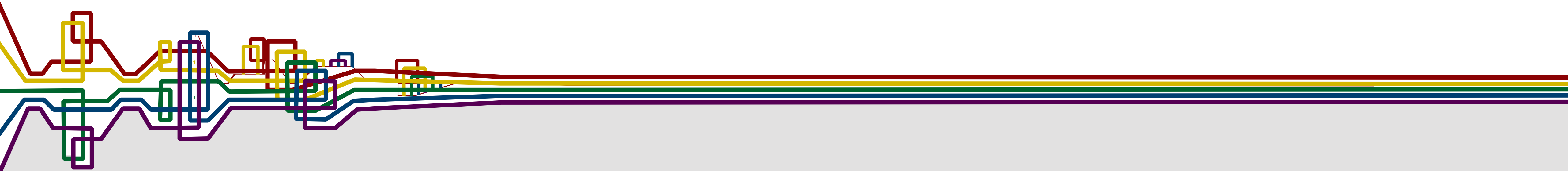


# DESIGNING FOR RESILIENCE WITH THE **B3 GUIDELINES**

**Richard Graves** AIA, Director, Center for Sustainable Building Research, University of Minnesota



# Potential Future Weather Changes

ipcc INTERGOVERNMENTAL PANEL ON climate change

IPCC WGI Interactive Atlas: Regional synthesis

Home About License

SELECT VISUALIZATION

MAP REGIONS COMBINATIONS

- South-Western South America (SWS)
- South-Eastern South America (SES)
- Southern South America (SSA)

EUROPE

- Mediterranean (MED)
- Western and Central Europe (WCE)
- Eastern Europe (EEU)
- Northern Europe (NEU)

NORTH - AMERICA

- Northern Central America (NCA)
- Western North America (WNA)
- Central North America (CNA)**
- Eastern North America (ENA)
- North-Eastern North America (NEN)
- North-Western North America (NWN)

SMALL ISLANDS

- Caribbean (CAR)
- Pacific Small Islands (PAC)

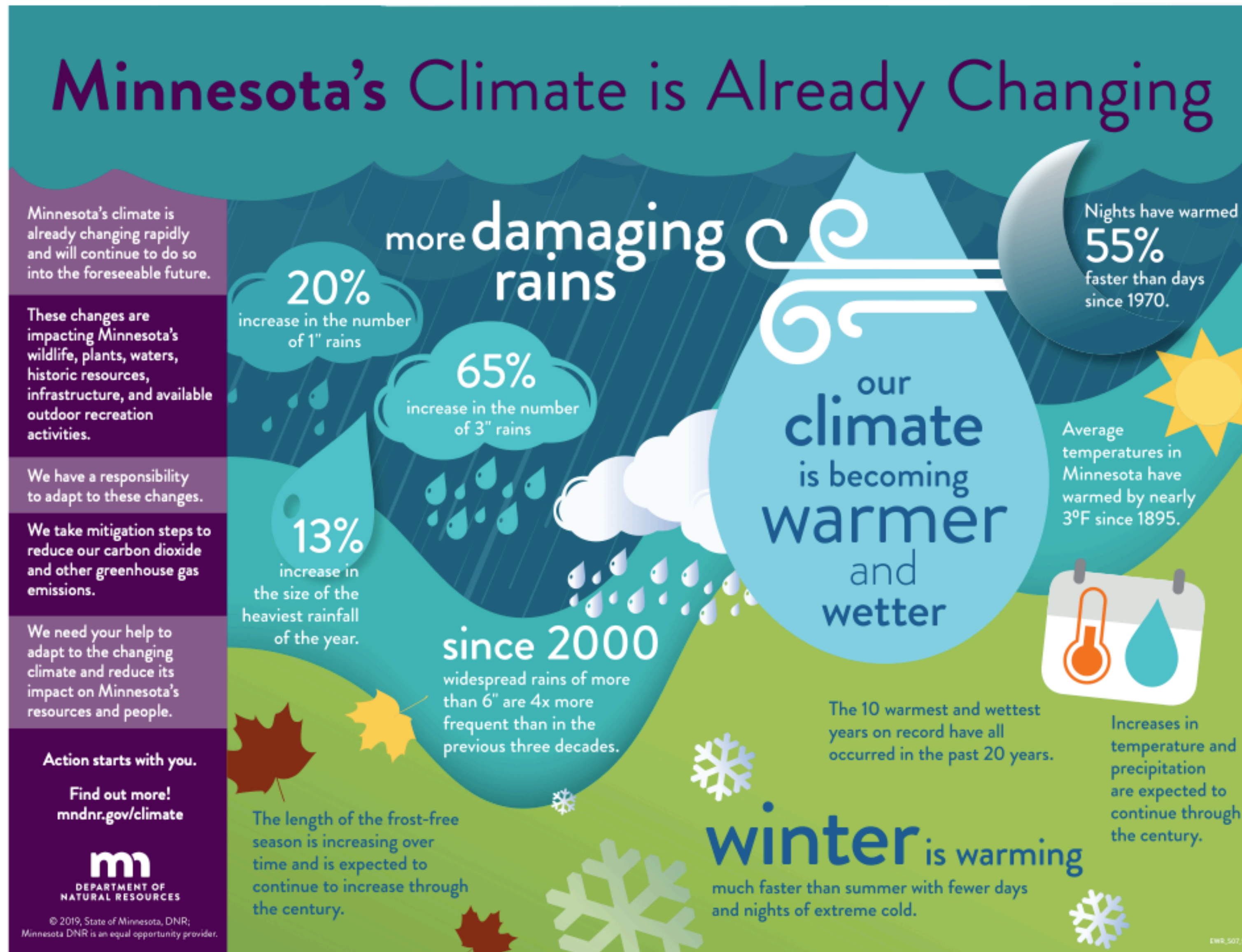
POLAR TERRESTRIAL

- Greenland/Iceland (GIC)
- Arctic North Europe
- Russian Arctic (RAR)
- Arctic Northwest North America
- Arctic Northeast North America
- West Antarctica (WAN)
- East Antarctica (EAN)

CID	FUTURE CHANGES	TREND / ATTRIBUTION
HEAT AND COLD 🔦		
Mean surface temperature	⬆️ High confidence of increase	⬆️ Upward trend without attribution
Extreme heat	⬆️ High confidence of increase	—
Cold spell	⬆️ High confidence of decrease	—
Frost	⬆️ High confidence of decrease	—
WET AND DRY 🔥		
River flood	⬆️ Medium confidence of increase	—
Heavy precipitation and pluvial flood	⬆️ High confidence of increase	⬆️ Upward trend with medium confidence of attribution
Aridity	⬆️ Medium confidence of increase	—
Agricultural and ecological drought	⬆️ Medium confidence of increase	—
Fire weather	⬆️ Medium confidence of increase	—
WIND 🌀		
Severe wind storm	⬆️ Medium confidence of increase	—
Tropical cyclone	⬆️ Medium confidence of increase	—
SNOW AND ICE ❄️		
Snow, glacier and ice sheet	⬆️ High confidence of decrease	⬆️ Downward trend without attribution

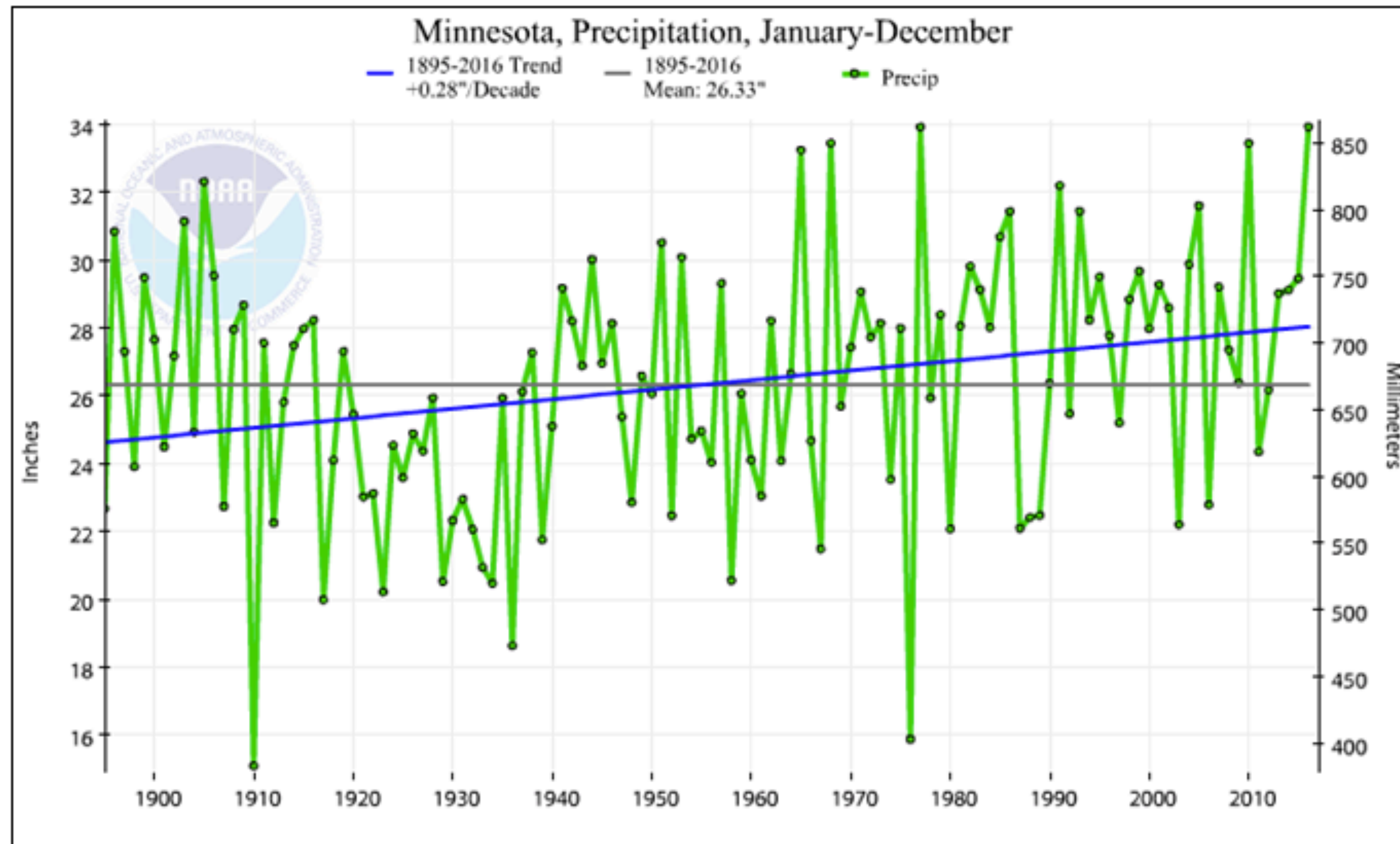


# Potential Future Weather Changes



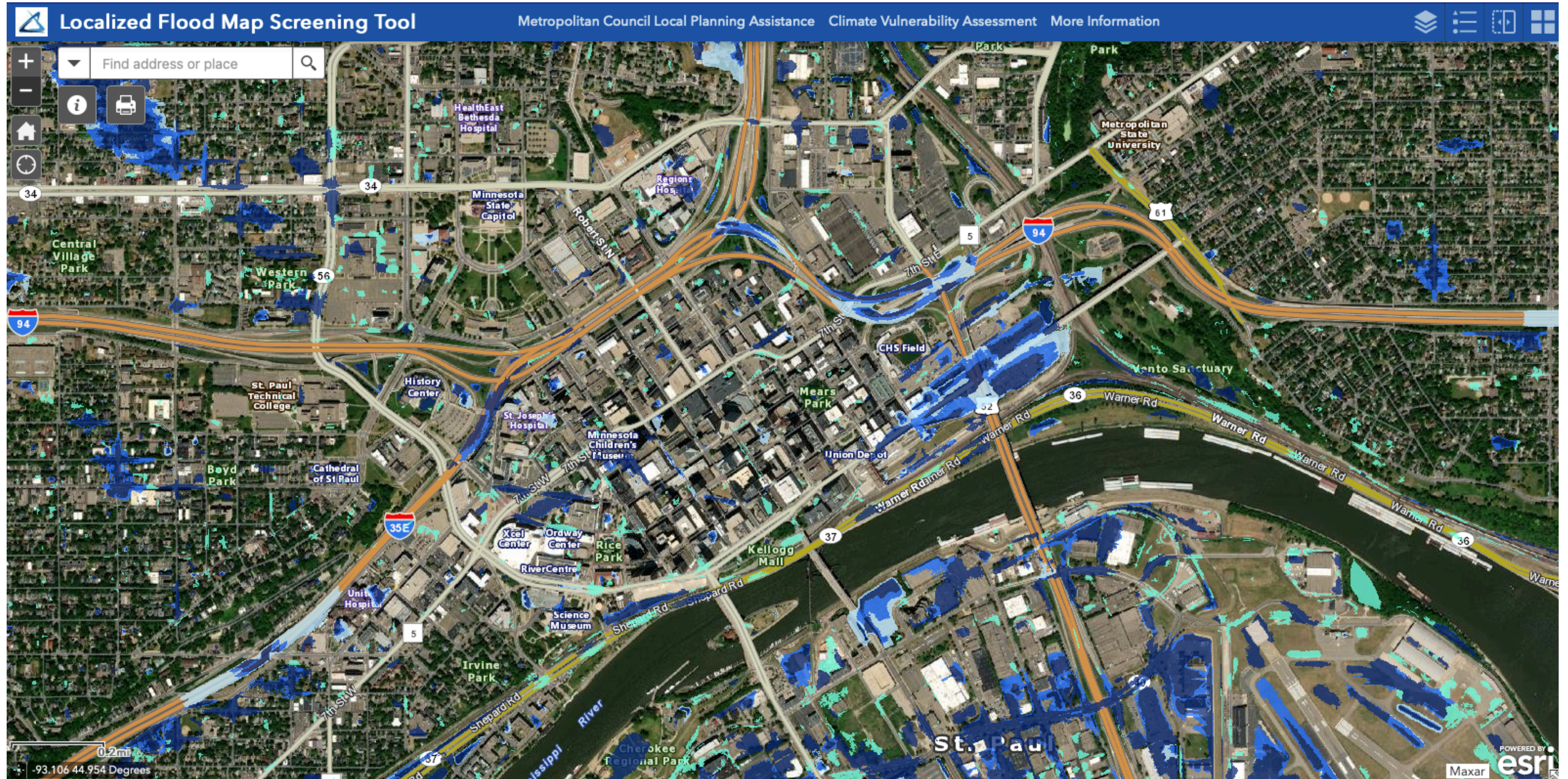
# Potential Future Weather Changes

Precipitation has been increasing in Minnesota over the last century, as shown in the Figure below, which illustrates historic annual precipitation, from 1865-2016.



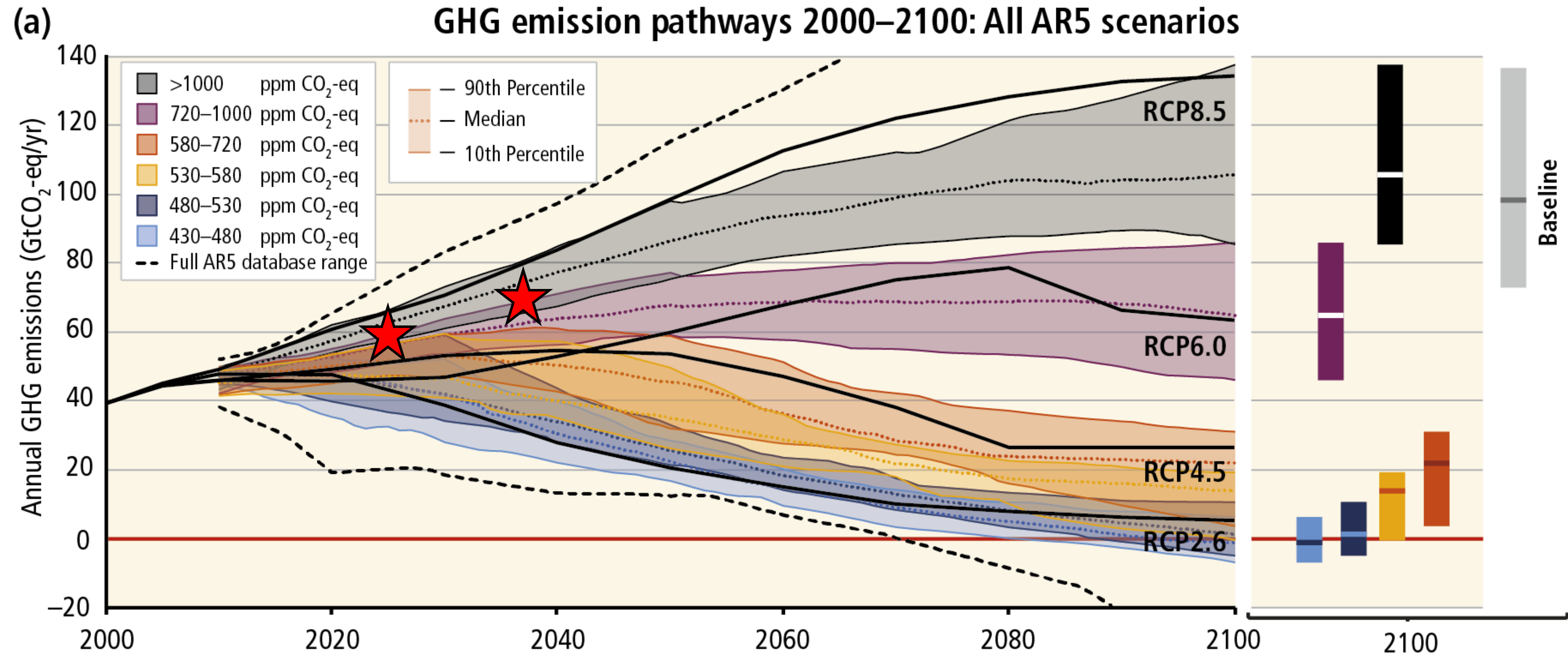


# Potential Future Weather Changes





# Potential Future Weather Changes



Intergovernmental Panel on Climate Change, Fifth Assessment Report. 2014

Resilient Adaptation of Sustainable Buildings Center for Sustainable Building Research  
University of Minnesota May 2018

# Potential Future Weather Changes

Strategy	Hours: Actual and Percentage					
	Now		2030		2040	
Comfort	942	11%	885	10%	936	11%
Sun Shading of Windows	586	7%	778	9%	817	9%
High Thermal Mass	154	2%	217	2%	240	3%
High Thermal Mass Night Flushed	154	2%	228	3%	256	3%
Direct Evaporative Cooling	109	1%	179	2%	198	2%
Two-Stage Evaporative Cooling	111	1%	192	2%	216	2%
Natural Ventilation Cooling	104	1%	162	2%	170	2%
Fan-Forced Ventilation Cooling	72	1%	104	1%	106	1%
Internal Heat Gain	1589	18%	1353	15%	1361	16%
Passive Solar Direct Gain Low Mass	899	10%	826	9%	796	9%
Passive Solar Direct Gain High Mass	624	7%	559	6%	539	6%
Wind Protection of Outdoor Spaces	259	3%	254	3%	249	3%
Humidification Only	0	0%	0	0%	0	0%
Dehumidification Only	491	6%	659	8%	692	8%
Cooling, add dehumidification if needed	305	3%	549	6%	604	7%
Heating, add humidification if needed	4791	55%	4545	52%	4436	51%

*Predicted Effectiveness of Comfort Strategies for Minneapolis / Saint Paul – Climate Consultant, UCLA Energy Design Tools Group*





# Potential Future Weather Changes

Strategy	Hours: Actual and Percentage					
	Now		2030		2040	
Comfort	942	11%	885	10%	936	11%
Sun Shading of Windows	586	7%	778	9%	817	9%
High Thermal Mass	154	2%	217	2%	240	3%
High Thermal Mass Night Flushed	154	2%	228	3%	256	3%
Direct Evaporative Cooling	109	1%	179	2%	198	2%
Two-Stage Evaporative Cooling	111	1%	192	2%	216	2%
Natural Ventilation Cooling	104	1%	162	2%	170	2%
Fan-Forced Ventilation Cooling	72	1%	104	1%	106	1%
Internal Heat Gain	1589	18%	1353	15%	1361	16%
Passive Solar Direct Gain Low Mass	899	10%	826	9%	796	9%
Passive Solar Direct Gain High Mass	624	7%	559	6%	539	6%
Wind Protection of Outdoor Spaces	259	3%	254	3%	249	3%
Humidification Only	0	0%	0	0%	0	0%
Dehumidification Only	491	6%	659	8%	692	8%
Cooling, add dehumidification if needed	305	3%	549	6%	604	7%
Heating, add humidification if needed	4791	55%	4545	52%	4436	51%

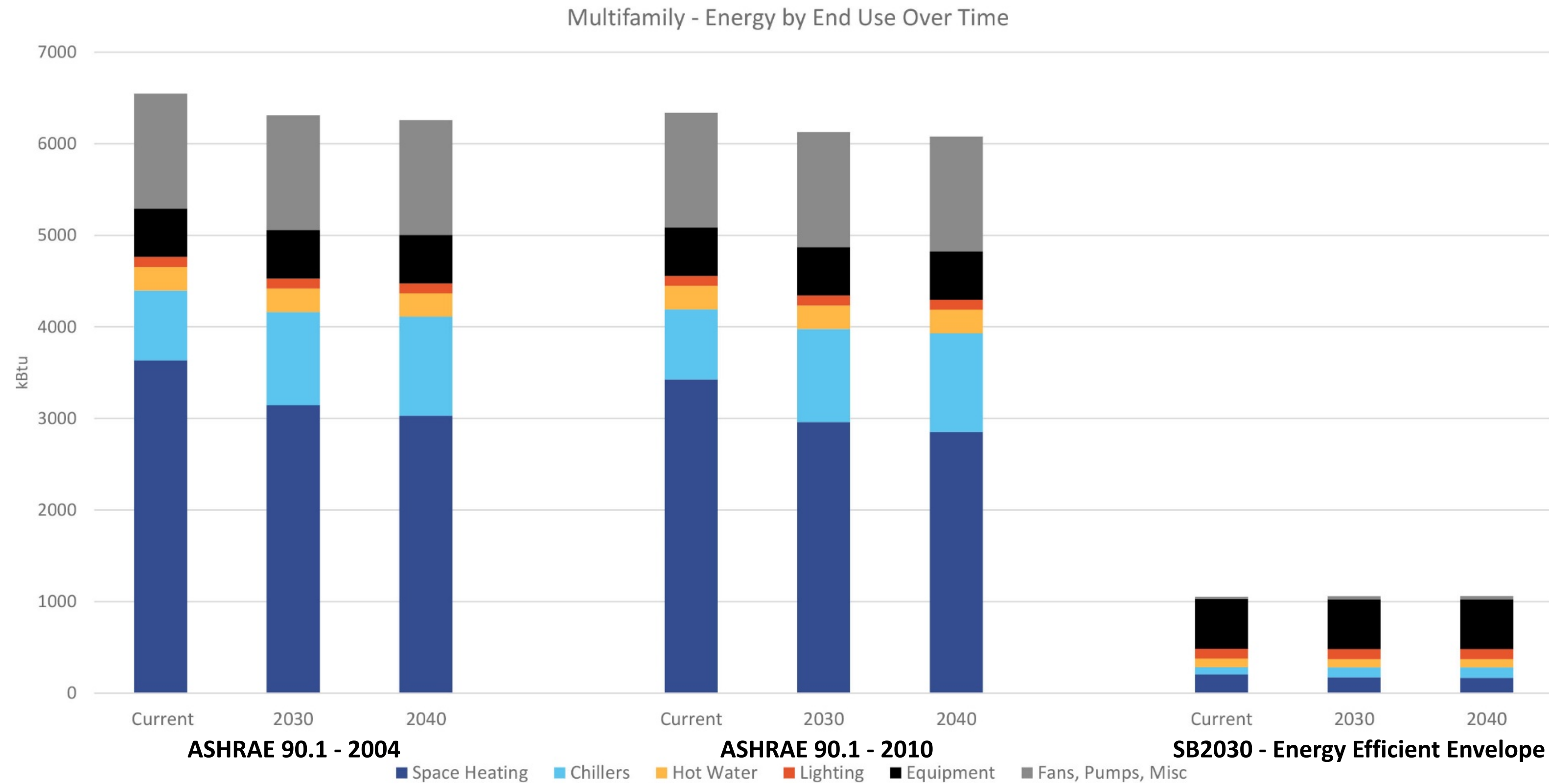
*Predicted Effectiveness of Comfort Strategies for Minneapolis / Saint Paul – Climate Consultant, UCLA Energy Design Tools Group*





# Potential Future Weather Changes

- Energy use in code buildings decreases over time
- Increase in cooling load is outweighed by decrease in heating loads
- Energy use in high performing buildings stable over time





# Needed Research

- Downscaling of Global Weather Data to Minnesota
- Application of Weather Data to Design and Operations
- Impact of Changing Climate of Energy Efficiency and Design
- Impact of Changing Climate on Site and Water Design
- Assessment of Additional Risks and Impacts
- Other?