**Hydrology and
Earth System
Sciences
Discussions**

Interactive
Comment

Interactive comment on "Copula-based statistical refinement of precipitation in RCM simulations over complex terrain" *by* P. Laux et al.

P. Laux et al.

patrick.laux@kit.edu

Received and published: 27 June 2011

We would like to thank the reviewer for his valuable comments which helped a lot to improve the quality of the manuscript. The comments are addressed in detail below.

REFEREE #2: Overview This manuscript presents a new application for the copulas in the area of bias correction, to improve RCM simulations. The authors further included large-scale weather scenarios to improve and analyse the effects of these weather patterns. This manuscript could potentially be more significant if the issues below are addressed.

One main comment: 1. The author suggested in the Introduction that multivariate

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

distributions such as multivariate normal could be used and that an alternative is a copula approach. My question is whether the copula approach significantly improves the modelling to warrant its use. That is, more justification may be required for using the copula approach over a multivariate normal.

ANSWER: Further explanations about these aspects are inserted in the section "Introduction" for clarification. Although not ultimately proven, an inspection of the empirical dependence structures (empirical Copulas) gives strong evidence for this inference. The empirical Copulas show strong (weak) asymmetric features along the major (minor) diagonal which cannot be modelled adequately by a Gaussian approach. This statement is also supported by the reference to the paper of Bárdossy and Pegram (2009). They show that a copula model is closer to the data i.e. precipitation time series for Baden Württemberg, than a conventional covariance model.

REFEREE #2:

Comments Abstract 1. Line 5: Wrong spelling "continuous"

ANSWER: Modified accordingly.

REFEREE #2: Introduction 1. Pg 3002, Line 15: Consider rephrasing to "for conducting climate change impact ..."

ANSWER: Modified accordingly.

REFEREE #2: 2. Pg 3003, Line 5: spelling "gridd" incorrect

ANSWER: Modified accordingly.

REFEREE #2: 3. Pg 3003, Line 15: would be good to explain why using simple correlation of multivariate normal is not appropriate in this case.

ANSWER: Please see comments given above.

REFEREE #2: 4. Pg 3003, Line 28: spelling "parametrisations" incorrect. 5. Pg 3004,

Line 23: spelling "intermittend" incorrect. 6. Pg 3004, LIne 27: "studied" instead of "studies".

ANSWER: Modified accordingly.

REFEREE #2: Modelling the dependence structure between modelled and observed rainfall 1. Pg 3007, Line 1: spelling "independend" incorrect.

ANSWER: Modified accordingly.

REFEREE #2: 2. Pg 3007, Line 19: please be consistent with how ARMA-GARCH is stated in the entire manuscript

ANSWER: Modified accordingly.

REFEREE #2: 3. Pg 3008, Eqn 1 should be revised, not immediately clear.

ANSWER: Equation 1 is modified for clarification.

REFEREE #2: 4. Pg 3008, Eqn 2: κ is not defined here.

ANSWER: A definition for κ is inserted.

REFEREE #2: 5. Pg 3009, Line 3-5 and Eqn 5 do not seem to correspond. There is no z term in Eqn 5. Please re-check this equation.

ANSWER: The reference to the corresponding equation, namely equation 4, has been corrected in the manuscript.

REFEREE #2: 6. Pg 3010, Line 8-9: this sentence is unclear, by "steady" I assume you mean constant.

ANSWER: See also comment of Referee #1; "steady" is replaced by "continuous".

REFEREE #2: 7. Pg 3010, Line 14-17: sentence is convoluted and more justification should be considered for the use of copulas here. 8. Pg 3010, Line 20-21: this sentence "no unique characterization of the copula for dry days" is not clear what the

author is trying to convey. Consider rephrasing.

ANSWER: The sentence is spitted up and modified. Former Line 20-21 is modified for clarification. Additionally, this aspect is discussed in section "Discussions" following suggestions of referee #3.

REFEREE #2: 9. Pg 3011, Line 19: missing reference.

ANSWER: Modified accordingly.

REFEREE #2: 10. Pg 3012, Line 1: incomplete reference to Salvadori and line 2: "Copulas Salvadori et al." does not make sense.

ANSWER: Reference is corrected.

REFEREE #2: Simulation results 1. Pg 3014, Line 16: would be informative to have p-value or Q-statistic of the test stated here.

ANSWER: The results (decisions of the Ljung-Box Q-test) are inserted. (see new Table 4). Section 4.1 "Analysis of ARMA-GARCH time series models" completely revised. We tested the null hypothesis that a series exhibits no autocorrelation (using different time lags) against the alternative hypothesis that the autocorrelation is nonzero. This test has been conducted at α=0.05 and α =0.01.

REFEREE #2: 2. Pg 3015, LIne 18-26: Does this mean that you do not use the Gumbel-Hougaard copula if the p-value is under 0.01? Because most of your analysis and results were based on Garmisch-Partenkirchen, which showed a p-value of 0.00.

ANSWER: Inspection of the empirical copulas and different theoretical Copula families exhibits the highest agreement with the Gumbel-Hougaard Copula. This "eyeball crite-rion" is supported by the test results given in Table 2. Gumbel-Hougaard Copula has the highest p-values among the tested theoretical Copulas in general. As there are only one exceptions (out of 132 cases), we decided to use Gumbel-Hougaard for all stations even though the p-value is below 0.01. The major motivation for this is to keep

both simulation results and Copula parameter Θ comparable. We arbitrarily selected station Garmisch-Partenkirchen for demonstration purposes. Selecting cases with the highest p-values could lead to the conclusion that the bias correction works for selected stations exclusively.

REFEREE #2: 3. Pg 3016, Line 1-9: How does Table 1 show the dependence of the altitude? This is not immediately obvious to the reader. Similarly with the next 2 statements, more background/justification/statistics is required for such conclusions. Furthermore, are these dependence to altitude and distance statistically significant? Are they purely due to difference in elevation, as the text seem to indicate?

ANSWER: As this aspect is rather of minor importance for this paper, we decided to completely cancel this section (also following the suggestion of Referee #3).

REFEREE #2: 4. Pg 3016, Line 10-12: Fig 17 does not correspond to your description here. Are you referring to Fig 14 instead?

ANSWER: The referee is right. We correspond to Fig. 14 instead, however, this Figure is not shown any more (see also next comment).

REFEREE #2: 5. Pg 3016, Line 25: It appears that the 'copula map' is missing and does not correspond to Fig 17. Hence any subsequent conclusions drawn from this figure cannot be verified.

ANSWER: Section "Dependence on altitude and distance" containing the Copula map completely cancelled.

REFEREE #2: 6. Fig 9 caption: "quartile" spelling incorrect.

ANSWER: We think the spelling is correct.

REFEREE #2: 7. Table 3: Showing the correlation values between RCM and copula-based simulations on the same table may be misleading since one is used to inform the other, which is not the case with the observed data.

ANSWER: Table 6 (old Table 3) is completely revised. The results are more detailed discussed in the text.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 3001, 2011.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper