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Local refinement of RCM simulations based on the theory of Copulas: An application to bias correct WRF precipitation for Germany

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Precipitation information is crucial for regional hydrological and agricultural climate change impact studies. Regional climate models (RCMs) are suitable tools to provide high spatial resolution precipitation products at regional scales, however, they are usually biased not only in absolute values, but also in reproducing observed spatial patterns. Therefore, bias correction techniques are required to obtain suited meteorological information on regional scale.

We present a Copula-based method to correct precipitation fields from the Weather Research and Forecasting (WRF) model by merging modelled fields with gridded observation data. Germany is selected as our research domain. High resolution (7km) WRF simulations are used in this study, which is driven by ERA40 reanalysis data for 1971-2000. REGNIE data from Germany Weather Service (DWD) were used as gridded observation data source (1km/daily) and rescaled to 7km for this application.

The critical step of this proposed bias correction approach is the establishment of bivariate Copula models, each of them consists of two marginal distributions and one Copula function. The marginal distributions are used to describe the statistical properties of REGNIE and WRF-ERA40 data, while the theoretical Copula function represents the dependence structure between REGNIE and WRF-ERA40 data. Based on this Copula model, the conditional distribution of REGNIE conditioned on WRF-ERA40 can be derived. To generate bias corrected WRF-ERA40 precipitation, a random sample of possible outcomes is drawn from this conditional distribution. This also allows for a quantitative estimation of the inherent uncertainties. The expectation/median/mode value of the stochastic samples can be used as an estimation of the corrected value. For the application, a split-sampling approach is used. Results show that the marginal distributions of REGNIE and WRF-ERA40 are different which implies deficiencies of the WRF-ERA40 simulations to reproduce the statistics of precipitation properly. Copula functions vary in space and time, which indicates varying dependence structures for different seasons and locations. The corrected WRF-ERA40 data are compared with REGNIE in the validation period. It shows that the Copula-based approach successfully corrects for the errors in WRF-ERA40 precipitation. The range of the daily mean precipitation bias over Germany is reduced from -39%–84% to -29%–15%. Especially in winter time, the bias is reduced from -40%–111% to -33%–26%.

The results are compared with two standard bias correction methods (linear scaling, quantile mapping) and discussed.