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Evaluating the performance of statistical downscaling and bias correction methods in a non-stationary climate

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Refining dynamical climate model results via statistical techniques that make use of observational data is a common approach that seeks to produce value-added data products suitable for use in many climate impacts applications. Many bias correction and statistical downscaling techniques exist, with all implicitly embracing a kind of stationarity assumption – a presumption that key aspects of statistical relationships that exist between observed climate data and a dynamical climate model's output remain constant over time, even as the climate itself may be changing. Here we present a sampling of results from two variants of a "perfect model" (PM) experimental framework designed to test to what extent a statistical downscaling or bias correction technique's performance during the observational period is indicative of its performance when applied to future climate projections. In both PM designs, dynamical model output having ∼25km horizontal grid resolution serves as a proxy for observations, both in the historical and future time periods. Having a proxy for future observations in the PM design allows quantitative assessments of whether bias correction and statistical downscaling method performance during the observational period (the period used to "train" the method) is indicative of the method's skill when it is applied to future climate projections. For the univariate statistical methods tested, we find the methods generally add value; however, in certain circumstances they can yield highly erroneous results. Importantly, we note that it is unlikely that typical evaluations based only on available historical data would be able to predict when and where a particular method would produce large errors when applied to future climate projections. Notable violations of the stationarity assumption are found to vary across statistical methods, geographically, seasonally, and with the amount of projected climate change. For some problematic cases, explanations are offered in terms of physical, statistical and methodological causes. Examples are presented of methodological modifications that in some circumstances can reduce the occurrence or severity of stationarity assumption violations.