The following descriptions of the dynamically downscaling simulations are from Wang, J., & Kotamarthi, V. R. (2015). High-resolution dynamically downscaled projections of precipitation in the mid and late 21st century over North America. *Earth's Future*, *3*(7), 268-288.

Global Climate Model

The global climate information used in this study is from a single run by the Community Climate System Model version 4 (CCSM4) at a resolution of 0.9° × 1.25° (latitude/longitude) as part of the fifth phase of the Coupled Model Intercomparison Project (CMIP5) archive. This is the only member of a six-member ensemble for future runs that saves the outputs every 6 h, providing details at the sub-daily scale and making the model suitable for driving regional climate models (RCMs). CCSM4 is a coupled atmosphere-ocean GCM (AOGCM) composed of four separate models simultaneously simulating the earth's atmosphere, ocean, land surface and sea-ice, and one central coupler component [1].

The future projection simulations are forced with radiative forcings consistent with a high emissions scenario (RCP8.5) and a midrange mitigation emissions scenario (RCP4.5), which represent a possible range of radiative forcing values in the year 2100 relative to pre-industrial values.

Bias Correction

This study applies the approach tested by Bruyère et al. [2], which corrects the mean errors in the GCM but retains the GCM's 6 h weather data, longer-period climate variability, and climate change signal. In this study, we correct the atmospheric components of CCSM4 by using the National Centers for Environmental Prediction (NCEP)–National Center for Atmospheric Research Reanalysis Project (NNRP) data over the period 1950–1979 (the base period). This period is chosen because it has no significant climate trend, and thus no trend needs to be removed before bias correction.

The bias correction steps are as follows. First, the 6 h NNRP data and CCSM4 outputs are broken down into a climatological mean plus a perturbation term:

$$\mathrm{CCSM} = \overline{\mathrm{CCSM}} + \mathrm{CCSM}'$$
$$\mathrm{NNRP} = \overline{\mathrm{NNRP}} + \mathrm{NNRP}'$$

Accordingly, the CCSM4 model output for the three time periods we model (1994–2004, 2044–2054, and 2084–2094) can be written as follows:

$$\mathrm{CCSM_c} = \overline{\mathrm{CCSM_c}} + \mathrm{CCSM_c'} = \left(\overline{\mathrm{CCSM_b}} - \overline{\mathrm{NNRP_b}}\right) + \overline{\mathrm{NNRP_b}} + \left(\overline{\mathrm{CCSM_c}} - \overline{\mathrm{CCSM_b}}\right) + \mathrm{CCSM_c'}$$

The subscripts b and c represent the base period (1950–1979) and the considered period (1994–2004, 2044–2054, or 2084–2094), respectively. Thus, the bias-corrected CCSM4 data $\mathrm{CCSM_c^*}$ in the three considered periods are constructed by removing the CCSM4's climatological bias $\overline{\mathrm{CCSM_b}} - \overline{\mathrm{NNRP_b}}$:

$$\mathrm{CCSM_c^*} = \overline{\mathrm{NNRP_b}} + \left(\overline{\mathrm{CCSM_c}} - \overline{\mathrm{CCSM_b}}\right) + \mathrm{CCSM_c'} = \left(\overline{\mathrm{NNRP_b}} - \overline{\mathrm{CCSM_b}}\right) + \overline{\mathrm{CCSM_c}} + \mathrm{CCSM_c'}$$
$$= \left(\overline{\mathrm{NNRP_b}} - \overline{\mathrm{CCSM_b}}\right) + \mathrm{CCSM_c}$$

The corrected atmospheric variables include zonal and meridional wind, geopotential height, temperature, and relative humidity at 6 h intervals, for three dimensions.

Regional Climate Model

This study uses the Weather Research and Forecasting (WRF) model version 3.3.1 to dynamically downscale CCSM4. The WRF model is applied at a horizontal resolution of 12 km, with 600 west-east × 515 south-north grid points and 28 vertical levels over most of North America. The physics schemes used in this study include the Grell-Devenyi convective parameterization, the Yonsei University planetary boundary layer scheme, the Noah land surface model, the longwave and shortwave radiative schemes of the Rapid Radiation Transfer Model for GCM applications, and the Morrison microphysics scheme. Weak interior nudging is applied above 850 hPa to wavelengths around 1200 km, with a nudging coefficient of 3×10^{-5} s^{-1}. In both historical and future simulations, a 1 year spin-up period is allowed for the model to reach equilibrium.

References

1. Gent, P. R. et al. (2011). The Community Climate System Model Version 4. *Journal of Climate*, *24*(19), 4973–4991.

2. Bruyère, C. L. et al. (2014). Bias corrections of global models for regional climate simulations of high-impact weather. *Climate Dynamics*, *43*(7–8), 1847–1856.