

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

Ganquan Mao<sup>1,2</sup>, Stefanie Vogl<sup>3</sup>, Patrick Laux<sup>1</sup>, Sven Wagner<sup>1,2</sup>, Harald Kunstmann<sup>1,2</sup>

<sup>1</sup> Institute of Meteorology and Climate Research (IMK-IFU), Karlsruhe Institute of Technology (KIT), Kreuzteckbahnstraße 19, 82467 Garmisch-Partenkirchen, Germany

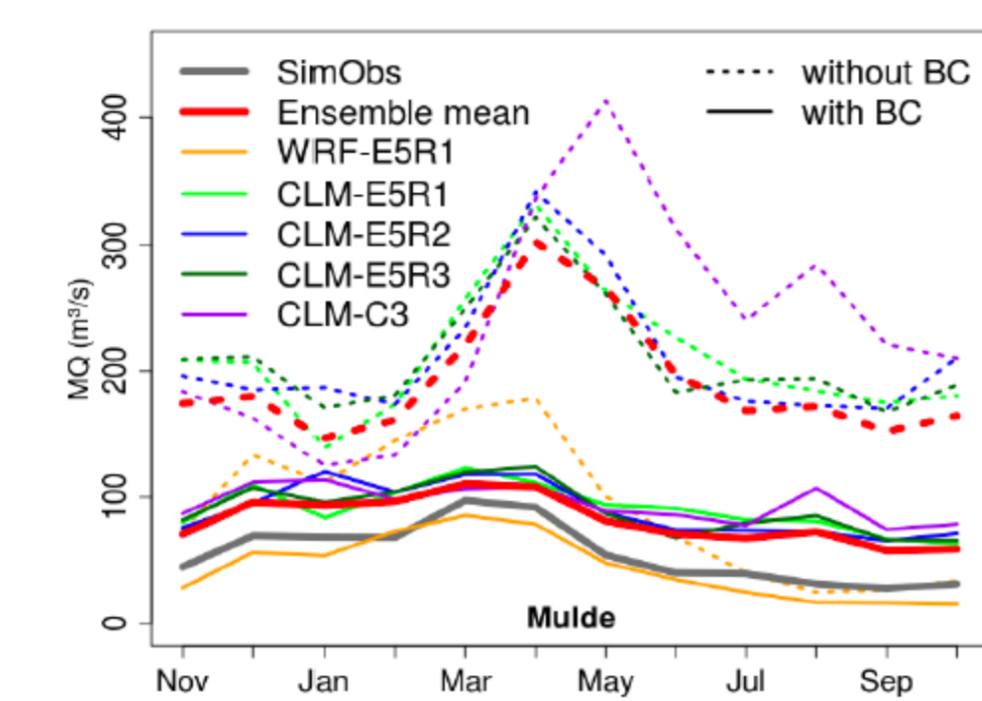
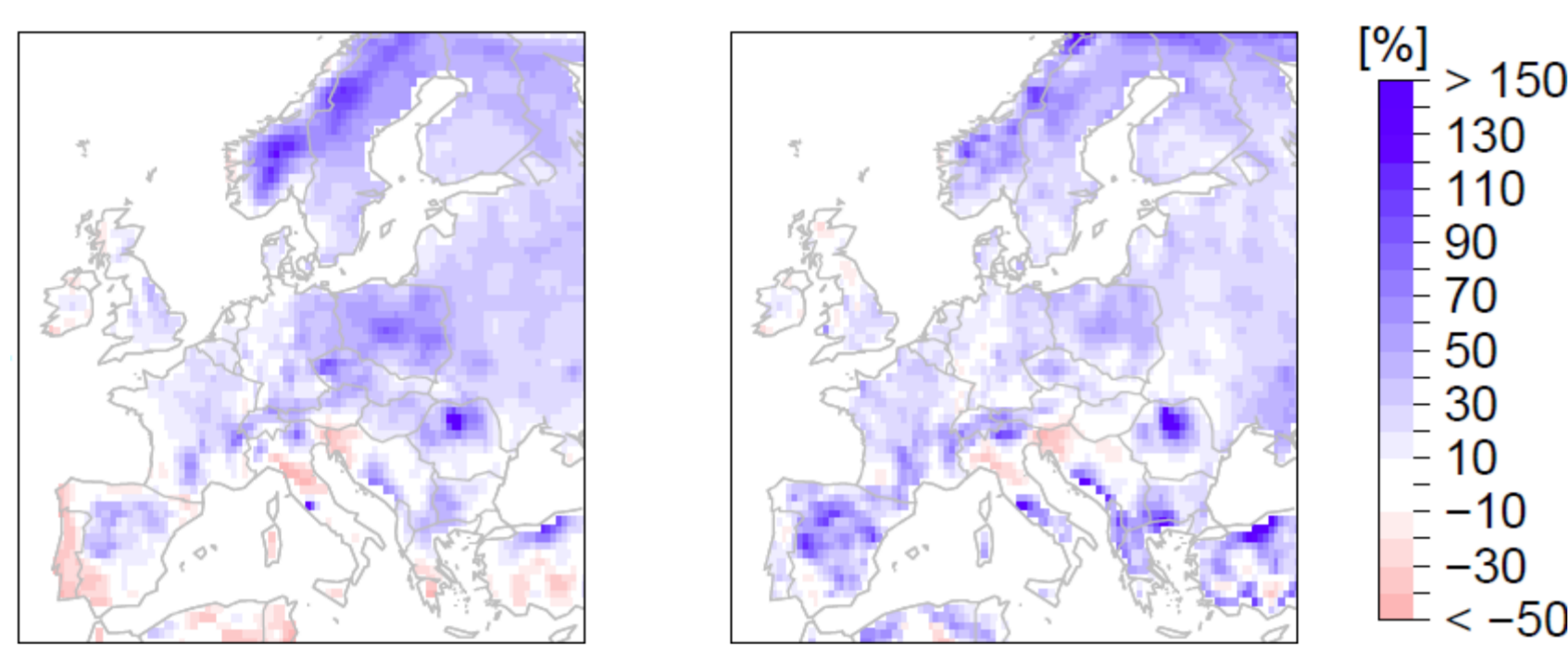
<sup>2</sup> Institute for Geography, University of Augsburg, Universitätsstraße 10, 86159 Augsburg, Germany

<sup>3</sup> Technische Hochschule Deggendorf, Edlmaierstraße 6 und 8, 94469, Deggendorf, Germany

Contact: ganquan.mao@kit.edu

## Introduction

Regional climate model (RCM) simulations often cannot be used directly for local climate change impact studies due to their inherent biases. Most of the bias correction procedures such as the quantile mapping correction employ a transfer function based on the statistical differences between RCM and observations for adjusting the RCM results. Apart from such transformation algorithms, a stochastic bias correction technique based on the concept of Copula theory is developed and applied to correct precipitation fields from the Weather Research and Forecasting (WRF) model.

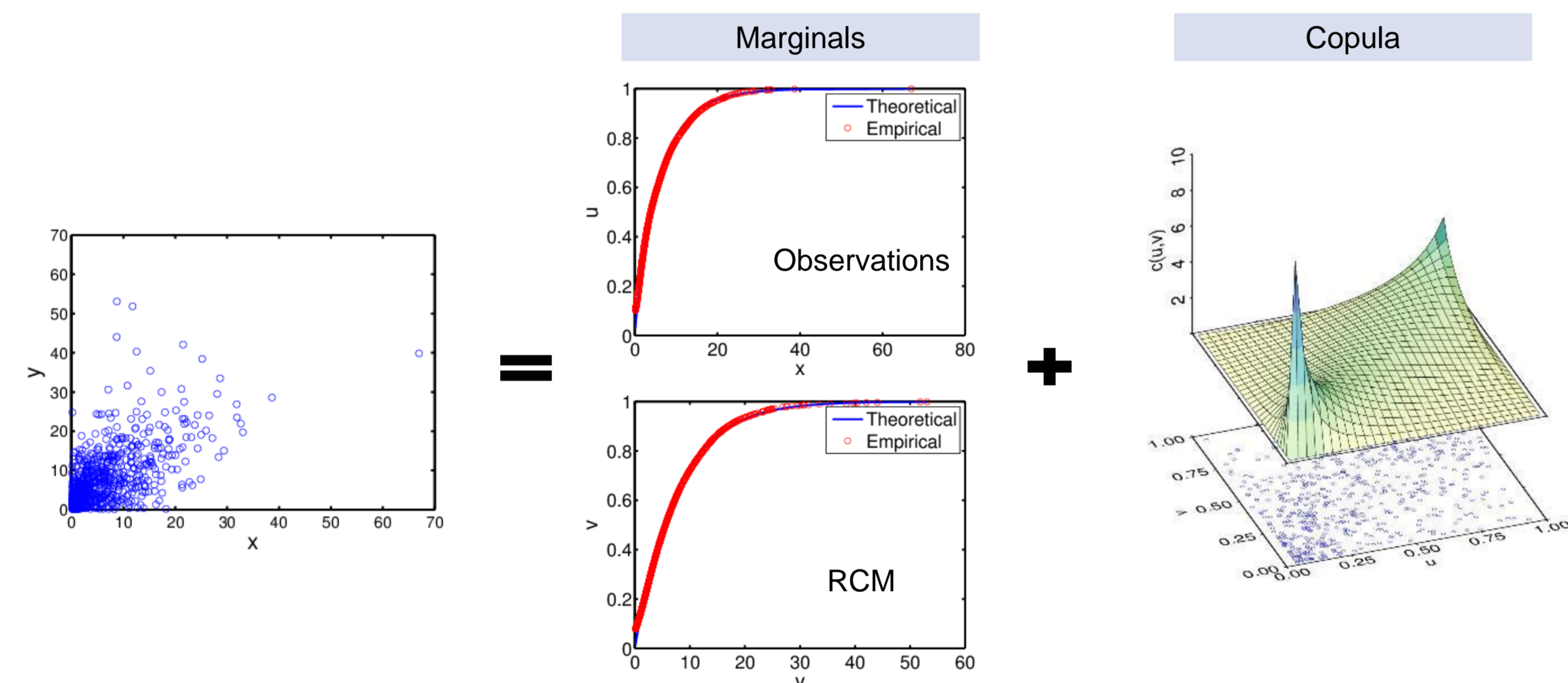


## Methodology

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):

$$H(x_1, \dots, x_n) = C_\theta(F_1(x_1), \dots, F_n(x_n)) \quad \bar{x} \in R^n \quad \theta = \{\theta_1, \dots, \theta_k\}$$

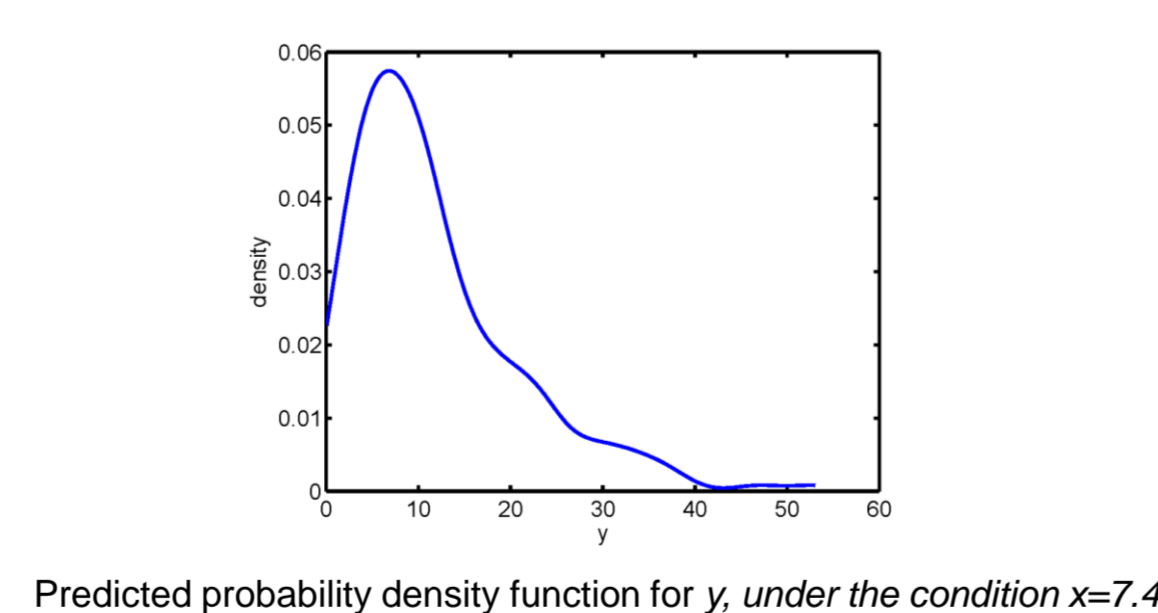
where  $C$ , called Copula, is unique if the marginal functions  $F_1, \dots, F_n$  are continuous. The Copula captures the features of dependence between the random variables. A bivariate Copula model consists of two marginal functions and a Copula function. The marginal functions describe the statistical aspects of variables and the Copula describes the dependence structure between the variables.



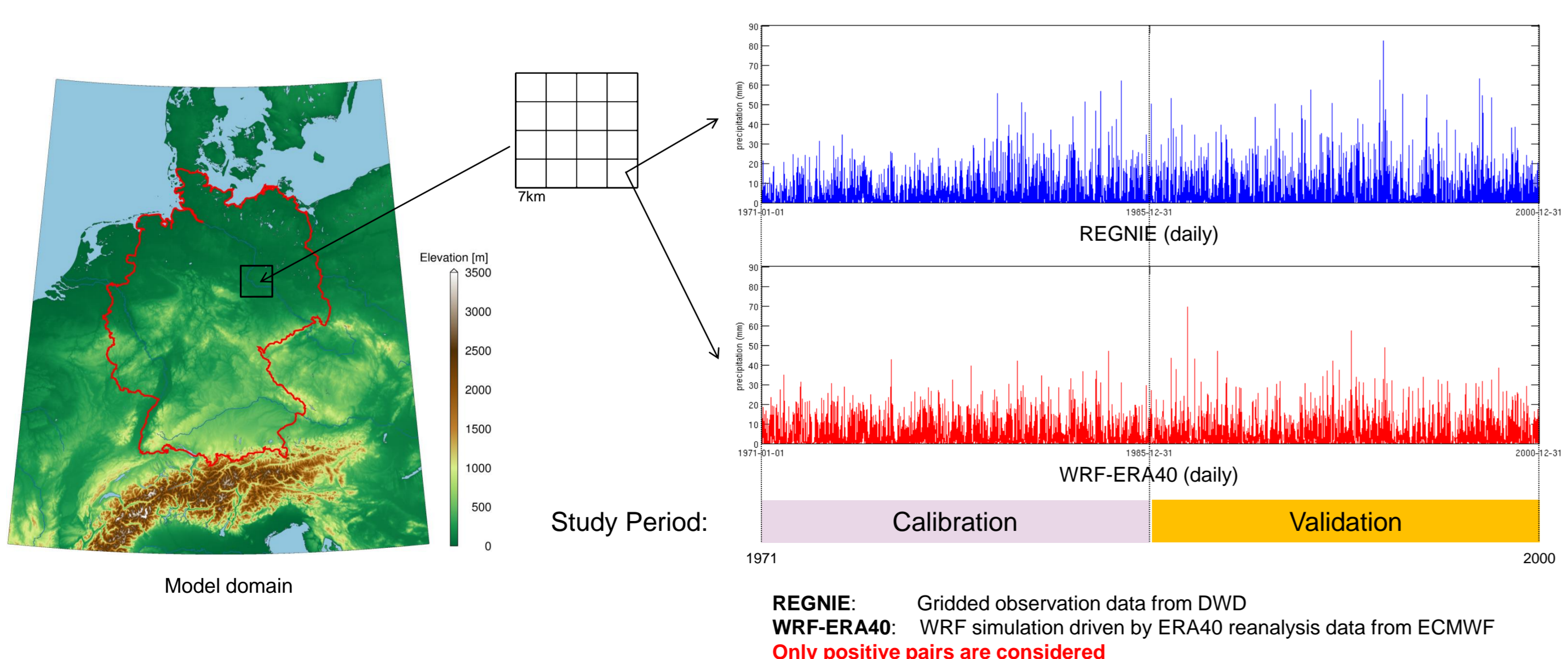
The Conditional distribution that derived from Copula model allows us to predict the value of one variable when the value of the other variable is given.

$$c_v(v) = P[V \leq v | U = u] = \frac{\partial C(u, v)}{\partial u}$$

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



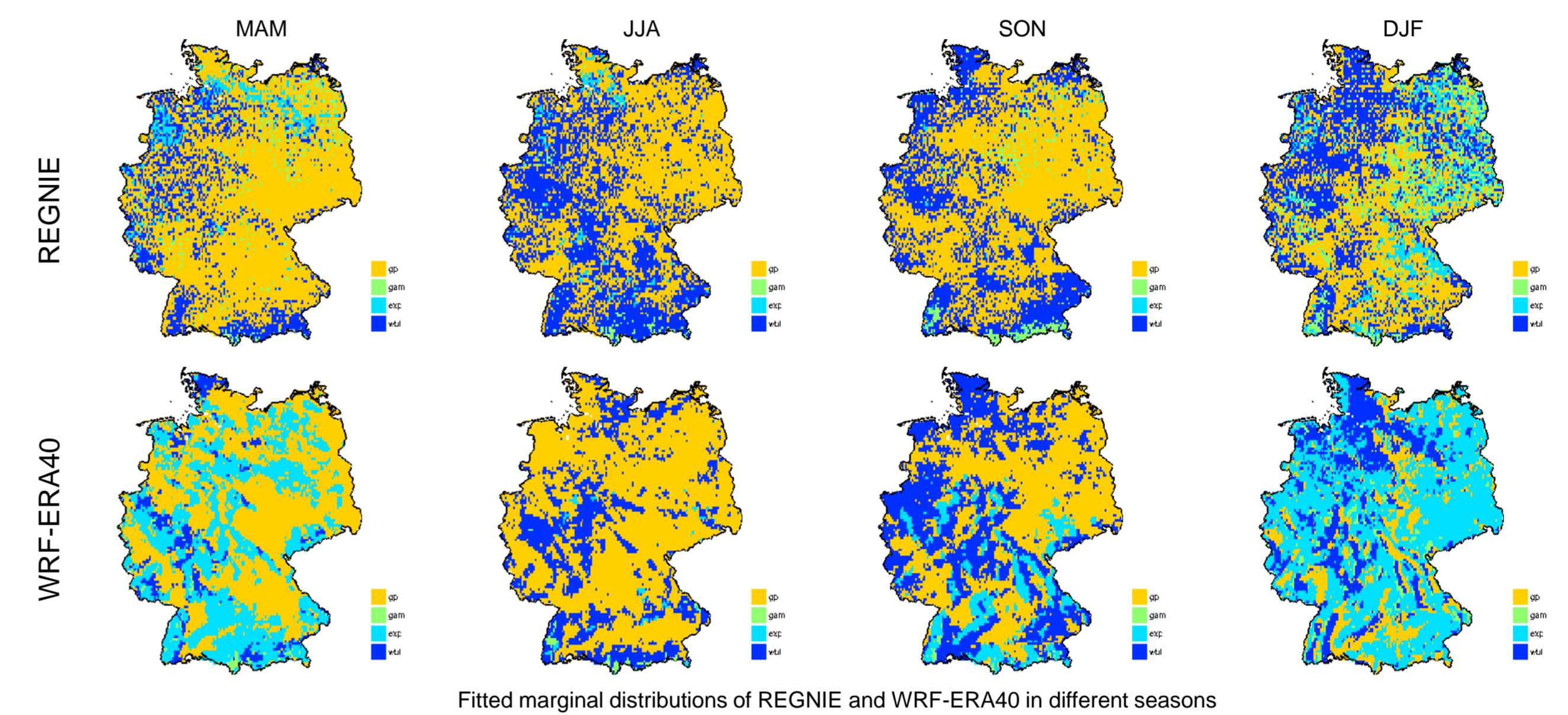
## Application



## Results

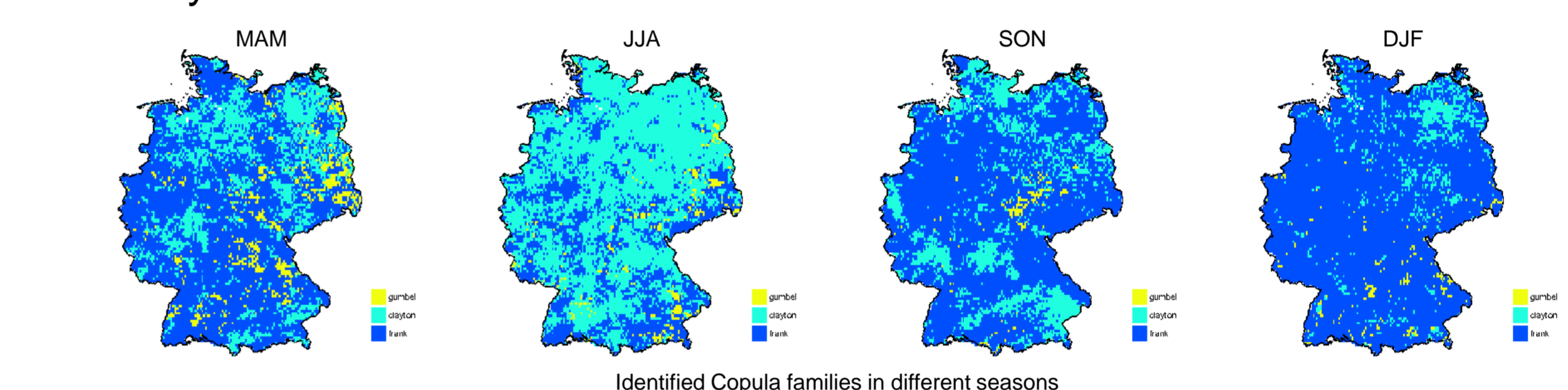
### Fitted marginal distributions from calibration period (seasonal)

- Family identification is based on the K-S test and Bayesian information criteria

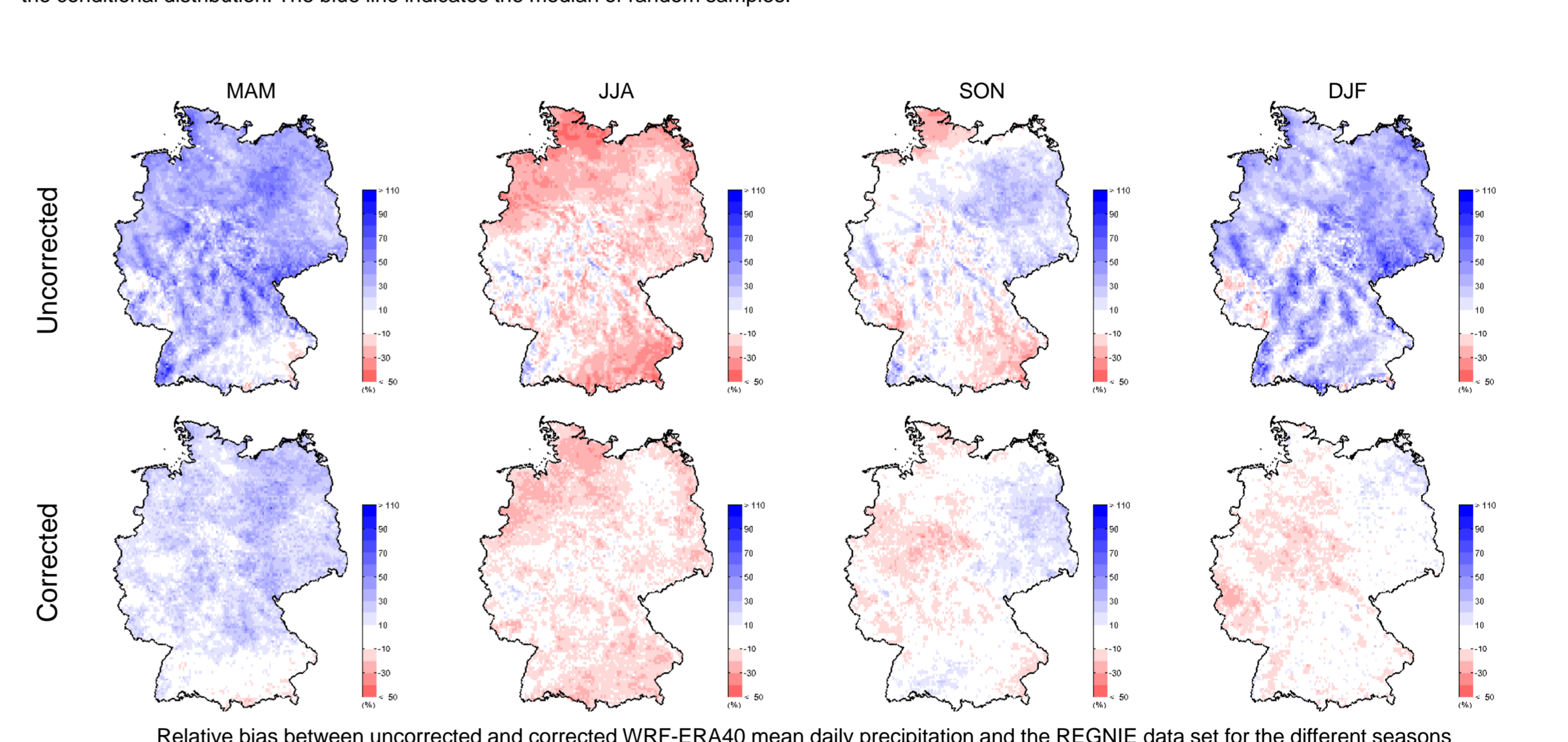
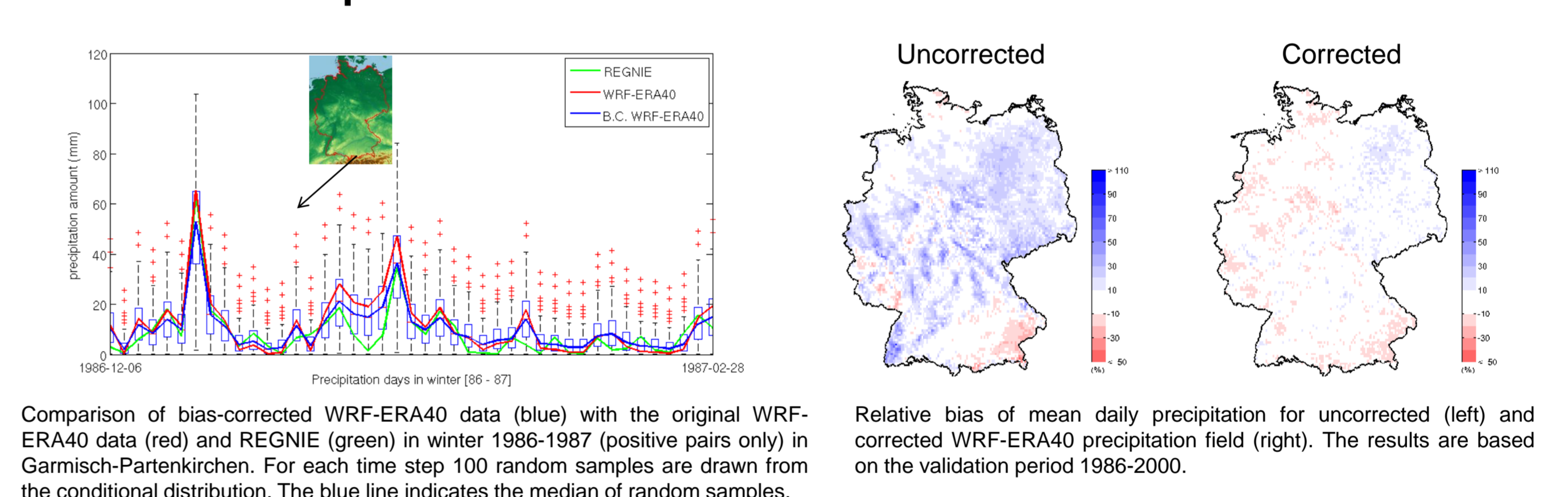


### Identified Copula families from calibration period (seasonal)

- Family identification is based on the Cramér-von Mises statistic



### Validation of Copula-based bias correction



## Conclusions and Outlook

- 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
- Fitted marginal distributions of REGNIE and WRF-ERA40 are different which indicates deficiencies of WRF-ERA40 simulations to reproduce the statistics of precipitation properly
- Copula based correction efficiently corrects most of the errors in WRF-ERA40 while it performs better for wet bias correction than dry bias correction
- The errors that WRF does not detect rainfall event correctly are not be able to correct by this method, and has to be investigated additionally

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