LUCCi Land Use and Climate Change Interactions in Central Vietnam

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Copula-based bias correction of RCM simulations for Southeast Asia

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Introduction

Hydro-meteorological information is crucial for regional and local impact studies. Regional Climate Models (RCMs) are suitable to dynamically downscale large-scale climate information to regional/local scales. However, even high resolution RCM results are still biased. As precipitation shows a high variability in space and time, it is difficult to correct.

Weather Research and Forecast (WRF) climate simulations from 1971-2000 are performed using ERA40 reanalysis data, hereinafter referred to as **WRF-ERA40** (Laux et al., 2012). Compared to gridded **APHRODITE** data a wet bias of WRF-ERA40 is observed (Fig. 1, left) which is higher for complex terrain (Fig. 1, right).

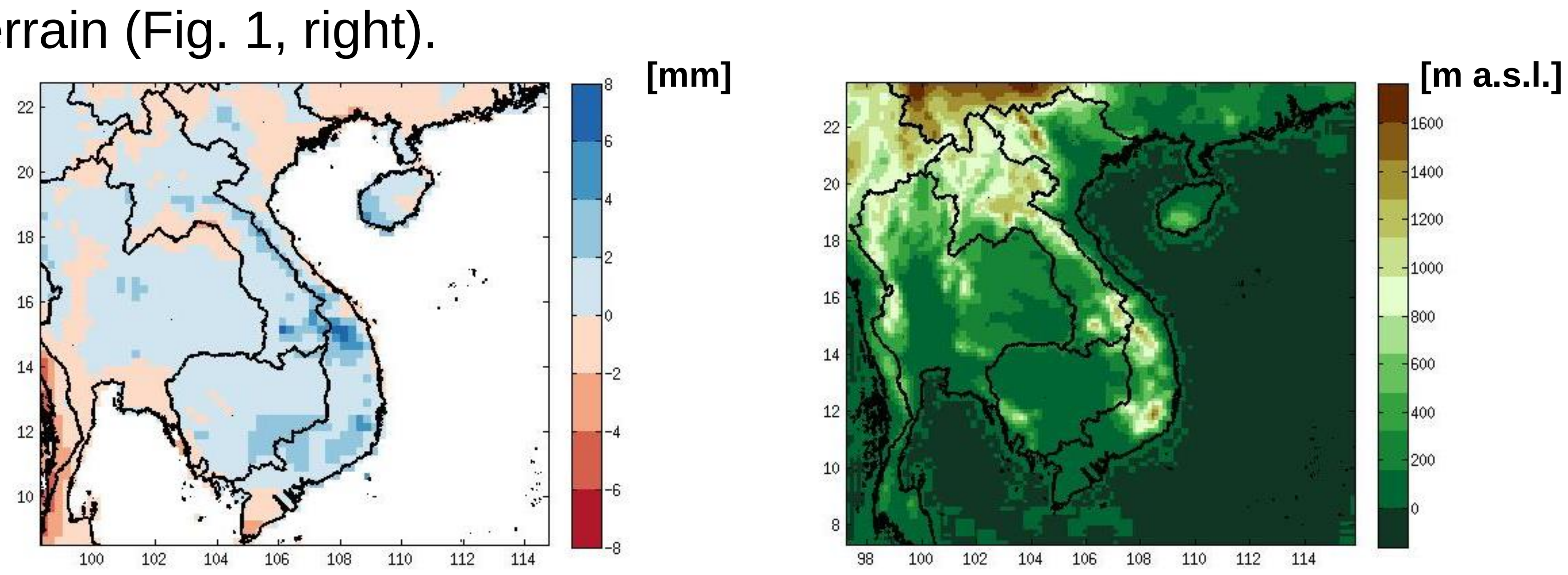


Fig. 1: Mean daily precipitation bias (WRF-ERA40 minus APHRODITE) for 1971-2000, (left). WRF-ERA40 (15 x 15 km) is re-gridded onto the APHRODITE grid (0.25°) using bilinear interpolation. Digital elevation model (DEM) as used in the WRF-ERA40 simulations (right).

Therefore, the **overall objective** is to correct the WRF-ERA40 climate simulations for their non-linear biases to obtain corrected high-resolution precipitation fields for impact studies. A Copula-based approach is used to find a link (dependence structure) between WRF-ERA40 and APHRODITE.

Background: Copula theory

Copulas are functions that link univariate distribution functions to form a multivariate distribution function (Sklar,1959). For any bivariate distribution function $F_{XY}(x,y)$ with univariate marginal distribution functions $F_X(x)$ and $F_Y(y)$ there exists a copula C:

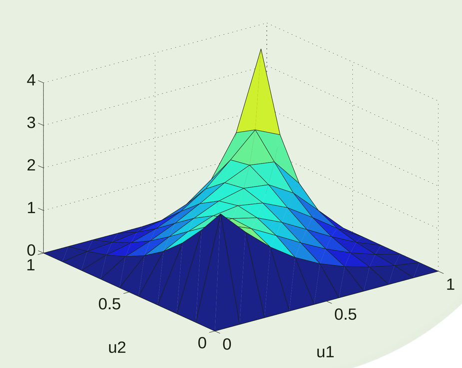
$$F_{XY}(x,y) = C(F_X(x), F_Y(y)) \qquad x, y \in \Re$$
$$= C(u,v) \qquad u,v \in [0,1]$$
$$C(u,v) = e^{\left\{-\left[(-\ln u)^{\theta}+(-\ln v)^{\theta}\right]^{\frac{1}{\theta}}\right\}}$$

e.g. CDF Gumbel-Hougaard Copula

Copulas allow to separate the dependence structure from the marginal distributions if the pdf c(u,v) is known. The construction of Copulas is thus reduced to the study of the relationship between the correlated *iid* variables, giving freedom for the choice of the univariate marginal distributions:

$$c(u,v) = \frac{\partial^2 C(u,v)}{\partial u \partial v}$$

$$f(x,y) = \underbrace{c(F_X(x), F_Y(y))}_{\text{pdf of Copula (copula density)}} \cdot \underbrace{f_X(x) \cdot f_Y(y)}_{\text{pdf 's of marginal distributions}}$$



Procedure and examples

The Copula is determined by *θ, which indicates the strength of* dependence among variables. Based on the conditional Copula distribution random samples of pseudo-observation conditioned on a certain data set can be modeled. In this case, the procedure consists of the following steps (Laux et al, 2011; Vogl et al., 2012):

1. Transform data pairs (WRF-ERA40, APHRODITE) into rank space by using the marginal distribution functions ($F(x_i) = u_i$):

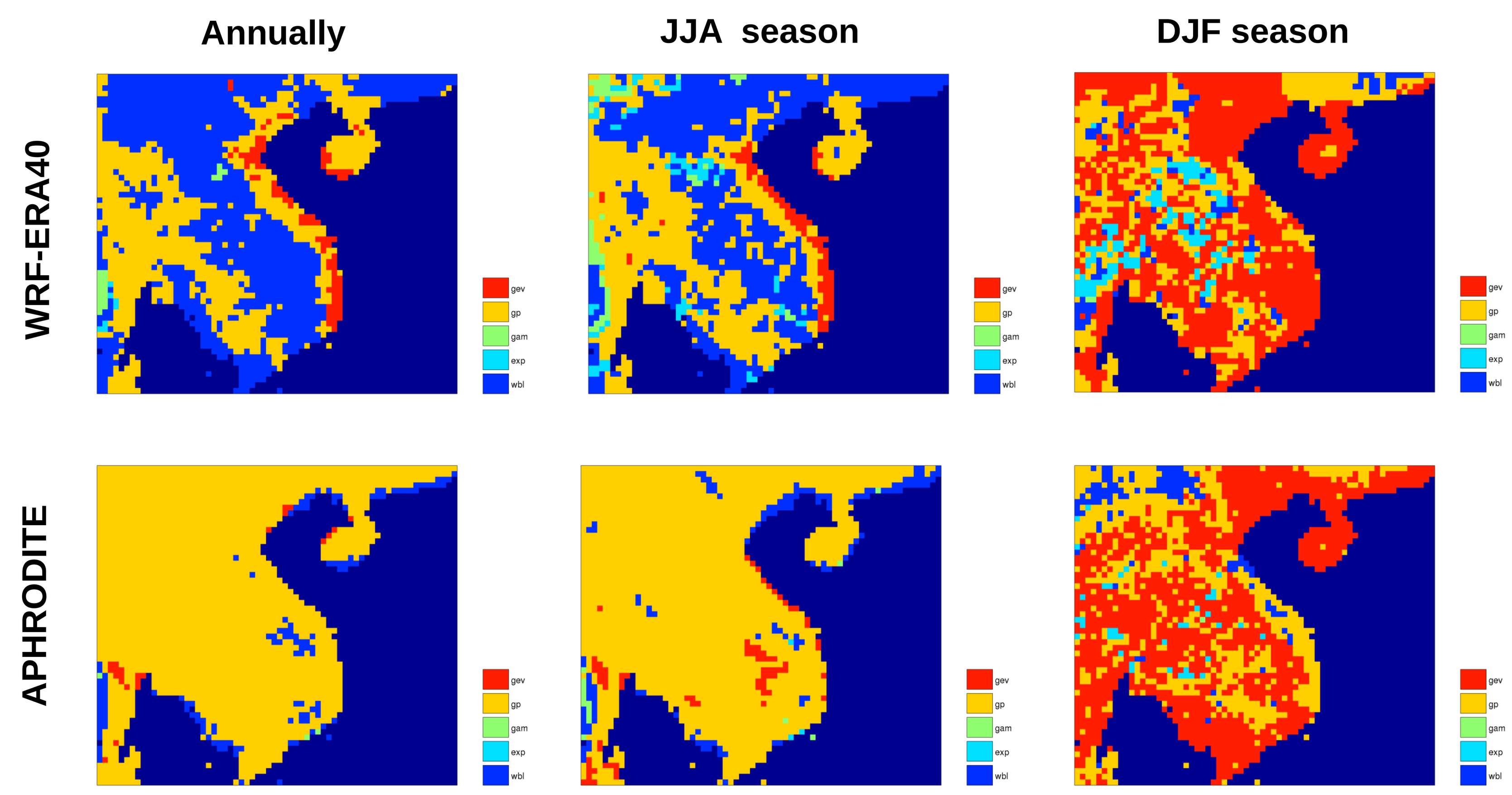


Fig. 2: Marginal distributions of WRF-ERA40 (top row) and APHRODITE precipitation data (bottom row) for 1971-2000 for the whole year, the JJA season, and the DJF season. A significance test based on the Akaike Information Criterion is performed to determine the family of the marginal distributions.

2. Fit a Copula function to data by using MLE:

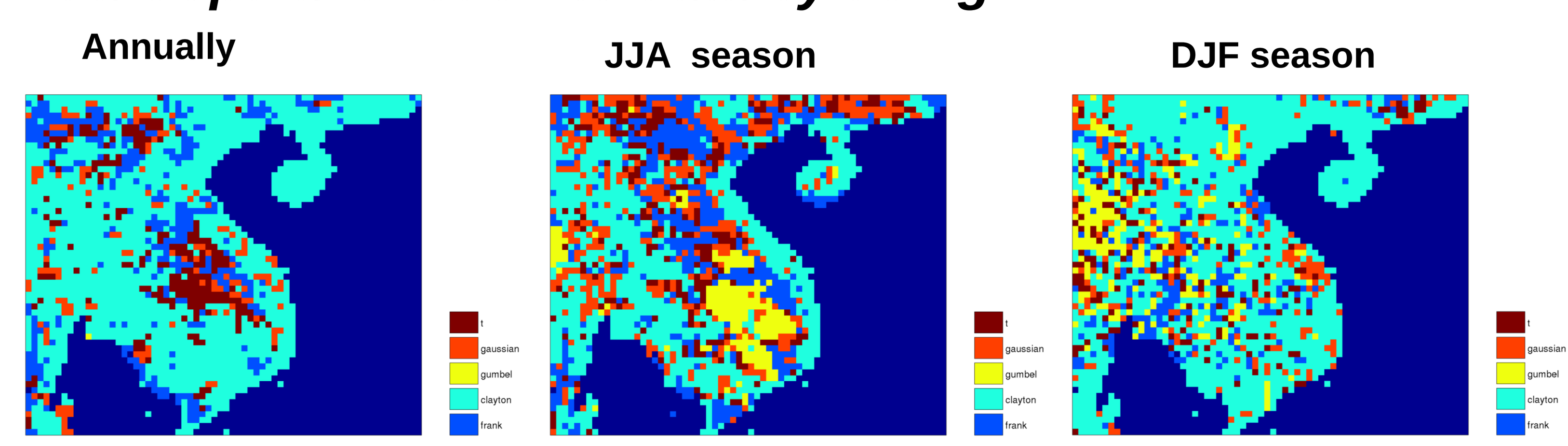


Fig. 3: Selected Copula family model based on Cramér-von Mises test statistic, for the whole year (left), the JJA season (middle), and the DJF season (right).

3. Generate random samples using conditional Copula CDF and transform back to data space ($F_i^{-1}(u_i)) = x_i$):

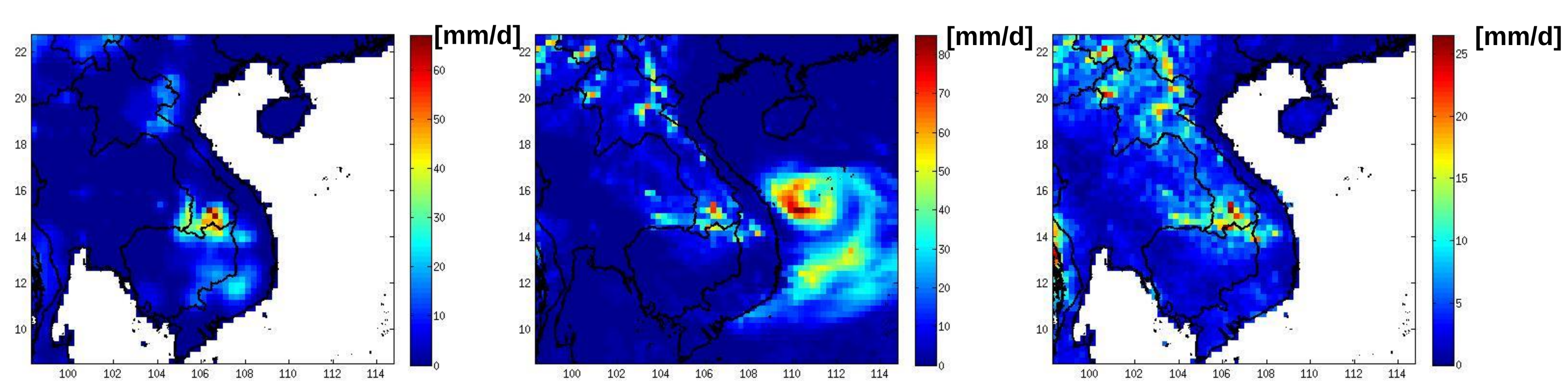


Fig. 4: Generated precipitation field of **30th July1986** for the APHRODITE observations (left), the WRF-ERA40 simulations (middle), and the median of the Copula-based bias correction using the Clayton Copula (θ = 1.7).

Summary & Conclusions

- Copulas are promising tools to model complex dependence structure as exists e.g. between modeled and observed rainfall
- Performance of the bias correction depends on many aspects (region, performance of RCM, observation data quality & density,)
- Further research is required to improve its performance
- Evaluation with state-of-art bias correction methods required

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