Improving the autocorrelation in disaggregated time series for urban hydrological applications

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Abstract

Time series with high temporal resolution are crucial for urban hydrology. Observed time series of this kind are very short in most cases, so they cannot be used. However, time series with lower temporal resolution (daily measurements) exist for much longer periods. The objective is to derive time series with a long duration and a high resolution by disaggregating time series of the non-recording stations with information of time series of the recording stations. The multiplicative, micro-canonical random cascade model is a well-known disaggregation model for daily time series. However, the autocorrelation in the disaggregated time series is often underestimated. An insufficient representation of the autocorrelation may lead to unrealistic results, if these time series are used as input for urban hydrological modeling. For the improvement of the autocorrelation, i) modifications of the cascade generator and ii) subsequent resampling approaches after the disaggregation process as well as combinations of i) and ii) are analyzed. The micro-canonical cascade model after Müller and Haberlandt (2018) is applied in this study, referred to as method A. With a branching number b=3 in the first disaggregation step, time steps with 8 h duration are generated from daily time series. With b=2 for all further disaggregation steps, a temporal resolution of 7.5 min is achieved. The final temporal resolution of 5 min results from a uniform transformation after the disaggregation process. The modifications of the cascade generator include the introduction of position dependence in the first disaggregation step (method B) and an extension of the position dependence for all disaggregation steps according to Lombardo et al. (2012) (method C). As a subsequent approach, a resampling algorithm based on Bárdossy (1998) is introduced to improve the autocorrelation.

Before an impact analysis of the aforementioned approaches on the autocorrelation can be applied, another issue of the disaggregation process has to be solved. The “standard” disaggregation process (Std) generates too many intensities lower than e.g. the resolution of the measuring device of the observed time series (e.g. Molnar and Burlando, 2005). This high fraction of small intensities can have a significant influence on the autocorrelation, although they are of no interest from a hydrological perspective. Two approaches are analyzed to solve this problem: i) a minimum rainfall amount (MRA), which has to be conserved by the cascade generator and ii) the mimicry of a measuring device (MMD), summing up all rainfall intensities lower than a chosen threshold until their total amount would cause a measurement.

The results for the autocorrelation for all combinations of methods A, B and C and the approaches regarding the minimum rainfall intensities Std, MRA and MMD are shown in Fig. 1. For method A, B and C, the standard approach leads to the highest and the MMD approach to the lowest deviations. Method A leads to the highest deviations regarding the median values for lag 1, 6 and 36, independent if the standard, MRA or MMD approach is applied. For the resampling, only time series disaggregated by the MMD-modification are used due to the best representation of the autocorrelation. This selection has two further advantages: The cascade

generator does not have to be changed from its original version in Olsson (1998) and all splittings are possible throughout the whole disaggregation process, independent of the rainfall amount of the time step. Also, the process of the rainfall measurement itself is simulated by the MMD approach, leading to a realistic simulation of both, rainfall itself and its measurement.

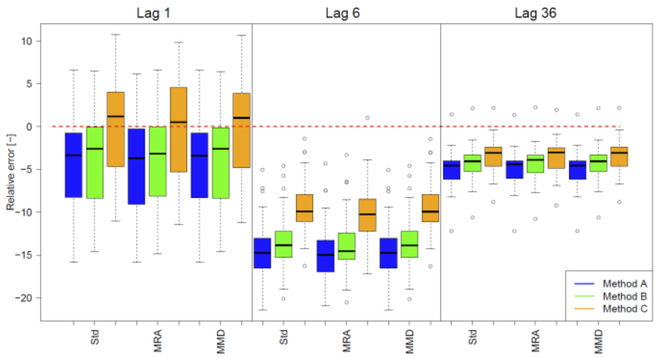

Fig. 1: Deviations of autocorrelation from disaggregated to observed time series as relative error for lags 1, 6 and 36 for 24 stations in Lower Saxony, Germany. The red dashed line indicates a rE=0

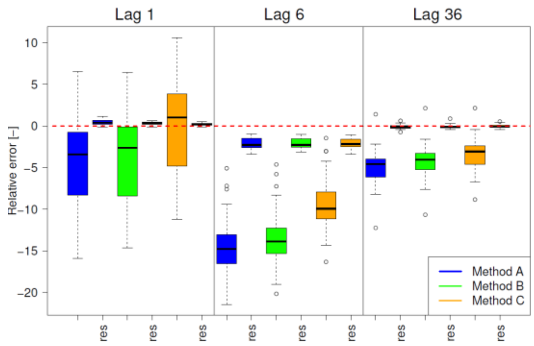

Fig. 2: Deviations of autocorrelation from disaggregated to observed time series before and after the resampling as relative error for lags 1, 6 and 36. All results are based on the MMD approach. The red dashed line indicates a rE=0, results for the resampled time series are labeled with 'res'.

The results of the resampling are presented in Fig. 2. A general improvement with only small deviations can be identified for all three methods A, B and C and for all stations. While for lag 1 and lag 36 almost a perfect fit can be achieved (|rE|<1 % for the majority of the stations), deviations up to rE<3.5 % still occur for lag 6. However, for all lags the autocorrelation is improved.

The intended application of the disaggregated rainfall time series as input for hydrological modeling demands a good representation of the observed extreme values. The improvement of the autocorrelation leads to a better representation of the rainfall structure during an event. However, by including only the autocorrelation in the objective function of the resampling process, a worsening of the total rainfall amounts of extreme values is observed. The challenging task for the resampling procedure is to improve the autocorrelation of the time series by keeping the good representation of the total rainfall amounts, which can be found after the disaggregation process (Müller and Haberlandt, 2018).

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