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Short communication

Assimilating urban heat island effects into climate projections

Benjamin J. Hatchett [a, *], Darko Koračin [b, c], John F. Mejía [c], Douglas P. Boyle [a]

[a] Nevada State Climate Office, University of Nevada, Reno, Reno, NV 89557, USA
[b] University of Split, Split, Croatia
[c] Division of Atmospheric Sciences, Desert Research Institute, Reno, NV 89512, USA

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ABSTRACT

An urban heat island (UHI) effect is identified in Reno, Nevada by analyzing regional temperature trends calculated from seven long-term observation stations for the summer and winter seasons between 1950 and 2014. The UHI is maximized during summer (June–August) and characterized by asymmetric increases in minimum (~1.1 °C/decade, $p < 0.01$) versus maximum temperature (~0.1 °C/decade, $p < 0.01$) trends in excess of trends from regional climate stations. Comparisons of historical Reno temperatures with an ensemble of 66 bias-corrected and downscaled global climate model (GCM) outputs spanning 1950–2014 demonstrates cold biases of 1.5–4.5 °C during summer with minimum temperature having the largest bias. We show that a secondary bias correction step utilizing the statistical downscaling method of quantile–quantile mapping (QQM) can reduce biases in future climate projections assuming no changes to the UHI. The QQM results in an additional total warming of ensemble mean temperatures by ~3 °C for downscaled GCM output and ~4 °C for re-gridded 1° grid resolution GCM output for 2030–2049 under the RCP8.5 emissions scenario. These temperature differences produce additional increases in summer potential evapotranspiration of 10% compared to non-QQM bias-corrected GCM output. It was shown that the QQM method represents a useful and computationally efficient method for bias correction of temperature projections for cities where UHI effects exist. Planning and impacts studies of urban water resources can benefit from these improved climate projections, particularly in regions where downscaled GCM output is unavailable.

Emissions of greenhouse gases and changes associated with land use and land cover change, i.e. growth of urban and agricultural land uses, represent important global scale anthropogenic perturbations to climate (Georgesu et al., 2014). Urbanization alters the land surface thermal and aerodynamic characteristics and enhances sensible heat transfer to the boundary layer, an effect known as the urban heat island (UHI; Oke, 1973). UHIs are generally studied through station-based comparisons of urban and rural temperatures (Oke, 1973). Using a combined observational and modeling approach, Zhao et al. (2014) found that humid regions are the most susceptible to UHI development because vegetative loss reduces convective heat transfer efficiency. However, as approximately 40% of the world's population resides in subtropical semi-arid or arid (dryland) areas and with increasing migrations to urban areas (United Nations, 2007), consideration of climate change impacts and how UHI effects may intensify these impacts is necessary. Commonly recognized impacts include increased frequencies of warm season hot spells, changes in the seasonal and daily timing, frequency and severity of urban floods, air and water pollution episodes, and strains on urban infrastructure (Major et al., 2011). Multimodel ensembles of global climate models (GCMs) forced by greenhouse gas emission scenarios project increases in mean temperatures (Cayan et al., 2010) and more frequent occurrences of record high temperatures (Abatzoglou and Barbero, 2014) across the western United States during the 21st century. Assessing both regional climate change and UHI impacts on urban areas are of great importance in order to develop sustainable urban policies (Chow et al., 2012).

The Great Basin of the western United States (Fig. 1a) is North America's largest dryland region. It is characterized by low ratios of precipitation (P) to potential evapotranspiration (PET; P/PET < 0.65) and mountainous basin and range topography. This study focuses on the city of Reno, Nevada (39.5°N, 119°W, population 400,000 in 2010), which is located along the western edge of the Great Basin in the rainshadow of the 3000 m high Sierra Nevada (Fig. 1b–c). The

* Corresponding author.
E-mail address: benjamin.hatchett@gmail.com (B.J. Hatchett).

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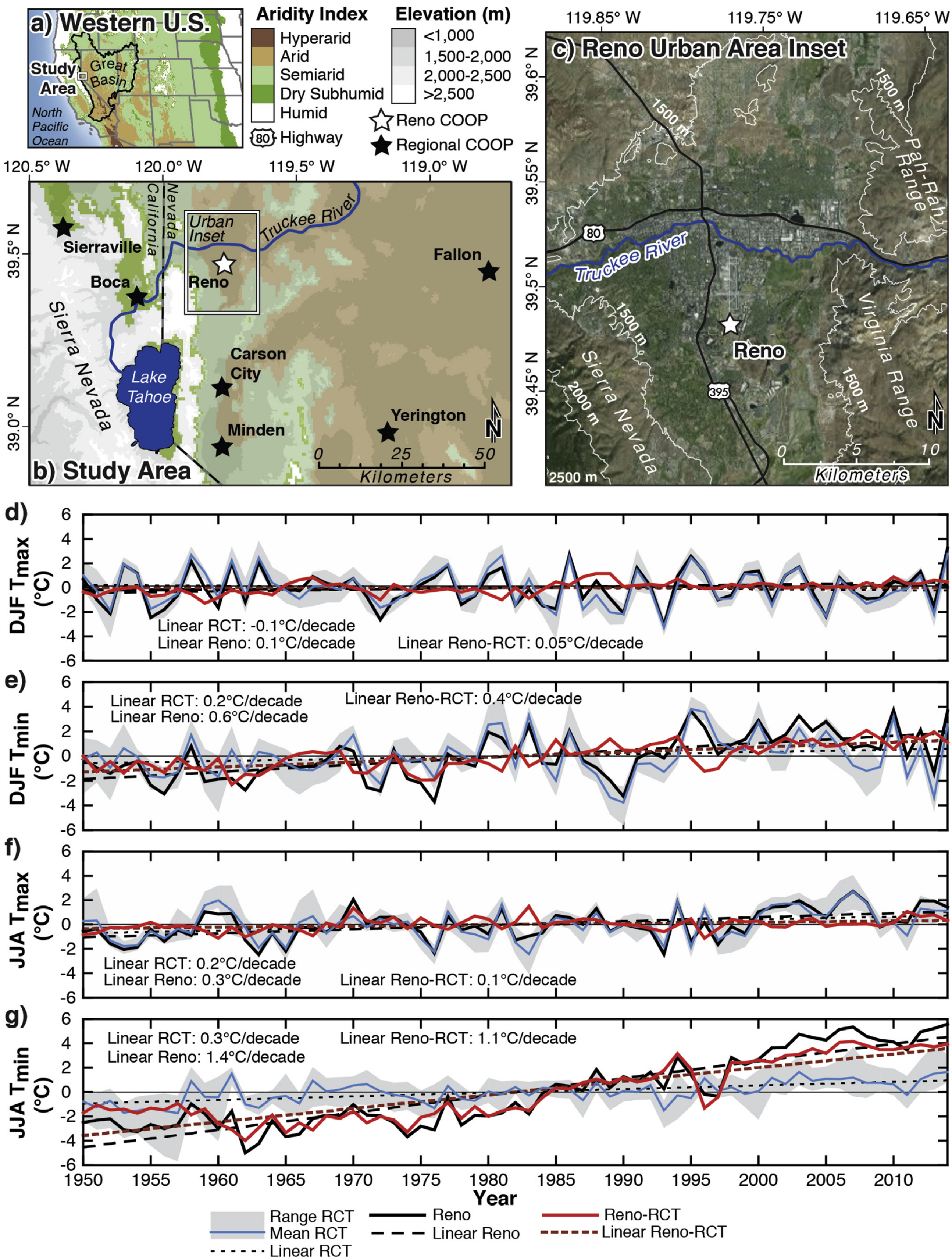

Fig. 1. a) Aridity map (P/PET) of the Western United States and the Great Basin. b) Aridity and elevation map of the western Great Basin with the study area of Reno, Nevada and the Cooperative Observational (COOP) weather stations used in the analysis. c) Aerial image and elevation contours of the Reno, Nevada urban area and location of major roads (black lines), the Truckee River (blue line), and the location of the urban weather station (white star). d-g) Time series of winter and summer maximum and minimum temperature for the mean of the seven regional weather stations (blue line) and the Reno station (black line) with the range of observations of the regional stations bounded by the grey fill and the Reno trend (red line) upon removal of the regional climate trend (RCT). Dashed lines show long-term linear trends. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)