Copula-based Bias Correction of RCM Derived Precipitation Assimilating REGNIE Data

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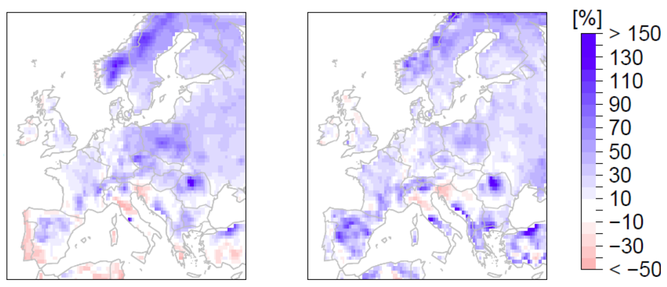
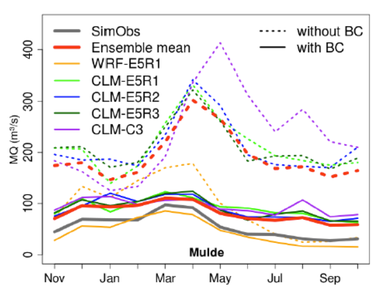
Motivation

- Precipitation derived from RCMs is crucial for many subsequent impact studies
- RCM derived precipitation is usually biased both in space, time and magnitude
- Bias is a crucial problem for subsequent hydrological impact studies
- Traditional bias correction (BC) methods: Mean value BC, Quantile mapping BC



Relative bias maps of annual mean precipitation for the ERA40 driven simulations with the CLM (left) and WRF (right) in comparison to the E-OBS data set from 1971 to 2000 (Berg et al., 2012)



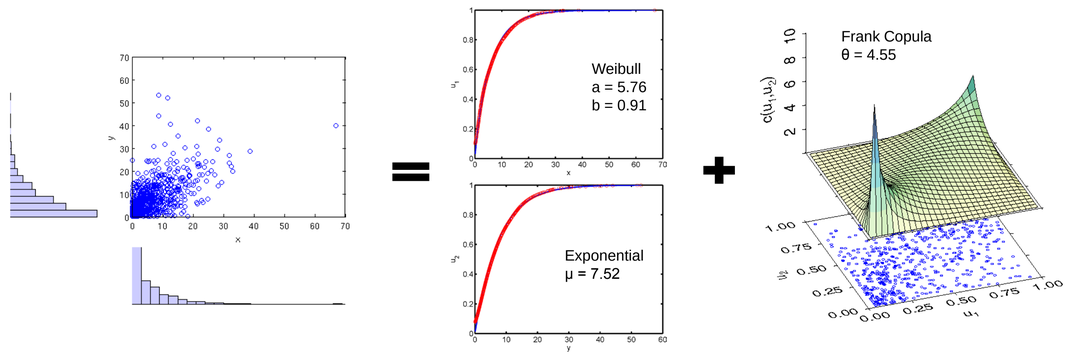
Effect of the bias corrected (BC) precipitation and temperature data to the mean monthly discharge (1971-2000) at gauge Bad Düben, Mulde. Simulations based on WaSiMETH (Ott et al., 2013)

Methodology

Copulas provide a functional link that connects multivariate probability distributions to their one-dimensional marginal distributions. The multivariate probability distribution, H, can be expressed in terms of its marginal functions F_i and the associated dependence function C (Sklar's Theorem):

$$H(x_1,...,x_n) = C_\theta(F_1(x_1),...,F_n(x_n)) \qquad \vec{x} \in R^n \qquad \theta = \{\Theta_1,...,\Theta_k\}$$

where C, called Copula, is unique if the marginal functions $F_1,\cdots,F_n$ are continuous. The Copula captures the features of dependence between the random variables.



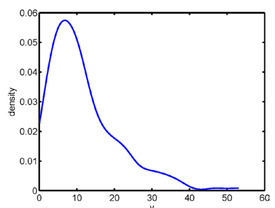
A Copula model consists of marginal functions and a Copula function. The marginal functions describe the statistical aspects of variables and the Copula describes the dependence structure between the variables.
The Copula model allows us to predict the probability of one variable when the value of other variables are given.

$$c_{u_1}(u_2) = P[U_2 \le u_2 \,|\, U_1 = u_1] = \frac{\partial C(u_1,u_2)}{\partial u_1}$$

The corresponding recipe comprises the following basic steps:

- Generate two independent uniform (0, 1) variates u_1 *and* t
- *Set* $u_2 = c_{u_1}^{(-1)}(t)$ *, where* $c_{u_1}^{(-1)}$ *denotes the quasi-inverse of* c_{u_1}
- *The desired pair is* (u_1, u_2)

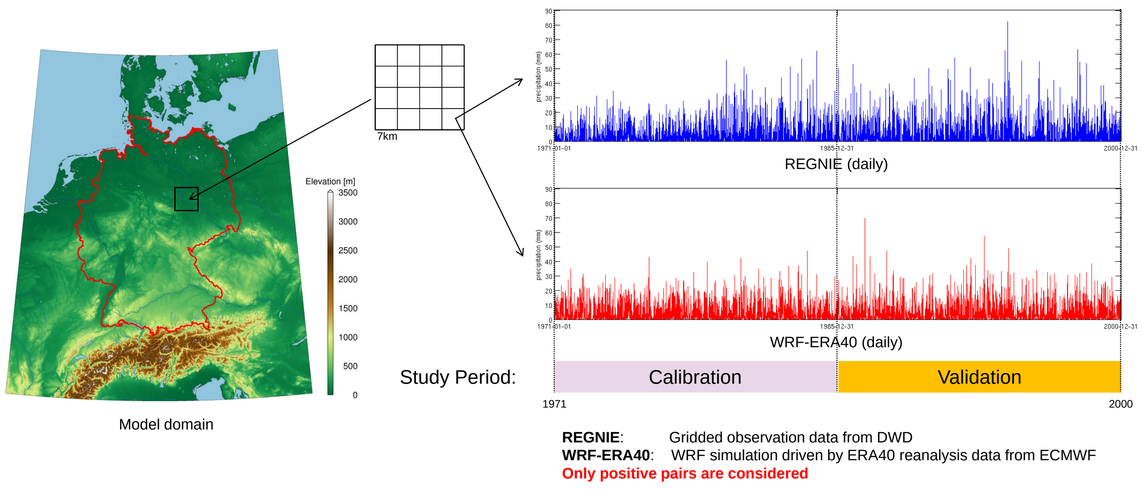
To assess the uncertainty associated with this prediction, we must repeat the prediction process a large number of times. This leads to an empirical predictive distribution.



Predicted probability density function for *y, under the condition x=7.4*

Application

Example: showing the calibration phase for the identification of the Copula model

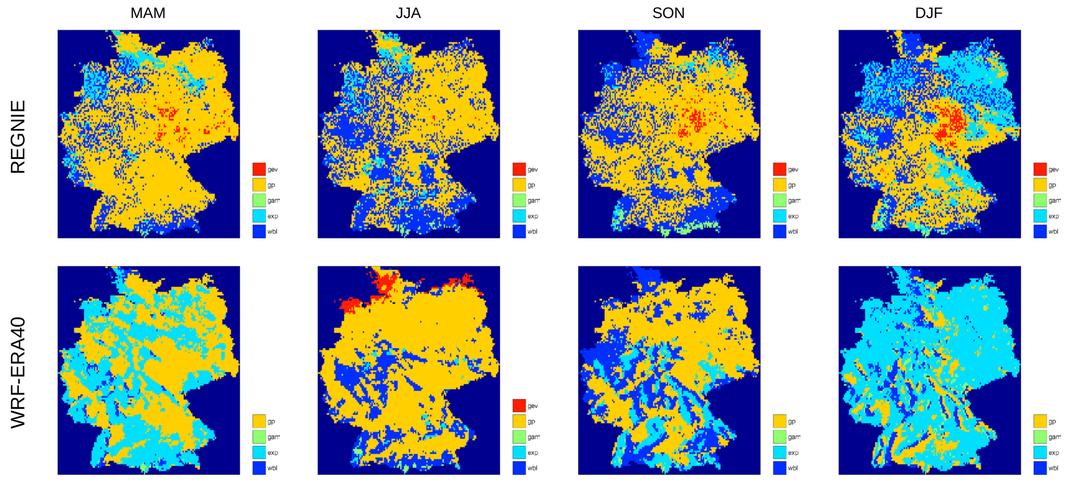


Model domain

REGNIE: Gridded observation data from DWD
WRF-ERA40: WRF simulation driven by ERA40 reanalysis data from ECMWF
Only positive pairs are considered

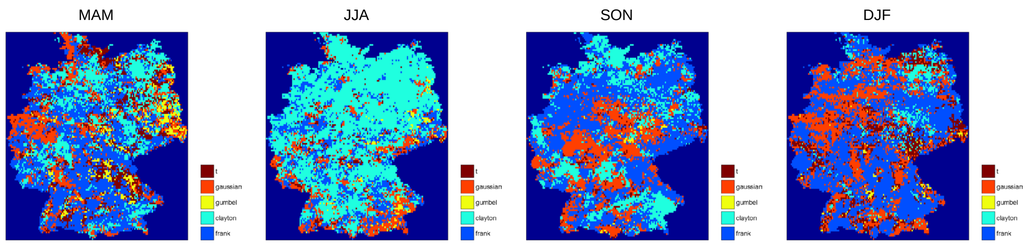
Results

Fitted marginal distributions (seasonal)
- Family identification is based on the Akaike and Bayesian information criteria
- Parameter estimation is based on Maximum Likelihood Estimation



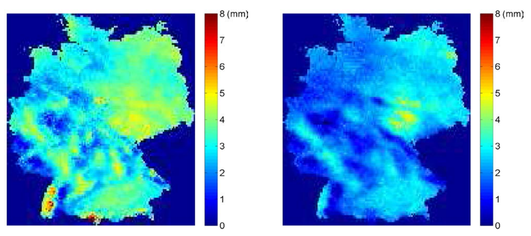
Fitted marginal distributions of REGNIE and WRF-ERA40 in different seasons

Identified Copula families (seasonal)
- Family identification is based on the Cramér-von Mises statistic
- Parameter estimation is based on Maximum Likelihood Estimation

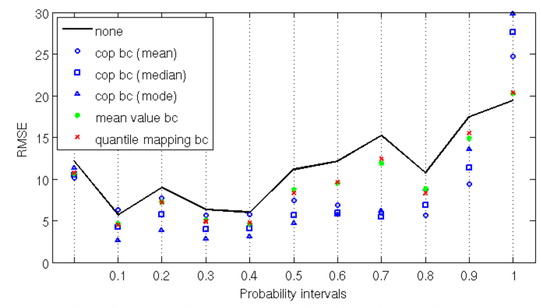


Identified Copula families in different seasons

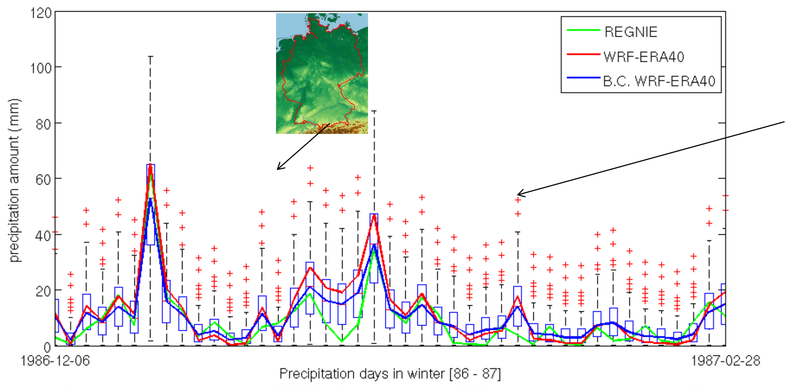
Copula based bias correction performance analysis



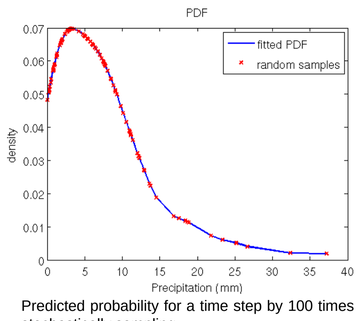
Bias maps of daily mean precipitation for uncorrected field (left) and corrected field by Copula based methods (right) from 1986 to 2000 in winter time (DJF) with only precipitation days



Total Root Mean Square Error and the RMSE for specific probability intervals ($RMSE_{0.1}$, $RMSE_{0.2}$, …, $RMSE_{1.0}$) of the grid cell near GAP in winter time (1986-2000)



Bias corrected time series of WRF-ERA40 data in winter [86-87] only with precipitation days. The blue line indicates the median of random samples



Predicted probability for a time step by 100 times stochastically sampling

Conclusions

- Copula based approach inherently allows for uncertainty estimation via stochastic sampling from the conditional Copula function
- Copula models are flexible as marginal distributions are independent from the Copula
- Copula based method performs better in different quantiles compared to traditional methods, except for extreme values

Outlook

- Use of non-parametric marginal functions instead of parametric marginal functions to check if the bias correction for extreme values improves
- Include additional information like temperature and relative humidity

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