Climate Science: History, Trends, and Future

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Dept of Soil, Water, and Climate

University of Minnesota

Climate Action Plan Kickoff for City of Minneapolis

Minneapolis Central Library

February 1, 2012

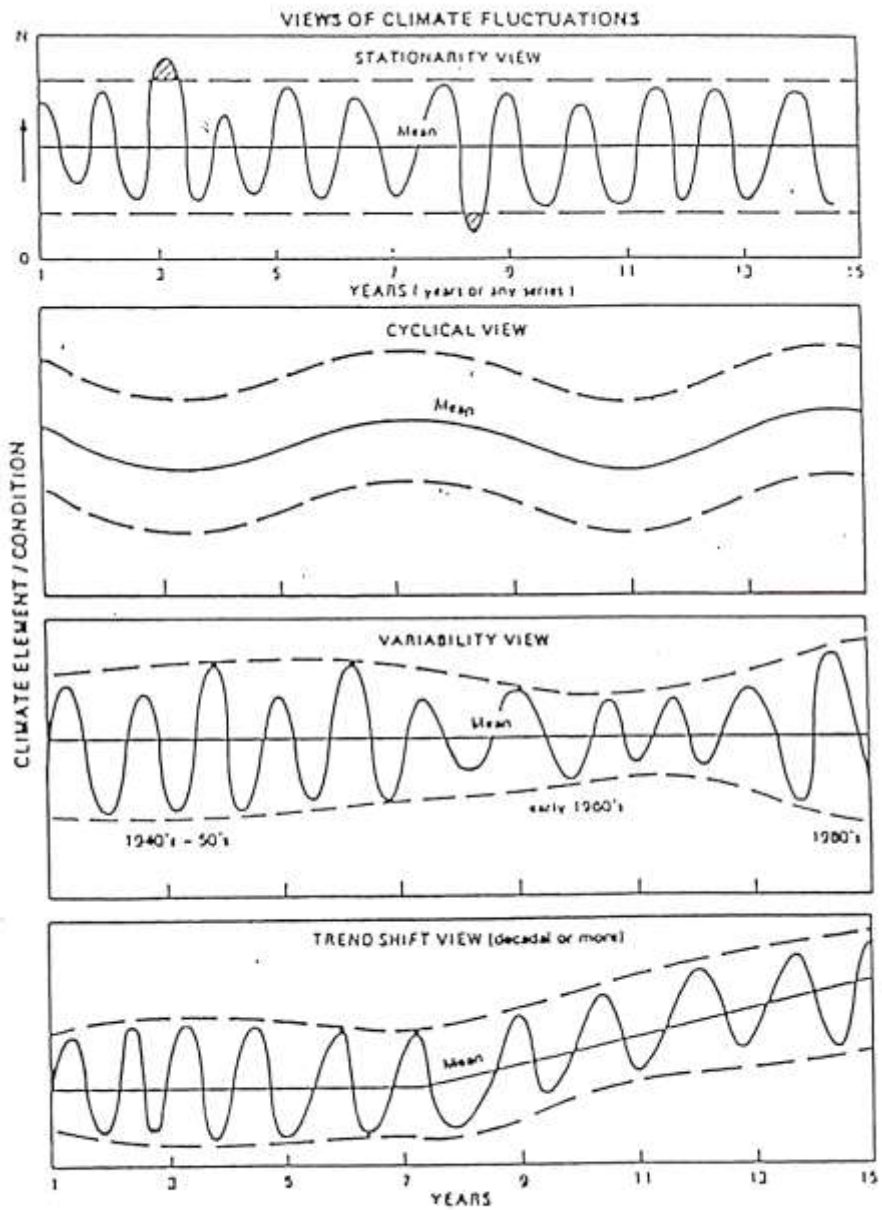


Figure 1. A schematic illustrating varying views of the temporal behavior of climate conditions.

Changnon et el

Stationary

Cyclical

Variability

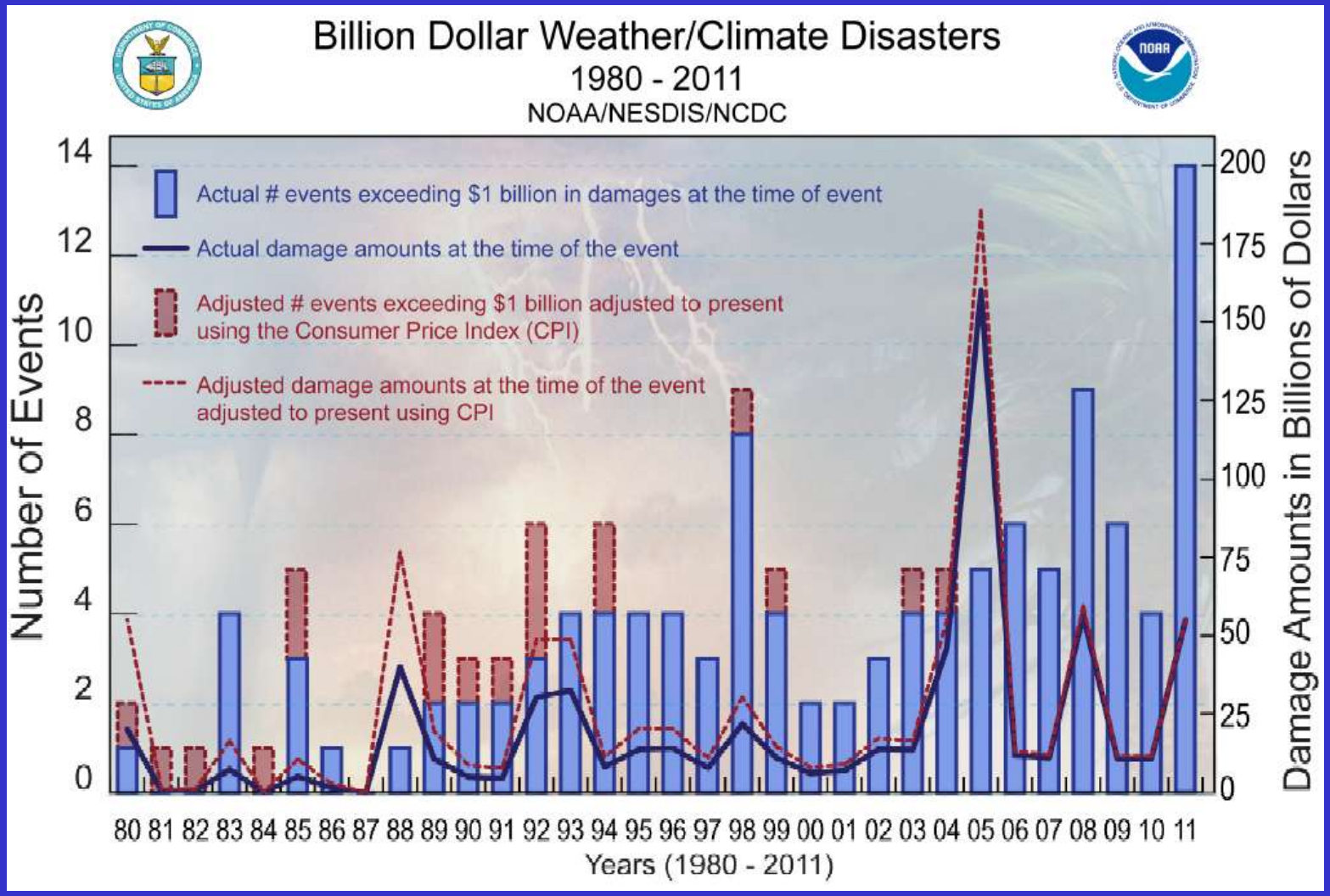
Trend Shift

Views of Climate Behavior

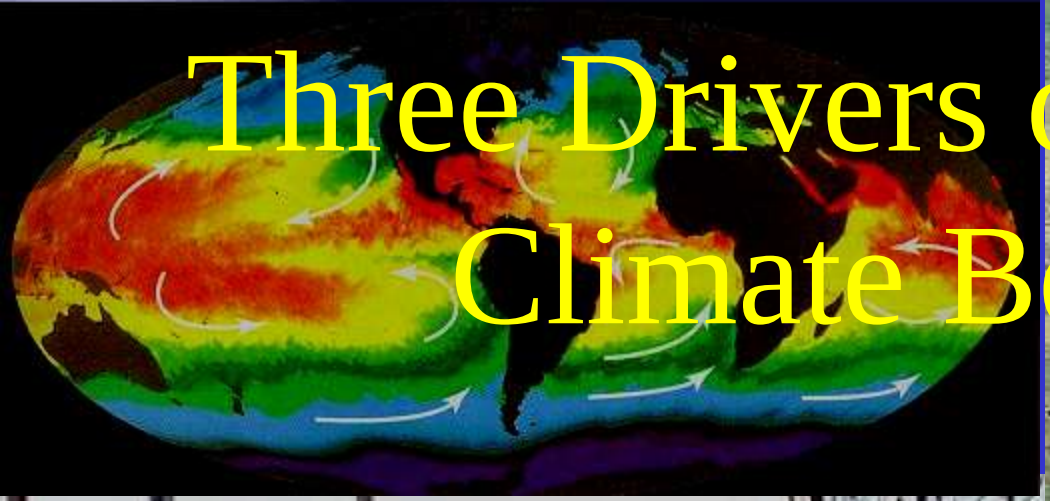
Vulnerability and Consequences Remain Key Societal Issues

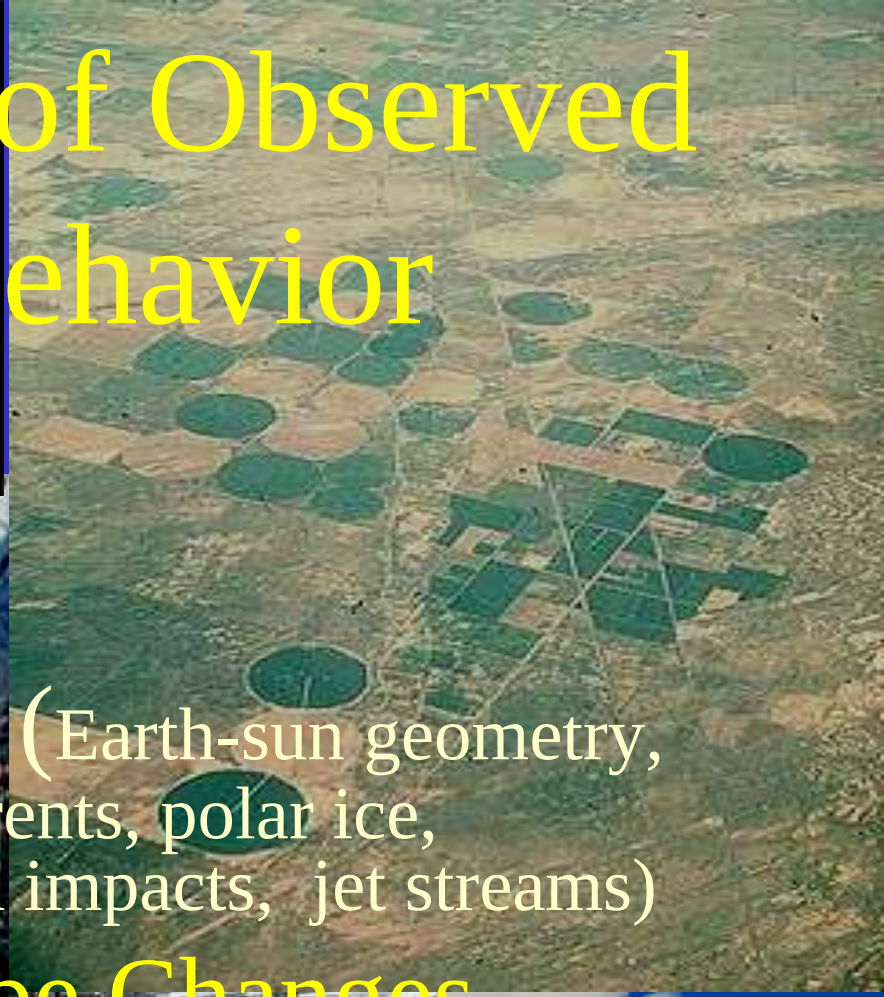
Implications for land use, building codes, insurance, and infrastructure

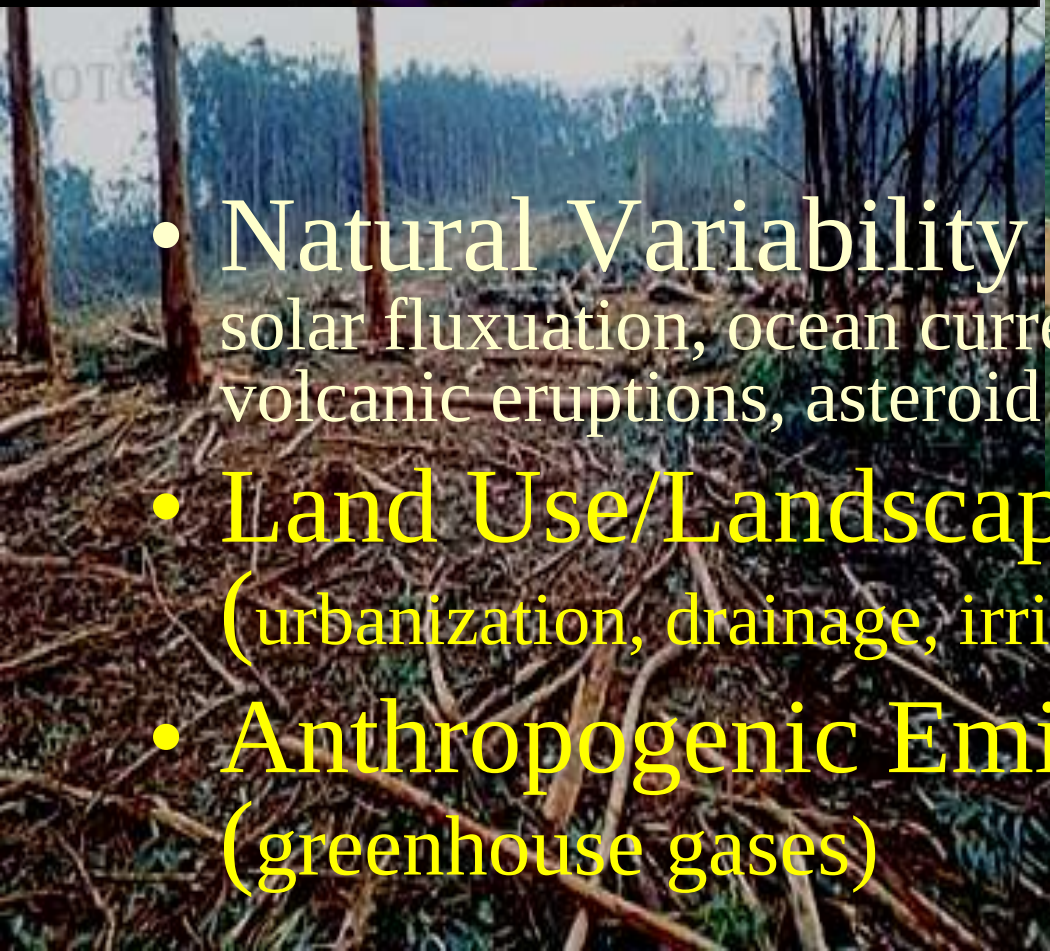
Nearly $1.8 trillion in losses from the past 31 years (current dollars)



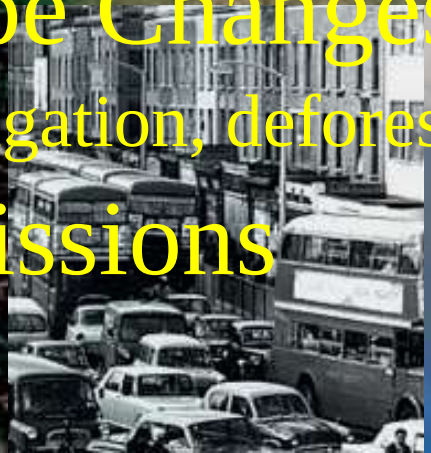
Three Drivers of Observed Climate Behavior





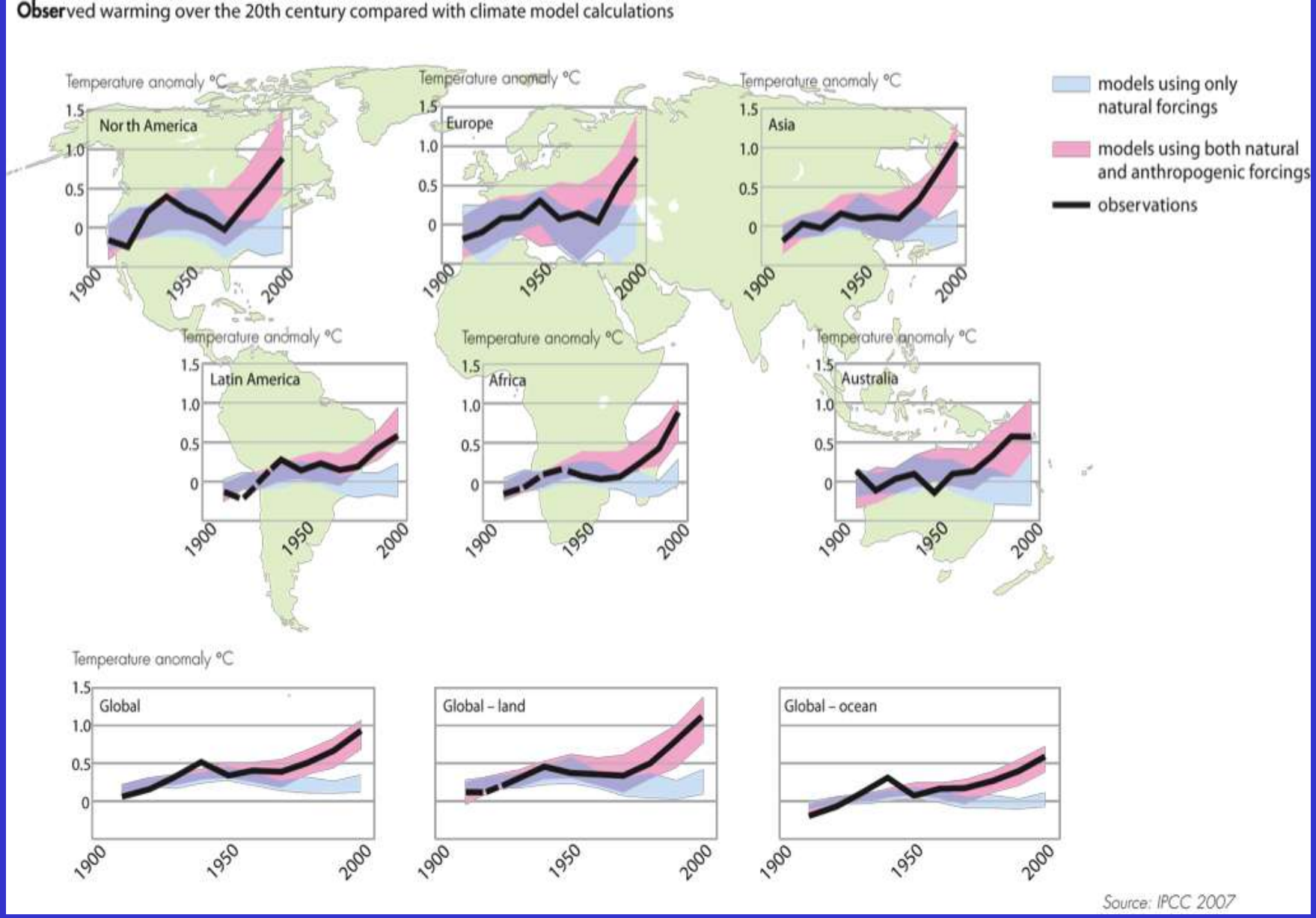


- Natural Variability (Earth-sun geometry, solar fluxuation, ocean currents, polar ice, volcanic eruptions, asteroid impacts, jet streams)
- Land Use/Landscape Changes (urbanization, drainage, irrigation, deforestation)
- Anthropogenic Emissions (greenhouse gases)



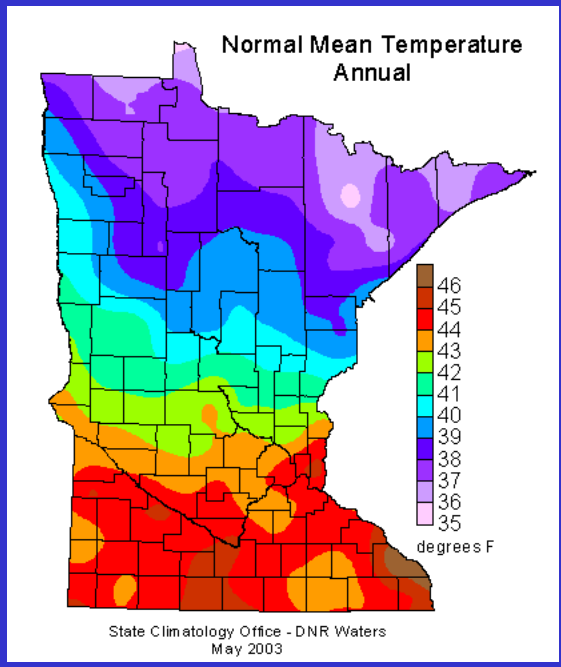
Three Reasons to Accept That Climate Change is Real

- **(1) Measured attributes of the Earth climate system are changing (temp, precip, cloud) according to NASA, NOAA, and Hadley Centre Data Sets.**
- **(2) Models mimic measured climate changes more accurately with parameterized human disturbance (land use, emissions) included.**
- **(3) Observed and measured physical and biological consequences fit with the measured climatic changes.**



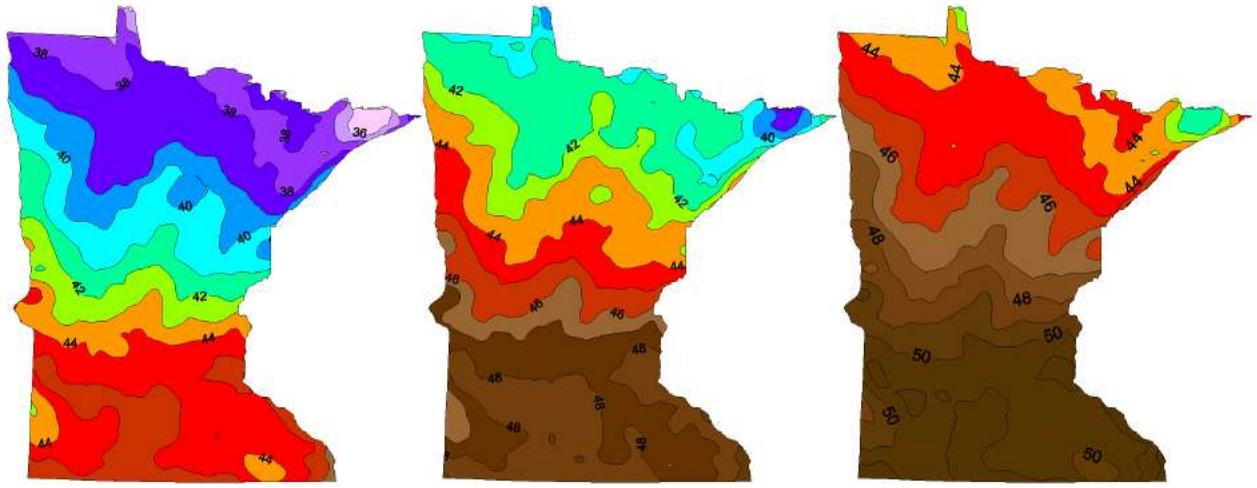
[by quantifying disturbance of the land and the atmosphere, the models show] "man's influence on climate has emerged from the background noise of natural variability." K. Emanuel

1971-200 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**

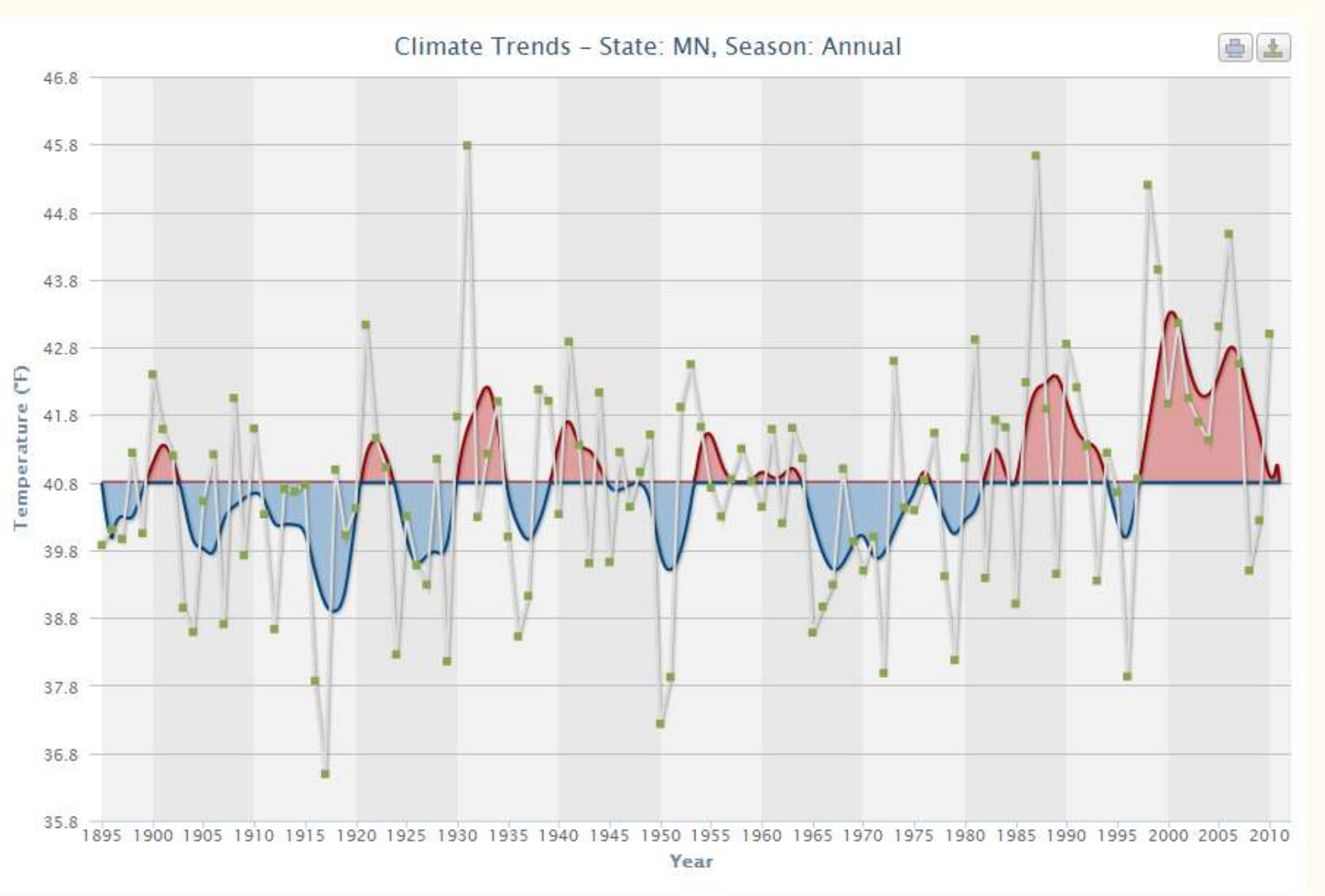
The A1 scenarios are of a more integrated world: characterized by:
rapid economic growth;
A global population that reaches 9 billion in 2050 and then gradually declines;
The quick spread of new and efficient technologies;
income and way of life converge between regions; extensive social and cultural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

RECENT SIGNIFICANT CLIMATE TRENDS IN MINNESOTA AND THE WESTERN GREAT LAKES

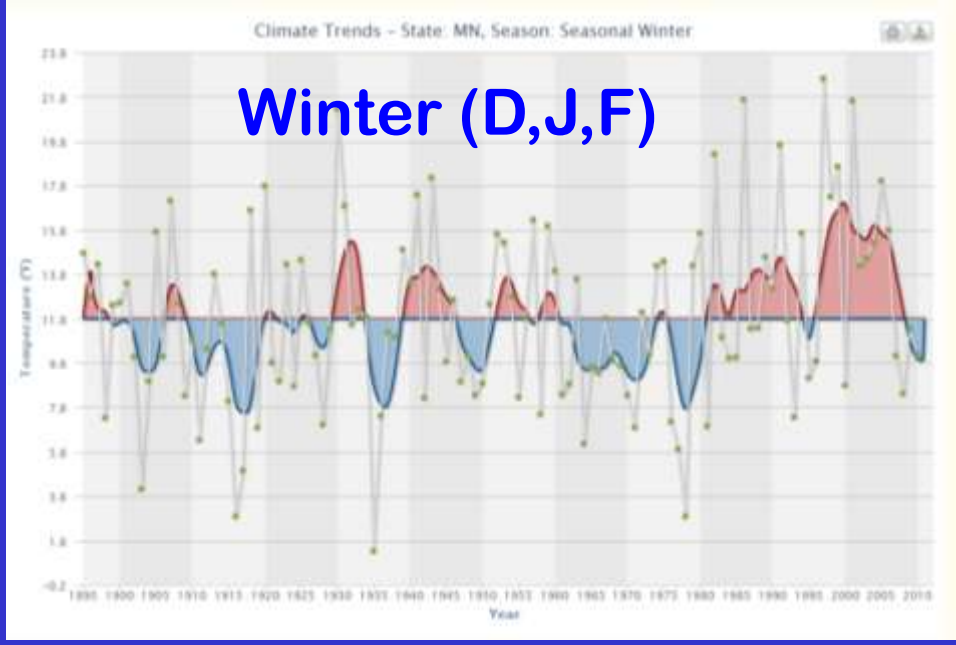
- *TEMPERATURE*: WARM WINTERS AND HIGHER MINIMUM TEMPERATURES

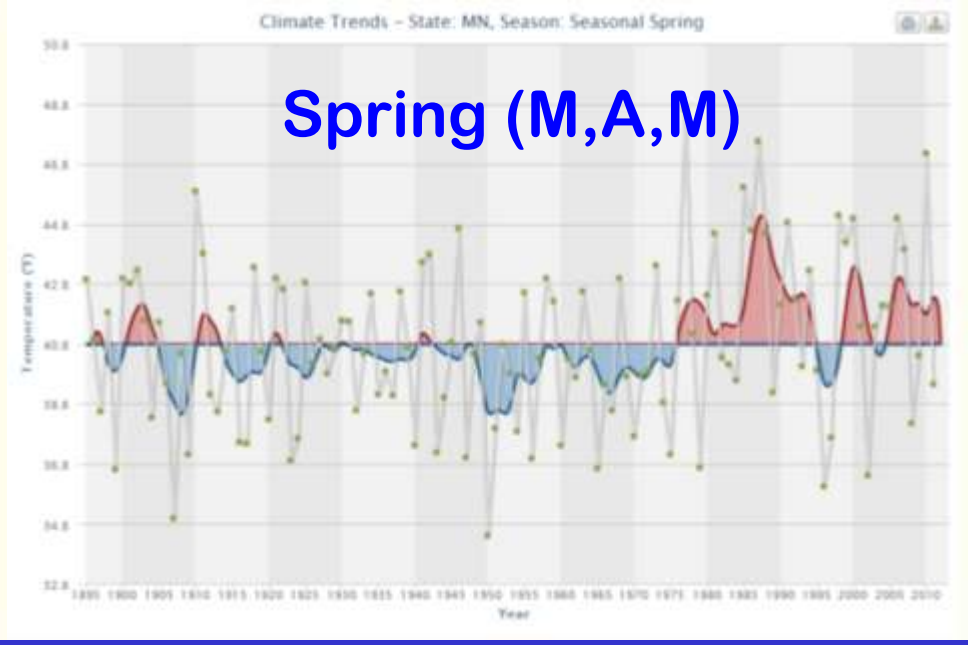
- *DEWPOINTS*: GREATER FREQUENCY OF TROPICAL-LIKE ATMOSPHERIC WATER VAPOR

- *MOISTURE*: AMPLIFIED PRECIPITATION SIGNAL (variability), CHANGE IN THUNDERSTORM CONTRIBUTION

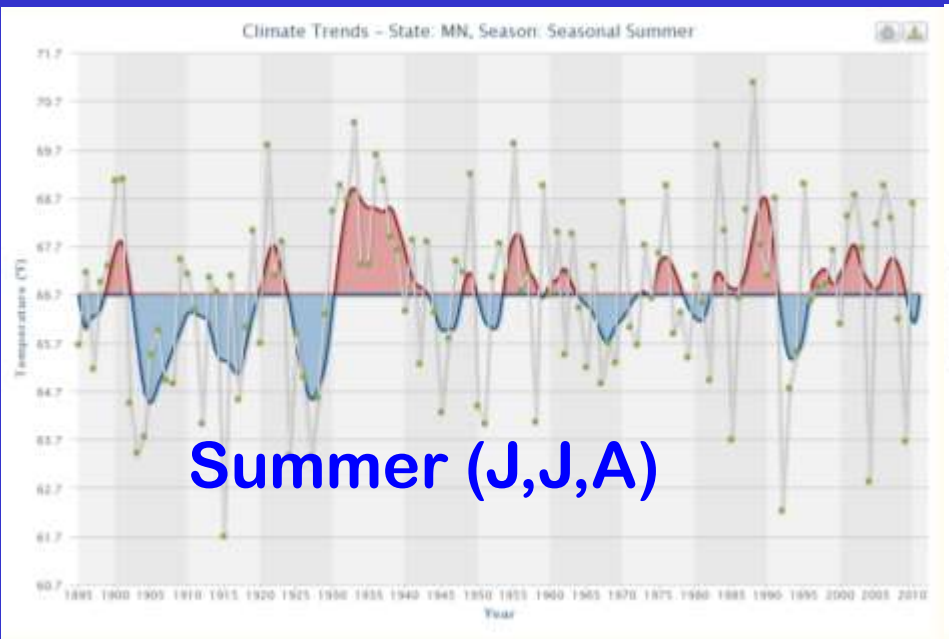


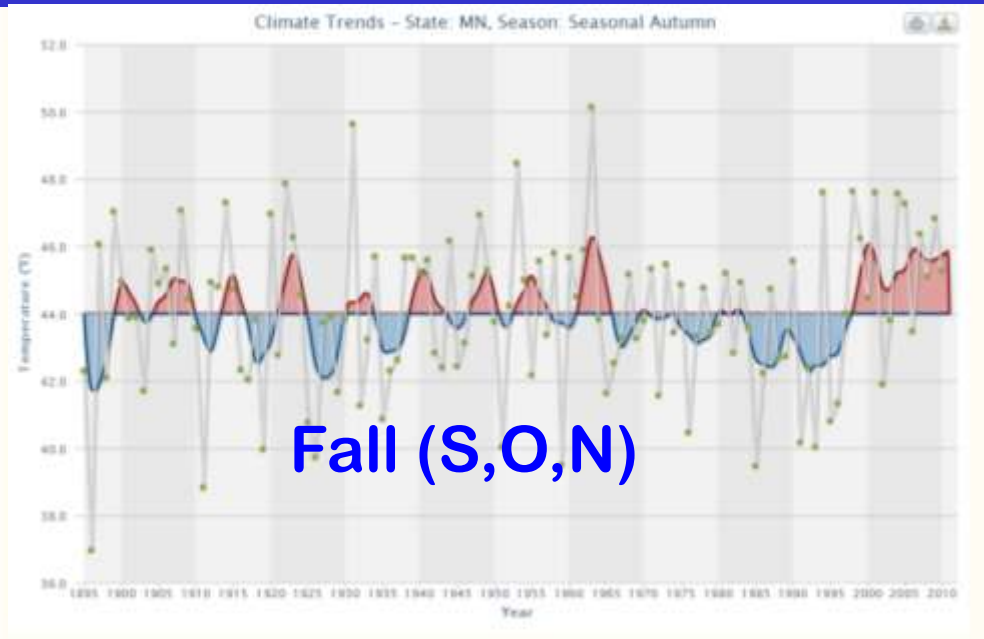
Statewide Annual Temperature History





Seasonal Temperature Trends in MN





Historical ranking and distribution of statewide mean daily temperature over the past 14 heating seasons (Nov-Mar) in MN: 1=warmest

Winter	Mean Temp (F)	Ranking (since 1895)
1997-1998	24.2	5th
1998-1999	23.0	8th
1999-2000	26.0	1st
2000-2001	15.8	79th
2001-2002	25.0	2nd
2002-2003	19.3	41st
2003-2004	20.3	28th
2004-2005	21.2	20th
2005-2006	23.2	6th
2006-2007	22.2	11th
2007-2008	16.7	63rd
2008-2009	16.7	72nd
2009-2010	21.5	17th
2010-2011	17.1	61st

Trends in average winter minimum temperatures Rochester, MN

Period of Record	Ave Min Temp in Deg. F
1951 - 1980	Jan 1.9
1961 - 1990	Jan 2.7
1971 – 2000	Jan 3.7
1981 - 2010	Jan 7.7
1951 - 1980	Feb 7.6
1961 - 1990	Feb 8.1
1971 – 2000	Feb 10.6
1981 - 2010	Feb 12.4
1951 - 1980	Mar 19.2
1961 - 1990	Mar 21.3
1971 – 2000	Mar 22.6
1981 - 2010	Mar 24.3

Trends in average winter minimum temperatures Collegeville, MN

Period of Record	Ave Min Temp in Deg. F
1951 - 1980	Jan -0.9
1961 - 1990	Jan 1.2
1971 – 2000	Jan 1.6
1981 - 2010	Jan 4.8
1951 - 1980	Feb 5.5
1961 - 1990	Feb 8.7
1971 – 2000	Feb 9.0
1981 - 2010	Feb 10.1
1951 - 1980	Mar 17.4
1961 - 1990	Mar 20.7
1971 – 2000	Mar 20.8
1981 - 2010	Mar 21.8

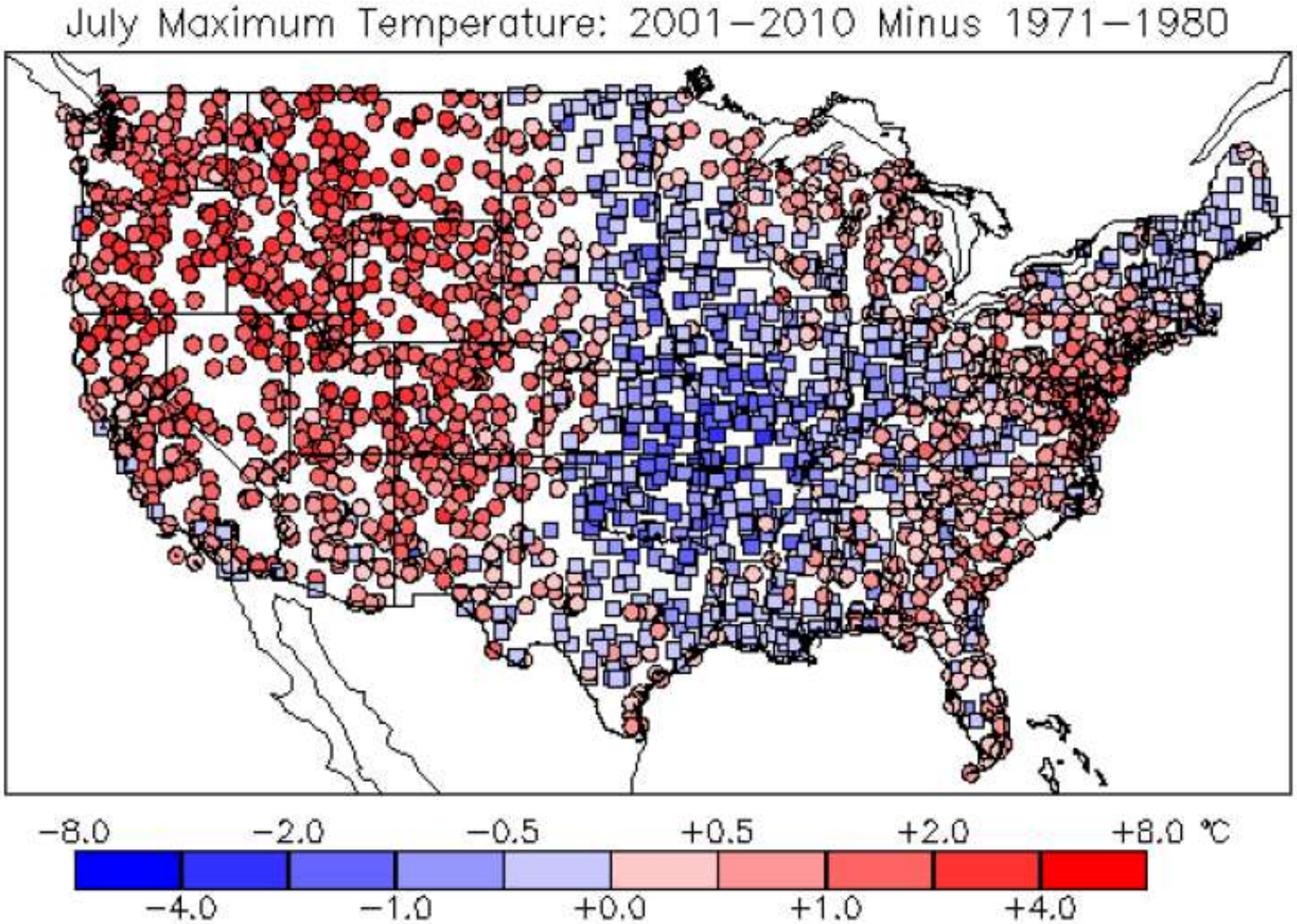


Figure 1. The difference between the decade-averaged maximum temperatures in July for the 2001-2010 period and the 1971-1980 period. Red circles (blue squares) indicate positive (negative) anomalies, i.e., warmer (cooler) conditions in the most recent decade versus the decade cycling off of the normals computation.

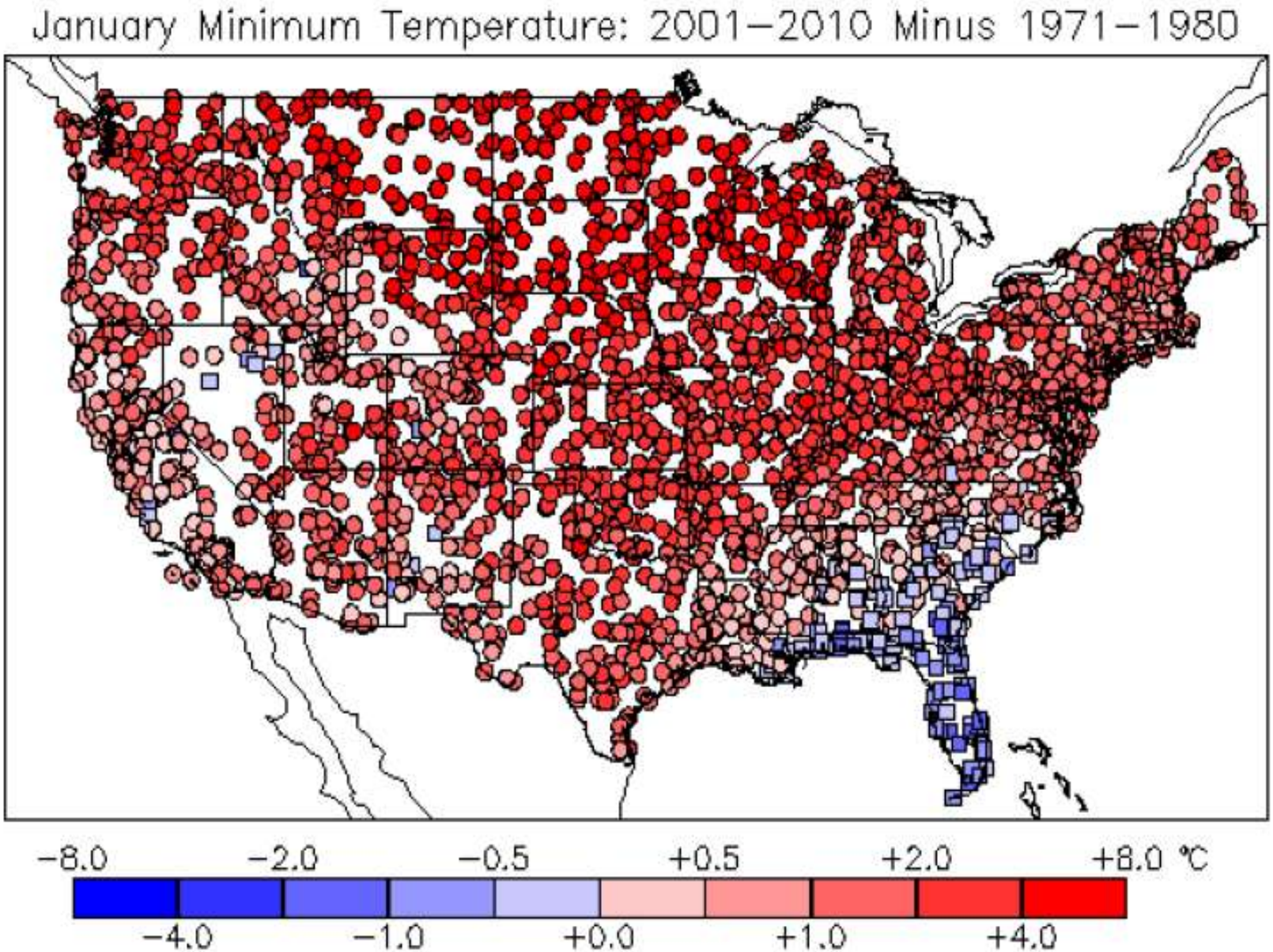


Figure 2. Same as Figure 1, but for January minimum temperatures.

Trends in mean monthly temperatures at Waseca, MN 1971-2000 normals vs 1981-2010 normals

Month	Change in value (deg F)
January	+2.3
February	+0.5
March	+0.8
April	+0.6
May	0.0
June	+0.3
July	+0.4
August	+0.5
September	+0.8
October	+1.1
November	+1.2
December	+1.1

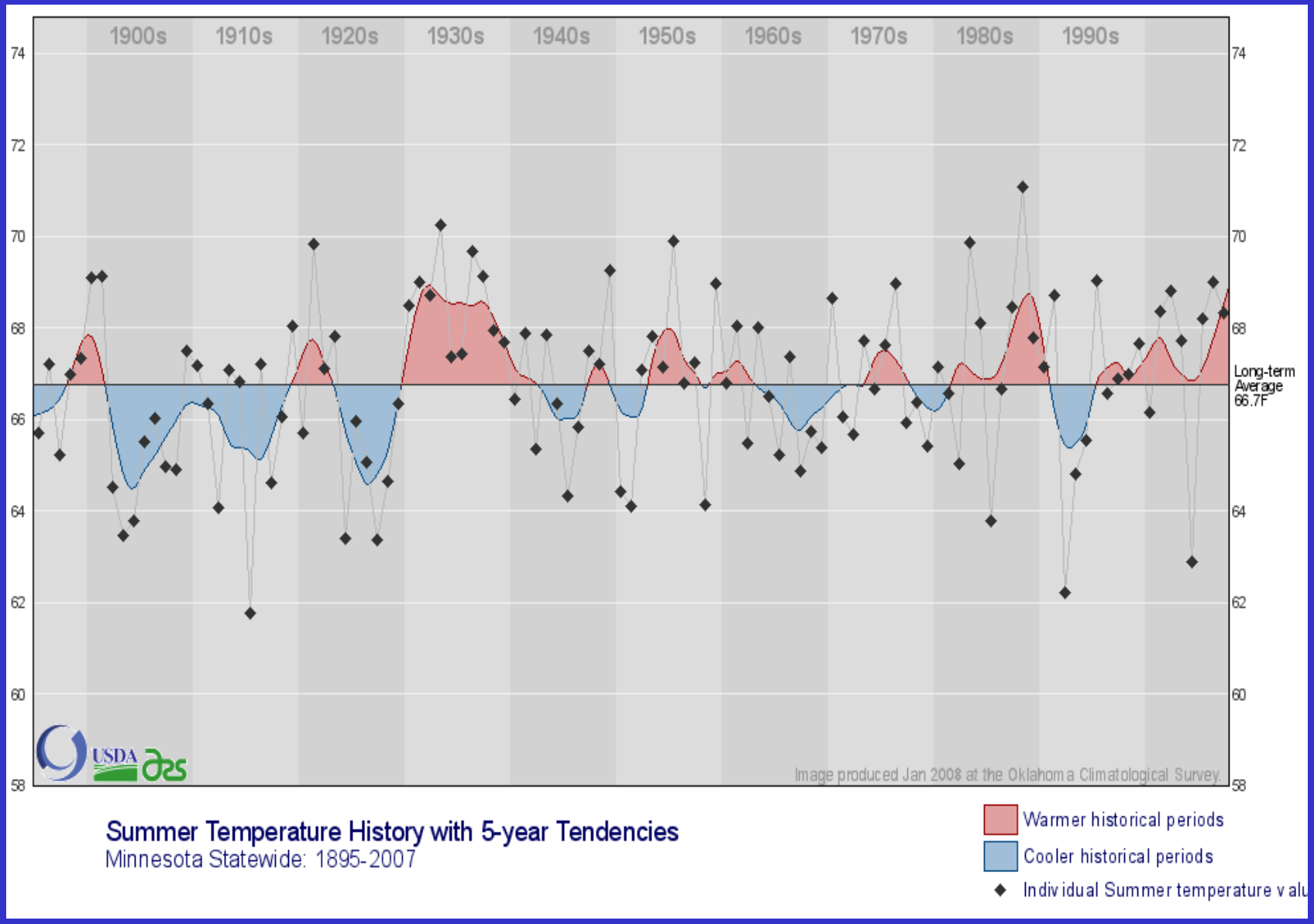
Trends in mean monthly temperatures at Chaska, MN 1971-2000 normals vs 1981-2010 normals (F)

Month	Min Change	Max Change	Mean Change
January	+3.2	+1.8	+2.5
February	+0.9	- 0.2	+0.3
March	+0.7	+0.2	+0.4
April	+0.7	+0.3	+0.5
May	+0.6	-1.6	-0.6
June	+1.5	-1.0	-0.3
July	+0.4	-0.5	-0.1
August	+0.6	-0.7	0.0
September	+1.1	-0.2	+0.4
October	+0.5	-0.7	-0.1
November	+1.2	+0.9	+1.0
December	+1.3	+0.8	+1.0

Possible Implications 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
- 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
- Increased number of freeze/thaw cycles
- Change in animal migration, hibernation, and foraging
- Longer exposure times to mold and allergens

Summer (J,J,A) Trend is Warmer



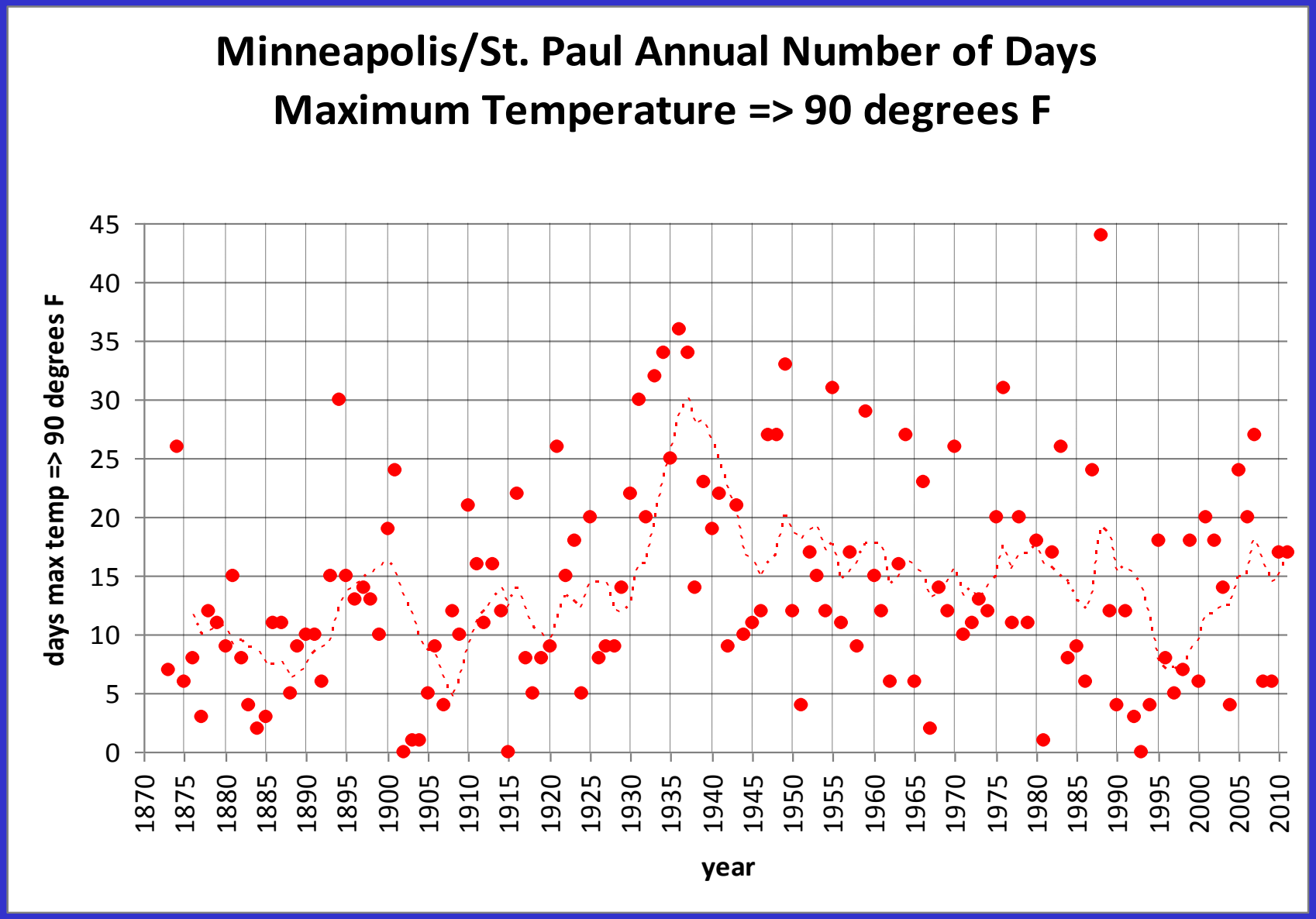
Minnesota Statewide May Through September Mean Temperature Ranking of the past 19 Air Conditioning Seasons (1994-2011)

1=warmest

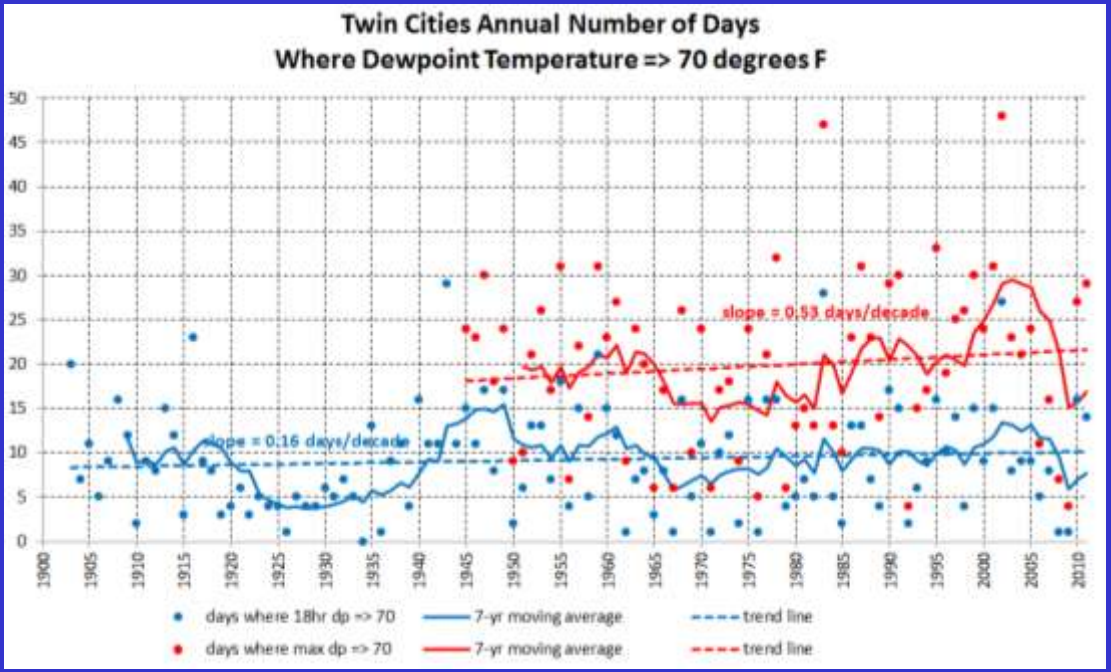
Year	Percentile Rank for 1895-2011	(mean temp)
1993	92	(59.9 F)
1994	43	(62.9 F)
1995 *	32	(63.3 F)
1996 *	63	(61.9 F)
1997	55	(62.1 F)
1998	6	(64.8 F)
1999 *	33	(63.3 F)
2000	52	(62.3 F)
2001 *	20	(63.8 F)
2002 *	31	(63.3 F)
2003 *	37	(63.1 F)
2004	88	(60.3 F)
2005 *	26	(63.6 F)
2006 *	17	(63.9 F)
2007 *	9	(64.6 F)
2008	69	(61.7 F)
2009	75	(61.4 F)
2010 *	28	(63.5 F)
2011 *	5	(64.9 F)

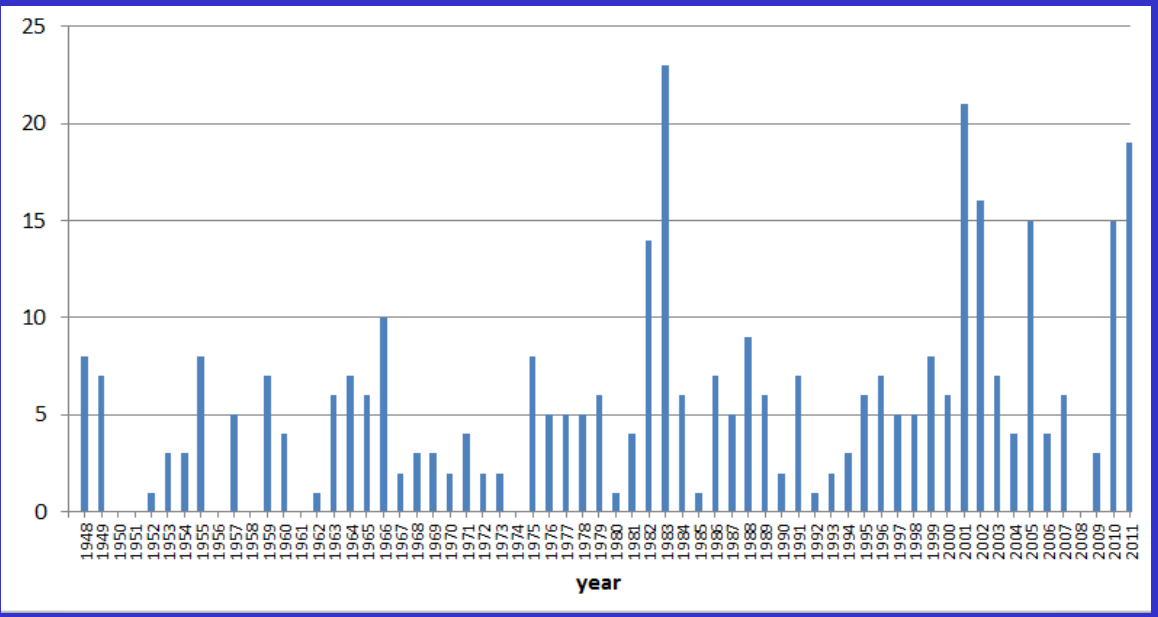
** Indicates dewpoints of 80 F or higher*

Recent trend in number of days with max temp of 90 F or higher is negative for Twin Cities



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





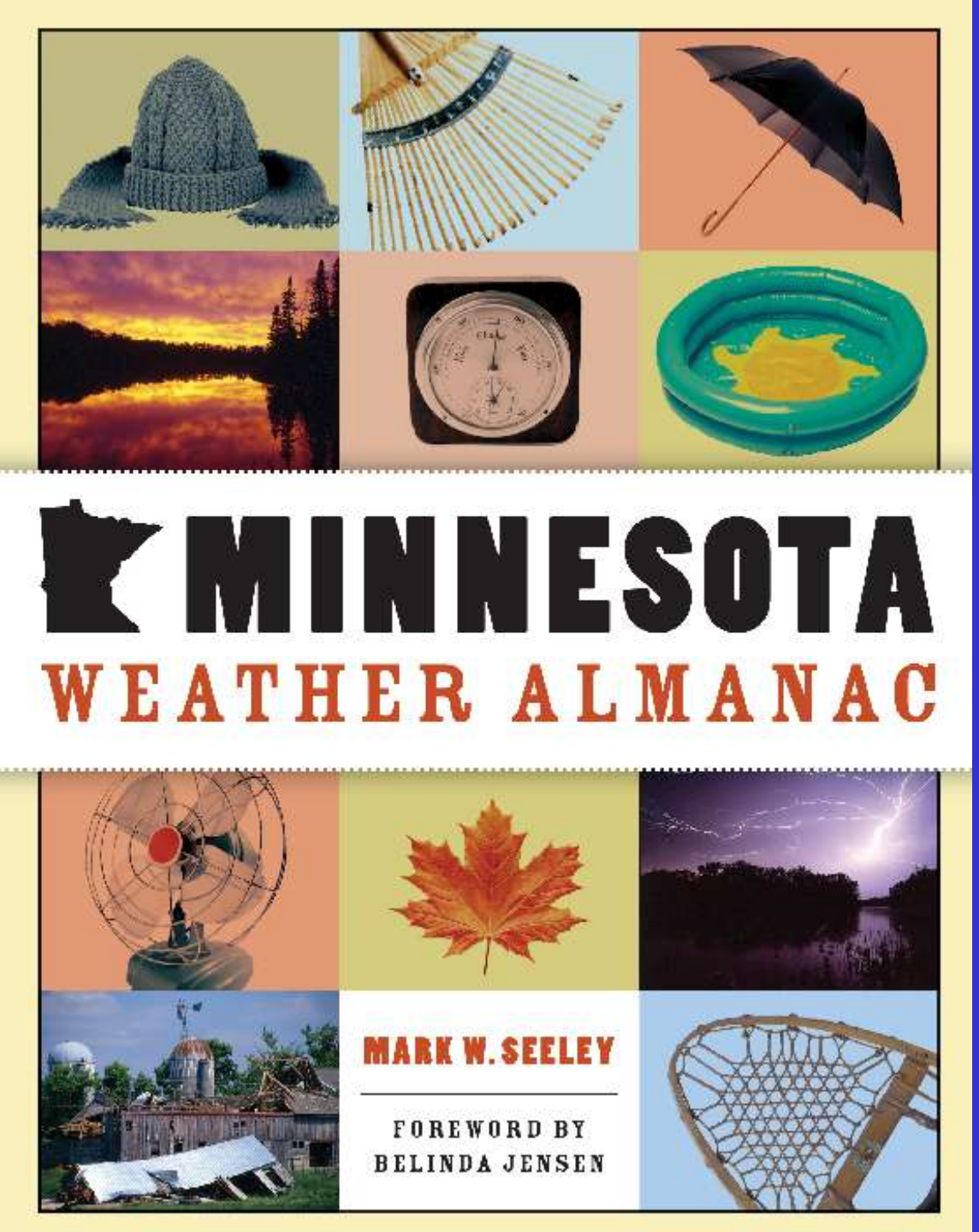
Hours with dewpoints of 70 degrees F or higher at Voyageurs National Park

Trends in average summer minimum temperatures St Peter, MN

Period of Record	Ave Min Temp in Deg. F
1951 -1980	Jun 56.7
1961 -1990	Jun 56.6
1971 -2000	Jun 56.7
1981 -2010	Jun 58.1
1951 -1980	Jul 61.1
1961 -1990	Jul 61.2
1971 -2000	Jul 61.3
1981 -2010	Jul 62.8
1951 -1980	Aug 58.5
1961 -1990	Aug 58.9
1971 -2000	Aug 59.0
1981 -2010	Aug 60.7

Frequencies of July tropical 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)
1949	223	98 - 112
1987	223	98 - 104
1955	206	98 - 113
1999	192	98 - 115 (116*)
1957	192	99 - 114
2001	182	98 - 110
1977	160	100 - 108
1983	157	102 - 110
1995	110	98 - 116
2002	305	98 - 109
2004	108	98 - 105
2011	243	98 - 118



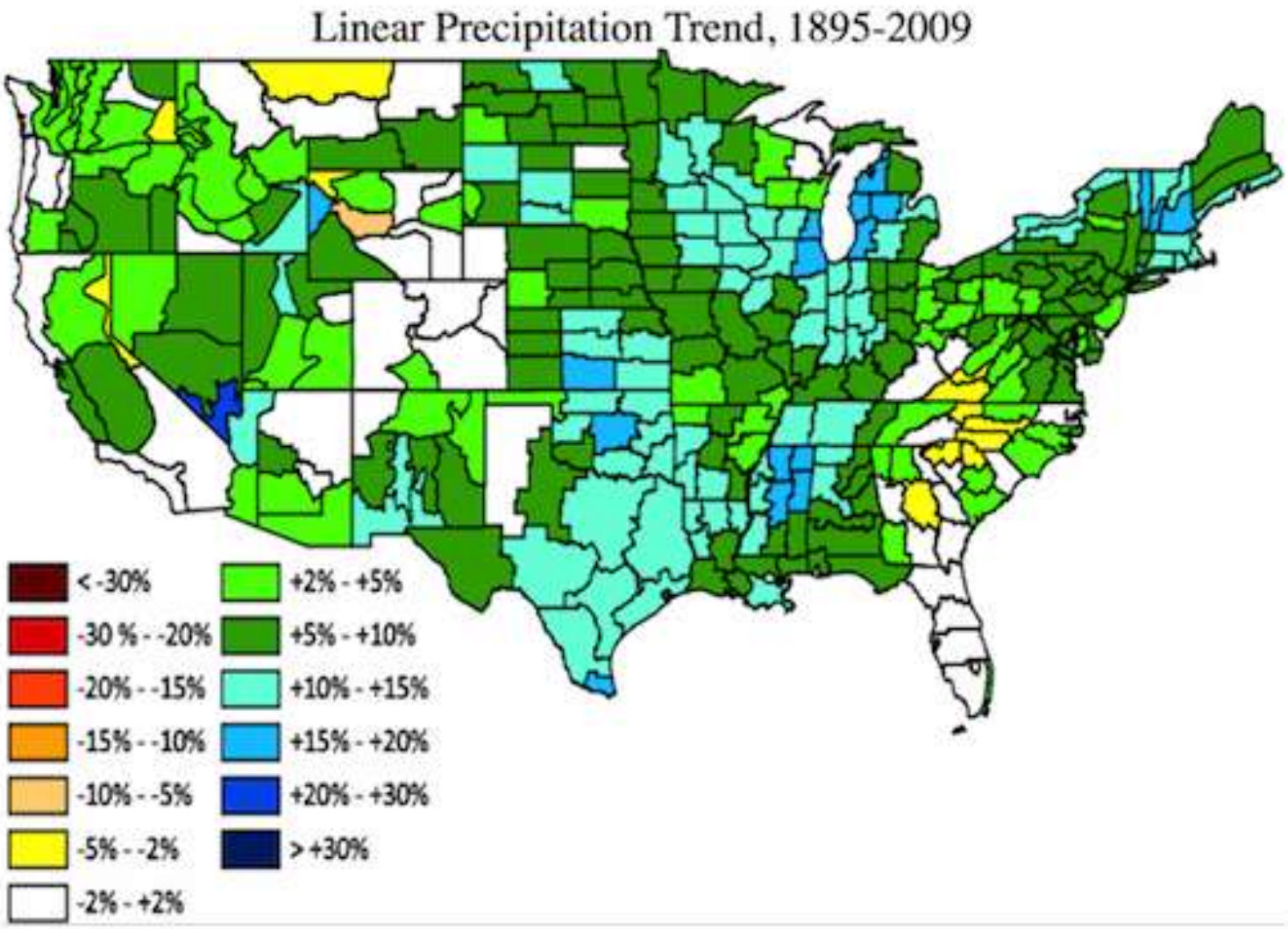
Historical Minnesota Heat Waves:

Red denotes dewpoint driven

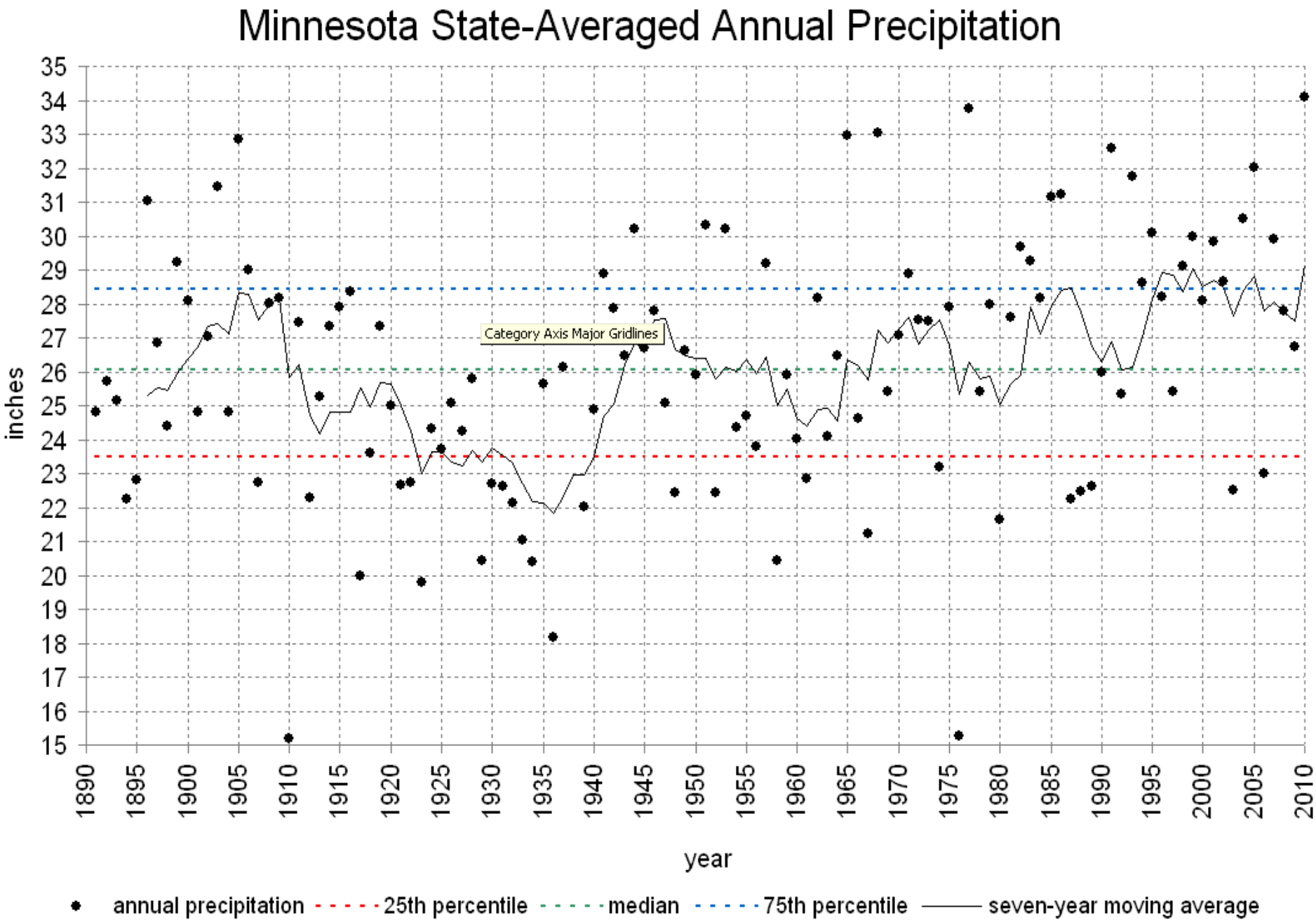
1883, 1894, 1901, 1910, 1917, 1921, 1931, 1933, 1934, 1936, 1937, 1947, 1948, 1949, 1955, 1957, 1959, 1964, 1976, 1977, 1983, 1988, 1995,1999, 2001, 2005, 2006, 2007, 2010, 2011

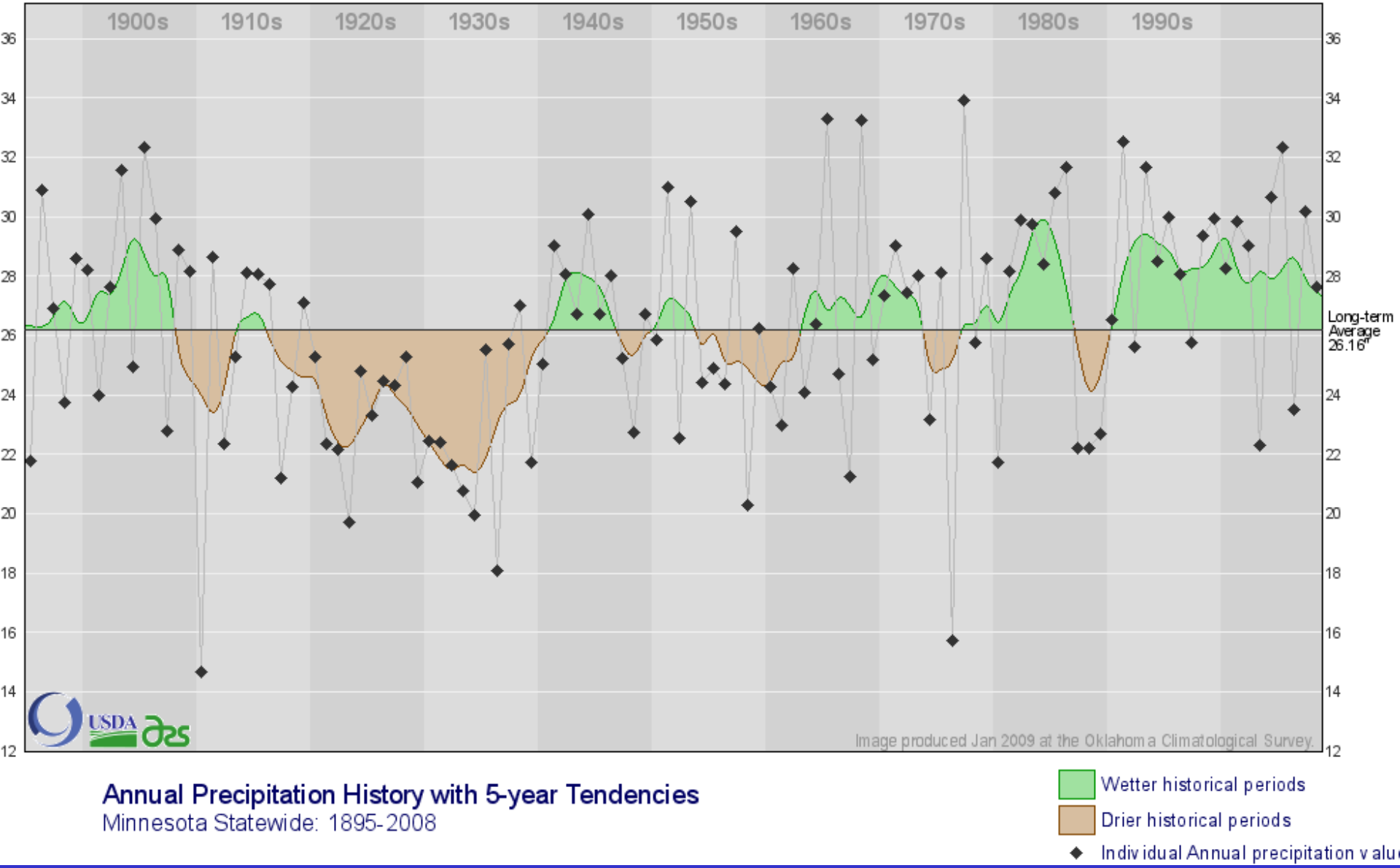
Possible Implications of Increased Frequency in Tropical Dew Points?

- 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

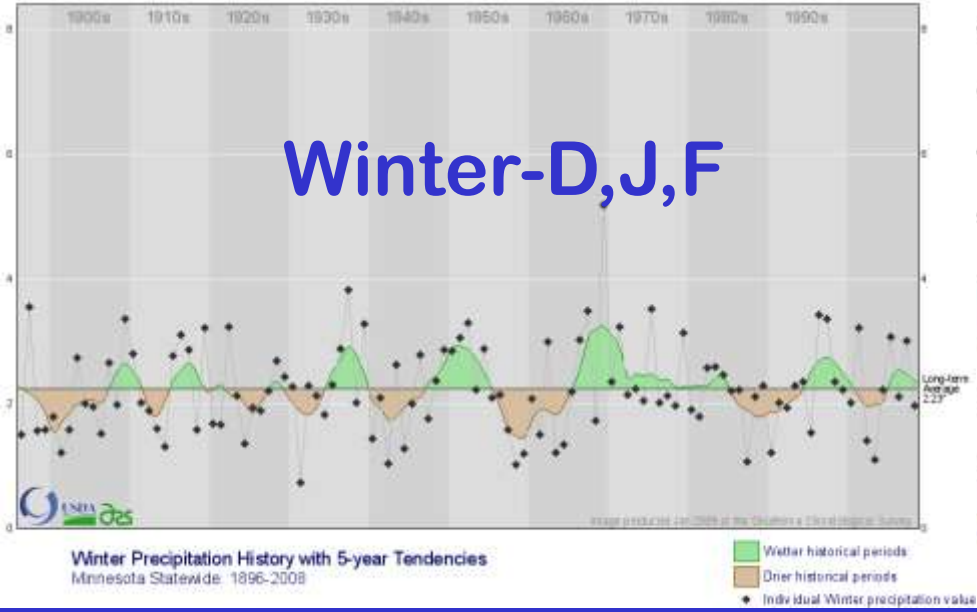


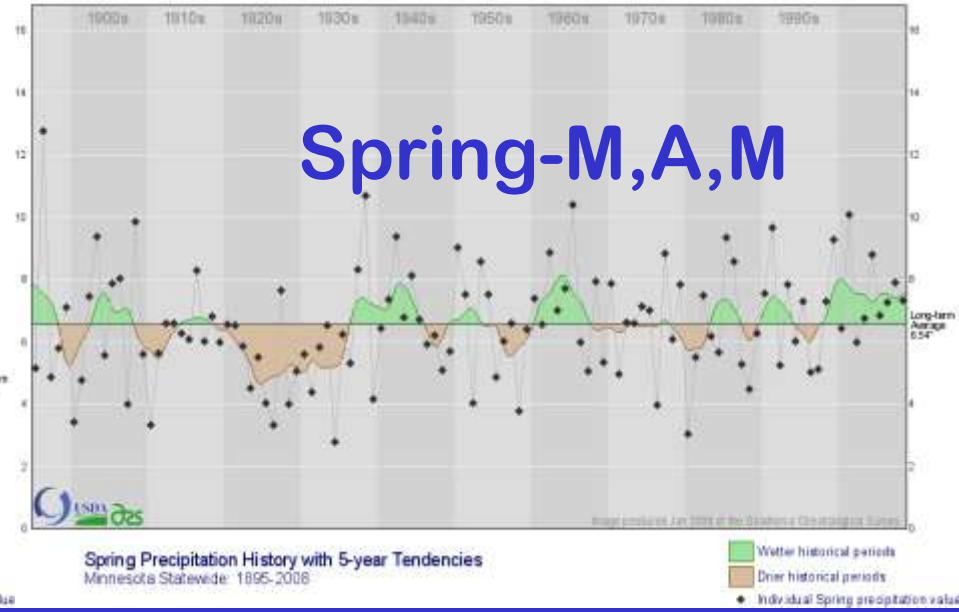
Long term trend in annual precipitation


Minnesota State-Averaged Annual Precipitation
inches
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
Category Axis Major Gridlines
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
year
annual precipitation
25th percentile
median
75th percentile
seven-year moving average

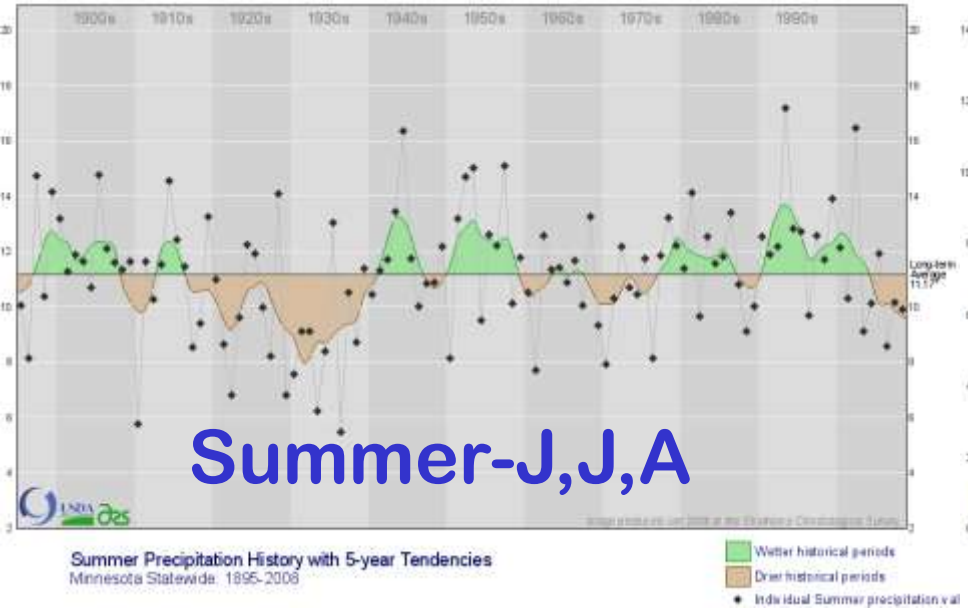


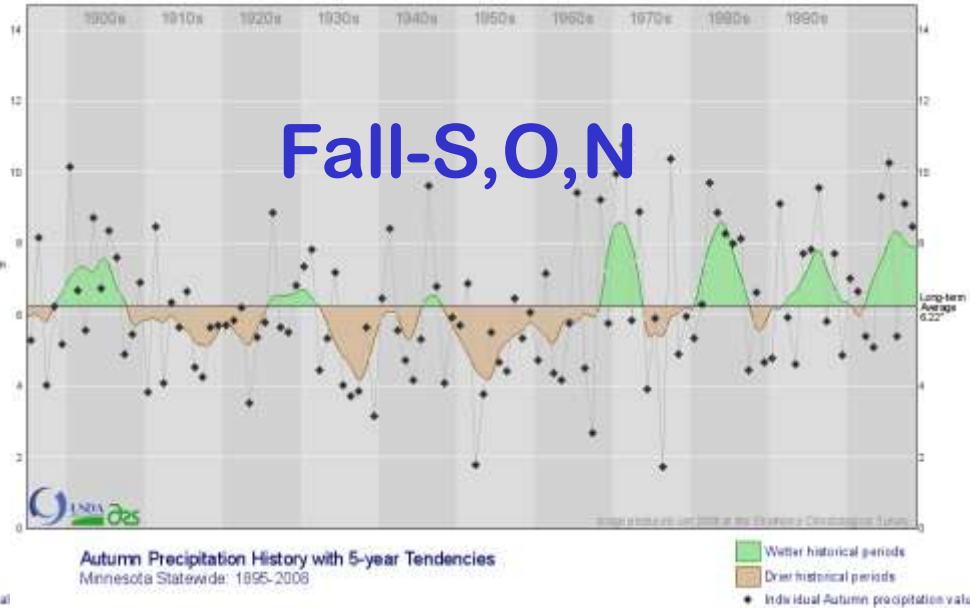
MN Annual Precipitation with 5-yr Tendencies





Seasonality in MN Precipitation Trends





Change in Annual Precipitation "Normals" at Waseca, MN

PERIOD	AMOUNT (IN.)
1921-1950	27.55″
1931-1960	27.82″
1941-1970	29.94″
1951-1980	30.62″
1961-1990	32.45″
1971-2000	34.69″
1981-2010	35.72″

30 percent increase
since 1921-1950 period

Change in Annual Precipitation Normals at Willmar, MN

PERIOD	AMOUNT (IN.)
1921-1950	23.01”
1931-1960	24.47”
1941-1970	27.63”
1951-1980	27.71”
1961-1990	28.21”
1971-2000	28.23”
1981-2010	29.39”

28 percent increase since 1921-1950 period

Change in Annual Precipitation "Normals" for Minneapolis/St Paul, MN

PERIOD	AMOUNT (IN.)
1941-1970	25.93″
1951-1980	26.36″
1961-1990	28.36″
1971-2000	29.40″
1981-2010	31.16″

20 percent increase since 1941-1970 period

Change in Annual Precipitation "Normals" at Brainerd, MN

PERIOD	AMOUNT (IN.)
1921-1950	23.03″
1931-1960	24.68″
1941-1970	25.59″
1951-1980	26.02″
1961-1990	26.40″
1971-2000	27.55″
1981-2010	28.38″

23 percent increase since 1921-1950 period

"……water vapor and clouds are far and away the most important greenhouse substances in the atmosphere [quantity, type, and distribution are important]" K. Emanuel

FORUM

THE CHANGING CHARACTER OF PRECIPITATION

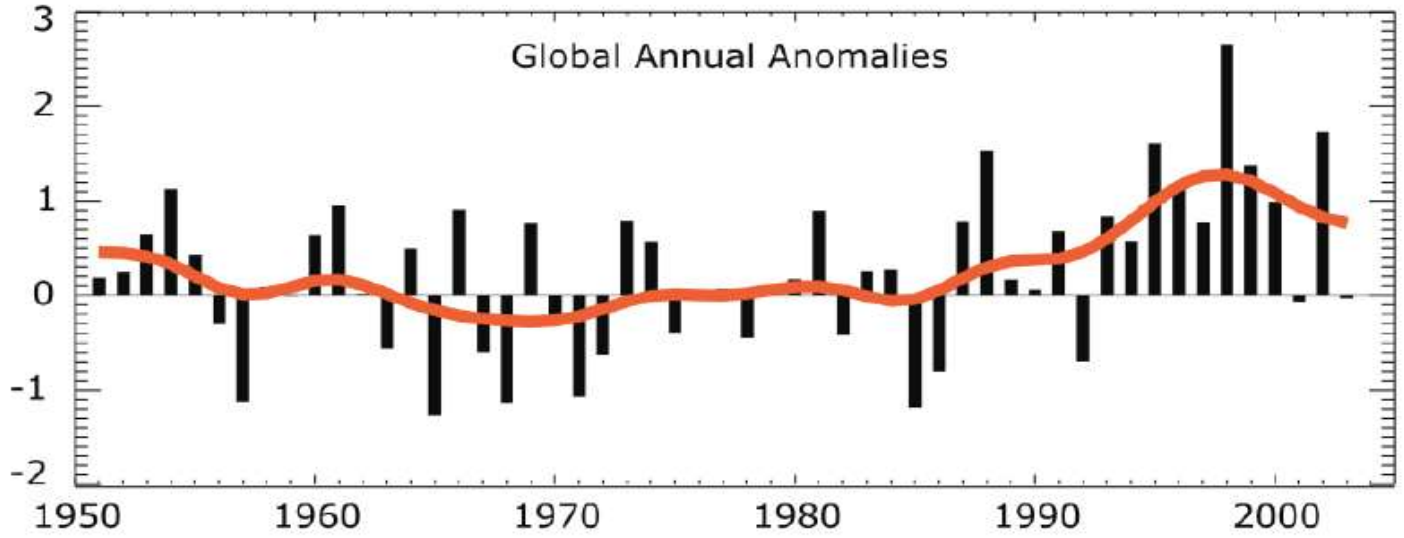
BY KEVIN E. TRENBERTH, AIGUO DAI, ROY M. RASMUSSEN, AND DAVID B. PARSONS

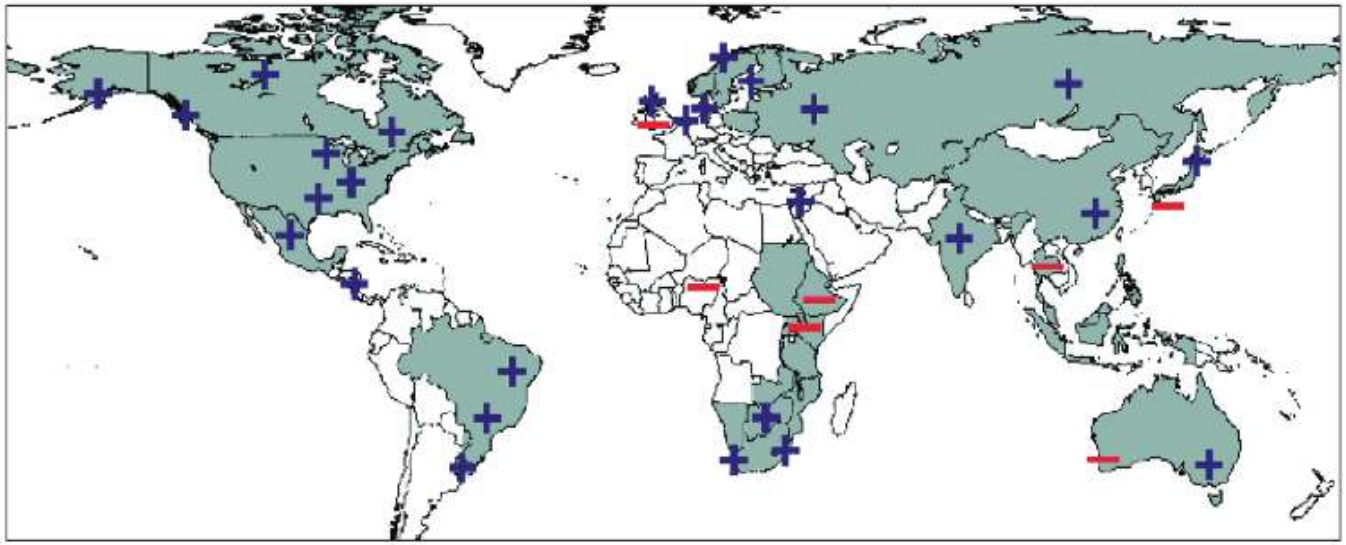
As climate changes, the main changes in precipitation will likely be in the intensity, frequency, and duration of events, but these characteristics are seldom analyzed in observations or models.

Why does it rain? If a parcel of air rises, it expands pushing underneath warmer air (advancing cold

Quantity is but one character of precipitation

Heavy Precipitation Trend (% from very wet days)





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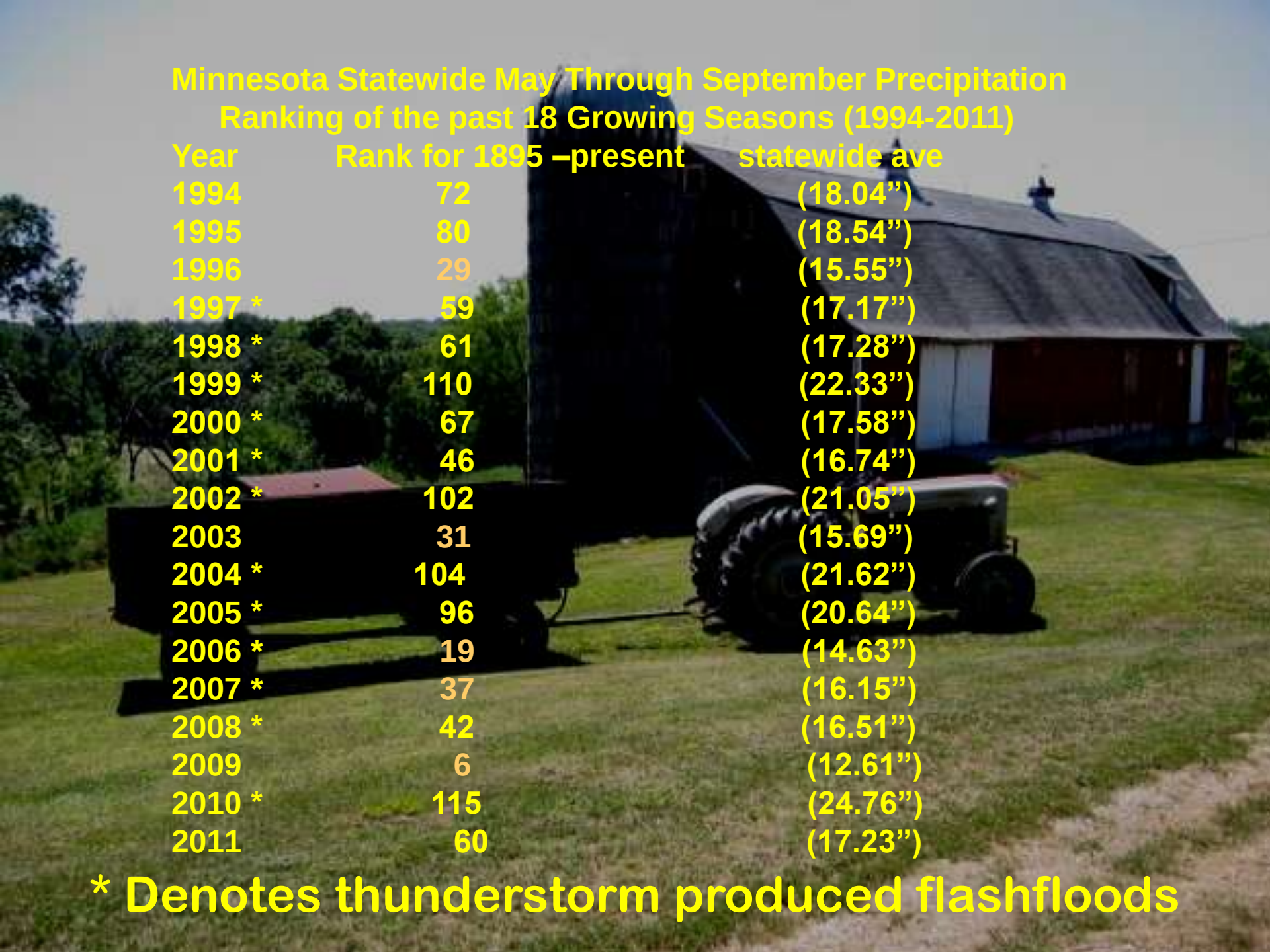
Regions where disproportionate changes in heavy and very heavy precipitation during the past decades were documented as either an ***increase (+) or decrease (–)*** *compared to the change in the annual and/or seasonal precipitation*

Historical recurrence interval of 2 inch rains in MN is once per year.

Observed 2 inch rainfalls for the period 1991 – 2010 and maximum single day value for various communities:

Location	No. 2 in. rains	Maximum Value (date)
Fairmont	33	6.20 (9/15/2002)
Albert Lea	33	7.50 (6/15/78)
Preston	32	6.60 (7/21/51)
Blue Earth	38	7.10 (9/15/2004)
Lake City	42	5.60 (5/28/70)
Waseca	38	5.40 (8/31/62)
Winnebago	40	8.64 (9/25/2005)
Bricelyn	38	9.22 (9/14/2004)
Amboy	36	9.48 (9/23/2010)
Hokah	32	15.10 (8/19/2007)



Minnesota Statewide May Through September Precipitation
Ranking of the past 18 Growing Seasons (1994-2011)

Year	Rank for 1895 –present	statewide ave
1994	72	(18.04”)
1995	80	(18.54”)
1996	29	(15.55”)
1997 *	59	(17.17”)
1998 *	61	(17.28”)
1999 *	110	(22.33”)
2000 *	67	(17.58”)
2001 *	46	(16.74”)
2002 *	102	(21.05”)
2003	31	(15.69”)
2004 *	104	(21.62”)
2005 *	96	(20.64”)
2006 *	19	(14.63”)
2007 *	37	(16.15”)
2008 *	42	(16.51”)
2009	6	(12.61”)
2010 *	115	(24.76”)
2011	60	(17.23”)

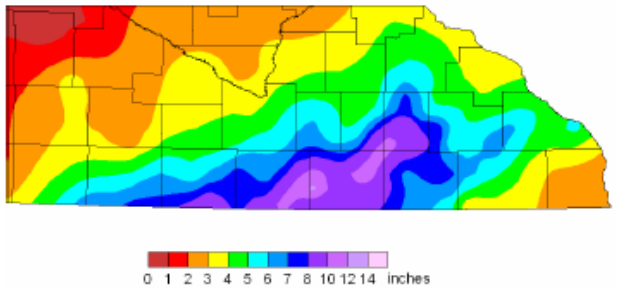
*** Denotes thunderstorm produced flashfloods**

Shift in Precipitation Recurrence Intervals

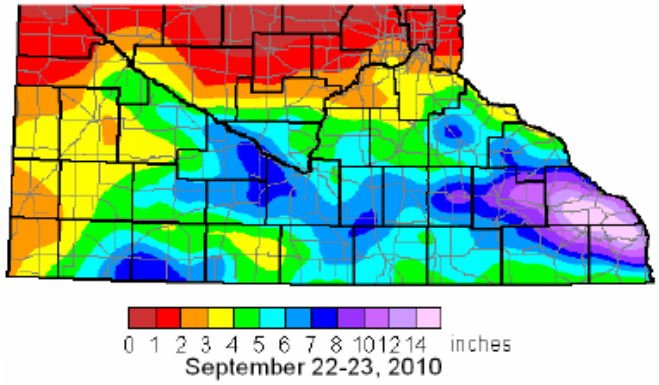
(3-1000 year events in southern MN)

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

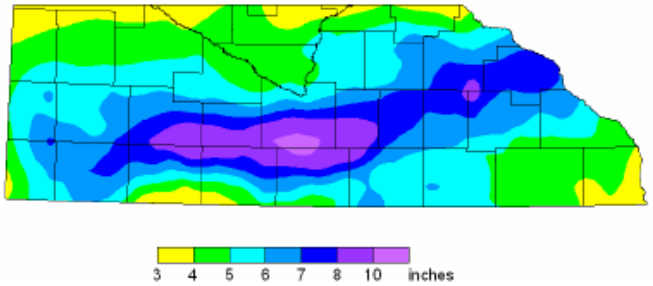
September 14-15, 2004



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

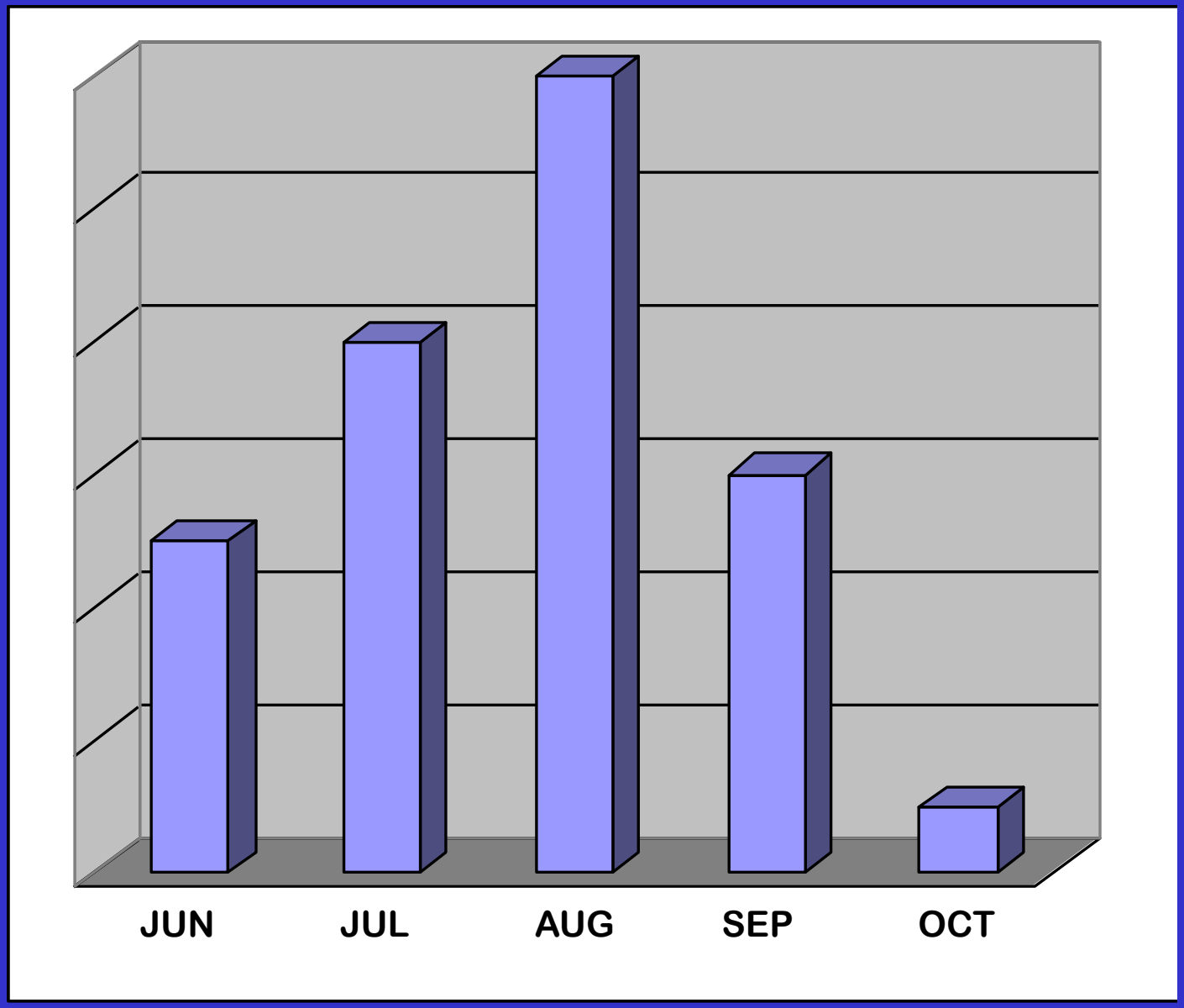


September 22-23, 2010



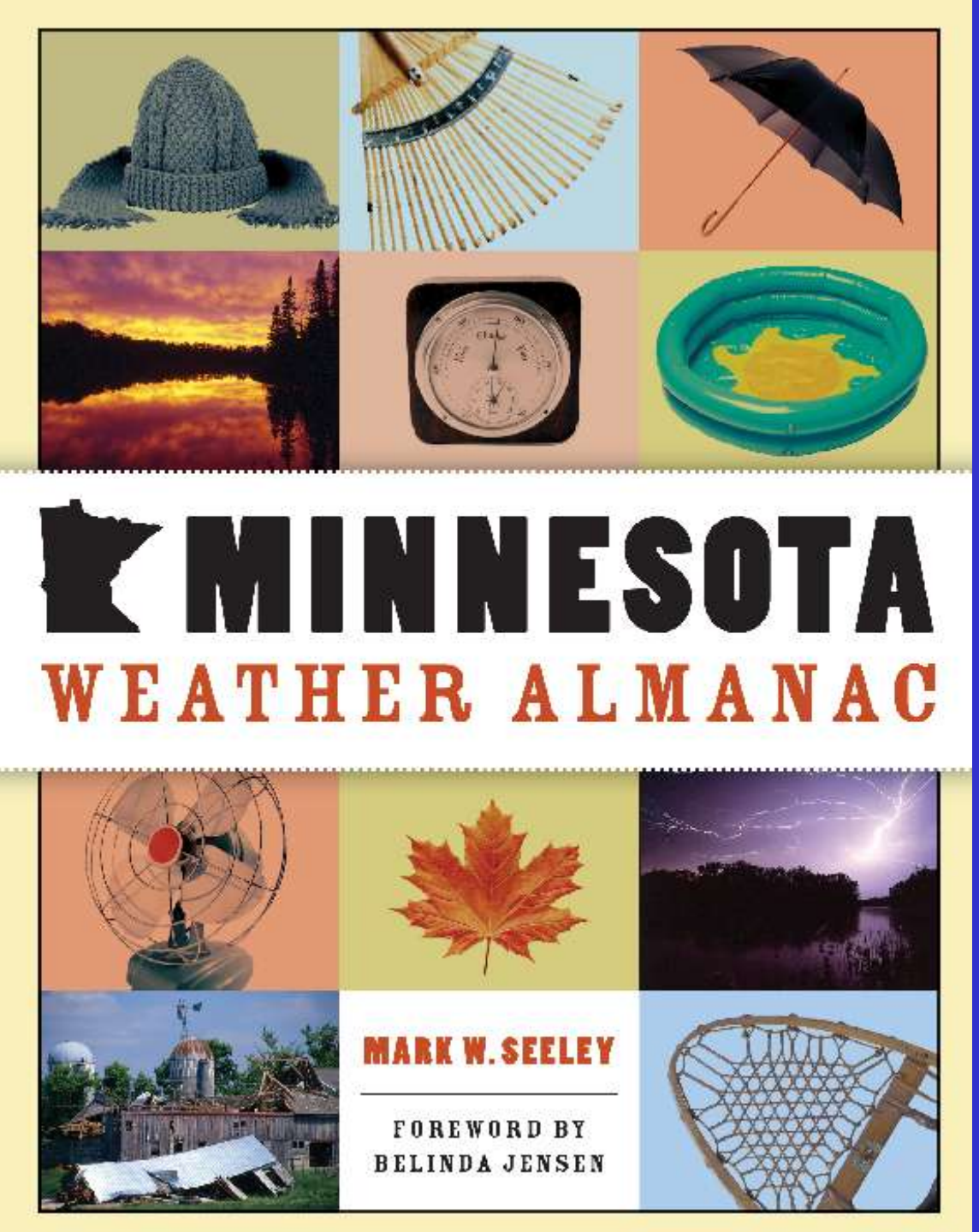
A 'by-eye' estimate of the total area covered by 10" of rain over the 7 years of 2004-2010 appears to be near 1400 sq. mi. or about 200 sq. mi per year. Given that the area of the southern 3 layers of counties looks to be approximately 20000 sq. mi. the areal fraction of the southern three counties covered 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.

©State Climatology Office, DNR-Eco/Waters, September 2010



Month exhibiting the highest annual 24-hr rainfall amount

1978-2009 (a shift in phase to later in the year)



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,

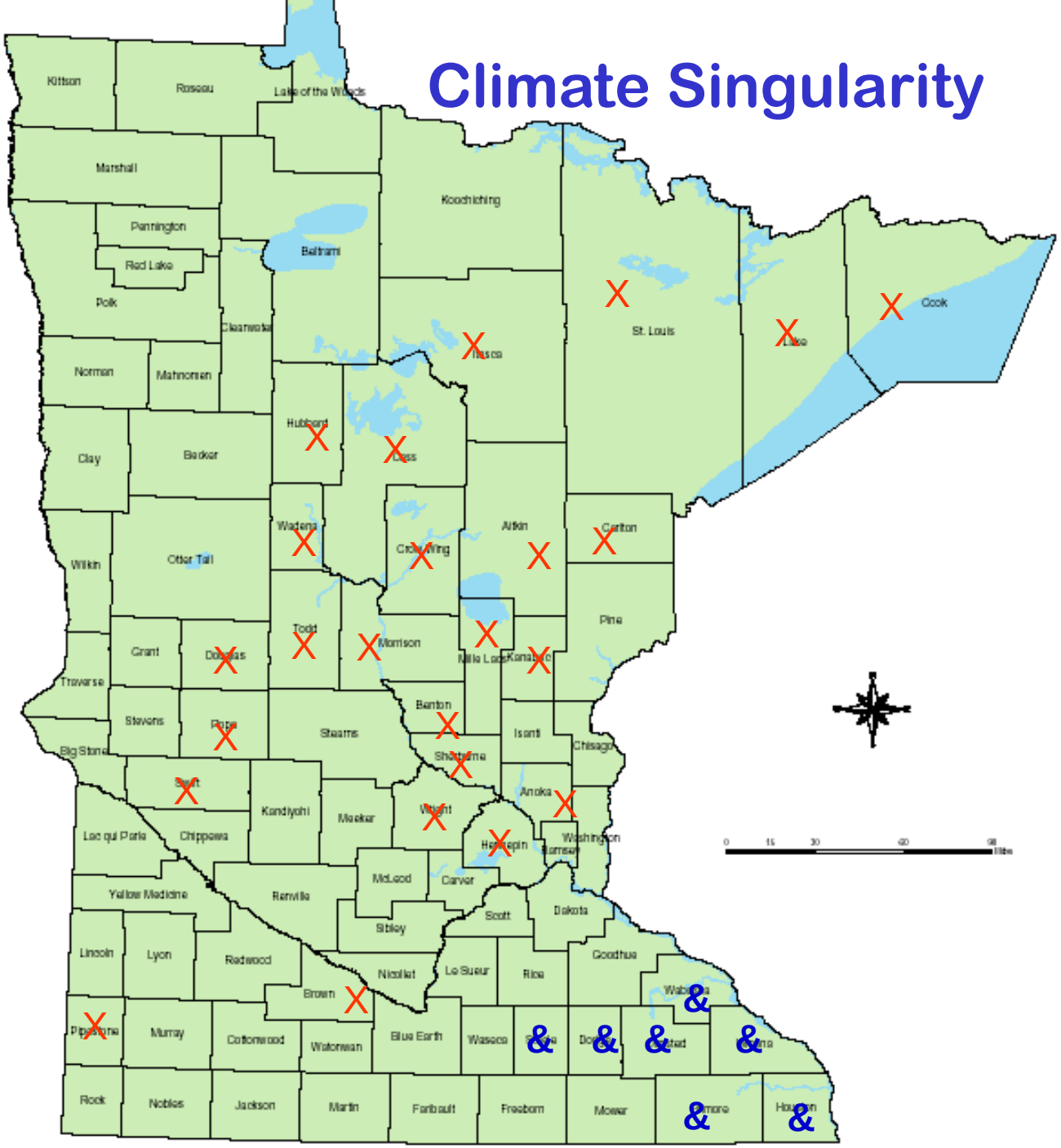
1987, 1988, 1997,
2005-2007 2008
2009, 2010, 2011

Climate Singularity

X = 24 counties included in USDA drought disaster declaration of August 7, 2007

Note: adjacent 32 counties were also eligible for assistance

&= Counties included in federal flood disaster declaration of August 20, 2007 and eligible for FEMA assistance



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

"I'll accept the notion of climate change when pigs and rabbits fly"

For those who doubt or wish to dismiss the evidence that climate is changing….the data indicate it is happening in Minnesota

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