Climate Variability, Climate Change in MO, and an Early Weather Outlook – Summer 2024

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Introduction

- Weather and Climate are both current issues that are pressing in recent years due to “extreme occurrences”.

Extreme Environmental Events

Climate change affects global temperature and precipitation patterns. These effects, in turn, influence the intensity and, in some cases, the frequency of extreme environmental events, such as forest fires, hurricanes, heat waves, floods, droughts, and storms.

GRADES
9 - 12+

SUBJECTS
Climatology, Earth Science, Ecology

IMAGE

Boise National Forest Fire

Research shows human-caused climate change has worsened the risk of extreme weather events like the wildfires of the western United

- The year 2023 – Heat waves and forest fires across the world.

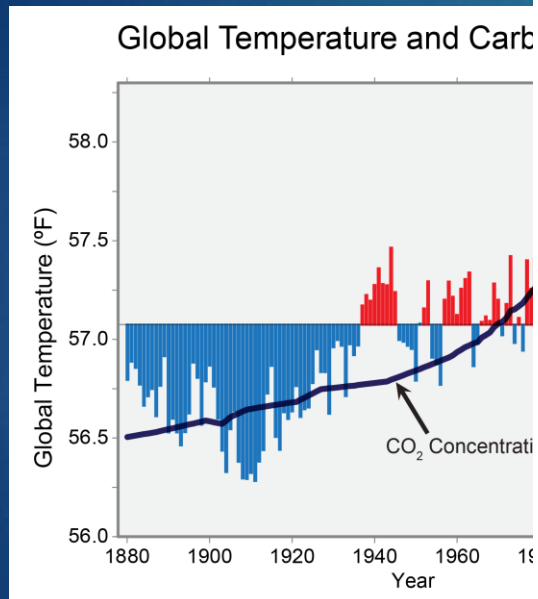
Introduction

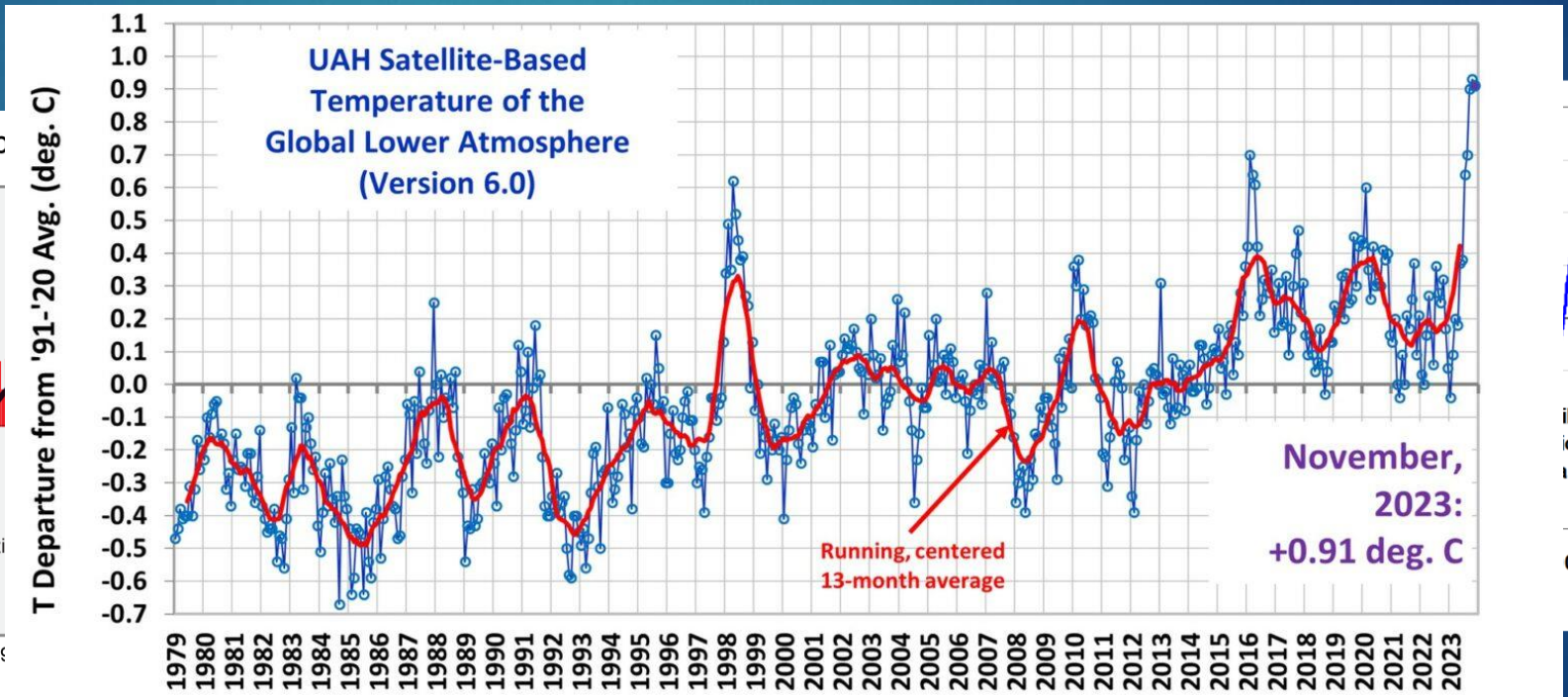
- Climate change as an issue has been wrestled with in political circles for a couple decades. http://ipcc.ch

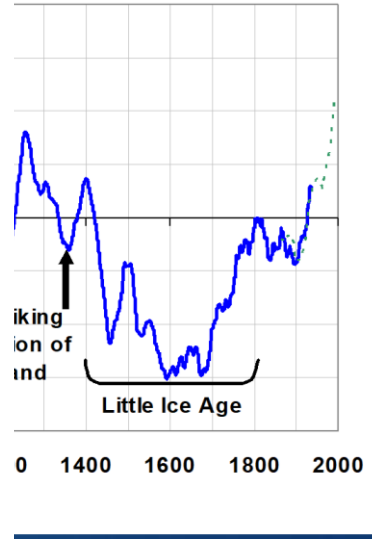
- There is no doubt that Earth's climate has warmed since the mid-to-late 1800s – and the rates have been different at different times.

Introduction

- Most acknowledge some role for humans – although many believe that humans are the sole cause of current climate c



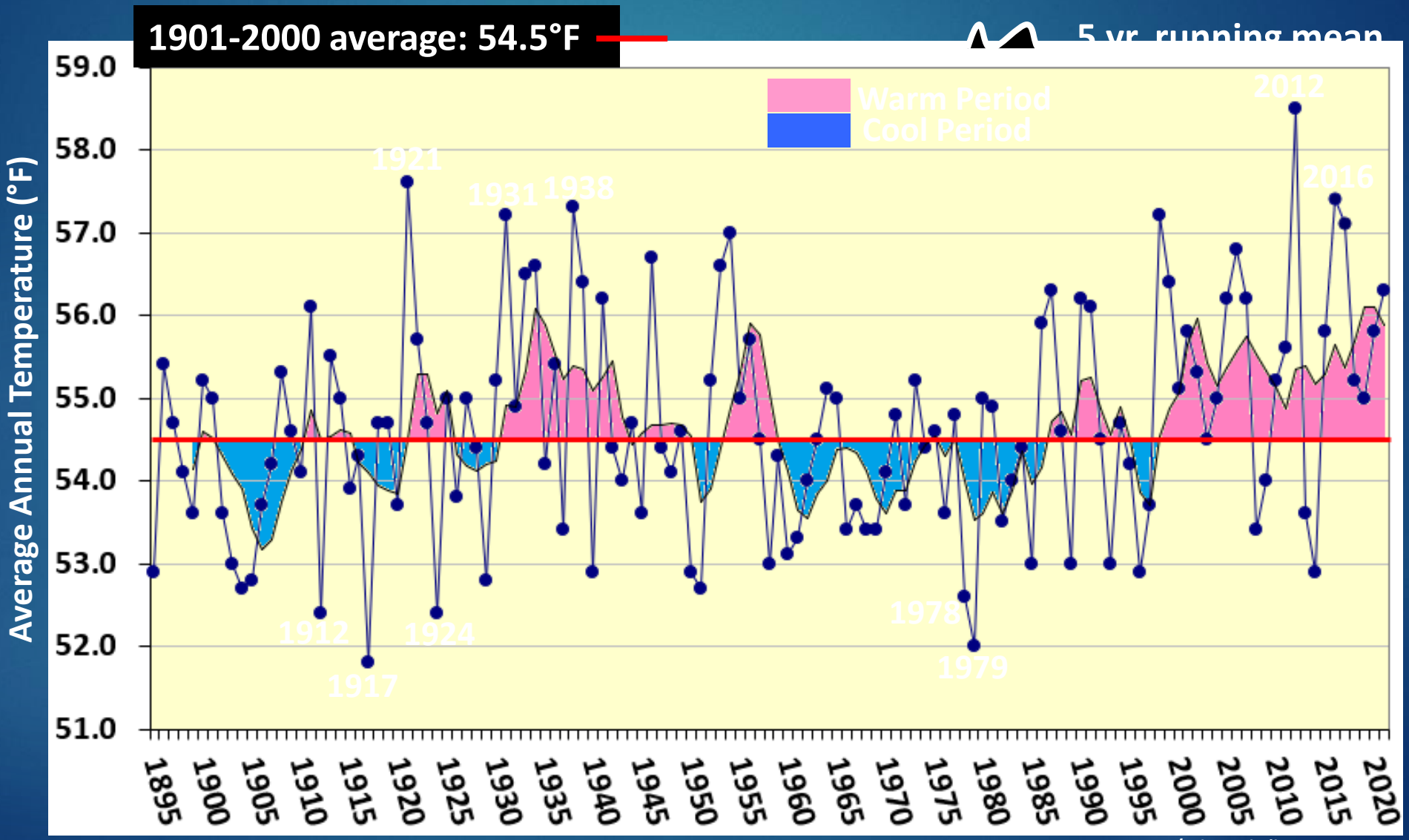




- Nonetheless climate has changed on earth for as long as there has been an atmosphere.

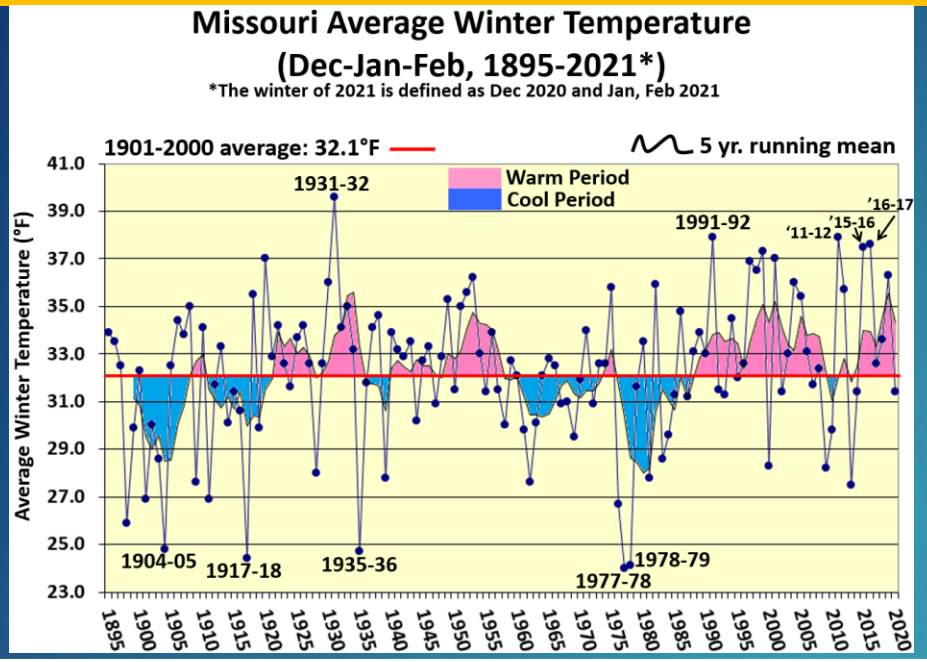
Missouri annual temperature trends have been warming since the late 1990's.

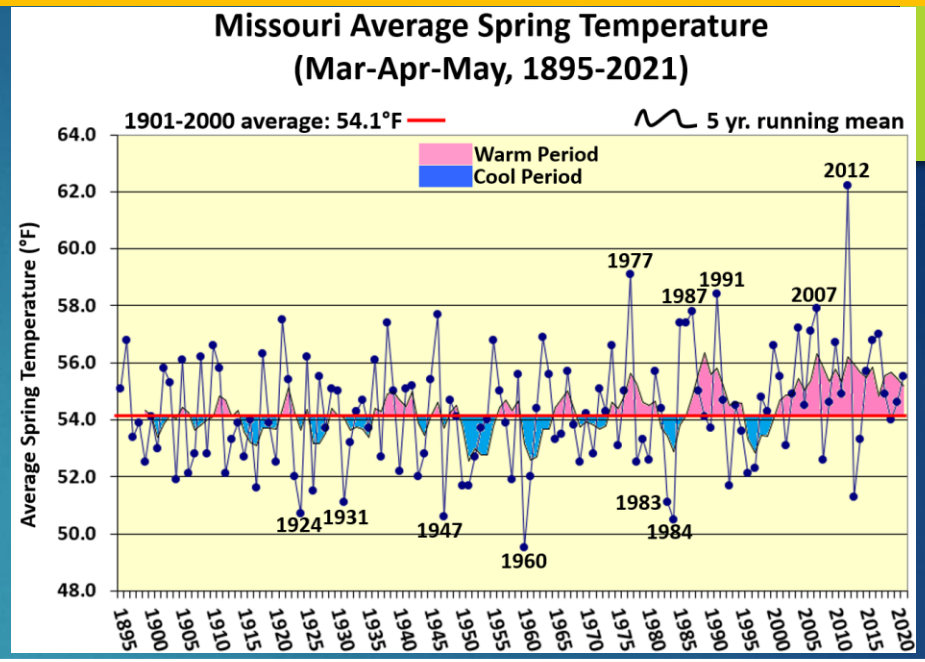
Missouri Average Annual Temperature (1895-2021)

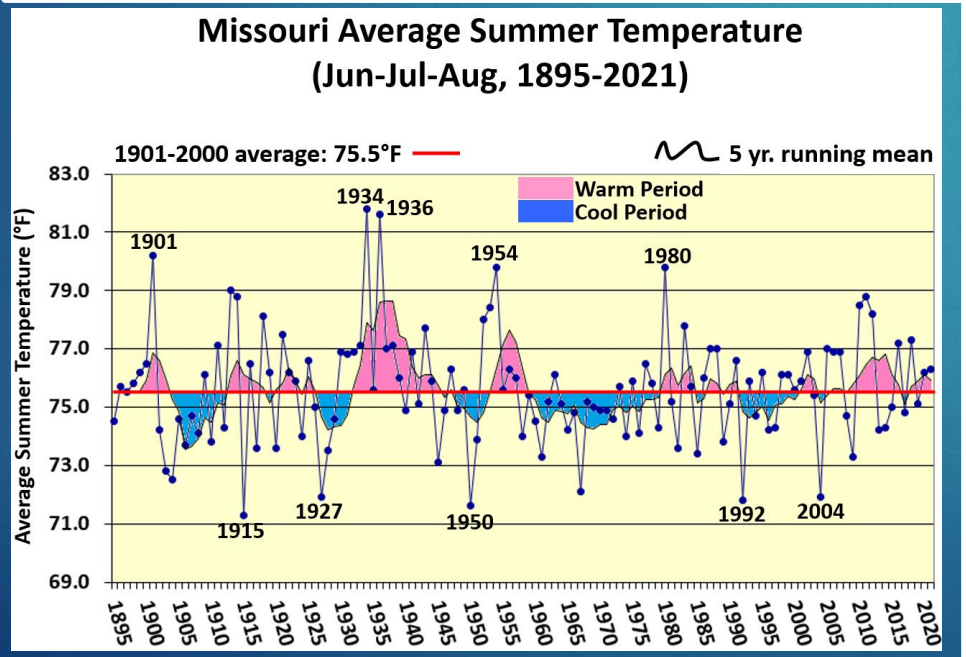


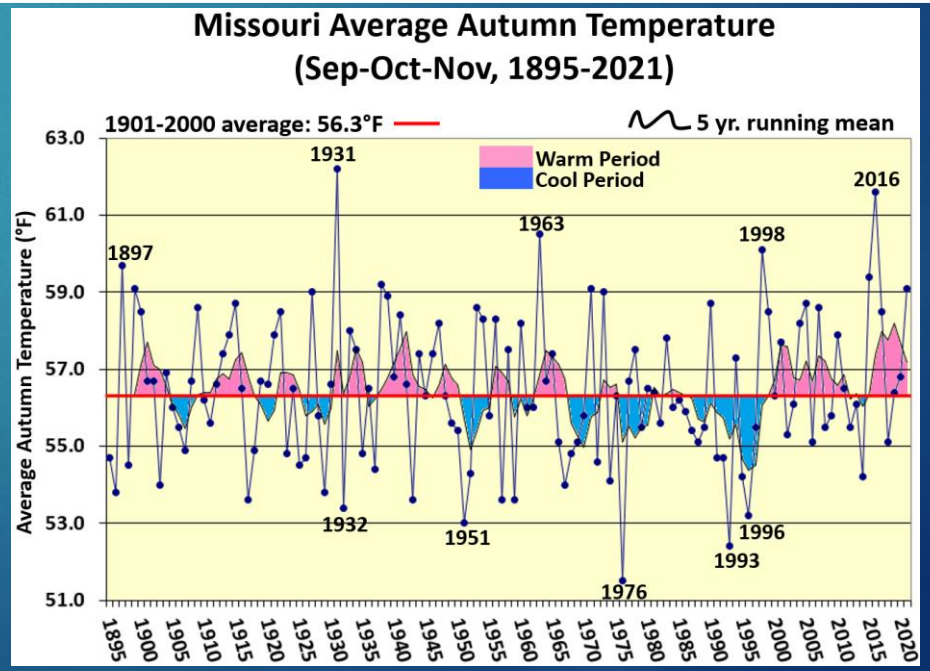
Source: NOAA/Missouri Climate Center

Missouri's strongest seasonal warming has been occurring in winter & spring.







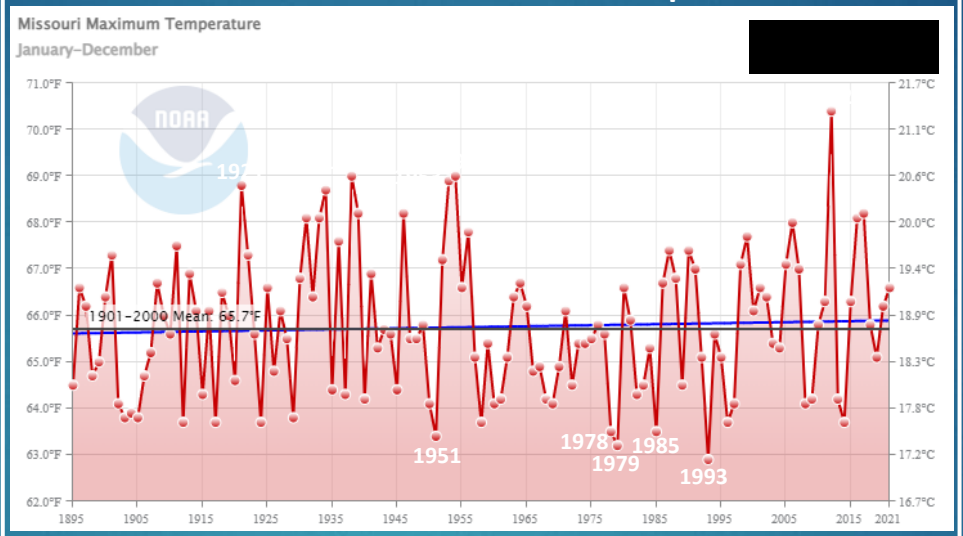


Source: NOAA/Missouri Climate Center

Missouri maximum and minimum annual temperature trends have been warming but the rate of warming has been faster with minimum temperature.

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
Climate at a Glance
www.ncdc.noaa.gov/cag/

Missouri Annual Maximum Temperature



1895-2021 Trend
(+0.2°F/Century)

For 17 out of the past 24 years (1998-2021), annual max temp has been above average, 71%.

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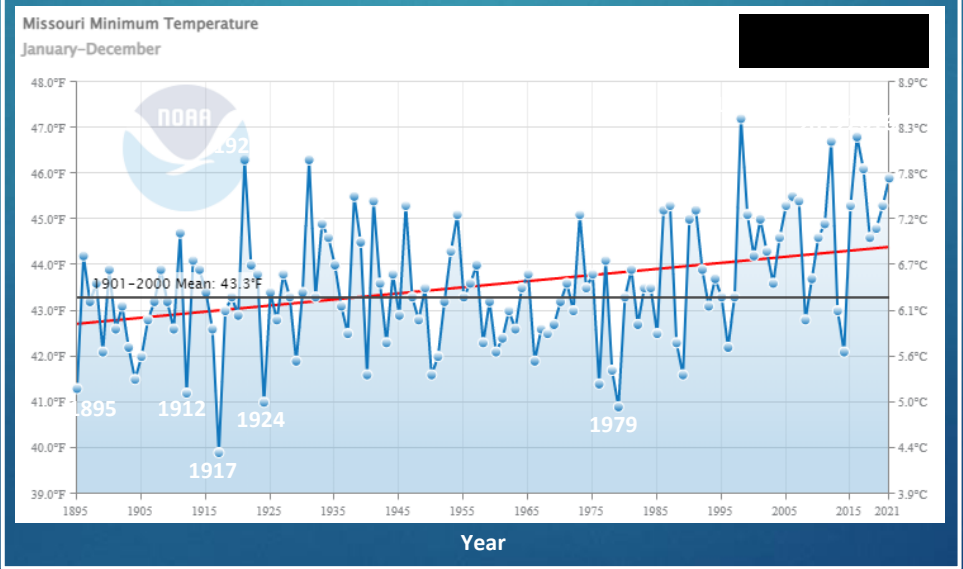
Missouri Annual Minimum Temperature



1895-2021 Trend
(+1.3°F/Century)

For 21 out of the past 24 years (1998-2021), annual min temp has been above average, 88%.

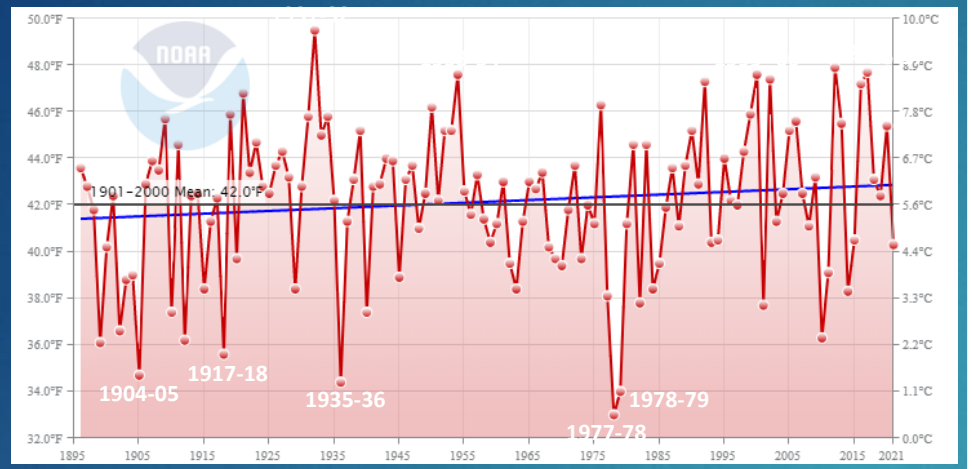
Missouri's strongest maximum temp warming has been occurring in winter & spring.

Missouri Winter Maximum Temperature
(Dec-Jan-Feb, 1895-2021*)

*The winter of 2021 is defined as Dec 2020 and Jan, Feb 2021

1901-2000 mean: 42.0°F

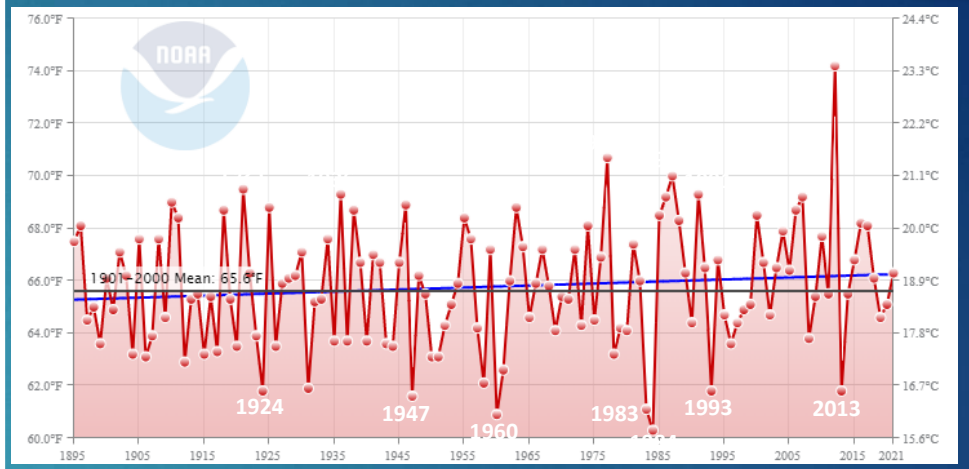
1896-2021 Trend (+1.2°F/Century)



Missouri Spring Maximum Temperature
(Mar-Apr-May, 1895-2021)

1901-2000 mean: 65.6°F

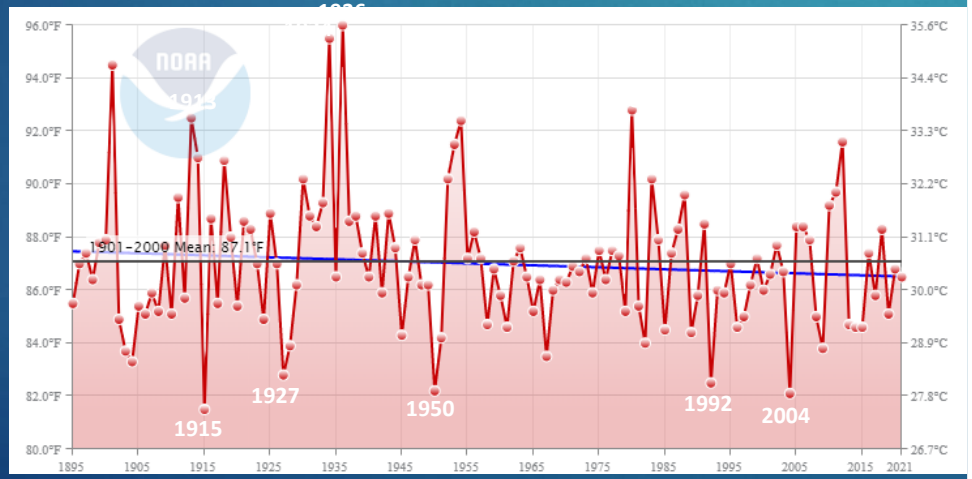
1895-2021 Trend (+0.8°F/Century)



Missouri Summer Maximum Temperature
(Jun-Jul-Aug, 1895-2021)

1901-2000 mean: 87.1°F

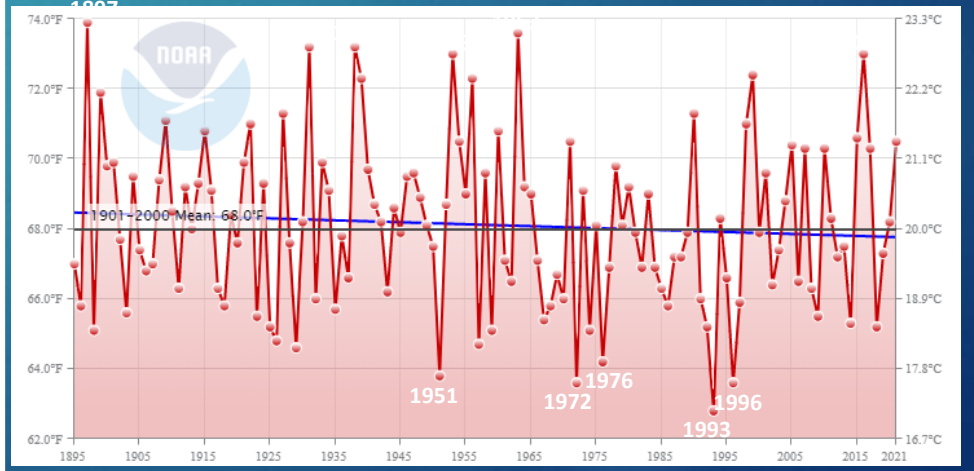
1895-2021 Trend (-0.8°F/Century)



Missouri Autumn Maximum Temperature
(Sep-Oct-Nov, 1895-2021)

1901-2000 mean: 68.0°F

1895-2021 Trend (-0.6°F/Century)



Climate At A Glance: www.ncdc.noaa.gov/cag/

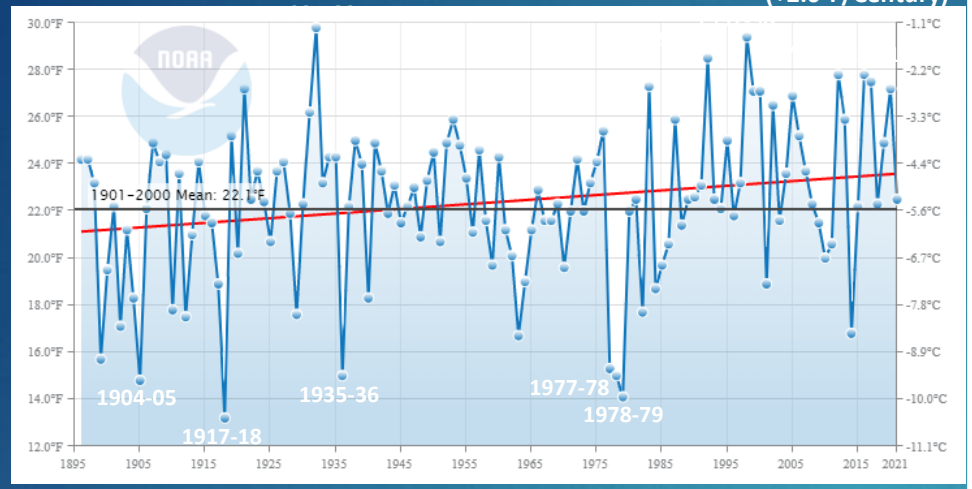
Missouri minimum temperature trends have been warming all four seasons.

Missouri Winter Minimum Temperature
(Dec-Jan-Feb, 1895-2021*)

*The winter of 2021 is defined as Dec 2020 and Jan, Feb 2021

1901-2000 mean: 22.1°F

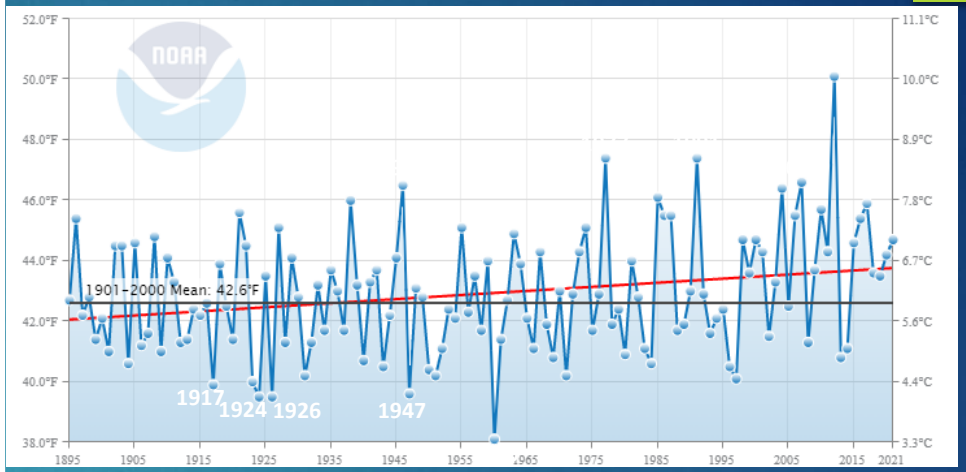
1896-2021 Trend (+2.0°F/Century)



Missouri Spring Minimum Temperature
(Mar-Apr-May, 1895-2021)

1901-2000 mean: 42.6°F

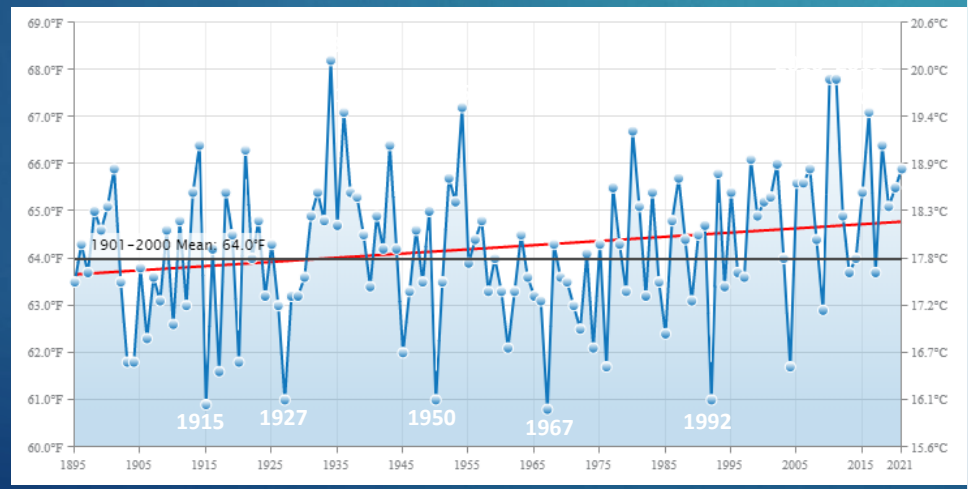
1895-2021 Trend (+1.4°F/Century)



Missouri Summer Minimum Temperature
(Jun-Jul-Aug, 1895-2021)

1901-2000 mean: 64.0°F

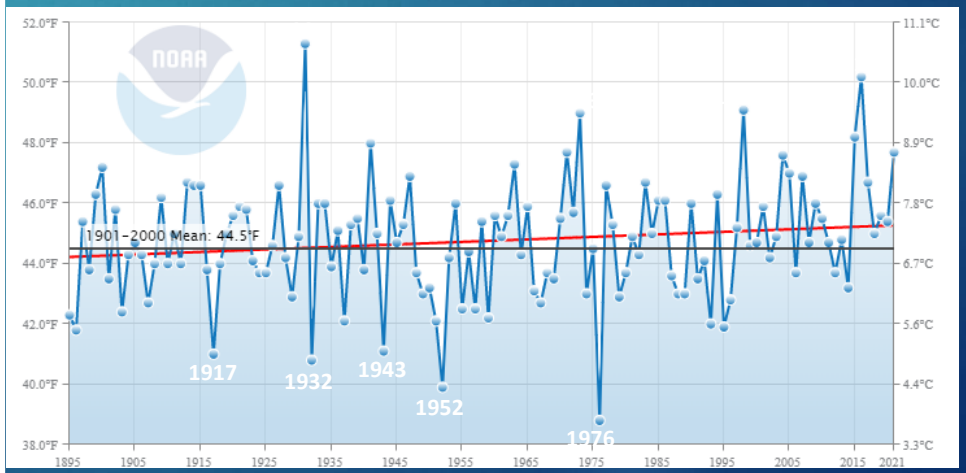
1895-2021 Trend (+0.9°F/Century)



Missouri Autumn Minimum Temperature
(Sep-Oct-Nov, 1895-2021)

1901-2000 mean: 44.5°F

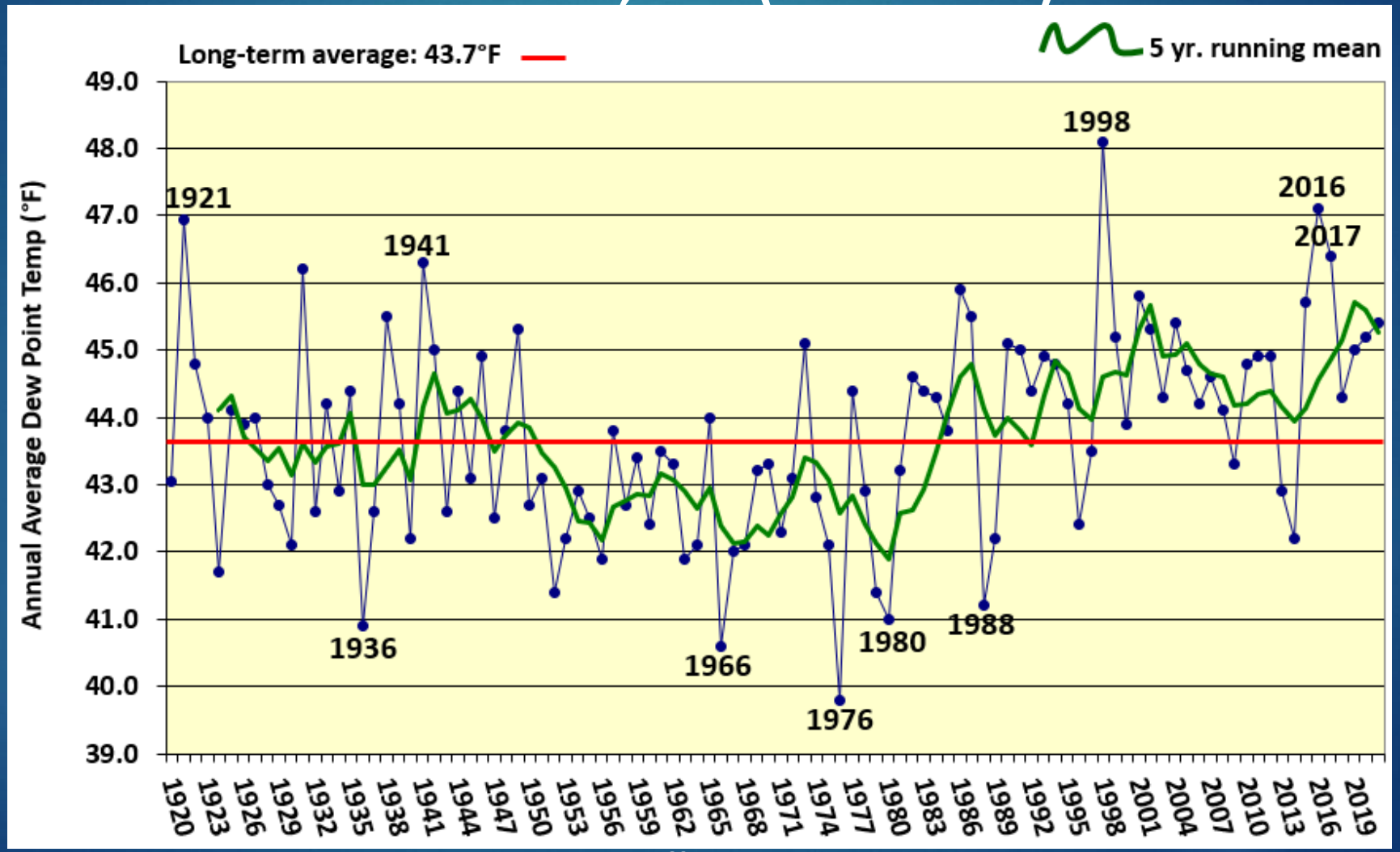
1895-2021 Trend (+0.8°F/Century)



Climate At A Glance: www.ncdc.noaa.gov/cag/

What are the climatic impacts of wetter precipitation trends?
-More humid environment.

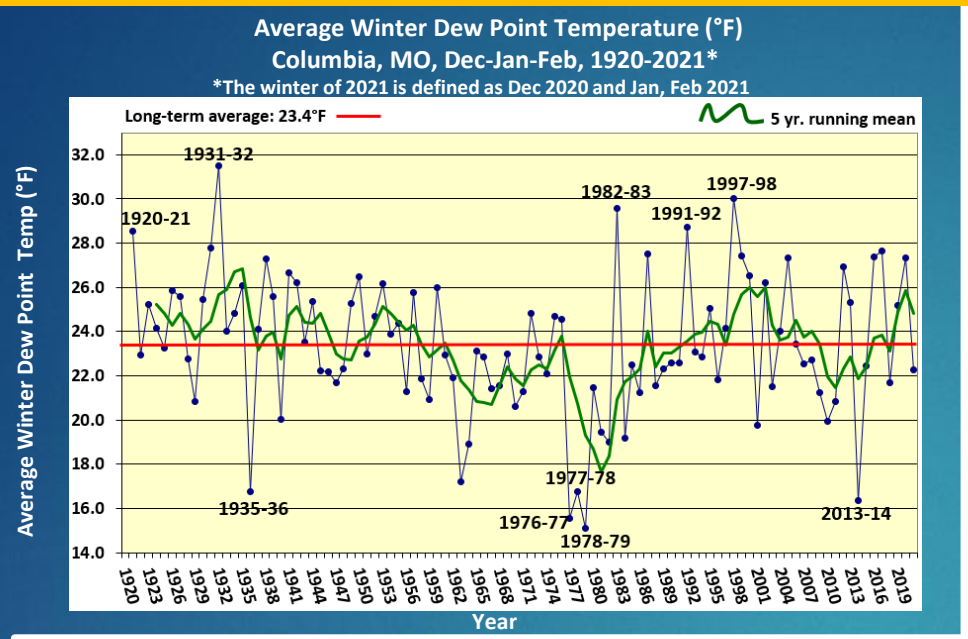
Average Annual Dew Point Temperature
Columbia, MO (1920-2021)

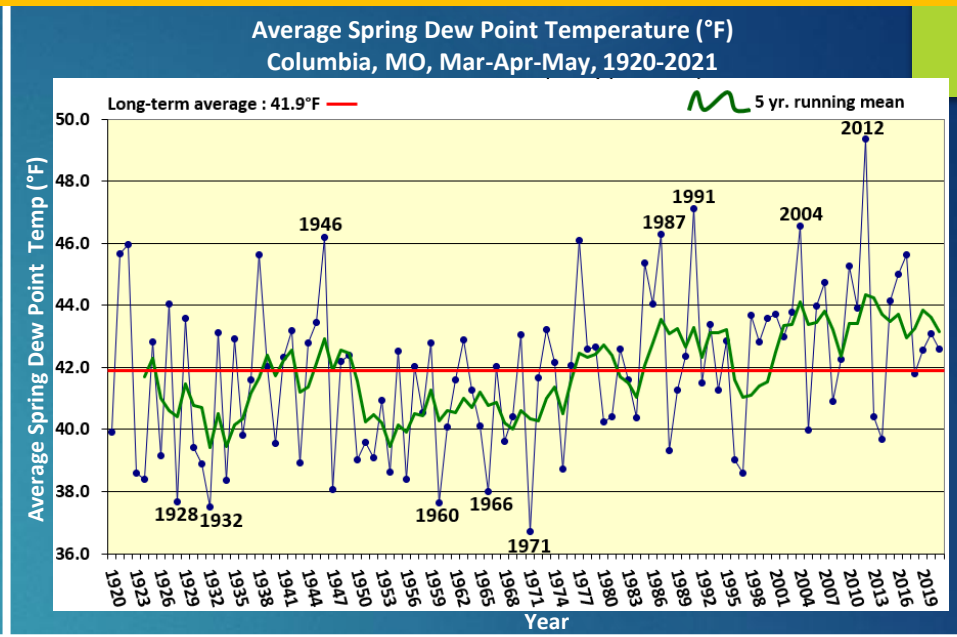


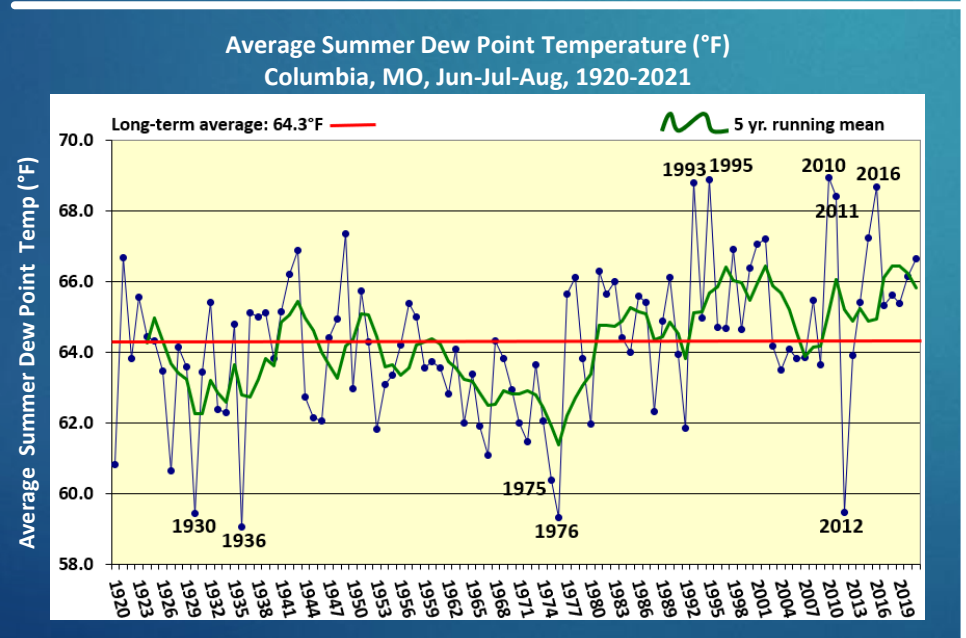
NOAA/Missouri Climate Center

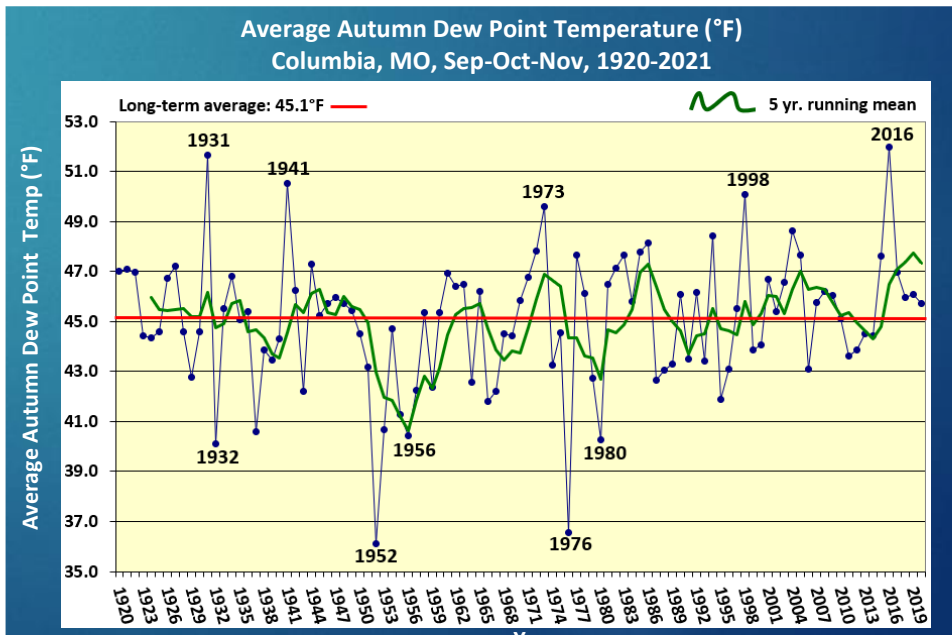
What are the climatic impacts of wetter precipitation trends?

-More humid environment, especially during the warm season.



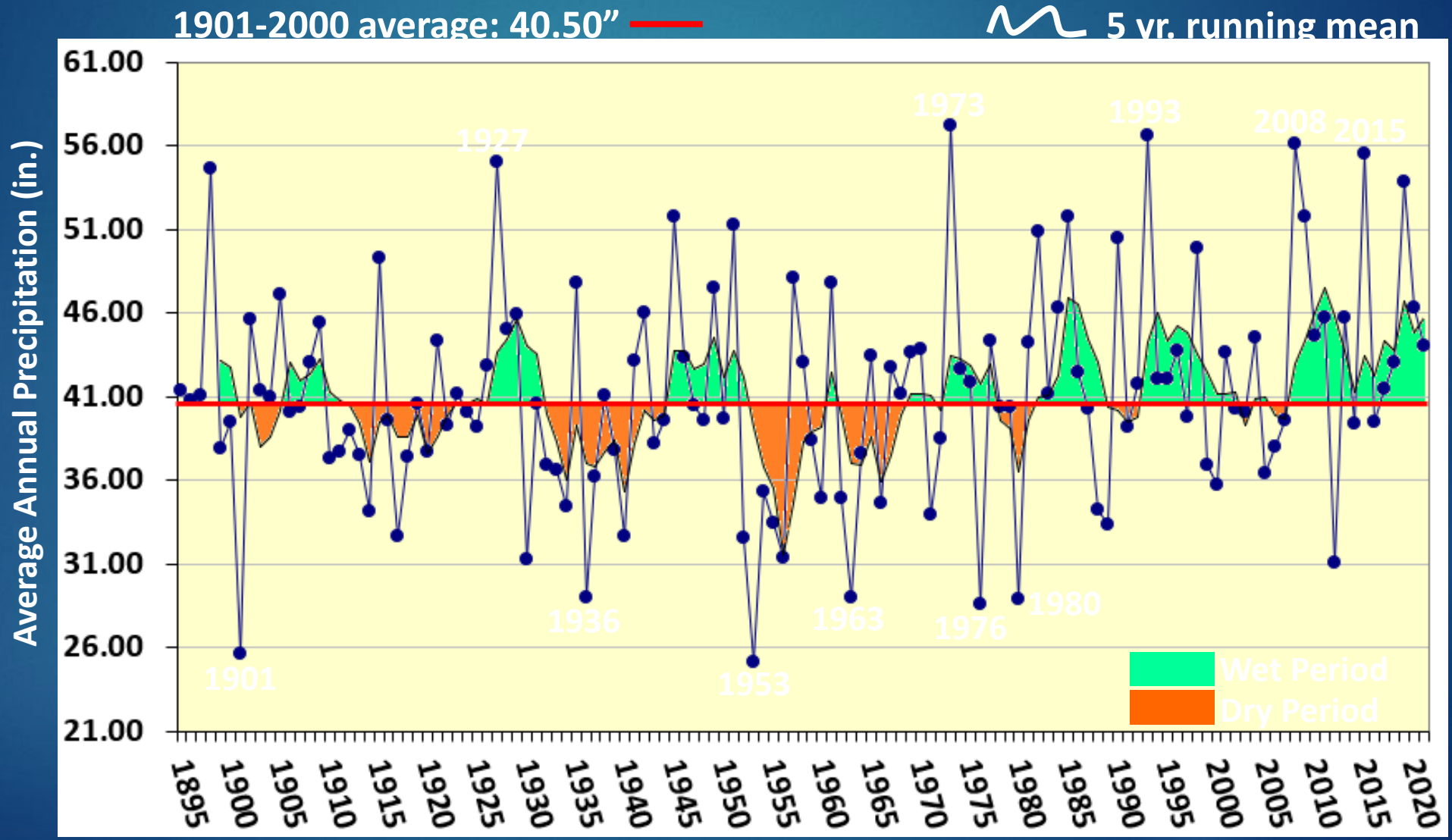






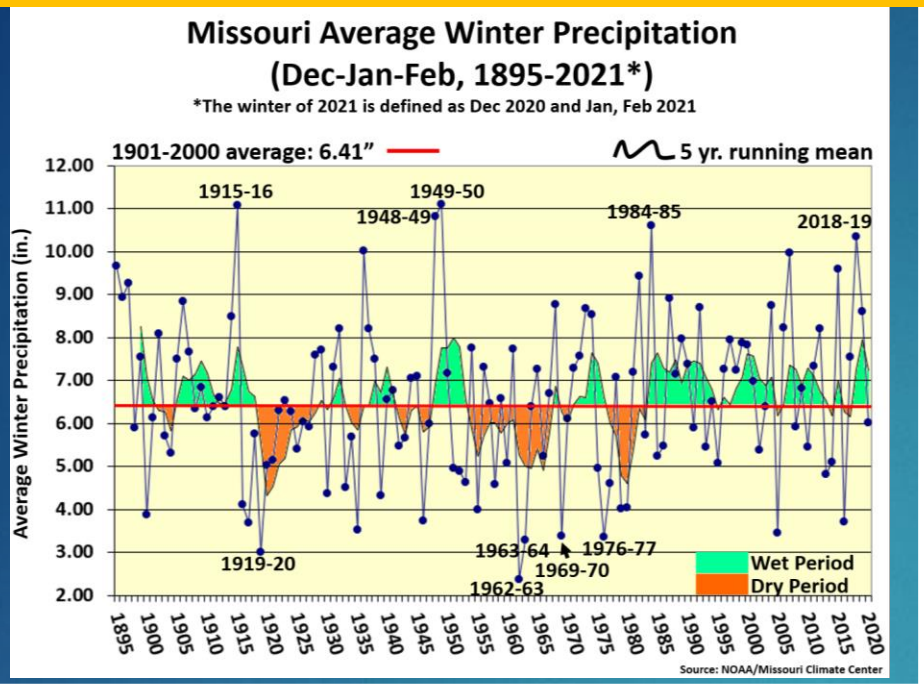
Missouri is experiencing an unprecedented wet period.

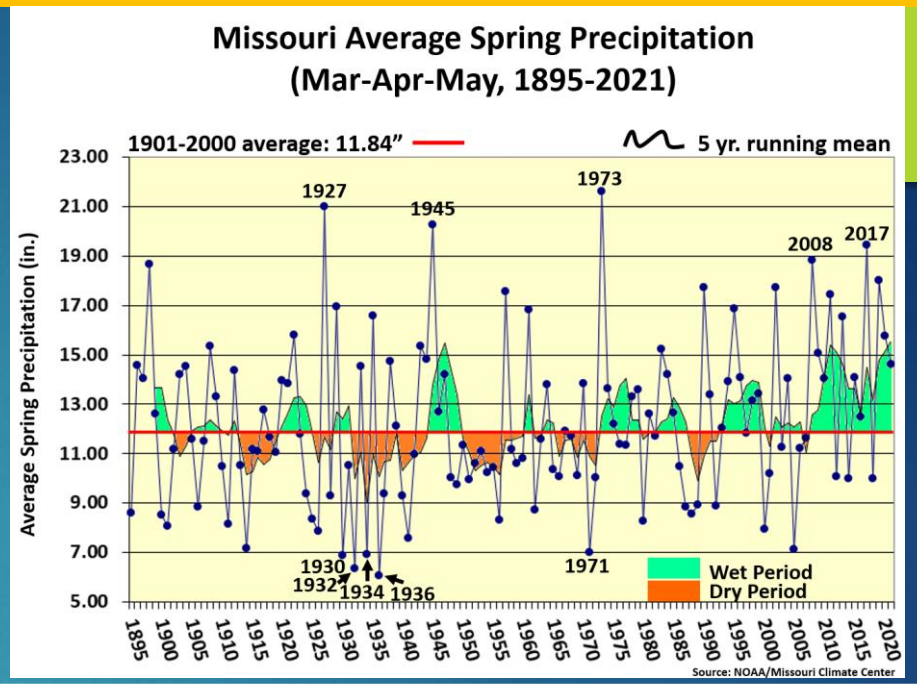
Missouri Average Annual Precipitation (1895-2021)

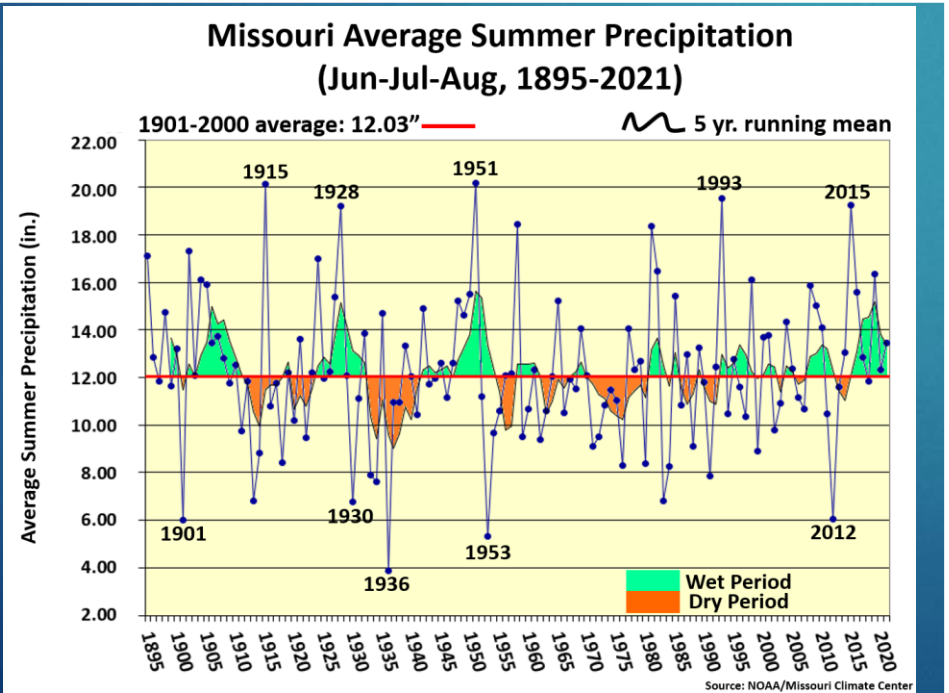


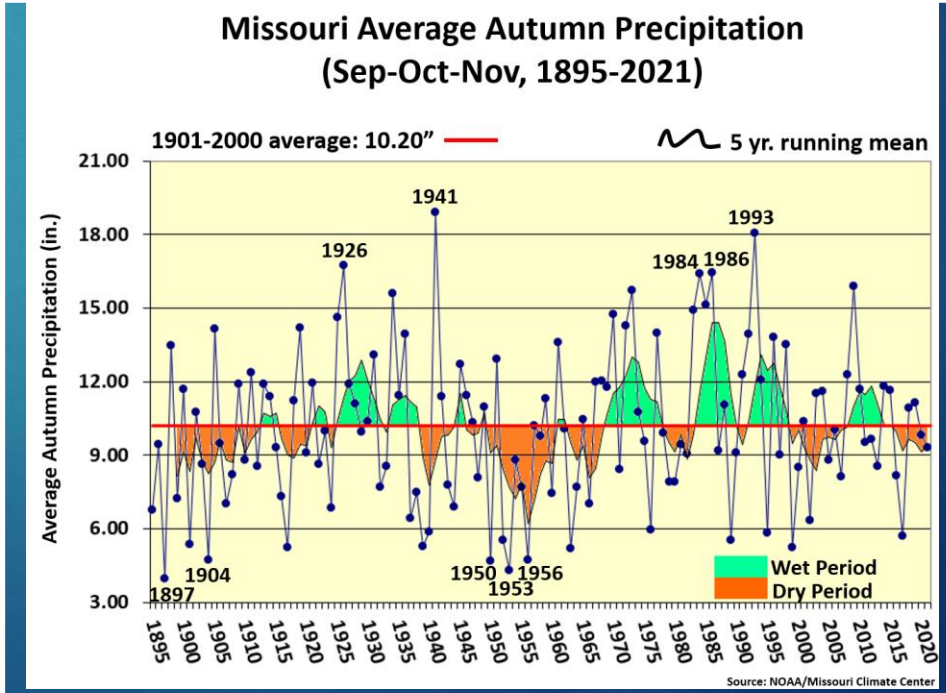
Source: NOAA/Missouri Climate Center

Missouri precipitation has been trending wetter all four seasons.



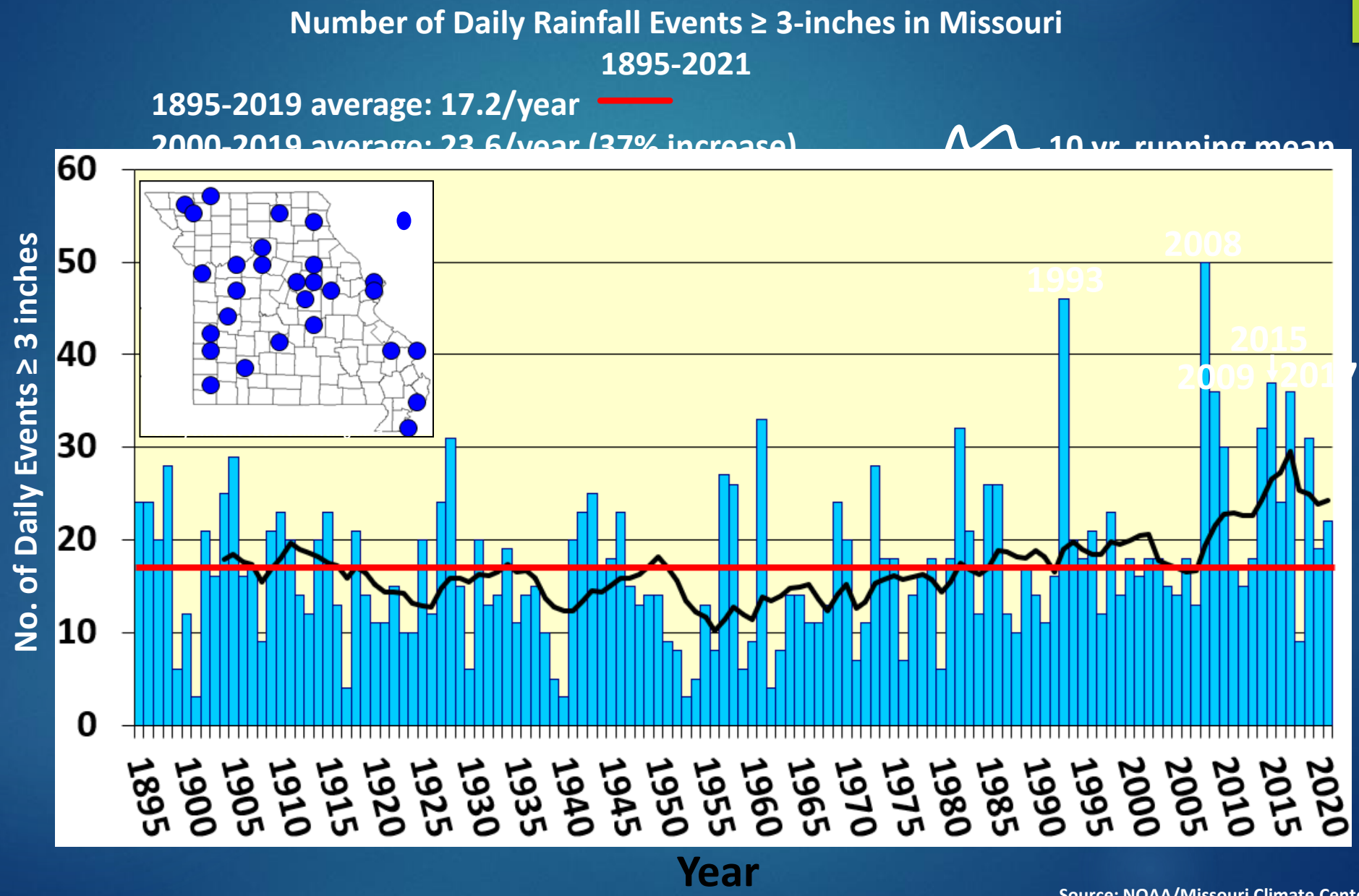






What are the climatic impacts of wetter precipitation trends?

-More extreme precipitation events, more flooding.

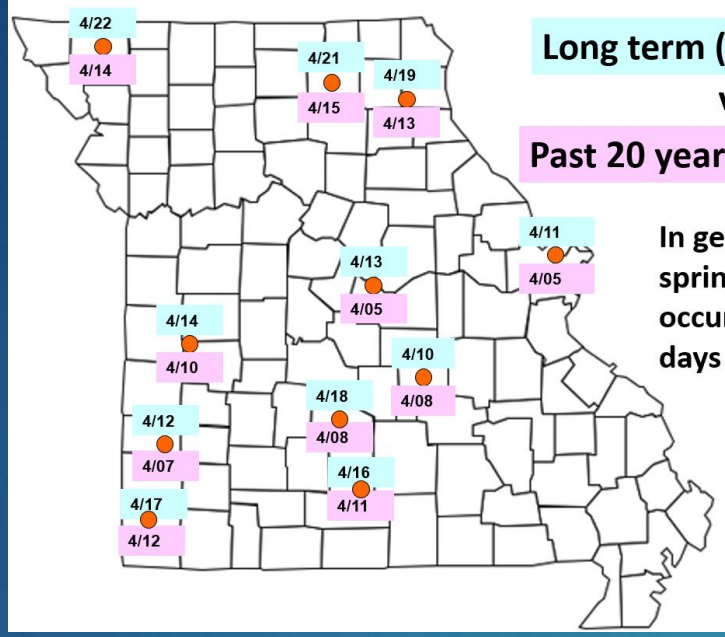


Source: NOAA/Missouri Climate Center

What are the climatic impacts from warmer spring and fall minimum temperatures?

-Longer growing season.

Median Date of Last Spring Frost (≤ 32°F)



Long term (1895-2019)

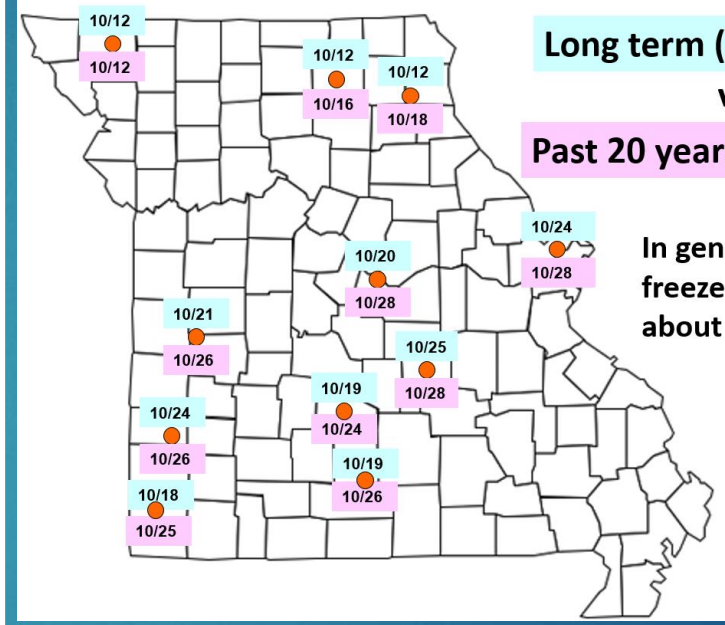
vs.

Past 20 years (2000-2019)

In general, the last spring freeze is occurring about 6 days ***earlier***…

Source: NOAA/Missouri Climate Center

Median Date of First Fall Frost (≤ 32°F)



Long term (1895-2019)

vs.

Past 20 years (2000-2019)

In general, the first fall freeze is occurring about 5 days ***later***…

Source: NOAA/Missouri Climate Center

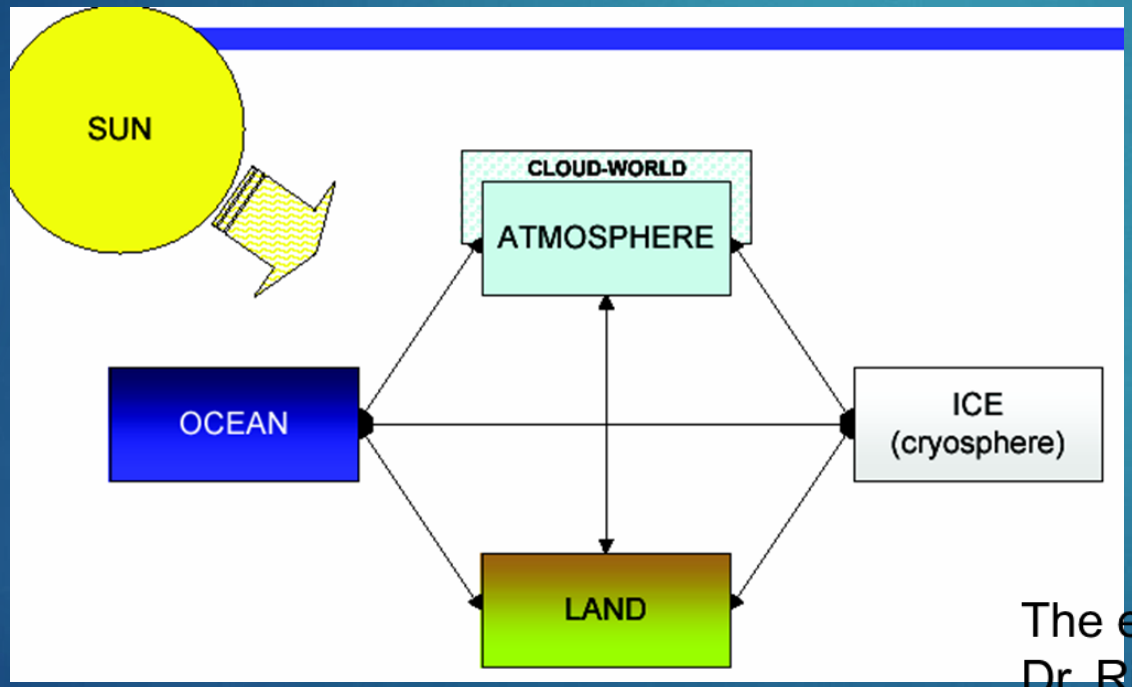
Definitions

- Weather – instantaneous conditions which can be measured using state variables.

- Climate - Is the long-term or time mean state of the earth-atmosphere system and the state variables along with higher order statistics. Also, we must describe extremes and recurrence frequencies

The Climate System – What is it?

- **The Earth-Atmosphere system is an integrated system of which the atmosphere is only one part!**



The earth-atmosphere system, courtesy of Dr. Richard Rood. (http://aoss.engin.umich.edu/class/aoss605/lectures/)

The Climate System

- The other parts of the climate system are:

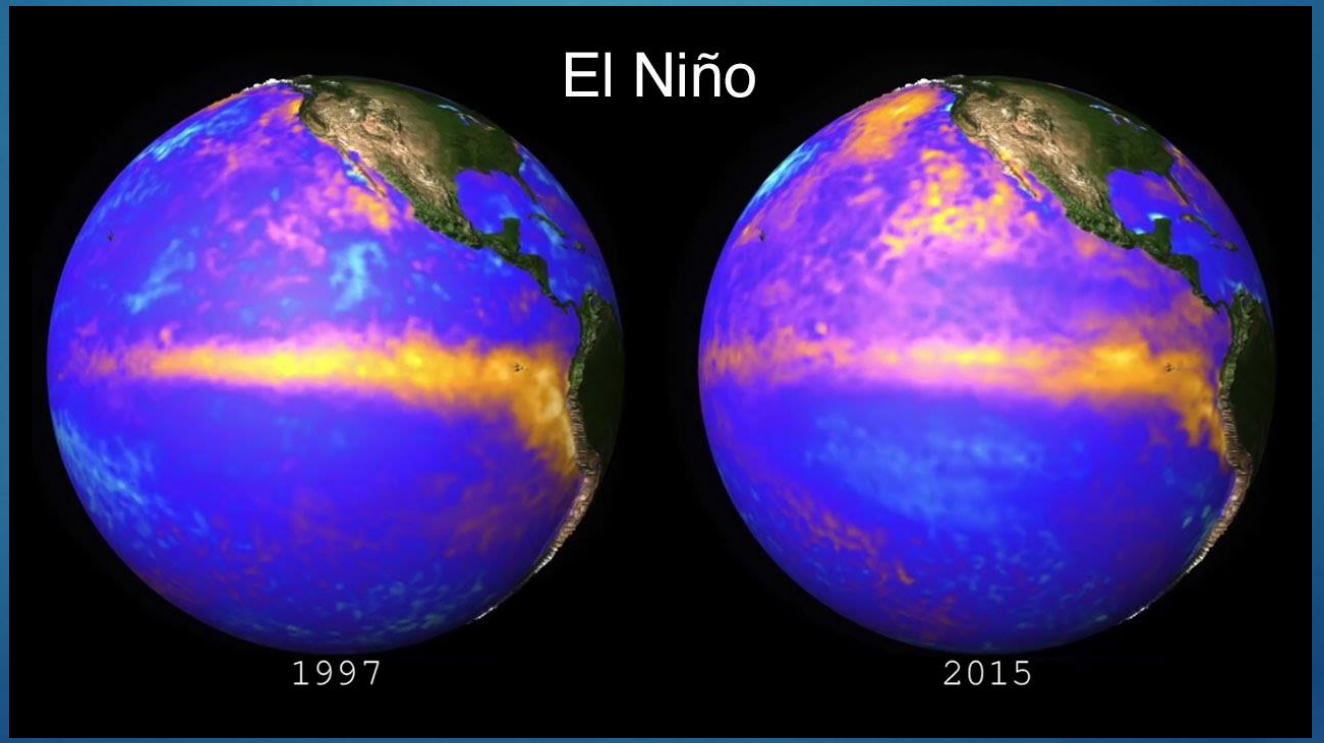
  - Cryosphere (Glaciers, Antarctica)
  - Oceans (and freshwater too)
  - Lithosphere (dirt, continents)
  - Biosphere (life → Plants and Animals)

Sub-seasonal and Seasonal Forecasting

- In this part of the world – there are three basic phenomena which drive sub-seasonal (one to four weeks) and seasonal range forecasting:
- El Niño and Southern Oscillation
- Atmospheric Blocking
- Teleconnections

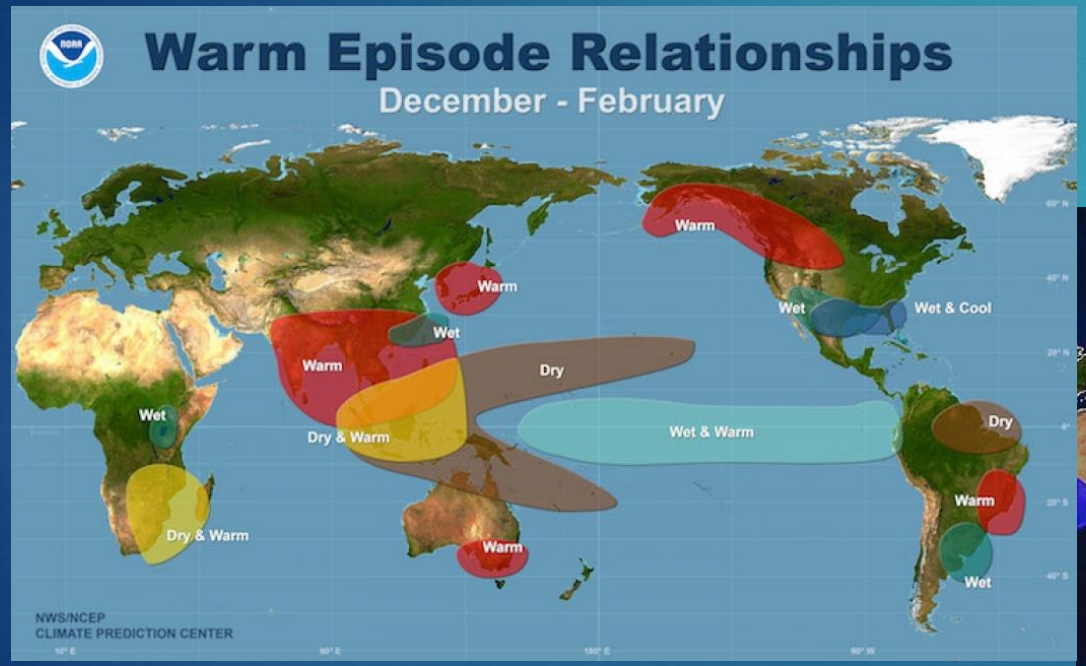
El Niño and Southern Oscillation (ENSO)

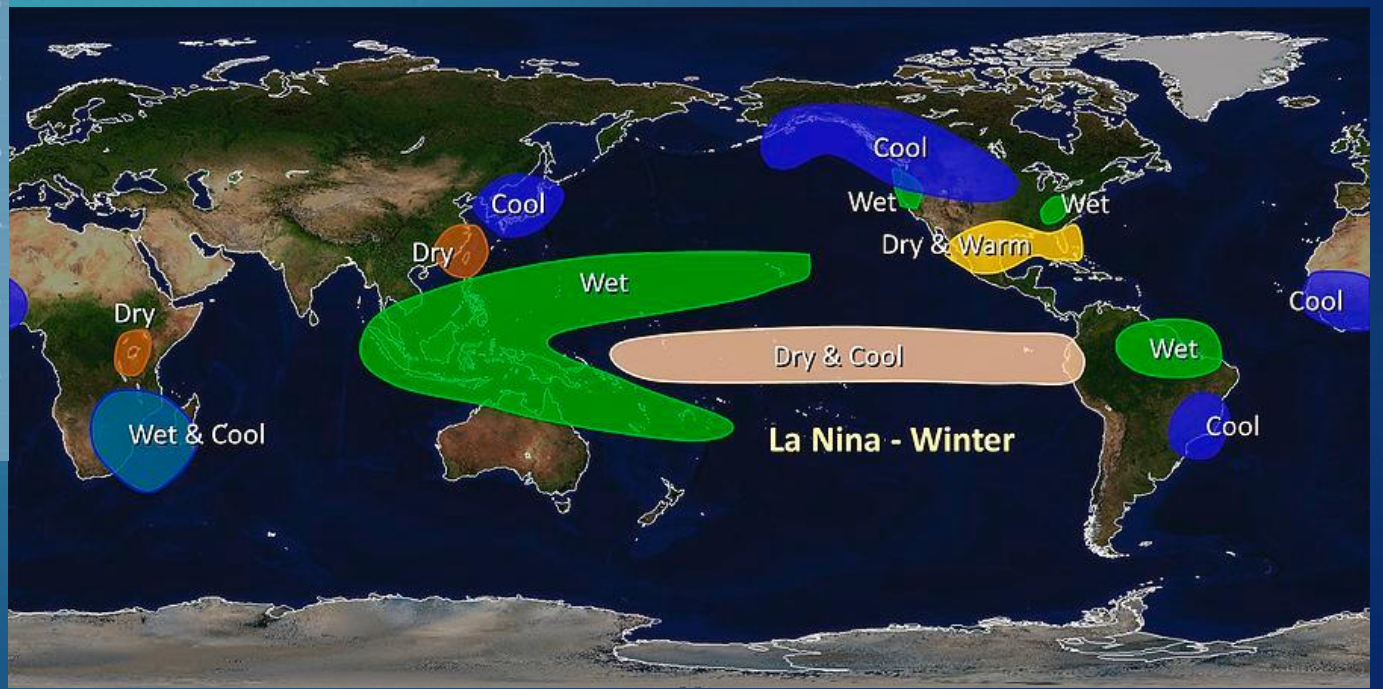
- is a two-to-seven year warming of water in the Eastern Tropical Pacific that impacts weather and climate world-wide.



ENSO Impacts

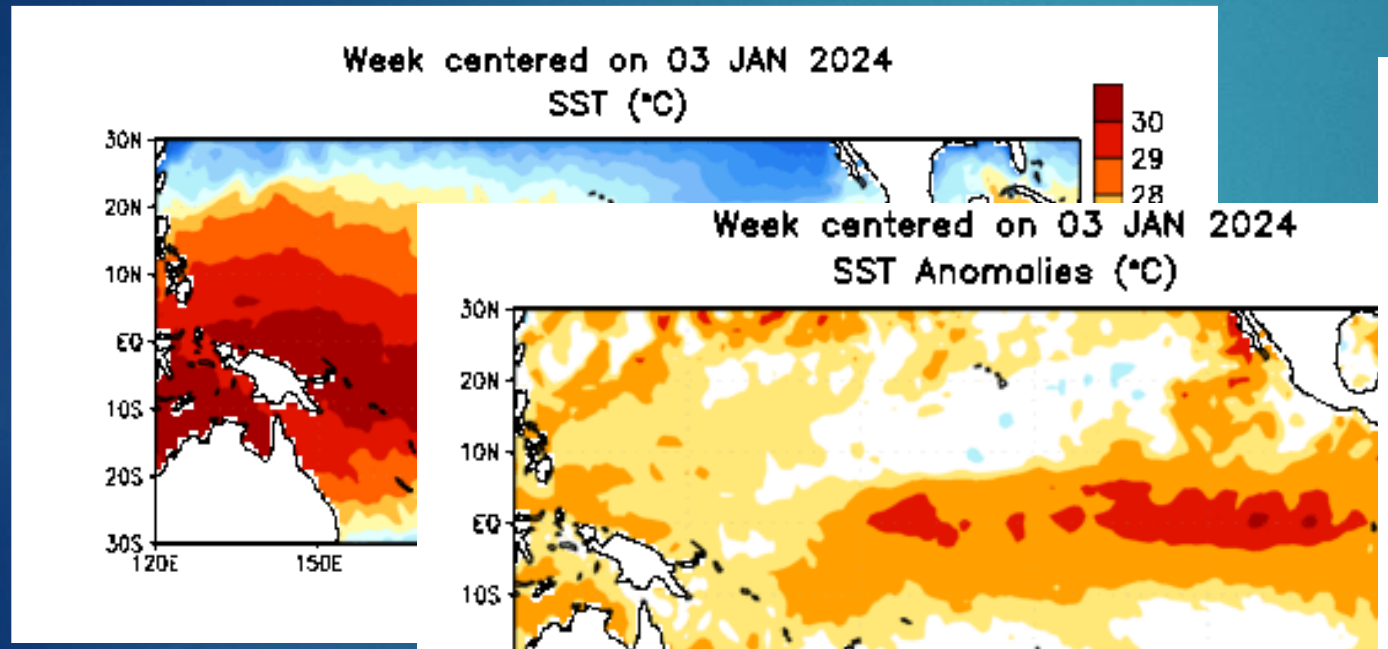
- Influences weather worldwide

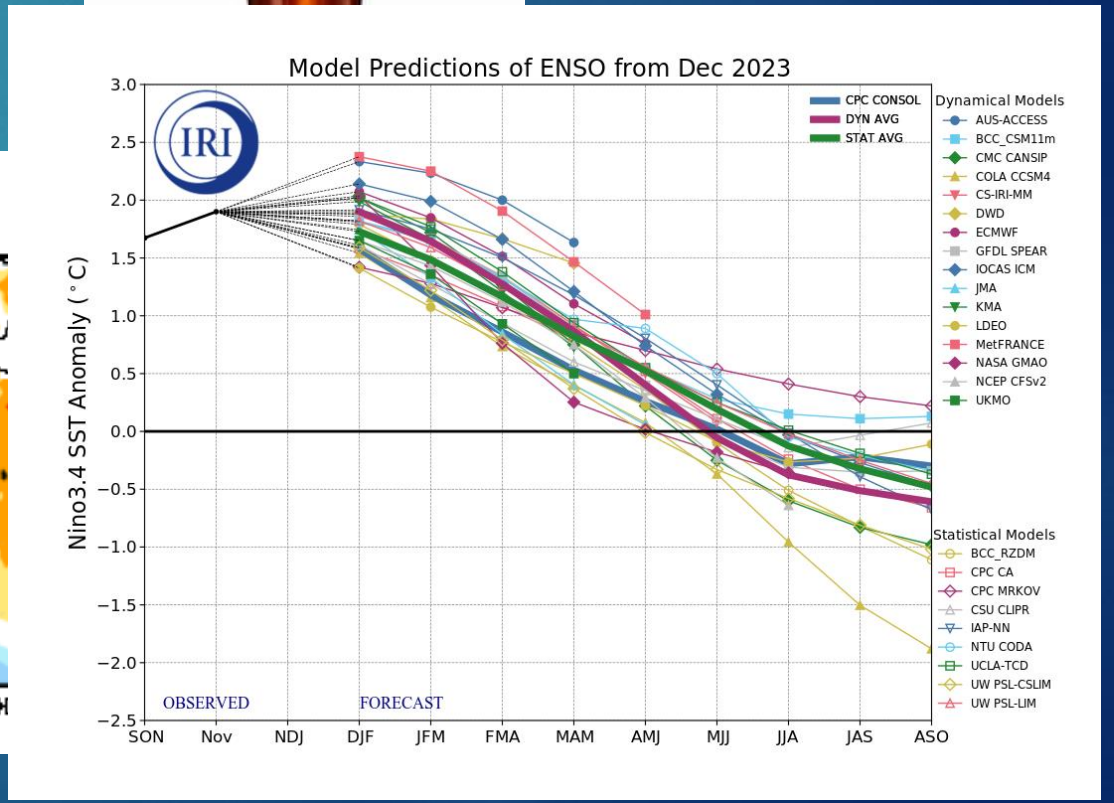




ENSO – Current State – Where are we going?

- January 2024 – El Niño – Classic…..

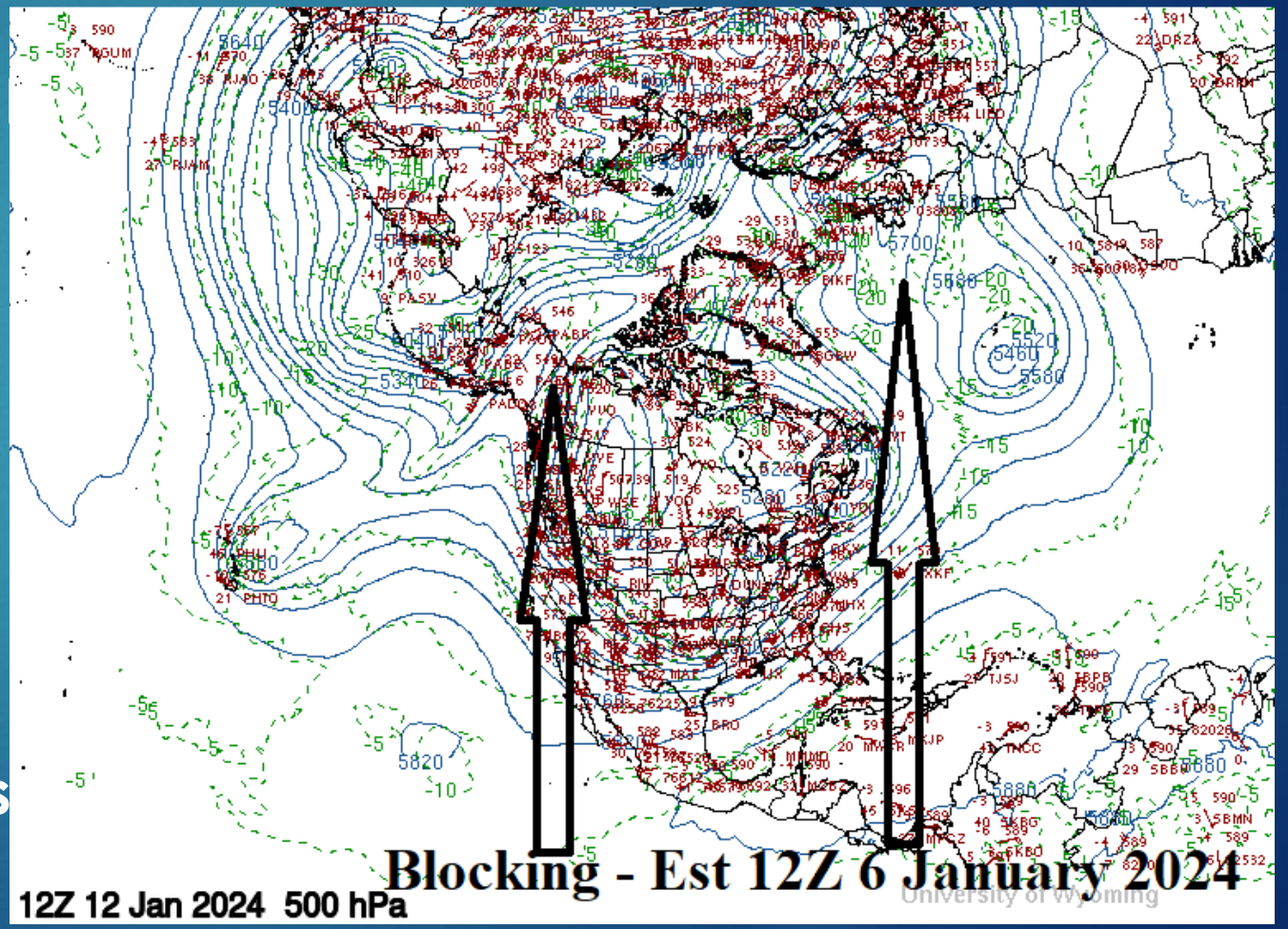




Atmospheric Blocking

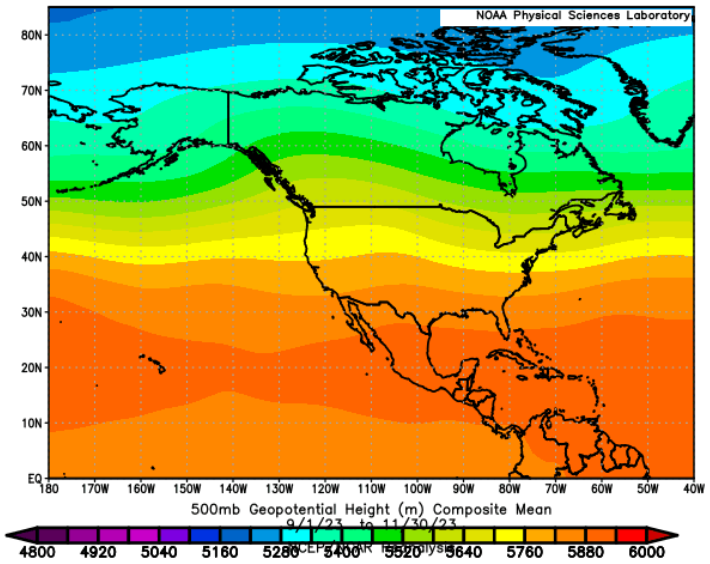
- Atmospheric jet stream

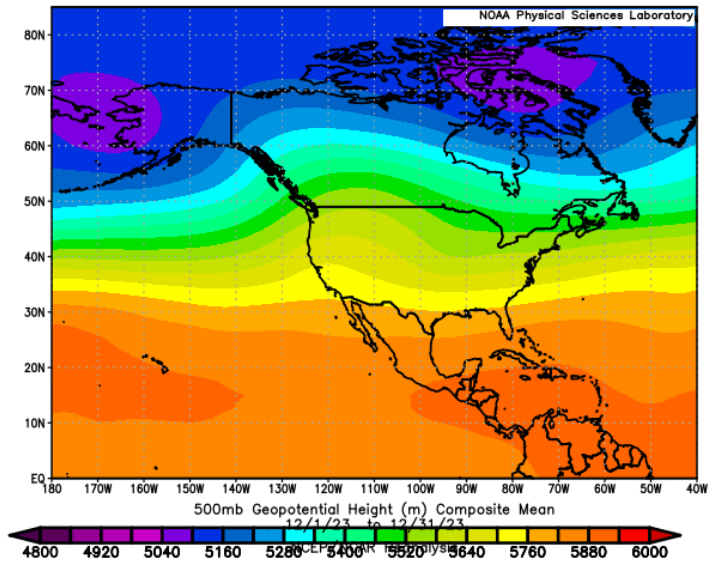
- Blocking - generically – mid-latitude anomalous

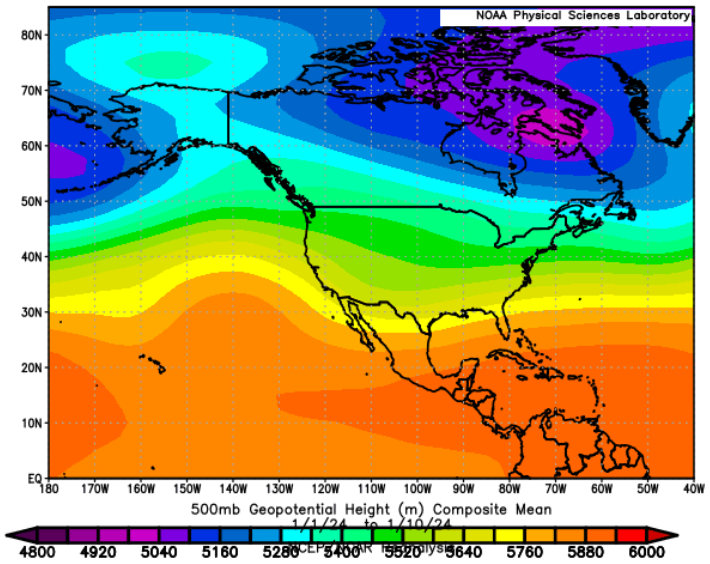


ATMOSPHERIC BLOCKING

- Fall 2023 versus Early Winter 2023 versus Early 2024
- +2.1 (+1.8) F +7.8 (+8.8) F - 4.6 (-5.1) F



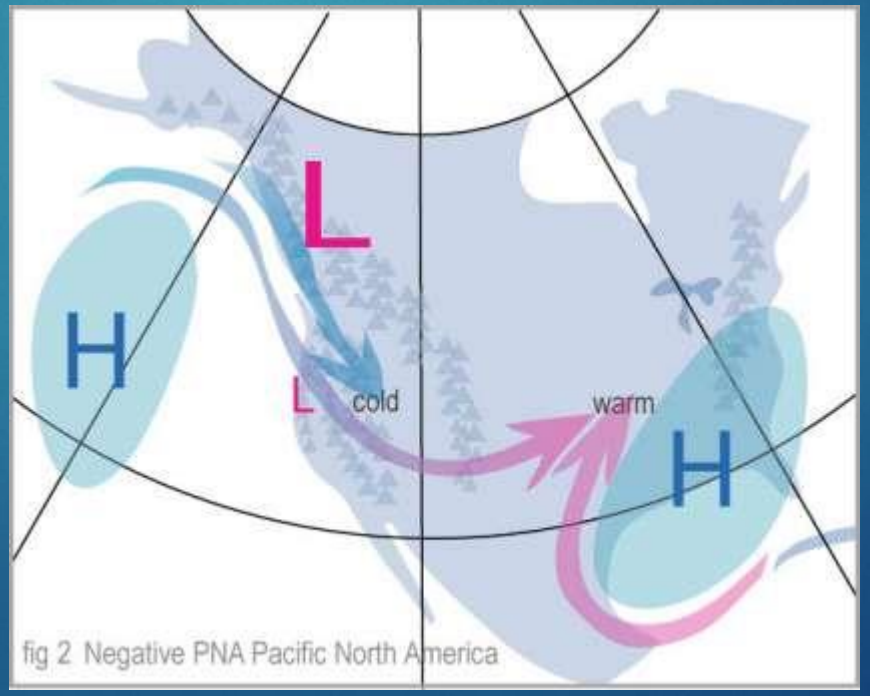


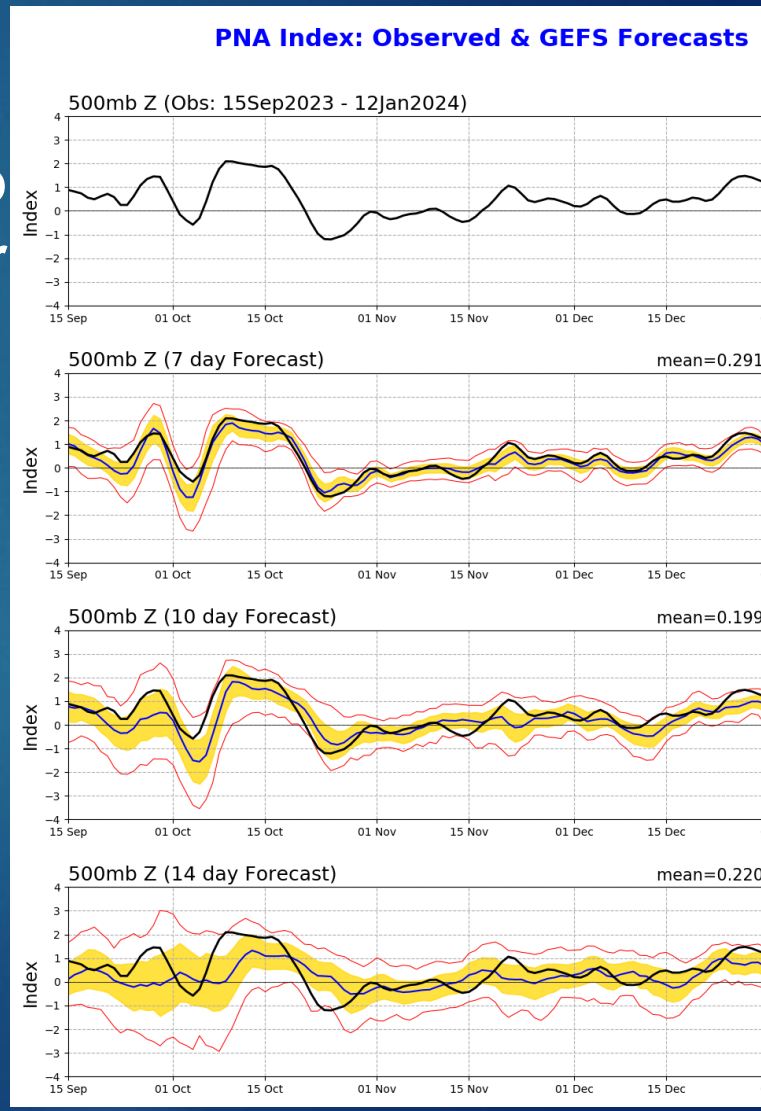


- Temperature versus the 30 year (130 year) average
- Very little blocking until Early 2024

Teleconnections

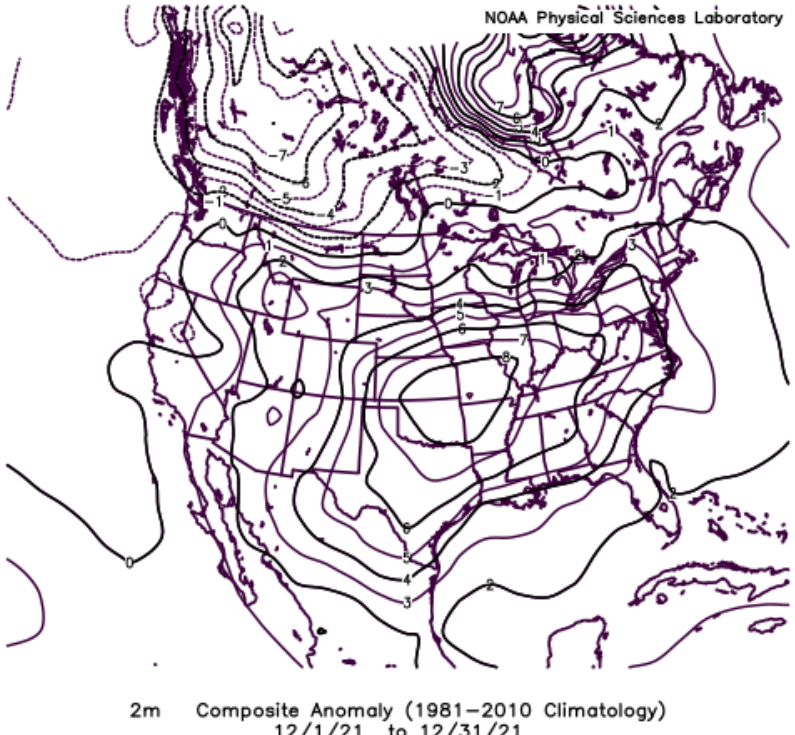
- Teleconnections – are typical jet stream wave p
  that impact certain large-scale areas of the wor
  – 10,000 km, one to two weeks).

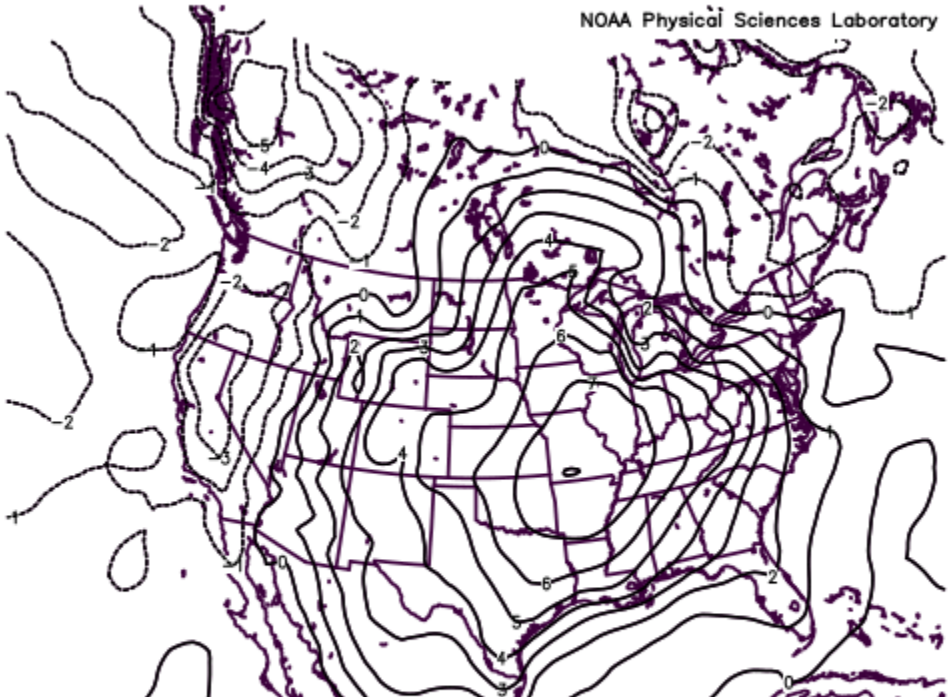




December 2021 versus 1889

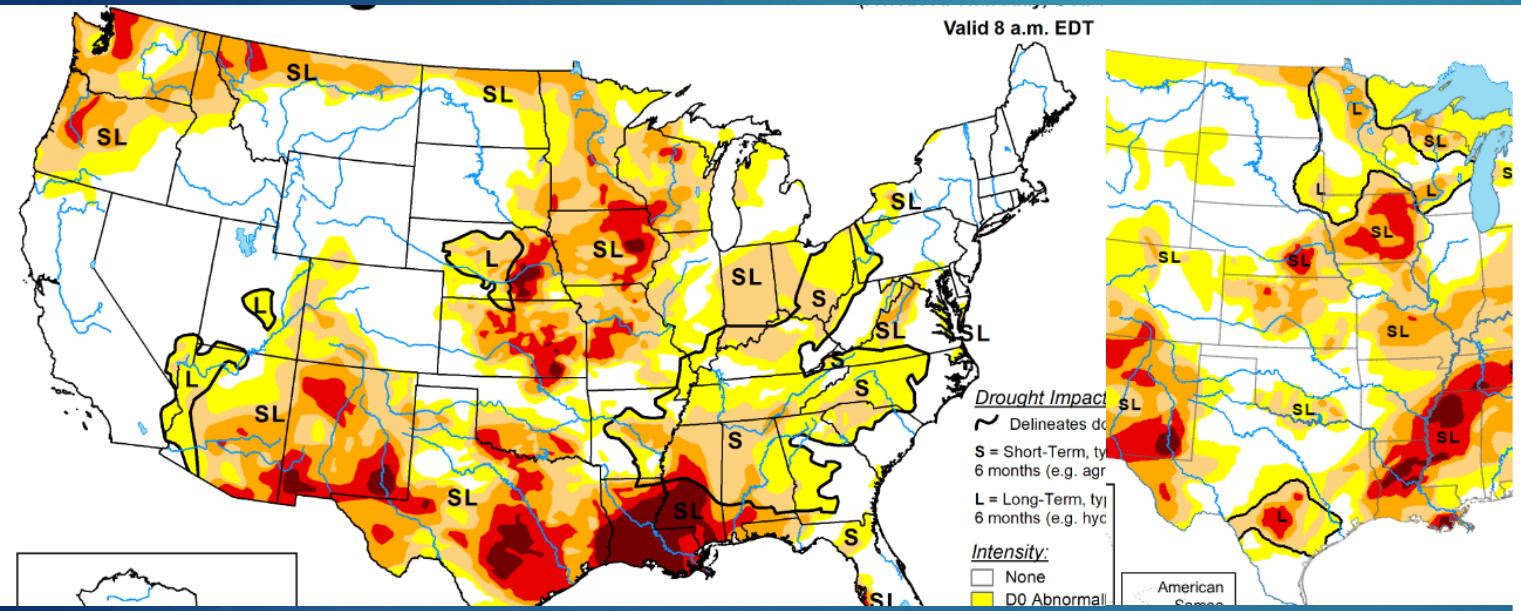
- December 2021 was anomalously warm – but we've seen it before.

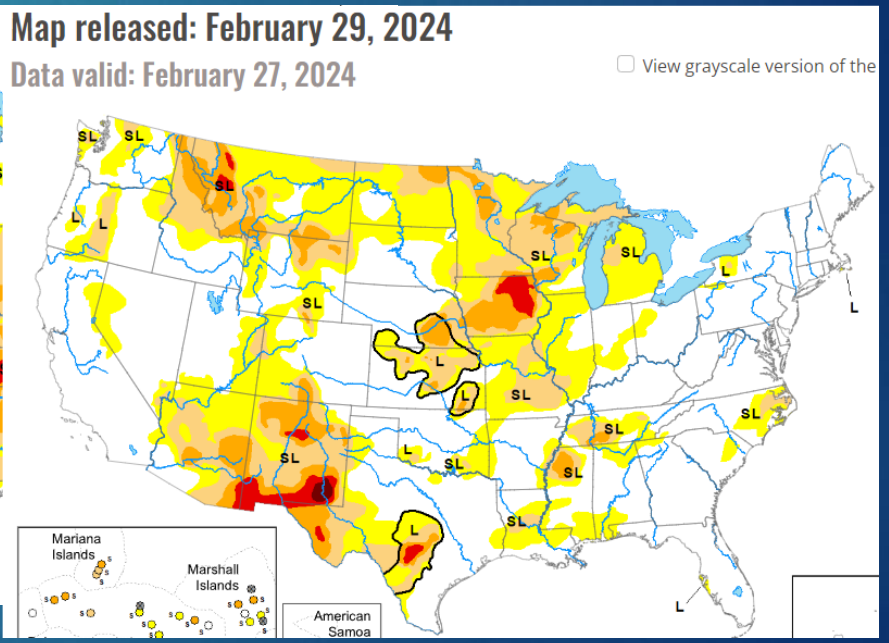




National Drought Monitor

- Current Drought Conditions – short-term no improvement
- 10 October 2023 9 January 2024 29 February 2024





Our Forecast – Summer 2023

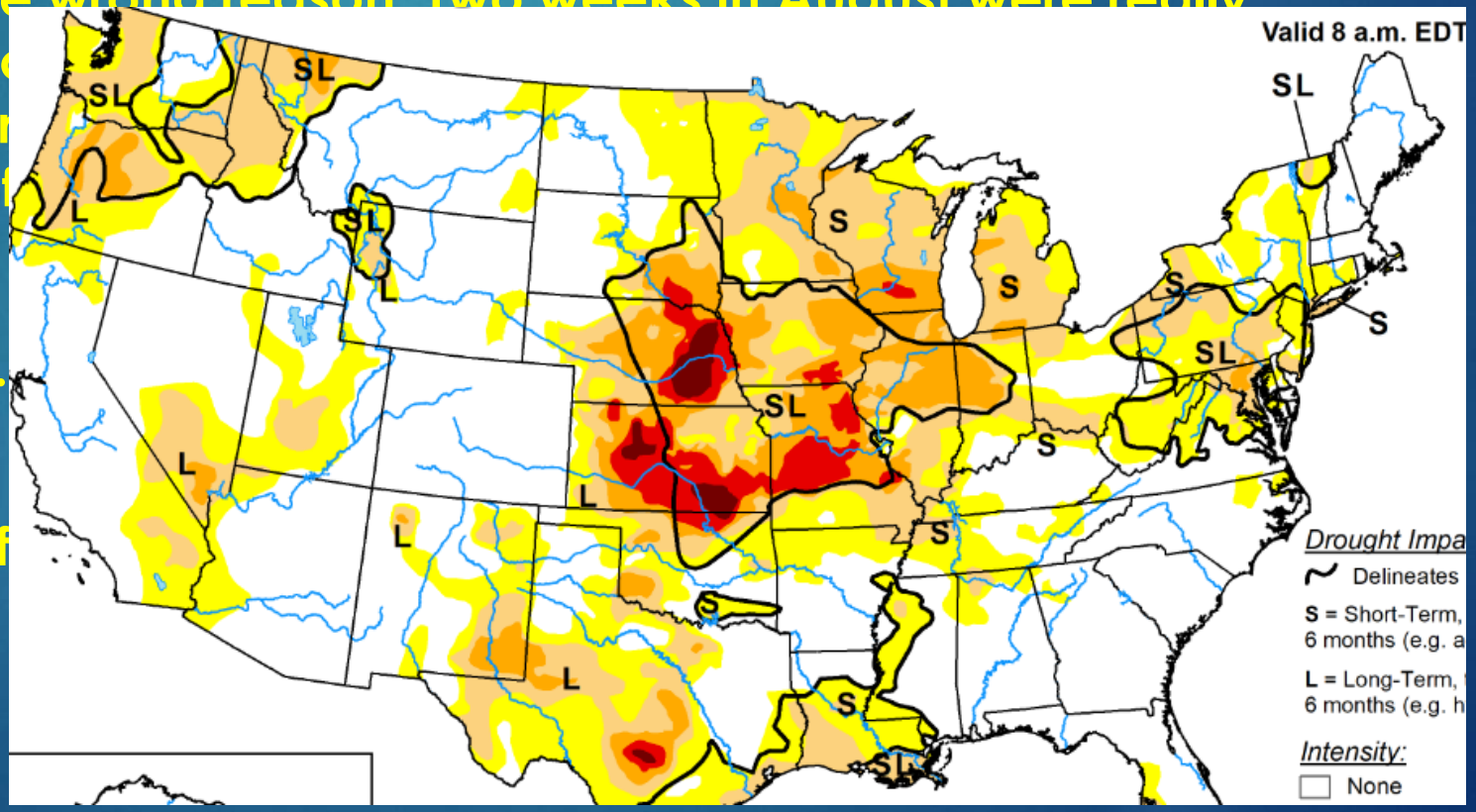
- We can also look to Summer 2008, 2011, and 2018 recently.
- Of these five summers two were dry and two wet, one near normal. Three were cooler than normal while two were warmer than normal.
- We think temperature will be near normal to maybe a bit above normal (~ 1.0 F), while precipitation will also be close to normal to above normal (up to +2.0 inches).
- We were actually +1.6 F above normal – Not bad, we'll give ourselves 1 point.

Our Forecast – Summer 2023 - Recap

- The precipitation was well above normal (HUH?) +4.10 inches. We were right for the wrong reason. Two weeks in August were really wet. We get 1 p
get a single poi
forecast got 3 o

- Ah Statistics……

- Reasoning: We f



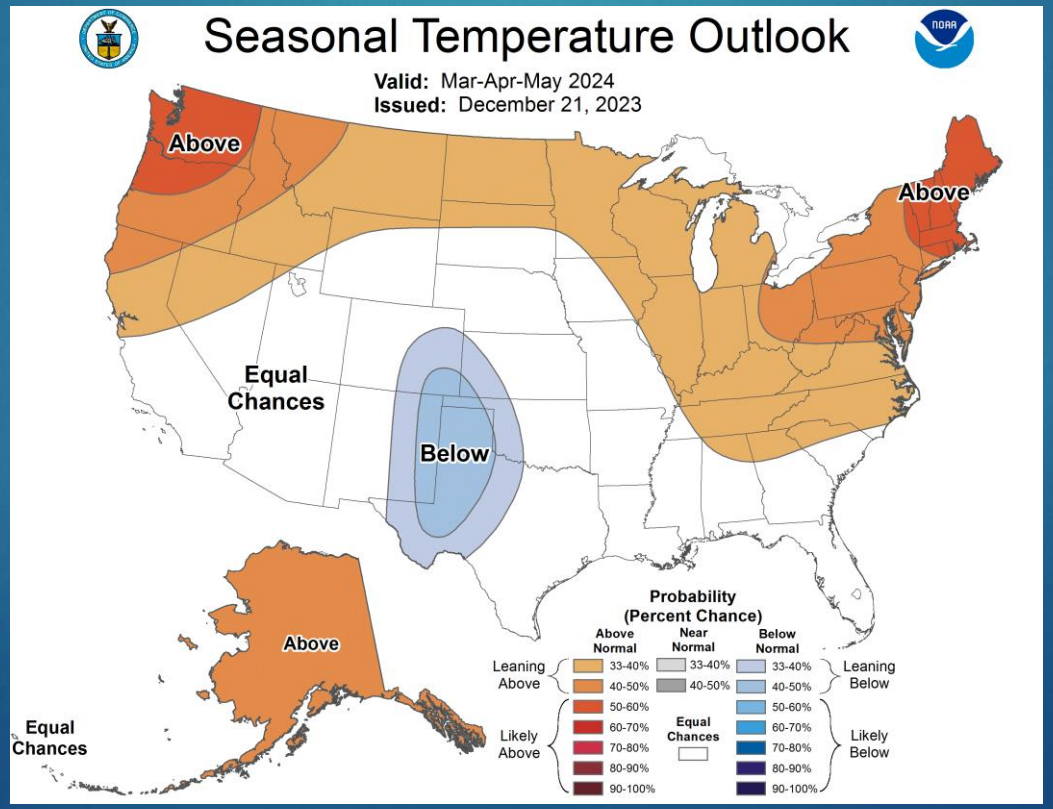
Our Forecast – Winter 2023 - 2024

- We're going to go with a slightly warmer winter than normal. We're looking at the recent "classic" El Ninos of 1997, 2014, 2015, and the El Nino of 2019. Temperature will be about 0.5-1.0 sigma above normal – which is about 1.5-3 F, with more humid conditions. Cool falls before and a warmer spring after are common. **(+5.1 F exactly as 2022-2023 - 1 point)**

- We're going to lean toward precipitation being above normal which tends to associate with ENSO classic. We'll also forecast snow to be around 10 – 15 inches this winter. Snow will come early and leave late. **So far up to 5.84 inches - +0.90 - 9.9 inches snow …….AOK…!**
  The precipitation is in the realm of normal so +1

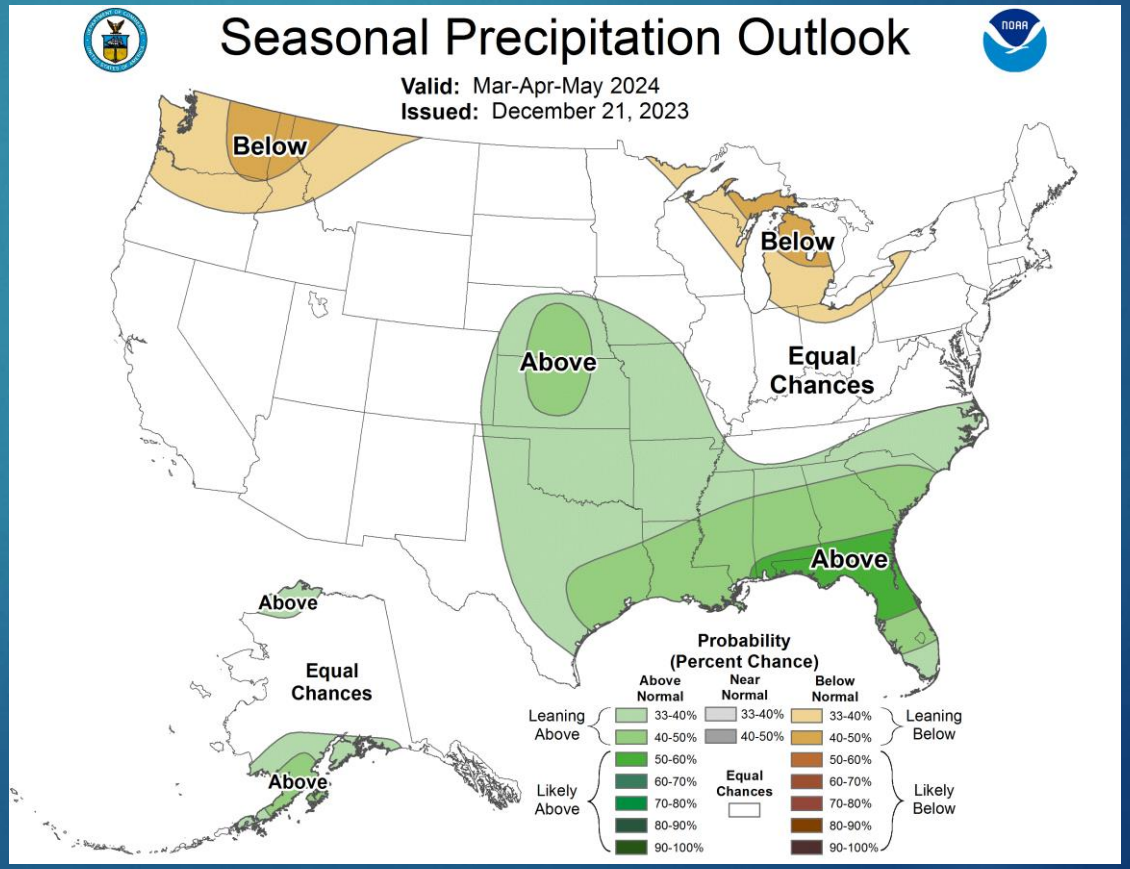
Spring 2024 – CPC outlooks

- Temperature – projections are for above average temperature across the northern and northeastern USA – Opposite of last year and typical ENSO classic.



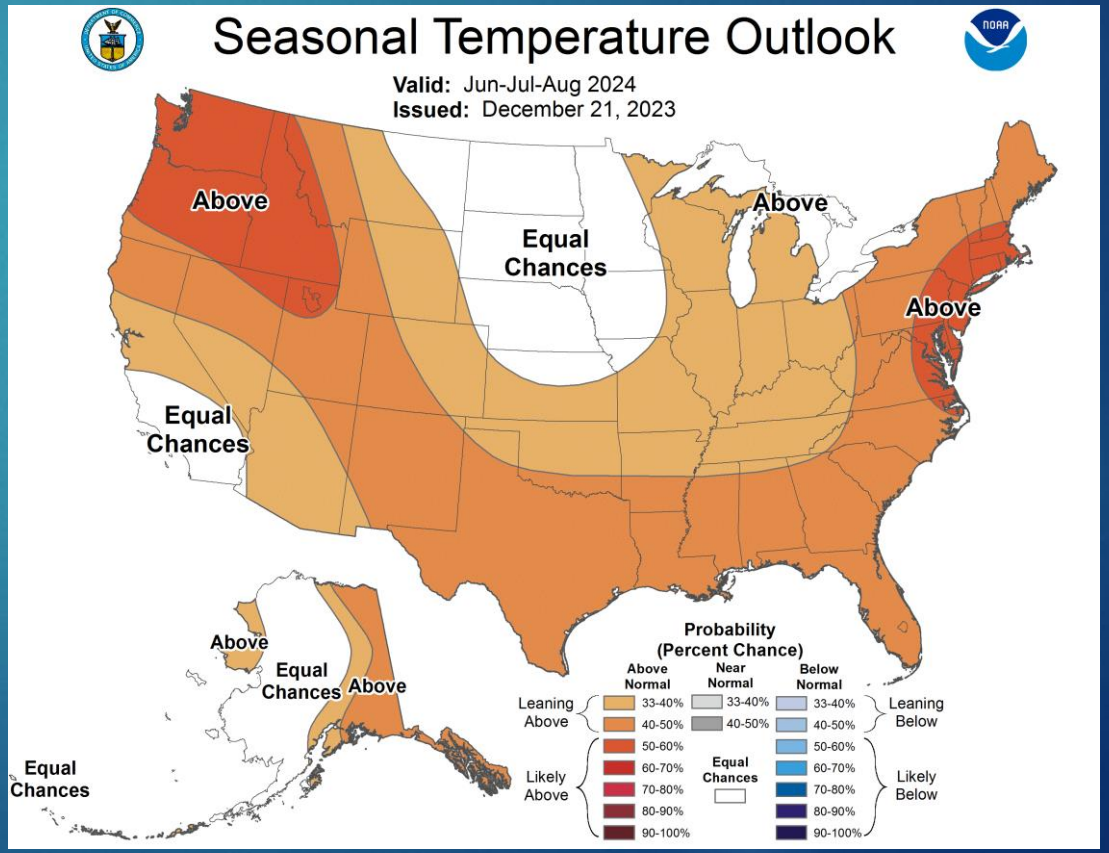
Spring 2024 – CPC Outlooks

- **Precipitation – look for drought to continue to improve? (so far so good….)**



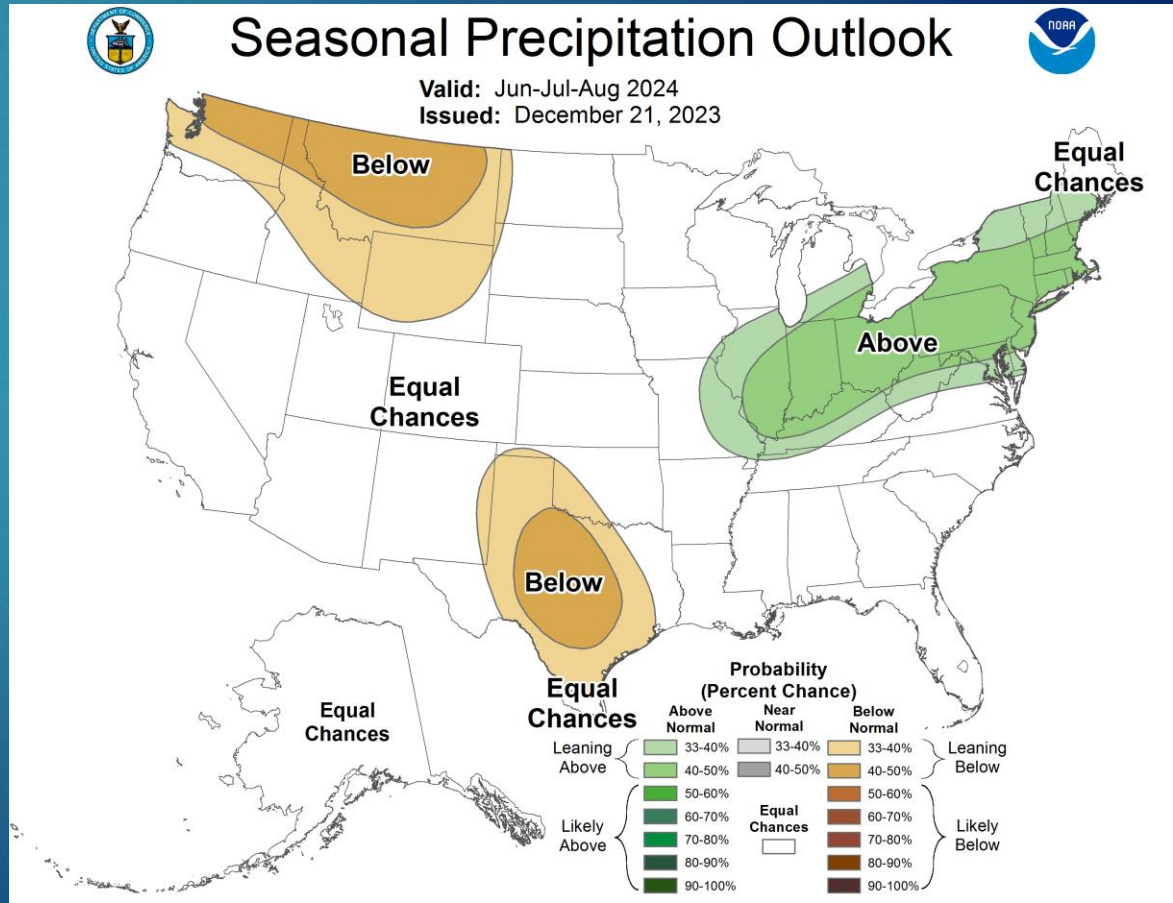
CPC Summer Outlook – 2024

- Temperature – the fifth straight year the forecast has look like this. We even trying?



CPC Summer Outlook 2024

- Precipitation – again consistent with dry conditions across the south, but wet in the Ohio valley? Looks like last year and three of the last four.



Summer 2024 Outlook

- CPC forecast is for a warm spring across the south and east coast and equal chances for the upper midwest. They are going for continued drought in the southern plains states but wet in the middle Mississippi and into the Ohio Valley and east. But, we're in an El Niño and going toward La Niña, and last year is looking like a good analog where MO is trapped between dry conditions west and wet conditions east.

- La Niña conditions were in place this time last year.

Summer 2024 Outlook

- A third factor has entered the fray – the Tonga – Hunga Volcano. This belched a lot of water vapor into the stratosphere. A greenhouse gas. See this link:

- https://scitechdaily.com/massive-tonga-volcano-eruption-blasted-enough-water-to-fill-58000-olympic-size-swimming-pools-into-stratosphere/?fbclid=IwAR2YO0fOm9fs-8tQNMQ_xQE-tmBwv4GgvpJyroGjWUAmBcKjuBMxtEli5GQ

Statistics for The Last 60 years

- Summers transition out of El Nino →
- 1966, 1970,1973,1977,1983, 1987,1992, 1998,2003, 2007,2010, 2016, 2020
- Treat as Bivariate → None cool wet
- None warm and normal or warm and dry → But, three (1983, 2007, 2016) and one (2010) lean that way (~30%).

Statistics for The Last 60 years

- Summers transition into La Nina →

- 1964*, 1967, 1970*, 1973*, 1988, 1998*, 2007*, 2010*, 2017, 2020*

- (treat as a bivariate) 1967 cold, leans dry

- None warm and dry → 1988 leans warm but dry 2010 leaned warm and leaned dry - 1964, 2007 normal leans dry

- 10% of these summers can be problematic, 40% "marginal".

Statistics for The Last 60 years

- Summers transition into Neutral →

- 1966*, 1968, 1977*, 1983*, 1989, 1992*, 2000, 2003*, 2008, 2011, 2016*, 2018

- (treat as a bivariate) 1989 cold, wet

- Three were warm or leans warm and dry or leans dry → 1983 leans warm and dry 2011 2018 warm and leans dry

- 25% of these summers can be problematic.

Our Forecast – Summer 2024

- Reasoning:

- We think that the El Nino will fade. We'll probably head into Neutral Conditions and not see a flip back to La Nina. This means the neutral years are good analogs. The best models project us to move out of El Nino conditions into cold netural or La Nina. As we go into mid-January, El Nino is solidly in place.

- So we're going to say that summer will be in the range of normal (within one half sigma of normal or +/- 1.2 F and the summer will be a bit drier than normal (0 – 5 inches below normal).

Community Collaborative Rain, Hail, and Snow Network

- Please consider joining CoCoRaHS. This data is used by agencies to decide crop loss information. It's worth it to you to join Missouri CoCoRaHS. (State Climatologist Zachary Leasor). MO has been a CoCoRaHS state since 2006.

- http://cocorahs.org

- Email: lupoa@missouri.edu
- leasorz@missouri.edu

Missouri Climate Center

- Missouri Climate Center
- http://climate.missouri.e

Climate Change

- **U.S Global Change Research Program:** http://www.globalchange.gov/
- **2018 National Climate Assessment:** https://nca2018.globalchange.gov/
- **2014 National Climate Assessment:** http://nca2014.globalchange.gov/
- **National Oceanic and Atmospheric Administration (NOAA):** http://www.noaa.gov/climate
- **NOAA Climate Portal:** https://www.climate.gov
- **NOAA U.S. Climate Resilience Toolkit:** https://toolkit.climate.gov
- **Midwestern Regional Climate Center﷯s Climate Trends Tool:** http://mrcc.isws.illinois.edu/mw_climate/climateTrends.jsp
- **USDA Midwest Regional Climate Hub:** https://www.climatehubs.oce.usda.gov/hubs/midwest
- **National Centers for Environmental Information State Climate Summaries:** https://statesummaries.ncics.org
- **NASA Global Climate Change:** http://climate.nasa.gov/
- **US EPA Climate Change:** https://19january2017snapshot.epa.gov/climate-impacts/climate-change-impacts-state_.html
- **Real Climate:** http://www.realclimate.org/
- **Climate Science Centers:** http://www.doi.gov/csc/index.cfm