Authors Response to: Interactive comment on "Circulation pattern based parameterization of a multiplicative random cascade for disaggregation of daily rainfall under nonstationary climatic conditions" by F. Serinaldi (Referee #1)

By: Lisniak, D., Franke, J. and Bernhofer, C.

We would like to thank Referee #1 for his time to review our manuscript and for his substantial and constructive comments. The references provided in the comments of Referee #1 are very useful in the scope of our work and will be taken into our further considerations. The remarks on improvements concerning the presentation of the data are much appreciated and will be implemented.

Our answers to the specific comments are structured as follows: We first repeat the part of the Referee's comment (in bold), which we will then reply to. Following this we will address the minor remarks made by Referee #1. Please note, that the diagrams shown in this authors comment are preliminary versions, which will be reworked for the revised manuscript.

Specific comments

Nevertheless, Lombardo et al. (2012) proved that the discrete branching algorithms are characterized by intrinsic nonstationarity. This aspect probably affects the simulated rainfall sequences in a way which could be not so evident in the rainfall summary statistics; however, the problem must be mentioned and/or taken into account by using for instance the algorithms suggested by Lombardo et al. (2012). It is worth noting that the spectral-based algorithms devised for the universal multifractal models are not affected by the above mentioned problem.

We appreciate the Referees suggestion to account for the non-stationarity of discrete branching algorithms and the provided reference to the work of Lombardo et al. (2012). Since for our work the cascade model was required to be discrete, we implicitly accepted its non-stationary characteristics. While we do not intend to include the Hurst-Kolmogorov cascade model in the scope of this work, we will add a discussion of the intrinsic nonstationarity of the

MRCs to the revised manuscript using the autocorrelation as derived by Lombardo et al. (2012).

[…] it is difficult to draw definite conclusions based on the ACFs without reporting the corresponding confidence intervals.

We will follow the remarks of the Referee and complement the ACF plots in Fig. 9 with their confidence intervals in the revised manuscript.

[…] it should be mentioned that the proposed models implicitly assume that the relationships between covariates (e.g., CPs) and parameters estimated in the calibration period are deemed to be valid also in the validation period.

As the Referee correctly points out, the disaggregation model with CPs is based on the assumption that the relationship between model parameters and large scale forcing remains valid in both periods, as well as in the future. It is true, that this might be a contradictory assumption when developing a method to account for climate projections, especially when considering the possible emergence of new weather situations (Trans Weather Patterns; Kreienkamp et al., 2010), which could occur in the future and cannot be statistically inferred from the current climate. However, we believe that such assumptions have to be made for climate impact studies, given the available data at the moment. While the relationship of MRC parameters to circulation patterns is assumed to be invariant in time, the non-linearity of the climate signal is represented by the changing frequencies of occurrence of the CPs, a method which was successfully applied in a preceding work by Franke and Bernhofer (2009). Of course such assumptions have to be validated in a historical experiment, which was attempted in this work.

However, further sources of complexity should be introduced only if there is a clear improvement. In my opinion, at the present stage, the empirical results shown in the manuscript do not clearly justify the use of CPs.

First of all we want to point out, that optimally a broader data set for the validation period plus additional study locations would be needed to draw definite conclusions on this matter. Unfortunately, both are not available to us at the moment.

Given the results of this validation, we agree that a clear improvement is not evident when using CPs as covariates. However, notwithstanding the above our aim was to show that the introduction of a new source of complexity does not lead to a decline in performance while using the statistical information carried by the CPs. Given the model results, this could be confirmed. Since our position is that the circulation patterns do have different scaling properties, the inclusion of these covariates enables the user to perform impact studies by accounting for the above mentioned climate signal of changing frequencies of the CPs occurrence.

To support this argumentation, we will add a diagram of scaling properties for the two outer extremes of CPs (i.e. CP1 as the driest and CP8 as the wettest class). Differences between these two circulation patterns are most obvious (Fig. C1), while intermediate CPs have their scaling properties in between these two. If the frequencies of occurrence of the CPs change, so should the statistical properties of the high resolution rainfall. This is accompanied by histograms of the relative frequencies of CPs for the two periods (Fig. C2) to emphasize our focus on coupling model parameters to this climate signal.

[…] both MRCs models and the rainfall generator should reproduce exactly the moments at the daily scale. Therefore, the bias of the moments at 24h time scale exhibited by the rainfall generator (bottom panel of Fig. 8) and the systematic bias of the CDF of 1h rainfall (Fig. 5) seem not to be consistent.

We thank the Referee for pointing out an error in the presentation of the data in Fig. 8. This is important, since this error is also present in Fig. 9. Here, data from the parameterization period has been accidentally used twice for plotting the moment scaling behaviour and autocorrelation function of the rainfall generator (P-Gen). This probably happened while changing the code for the layout of these figures and erroneously inserting the same data source for two different periods. Unfortunately this was done after the proofreading and shortly before submission. We have corrected this mistake and inserted the proper source data. The revised plots can be seen in Fig. C3 below for the moment-scale relationship, and in Fig. C4 below for the autocorrelation function respectively.

The Authors discuss the difference between the scaling properties of the rainfall for the periods 1969-1979 and 1989-1999 on the basis of the moment-scale power-law relationships shown in Fig. 3. The overlap of different moments makes the comparison rather difficult. However, a careful inspection reveals that the difference of the slopes could be not so evident. In particular, given the small sample size (5 points), the difference could be not statistically significant. I suggest (1) to redraw the figure to make it clearer (avoiding any overlap), (2) to test the difference of the slopes and (3) to complement the figure with the diagrams of the exponent of the moment scaling relationships K(q) taking the uncertainty into account. A discussion about the uncertainty of K(q) is provided by Villarini et al. (2007).

We will address the suggestions made by the Referee in the order of their appearance:

(1) We have redrawn Fig. 3 and aligned the intercepts of the linear regressions for each moment of the validation period with the respective intercepts of the parameterization period at the scale of 1 h to avoid overlap and to have a clearer view on the differences in their slopes (see Fig. C5 below).

(2) Using a t-test, the hypothesis of similar slopes between the moment-scale power-law relationships of the two periods can be rejected for moments of order $q > 1$ at a significance level of 5 %. Thus we conclude that the scaling behaviour of the two periods differ.

(3) The K(q) plots for the two periods, empirically determined from the slopes of the moment-scale power-law relationships in Fig. C5, are provided in Fig. C6 below. Please note, that while in the original manuscript K(q) is denoted as $\tau(q)$, we will denote it as K(q) in our reply. The uncertainty of the exponent K(q) of the moment scaling relationship is the 90% confidence interval of the ordinary least squares regression used to approximate the linear relationship between scale T and moments M_q in Fig. C5. Although Villarini et al. (2007) describe in their paper different

regression frameworks for the construction of the scaling function we believe that the ordinary least square method is sufficient for presentation purposes, despite the inherent assumptions of homoscedasticity and independence of the (supposed) zero-mean residuals.

We see that the suggestions made by Referee #1 are reasonable and help to significantly improve the presentation. The points addressed above support our statements concerning the difference between the scaling properties of the two periods and will be implemented in a revised version of the manuscript.

Minor remarks

We will now address the minor remarks of Referee #1 in their order of occurrence:

P10118 L20: We thank Referee #1 for the reference to this great paper by Mascaro et al. (2013). We will add a discussion on the problem of signal sampling using discrete counting (DC) and continuous counting (CC) of tipping-bucket data and its possible impacts on our work, specifically concerning the temporal resolution of 1 hour, to the revised manuscript. Unfortunately we can not account for this problem, since we have no actual records of the bucket tips. Another point of interest for us in the work of Mascaro et al. is the identified link between synoptic circulations and metrics of spatial rainfall patterns. However, in our work we are more interested in temporal rainfall.

P10126 L1: We changed “he” to “the”.

P10128 L5-10: The potential to explain changes in natural systems in terms of fluctuations of a stationary process is widely discussed in the literature (e.g. Koutsoyiannis, 2011) and goes back as far as to the work of Hurst (1951). While we agree that a closer investigation of our results in this viewpoint is an interesting topic for future work, our approach for this work is a different one. We believe that a proper discussion of this topic in the current work lacks the necessary data basis to include or rule out these effects.

P10128 L1-10: The orders of Fig. 8 and Fig. 9 have been switched with Fig. 6 and Fig. 7 to match their first mentioning in the text.

References

Franke, J. and Bernhofer, C.: A method for deriving a future temporal spectrum of heavy precipitation on the basis of weather patterns in low mountain ranges, Meteorol. Appl., 16, 513–522, doi:10.1002/met.149, 2009.

Hurst, H. E.: Long term storage capacities of reservoirs, Trans. ASCE, 116, 776–808, 1951

Koutsoyiannis, D.: Hurst-Kolmogorov Dynamics and Uncertainty, Journal of the American Water Resources Association (JAWRA), 47(3), 481-495, DOI: 10.1111/j.1752-1688.2011.00543.x, 2011

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Villarini, G., Lang, J. B., Lombardo, F., Napolitano, F., Russo, F., Krajewski, W. F.: Impact of different regression frameworks on the estimation of the scaling properties of radar rainfall, Atmospheric Research, 86(3–4), 340-349, 2007.

Figures

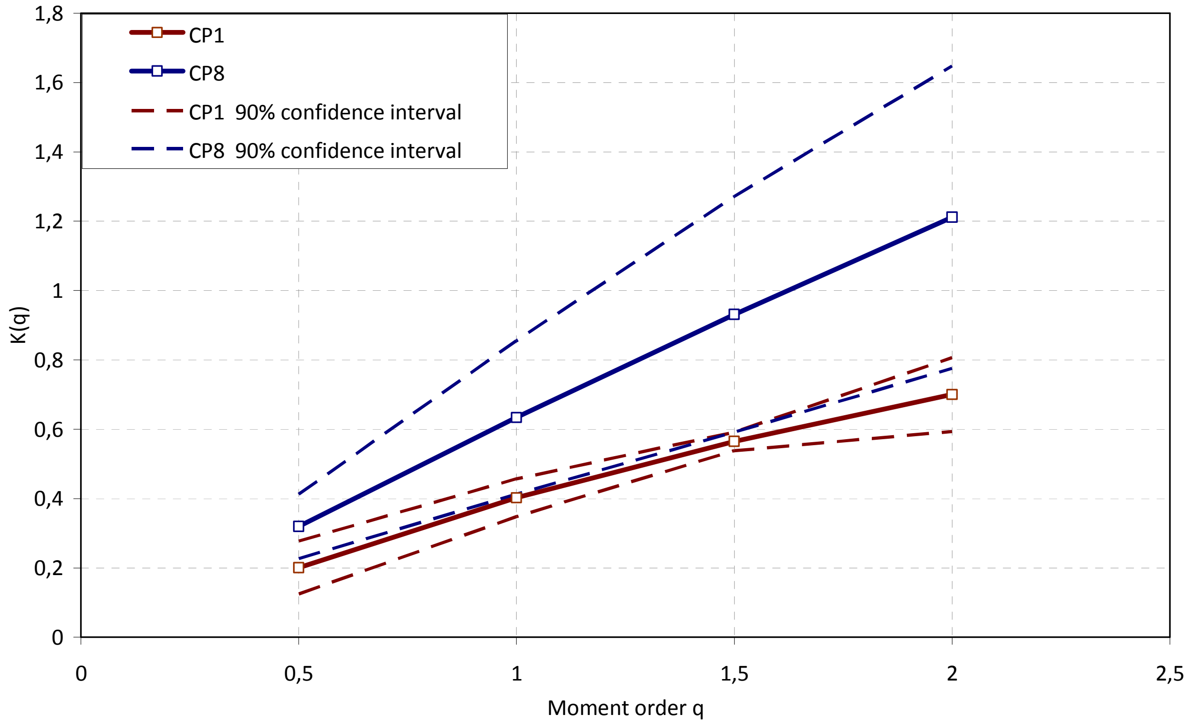

Figure C1: Exponents K(q) of the moment-scale relationship for the driest (CP1) and the wettest circulation pattern class (CP8) in the parameterization period with their corresponding uncertainties.

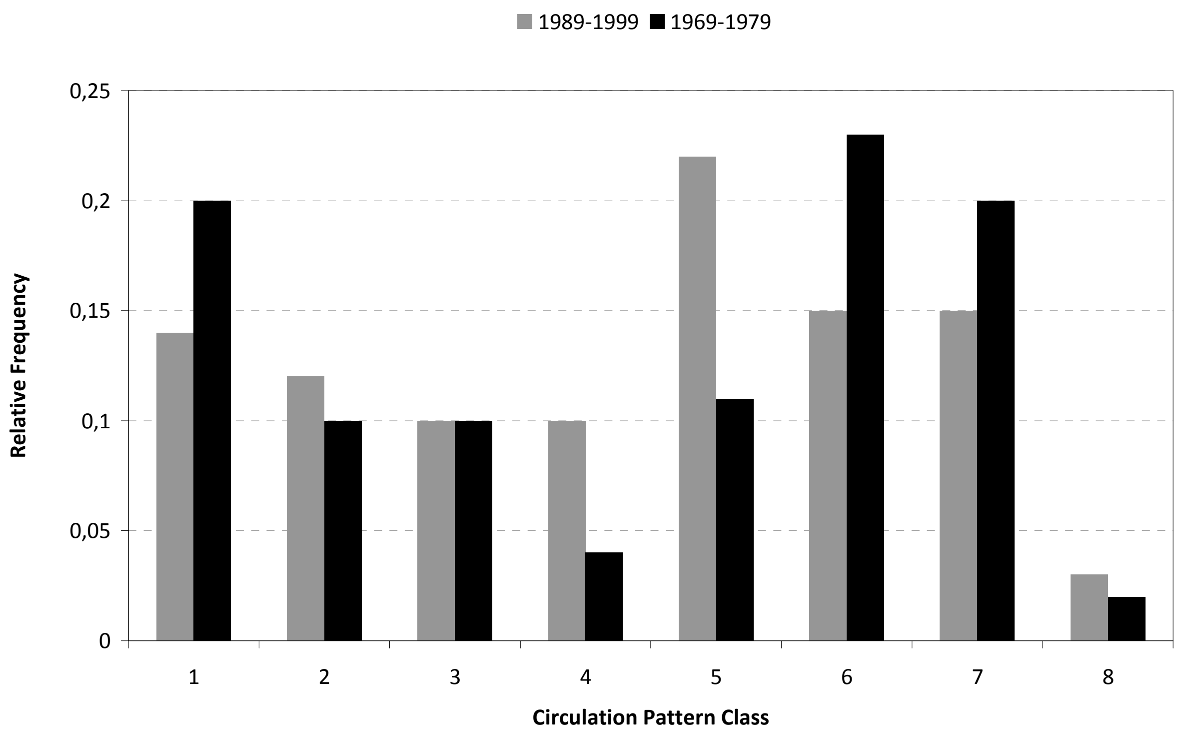

Figure C2: Relative frequencies of occurrence for circulation pattern classes in the parameterization period (1989-1999) and validation period (1969-1979).

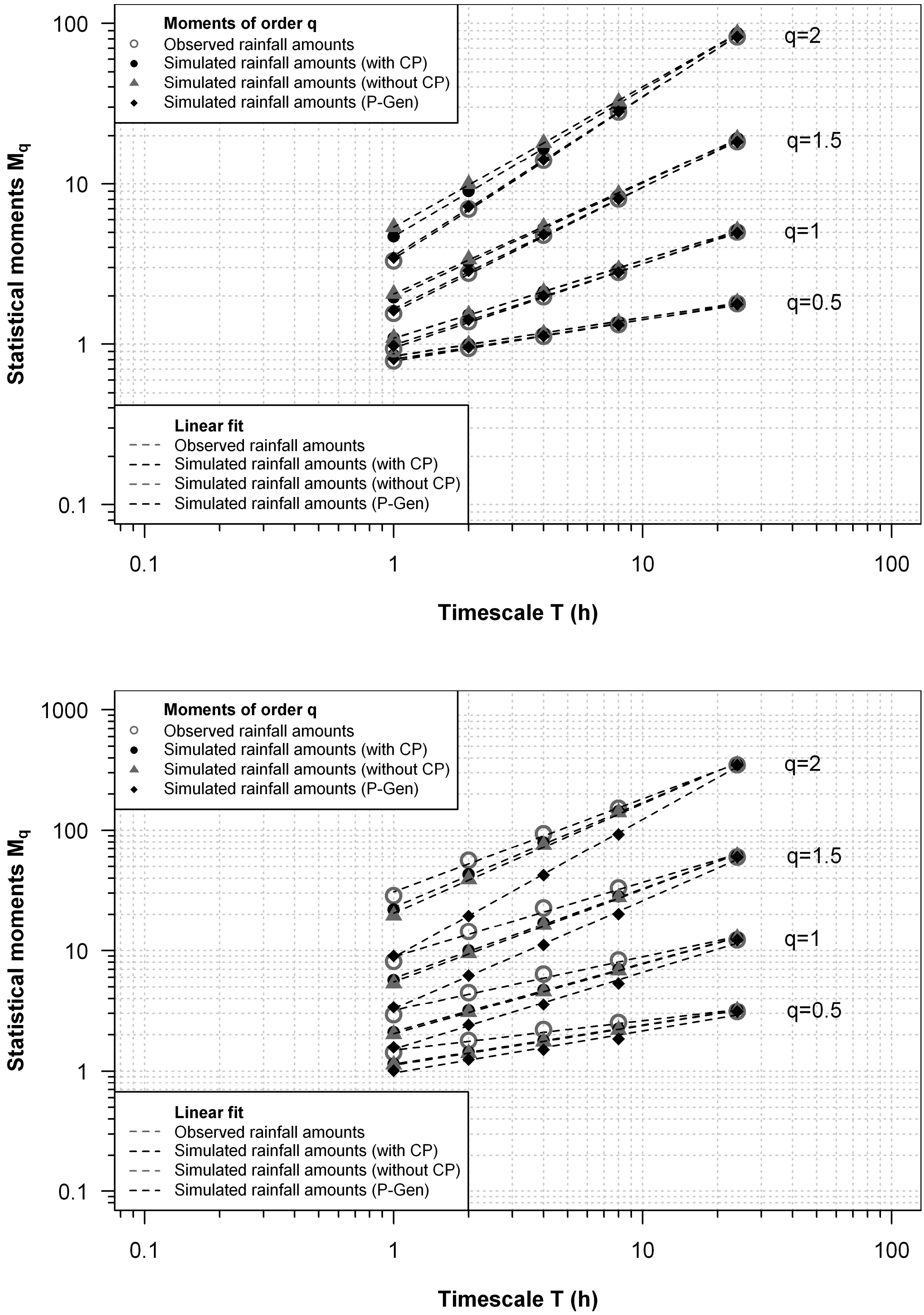

Figure C3: Revised version of Fig. 8 of the manuscript, with the moment-scale relationship of the rainfall generator (P-Gen) for the validation period (bottom panel) now correctly plotted using the proper source data.

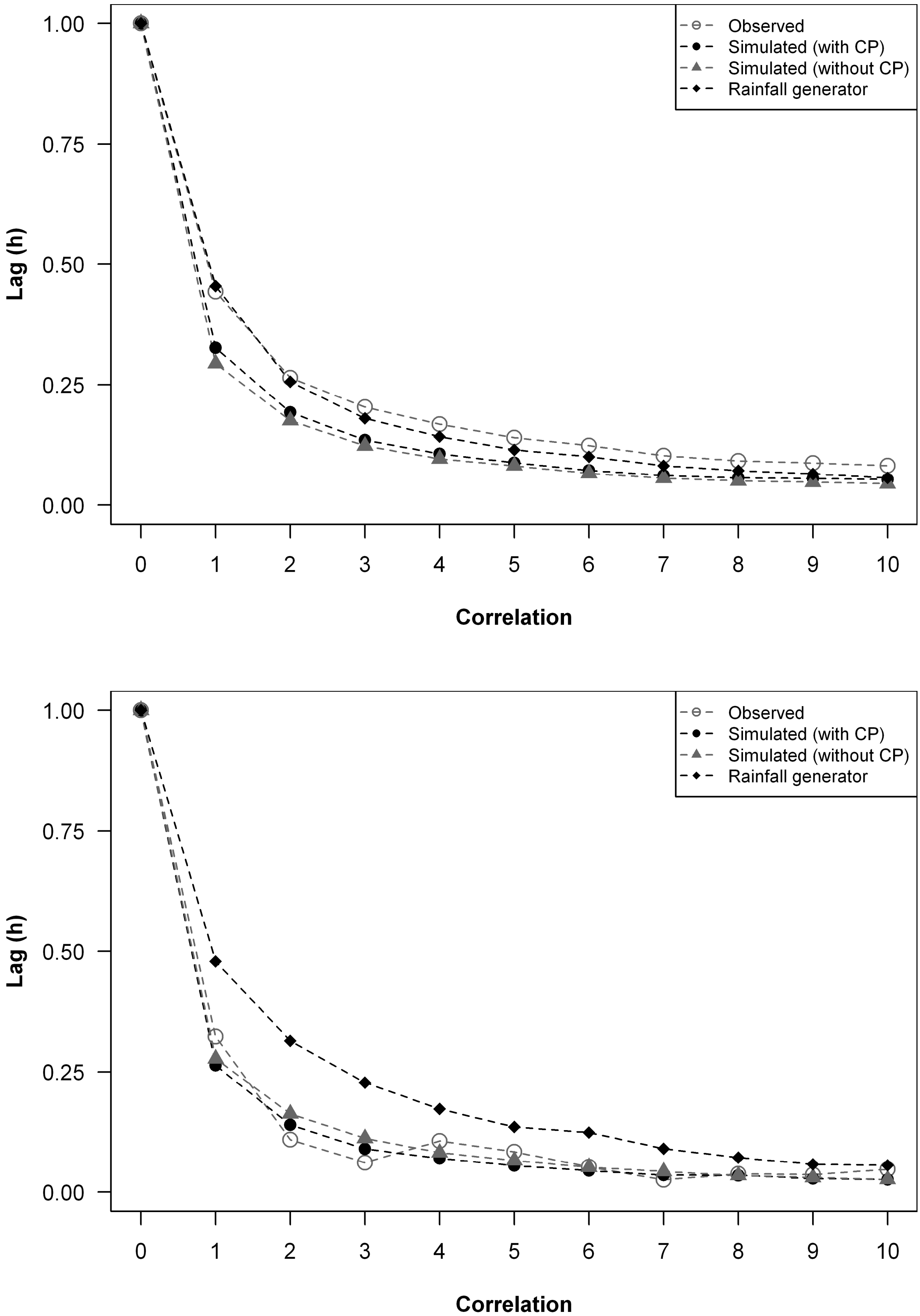

Figure C4: Revised version of Fig. 9 of the manuscript, with the autocorrelation function of the rainfall generator time series (P-Gen) for the validation period (bottom panel) now correctly plotted using the proper source data.

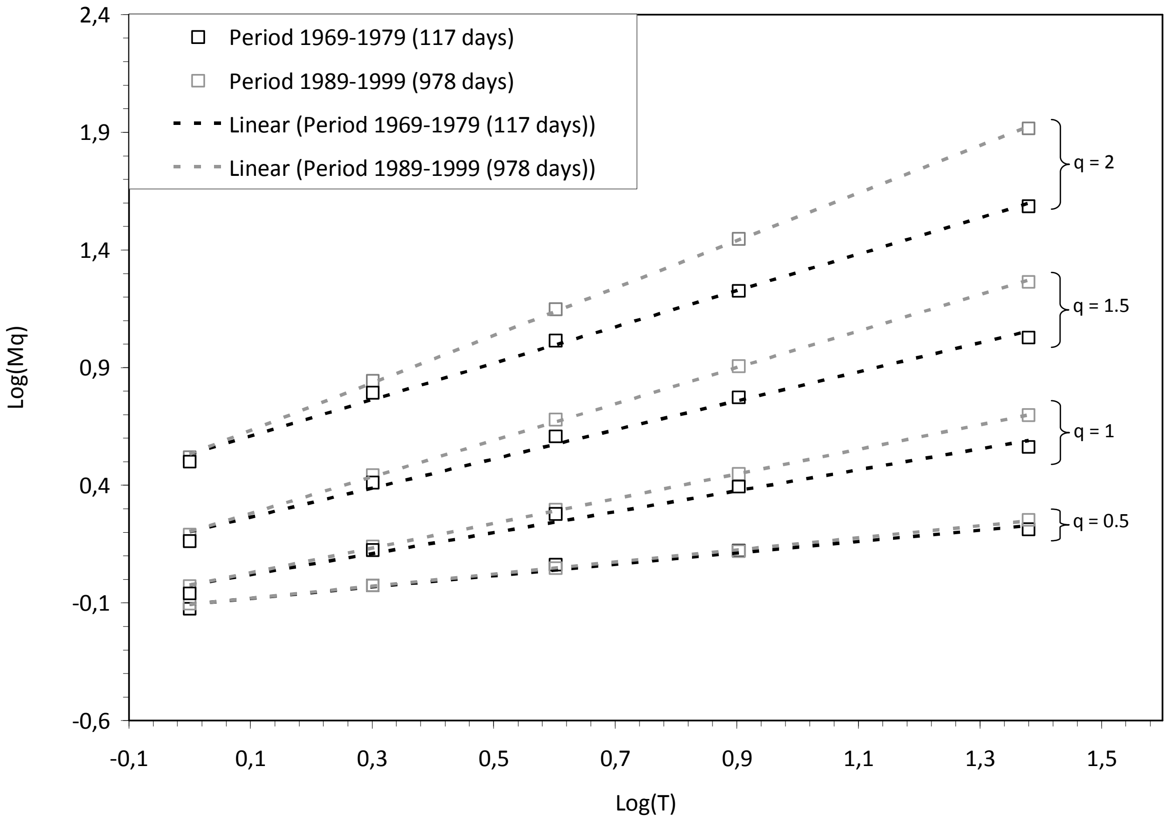

Figure C5: Moment-scale power-law relationships of the parameterization period (1989-1999) and the validation period (1969-1979). Moments of validation period are shifted to match the intercept of the corresponding regression line of the parameterization period to better compare their slopes.

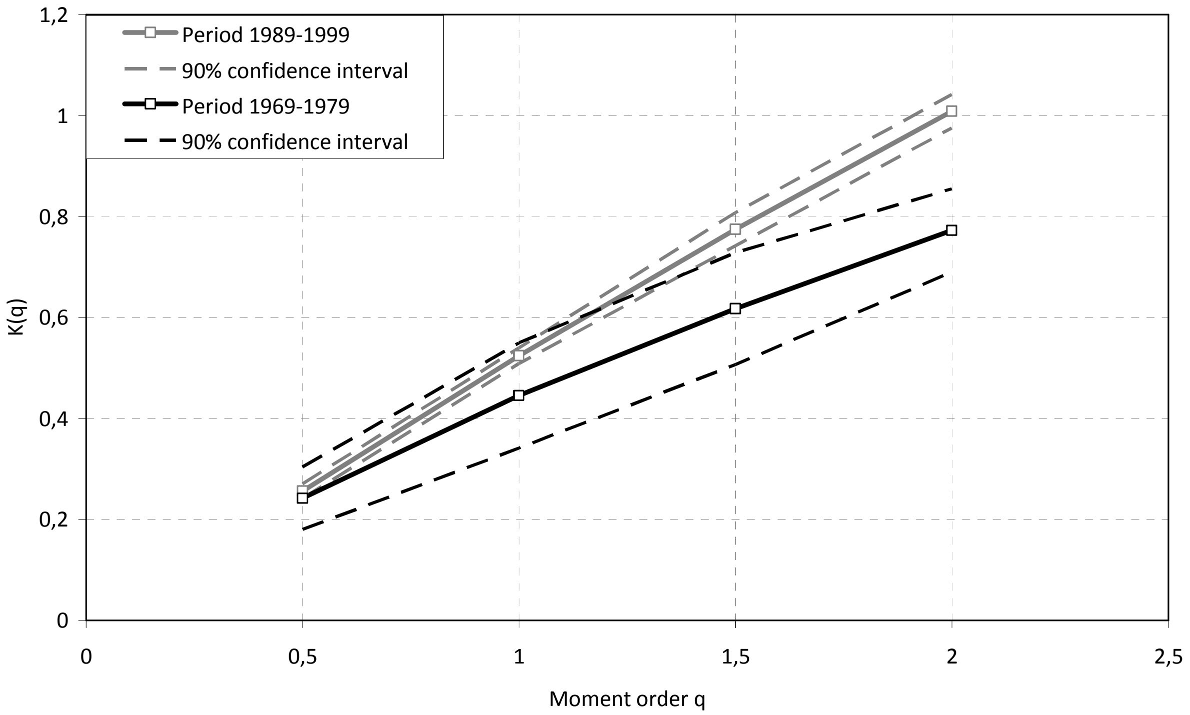

Figure C6: Exponents K(q) of the moment-scale relationship for the parameterization period (1989-1999) and the validation period (1969-1979) with their corresponding uncertainties.