Weather, Climate Change, and Impacts in Minnesota

Dr. Mark Seeley
Department of Soil, Water, and Climate
University of Minnesota
St Paul, MN 55108

“Morris Area Climate Dialogue”
Jefferson Center and IATP
June 12, 2014
Morris, MN

UNIVERSITY OF MINNESOTA
EXTENSION


102 degrees F at Crookston, MN
June 12, 1893


-23 degrees F at Remer, MN
June 12, 1985


8” thunderstorm rainfall
at Minnesota City, MN
June 12, 1899


Ice pack in Duluth Harbor
finally breaks up
June 12, 1917

TOPICS

Brief History

Climate Change Disparities

Changing Minnesota Climate Features

Climate Consequences

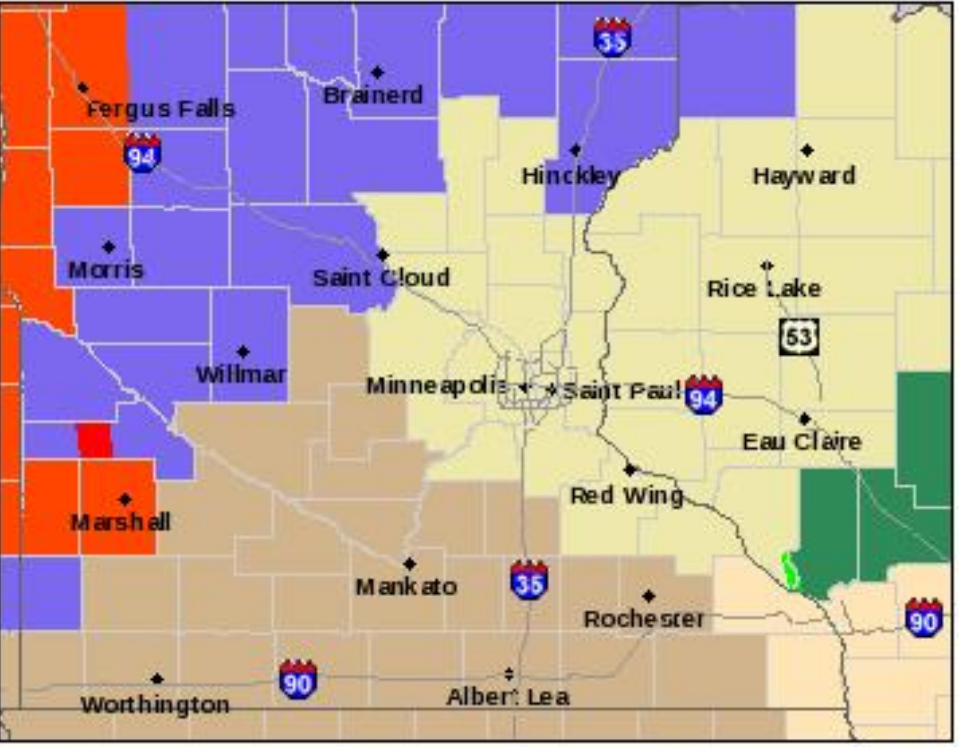
Comments on Extremes

Chronology of Minnesota Weather and Climate-Related Disasters: A sample listing since 1976

1976 Drought-Creation of Extension Climatologist Faculty Position
1978 flash floods in Rochester area (Zumbro R. July and Sept)
1979 flooding, late planting, delayed harvest
1980 drought in western MN counties
Threat of snow loads in winters of 1981-82, 1983-84. 2000-2001, 2010-2011
1983, 1995, 1999, 2001, 2005, 2011 Heat Waves (Health and Livestock Stress)
1984 drought in western Minnesota
1987 , 1989, 2013 severe winterkill of forage crops
1988 drought statewide*
1989 Red River spring flooding
1991 floods in southern Minnesota
1992 Chandler tornado
1993 floods on Minnesota and Mississippi Rivers
1995 derecho Itasca State Park and heat wave
1997 statewide spring floods*
1998 March tornado outbreak in southern MN*
1999 derecho in BWCA and heat wave
Denotes over $1 billion in losses

Chronology of Minnesota Weather and Climate-Related Disasters: A sample listing (continued)

2000 Granite Falls Tornado
2001 spring floods on Minnesota and Mississippi Rivers
2002 flash floods in northern Minnesota
2004 flash floods in southern Minnesota
2007 Flash floods in SE Minnesota (simultaneous with drought)
2005-2012 Drought response every summer
2009 Red River spring snow melt flooding (66 days Moorhead)
2010 Tornado Outbreak (48 on June 17th, 113 total), Red River Flooding
2011 Red River Flooding/Hennepin/Anoka Tornadoes
2012 Flash floods Cannon River and Duluth (simultaneous with drought)
2013 Winterkill, April Ice Storm, Prevented Planting from a wet spring

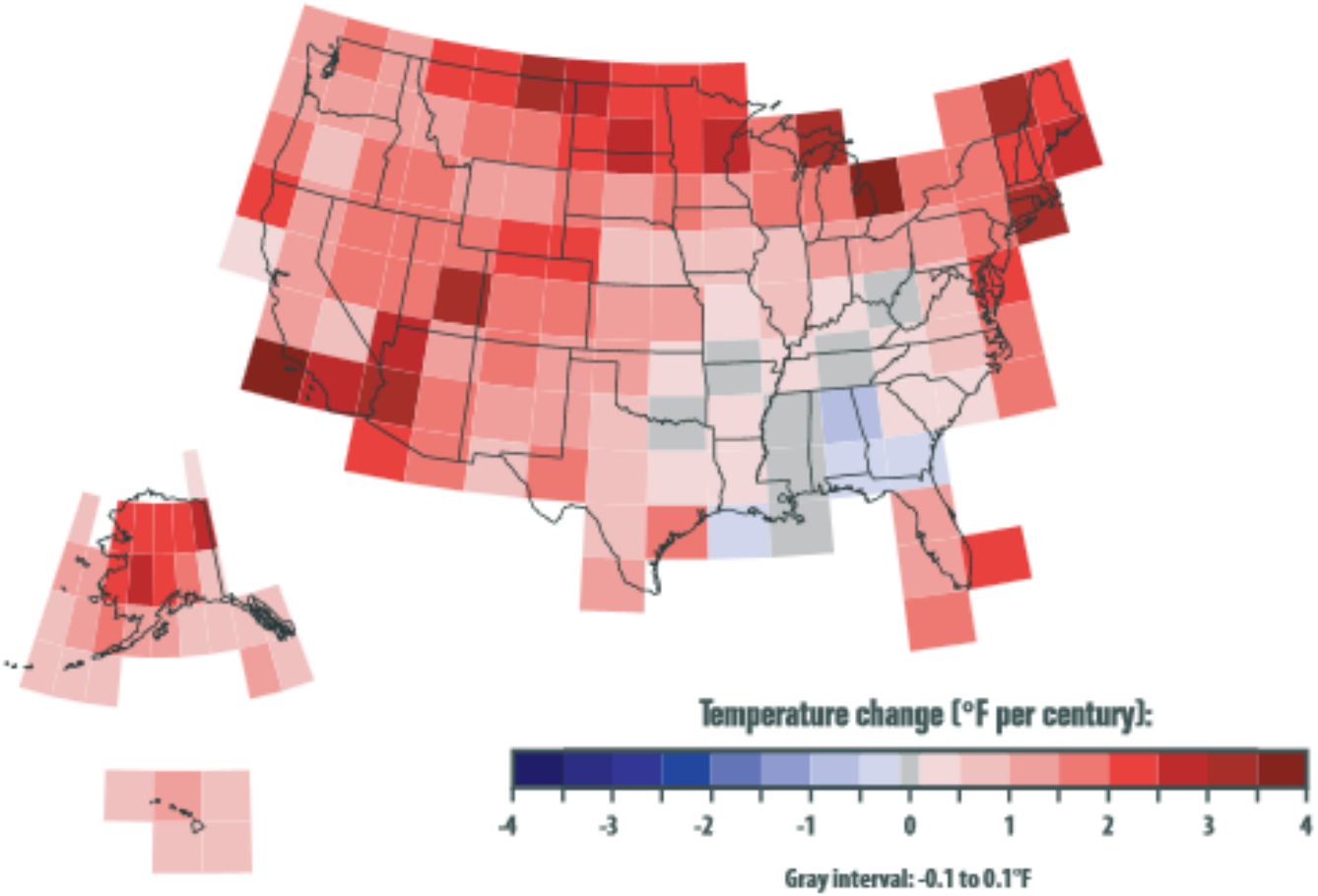


A Weather Singularity

Tornado Warning and Tornado Warning in Lac Qui Parle County on March 31, 2014

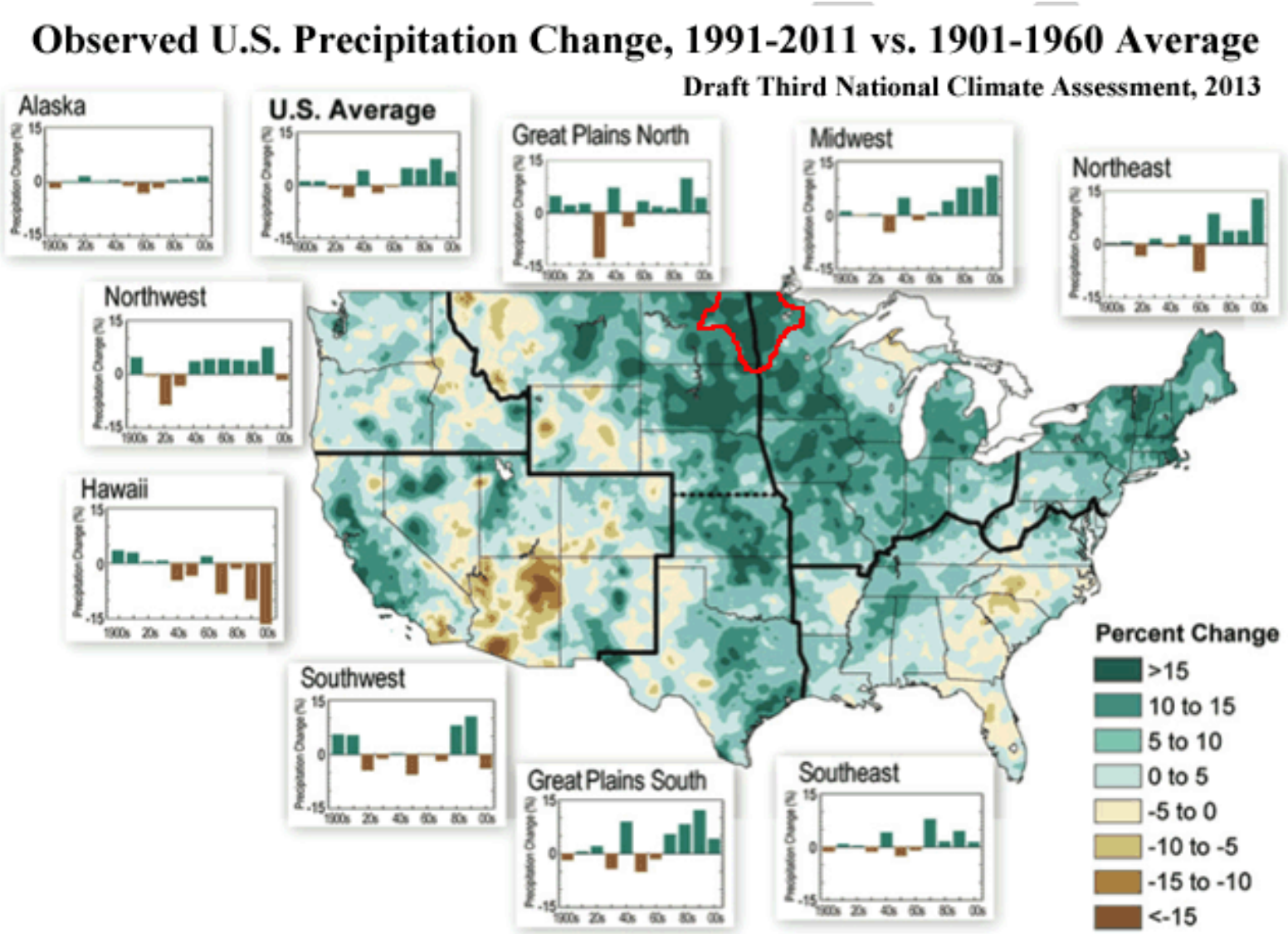
Figure 3. Rate of Temperature Change in the United States, 1901–2008

This figure shows how average air temperatures have changed in different parts of the United States since the early 20th century (since 1901 for the lower 48 states, 1905 for Hawaii, and 1918 for Alaska).

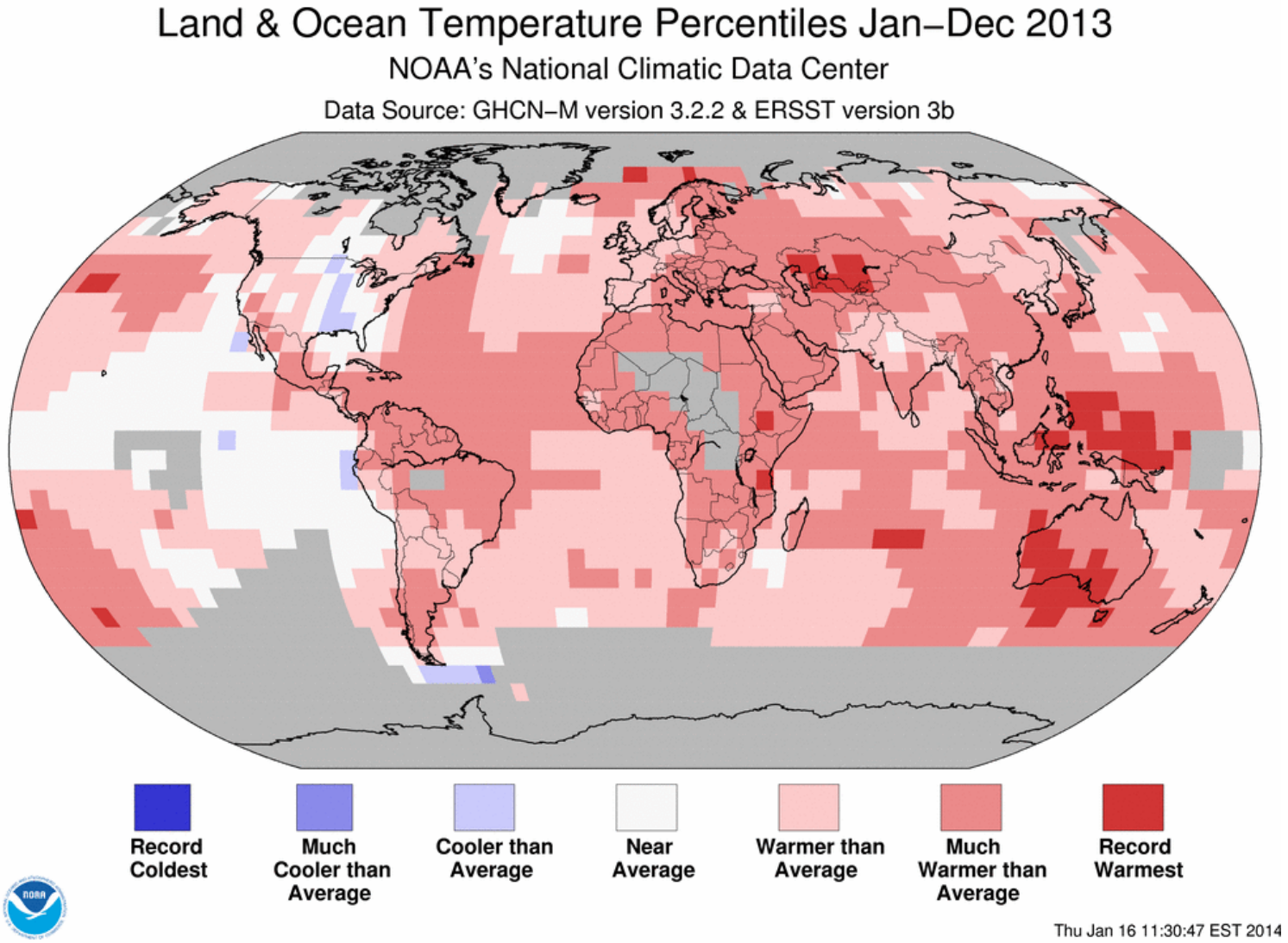


Data source: NOAA, 2009*

Disparity in the pace of climate change and the response to it



Geographic Disparity in Precipitation Change-IPCC 2013

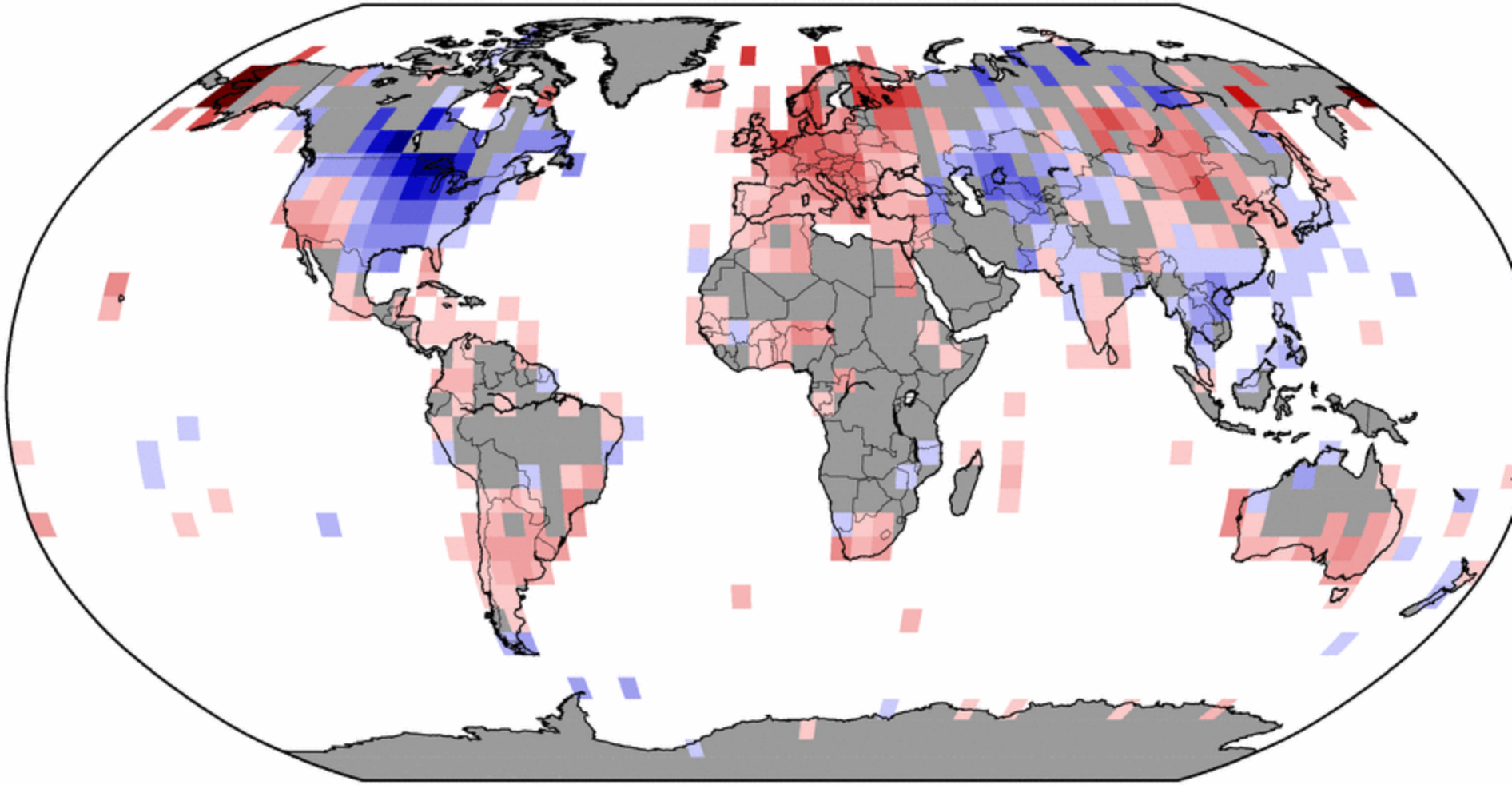


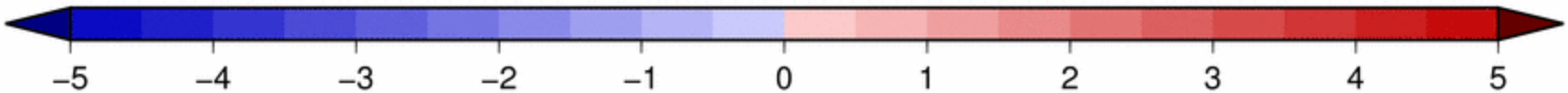
Globally averaged annual temperature for 2013 tied for the 4th warmest year since 1880 and was the 37th consecutive year with a global average that was above the 20th Century mean.

Land–Only Temperature Anomalies Dec 2013–Feb 2014

(with respect to a 1981–2010 base period)

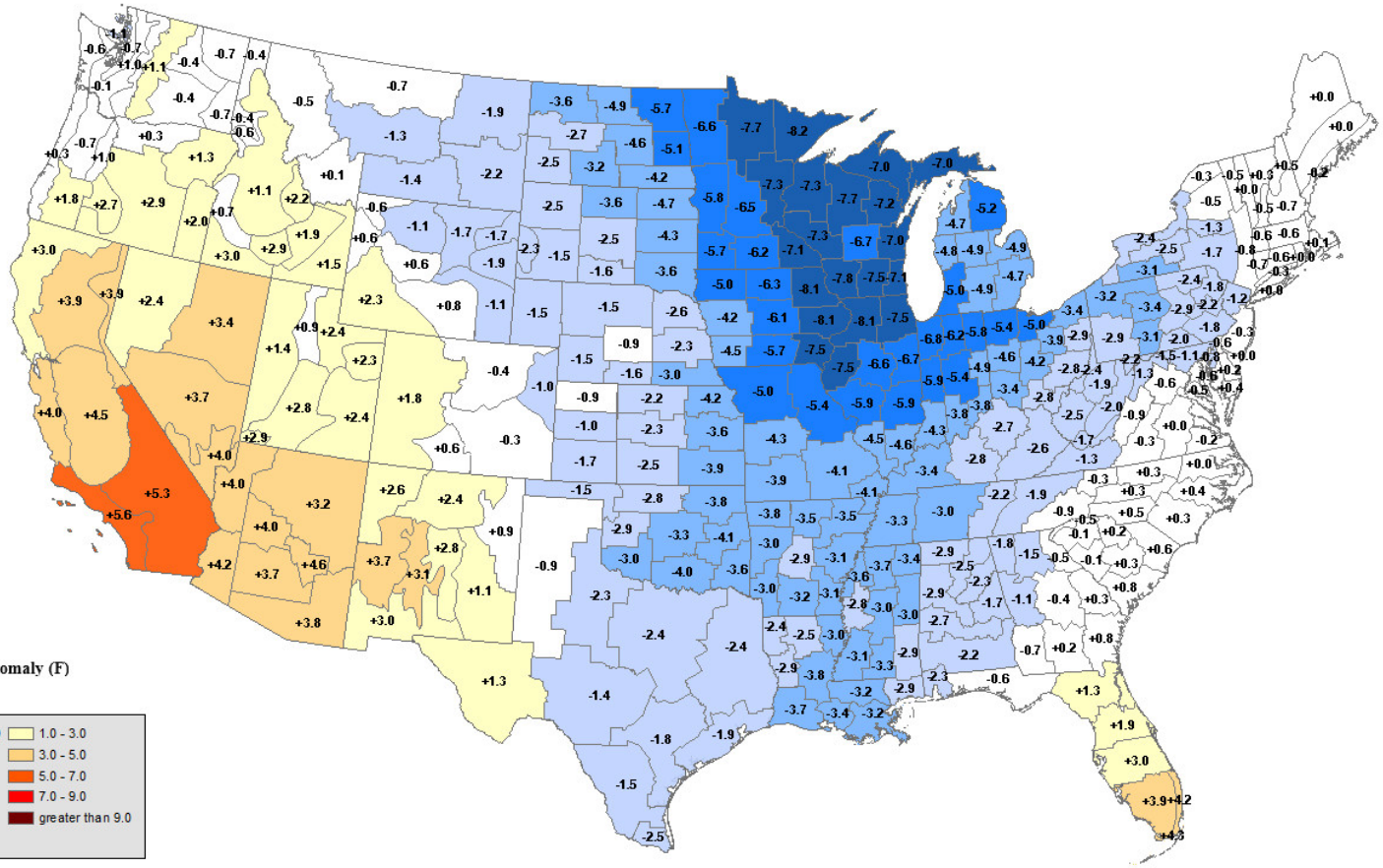
Data Source: GHCN–M version 3.2.2





Degrees Celsius

Divisional Average Temperature Anomalies
December 2013 - February 2014



Temperature Anomaly (F)

less than - 9.0	1.0 - 3.0
-9.0 - -7.0	3.0 - 5.0
-7.0 - -5.0	5.0 - 7.0
-5.0 - -3.0	7.0 - 9.0
-3.0 - -1.0	greater than 9.0
-1.0 - 1.0	

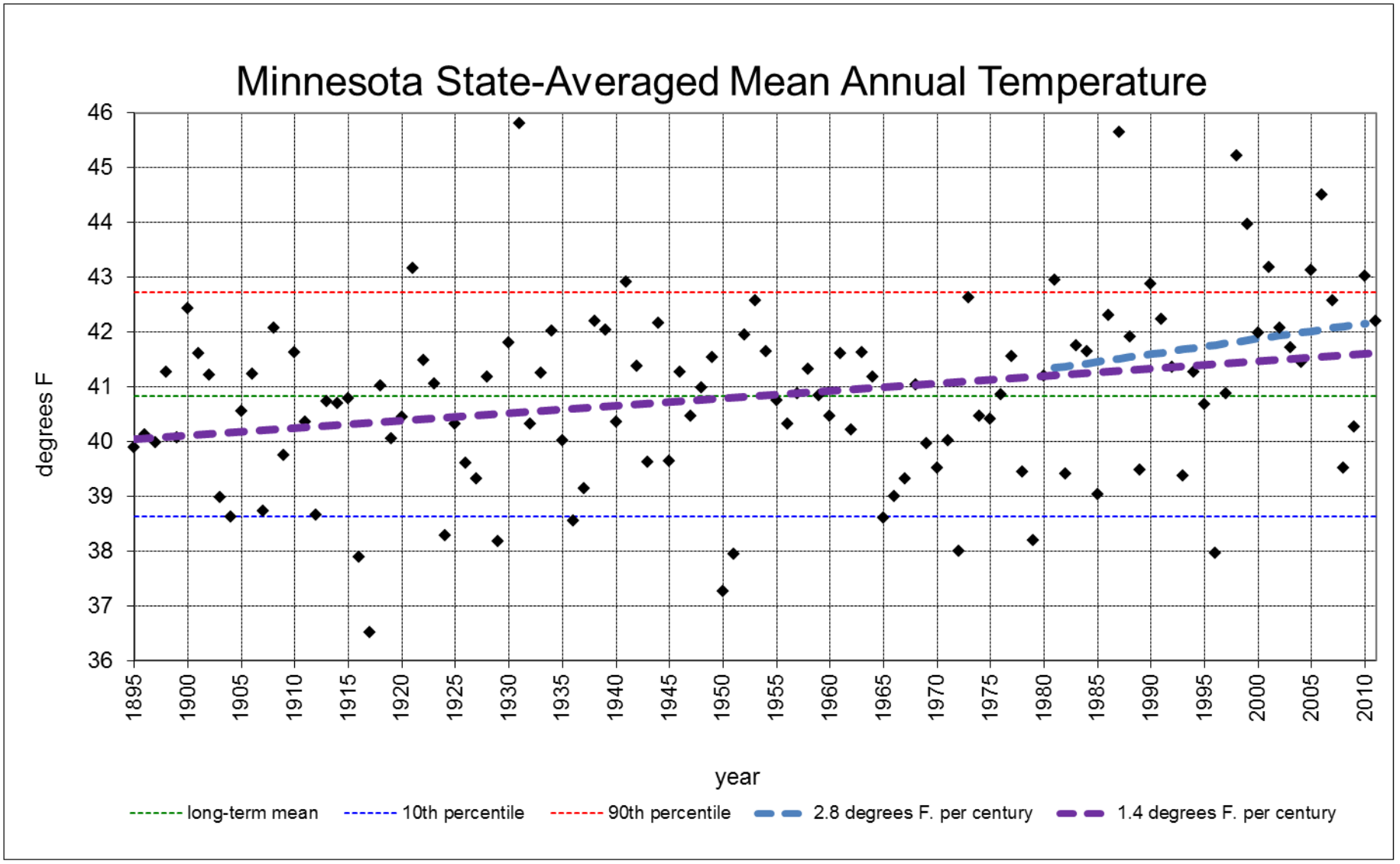
NOAA / NCDC

RECENT SIGNIFICANT CLIMATE TRENDS IN MINNESOTA AND THE WESTERN GREAT LAKES

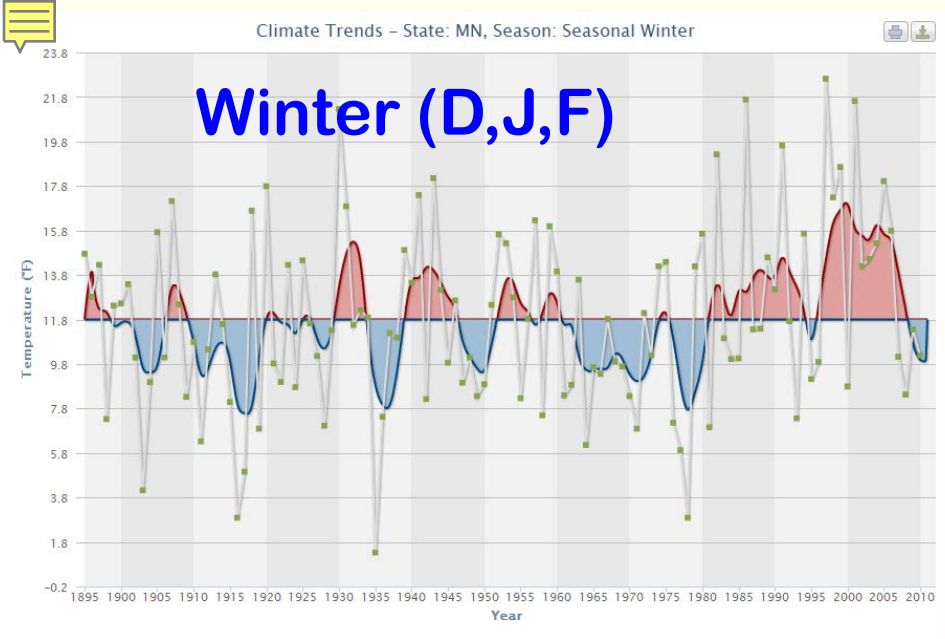
- *TEMPERATURE*: WARM WINTERS AND HIGHER MINIMUM TEMPERATURES

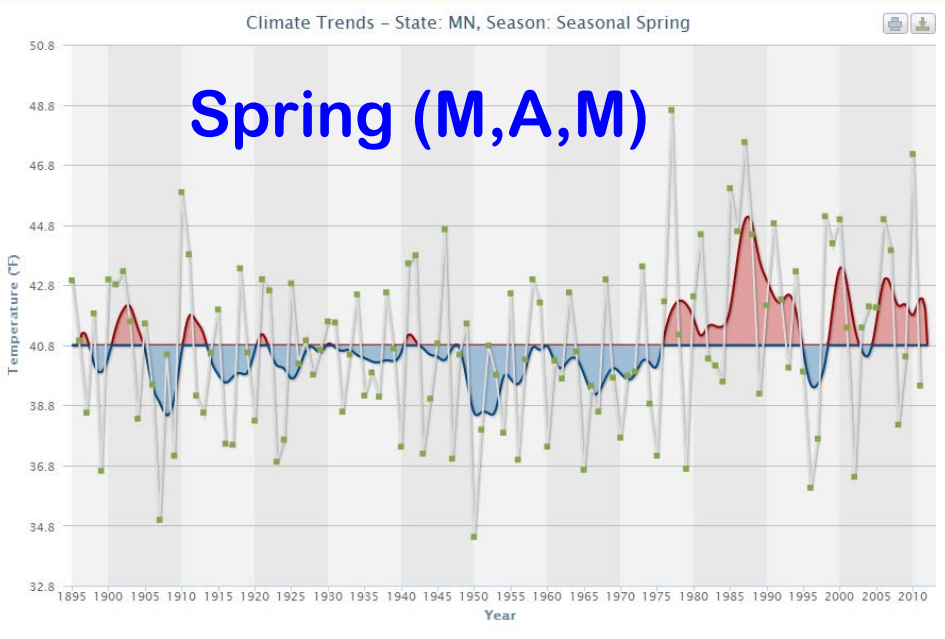
- *DEWPOINTS*: GREATER FREQUENCY OF TROPICAL-LIKE ATMOSPHERIC WATER VAPOR

- *MOISTURE*: AMPLIFIED PRECIPITATION SIGNAL, THUNDERSTORM CONTRIBUTION

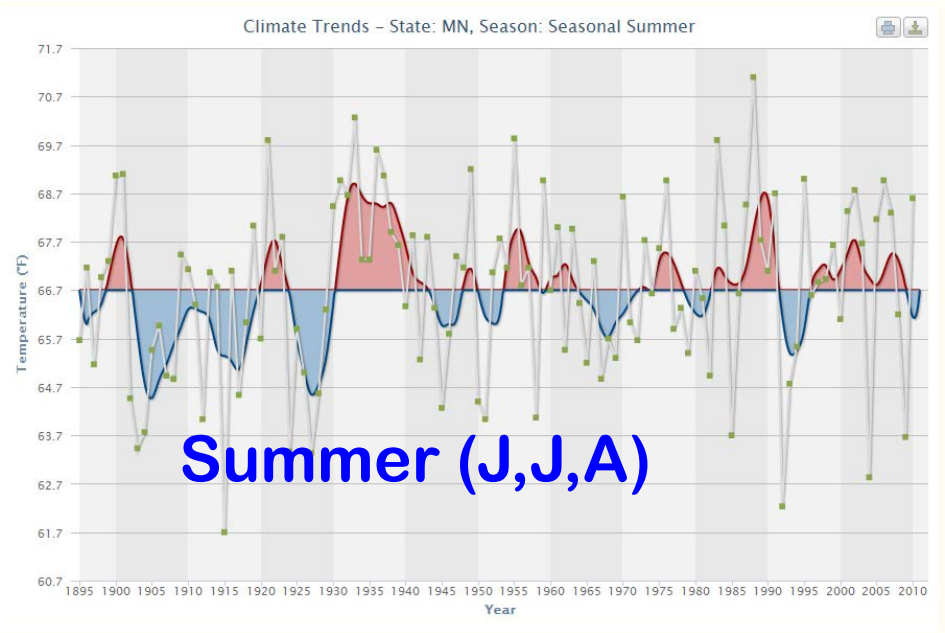


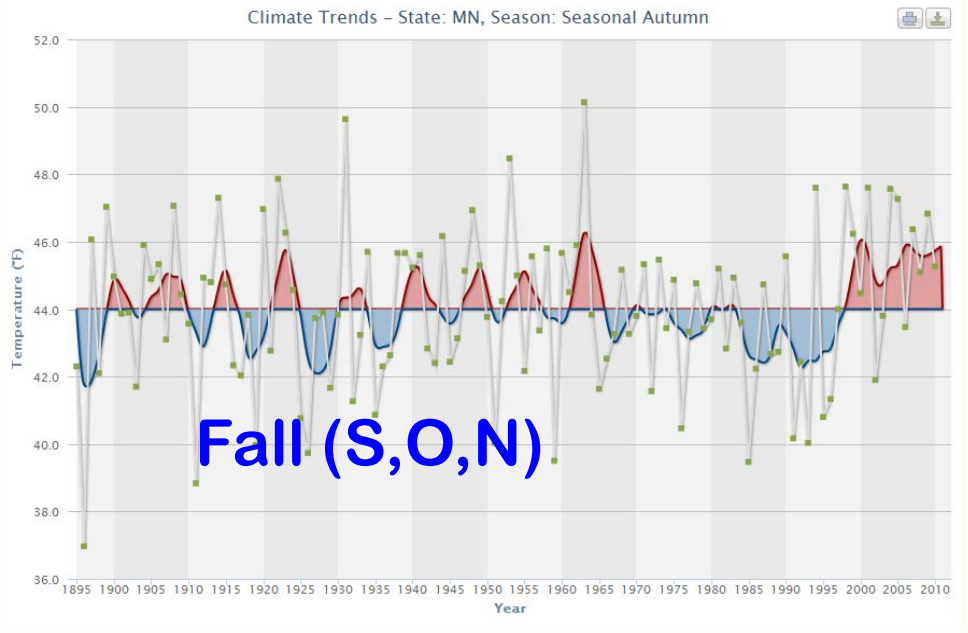
Temp trend is upward and more frequently above the 90th percentile





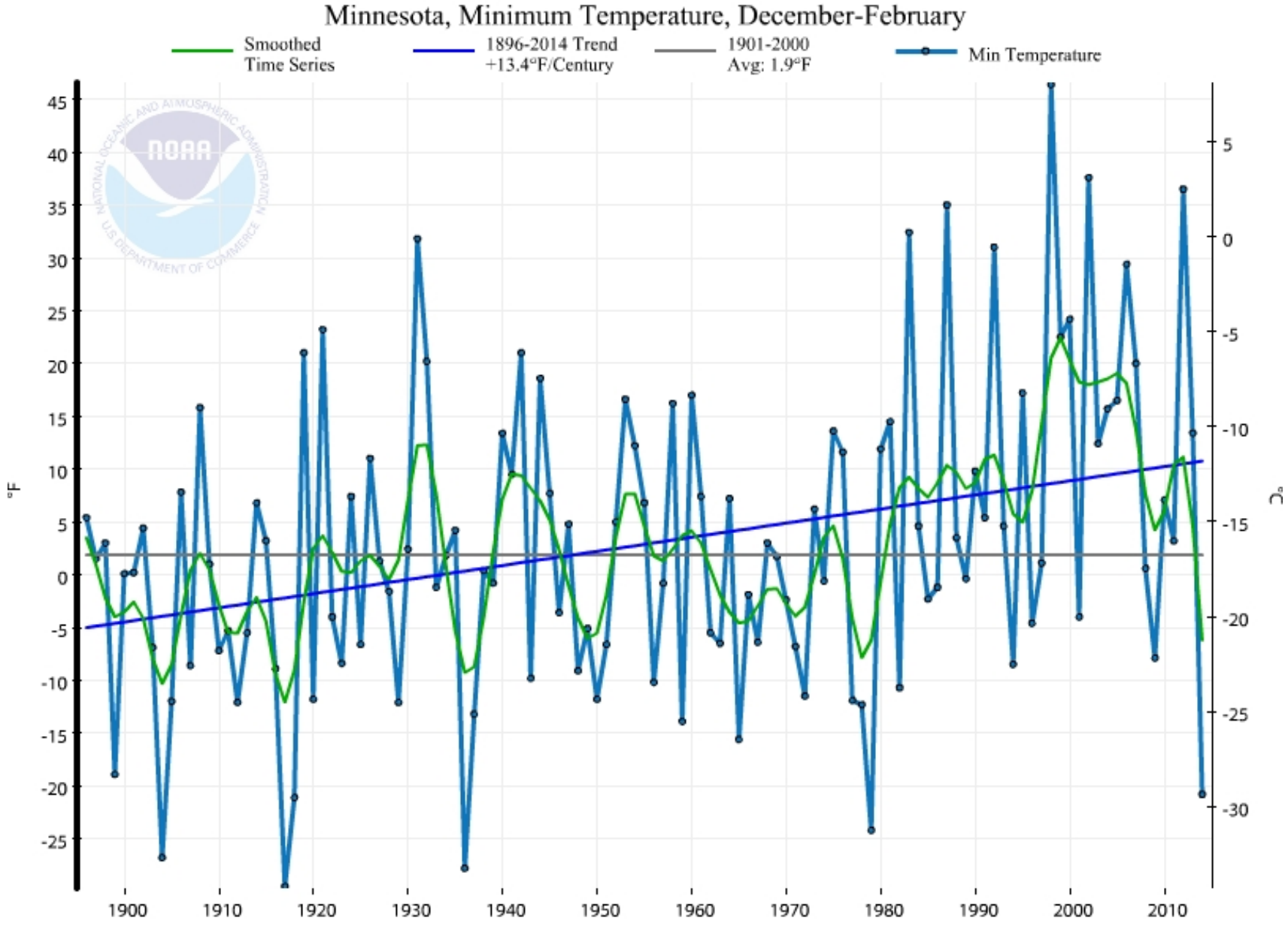
Seasonal Temperature Trends in MN





Historical ranking and distribution of statewide mean daily temperature over the past 17 heating seasons (Nov-Mar) in MN: 1=warmest

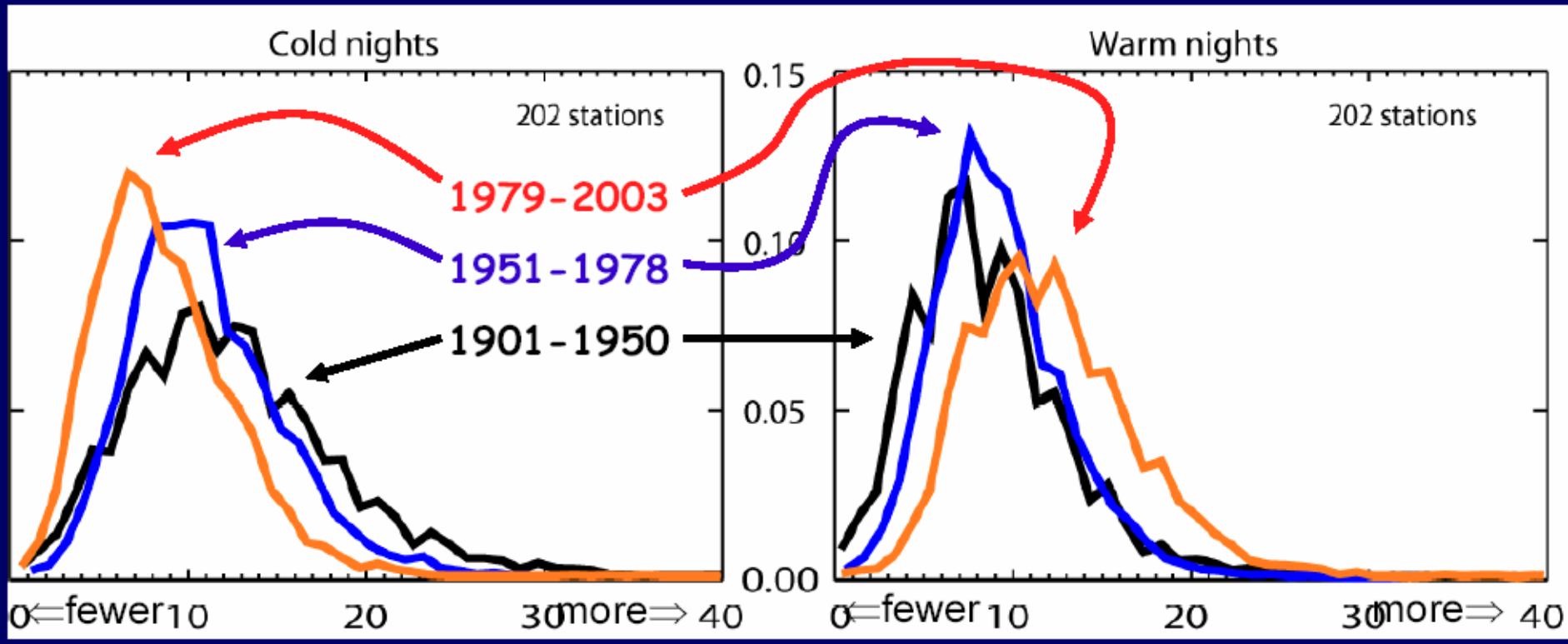
Winter	Mean Temp (F)	Ranking (since 1895- 120 years)
1997-1998	24.2	4th
1998-1999	23.0	8th
1999-2000	26.0	2nd
2000-2001	15.8	79th
2001-2002	25.0	3rd
2002-2003	19.3	34th
2003-2004	20.3	23th
2004-2005	21.2	16th
2005-2006	23.2	7th
2006-2007	22.3	11th
2007-2008	16.9	63rd
2008-2009	16.4	69th
2009-2010	21.5	13th
2010-2011	17.1	61st
2011-2012	27.8	1st
2012-2013	18.6	40th
2013-2014	11.7	113th


Minnesota, Minimum Temperature, December-February
Smoothed Time Series
1896-2014 Trend +13.4°F/Century
1901-2000 Avg: 1.9°F
Min Temperature
°F
°C
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
5
0
-5
-10
-15
-20
-25
-30
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Trends in average winter minimum temperatures Milan, MN

Period of Record	Ave Min Temp in Deg. F
1951 - 1980	Jan -4.3
1961 - 1990	Jan -0.9
1971 - 2000	Jan 0.3
1981 - 2010	Jan 3.7
1951 - 1980	Feb 2.3
1961 - 1990	Feb 5.3
1971 - 2000	Feb 8.2
1981 - 2010	Feb 9.3
1951 - 1980	Mar 15.1
1961 - 1990	Mar 19.2
1971 – 2000	Mar 21.0
1981 - 2010	Mar 22.0

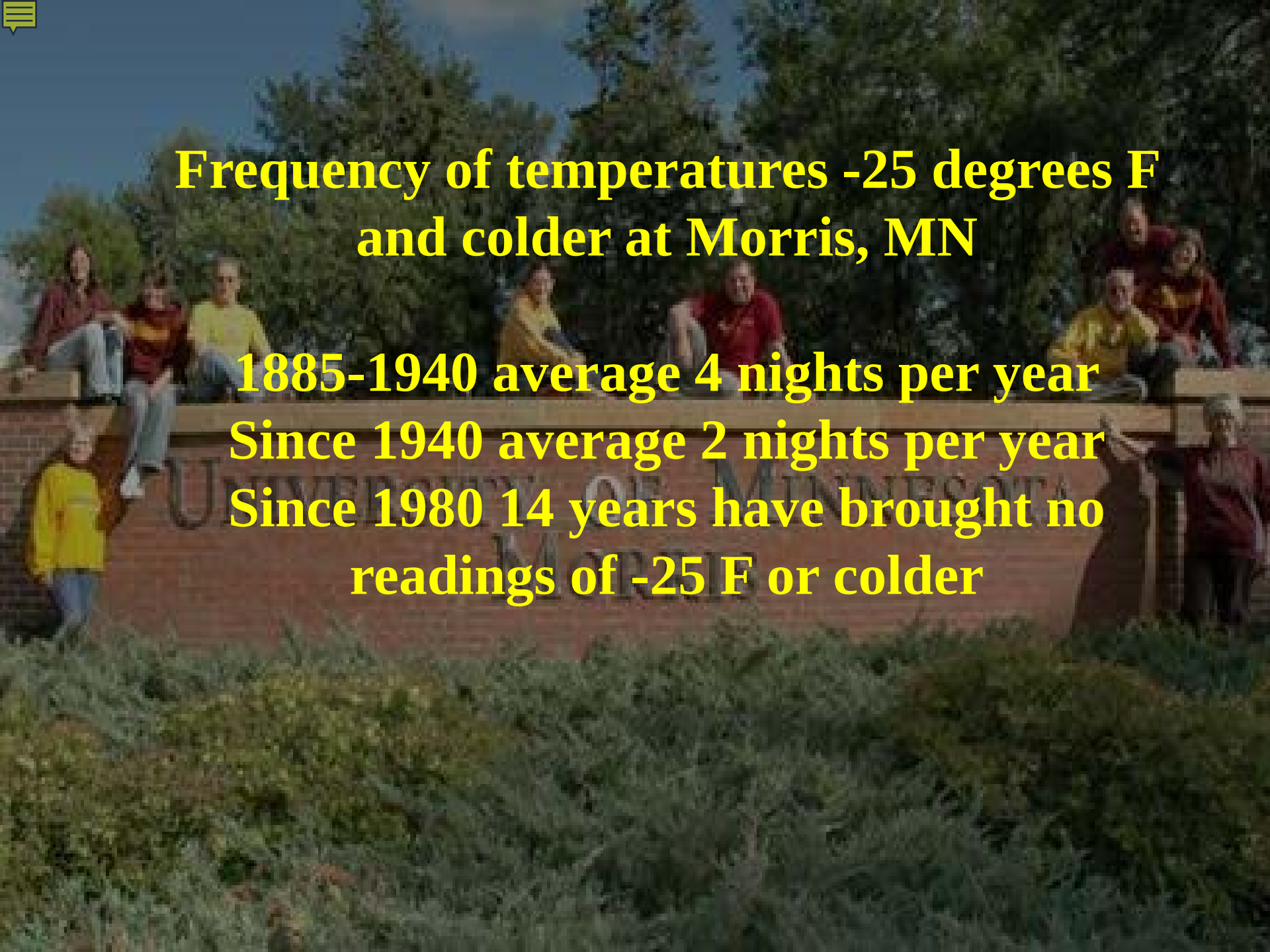
Warm nights are increasing; cold nights decreasing



IPCC-2007

Frequency of occurrence of cold or warm temperatures for 202 global stations for 3 time periods:
1901 to 1950 (black), 1951 to 1978 (blue) and 1979 to 2003 (red).

Warming is weighted towards minimum temperature change



Frequency of temperatures -25 degrees F and colder at Morris, MN

1885-1940 average 4 nights per year
Since 1940 average 2 nights per year
Since 1980 14 years have brought no readings of -25 F or colder

Trends in mean monthly temperatures at St Cloud, MN 1971-2000 normals vs 1981-2010 normals (F)

Month	Min Change	Max Change	Mean Change
January	+3.0	+2.7	+2.8
February	+0.8	+1.1	+0.9
March	+0.7	+1.3	+1.0
April	+0.5	+1.4	+0.9
May	+0.1	-0.2	-0.1
June	+0.7	+0.2	+0.5
July	+0.5	+0.6	+0.5
August	+0.5	+0.7	+0.6
September	+0.9	+1.3	+1.2
October	+0.6	+0.3	+0.4
November	+1.3	+1.8	+1.6
December	+1.6	+1.5	+1.5

Trends in mean monthly temperatures at Willmar 1971-2000 normals vs 1981-2010 normals (F)

Month	Min Change	Max Change	Mean Change
January	+3.4	+1.5	+2.9
February	+0.8	+0.9	+0.8
March	+0.9	+1.2	+1.0
April	+0.7	+1.5	+1.1
May	+0.1	-0.1	NC
June	+0.5	+0.2	+0.3
July	+0.7	+0.5	+0.6
August	+0.4	+0.7	+0.5
September	+0.9	+1.0	+0.9
October	+0.5	+0.5	+0.5
November	+1.3	+2.3	+1.7
December	+2.1	+1.7	+1.8

Trends in mean monthly temperatures at Fergus Falls, MN 1971-2000 normals vs 1981-2010 normals (F)

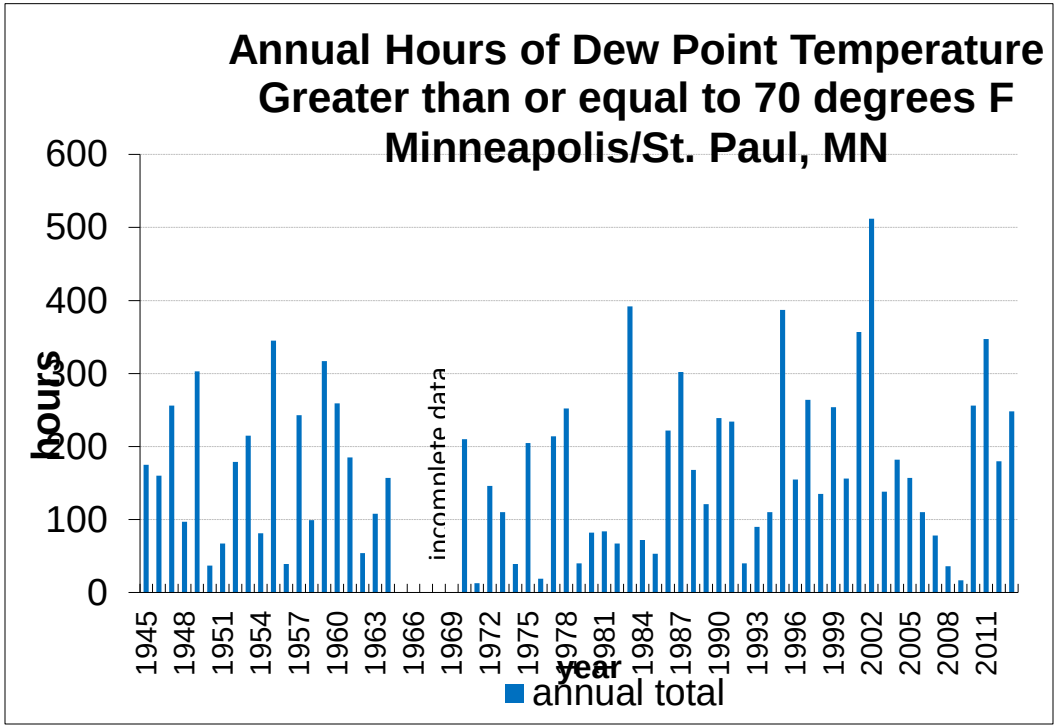
Month	Min Change	Max Change	Mean Change
January	+2.8	+2.5	+2.6
February	+0.9	+0.3	+0.6
March	+1.6	+1.0	+1.3
April	+0.8	+1.1	+0.9
May	-0.2	-0.4	-0.4
June	+0.4	NC	+0.2
July	+0.3	+0.2	+0.3
August	+0.6	+0.4	+0.4
September	+1.5	+0.6	+1.1
October	+0.8	-0.2	+0.3
November	+0.6	+1.8	+1.6
December	+1.0	+1.6	+1.5

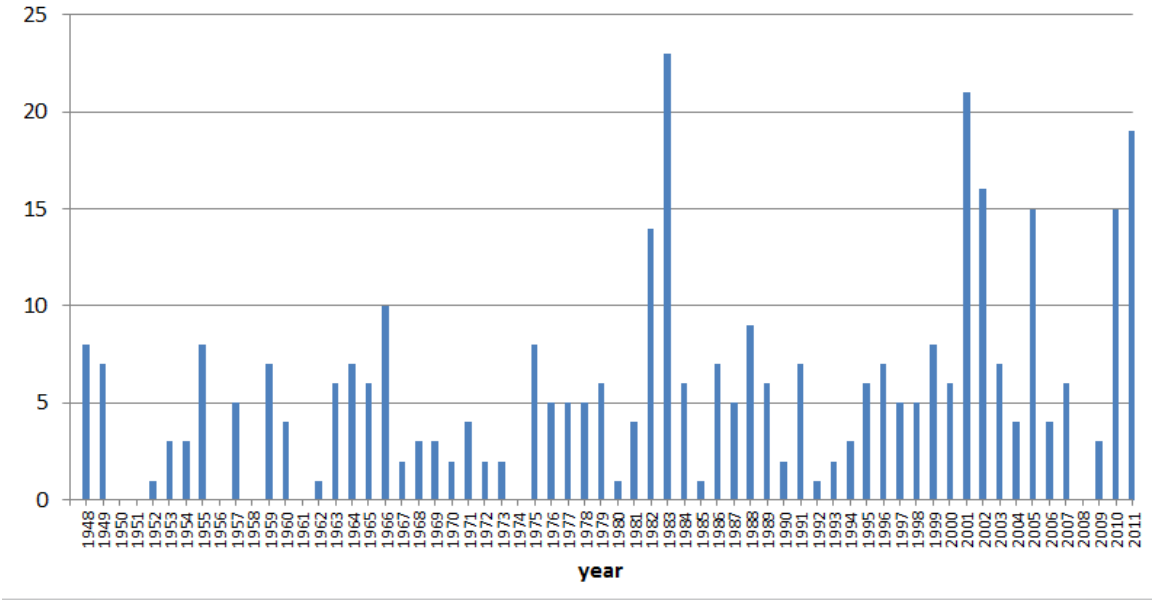
Consequences of Warm Winters and Higher Minimum Temperatures

- Change in depth and duration of soil and lake freezing
- More rapid breakdown of crop residues
- Later fall nitrogen applications (soil temp too high)
- Longer outdoor construction season, fewer adverse weather days
- Change in over winter survival rates of insect pests and plant diseases, and soil microbes
- Reduced energy use for heating (fewer HDD)
- Change in Plant Hardiness Zones
- Longer frost-free growing seasons
- Increased number of freeze/thaw cycles (damaged roads)
- Change in animal migration, hibernation, and foraging
- Longer exposure times to mold and allergens

Trend in episodes of dewpoints of 70 F or higher

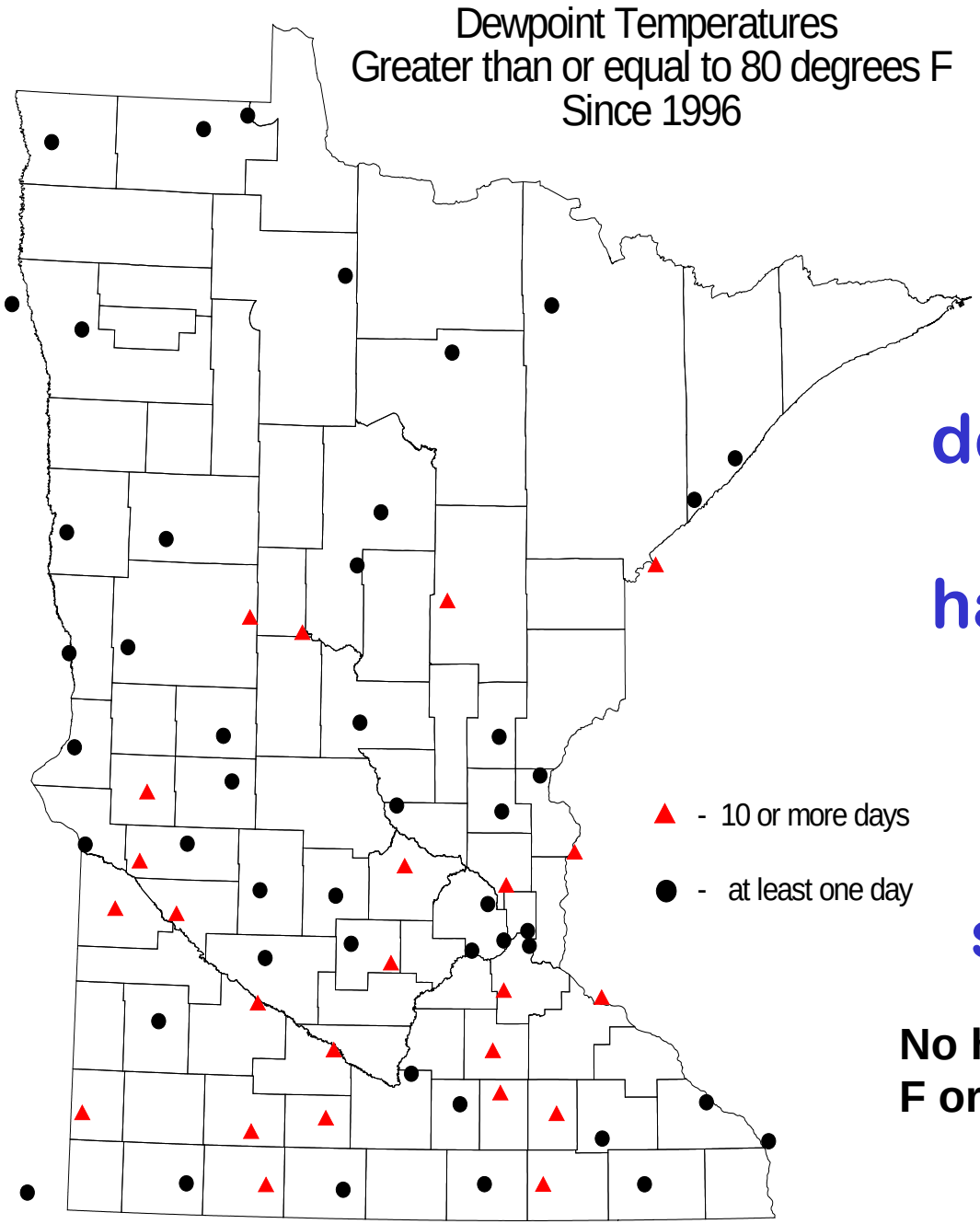
Latitude 45 degrees





Hours with dewpoints of 70 degrees F or higher at Voyageurs National Park

Latitude 48.5 degrees

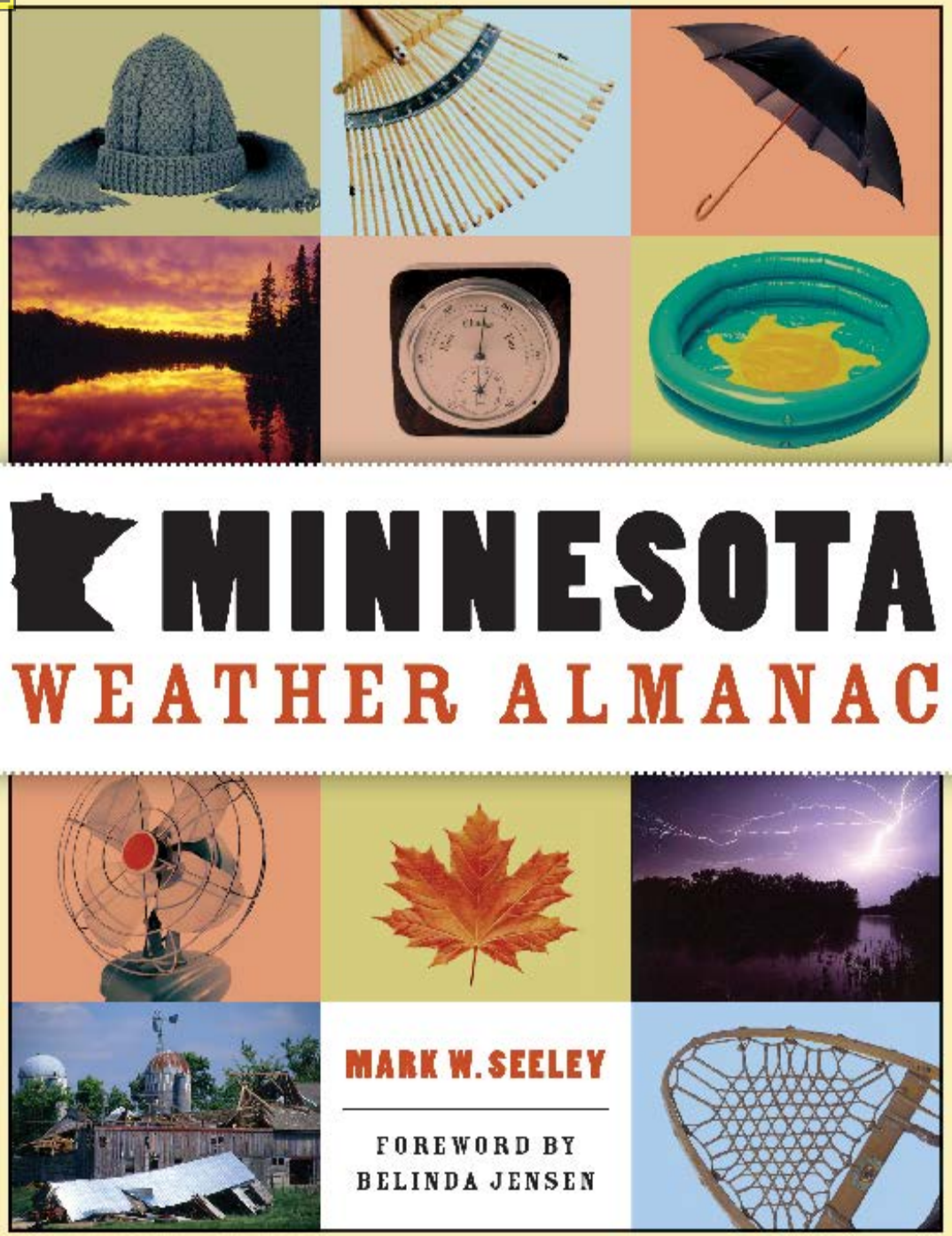


Since 1996 dewpoints of 80 F or higher. Readings have been statewide with highest frequencies in central and southern counties

No history of dewpoints of 80 F or higher prior to 1983

Frequencies of tropical-like dew points (70 F or higher) and associated Heat Index values for the Twin Cities since 1945

Year	Hours with DP of 70 F or greater	Range of Heat Index Values (F)
1947	256	99 - 112
1949	303	98 - 112
1955	345	98 - 113
1957	243	98 - 112
1959	317	99 - 113
1960	259	98 - 112
1978	252	99 - 114
1983	392	102 - 110
1987	302	98 - 104
1995	387	98 - 116
1997	264	98 - 113
1999	254	98 – 116
2001	357	98 - 110
2002	512	98 – 109
2010	256	98 - 111
2011	347	98 – 118 (*134)
2013	248	99 - 105



Historical Minnesota Heat Waves:

Red denotes dewpoint driven

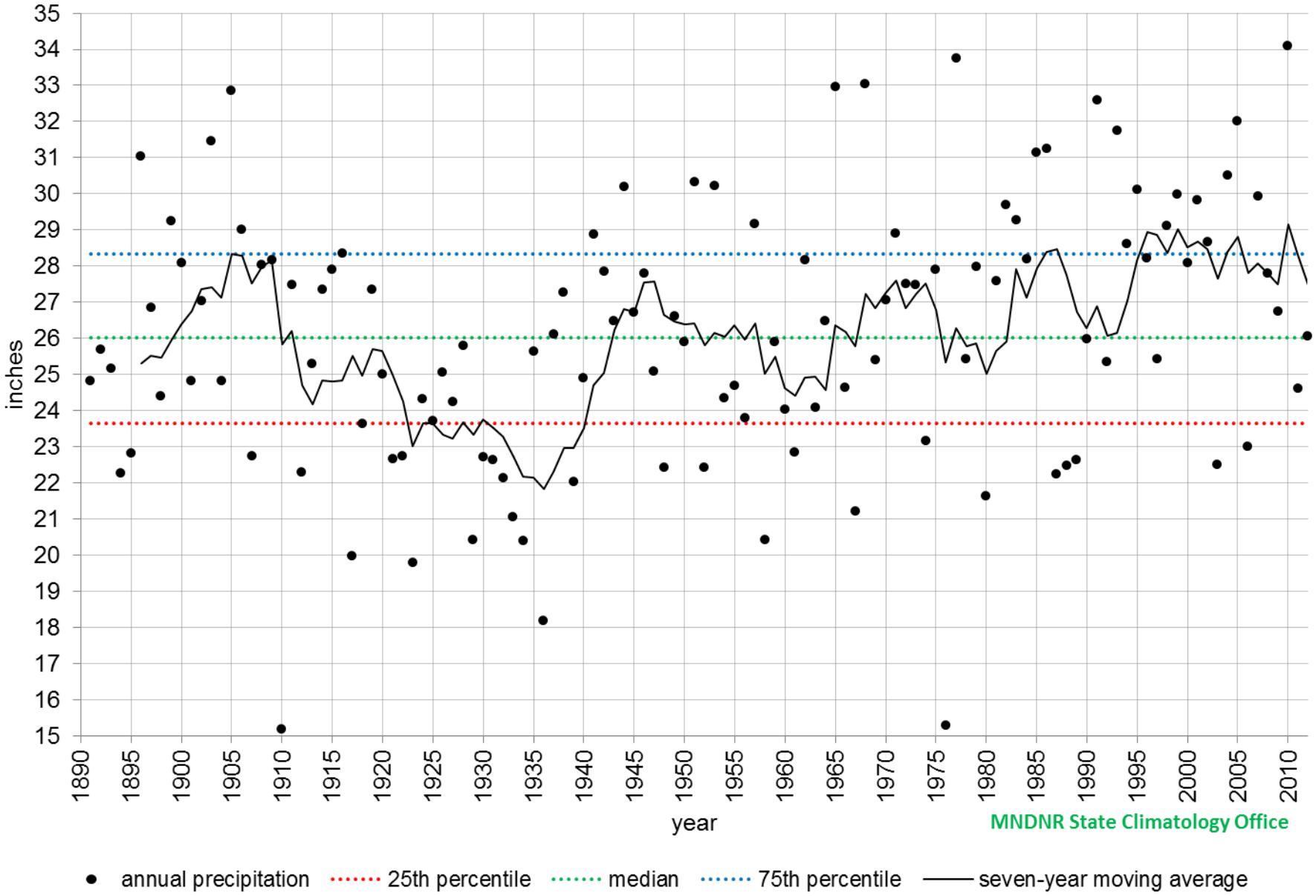
1883, 1894, 1901, 1910, 1917, 1921, 1931, 1933, 1934, 1936, 1937, 1947, 1948, 1949, 1955, 1957, 1959, 1964, 1976, 1977, 1983, 1988, 1995,1999, 2001, 2005, 2006, 2007, 2010, 2011, 2012, 2013

(pattern is episodic but increasing in frequency)

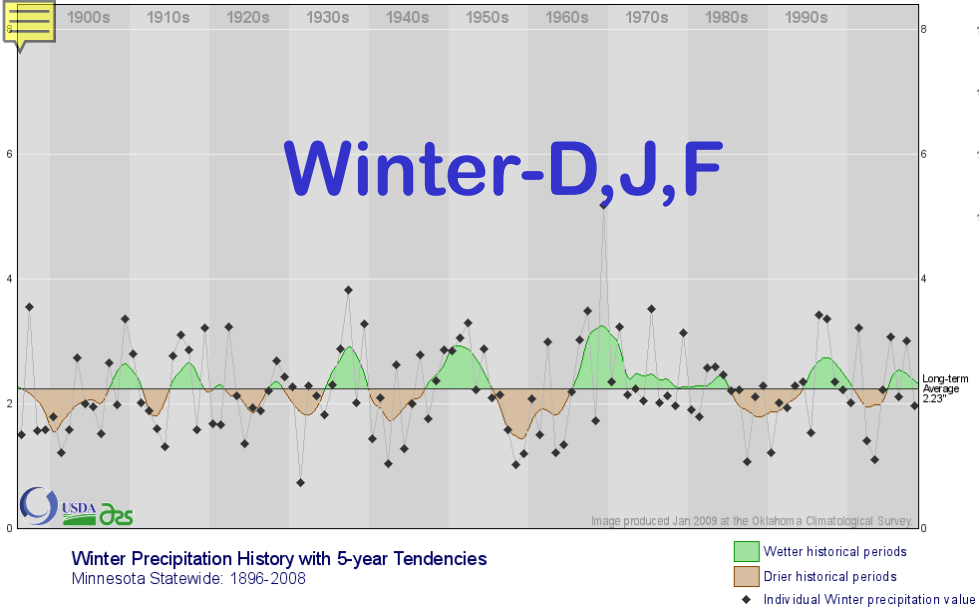
Consequences of Increased Frequency in Tropical-like Dew Points

- Dynamics of pathogen, insect, and microorganism populations
- Efficacy and persistence of herbicides (volatility)
- Elevated water temperatures, algae blooms
- Increased workload in heat related health care (exposure differentials, MS, COPD, Obesity)
- Increased stress on livestock (change in ration, water, reduced milk production and reproduction problems)
- Increased demand for air conditioning

Minnesota State-Averaged Annual Precipitation

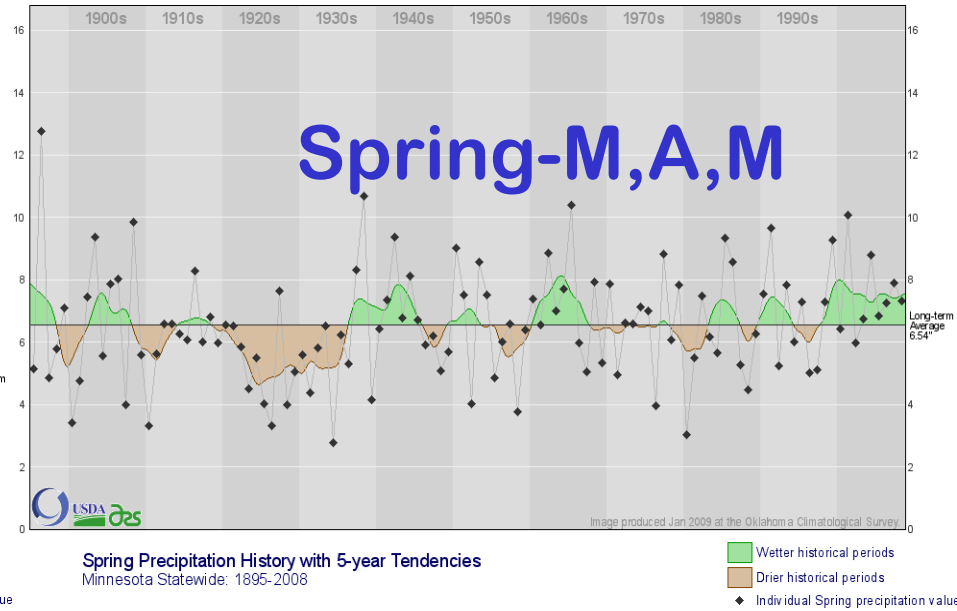


Seasonality in MN Precipitation Trends



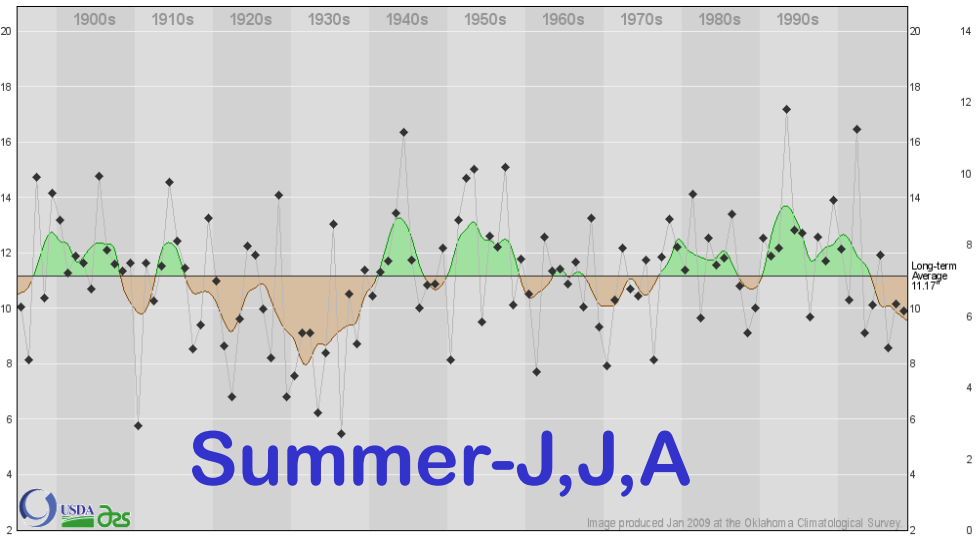
Winter Precipitation History with 5-year Tendencies
Minnesota Statewide: 1896-2008

Wetter historical periods
Drier historical periods
Individual Winter precipitation value



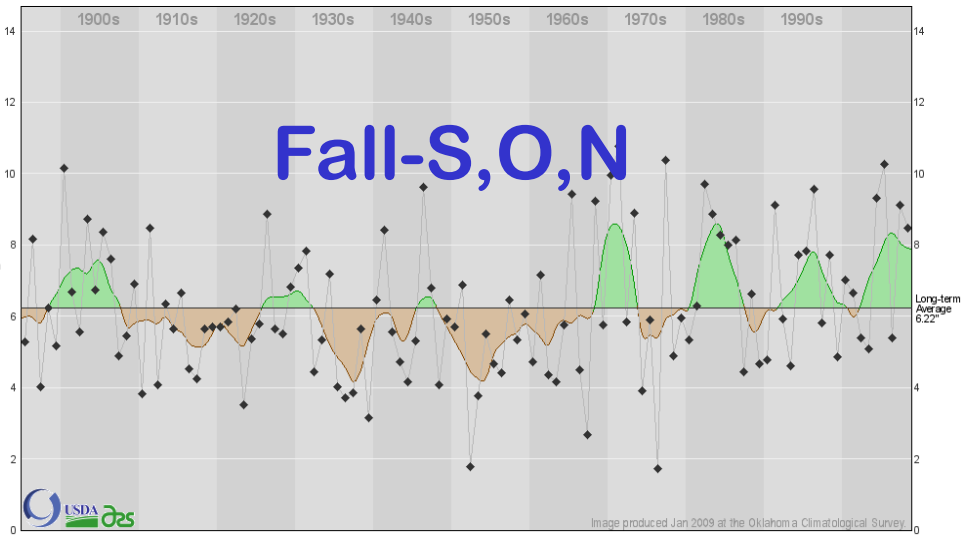
Spring Precipitation History with 5-year Tendencies
Minnesota Statewide: 1895-2008

Wetter historical periods
Drier historical periods
Individual Spring precipitation value



Summer Precipitation History with 5-year Tendencies
Minnesota Statewide: 1895-2008

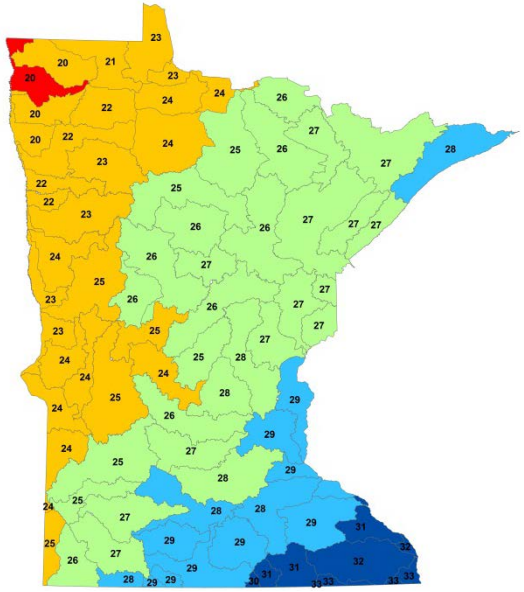
Wetter historical periods
Drier historical periods
Individual Summer precipitation val



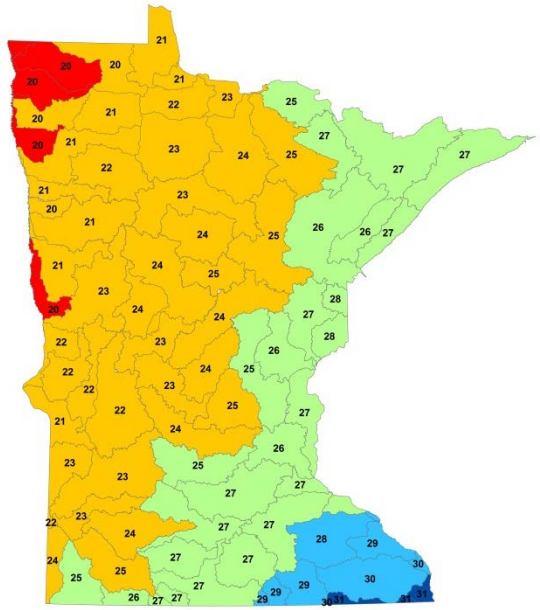
Autumn Precipitation History with 5-year Tendencies
Minnesota Statewide: 1895-2008

Wetter historical periods
Drier historical periods
Individual Autumn precipitation valu

Average Annual PPT 1891-1920, in



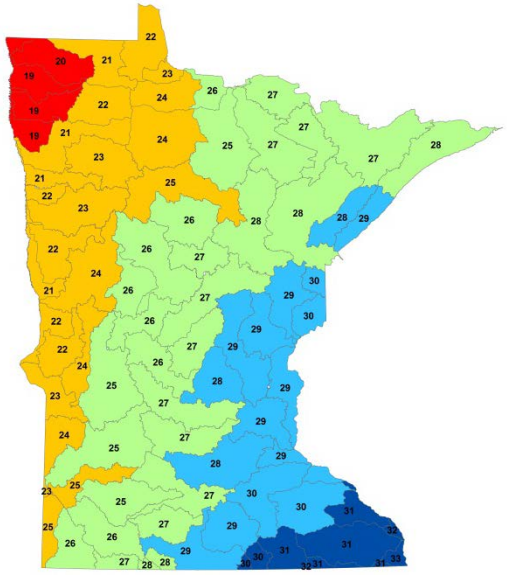
Average Annual PPT 1921-1950, in



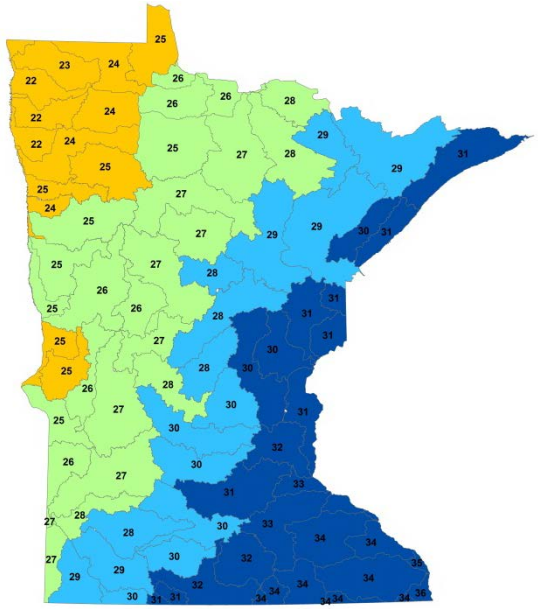
Avg. Annual PPT, in

- < 20
- 21 - 25
- 26 - 28
- 29 - 30
- > 30

Average Annual PPT 1951-1980, in



Average Annual PPT 1981-2010, in



Source: MN-SCO

Change in Annual Precipitation Normal at Milan, MN

PERIOD	AMOUNT (IN.)
1921-1950	21.53”
1931-1960	23.57”
1941-1970	25.53”
1951-1980	25.13”
1961-1990	24.12”
1971-2000	24.71”
1981-2010	26.14”

21 percent increase since 1921-1950

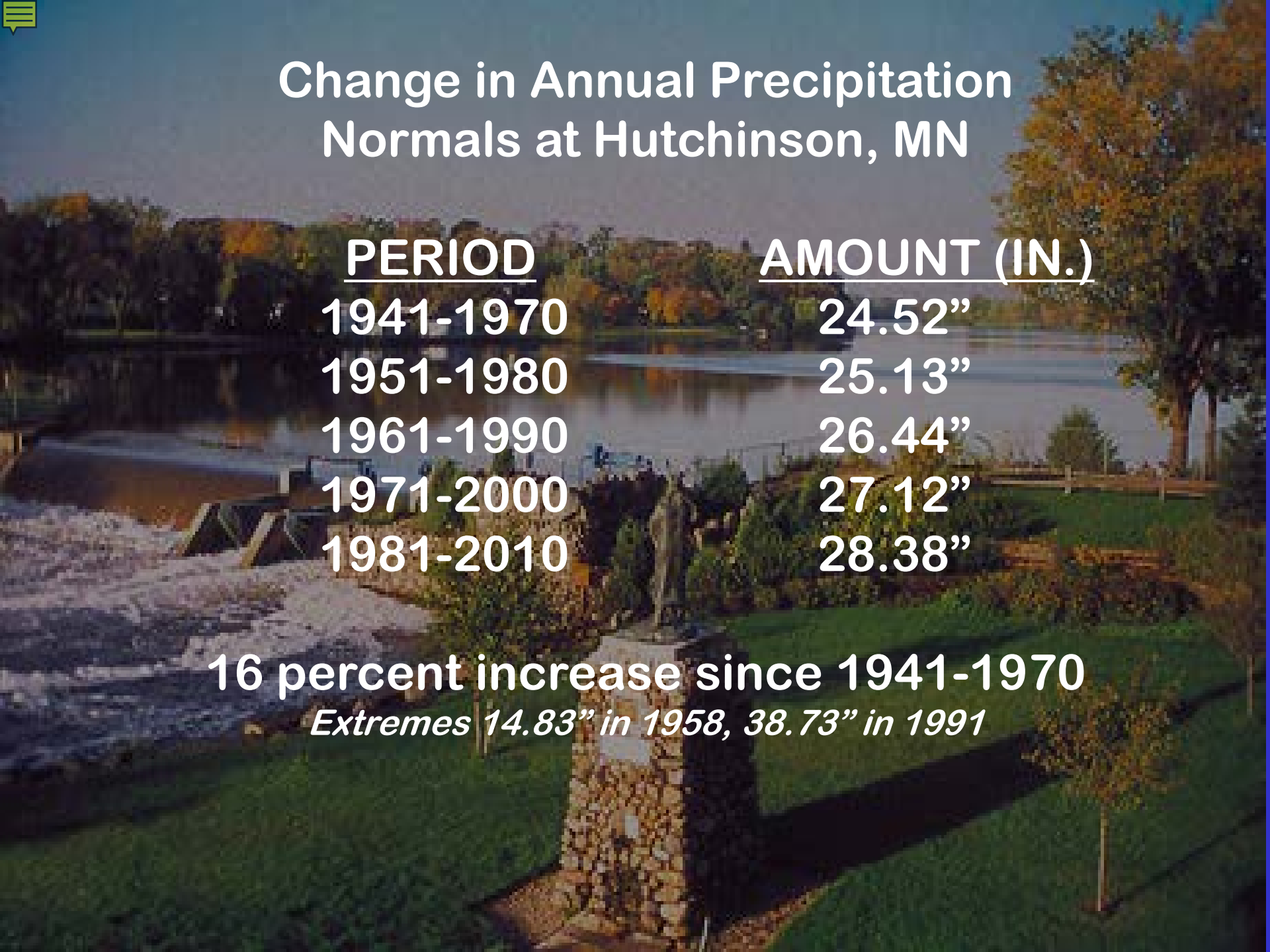
Extremes 7.91” in 1976, 39.58” in 1995

Change in Annual Precipitation Normals at Glenwood, MN

PERIOD	AMOUNT (IN.)
1931-1960	20.64”
1941-1970	20.60”
1951-1980	24.09”
1961-1990	24.19”
1971-2000	24.71”
1981-2010	25.71”

25 percent increase since 1931-1950

Extremes 16.55” in 1987, 36.90” in 2005

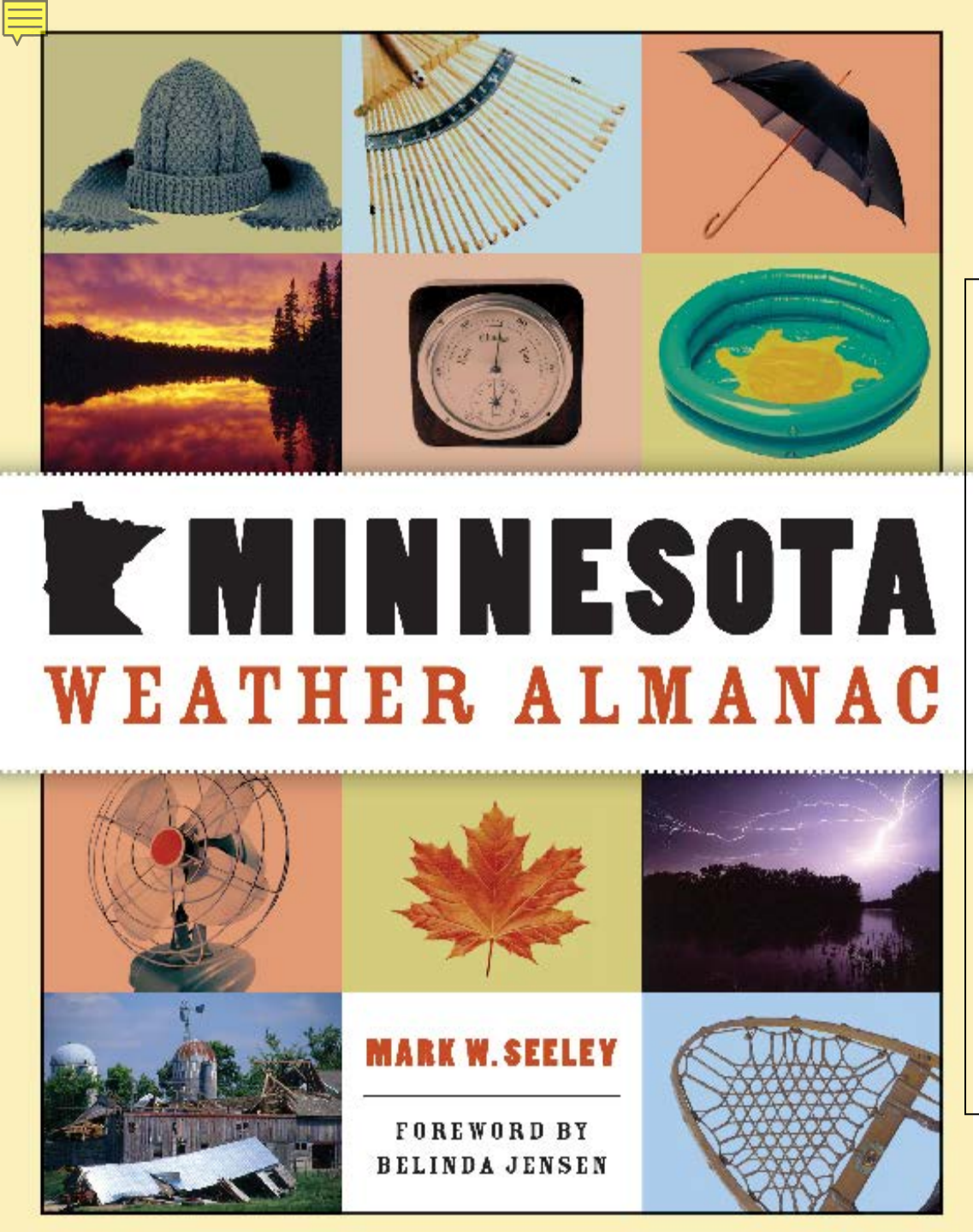


Change in Annual Precipitation Normals at Hutchinson, MN

PERIOD	AMOUNT (IN.)
1941-1970	24.52”
1951-1980	25.13”
1961-1990	26.44”
1971-2000	27.12”
1981-2010	28.38”

16 percent increase since 1941-1970

Extremes 14.83” in 1958, 38.73” in 1991



Measurable Attributes of Precipitation

Quantity

Type (liquid,frozen)

Intensity *(9-15")*

Frequency *(74-145 days)*

Duration *(10 days)*

Seasonality *(shifting)*

Landscape relationship

(interception, absorption, runoff, evaporation)

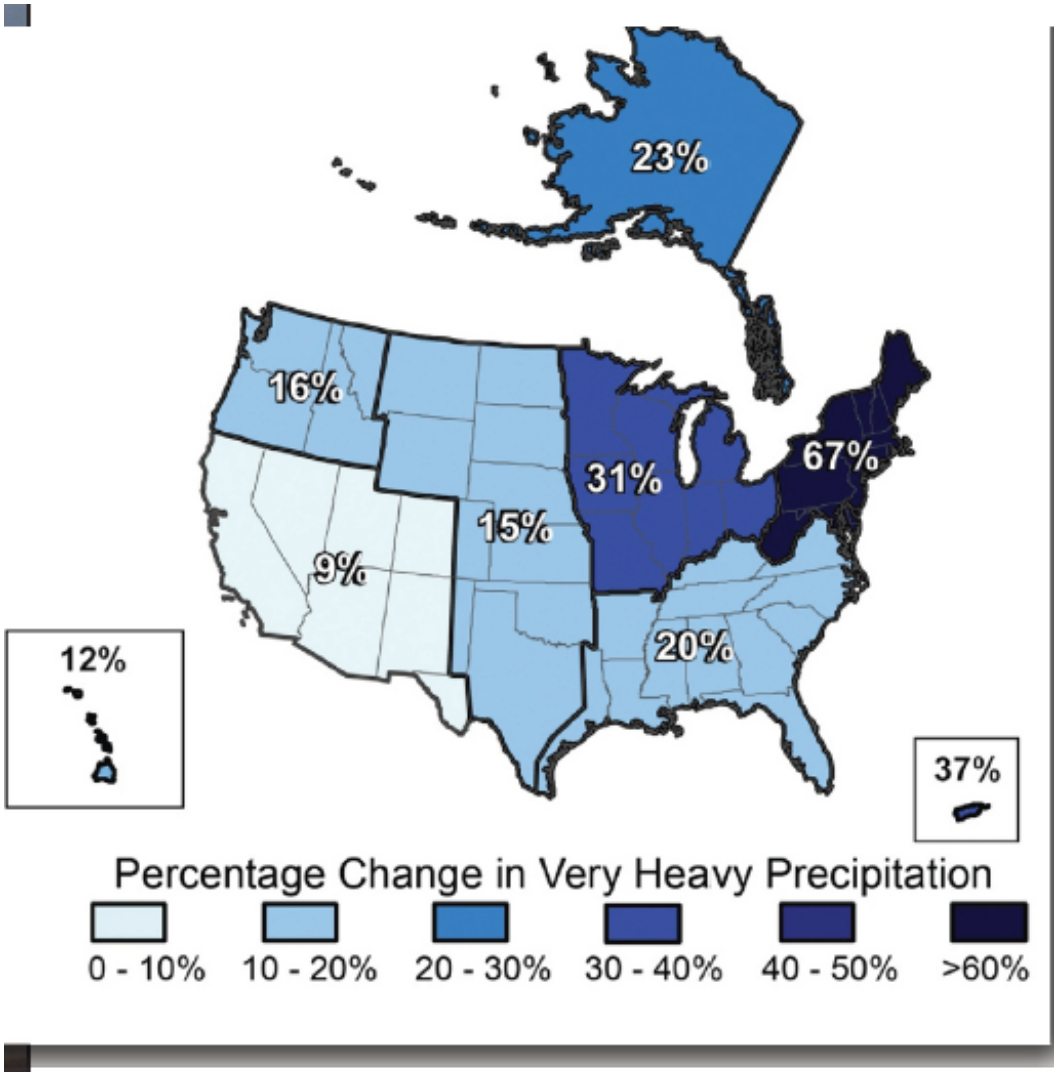
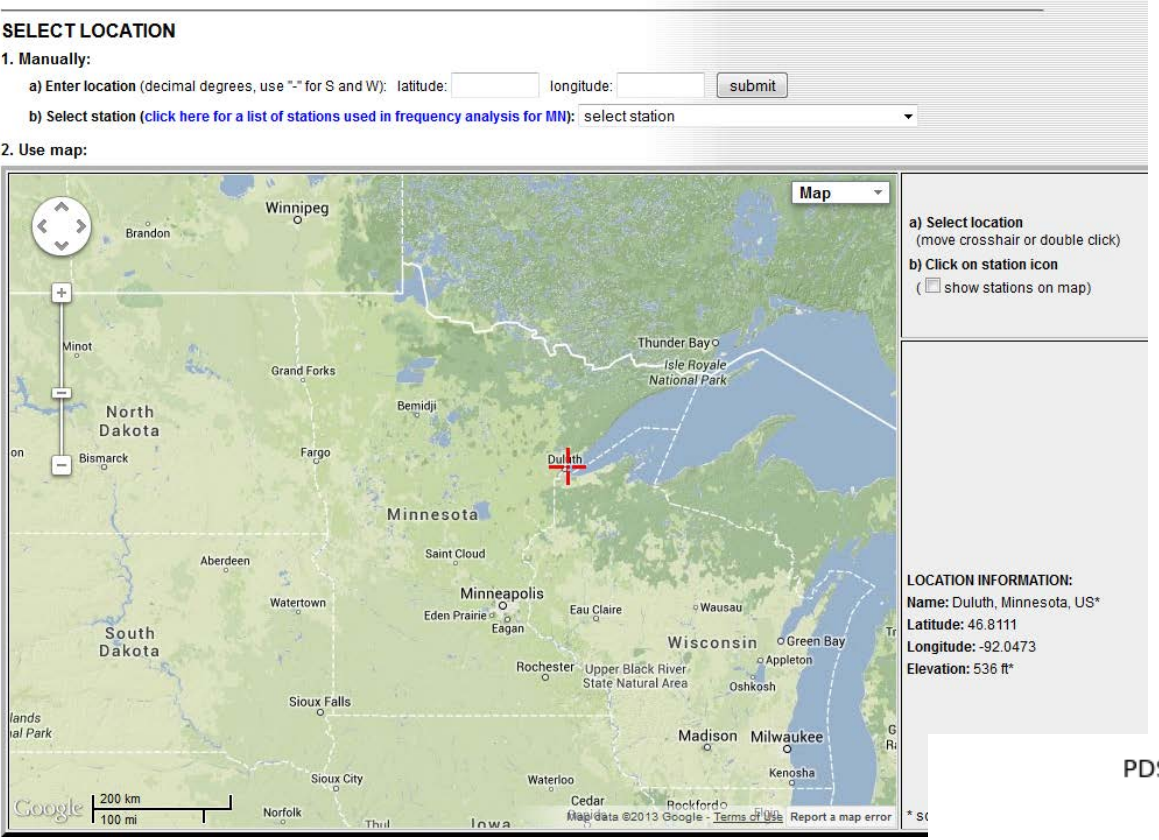
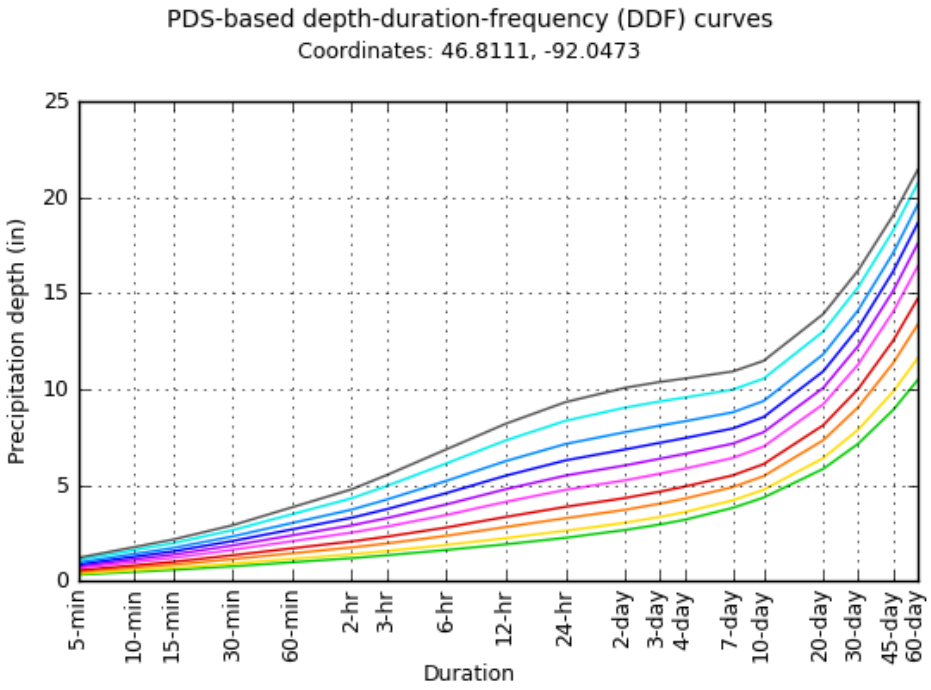


Figure 1-1. **Increase in very heavy precipitation in the US.** Climate change has regional implications for Iowa and the Midwest. Shown here is the increase in very heavy precipitation in different regions of the US from 1958 to 2007. Very heavy precipitation is defined as the heaviest 1% of all events. (Karl et al. 2009)

Access to NOAA-Atlas 14



WEB SITE:
http://www.dnr.state.mn.us/climate/noaa_atlas_14.html



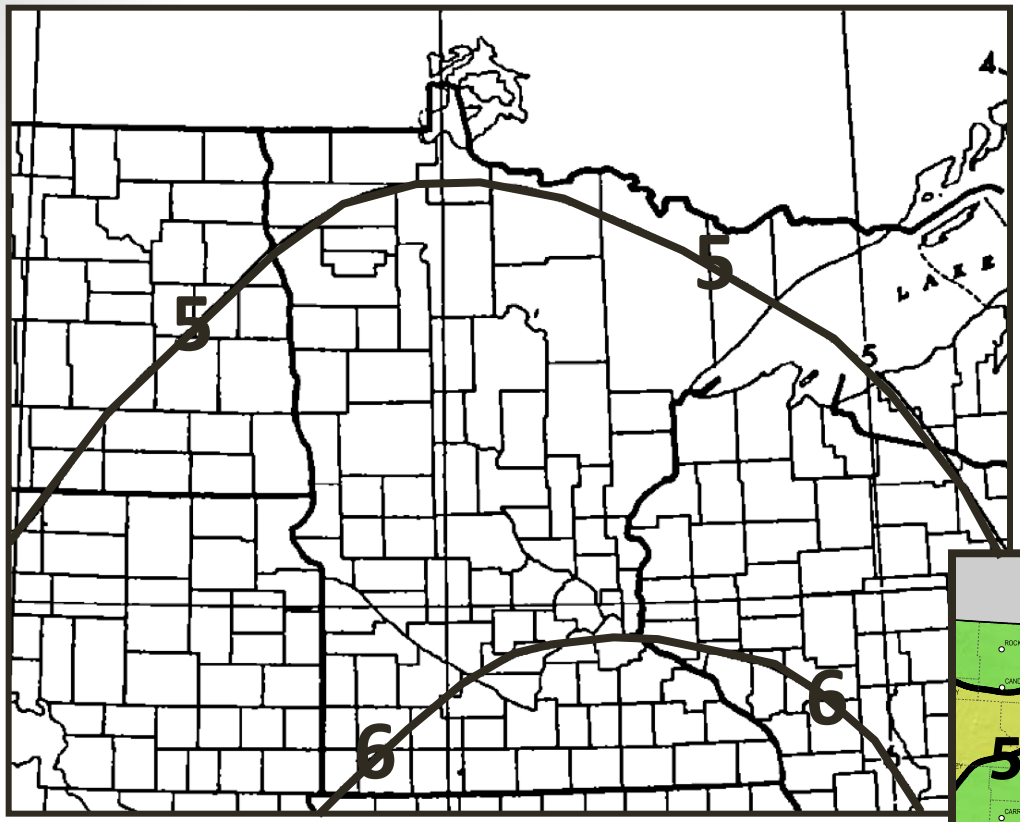
PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.337 (0.297-0.388)	0.412 (0.362-0.475)	0.536 (0.470-0.618)	0.640 (0.558-0.741)	0.786 (0.661-0.935)	0.900 (0.740-1.08)	1.02 (0.807-1.25)	1.14 (0.864-1.42)	1.29 (0.948-1.66)	1.42 (1.01-1.84)
10-min	0.494 (0.435-0.569)	0.603 (0.531-0.695)	0.784 (0.688-0.906)	0.937 (0.817-1.08)	1.15 (0.968-1.37)	1.32 (1.08-1.58)	1.49 (1.18-1.82)	1.66 (1.26-2.08)	1.90 (1.39-2.43)	2.08 (1.48-2.69)
15-min	0.602 (0.531-0.694)	0.736 (0.647-0.848)	0.957 (0.838-1.10)	1.14 (0.996-1.32)	1.40 (1.18-1.67)	1.61 (1.32-1.93)	1.81 (1.44-2.22)	2.03 (1.54-2.54)	2.31 (1.69-2.96)	2.53 (1.81-3.28)
30-min	0.812 (0.715-0.935)	0.999 (0.879-1.15)	1.31 (1.15-1.51)	1.57 (1.37-1.82)	1.93 (1.63-2.30)	2.21 (1.82-2.66)	2.50 (1.99-3.06)	2.79 (2.13-3.50)	3.19 (2.33-4.08)	3.48 (2.48-4.51)
60-min	0.997 (0.878-1.15)	1.25 (1.10-1.44)	1.67 (1.46-1.92)	2.02 (1.76-2.34)	2.51 (2.11-2.99)	2.90 (2.38-3.49)	3.29 (2.61-4.04)	3.70 (2.81-4.63)	4.24 (3.10-5.43)	4.66 (3.32-6.04)
2-hr	1.18 (1.05-1.35)	1.50 (1.32-1.71)	2.02 (1.78-2.32)	2.47 (2.16-2.84)	3.09 (2.62-3.66)	3.58 (2.96-4.28)	4.08 (3.27-4.98)	4.60 (3.53-5.73)	5.30 (3.92-6.74)	5.84 (4.20-7.51)
3-hr	1.29 (1.15-1.47)	1.64 (1.45-1.87)	2.22 (1.96-2.54)	2.72 (2.39-3.12)	3.43 (2.92-4.05)	3.99 (3.32-4.76)	4.57 (3.67-5.55)	5.17 (3.99-6.42)	5.99 (4.45-7.59)	6.63 (4.80-8.49)
6-hr	1.54 (1.38-1.75)	1.91 (1.70-2.16)	2.53 (2.25-2.87)	3.08 (2.72-3.51)	3.88 (3.34-4.58)	4.53 (3.80-5.38)	5.21 (4.23-6.31)	5.93 (4.63-7.33)	6.93 (5.21-8.74)	7.72 (5.65-9.81)
12-hr	1.89 (1.69-2.12)	2.22 (1.99-2.49)	2.81 (2.51-3.16)	3.34 (2.97-3.78)	4.15 (3.61-4.88)	4.83 (4.09-5.72)	5.56 (4.56-6.70)	6.34 (5.01-7.80)	7.46 (5.67-9.36)	8.36 (6.17-10.5)
24-hr	2.23 (2.01-2.48)	2.55 (2.30-2.85)	3.14 (2.82-3.52)	3.69 (3.29-4.14)	4.51 (3.95-5.27)	5.21 (4.45-6.13)	5.96 (4.94-7.14)	6.79 (5.41-8.29)	7.96 (6.11-9.92)	8.91 (6.65-11.1)
2-day	2.51 (2.28-2.79)	2.91 (2.63-3.23)	3.61 (3.25-4.01)	4.23 (3.79-4.71)	5.14 (4.52-5.94)	5.91 (5.07-6.87)	6.71 (5.58-7.95)	7.57 (6.07-9.15)	8.78 (6.80-10.8)	9.74 (7.35-12.1)
3-day	2.74 (2.49-3.03)	3.17 (2.87-3.50)	3.91 (3.53-4.32)	4.56 (4.11-5.07)	5.53 (4.87-6.35)	6.33 (5.45-7.33)	7.17 (5.99-8.45)	8.06 (6.50-9.70)	9.32 (7.26-11.4)	10.3 (7.83-12.8)
4-day	2.95 (2.69-3.25)	3.39 (3.08-3.73)	4.15 (3.77-4.58)	4.83 (4.36-5.35)	5.82 (5.14-6.66)	6.64 (5.73-7.66)	7.50 (6.29-8.81)	8.42 (6.81-10.1)	9.70 (7.58-11.9)	10.7 (8.16-13.2)
7-day	3.51 (3.20-3.84)	3.99 (3.64-4.37)	4.81 (4.38-5.28)	5.53 (5.01-6.08)	6.56 (5.80-7.43)	7.39 (6.41-8.45)	8.25 (6.96-9.62)	9.16 (7.46-10.9)	10.4 (8.20-12.6)	11.4 (8.77-14.0)
10-day	4.01 (3.68-4.38)	4.54 (4.15-4.95)	5.41 (4.94-5.91)	6.15 (5.59-6.75)	7.21 (6.39-8.12)	8.05 (7.00-9.15)	8.91 (7.53-10.3)	9.81 (8.01-11.6)	11.0 (8.72-13.3)	12.0 (9.26-14.6)
20-day	5.50 (5.07-5.95)	6.13 (5.64-6.64)	7.16 (6.57-7.77)	8.01 (7.32-8.72)	9.17 (8.15-10.2)	10.1 (8.79-11.3)	11.0 (9.31-12.5)	11.9 (9.74-13.8)	13.0 (10.4-15.6)	13.9 (10.9-16.9)
30-day	6.73 (6.22-7.25)	7.48 (6.90-8.06)	8.68 (7.99-9.38)	9.64 (8.84-10.5)	10.9 (9.74-12.1)	11.9 (10.4-13.3)	12.8 (11.0-14.6)	13.8 (11.4-16.0)	15.0 (12.0-17.7)	15.8 (12.4-19.1)
45-day	8.26 (7.66-8.87)	9.20 (8.52-9.88)	10.7 (9.85-11.5)	11.8 (10.9-12.8)	13.3 (11.9-14.6)	14.4 (12.7-16.0)	15.4 (13.2-17.4)	16.4 (13.6-18.9)	17.6 (14.2-20.7)	18.5 (14.6-22.1)
60-day	9.56 (8.88-10.2)	10.7 (9.91-11.4)	12.4 (11.5-13.3)	13.8 (12.7-14.8)	15.5 (13.8-16.8)	16.7 (14.7-18.4)	17.8 (15.2-20.0)	18.8 (15.6-21.6)	20.0 (16.2-23.5)	20.9 (16.6-24.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

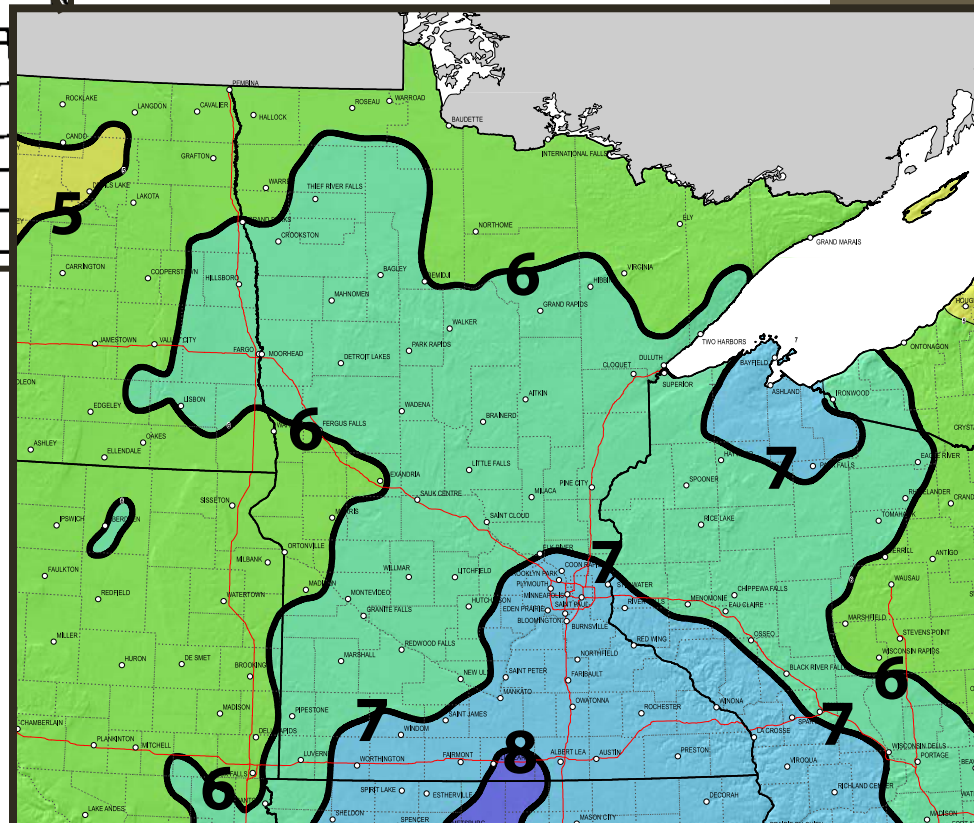
Rainfall Recurrence Table for Alexandria, MN

1961 Estimate



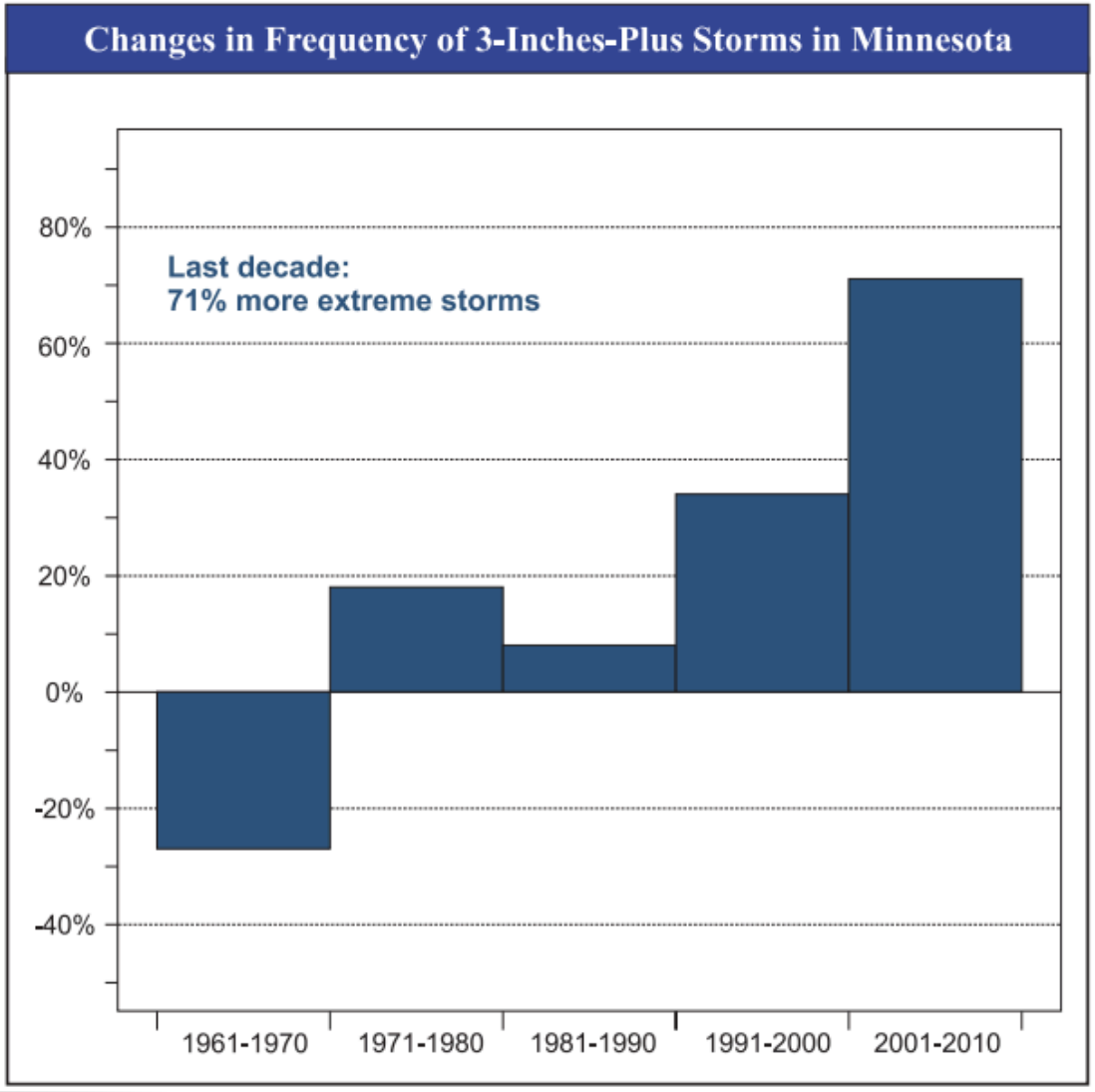
100-year 24-hour rainfall event (in)

2013 Estimate



NWS Atlas 14

Trends in MN Flash Flooding Events



Top 10 Flash Flooding Years from 1961-2011
(1) 2002
(2) 2010
(3) 1978
(4) 2004
(5) 2005
(6) 1991
(7) 2000
(8) 1995
(9) 1973
(10) 1981

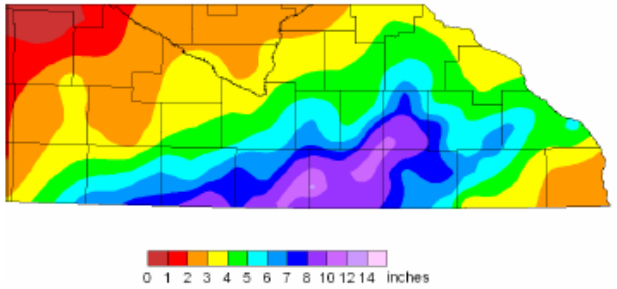
Rocky Mountain Climate Organization and Natural Resources Defense Council

Shift in Precipitation Recurrence Intervals

Three one thousand year events since 2004

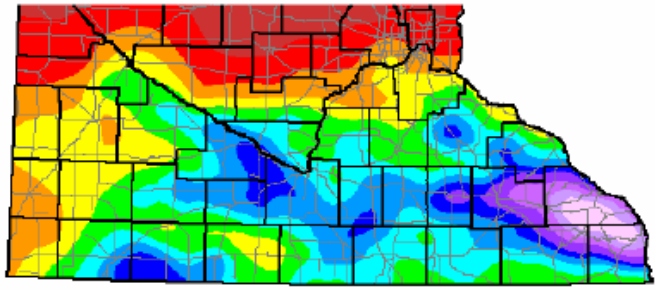
'1000-yr (approx.) events' in Southern Minnesota in the last decade.

September 14-15, 2004



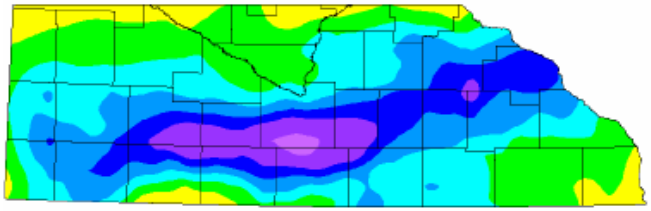
0 1 2 3 4 5 6 7 8 10 12 14 inches

August 18 through August 20 (8:00 AM CDT), 2007



0 1 2 3 4 5 6 7 8 10 12 14 inches

September 22-23, 2010



3 4 5 6 7 8 10 inches

A 'by-eye' estimate of the total area covered by 10" of rain over the 7 years of 2004-2010 appears to be near 1400 sq. mi. or about 200 sq. mi per year. Given that the area of the southern 3 layers of counties looks to be approximately 20000 sq. mi. the areal fraction of the southern three counties covered by 10" per year appears to be approximately 1/100; i.e. at the rate of coverage for the last 7 years an area equal to the whole southern three county area could be covered in about 100 years.

Wright Flood

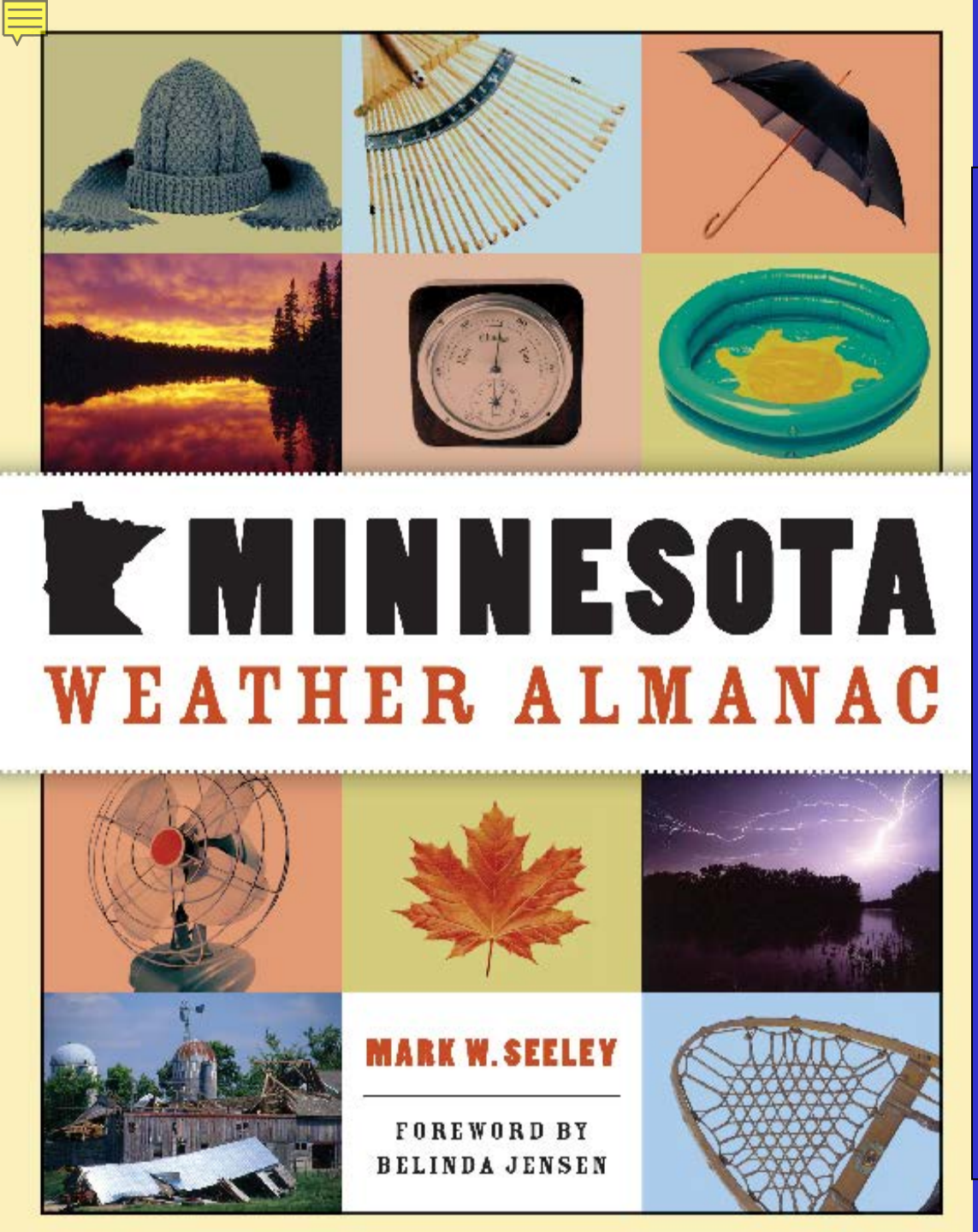
July 17-19, 1867

All-time greatest MN flash flood with 30-36 inches of rainfall

Chippewa River 4 miles wide

Mississippi River rose by 12 ft in 24 hours

All log booms on the Mississippi were flushed (35 million logs)



Historic Droughts

(Associated fires)

1829, 1852, 1856

1863-1864, 1871-1872

1894, 1896, 1900,

1910, 1918, 1921-1923

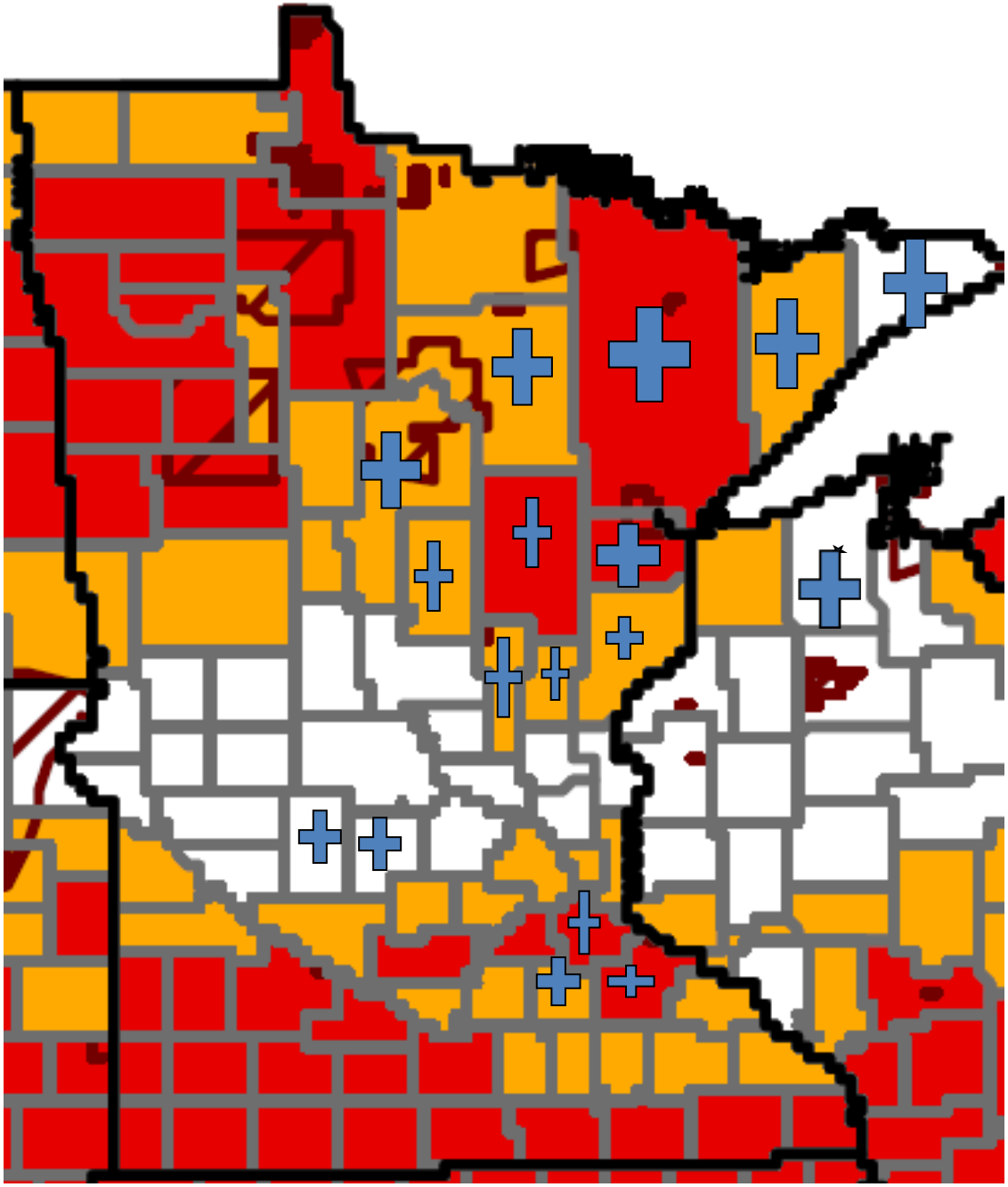
1926, 1929-1934,

1936-1939, 1948,

1954-1956, 1961,

1976, 1980, 1984,

1987, 1988, 1997, 2006, 2007, 2009, 2010, 2011, 2012, 2013



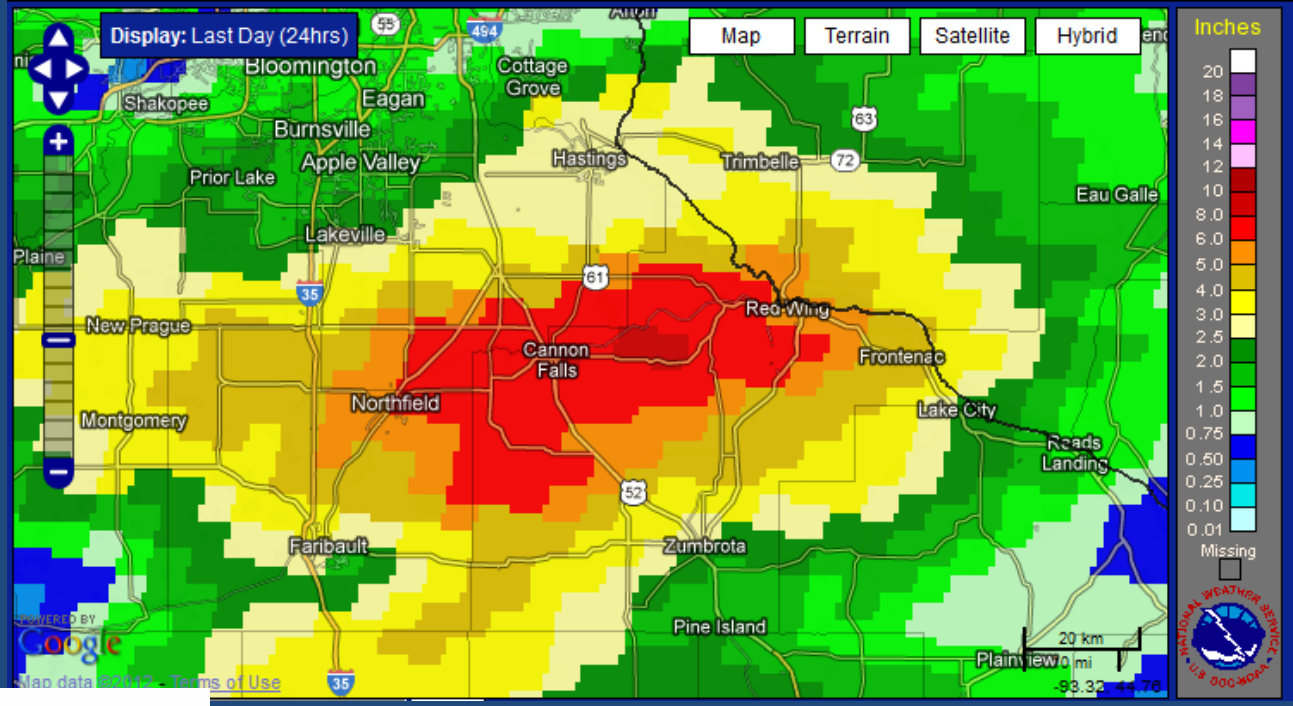
MN Counties designated for federal disaster assistance in 2012

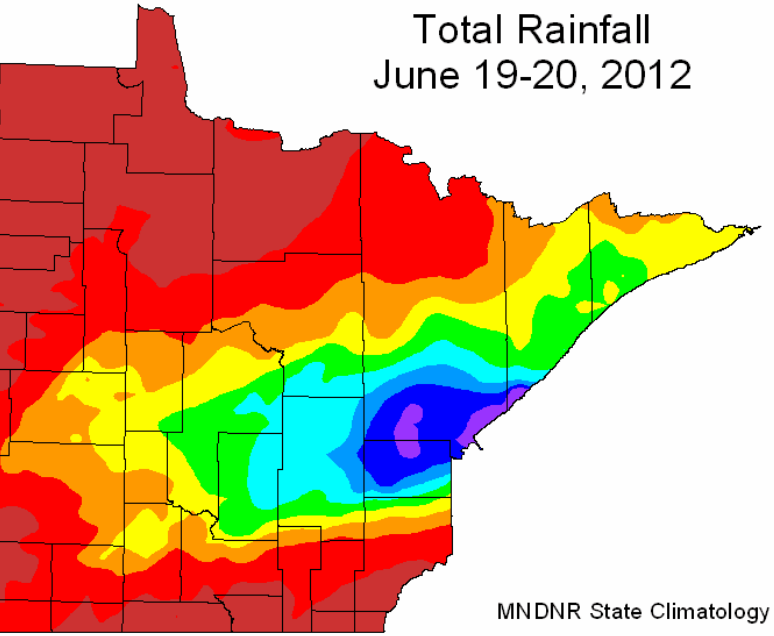
All are associated with drought except those with ✚

which designates for flood or severe storm

June 14, 2012

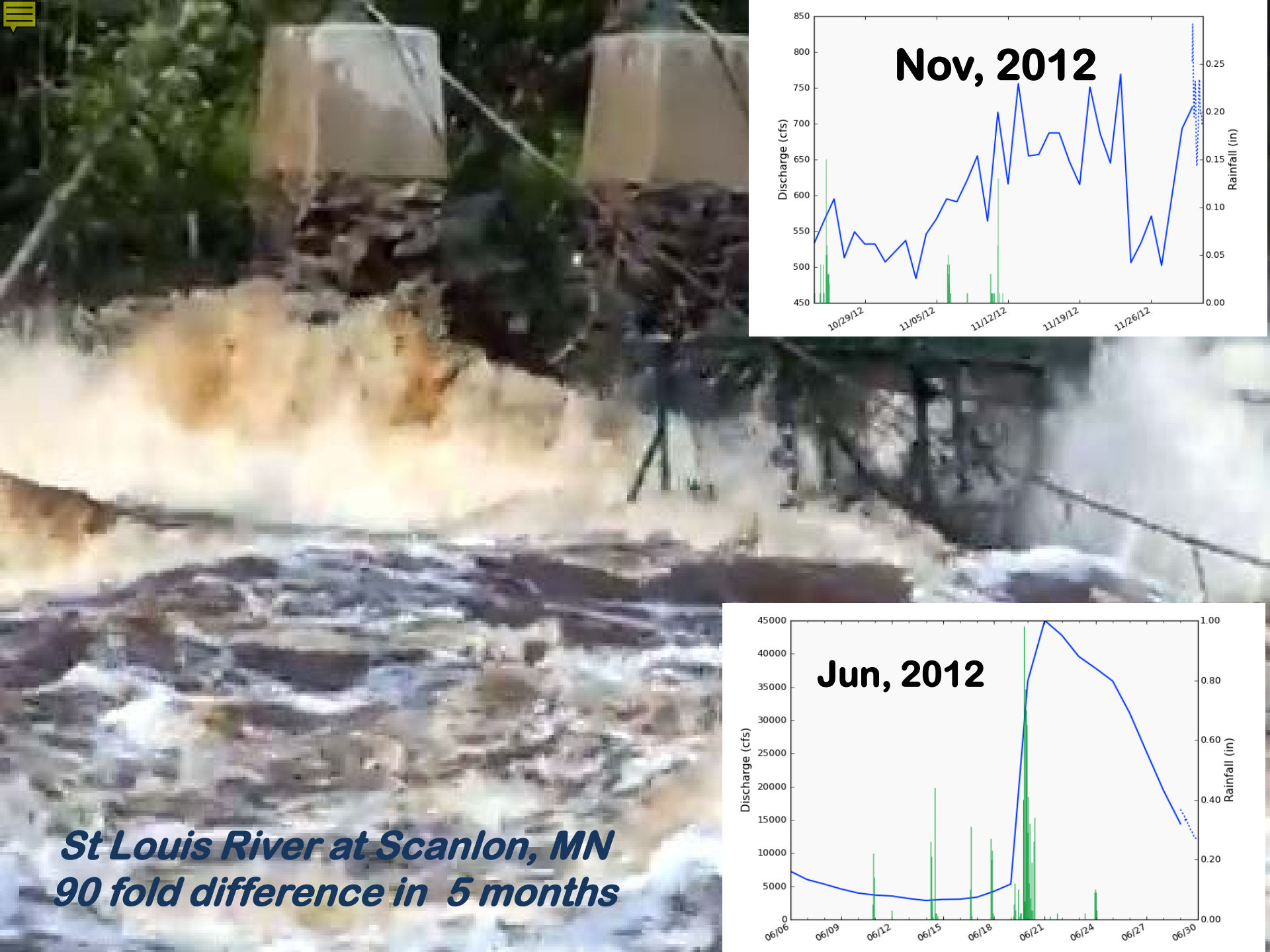
nearly 9 inches of rainfall at Cannon Falls.





June 19-20, 2012

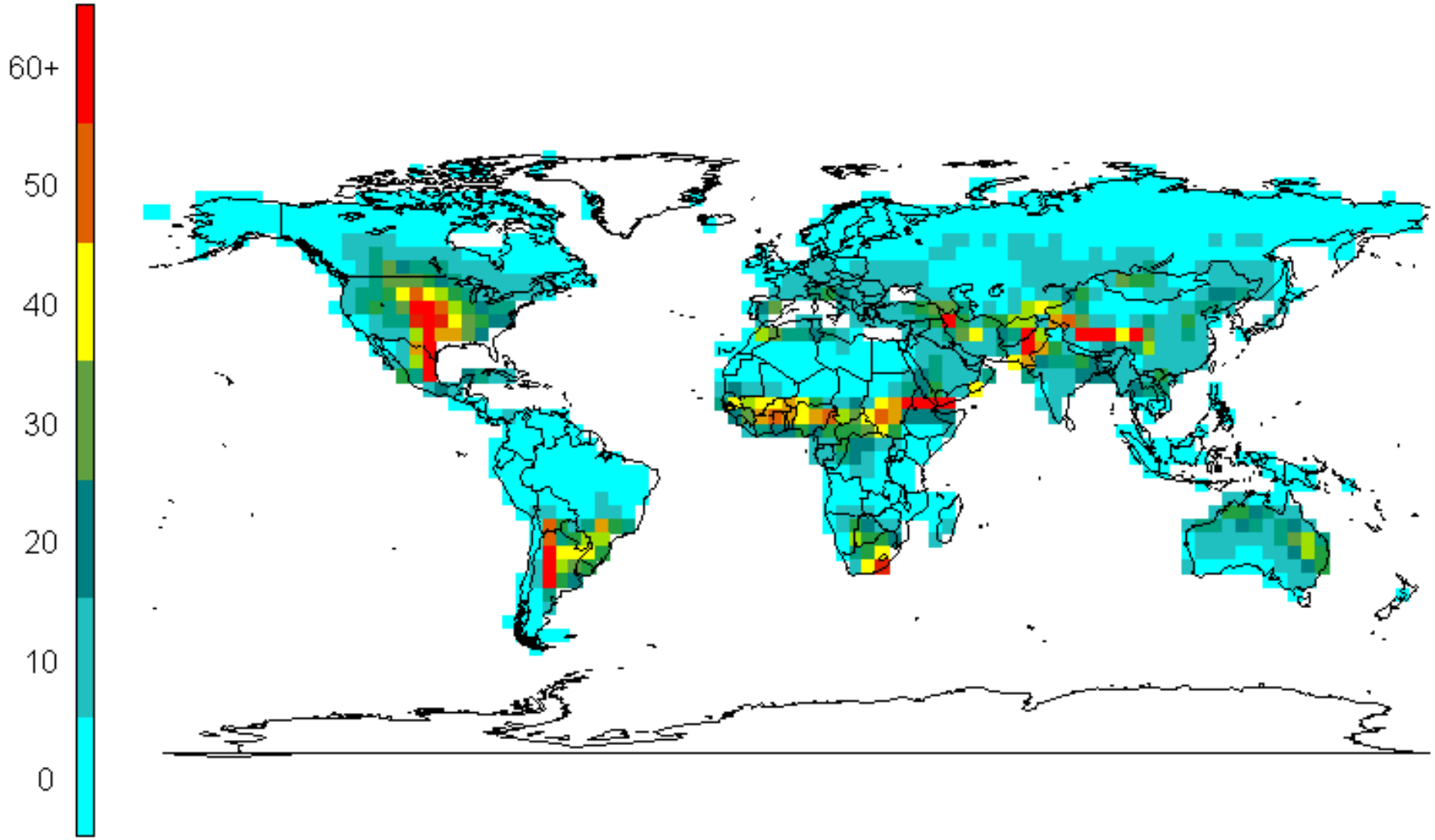
7-10 inches of rainfall in parts of Carlton, St Louis, and Lake Counties


Nov, 2012
Discharge (cfs)
Rainfall (in)
850
800
750
700
650
600
550
500
450
0.25
0.20
0.15
0.10
0.05
0.00
10/29/12
11/05/12
11/12/12
11/19/12
11/26/12
Jun, 2012
Discharge (cfs)
Rainfall (in)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1.00
0.80
0.60
0.40
0.20
0.00
06/06
06/09
06/12
06/15
06/18
06/21
06/24
06/27
06/30
St Louis River at Scanlon, MN
90 fold difference in 5 months

Possible Implications of Changes in Precipitation Quantity and Character

- Altered irrigation, drainage, runoff, sediment, and shoreline management
- Change in storm sewer runoff design
- Modified fisheries management
- Mitigation of soil erosion
- Mitigation of flooding potential
- Better management of blowing snow and spring snowmelt runoff

Days per Year with Favorable Severe Parameters



from Brooks et al, NOAA-SSL, 2012

2010 Minnesota Tornadoes

48 on June 17, 2010

OPERATIONAL EF SCALE	
EF Number	3 Second Gust (mph)
0	65-85
1	86-110
2	111-135
3	136-165
4	166-200
5	Over 200

Tornado Enhanced Fujita Intensity Rating

- = EF4 (4)
- = EF3 (4)
- = EF2 (8)
- = EF1 (31)
- = EF0 (66)

Total = 113

First ever EF-5 Tornado in Canada, (Elie, Manitoba) June 22, 2007

First 4 inch thunderstorm rainfall Churchill, Manitoba, Aug 24, 2010

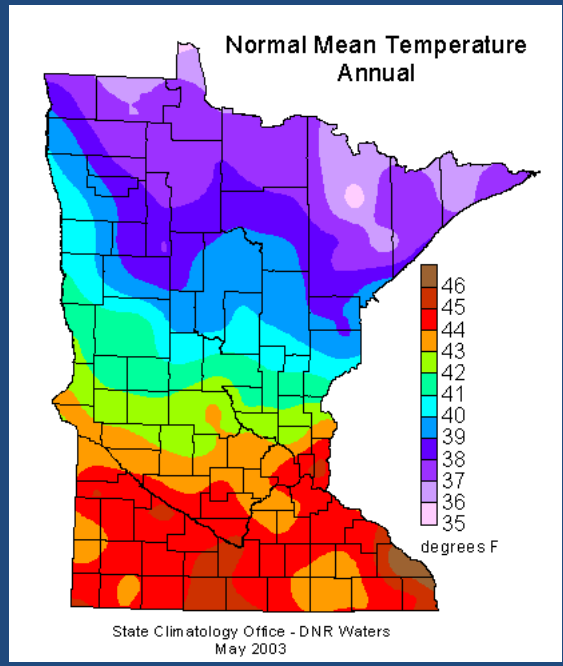
Located at nearly 59 degrees N. latitude, Churchill, Manitoba reported their first ever 4.12 inch thunderstorm rainfall on August 24, 2010! Previous record was 2.45 inches.

For those who doubt or wish to dismiss the evidence that climate is changing ….the data indicate it is happening and already producing consequences. It is clearly poor judgment to ignore this!

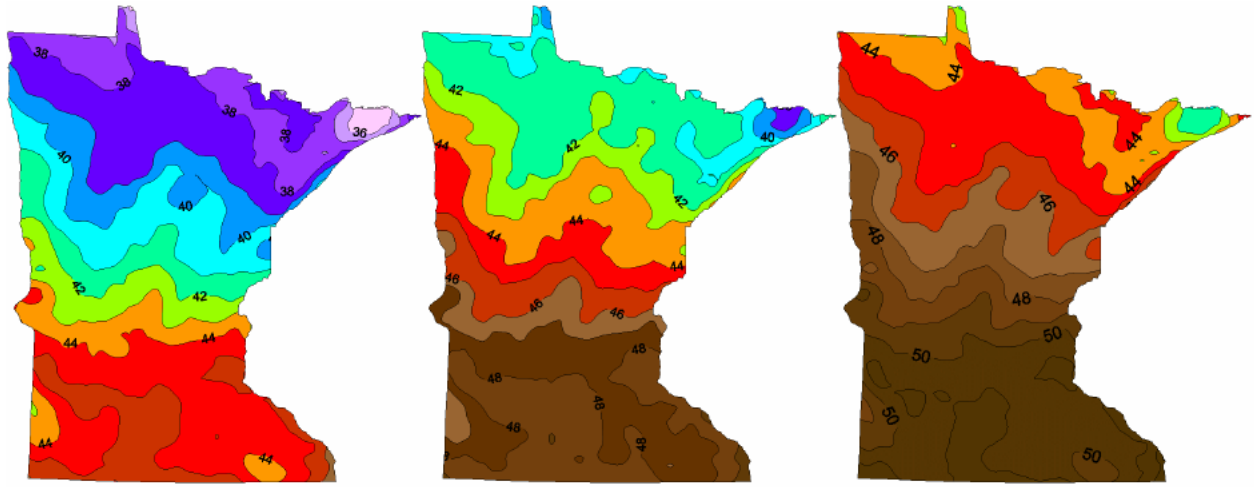
www.cloudappreciationsociety.org

1971-2000 Annual Mean Annual Temperature Map

Decadal average annual temperature from 16 GCM models runs showing 275 mile northern migration of the 44 degrees F isotherm
Source: CMIP-Lawrence-Livermore and MN State Climatology Office



The following maps are A1B decadal average from 16 GCM models (39 runs).
The color scheme is the same one used in our most recent (1971-2000) annual 'normal' map at http://www.climate.umn.edu/doc/historical/temp_norm_adj.htm



1981-1990 **2031-2040** **2061-2070**

The A1 scenarios are of a more integrated world: characterized by:
rapid economic growth;
A global population that reaches 9 billion in 2050 and then gradually declines;
The quick spread of new and efficient technologies;
income and way of life converge between regions; extensive social and cultural interactions.
A1B - A balanced emphasis on all energy sources.