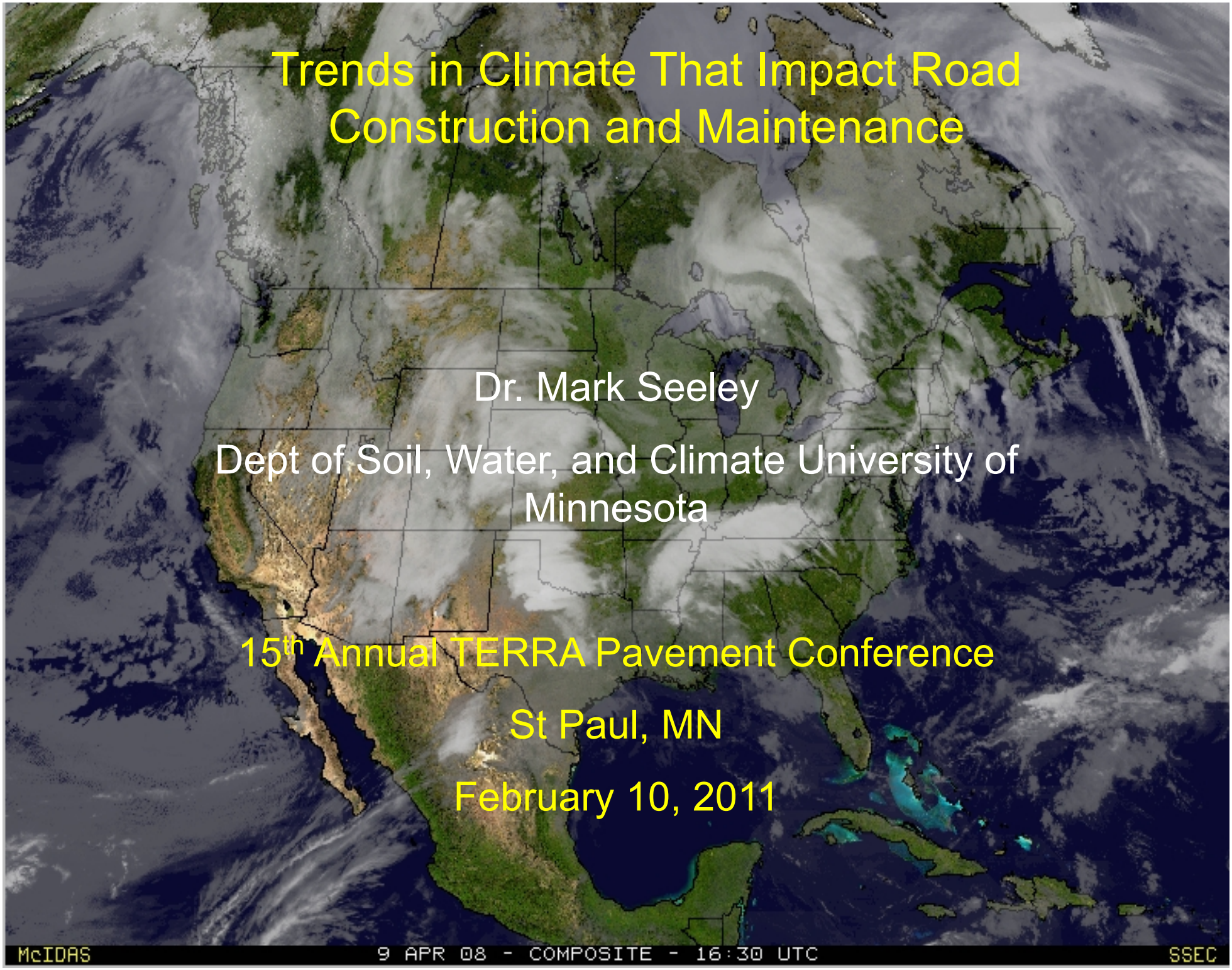
Trends in Climate That Impact Road Construction and Maintenance
Dr. Mark Seeley
Dept of Soil, Water, and Climate University of Minnesota
15th Annual TERRA Pavement Conference
St Paul, MN
February 10, 2011
McIDAS
9 APR 08 - COMPOSITE - 16:30 UTC
SSEC

National Weather Service Event Definitions/Thresholds

WARM SEASON EVENTS	THRESHOLDS
SEVERE THUNDERSTORM WARNING	WINDS>=58 mph (or implied by damage), and/or HAIL >= 3/4 inch
TORNADO WARNING	Spotter Report and/or Radar Indicated and/or Environment Supported
FLASH FLOOD WARNING	Life/Property threat within 6 hours.
FLOOD WARNING	Life/Property threat within 6 to 12 hours.
FLOOD WARNING (MAIN STEM RIVER)	Life/Property threat beyond 12 hours.
URBAN AND SMALL STREAM FLOOD ADVISORY	Inconvenience flooding 0 to 24 hours.
COLD SEASON EVENTS	**THRESHOLDS**
WINTER STORM WATCH	Issued when there is a likelihood a warning will eventually be issued. Watches are normally valid for possible events occurring 12 to 48 hours, but may be pushed to 6 hours if uncertainty still exists.
WINTER STORM WARNING	Heavy Snow 6" or more within 12 hours, or 8" within 24 hours. Warnings may also be issued for smaller amounts if there is significant blowing snow, low wind chills, sleet, freezing rain, etc.
HEAVY SNOW WARNING	Heavy snow 6" or more within 12 hours, or 8" within 24 hours. No other significant winter events such as blowing snow, low wind chills, sleet, freezing rain expected.
BLIZZARD WARNING (GROUND BLIZZARD WARNING)	Sustained winds or frequent gusts greater than or equal to 35 mph and falling or blowing snow with visibility less than 1/4 mile for greater at least 3 hours. Ground blizzard only deals with blowing snow.
ICE STORM WARNING	Ice accumulations of at least 1/4" expected.
LAKE SNOW WARNING	6" of snow within 12 hours, or 8" within 24 hours as a result of Lake Effect.
WIND CHILL WARNING	Widespread wind chills of 35 degrees below zero or lower with winds greater than 10 mph. In some parts of southern Minnesota, the threshold may be 30 below.
WINTER WEATHER ADVISORY	Mix of snow, sleet, freezing rain/drizzle, fog wind, etc.
SNOW ADVISORY	Less than 6" of snow expected in 12 hours or 8" in 24 hours. Normally a minimum of 3" but advisories for less than 3" are allowed at forecaster discretion.
LAKE SNOW ADVISORY	Lake Effect snow producing less than 6" in 12 hours or 8" in 24 hours. Normally a minimum of 3" but advisories for less than 3" are allowed at forecaster discretion.
FREEZING RAIN/FREEZING DRIZZLE	Light freezing rain or freezing drizzle. Ice accumulations remaining below 1/4".
WIND CHILL ADVISORY	Widespread wind chills of 25 degrees below zero or lower with winds at least 10 mph. In some parts of southern Minnesota, the threshold may be 20 below.
BLOWING SNOW ADVISORY	Wind-driven snow resulting in visibilities occasionally 1/4 mile or lower.
OTHER EVENTS	**THRESHOLDS**
HIGH WIND WARNING	Sustained winds at least 40 mph for 1 hour or more, or gusts to 58 mph or more. May be preceded by a High Wind Watch.
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WIND ADVISORY	Sustained winds of at least 30 mph for 1 hour or more, or gusts from 45 to 57 mph.
HEAT ADVISORY	During a 24 hour period, the Heat Index ranges from 105 to 114 degrees during the day, and remains at or above 80 degrees at night.
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FREEZE ADVISORY	Widespread temperatures of 32 degrees or lower. May or may not be accompanied by frost. Issued only during growing season.
FROST ADVISORY	Formation of thin ice crystals on ground or other surfaces. Usually occurs with light wind. Frost may occur even though standard observing level temperatures (5 feet above ground) are in the mid to upper 30s. Issued only during growing season.

ADVERSE WEATHER HAZARDS

- WINTER STORMS (BLIZZARDS, HEAVY SNOWS, DANGEROUS WINDCHILL)
- CONVECTIVE STORMS (THUNDERSTORMS, HAIL, HEAT)

NWS Winter Weather Criteria

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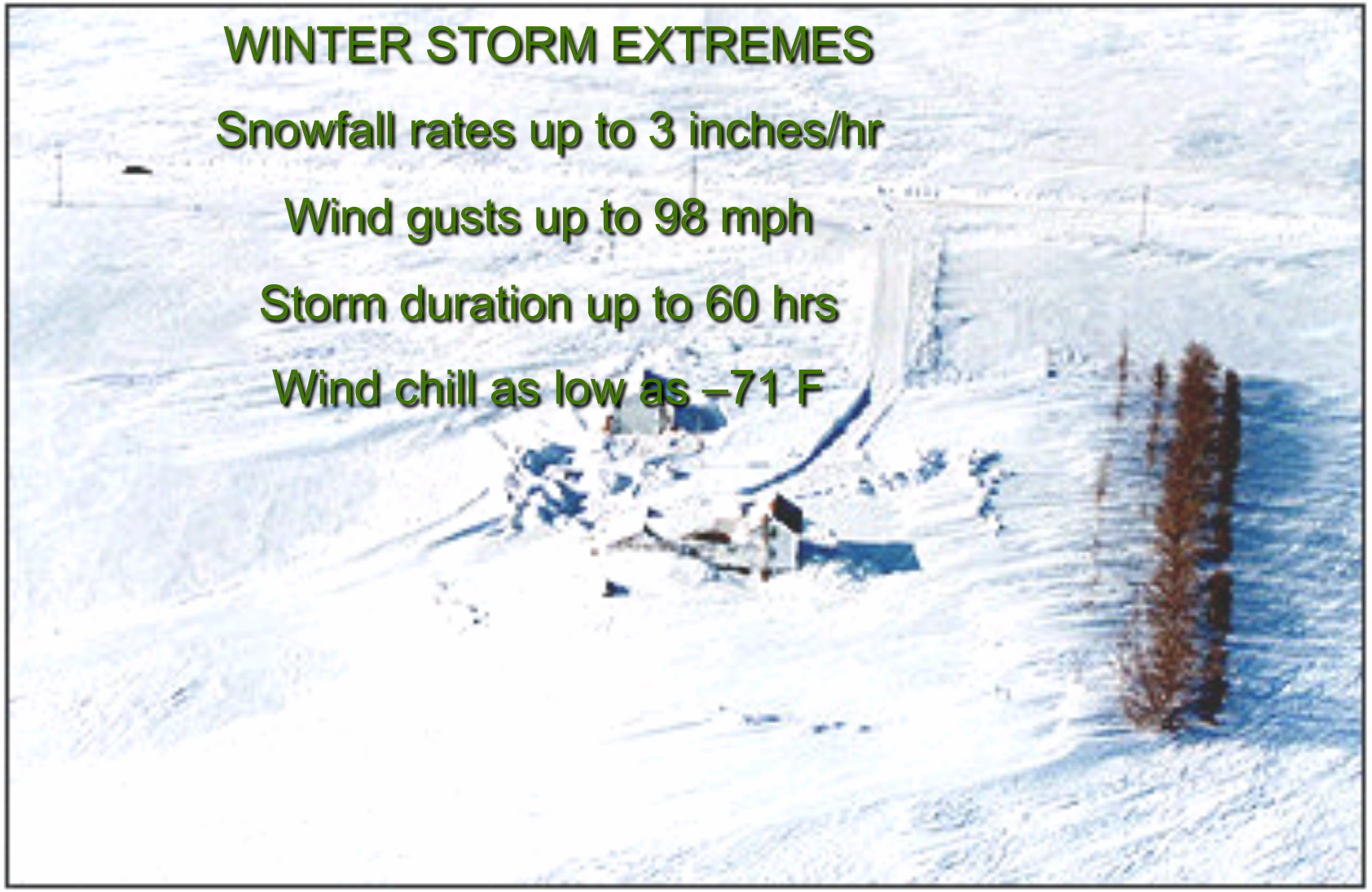
WINTER STORM HAZARD CHARACTERISTICS:

- ICE OR SNOW DEPOSITION
- REDUCED VISIBILITY
- STRONG WINDS
- DANGEROUS WIND CHILL VALUES


WINTER STORM EXTREMES
Snowfall rates up to 3 inches/hr
Wind gusts up to 98 mph
Storm duration up to 60 hrs
Wind chill as low as –71 F

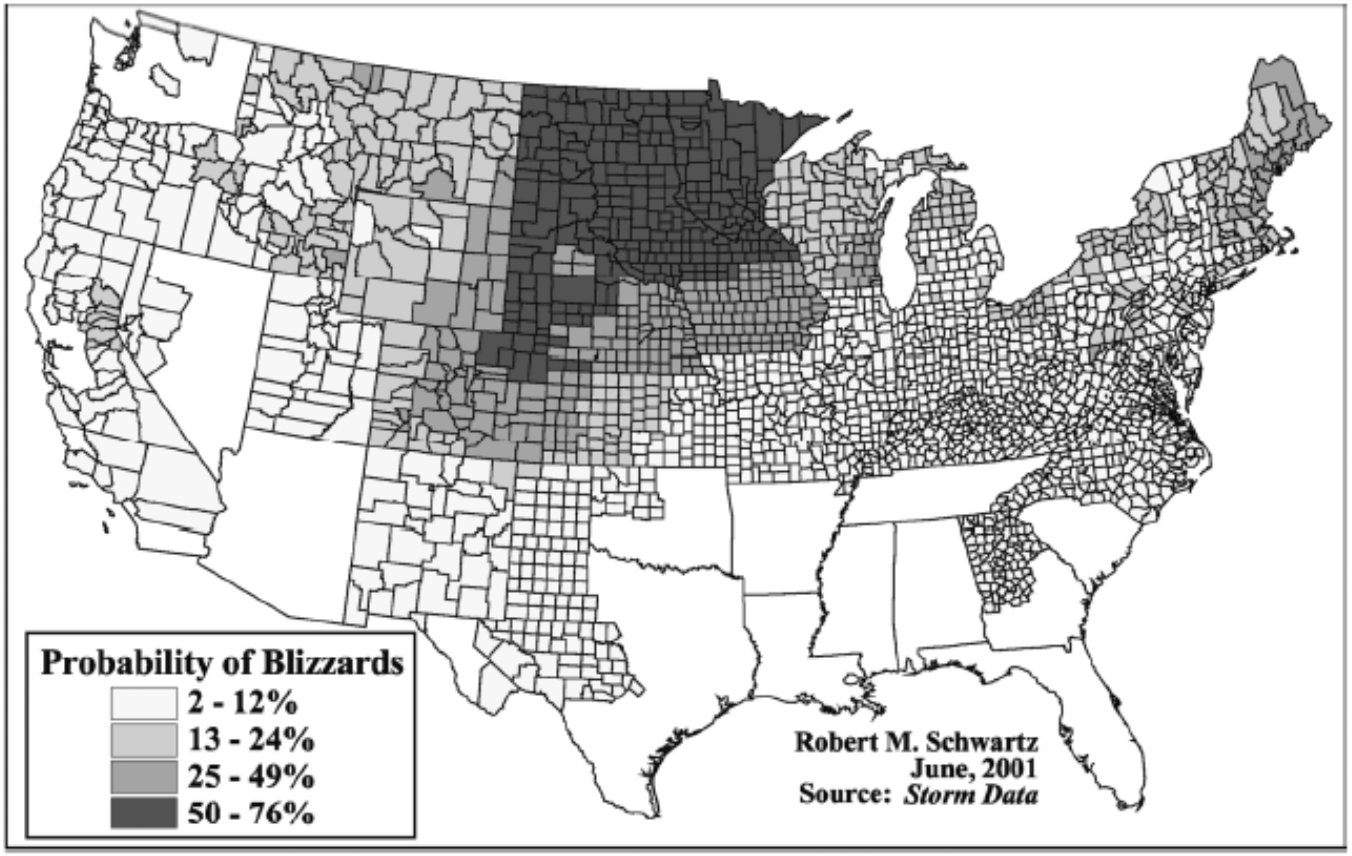


FIG. 4. Annual probability of a blizzard by county, based on the frequency of blizzards during 1959/60 to 1999/2000.

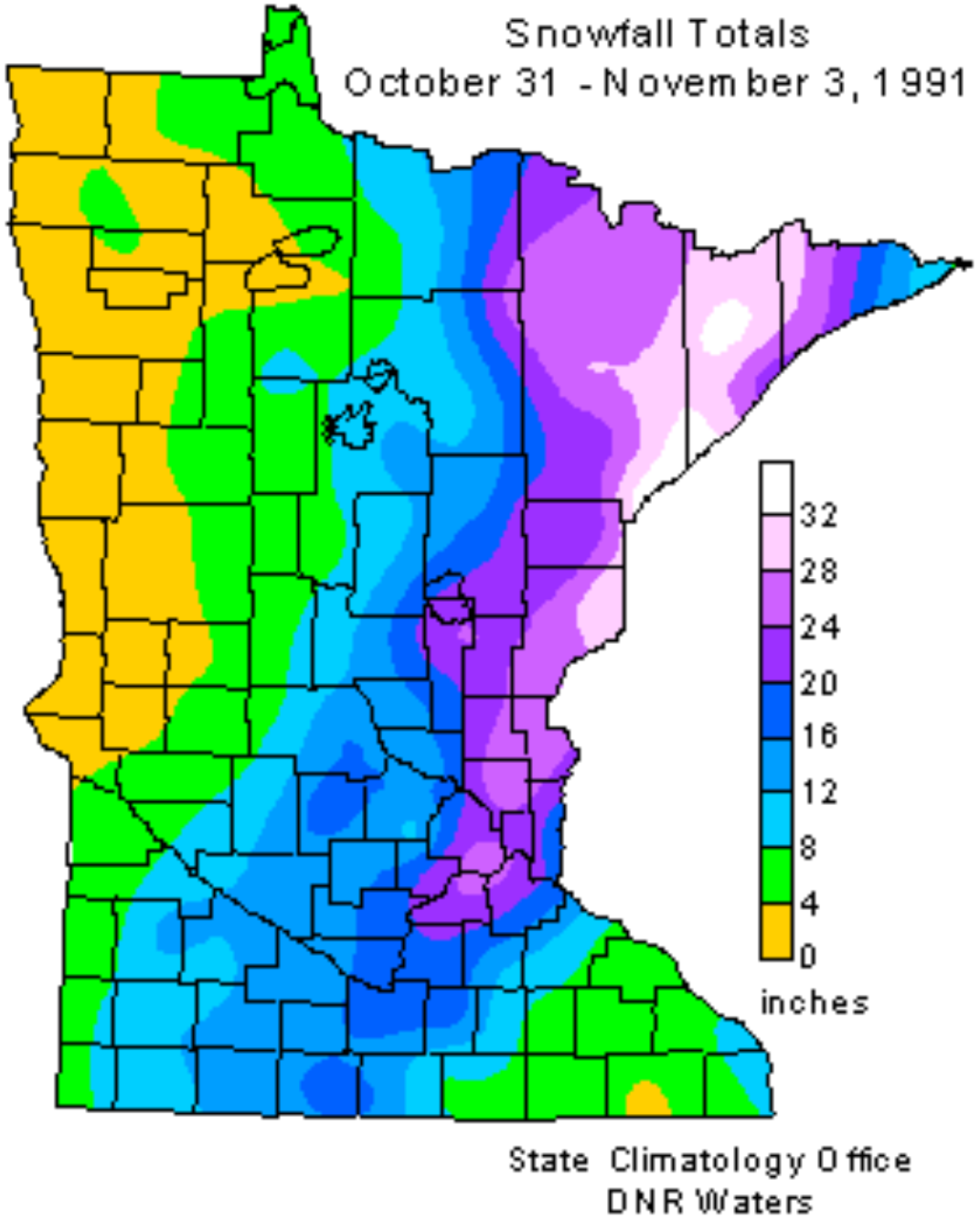
Annual Probability of Blizzards

Top Single Day or Multiple Day Snowfalls

Top Ten Snowfalls for the Twin Cities

This list is for snowfall from 1891-1999

#	Month & Day	Year	Inches
1.	Oct 31-Nov 3	1991	28.4
2.	Jan 22-Jan 23	1982	20.0
3.	Jan 20-Jan 21	1982	17.4
4.	Nov 11-Nov 12	1940	16.8
5.	Mar 3-Mar 4	1985	16.7
5.	Mar 11-Mar 14	1940	16.7
7.	Dec 27-Dec 28	1982	16.5
8.	Jan 20-Jan 21	1917	16.0
8.	Mar 8-Mar 9	1999	16.0
10.	Mar 31	1985	14.7

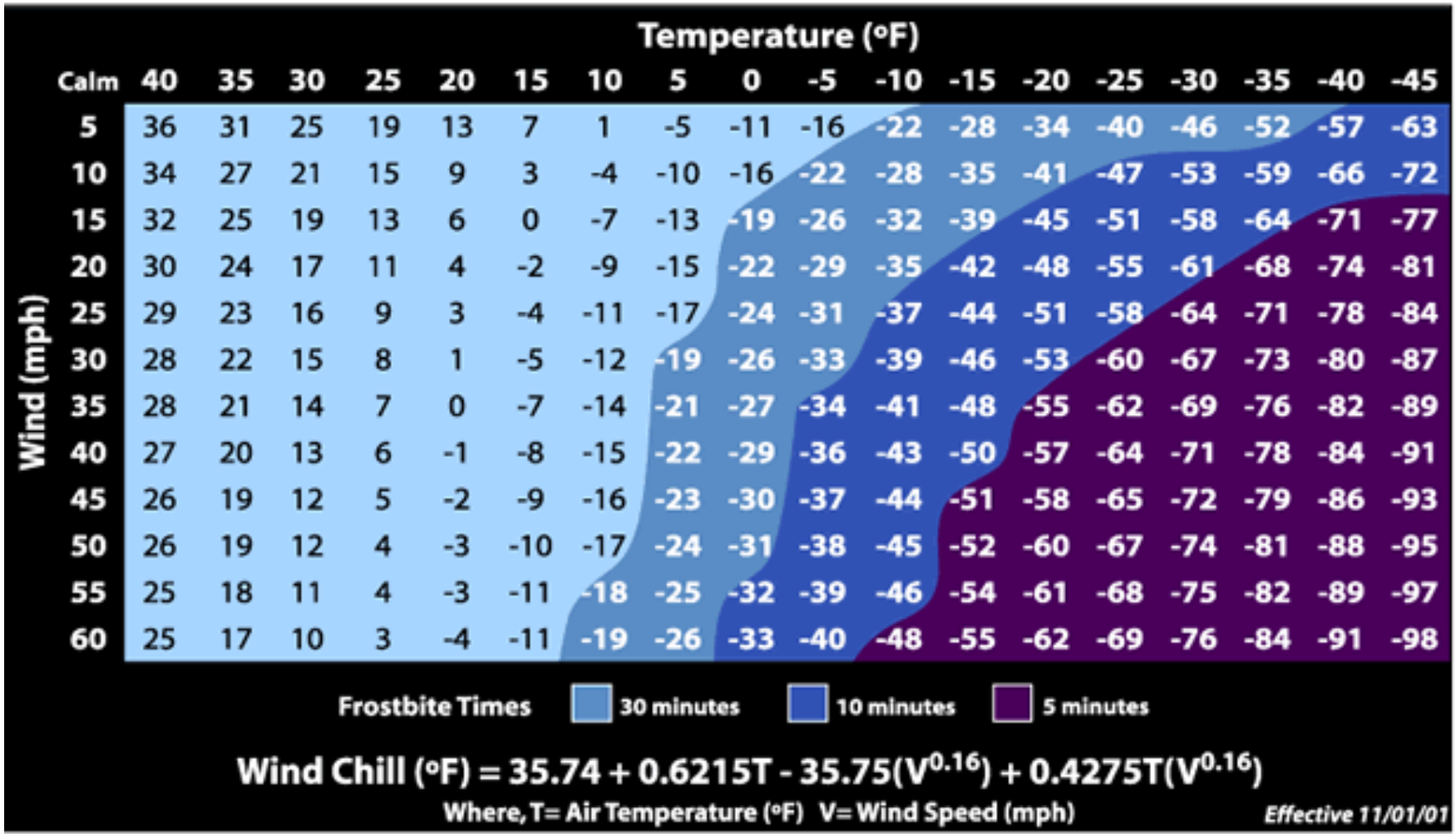


Halloween blizzard

Frequency of snowfalls of 3″ or greater in the Twin Cites since 1949.

Months	No. of yrs with at least one	No. of yrs with multiple falls
DEC	27 (45 pct)	15 (25 pct)
JAN	35 (57 pct)	17 (28 pct)
FEB	35 (58 pct)	14 (23 pct)

NWS Windchill Chart

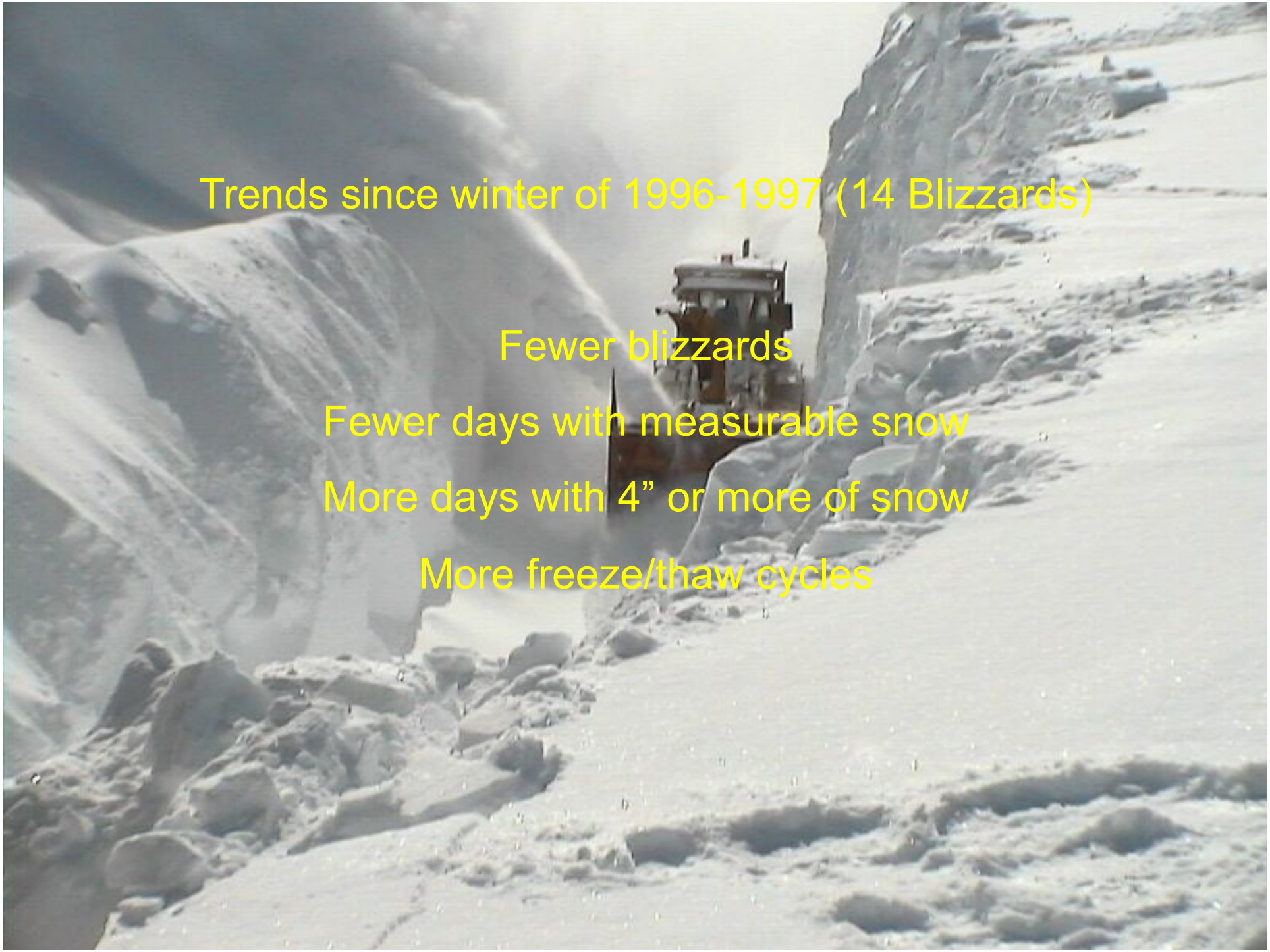


$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01


Coldest Windchill Conditions
Jan 22, 1936 -67 F
Dec 23, 1983 -55 F
Feb 3, 1989 -49 F
Jan 18, 1994 -48 F
Feb 2, 1996 -48 F
Jan 30, 2004 -43 F


Trends since winter of 1996-1997 (14 Blizzards)
Fewer blizzards
Fewer days with measurable snow
More days with 4” or more of snow
More freeze/thaw cycles

ADVERSE WEATHER HAZARDS

- CONVECTIVE STORMS (THUNDERSTORMS, HAIL, HEAT

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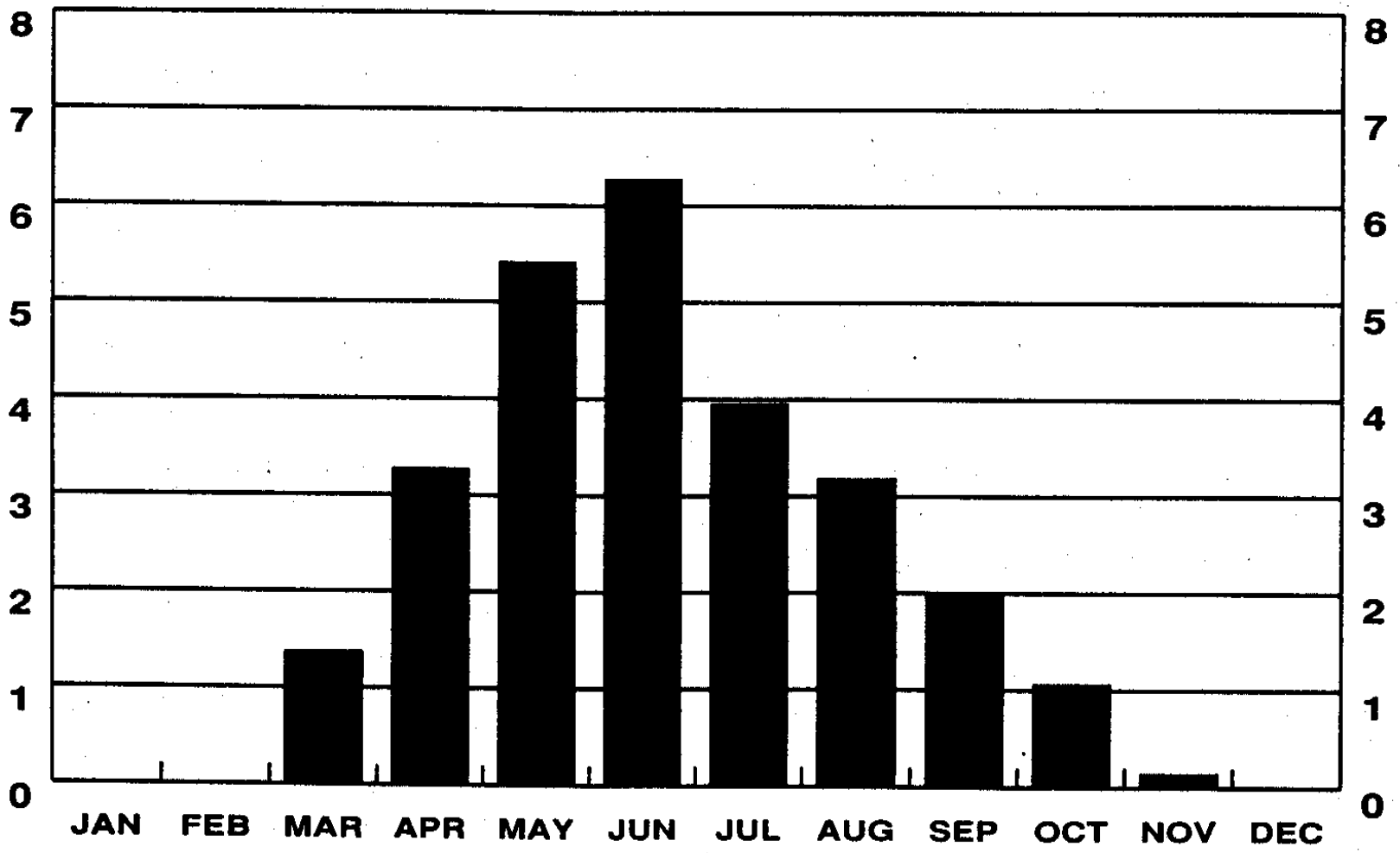
FREQUENCY OF THUNDERSTORMS IN THE TWIN CITIES

• JAN	• ONCE/15 YRS
• FEB	• ONCE/5 YRS
• MAR	• ONCE/YR
• APR	• 2-3 TIMES/YR
• MAY	• 5-6 TIMES/YR
• JUN	• 7-8 TIMES/YR
• JUL	• 7-8 TIMES/YER
• AUG	• 6-7 TIMES/YR
• SEP	• 4-5 TIMES/YR
• OCT	• 1-2 TIMES/YR
• NOV	• ONCE/2 YRS
• DEC	• ONCE/10 YRS

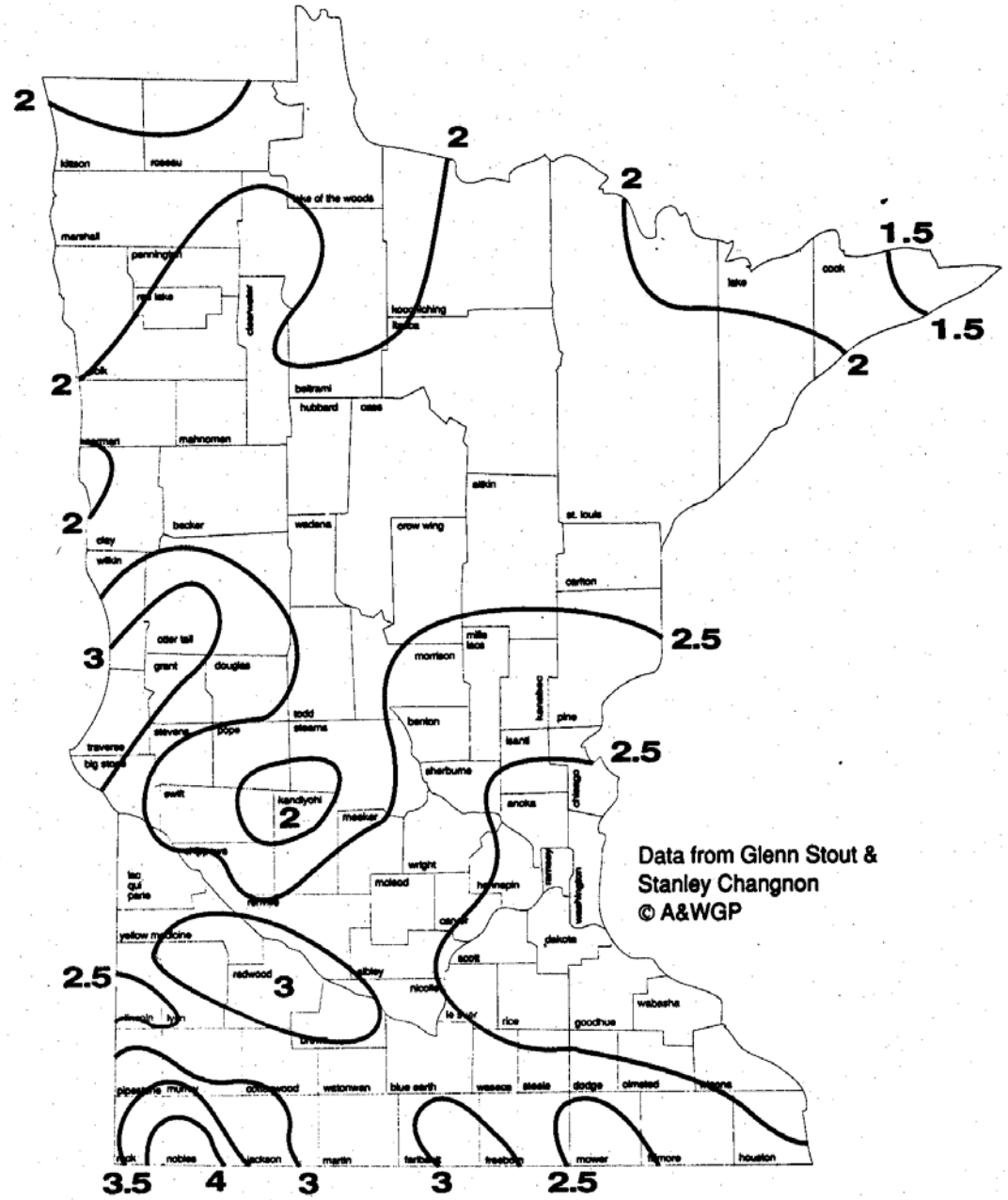
MINNESOTA HAIL STORMS

10-year number for an average location

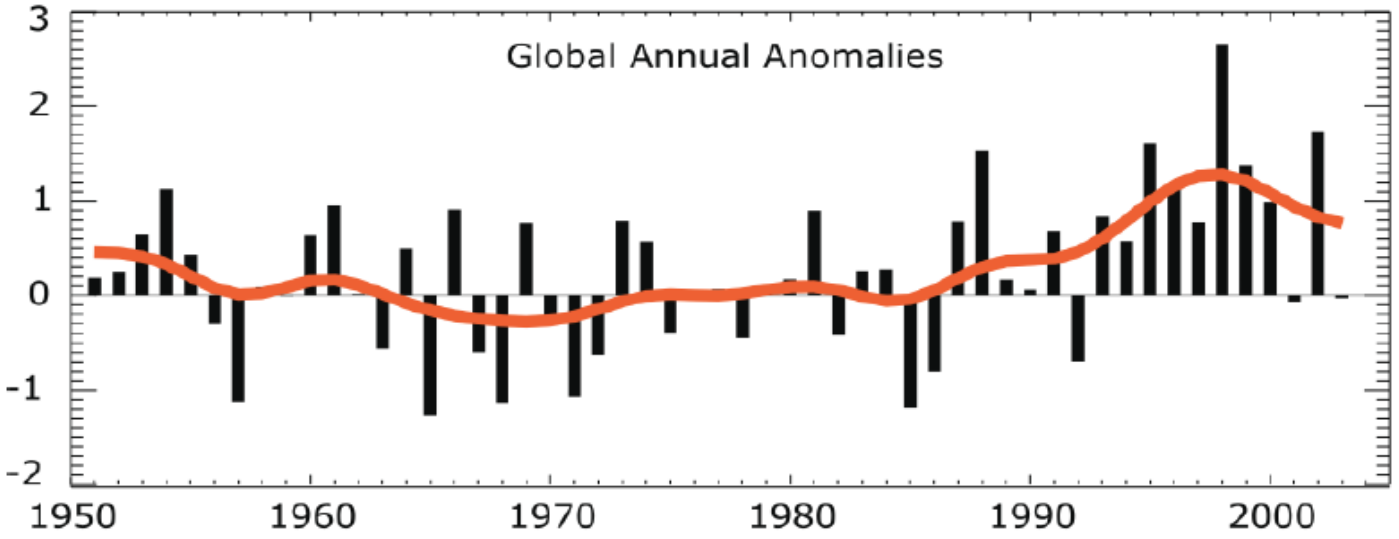


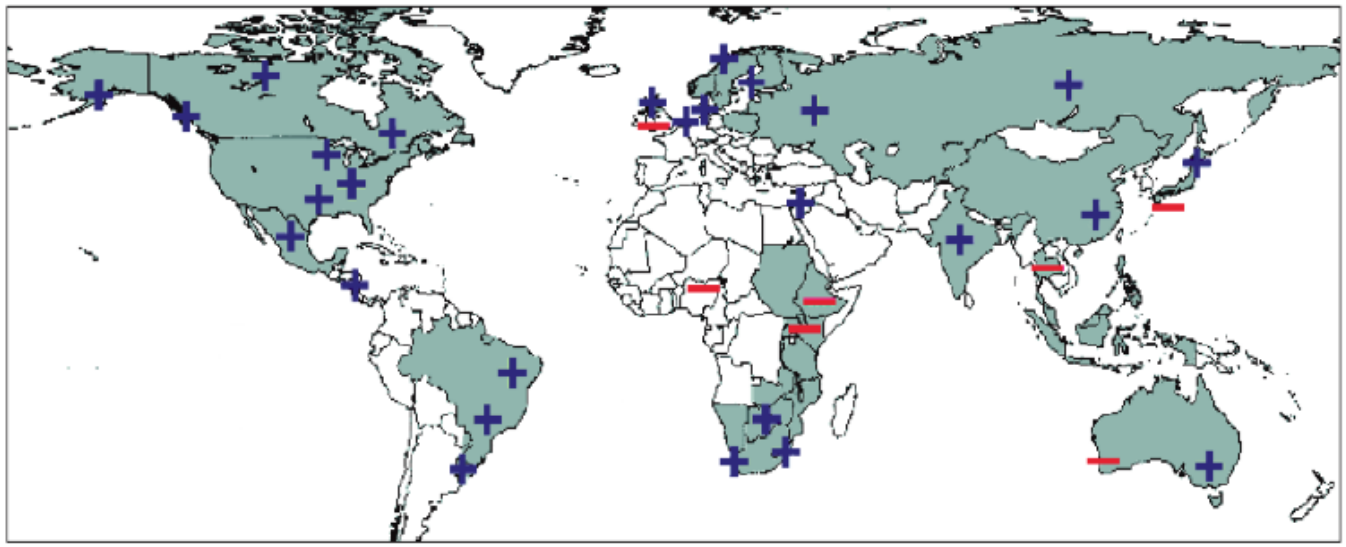
Data from Glenn Stout & Stanley Changnon © A&WGP

HAIL DAYS PER YEAR



Heavy Precipitation Trend (% from very wet days)





From IPCC

2007

*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.

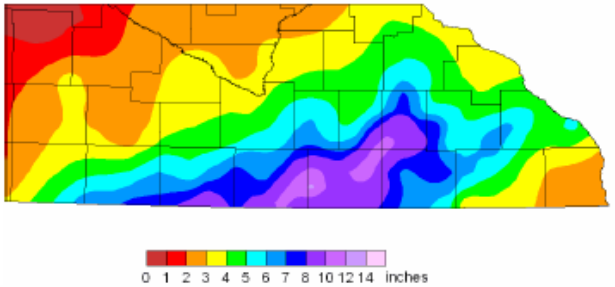
Observed 2 inch rainfalls for the period 1991 – 2010 and maximum single day value for various communities:

Location	No. 2 in. rains	Maximum Value (date)
Twin Cities	**28**	**9.15 (7/23/87)**
Albert Lea	**33**	**7.50 (6/15/78)**
Preston	**36**	**6.60 (7/21/51)**
Red Wing	**29**	**7.78 (7/1/78)**
Lake City	**38**	**5.60 (5/28/70)**
Waseca	**38**	**5.40 (8/31/62)**
Winnebago	**40**	**8.64 (9/25/2005)**
Bricelyn	**35**	**9.22 (9/14/2004)**
Amboy	**34**	**4.69**

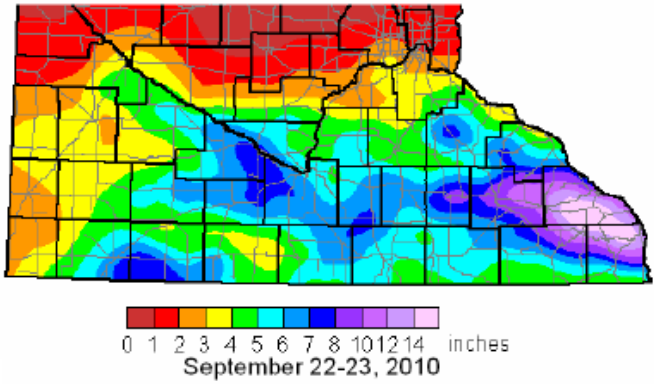
Shift in Precipitation Recurrence Intervals

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

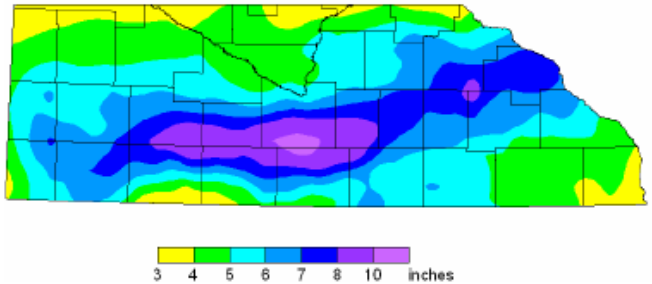
September 14-15, 2004



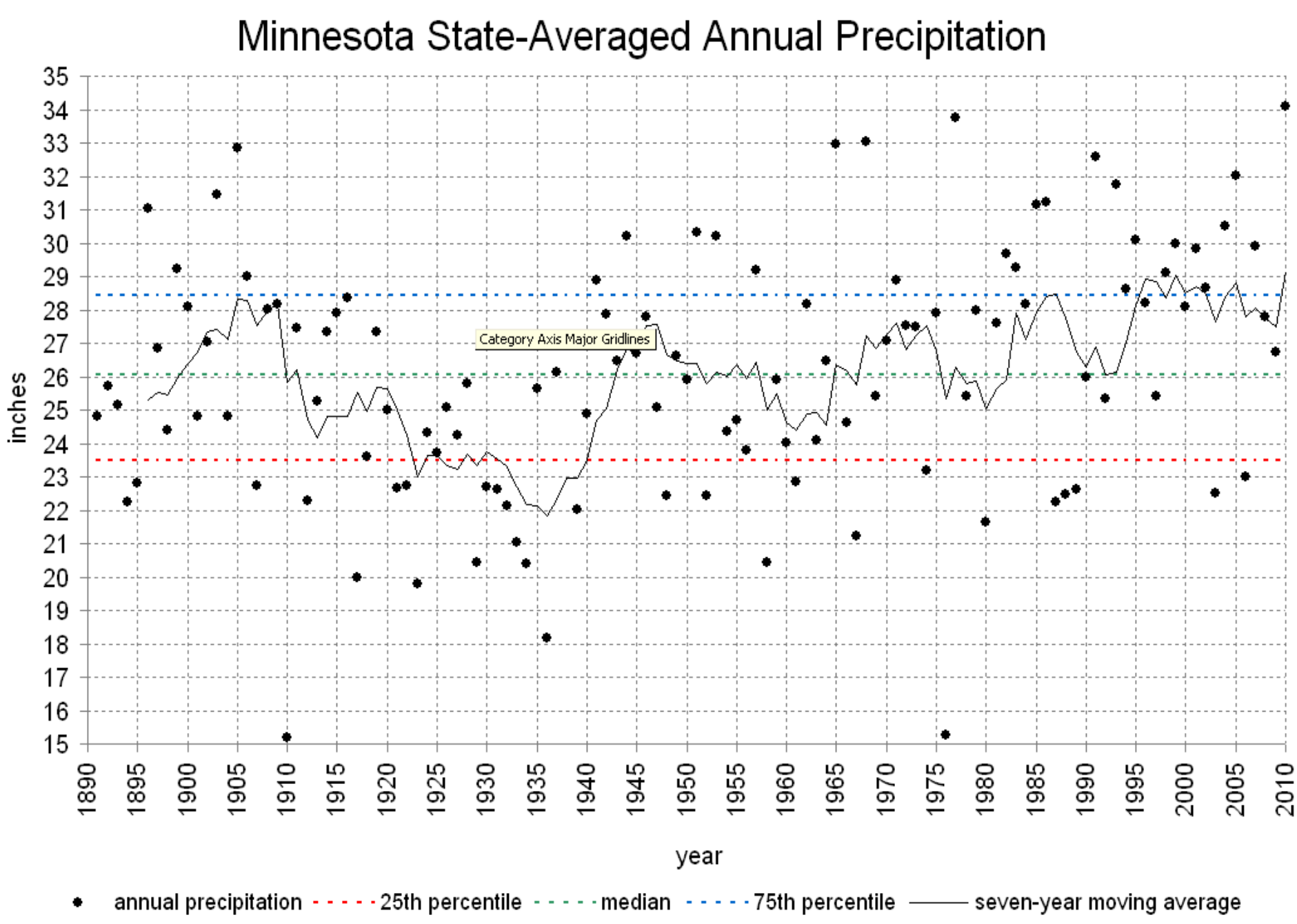
August 18 through August 20 (8:00 AM CDT), 2007



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.


Minnesota State-Averaged Annual Precipitation
inches
year
Category Axis Major Gridlines
annual precipitation
25th percentile
median
75th percentile
seven-year moving average

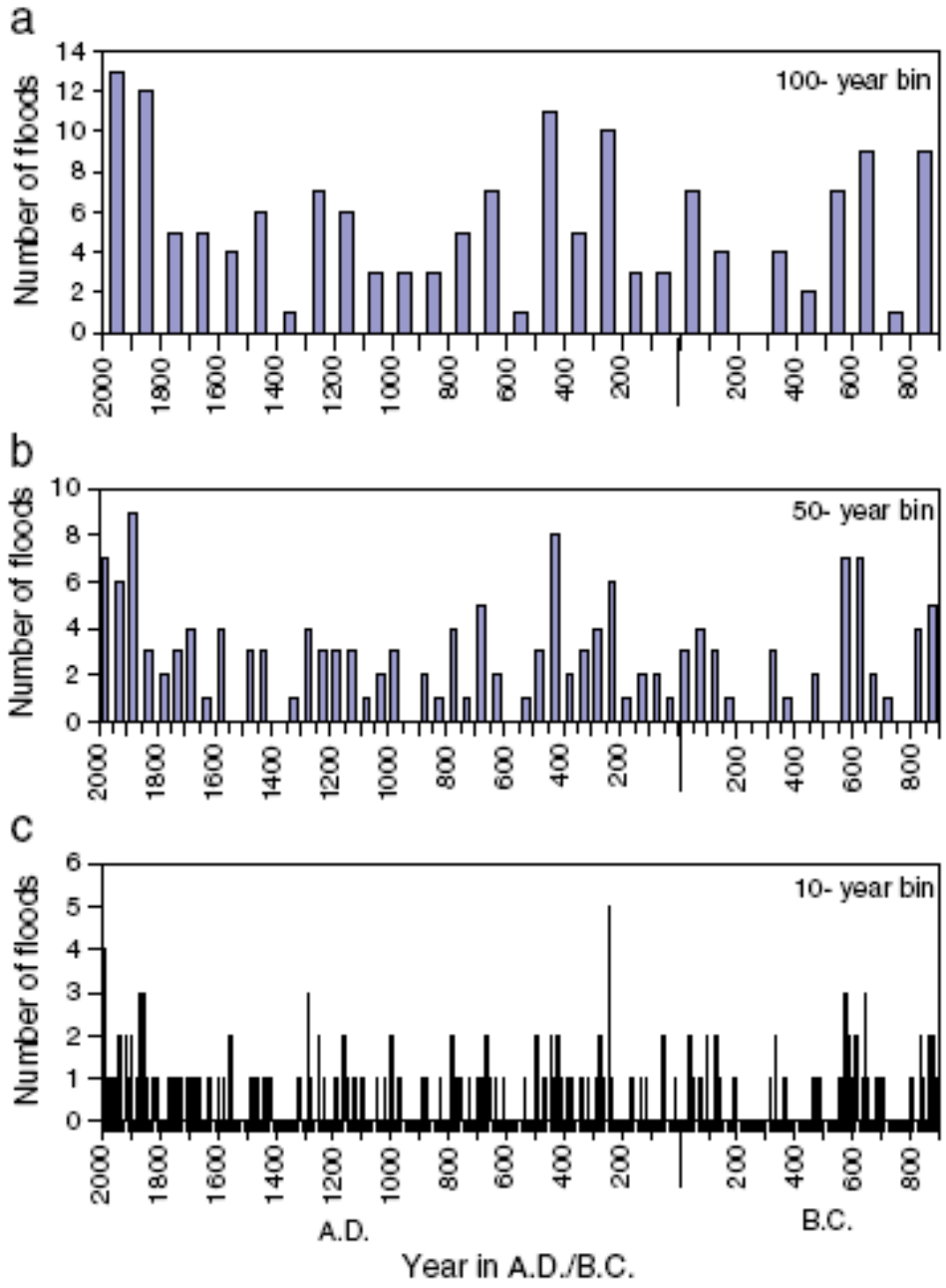
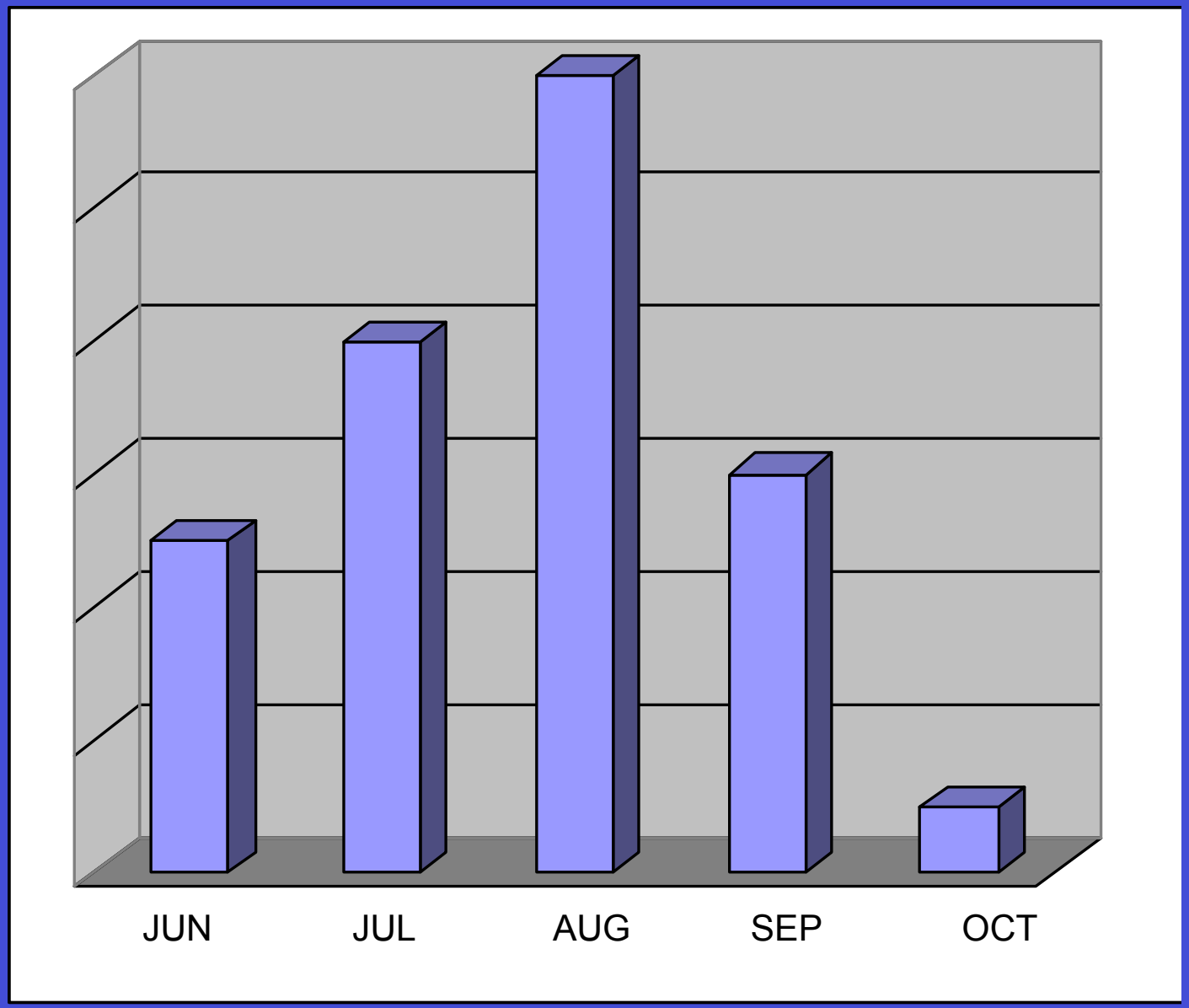


Fig. 9. Plots showing number of floods per 100 yr (a), per 50 yr (b), and per decade (c).

3000 years of flood frequency in SE MN (Spring Valley) reconstructed

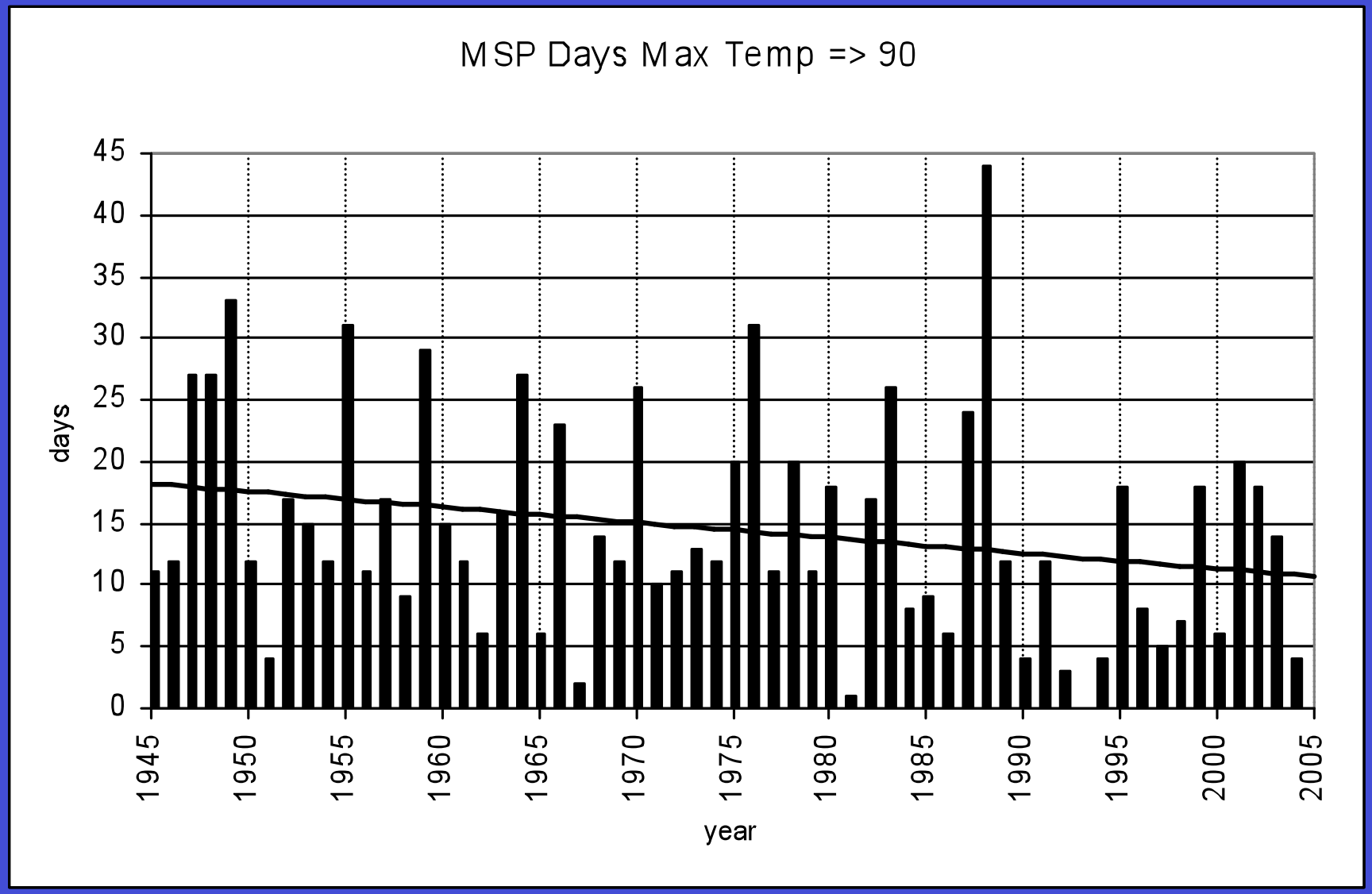
From: S. Dasgupta et al, Earth and Planetary Science Letters, 300: pp 46-54, 2010



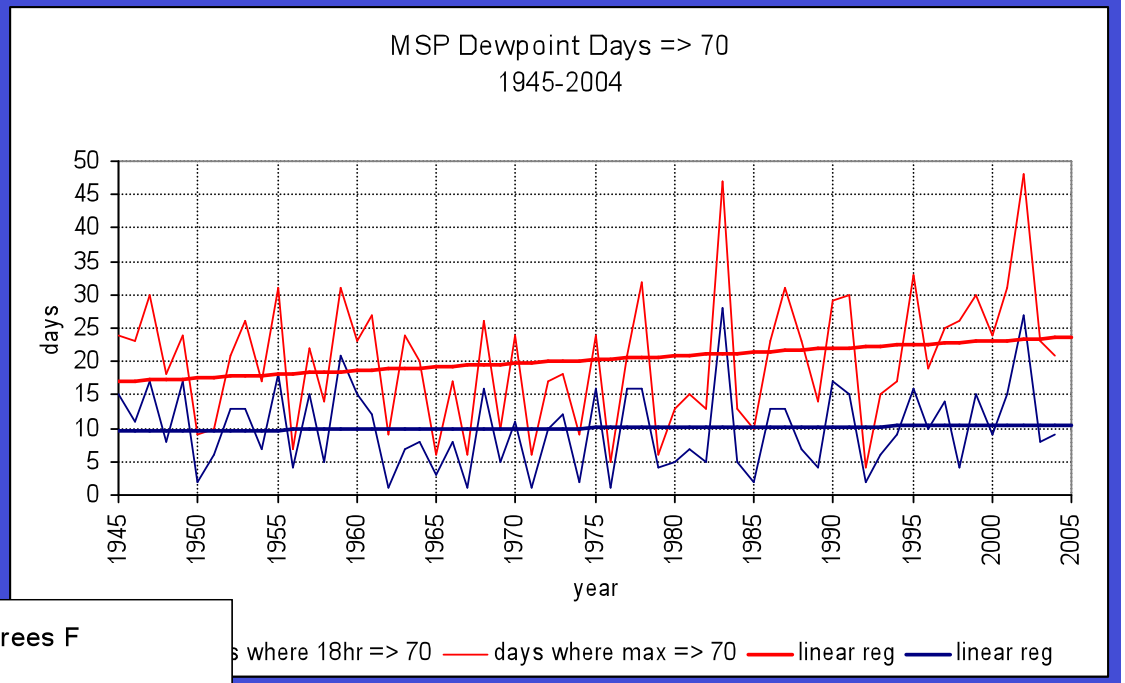
Month exhibiting the highest annual 24-hr rainfall amount

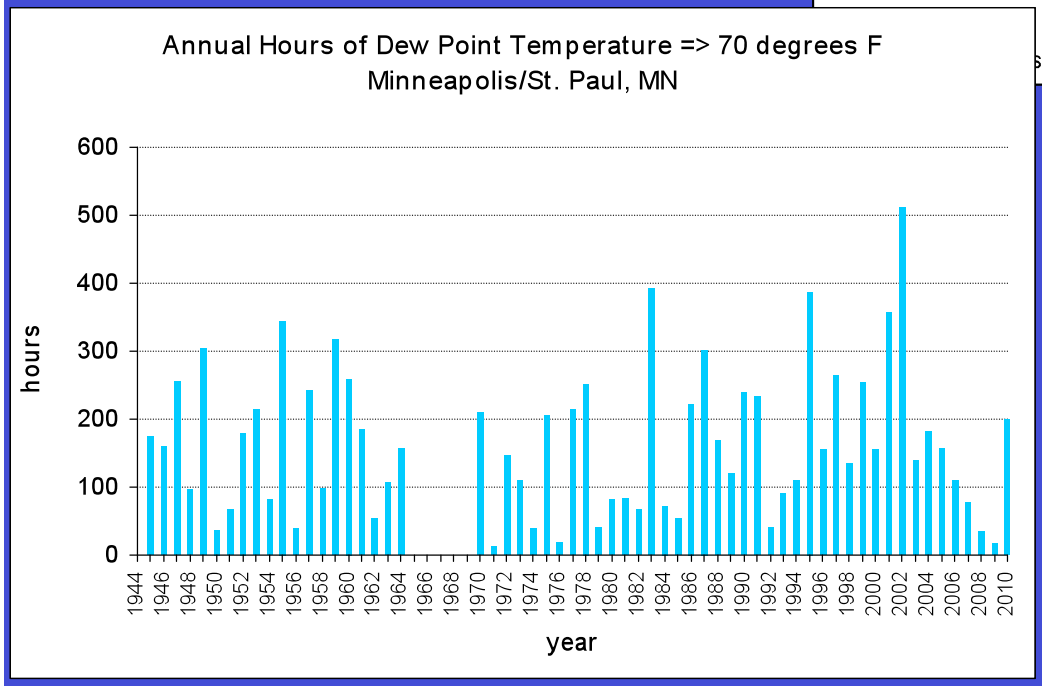
1978-2009 (a shift in phase to later in the year)

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



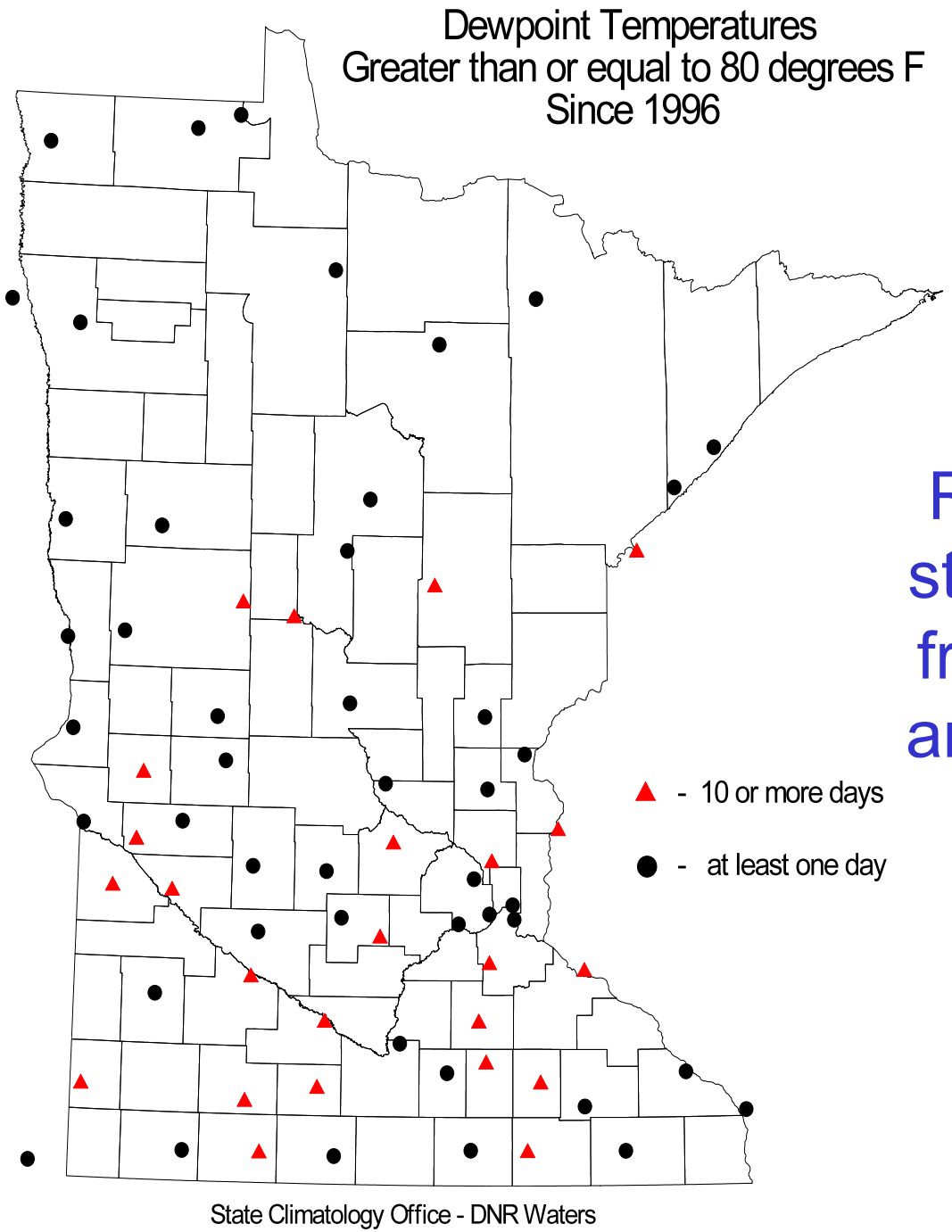
Trend in dewpoints of 70 F or higher in the Twin Cities



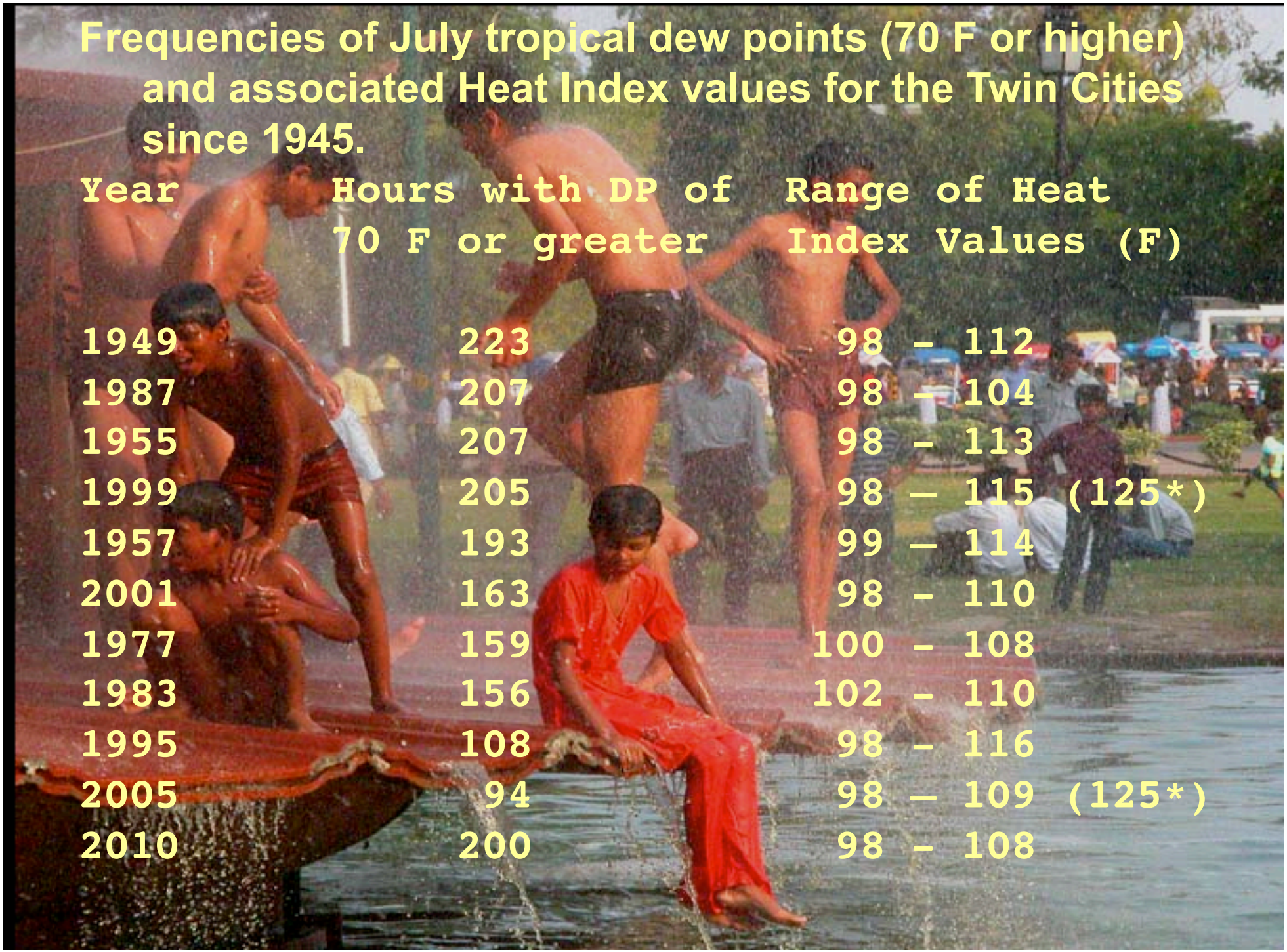


Waseca, MN Average Monthly Minimum Temperature Pattern													
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1951-1980	0	6.4	18.2	34.1	45.9	55.7	59.9	57.5	48	37.2	23.2	9.2	33
1961-1990	0.2	6.3	20.0	34.3	46.1	55.8	60.3	57.2	48.1	36.5	23.4	7.0	32.8
1971-2000	1.5	8.9	21.8	34.6	47.3	56.8	60.6	58.3	48.5	36.4	23	7.9	33.8
1978-2007	4.2	8.7	21.8	35.0	47.5	57.4	61.2	58.8	49.4	36.5	23.6	9.6	34.5
Waseca, MN Average Monthly Maximum Temperature Pattern													
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1951-1980	19.9	26.4	36.6	55.3	69.6	78.5	82.4	80	72	60.4	41.7	26.7	54.1
1961-1990	20.1	25.8	37.9	55.0	69.2	78.4	82.3	79.4	71.4	59.1	41.1	24.7	53.5
1971-2000	20.6	26.9	38.8	55.1	69.4	78.7	81.8	79.5	71.8	59	39.8	25.1	53.9
1978-2007	22.3	26.8	39.0	56.1	69.2	78.8	82.1	79.6	72.5	58.9	40.8	26.6	54.4

Temperature Tendencies at Waseca, MN

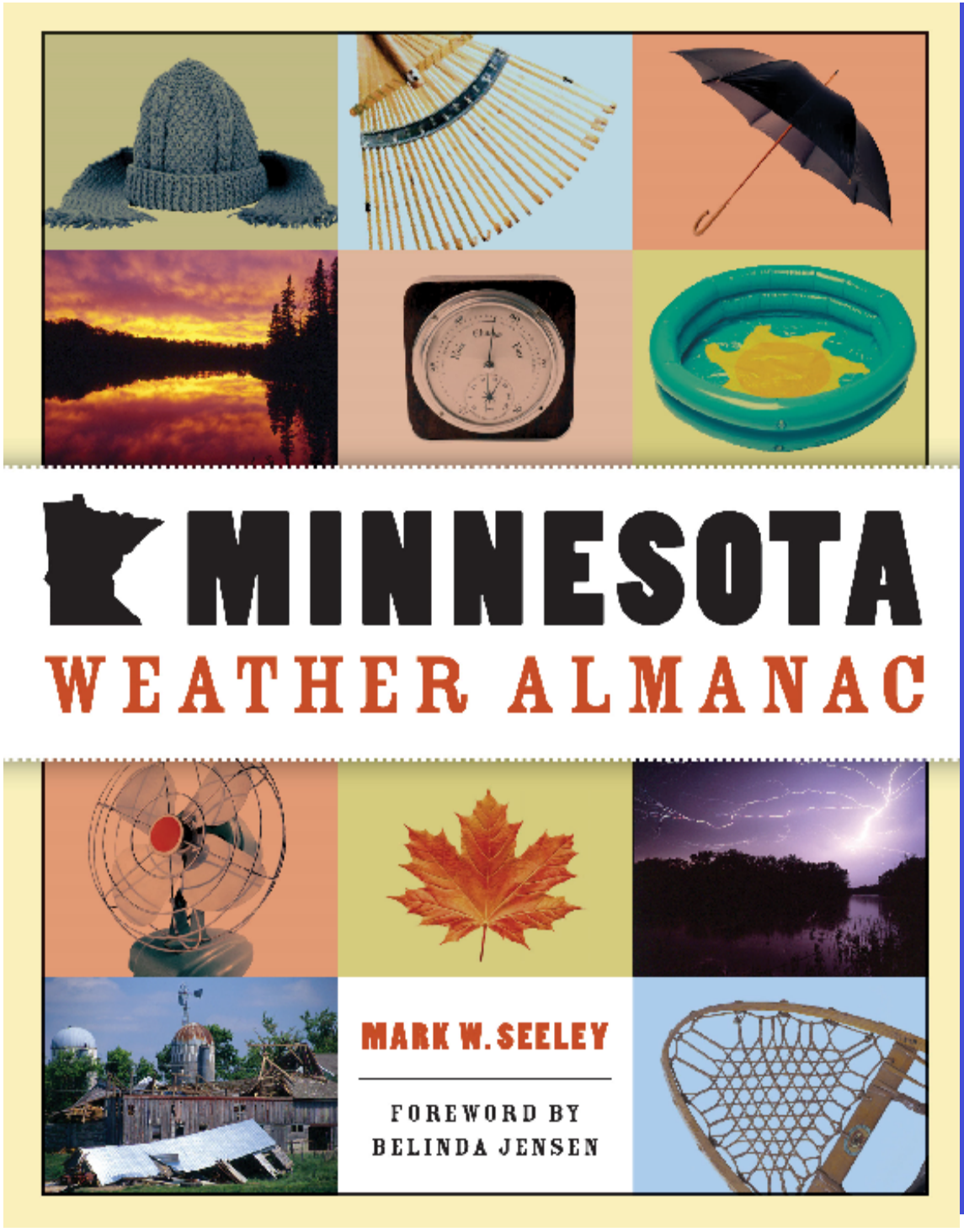


DP 80 F or higher. Readings have been statewide with highest frequencies in central and southern counties



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

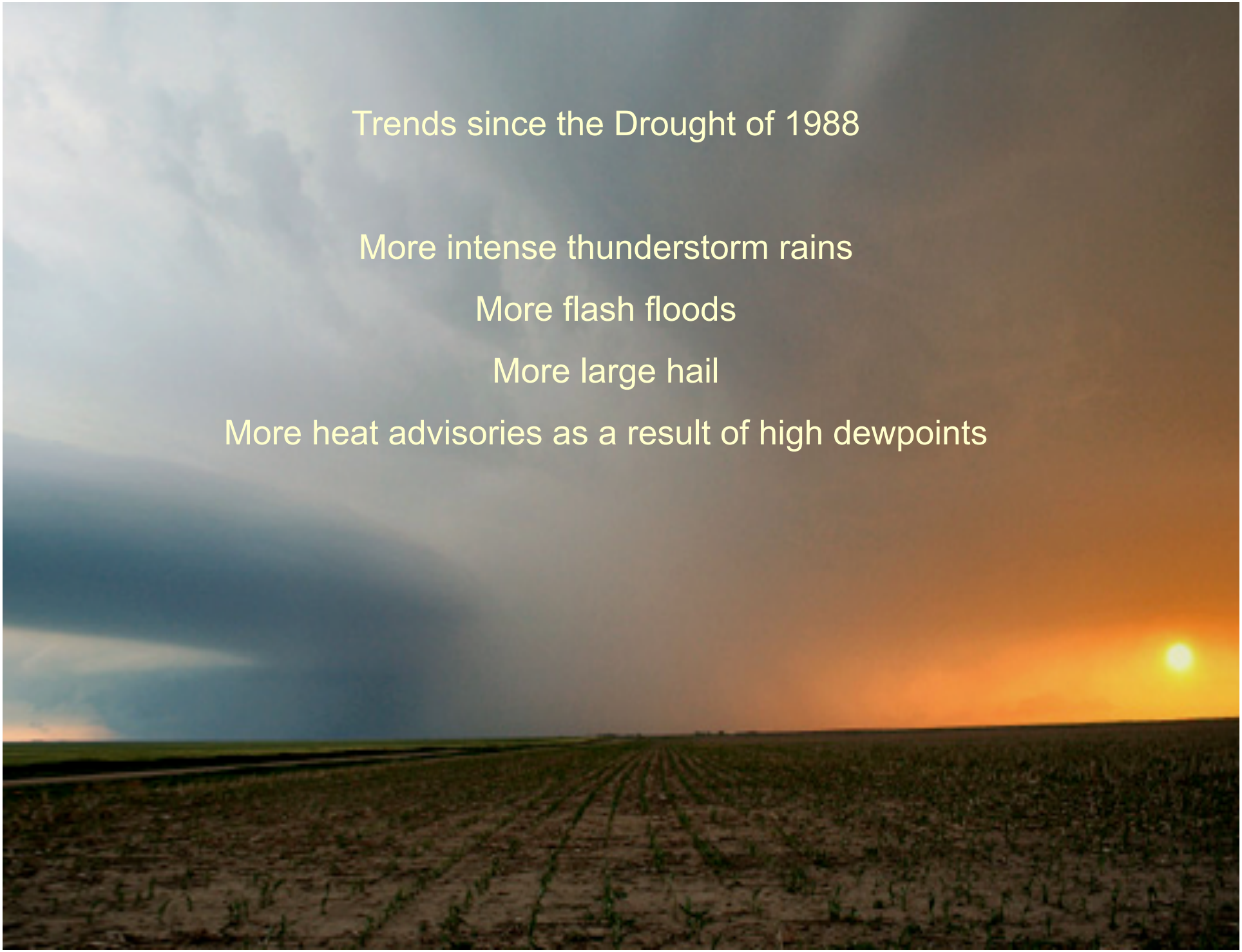
Year	Hours with DP of 70 F or greater	Range of Heat Index Values (F)
1949	223	98 - 112
1987	207	98 - 104
1955	207	98 - 113
1999	205	98 – 115 (125*)
1957	193	99 – 114
2001	163	98 - 110
1977	159	100 - 108
1983	156	102 - 110
1995	108	98 - 116
2005	94	98 – 109 (125*)
2010	200	98 - 108



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


Trends since the Drought of 1988
More intense thunderstorm rains
More flash floods
More large hail
More heat advisories as a result of high dewpoints

“I’ll accept the notion of climate change when pigs and rabbits fly”

www.cloudappreciationsociety.org