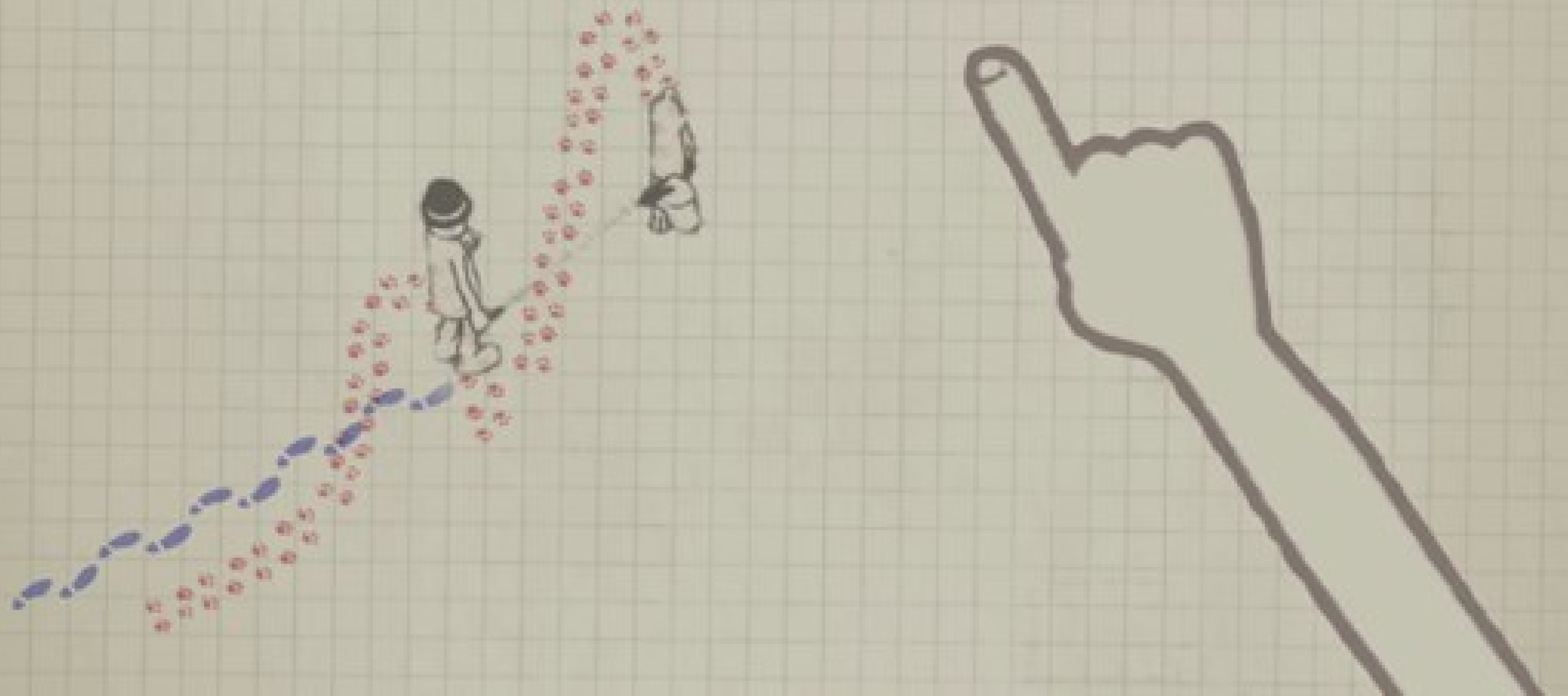

06-13-2023 | 11:50:20 UTC | GOES-16 | GeoColor



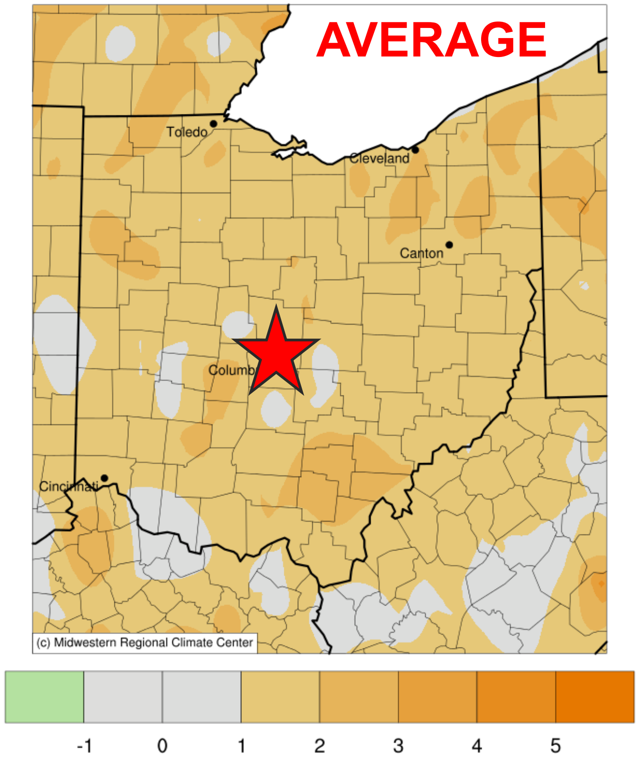
Recent Weather in Context

Photo Credit: Sam Custer

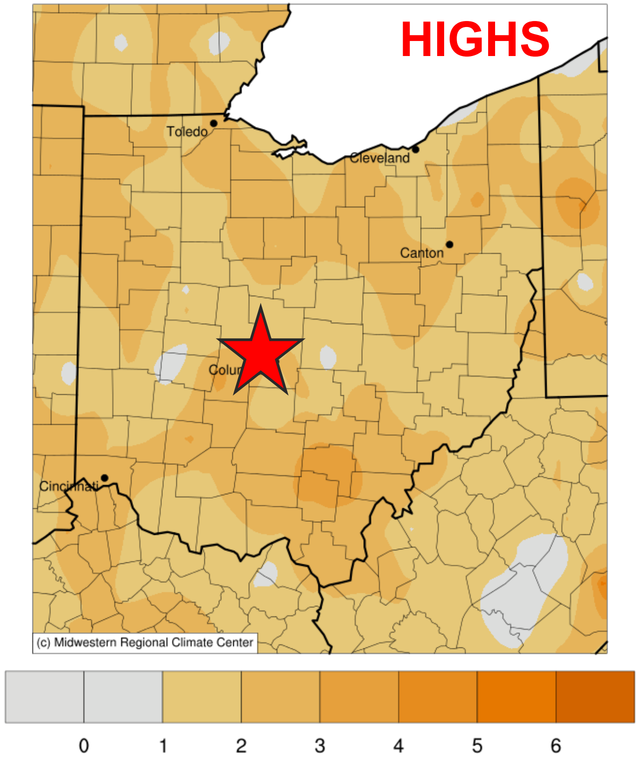
2023 YTD Temperatures

6th Warmest (1895-2023)

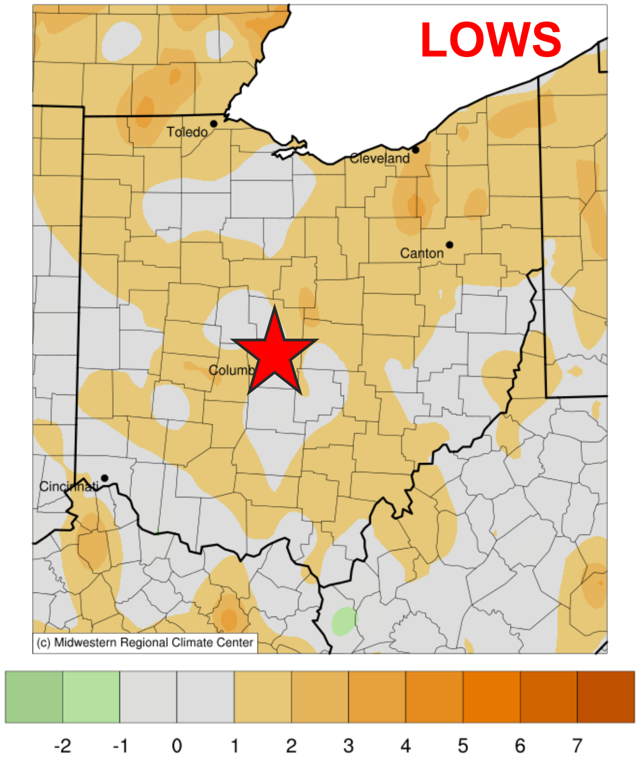
Average Temperature (°F): Departure from 1991-2020 Normals
January 01, 2023 to August 07, 2023



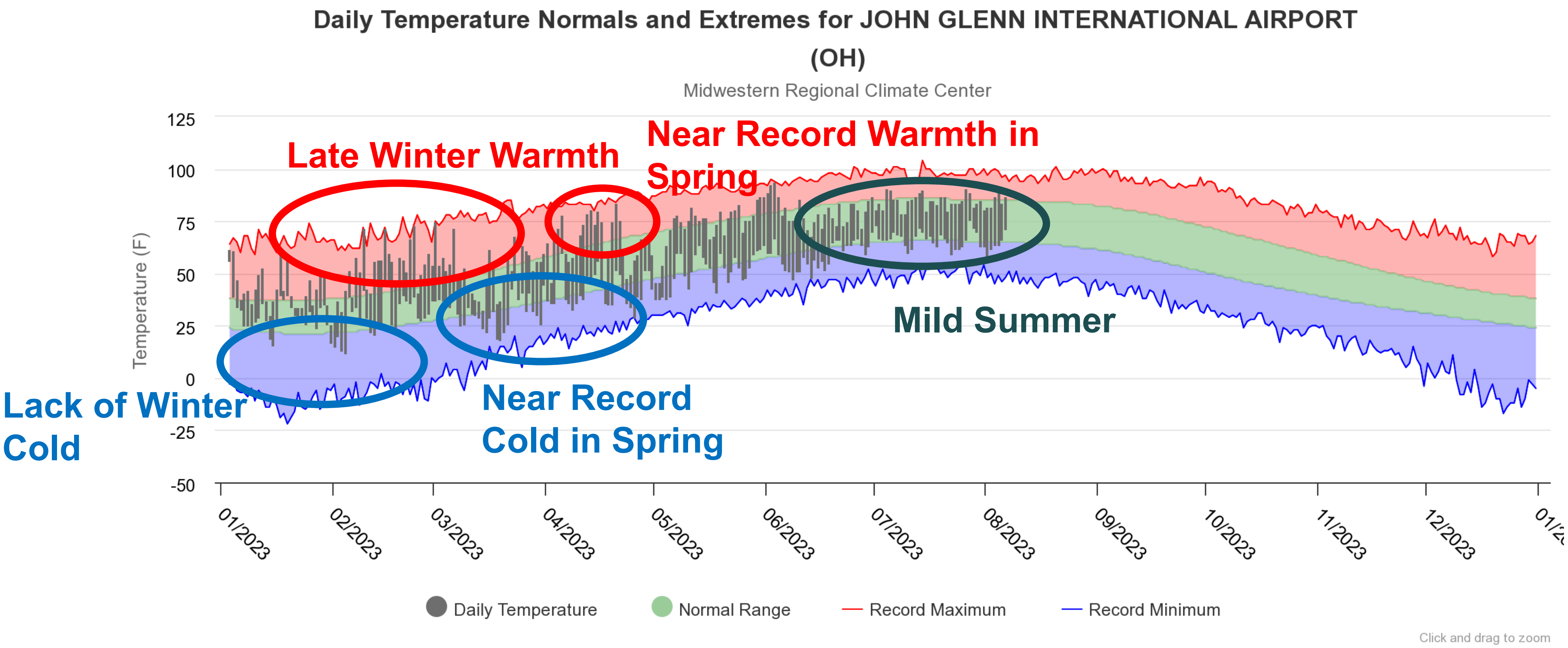
Average Maximum Temperature (°F): Departure from 1991-2020 Normals
January 01, 2023 to August 07, 2023



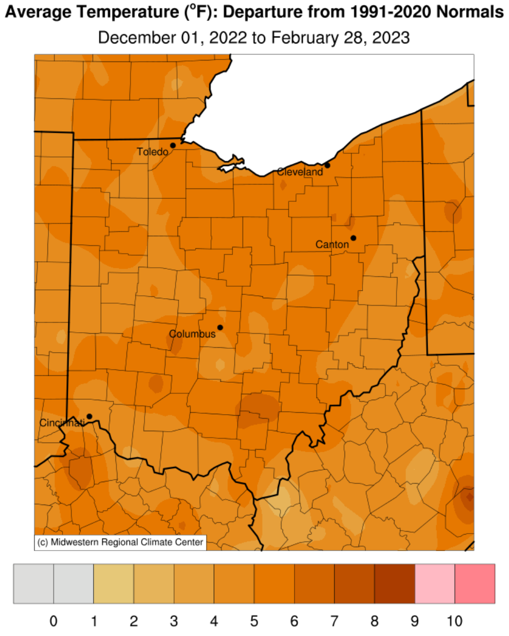
Average Minimum Temperature (°F): Departure from 1991-2020 Normals
January 01, 2023 to August 07, 2023



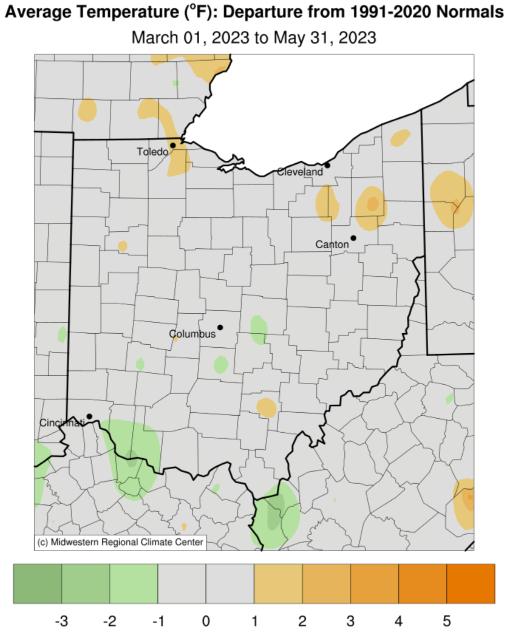
2023 Temperature Summary: Columbus, Ohio



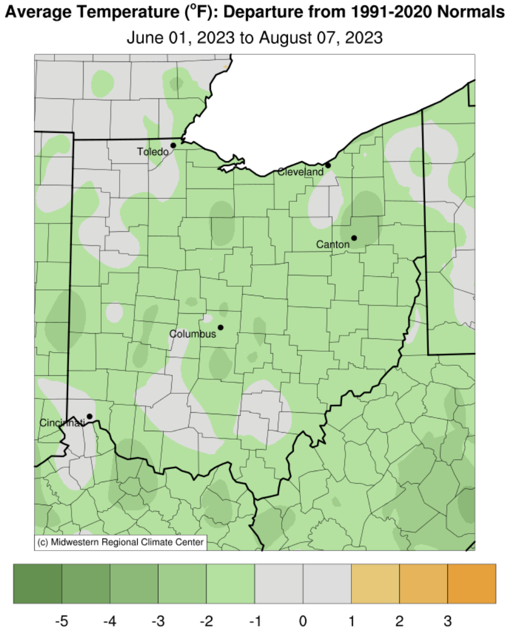
2023 Seasonal Temperatures So Far



WINTER



SPRING



SUMMER

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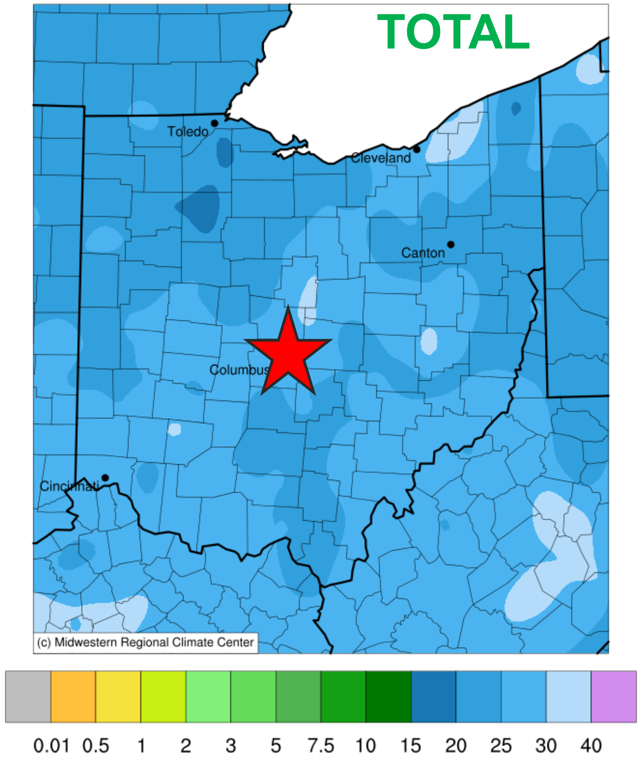
Fall

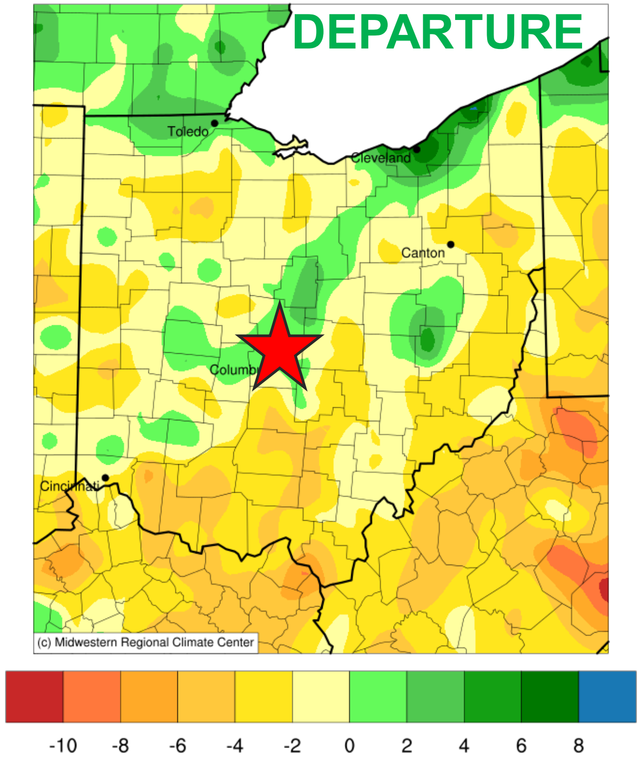
2023 YTD Precipitation

62nd Driest (1895-2023)

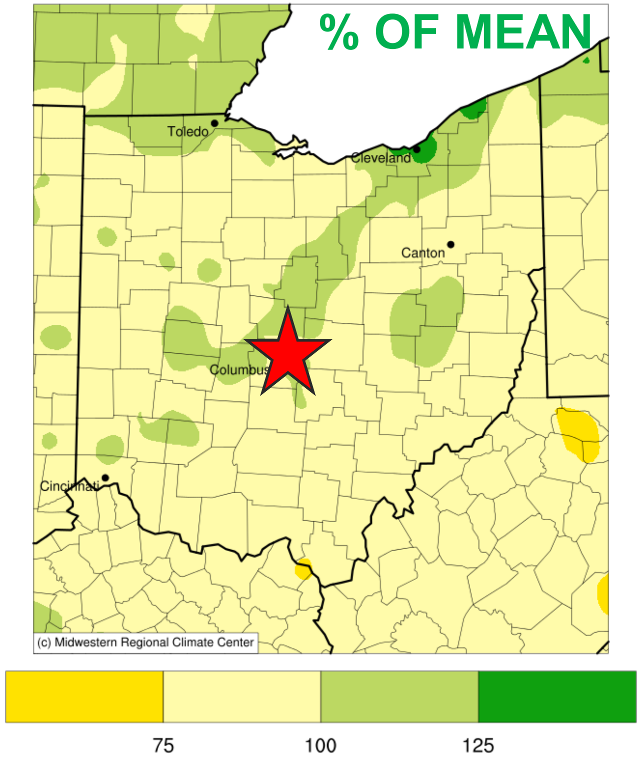
Accumulated Precipitation (in)
January 01, 2023 to August 07, 2023



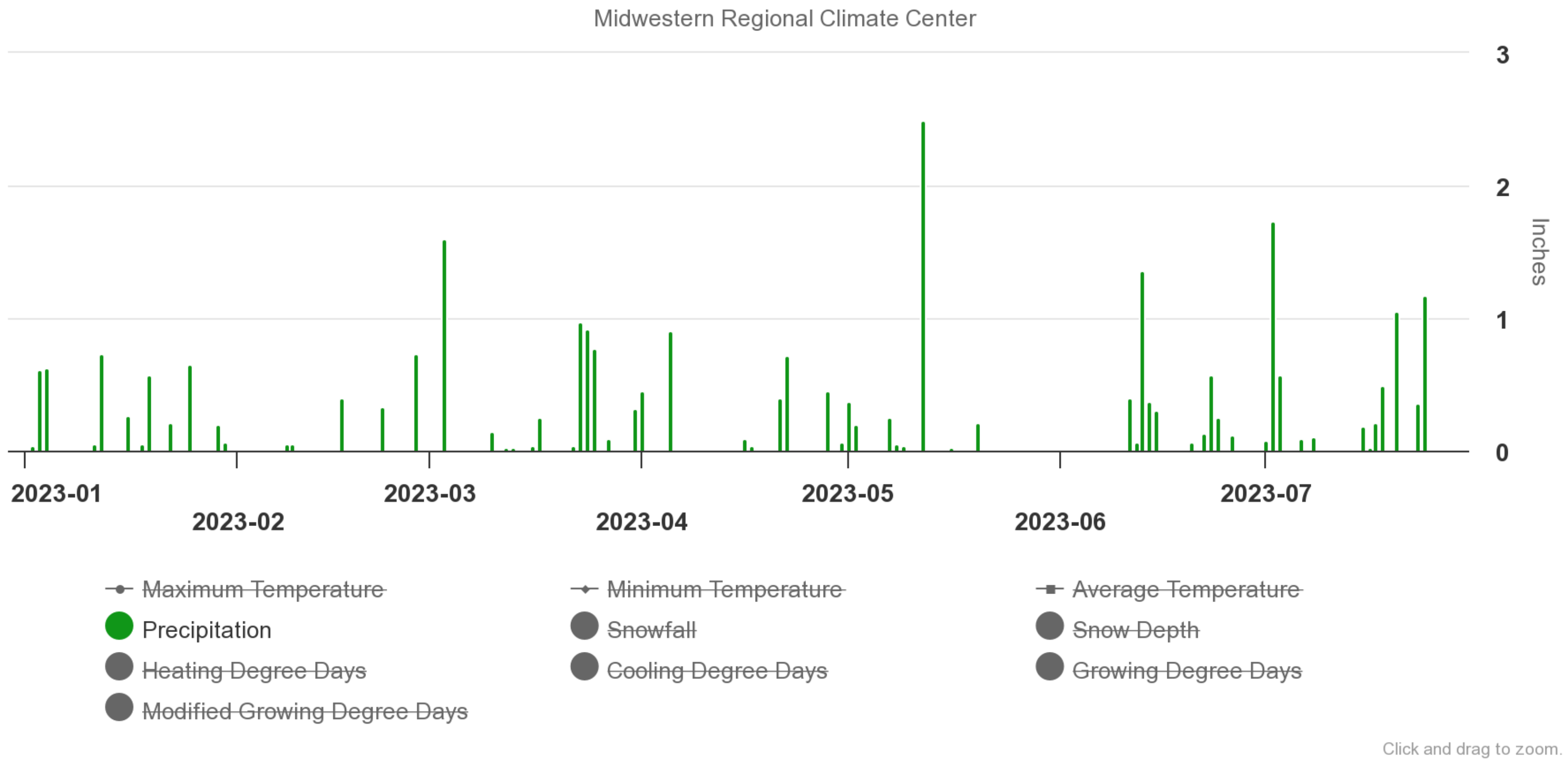
Accumulated Precipitation (in): Departure from 1991-2020 Normals
January 01, 2023 to August 07, 2023



Accumulated Precipitation (in): Percent of 1991-2020 Normals
January 01, 2023 to August 07, 2023

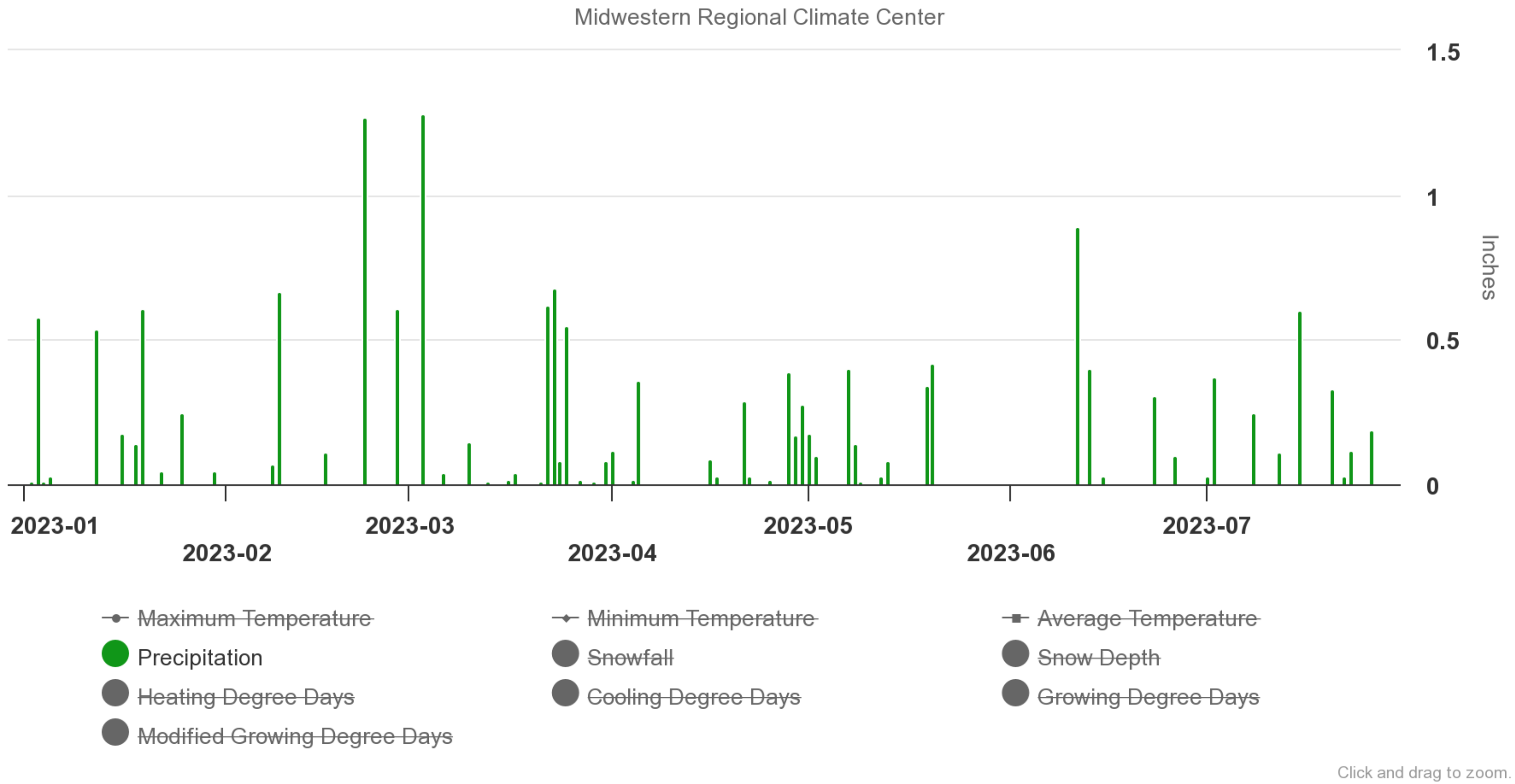


2023 Precipitation Summary: Columbus



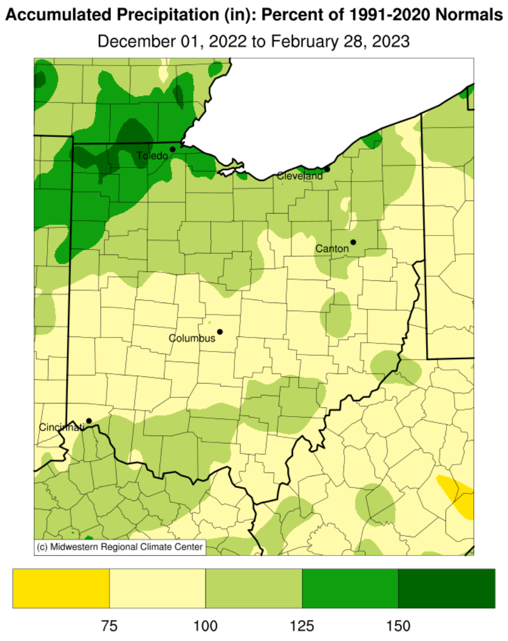
3 events 1-1.50” (~13%)
3 events over 1.5” (~21%)
6 days = ~34% of precipitation (27.66”)

2023 Precipitation Summary: Findlay

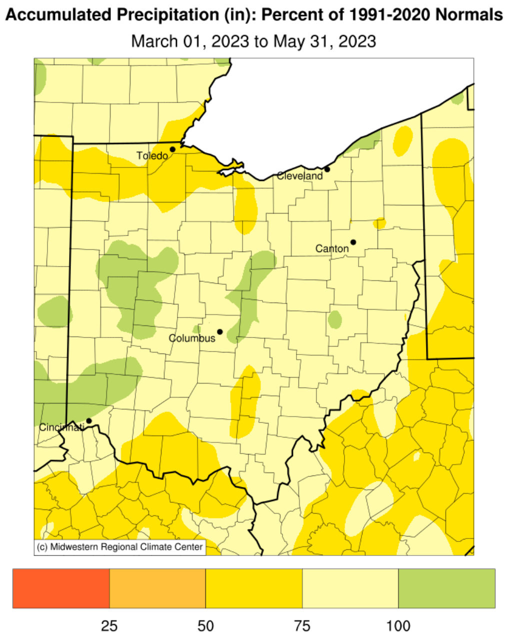


2 events 1-1.50” (~15%)
2 days = ~15% of precipitation (17.16”)

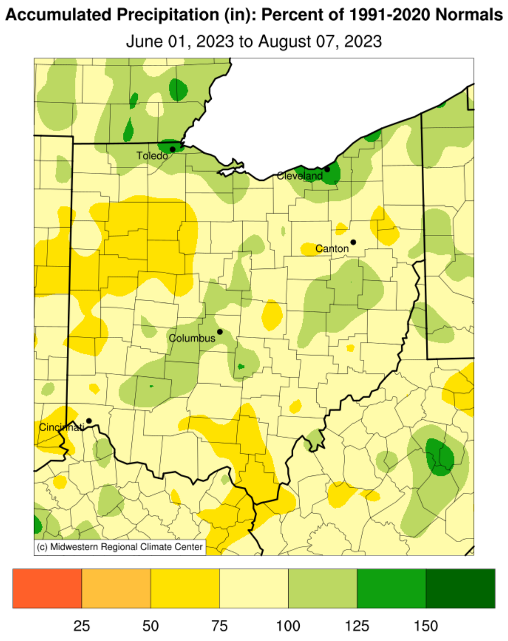
2023 Seasonal Precipitation So Far



WINTER



SPRING



SUMMER

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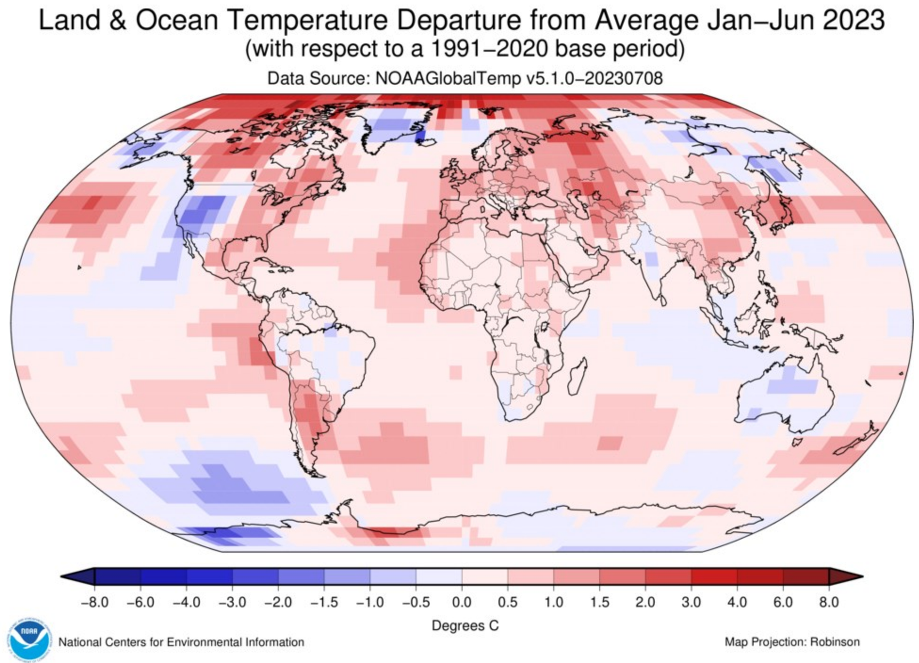
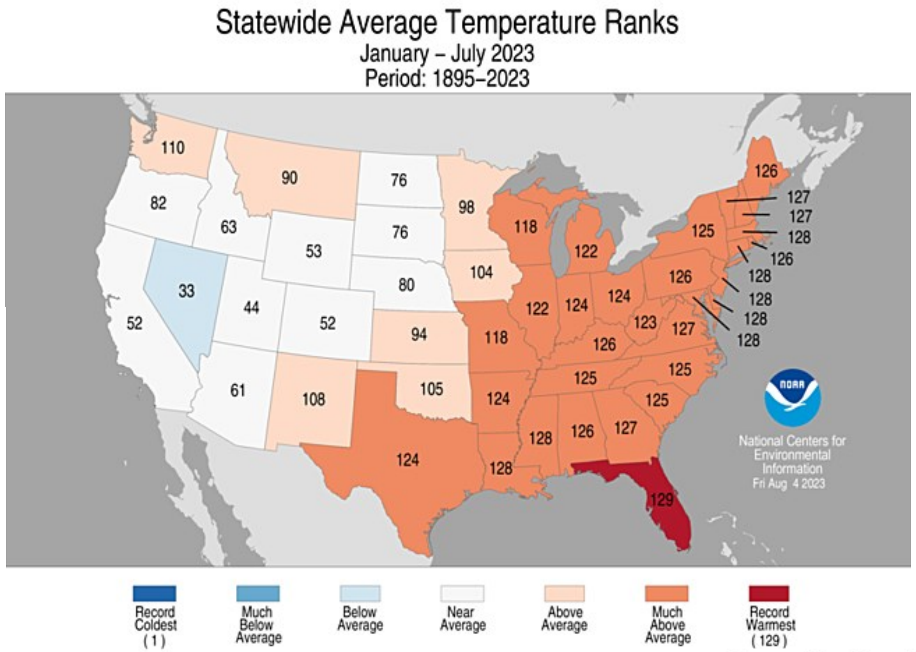
Fall

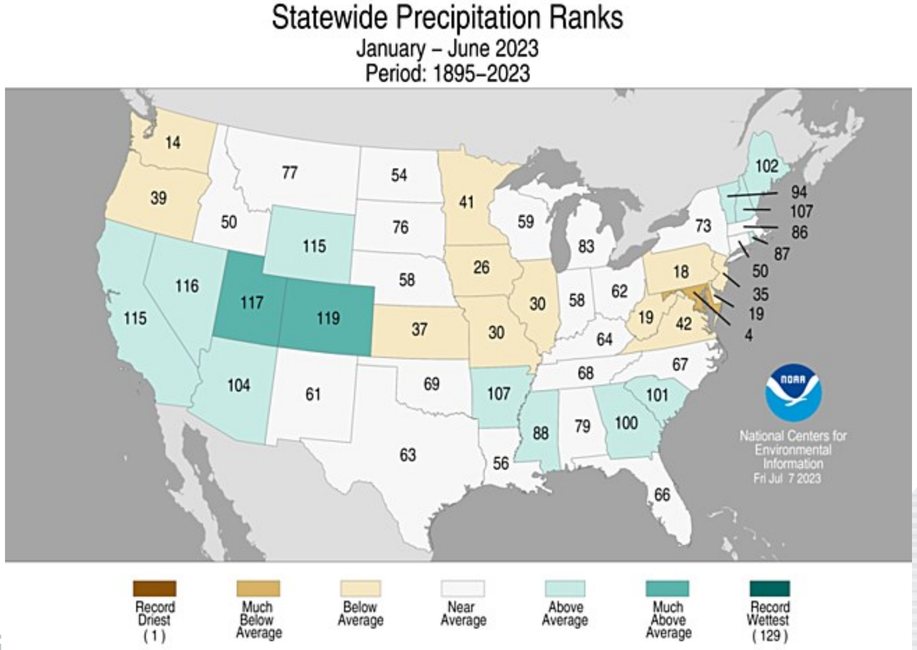
CFAES

Global and US



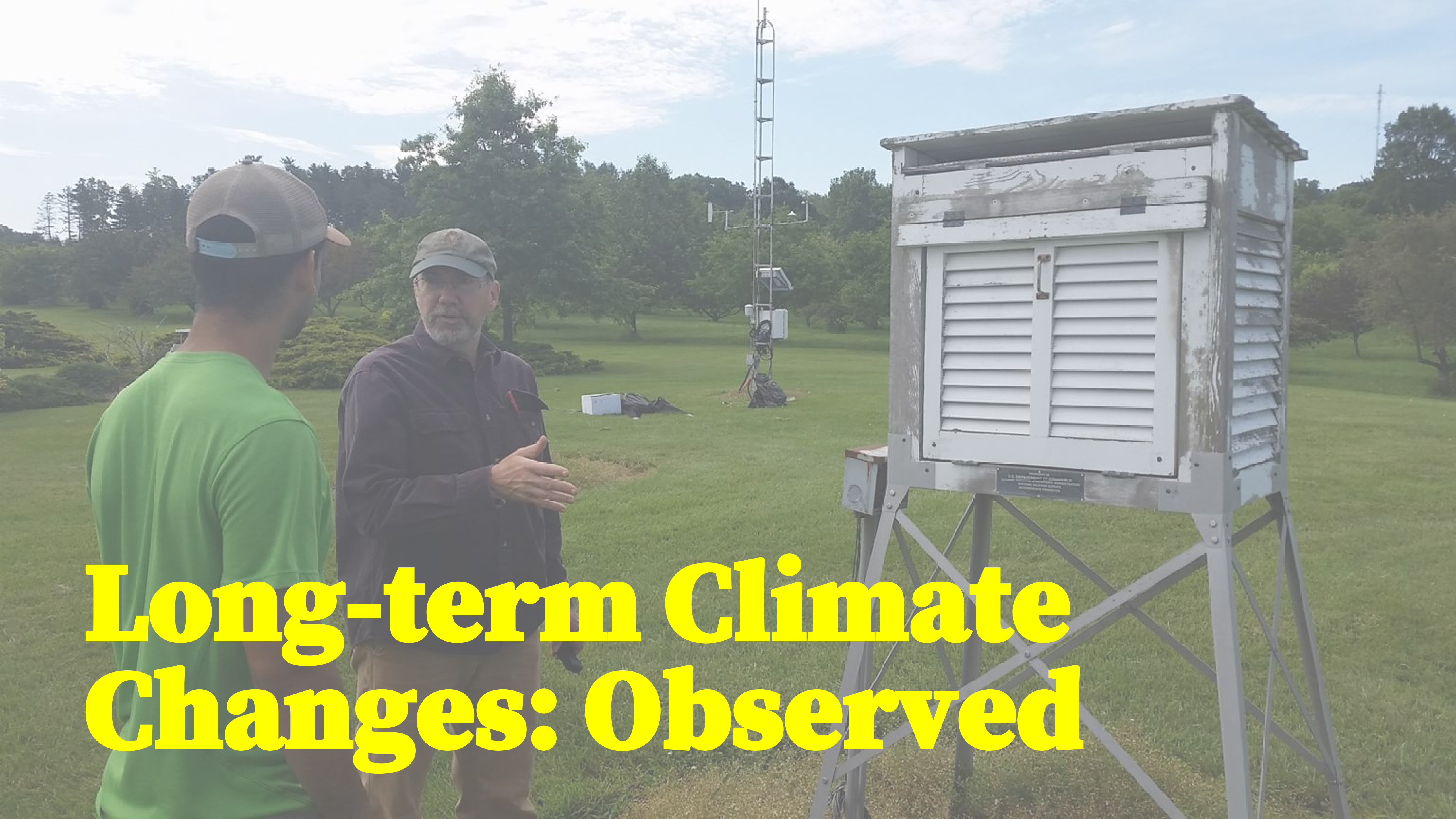


*Ranks as the 16th warmest and 55th wettest since 1895

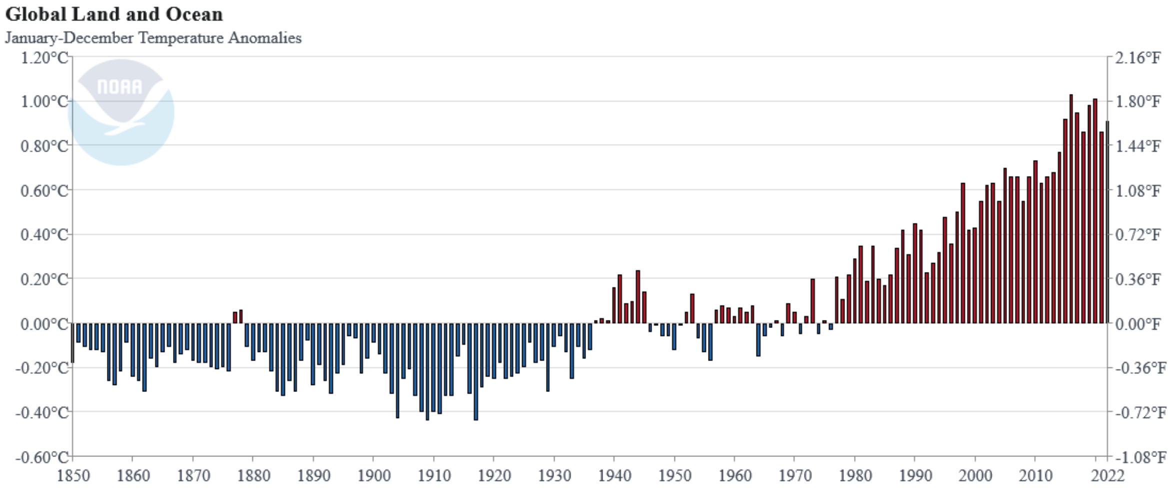


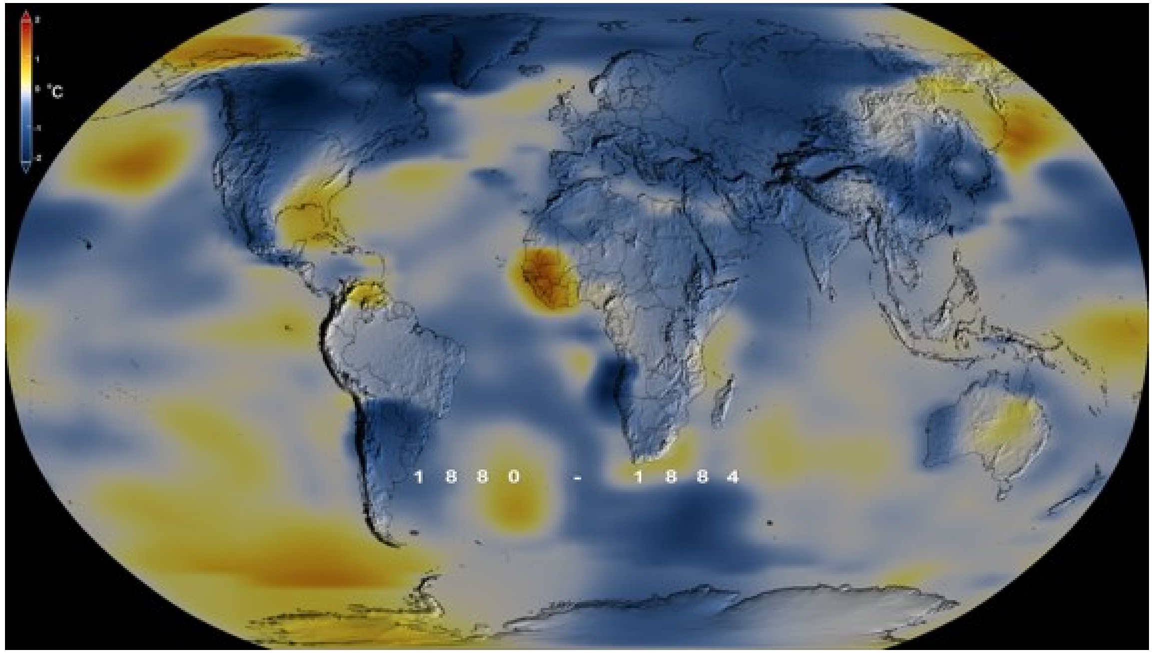
The January–June global surface temperature ranked third warmest in the 174-year record at 1.01°C (1.82°F) above the 1901-2000 average of 13.5°C (56.3°F).

Long-term Climate Changes: Observed



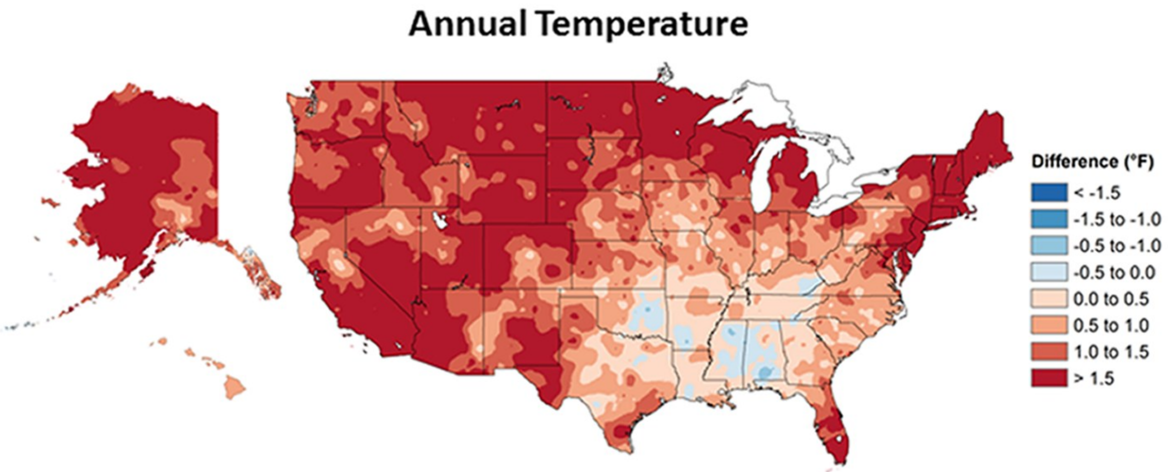
Global Assessment





- 2022 is the 6th warmest year since 1850
- Top 10 warmest years have occurred since 2010
- If you were born after February 1985, you have never experienced a cooler than average month for the planet!

4th National Climate Assessment

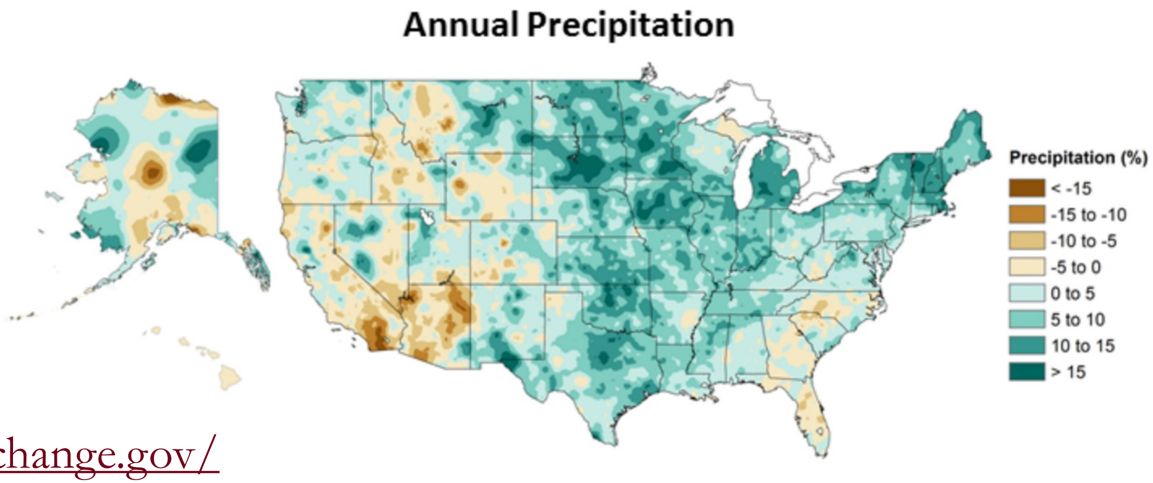


TEMPERATURE

- More than 95% of the land surface demonstrated an increase in annual average temperature
- Greatest and most widespread in winter

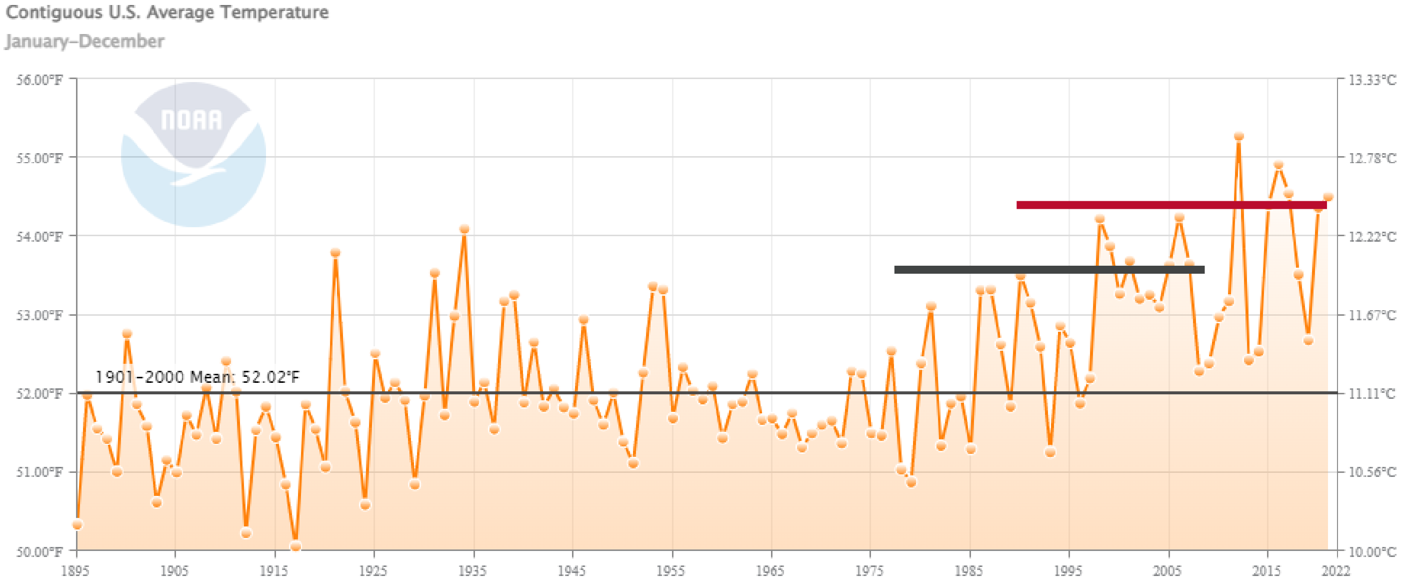
PRECIPITATION

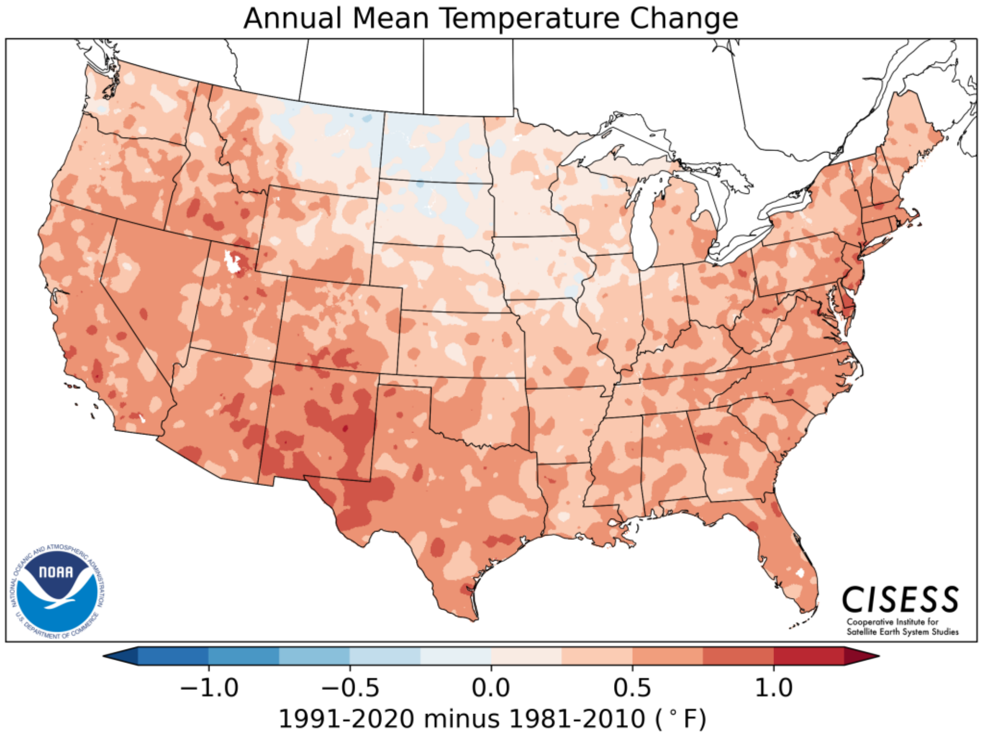
- National average increase of 4% since 1901
- Includes changes to seasonal trends and intensity



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

NWS New “Normals”: Temperature



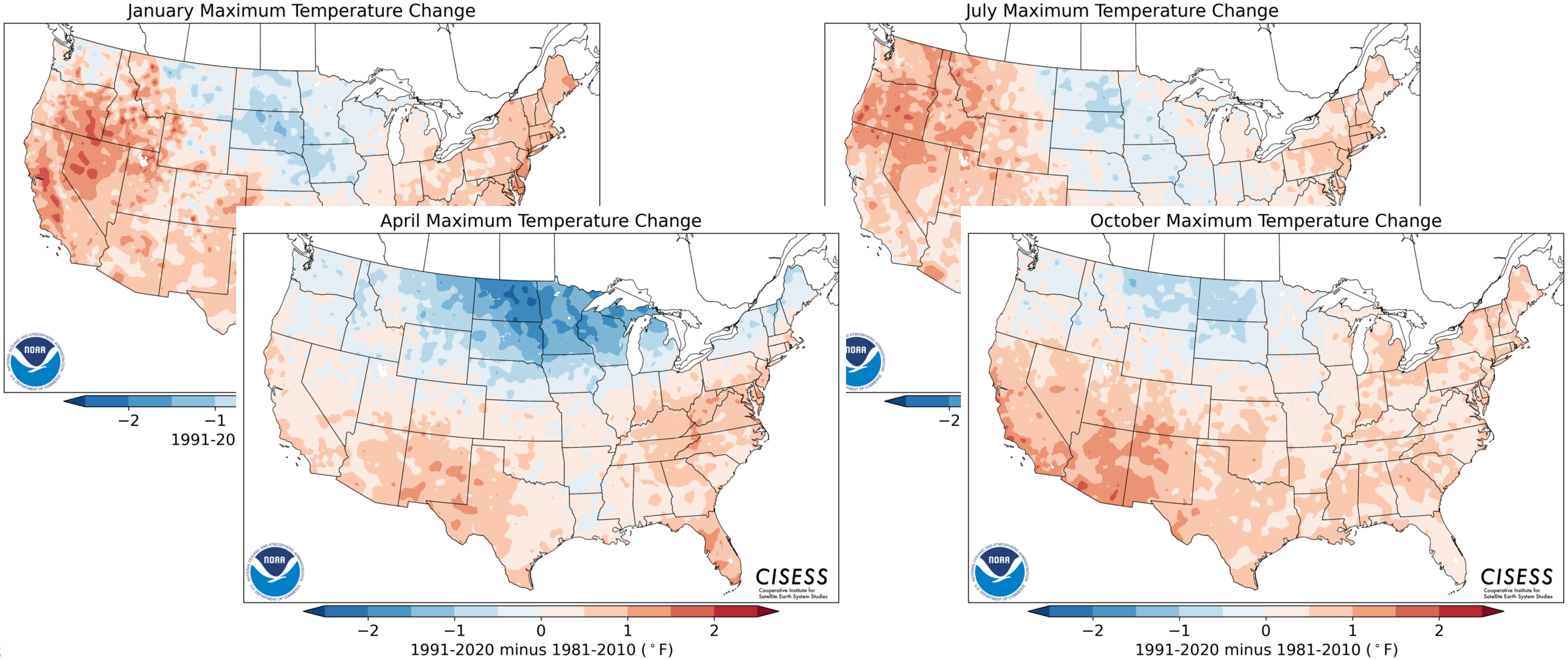


NOAA National Centers for Environmental information, Climate at a Glance: Statewide Time Series, published January 2022, retrieved on January 11, 2022 from https://www.ncdc.noaa.gov/cag/

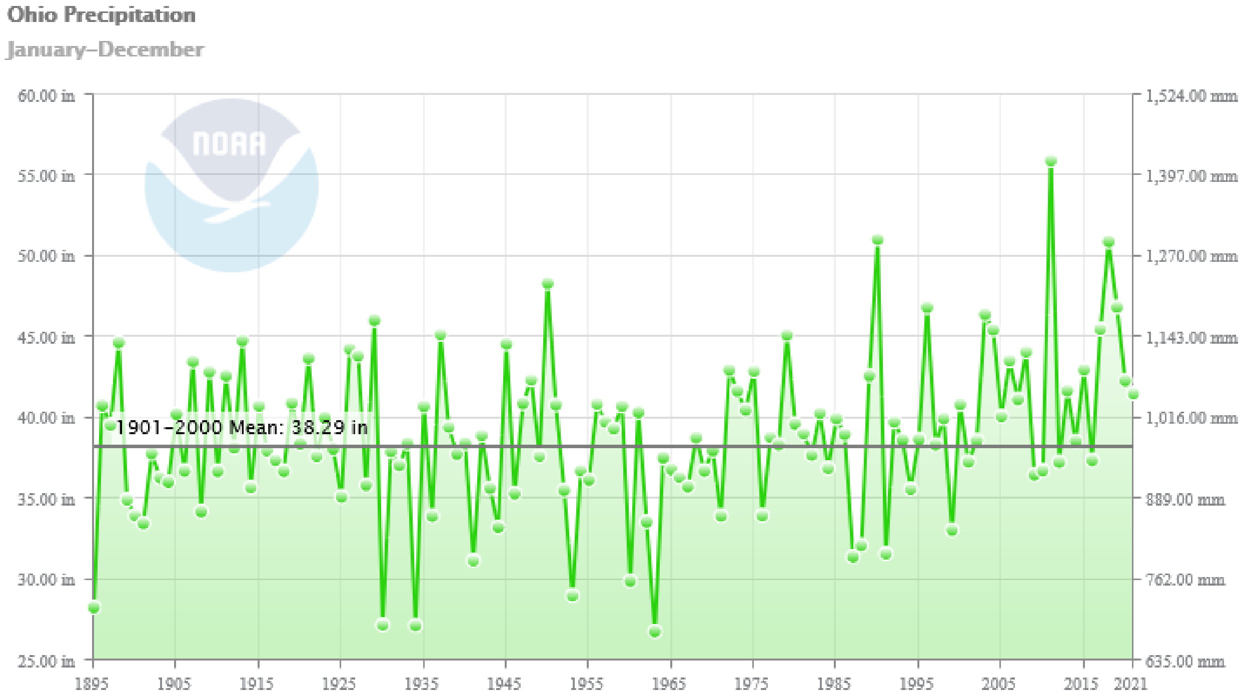
https://www.ncei.noaa.gov/products/us-climate-normals

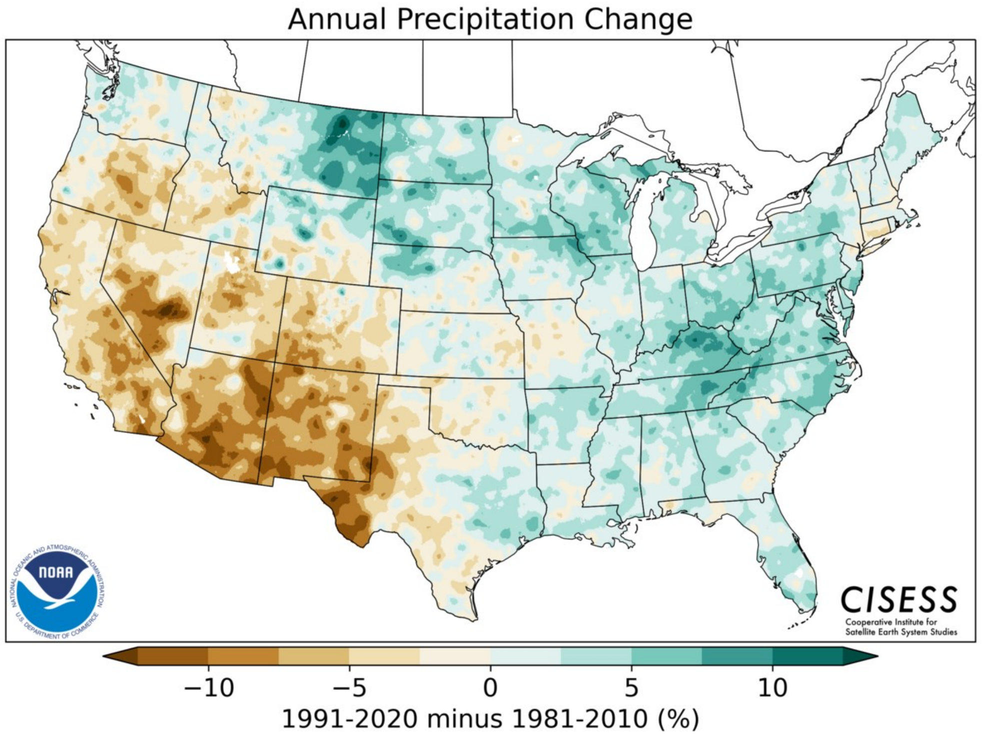
Seasonal Changes

https://www.ncei.noaa.gov/products/us-climate-normals



NWS New "Normals": Precipitation



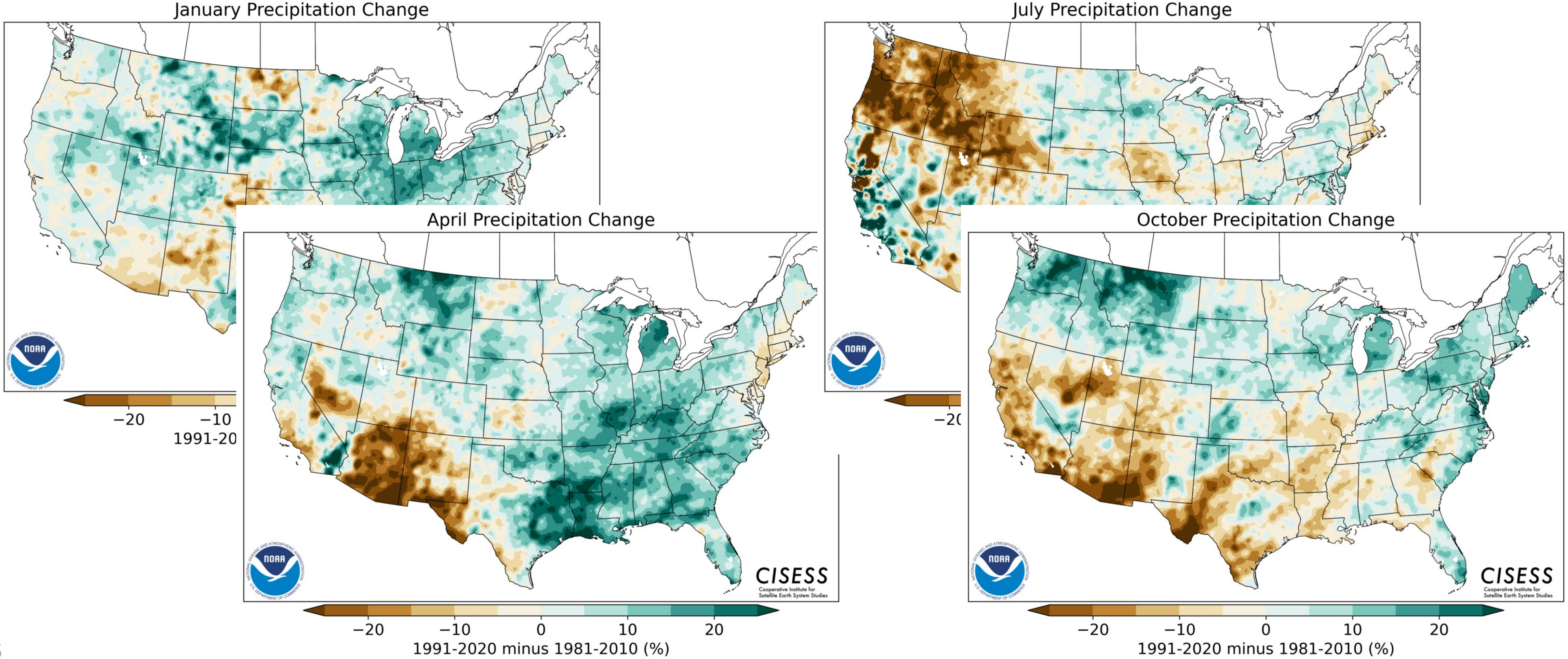


NOAA National Centers for Environmental information, Climate at a Glance: Statewide Time Series, published January 2022, retrieved on January 11, 2022 from https://www.ncdc.noaa.gov/cag/

https://www.ncei.noaa.gov/products/us-climate-normals

Seasonal Changes

https://www.ncei.noaa.gov/products/us-climate-normals



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Top 10

TEMPERATURE			
RANK	YEAR	AVERAGE	DIFFERENCE
1	1998	54.1	2.4
2	2012	54.0	2.4
3	2016	53.6	1.9
4	1921	53.5	1.8
5	2017	53.2	1.6
5	2021	53.2	1.6
7	1991	53.1	1.5
8	2020	53.0	1.4
9	1931	52.9	1.3
10	2006/1990	52.7	1.0

PRECIPITATION			
RANK	YEAR	TOTAL	DIFFERENCE
1	2011	55.95	14.85
2	1990	51.07	9.97
3	2018	50.93	9.83
4	1950	48.34	7.24
5	2019	46.87	5.77
6	1996	46.85	5.75
7	2003	46.42	5.32
8	1929	46.07	4.97
9	2017	45.51	4.41
10	2004	45.45	4.35

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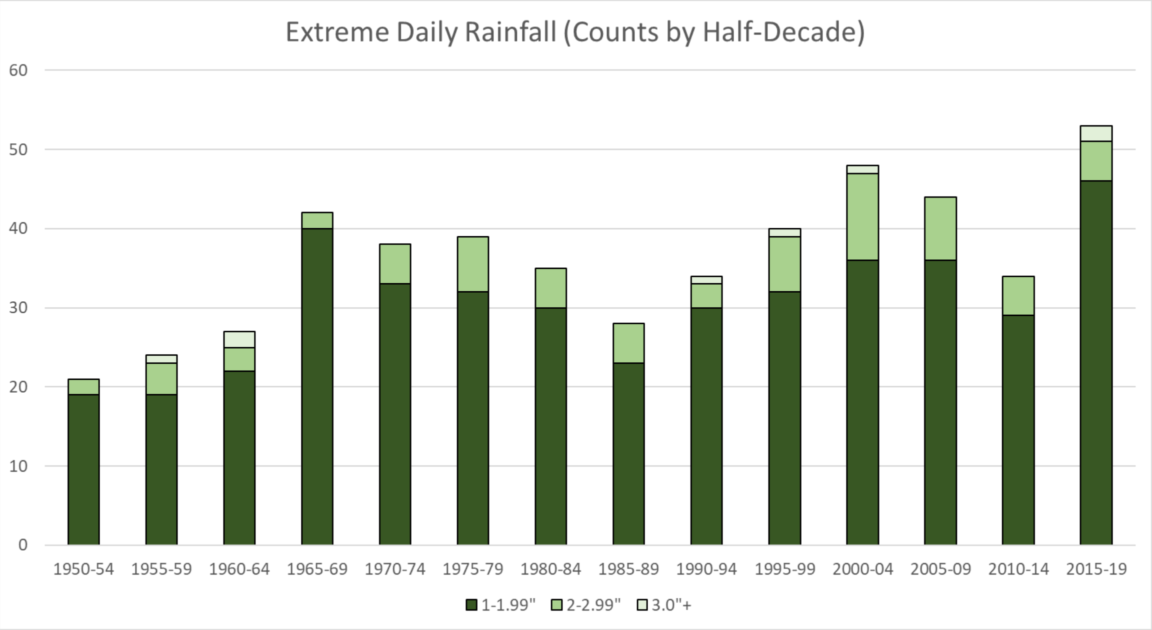
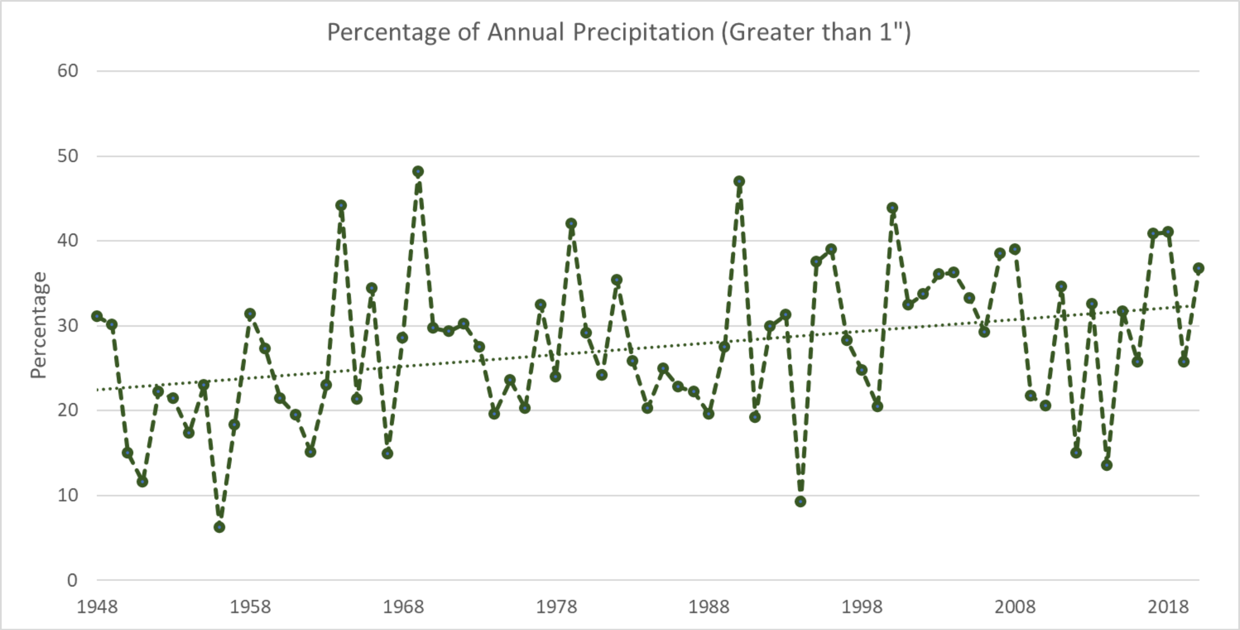
Recent Precipitation Intensity Changes in Columbus



Number of 1” or greater events per 5-yr increments from 1950-2019



1” or greater events expressed as a percentage of the total number of rain events by year between 1948 and 2020

Urban Flooding

May 19, 2020: Columbus

Catherine Ross
@CatherineRossTV · Follow

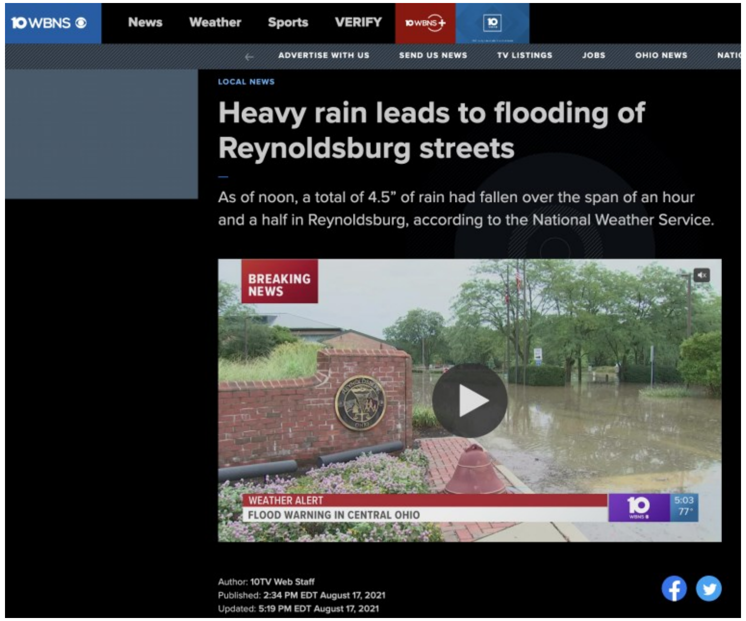
Neighbors tell me the area is flood prone but they've never seen water this deep on the street

9:01 AM · May 19, 2020

15 Reply Copy link

Read 3 replies

August 17, 2021: Reynoldsburg



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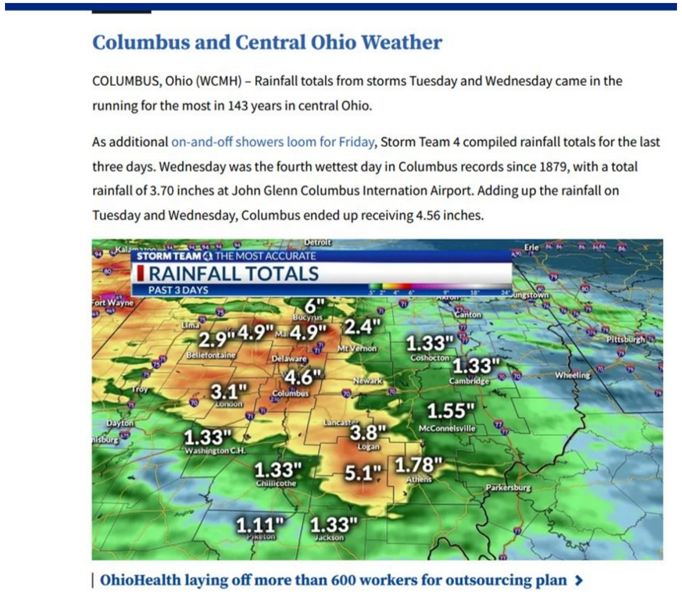
LOCAL NEWS

Heavy rain leads to flooding of Reynoldsburg streets

As of noon, a total of 4.5" of rain had fallen over the span of an hour and a half in Reynoldsburg, according to the National Weather Service.

Author: 10TV Web Staff
Published: 2:34 PM EDT August 17, 2021
Updated: 5:19 PM EDT August 17, 2021

July 6, 2022: Columbus



Columbus and Central Ohio Weather

COLUMBUS, Ohio (WCMH) – Rainfall totals from storms Tuesday and Wednesday came in the running for the most in 143 years in central Ohio.

As additional on-and-off showers loom for Friday, Storm Team 4 compiled rainfall totals for the last three days. Wednesday was the fourth wettest day in Columbus records since 1879, with a total rainfall of 3.70 inches at John Glenn Columbus Internation Airport. Adding up the rainfall on Tuesday and Wednesday, Columbus ended up receiving 4.56 inches.

| OhioHealth laying off more than 600 workers for outsourcing plan ›

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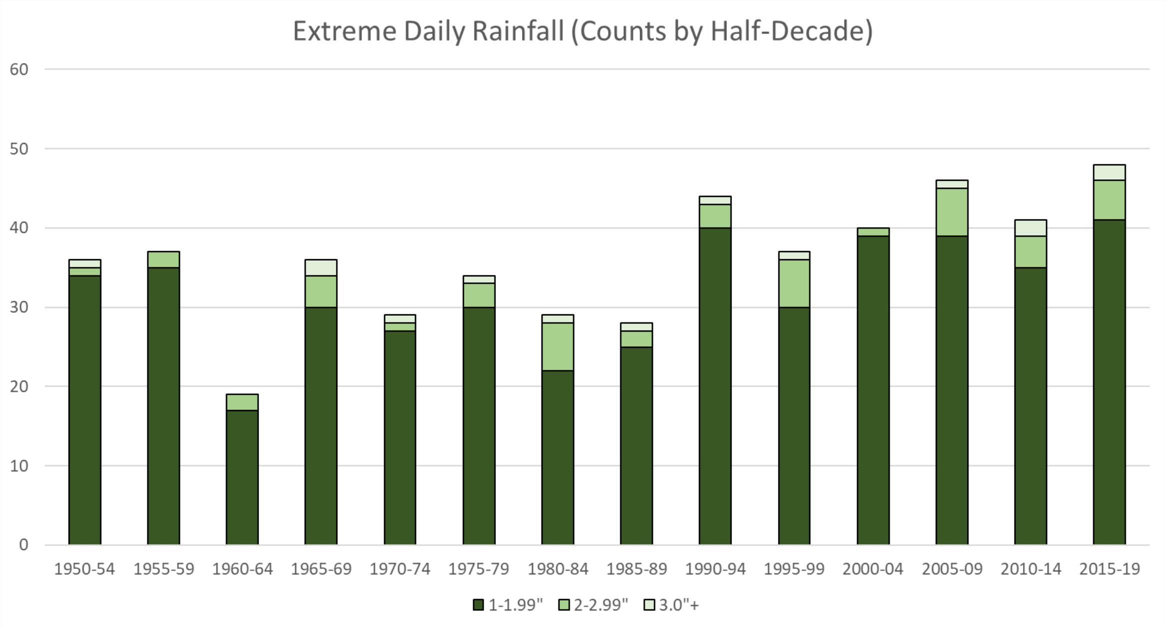
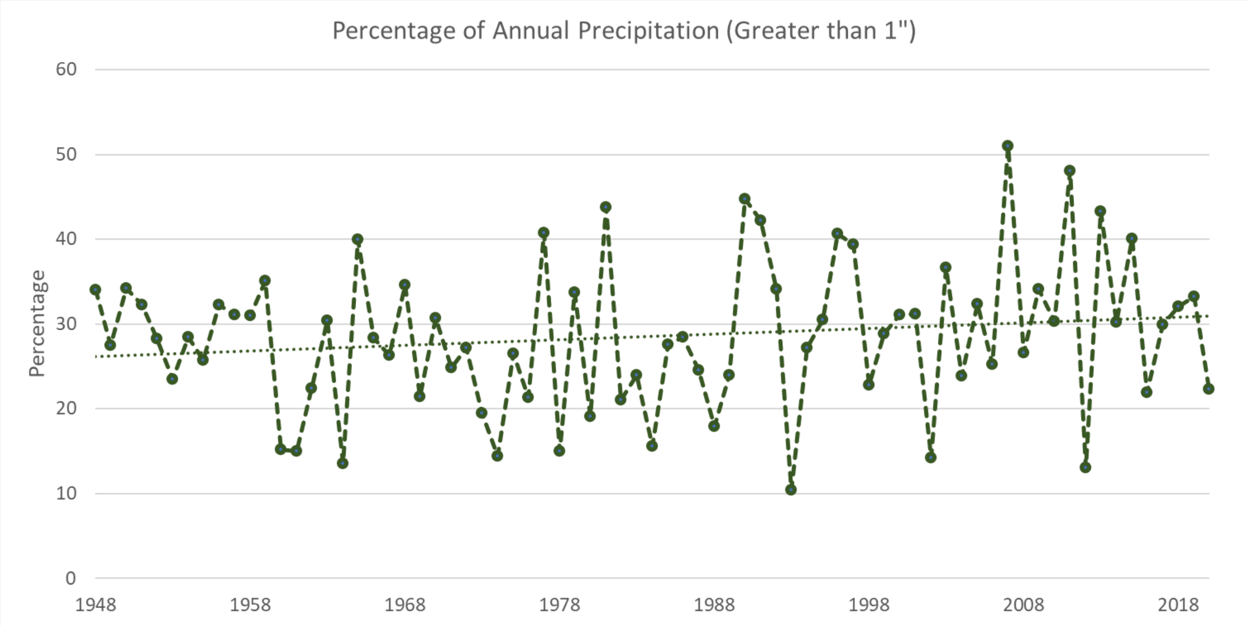
Urban Flooding

Recent Precipitation Intensity Changes in Defiance

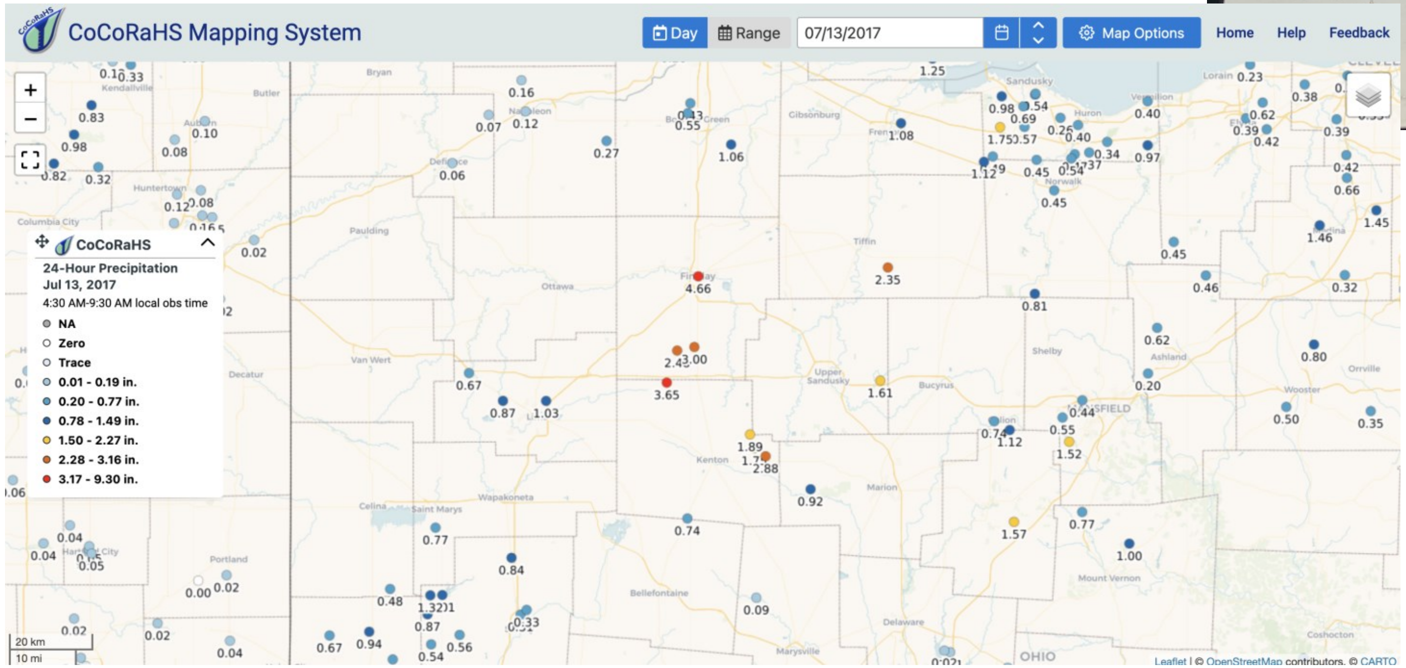


Number of 1” or greater events per 5-yr increments from 1950-2019



1” or greater events expressed as a percentage of the total number of rain events by year between 1948 and 2020

Rural Flooding



Rural Flooding


FOX28

Wessler Engineering


Licking County Sheriff

Wessler Engineering

Rivers and Lakes

Increasing Risk of Extreme Rainfall

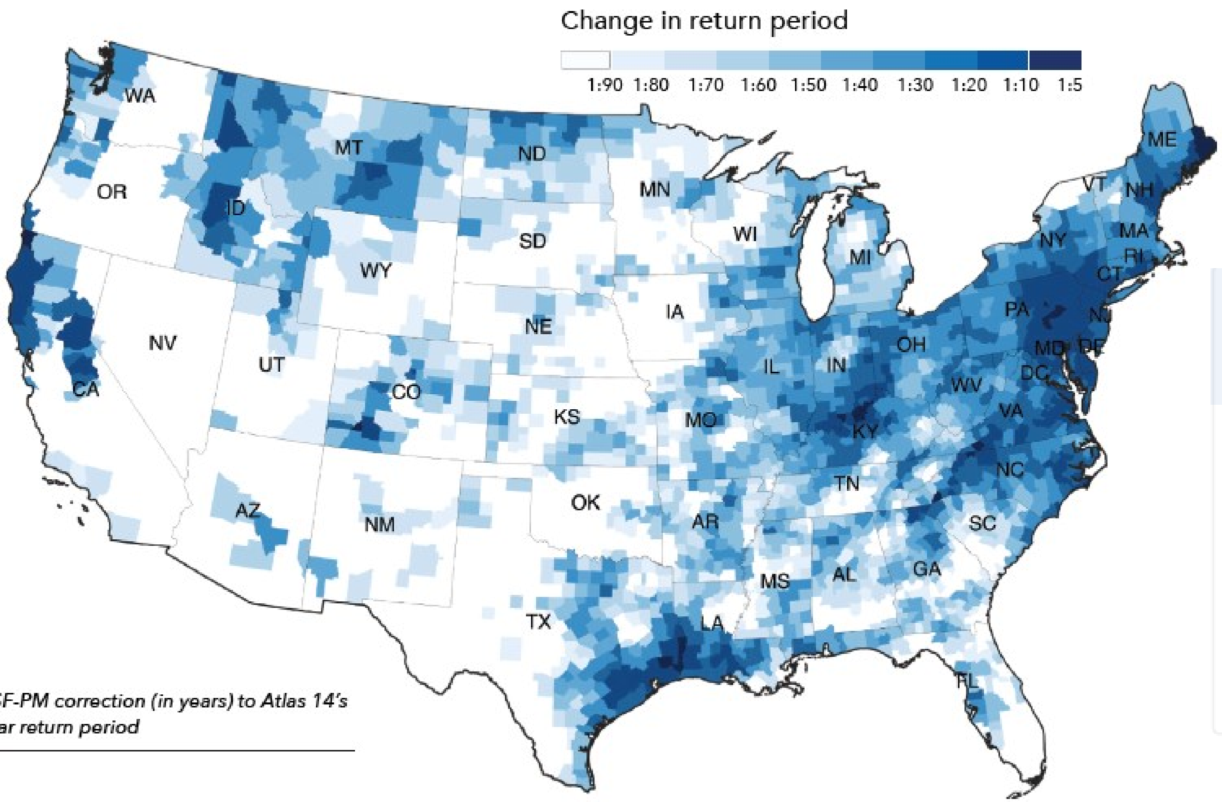


Figure 3: FSF-PM correction (in years) to Atlas 14's 1-in-100 year return period

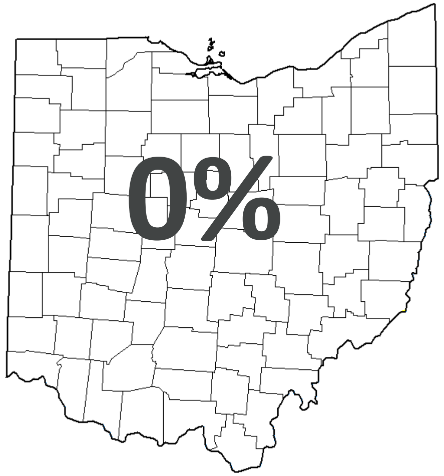
First Street Foundation:
https://firststreet.org/research-lab/published-research/article-highlights-from-the-precipitation-problem/

Table 3: Selected highly populated cities impacted by Atlas 14 to FSF-PM corrections

City	Atlas 14	Corrected for today	30 year correction
Baltimore, Maryland	1 in 100	1 in 14 (+614%)	1 in 12 (+733%)
Dallas, Texas	1 in 100	1 in 21 (+376%)	1 in 18 (+456%)
Washington, D.C.	1 in 100	1 in 21 (+376%)	1 in 19 (+426%)
New York City, New York	1 in 100	1 in 23 (+335%)	1 in 19 (+426%)
Philadelphia, Pennsylvania	1 in 100	1 in 29 (+245%)	1 in 20 (+400%)
Chicago, Illinois	1 in 100	1 in 29 (+245%)	1 in 26 (+285%)
Detroit, Michigan	1 in 100	1 in 34 (+194%)	1 in 16 (+525%)
Boston, Massachusetts	1 in 100	1 in 37 (+170%)	1 in 33 (+203%)

Drought – "In a Flash"

U.S. Drought Monitor
Ohio

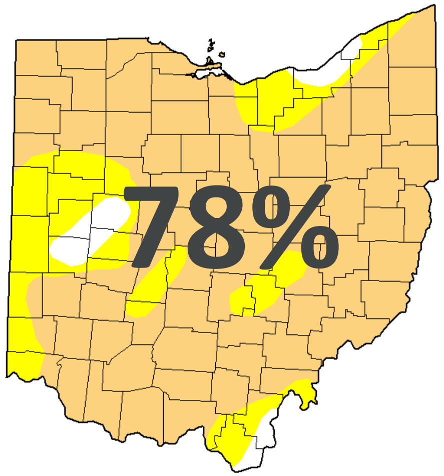


May 16, 2023
(Released Thursday, May. 18, 2023)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	99.99	0.01	0.00	0.00	0.00	0.00
Last Week 05-09-2023	99.99	0.01	0.00	0.00	0.00	0.00
3 Months Ago 02-14-2023	93.30	6.70	0.00	0.00	0.00	0.00
Start of Calendar Year 01-03-2023	57.14	42.86	27.16	0.00	0.00	0.00
Start of Water Year 09-27-2022	93.91	6.09	0.00	0.00	0.00	0.00
One Year Ago 05-17-2022	100.00	0.00	0.00	0.00	0.00	0.00

U.S. Drought Monitor
Ohio



June 13, 2023
(Released Thursday, Jun. 15, 2023)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	3.59	96.41	78.17	0.00	0.00	0.00
Last Week 06-06-2023	2.10	97.90	62.00	0.00	0.00	0.00
3 Months Ago 03-14-2023	100.00	0.00	0.00	0.00	0.00	0.00
Start of Calendar Year 01-03-2023	57.14	42.86	27.16	0.00	0.00	0.00
Start of Water Year 09-27-2022	93.91	6.09	0.00	0.00	0.00	0.00
One Year Ago 06-14-2022	100.00	0.00	0.00	0.00	0.00	0.00

Intensity:
- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

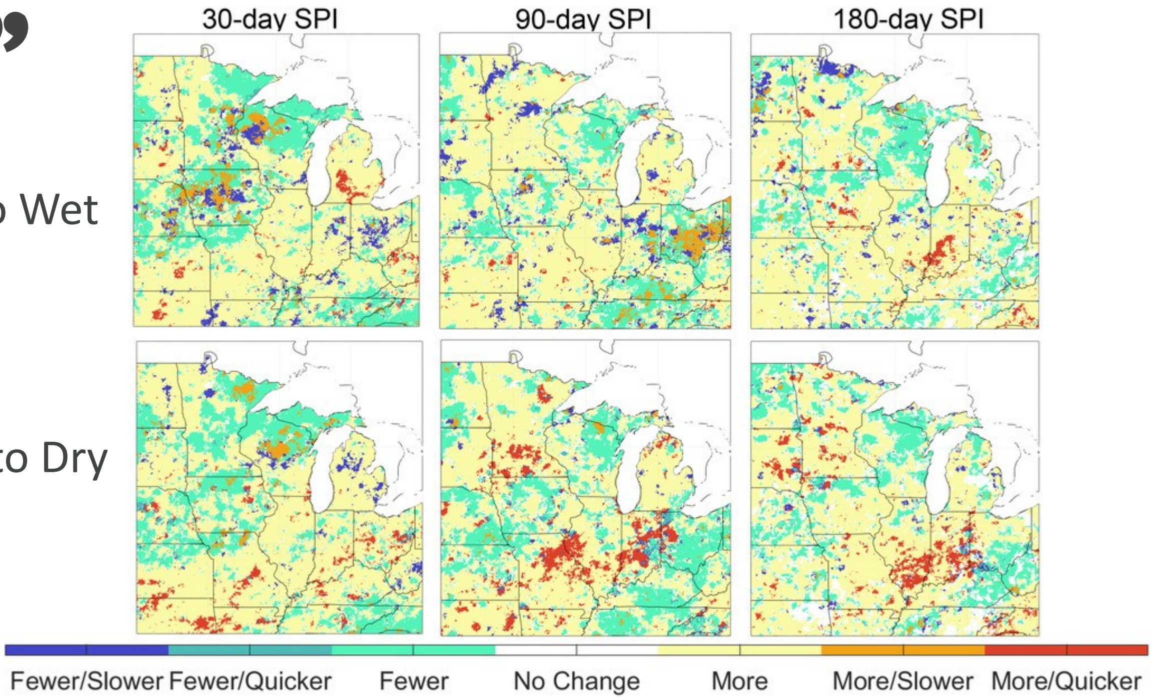
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx

Author:
Adam Hartman
NOAA/NWS/NCEP/CPC

droughtmonitor.unl.edu

Dry to Wet

Wet to Dry



*Red areas indicate parts of Missouri, Illinois, Indiana, and Ohio have experienced more frequent and more rapid wet to dry transitions over the last few decades.

Ford, T. W., L. Chen, and J. T. Schoof, 2021: Variability and Transitions in Precipitation Extremes in the Midwest United States. *J. Hydrometeor.*, **22**, 533–545, https://doi.org/10.1175/JHM-D-20-0216.1.

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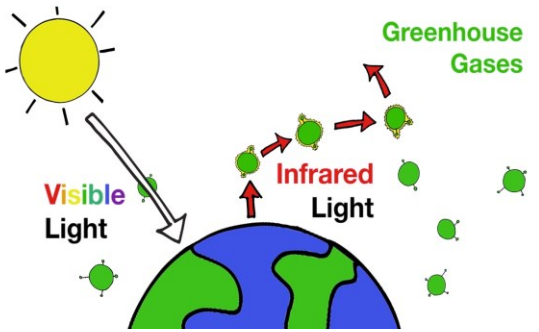
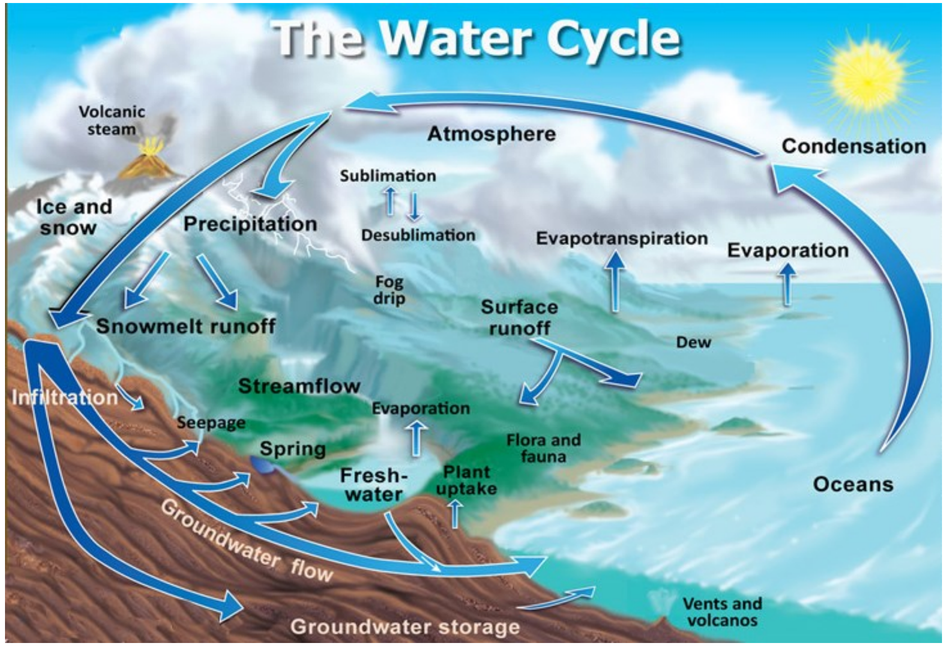
How the Atmosphere Warms & Why It Matters



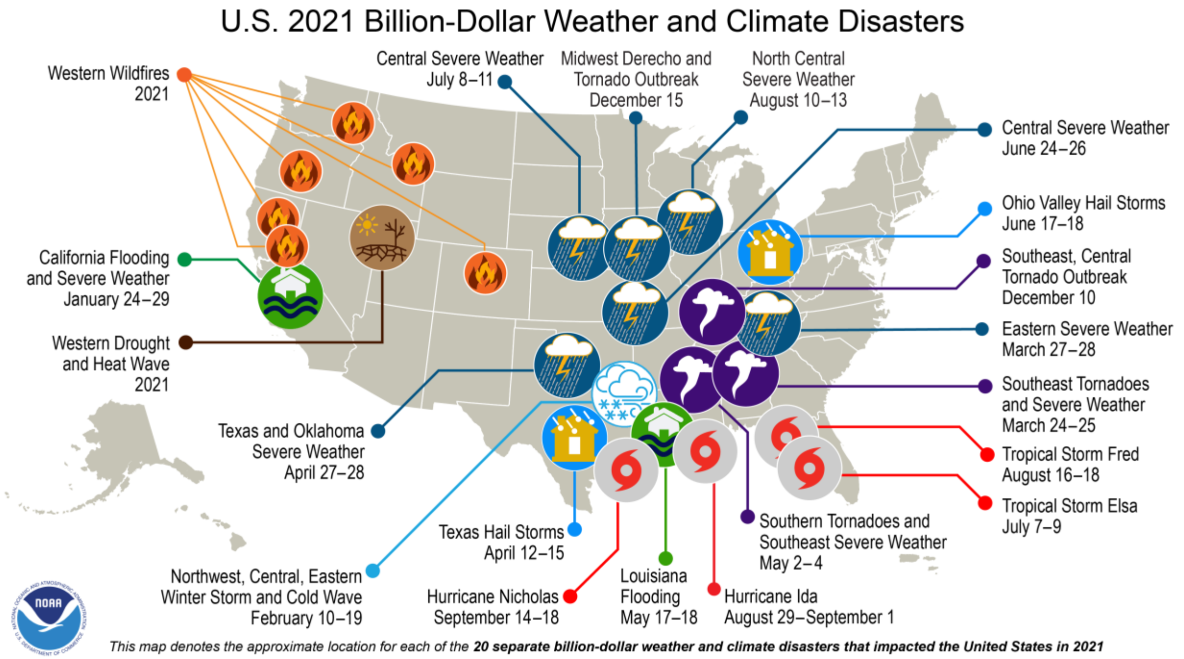
CO_2 and evaporated water become warmer as they absorb infrared radiation from earth's surface trying to escape to space.

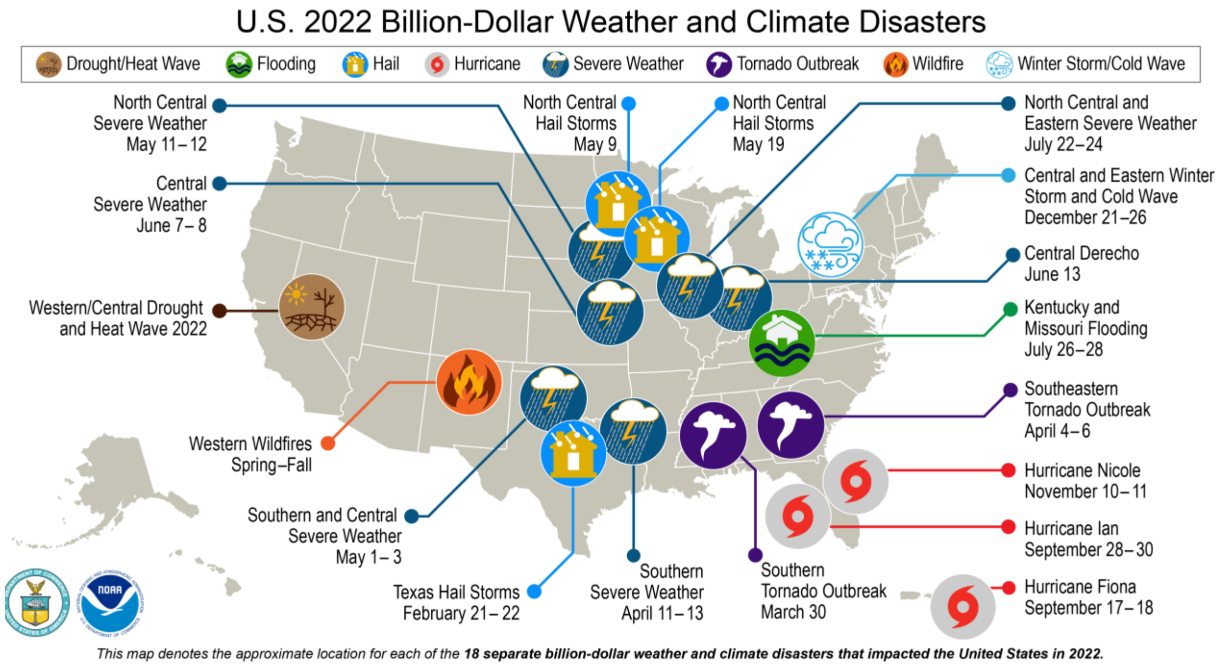
HowGlobalWarmingWorks.org, 2014

- **Water Vapor** is the most dominant greenhouse gas
  - Is a function of temperature
  - Evaporation – the rate depends on the temperature of the ocean and air
  - "Extra" water in the atmosphere falls a precipitation within a week or two
- **CO2** added to the atmosphere as a GHG → atmosphere warms → increases evaporation → warms the air further

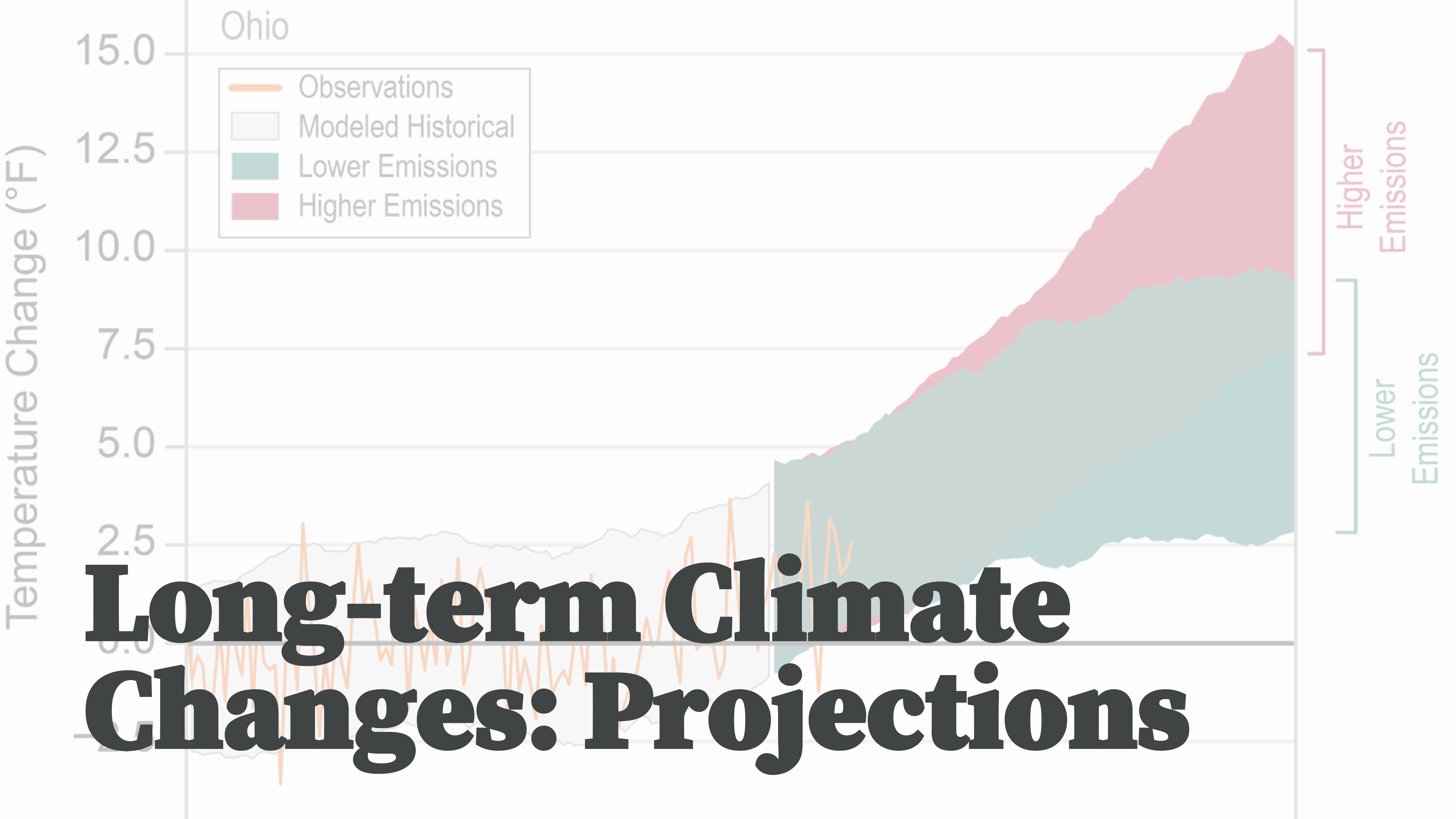


2021 & 2022 Billion Dollar Disasters



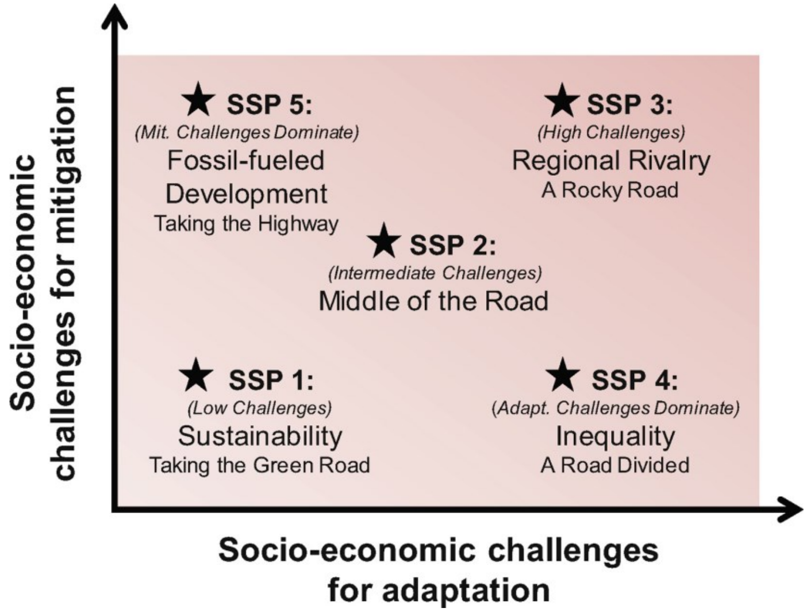


NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2022). https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73

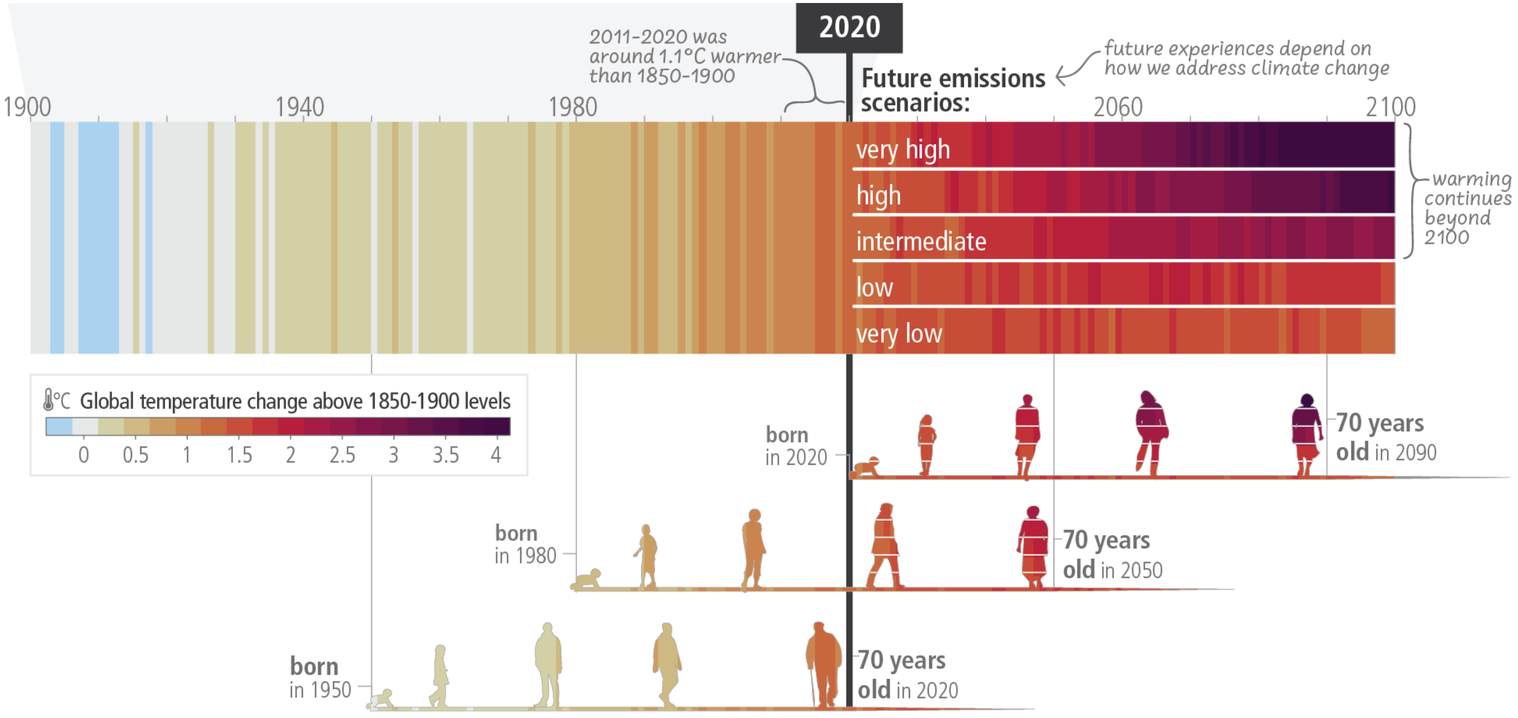


Long-term Climate Changes: Projections

Model Scenario Uncertainty (What will we do?)



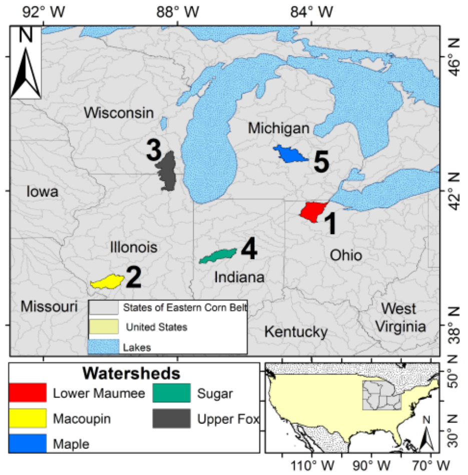
O'Neill et al. 20187: https://doi.org/10.1016/j.gloenvcha.2015.01.004

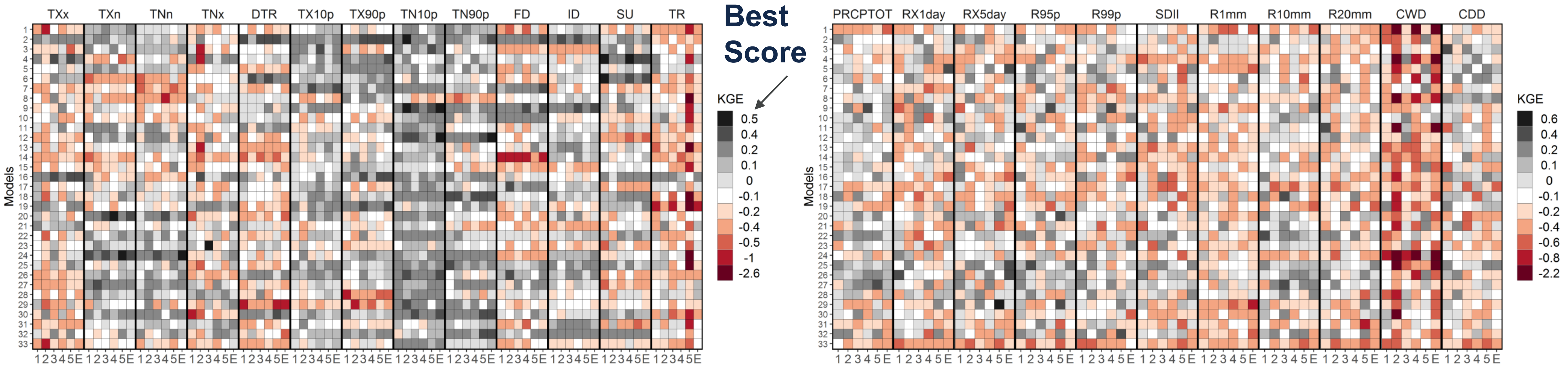


https://www.ipcc.ch/report/sixth-assessment-report-cycle/

Models Demand Careful Interpretation

- Single model performance varies across all basins and Eastern Corn Belt
- Single model performance varies across all variables
- Collective model performance for SOME variables (e.g., TN10p)
- Some model standouts – Are there better models?





Wilson et al. 2022; https://doi.org/10.1016/j.wace.2022.100467

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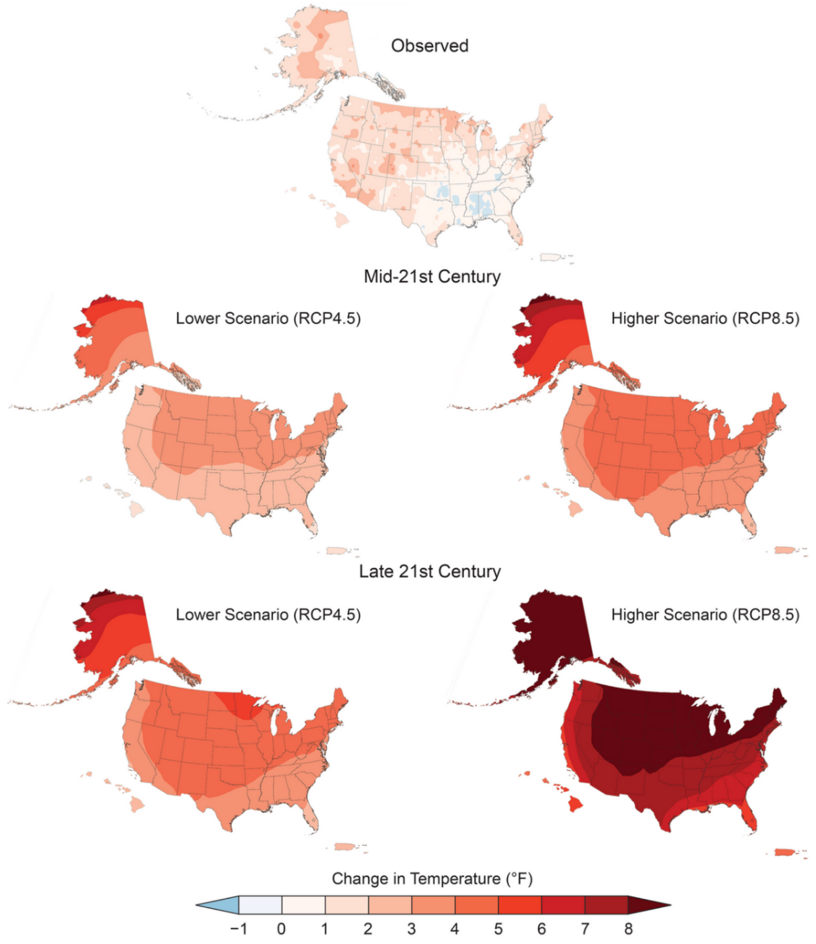
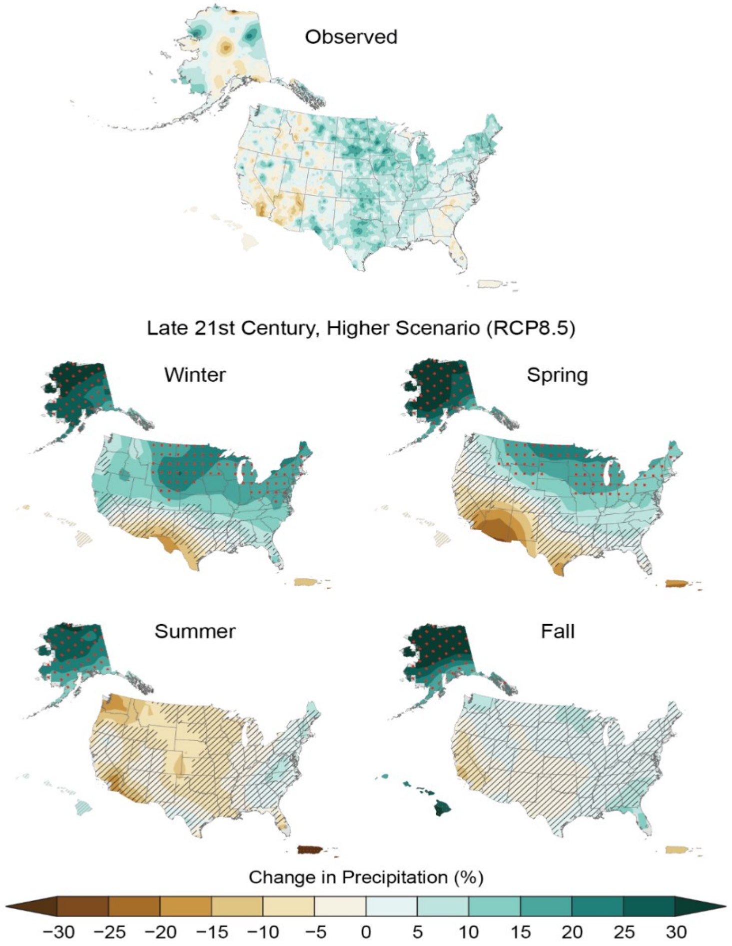
Our Future Climate: Temperature



- Likely reflected by winter warming and warmer nighttime temperatures
- Mid-Century Change: 3-5°F warmer
- Late-Century Change: 4-8°F warmer

Our Future Climate: Precipitation



- Driven by increased water vapor (humidity)
- Seasonal changes atmospheric circulation
- Wetter cool season; drier summer season = could mean intensified drought

Change in Number of Days > 90°F

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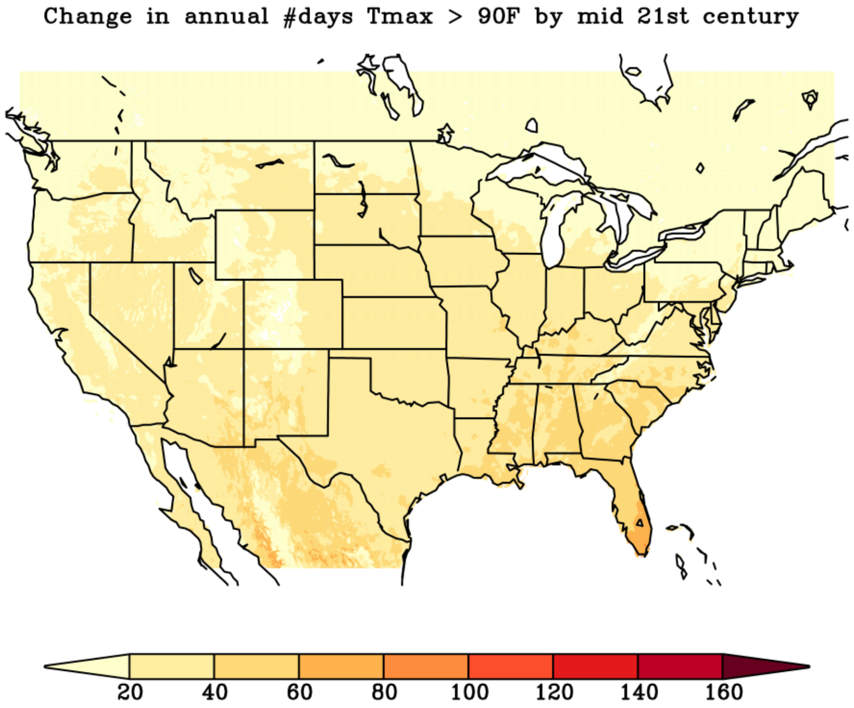
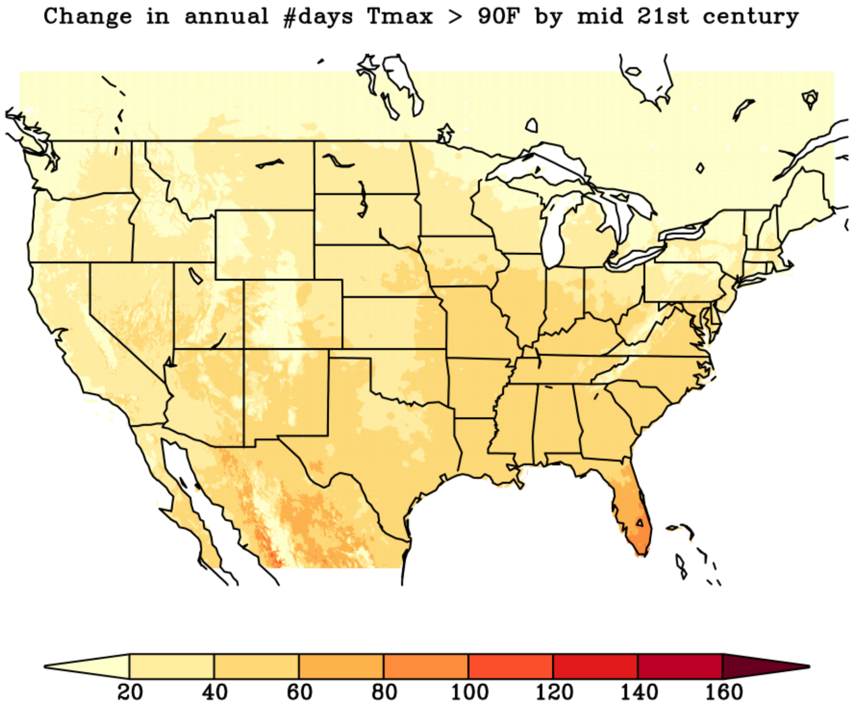
Intermediate Scenario



Very High Scenario

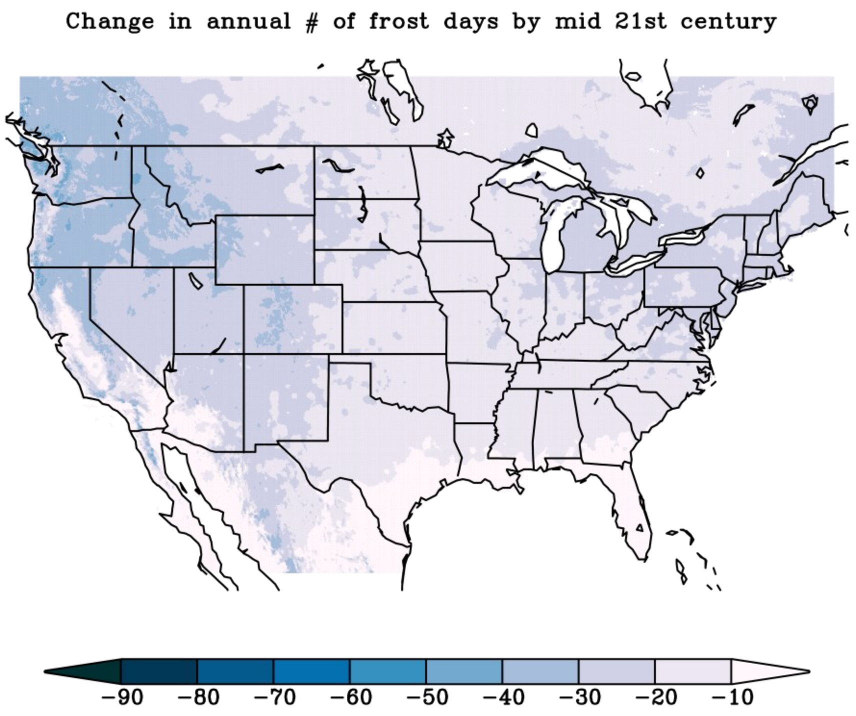


https://scenarios.globalchange.gov/loca-viewer/

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

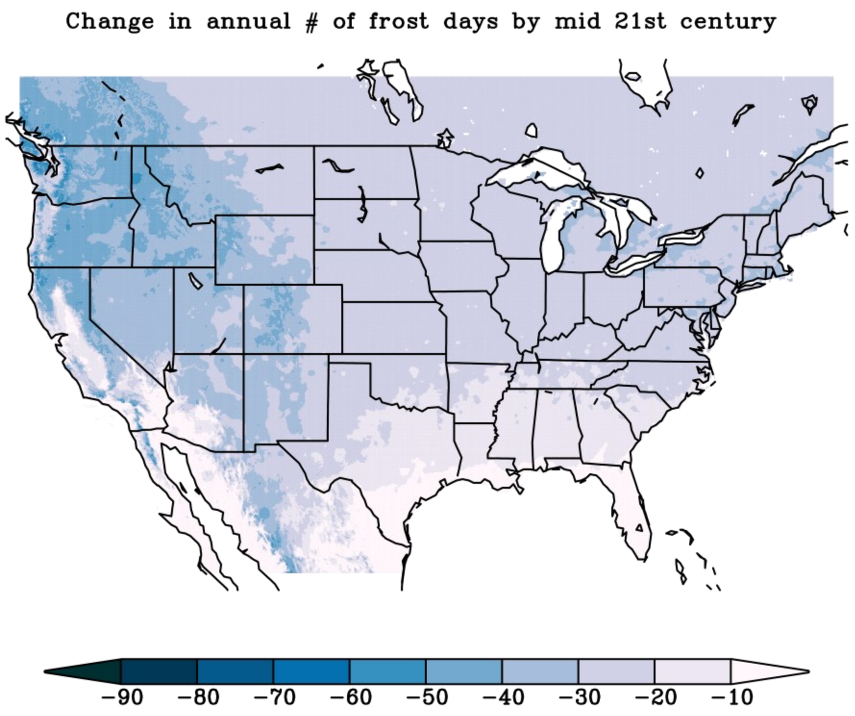
Change in Number of Nights < 32°F

Intermediate Scenario



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

Very High Scenario



- Contemporary Period (1976-2005): 80-160 days per year

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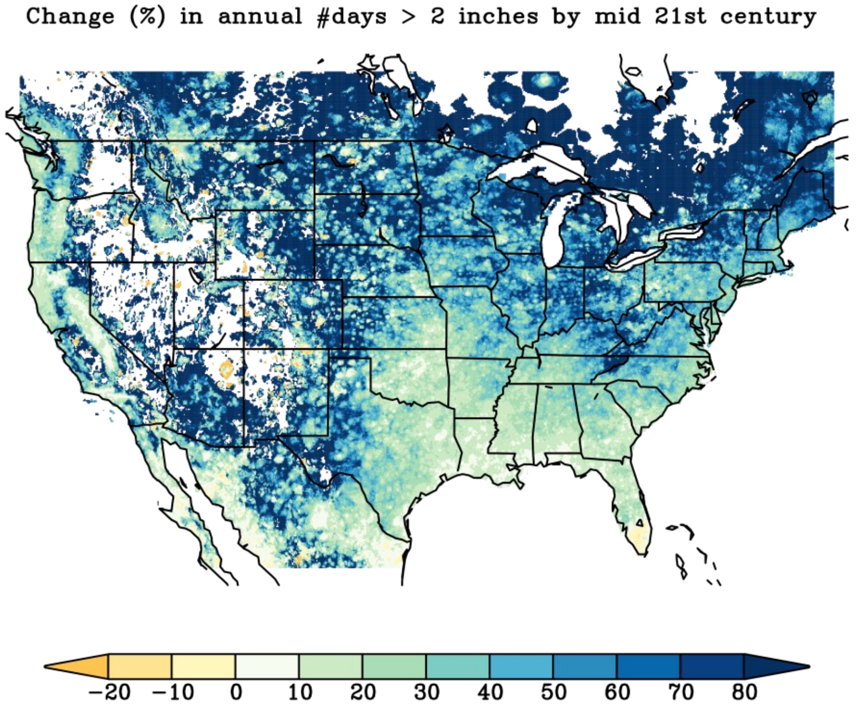
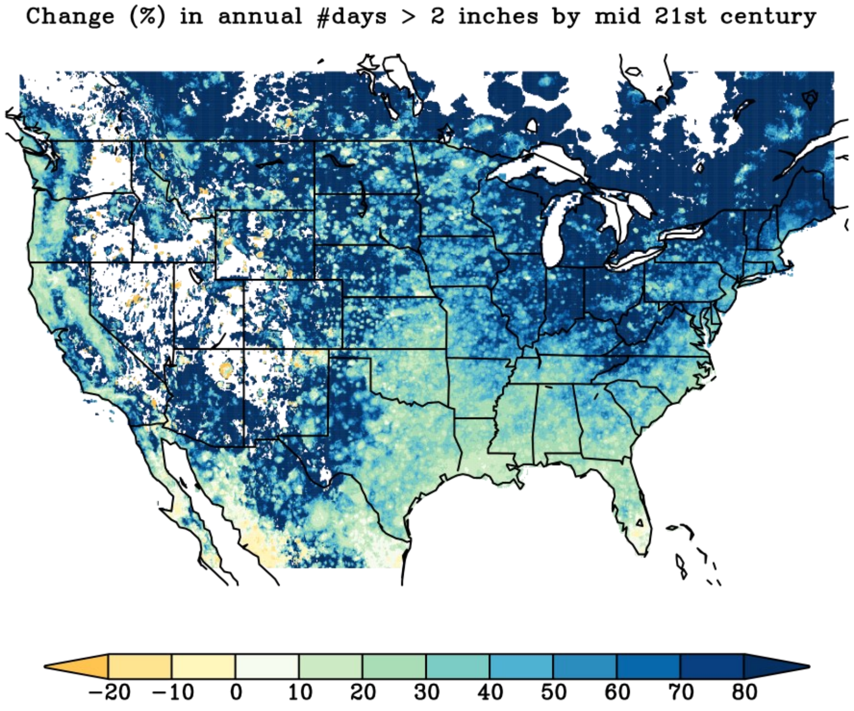
Change in Mean Annual Days w/Precipitation > 2”

Intermediate Scenario



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

Very High Scenario



- Contemporary Period (1976-2005): < 1 per day

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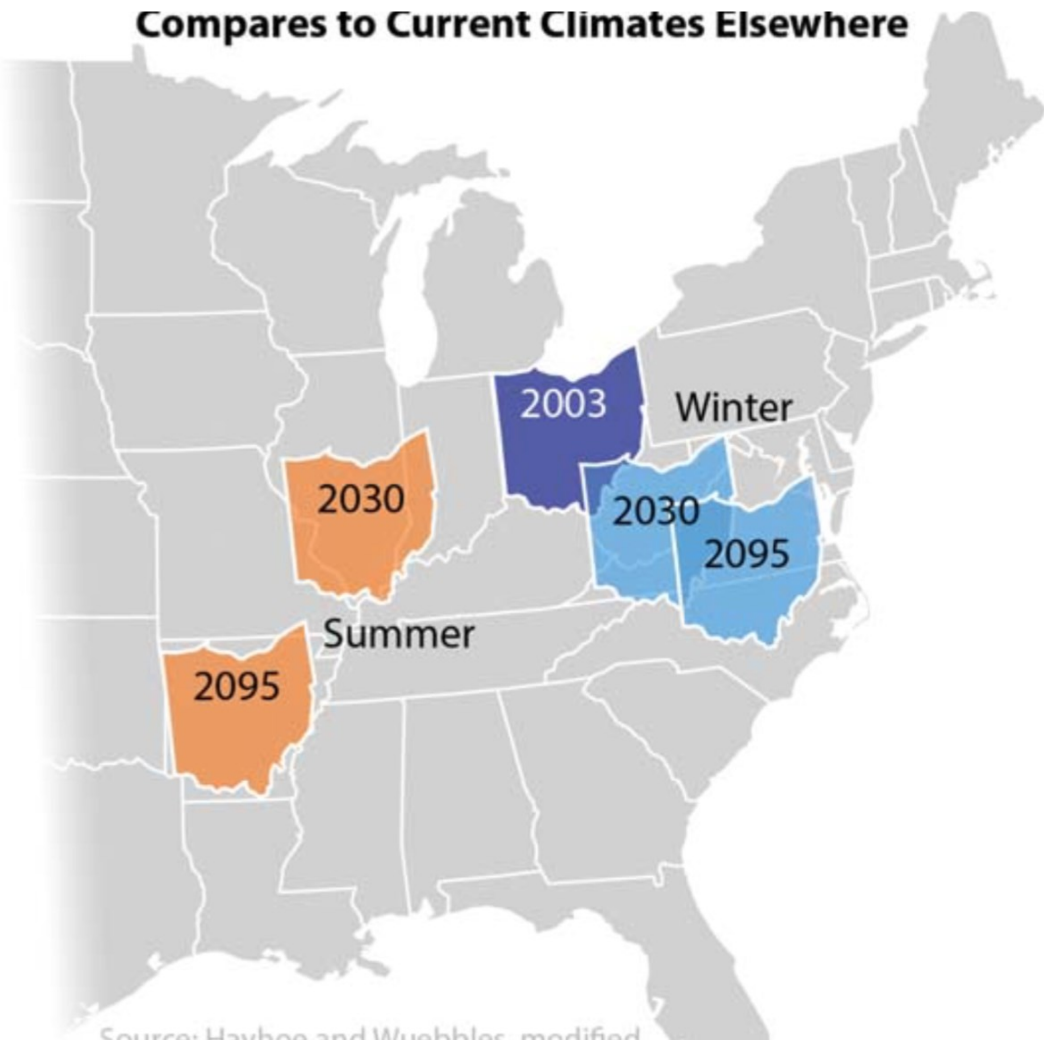
Our New Normal

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



Assessing the Risk

Temperature

- Demand for water and energy increases
- Heat-related illnesses increase
- Heatwave burdens on small and local business, gardeners
- Deteriorated air quality – western wildfire smoke induced health issues

Precipitation

- Increased risk of damage to energy & water infrastructure
- Management challenges of rapid oscillations between extreme wet and dry
- Exposure to waterborne pathogens and vector control
- Property damage due to extreme weather events
- Reduced water quality

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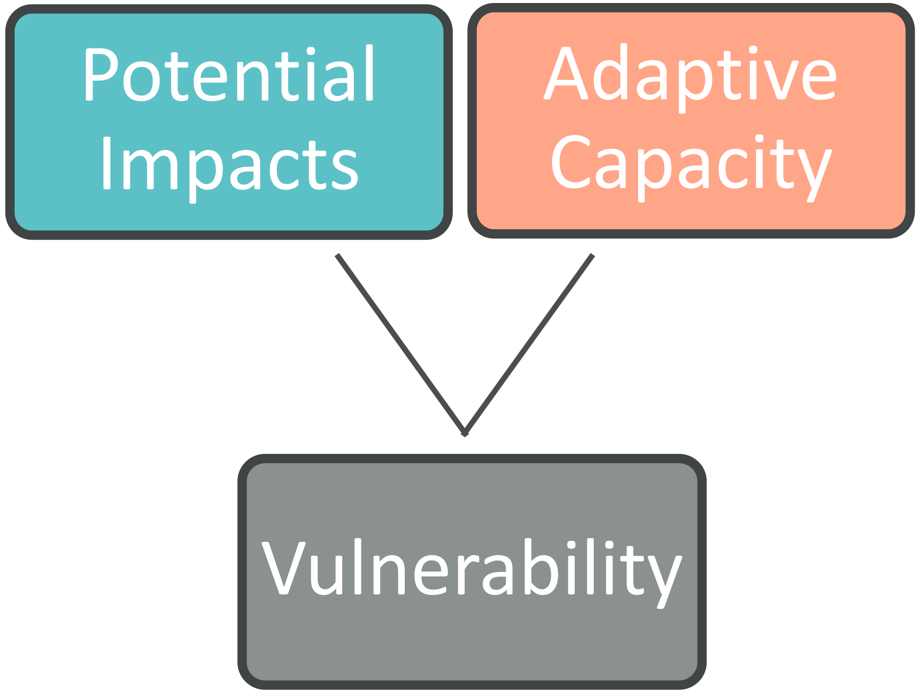
Adaptation: There is No Single Answer

Every landowner is different



Potential Impacts

- What is the operation exposed to (Changes in temperature, rainfall, storms, weeds, stressors)?
- How sensitive is your operation to those changes?

Adaptive Capacity

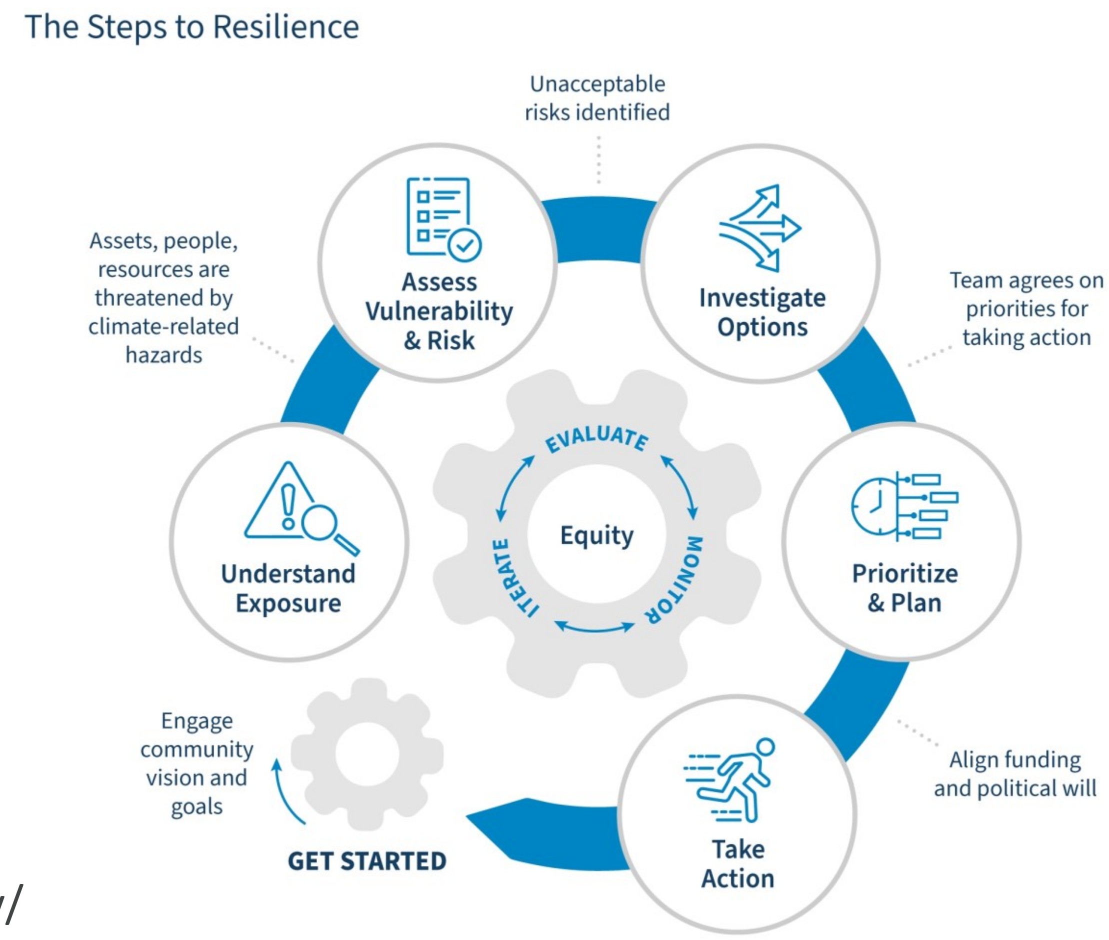
- How well can the operation cope with the potential impacts?
- How resilient is the operation? (assuming no change in management intervention)

Each decision is unique and will vary based upon:
People: Values, Culture, & Resources
Place: Location & Site Conditions
Purpose: Goals & Objectives
Practices: Equipment, Procedures, & Methods

Adapting to Changing Water Cycle

- 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?
  - Improve water harvesting and storage
  - Improve irrigation efficiency
  - Reduced evaporation of soil water through mulching with organic materials, mulching with plastic, rapid crop canopy development/closure
  - Combatting higher humidity and/or extreme weather

Building Resilience



U.S. Climate Resilience Toolkit - https://toolkit.climate.gov/

Climate Impacts on Water Utilities

US EPA: Climate Change Adaptation Resource Center
https://www.epa.gov/arc-x/climate-impacts-water-utilities

1. Drought

1. Construct New Infrastructure (aquifer storage and recovery, expand current sources, increase water storage capacity) or Retro fit
2. Increase System Efficiency (finance gray water systems or conjunctive use)
3. Monitoring and modeling
4. Implement watershed management
5. Modify water demand (reduce water at power facilities, reduce ag demand, water conservation)

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Climate Impacts on Water Utilities

US EPA: Climate Change Adaptation Resource Center
https://www.epa.gov/arc-x/climate-impacts-water-utilities

1. Drought
2. Storms and Flooding

1. Construct New Infrastructure (Build flood barriers to protect infrastructure, alternative or on-site power supply, relocate facilities to higher ground)
2. Understand changes to extreme precipitation events –know limitations!
3. Work with regional floodplain managers and stakeholders to explore non-structural flood management techniques
4. Implement green infrastructure (e.g., bio-retention areas, swales, replace impervious surfaces with other materials/vegetation)
5. Understand local drivers to flooding events
6. Improve pumps for backflow prevention

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Climate Impacts on Water Utilities

US EPA: Climate Change Adaptation Resource Center
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1. Drought
2. Storms and Flooding
3. Source Water Quality

1. Model causes of water quality changes (University-Extension resources)
2. Diversify water supply sources
3. Increase storage capacity
4. Manage reservoir water quality
5. Retrofit intakes to accommodate lower flow or water levels
6. Managing Harmful Algal Blooms

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Climate Impacts on Water Utilities

US EPA: Climate Change Adaptation Resource Center
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1. Drought
2. Storms and Flooding
3. Source Water Quality
4. General Utility Preparedness

1. Improve efficiency and optimize operations
2. Consider the insurance and financial instruments to build resilience
3. Conduct climate change impacts and adaptation training
4. Develop and practice emergency response plans
5. Integrate climate change into capital improvement plans
6. Update drought contingency plans

https://tinyurl.com/epa-climate-utilities
https://toolkit.climate.gov/

Takeaways

- Weather and Climate are related but describe different scales of events.
- It's personal!
- It is getting warmer and wetter in Ohio – especially winters and springs.
- Intensity of rainfall increasing along with seasonal distribution changes.
- Future looks even warmer with swings between extreme hydro extremes likely – embracing the uncertainty in planning
- Understanding local impacts and improved management are key to building resilience to changing conditions

Thank You!

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