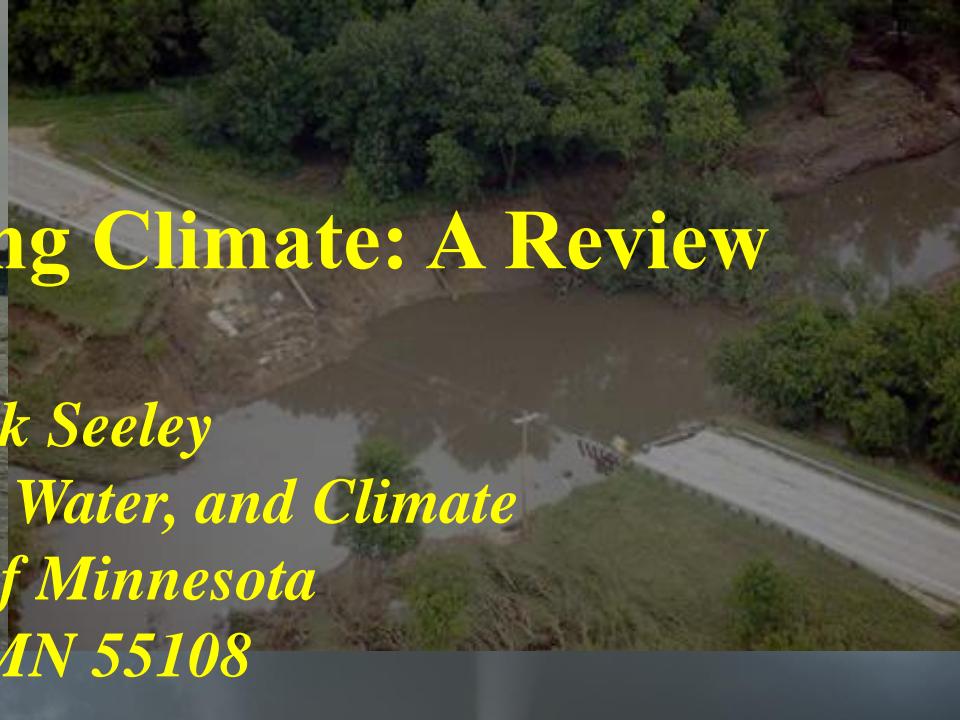




Minnesota's Changing Climate: A Review



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Climate Minnesota: Local Stories, Community Solutions

**May 18, 2015
Duluth, MN**





101 degrees F at Fairmont, MN
May 18, 1934



Thunderstorm, 5.01"
Rainfall at Lanesboro, MN
May 18, 2000



16 degrees F at Duluth, MN
May 18, 1924



2.3" of snowfall at
Hibbing, MN
May 18, 1968

Segments

Disparities in Climate Change Attributes

Examination of Extremes

Remarks on Consequences



Students Measure Changes in Ice and Snow

This short video features the Alaska Lake Ice and Snow Observatory Network (ALISON project), a citizen science program in which 4th and 5th graders help scientists study the relationships between climate change and lake ice and snow conditions.

[read more](#)

Recent Topics



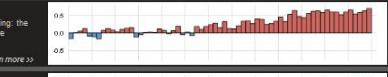
July 3, 2012 Filed in: [Teaching Climate](#)

February 13, 2013 Filed in: [Supporting Decisions](#)

November 17, 2014 Filed in: [Supporting Decisions](#)

Global Climate Dashboard

Global Average Temperature (°C)
The temperature near Earth's surface is rising: the bars show each year's average temperature compared to the 20th century average.



Carbon Dioxide (ppm)
The amount of carbon dioxide in the atmosphere has risen by 25% since 1958, and by about 40% since the Industrial Revolution.



Spring Snow Cover (million km²)
Snow is melting earlier: each bar shows spring snow cover in the Northern Hemisphere compared to the long-term average.



Temperature
Sea Level
Sun's Energy

Carbon Dioxide
Arctic Sea Ice
Glaciers

Temperature

Carbon Dioxide

Sea Level

Arctic Sea Ice

Sun's Energy

Glaciers

Temperature

Carbon Dioxide

Sea Level

Arctic Sea Ice

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Sun's Energy

Glaciers

Temperature

Carbon Dioxide

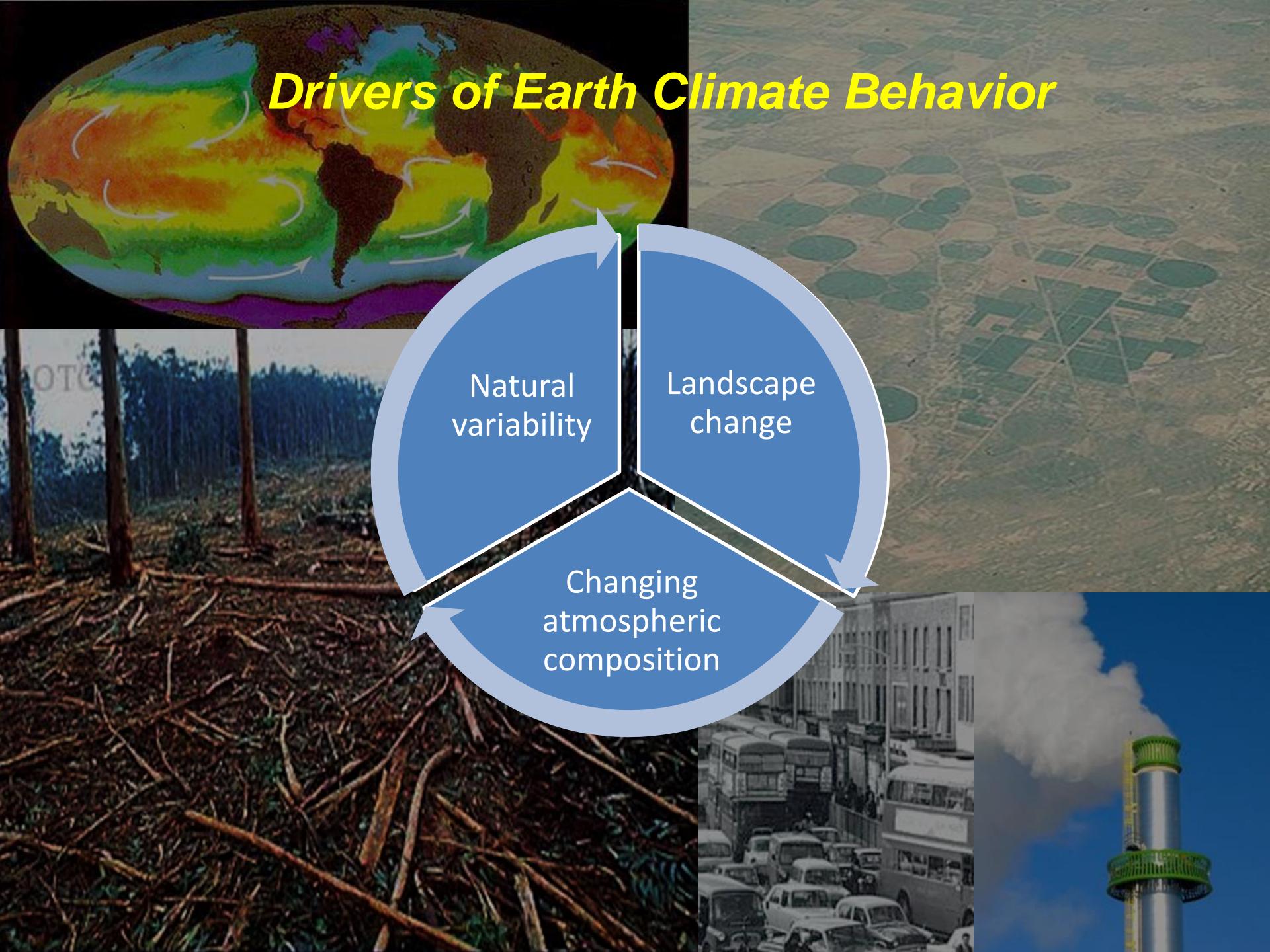
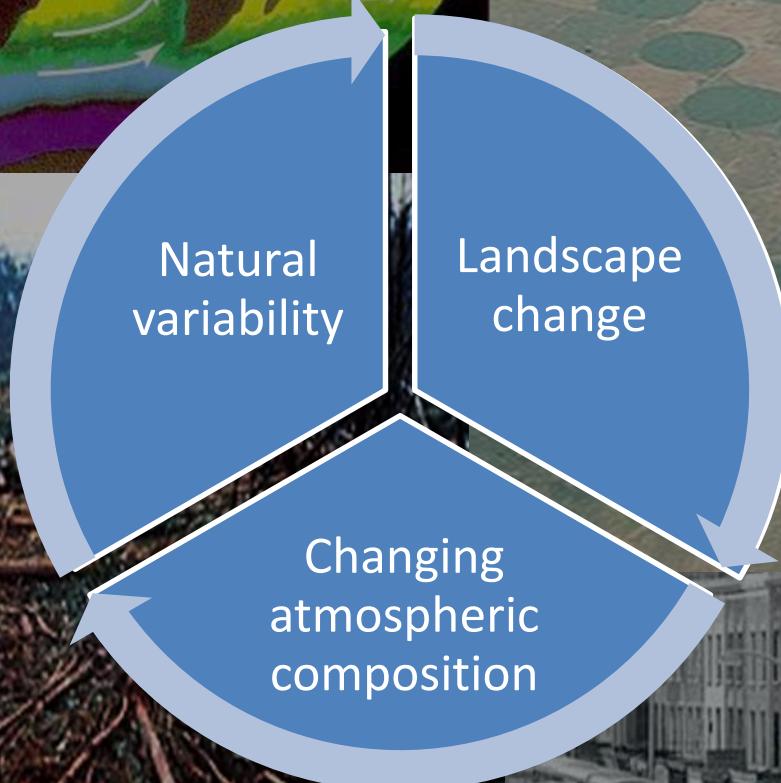
Sea Level

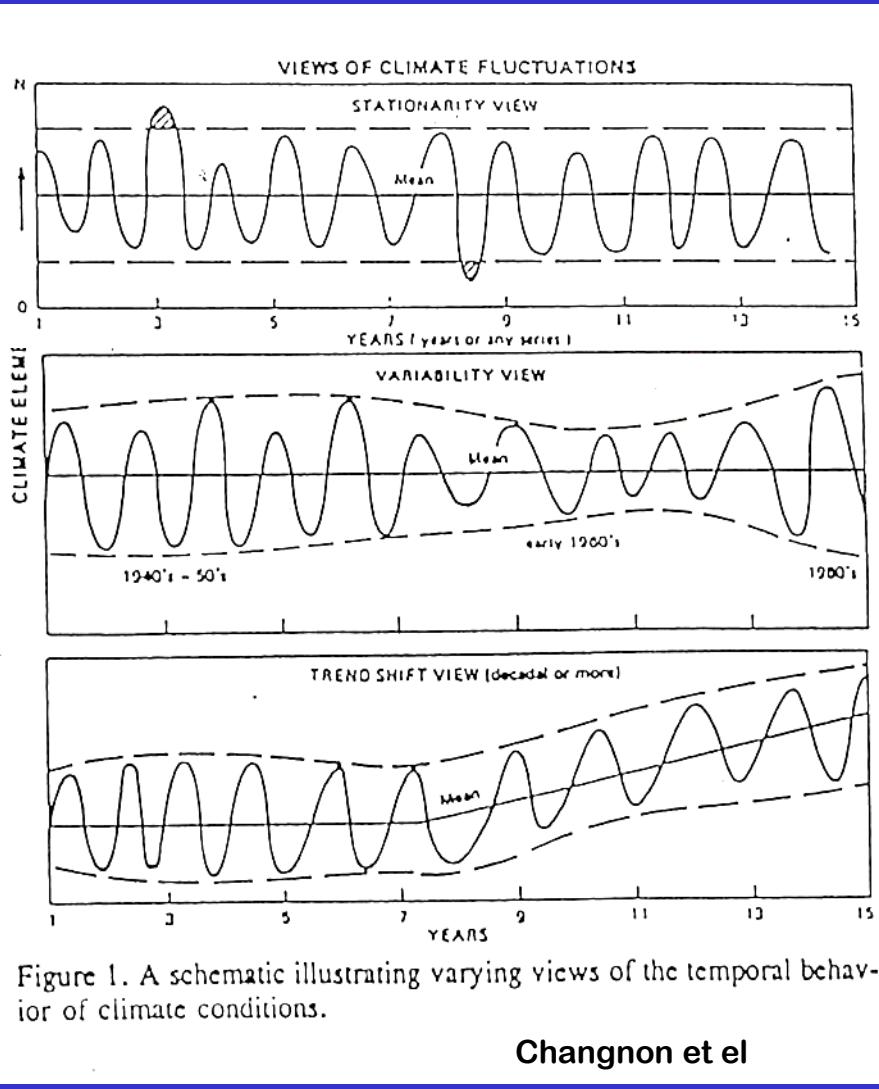
Arctic Sea Ice

Sun's Energy

Glaciers</b

Drivers of Earth Climate Behavior





Stationary (1)

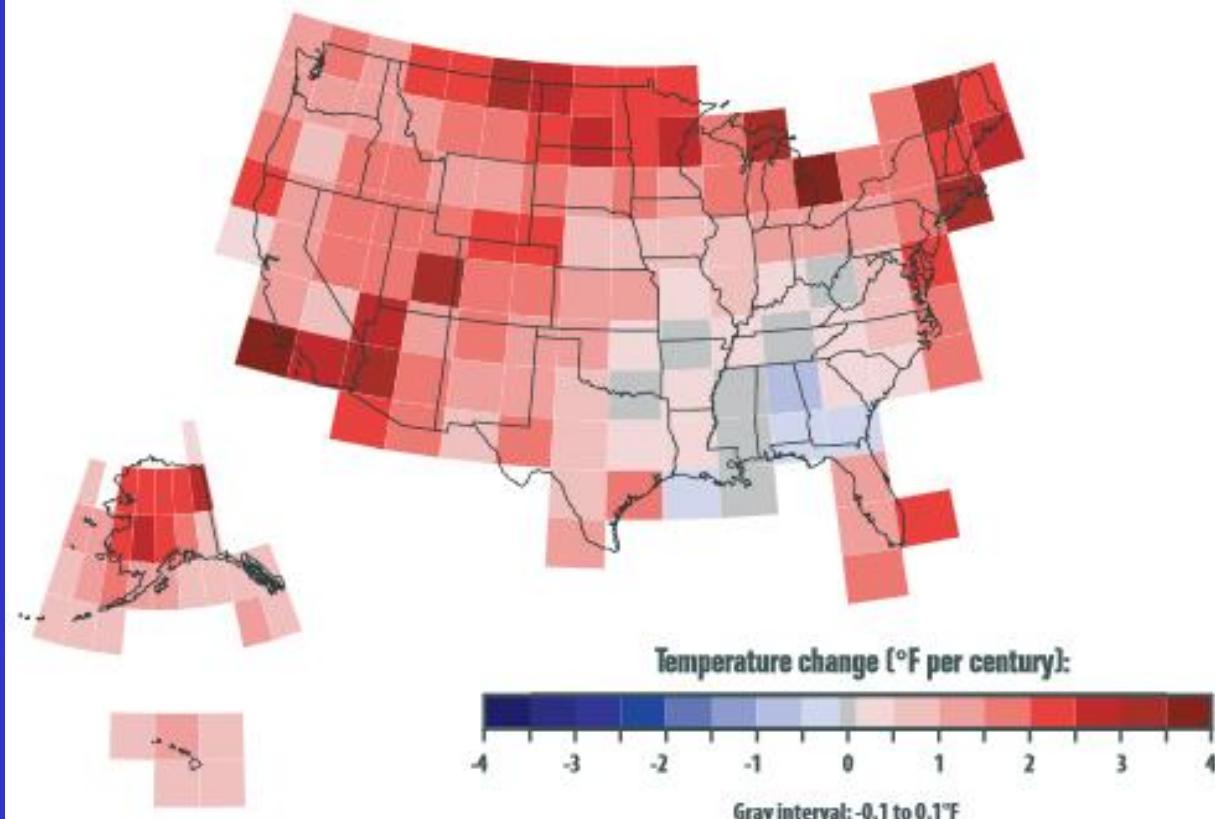
Variability (2)

Trend Shift (3)

Perceptions of climate behavior are built into the management of natural resources and the design of our infrastructure and its management...But climate behavior is changing!

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).

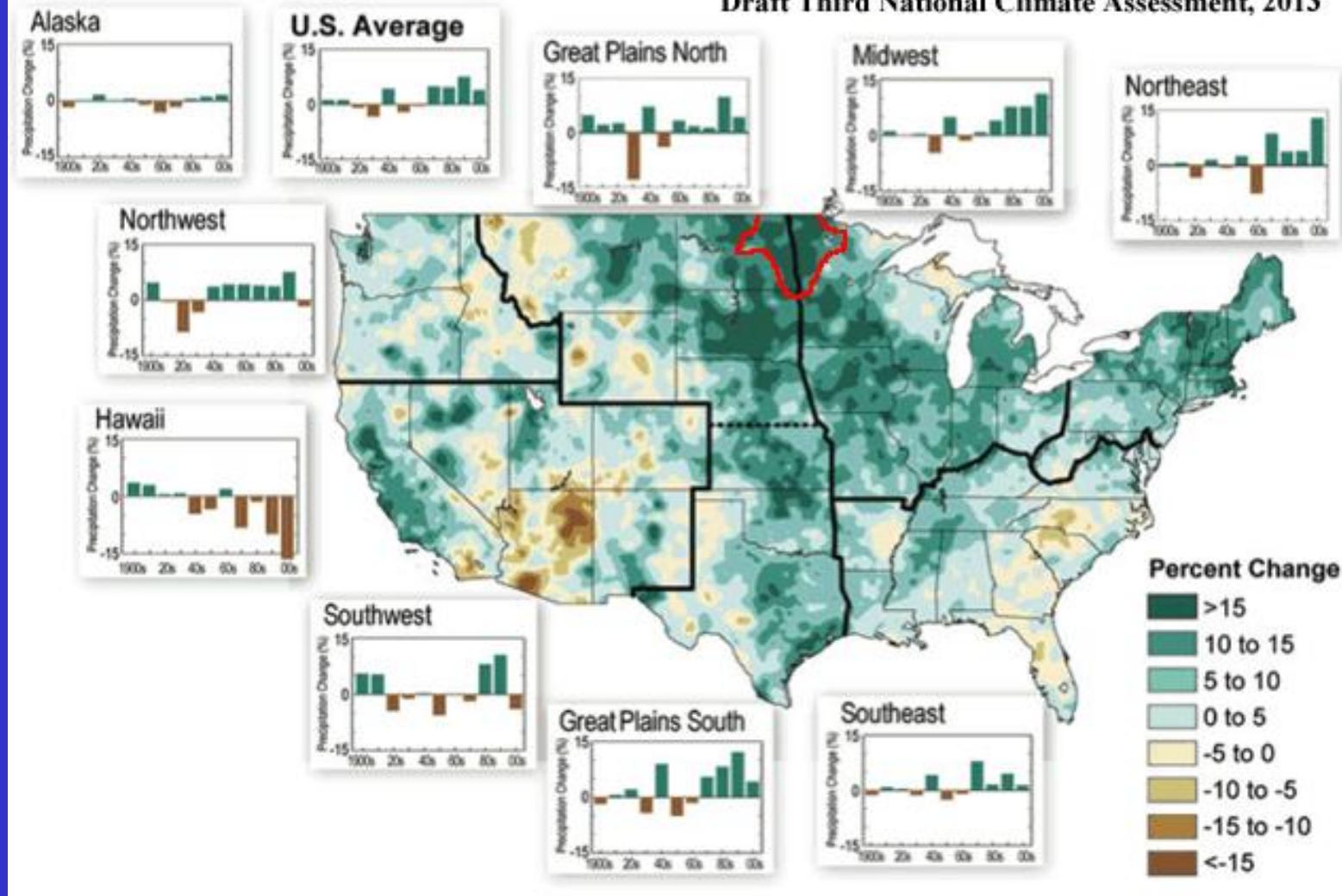


Data source: NOAA, 2009*

**Disparity in the pace of climate change
relative to temperature**

Observed U.S. Precipitation Change, 1991-2011 vs. 1901-1960 Average

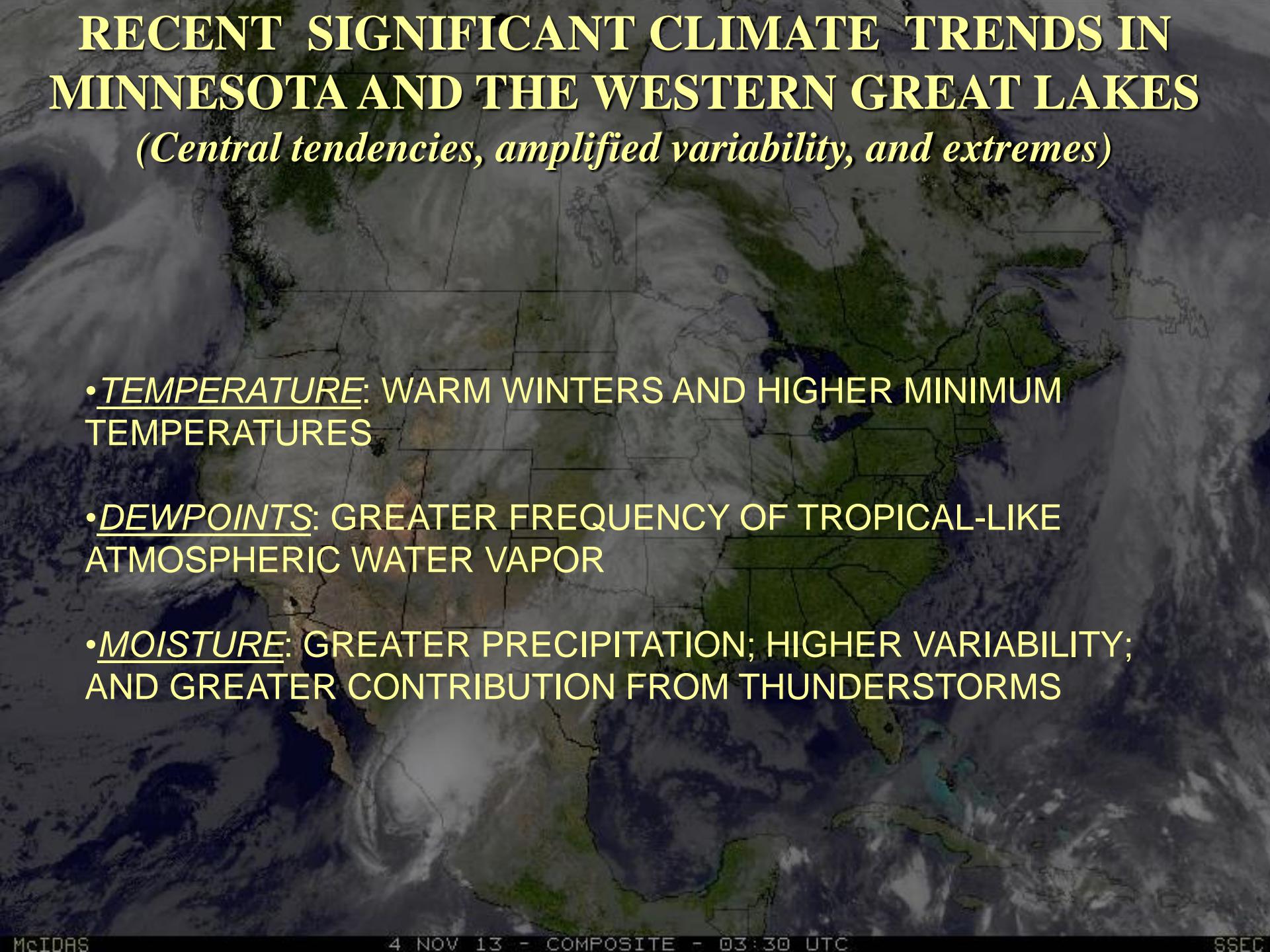
Draft Third National Climate Assessment, 2013



Geographic Disparity in Precipitation Change-IPCC 2013

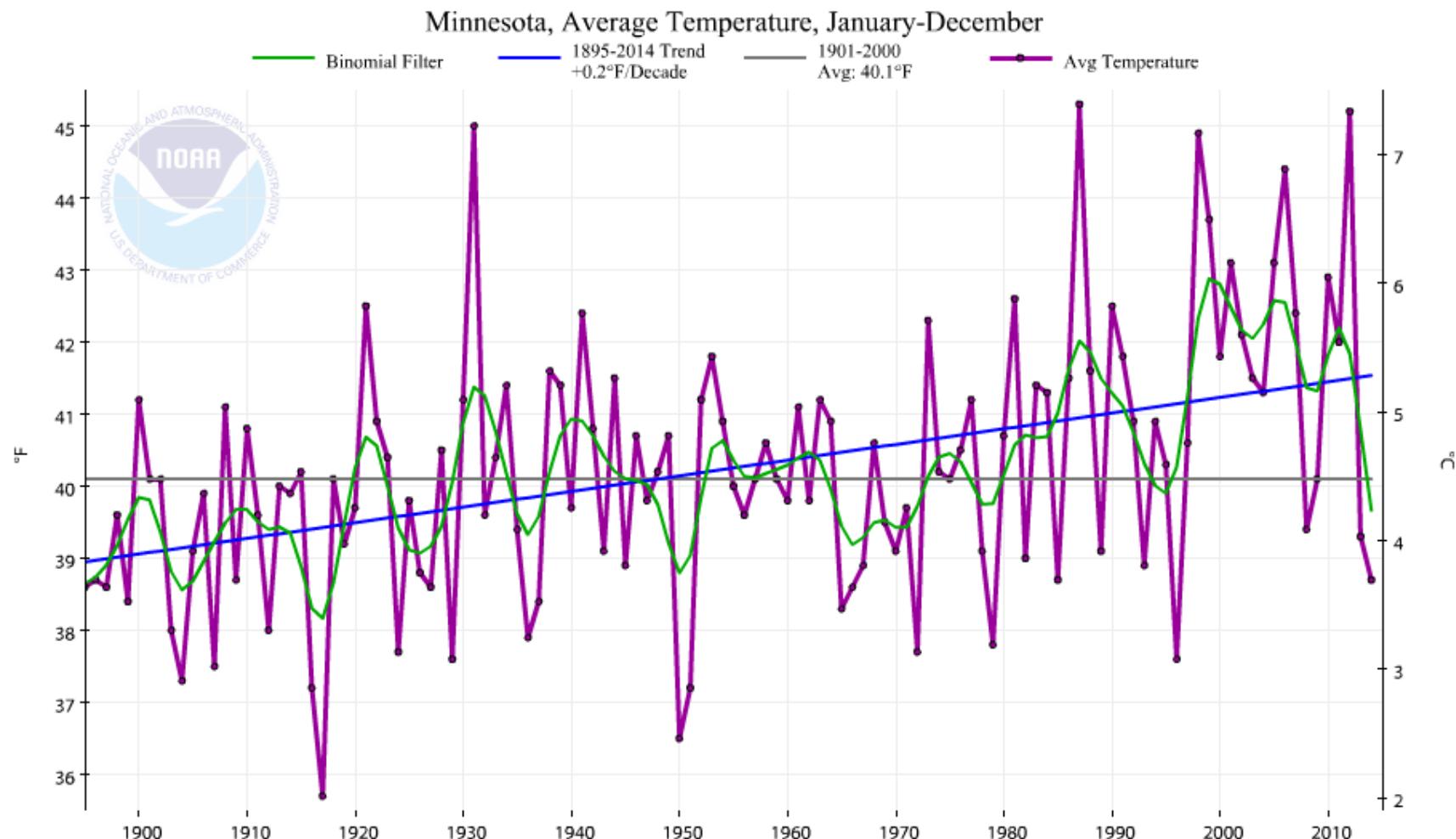
RECENT SIGNIFICANT CLIMATE TRENDS IN MINNESOTA AND THE WESTERN GREAT LAKES

(Central tendencies, amplified variability, and extremes)

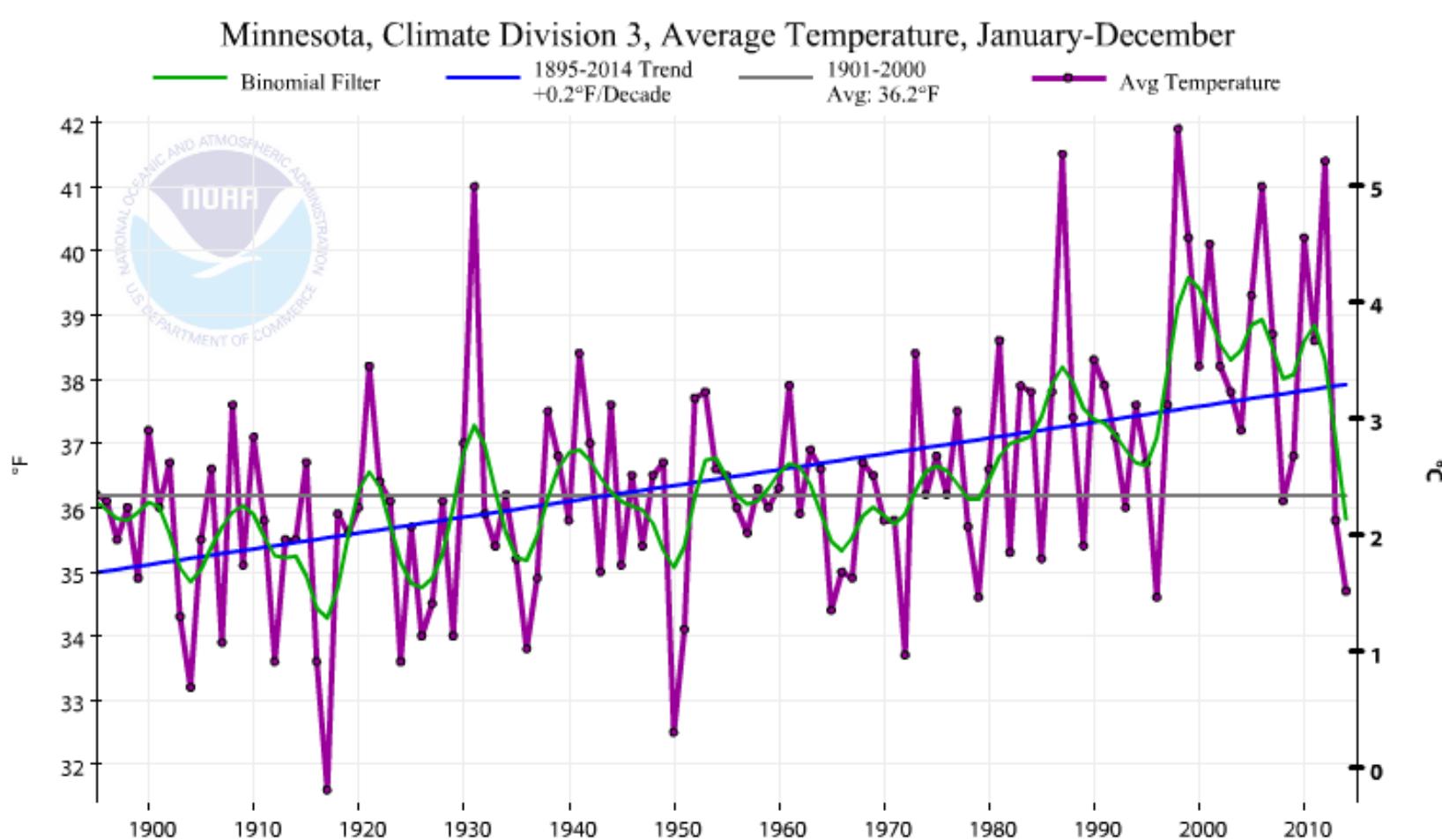


- TEMPERATURE: WARM WINTERS AND HIGHER MINIMUM TEMPERATURES
- DEWPOINTS: GREATER FREQUENCY OF TROPICAL-LIKE ATMOSPHERIC WATER VAPOR
- MOISTURE: GREATER PRECIPITATION; HIGHER VARIABILITY; AND GREATER CONTRIBUTION FROM THUNDERSTORMS

Minnesota Mean Annual Temperature Trends



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



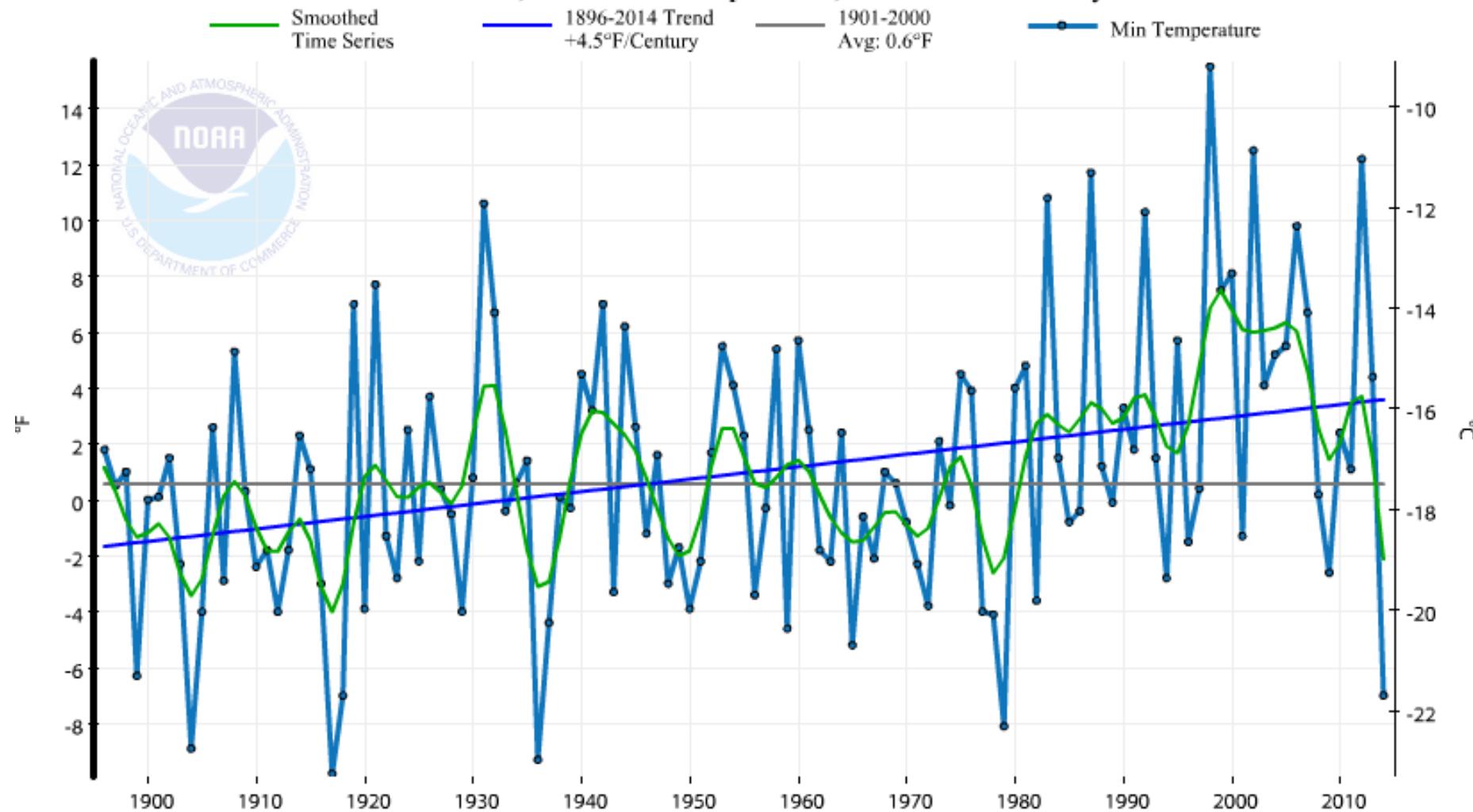
Northeastern Minnesota Annual Temperature Trend

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

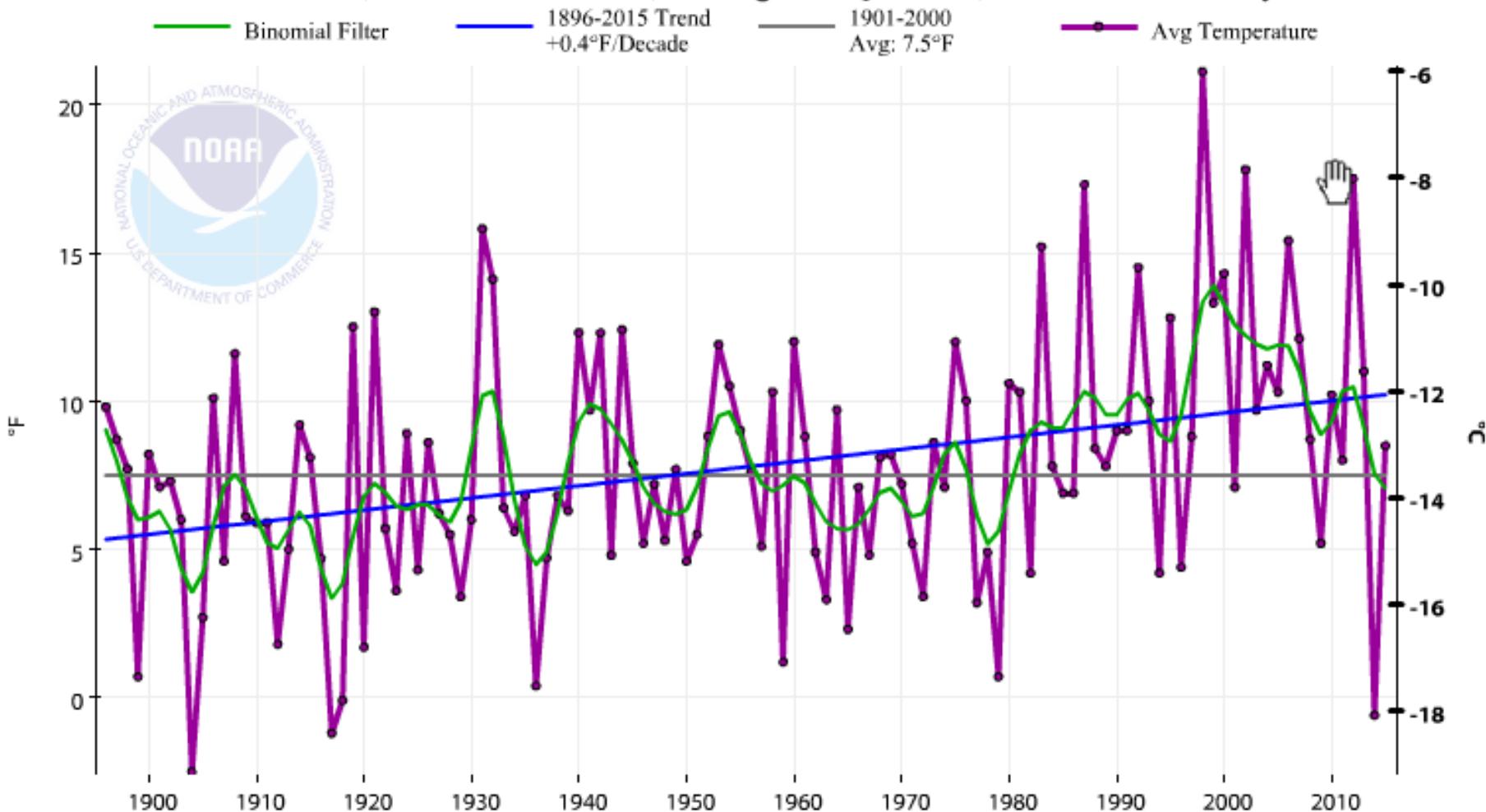
Month	Min Change	Max Change	Mean Change
<u>January</u>	+2.8	+0.8	+1.8
<u>February</u>	+0.9	-0.7	+0.1
<u>March</u>	+0.8	0.0	+0.4
<u>April</u>	+0.9	-0.2	+0.3
<u>May</u>	+0.2	-2.0	-1.0
<u>June</u>	+0.4	-1.4	-0.5
<u>July</u>	+0.3	-0.8	-0.3
<u>August</u>	+0.8	-0.1	+0.3
<u>September</u>	+1.1	+0.2	+0.7
<u>October</u>	+0.4	-1.4	-0.5
<u>November</u>	+1.3	+0.1	+0.7
<u>December</u>	+1.8	-0.3	+0.7

Minnesota Winter Season Minimum Temperature Trends

Minnesota, Minimum Temperature, December-February



Minnesota, Climate Division 3, Average Temperature, December-February



Trends in Winter Season Minimum Temperature for Northeastern, MN

Trends in average winter minimum temperatures Two Harbors, MN

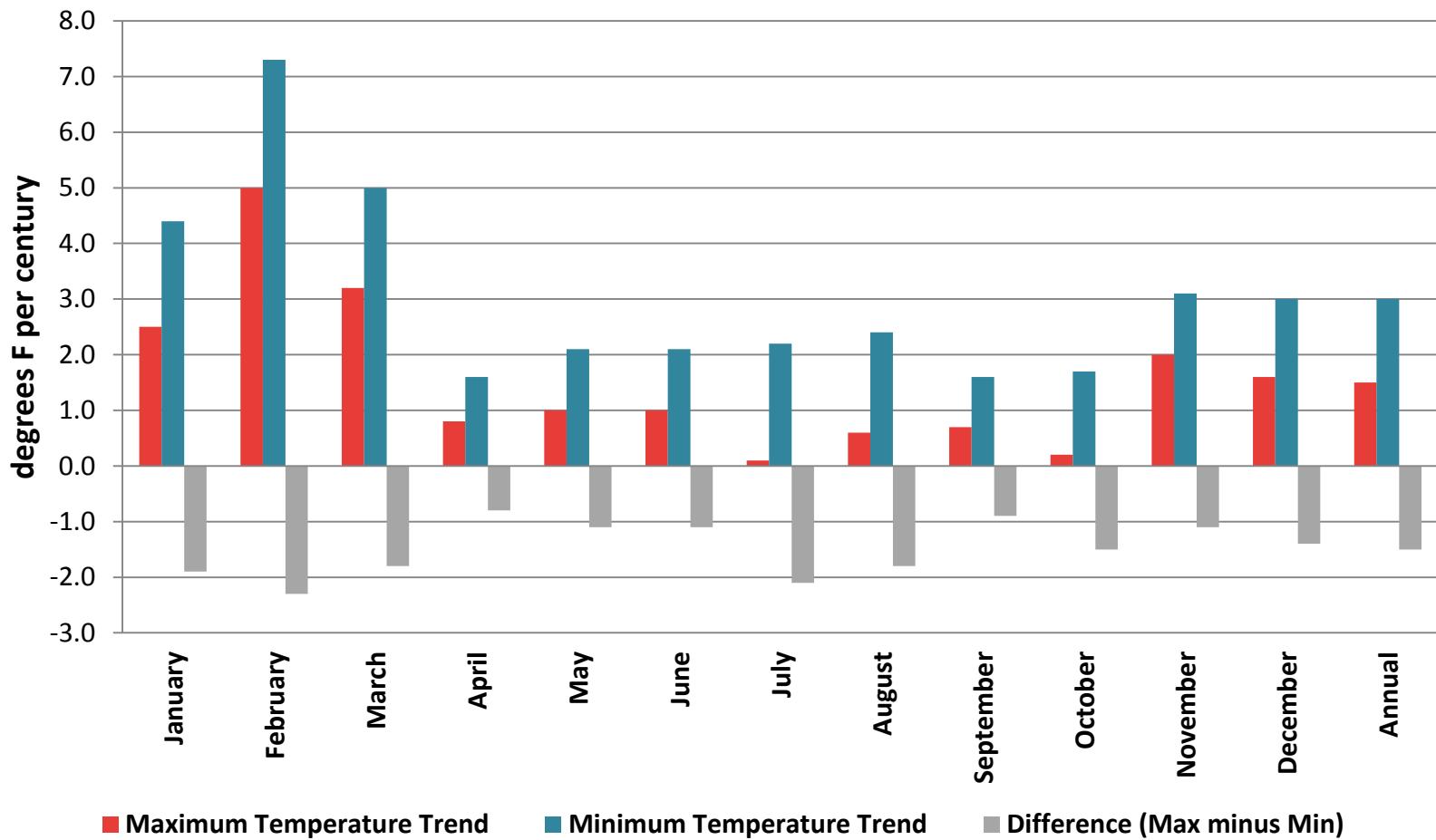
Period of Record

<u>Period of Record</u>	<u>Ave Min Temp in Deg. F</u>
1951 - 1980	Jan 2.3
1961 - 1990	Jan 3.3
1971 - 2000	Jan 5.0
1981 - 2010	Jan 7.4
1951 - 1980	Feb 6.3
1961 - 1990	Feb 7.3
1971 - 2000	Feb 10.1
1981 - 2010	Feb 11.3
1951 - 1980	Mar 17.3
1961 - 1990	Mar 19.2
1971 - 2000	Mar 20.3
1981 - 2010	Mar 21.2

Trends in average winter minimum temperatures for Cloquet, MN

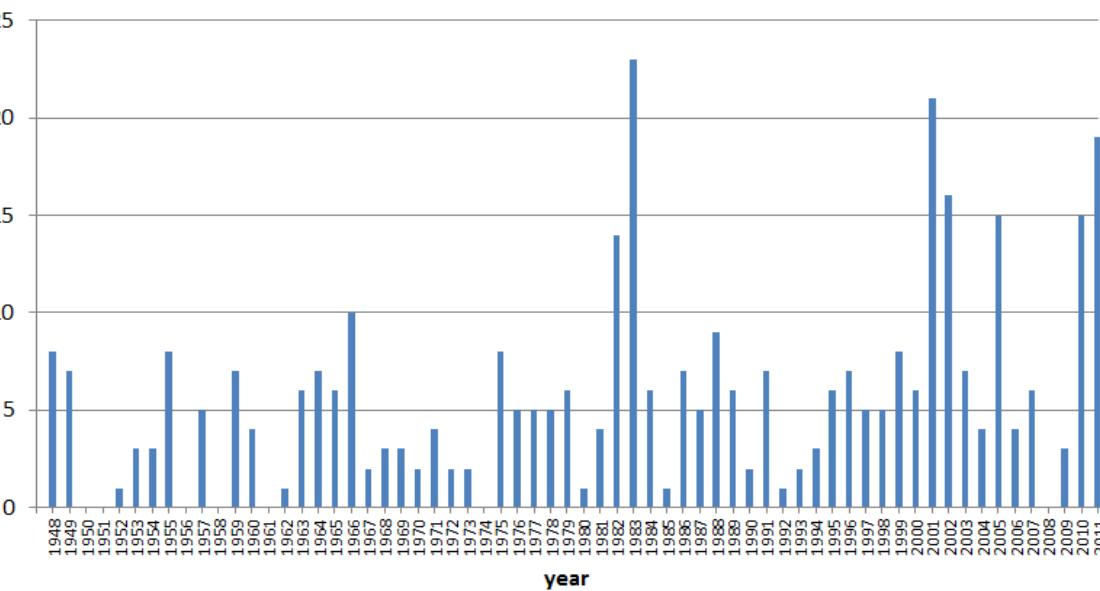
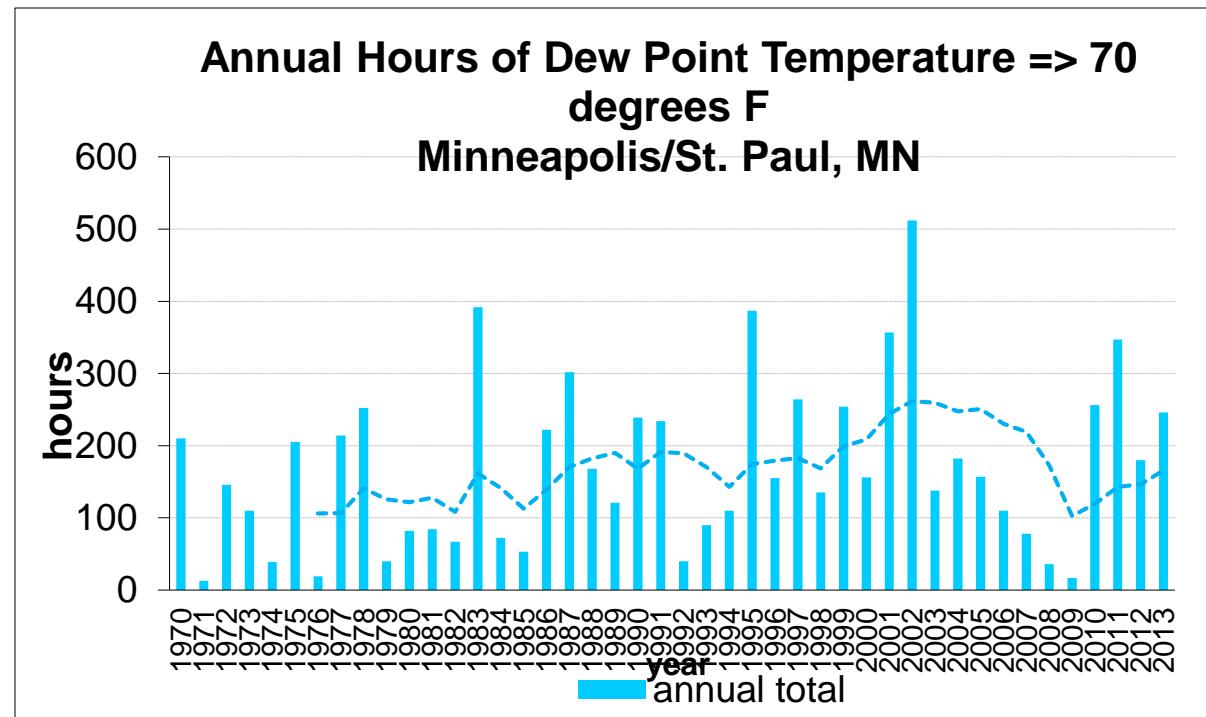
<u>Period of Record</u>	<u>Ave Min Temp in Deg. F</u>
1951 - 1980	Jan -3.5
1961 - 1990	Jan -1.4
1971 - 2000	Jan -1.2
1981 - 2010	Jan 1.4
1951 - 1980	Feb 1.5
1961 - 1990	Feb 4.5
1971 - 2000	Feb 4.8
1981 - 2010	Feb 5.4
1951 - 1980	Mar 13.4
1961 - 1990	Mar 15.7
1971 - 2000	Mar 16.2
1981 - 2010	Mar 16.5

Minnesota State-Averaged Temperature Trends 1895-2013



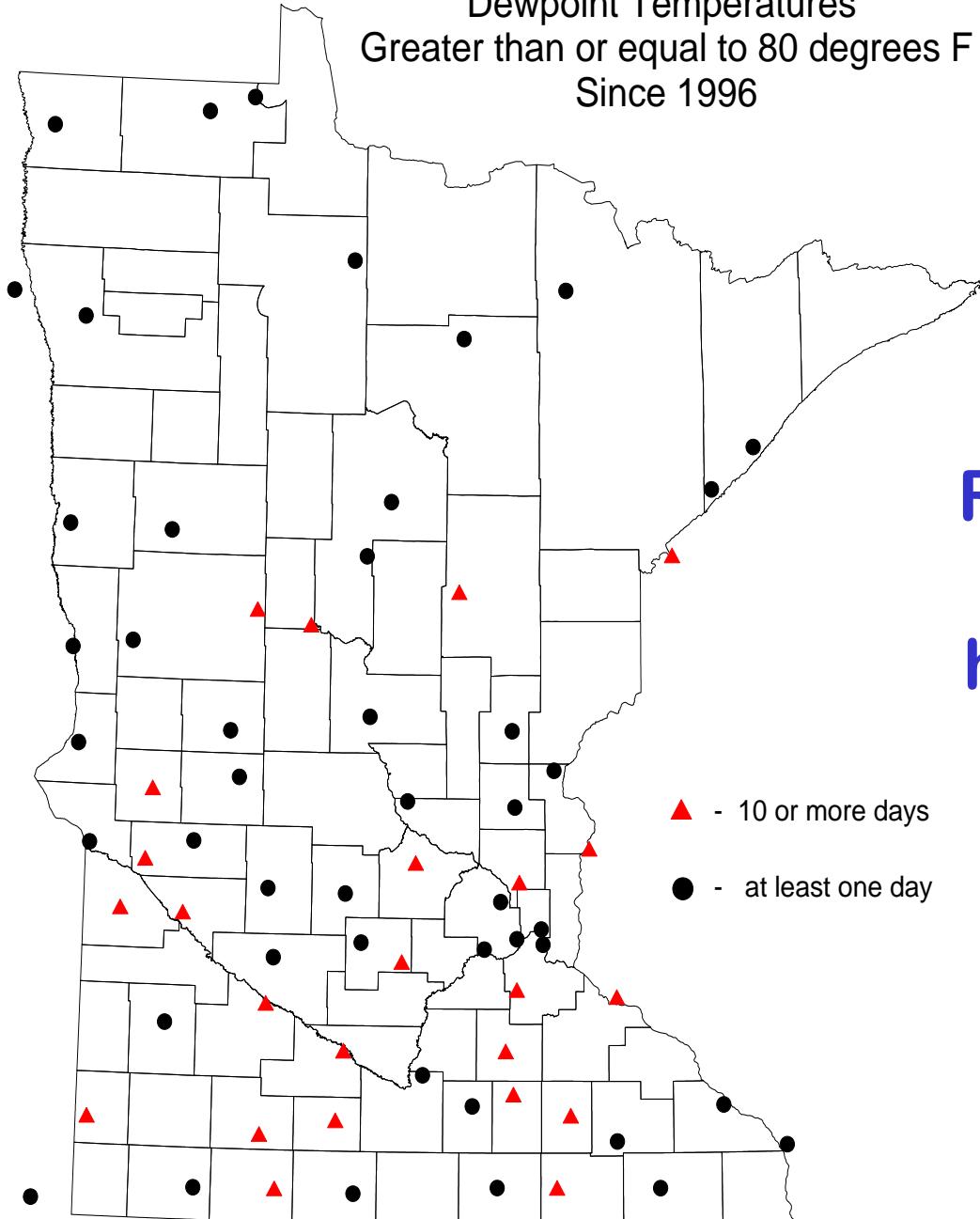
Trend in dewpoints of 70 F or higher in the Twin Cities

Latitude 45 degrees



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

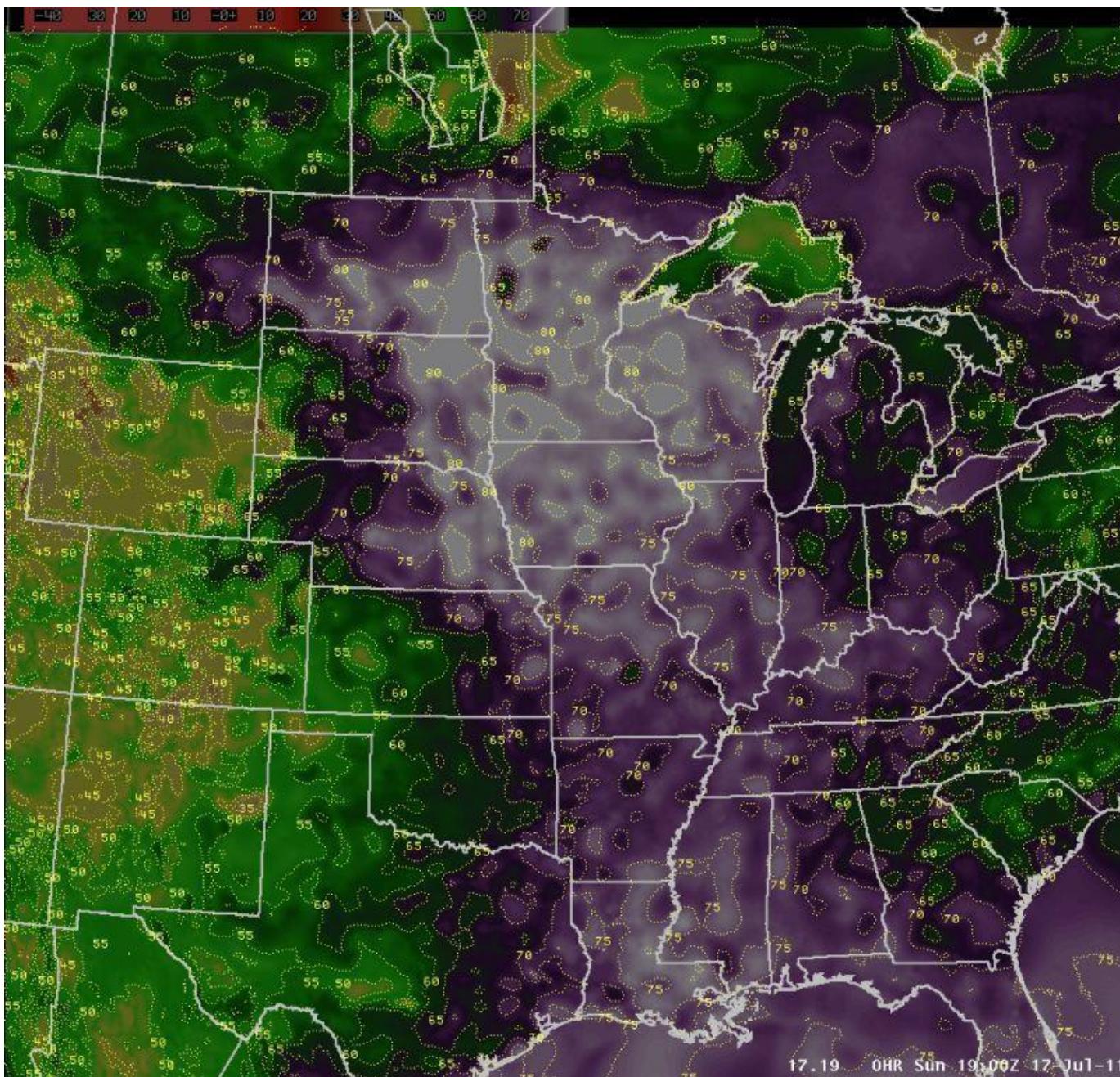
Latitude 48.5 degrees



**DP 80 F or higher.
Readings have been
statewide with
highest frequencies
in central and
southern counties**

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

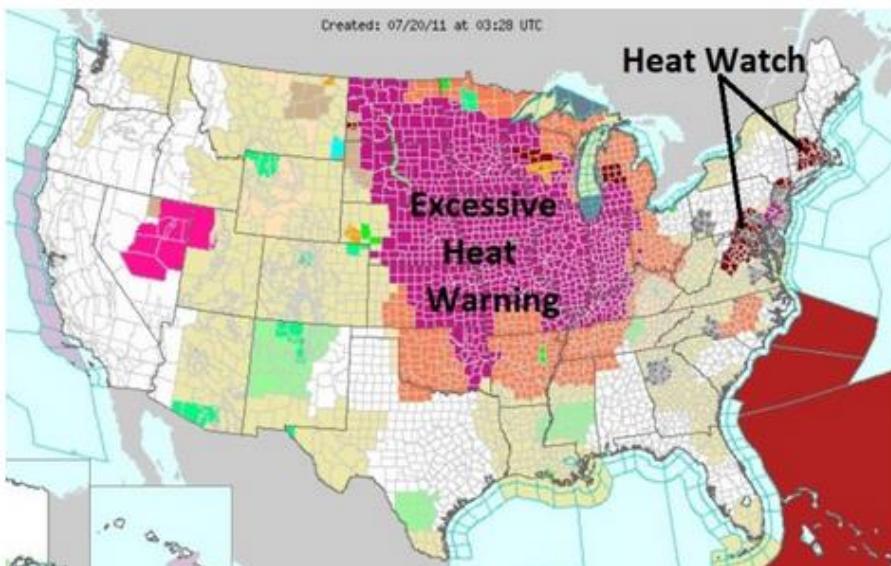
Year	Hours with DP of	Range of Heat
	70 F or greater	Index Values (F)
1947	256	99 - 112
1949	303	98 - 112
1955	345	98 - 113
1957	243	98 - 112
1959	317	99 - 113
1960	259	98 - 112
1978	252	99 - 114
1983	392	102 - 110
1987	302	98 - 104
1995	387	98 - 116
1997	264	98 - 113
1999	254	98 - 116
2001	357	98 -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



**Large Geographic
Expanse of 80°F
Dew points on July
19, 2011**



The Great Heatwave of '11. Heat indices will top 100 again today from the Great Plains eastward to the Great Lakes, Ohio Valley and southeastern USA, gripping the eastern 2/3rds of America.



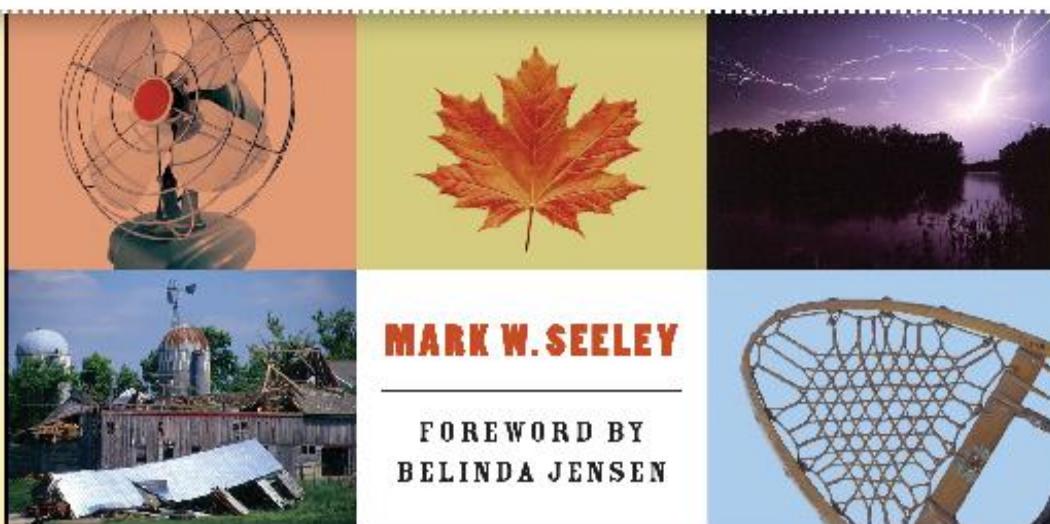
July 19,20, 2011 Heat Wave

Heat Index:

- 99°F Two Harbors**
- 98°F Cloquet**
- 102°F Hibbing**
- 101°F Duluth**
- 112°F Fergus Falls**
- 116°F Hallock**
- 117°F Fargo**
- 134°F Moorhead**



MINNESOTA WEATHER ALMANAC



MARK W. SEELEY

FOREWORD BY
BELINDA JENSEN

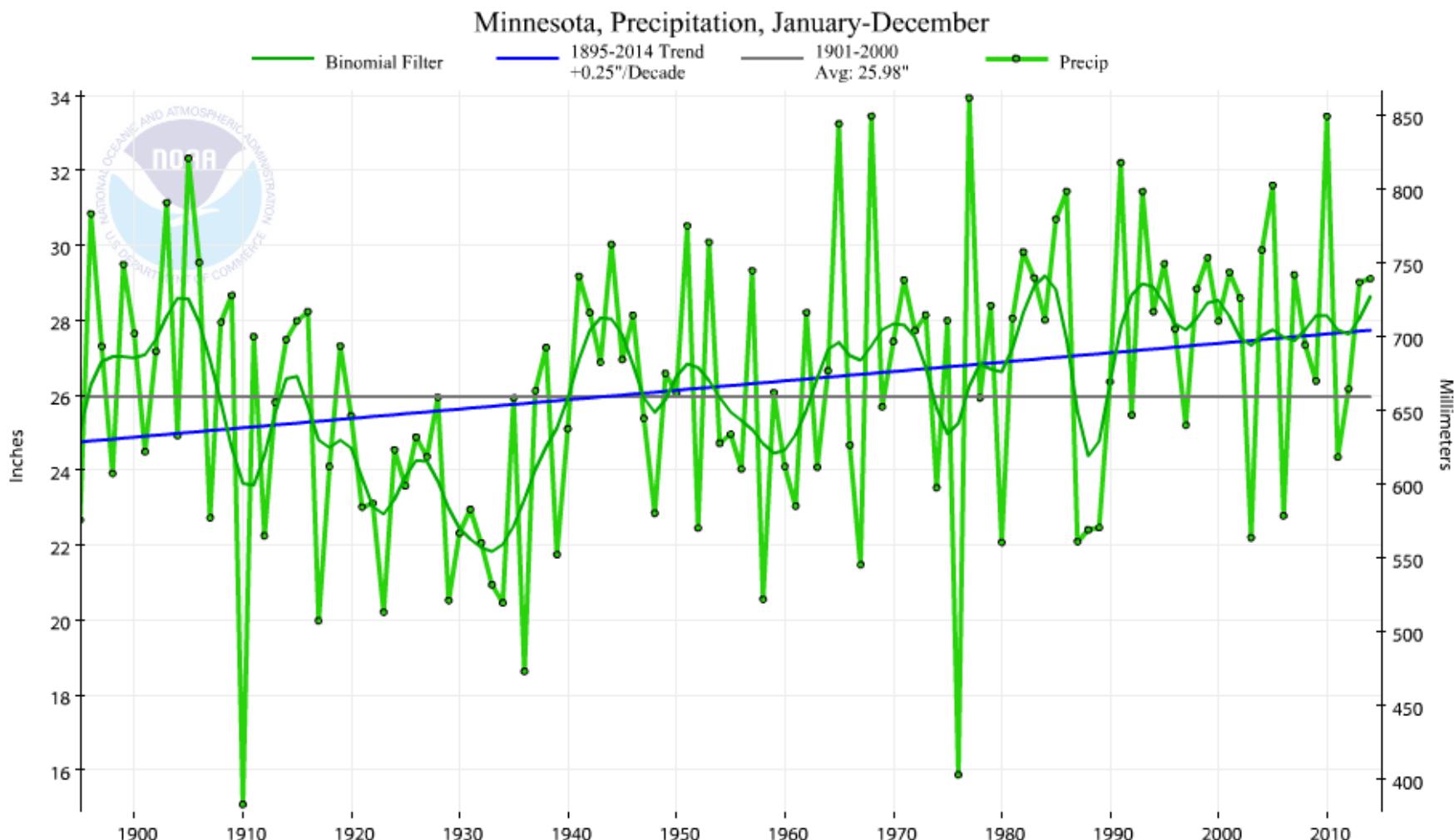
Historical Minnesota Heat Waves:

Red denotes dewpoint driven

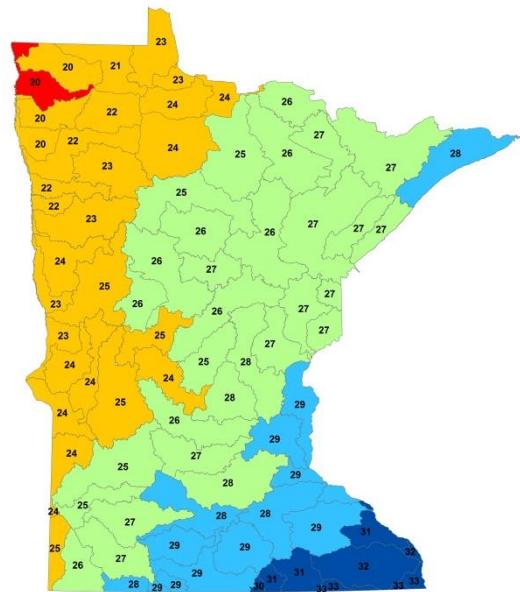
1883, 1894, 1901,
1910, 1917, 1921,
1931, 1933, 1934,
1936, 1937, 1947,
1948, 1949, 1955,
1957, 1959, 1964,
1976, **1977, 1983,**
1988, **1995, 1999,**
2001, 2005, 2006,
2007, 2010, 2011,
2012, 2013

(pattern is episodic but
increasing in frequency)

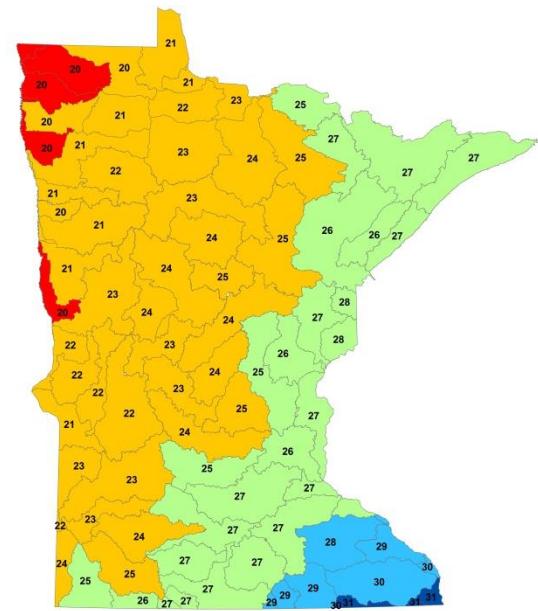
Minnesota Annual Precipitation Trends



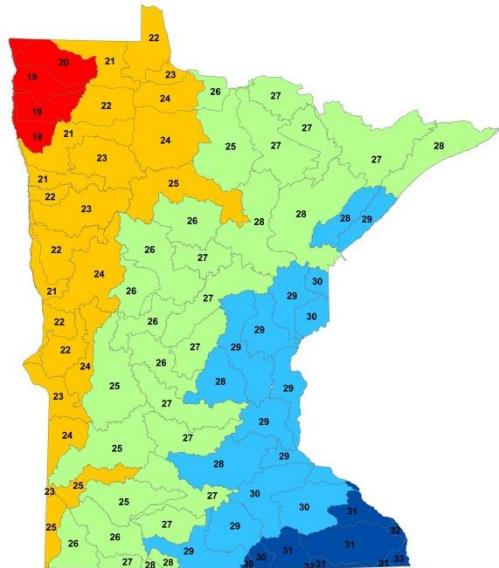
Average Annual PPT 1891-1920, in



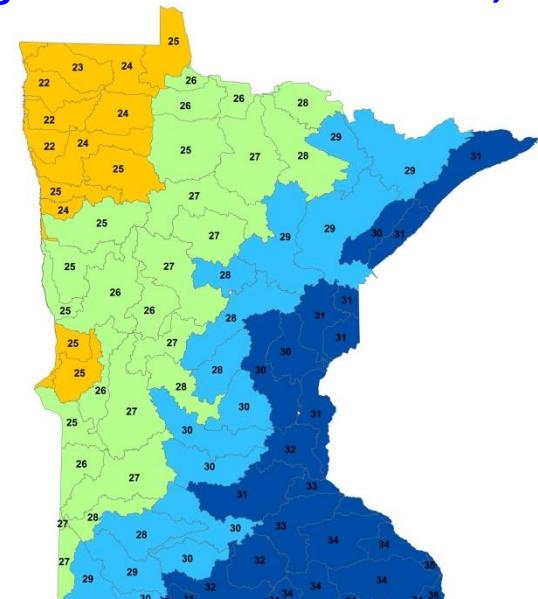
Average Annual PPT 1921-1950, in



Average Annual PPT 1951-1980, in

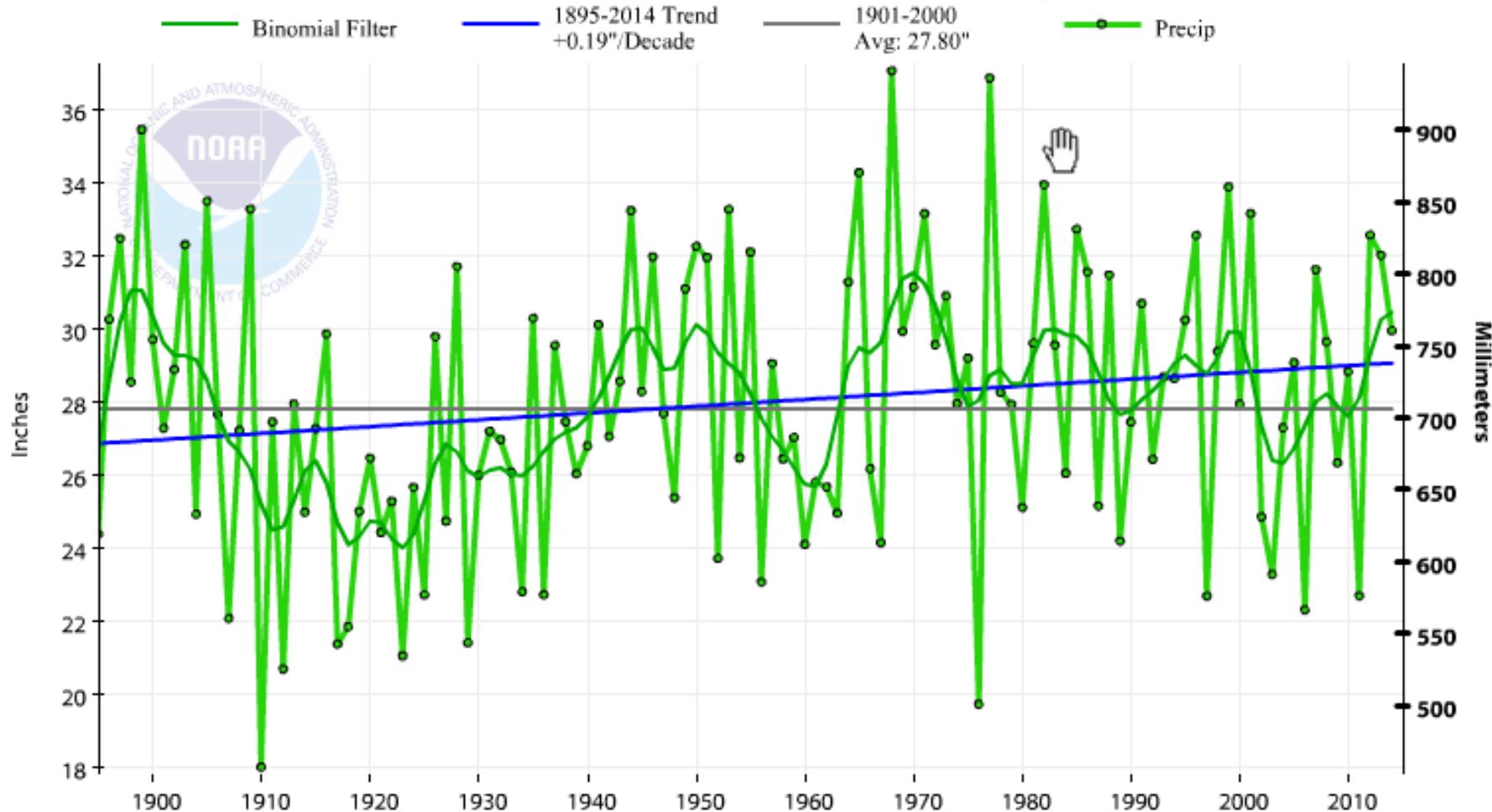


Average Annual PPT 1981-2010, in



Source: MN-SCO

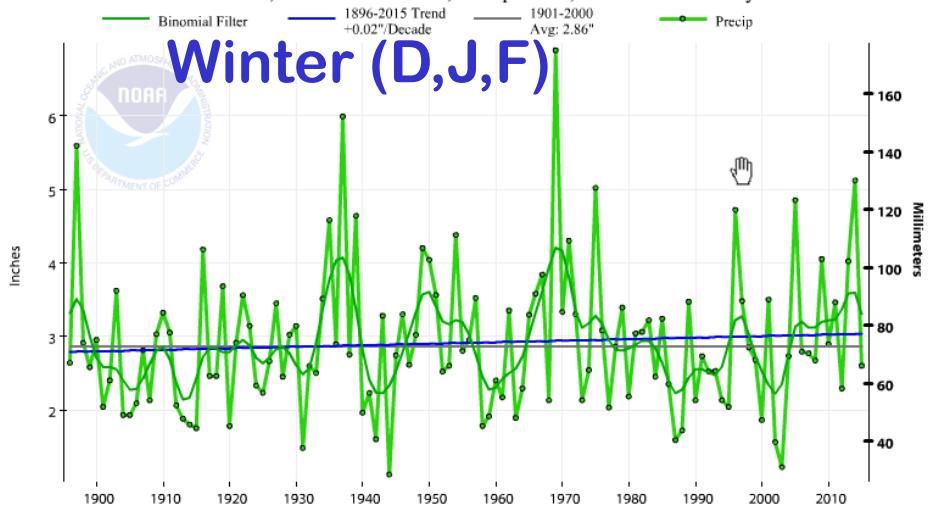
Minnesota, Climate Division 3, Precipitation, January-December



Northeastern Minnesota Annual Precipitation Trend

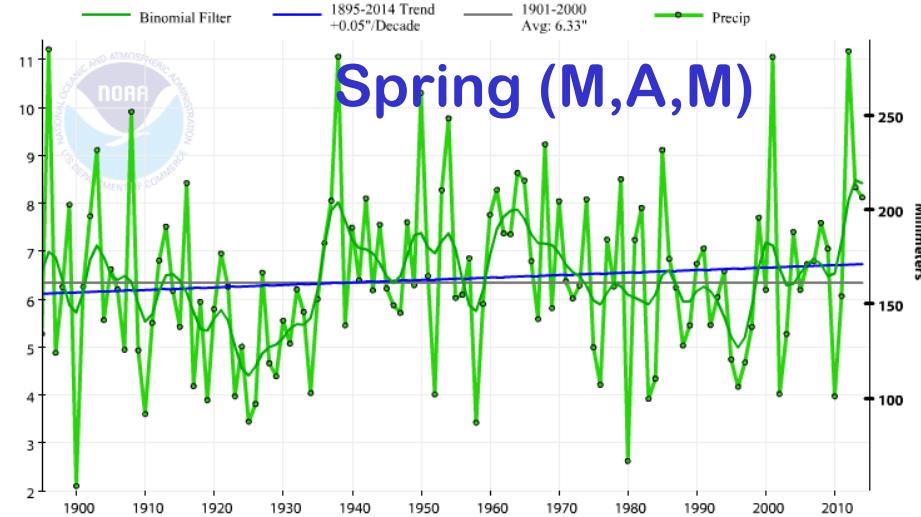
Move mouse towards an axis until highlighted. Left-click mouse to pan. Shift key + left-click to zoom.

Minnesota, Climate Division 3, Precipitation, December-February

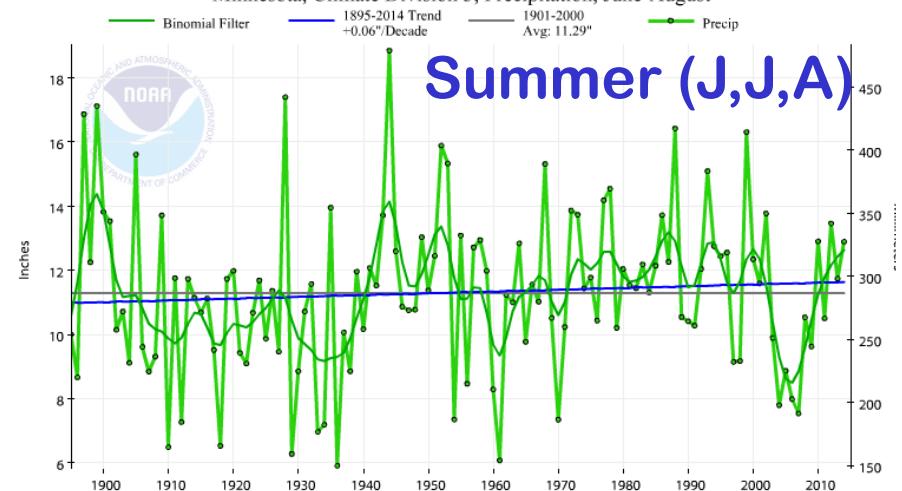


Seasonality in Northeastern MN Precipitation Trends

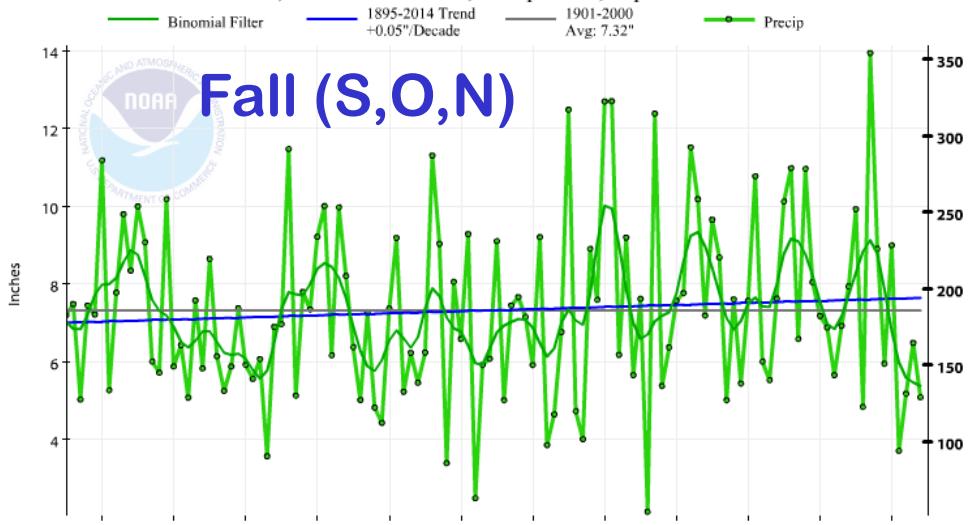
Minnesota, Climate Division 3, Precipitation, March-May



Minnesota, Climate Division 3, Precipitation, June-August



Minnesota, Climate Division 3, Precipitation, September-November



Change in Annual Precipitation “Normals” at Cloquet, MN

<u>PERIOD</u>	<u>AMOUNT (IN.)</u>
1921-1950	27.94"
1931-1960	29.05"
1941-1970	30.25"
1951-1980	29.93"
1961-1990	30.59"
1971-2000	31.77"
1981-2010	31.83"

14 percent increase
since 1921-1950 period

Extremes: 19.30" in 1918, 42.53" in 1991

Change in Annual Precipitation Normals at Two Harbors, MN

<u>PERIOD</u>	<u>AMOUNT (IN.)</u>
1951-1980	27.69"
1961-1990	28.76"
1971-2000	30.44"
1981-2010	31.11"

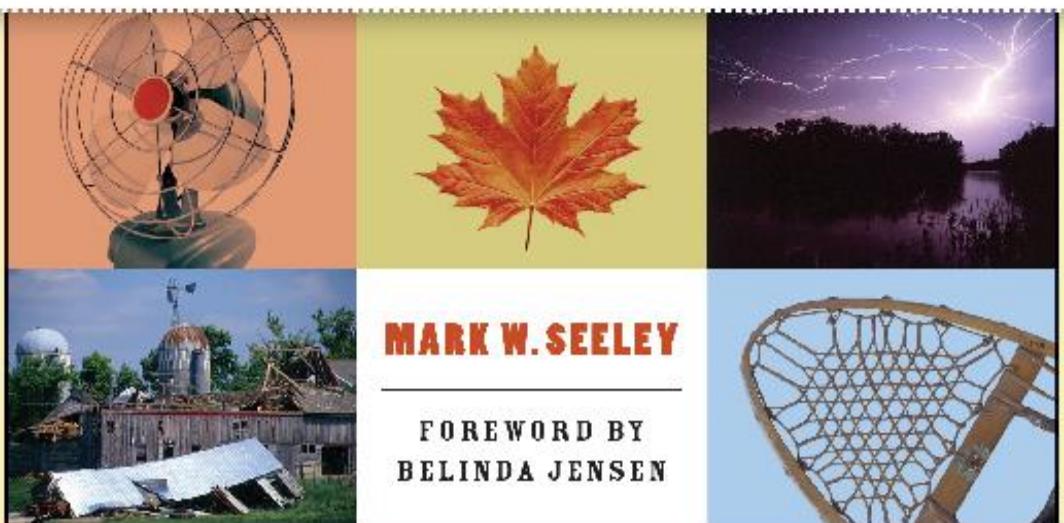
12 percent increase since 1951-1980
period



Measurable Attributes of Precipitation



MINNESOTA WEATHER ALMANAC



Quantity

Type (liquid, frozen)

Intensity (9-15")

Frequency (74-145 days)

Duration (10 days)

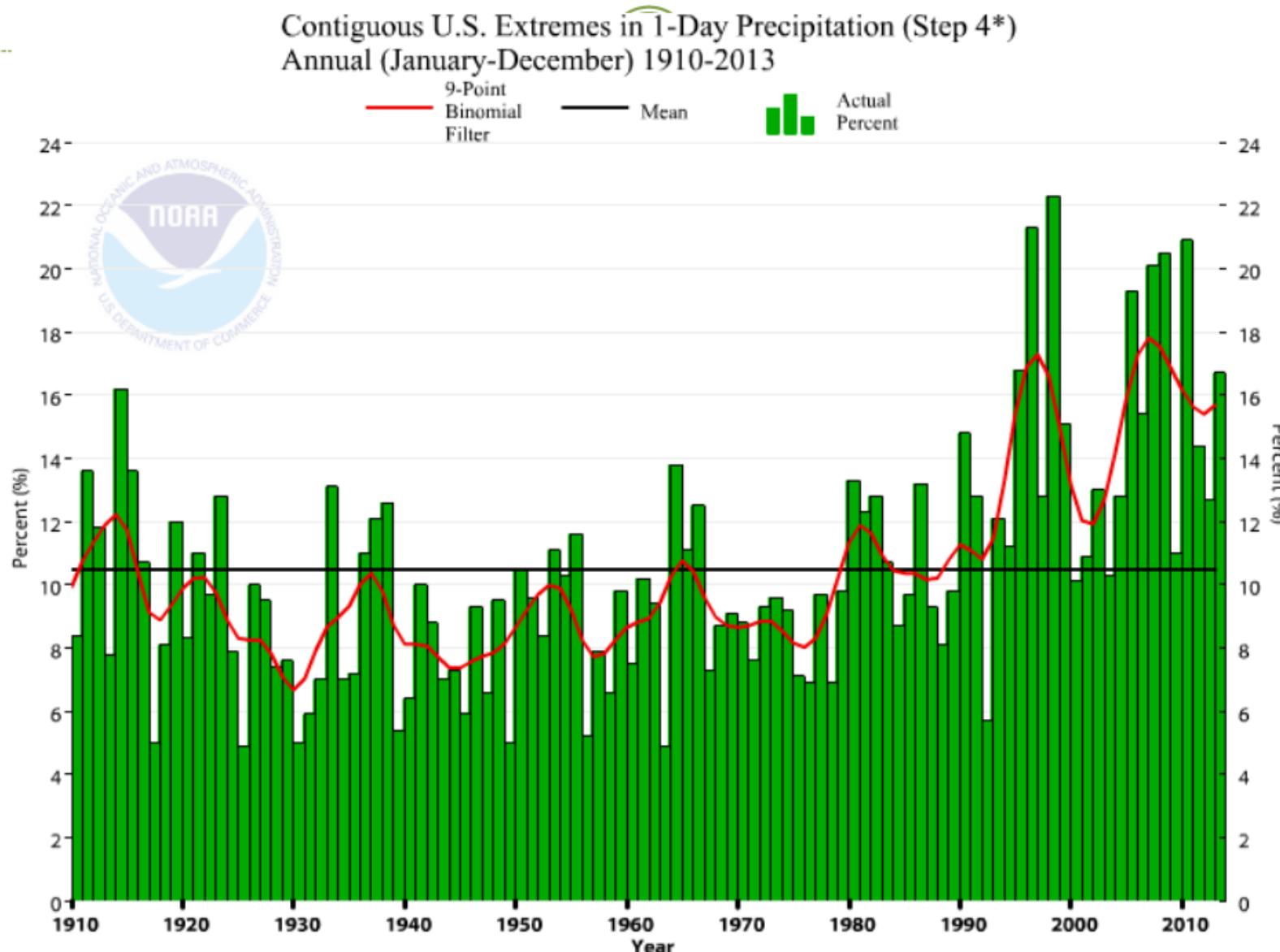
Seasonality (shifting)

Landscape relationship

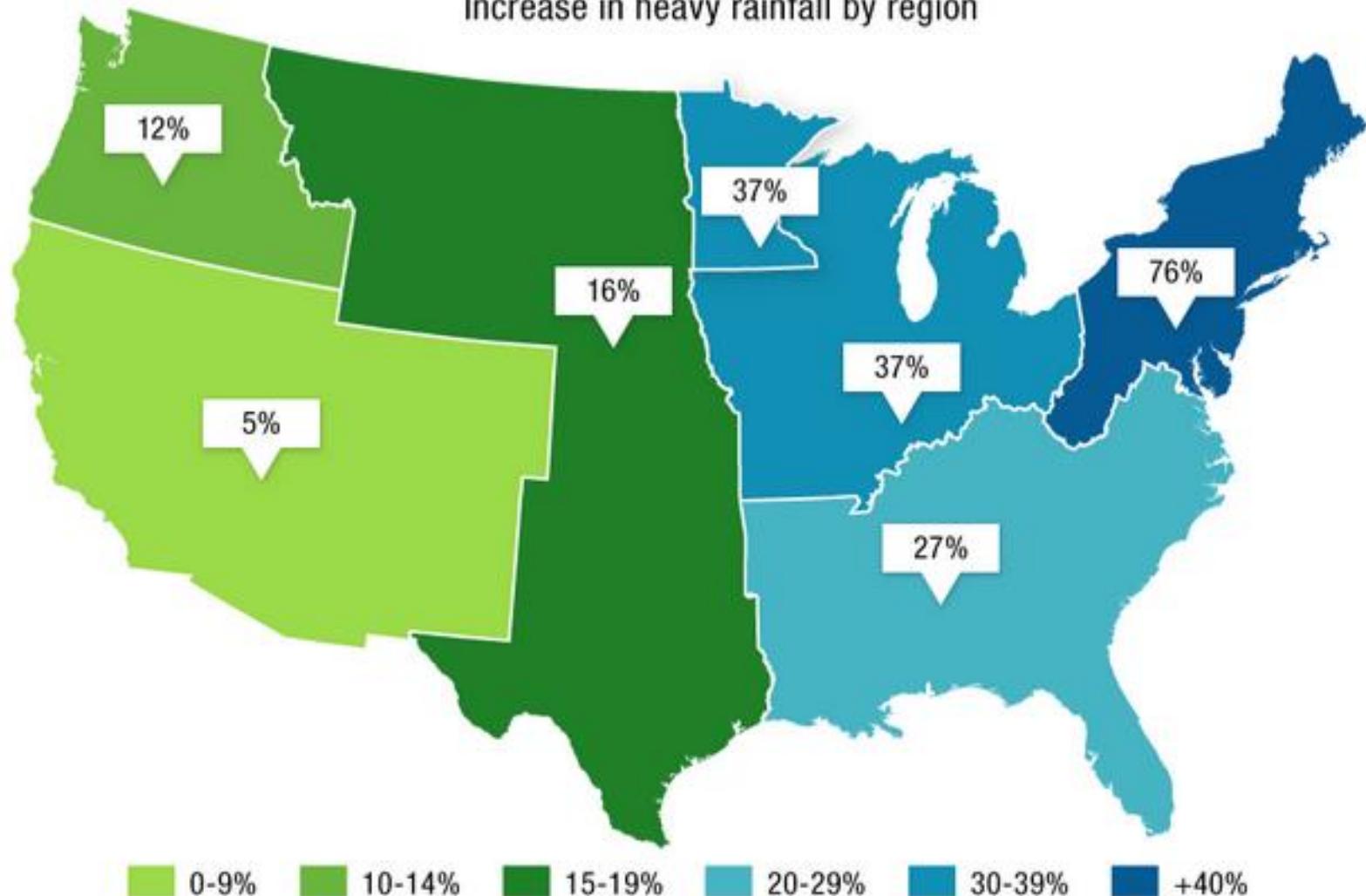
*(interception, absorption,
runoff, evaporation)*

National Heavy Precipitation Changes

(www.ncdc.noaa.gov/extremes/cei)



Increase in heavy rainfall by region



Source: National Climate Assessment, National Climatic Data Center

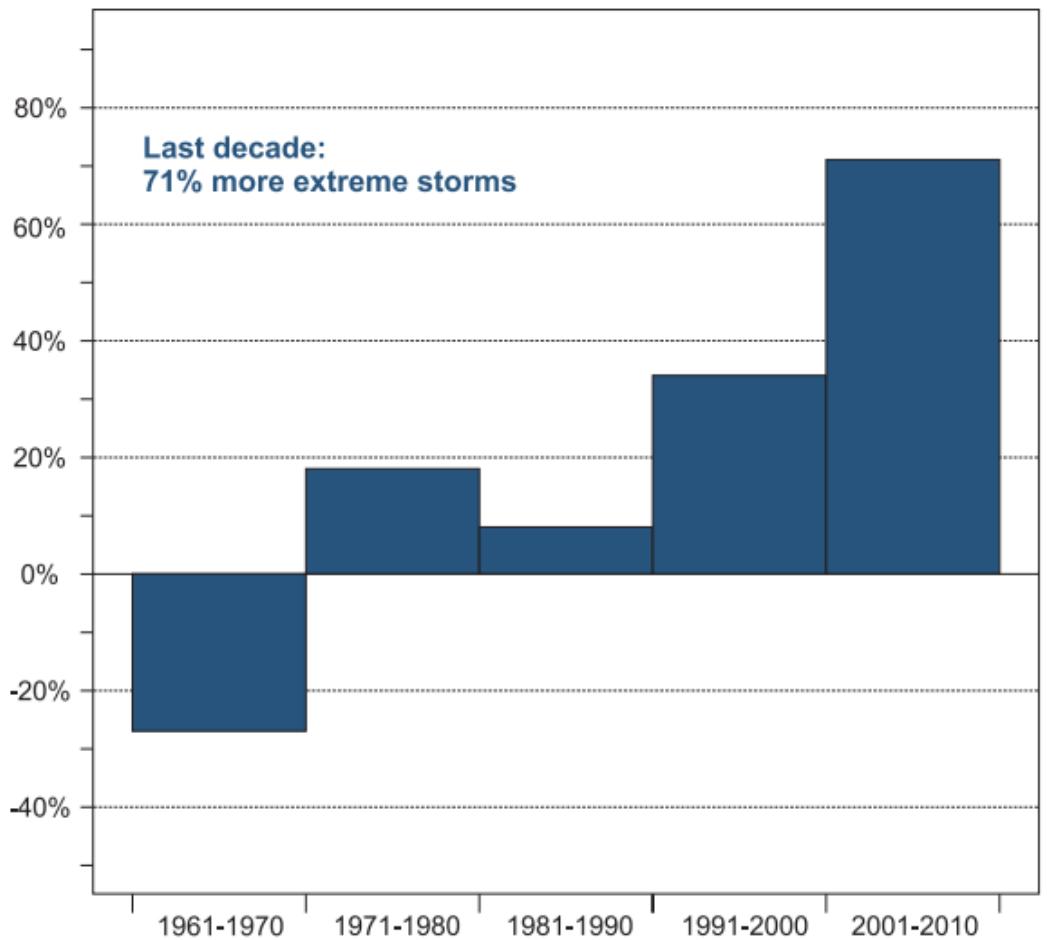
Historical recurrence interval of 2" rains in northern MN is once every two yrs

Observed 2 inch rainfalls for the period 1991 – 2014 (most recent 24 years) and maximum single day value for MN communities:

Location	No. 2 in. rains	Maximum Value (date)
Duluth	24	5.20 (7/21/1909)
Two Harbors	23	10.45 (6/20/2012)
Cloquet	25	8.44 (9/6/1990)
Leech Lake	22	7.02 (7/10/1954)
Wright	22	6.11 (6/20/2012)
Moose Lake	24	4.98 (7/20/1927)
Pokegama	28	5.62 (10/10/1973)
Hibbing	22	5.75 (8/13/1988)
Thorhult	26	6.50 (8/1/2001)

Trends in MN Flash Flooding Events

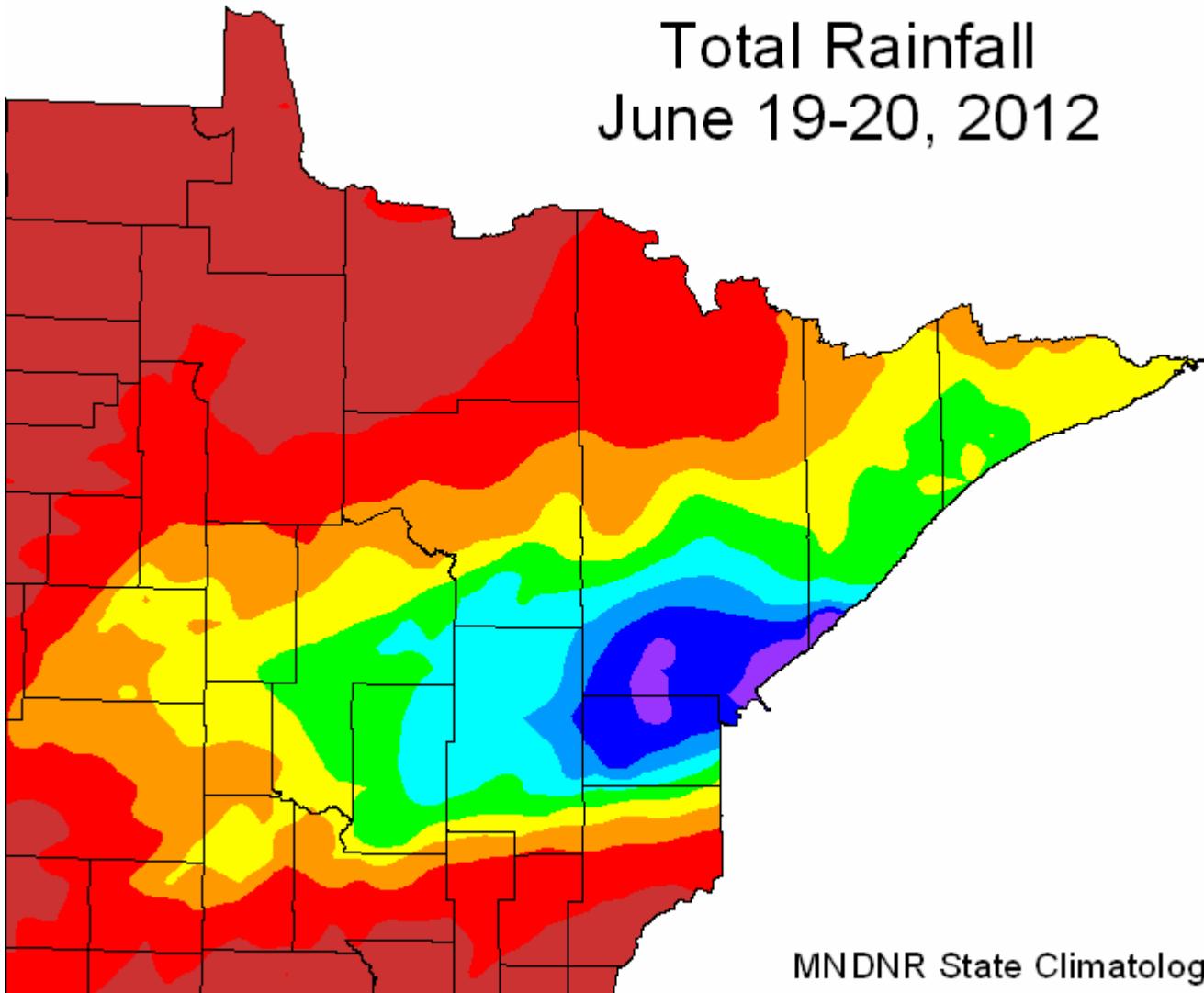
Changes in Frequency of 3-Inches-Plus Storms in Minnesota



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

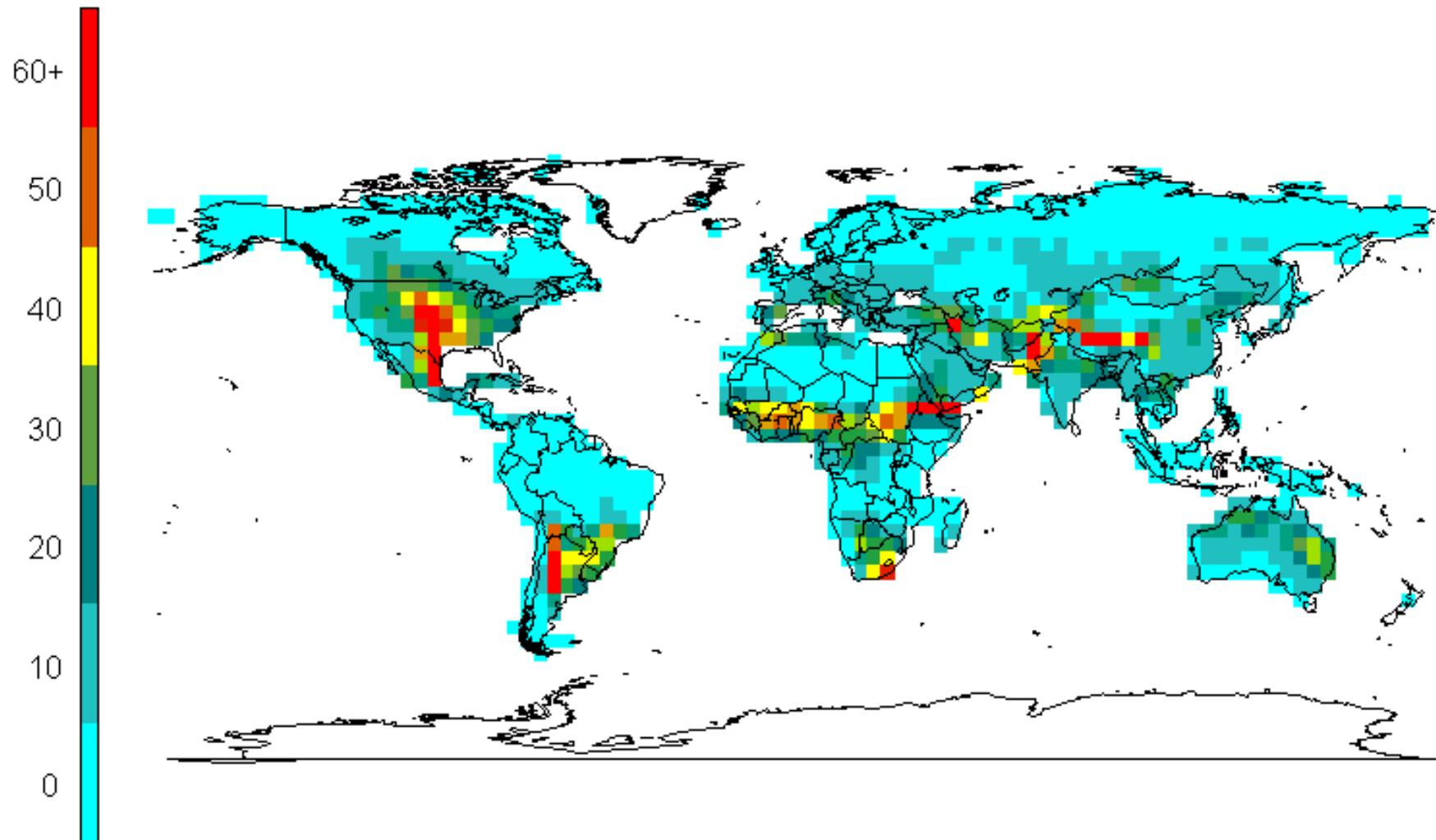
Total Rainfall June 19-20, 2012



NE Duluth 9.70"
Two Harbors 10.69"
Cloquet 8.35"
Grand Rapids 5.44"
Floodwood 6.61"

June 19-20, 2012
*7-10 inches of
rainfall in parts of
Carlton, St Louis,
and Lake Counties*

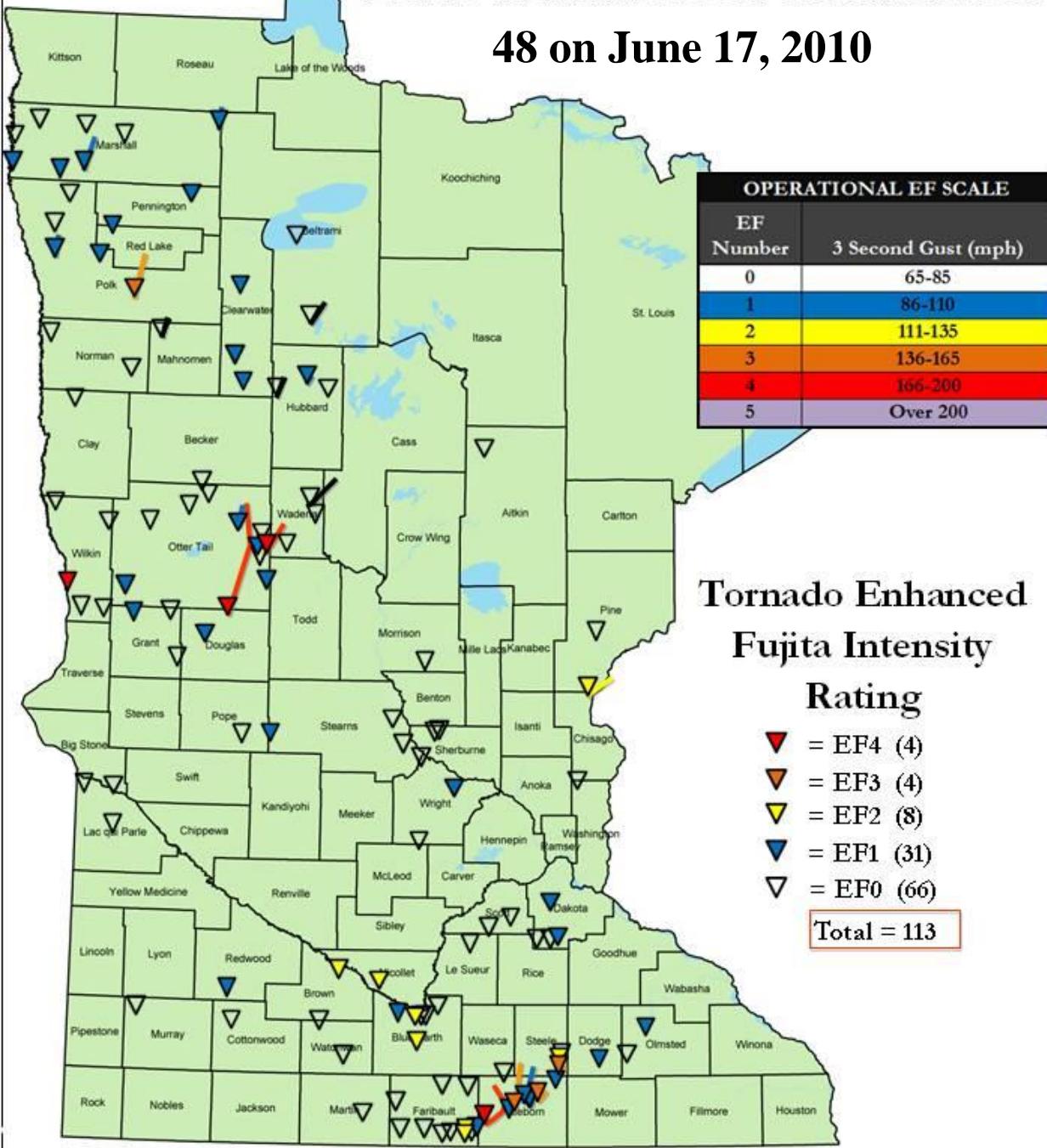
Days per Year with Favorable Severe Parameters



from Brooks et al, NOAA-SSL, 2012

2010 Minnesota Tornadoes

48 on June 17, 2010



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.

Observations – Minnesota Trends

Minnesota Mega-rain Events

August 6, 1866, Southern Minnesota

July 17-19 1867, Central Minnesota

July 20-22, 1909, Northern Minnesota

September 9-10, 1947 Iron Range

July 21-22, 1972, Grand Daddy Flash Flood

June 28-29, 1975, Northwest Minnesota

July 23-24, 1987, Twin Cities Superstorm

June 9-10, 2002, Northern Minnesota

September 14-15, 2004 Southern Minnesota

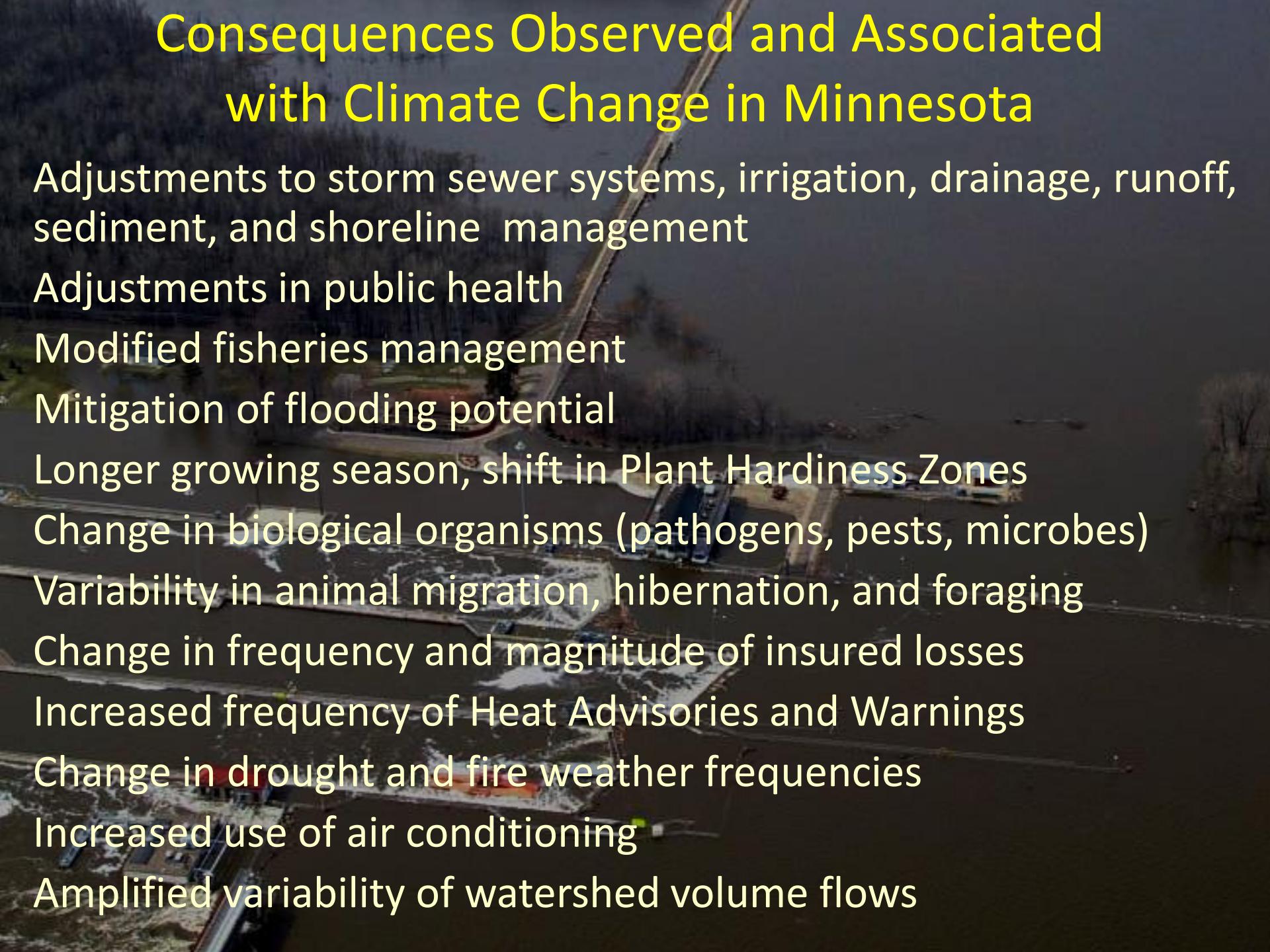
August 18-20, 2007, Southern Minnesota

September 22-23, 2010 Southern Minnesota

June 19-20, 2012, Northeast Minnesota

Three in northwestern Minnesota!

Consequences Observed and Associated with Climate Change in Minnesota

- 
- A dark, grainy aerial photograph showing a severe flooding event. A river or large stream has溢出 (over溢出) its banks, inundating a residential neighborhood. Numerous houses are completely submerged, and the surrounding streets are flooded. The water level is very high, reaching well above the ground level of the houses.
- Adjustments to storm sewer systems, irrigation, drainage, runoff, sediment, and shoreline management
 - Adjustments in public health
 - Modified fisheries management
 - Mitigation of flooding potential
 - Longer growing season, shift in Plant Hardiness Zones
 - Change in biological organisms (pathogens, pests, microbes)
 - Variability in animal migration, hibernation, and foraging
 - Change in frequency and magnitude of insured losses
 - Increased frequency of Heat Advisories and Warnings
 - Change in drought and fire weather frequencies
 - Increased use of air conditioning
 - Amplified variability of watershed volume flows

Rabbits in the sky



A Poodle in the sky



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



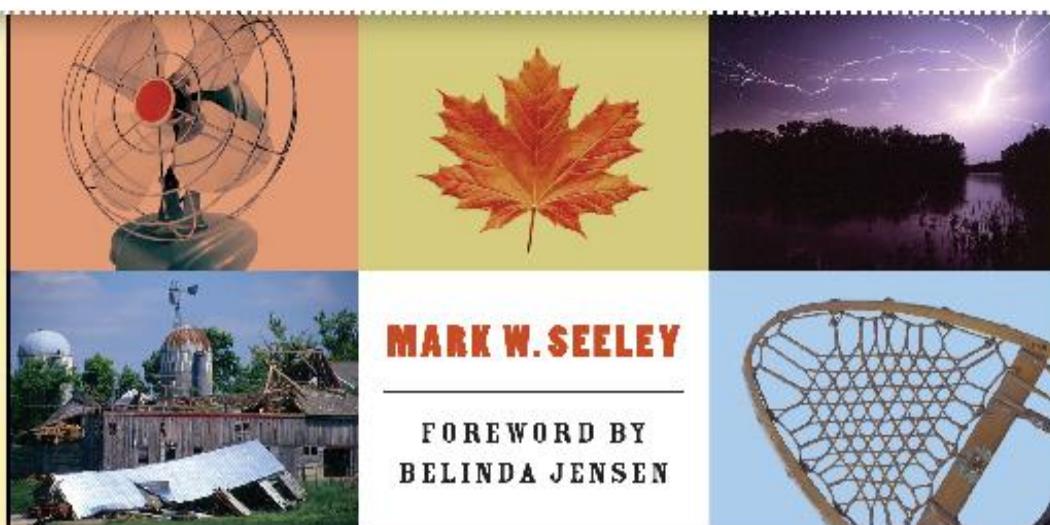
Snail in the sky



Pig in the sky



MINNESOTA WEATHER ALMANAC



Historical Minnesota Climate Adaptations:

Agriculture (tillage, drainage, irrigation, crop selection, livestock rationing, veterinary care)

Transportation (road materials, load limits, road repairs, bridges and conduits, snow drift control)

Navigation (Great Lakes shipping, Mississippi River barge traffic)

Wildfire (prevention and management)

Flood mitigation (MN-ASFPM, Army Corps, Municipalities, DNR, NOAA)

Public Health (clinic operations, prevention, inoculations)

Energy (adjustments in demand and supply, with diversification)

Architecture (design and materials)