Changing Climates and Extreme Weather for Minnesota

2022 MN Energy Expo

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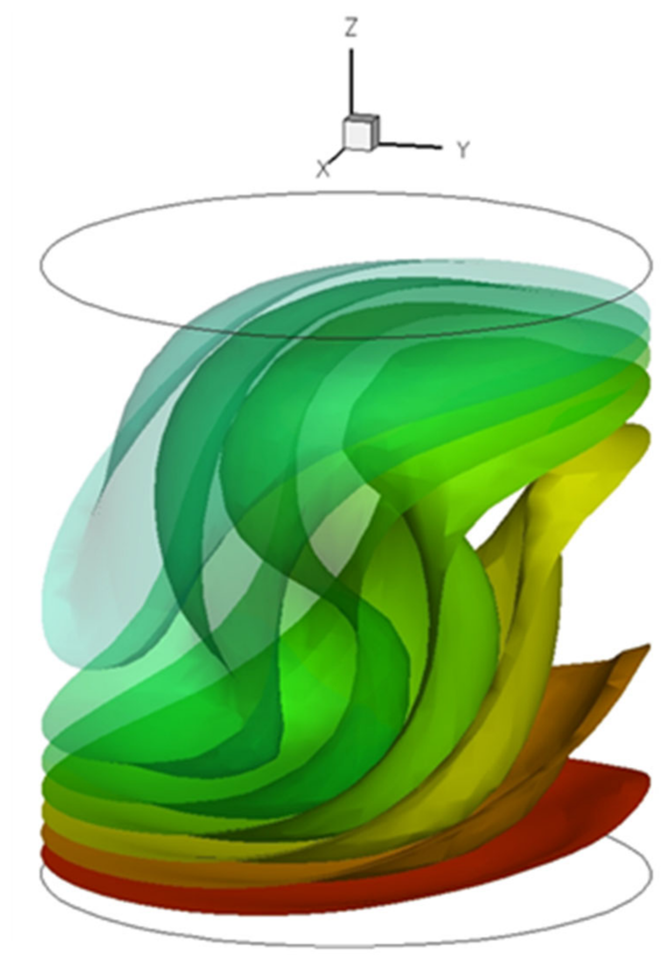
DYNAMICAL SYSTEMS

Local maximums and minimums may seem in opposition to global values.

Change is not uniform and not constant.



SPOILERS

- Climate change is occurring, but with some benefits.
- Extreme weather may be a more concerning issue.
- Design focus is shifting even more toward risk management.
- If anything, the interrelation of design factors is increasing.

1

CLIMATE CHANGE AND EXTREME WEATHER

Let's start with some background.

"...years that look normal now would have been extreme 50 years ago. That's how climate change works. Today's outliers become tomorrow's averages."

William Colgan, Glaciologist

DEFINITIONS

- **Weather** is the state of the atmosphere at any given time and place.
- **Climate** is the long-term average of the weather in a given place.
- **Extreme Weather** is very rare and/or very damaging.

ACRONYMS

- **GCM** – Global Climate Model.
- **IPCC** – Intergovernmental Panel on Climate Change.
- **RCP** - Representative Concentration Pathways.
- **AMY** - Actual Meteorological Year
- **TMY** - Typical Meteorological Year

RCP SCENARIOS

RCP 2.6 – Low greenhouse gas concentration levels. It is a "peak-and-decline" scenario. The most benign climate scenario of the four.

RCP 4.5 – Assumes a stabilization will occur shortly after 2100, and assumes less emissions than RCP 6.0.

RCP 8.5 – Increasing GHG emissions over time, and factors in the highest GHG concentration levels of all the scenarios by 2100.

Source: https://www.epa.gov/enviroatlas/changes-over-time

GLOBAL TEMPERATURE CHANGE

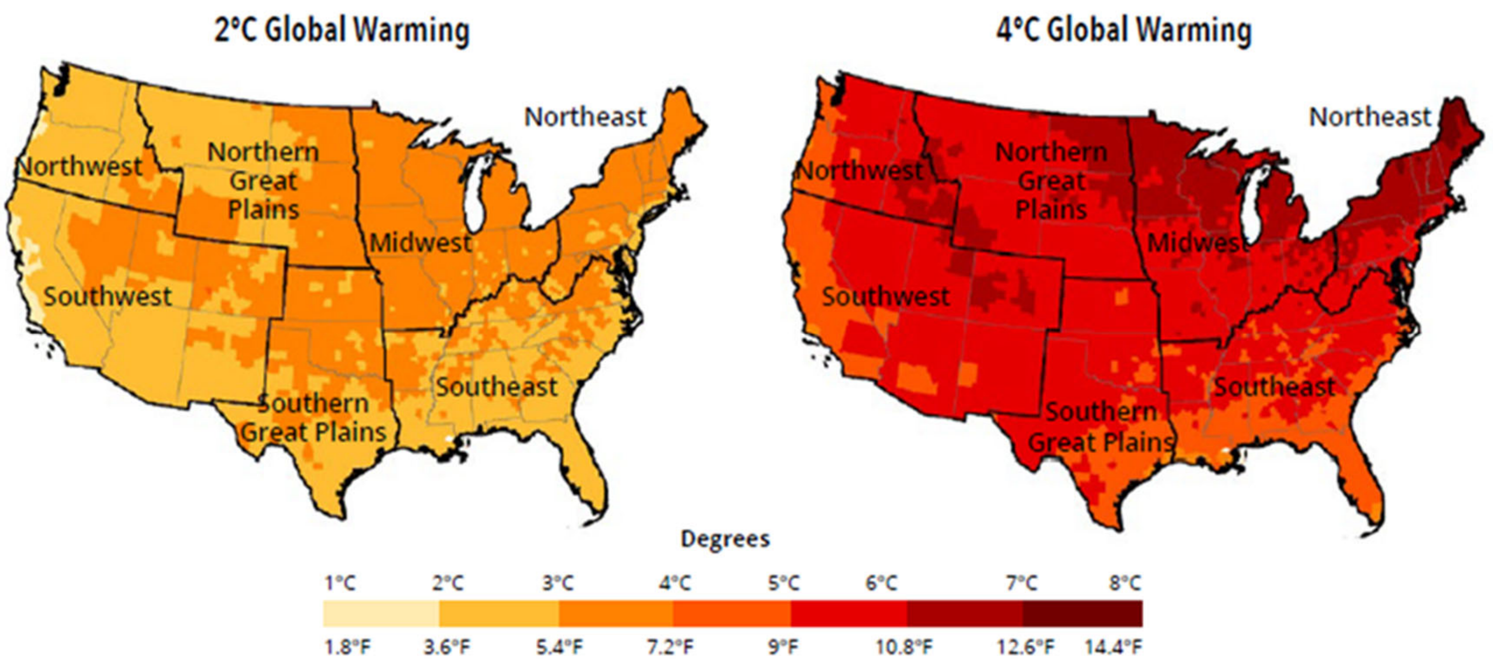
Table A.2 Projected Change in Global Mean Surface Air Temperature and Global Mean Sea Level Rise for the Mid to Late Twenty-First Century relative to the Reference Period, 1986–2005 (I-P) (IPCC 2014b, Section 12.4, Table 12.2, Table 13.5)

	Scenario	2046–2065		2081–2100	
		Mean	**Likely Range***	**Mean**	**Likely Range***
Global Mean Surface Temperature Change, °F	RCP2.6	1.8	0.7 to 2.9	1.8	0.5 to 3.1
	RCP4.5	2.5	1.6 to 3.6	3.2	2.0 to 4.7
	RCP6.0	2.3	1.4 to 3.2	4.0	2.5 to 5.6
	RCP8.5	3.6	2.5 to 2.9	6.7	4.7 to 8.6
Global Mean Sea Level Rise, ft	RCP2.6	0.80	0.56 to 1.05	1.31	0.85 to 1.80
	RCP4.5	0.85	0.62 to 1.08	1.54	1.05 to 2.07
	RCP6.0	0.82	0.59 to 1.05	1.57	1.08 to 2.07
	RCP8.5	0.98	0.72 to 1.25	2.07	1.48 to 2.69

* Calculated from 5% to 95% model ranges.

Source: ASHRAE Position Document on Climate Change (2018, reaffirmed 2021)

CHANGE IS NOT UNIFORM



Source: Climate Change and Social Vulnerability in the United States, EPA 2021.

PRIMARY CLIMATE CHANGE IMPACTS

Air Quality and Health

New asthma diagnoses in children age 0 to 17 due to particulate air pollution, and premature deaths in adults ages 65 and older due to particulate air pollution.

Extreme Temperature and Health

Deaths due to extreme temperatures.

Extreme Temperature and Labor

Deaths due to extreme temperatures.

Coastal Flooding and Traffic

Traffic delays due to high-tide flooding and extreme temperature and precipitation.

Coastal Flooding and Property

Property inundation due to sea level rise, and exclusion from protective adaptation measures.

Inland Flooding and Property

Property damage or loss due to inland flooding.

Source: Climate Change and Social Vulnerability in the United States, EPA 2021.

TYPES OF EXTREME WEATHER

- Extreme Cold Events
- Extreme Heat Events
- Extreme Rainfalls
- Extreme Snow and Ice Storms
- Droughts
- Wildfires
- Severe Convective Storms
- Tropical Cyclones and Hurricanes

Incidents of extreme weather are projected to increase as a result of climate change.

2

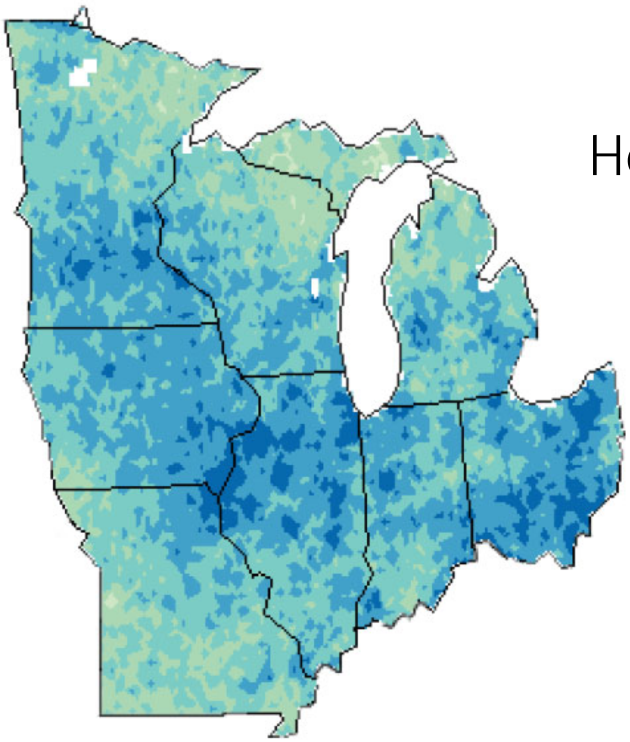
MINNESOTA SPECIFIC

What kinds of things can we expect locally?

“Minnesota is the state with the strongest winter warming in the contiguous United States.“

Leiss et al., 2021

WE WILL BE WETTER



Heavy precipitation events (summer and winter) will become more likely.

Source: Third National Climate Assessment, U.S. Global Change Research Program

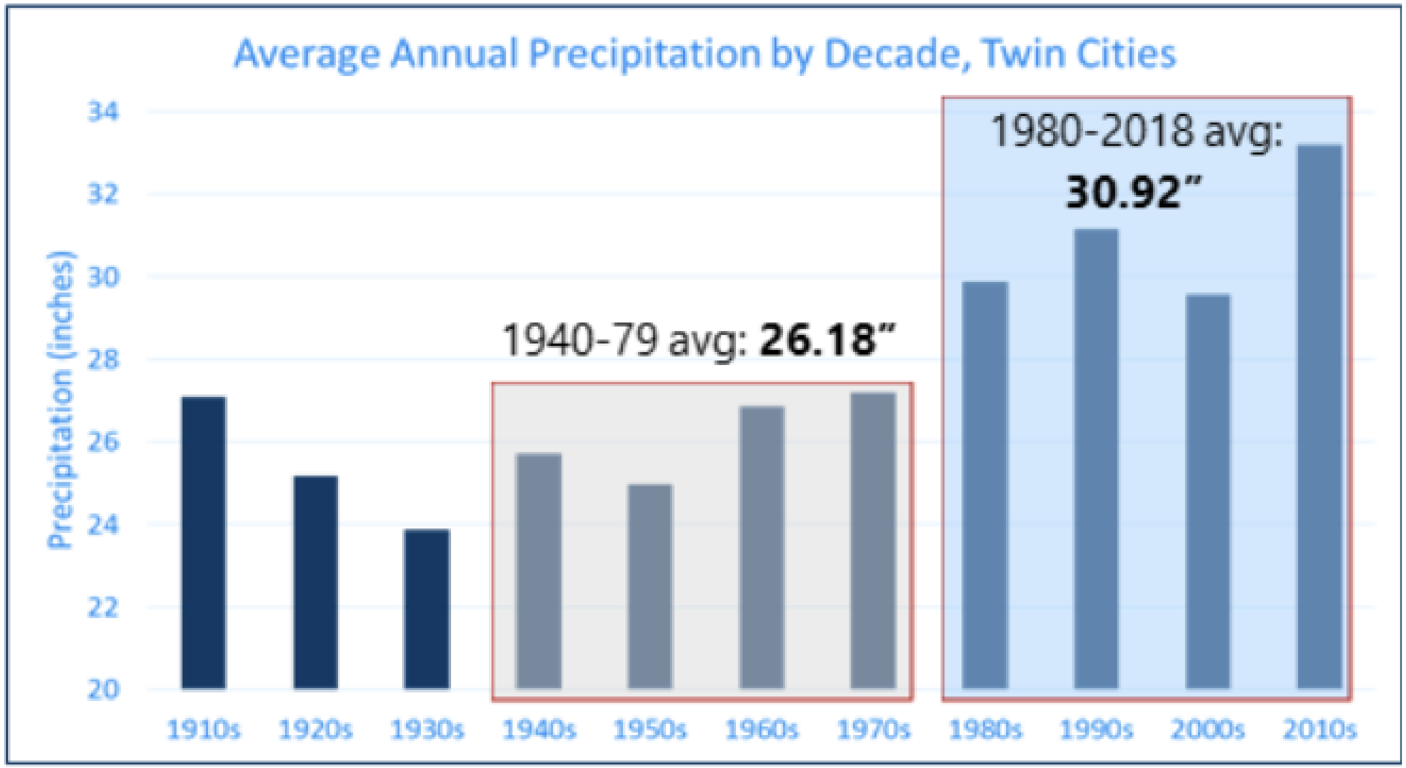
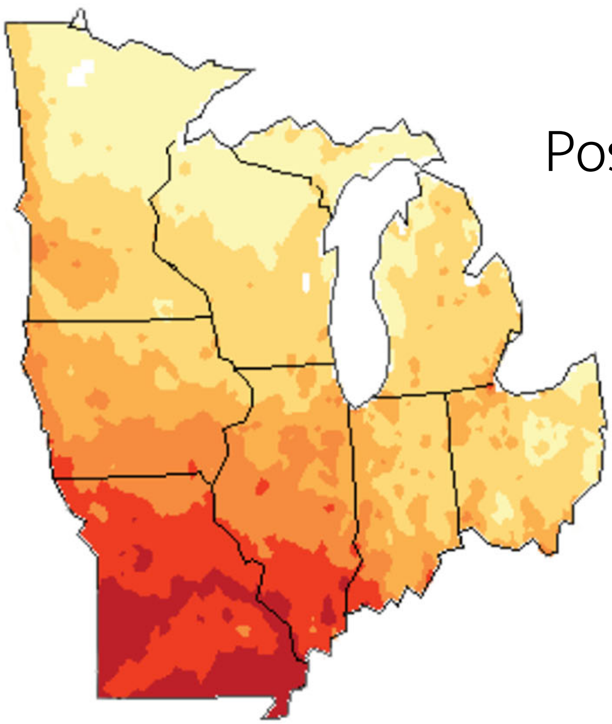


Figure 1: Average annual precipitation by decade in the Twin Cities
Source: Minnesota Department of Natural Resources, 2019

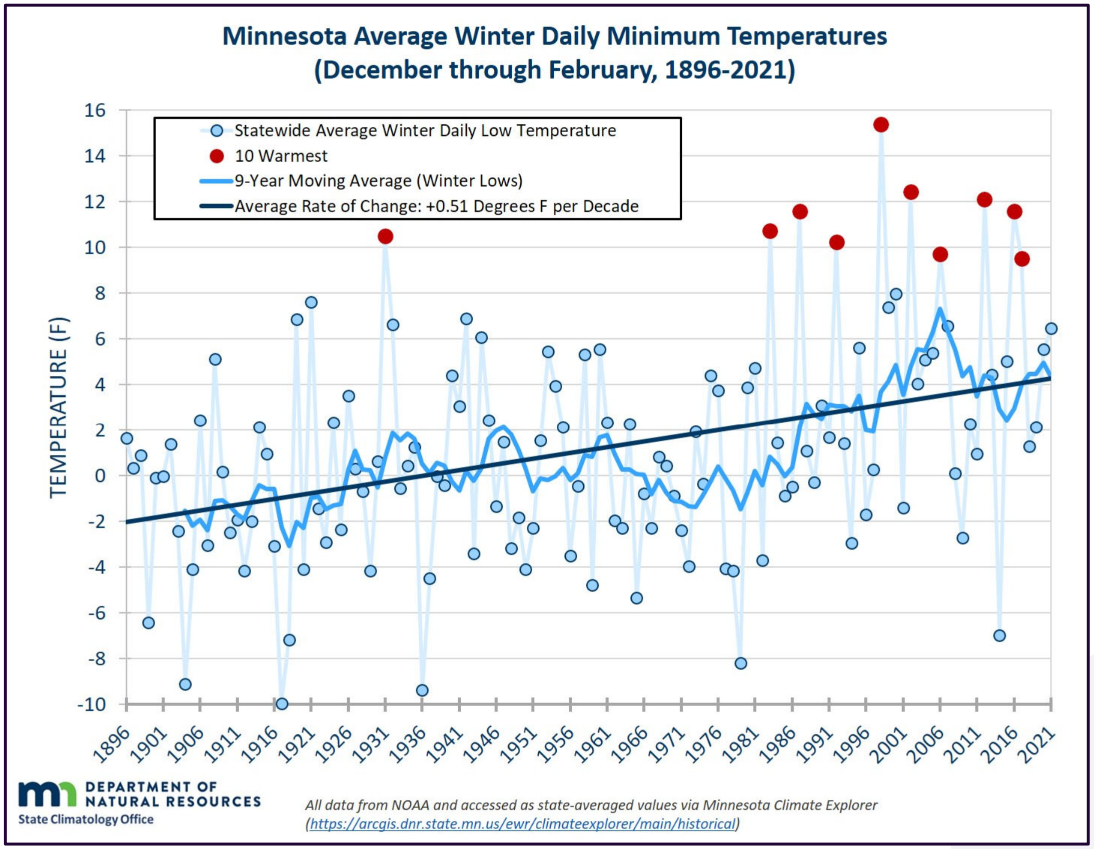
WE WILL BE HOTTER



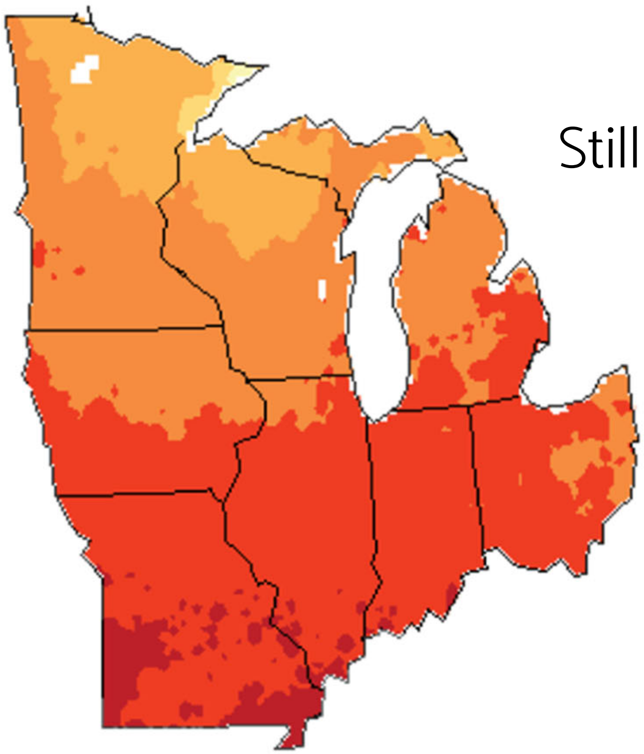
Possible drought conditions are increased at least to mid-century.

Source: Third National Climate Assessment, U.S. Global Change Research Program

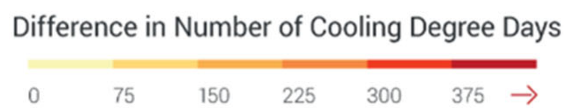
CHANGING WINTERS



IMPACT ON COOLING



Still heating dominated, but with increasing need to address cooling.



Source: Third National Climate Assessment, U.S. Global Change Research Program

CHANGES TO DEW POINT

"On July 19, 2011, the dew point temperature reached 82°F in the Twin Cities. On that same day, the state record dew point temperature was reached in Moorhead, Minnesota with a dew point temperature of 88°F. The only other spot in the Western Hemisphere with a dew point temperature in the 80s that day was in the Amazon Jungle in South America."

Source: Minnesota Extreme Heat Toolkit
Minnesota Department of Health

SPECIFICS

- **Winter temperatures** may rise twice as fast as average annual.
- **Overnight low** temperatures are rising faster than maximum temperatures.
- **Temperature rise** in northern MN is almost twice that for southern MN.

DROUGHT

Source: Images taken from CNN.com.

POLAR VORTICES

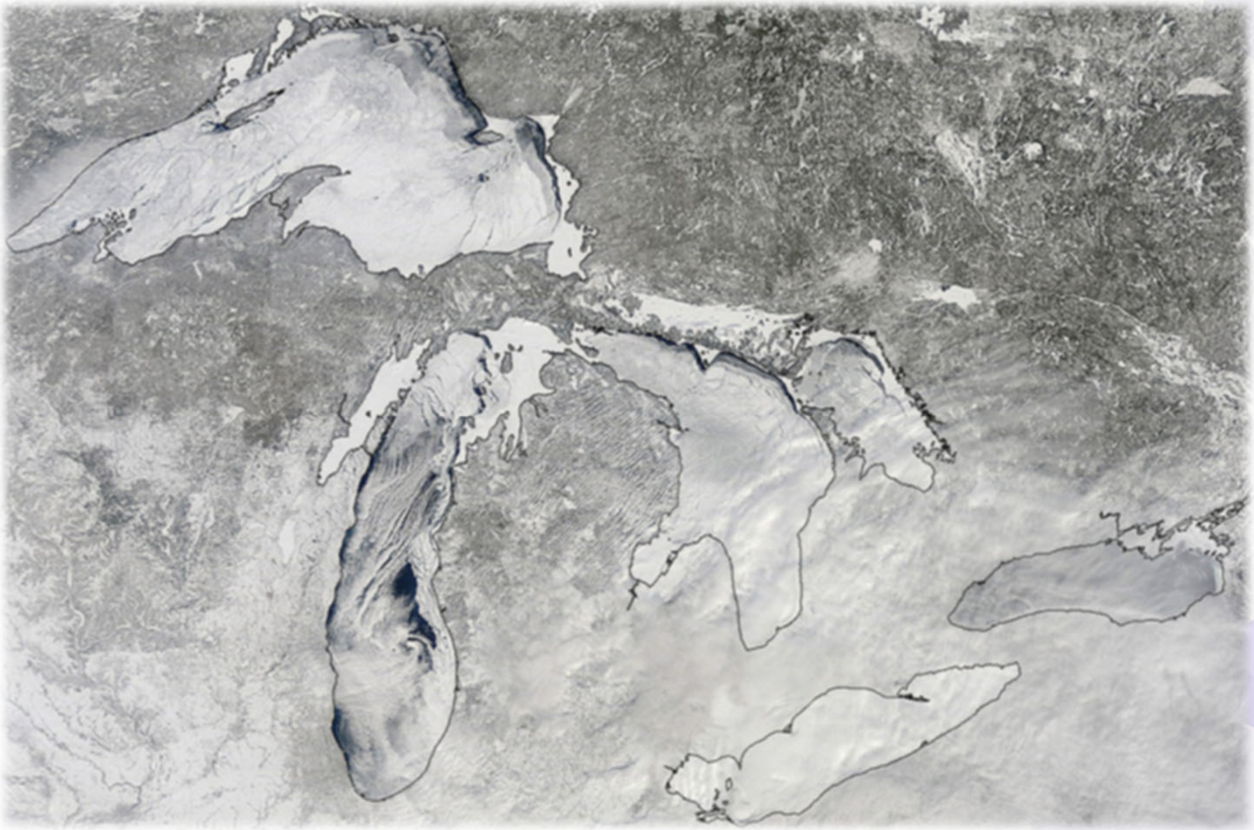


Image Source: NASA

WILDFIRES

Unhealthy air quality caused by Canadian wildfires. Photo: Minnesota Pollution Control Agency, 2015

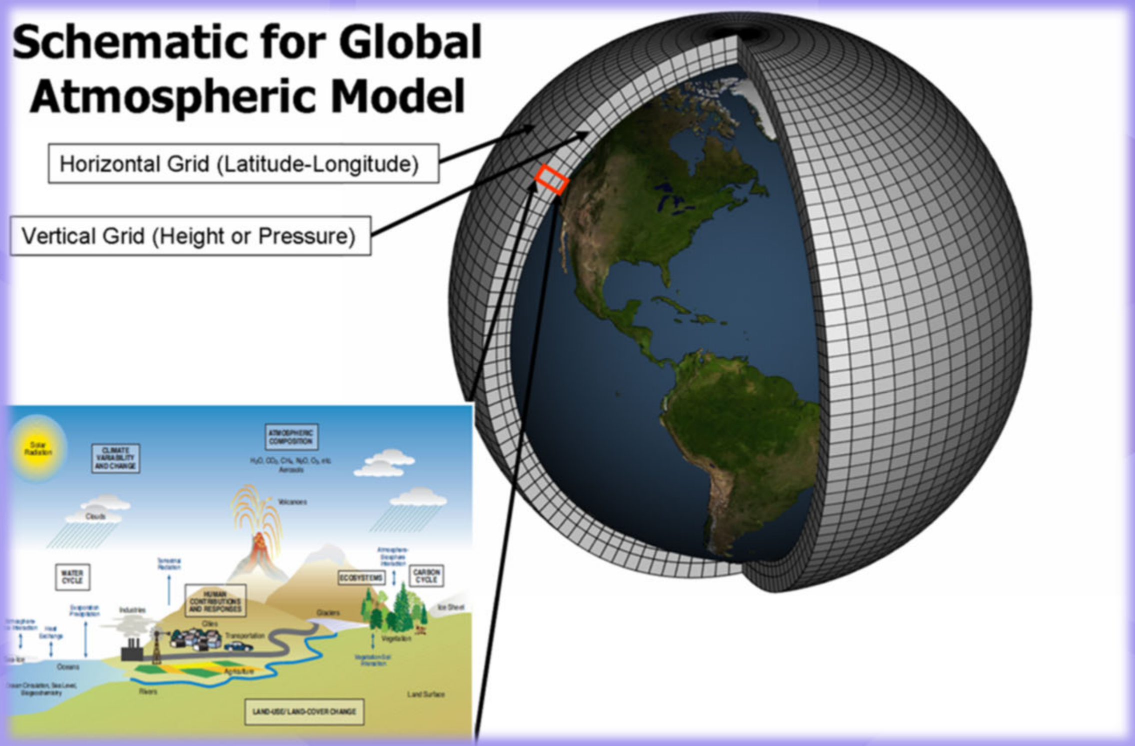
“Minnesota could become the new Kansas. We have a perfectly good Kansas now. We don’t need a second one in Minnesota.”

Lee Frelich, Director

U of MN Center for Forest Ecology

MODELING ON MULTIPLE SCALES

Predicting regional patterns requires a finer simulation grid.



https://www.gfdl.noaa.gov/climate-modeling/

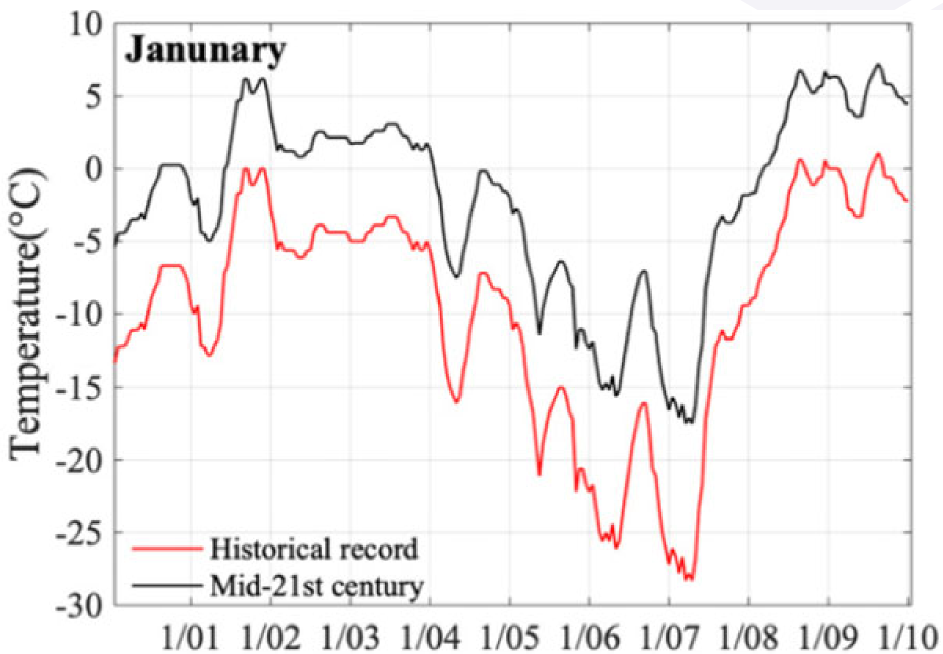
ADAPTING WEATHER DATA

- Computational power limits the resolution of global climate models (e.g. 300 km x 300 km and 24 hours).
- Morphing adjusts present design weather data using global circulation and regional climate models.
- Spatial downscaling by extrapolation or statistical methods.

A methodology for evaluating the effects of climate change on climatic design conditions for buildings and application to a case study in Madison, Wisconsin
by Gesangyangji et al., 2022

METHOD

- University of Wisconsin Probabilistic Downscaling (UWPD) model.
- GCM results for all four values of RCP were used.
- Daily varying probability density functions (PDF) are used.
- The results include both the effects of large-scale and local-scale variations.



A methodology for evaluating the effects of climate change on climatic design conditions for buildings and application to a case study in Madison, Wisconsin by Gesangyangji et al., 2022

RESULTS

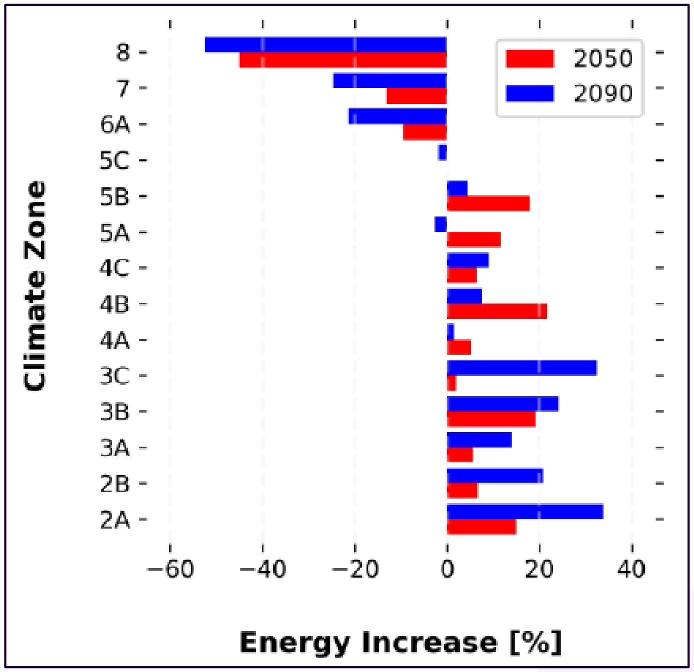
- Under a "RCP 8.5 scenario, building heating and cooling in Madison is projected to resemble the current heating demand in Chicago, IL, and cooling demand in Baltimore, MD, by mid-century."
- "By late-century, Madison is projected to experience the current heating demand in St. Louis, MO, and cooling demand in Augusta, Georgia."

All other things being equal.

Nationwide Impacts of Future Weather on the Energy Use of Commercial Buildings by Muehleisen et al., 2020.

METHOD

- Started with a GCM using RCP-8.5.
- GCM data is used as boundary conditions for a Weather Research and Forecasting Model (WRF).
- Resulting grid size is 12 km x 12 km.
- Data and computationally time intensive.
- Resulting weather was fed into EnergyPlus to determine energy impacts.



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DESIGN IMPACTS

Promoting adaptation and resilience.

“Existing practice and recommendations must be examined against the backdrop of a change climate.”

Chapter 36, ASHRAE Fundamentals

UNMET COOLING HOURS

- Weather design conditions can be expected to change during a system's lifetime (25-30 years).
- A starting 0.4% design condition means the system cannot meet load for 1 hr/day during 30 of the hottest days.
- This design condition shifts to a 2% condition during the system lifetime.
- Non-attainment shifts to 3-4 hrs/day for 50 of the hottest days.

Source: ASHRAE 2021 Fundamentals

ADAPTATION

- Bypass systems to minimize energy use until contaminant removal is needed.
- Pressurization and smoke mitigation.
- Moisture monitoring and flood resistant materials.
- Shelter-in-place capabilities.
- Maintenance to prevent failure at the worst possible times.

Source: ASHRAE 2021 Fundamentals

DESIGN ~~SOLUTIONS~~ TRADEOFFS

- Improved insulation (?).
- Natural ventilation will need to be supplemented.
- Mid-life replacement strategies.
- Passive techniques to reduce summer heat gain.
    - Roof strategies to reduce urban heat island.

If anything, interdependence of systems will increase.

INDOOR AIR QUALITY

POTENTIAL ISSUES

- Increase in wildfires will raise the amount of fine particulates.
- Drought will lead to more windblown dust.
- Increased moisture will lead to greater mold.

POTENTIAL SOLUTIONS

- Increased residential mechanical ventilation.
- Positive pressurization and filtration.
- Revised building codes and standards.

POTENTIAL POWER LOSS

POTENTIAL ISSUES

- Extreme weather straining peak capacity (e.g. heat waves).
- Extreme weather damaging infrastructure (e.g. convective events).
- Cyberattacks.

POTENTIAL SOLUTIONS

- Thermal storage.
- Selective control of indoor environment.
- Backup power.

MITIGATION EFFORTS

- Reduction of energy use and promotion of renewable energy.
- Electrification of heating (e.g. increased use of heat pumps).
- Refrigerants with lower Global Warming Potential (GWP) such as natural refrigerants.

~~SPOILERS~~ CONCLUSIONS

- Climate change is occurring, but with some benefits.
- Extreme weather may be a more concerning issue.
- Design focus is shifting even more toward risk management.
- If anything, the interrelation of design factors is increasing.

THANK YOU

Are there any questions?

CREDITS

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- Presentation template by SlidesCarnival
- The presentation and full reference list will be available at https://cornerstone.lib.mnsu.edu/.
- patrick.tebbe@mnsu.edu

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Presented at the 2022 MN Energy Expo, November 1st, 2022.

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