

# Investigating local extreme value statistics based on 10 years of radar observations

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## 1 Introduction

For the design of hydrological structures, results from extreme value statistics of long time series (> 30 years) of rain gauge measurements are traditionally used in hydrology. These statistics are not necessarily available for locations where they are required.

Radar data have now been observed in Germany for more than 10 years, and so first statistical comparisons between rain gauge and radar observations can be performed.

## 2 Investigation Setup

For four rain gauge locations in the Wupper area, radar time series have been analysed. For each location, statistics were derived from

- 9 pixels: the central pixel containing the rain gauge and the eight surrounding ones;
- 2 to 3 radar sites: all radar measurements covering the rain gauge location;
- 1 composite from three radars;
- 2 adjustments methods: both based on daily adjustment with an IDW scheme, one with and the other one without image interpolation (advection scheme, see (Jasper-Tönnies, et al., 2014));
- 4 time aggregations: for each analysis four time aggregations were analysed for the statistics: 5, 15, 30 and 60 minutes.

Uncertainties are present in many of the measurement processing steps for both, radar and rain gauge measurements. These are explained.

Figure 1 is showing the investigation setup with the rain gauge locations and the radar pixels used for the analysis from each of the individual radars and the composite image. Since the key question was on the extreme events, for each pixel and each duration class (5 min, 15 min, 30 min, 60 min), the highest 20 events were selected and compared. This comparison took place in two different ways for the nine-pixel areas:

- Event-based analysis: the statistics of the observed event (mean value and standard deviation over the nine pixels) was produced and compared.
- Extreme-value based analysis: the statistics of the highest-ranked values of the nine pixels was produced and compared, so that these values usually were derived from different events.

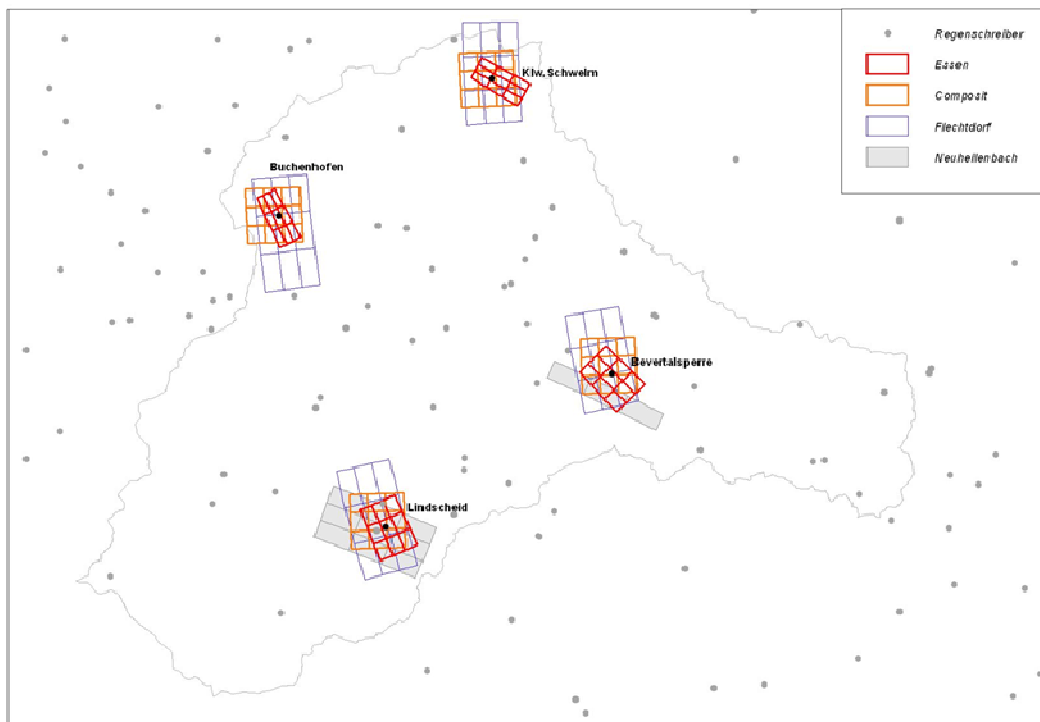


Figure 1. The selected rain gauge locations and the analyzed radar pixels (three individual radars and composite)

### 3 Statistical comparisons

#### 3.1 Analysis parameters

In order to provide an analysis of the most important events, they were ranked from 1 to 20. Within these events were compared their appearance, the spread between the nine pixels, the mean value, and the middle value. For the event analysis, it was also interesting to look into the number of pixels from the nine-pixel set accompanying an extreme value. The following questions were investigated:

- Are extreme events at rain gauges and from radar comparable?
- What is the difference between the event analysis and the extreme-value based analysis?
- Does the compositing of radars modify extreme values?
- Are extreme values different for different adjustment schemes?

#### 3.2 Are extreme events at rain gauges and from radar comparable?

To answer this question, two checks were performed: on the same event date and on the same extreme values, regardless of the event. Additionally, a preliminary comparison of the four rain gauges has to be performed in order to get an impression about their behavior and uncertainty.

##### 3.2.1 Rain gauge intercomparison

The rain gauge intercomparison has been performed in two ways: firstly, the extreme values of the four analyzed gauges between 2001 and 2010 were compared, and secondly, these values were compared to previous statistics based on longer observations.

Figure 2 shows that the variation for the extreme values between 2001 and 2010 between the rain gauge stations is notable and in the order of 20% for the standard deviation. The comparison to extreme value statistics from two statistics, a station statistics over the longest observed time period for the stations, and the German Weather Service KOSTRA statistics (DWD, 2005) covering the whole country, shows that for a 10-year event with a duration of 60 minutes, the results are also variable: the mean value from KOSTRA is 34.8 mm (coefficient of variation: 3%), of the long term statistics 27.2 mm (13%) and of this analysis 29.6 mm (22%).

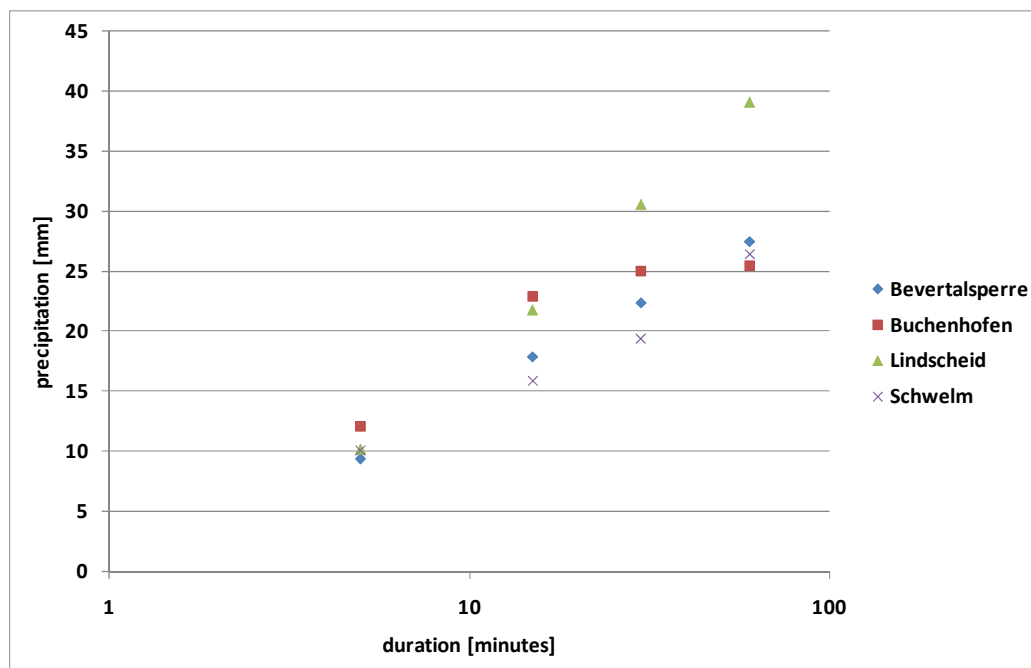


Figure 2. Highest values at the rain gauge locations for selected durations

### 3.2.2 Event consistency between rain gauges and radar

The radar data has been adjusted based on daily station values (Frerk, et al., 2012) where the four analyzed stations have also been incorporated. Therefore, differences in extreme values for shorter time steps have to be expected.

The five highest events observed at the rain gauges appeared in the highest 20 events at one or more of the nine pixels on average in 85% of the cases for a 5 minute duration, 90% for 15 minutes, 100% for 30 minutes and 100% for 60 minutes.

Thus, radar and rain gauges are basically observing the same extreme events.

### 3.2.3 Extreme value consistency between rain gauges and radar

The obtained extreme values for the radar depended much on the selected radar site and on the adjustment method. Here, for instance, the spread for hourly values was 21.6 mm to 25.3 mm from radar data at Beveralsperre station where the station value was 27.5 mm. Other stations displayed higher spread and higher deviations from the rain gauge values. A more complete overview is given by Table 1.

Thus, the extreme value consistency between rain gauges and radar at the same location is not better than satisfactory in the analyzed data set.

Table 1: Range of extreme values obtained by different radar analysis schemes, compared to rain gauge values.

|        | Beveralsperre |            |           | Buchenhofen |            |           | Lindscheid |            |           | Schwelm   |            |           |
|--------|---------------|------------|-----------|-------------|------------|-----------|------------|------------|-----------|-----------|------------|-----------|
|        | min radar     | rain gauge | max radar | min radar   | rain gauge | max radar | min radar  | rain gauge | max radar | min radar | rain gauge | max radar |
| 5 min  | 5.2           | 9.4        | 11.5      | 5.9         | 12.1       | 16        | 6.5        | 10.2       | 13.6      | 5.1       | 10.1       | 11        |
| 15 min | 11.5          | 17.9       | 18.8      | 14.9        | 22.9       | 21.5      | 15.6       | 21.8       | 20.8      | 9.4       | 15.9       | 21.8      |
| 30 min | 16.4          | 22.4       | 21.8      | 18.5        | 25         | 25        | 18.6       | 30.6       | 25.6      | 14.6      | 19.4       | 25.4      |
| 60 min | 21.6          | 27.5       | 25.3      | 20.9        | 25.4       | 29.3      | 22.4       | 39.1       | 32.4      | 18.9      | 26.4       | 34        |

The variation between the four stations is in the same order of magnitude as the variation between the nine pixels of the nine pixel surrounding of the gauge site. Figure 3 shows the mean variation of the radar values over all radar sites and all stations for a duration of 15 minutes, as well as the highest values measured at the rain gauges for this duration. It can be seen that the spread in terms of standard deviation for radar (13%) and for rain gauges (16%) is similar, whereas the precipitation level seen by radar is slightly lower (16.4 mm against 19.6 mm).

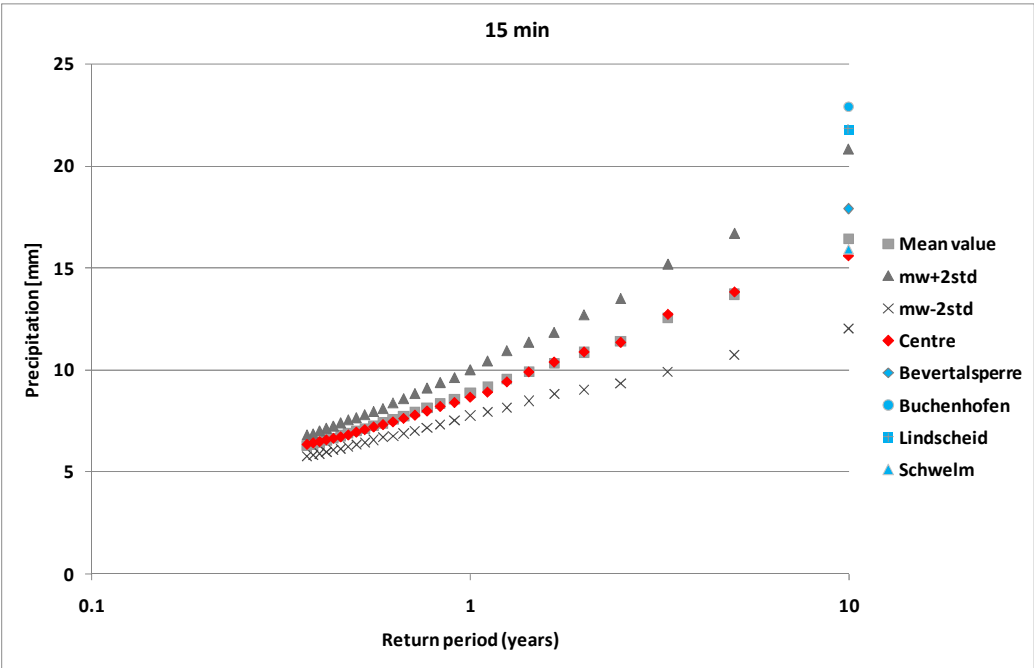


Figure 3. Spread of radar values over the nine pixels for a duration of 15 minutes, all radars and stations; compared to highest rain gauge measurements at the four stations (in blue)

3.3 What is the difference between the event analysis and the extreme-value based analysis?

3.3.1 Extreme events at the nine pixels

The difference between the statistical view on the pixel time series and the event view is that for the first analysis, for each pixel the respective highest values are ranked whereas for the second one all values of a common event are analyzed. This results in higher values when the pixel values for the individually ranked statistics are used than when the event statistics is produced. Table 2 shows the average number of pixels per event (of the 20 highest ranked events) which are to be found in the ranked statistics among the highest 27 ranks. It is clearly visible that a shorter time step results in a smaller number of pixels being in the ranked statistics.

Table 2: Number of pixels per event which are contained in pixel events. Possible maximum is 9.

|        | Bevertalsperre | Buchenhofen | Lindscheid | Schwelm | average |
|--------|----------------|-------------|------------|---------|---------|
| 5 min  | 4.60           | 5.85        | 6.35       | 5.65    | 5.61    |
| 15 min | 5.95           | 6.40        | 7.30       | 6.85    | 6.63    |
| 30 min | 6.50           | 6.95        | 7.60       | 6.80    | 6.96    |
| 60 min | 6.90           | 6.95        | 7.40       | 7.25    | 7.13    |

Examples for 5 minute duration and 60 minute duration at Lindscheid station with Essen radar show that the variation between the nine pixels can be large (Figure 4). The amount of variation is relatively random being function of the stations and used radar site.

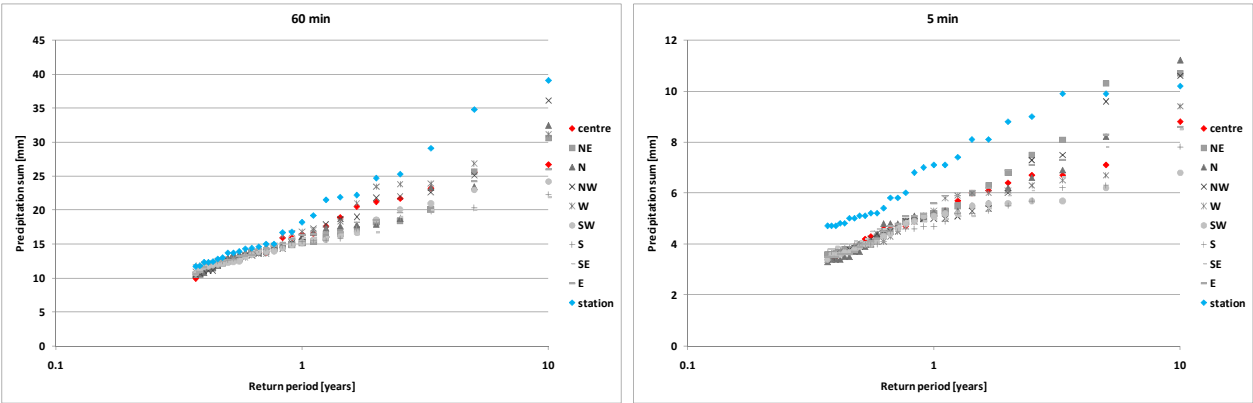


Figure 4. Radar values at the nine pixels around Lindscheid location for Essen radar and a duration of 5 minutes (left) and 60 minutes (right); compared to rain gauge measurements (in blue)

### 3.3.2 Difference in mean value for events and extreme-value based analysis

The difference of the values between both statistics (Figure 5) can be interpreted as the difference between the highest events on a pixel level (1 km<sup>2</sup>) and on a 9 km<sup>2</sup> area – or the areal reduction of 1 km<sup>2</sup> values for an area which is nine times larger. The example of station Bevertalsperre reveals a difference between gauge (18 mm) and radar event (12 mm) for a return period of once in ten years in the order of 6 mm. The radar statistics (16 mm) shows values much closer to the rain gauge value.

### 3.3.3 Summary

Thus, rare events are systematically lower over a 9 km<sup>2</sup> area than the mean of ranked pixel events. This is observed between the highest values down to events occurring approximately once per year. For more frequent events, a clear distinction is not possible any more (example in Figure 5).

A conclusion from this is that for hydrological design, point precipitation has to be areally reduced also for areas as small as 9 km<sup>2</sup> since the observed areal precipitation events are lower than the highest point events (at 1 km<sup>2</sup>).

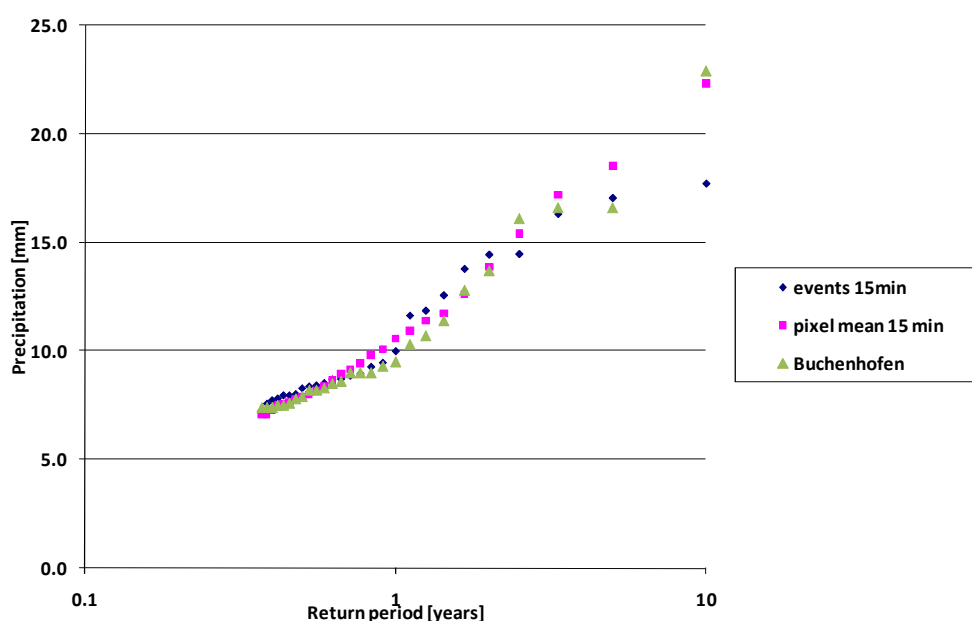


Figure 5. Comparison of event values, radar statistics values and rain gauge values for a duration of 15 minutes, Buchenhofen station

### 3.4 Does the compositing of radars modify extreme values?

Compositing has been performed using on a weight-based scheme (Einfalt, et al., 2012) which gives a higher weight to pixels close to the radar than the ones far from the radar site.

The difference between composite and single radar values remains within the bandwidth of uncertainty of 20% which can be observed between the single pixels (see section 3.3). Figure 6 shows a case for Bevertalsperre for a duration of 60 minutes supporting this finding.

Thus, there is no systematic difference between the use of single radar extreme values and composite extreme values.

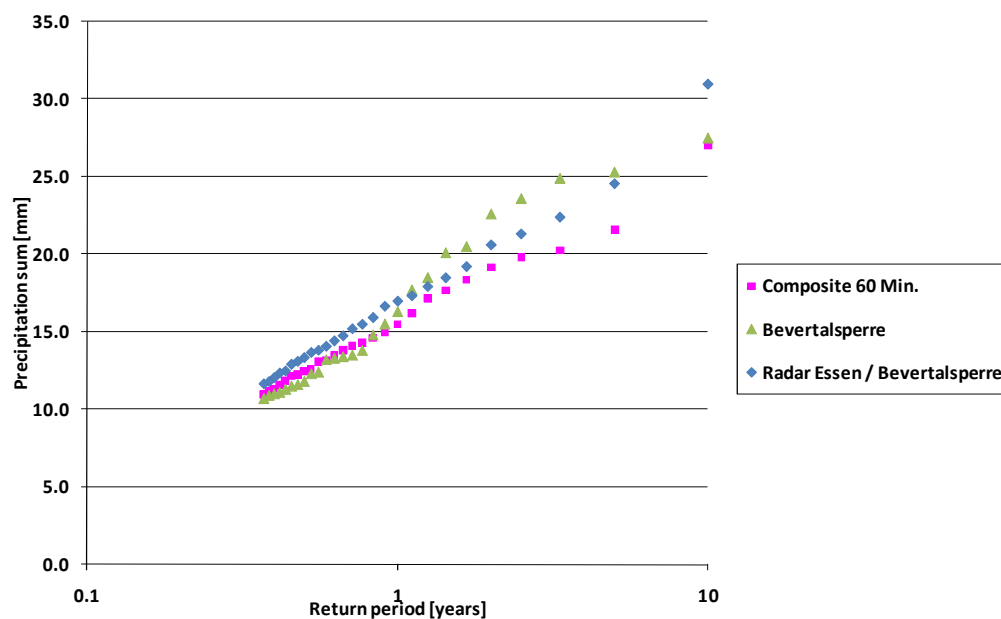


Figure 6. Comparison of composite values, single radar values and rain gauge values for a duration of 60 minutes, Bevertalsperre station

### 3.5 Are extreme values different for different adjustment schemes?

The interpolation scheme for adjustment is smoothing the values of the radar measurements in a way similar to the local observation by rain gauges. Therefore, the variability of obtained values is less for this adjustment scheme than for an ordinary one without this technique. This effect is more pronounced for shorter durations (5 and 15 minutes) than for larger ones (Figure 7).

The answer to the above question therefore is: yes, the extreme values are different for the different adjustment schemes.

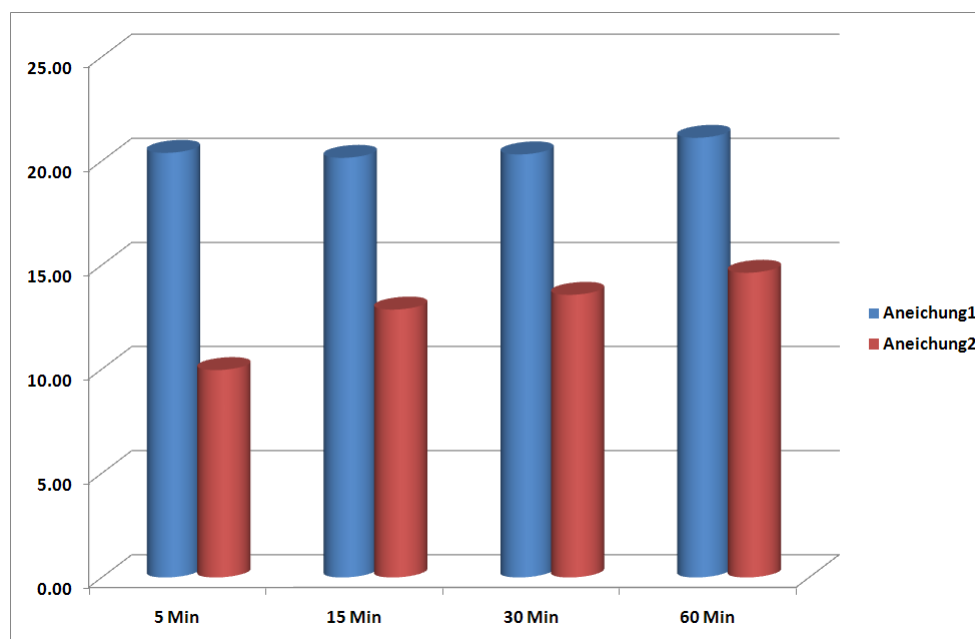


Figure 7. Comparison of variability of the highest values from ten years for standard adjustment (blue) to interpolated adjustment (red) for all stations and all radars

## 4 Discussion

Results show that

- although there are differences in the events at the rain gauge and the radar, the resulting extreme value statistics are very similar,
- spatial statistics of single extreme events perform different than statistics from connected single pixels,
- the standard deviation of the nine pixels can be large, especially for rare events,

- statistics for shorter time intervals (5 min, 15 min) show a much higher spread between the nine pixels than the two longer time intervals,
- the adjustment method with the advection scheme provides results with the lowest spread between the pixel results.

## 5 Conclusions

Radar statistics at a point have the tendency to be slightly lower than the ones from rain gauges. Whether this has to be attributed to the spatial character of the measurements, is currently not clear.

Compositing does not modify the extreme value statistics of single radars. Therefore, the statistics and time series from composite data can be used in the same way as data from a single radar site.

Even small-scale events over an area of 9 pixels show a significantly lower areal precipitation amount than single pixels, in particular for rare events.

The variation over the 9-pixel-neighbourhood can be large – the resulting value of 20% has to be considered as uncertainty estimate for adjustment by rain gauges, because of drift effects, coordinate mismatch and smoothing effects over a pixel area.

## References

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