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Multivariate bias correction of meteorological variables for hydrological applications in a data-scarce Alpine catchment

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Bias correction algorithms are nowadays widely used for post-processing output from climate and weather models. However, most of the techniques focus on a single variable and do not take the dependence structures of the different post-processing variables into account. In this study, the development of a novel multivariate bias correction technique based on Vine Copulas is presented. Furthermore, another existing multivariate technique was utilized. The two different multivariate bias correction techniques were applied to hourly regional climate model (RCM) simulations at a resolution of 5 km for the Berchtesgaden National Park in the German Alpine region. In such a complex terrain, a high spatial heterogeneity of the variables may exist. In the absence of long and complete observed time series, hydrological modelers are confronted with huge uncertainties regarding the meteorological input data. RCMs may provide such time series for historical and future periods, but even for high spatial resolutions, their output is usually afflicted by biases. Furthermore, the observed multivariate dependence structures of the different meteorological variables may not be reproduced properly by the RCM. These deficiencies limit the applicability of RCMs for hydrological impact studies since snow melt processes and runoff formation in Alpine catchments are influenced by several meteorological variables like near-surface temperature, precipitation and shortwave downwelling radiation. In a first step, a univariate Quantile-Mapping (QM) was performed to correct the univariate bias of the RCM simulations. To this end, the distribution parameters of ungauged sites were estimated based on the site's elevation. An analysis of the multivariate dependence structures revealed that the univariately bias corrected QM time series exhibit similar dependence structures for most variables. However, due to the complex runoff formation processes in this region, a further improvement of the multivariate dependence structures was sought and two different multivariate techniques were applied. The novel technique employs four-dimensional Vine Copulas to simulate the meteorological variable which deviates the most from the observed dependence structures. The other technique rearranges the temporal order of the QM series by accounting for multivariate rank dependences, based on a modified Schaake shuffling. An evaluation of the multivariate techniques in comparison to univariate Quantile Mapping is given to illustrate how the dependence structure of the bias corrected time series is altered. This evaluation is based on absolute differences of the dependence measure Kendall's Tau between observed and bias corrected series. The Vine Copula-based method has reduced the sum of absolute differences of Kendall's Tau of the univariately corrected QM series by as much as 64% in the winter season DJF.