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Interactive Comment

Interactive comment on "A space-time hybrid hourly rainfall model for derived flood frequency analysis" *by* U. Haberlandt et al.

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GENERAL REMARKS:

We are very grateful to Claus Haslauer, Ferdinand Beck and Jan Bliefernicht for the time they have taken and for their exhaustive and detailed review. We have thoroughly revised our manuscript and belief it has been improved in this process. We will respond to all specific comments in the following.

SPECIFIC COMMENTS:

Abstract:

The model has been developed using observed rainfall data and has been applied in the case study for extension of short rainfall time series. This has been made clearer now in the abstract. However, the model has also the potential to be applied for unobserved regions if the parameters are regionalised. This has already been demonstrated for this type of ARM in (Haberlandt, 1998). Besides, the target criteria for the objective function in the second part of the model are already estimated at the regional level as functions of separation distance between two stations allowing resampling for any two (unobserved) locations within the study area.

Step 1: rainfall generation pp. 2463/ 2464:

1) To generate the two dependent random variables wsd and wsi using the copula model the procedure outlined in Appendix A of the paper by De Michele and Salvadori (2003) was followed. This information has been added to the text now. However, in order to avoid lengthy technical details we preferred not to repeat the description of that algorithm here.

2) The precipitation occurrence process can be treated as an alternating renewal process if the durations of the spells are independent and the unique spell states are identically distributed (see also response to step1/4). The text has been modified accordingly.

3) We have changed the formulations as suggested.

4) The referees raise here an important issue, which has not been discussed sufficiently in the manuscript. Rainfall events are defined in fact by a minimum rainfall amount Wmin and a minimum separation time between events Dmin. A discussion about the significance and estimation of the two criteria has been added now to the text in the application section 3.3.

Step 2: resampling, spatial dependence properties pp. 2465/2466:

1) Yes, that is certainly a simplification with the addition that n is the number of the simultaneously observed non-missing hours. We have changed the equation.

2) The descriptions concerning the equations 8 and 9 have been changed, to explain in

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words the meaning of the criteria. In addition some comments on how the three criteria complement each other have been added.

3) We have changed the sign in Eq. 7 from "equal" to "almost equal" to indicate that n11/n is just an estimate of the probability.

Resampling algorithm pp. 2467/2468:

1) The description for steps 1 and 2 has been revised.

2) Currently, the stations are drawn at random. The degrees of freedom for resampling decrease from the first to the last station included. This can be seen at the objective function values Oi, which increase from i=1,...,N. However, the differences are not important for a small number of stations like N=2,...,4. Tests have shown that the total objective function value over all stations is independent from the order. In future work the effect of the order on the hydrological simulation results needs to be assessed.

3) After each swap of two events the event series has to be disaggregated into a time series of equidistant hourly values, the three target criteria have to be recalculated from the hourly values and the objective function has to be evaluated. With long time series e.g. of 100 years the number of required iterations is greater than 10ˆ7, which causes a very high numerical demand. With the restriction to a maximum distance between two events for swapping (e.g. some months) only much shorter time period need to be disaggregated and considered for updating of the target criteria. So, the speed of the algorithm increases significantly. Tests have shown that not only the simulation is much faster, but also the performance of the algorithm is better. This restriction can be set in step 3, not in step 8, which regulates only the annealing temperature T.

4) We have made it clearer now that step 6 is required to find a "good solution" often near the optimum. Our first approach was indeed to resample all stations at once. However, the algorithm did not converge to a good solution, probably because in this multivariate case too many degrees of freedom are possible. We have commented on

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that in the text now.

Description of data; pp. 2468/2469:

1) We added a new table 1 now, which lists all 11 recording (hourly) stations and indicates which stations are operated all year, which are operated only during the summer season and which stations are used for the Selke and Holtemme basins, respectively. We also added numbers to the station symbols in Fig. 3 allowing a better identification.

a. Two stations for the winter season and six stations for the summer season are included for resampling in the Holtemme basin. Note, that the all year stations are used for both summer and winter seasons and one station is used for both basins. Table 1 should make this clearer now.

b. The daily stations are the 19 non-recording stations indicated in Fig. 3. They are used only as additional information for hydrological modelling. The text has been modified in a similar way as suggested to make things more clear.

c. Yes, the Thiessen method is applied for both observed and synthetic rainfall data to prepare areal rainfall time series for the subcatchments of the Selke and Holtemme basins, respectively. This is mentioned in the text now.

2) The legend of Fig. 3 has been updated accordingly and the gauges are mentioned in the text now.

3) Fig. 3 has been extended now showing the total Bode river basin including elevations.

Chapter 3.3 p. 2472:

1) The estimation of the mean annual rainfall sum depends on the correct estimation of all spell variables. A slight underestimation of wsi and wsd together with a slight overestimation of dsd might cause a significant underestimation of the mean annual rainfall. On reason for the somewhat larger deviations between observed and simulated

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annual rainfall sums could in fact be related to the conditional estimation of wsi on wsd using the copula. This has to be investigated in more detail in future research. Anyway, from the results of the derived flood frequency analysis it can be seen that the mean annual rainfall is not decisive here, because the floods generated by synthetic rainfall tend to overestimate the observed floods (see former Fig. 9).

2) The main reasons for selecting the test sites are that the catchments are mostly free from anthropogenic influences and the good data availability. The extension of the Selke basin to on gauge downstream would not improve the rainfall data situation in the winter season. There would still be only one hourly station available.

Conclusions p. 2475:

We have removed this statement from the abstract and the conclusion. Those results are in fact not presented and we have decided not to add those results here in detail. This would go beyond the scope of the paper. In addition we have renamed the section in "Summary and conclusions" as suggested and slightly modified.

TECHNICAL CORRECTIONS:

All technical corrections have been considered in the revision of the manuscript. No comments require an additional response here.

CITED REFERENCES:

De Michele, C., and Salvadori, G.: A Generalized Pareto intensity-duration model of storm rainfall exploiting 2-Copulas, J. Geophys. Res., 108(D2), 4067, doi:4010.1029/2002JD002534, 2003.

Haberlandt, U.: Stochastic rainfall synthesis using regionalized model parameters, Journal of Hydrologic Engineering, 3, 160-168, 1998.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 2459, 2008.