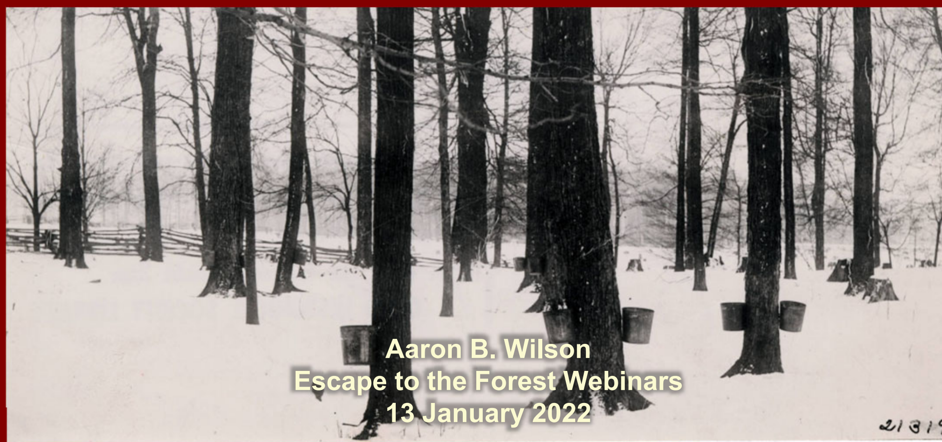
Extreme Weather and Other Climate Change Considerations in Maple Syrup Production

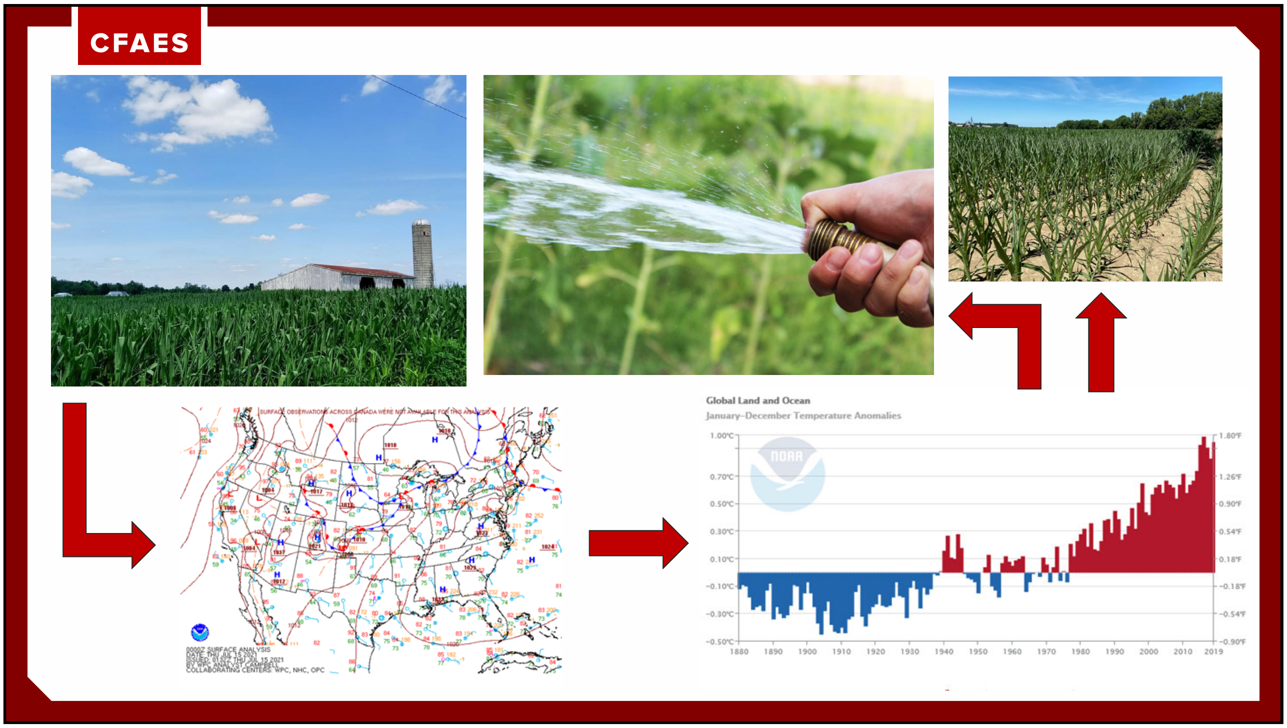


The Ohio State University
College of Food, Agricultural, and Environmental Sciences

Photo Credit: Ohio History Connection: "21319 Timber Management, Forest Products, Ohio. Part of R. O. Hinsdale's sugar camp."

1

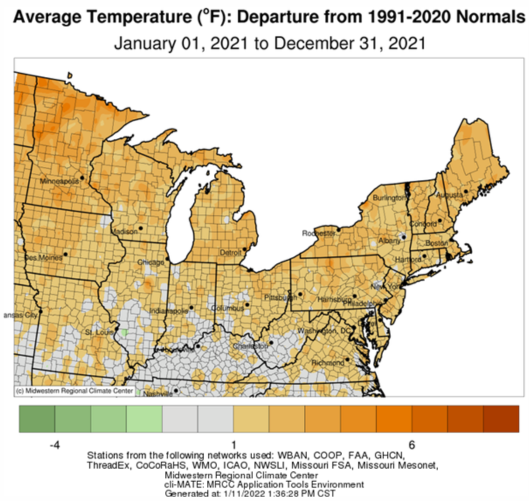
2

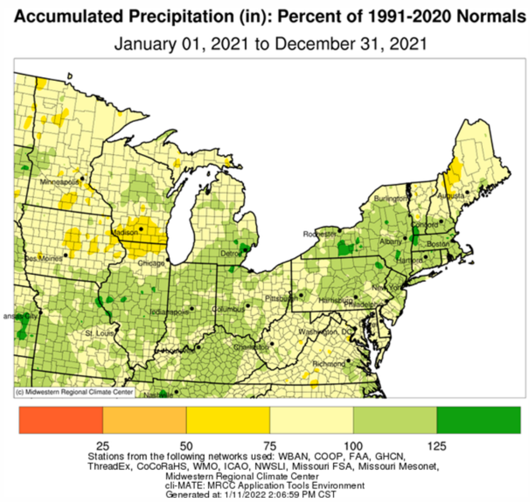

CFAES
Global Land and Ocean
January–December Temperature Anomalies

3


Was 2021 Warmer/Cooler and
Drier/Wetter than Average?

4





OH- 5th, PA-4th, & WV = 10th Warmest (1895-present)

OH- 29th & PA-: 27th Wettest; WV-34th Driest

NE Region 2021 Climate

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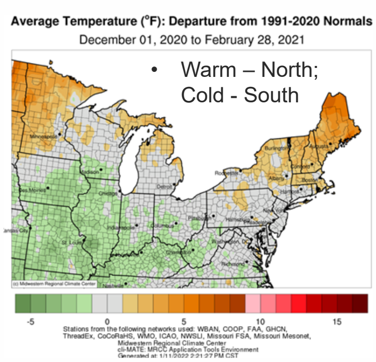
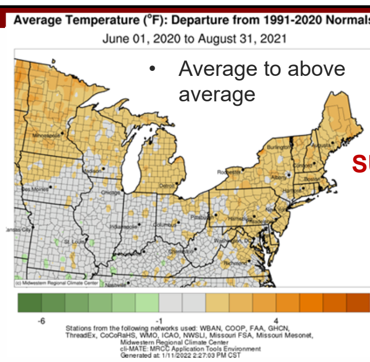
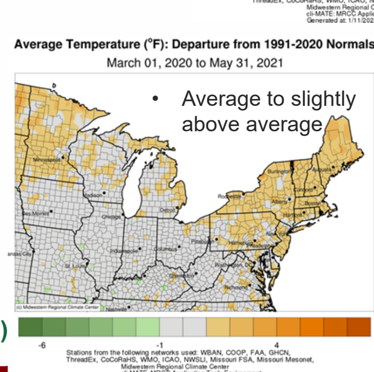
Seasonal Temperatures



WINTER (Dec-Feb)

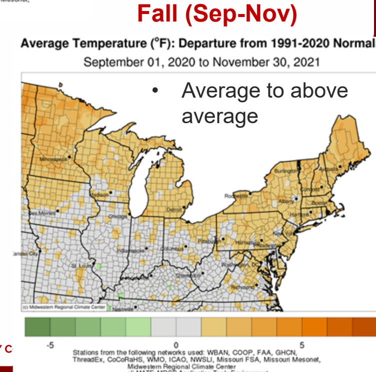


SUMMER (Jun-Aug)

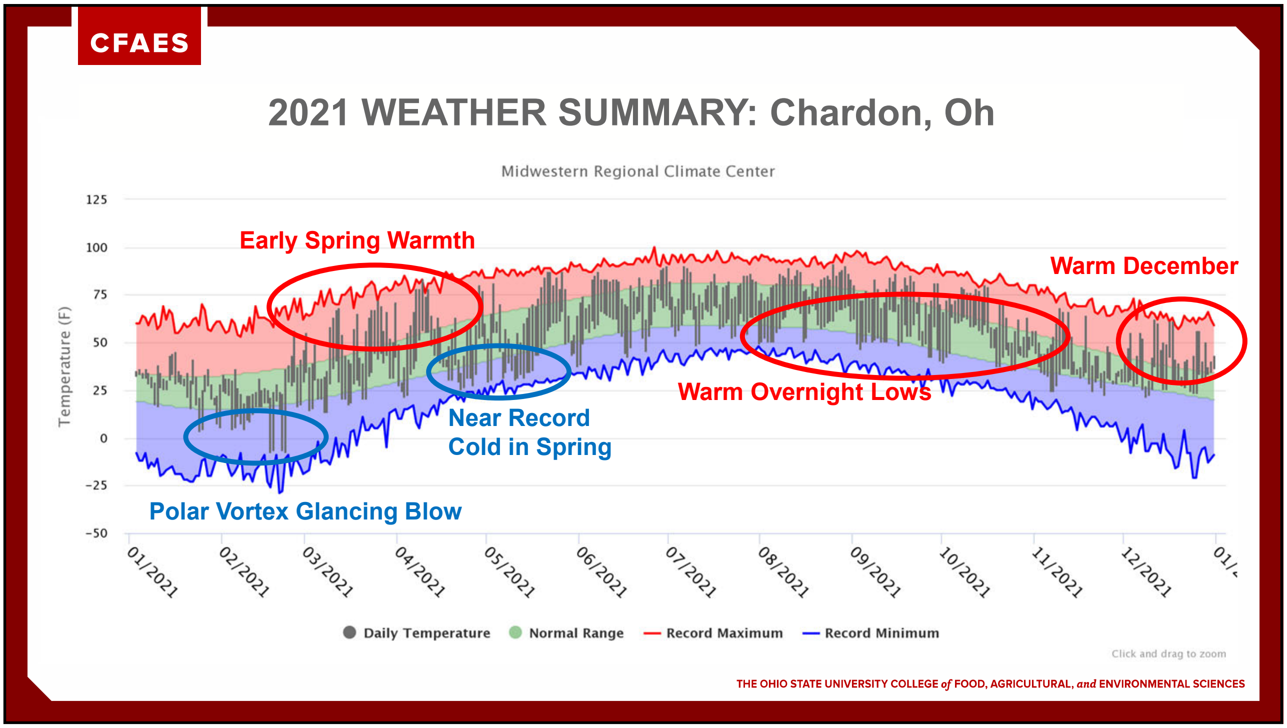


SPRING (Mar-May)

Fall (Sep-Nov)



6


CFAES
2021 WEATHER SUMMARY: Chardon, Oh
Midwestern Regional Climate Center
Temperature (F)
125
100
75
50
25
0
-25
-50
Early Spring Warmth
Warm December
Warm Overnight Lows
Near Record
Cold in Spring
Polar Vortex Glancing Blow
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
07/2021
08/2021
09/2021
10/2021
11/2021
12/2021
Daily Temperature
Normal Range
Record Maximum
Record Minimum
Click and drag to zoom
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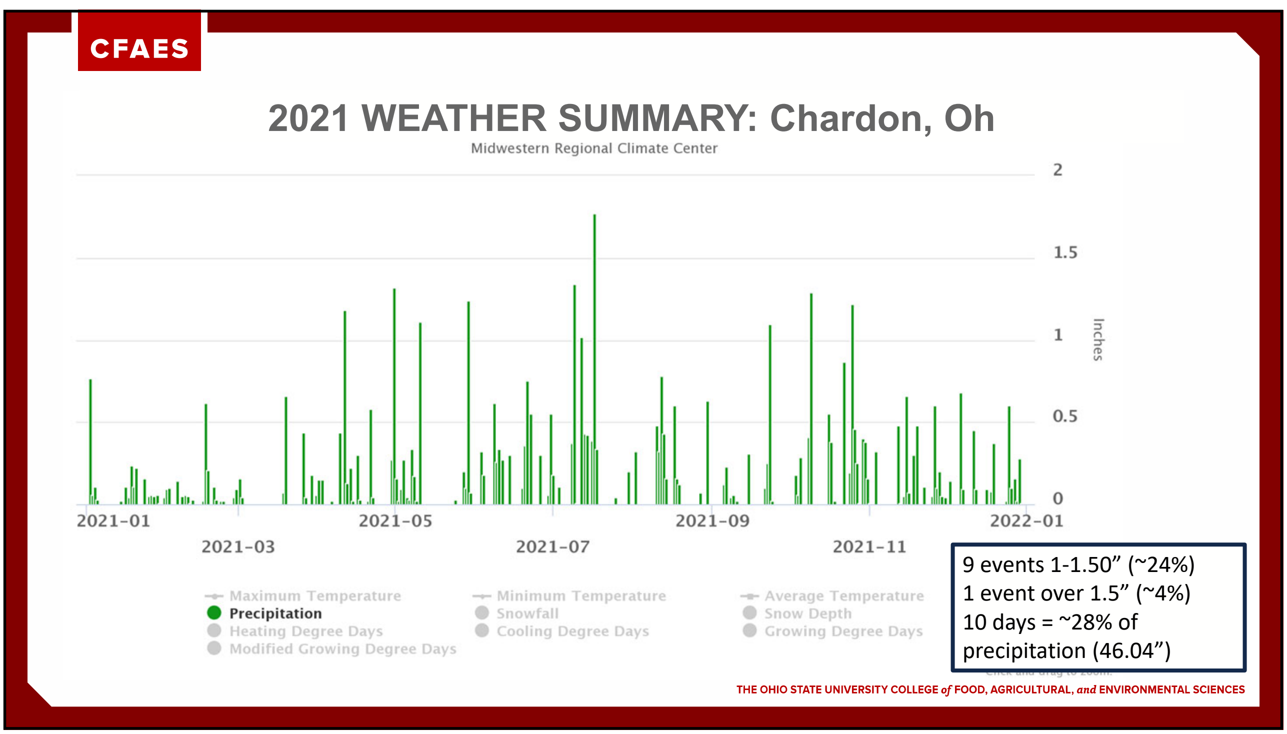
CFAES
2021 WEATHER SUMMARY: Chardon, Oh
Midwestern Regional Climate Center
2
1.5
1
0.5
0
Inches
2021-01
2021-03
2021-05
2021-07
2021-09
2021-11
2022-01
Maximum Temperature
Precipitation
Heating Degree Days
Modified Growing Degree Days
Minimum Temperature
Snowfall
Cooling Degree Days
Average Temperature
Snow Depth
Growing Degree Days
9 events 1-1.50” (~24%)
1 event over 1.5” (~4%)
10 days = ~28% of
precipitation (46.04”)
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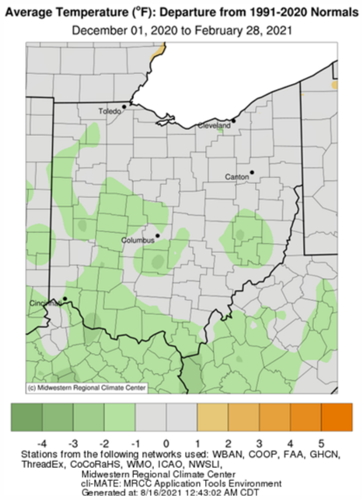
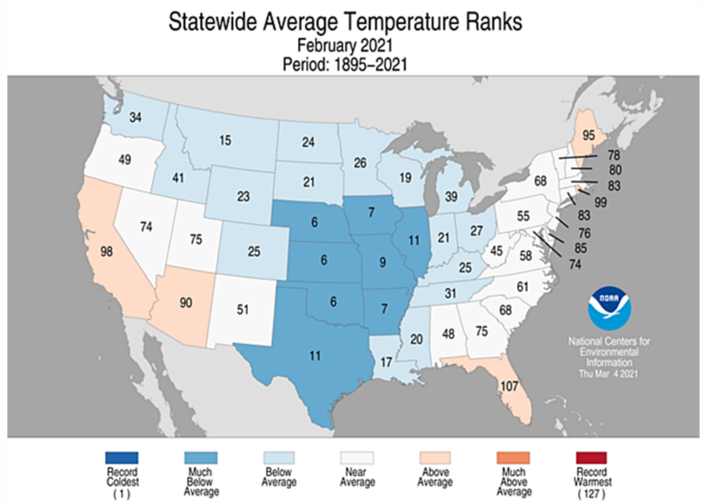
Winter Temperatures





- 27th Coldest February (1895-present)

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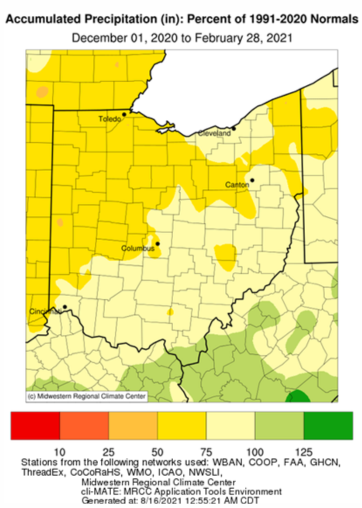
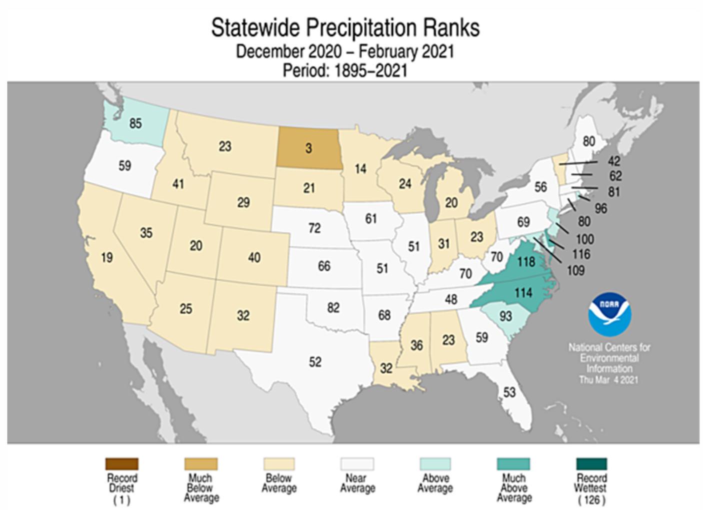
Winter Precipitation





- 23rd Driest Winter on Record (1895-present)

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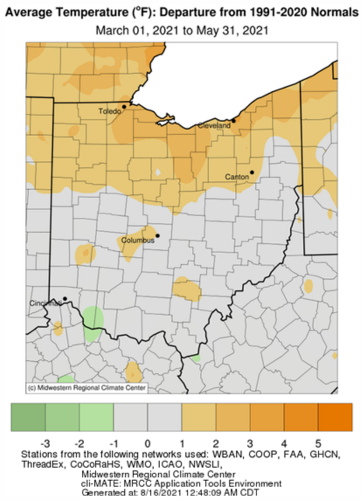
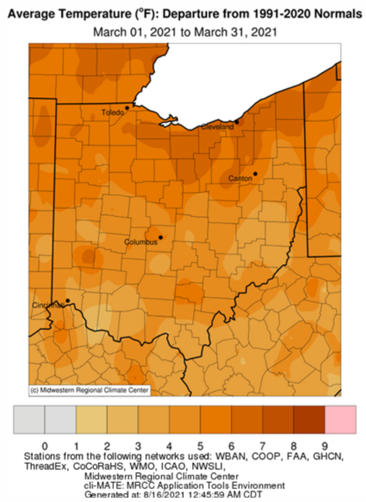
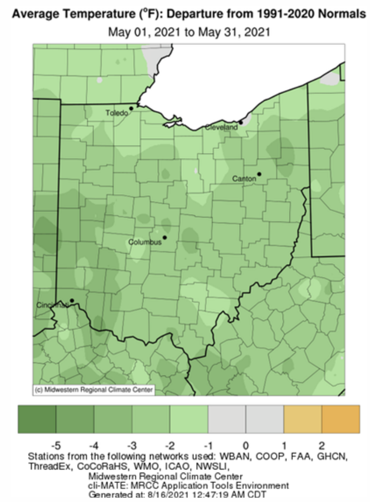
Spring Temperatures







- 12th Warmest March (1895-present)
- 47th Coldest Spring

Whiplash, anybody?

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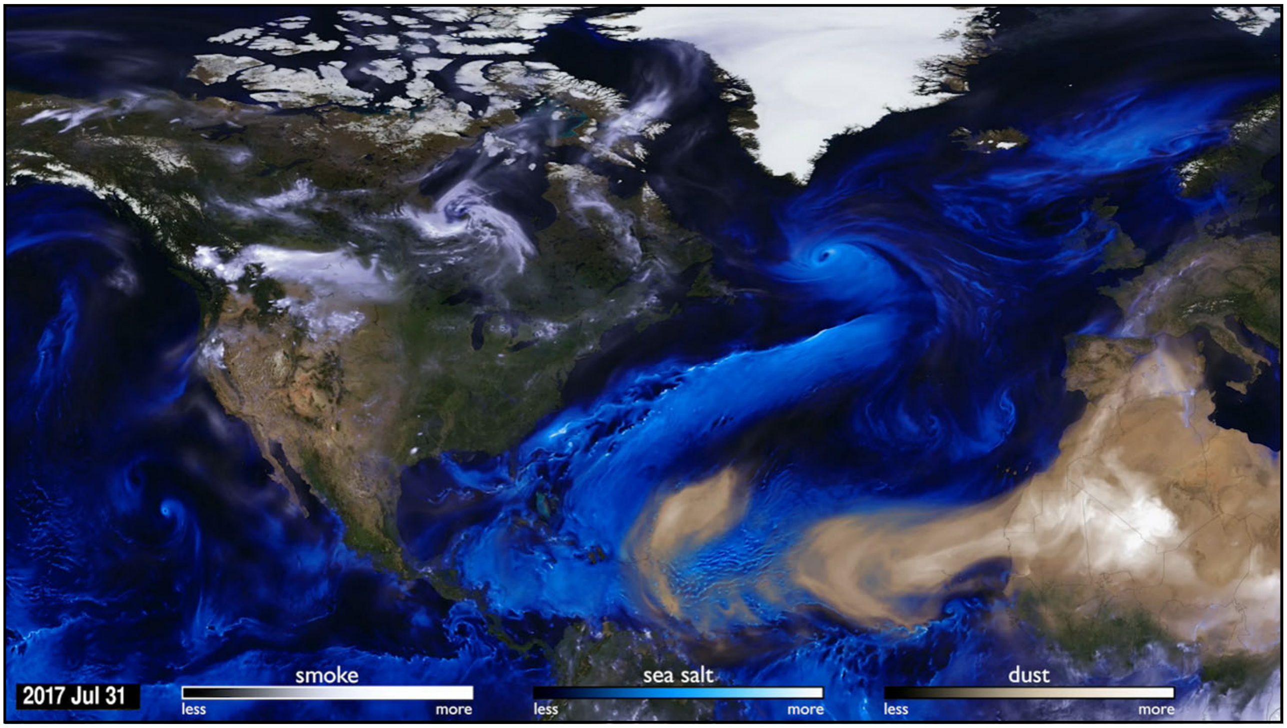
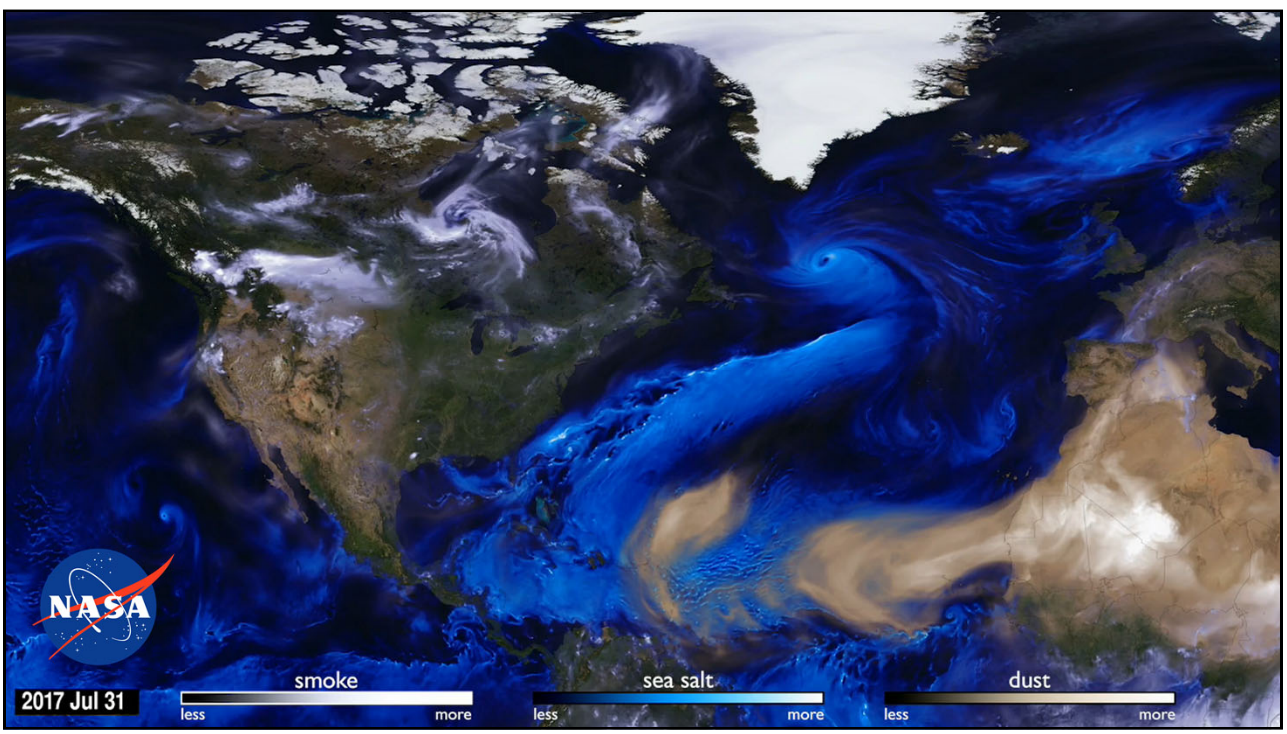
12


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

13


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

14

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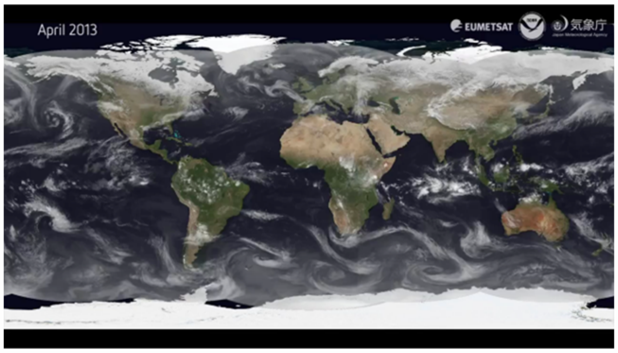
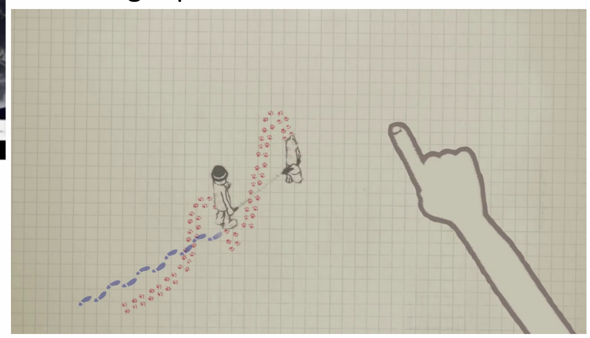
WEATHER AND CLIMATE

Video from UCAR: Center for Science Education - https://scied.ucar.edu/dog-walking-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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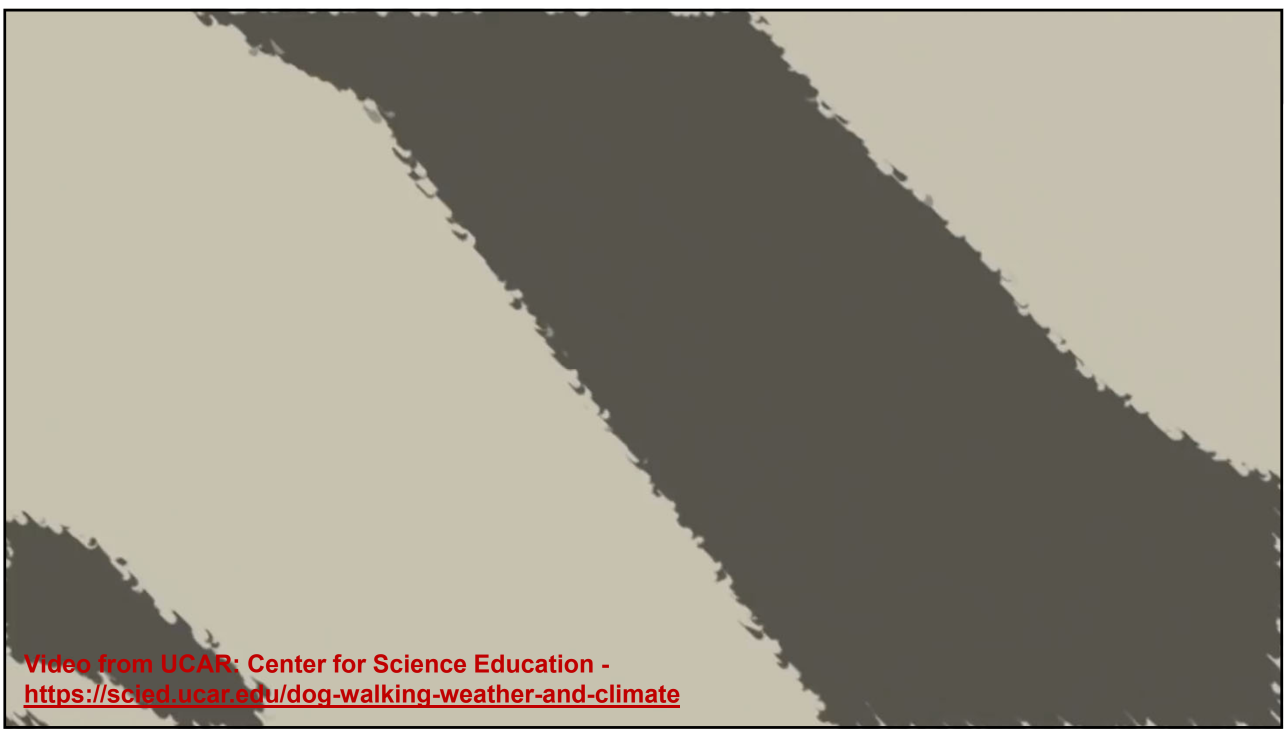

Video from UCAR: Center for Science Education -
https://scied.ucar.edu/dog-walking-weather-and-climate

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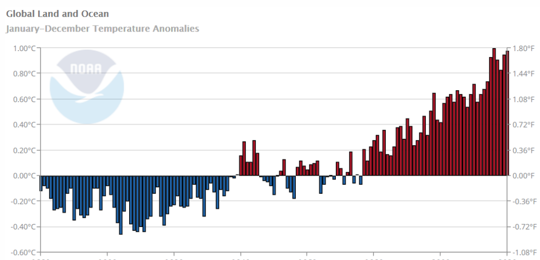
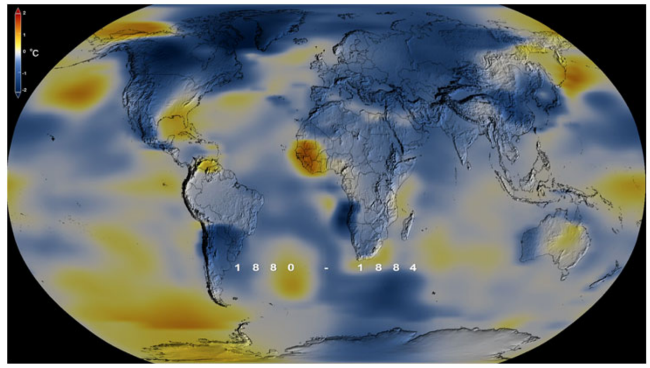
GLOBAL ASSESSMENT





- 2020 is now 2nd warmest year since 1880 (only behind 2016 by 0.04°F)
- Top 10 warmest years have occurred since 2005
- If you were born after February 1985, you have never experienced a cooler than average month for the planet!
- 2021 currently 6th warmest – Will know next week!

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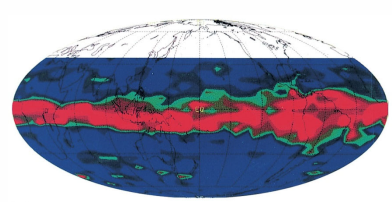
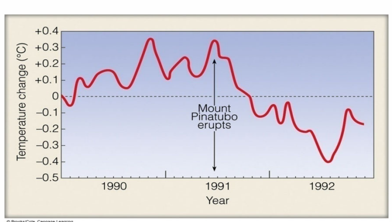
Volcano Impacts are Short-lived

- Only 3 months after the eruption of Mt. Pinatubo, Philippines, the plume girdles the equator in the stratosphere at an altitude near 25 km. (NASA)
- Average global temperature by July 1992, decreased by almost 0.5°C (0.9°F) from the 1981 to 1990 average (dashed line).





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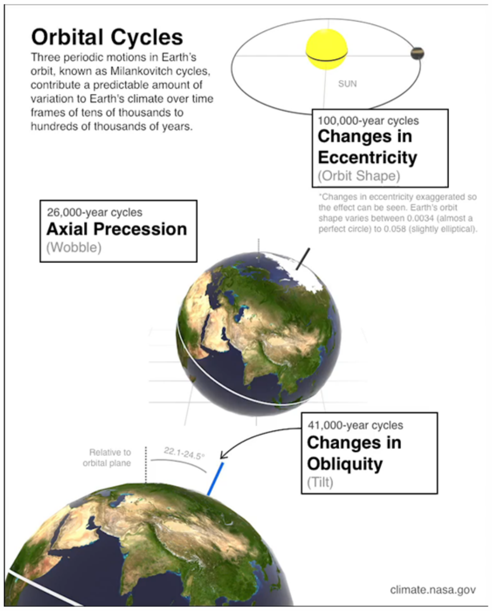

EARTH'S ORBITAL CHANGES

- **Eccentricity:** 100K yrs., Varies the amount of radiation the Earth receives during the seasons
- **Precession:** 23K yrs., Earth Wobbles, Closest to sun in January
- **Obliquity:** 41K yrs., Earth is tilted, Less tilt = cooler summers

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History of CO_2

Joseph Fourier: French, 1768-1830, Greenhouse Effect

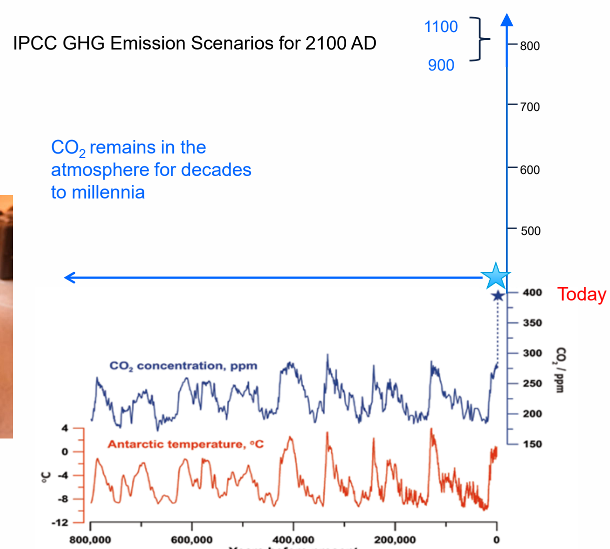
Eunice Newton Foote: American, 1819 – 1888; warming effects of sunlight on different gases

John Tyndall: English, 1820-1893, greenhouse gases

Svante Arrhenius: Swedish, 1859-1927, calculated warming of 2x carbon dioxide concentration

Guy Callendar: English, 1898-1964, temperature anomaly linked to combustion

Charles Keeling: American, 1928-2005, measured carbon dioxide concentrations



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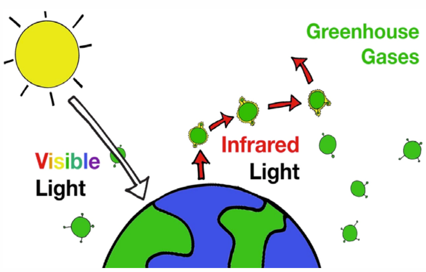
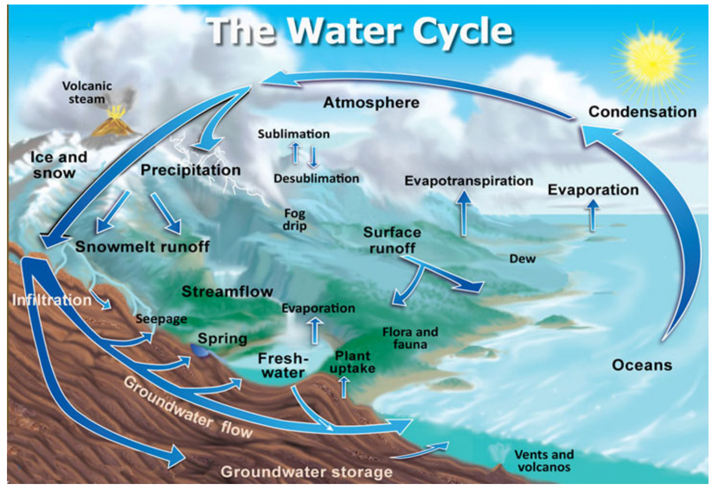
HOW THE ATMOSPHERE WARMS & WHY IT MATTERS



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

HowGlobalWarmingWorks.org, 2014



John Evans and Howard Periman, USGS - http://ga.water.usgs.gov/edu/watercycle.html

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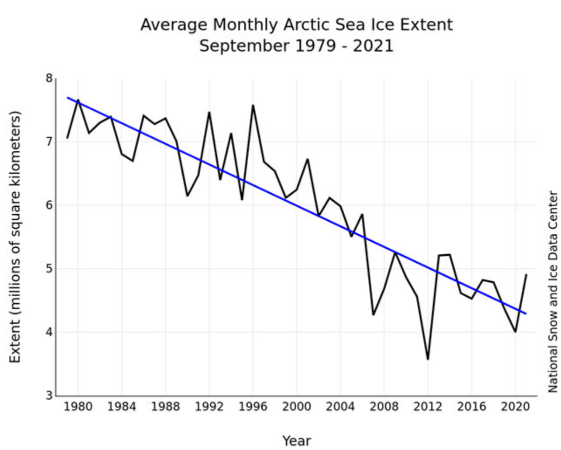
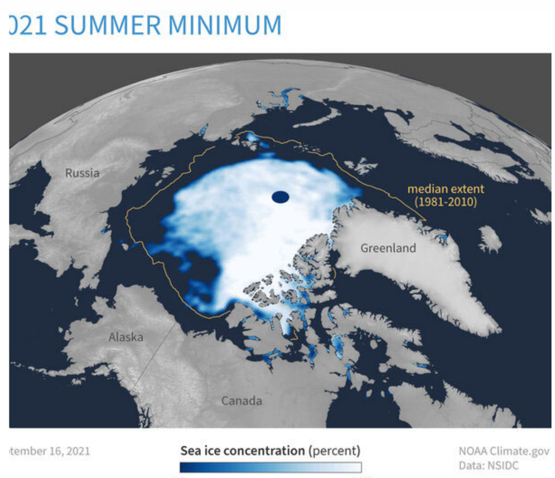
LOSS OF ARCTIC SEA ICE





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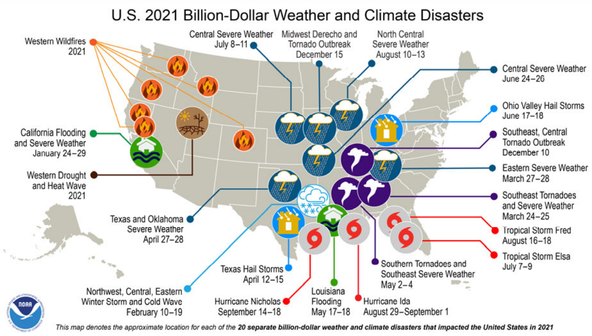

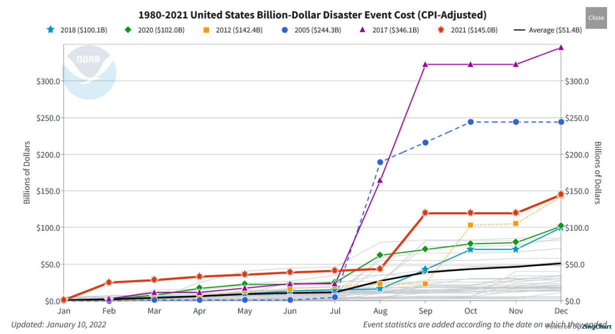

BILLION DOLLAR DISASTERS

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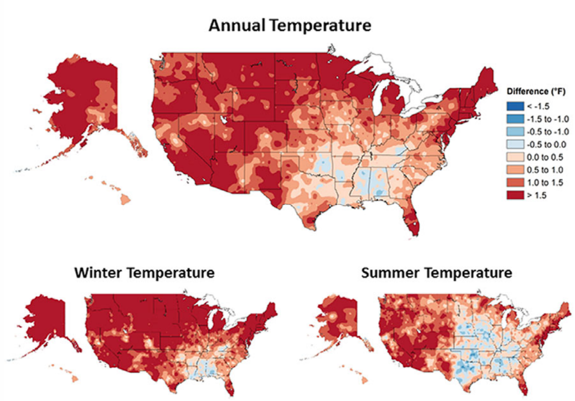
SEASONAL DIFFERENCE IN WARMING TEMPERATURES



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

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/

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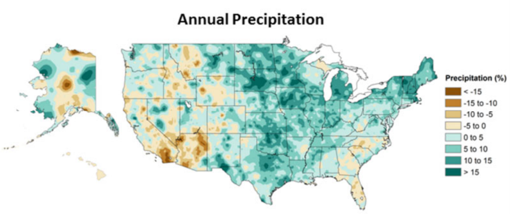
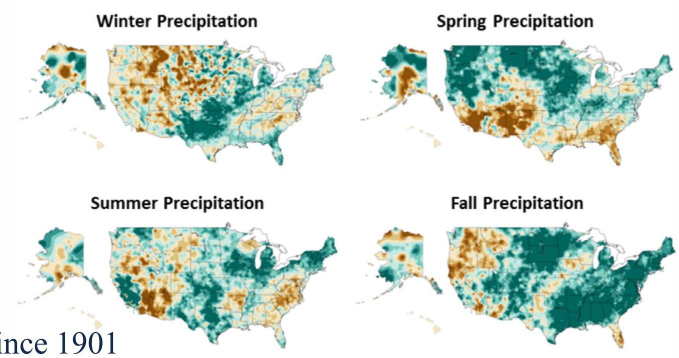
ANNUAL & SEASONAL CHANGES IN PRECIPITATION





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

- National average increase of 4% 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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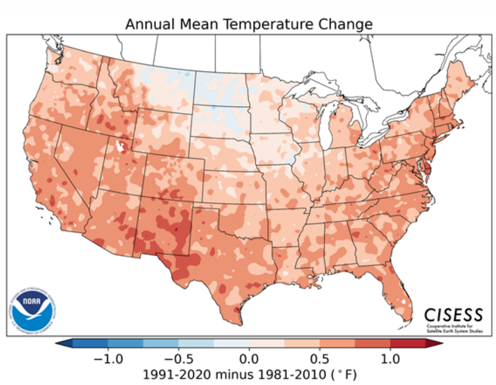
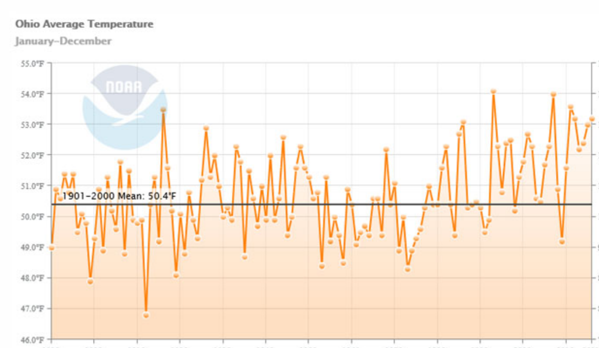
NWS New Normals: Temperature



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



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/

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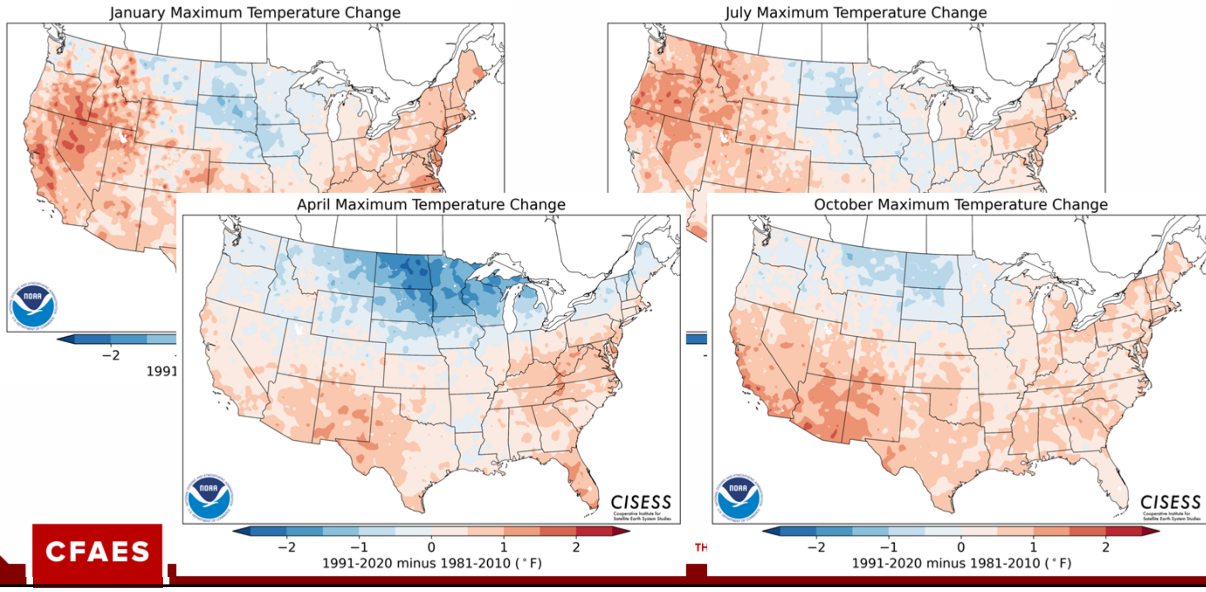
NWS New Normals

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



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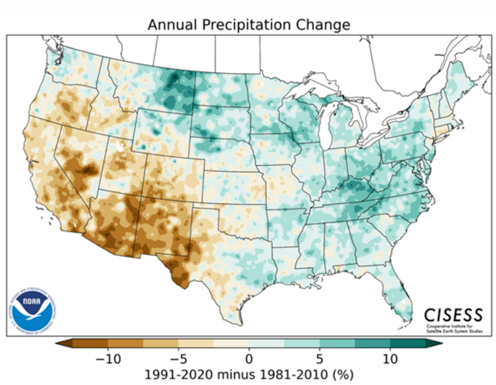
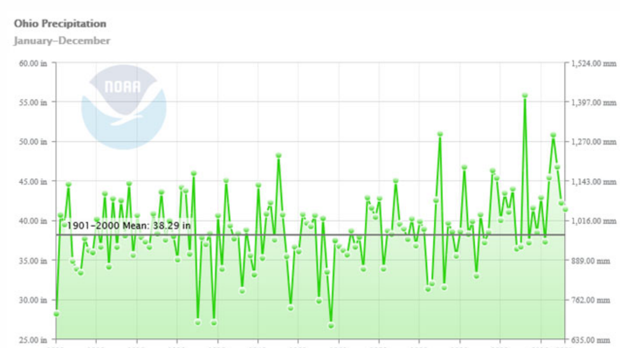
NWS New Normals: Precipitation



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



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/

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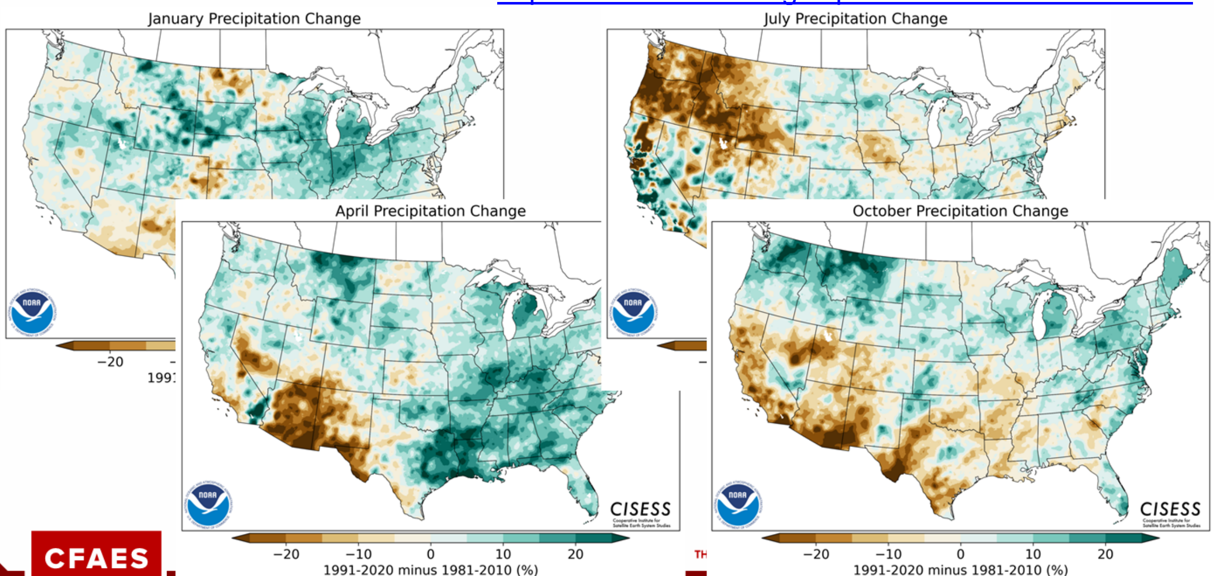
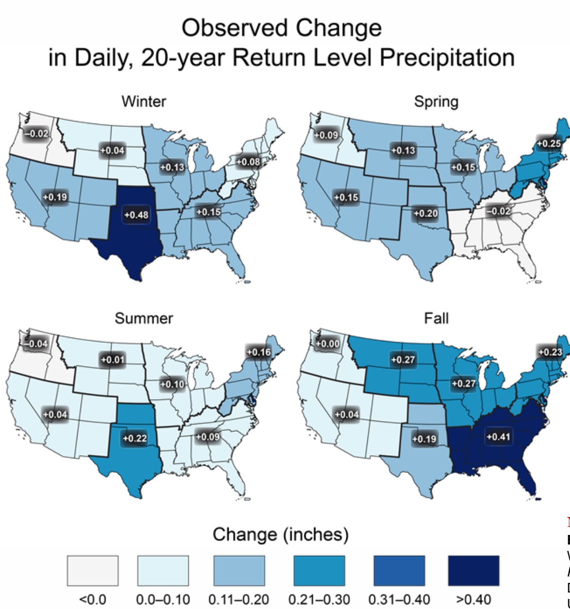
NWS New Normals

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



29



Regional: 20-Year Return Level Precipitation

- Extreme precipitation events are generally observed to increase in intensity by about 6% to 7% for each degree Celsius of temperature increase.
- Shows how much more precipitation occurs in a 1 in 20-year daily event. e.g., across the Midwest 0.27” more per this type of event.

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

Easterling, D.R., K.E. Kunkel, J.R. Arnold, T. Knutson, A.N. LeGrande, L.R. Leung, R.S. Vose, D.E. Waliser, and M.F. Wehner, 2017: Precipitation change in the United States. In: *Climate Science Special Report*: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 207-230, doi: 10.7930/J0H993CC.

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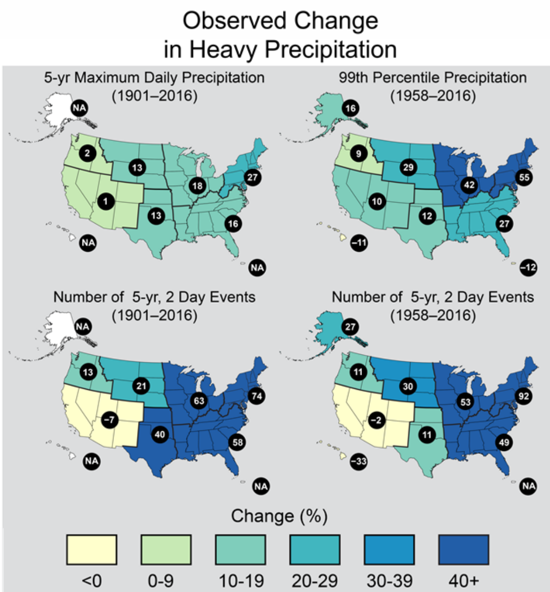

Regional: Heaviest Precipitation

- 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
- Think of the top right figure as the percentage increase in the 1-100 year events. 42% higher probability now in Midwest

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

Easterling, D.R., K.E. Kunkel, J.R. Arnold, T. Knutson, A.N. LeGrande, L.R. Leung, R.S. Vose, D.E. Waliser, and M.F. Wehner, 2017: Precipitation change in the United States. In: *Climate Science Special Report*: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 207-230, doi: 10.7930/J0H993CC.

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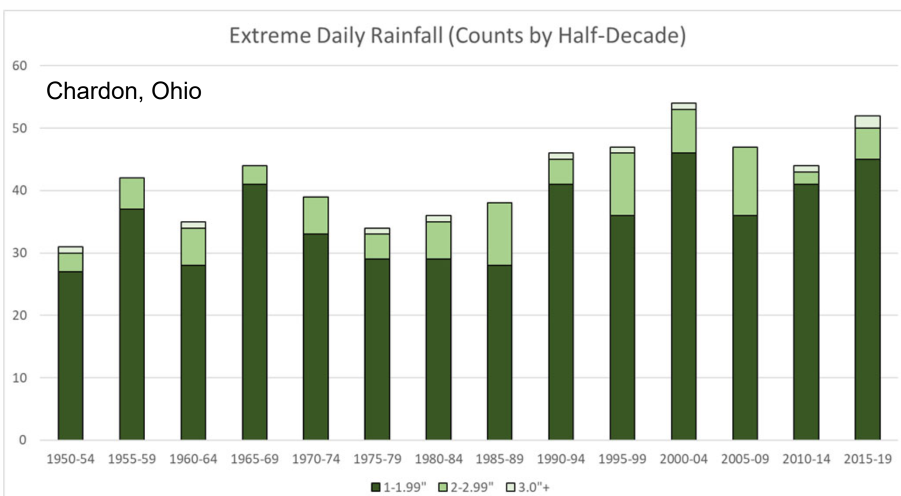
Extreme Daily Event (Pentad) Trends



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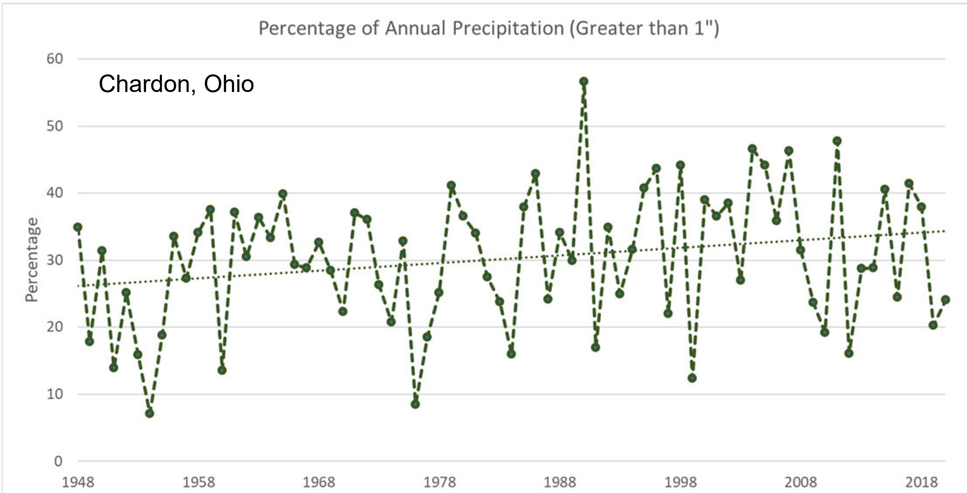
Portion of Rainfall Falling as Heavier Events



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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
6	2021	53.2	1.5
7	1991	53.1	1.5
8	2020	53.0	1.4
9	1931	52.9	1.3
9	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

- 5 of the top 10 warmest/ 6 of the top 10 wettest have occurred since 2003
- 9 of the top 10 warmest/ 8 of the top 10 wettest since 1990

OHIO'S TOP 10

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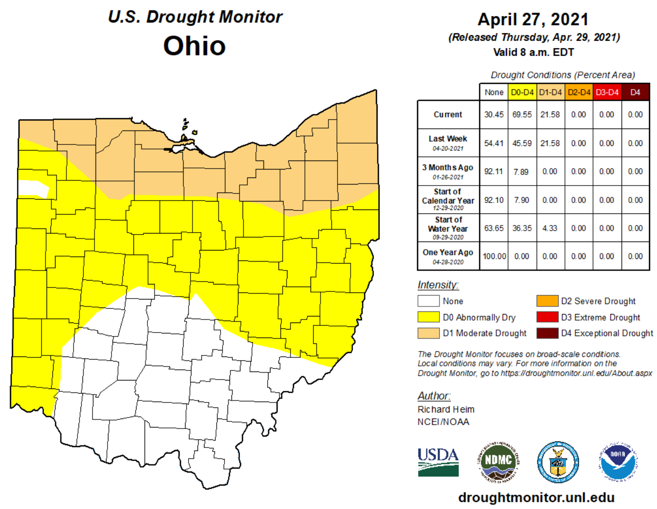
We Still See Drought

- Distinguish meteorological drought (lack of precipitation) from agricultural drought (soil moisture deficit) and hydrological drought (runoff deficit)
- Precipitation trends lead to lower confidence in detectable changes in meteorological drought
- Recent droughts distinguished from past (1930s/50s)
- Droughts drier due to warmer temperatures and increased evaporation



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	30.45	69.55	21.58	0.00	0.00	0.00
Last Week 04-20-2021	54.41	45.59	21.58	0.00	0.00	0.00
3 Months Ago 01-26-2021	92.11	7.89	0.00	0.00	0.00	0.00
Start of Calendar Year 12-29-2020	92.10	7.90	0.00	0.00	0.00	0.00
Start of Water Year 09-29-2020	63.65	36.35	4.33	0.00	0.00	0.00
One Year Ago 04-28-2020	100.00	0.00	0.00	0.00	0.00	0.00

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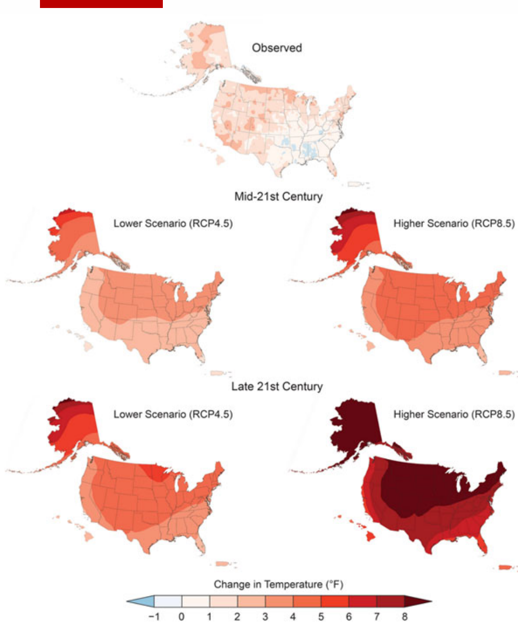

OUR FUTURE CLIMATE: TEMPERATURE

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

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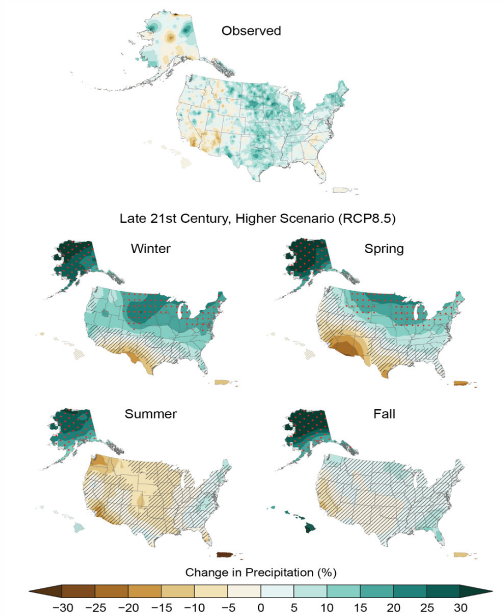

OUR FUTURE CLIMATE: PRECIPITATION

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

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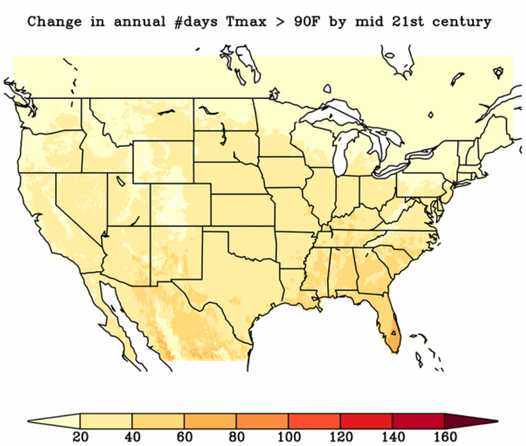
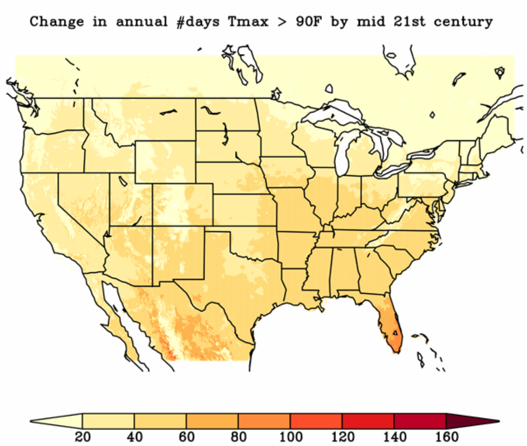
https://scenarios.globalchange.gov/loca-viewer/

CHANGE IN # OF DAYS > 90°F

Lower Emissions



Higher Emissions



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

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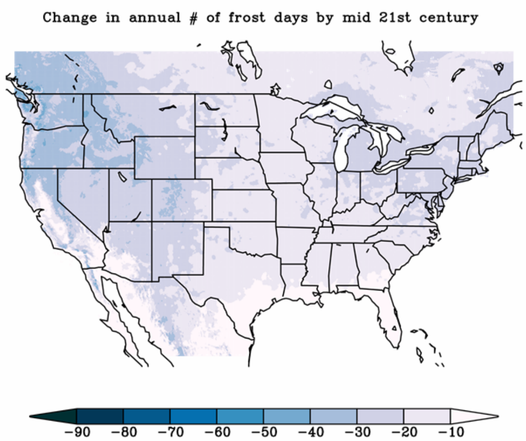
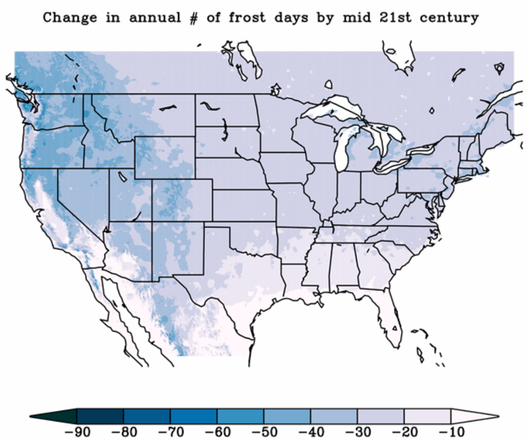
https://scenarios.globalchange.gov/loca-viewer/

CHANGE IN # OF NIGHTS > 32°F

Lower Emissions



Higher Emissions



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

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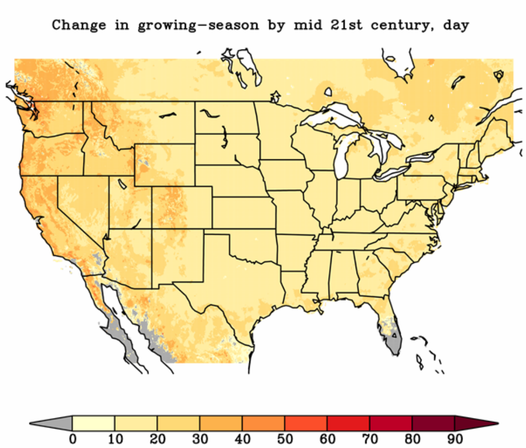
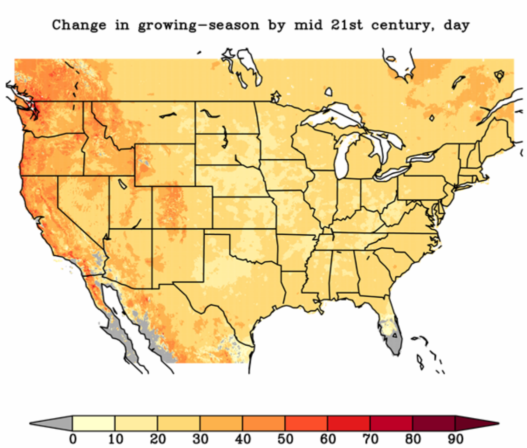
CHANGE IN GROWING SEASON LENGTH

Lower Emissions



Higher Emissions



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

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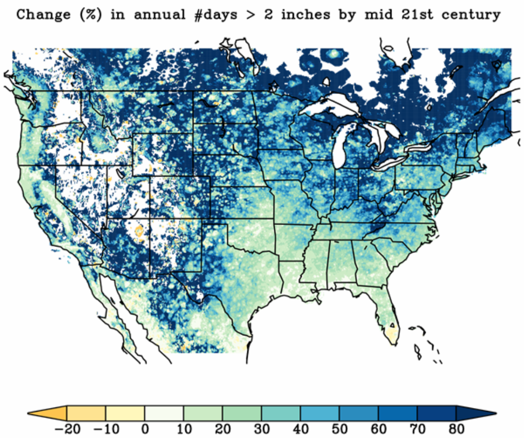
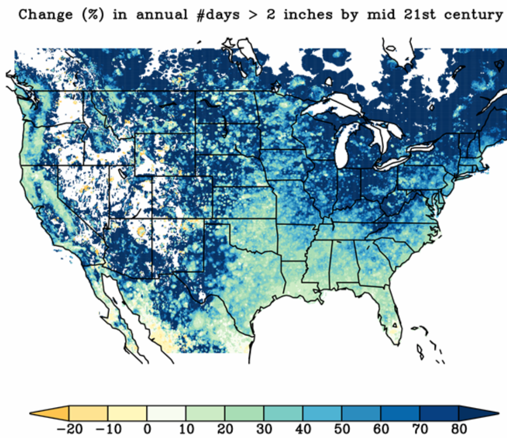
https://scenarios.globalchange.gov/loca-viewer/

CHANGE IN MEAN ANNUAL DAYS WITH PRECIPITATION > 2”

Lower Emissions



Higher Emissions



(1976-2005): < 1 day

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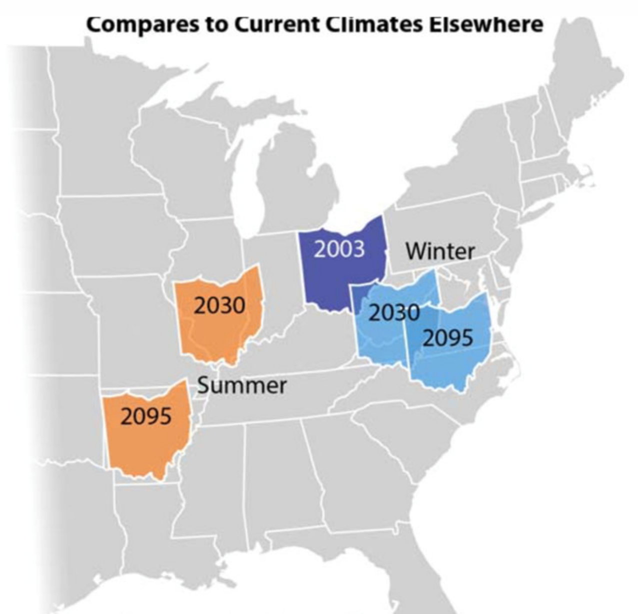
WHAT IF THIS IS OUR NEW NORMAL?

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



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WEIGHING OPPORTUNITIES & CHALLENGES

- Longer growing seasons
- Crops grown in new areas – new markets
- Longer grazing period
- Reduced maintenance costs
- Opportunities to increase trade

- Additional (sustained) heat stress on humans and livestock
- Lower food productivity and reduced quality
- Increased weed pressure, insects, and potential disease
- Unpredictable growing seasons
- Invasive, non-native plants and animals' ranges are expanding

- Greater Flood Risk (Increased Frequency of Flooding)
- Health risks associated with floods
- Increased transportation issues
- Reduced Water Quality – intense runoff, soil loss, and contamination
- Potential for summer droughts and seasonal water shortages

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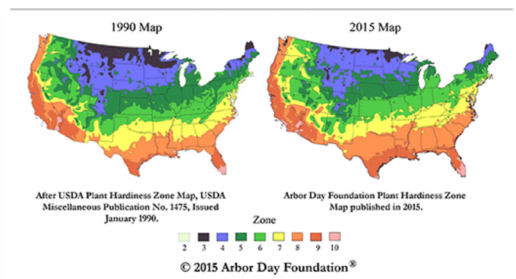
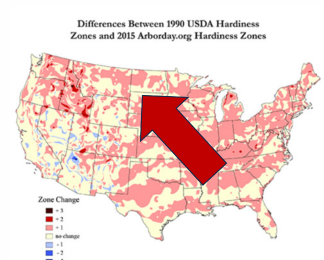
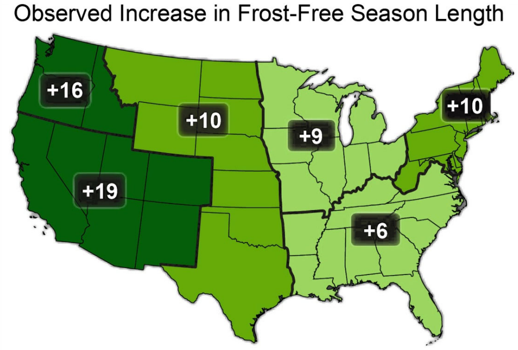
Impacts: Increasing Temperatures





- Overall Northwestward Shift in Growing Zones…Maples on the move?
- False Springs
  - 4 out of top 10 Warmest Feb-Mar have occurred since 2000
    - 2012: warmest
    - 2017: 3rd warmest
    - 2000: 5th warmest
    - 2016: 9th warmest

Observed Increase in Frost-Free Season Length



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Some Key Climate Threats to Maple Syrup Production

Availability of trees to tap

- Suitable habitat for the sugar maple tree likely to decline in most of its U.S. range by 2100, especially across the southern and southwestern part of its range, but large range could mean acclimation
- Some expansion of habitat is possible in parts of the Great Lakes, Southern Canada, and Maine
- Max sap flow likely to move north by ~400 km by 2100

Tree health

- Reduced snow-pack during the winter can cause root die-back and reduced shoot growth, deeper frost depth which impact growth
- More frequent spring frost can negatively impact trees that respond to warmer temperatures by breaking bud earlier.
- Growth declines in mature trees in recent decades may be related to rising temperatures.

Tapping season characteristics

- Tapping season is starting earlier with a shorter duration and becoming more variable.

Climate change effects on sap quality

- Climate change is likely to influence sugar content, mineral profile, and secondary metabolite chemicals of sugar maple.
- Warmer summer temperatures may reduce sugar content by impacting respiration rates and carbon storage

Giesting, K. 2020. Maple Syrup. USDA Forest Service Climate Change Resource Center.
www.fs.usda.gov/ccrc/topics/maple-syrup

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Additional Resources per USDA/US Forest Service

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SUGAR MAPLE CHANGES

Forest Ecology and Management 448 (2019) 187–197

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Finding the sweet spot: Shifting optimal climate for maple syrup production in North America

Joshua M. Rapp[a,b,*], David A. Lutz[c], Ryan D. Huish[d], Boris Dufour[e], Selena Ahmed[f], Toni Lyn Morelli[g,a], Kristina A. Stinson[a,b]

- Two climate sensitive components: sugar content and sap flow
- Stands spanning latitudinal range over 2–6 years to predict the role of climate variation on sugar content and sap flow
- Sap collection advanced by 4.3 days for every 1°C increase in March mean temperature
- Sap volume peaked at a January-May mean temperature of 1 °C
- Sap sugar content declined by 0.1 °Brix for every 1 °C increase in previous May-October mean temperature

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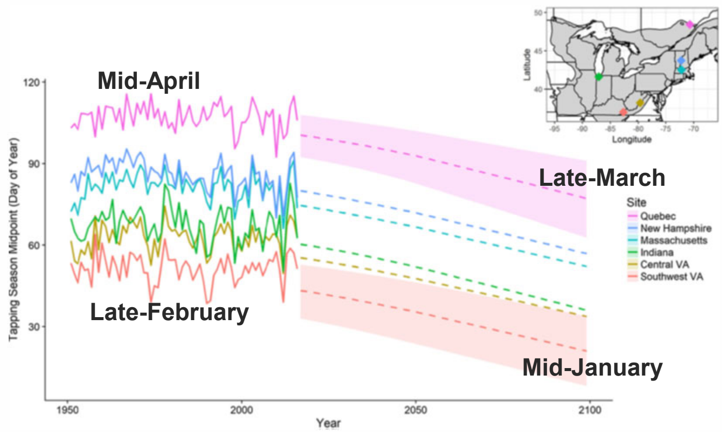
SUGAR MAPLE CHANGES: Tapping Season Midpoint

- Clear trend toward earlier timing by the end of the century for all sites
- Midpoint of the tapping season about one month earlier by the end of the century compared to the historical period for all sites (1950-2016)



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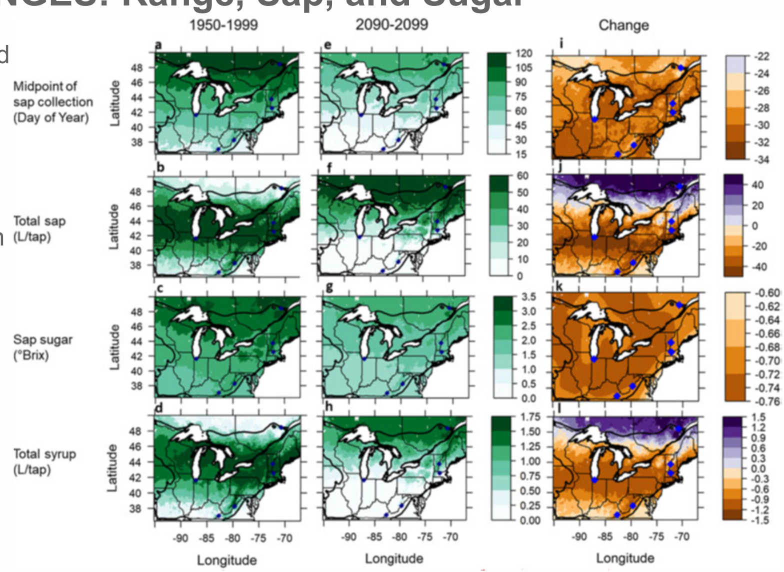
SUGAR MAPLE CHANGES: Range, Sap, and Sugar

- Sap collection midpoint is projected to be in March or later only half of the time or less across the southern two-thirds of range
- Southern half of sugar maple's range; 30–40 L/tap less sap per year is projected to be collected on average.
- Sap sugar content is projected to be 0.55–0.65 °Brix lower on average (Fig. 6k), with most years below 2.2 °Brix over most of the range.
- Optimal production is projected to shift northward by the end of the century,



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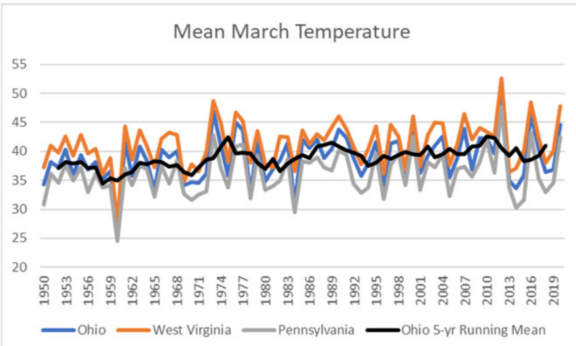
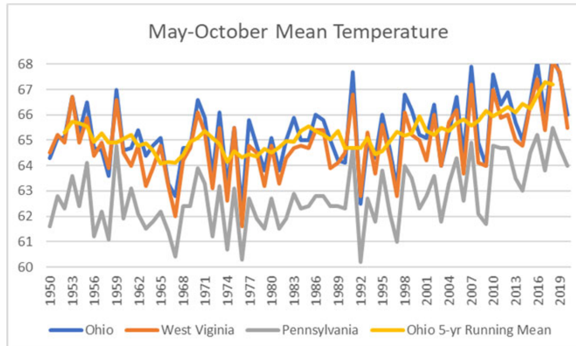
Back of the Envelope Calculations





3.78°F = 2.1°C*4.3days = 9 days earlier

1.9°F = 1°C*0.1 °Brix = Decrease 0.1 °Brix

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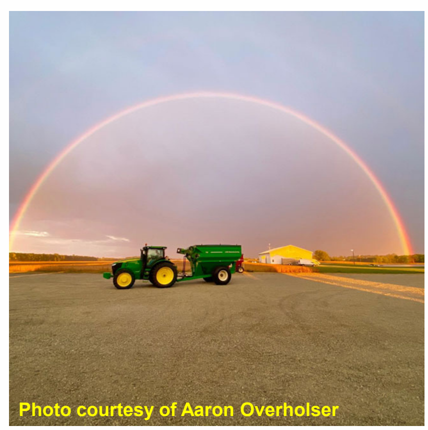
1. Climate change is happening.
2. We are currently experiencing the effects.
3. Humans are the cause.
4. The scientific evidence is overwhelming.
5. We can do something about it.

Mitigate: Stop or limit climate change impacts by reducing greenhouse gas emissions.

Adapt: Change infrastructure, planning, and behaviors to adjust to climate change impacts.

Suffer: Face the consequences of failing to mitigate or adapt. Populations already experiencing adversity are likely to be the most negatively impacted.



It Takes Action

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Maple Production Strategies

- Will differ based on geography
- Diversify species to include red maple and birch
- Technology (vacuum tubing, spouts, and processing technology)
- Increasing taps
- Shift seasons to take advantage of sap flow
- Innovation and marketing different attributes of maple – late season "buddy" syrup (sweetening agent)
- Limit other environmental stressors (acid rain and pests) to decrease the effects

NECSC Northeast Climate Science Center

Tapping in the snow at 3500 feet near Spruce Knob WV. Photo from Mike Rechlin.

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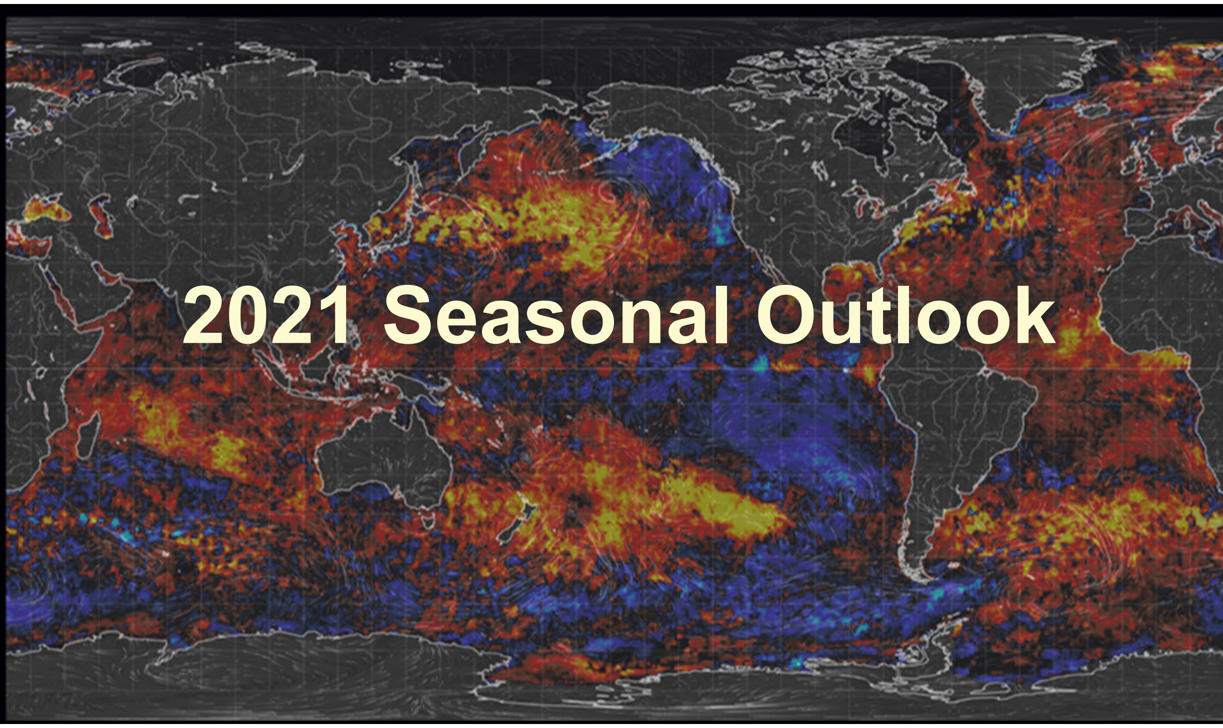

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El Nino Southern Oscillation (ENSO)

- During an El Niño (La Niña), tropical Pacific Ocean temperatures warm (cool) relative to average and impact patterns of tropical rainfall from Indonesia to the west coast of South America
- Impact weather patterns across the globe, most notably in the Ohio Valley and NE during winter

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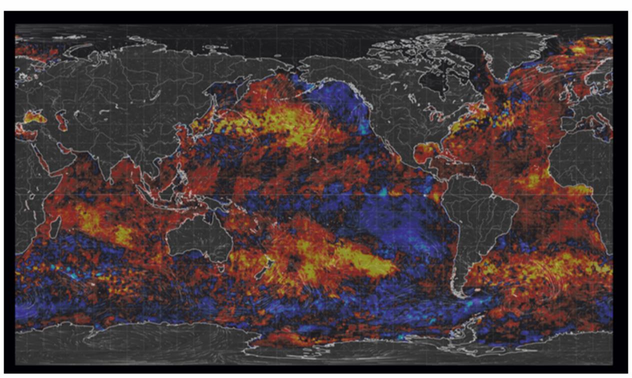
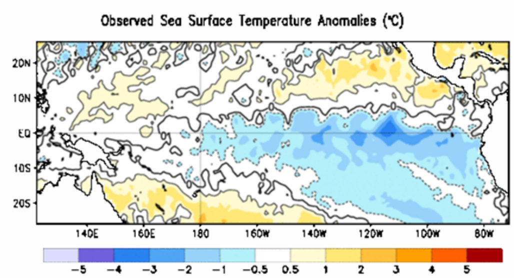
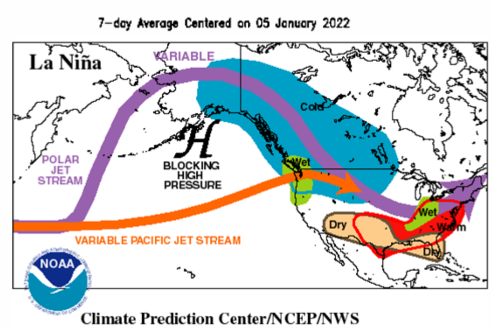
Current Conditions







- La Niña in place and will continue through winter
- Wavy jet stream and wet conditions in Ohio

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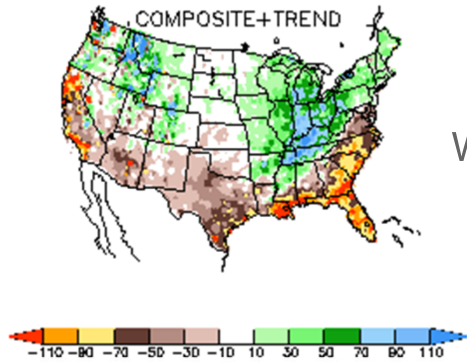
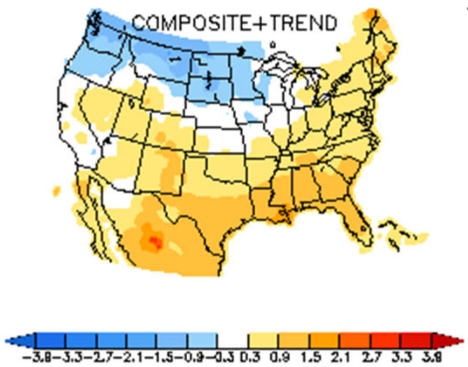
La Niña Conditions

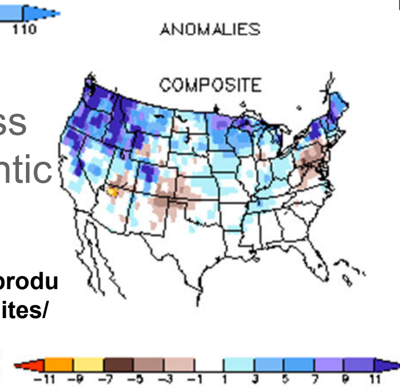


Wetter

Warmer – highly variable



Snowier – Ohio; Less Snow in the Mid-Atlantic



https://www.cpc.ncep.noaa.gov/products/precip/CWlink/ENSO/composites/

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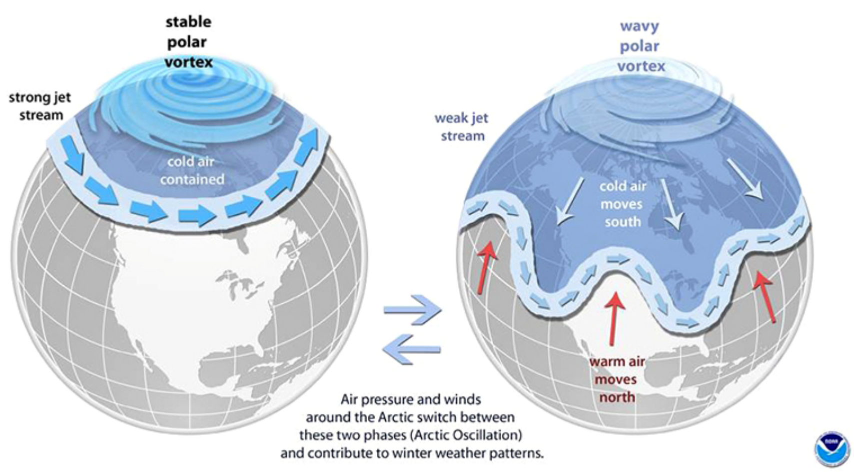
"POLAR VORTEX" EVENTS



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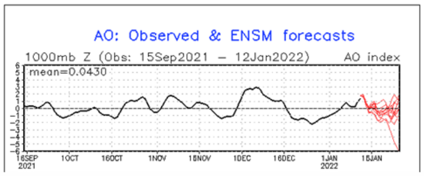
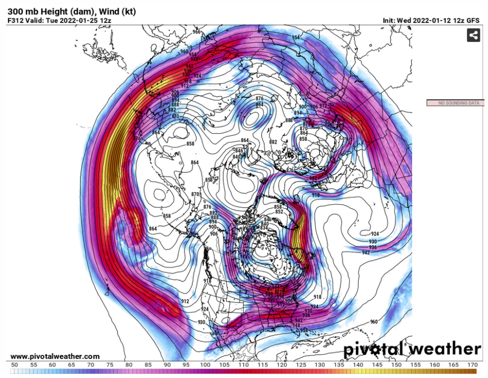
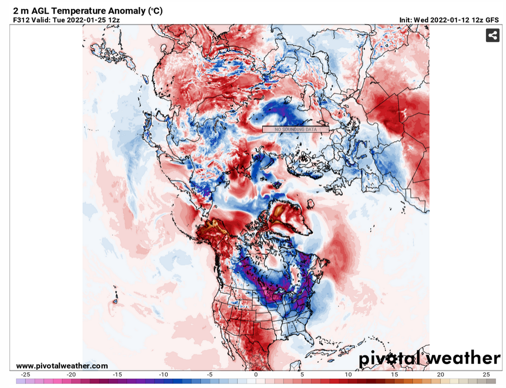
Current Arctic Oscillation

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao.shtml







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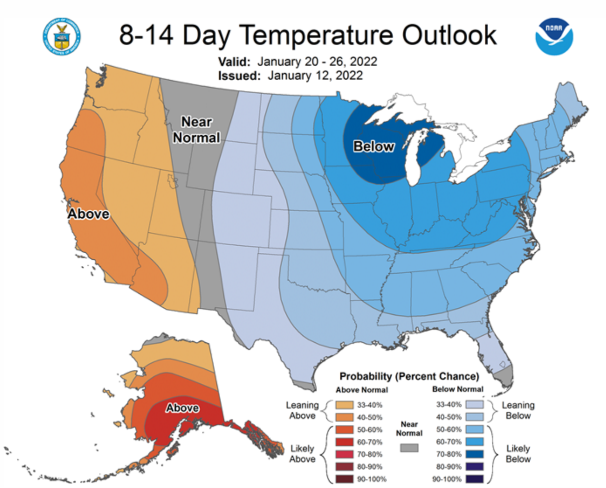
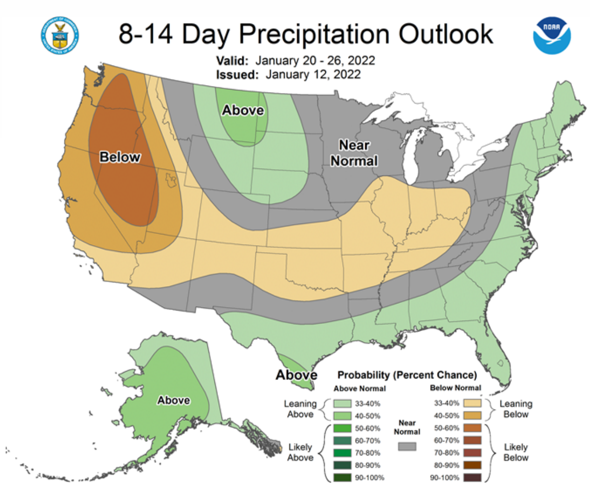
8-14 Day Outlook





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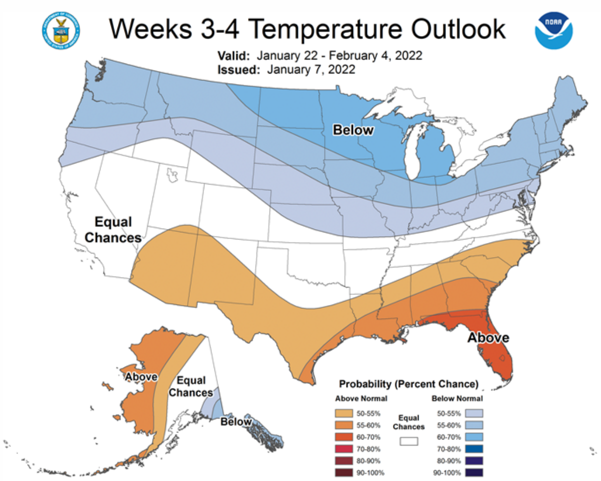
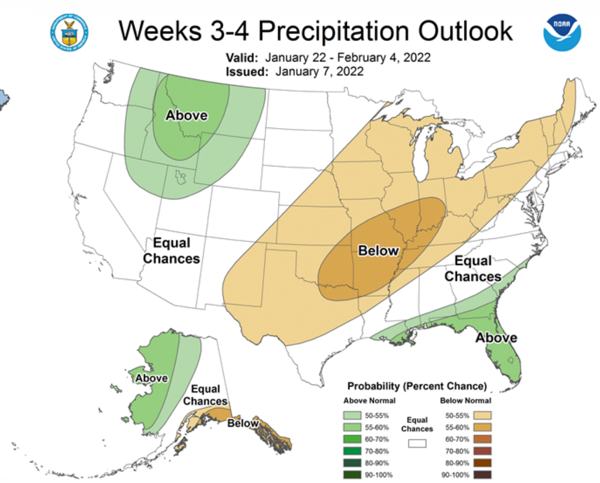
3-4 Week Outlook (January 22 – February 4)





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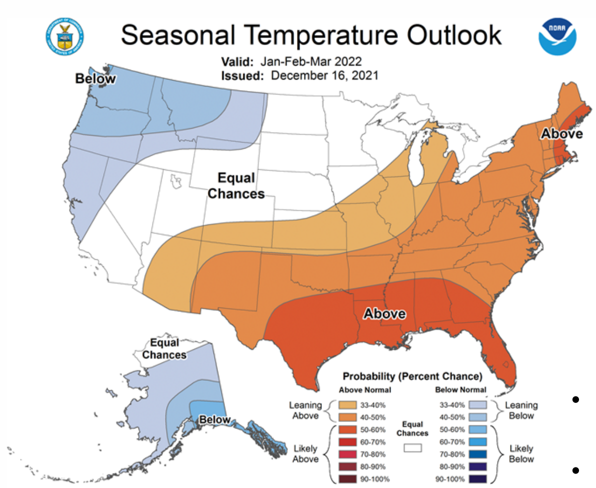
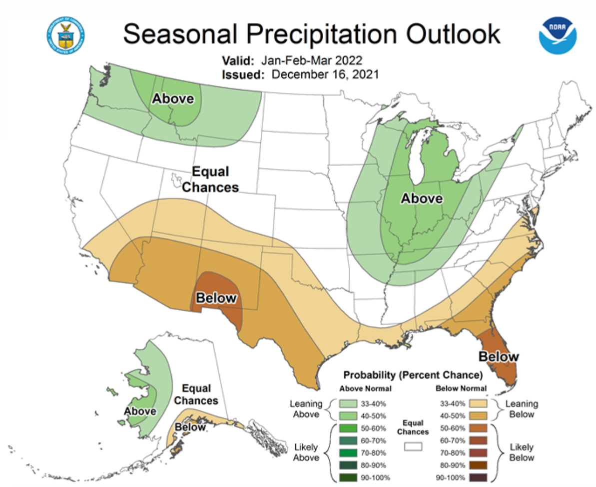
Seasonal Outlook: Winter





- Highly variable weather will continue with a few cold snaps
- Overall, wetter and warmer than average = MUD!

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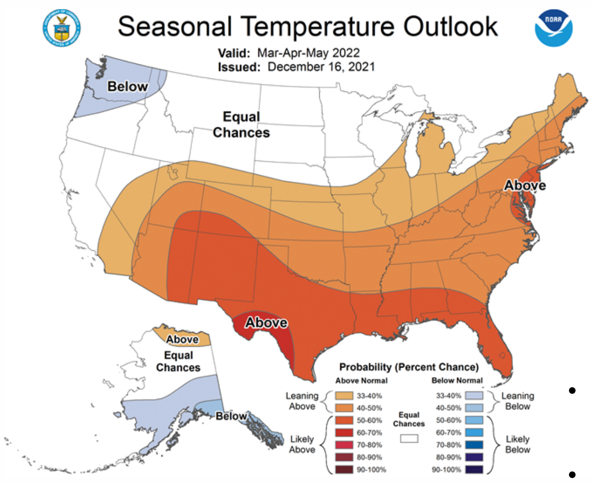
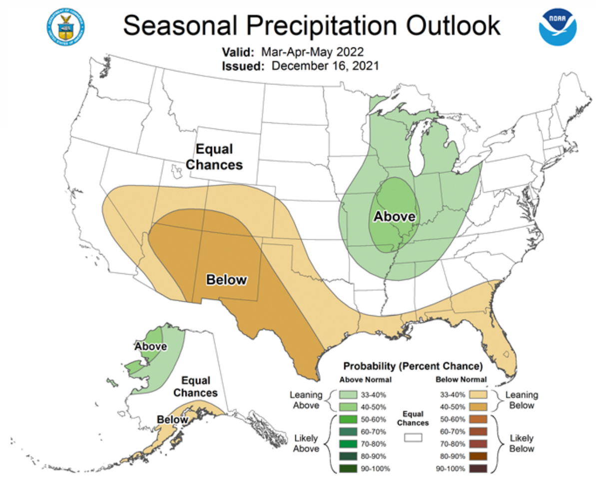
Seasonal Outlook: Spring





- Wet conditions likely continue into spring
- Could slow soil temperatures

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Summary

- Climate Change is Real and it's Personal
- Conditions are warming (especially in winter and at night) and becoming more variable
- Precipitation is increasing (fall-spring) and becoming more intense
- Climate change impacts tree range, health, volume of sap and sugar content
- How do we adapt? What does the future hold for the industry?
- La Nina conditions likely mean warmer than average, highly variable, and wetter than average 2022 winter season

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Thanks, and Have A Great Season!
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Photo Credit: Keith Robinson, flickr, Taken Feb 22, 2010 “in the sugarbush at Pattison Park in Clermont County Ohio”

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