Understanding Climate Change: Evidence, Consequence, Implication

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PILD Conference
J CEP
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Examples of good climate science overviews

Scientist/citizen perspectives

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

NOAA's National Climatic Data Center
Vulnerability and Consequences Remain Key Societal Issues
Implications for land use, building codes, insurance, and infrastructure


NOAA/NESDIS/NCDC

- Actual damage amounts at the time of the event
- Damage amounts normalized to 2007 using a Gross National Product (GNP) inflation index
- Number of events per year that exceed a cost of 1 billion dollars in damages

Years (1980 - 2007)

Damage Amounts in Billions of Dollars

Number of Events

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8

80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07
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
IPCC 2007
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Big Picture Climate Change
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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 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

Fall 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
Seasonal Temperature Trends in MT

Winter

Spring

Summer

Fall

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

Autumn Temperature History with 5-year Tendencies
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Asymmetry in temperature change IPCC 2007
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Figure 3.20

IPCC 2007 (Santer)

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

b) Global ocean mean (%)
Water vapor amplifies the effects of other greenhouse gases that have warmed the oceans-Santer (2007)

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

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 clouds, but few observations of these processes are available⁴. Similarly, the relative contributions to atmospheric moisture from local evaporation and humidity from oceanic sources are uncertain⁴. Lighter isotopes of water vapour preferentially evaporate whereas heavier isotopes preferentially condense⁵, 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 spacecraft⁶,⁷, to across all observations. With this correction, the distribution of TES ⁸D 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 simulations⁸. The bias correction accounts for the a priori constraint and vertical resolution of the HDO and H₂O profile retrievals (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 ⁸D with higher latitudes that is robust irrespective of the bias (Fig. 1). This so-called “latitude effect” is
Big Picture Climate Change

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• **Anthropogenic Emissions** (greenhouse gases)
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

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

Statewide Annual Temperature Trend in Minnesota
Seasonal Temperature Trends in MN

Winter

Summer

Spring

Fall

Winter Temperature History with 5-year Tendencies
Minnesota Statewide 1895-2007

Spring Temperature History with 5-year Tendencies
Minnesota Statewide 1895-2007

Summer Temperature History with 5-year Tendencies
Minnesota Statewide 1895-2007

Autumn Temperature History with 5-year Tendencies
Minnesota Statewide 1895-2007
Historical ranking and distribution of mean daily temperature over the past eleven winters (Nov-Mar) in MN

<table>
<thead>
<tr>
<th>Winter</th>
<th>Mean Temp (F)</th>
<th>Ranking (since 1895)</th>
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<tr>
<td>1997-1998</td>
<td>24.2</td>
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<tr>
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<td>23.0</td>
<td>106&lt;sup&gt;th&lt;/sup&gt;</td>
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<td>113&lt;sup&gt;th&lt;/sup&gt;</td>
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<td>15.8</td>
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<td>2001-2002</td>
<td>25.0</td>
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<td>19.3</td>
<td>73&lt;sup&gt;rd&lt;/sup&gt;</td>
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<td>20.3</td>
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### Trends in average winter minimum temperatures Rochester, MN

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<td>1961 - 1990</td>
<td>Mar 21.3</td>
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<td>1971 - 2000</td>
<td>Mar 22.6</td>
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# Trends in average winter minimum temperatures Collegeville, MN

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<td>1971 - 2000</td>
<td>Mar 20.8</td>
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**Trends in average winter minimum temperatures International Falls, MN**

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Possible Implications of Warm Winters and Higher Minimum Temperatures

- Change in depth and duration of soil and lake freezing
- 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 points.
Number of days with max temp of 90 F or higher
Trend in dewpoints of 70 F or higher in the Twin Cities
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
<table>
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<tr>
<th>Dewpoint (°F)</th>
<th>90</th>
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Historic Minnesota Heat Waves:

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

<table>
<thead>
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<th>Year</th>
<th>Hours with DP of 70 F or greater</th>
<th>Range of Heat Index Values (F)</th>
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<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
- 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
Annual Precipitation History with 5-year Tendencies
Virginia Statewide, 1895-2007

Statewide Annual Precipitation Trend for Virginia
Statewide Annual Precipitation Trend in Illinois
## 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”</td>
</tr>
<tr>
<td>1931–1960</td>
<td>27.82”</td>
</tr>
<tr>
<td>1941–1970</td>
<td>29.94”</td>
</tr>
<tr>
<td>1951–1980</td>
<td>30.62”</td>
</tr>
<tr>
<td>1961–1990</td>
<td>32.45”</td>
</tr>
<tr>
<td>1971–2000</td>
<td>34.69”</td>
</tr>
<tr>
<td>1978–2007</td>
<td>35.84”</td>
</tr>
</tbody>
</table>

30 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>23.01”</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
Change in Annual Precipitation Normals at Walker, MN

<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
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
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.
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