

Tree Damage nr Two Harbors, Dec 2022.
Courtesy P. Goff



Ef-4 Tornado near Dalton, July 2020. Courtesy John Nordstrom



Flooding in Rushford, MN, Aug 2007. Courtesy MN DNR Floodplain Program

What Minnesota's Changing Climate Means for Weather Disasters & Emergencies

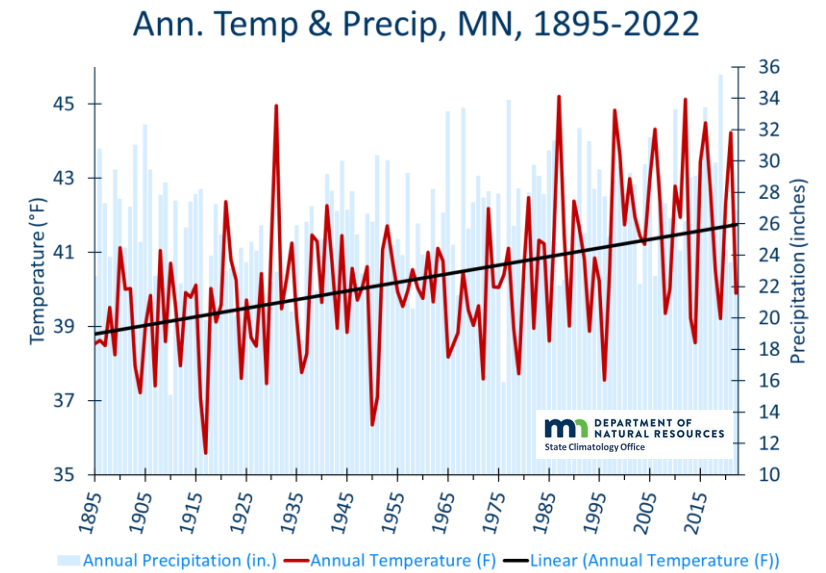
Kenny Blumenfeld | Sr. Climatologist, Minnesota DNR

Items to bear in mind

1. Our climate has extreme **Variability** (ups and downs), and always will
2. Our climate is experiencing ongoing **Trends** (persistent changes)
→ **Variability + Trends can cause unprecedented conditions**
3. We have not yet experienced all changes
4. We must accept nuances **and** expect surprises (climate cannot always follow bullet points)

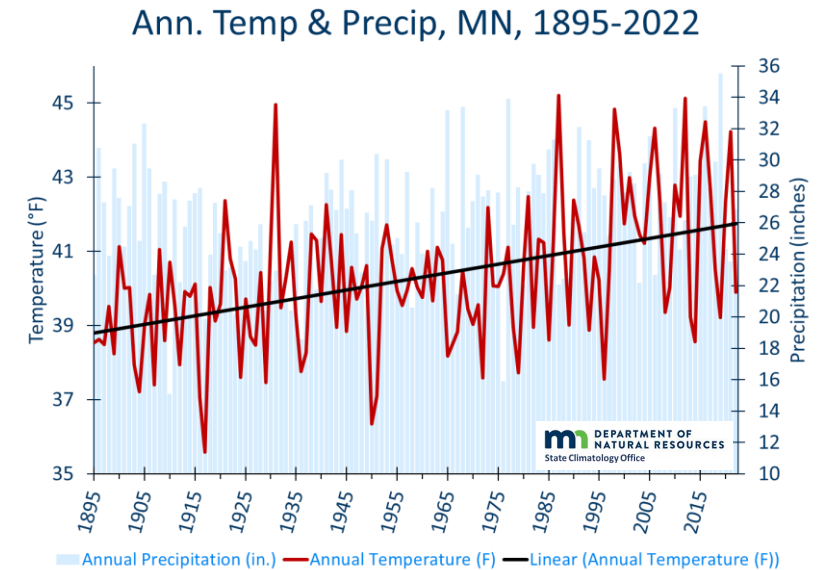
Some Facts

1. Minnesota: naturally “extreme” climate with high variability and many weather hazards
2. Human greenhouse gas emissions cause global temperatures to rise
 - Cause of almost all long-term warming past 100+ years
 - Short-term ups and downs (1-48 months) from natural factors
3. Rising global temperatures = more access to heat and water vapor



Facts (continued)

4. Minnesota's climate is changing (because of 2 & 3)
5. **Some Minnesota hazards “worsening”**
6. **Some not worsening YET**
7. **Some not worsening and unlikely to do so**
8. **Some uncertain or changing in other ways**
9. **Some new/hybrid hazards emerging**



1. Is a given weather hazard becoming:

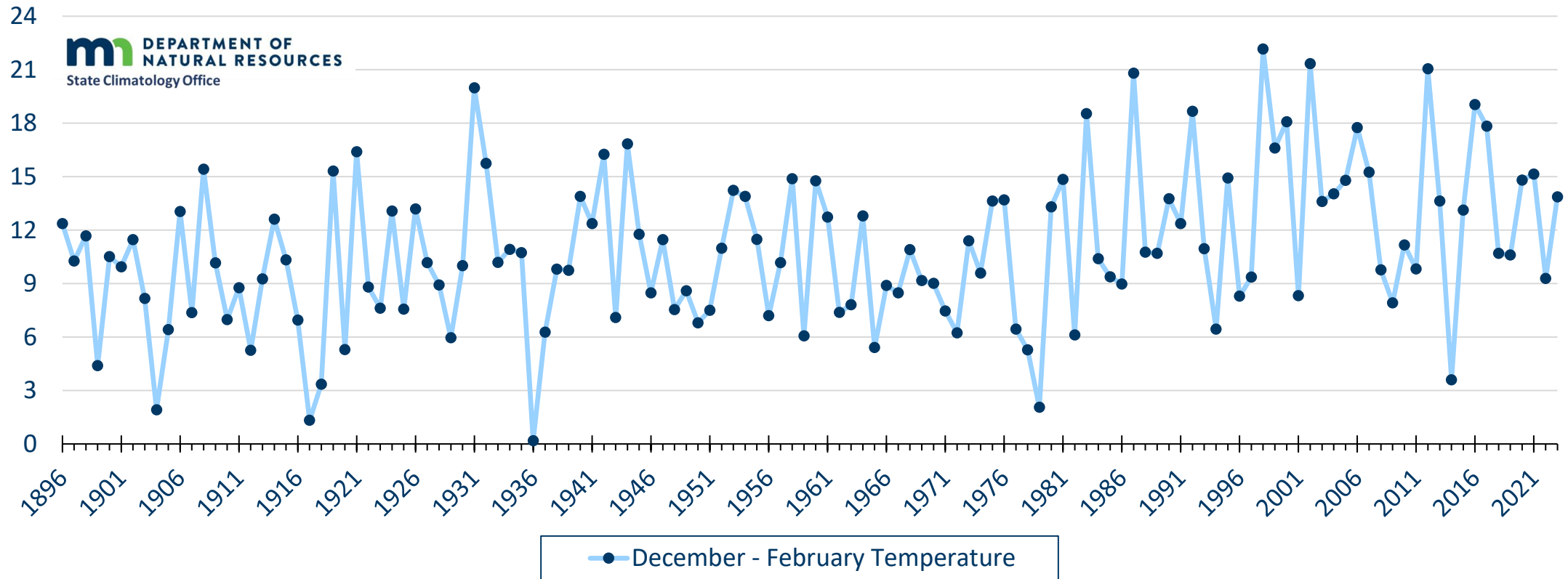
- More frequent?
- More intense?
- Longer-lasting?
- Larger?

2. Is its timing or seasonality changing?



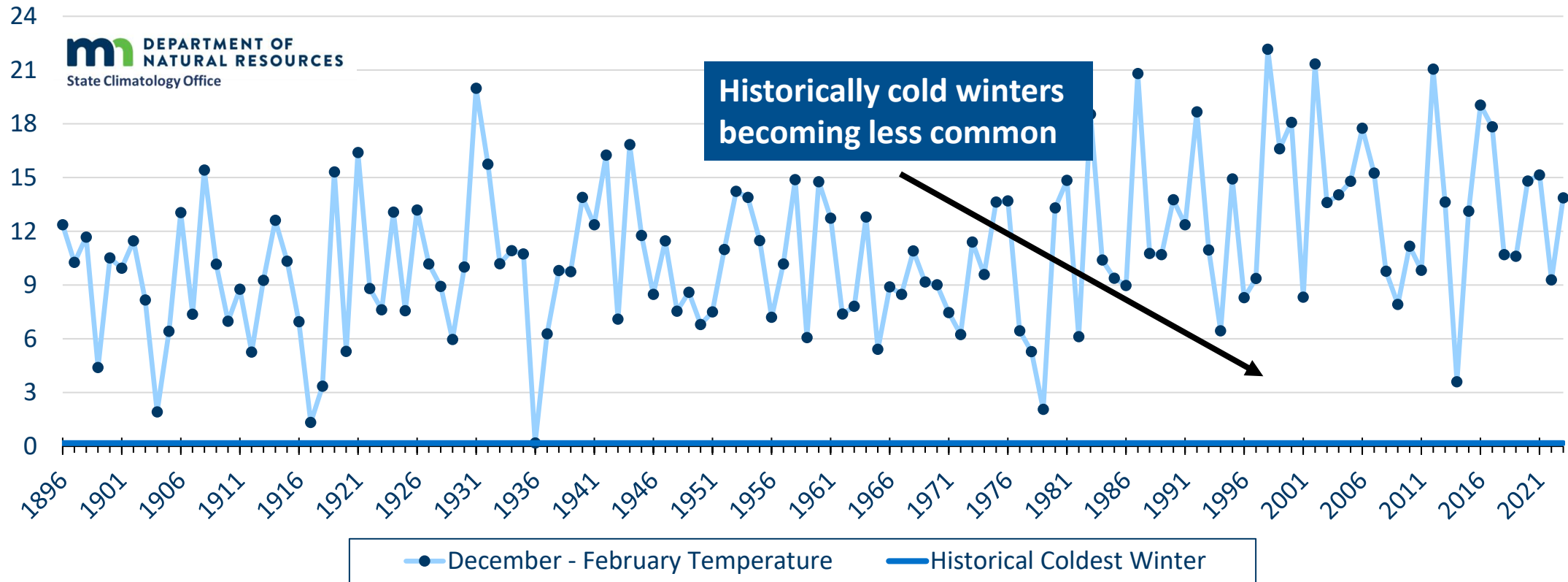
Looking for change: Do values approach or exceed ranges more than they used to?

Winter Average Temperatures (December-February) Minnesota, 1896-2023



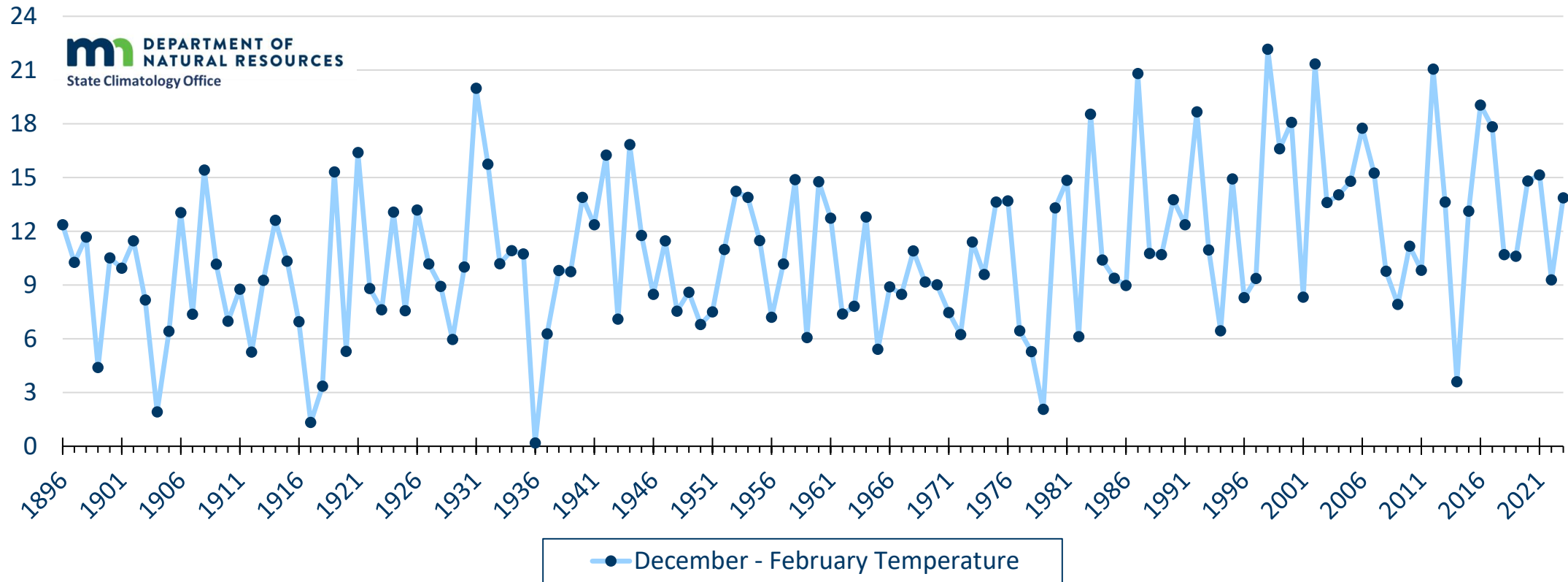
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Winter Average Temperatures (December-February) Minnesota, 1896-2023



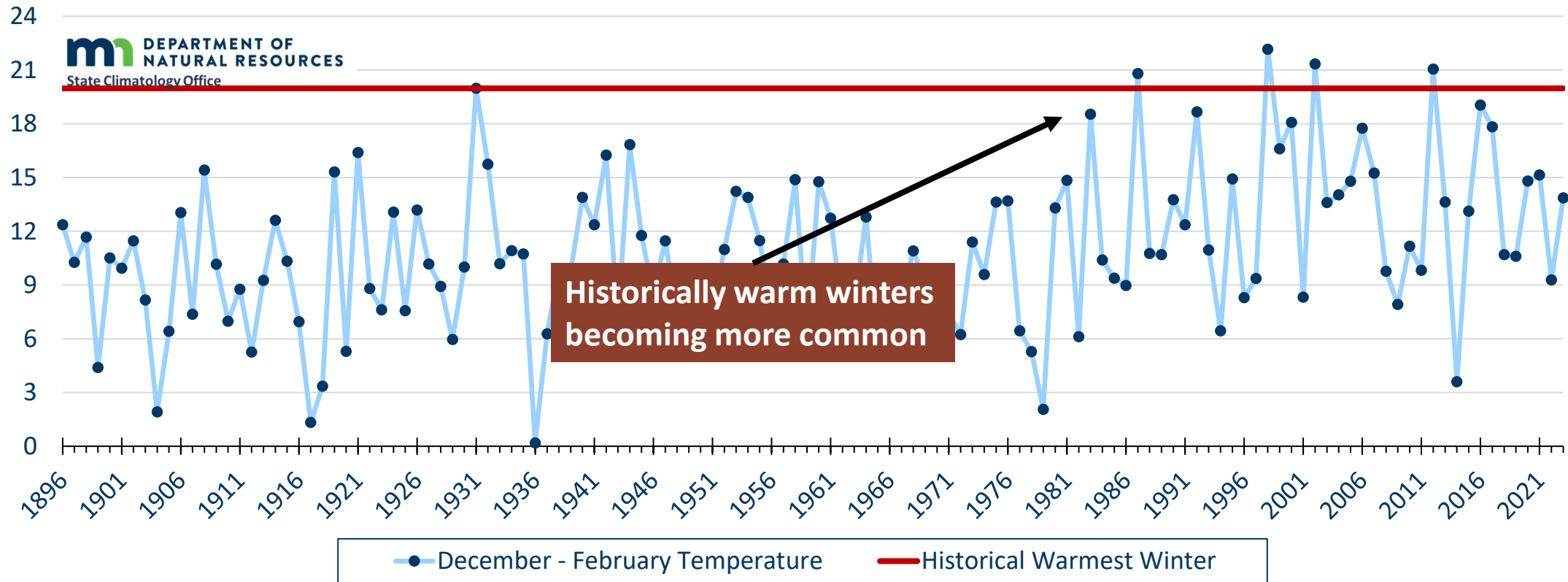
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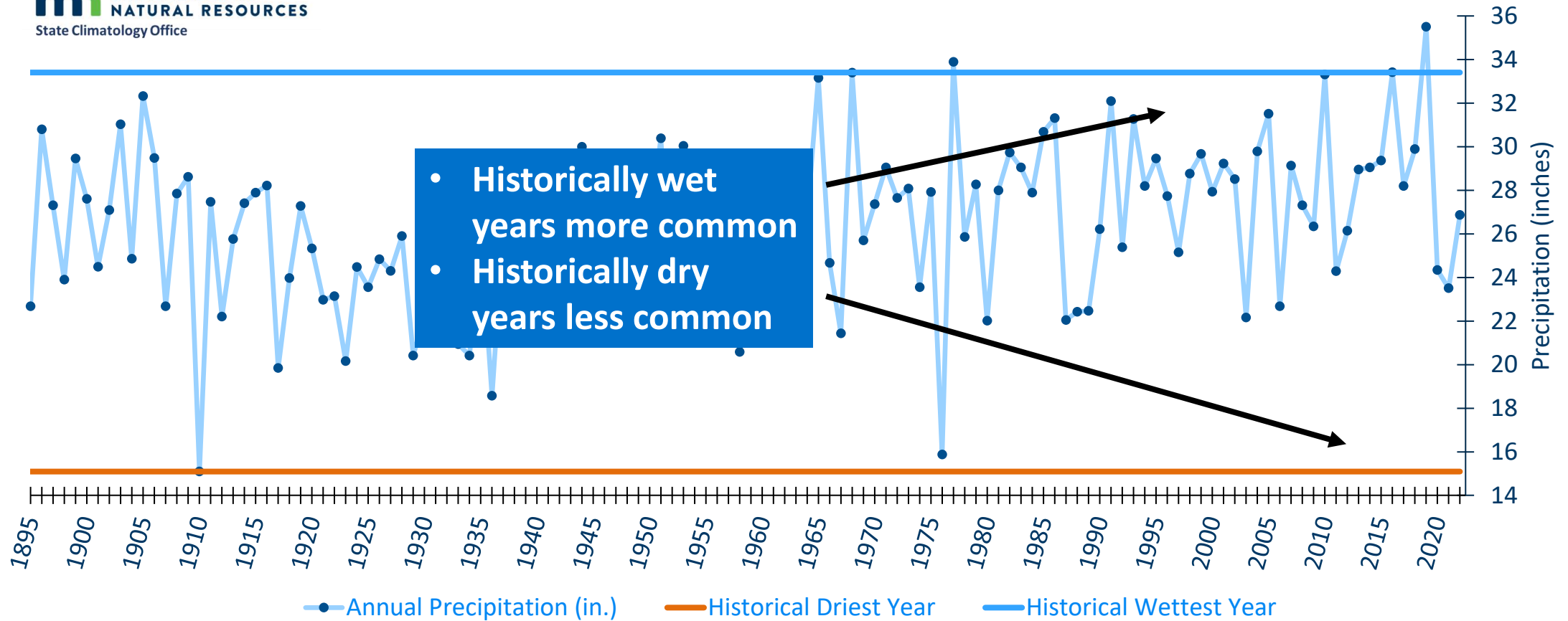
Winter Average Temperatures (December-February) Minnesota, 1896-2023



Looking for change: Do values approach or exceed ranges more than they used to?

Annual Precipitation, Minnesota, 1895-2022

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These MN hazards are becoming More Frequent, More Intense, Longer-Lasting, or Larger

“WORSENING”

1. Wet periods, heavy rain
2. Heavy snow
3. Humid heat waves (slight increases)

Climate tie-in: more available water vapor because of higher global temperatures

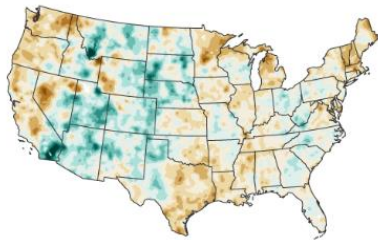
1991-2020 Wettest “Normals” Period on Record

Climate “normal”: an adjusted 30-year average, based on data ending in a “zero” year (e.g., 2020)

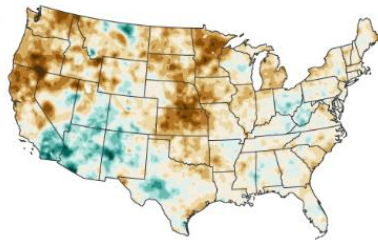
<https://www.climate.gov/news-features/understanding-climate/climate-change-and-1991-2020-us-climate-normals>

U.S. ANNUAL PRECIPITATION COMPARED TO 20th-CENTURY AVERAGE

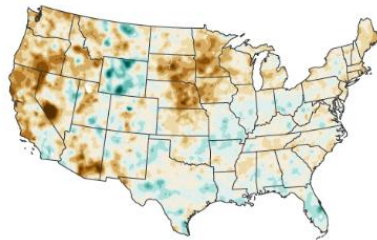
1901–1930



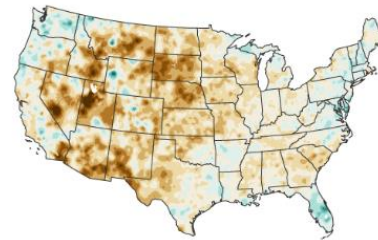
1911–1940



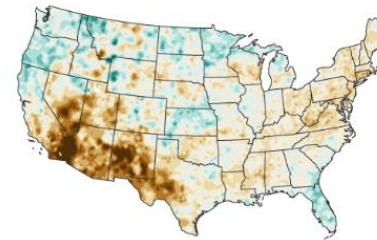
1921–1950



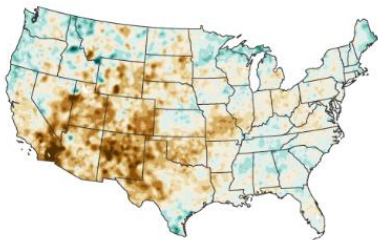
1931–1960



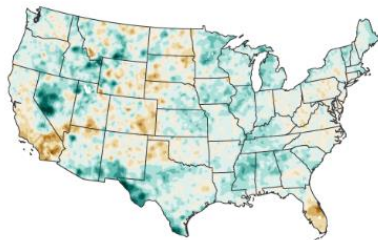
1941–1970



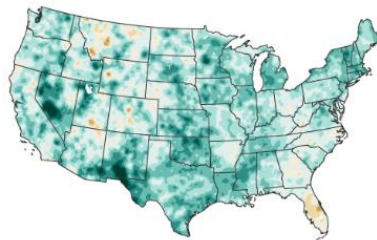
1951–1980



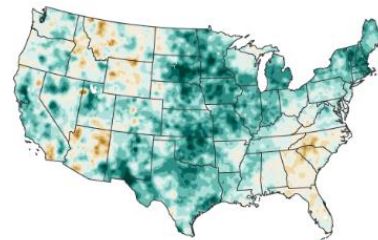
1961–1990



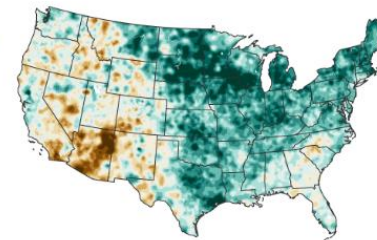
1971–2000



1981–2010



1991–2020



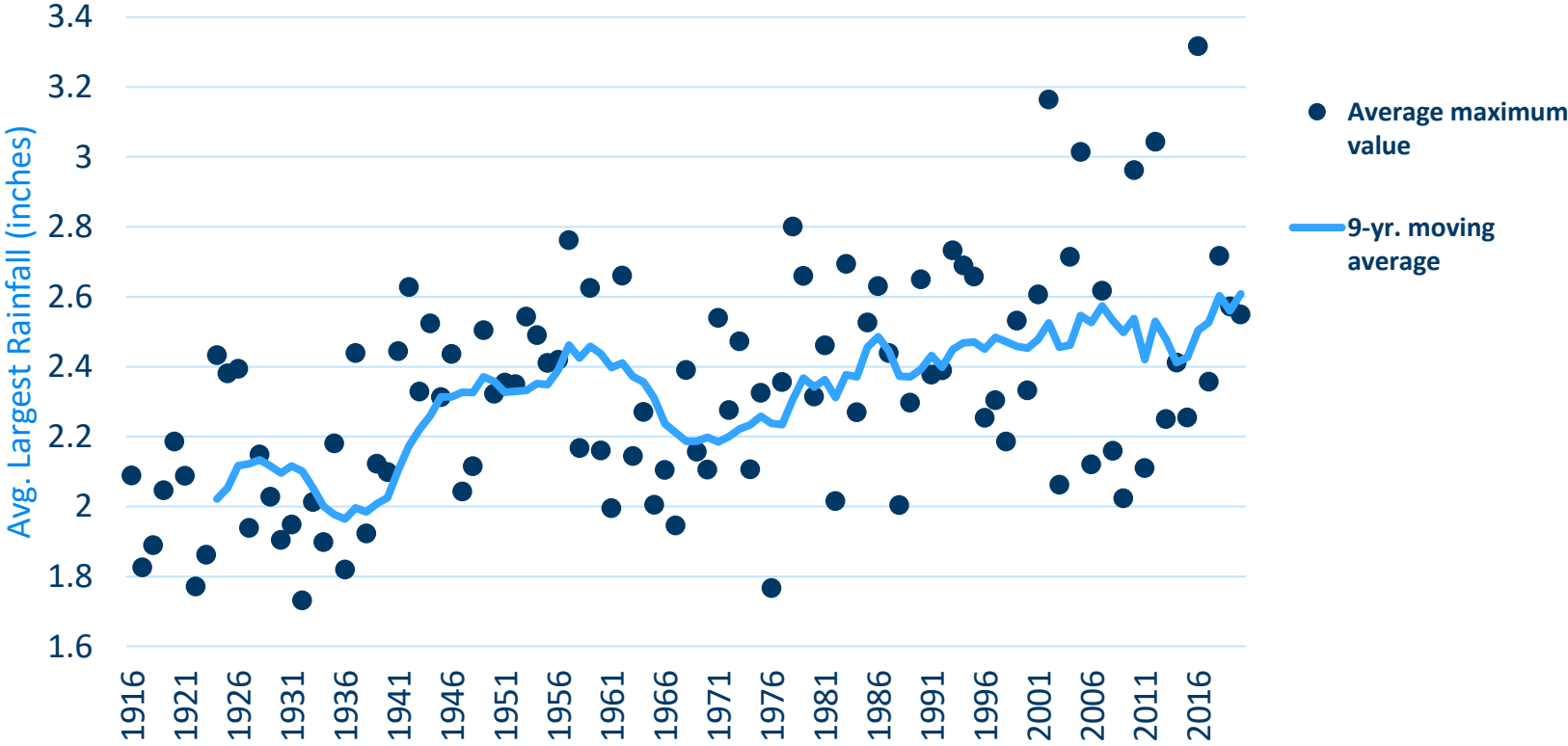
30-year Normal
compared to 1901–2000



NOAA Climate.gov
Data: NCEI

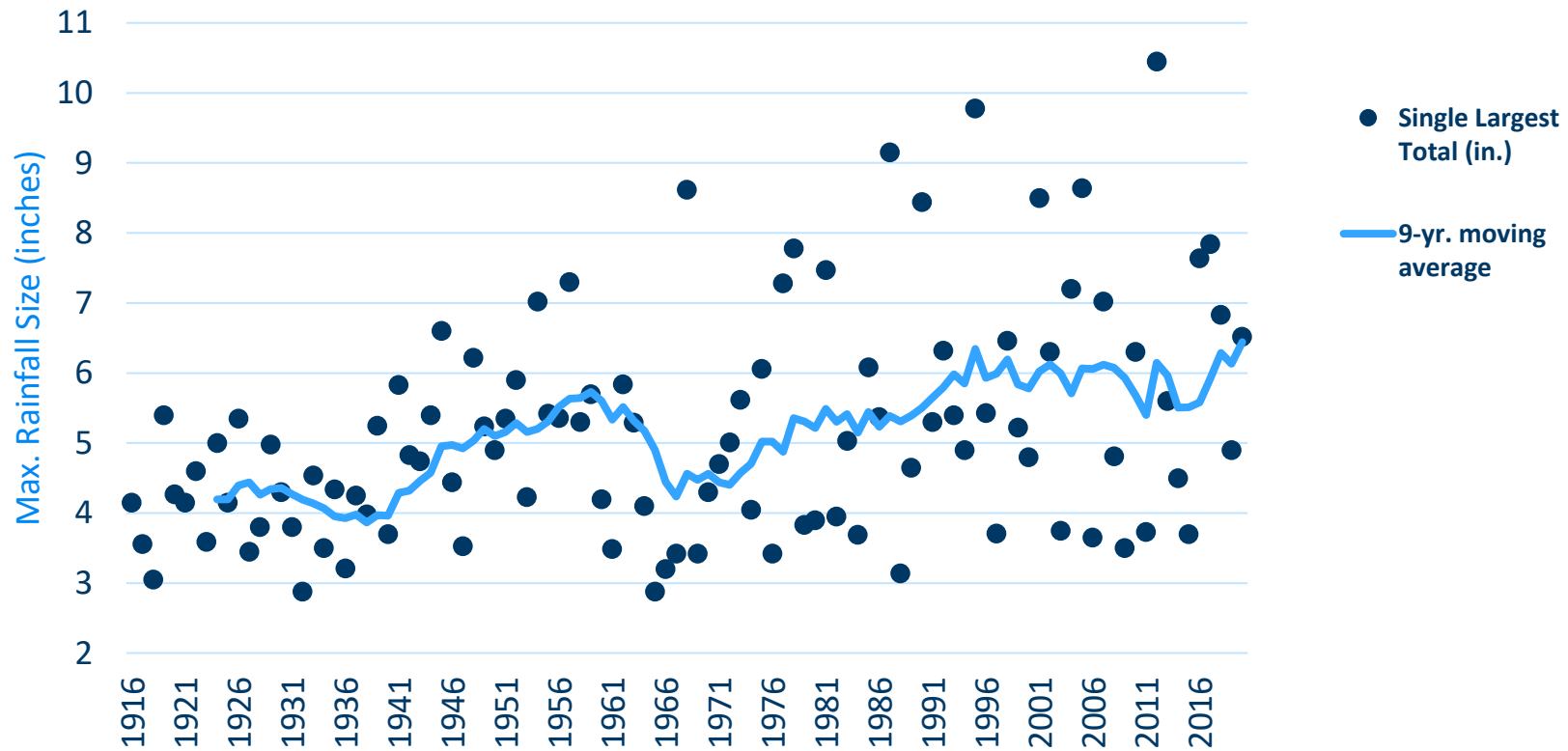
Increasing size of largest annual daily rainfall for a typical station

Average Largest Daily Rainfall Each Year
38 Historical Stations, 1916-2020



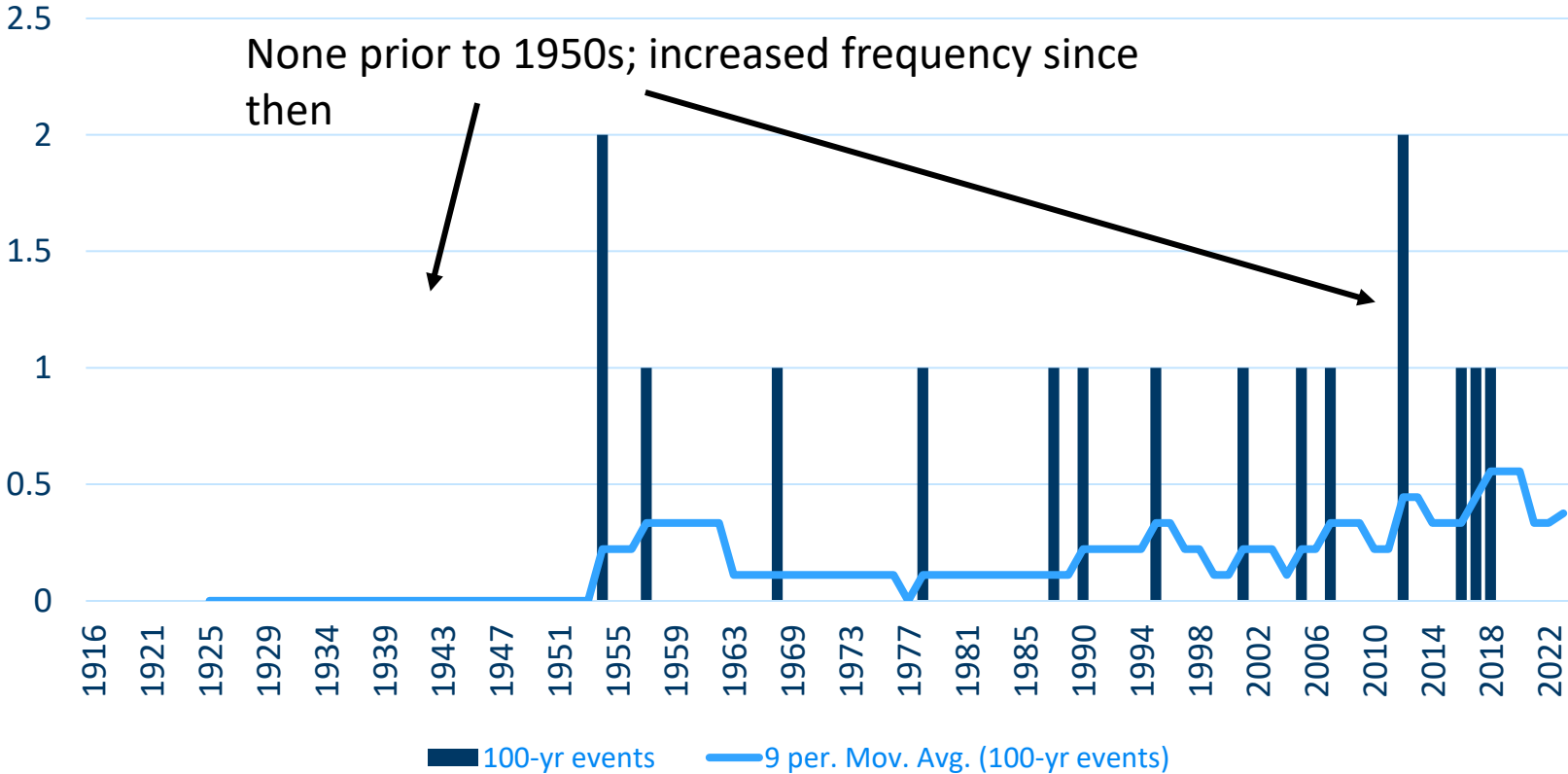
Size of largest rainfall in historical network increasing

Largest Daily Rainfall Each Year from Any Station
38 Historical Stations, 1916-2020



Increase in 100-year daily rainfall events

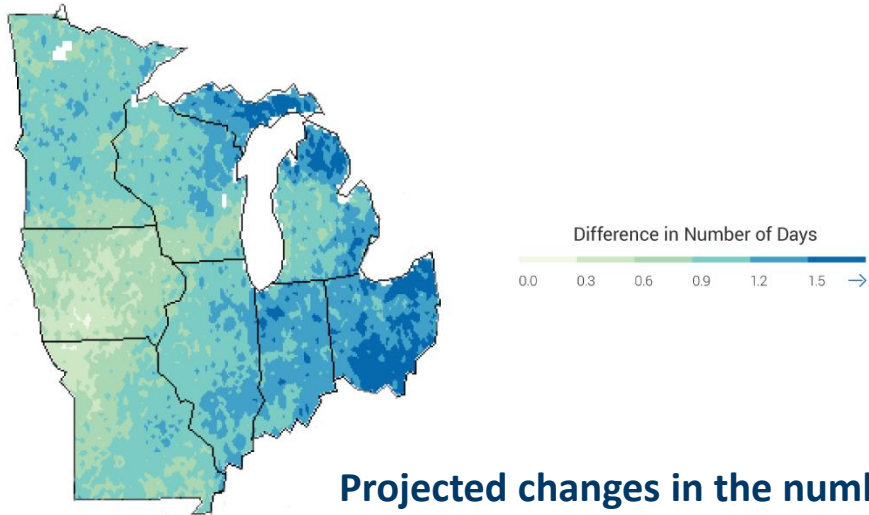
Count of "100-year" Precipitation Events by Year, 1916-2020
From 38 Stations



This WAS NOT a 100-year event (June 17, 2018, Gooseberry Falls SP)

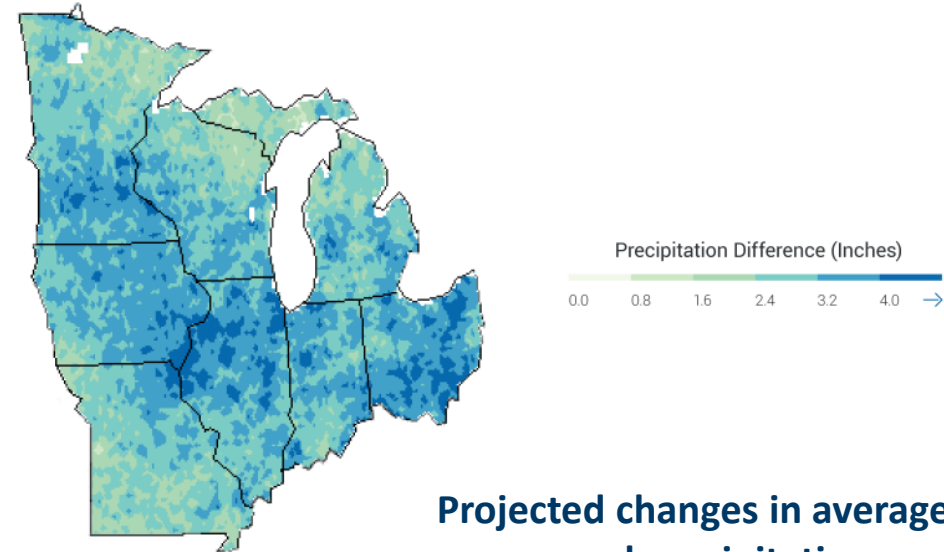


More precipitation and more heavy precipitation projected



Projected changes in the number of days with very heavy precipitation (top 2% of all rainfalls each year) for the middle of the current century (2041-2070) relative to the end of the last century (1971-2000) under continued emissions (A2 scenario).

Source: 2014 National Climate Assessment, [Midwest Chapter](#)

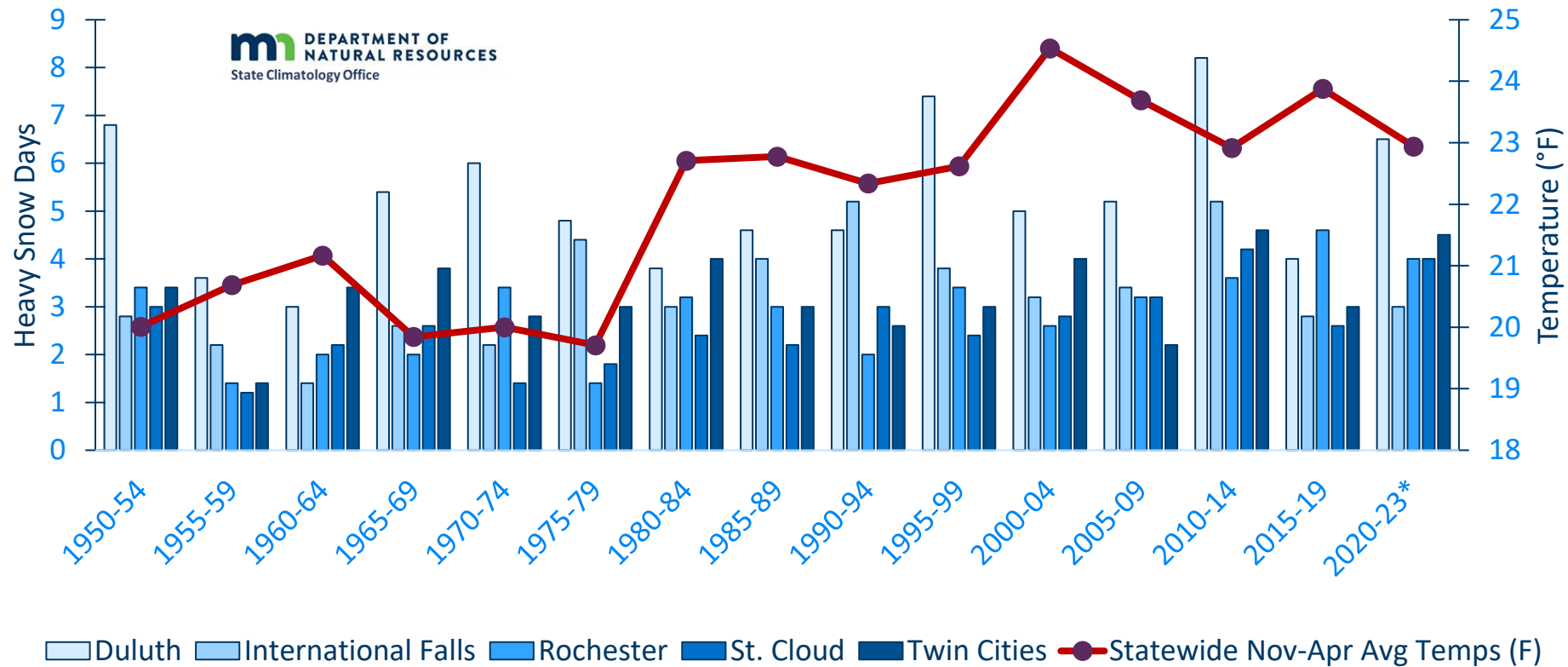


Projected changes in average annual precipitation for the middle of the current century (2041-2070) relative to the end of the last century (1971-2000) under continued emissions (A2 scenario).

Source: 2014 National Climate Assessment, [Midwest Chapter](#)

Heavy Snow Increasing Across MN (even as winters warm)

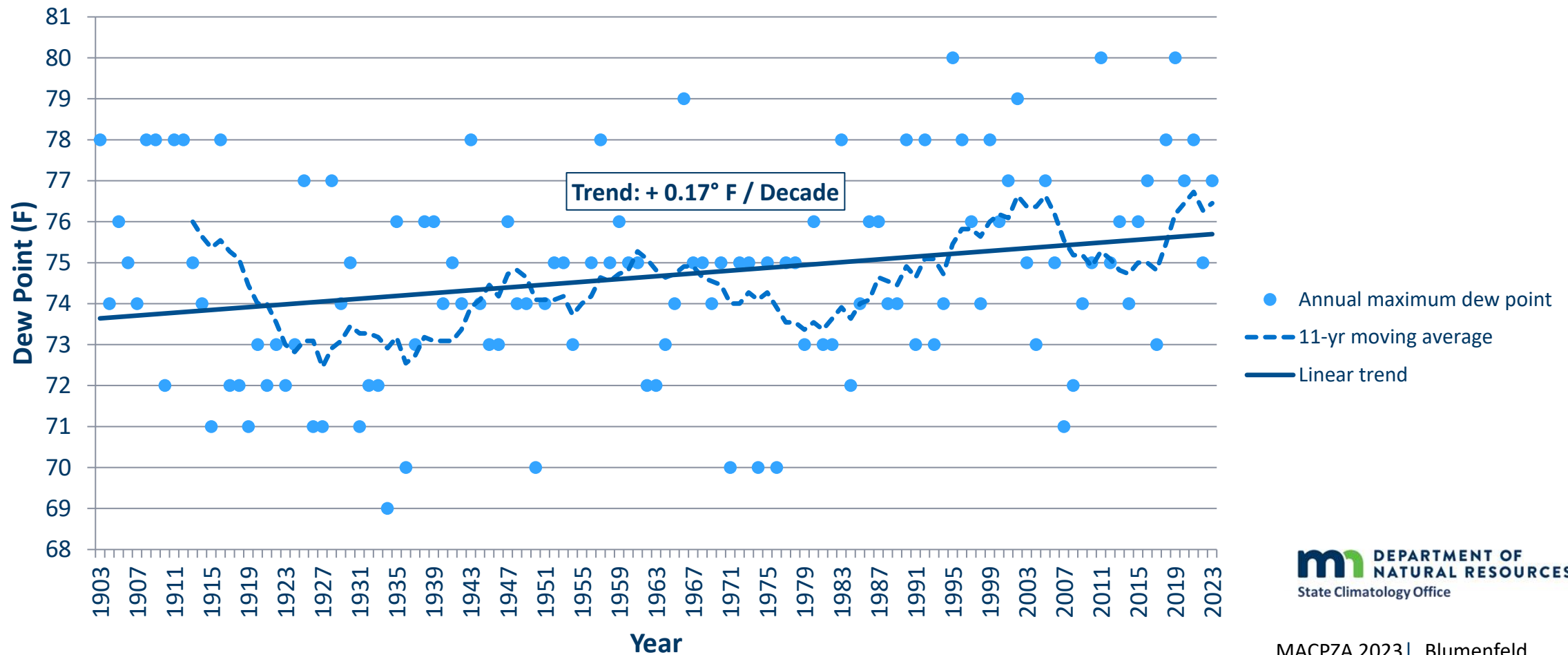
Average Seasonal Heavy Snow Days (4+ inches) and Statewide Average November - April Temperature



- Snow data from NOAA/NWS Cooperative Network, accessed via Applied Climate Information System (ACIS) (<https://xmacis.rcc-acis.org/>).
- Temperature data obtained from NOAA via Minnesota Climate Explorer (<https://arcgis.dnr.state.mn.us/ewr/climateexplorer/main/historical>)

Extreme humidity beginning to increase

Highest Annual 6 PM CST Dew Points
Minneapolis-St. Paul, 1903-2023

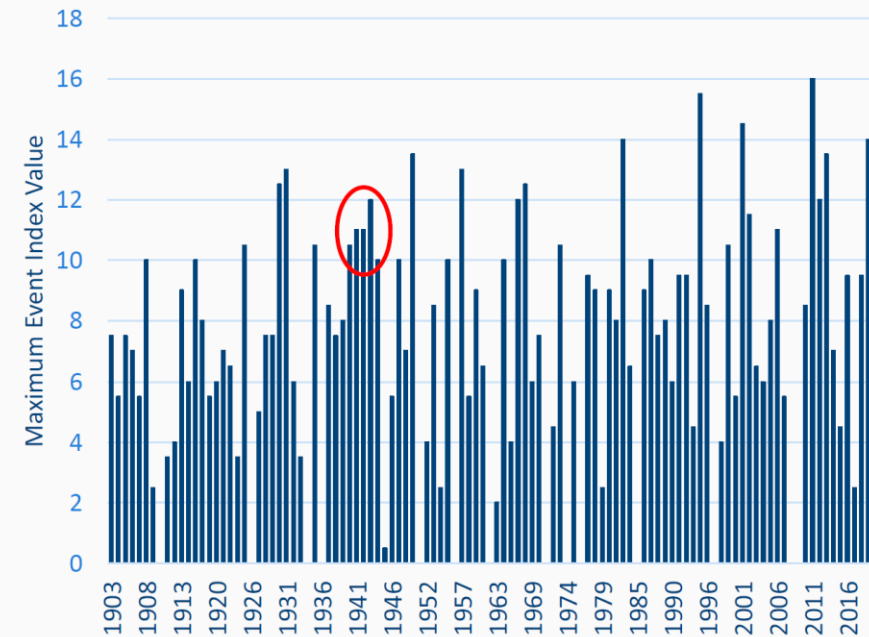


Extreme humidity beginning to increase

Highest 7 PM dew points on record: Most of the highest values have been recorded in recent 30 years (since 1990). The current period sees greater dew point extremes than any other period on record.

Date	Temperature (°F)
7/19/2019	80
7/17/2011	80
7/12/1995	80
7/20/2002	79
7/10/1966	79
6/16/2018	78
7/19/2011	78
7/22/1999	78
8/6/1996	78
8/12/1995 (12 others)	78

Maximum Humid Heat Event Intensity
Twin Cities, 1903-2019



These MN hazards are NOT YET becoming More Frequent, More Intense, Longer-Lasting, or Larger

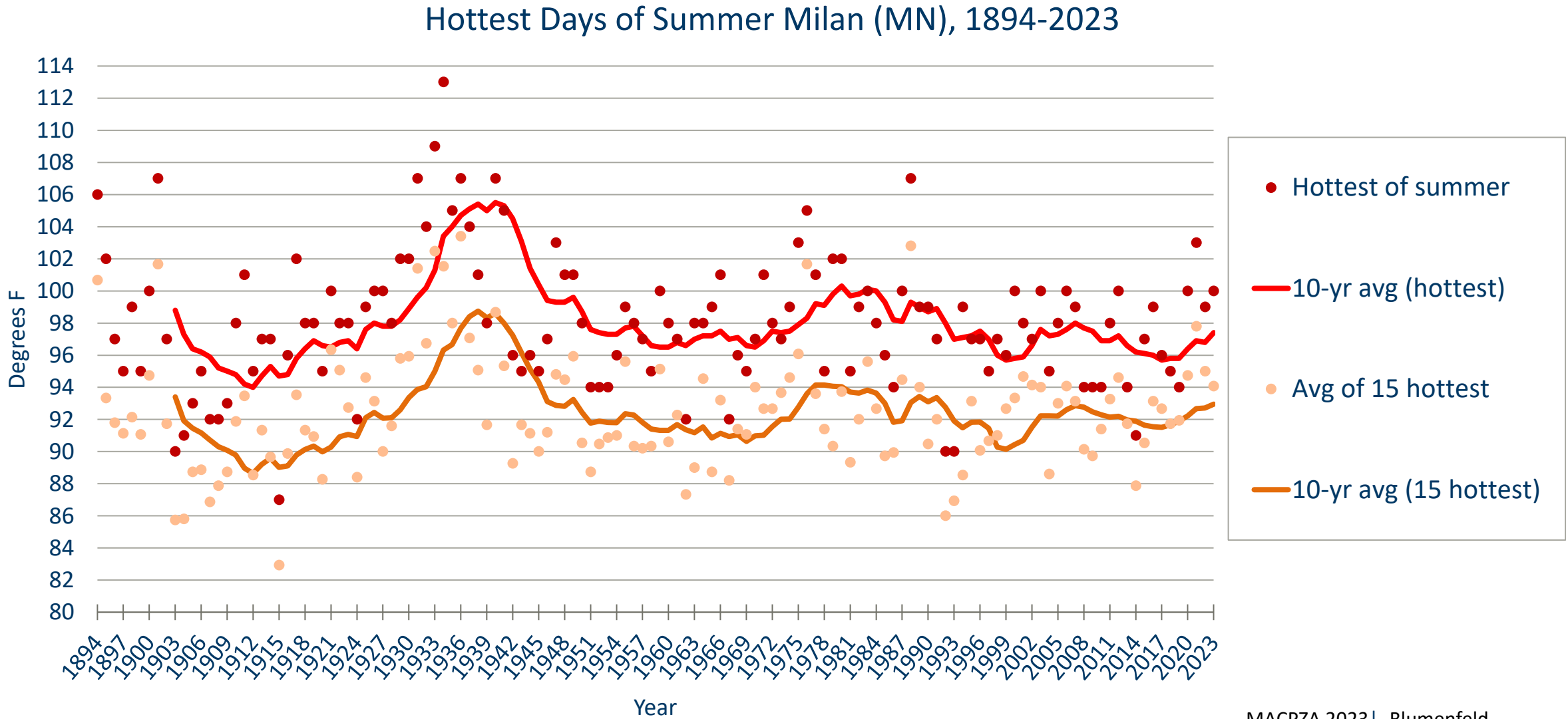
“NOT WORSENING YET”

1. High temperature extremes (all-time records untouched for 80+ years)
2. Counts of 90° or 100° F days (steady or slight downward trend)
3. Drought (long-term decreases in all measures, **even when including current episode**)

→BUT projections unanimous that increases coming

→***Climate tie-in: more heat all over the planet, eventually including our summers. Future dry periods will come with more heat.***

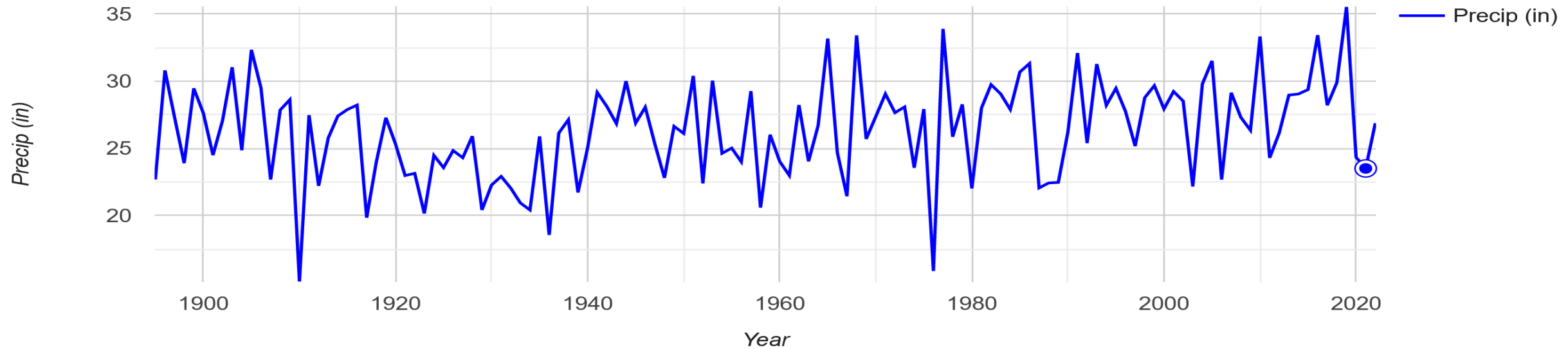
Through 2023, no clear trend towards worse heat (yet)



Downward spikes indicate historical dry episodes



Precipitation For Minnesota, January-December

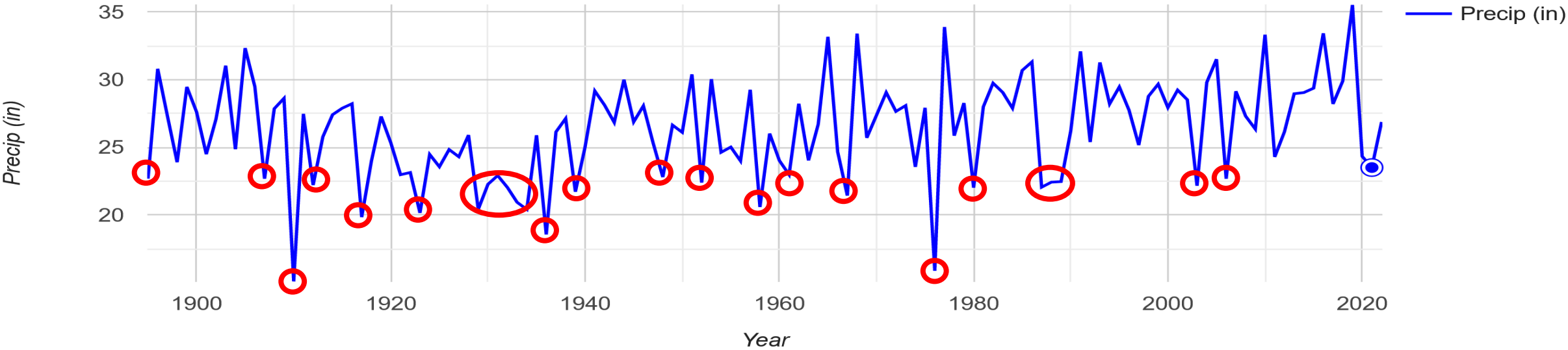


2021: 29th Driest Year on Record



2020-2023 is (currently) the wettest “dry period on record!

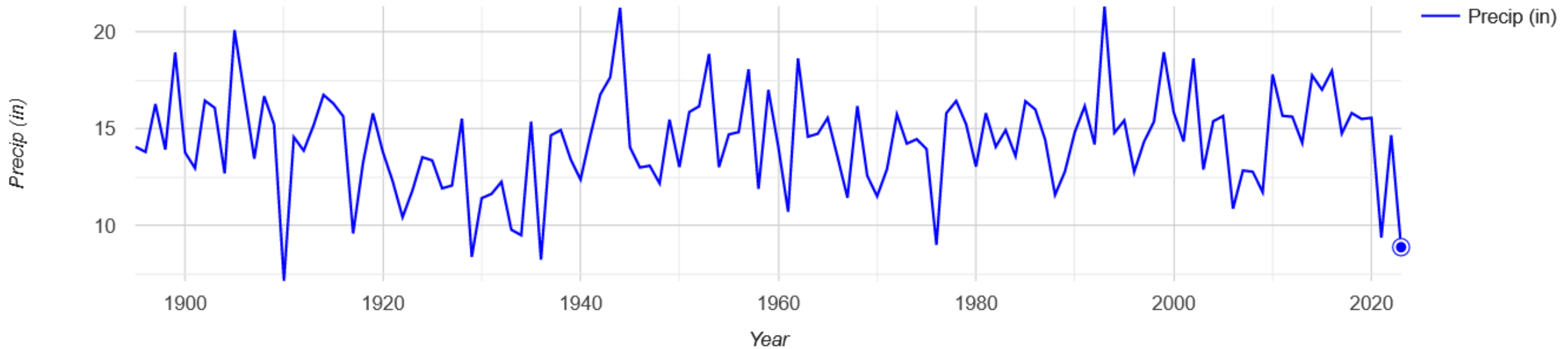
Precipitation For Minnesota, January-December



May- August 2023: 4th driest since 1895



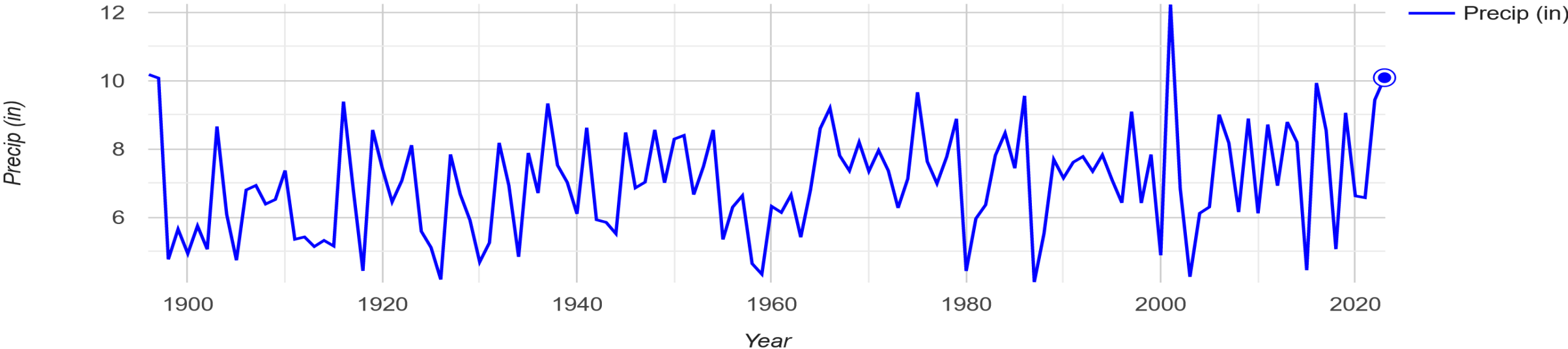
Precipitation For Minnesota, May-August



November 2022 – April 2023: 3rd wettest since 1895



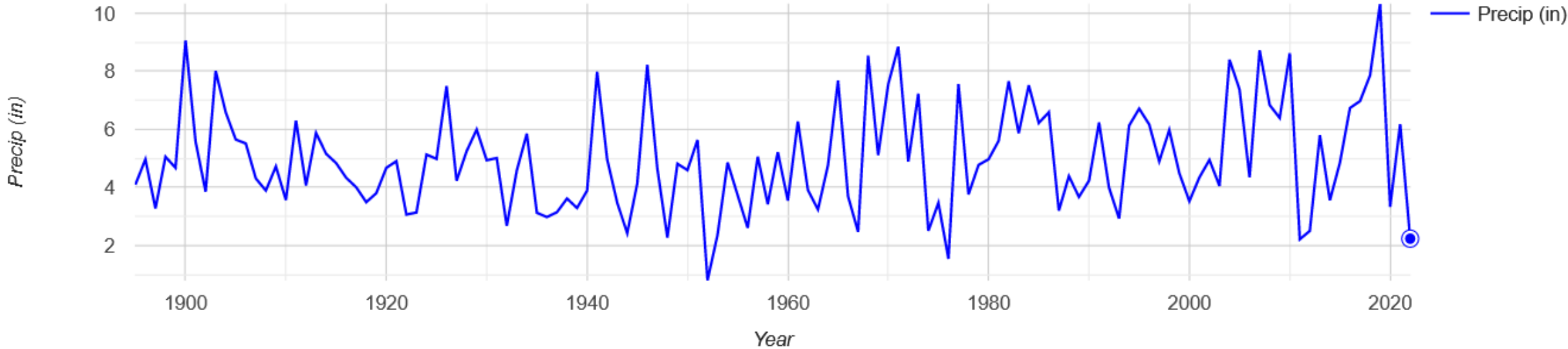
Precipitation For Minnesota, November-April



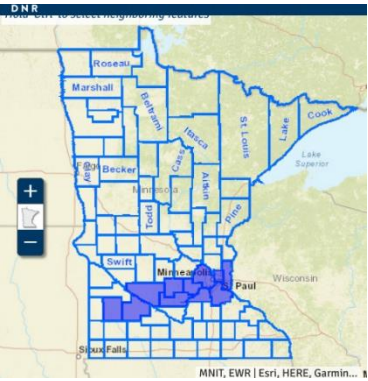
September - October 2022: 4th driest since 1895



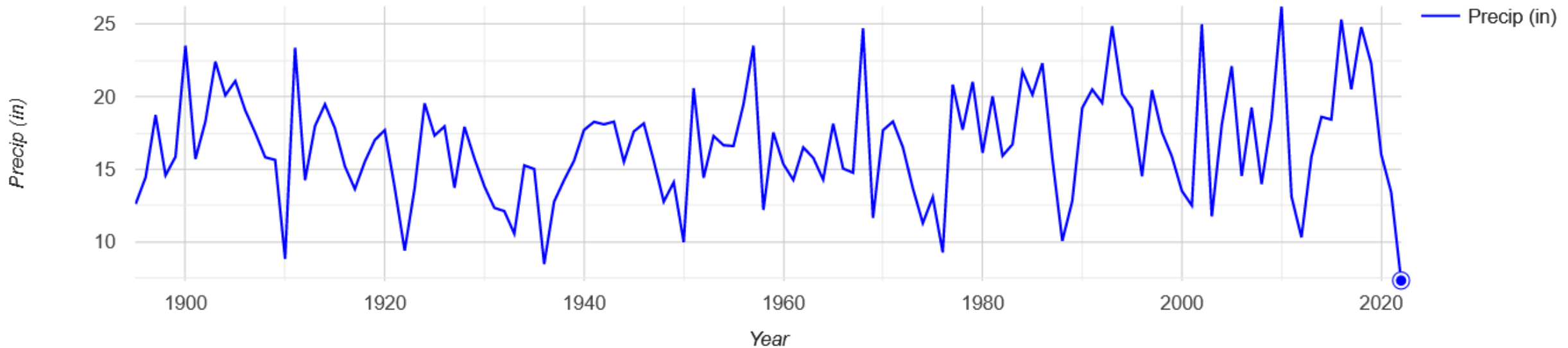
Precipitation For Minnesota, September-October



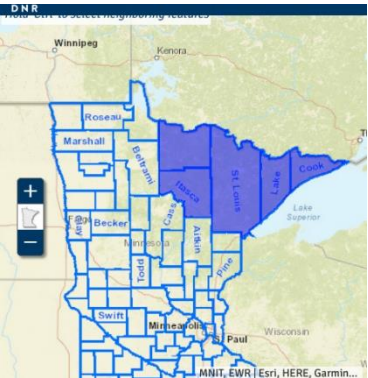
June - October 2022: #1 driest since 1895 in some areas



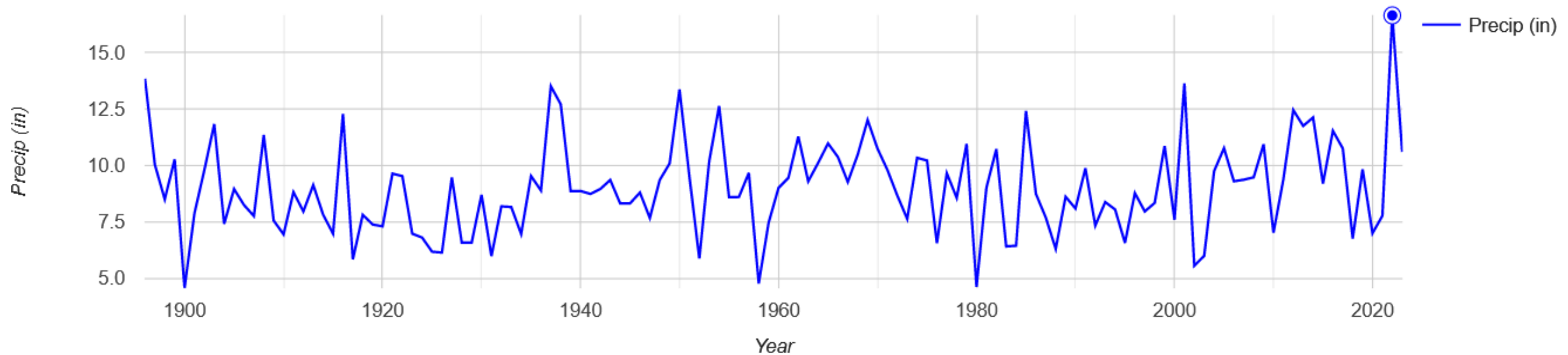
Precipitation For Selected Counties, June-October



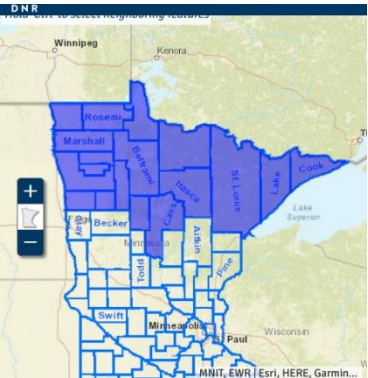
December 2021 - May 2022: #1 wettest in some areas



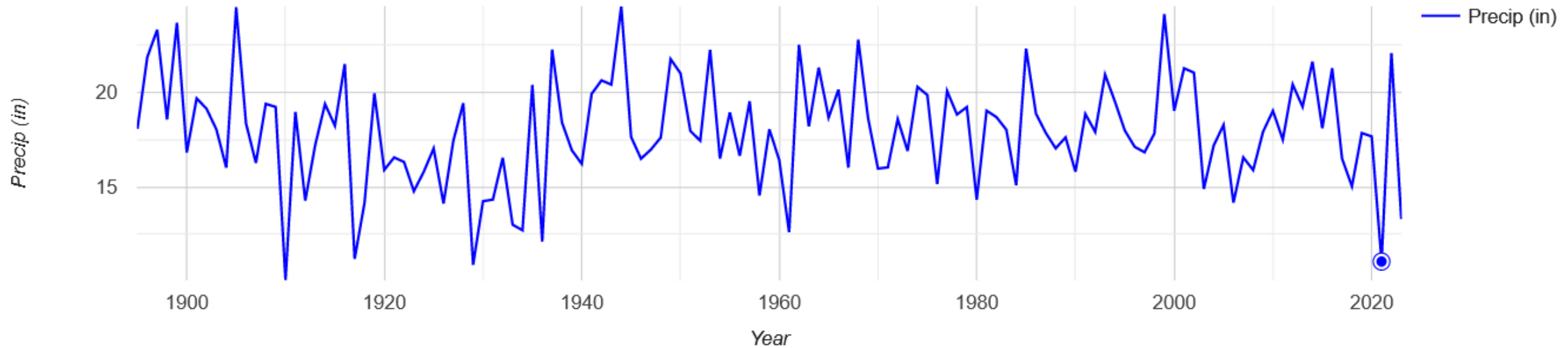
Precipitation For Selected Counties, December-May



January - August 2021: 3rd driest northern MN



Precipitation For Selected Counties, January-August



However, more warming and heat extremes on the way

Projections indicate:

- Continued warming
- More summer heat extremes
For all future scenarios

→ *This will almost certainly increase episodic drought severity also*

Projected Change in the Number of Days Over 90°F
Period: 2041-2070 | Lower Emissions: B1

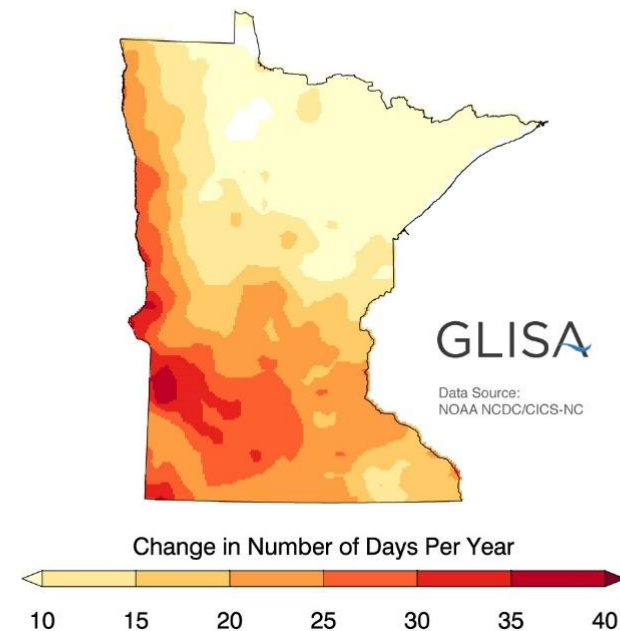
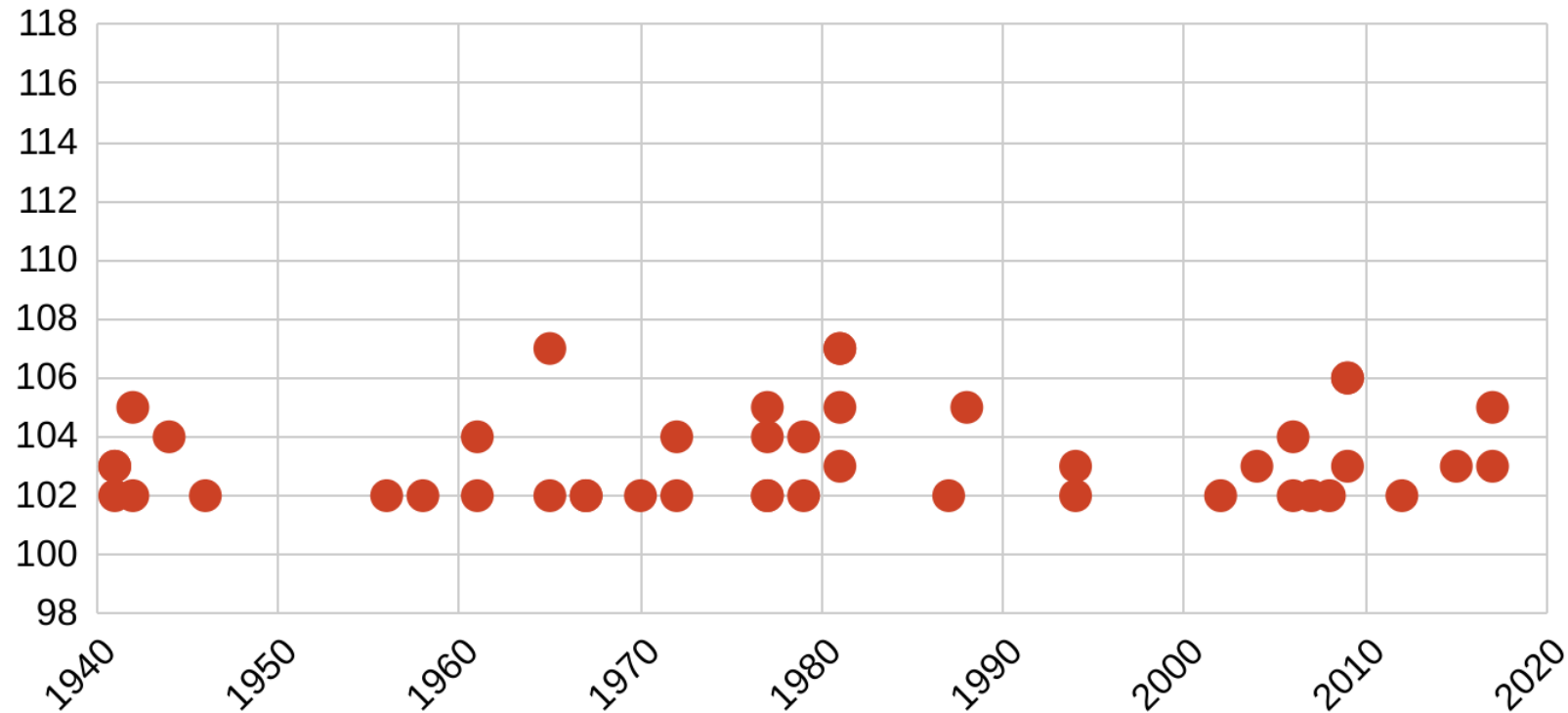


Image produced from NOAA projections by GLISA (Great Lakes Integrated Science + Assessments), derived from models in 2014 National Climate Assessment, [Midwest Chapter](#)

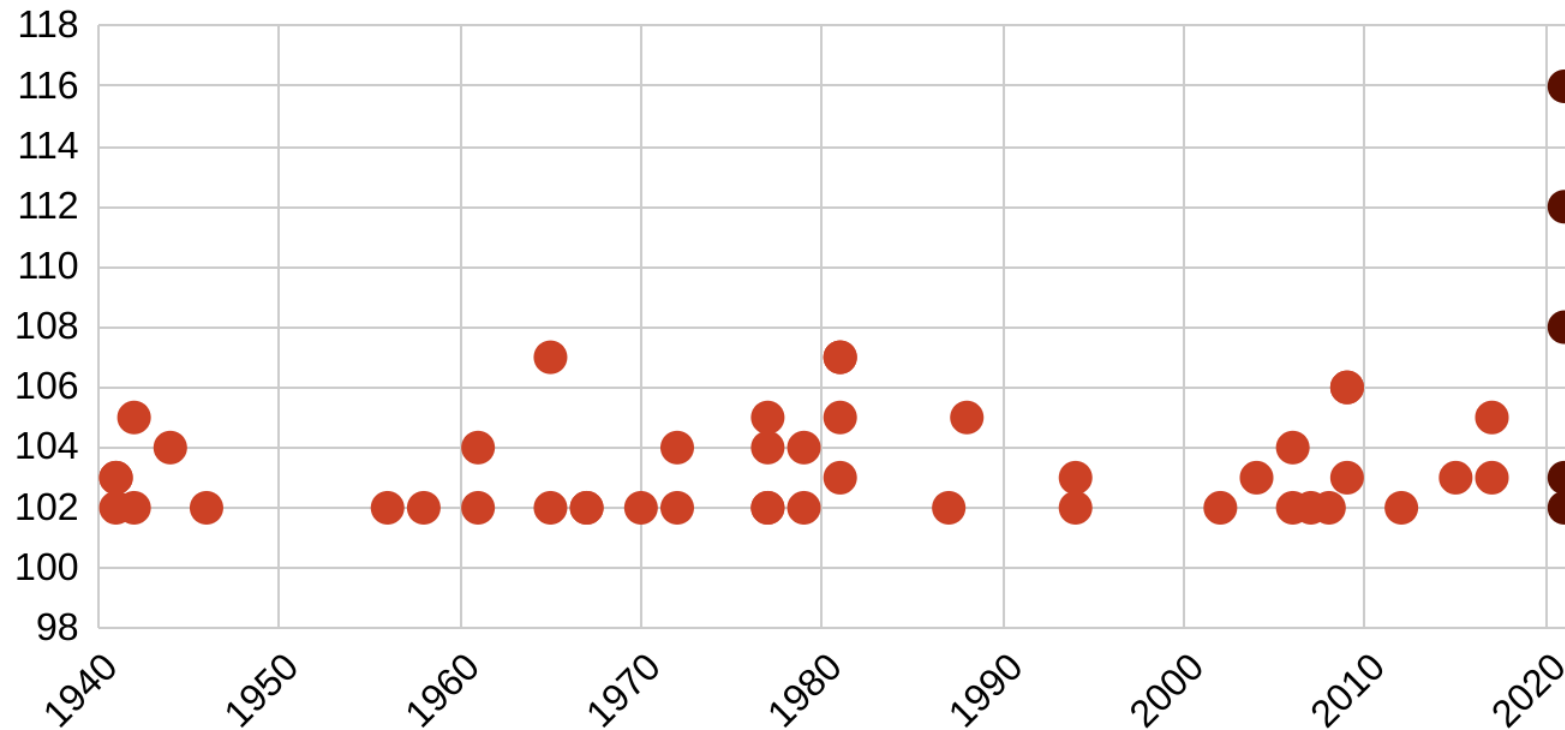
Expect Surprises Too

50 Highest Temperatures on Record, Portland, OR



New Heat Extremes May Arrive Abruptly

50 Highest Temperatures on Record, Portland, OR



These MN hazards are NOT becoming and SHOULD NOT become More Frequent, More Intense, Longer-Lasting, or Larger

“NOT WORSENING AND UNLIKELY TO DO SO”

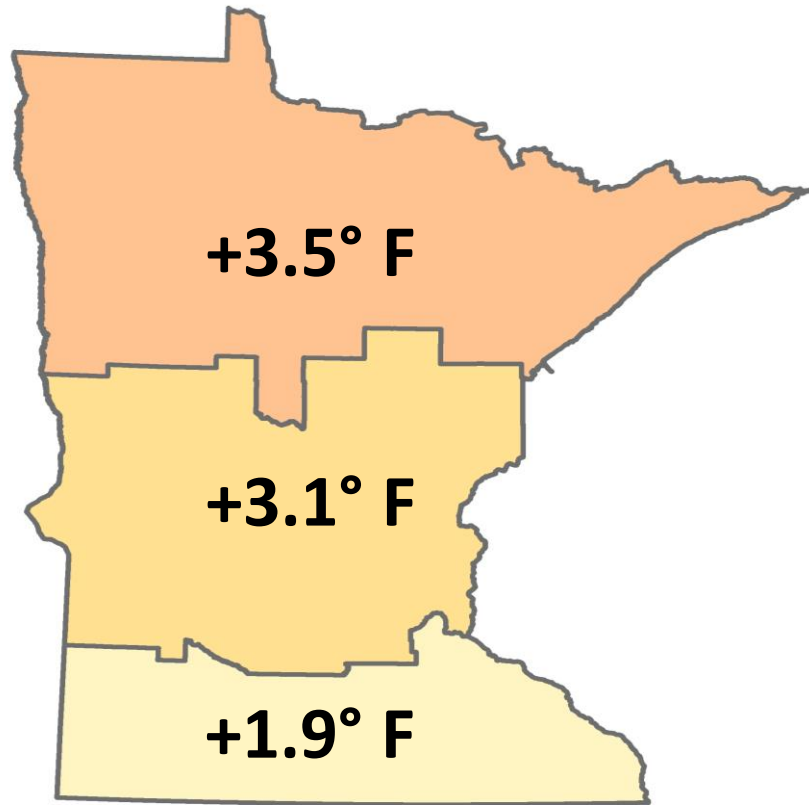
1. Low temperature and wind chill extremes (much less frequent, much less severe)
2. Counts of 0°, -20° or -40° F temperatures (strong decrease)

→Fastest-changing part of MN climate

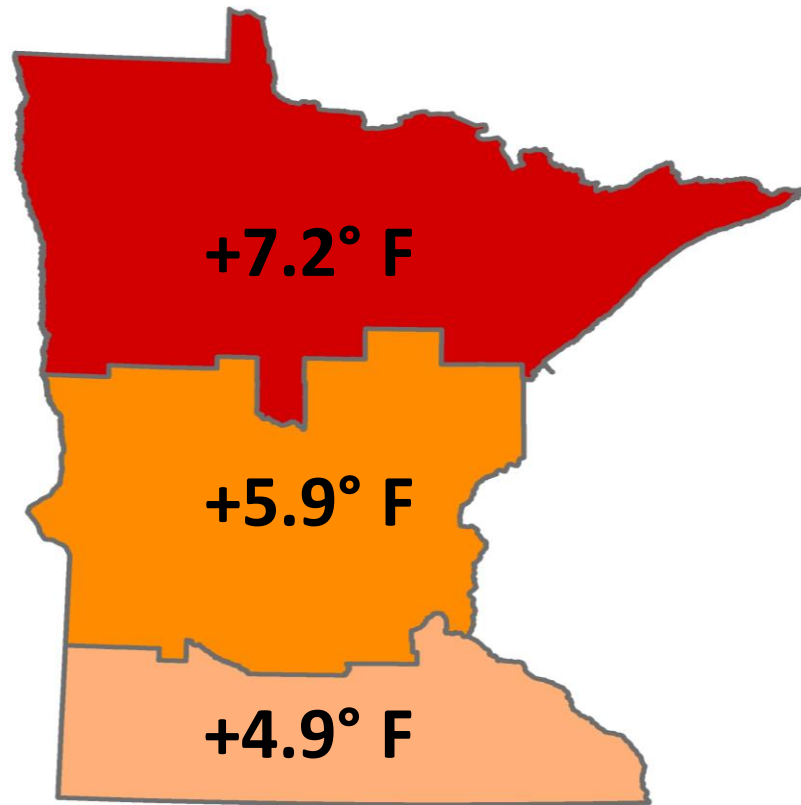
→***Climate tie-in: greenhouse effect always largest during winter so increased GHGs affecting cold conditions most***

Faster warming in winter, at night, and with northward extent

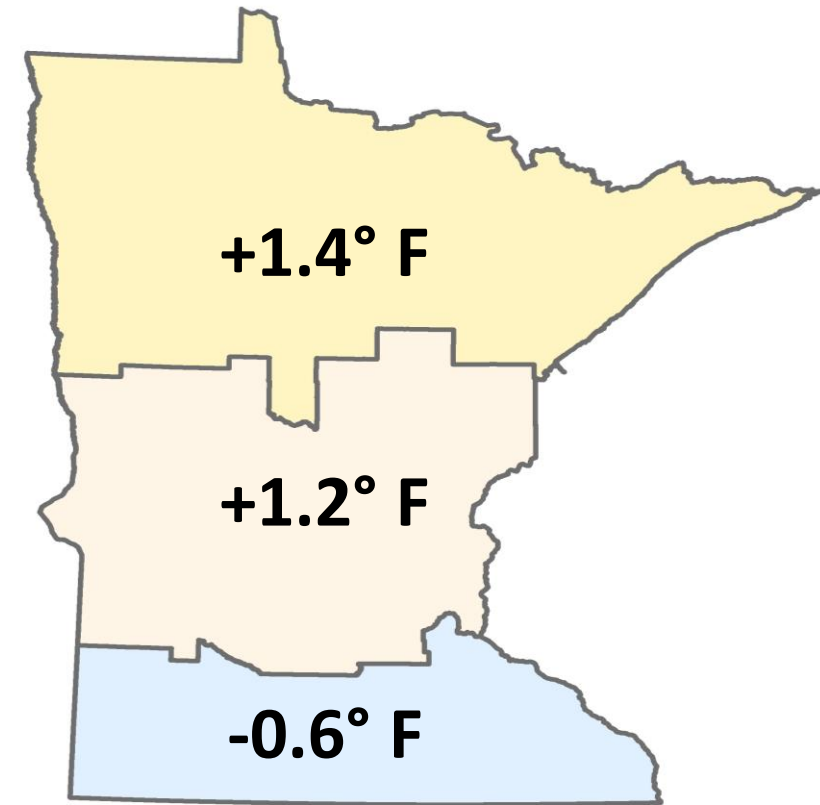
Total temperature change since 1895



Annual Average
(through 2022)



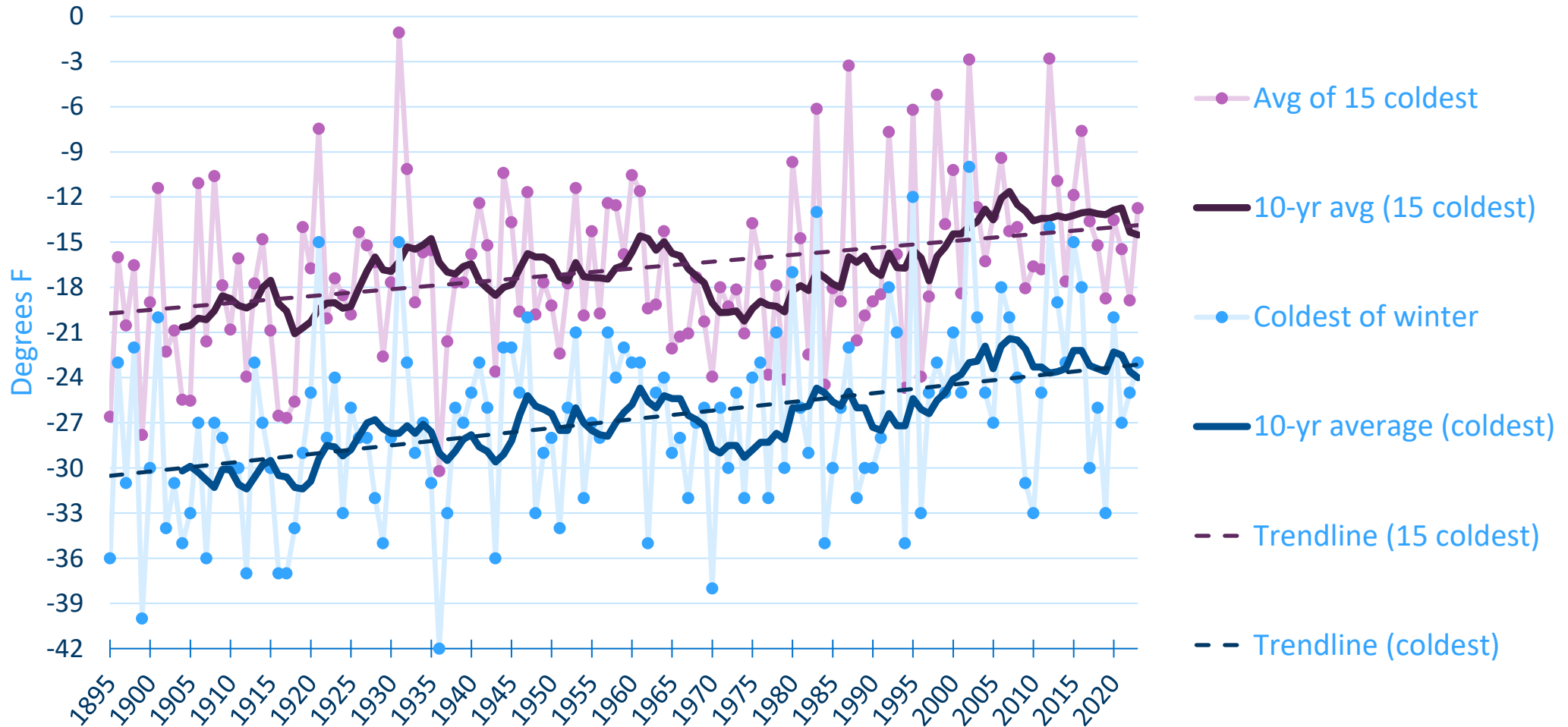
December - February
Lows (through 2023)



June - August Highs
(through 2023)

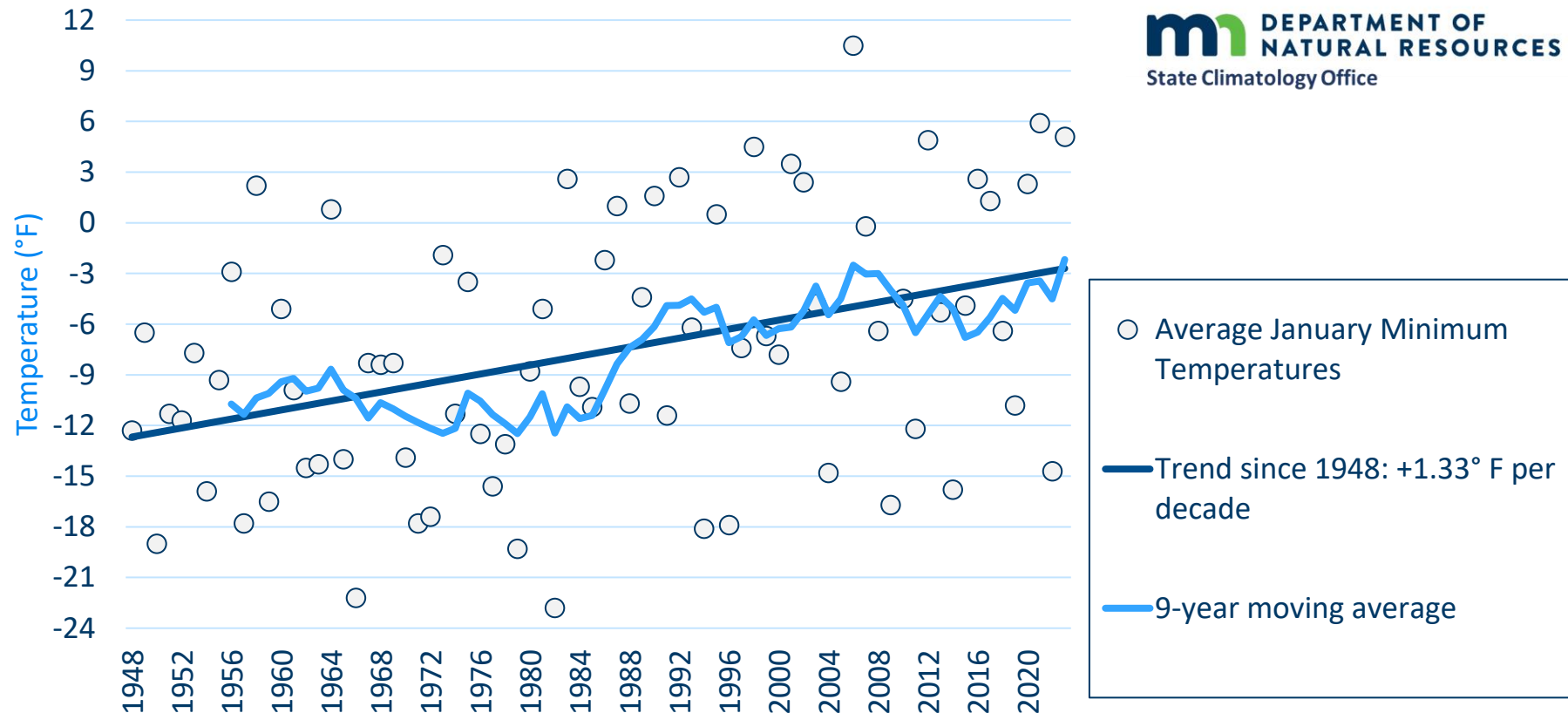
Fewer/lesser cold extremes

Lowest Lows of Winter, Milan (MN), 1895-2023

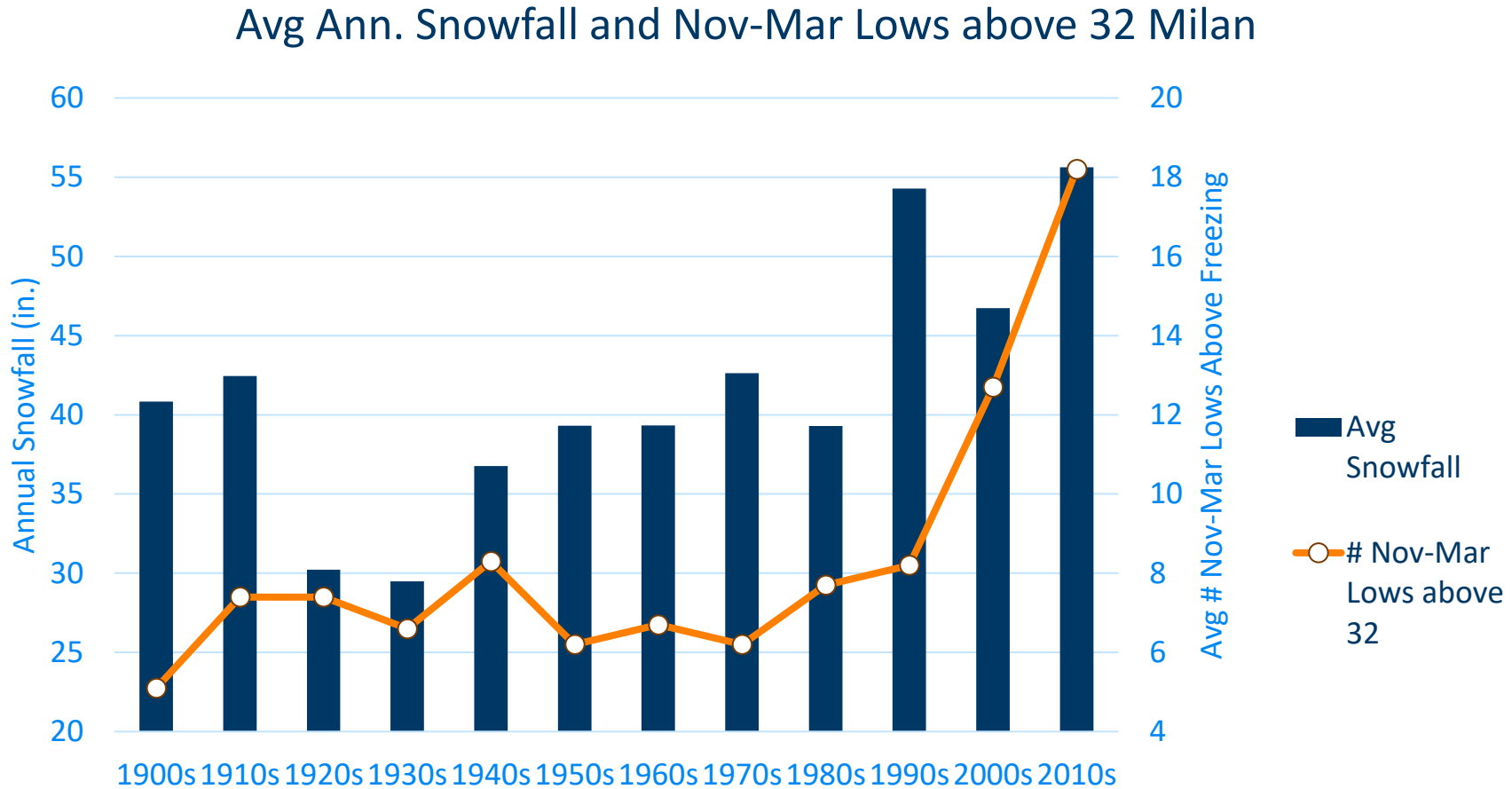


Typical Jan. night in International Falls now ~ 10° F warmer!

Average January Daily Minimum Temperatures International Falls, 1948-2023

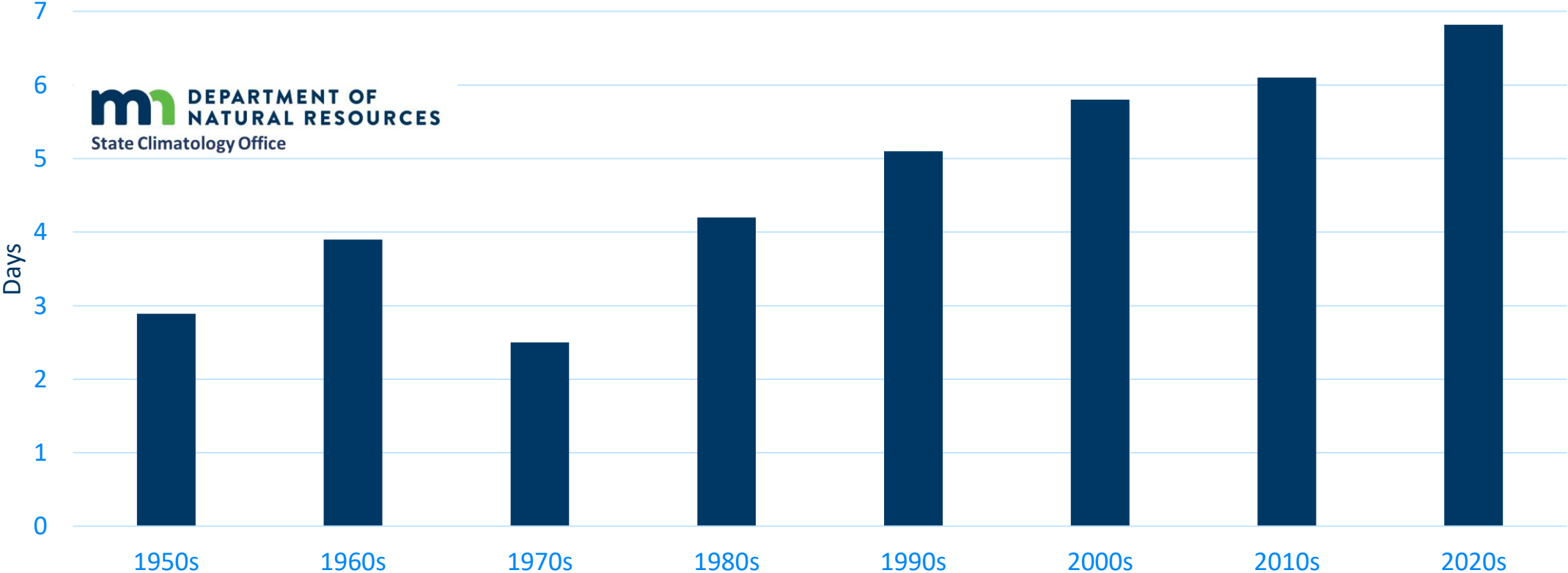


Combined trends: more snow AND more thaws



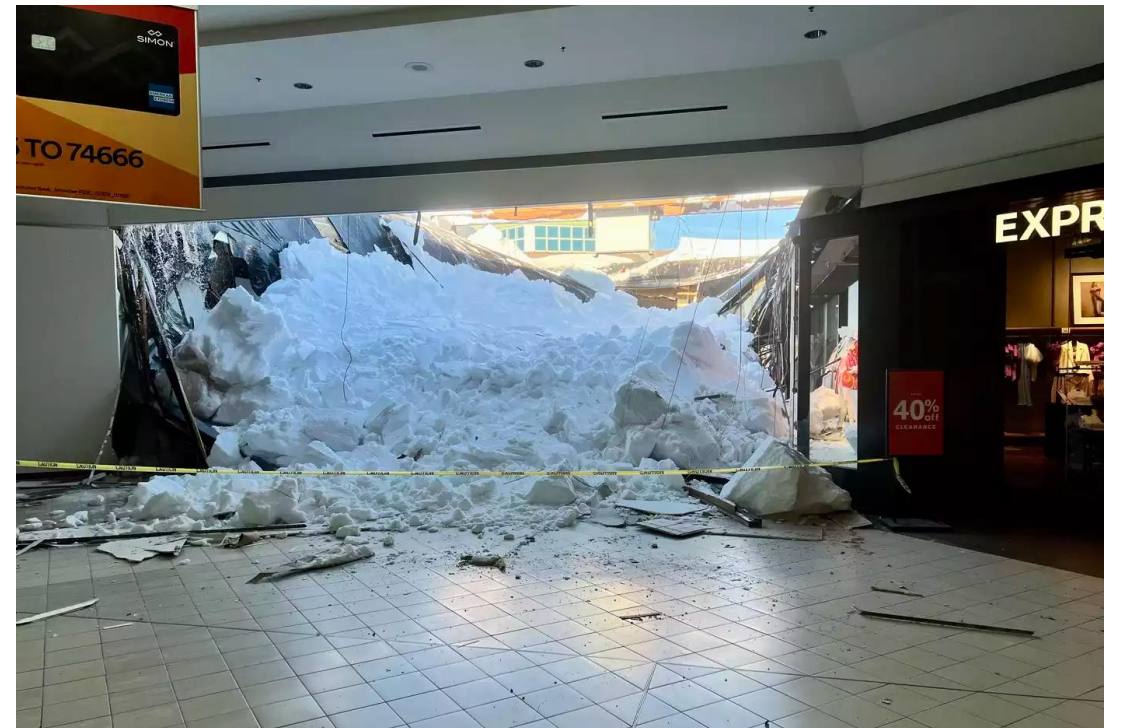
Winter Rain More Common

Annual Winter Rain Days (December – February), Twin Cities



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Wet Snow & Rain in Winter is a Problem



Scott Skar via MPR

These MN hazards are responding to non-climatic factors or unclear

“UNCERTAIN”

1. Severe Convective Storms (tornadoes, hail, derechos) not increasing

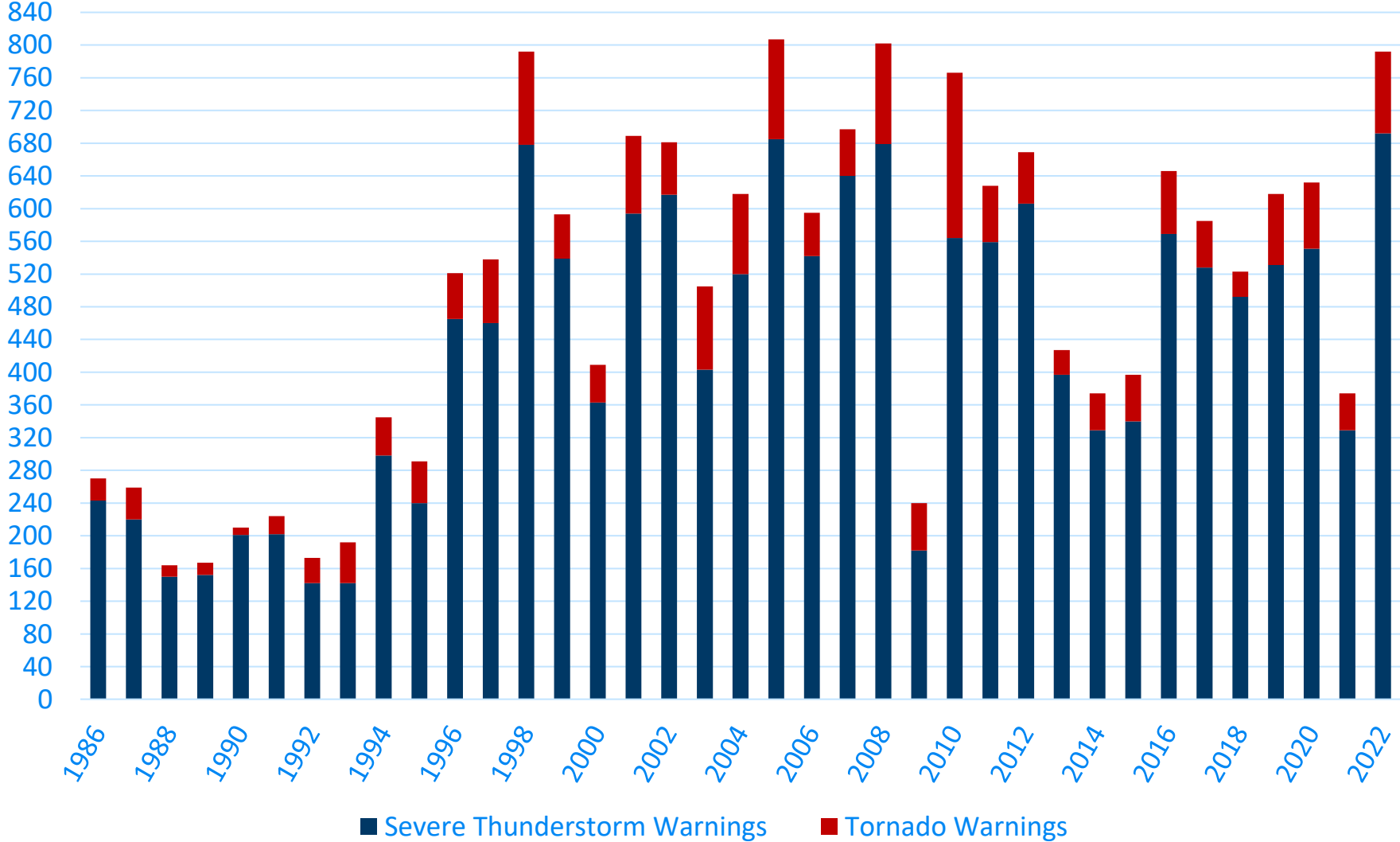
→ **Seasons expanding, however!**

2. Pressure gradient winds and mid-latitude cyclones

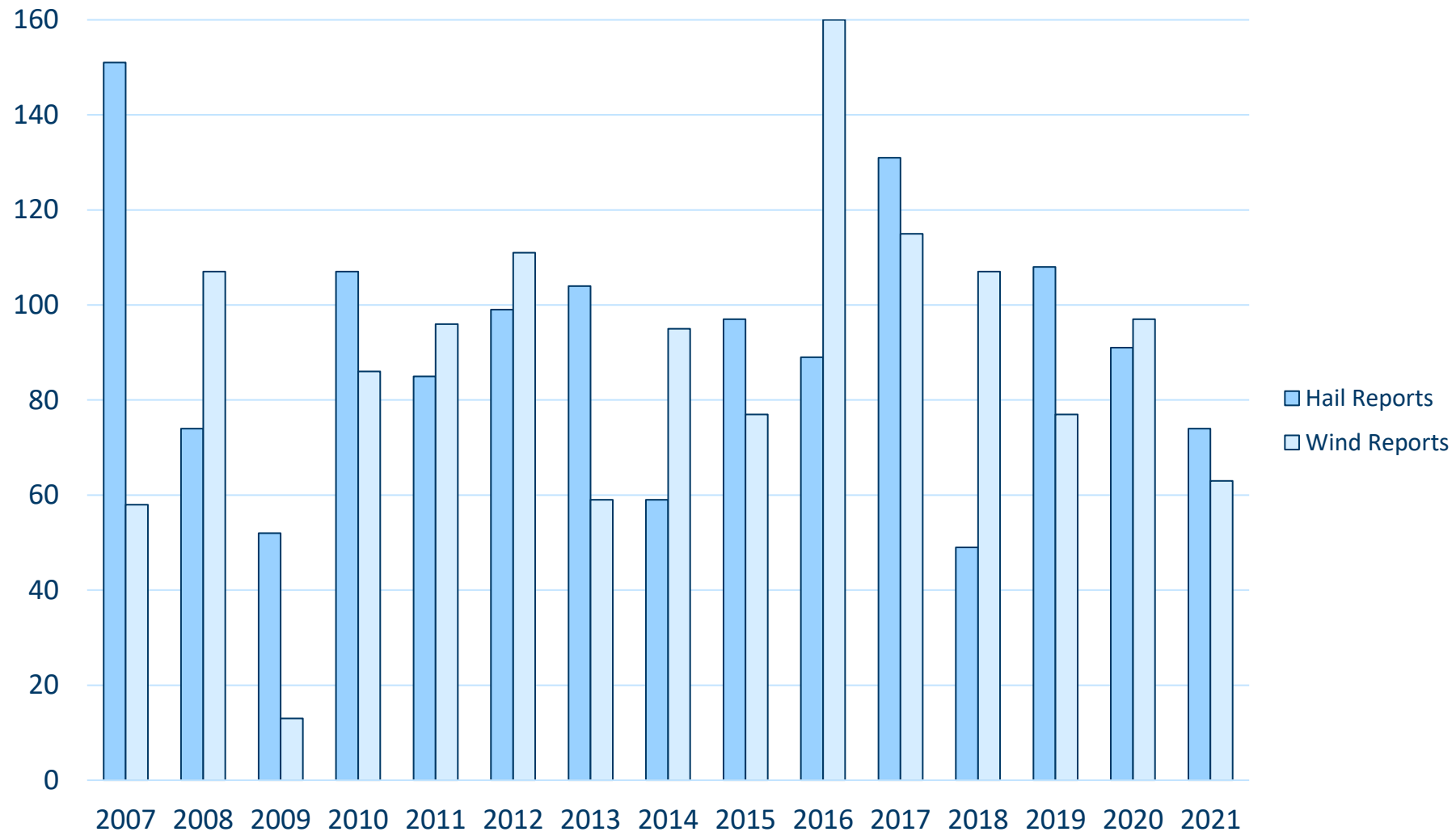
→ Apparent increases undermined by sensing/observational changes

→ ***Climate tie-in: Localized or regional hazards rely on localized/regional processes more so than global ones, but overall warming expands potential season***

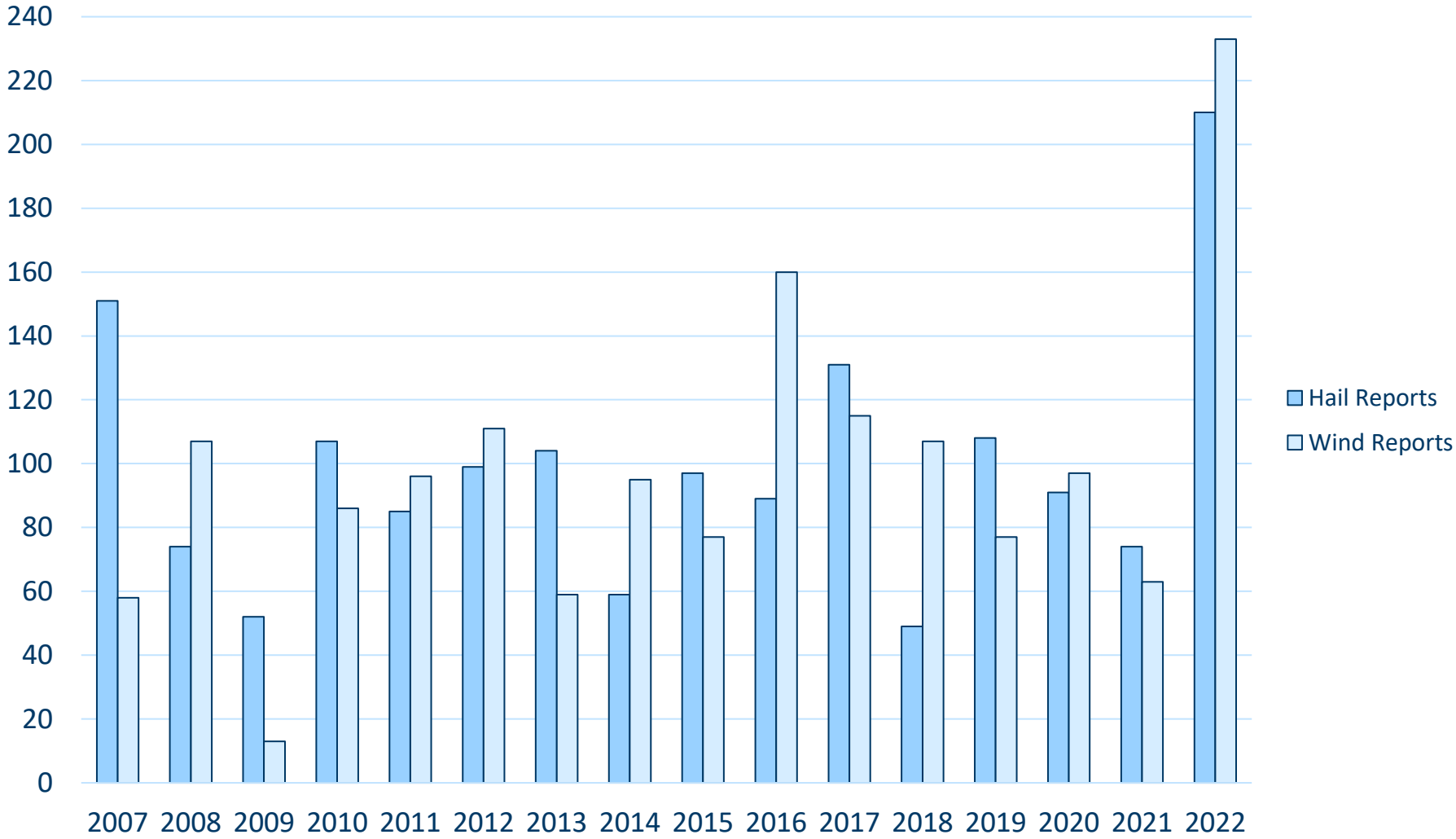
Severe Thunderstorm and Tornado Warnings for Minnesota By year



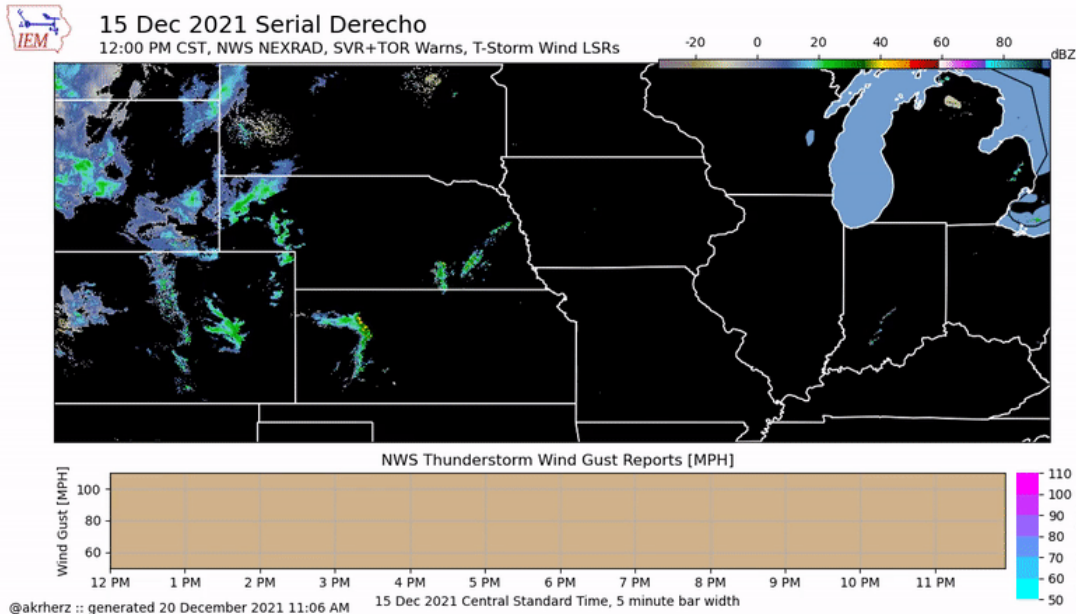
Annual Reports of Hail 1.5+ inches or Winds 60+ kts (~70 mph) Minnesota, 2007-2021



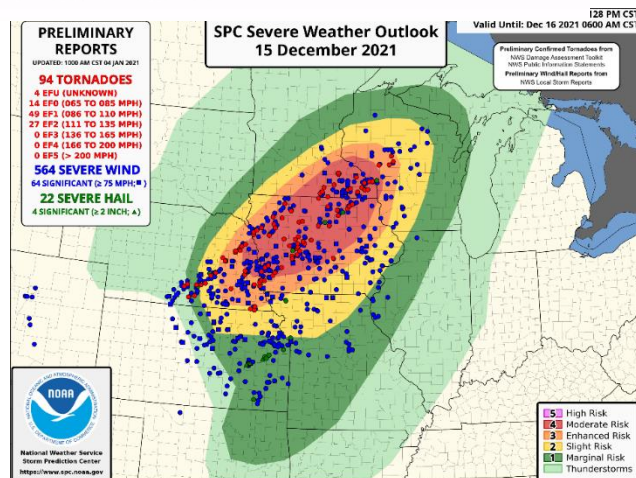
Annual Reports of Hail 1.5+ inches or Winds 60+ kts (~70 mph) Minnesota, 2007-2022



December 15, 2021: Tornadoes and derecho



- Severe weather season has expanded
 - Earlier (early March tornadoes)
 - Later (mid-December severe weather outbreak)
 - Northward (Boundary Waters tornado October 2021)
- Increased potential for hazard “cascades” following power outages



These MN hazards are secondary, combined, or “new”

“HYBRID or EMERGING”

1. Wildfire (not just from drought, but from ecological stress)
2. Degraded air quality (especially from wildfire smoke)

→ Normal hazards but becoming more likely

→ ***Climate tie-in: warm winters and altered hydrothermal budgets pushing some forests/vegetation beyond tolerances***



Courtesy: Greta Kaul

Important considerations

- Episodic precipitation extremes increasing in all seasons and likely to continue
 - Damage from flash floods, excessive snow, compound snow/rain loading
- Future (mid-century and beyond) likely to include historic and unprecedented heat extremes and cooling needs
- Although tornadoes, straight-line winds, and large hail have unclear trends, “cascading hazards” related to them likely because of seasonal expansion

In Summary

1. Minnesota experiencing wettest period on record, with more frequent and larger extremes, even when accounting for current drought
2. Also warming rapidly, with profound increases during winter
3. Further increases in precipitation/extremes, warming, and potentially major heat extremes on the way, with more significant drought as increased heat kicks in
4. Severe weather season is expanding
5. Wildfire and degraded air quality are new/emerging hazards

Thank You!

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