Impact related analysis of extreme rainfall events

T. Einfalt[1]* & M.Scheibel[2]

[1]*hydro & meteo GmbH, Lübeck, Germany*

[2]*Wupperverband, Wuppertal, Germany*

**Corresponding author email: einfalt@hydrometeo.de*

Highlights

- Impact and effect related analysis of damage events instead of pure precipitation analysis.
- Comparable results for different events by unified procedure
- Scalable for different regions and learning through growing database

Introduction

Damage producing rainfall events require a detailed and reliable analysis of damage causes including the impact of hydrological and meteorological processes. Only the integrated analysis of the rainfall contribution linked to the initial hydrological state and following flow behaviour allows to judge the severity of an event.

Damage is then caused to vulnerable spots and structures within the catchment system. The required vulnerability analysis of the catchment means: Learning to understand the hydrological system, deriving system reaction times – defining required forecast time for a timely and precise warning for individual objects to protect.

After that, possible protection measures can be set up, 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.

Methodology

Common procedures of extreme rainfall analysis are not appropriate to reflect damage causes. Most often, only the rainfall over the damage area is considered but not the hydrological context. However, even in urban areas initial conditions are important, and the effective response area is not a single point of impact (radar grid cell vs. reacting catchment). Furthermore, a series of multiple rain cells during “one” event may be underestimated with respect to its impact.

A procedure to produce reliable results from radar-based event evaluation should be based on the following minimum standards (Einfalt & Scheibel, 2018; Scheibel, 2018):

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 km2, a sensitivity analysis of the result is required, giving the 90%-percentile of the adjustment procedure.

6. Uncertainty assessment of the result

In order to give a reliable information to other parties, results have to be accompanied by uncertainty bounds. Else, the obtained result may be random without recognition. Suitable methods for this include

- the estimation of the radar data adjustment quality which can be obtained by cross validation of the used rain gauges
- the spatial comparison of the results using the eight neighbouring radar pixels as base for computation of a spatial variance
- variation of the Z-R relationship if the two above methods are not conclusive

7. 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.

8. Hydrological context

The damage does not need to occur in the area affected by severe precipitation. Knowing the location of the most severe precipitation, an analysis is performed on flow paths derived from topography and integration periods, ranging from 5 minutes to 24 hours for summer events. This analysis needs to take into account antecedent precipitation index and soil conditions.

Conclusions and future work

A structured procedure has been developed with the following properties:

- producing comparable results for different damage producing rainfall events
- taking hydrological boundary conditions into account
- giving information on damage causes and statistical return periods
- an objective procedure applicable for court hearings
- identification of hot-spots and their possible better protection (Figure 1)

- raining awareness of ground-owners for personal safety

Figure 1: Example of a house protection (see the wall in different heights as function of the safety level required) in a municipality after a damage caused by high downhill flow on the street

The approach will be illustrated on a best practice example of damage producing rain events in May 2018 in the Wupper area, Germany, as well as for several court procedures.

Additional future work is required to differentiate between events of similar magnitude with and without damage: which are the drivers that one event "behaves" differently than the other one? For this, approaches like multi-parameter statistical analyses of large numbers of events and their classification are useful (e.g. Thomassen et al., 2018).

References

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