Radar data for long-term simulation - a viable alternative to rain gauges?

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Highlights

- Radar data as provided by the German Weather Service (RADKLIM) are a useful alternative to rain gauges for long-term simulations.
- Uncertainties in radar are lower for moderate events accounting for most of the rainfall volume.
- RADKLIM data are not suitable for model calibration without further processing.

Introduction

Spatial and temporal resolution of precipitation, as well as accuracy are highly important for any task in urban drainage modelling. Radar data provide information that is highly resolved in space and time, but accuracy is limited due to uncertainties in the transformation from reflectivity to rain intensity and other steps of data treatment. The combined effect of resolution and accuracy on simulation results depends i.a. on the configuration of the drainage system, on the rainfall characteristics and on the type of model. In this study we focus on the application for management of combined sewer overflows (CSO).
In Germany, like in other central European countries, overflow activity is often monitored to ensure proper operation and to check underlying models for plausibility. Activity is often expressed by frequency and duration on a monthly or annual basis as these quantities are easy to determine. Volume measurements are less common as they are more complex and expensive. To assess the performance of a combined drainage system and to improve the corresponding models observed CSO activity has to be linked to precipitation in the catchment of each overflow structure. As rain gauges are generally not available in this spatial resolution weather radar is often discussed as an alternative source of precipitation data. The German Meteorological Service (Deutscher Wetterdienst, DWD) provides data as raster composites in a resolution of 1 km² in 5 min time steps for free.
This study analyzes the impact of the precipitation data source (DWD radar vs. rain gauges) on simulated CSO activity (frequency, duration, volume) using continuous long-term simulations with a hydrological drainage model (KOSIM; itwh, 2020).

Methodology

For the comparison precipitation time series of 2 years were used. Ground data were collected by 12 weighing rain gauges (OTT, Pluvio) installed in the city of Reutlingen (southern Germany) and one rain gauge operated by the DWD (see figure 1). The corresponding radar data were downloaded from the DWD website (RADKLIM: YW composite from C-band radar with temporal resolution of 5 minutes; DWD, 2004). The DWD radar data were autogenerated as part of the RADOLAN and RADKLIM processing routines. (DWD, 2004, 2017).
To compare the different gauge and radar datasets time series had to be generated by extracting the data of each raster field from the stack of raster composites. Time-series were analysed for data gaps, consistency and homogeneity. Statistical indicators were calculated by deviation-, double-sum and correlation-/regression-analyses. The time-series generation and statistical analyses were automated using R scripts. The analysis included both single events and complete periods. Events were separated

according to Joo et al. (2014) by coefficient of variation. To evaluate the quality of measured datasets, autocorrelation was calculated and compared for each source of precipitation data.

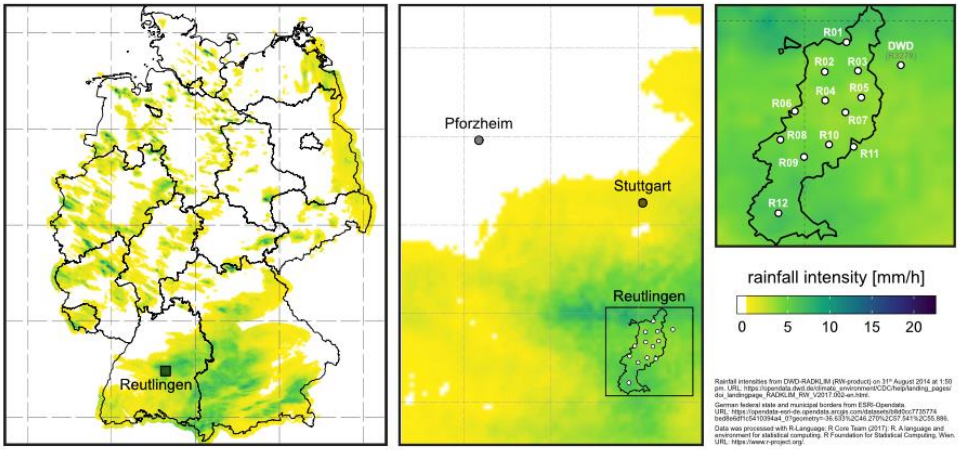

Figure 1: Location of rain gauges in Reutlingen, DWD rain gauge (R3278) and position of raster fields

The propagation of deviations in precipitation data to results of CSO activity is highly case sensitive. To assess the impact for a wide range of potential cases the simulation study used a modified and simplified virtual system according to Müller (2017). A catchment area with 15 ha of impervious area and 3,000 inhabitants was connected to one single CSO structure. To create different cases, specific storage volume V_S and continuation flow q_r at the CSO were varied in a wide range (V_S = {0; 10; 20; 40 m^3/ha_{imp}} and throttle discharge q_r = {0.3; 0.5; 1.0; 2.0; 5.0 l/(s·ha_{imp})}. Simulations were performed using data of rain gauge R05 and the corresponding radar field.

Results and discussion

The comparison of gauge and radar measurement data shows that radar data (YW) systematically underestimates the precipitation sums for the whole time-series up to 7.4 %. Large part of the 499 events showed significant deviations between ground and radar measurement with respect to volume error, shape and peak. Deviation in volume is highest in winter months. Frequency distribution of zero values showed that mainly low rain intensities are missing in the radar data sets. This might be due to wind drift and attenuation effects. Furthermore, high intensities are underestimated in radar data sets due to spatial smoothing effects as suspected by Kreklow et al. (2020). Smoothing algorithms are implemented for clutter correction and are executed automatically within the routines (DWD, 2004).
In the following we present only results of the long-term simulation. Statistics for single events will be included in the presentation. Simulations over two years show a high level of agreement between impounding and overflow durations obtained with radar and with rain gauge data (figure 2). The deviation increases with decreasing continuation flow. The overflow volume shows significant deviations between radar and rain gauge. Radar based data underestimate the discharge which confirms the results of the previous analysis of precipitation data (not discussed here).
The subsequently performed simulations with different precipitation inputs showed marginal differences (less than 10 % deviation) for time of impoundment and overflow for the tested CSO structures (Figure 2).
Both, the incorrect description of small rain intensities as well as the overcorrection of high rain intensities in the radar data sets due to spatial smoothing, leads to displacements in event-specific autocorrelation functions and indicates the differences in simulation results.

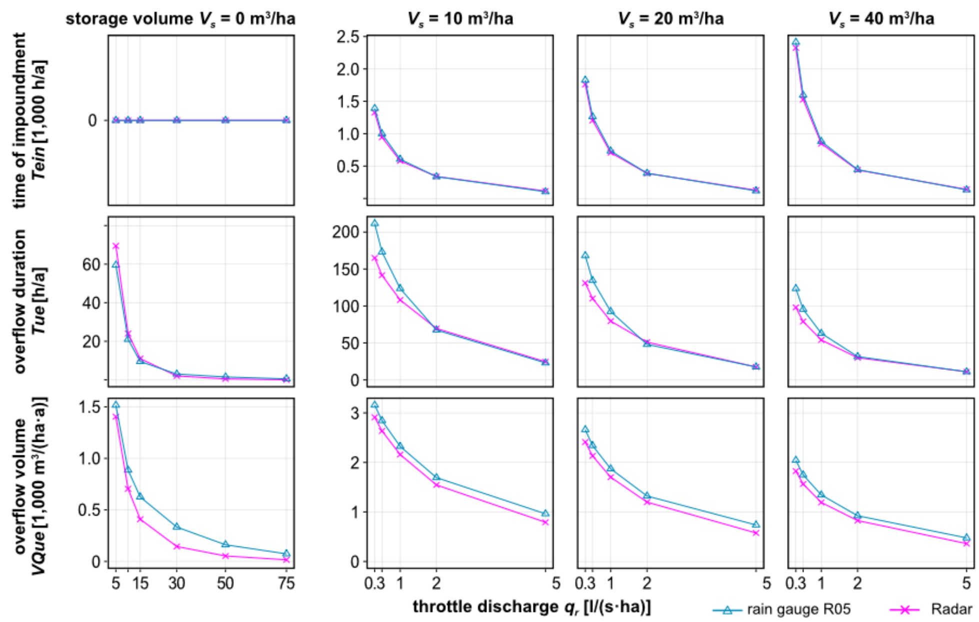

Figure 2. Results of precipitation-runoff simulations for generated long-term time-series data.

Conclusions and future work

The use of radar-data, especially registered and processed by the DWD within RADOLAN and RADKLIM, has to be considered differentiated due to smoothing. If volume forming events with low intensities and long durations are important this effect is negligible. For modeling extreme events these peaks are important and therefore RADKLIM processed data is inappropriate. In this work the influence of attenuation has not been taken into account. Finally, the investigations concerning comparisons of radar and different rain-gauge data as well as the simulation showed that radar data can be used for long-term hydrological modeling. The data also allows to take into account effects of spatial distribution of precipitation in long-term simulations which have to be investigated in future work.

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