Some requirements for extreme rainfall event analyses and communication

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Abstract

Event analysis of (mostly) damage producing events requires a repeatable and impact related procedure to be comparable. A best practice example is used for a tentative definition of such a method.

1. Introduction

Damage producing rainfall events require a detailed and reliable analysis of damage causes including the impact of hydrological and meteorological processes. The associated rainfall contribution linked to the initial hydrological state and following flow behavior helps to understand the severity of an event and the vulnerability within the catchment system. From that, possible protection measures can be derived, and responsibilities can be determined. From this, compensation claims and future mitigation measures can be derived. In recent years

- Occurrences of heavy rainfall and damage have increased,
- extreme events call for action of the whole municipal community and not only the single citizen or technical and hazard departments,
- the analysis of heavy rainfall requires a thorough and well-organized inspection of all available data (weather radar, station data, flow rates and paths and damage data),
- it is important to rely on quality controlled high-resolution data and objective observations for detailed analyses in urban areas, because the events occur locally, and the flow system structure is complex.
- events with different hydrological situations and effects have shown that simple statistic approaches do not appropriately explain the observed impact

Guidelines or standards currently do not exist for a proper procedure, and recent examples have shown that there is a need for a best practice definition and good communication.

2. Experience from the Münster flood event of 2014

The event in Münster was the highest event in northern Germany for daily rainfall sums. It caused electricity blackout, flooding of a large part of the city and proved to be a severe challenge for emergency services because only one third of incoming emergency calls could be covered.

Radar characteristics. Radar data have been processed by the German Weather Service (DWD) with their RADOLAN product. It became clear in the event analysis that the sparse rain gauge network REGNIE (Figure 1, left) was not able to detect the extreme event. The network density also plays a role for radar adjustment (Figure 1, centre) where the adjusted radar still considerably underestimates the peak precipitation sum of 292 mm measured by the rain gauge of the State Environmental Agency (Figure 1, right). The DWD first questioned the high precipitation amounts (DWD, 2014) but later acknowledged that their own values had been too low.

Damage information. About 30.000 insured loss cases with overall costs of 200 million Euro were reported (GDV, 2015).

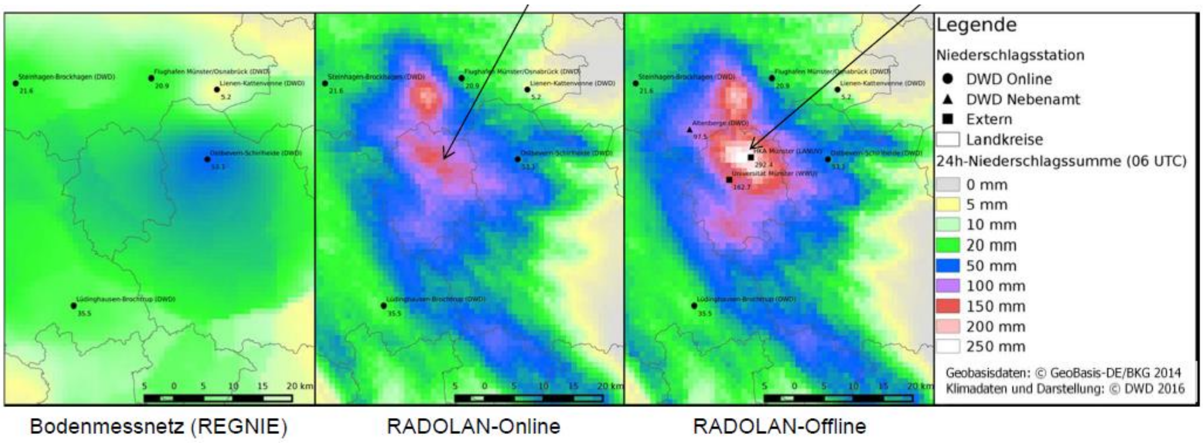

Figure 1. Rainfall event sum for Münster, seen by REGNIE rain gauges (left), online adjusted radar (centre) and offline analysed radar (right) – from Winterrath (2017).

3. Best practice example: the Wuppertal flood event of 29 May 2018

The heavy rainfall event in Wuppertal, which caused

- the Wupper to extremely rise in just one hour with the highest peak in 80 years
- overflowing and eroded creeks with debris, waste and driftwood at the rakes
- large flooded areas beyond the rivers and creeks
- the roof of a petrol station and from a part of the university to collapse
- flooded infrastructure and buildings

happened in May as the first one in a series of three events striking Wuppertal within two weeks' time. The city of Wuppertal is situated in a steep and highly urbanized landscape (Scheibel, 2018).

Because of the emotional situation of being flooded and the mentioned need for mitigation, understanding what has happened in the sense of cause and effect relationship is very important. Therefore, the understandable communication of cause and impact is a challenge which is needed to determine responsibilities and (future) measures to enhance the resilience against flooding. Return periods of rainfall events are different to the ones from water levels at a certain creek since it is a (random) point-based return period and can occur at different places in one area even within a short period. Water level statistics is based on a fixed point in the water system as a representative being the concentration point of the summarized random effects from the whole catchment.

In the current event, a huge amount of the flooded areas where not directly affected by overflowing creeks because there were no creeks close by to discharge the water through the city– the main roads served this purpose. Antecedent conditions were very dry and the river Wupper in the middle of the valley was able to drain the water out of the area very quickly, so that inspite of the extreme event, nobody was harmed. But by that, the Wupper river went from low flow to its highest observed water level in 80 years and that was close to overflowing at other points along the river course.

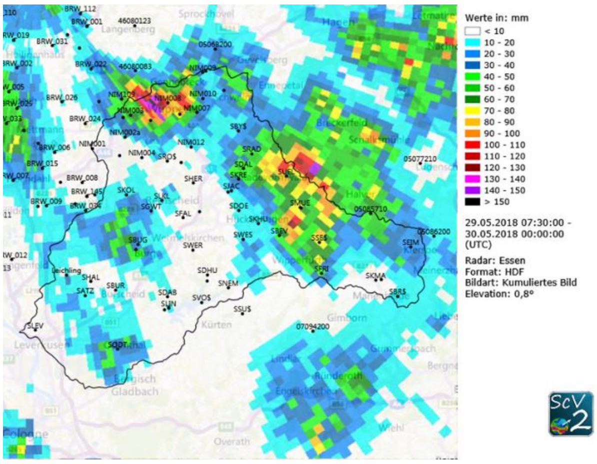

Figure 2. Event sum for the 29 May 2018

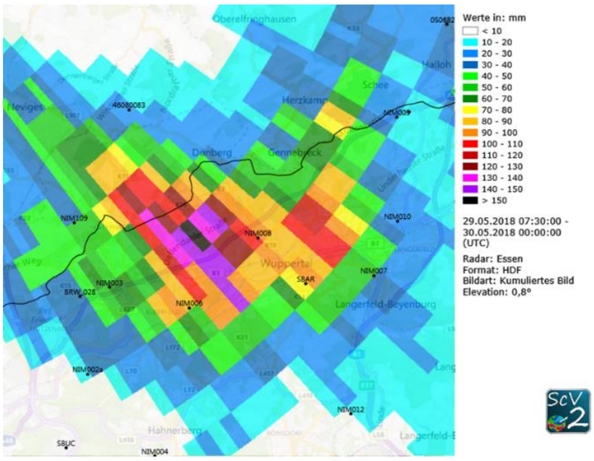

Figure 3. Zoom on the city of Wuppertal

To understand the event with all the different effects related to small creeks, rakes, the river Wupper and the surface runoff it is not possible to just look on long-term station statistics compared to measurements during the event. Only some stations were affected directly by the storm cell (see figure 3) so that the peak of more than 150 mm would hardly be identified. To gain knowledge about the small-scale effects the most realistic areal preicipation had to be found. Therefore, radar data was adjusted to a dense network of rain gauge station data (see figure 2). The adjustment was performed with 37 of the 44 rain gauges. Seven rain gauges were used for the verification of the obtained results. Criteria for the adjustment were the coefficient of determination R^2 and the slope which should be as close to 1.00 as possible. Decision criterium for the verification was the mean absolute error (MAE).

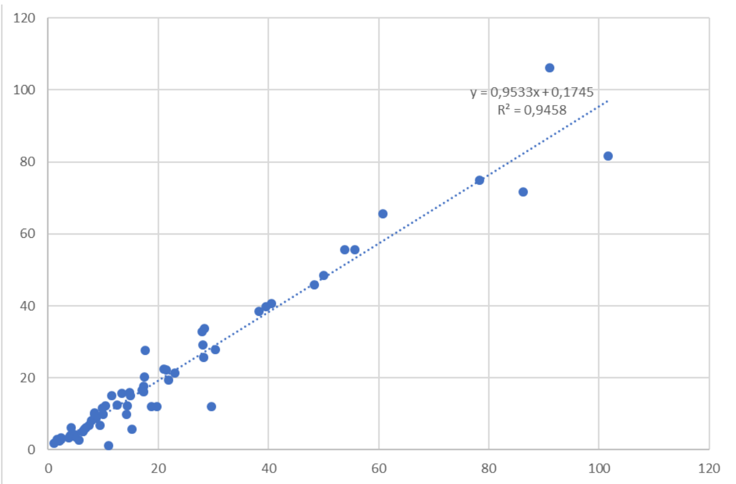

Figure 4. Adjustment check on the event sum [in mm]

Table 1. MAE of seven verification stations [in mm]

Verification with 7 stations	
no adjustment	**19.00**
adjustment without attenuation correction	**10.39**
adjustment with attenuation correction	**7.49**

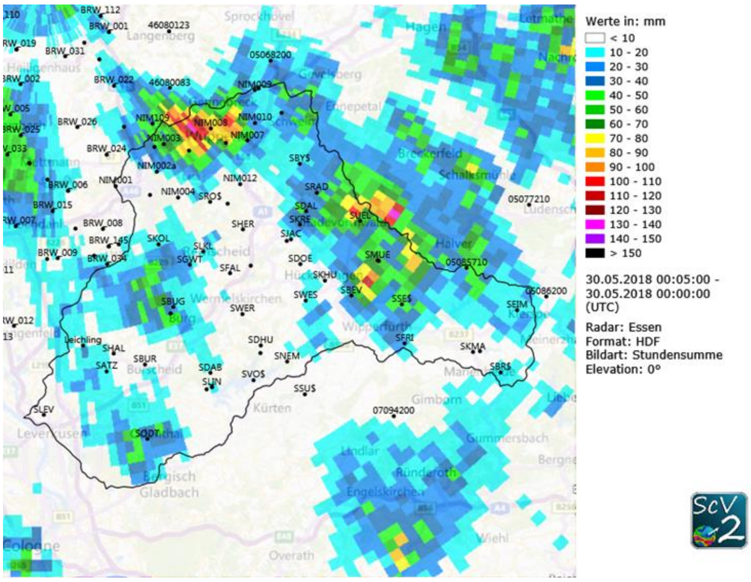

Figure 5. Maximum hourly sum

The comparison of the maximum hourly sum (> 120 mm) to the corresponding extreme value statistics KOSTRA 2010R shows that the sum at the highest pixel in Wuppertal is well beyond a return period of once in 100 years for 60 minutes (48.6 mm). According to the Rainstorm Severity Index defined by Schmitt et al. (2018), the event was at index level 11 from 12. The index describes 12 levels of severity where level 7 corresponds to a return period of 100 years, and level 12 is beyond all expectations.

The reaction of the catchment was different between the first and the following events. This proves that – even in highly urbanized areas and during such an extraordinary event – the soil conditions due to the antecedent rainfall can be sensitive for the runoff generation. As an example, there was one creek where the discharge from the first event was a ten year flood with a higher areal rainfall (74 mm with API = 6,5mm) then in the second event (58 mm and API = 76 mm) 3 days later with a fifty years flood and nearly the same return period one week later (but 35 mm and an API of still 59 mm).

4. A possible standard procedure

A procedure to produce reliable results from radar-based event evaluation should be based on the following minimum standards:

1. **Initial conditions must be known**

   Parameters like soil wetness, the current capacity of the sewer / river system and corresponding retention facilities are required for a proper analysis.

2. **Span the entire event**

   The basic data for the event analysis should span the entire event, including at least 24 hours before damage occurrence to include a potential time of water accumulation on the ground and possible basin retention times.

3. **Use of radar data**

   Radar data are required with a time step of 5 or 6 minutes or less so that statistical assessments can be performed and a spatial resolution 1 x 1 km or better.

4. **Quality control of radar data**

Radar data must be quality controlled according to the state of the art of radar data processing. This includes corrections for clutter, blockage, attenuation, hail, bright band (if applicable), temporal interpolation and second trip echoes.

5. Use of quality-controlled rain gauge data

Rain gauges must be used as ground reference for radar adjustment when reflectivity data are used. Adjustment must be performed according to national and international regulations. If available, stations close to the damage site of all operators shall be included. Because adjustment procedures are sensitive to rain gauge data, the measurements from rain gauges must be quality controlled as well. If the gauge network density is less than 1 gauge per 10 km^2, a sensitivity analysis of the result is required, giving the 90%-percentile of the adjustment procedure.

6. Comparison to extreme value statistics for precipitation and related area

For the event severity classification as “exceptional” or “not exceptional”, an extreme value statistics / design storms of locally representative stations (point or grid) are required. The classification is then performed for the related areal precipitation derived from the station adjusted radar data. The affected area is derived from topography and resulting flow paths and the selected integration periods, ranging from 5 minutes to 24 hours for summer events, should be derived from concentration times and history of the event (overlaying of different cells, antecedent precipitation index and soil condition e.g.).

5. Conclusions

With the objective to give a framework to produce comparable and impact related radar-based rain event evaluations, a structured procedure has been developed. The approach has been illustrated on a best practice example of damage producing rain events in May 2018 in the Wupper area, Germany.

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