Climate Change Impacts in Minnesota
How do we know?

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January 15, 2019

University of Minnesota
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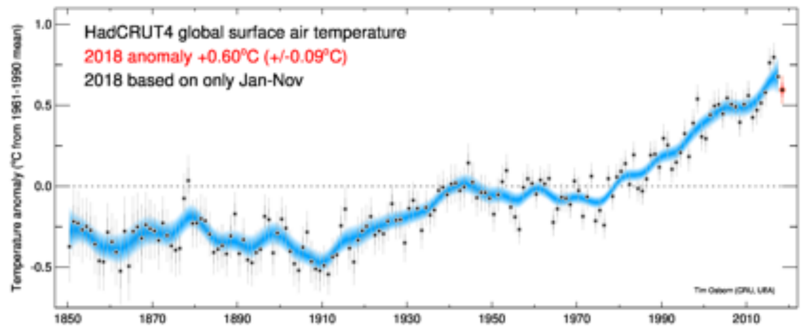
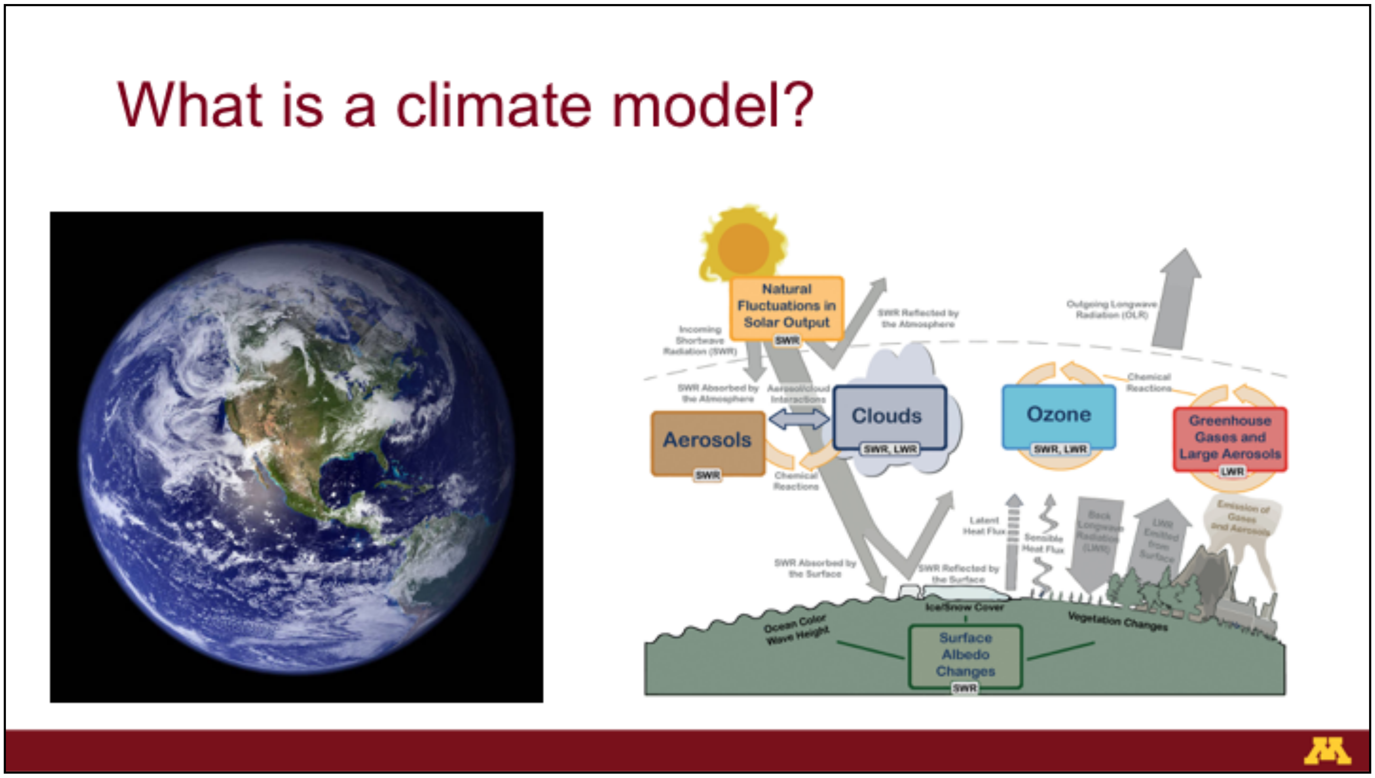
How do we know climate change in Minnesota is caused by humans?

- Physics
- Historical record
- Climate models



How do we know? Physics states that increases in global greenhouse gas concentration will lead to warming overall, but this warming is not constant across the globe. Our historical record shows an increase in warming since 1970. Climate models are used to understand this warming, and show that this much warming would not occur without our current concentration of greenhouse gases, particularly carbon dioxide.

https://crudata.uea.ac.uk/~timo/diag/tempdiag.htm



A climate model takes all the components of Earth: land, ocean, lakes, ice, atmosphere and represents them as a system of forcings, responses, and changing elements called 'variables' (e.g., temperature, precipitation, humidity, wind, aerosols, clouds)

Image of Earth from NASA
https://solarsystem.nasa.gov/resources/786/blue-marble-2002/

Diagram on right is Figure 1-1 in

Cubasch, U., D. Wuebbles, D. Chen, M.C. Facchini, D. Frame, N. Mahowald, and J.-G. Winther, 2013: Introduction. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

What is a climate model?

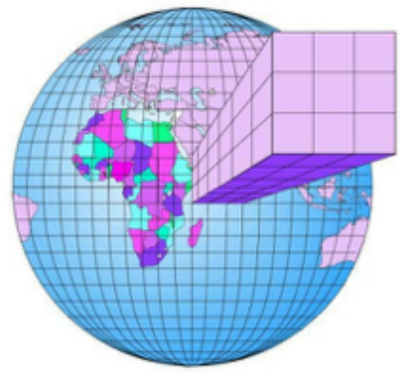
$$\frac{Du}{Dt}-\frac{uv\tan\phi}{a}+\frac{uw}{a}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+2\Omega v\sin\phi-2\Omega w\cos\phi+F_{rx}$$

$$\frac{Dv}{Dt}+\frac{u^2\tan\phi}{a}+\frac{vw}{a}=-\frac{1}{\rho}\frac{\partial p}{\partial y}-2\Omega u\sin\phi+F_{ry}$$

$$\frac{Dw}{Dt}-\frac{u^2+v^2}{a}=-\frac{1}{\rho}\frac{\partial p}{\partial z}-g+2\Omega u\cos\phi+F_{rz}$$

$$u_T=-\frac{1}{f}\frac{\partial}{\partial y}(\Phi_1-\Phi_0),\qquad v_T=\frac{1}{f}\frac{\partial}{\partial x}(\Phi_1-\Phi_0)$$

$$c_v\frac{DT}{Dt}+p\frac{D\alpha}{Dt}=J\qquad \delta\Phi=\Phi_1-\Phi_0=R\langle T\rangle\ln\left(\frac{p_0}{p_1}\right)$$



Models perform billions of calculations over thousands of points called ‘grid cells’ on Earth’s surface and extending up into the atmosphere and down into the ocean and land surface. It solves these equations over and over at each point, stepping through time, to represent the state of Earth at any instance. This is also how weather models work, however, when we begin a weather model we insert the current state of the system based on real time observations to predict the state at several times throughout one week. We run climate models to represent thousands of years in the past, to a hundred years in the future.

It is impossible to exactly represent every characteristic and process within the model. At the edge of our knowledge we insert ‘parameters’ into the equations. These parameters are tweaked to produce output that matches reality.

Who creates these models?

There are ~40 global climate models from ~10 nations generally accepted and used in the IPCC and other assessments.

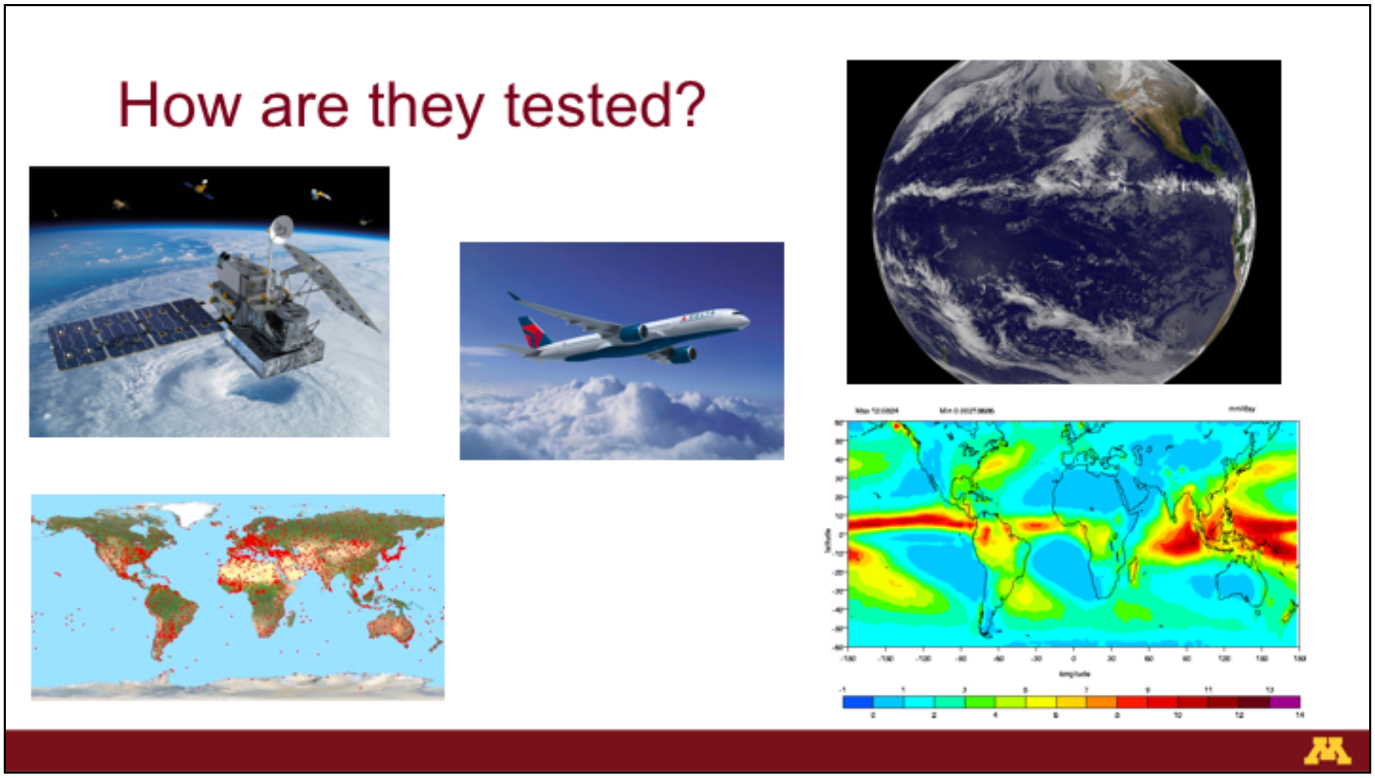
These models are mainly maintained by national laboratories with employees whose full time job is to test them, improve them, and coordinate with users.

Scientists like those at UMN might focus on one or two parts of the models to test, break, modify, and eventually improve the model components while answering research questions

For the IPCC AR5, 42 models were used from 12 nations:

USA (10), UK (4), Canada(2), Germany (3), France (4), Italy (1)
Norway (2), Russia (1), Japan(5), China (6), Korea (1), Australia (3)

NASA photo: Tom Trower, Ames Research Center



We compare specific variables like temperature, precipitation, relative humidity, etc. with observations from satellites, aircraft and other mobile platforms, ground-based networks, and field campaigns after mapping the data to a grid that matches that of the model. We also evaluate the ability of models to represent *emergent behaviors*. These are not a result of small scale physics but of complex interactions of the Earth system like El Nino and the inter-tropical convergence zone.

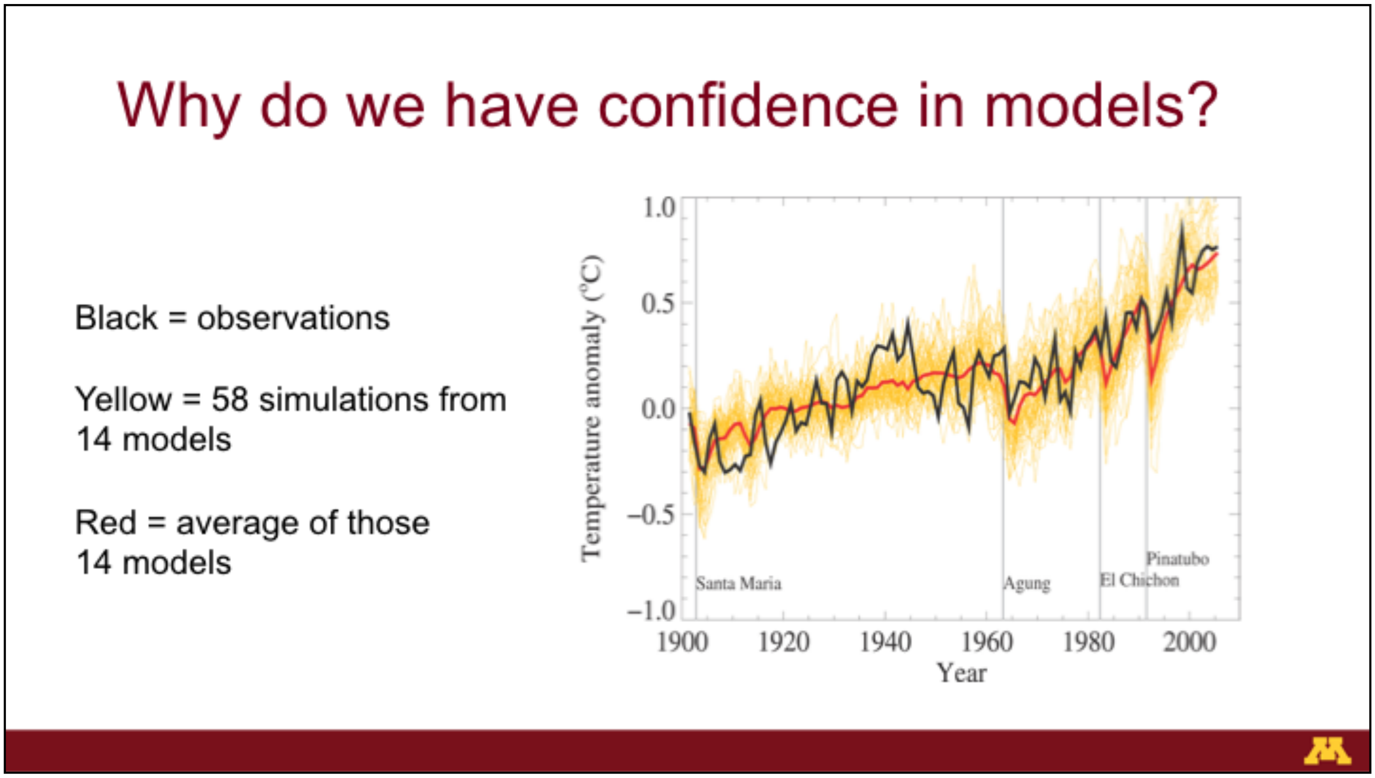
The US Global Change Research Program has created a database of observational climate records for scientists, the public, and policymakers. These types of data are used to test that models correctly represent the past and our current climate before using them to make projections for the future.

Global Change Information System www.globalchange.gov

Photos:

Upper left: NASA-JAXA Global Precipitation Measurement (GPM) Core Observatory

This satellite image shows a textbook Intertropical Convergence Zone (ITCZ) on 24 November 2010 that stretches all the way across the Pacific Ocean. New research improves understanding of ITCZ and shows that rainfall in the zone is intensifying. Credit: NASA GOES Project Science



1. Model fundamentals based on <u>established</u> physical laws (e.g., conservation of energy)

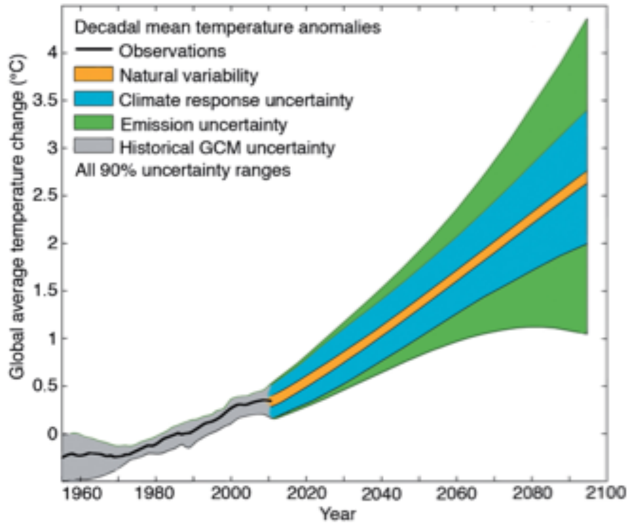
2. Models can simulate important aspects of the current climate (e.g., Inter-tropical convergence zone, seasonal cycle in temperature, precipitation)

3. Models are able to reproduce features of past climates and climate changes (e.g., Last Glacial Maximum, mid-Holocene warming, 20th century warming)

A specific model is usually run in various ways: both beginning with different ‘states’ of the system, and with different parameterizations to determine how robust the output is. That is how 14 models produce 58 simulations in the figure above. Significant volcanic eruptions are noted.

Gavin Schmidt at NASA-GISS has shown that the average of all models (the red line) performs better than any single model alone. This is why it is important to have a suite of global climate models to best project our future climate.

No model is perfect



Climate models must represent the physics, chemistry, and biology of all of Earth's systems, as well as the human system. We can't represent these exactly so the use of parameters inserts some uncertainty into models. Models also vary in how the equations are structured—in essence each model has its own personality. We do not know what our emissions of greenhouse gases will be in the future, therefore we simulate multiple 'scenarios' in order to examine potential outcomes.

Figure is FAQ 1.1, Figure 1 from IPCC AR5 | Schematic diagram showing the relative importance of different uncertainties, and their evolution in time. (a) Decadal mean surface temperature change (degrees C) from the historical record (black line), with climate model estimates of uncertainty for historical period (grey), along with future climate projections and uncertainty. Values are normalised by means from 1961 to 1980. Natural variability (orange) derives from model interannual variability, and is assumed constant with time. Emission uncertainty (green) is estimated as the model mean difference in projections from different scenarios. Climate response uncertainty (blue-solid) is based on climate model spread, along with added uncertainties from the carbon cycle, as well as rough estimates of additional uncertainty from poorly modelled processes. Based on Hawkins and Sutton (2011) and Huntingford et al. (2009).

Cubasch, U., D. Wuebbles, D. Chen, M.C. Facchini, D. Frame, N. Mahowald, and J.-G. Winther, 2013: Introduction. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

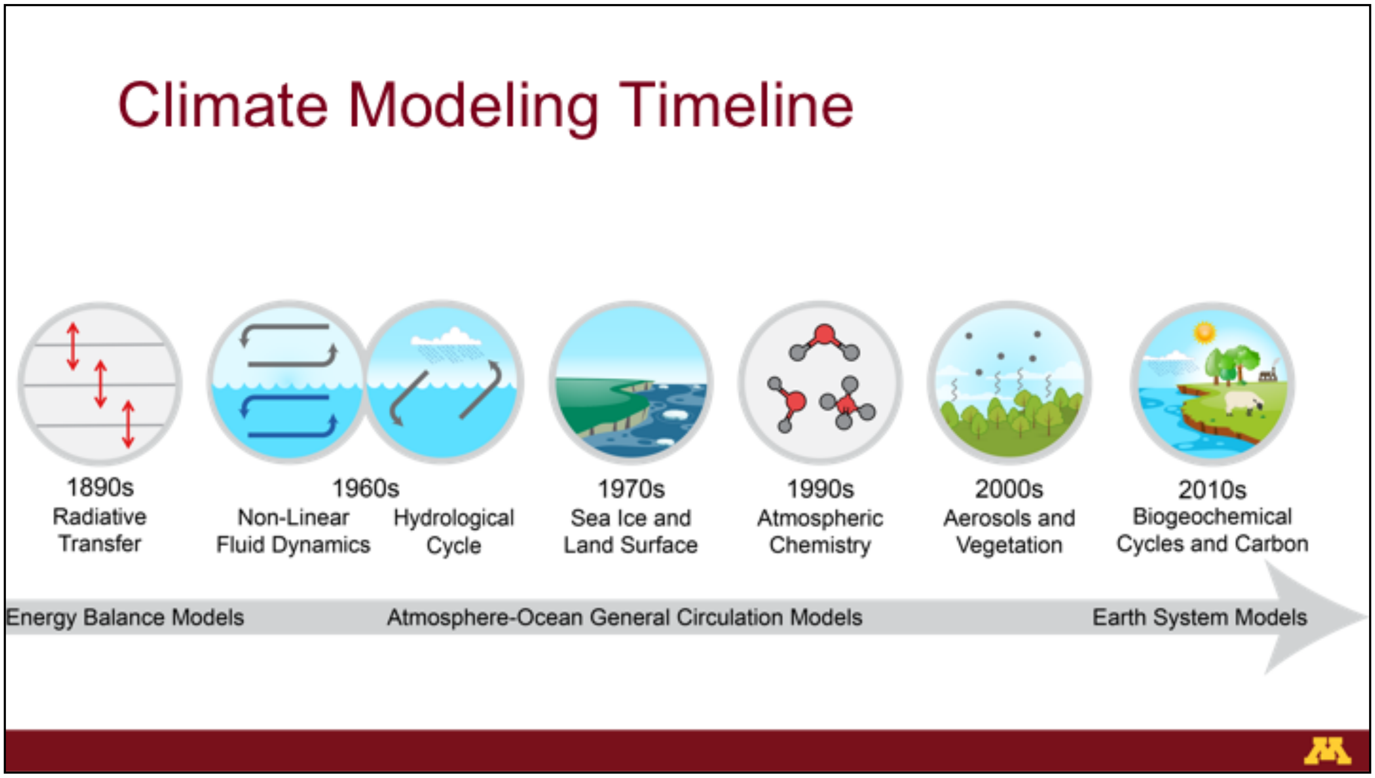


Figure 4.3 National Climate Assessment 2017

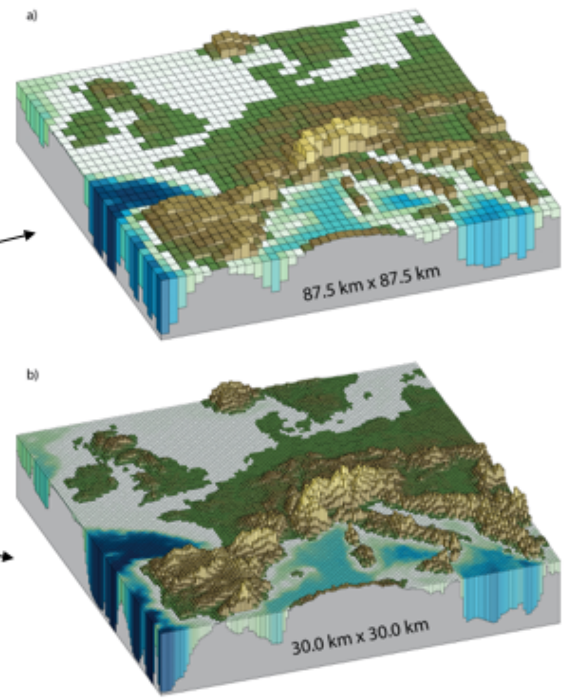
We still don’t represent cities of any size, or management of the land (including crops--a large biome of MN).

Until these are able to be simulated in global climate models, we use weather models to ‘downscale’. Instead of forecasting weather out one week, we run them to answer similar questions for which we use global models, just at a more detailed, smaller scale. For example, we can see what happens to surface temperature when we convert pine forest to potatoes, or what happens to rainfall at the end of the century when CO2 concentrations are 850 ppm?

Best global vs regional models

87 km = 54 miles = distance from Thief River Falls to Grand Forks

30 km = 19 miles = distance from St Louis Park to Maplewood



87 km = 54 miles more than Alexandria to Fergus Falls, Thief River Falls to Grand Forks

30 km = 19 miles St Louis Park to Maplewood, entire width of Twin Cities in one regional model grid cell

Best regional models are 10km on a side, 4 km is innovative and possible now with right computer

This means there is a single value in the entire grid cell

Figure 1-14 in

Cubasch, U., D. Wuebbles, D. Chen, M.C. Facchini, D. Frame, N. Mahowald, and J.-G. Winther, 2013: Introduction. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

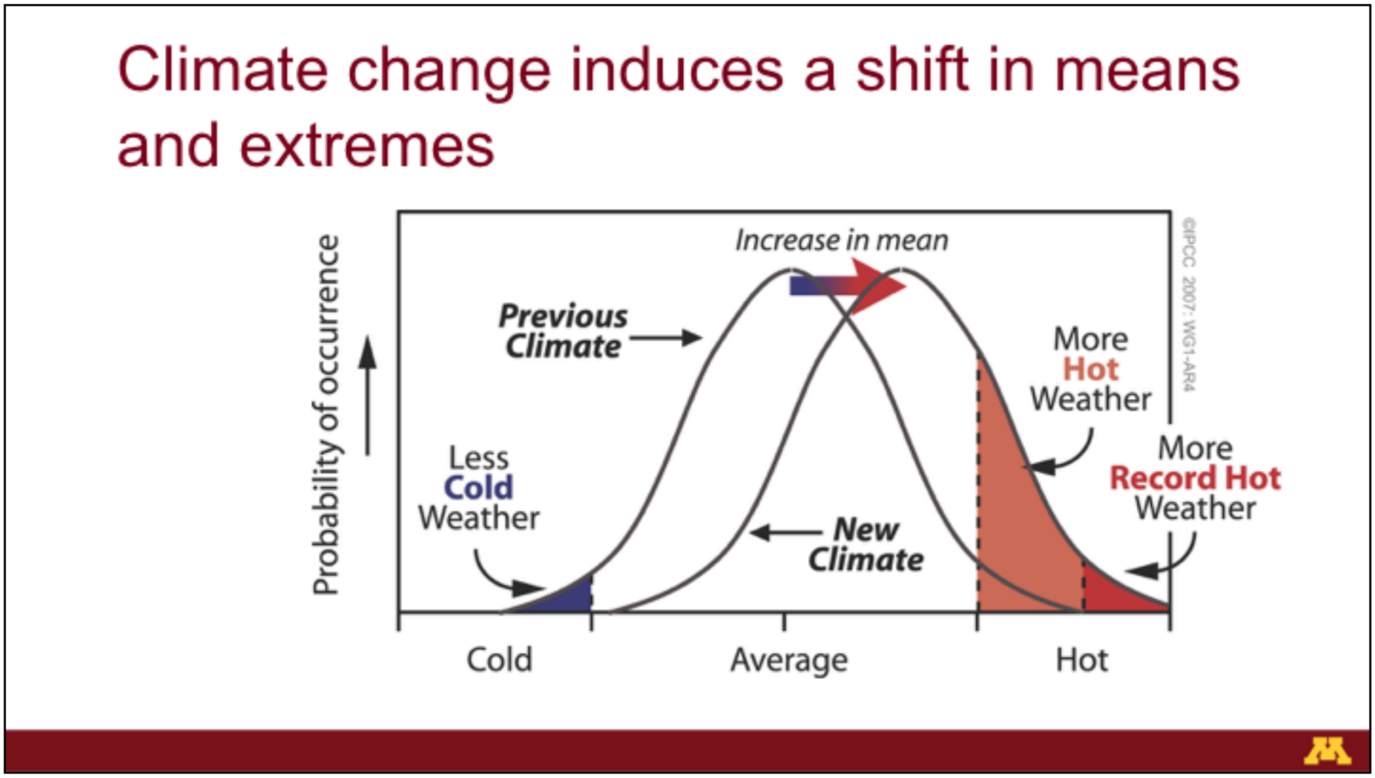
Climate vs Weather, Means vs Extremes

- Climate is your personality, weather is your mood
- Climate is what you expect, weather is what you get

Climate: in Minneapolis-St Paul, a high of 24 is the average for January 4th

Weather: January 4th 2019 had a high of 47, breaking the record of 41 by 6 degrees which is a substantial (usually they are broken by a few degrees at most, 14% of time they are broken by 6 degrees or more according to Mark Seeley)

Mark Seeley also points out that nearly all winter high temperature records are broken when there is no snow cover—implying that more records will be broken as snow shifts to rain in the future.



We are affected by weather, not climate per se, therefore we need to prepare for changes in weather—the 'extremes' of this distribution figure. A similar figure could be visualized for other variables like precipitation. Regional models are better able to represent these events than global models. They are run over a subregion of the globe, at more frequent time intervals for a shorter length of time, and at a finer spatial scale (i.e., smaller, higher density, grid cells).

To 'downscale' global projections to a finer grid, scientists have two options:

(1) Use a regional model to explicitly simulate finer scale processes (like thunderstorms), or

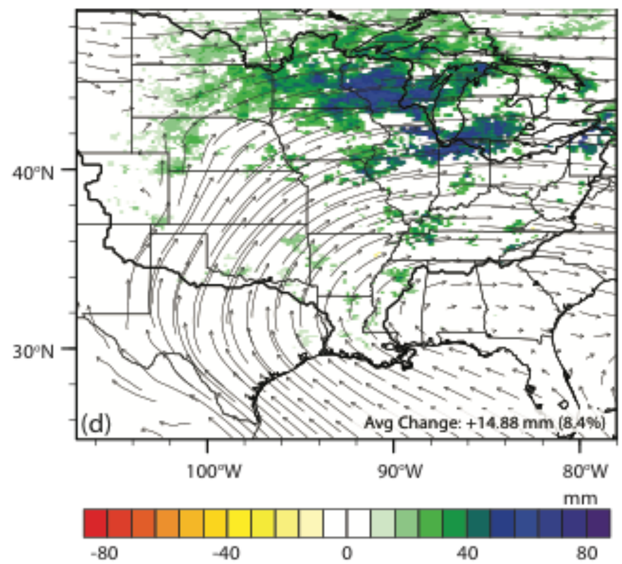
(2) Use known relationships across a finer grid (e.g., changes in elevation across a grid cell) to statistically extrapolate global projections

Both methods are used. The former is more time and computing intensive but uses physics in the model, generally considered more robust. The latter is quicker and uses less computing, therefore can be performed on a larger domain, but is generally not preferred if the latter option is available.

Box TS-5, Figure 1. IPCC AR4

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood and D. Wratt, 2007: Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2007

Why do we need ‘downscaled’ models?



Annual precipitation is expected to continue to increase, however, where, when, and how much is what matters

More rainfall (less snowfall) coming in less frequent bursts might not be readily available

More spring rainfall and less summer rainfall, as many models project, could lead to drought and other impacts in fall and even into the following spring (Fig 12.2 IPCC AR5)

Even heavy rainfall events simulated in global climate models do not have the details found in regional models that are relevant to planning

Regional models can include details not found in global models

Characteristics like the land surface (crops, urban areas)

Processes like air chemistry, subsurface water, nutrients, management, severe storms

These are results from one of the many weather models forecasters use. My group used it to evaluate possible impacts to water resources with various scenarios of planting grasses for bioenergy across the CornBelt. This is just one example of the hundreds of research projects that use regional models to ‘downscale’ to finer spatial scales. This shows the simulated change in spring + summer rainfall from the 2005-2014 mean resulting from increased evaporation from bioenergy grasses. Harding et al. 2016, Impacts of second-generation biofuel feedstock production in the central U.S. on the hydrologic cycle and global warming mitigation potential. ☐10.1002/2016GL069981

In Chapter 9 of the AR5, the IPCC states, with high confidence, that regional models add value. Relevant to Minnesota are improvements in

simulation of convective precipitation (Rauscher et al., 2010), near-surface temperature (Feser, 2006), near-surface temperature and wind (Kanamaru and Kanamitsu, 2007), temperature and precipitation (Lucas-Picher et al., 2012b), extreme precipitation (Kanada et al., 2008), strong mesoscale cyclones (Cavicchia and Storch, 2011), cutoff lows (Grose et al., 2012), polar lows (Zahn and von Storch, 2008) and higher statistical moments of the water budget (e.g., Bresson and Laprise, 2011).

Climate Change Impacts in Minnesota: What do we know?

Tracy E. Twine, Department of Soil, Water, & Climate

January 15, 2019

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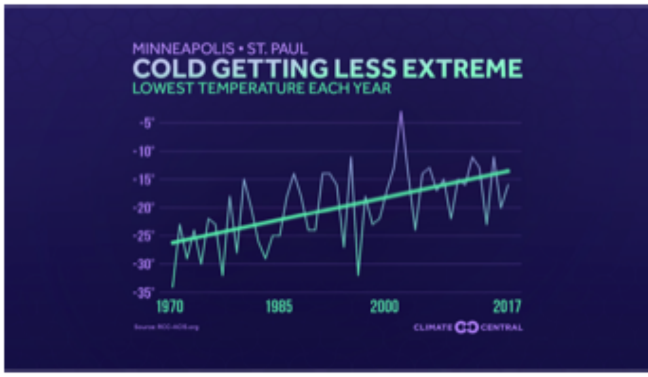
2018 likely to be 4th hottest year on record for our planet. What does climate change mean for Minnesota?

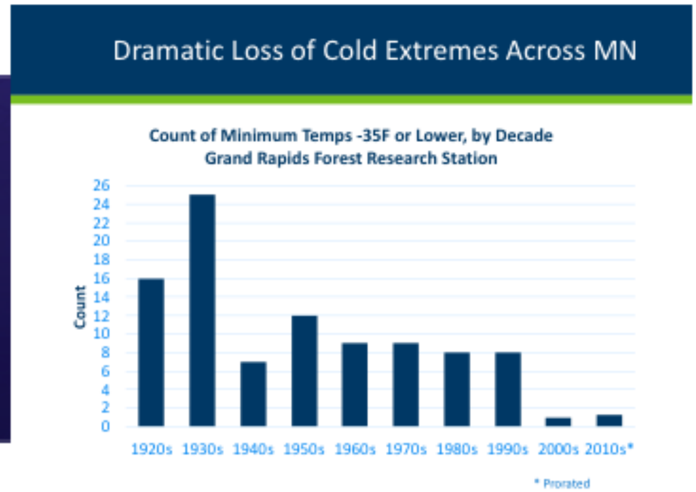
Winter warming **13x** faster than summer in Minnesota

Season	Average change per decade since 1895	Average change per decade since 1970
Winter (Dec – Feb)	+ 0.40 ℉	+ 1.2 ℉
Summer (Jun – Aug)	+0.13 ℉	+0.09 ℉

Data from MN DNR State Climatology Office

Lows are no longer low

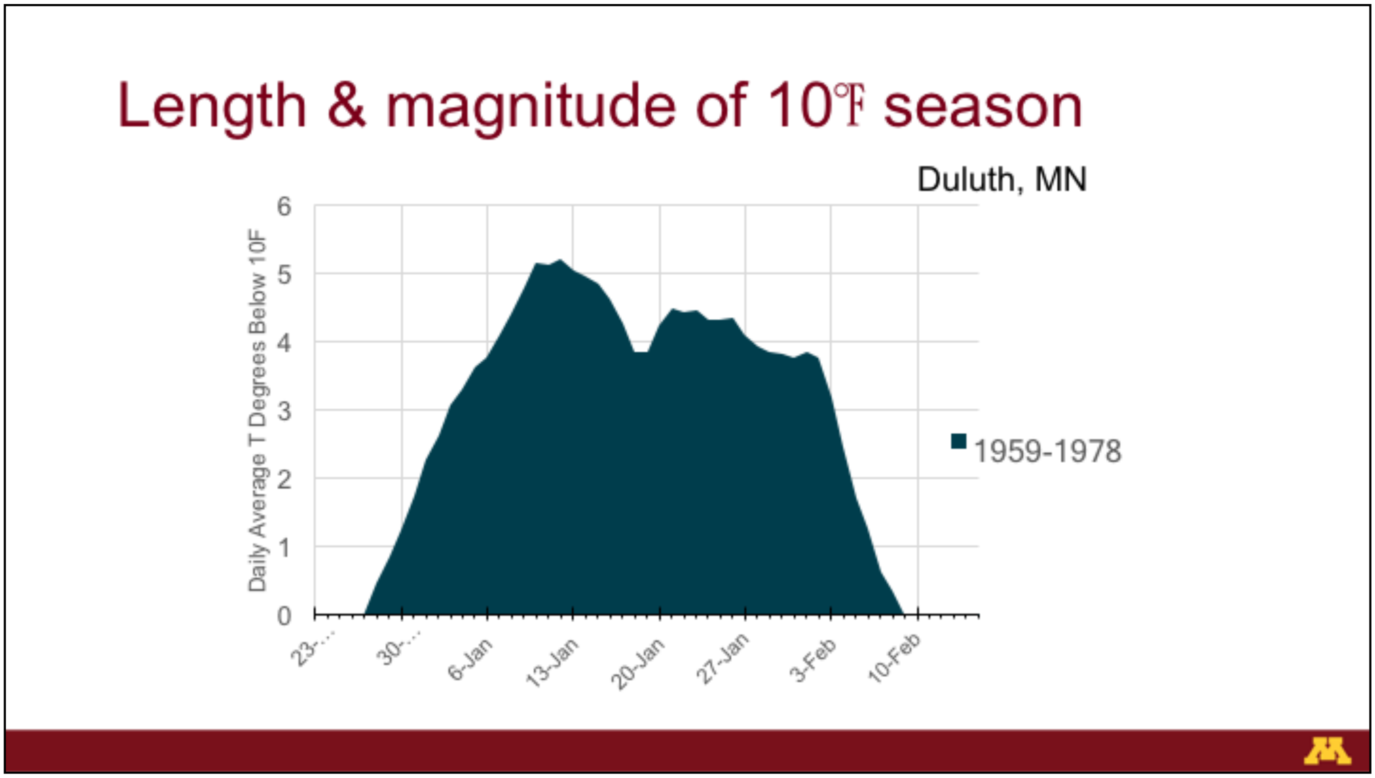




Minneapolis and Mankato are the #2 and #3 fastest warming cities in the US

Source: Climate Central analysis from Applied Climate Information System

http://www.rcc-acis.org/ (NOAA Regional Climate Centers)

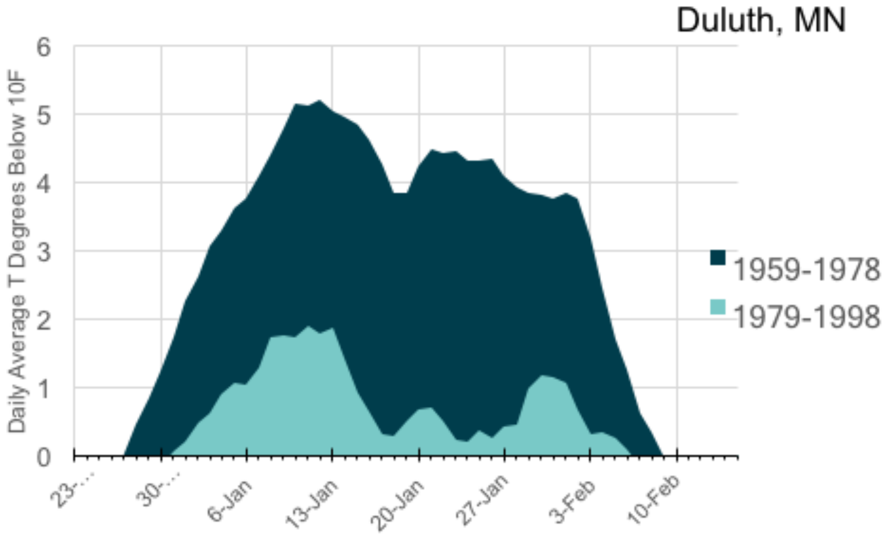


Data from MN DNR State Climatology Office

The height of the graph gives a sense of how much below 10 degrees Fahrenheit that date is, on average.

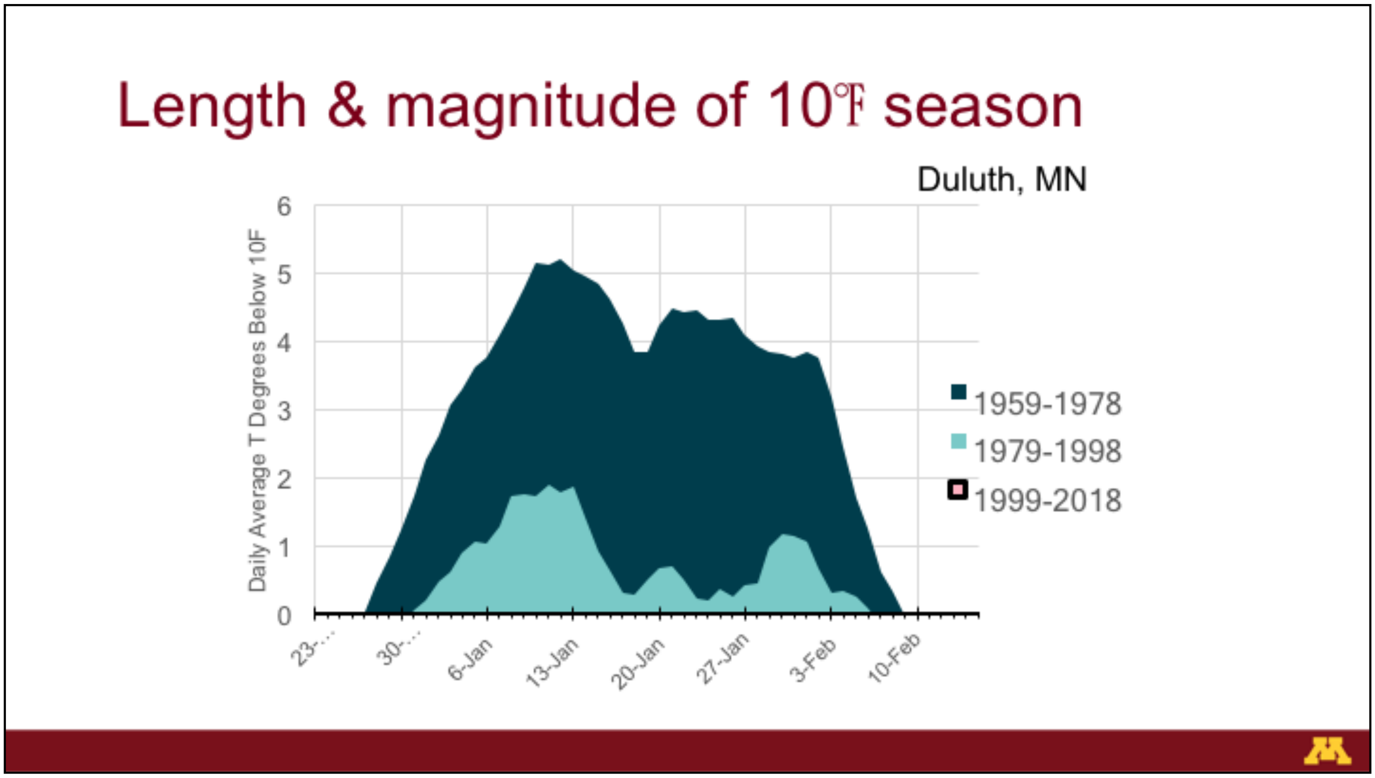
The 1959-1978 average length of days below 10F is 45 days.

Length & magnitude of 10℉ season



Data from MN DNR State Climatology Office

The 1979-1998 average length of days below 10F is 38 days but temperatures are not as low as the previous time period.



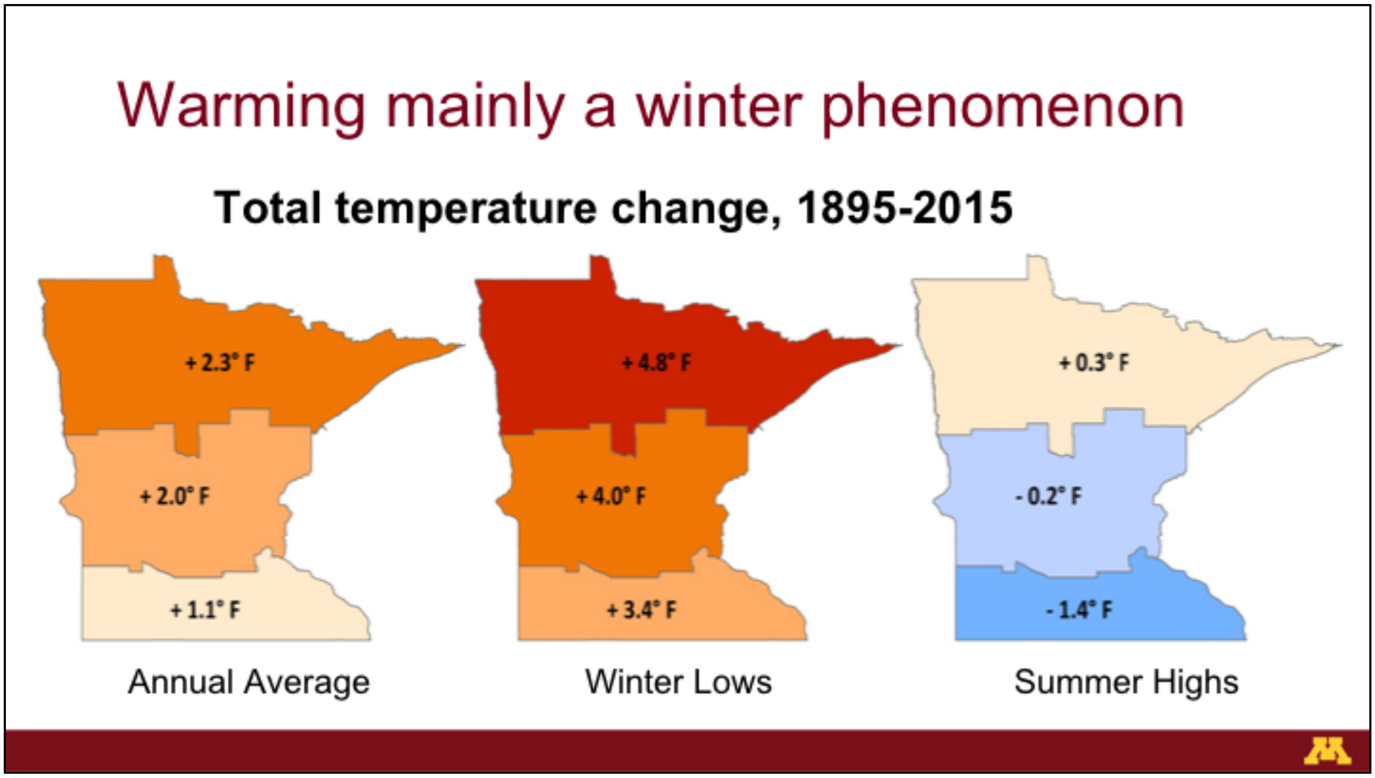
Data from MN DNR State Climatology Office

By the next averaging period—1999-2018, the below 10F season in Duluth is gone.

There are, on average, no days expected to be below 10F anymore.

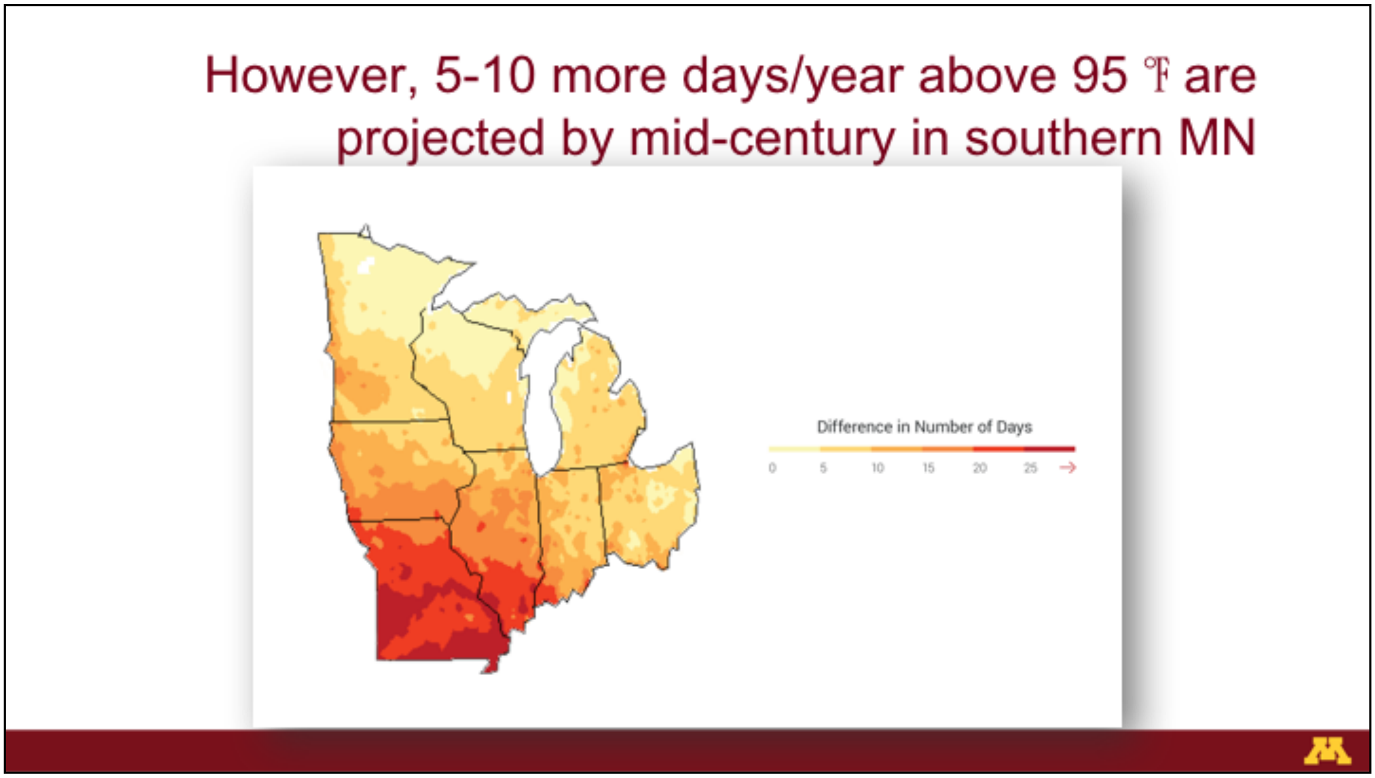
Lake ice season is shortening. According to a MN DNR State Climatology analysis,

The long term decline rate is 1.8 days per decade. More recently, 1987-2017 the decline rate is 4.2 days per decade.



Extreme summer heat shows no trend, although models project it will happen in future

Slide courtesy MN DNR State Climatology Office



Source: 2014 National Climate Assessment, Midwest Chapter

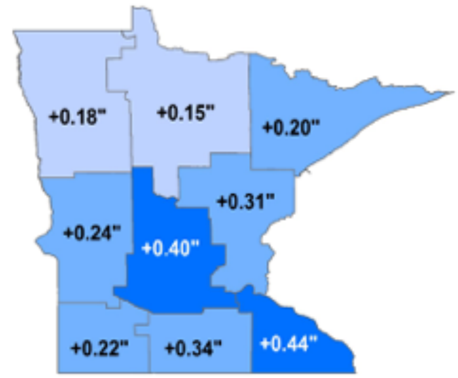
Hayhoe, K., Stoner, et al., (2013), Development and Dissemination of a High-Resolution National Climate Change Dataset. http://cida.usgs.gov/thredds/fileServer/dcp/files/Hayhoe_USGS_downscaled_database_final_report.pdf.

Data are statistically downscaled--this uses known local features in equations to 'map' global climate projections to a finer grid. This is a simpler method than dynamically downscaling global models with regional models.

Minnesota is getting wetter everywhere and in all seasons

Season	Total Precipitation change 1895-2016
Winter (Dec – Feb)	+ 6% (0.13")
Spring (Mar – May)	+ 15% (0.93")
Summer (Jun – Aug)	+ 11% (1.21")
Fall (Sep – Nov)	+ 11% (0.66")
Growing Season (May – Sep)	+ 9% (1.55")
Annual	+ 12% (2.98")

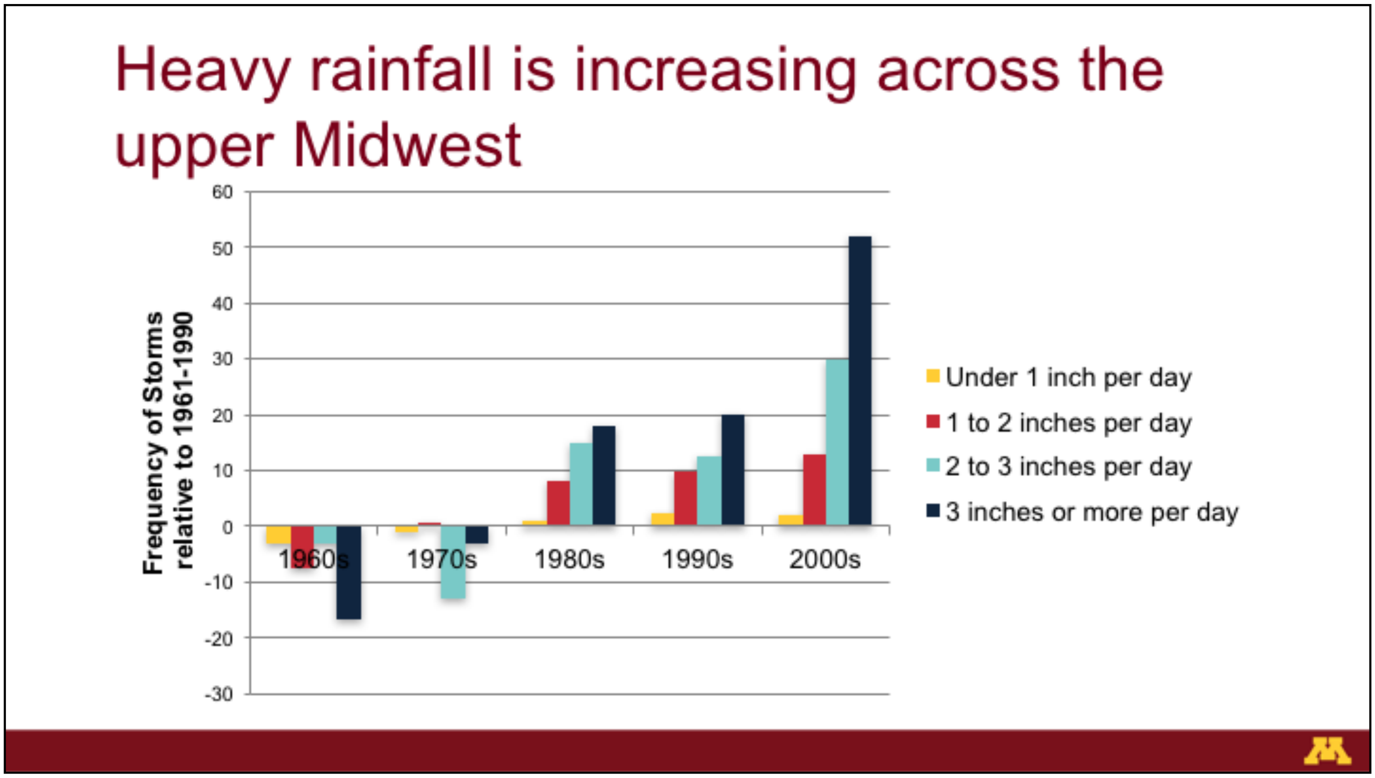
Average change per decade



Data courtesy MN DNR State Climatology Office with Data source for right figure: http://www.ncdc.noaa.gov/cag/

Harmony, MN record breaking precipitation—according to Mark Seeley,

In 2016 Waseca recorded 56.24 inches of precipitation, setting a new statewide annual precipitation record. In 2018 five southeastern Minnesota climate stations reported 50 inches of annual precipitation and two of them broke the state record: Caledonia (Houston County) reported 57.97 inches; and Harmony (Fillmore County) reported 60.21 inches. At Caledonia the record total precipitation was greatly enhanced by an intense thunderstorm that delivered 8.10 inches there on August 28th. However at Harmony the new precipitation record was set because of more frequent heavy rains and not so much individual record-setting rainfalls.



Yet global models predict greater runoff and lower soil moisture, thus this increase in water is less available for plants

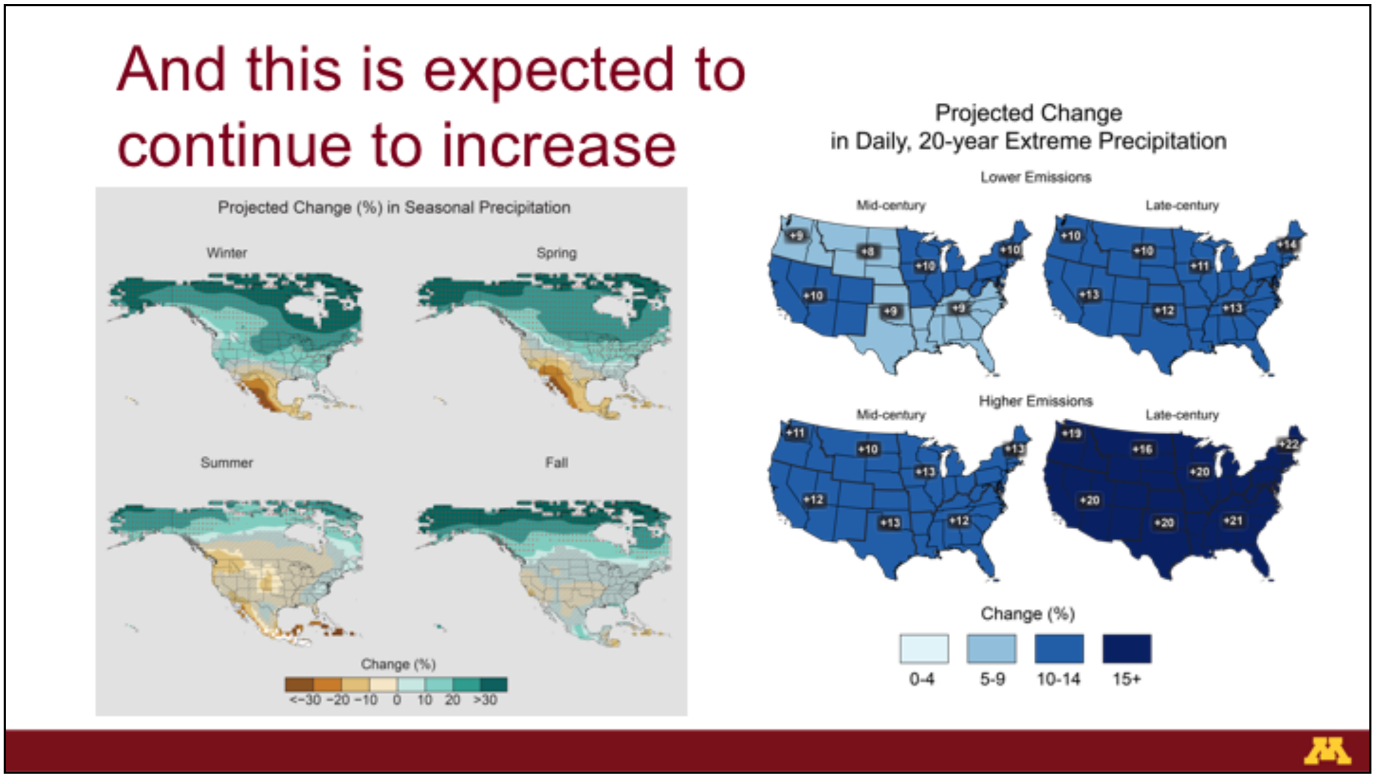
Data from DNR: 3 mega-events in 27 years (1973-99), 8 in 18 years (2000-2017), consistent with projections

Figure courtesy Dr. Peter Snyder, UMN. Data source for figure US Historical Climatology Network: http://www.ncdc.noaa.gov/ushcn/

Studies have determined that this increase is attributed to both anthropogenic and natural forcing

Table 7.1 in NCA2017

Knutson, T. R., F. Zeng, and A. T. Wittenberg, 2014: Seasonal and annual mean precipitation extremes occurring during 2013: A U.S. focused analysis [in "Explaining Extreme Events of 2013 from a Climate Perspective"]. *Bulletin of the American Meteorological Society*, **95 (9)**, S19–S23, doi:10.1175/1520-0477-95.9.S1.1.



What does a 25% average increase in spring rain mean across Minnesota? Is this expected everywhere?

What about 5% decrease in summer? Global projections lack details within our state.

Figures 7.5 (RCP8.5) and 7.7 (RCP4.5 and RCP8.5) of National Climate Assessment 2017

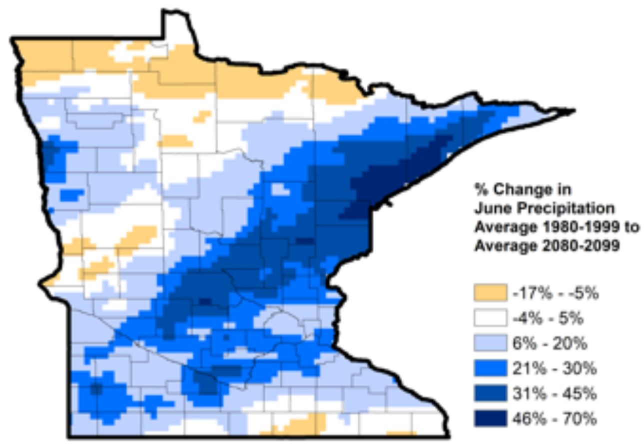
Data are statistically downscaled averages of 16 models--this uses known local features in equations to 'map' global climate projections to a finer grid. This is a simpler method than dynamically downscaling global models with regional models.

Data source for left: Taylor, K.E., R.J. Stouffer, G.A. Meehl: An Overview of CMIP5 and the experiment design." Bull. Amer. Meteor. Soc., 93, 485-498, doi:10.1175/BAMS-D-11-00094.1, 2012.

And for right: Pierce, D. W., D. R. Cayan, and B. L. Thrasher, Statistical Downscaling Using Localized Constructed Analogs (LOCA)*, Journal of Hydrometeorology, 15(6), 2558-2585, 2014; and Pierce, D. W., D. R. Cayan, E. P. Maurer, J. T. Abatzoglou, and K. C. Hegewisch, 2015: Improved bias correction techniques for hydrological simulations of climate change. J. Hydrometeorology, v. 16, p. 2421-2442. DOI: http://dx.doi.org/10.1175/JHM-D-14-0236.1

Early summer increase in rainfall

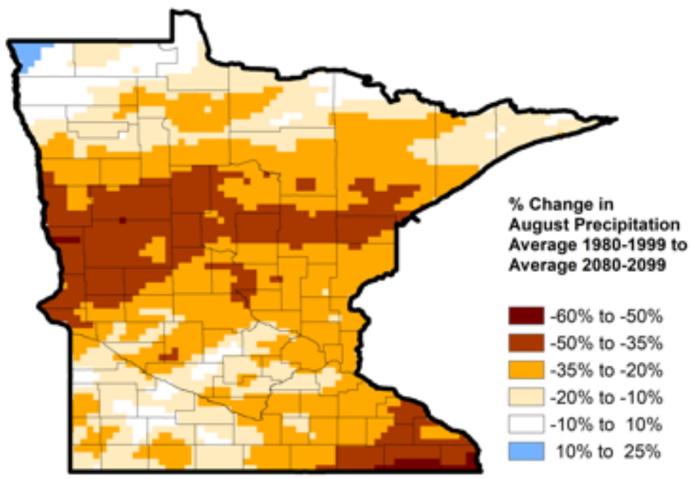
- In fact, the 25% average increase misses details across the state
- This figure is just one realization of a dynamically downscaled dataset being created at UMN



These model results are 'hot off the presses' from an LCCMR-funded project and will be averaged with other runs (to form an ensemble mean as is done with global models to test for robustness).

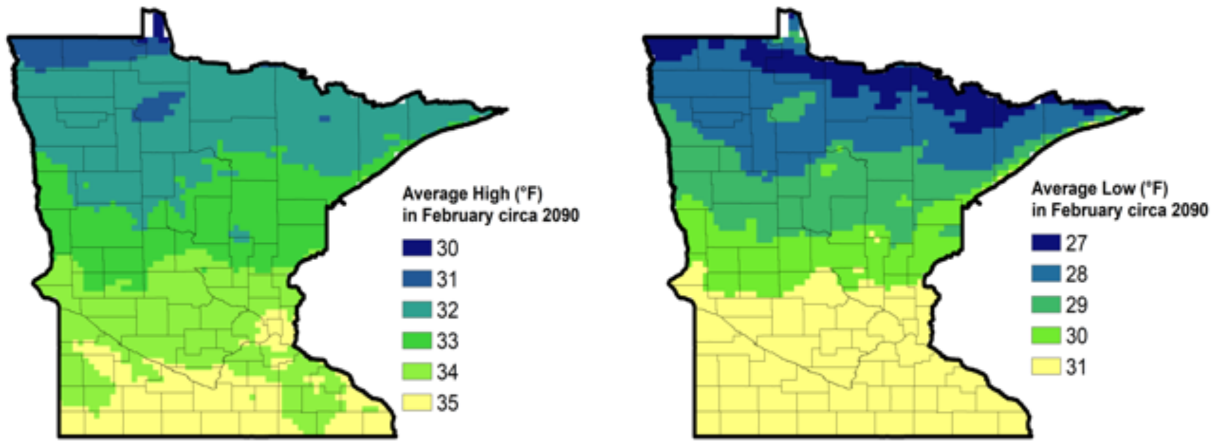
These data are driven with the CNRM-CM5 global climate model and downscaled with the Weather Research and Forecast (WRF) model. Nine other global models are being downscaled with WRF at this time and will be averaged with the data shown here.

Late summer decrease in rainfall



This is just one realization of downscaled data from a global climate model. Nine more will be averaged with this to create an ensemble.

Winter temperatures near freezing



About 5 degrees above current average high in MSP (29F)

About 18 degrees above current average low in MSP (13F)

Across the state current lows are below freezing. As these temperatures average near freezing, there are more chances of freeze/thaw which could lead to more hazardous traffic/walking conditions.

Climate Change Impacts in Minnesota: Across Geography

Peter B. Reich, Department of Forest Resources, University of Minnesota

January 15, 2019

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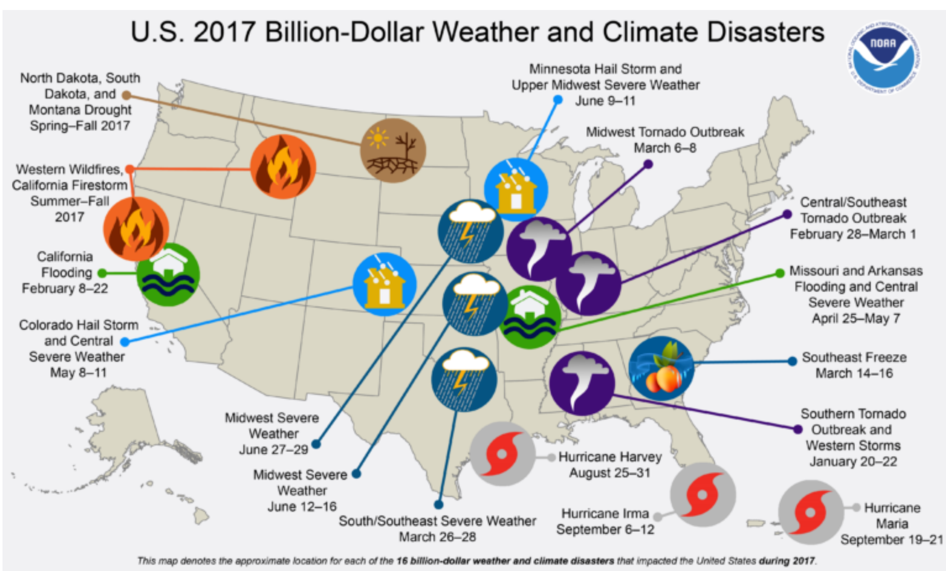
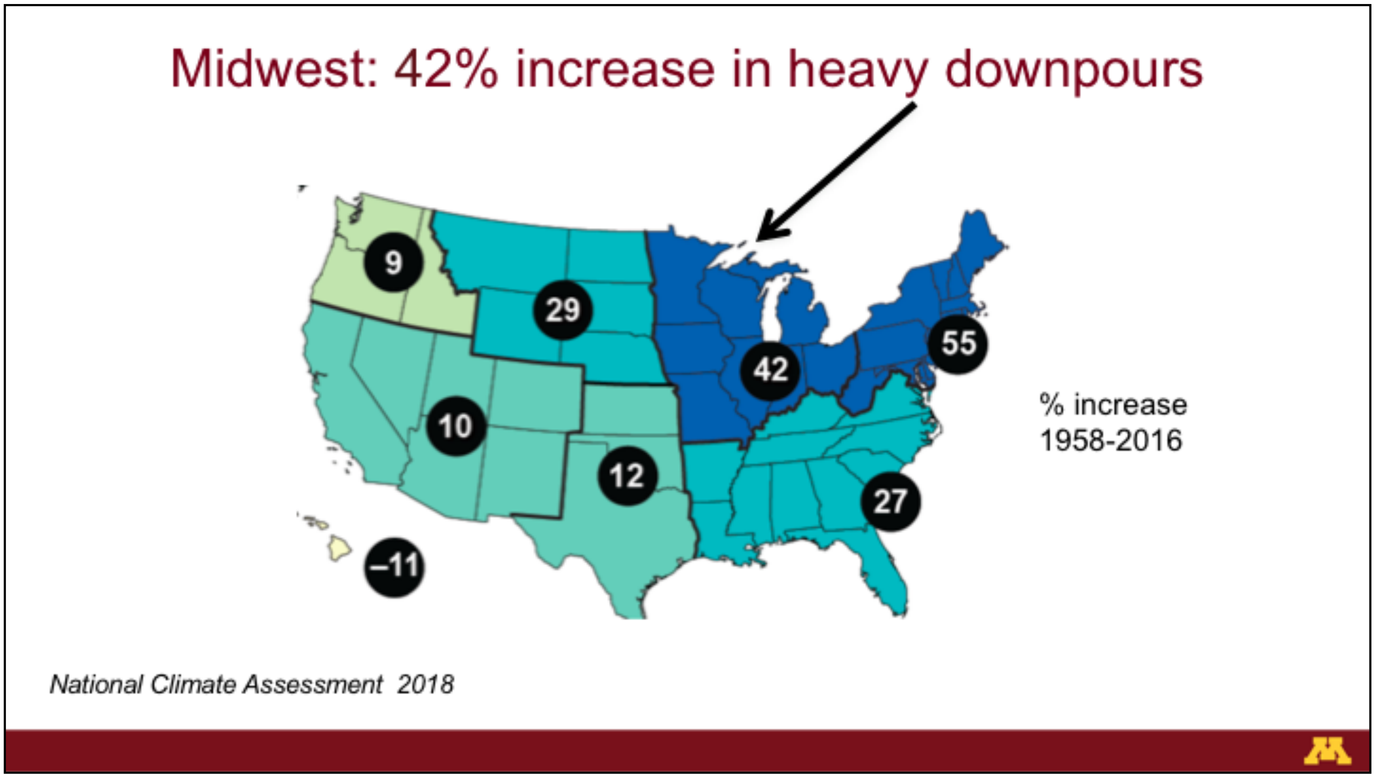
Climate change is “extremes”
(not just “a little warmer on average”)



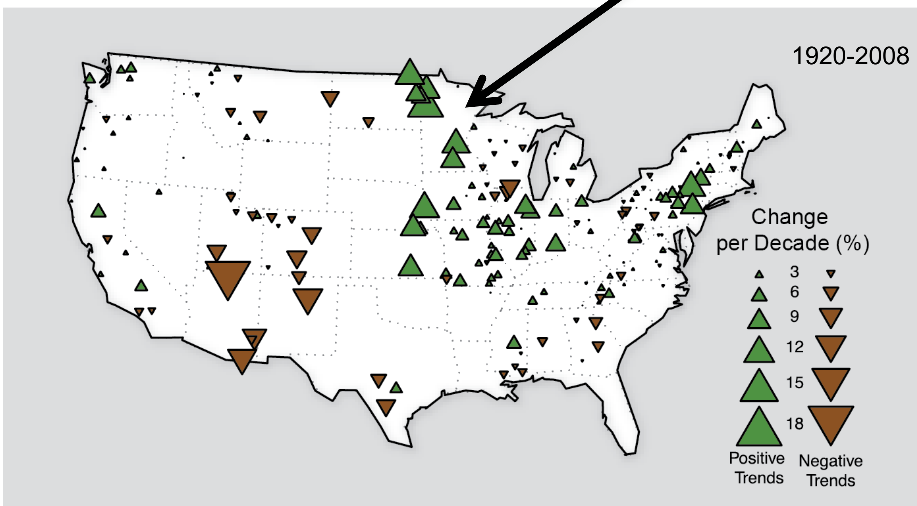
Increase in MN severe weather events

- Heatwaves
- Droughts
- Heavy rainfall & floods
- Windstorms
- wildfires



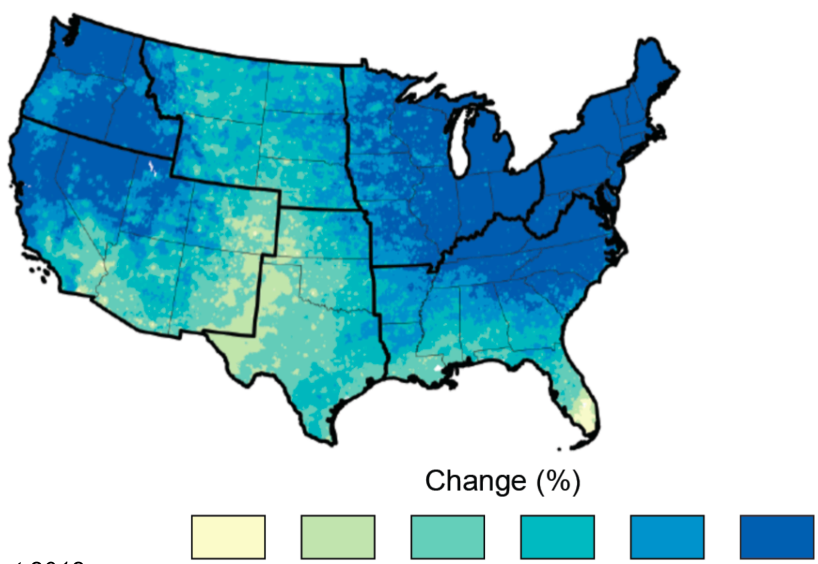
42% increase in rain amounts in the heaviest (1 in 100) rain events for north central states

Increase in floods



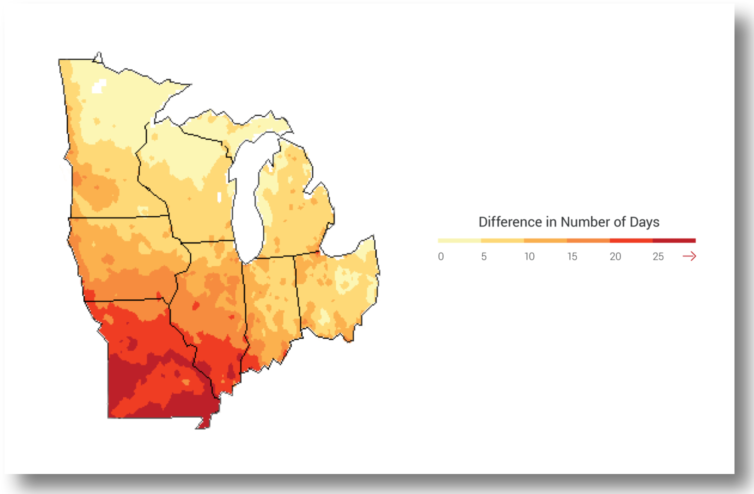
NCA 2014

More increases predicted in heavy downpours



National Climate Assessment 2018

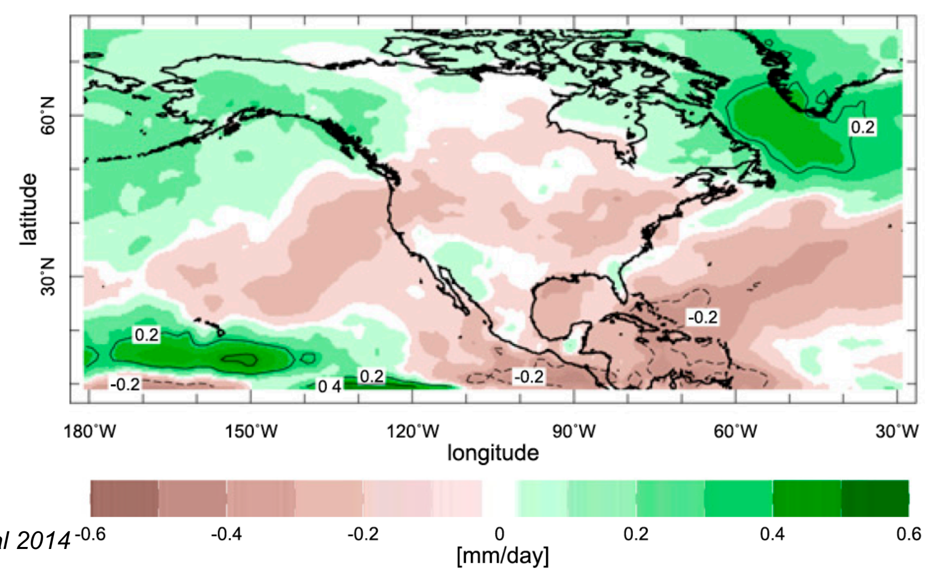
More days above 95 F projected by mid-century



Source: 2014 National Climate Assessment, Midwest Chapter

Summers drier by 2030s

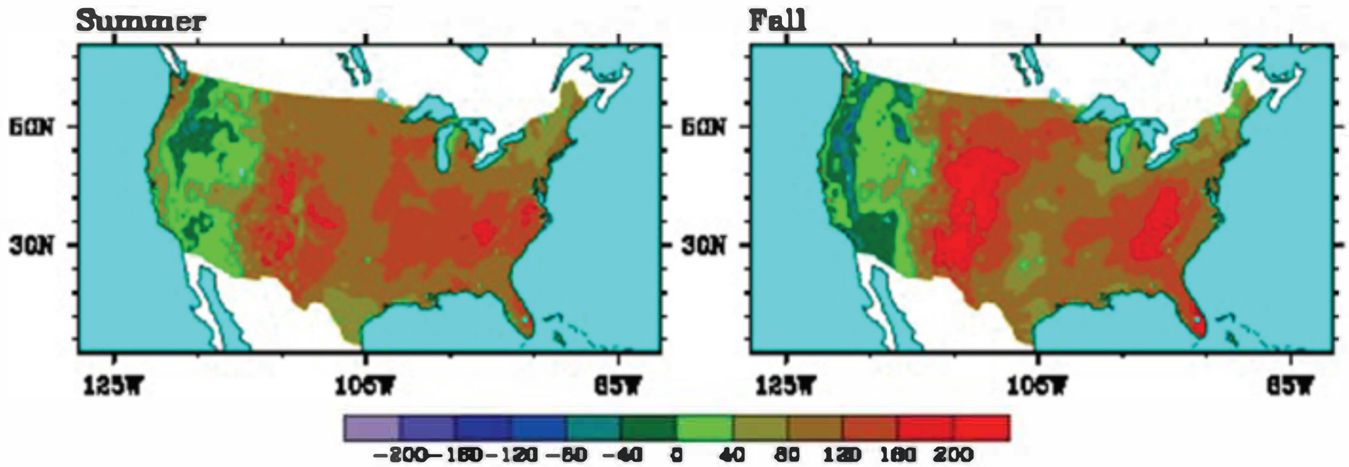
(brown: less soil water than 1990s)



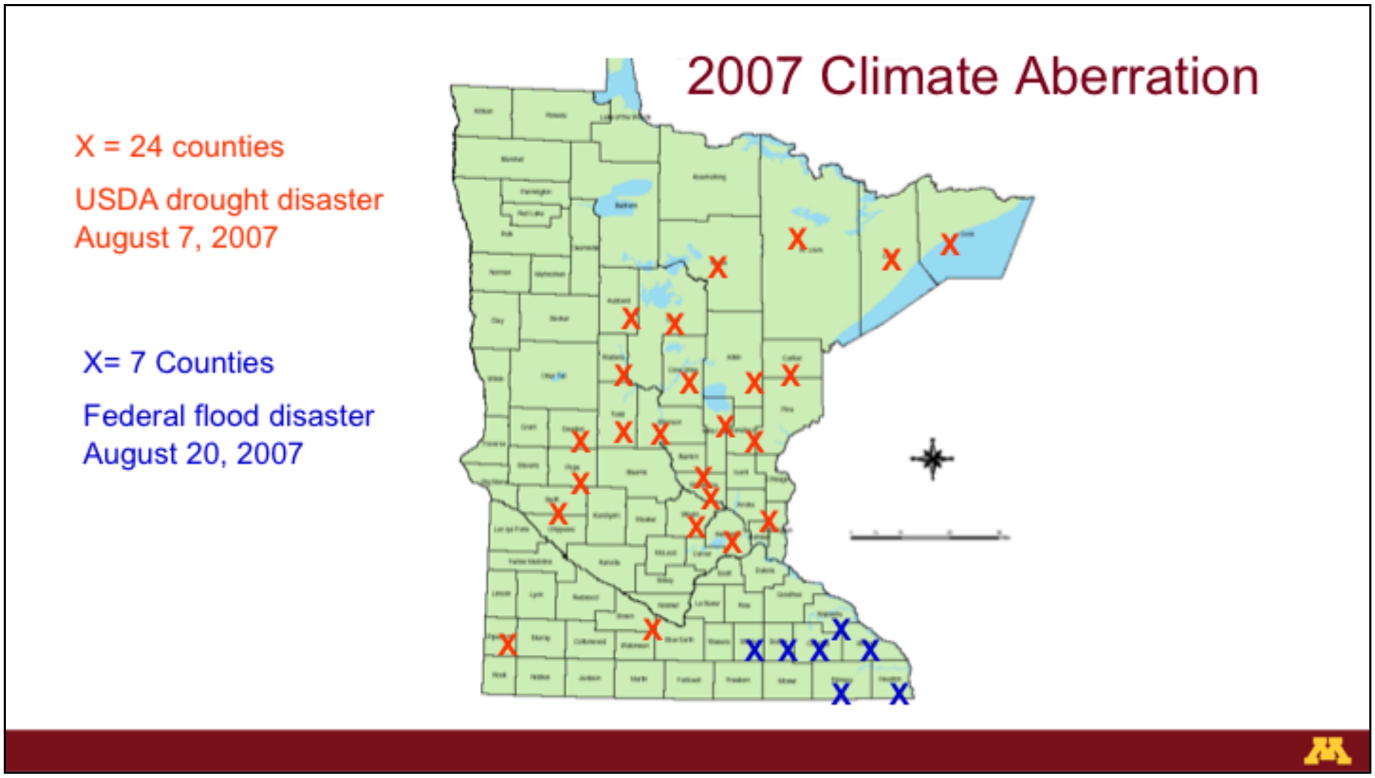
Seager et al 2014

Changes in wildfire potential (1980s to 2050s)

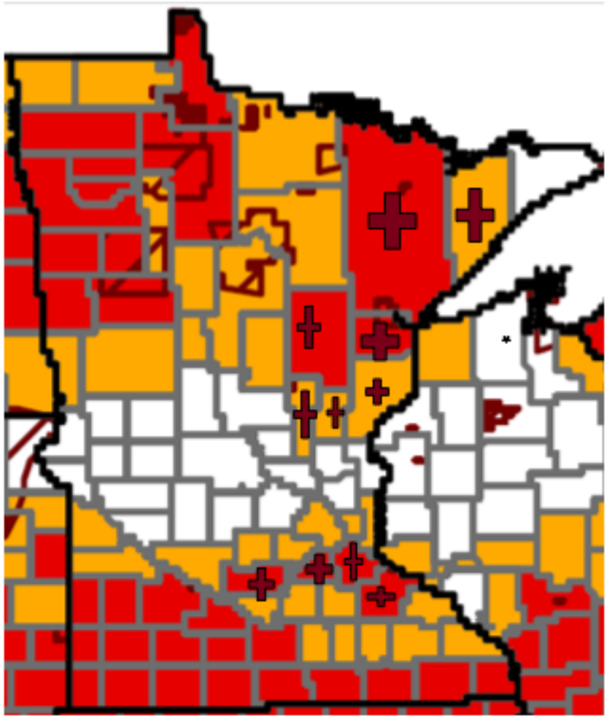
Brown and red = largest increases



Liu et al 2013



August, 2007, a climate singularity…24 counties declared drought disasters by USDA, 7 counties declared flood disasters by FEMA. This has never happened in state history.

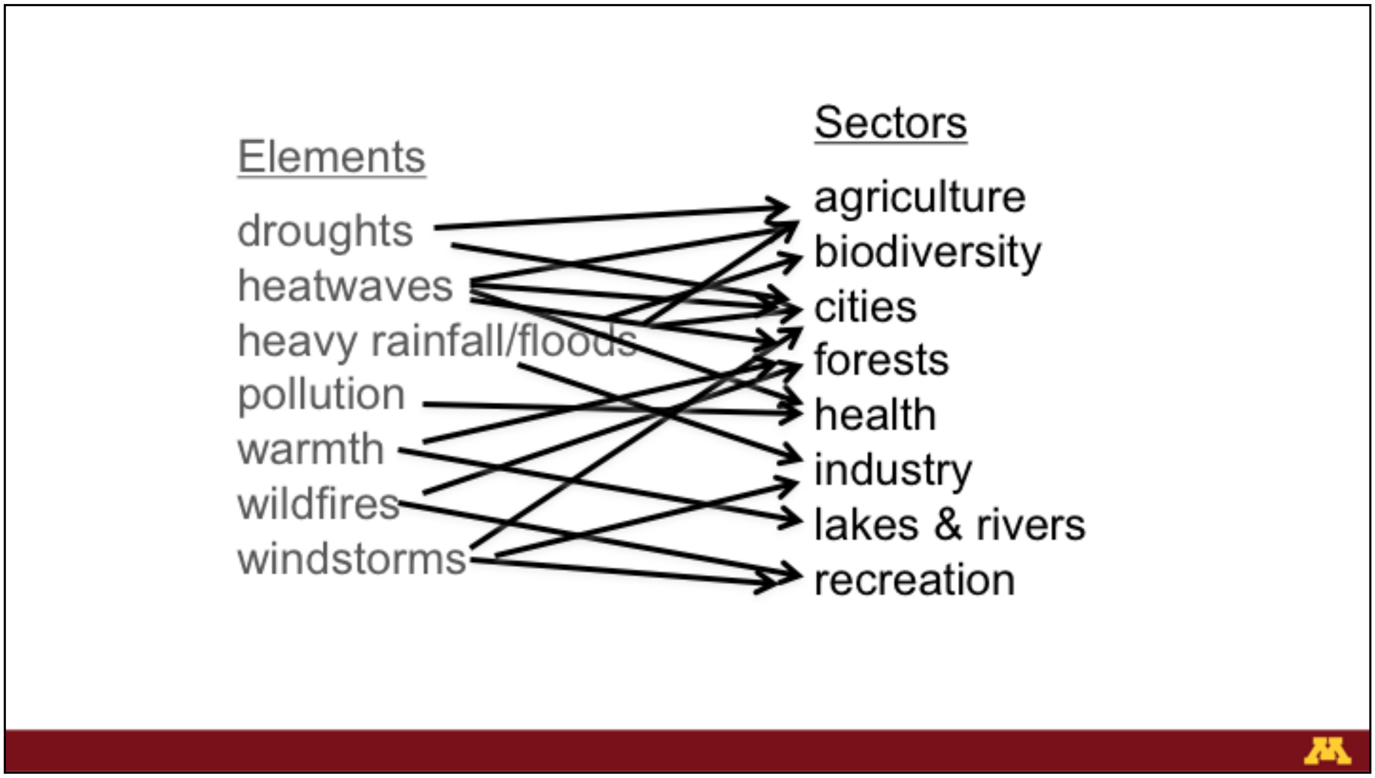


MN Counties 2012:

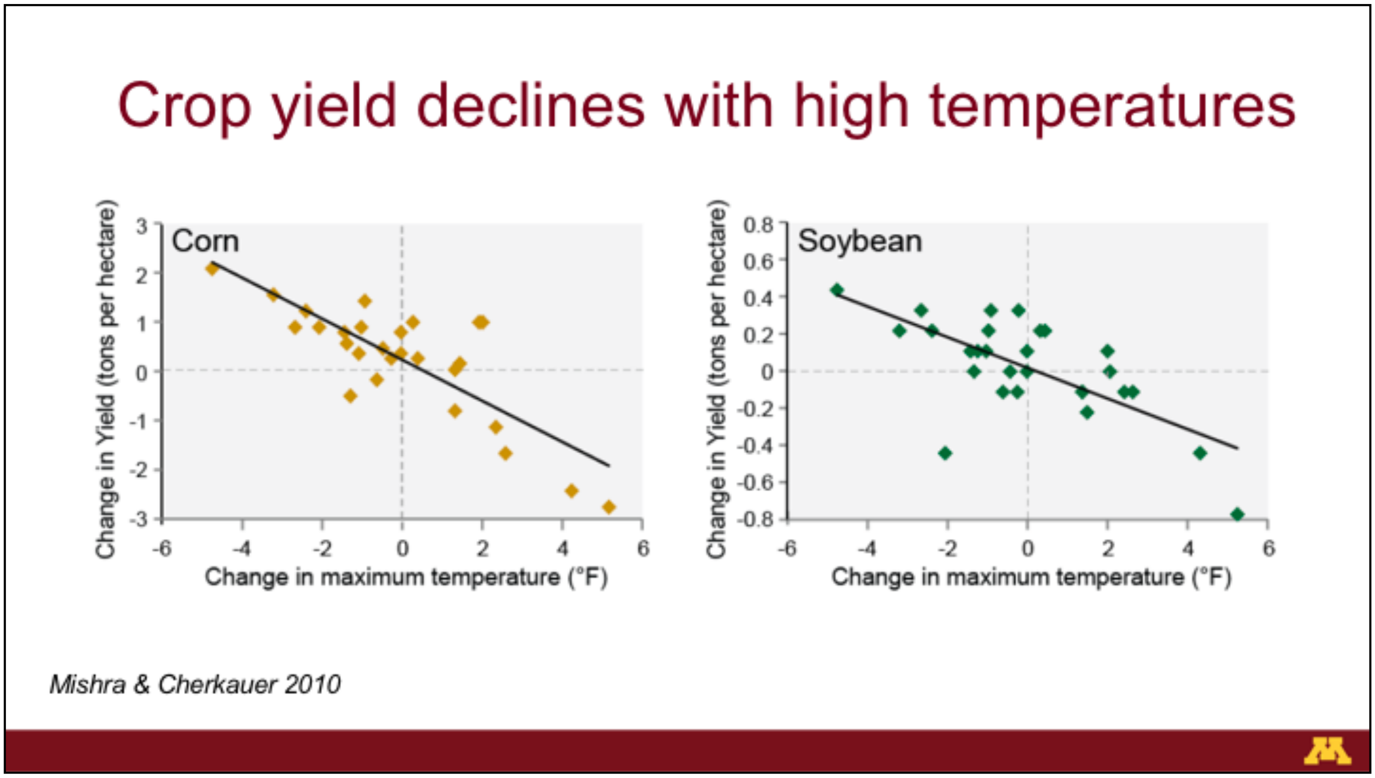
USDA federal drought disaster assistance (yellow and red)

FEMA flood disaster assistance (✚)

1st time Minnesota counties simultaneously eligible for drought & flood assistance


Elements
droughts
heatwaves
heavy rainfall/floods
pollution
warmth
wildfires
windstorms
Sectors
agriculture
biodiversity
cities
forests
health
industry
lakes & rivers
recreation

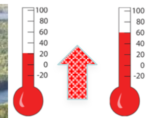
Agriculture



Mishra & Cherkauer 2010. Retrospective droughts in the crop growing season: Implications to corn and soybean yield in the Midwestern United States. Agricultural and Forest Meteorology 150(7-8):1030-1045

Grand Forks and E Grand Forks flood 1997; Duluth June 2012

What happens as we turn up the heat?



Forests

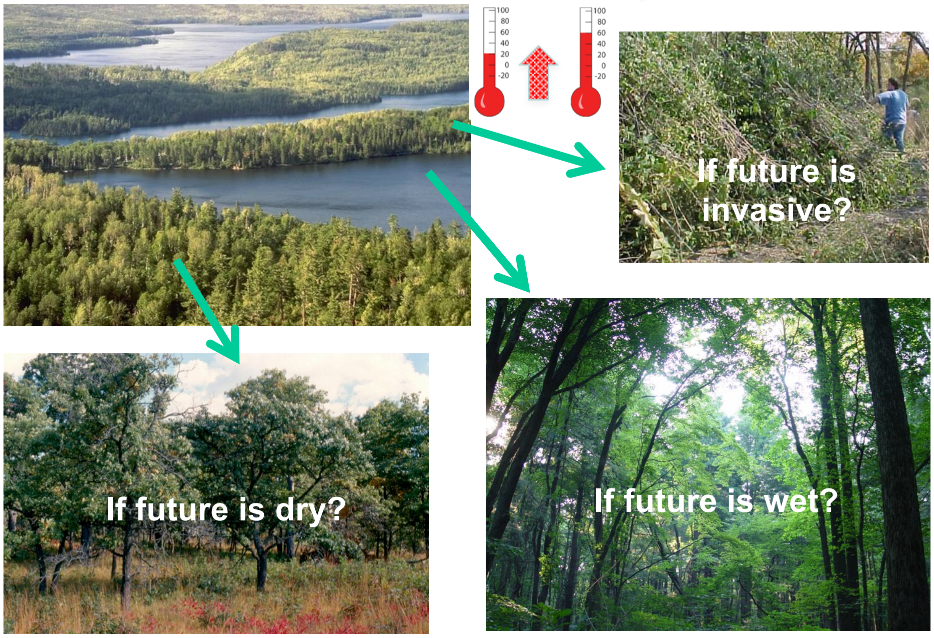
Direct temperature effects

Climate change-related drought

Indirect effects (insects, wind, fire)

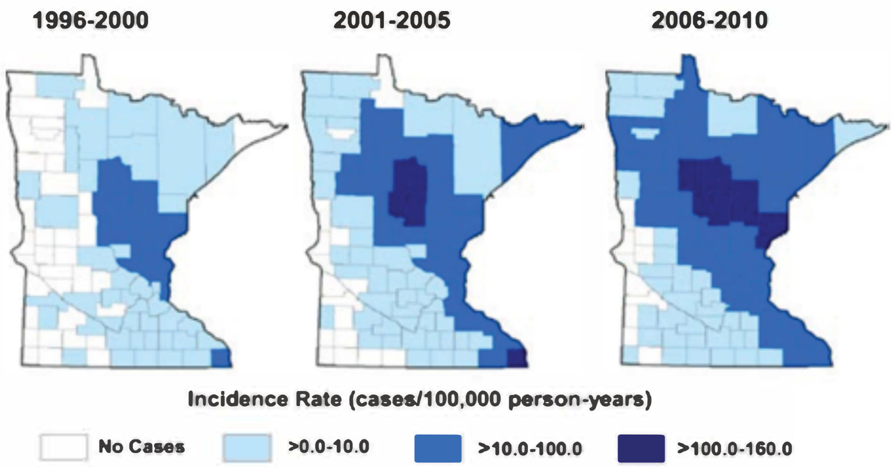
What happens as we turn up the heat?

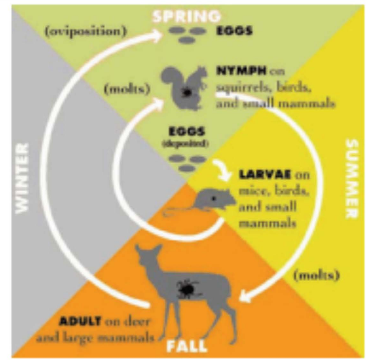
Forests



Human Health

Spread of Lyme Disease, MN





Air Quality

Smog

Allergens

Wildfire Smoke

How does climate change worsen asthma?

1. Pollen- Heat and increased carbon dioxide increase the duration of the pollen season, the allergenicity (a measure of how much particular allergens, such as ragweed, affect people) of pollen triggering asthma attacks and taking away from productivity of Minnesotans- https://health2016.globalchange.gov/air-quality-impacts

- Neil, K., and J. Wu, 2006: Effects of urbanization on plant flowering phenology: A review. *Urban Ecosystems*, **9**, 243-257. George, K., L. H. Ziska, J. A. Bunce, and B. Quebedeaux, 2007: Elevated atmospheric CO2 concentration and temperature across an urban–rural transect. *Atmospheric Environment*, **41**, 7654-7665.

2. **Climate Penalty Factor- Heat and Ozone**

- The American Lung Association puts out a report every year called the State of the Air. In the report, they discuss the air quality progress in different parts of the country. Minnesotan cities rank amongst the cleanest top 25 cities! But, this is threatened by increasingly warm summers. The damage to our climate causes hotter summers. This causes stagnation of polluted air. These pollutants then bake together in the hot sun to form high levels of ground-level ozone that is a known trigger for asthma attacks.

Resource: State of the Air 2018 report- https://www.lung.org/assets/documents/healthy-air/state-of-the-air/sota-2018-full.pdf

3. Wildfires:

- Climate change will worsen the intensity and duration of wildfires. This smoke travels to Minnesota from Canada and the NorthWest US causing poor air quality. The main pollutant in wildfire smoke is called Particulate Matter- PM2.5. This is a microscopic pollutant that causes heart attacks and triggers asthma. The American Heart Association put out a statement in 2010 outlining the “causal” link between PM2.5 and cardiovascular mortality. This is very significant in scientific terms, as now there is as strong a link between smoking and lung cancer as there is between air pollution and deaths. There is NO safe level of PM2.5

Resource: American Heart Association statement on https://dnr.wi.gov/topic/AirQuality/documents/AHA_Circulation_2010.pdf

4. Mold:

- With increased precipitation in Minnesota, we will see an increase in chronic flooding of homes. Water damaged homes lead to a rise in mold and respiratory related illnesses. This was best demonstrated after hurricane Katrina. Unfortunately, this impacts low-income families and is also an issue of equitable housing. J Environ Public Health 2017;2017:2793820. doi: 10.1155/2017/2793820. Epub 2017 Apr 9. Increased Sensitization to Mold Allergens Measured by Intradermal Skin Testing following Hurricanes. Saporta, Hurst

If we lose recreational opportunity, negative for physical and mental health

Ice houses Jan 2019, Clear Lake, Waseca; algal bloom Peliter Lake, Centreville, MN also found in Lake Carver, Woodbury.

Impacts!

- Many challenges
- Opportunities to adapt and mitigate
- Thursday session

Regions, land uses, and landscape elements differ in vulnerability to different components of climate change

Changes in climate dimensions themselves will vary state-wide

The result: agriculture, cities, forests, human health, and waters will be impacted by different aspects of changing climate, at different times and places

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