Impacts of Climate Change on Agricultural Production

Dr. Mark Seeley
Dept of Soil, Water, and Climate
University of Minnesota
Galaxy III Conference
J CEP
September 17, 2008
Indianapolis, IN
Examples of good climate science overviews

Scientist/citizen perspectives

www.ipcc.ch (4th Assessment)
Shocking News in 2007

Loss in Polar Ice
Figure 1. A schematic illustrating varying views of the temporal behavior of climate conditions.

Changnon et al.
Global Distribution of Atmospheric Carbon Dioxide
NOAA CMDL Carbon Cycle Greenhouse Gases

Three dimensional representation of the latitudinal distribution of atmospheric carbon dioxide in the marine boundary layer. Data from the NOAA CMDL cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Principal investigators: Pieter Tans and Thomas Conway, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado. (303) 497-6678 (pieter.tans@noaa.gov, http://www.cmdl.noaa.gov/ccgg).
Drivers of Observed Climate Behavior

(Is the attribution dilemma now a moot point?)

- **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)
Modelled response to all forcings agrees best with observations

Models fit better with natural and human drivers of climate behavior (Env.Canada)

Regardless of Climate Change, Societal Vulnerability is Increasing

Dollar amounts shown are approximate damages/costs in $ billions. Location shown is the general area for the regional event. Several hurricanes made multiple landfalls.

Additional information for these events is available at NCDC WWW site www.ncdc.noaa.gov/old/reports/billionz.html

The U.S. has sustained 78 weather related disasters over the last 28 years with overall damages/costs exceeding $1.0 billion for each event. 66 of the disasters occurred during or after 1990. Total costs for the 78 events were 600 billion using a GNP inflation index.
Vulnerability and Consequences Remain Key Societal Issues
Implications for land use, building codes, insurance, and infrastructure
IPCC 2007

Reconciliation of the surface and upper air trends
Big Picture Climate Change
Synopsis Points of Agreement (IPCC-2007)

- **N. Hemisphere Bias**
- Latitude Bias
- Seasonal Bias
- Minimum Temperature Bias
- Amplification of Hydrologic Cycle
- Highly Complex Water Vapor Signal
- Attribution Dilemma
Figure 3.6 IPCC 2007

Globe

Northern Hemisphere

Southern Hemisphere
IPCC 2007: Expected future temperature changes mimic current trends

**Projections of Future Changes in Climate**

Projected warming in 21st century expected to be **greatest** over land and at most high northern latitudes and **least** over the Southern Ocean and parts of the North Atlantic Ocean.
Synopsis Points of Agreement (IPCC-2007)

- N. Hemisphere Bias
- **Latitude Bias**
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- Attribution Dilemma
Figure 3.7

- Amplified
- Moderate
- Marginal
Big Picture Climate Change
Synopsis Points of Agreement
(IPCC-2007)

• N. Hemisphere Bias
• Latitude Bias
• **Seasonal Bias**
• Minimum Temperature Bias
• Amplification of Hydrologic Cycle
• Highly Complex Water Vapor Signal
• Attribution Dilemma
Seasonality in temperature change

MAM

Trend
1979 to 2005

JJA

SON

DJF

°C per decade

<-1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0 0.1 0.3 0.5 0.7 0.9 1.1 1.3
Annual Temperature Trend for Nebraska
Seasonal Temperature Trends in NE

Winter

Summer

Spring

Fall

Winter Temperature History with 5-year Tendencies
Nebraska Statewide: 1895-2007

Spring Temperature History with 5-year Tendencies
Nebraska Statewide: 1895-2007

Summer Temperature History with 5-year Tendencies
Nebraska Statewide: 1895-2007

Autumn Temperature History with 5-year Tendencies
Nebraska Statewide: 1895-2007
Trend in Annual Temperature for Montana

Annual Temperature History with 5-year Tendencies
Montana Statewide: 1895-2007

Trend in Annual Temperature for Montana
Seasonal Temperature Trends in MT

Winter

Spring

Summer

Fall
Annual Temperature History with 5-year Tendencies
Minnesota Statewide: 1895-2007

Statewide Annual Temperature Trend in Minnesota
Seasonal Temperature Trends in MN

Winter

Seasonal Temperature History with 5-year Tendencies
Minnesota Statewide: 1895-2007

Spring

Seasonal Temperature History with 5-year Tendencies
Minnesota Statewide: 1895-2007

Summer

Seasonal Temperature History with 5-year Tendencies
Minnesota Statewide: 1895-2007

Fall

Seasonal Temperature History with 5-year Tendencies
Minnesota Statewide: 1895-2007
Big Picture Climate Change
Synopsis Points of Agreement (IPCC-2007)

- N. Hemisphere Bias
- Latitude Bias
- Seasonal Bias
- Minimum Temperature Bias
- Amplification of Hydrologic Cycle
- Highly Complex Water Vapor Signal
- Attribution Dilemma
Asymmetry in temperature change IPCC 2007
### Waseca, MN Average Monthly **Minimum Temperature Pattern**

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<th>May</th>
<th>Jun</th>
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<th>Aug</th>
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### Waseca, MN Average Monthly **Maximum Temperature Pattern**

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**Upward Temperature Tendencies at Waseca, MN**
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.
Synopsis Points of Agreement
(IPCC-2007)

- N. Hemisphere Bias
- Latitude Bias
- Seasonal Bias
- Minimum Temperature Bias
- *Amplification of Hydrologic Cycle*
- Highly Complex Water Vapor Signal
- Attribution Dilemma
Climate Trend Research Suggests Increased Precipitation In Mid to High Latitudes
Projections of Future Changes in Climate

Projected Patterns of Precipitation Changes

Precipitation *increases* *very likely* in high latitudes

Decreases *likely* in most subtropical land regions

IPCC 2007: Expected future precipitation changes mimic current trends
Fig. 13. Regions defined by the linear trends for 1950–94 in annual thunderstorm rainfall. Shown are the highest and lowest percentage changes, based on linear trends for 1950–94, found at stations within the designated areas.
Heavy Precipitation Trend (% from very wet days)

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.
Land precipitation is changing significantly over broad areas. IPCC reported shifts in average precipitation quantities. Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability.
Statewide Annual Precipitation Trend for North Dakota

Annual Precipitation History with 5-year Tendencies
North Dakota Statewide: 1895-2007

Statewide Annual Precipitation Trend for North Dakota
Statewide Annual Precipitation Trend in Iowa

Annual Precipitation History with 5-year Tendencies
Iowa Statewide: 1895-2007

Statewide Annual Precipitation Trend in Iowa
Annual Precipitation History with 5-year Tendencies
Indiana Statewide: 1896-2007

Statewide Annual Precipitation Trend in Indiana
Big Picture Climate Change
Synopsis Points of Agreement
(IPCC-2007)

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- Attribution Dilemma
a) Column Water Vapour, Ocean only: Trend, 1988-2004

b) Global ocean mean (%)
Increase in Atmospheric Moisture Tied To Human Activities

Science Daily — Observations and climate model results confirm that human-induced warming of the planet is having a pronounced effect on the atmosphere’s total moisture content.

“When you heat the planet, you increase the ability of the atmosphere to hold moisture,” said Benjamin Santer, lead author from Lawrence Livermore National Laboratory’s Program for Climate Modeling and Intercomparison. “The atmosphere’s water vapor content has increased by about 0.41 kilograms per square meter (kg/m²) per decade since 1988, and natural variability in climate just can’t explain this moisture change. The most plausible explanation is that it’s due to the human-caused increase in greenhouse gases.”

More water vapor — which itself a greenhouse gas — amplifies the warming effect of increased atmospheric levels of carbon dioxide. This is what scientists call a “positive feedback.”

Using 22 different computer models of the climate system and measurements from the satellite-based Special Sensor Microwave Imager (SSMI), atmospheric scientists from LLNL and eight other international research centers have shown that the recent increase in moisture content over the bulk of the world’s oceans is not due to solar forcing or gradual recovery from the 1991 eruption of Mount Pinatubo. The primary driver of this “atmospheric moistening” is the increase in carbon dioxide caused by the burning of fossil fuels.

“This is the first identification of a human fingerprint on the amount of water vapor in the atmosphere,” Santer said.

“Fingerprint” studies seek to identify the causes of recent climate change and make rigorous comparisons of modeled and observed climate change patterns. To date, most fingerprint studies have focused on temperature changes at the Earth’s surface, in the free atmosphere, or in the oceans, or have considered variables whose behavior is directly related to changes in atmospheric temperature.

Water vapor’s role in climate change is complicated… it is different over the oceans and land — different isotopic signatures — Worden

Water vapor amplifies the effects of other greenhouse gases that have warmed the oceans — Santer (2007)

LETTERS

Importance of rain evaporation and continental convection in the tropical water cycle

John Worden¹, David Noone², Kevin Bowman¹ & the Tropospheric Emission Spectrometer science team and data contributors*

Atmospheric moisture cycling is an important aspect of the Earth’s climate system, yet the processes determining atmospheric humidity are poorly understood⁴. For example, direct evaporation of rain contributes significantly to the heat and moisture budgets of the troposphere, but few observations of these processes are available⁵. Similarly, the relative contributions to atmospheric moisture over land from local evaporation and humidity from oceanic sources are uncertain⁶. Lighter isotopes of water vapour preferentially evaporate whereas heavier isotopes preferentially condense⁷ and the isotopic composition of ocean water is known. Here we use this information combined with global measurements of the isotopic composition of tropospheric water vapour from the Tropospheric Emission Spectrometer (TES) aboard the Aura spacecraft⁸⁹, to across all observations. With this correction, the distribution of TES 3D measurements is consistent with comparisons to theoretical modelling of infrared spectroscopic HDO line strengths, recent aircraft measurements, values expected near the ocean surface, and general circulation model simulations⁹. The bias correction accounts for the a priori constraint and vertical resolution of the HDO and H2O profile retrieval (see Supplementary Information). Such a bias reduces the confidence one can place on absolute measures of hydrologic cycling derived from the data, but comparisons between different subsets avoid the impact of the bias on findings. For instance, the spatial distribution of observations shows a decrease of both water vapour amount and 3D with higher latitudes that is robust irrespective of the bias (Fig. 1). This so-called ‘latitude effect’ is
Big Picture Climate Change
Synopsis Points of Agreement
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Drivers of Observed Climate Behavior

(Is the attribution dilemma now a moot point?)

• 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)
Keck’s Swamp
Angel at work in the 19th Century across southern MN

Wetland drainage in Martin County, MN circa 1915
Regardless of causes, depiction of landscapes showing physical and biological consequences of recent climate change

From: IPCC 4th Assessment 2007
PROJECTIONS OF FUTURE CHANGES IN CLIMATE

• *Very likely* that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent

• *Likely* that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation
  • less confidence in decrease of total number

• *Extra-tropical storm tracks* projected to move poleward with consequent changes in wind, precipitation, and temperature patterns

IPCC 2007: Need to contemplate adaptive strategies for these changes
An Example of Climate Change Education in Minnesota

Facts
Scientific Knowledge
Experiential Knowledge
Observations
Engagement on Values
Public Action
RECENT SIGNIFICANT CLIMATE TRENDS IN 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
Statewide Annual Temperature Trend in Minnesota
Seasonal Temperature Trends in MN

Winter

Summer

Fall

Spring

Winter Temperature History with 5-year Tendencies
Minnesota Statewide: 1896-2007

Spring Temperature History with 5-year Tendencies
Minnesota Statewide: 1896-2007

Summer Temperature History with 5-year Tendencies
Minnesota Statewide: 1896-2007

Autumn Temperature History with 5-year Tendencies
Minnesota Statewide: 1896-2007
### Historical Ranking and Distribution of Mean Daily Temperature over the Past Eleven Winters (Nov-Mar) in MN

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<th>Mean Temp (F)</th>
<th>Ranking (since 1895)</th>
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<td>24.2</td>
<td>109&lt;sup&gt;th&lt;/sup&gt;</td>
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## Trends in average winter minimum temperatures Rochester, MN

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<td>1971 - 2000</td>
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## Trends in average winter minimum temperatures Collegeville, MN

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Trends in average winter minimum temperatures International Falls, MN

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<td>Mar 12.3</td>
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<td>1971 - 2000</td>
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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
Most Striking 19th Century Winter Weather Stories:

- March 1843
- Winter 1856-1857
- Winter 1877-78
- Christmas 1879
- Winter 1880-81
Minnesota is not considered an equatorial-like torrid environment.

But, let's consider trends in dew point.
Number of days with max temp of 90 F or higher
Trend in dewpoints of 70 F or higher in the Twin Cities

MSP Dewpoint Days => 70
1945-2004

days

year

days where 18hr => 70  days where max => 70  linear reg  linear reg
Dewpoint Temperatures
Greater than or equal to 80 degrees F
Since 1996

Readings have been statewide with highest frequencies in central and southern counties

RST Heat Index 114-118 F, July of 1999
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</tbody>
</table>
Historic Minnesota Heat Waves:
Red denotes dewpoint driven

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Hours with DP of 70 F or greater</th>
<th>Range of Heat Index Values (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>223</td>
<td>98 – 112</td>
</tr>
<tr>
<td>1987</td>
<td>207</td>
<td>98 – 104</td>
</tr>
<tr>
<td>1955</td>
<td>207</td>
<td>98 – 113</td>
</tr>
<tr>
<td>1999</td>
<td>205</td>
<td>98 – 115 (124*)</td>
</tr>
<tr>
<td>1957</td>
<td>193</td>
<td>99 – 114</td>
</tr>
<tr>
<td>2001</td>
<td>163</td>
<td>98 – 110</td>
</tr>
<tr>
<td>2002</td>
<td>161</td>
<td>107 – 109</td>
</tr>
<tr>
<td>1977</td>
<td>159</td>
<td>100 – 108</td>
</tr>
<tr>
<td>1983</td>
<td>156</td>
<td>102 – 110</td>
</tr>
<tr>
<td>1995</td>
<td>108</td>
<td>98 – 116</td>
</tr>
<tr>
<td>2006</td>
<td>101</td>
<td>102 – 115</td>
</tr>
</tbody>
</table>

*state record tied briefly in July 2005*
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
MN Annual Precipitation with 5-yr Tendencies

Annual Precipitation History with 5-year Tendencies
Minnesota Statewide: 1895-2007

- Wetter historical periods
- Drier historical periods
- Individual Annual precipitation value

Image produced Jan 2008 at the Oklahoma Climatological Survey
Seasonality in MN Precipitation Trends

Winter

Spring

Summer

Fall
Change in Annual Precipitation "Normals" at Waseca, MN

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>AMOUNT (IN.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1921–1950</td>
<td>27.55&quot;</td>
</tr>
<tr>
<td>1931–1960</td>
<td>27.82&quot;</td>
</tr>
<tr>
<td>1941–1970</td>
<td>29.94&quot;</td>
</tr>
<tr>
<td>1951–1980</td>
<td>30.62&quot;</td>
</tr>
<tr>
<td>1961–1990</td>
<td>32.45&quot;</td>
</tr>
<tr>
<td>1971–2000</td>
<td>34.69&quot;</td>
</tr>
<tr>
<td>1978–2007</td>
<td>35.84&quot;</td>
</tr>
</tbody>
</table>

30 percent increase since 1921–1950 period
## Change in Annual Precipitation Normals at Willmar, MN

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>AMOUNT (IN.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1921-1950</td>
<td>23.01”</td>
</tr>
<tr>
<td>1931-1960</td>
<td>24.47”</td>
</tr>
<tr>
<td>1941-1970</td>
<td>27.63”</td>
</tr>
<tr>
<td>1951-1980</td>
<td>27.71”</td>
</tr>
<tr>
<td>1961-1990</td>
<td>28.21”</td>
</tr>
<tr>
<td>1971-2000</td>
<td>28.23”</td>
</tr>
<tr>
<td>1978-2007</td>
<td>28.61”</td>
</tr>
</tbody>
</table>

24 percent increase since 1921-1950 period
<table>
<thead>
<tr>
<th>PERIOD</th>
<th>AMOUNT (IN.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1921-1950</td>
<td>23.51”</td>
</tr>
<tr>
<td>1931-1960</td>
<td>24.94”</td>
</tr>
<tr>
<td>1941-1970</td>
<td>27.03”</td>
</tr>
<tr>
<td>1951-1980</td>
<td>26.39”</td>
</tr>
<tr>
<td>1961-1990</td>
<td>27.50”</td>
</tr>
<tr>
<td>1971-2000</td>
<td>27.52”</td>
</tr>
<tr>
<td>1978-2007</td>
<td>27.74”</td>
</tr>
</tbody>
</table>

18 percent increase since 1921-1950 period
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 – 2007 (most recent 17 years) and maximum single day value for MN communities:

<table>
<thead>
<tr>
<th>Location</th>
<th>No. 2 in. rains</th>
<th>Maximum Value (date)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zumbrota</td>
<td>30</td>
<td>6.46 (6/27/98)</td>
</tr>
<tr>
<td>Albert Lea</td>
<td>28</td>
<td>7.50 (6/15/78)</td>
</tr>
<tr>
<td>Forest Lake</td>
<td>31</td>
<td>6.50 (6/1/65)</td>
</tr>
<tr>
<td>Red Wing</td>
<td>27</td>
<td>7.78 (7/1/78)</td>
</tr>
<tr>
<td>Lake City</td>
<td>32</td>
<td>5.60 (5/28/70)</td>
</tr>
<tr>
<td>Waseca</td>
<td>31</td>
<td>5.40 (8/31/62)</td>
</tr>
<tr>
<td>Mankato</td>
<td>26</td>
<td>6.23 (6/9/2004)</td>
</tr>
<tr>
<td>Rosemount</td>
<td>25</td>
<td>5.80 (7/24/87)</td>
</tr>
<tr>
<td>Hokah</td>
<td>27</td>
<td>15.10 (8/19/2007)</td>
</tr>
<tr>
<td>Rochester</td>
<td>28</td>
<td>5.16 (8/18/2007)</td>
</tr>
</tbody>
</table>
X = 24 counties included in USDA drought disaster declaration of August 7, 2007.

Note: adjacent 32 counties were also eligible for assistance.

X = Counties included in federal flood disaster declaration of August 20, 2007 and eligible for FEMA assistance.
Most Striking 19th Century Flashflood Weather Stories:

August 6-8, 1866 (Wisel Flood)
July 17-19, 1867 (Wright Flood)
Increased contribution from thunderstorms also means amplified dryness.
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
Possible Implications of a Amplified Precipitation Variability

- Irrigation, drainage, runoff, sediment, and shoreline management
- Change in storm sewer runoff design
- Amplified hydrographs, lake level variation
- Mitigation of soil erosion
- Mitigation of increased flooding potential
- Mitigation of blowing snow and management of roads and highways
Minnesota Statewide May Through September Precipitation

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentile Rank for 1895 to 2006 (amount)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991 *</td>
<td>103  (21.37&quot;)</td>
</tr>
<tr>
<td>1992</td>
<td>58  (17.12&quot;)</td>
</tr>
<tr>
<td>1993 *</td>
<td>113  (23.65&quot;)</td>
</tr>
<tr>
<td>1994</td>
<td>72  (18.04&quot;)</td>
</tr>
<tr>
<td>1995</td>
<td>80  (18.54&quot;)</td>
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<tr>
<td>1996</td>
<td>29  (15.55&quot;)</td>
</tr>
<tr>
<td>1997 *</td>
<td>59  (17.17&quot;)</td>
</tr>
<tr>
<td>1998 *</td>
<td>61  (17.28&quot;)</td>
</tr>
<tr>
<td>1999 *</td>
<td>110  (22.33&quot;)</td>
</tr>
<tr>
<td>2000 *</td>
<td>67  (17.58&quot;)</td>
</tr>
<tr>
<td>2001 *</td>
<td>46  (16.74&quot;)</td>
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<tr>
<td>2002 *</td>
<td>102  (21.05&quot;)</td>
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<tr>
<td>2003</td>
<td>31  (15.69&quot;)</td>
</tr>
<tr>
<td>2004 *</td>
<td>104  (21.62&quot;)</td>
</tr>
<tr>
<td>2005 *</td>
<td>96  (20.64&quot;)</td>
</tr>
<tr>
<td>2006 *</td>
<td>19  (14.63&quot;)</td>
</tr>
<tr>
<td>2007 *</td>
<td>37  (16.15&quot;)</td>
</tr>
</tbody>
</table>

* Denotes thunderstorm produced flashfloods

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentile Rank for 1895-2006</th>
<th>(mean temp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>99</td>
<td>(64.2 F)</td>
</tr>
<tr>
<td>1992</td>
<td>7</td>
<td>(60.0 F)</td>
</tr>
<tr>
<td>1993</td>
<td>7</td>
<td>(60.0 F)</td>
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<tr>
<td>1994</td>
<td>66</td>
<td>(62.8 F)</td>
</tr>
<tr>
<td>1995</td>
<td>79</td>
<td>(63.3 F)</td>
</tr>
<tr>
<td>1996</td>
<td>40</td>
<td>(61.9 F)</td>
</tr>
<tr>
<td>1997</td>
<td>48</td>
<td>(62.1 F)</td>
</tr>
<tr>
<td>1998</td>
<td>108</td>
<td>(64.8 F)</td>
</tr>
<tr>
<td>1999</td>
<td>78</td>
<td>(63.3 F)</td>
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<tr>
<td>2000</td>
<td>53</td>
<td>(62.3 F)</td>
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<tr>
<td>2001*</td>
<td>93</td>
<td>(63.8 F)</td>
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<tr>
<td>2002*</td>
<td>80</td>
<td>(63.3 F)</td>
</tr>
<tr>
<td>2003*</td>
<td>73</td>
<td>(63.1 F)</td>
</tr>
<tr>
<td>2004</td>
<td>12</td>
<td>(60.3 F)</td>
</tr>
<tr>
<td>2005*</td>
<td>85</td>
<td>(63.6 F)</td>
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<tr>
<td>2006*</td>
<td>96</td>
<td>(63.9 F)</td>
</tr>
<tr>
<td>2007*</td>
<td>104</td>
<td>(64.6 F)</td>
</tr>
</tbody>
</table>

For comparison 1988 ranked 113th (66.6 F), 1936 ranked 112th (65.8 F)

* Denotes summer dewpoint of 80 F or higher
Direct effects of climate change
Skewed to mid-latitudes
Longer growing season
Asymmetric temp change with higher minimum temperatures and more degree days
Carbon dioxide fertilization, more biomass and improved WUE
Amplified moisture stress seen both as saturated soils and drought buffered by soil type and tile drainage
High dewpoints that may favor crop disease
Indirect effects of Climate Change:
Milder winters, survivability of pests
Population turnover rates of plant pests
Migration patterns of pests (wind patterns)
More rapid degradation of crop residues
More risk to leaching loss of nutrients
More erosive events
Changed interactions with surrounding ecosystems
Declining irrigation resources
Change in crop rotations
More expensive inputs
In a broader context:

Climate change, coupled with increasing societal vulnerability mean that we are headed down a dangerous road?

What shall we do? Need to engage on this issue.
What should the context be for community discussion of climate change?

- **Cognitive** (scientific)
- **Emotional** (risk)
- **Ethical** (stewardship)
- **Political** (leadership)
WHAT DO YOU CARE ABOUT? PERSPECTIVES SHOULD BE RESPECTED AS CLIMATE CHANGE IMPACTS WILL BE DIFFERENTIAL

Christian-based Bread for the World fight against hunger and malnutrition

World Health Organization efforts to mitigate preventable mortality

The United Nations’ Millennium Project mission to eradicate poverty

Amnesty International mission to promote human rights

The Environmental Stewardship Ethic adds a layer of complexity to our other philanthropy
Despite speculation that science and technology will solve the problems of climate change, there is a significant role for the conservation ethic and lifestyle – this could help reduce the human footprint on the environment.

What'sNew2006.com - 2006 Toyota Prius Hybrid
For each generation environmental challenges and even life-long endeavors are bookmarked by weather events and climate episodes that are unique.

History shows that Minnesota citizens come together to take community action more frequently around shared values and than on scientific knowledge alone.

With respect to the environment, let our generation’s confession be: “Lord, I know I ain’t what I ought to be, but I am thankful that I ain’t what I was.”
Web site resources for 2008 updates and summaries

www.extension.umn.edu/Climate/

www.climate.umn.edu

Information providers:
U of MN (CFANS,ROCs)
Extension
State Agencies
Federal Agencies