

# Minnesota's Climate at the End of the 21<sup>st</sup> Century

Dr. Tracy E Twine, Associate Professor  
Department of Soil, Water, and Climate

April 25, 2022



UNIVERSITY OF MINNESOTA  
**Driven to Discover®**

# Minnesota is getting warmer and wetter



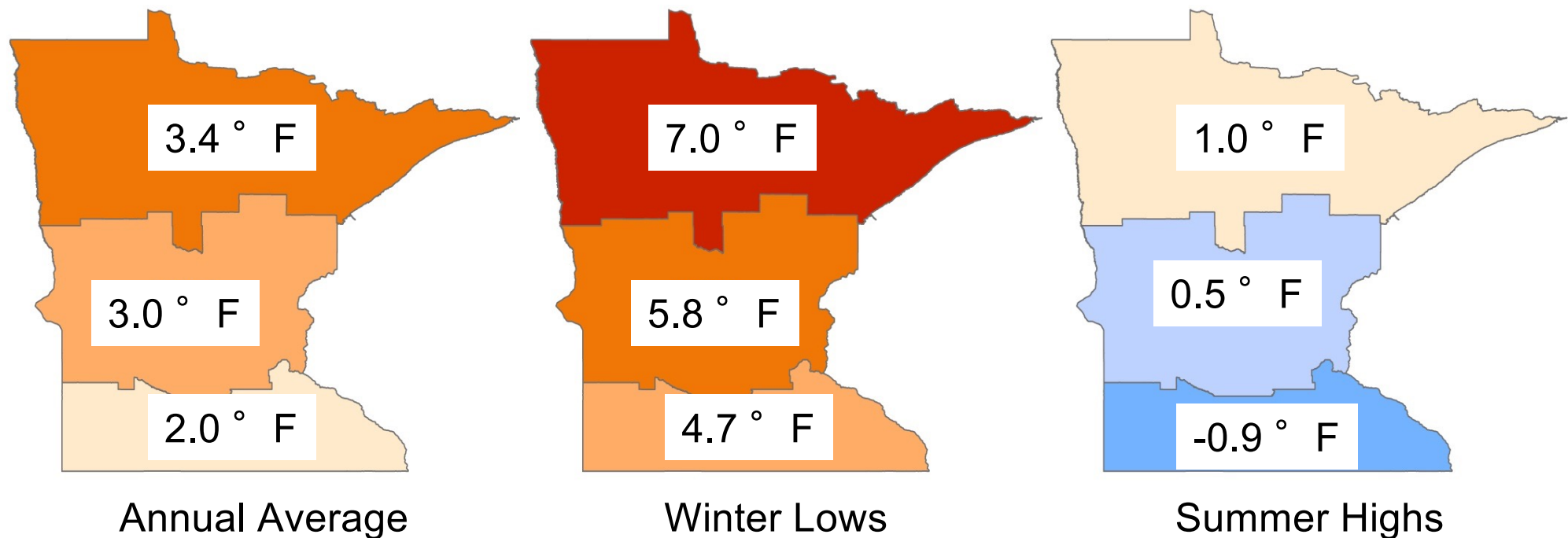
USGS April 18, 1997

NWS August 2007



# Warming has been mainly a winter phenomenon

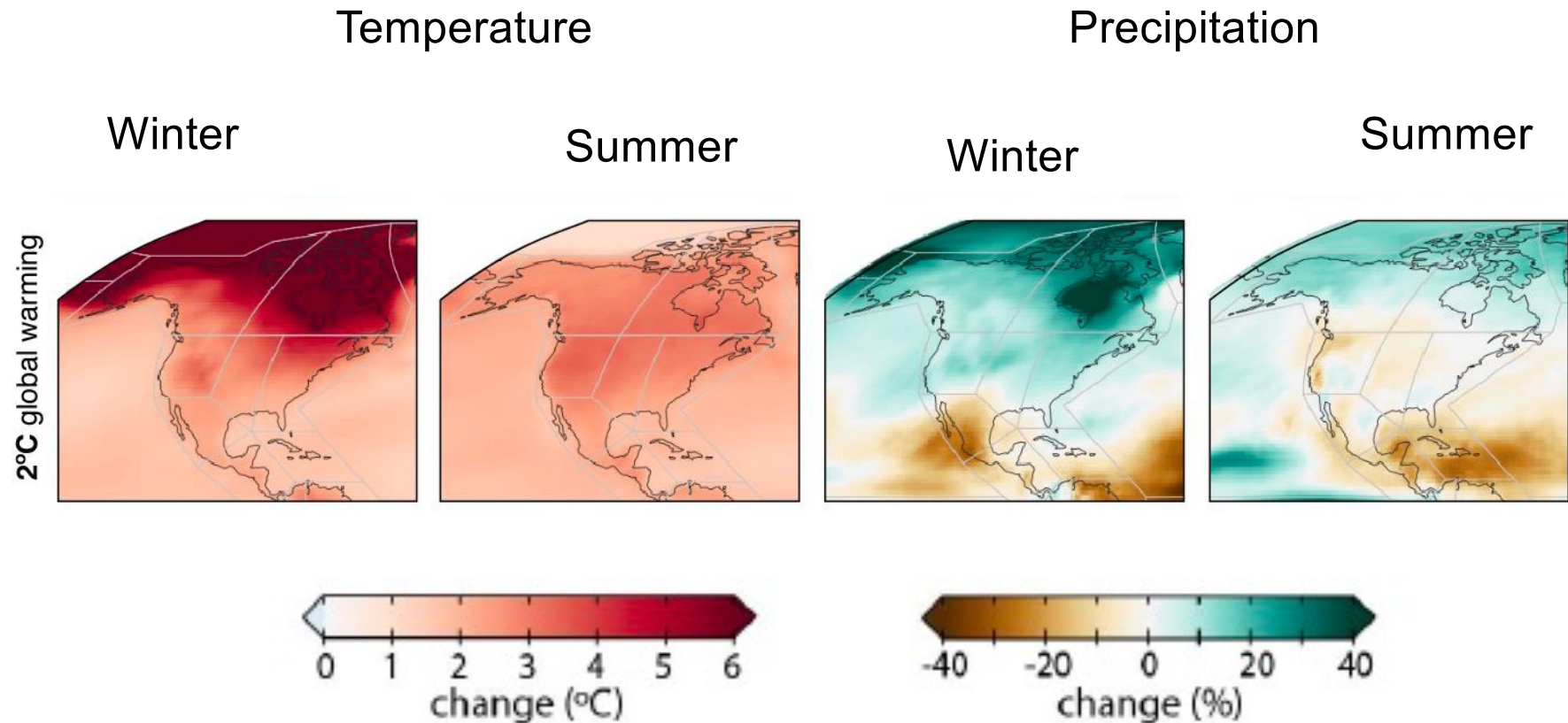
## Total temperature change, 1895-2019



Slide: Dr. Kenny Blumenfeld, MN DNR State  
Climatology Office, data from [ncei.noaa.gov](http://ncei.noaa.gov)



# Climate Models project these trends to continue



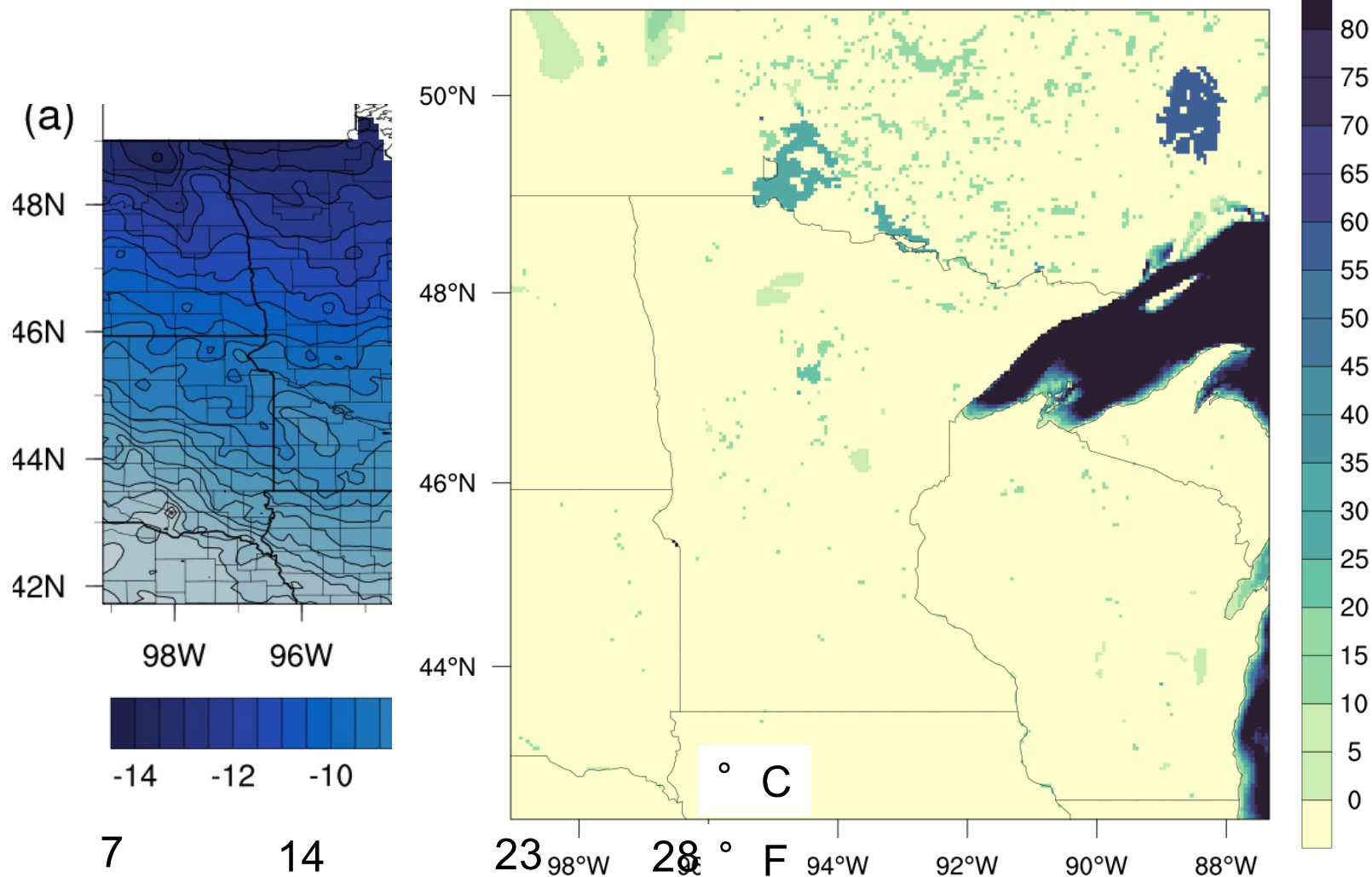
Change from 1850-1900 average

Slide: IPCC AR6 Working Group I



# But when? Where? How often?

Lake Depth in meters



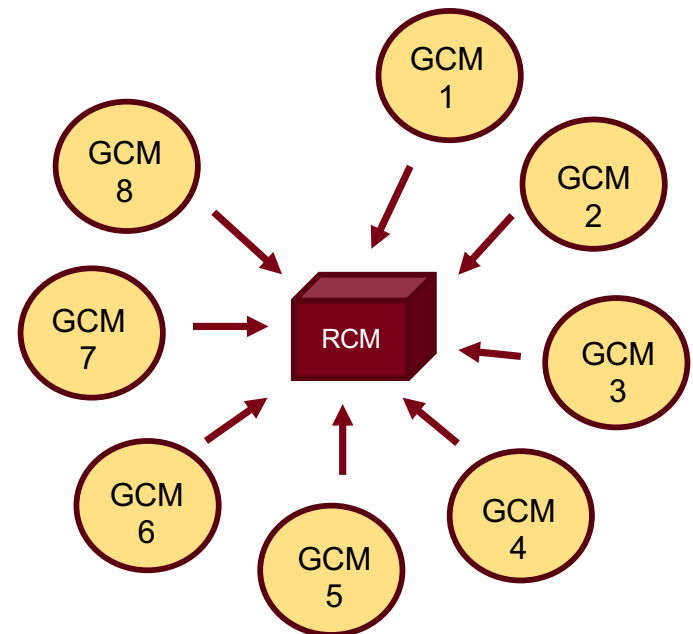
Liess et al. 2022



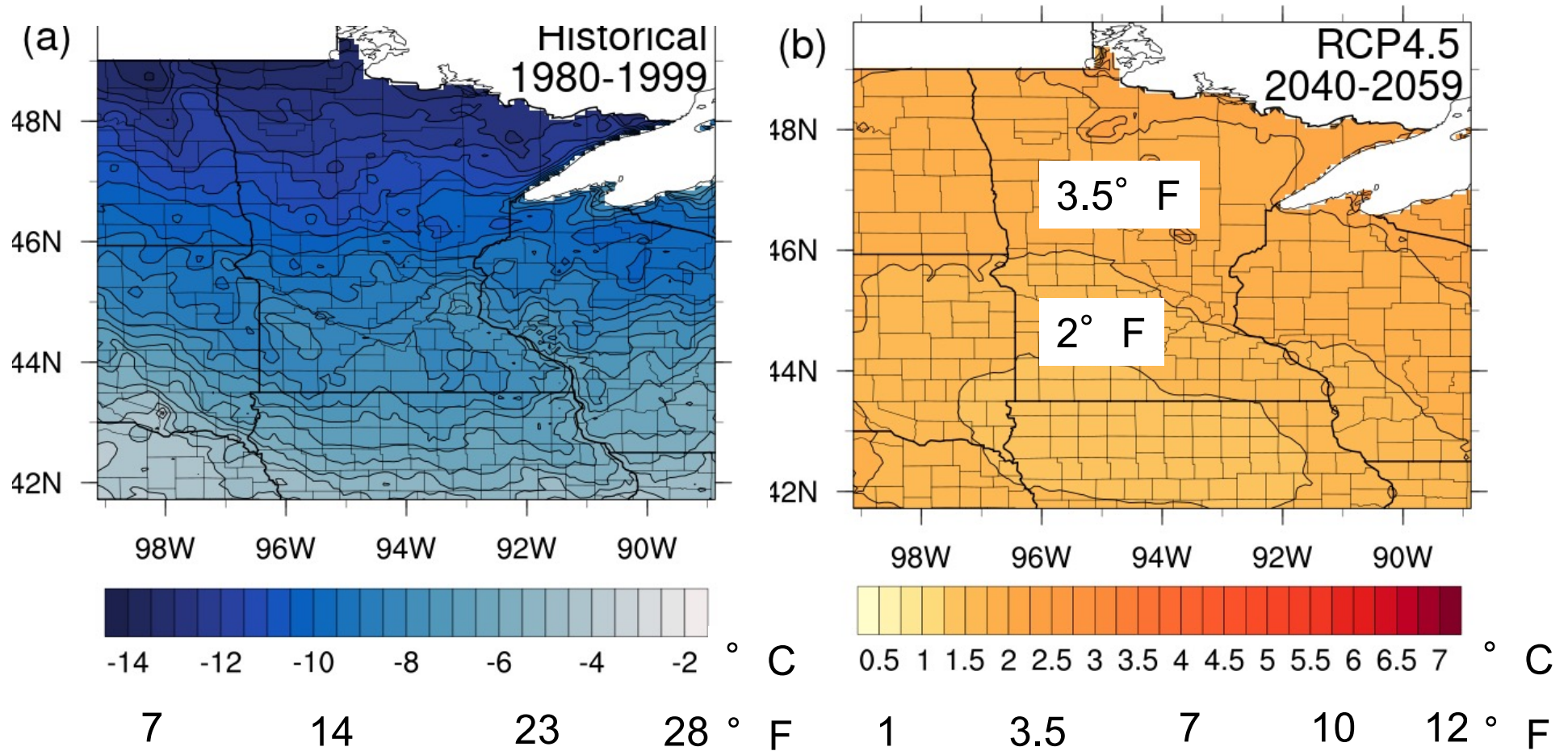


# Dynamically downscaled data across Minnesota

- Use 8 global models in the Weather Research & Forecast (WRF) regional model at 10 km
- Use historic observations to bias-adjust WRF output



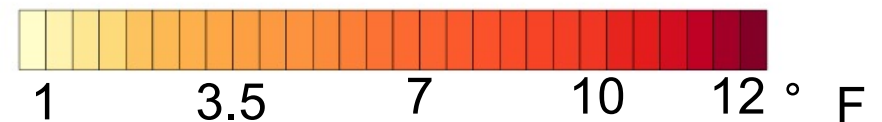
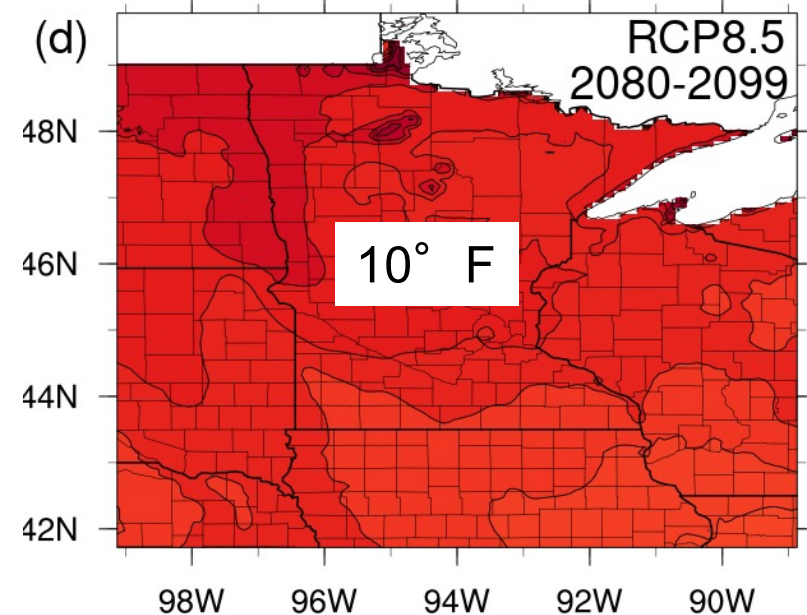
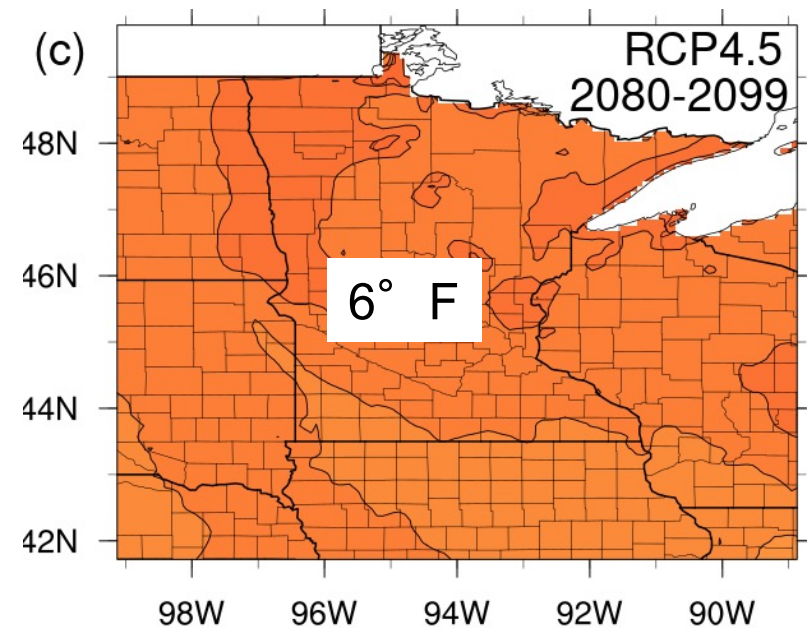
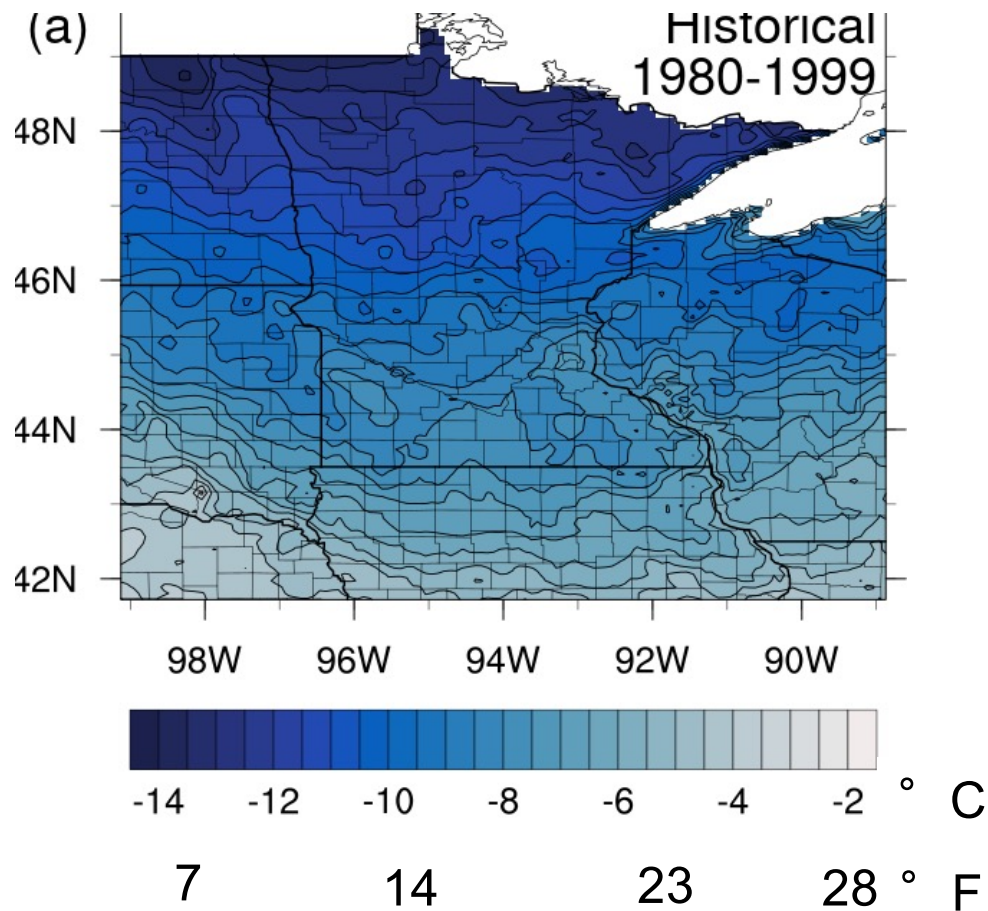
# Winter Warming at Mid Century



Liess et al. 2022;  $p < 0.05$



# Winter Warming at End Century

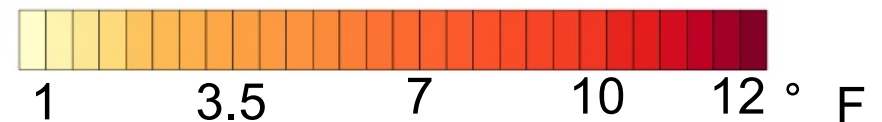
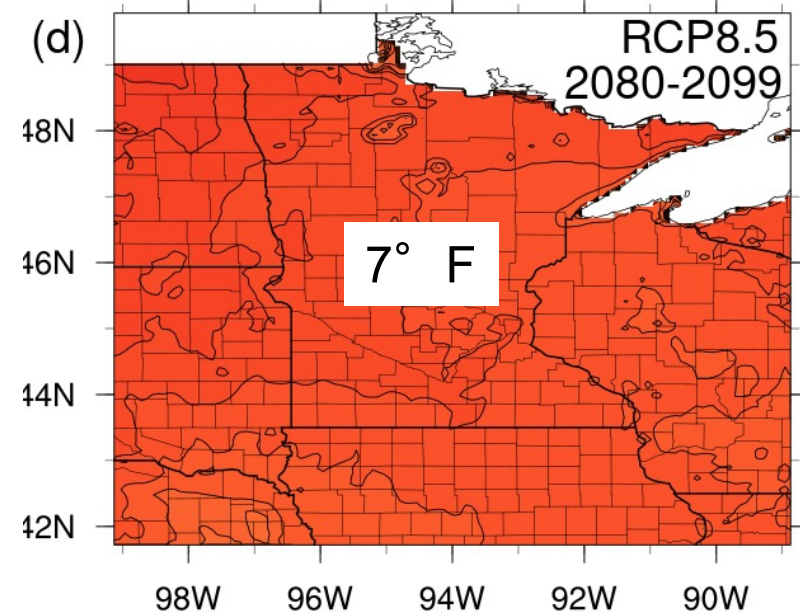
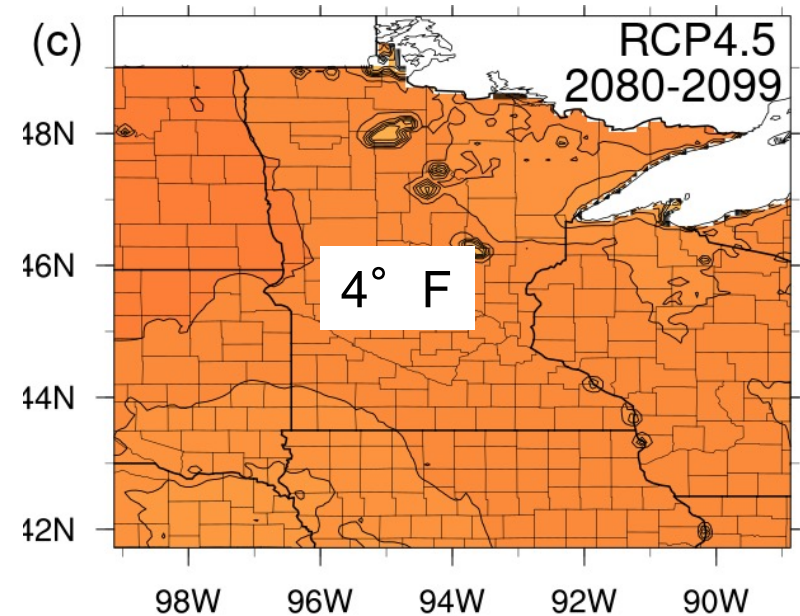
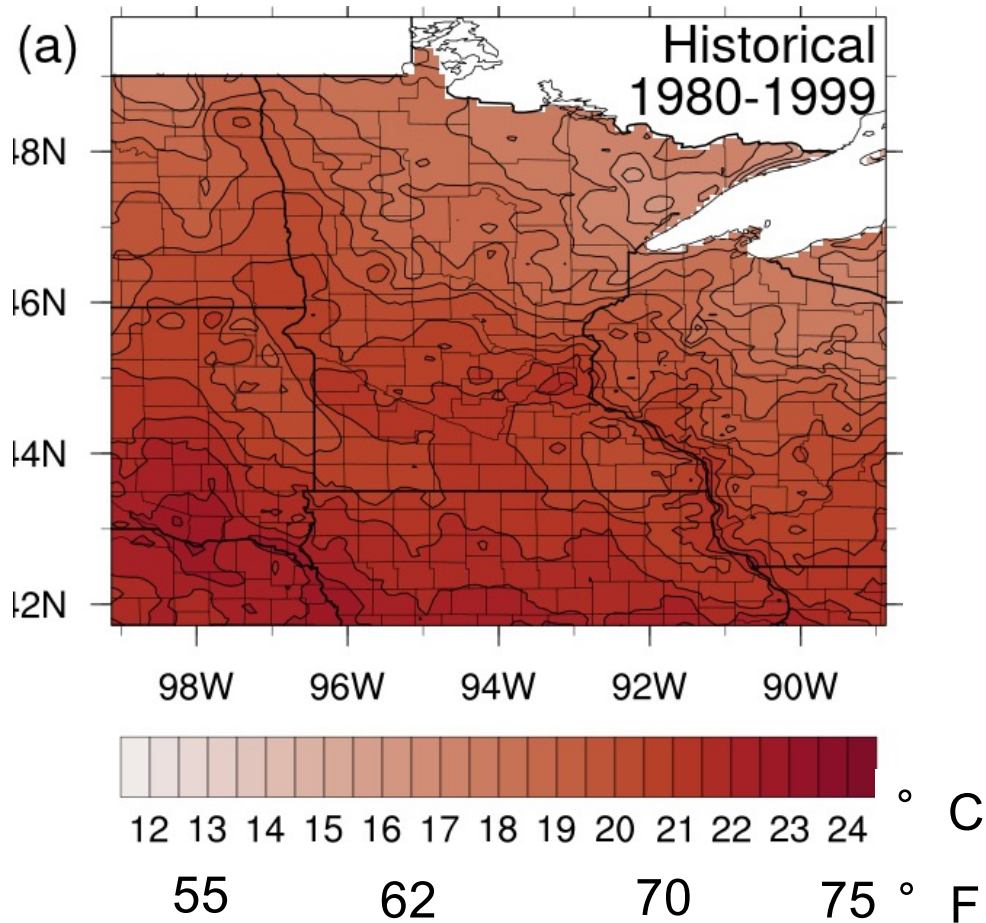


Liess et al. 2022;  $p < 0.05$





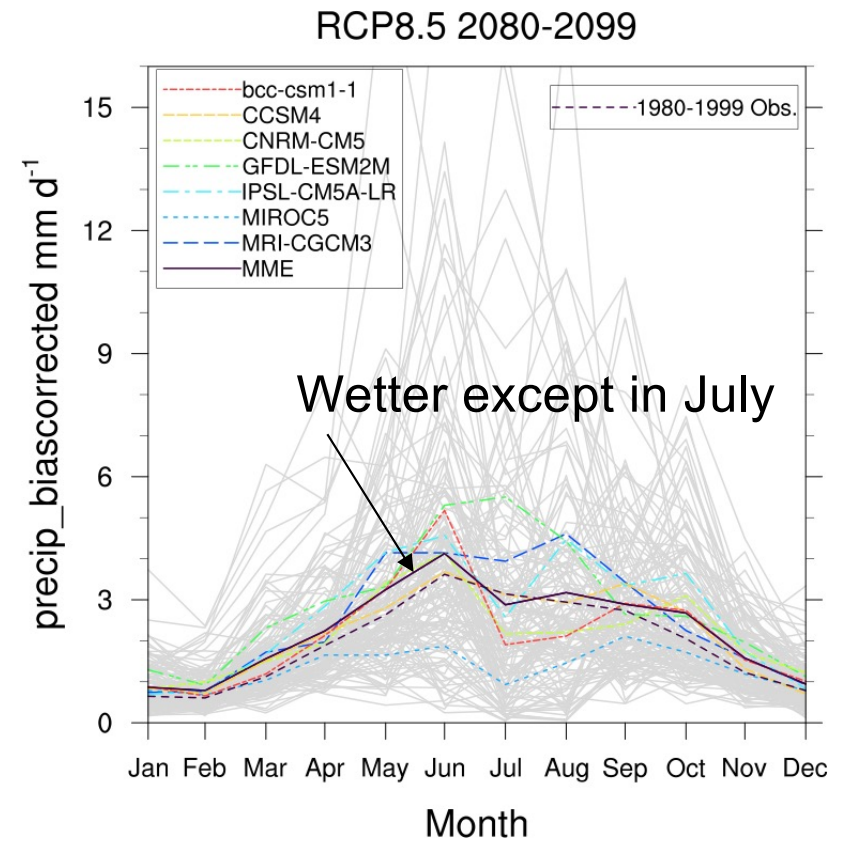
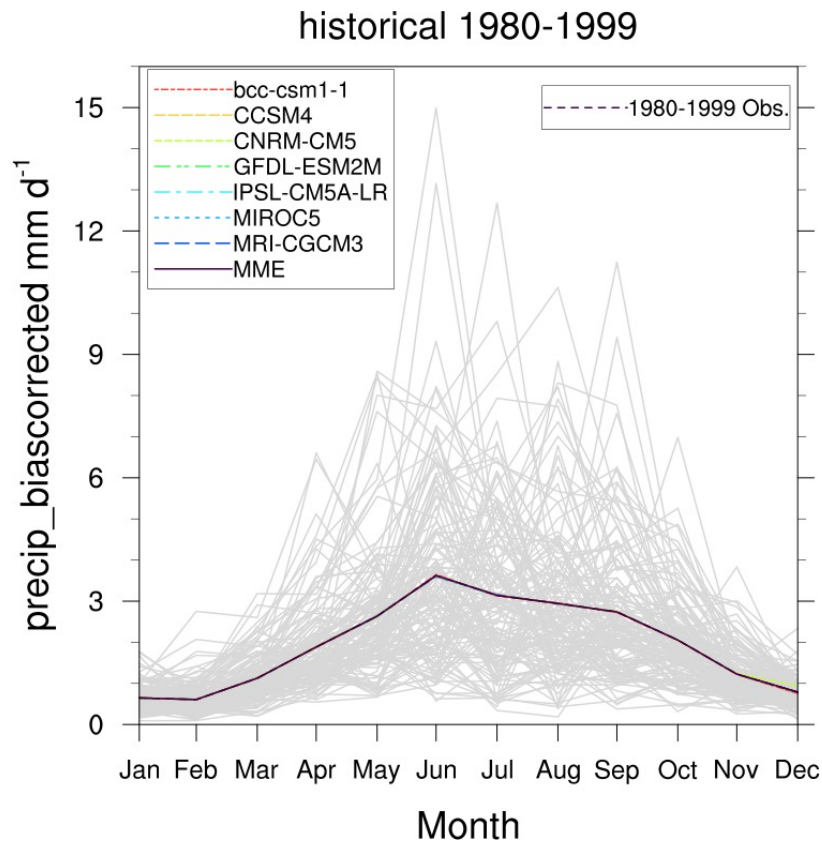
# Summer Warming at End Century



Liess et al. 2022;  $p < 0.05$



# Projected Precipitation Changes

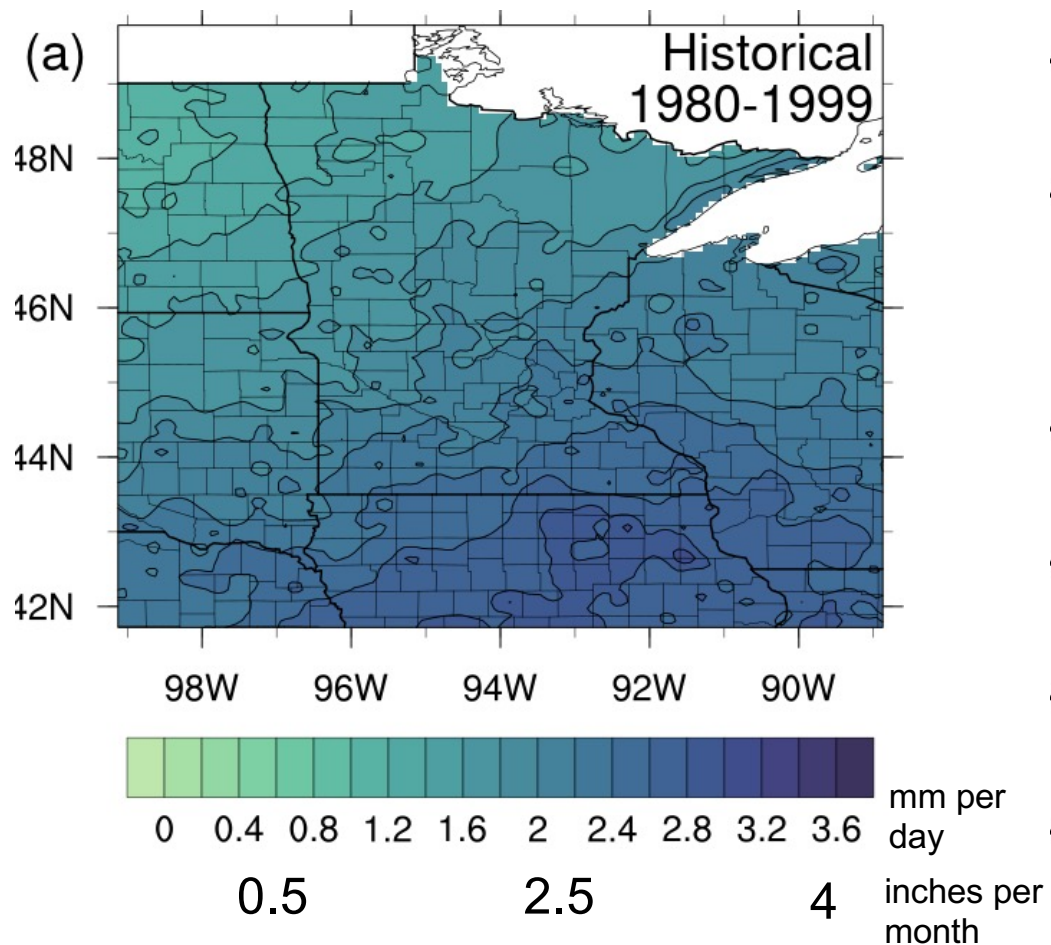


Liess et al. 2022;  $p < 0.05$

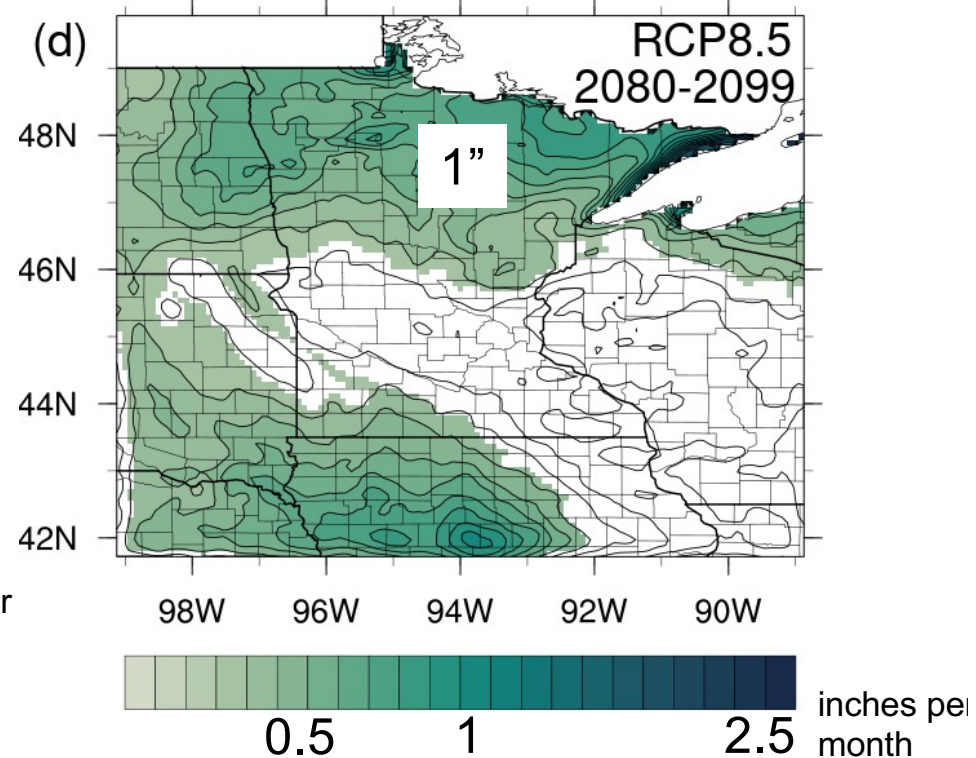
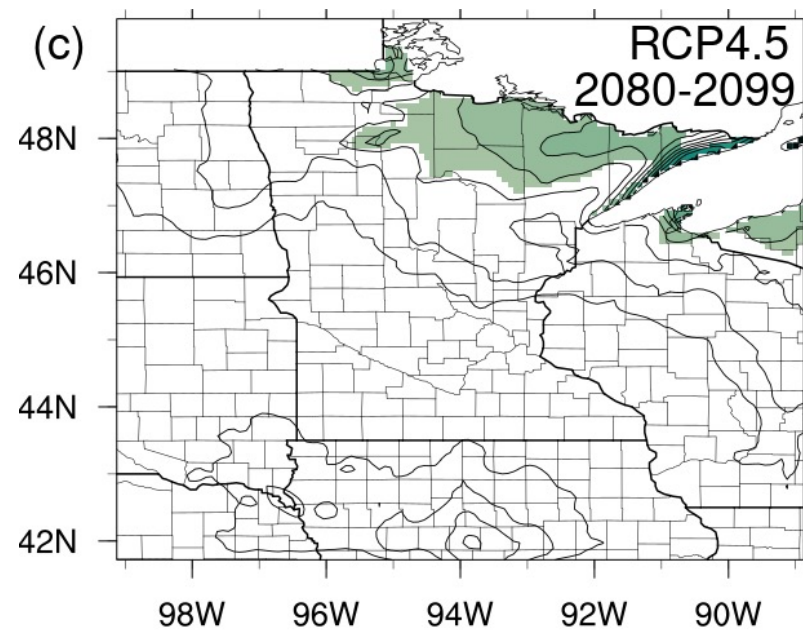




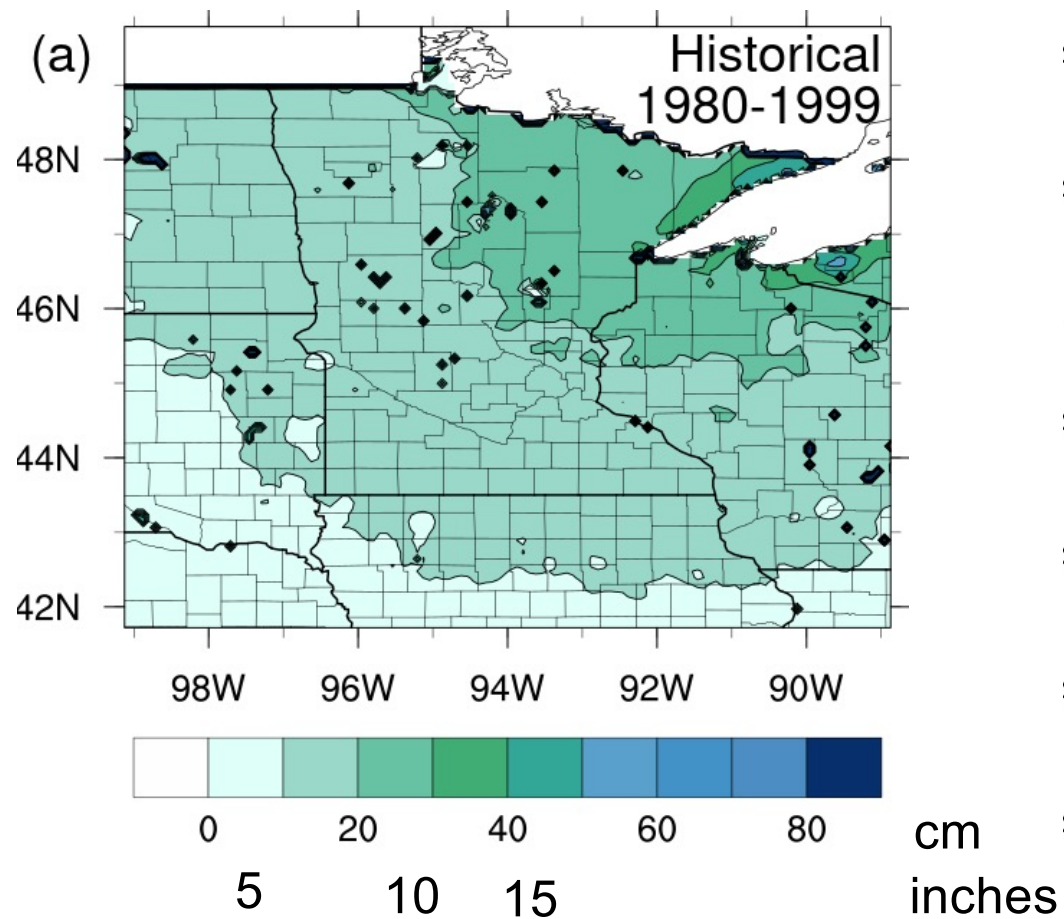
# Spring Precipitation



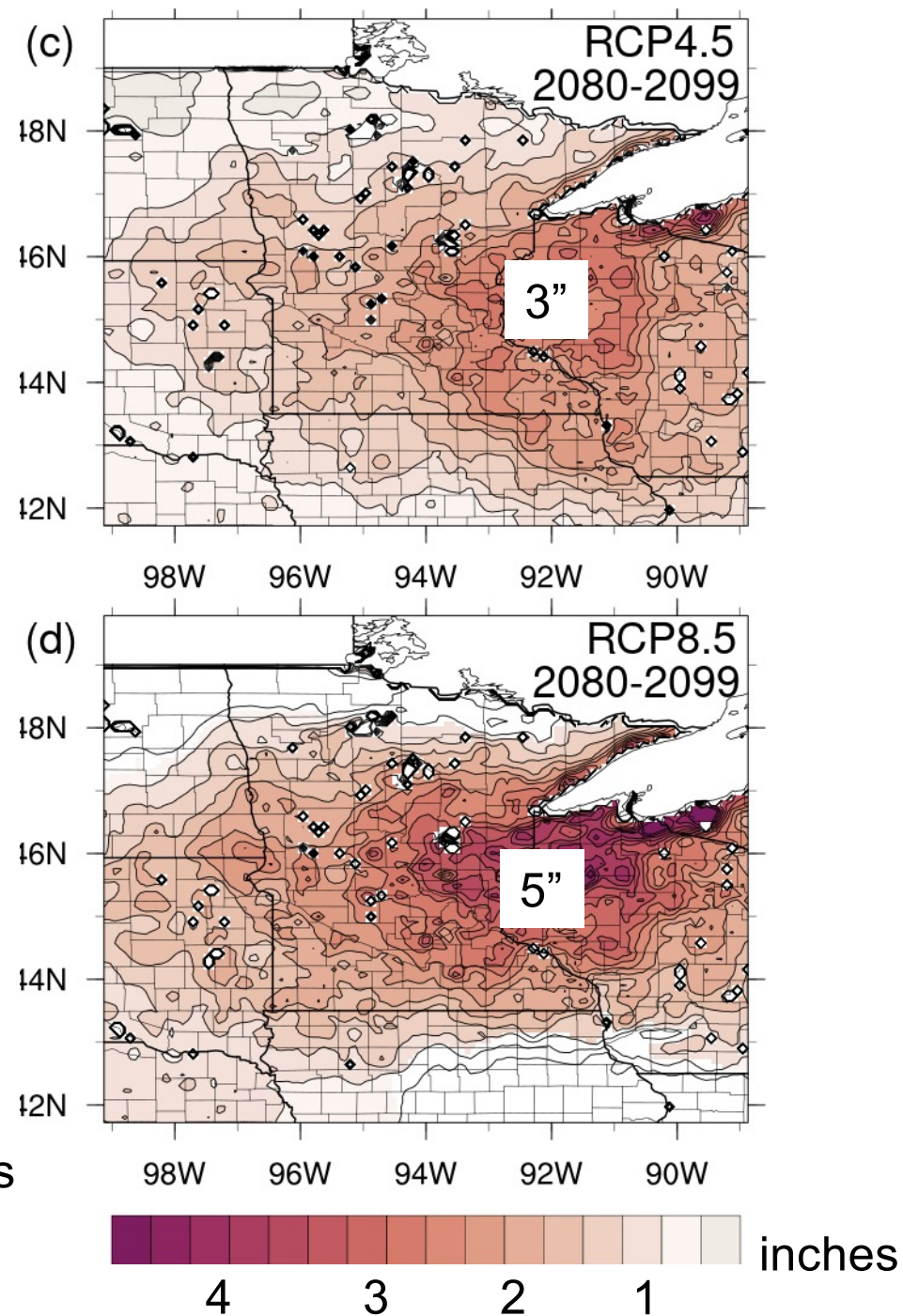
Liess et al. 2022;  $p < 0.05$



# Snow Depth

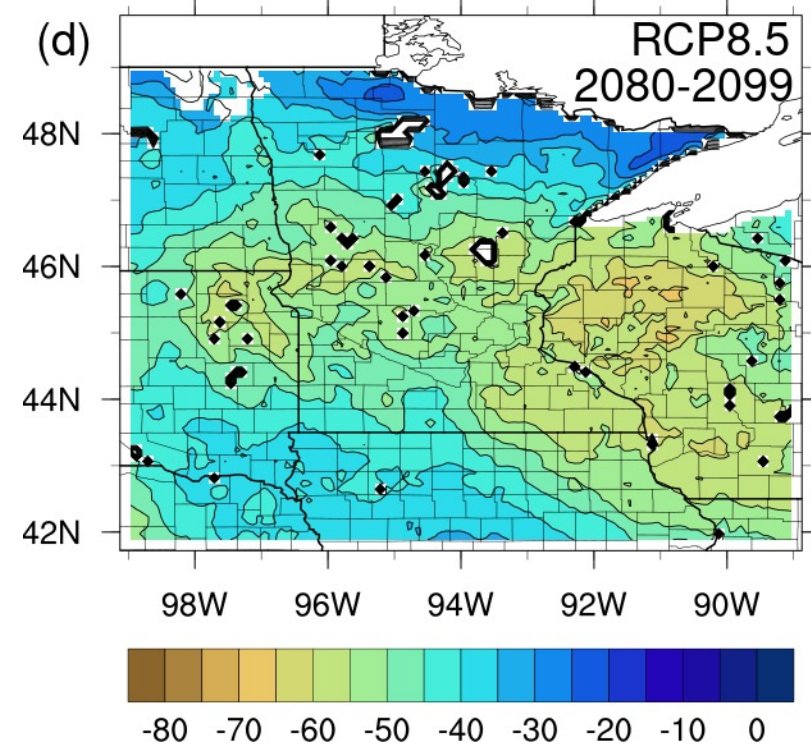
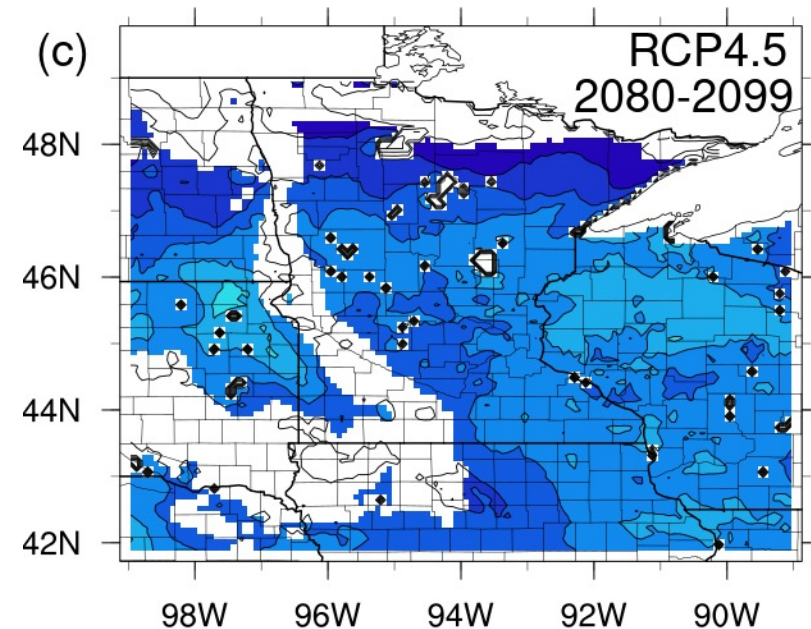
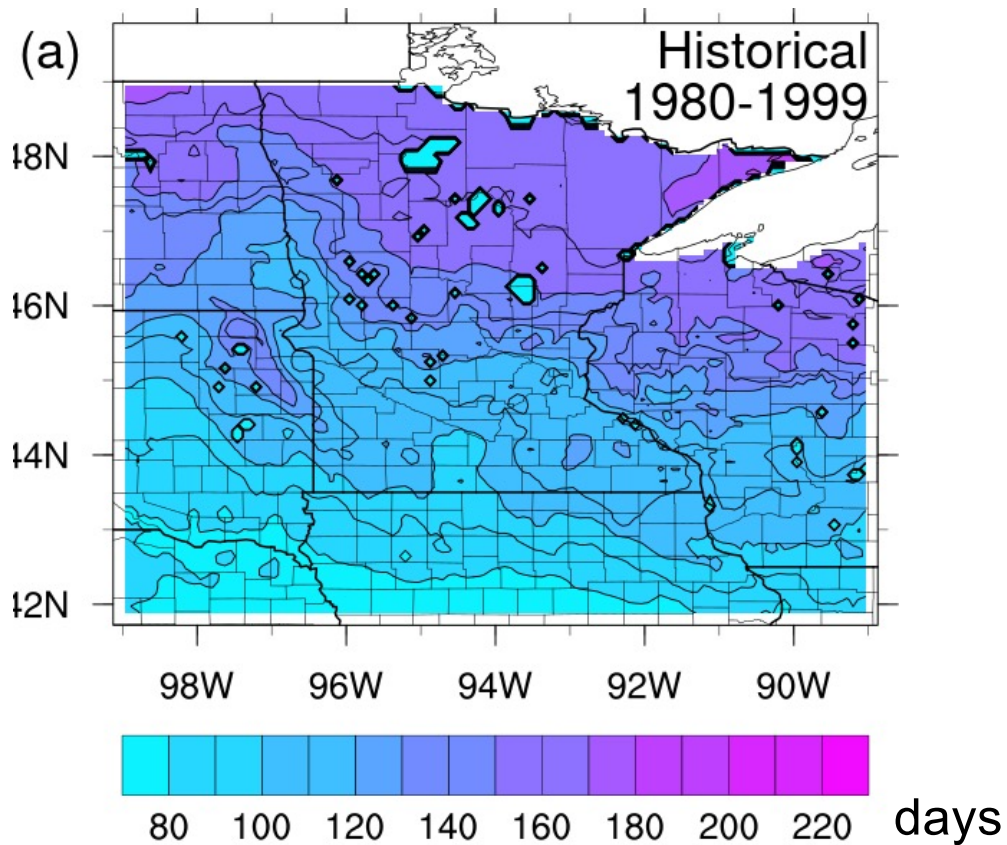


Liess et al. 2022;  $p < 0.05$





# Number of Days with Snow Cover



Liess et al. 2022;  $p < 0.05$



# Conclusions

## **This study:**

- Continued warming in winter
- Increase in summer warming
- Fewer days with snow on ground
- Can be mitigated with reductions in greenhouse gas emissions
- Will need to adapt as well

## **In the works:**

- Updating with CMIP6 data
- Refining with lake modeling
- How to help people use this data?



# Authors of the Study

- Stefan Liess
- Tracy Twine (twine@umn.edu)
- Peter Snyder
- William Hutchison
- Gabriel Konar-Steenberg
- Bonnie Keeler
- Kate Brauman



Thanks to the Minnesota Supercomputing Institute





UNIVERSITY OF MINNESOTA

**Driven to Discover®**

Crookston Duluth Morris Rochester Twin Cities

The University of Minnesota is an equal opportunity educator and employer.