Extended Data for: Efficiency-weighted cooling degree days reveal opposing temperature and humidity effects on energy demand

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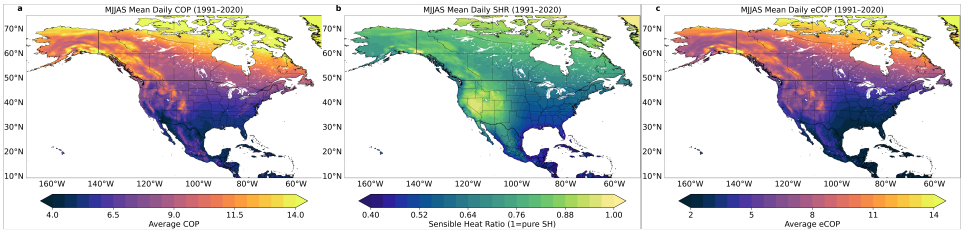

Fig. 1 Extended summer mean fields of coefficient of performance, sensible heat ratio, and effective coefficient of performance over North America. (a) May-September (MJJAS) mean daily coefficient of performance (COP), 1991–2020. (b) MJJAS mean daily sensible heat ratio (SHR), 1991–2020. (c) MJJAS mean daily effective coefficient of performance (eCOP), 1991–2020.

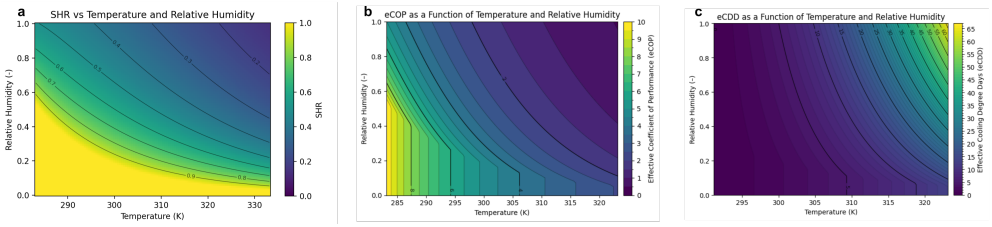

Fig. 2 Thermodynamic relationships among coefficient of performance, sensible heat ratio, and effective cooling degree days as functions of temperature and relative humidity. (a) Sensible heat ratio (SHR). (b) Effective coefficient of performance (eCOP). (c) Effective cooling degree days (eCDD).

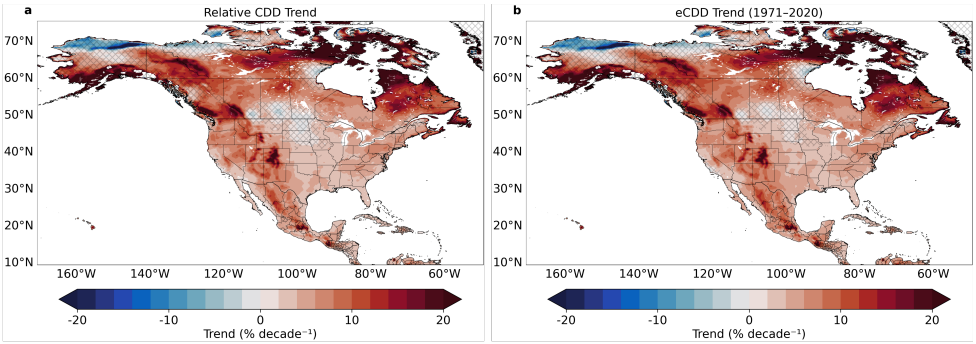

Fig. 3 Relative trends in cooling degree days and effective cooling degree days over North America. (a) Relative cooling degree days (CDD) trend (% decade^{-1}) computed from annual May-September (MJJAS) cooling degree days over 1971–2020. (b) Relative effective cooling degree days (eCDD) trend (% decade^{-1}) for the same period. Trends are expressed relative to their respective climatological means. Crosshatching indicates regions where trends are not statistically significant at the 95% confidence level.

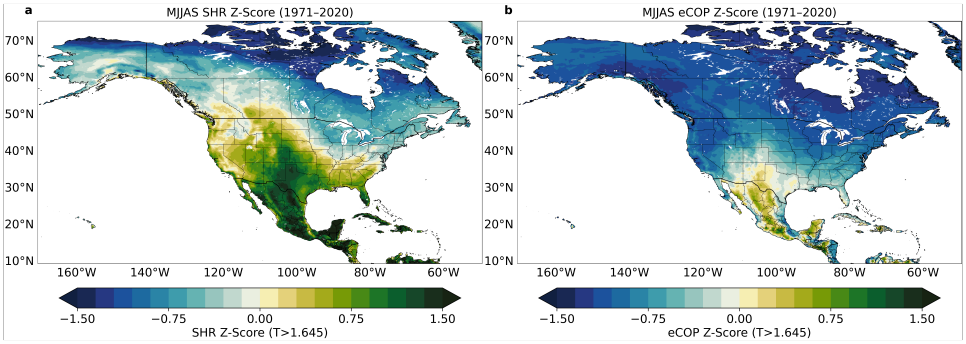

Fig. 4 Hot-day z-score fields of sensible heat ratio and effective coefficient of performance over North America. (a) Sensible heat ratio (SHR) z-score for days exceeding the 95th percentile of temperature ($T > 1.645$), 1971–2020. (b) Effective coefficient of performance (eCOP) z-score for the same hot-day subset, 1971–2020. Both panels show standardized anomalies relative to the full-period daily distributions.

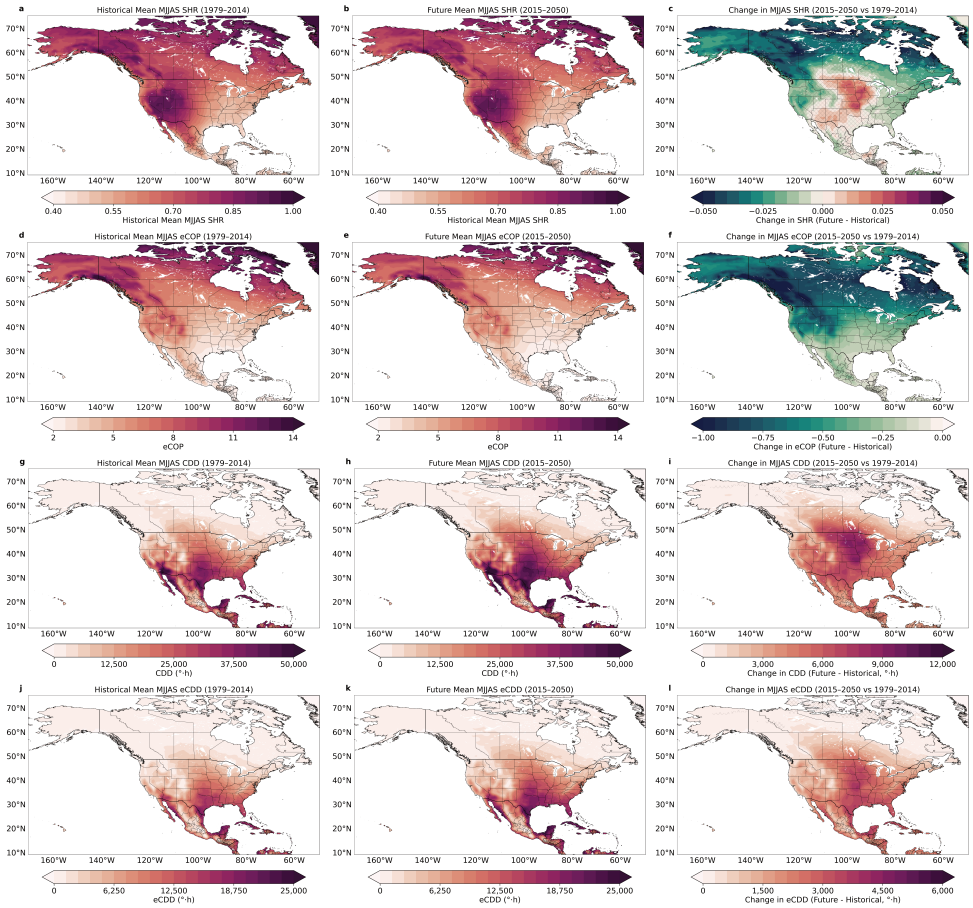

Fig. 5 Present (1979–2014), future (2015–2050), and their difference in key metrics over North America. (a–c) Present, future, and future minus present changes in May-September (MJJAS) sensible heat ratio (SHR). (d–f) As in (a–c), but for effective coefficient of performance (eCOP). (g–i) As in (a–c), but for cooling degree days (CDD). (j–l) As in (a–c), but for effective cooling degree days (eCDD). All quantities are computed from CMIP-based fields and averaged over the extended summer season (MJJA). Change panels show future (2015–2050) values relative to the historical baseline (1979–2014). Note that eCDD and CDD are in degree-hours, and to convert to degree-days need to be divided by 24.

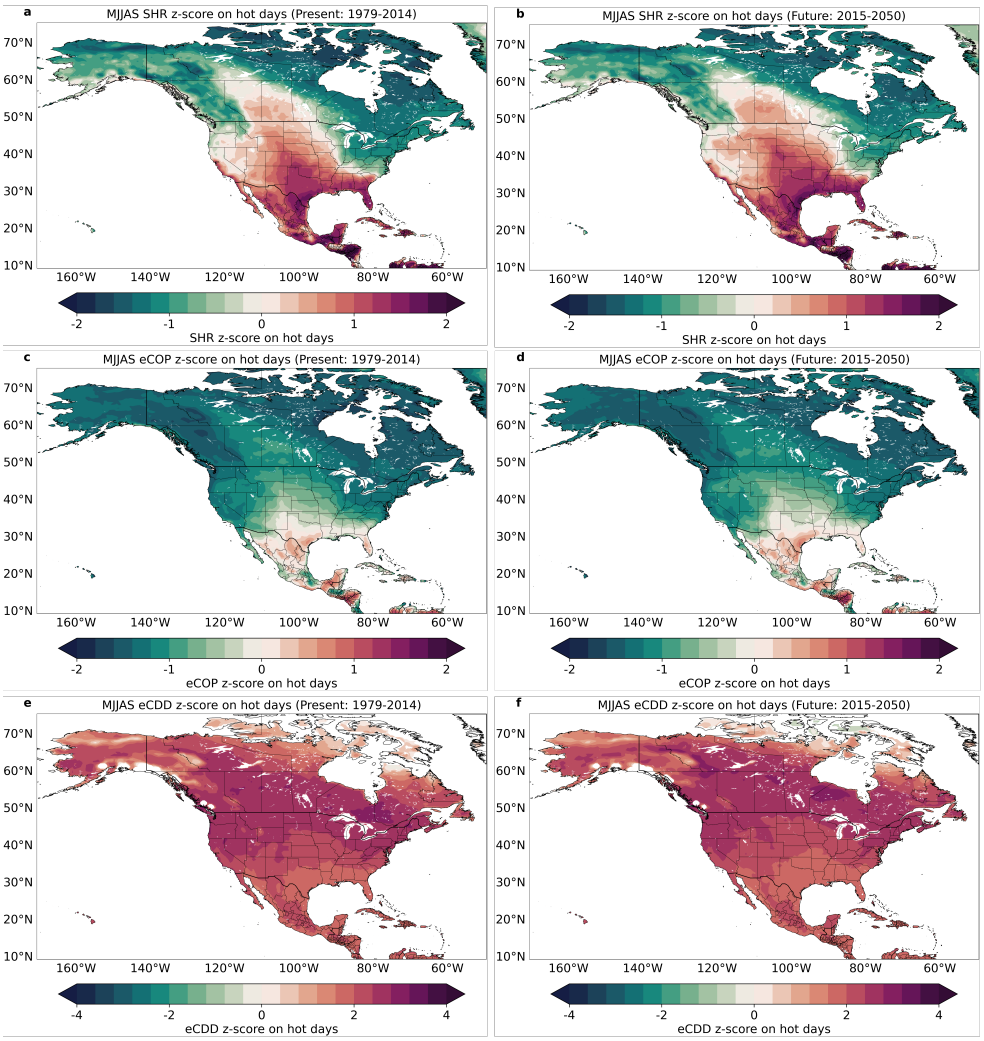

Fig. 6 Present and future hot-day z-scores of sensible heat ratio, effective coefficient of performance, and effective cooling degree days over North America. (a,b) sensible heat ratio (SHR) z-scores on hot days for the present period (1979–2014) and future period (2015–2050), respectively. (c,d) effective coefficient of performance (eCOP) z-scores on hot days for the present and future periods. (e,f) effective cooling degree days (eCDD) z-scores on hot days for the present and future periods. In all panels, hot days are defined using the same percentile threshold within each period, and z-scores are computed separately for the present and future periods using each period's own climatological mean and standard deviation.

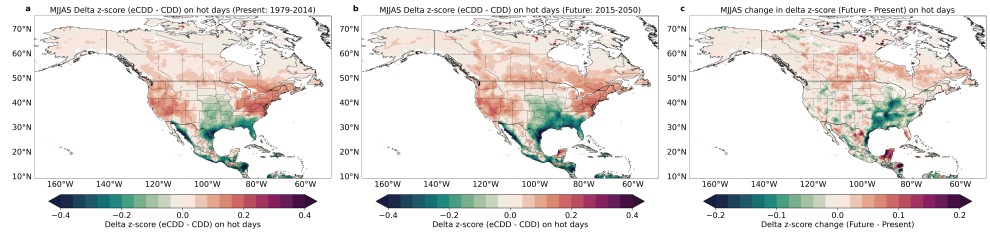

Fig. 7 Present and future hot-day z-scores of effective cooling degree days and effective cooling degree days over North America. (a) Difference in effective cooling degree days (eCDD) hot-day z-scores (Present) and the effective cooling degree days (CDD) hot-day z-scores (Present). (b) Difference in eCDD hot-day z-scores (Future) and the CDD hot-day z-scores (Future). (c) Difference in eCDD hot-day z-scores (Future − Present) and the CDD hot-day z-scores (Future − Present). In all panels, hot days are defined using the same percentile threshold within each period, and z-scores are computed separately for the present and future periods using each period's own climatological mean and standard deviation.

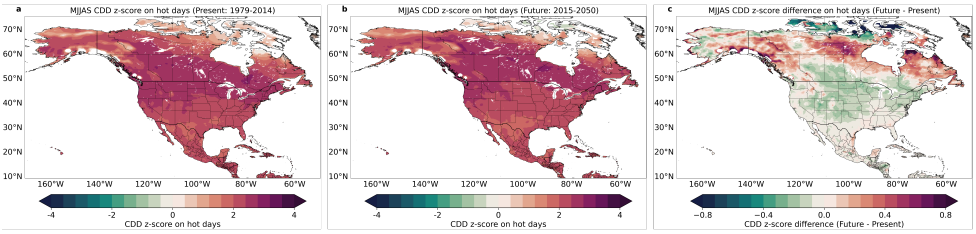

Fig. 8 Cooling degree days composites on hot days in the present and future. (a) cooling degree days (CDD) z-score anomaly on hot days (1979–2014), (b) CDD z-score on hot days (2015–2050), and (c) CDD z-score difference on hot days (Future – Present). Hot days are defined using the same temperature threshold as in the main eCDD analysis. Z-scores in each period are calculated relative to that period's own climatology.

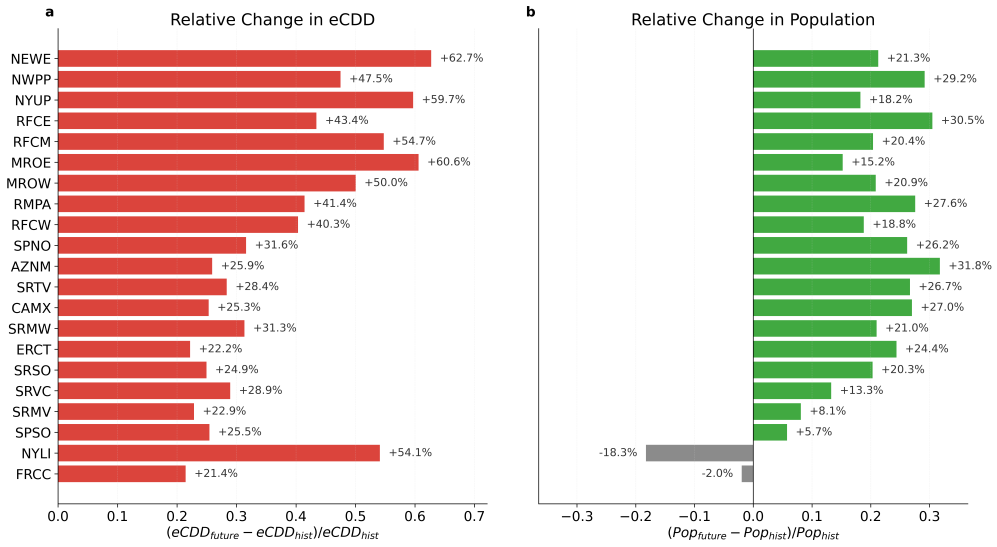

Fig. 9 Relative changes in regional effective cooling degree days and population. (a) Relative change in area-averaged effective cooling degree days (eCDD) over EPA eGRID regions, expressed as $(\mathrm{eCDD}_{\mathrm{future}} - \mathrm{eCDD}_{\mathrm{hist}})/\mathrm{eCDD}_{\mathrm{hist}}$. (b) Relative change in area-averaged population over the same EPA eGRID regions, expressed as $(\mathrm{Pop}_{\mathrm{future}} - \mathrm{Pop}_{\mathrm{hist}})/\mathrm{Pop}_{\mathrm{hist}}$. Positive values indicate population growth and negative values indicate population decline.