AGU PUBLICATIONS

Supporting Information for

High-resolution Climate Projections over Minnesota for the 21st Century

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Introduction

This supporting information contains a comparison of the original WRF model results and input data from CMIP5 GCMs for 2-m temperature and precipitation to PRISM observations before bias adjustment has been applied (Figures S1 and S2). Furthermore, we show a comparison between the WRF model results and their GCM input data for the spatial analysis of trends for the three future scenarios before bias adjustment has been applied (Figures S3-S6). Linear bias adjustment implies a similar trend (not shown). Separate figures are provided for each season at the 10 x 10 km spatial resolution of the WRF simulations. Dotted areas indicate that the difference between the compared values is not statistically significant based on the 95% confidence interval obtained by a t-test. The artificially high level of detail in the GCM analysis is due to the overlapping grid resolutions of the GCMs, not due to the physics of small-scale features like lakes. The area-average of the monthly adjustment factor for snow depth is also provided as comparison between GCM and WRF output data (Figure S7).

The main text includes the time series of absolute 2-m temperature and precipitation area averages. Here we add the anomalies to the historical mean values and their standard deviations for 2-m temperature, precipitation, and snow depth for greater visibility of the trends between the scenarios (Figures S8-S10).

Temperature trends analogous to Figures 5 and 6, but separated by GCM input show the importance of an MME approach (Figures S11-S12). Precipitation trends analogous to Figure 7 but for LOCA projections identify the differences to statistical projections (Figure S13).

Lastly, results for non-adjusted snow depth are added that can be compared to the bias adjusted version in Figures 8, 9, and S10, respectively (Figures S14-S16).

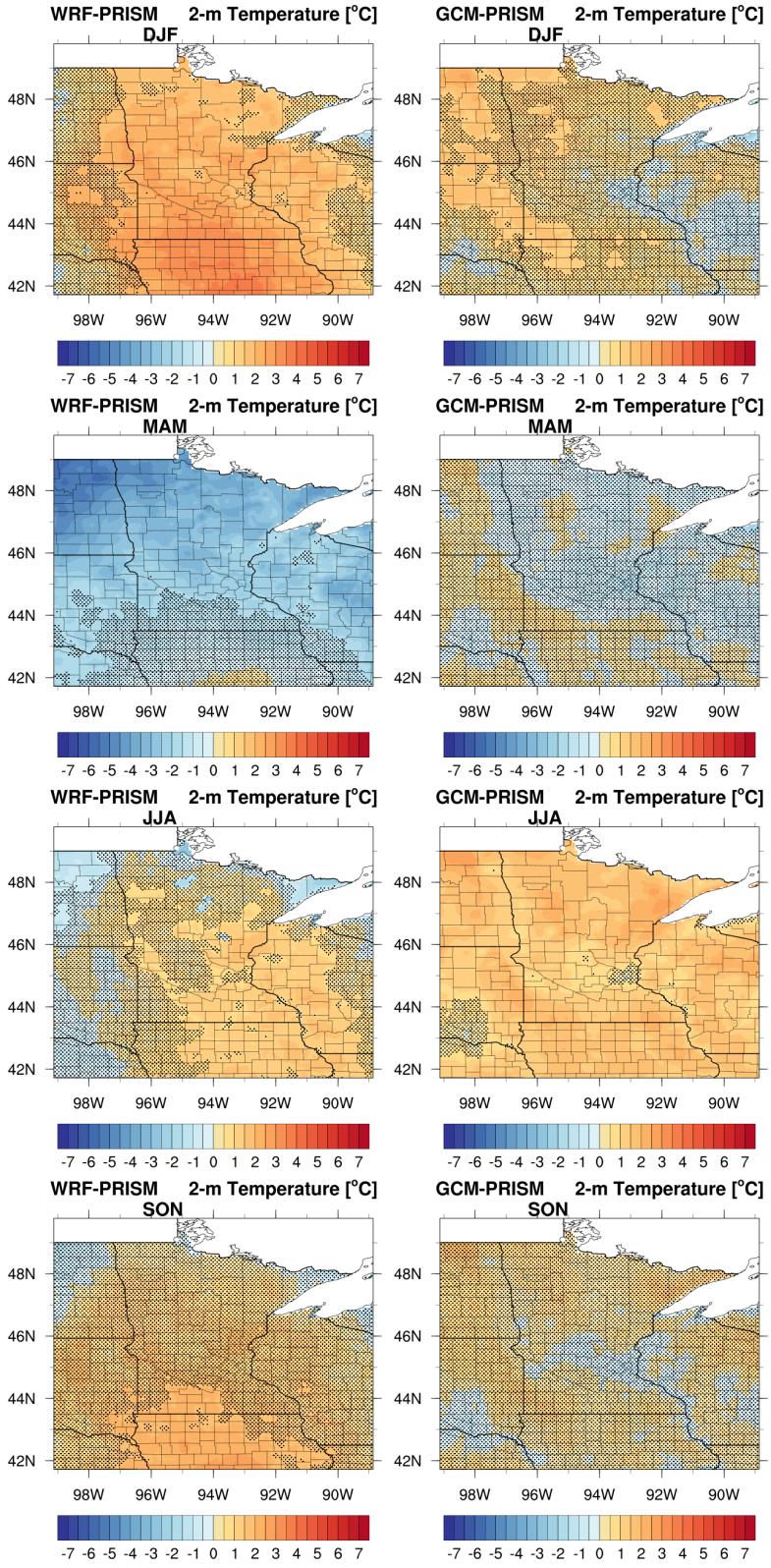


Figure S1. Difference in 2-m temperature between (left) historical WRF simulations and PRISM data, and (right) historical GCM input data and PRISM data for all four seasons.

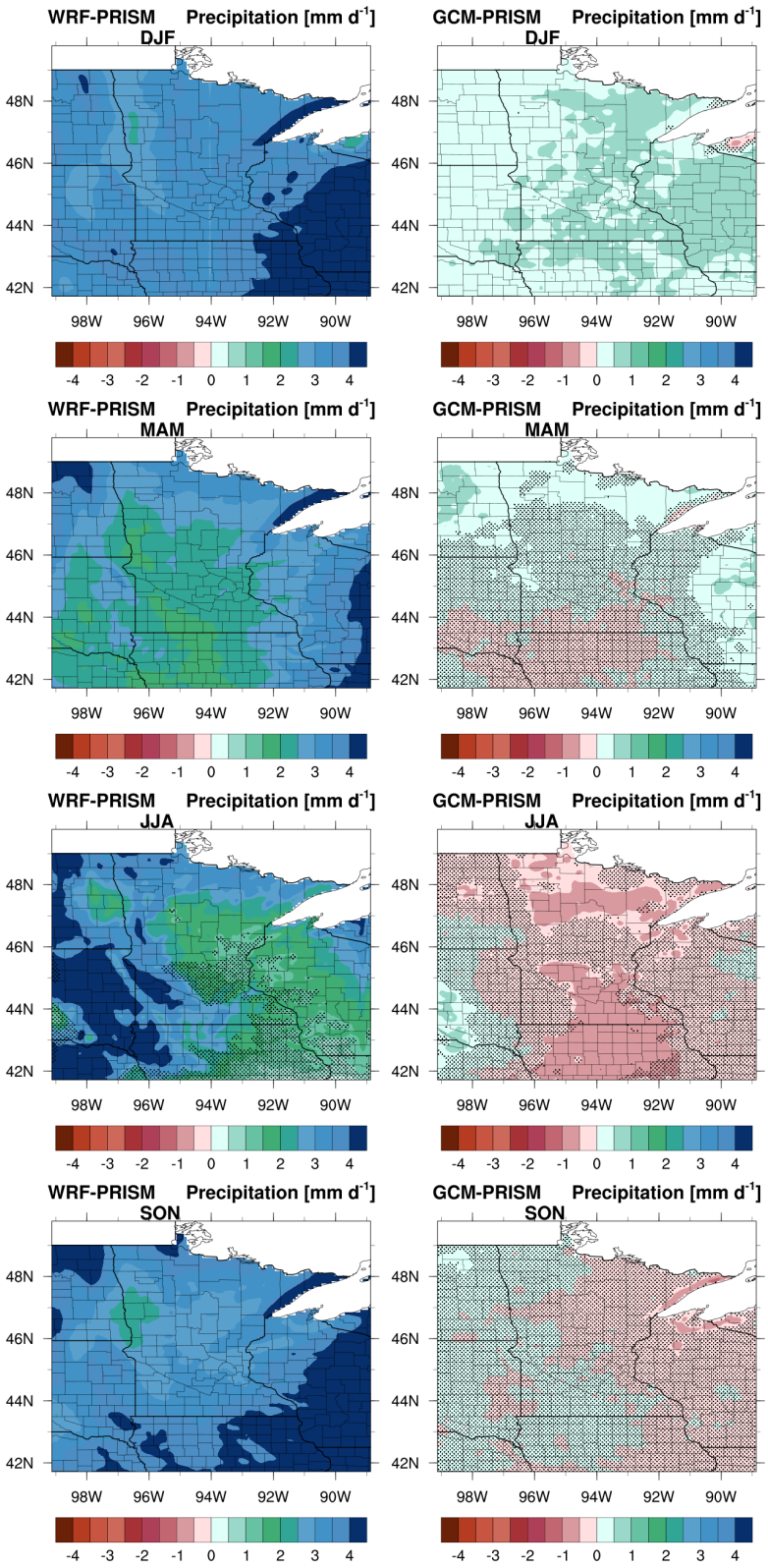


Figure S2. As Figure S1, but for precipitation.

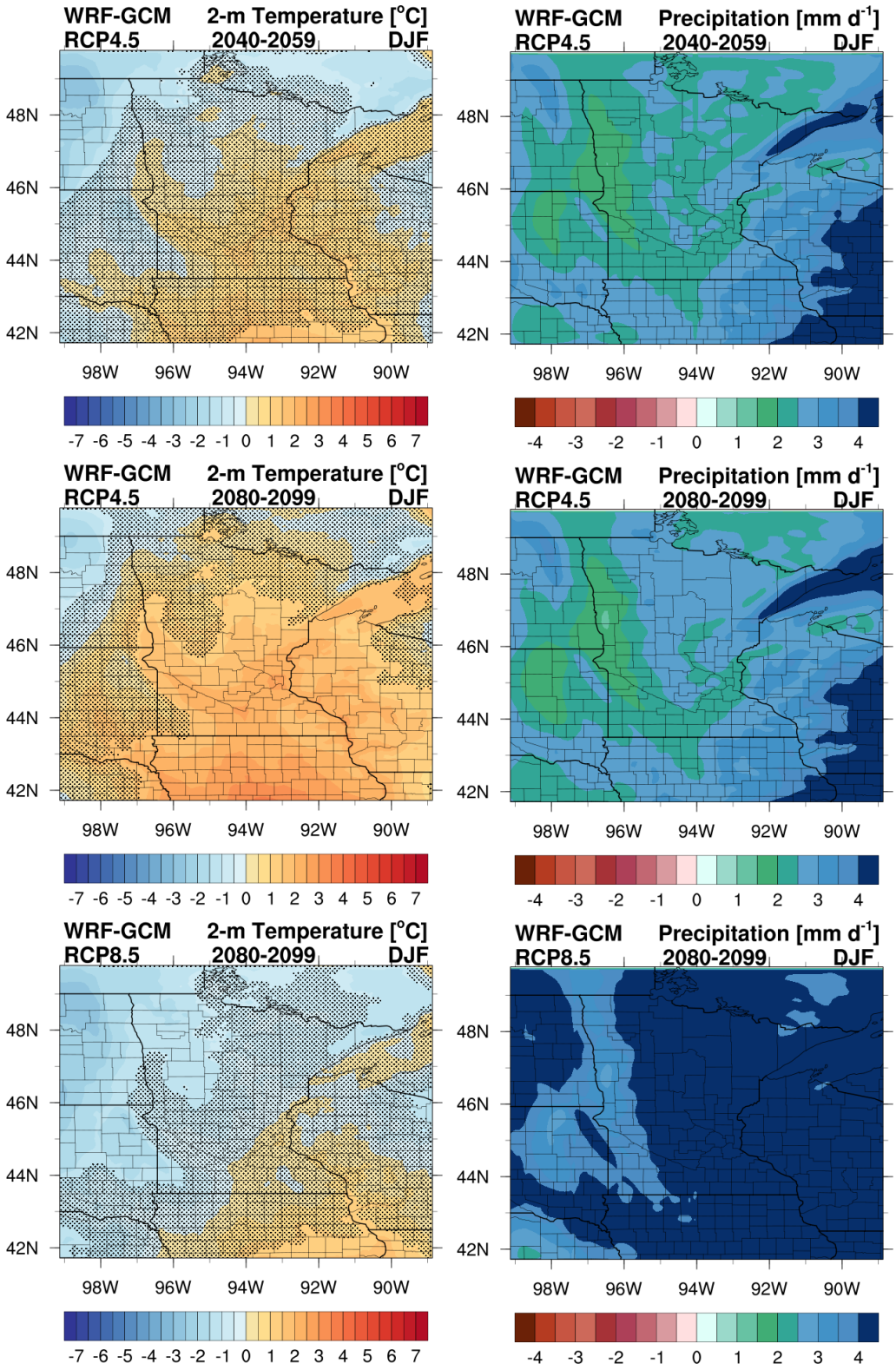


Figure S3. Difference between WRF simulations and GCM input data for the three future scenarios during winter for (left) 2-m temperature and (right) precipitation.

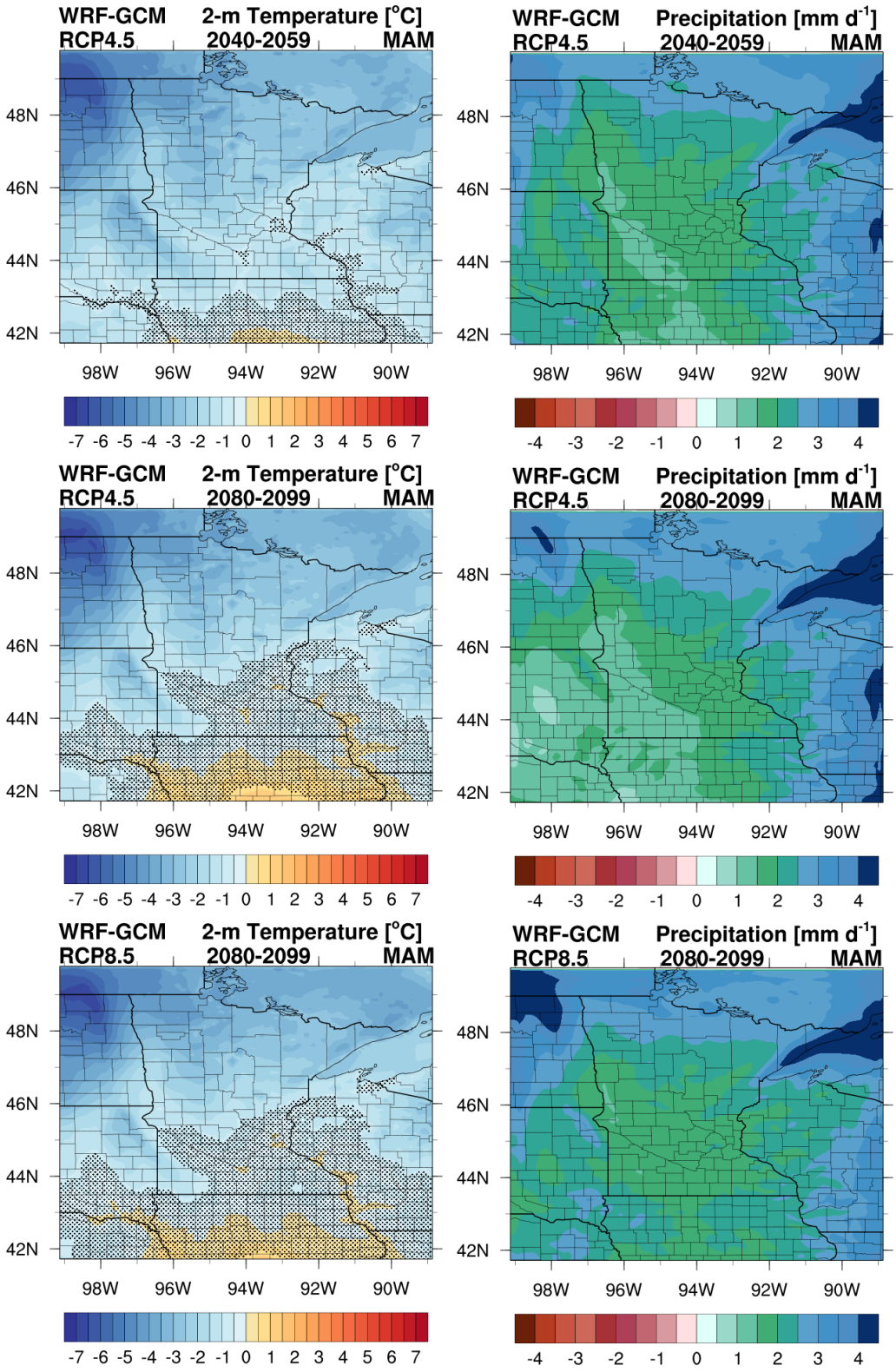


Figure S4. As Figure S3, but for spring.

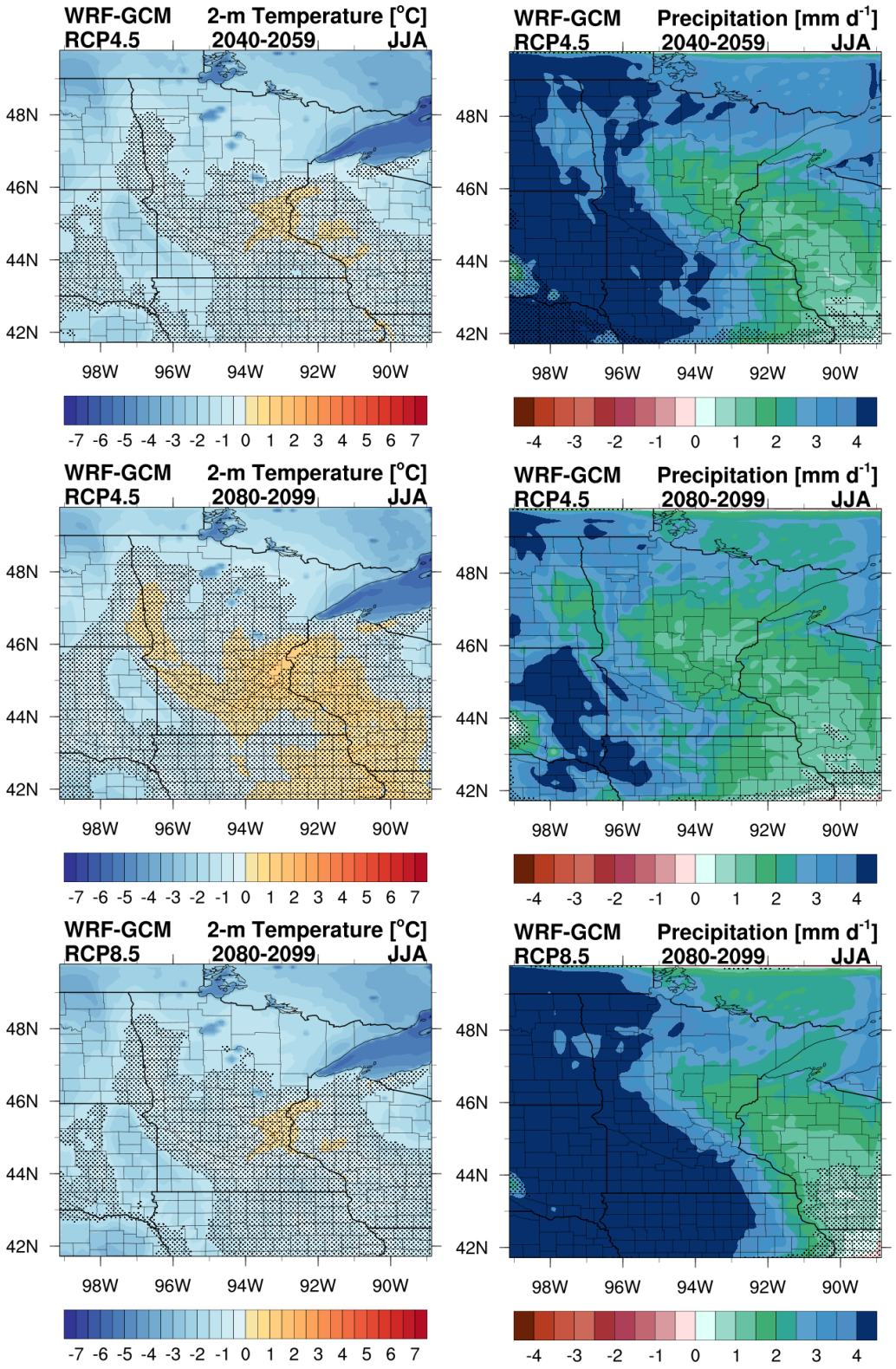


Figure S5. As Figure S3, but for summer.

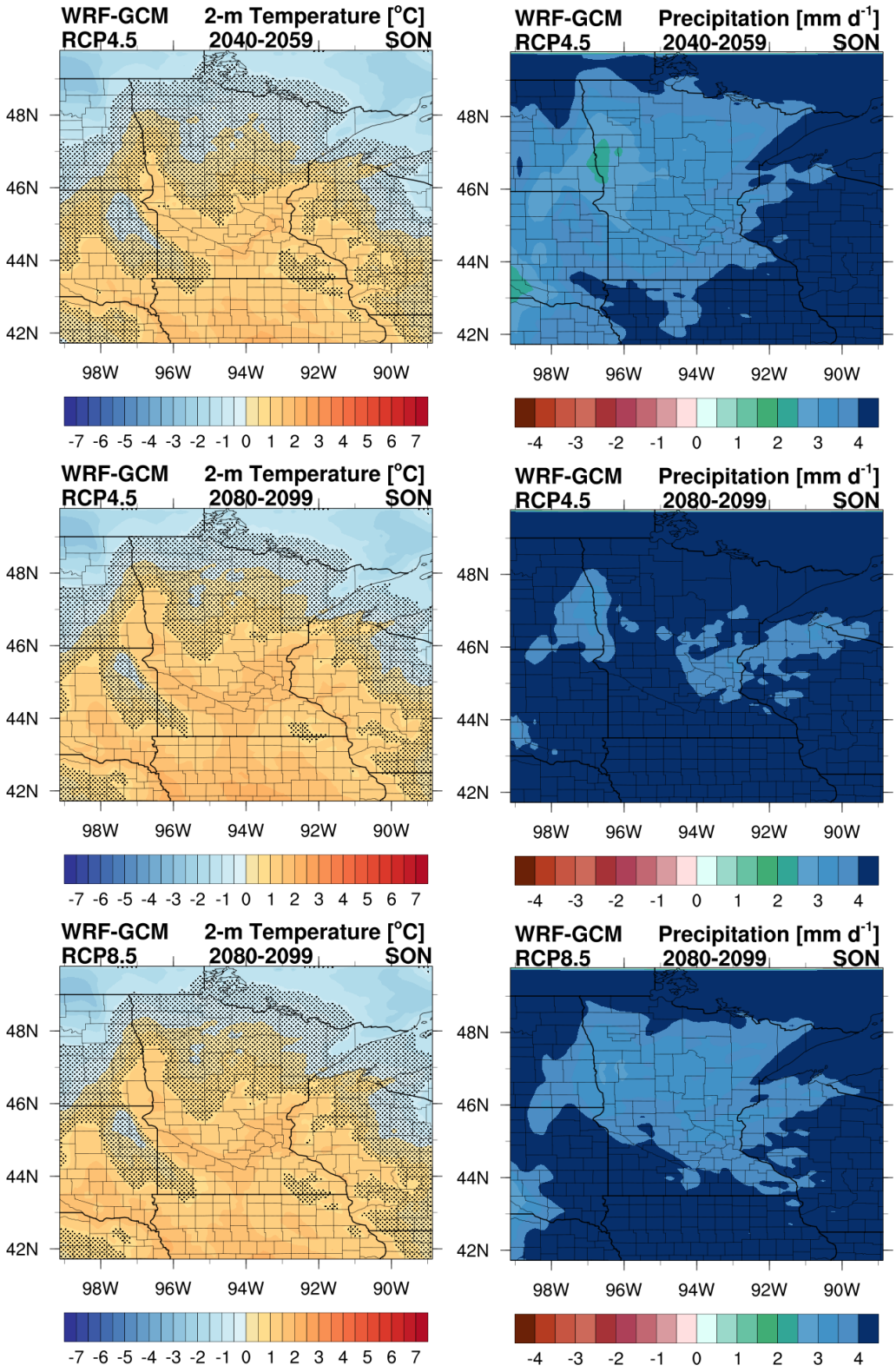


Figure S6. As Figure S3, but for fall.

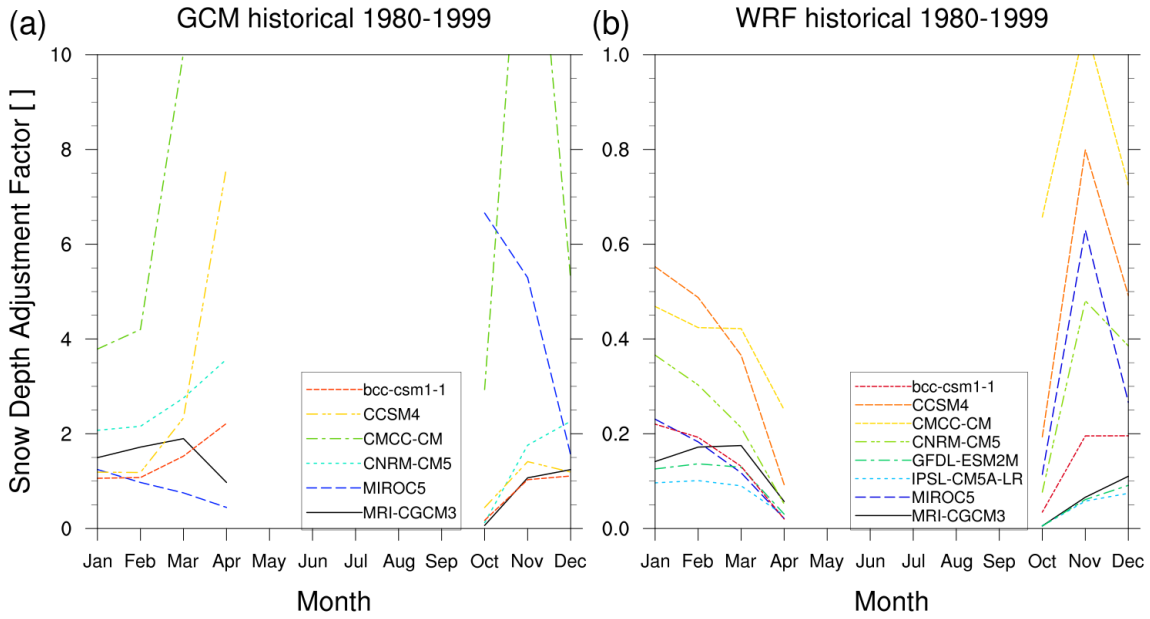


Figure S7. Bias adjustments area-averaged over every grid cell within the state of Minnesota for (a) snow depth difference between GCM runs (where available) and NSIDC, (b) as (a) but for snow depth difference between WRF runs and NSIDC. Please note the different scales in the y-axes.

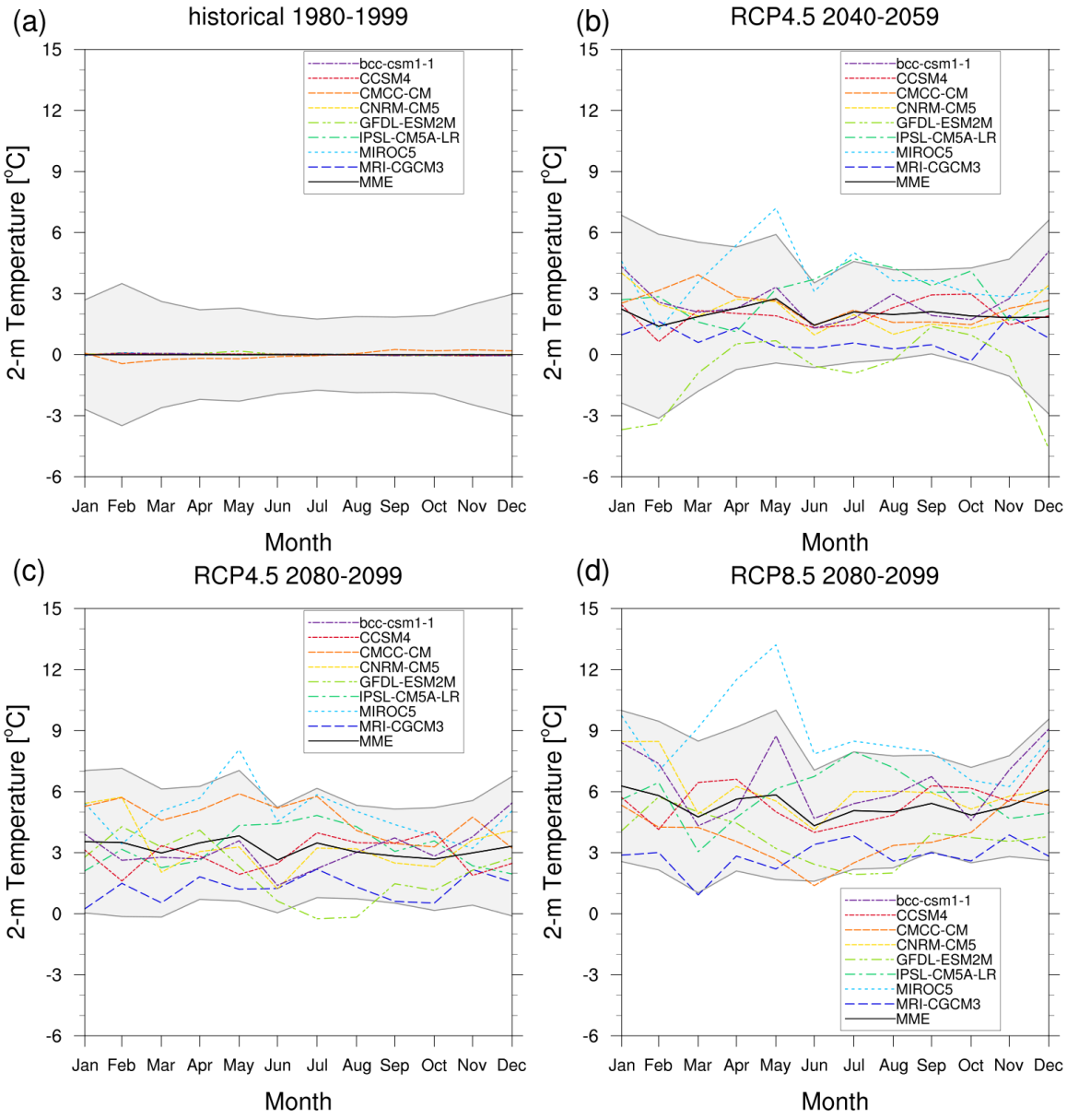


Figure S8. Monthly average 2-meter temperature difference to the historical PRISM record averaged over every grid cell within the state of Minnesota for each WRF-downscaled GCM (colors) and the multi-model mean (MME; black line). Also shown are the standard deviations of all years of the 20-year WRF simulations for all GCMS (160 realizations; gray shading).

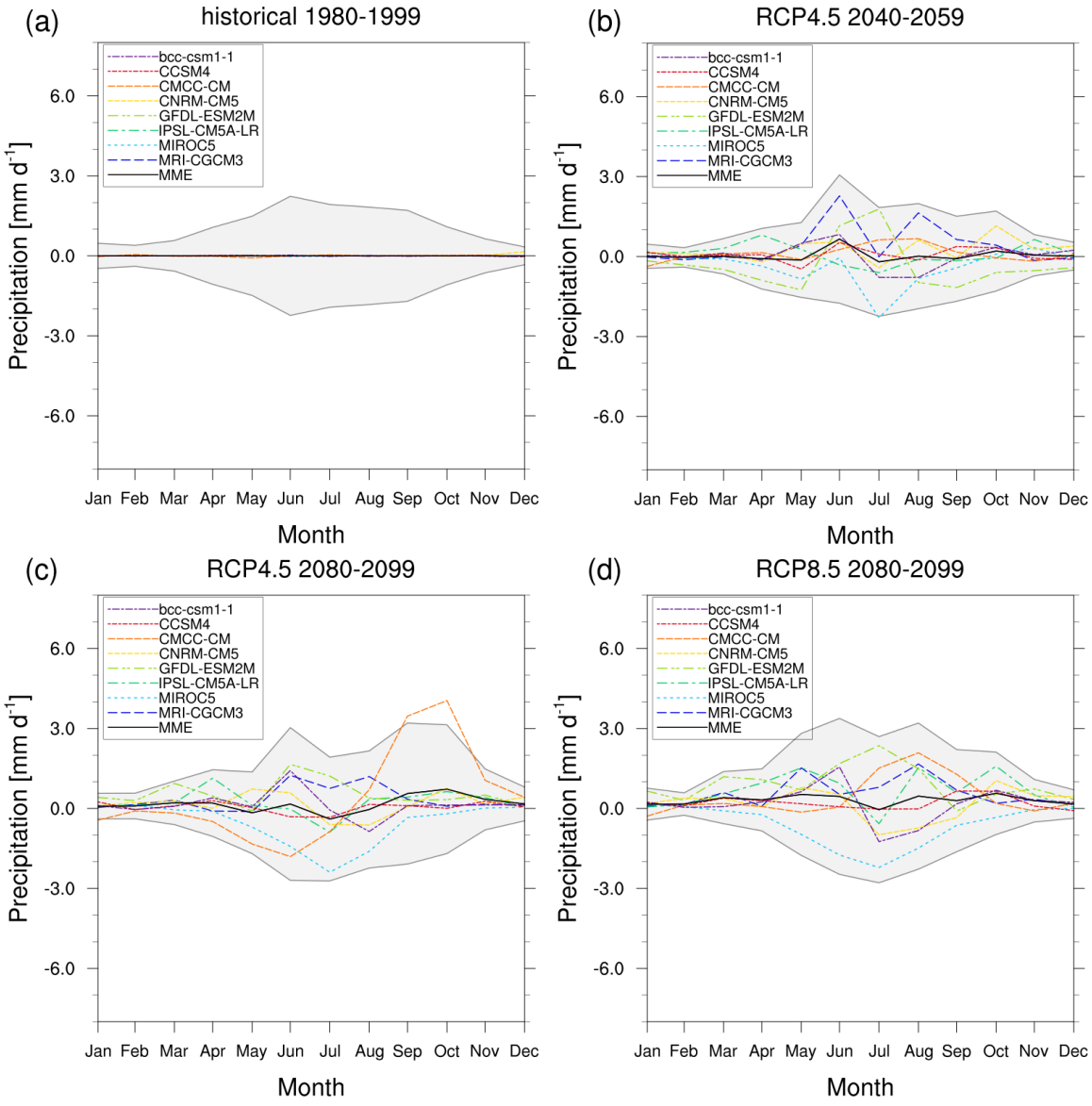


Figure S9: As Figure S8, but for precipitation.

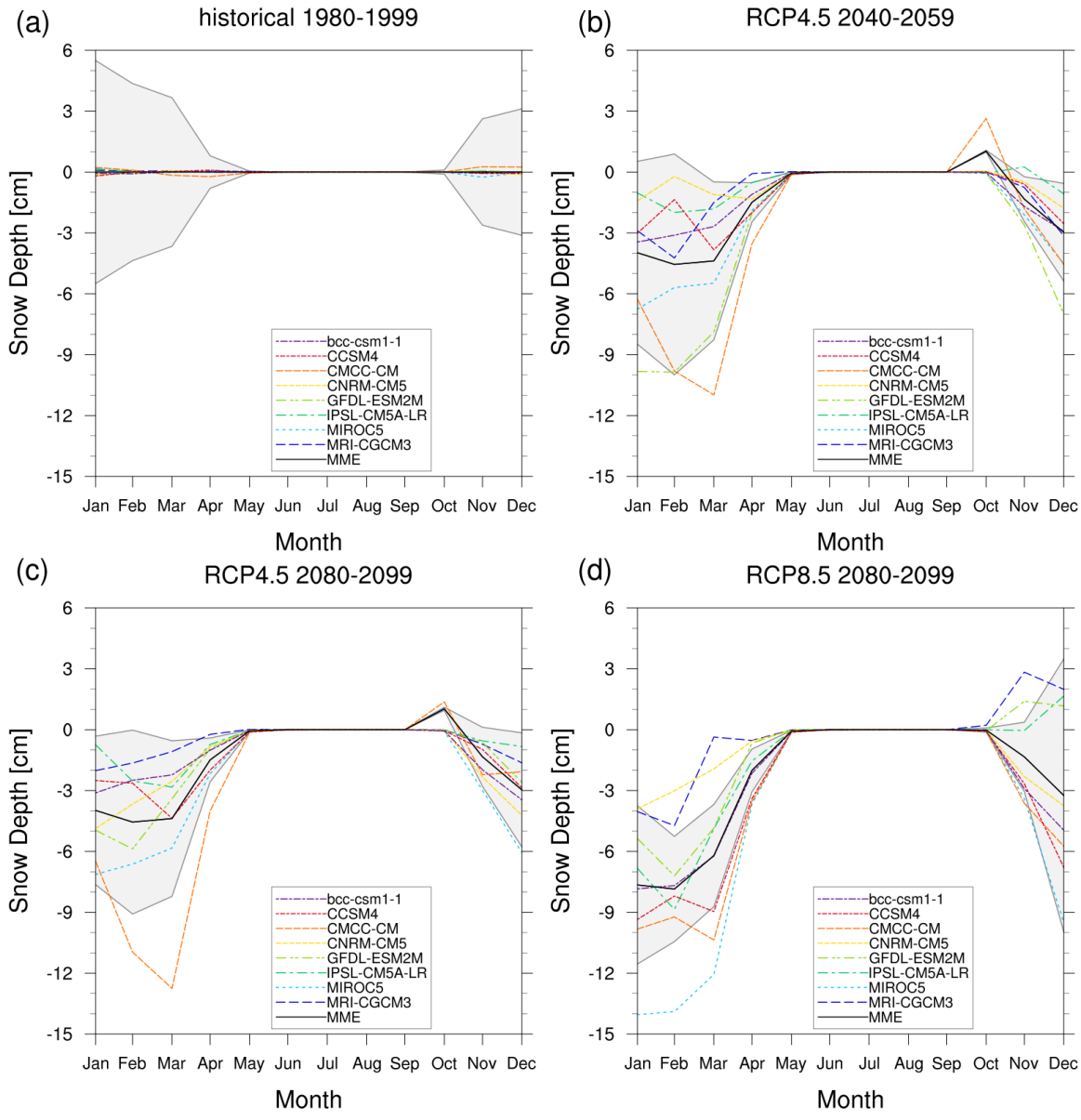
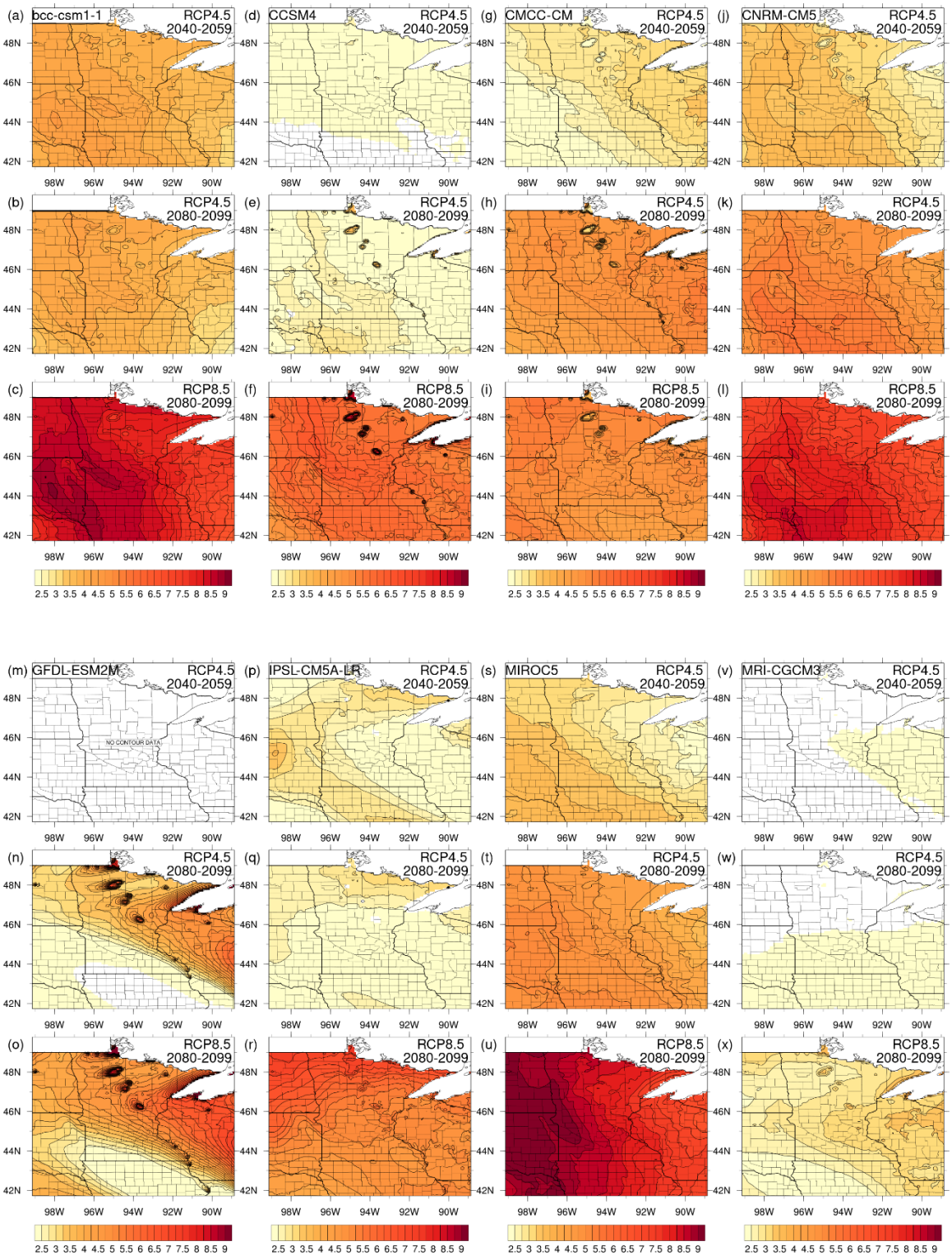


Figure S10: As Figure S8, but for snow depth.


(a) bcc-csm1-1 RCP4.5 2040-2059
(b) RCP4.5 2080-2099
(c) RCP8.5 2080-2099
(d) CCSM4 RCP4.5 2040-2059
(e) RCP4.5 2080-2099
(f) RCP8.5 2080-2099
(g) CMCC-CM RCP4.5 2040-2059
(h) RCP4.5 2080-2099
(i) RCP8.5 2080-2099
(j) CNRM-CM5 RCP4.5 2040-2059
(k) RCP4.5 2080-2099
(l) RCP8.5 2080-2099
(m) GFDL-ESM2M RCP4.5 2040-2059
NO CONTOUR DATA
(n) RCP4.5 2080-2099
(o) RCP8.5 2080-2099
(p) IPSL-CM5A-LR RCP4.5 2040-2059
(q) RCP4.5 2080-2099
(r) RCP8.5 2080-2099
(s) MIROC5 RCP4.5 2040-2059
(t) RCP4.5 2080-2099
(u) RCP8.5 2080-2099
(v) MRI-CGCM3 RCP4.5 2040-2059
(w) RCP4.5 2080-2099
(x) RCP8.5 2080-2099
48N
46N
44N
42N
98W 96W 94W 92W 90W
2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9

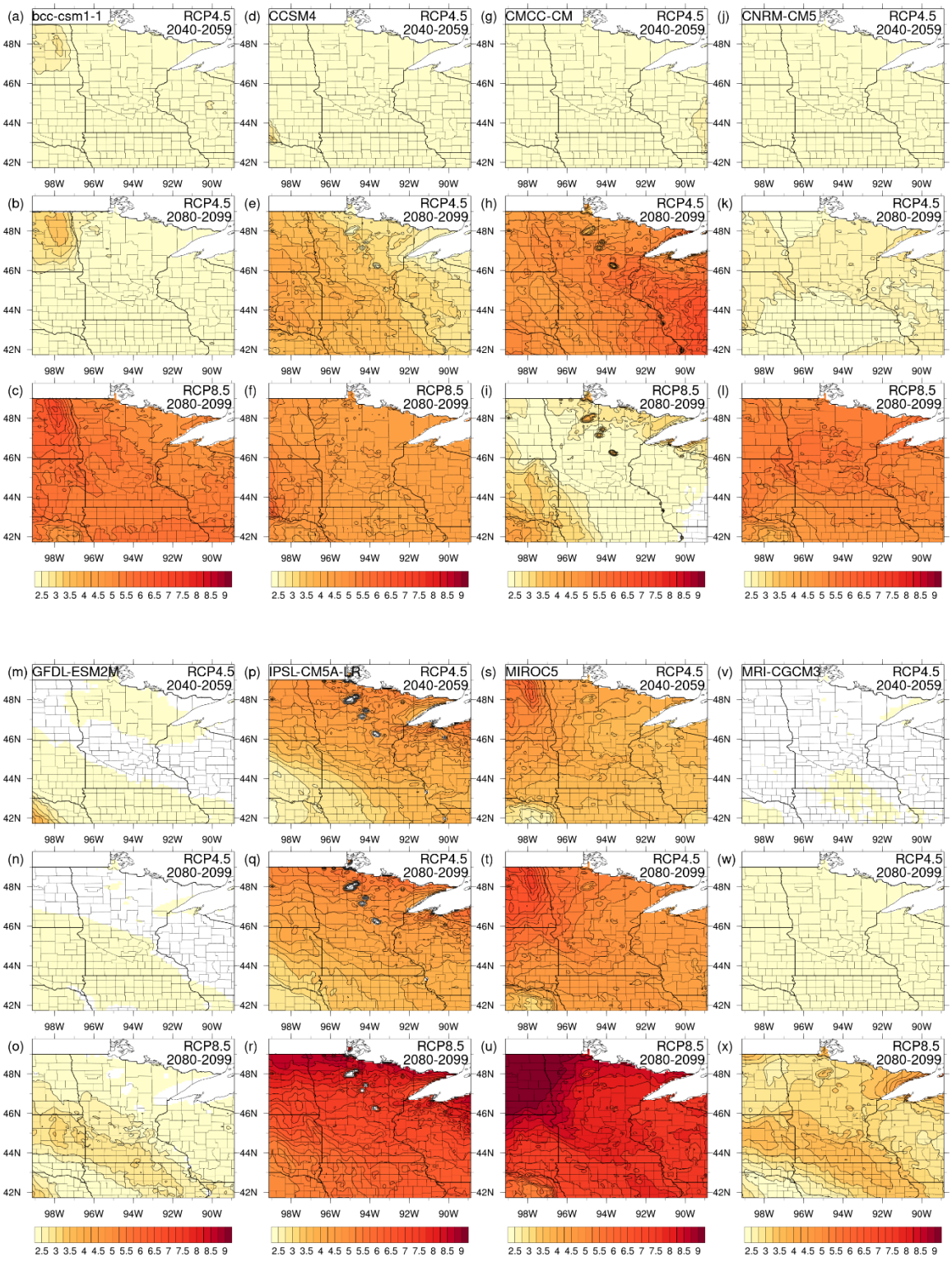


Figure S12. As Figure S11, but for summer and compared to the historical period in Figure 6a.

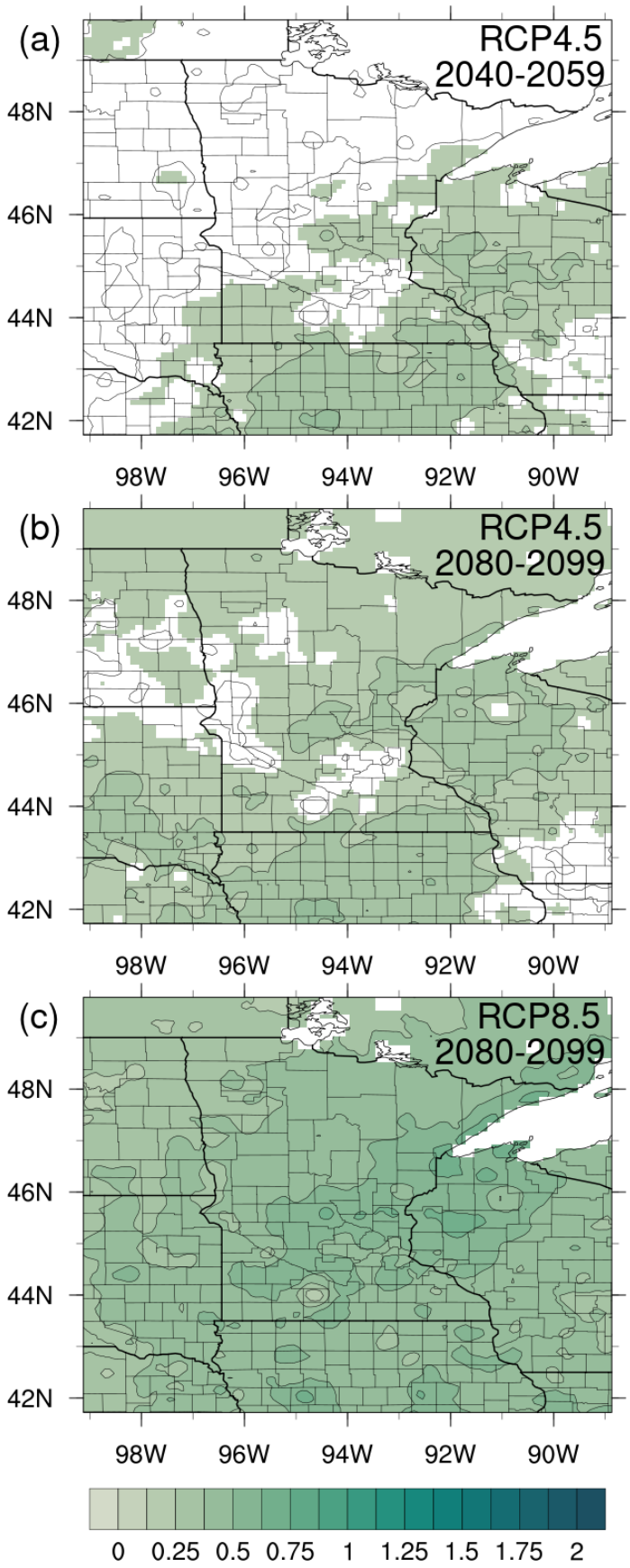


Figure S13: As Figure 7, but for spring (March-May) LOCA statistical precipitation anomalies [mm d^{-1}] compared to historical data. Historical data are similar to Figure 7a.

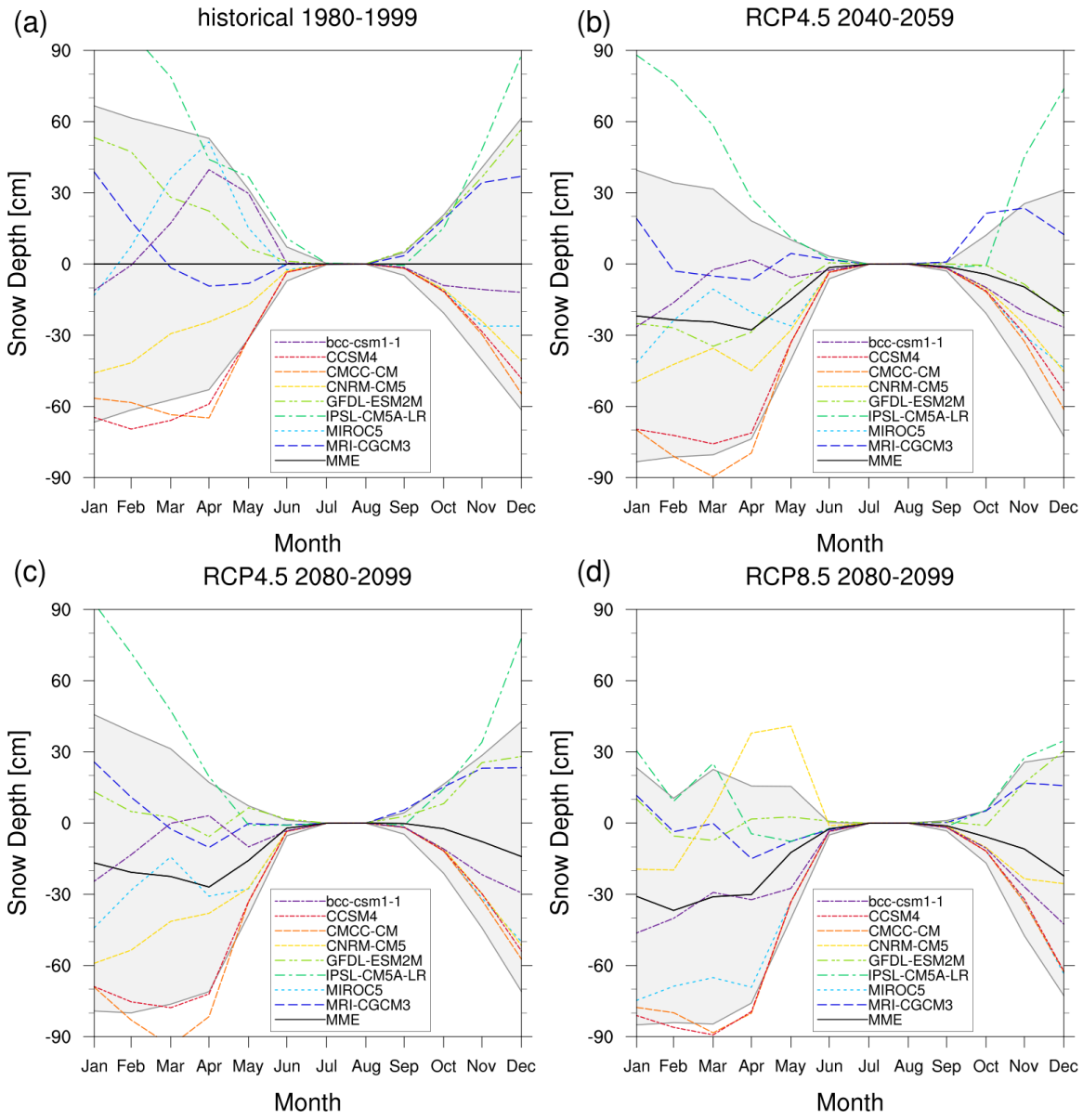


Figure S14. Non-adjusted monthly-average snow depth difference to the historical WRF MME simulation averaged over every grid cell within the state of Minnesota for each WRF-downscaled GCM (colors) and the scenario MME (black line). Also shown are the standard deviations of all years of the 20-year WRF simulations for all GCMS (160 realizations; gray shading).

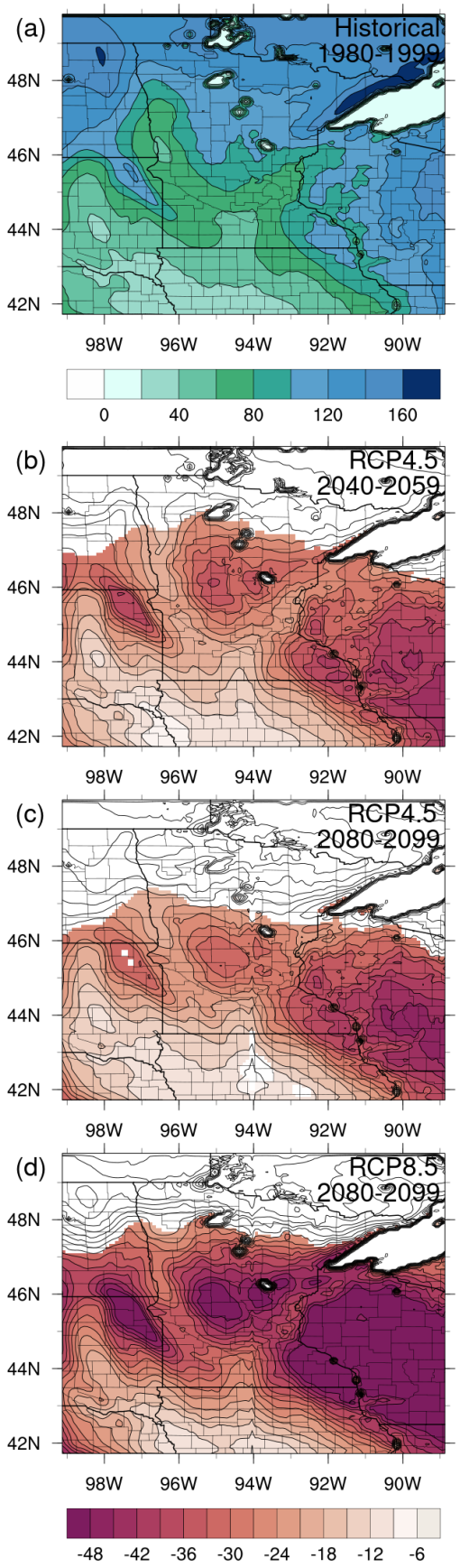


Figure S15. Average winter (December-February) MME non-adjusted snow depth in cm for (a) historical simulations and (b-d) anomalies of each RCP scenario compared to the historical WRF MME. Shading in (b-d) indicates statistically significant changes over U.S. land points at the 95% confidence interval. Please note that there is a different color bar for (a) than for (b-d).

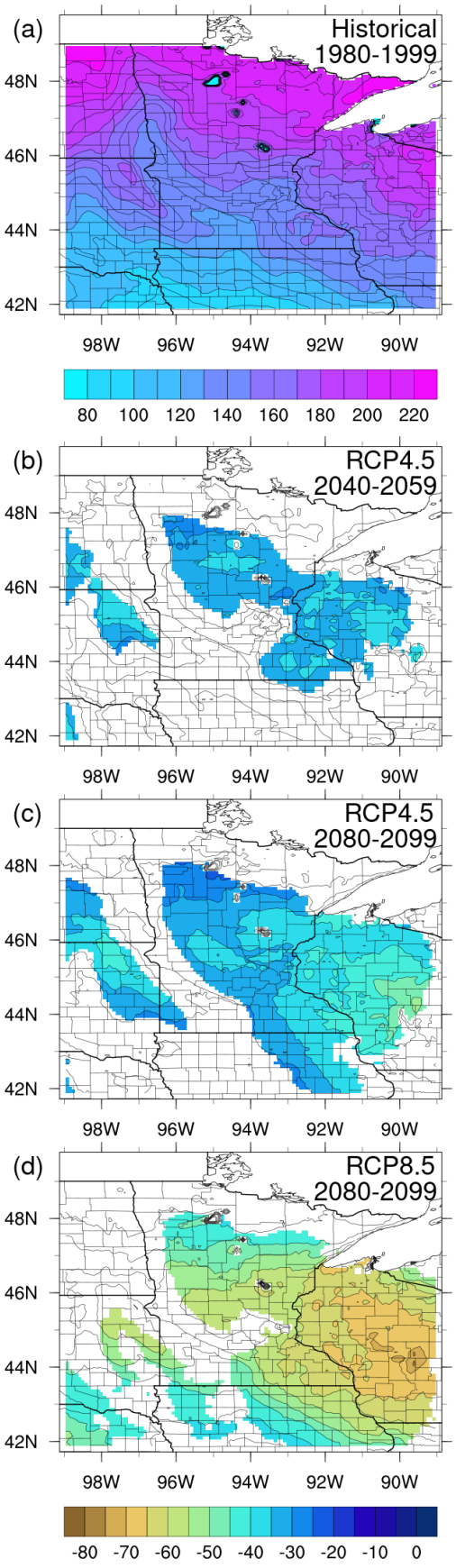


Figure S16. As Figure 9, but for MME days per year and difference in days per year with non-adjusted snow height above 2.54 cm (one inch).