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Searching for rainfall truth: multisensor thunderstorm analysis

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Abstract. A study using four different radars and multiple raingauges has been performed in order to determine the most realistic rainfield during a small scale heavy rainfall event. The results show that a more detailed view on small scale rainfall also raises more questions, particularly on the comparability between different radar stations and the comparability between raingauges and radar stations. One of the findings of the project suggests that the more detailed the spatial and temporal rainfall information is the more doubts become visible about the exactness of the quantitative rainfall results.

1 Introduction

Four different radars of German Weather service (DWD) and Bonn University and multiple raingauges have been used to investigate into the character and the damage of five small scale heavy rainfall events (Jessen et al., 2003). Here, some aspects of the event of 28 July 2002 are presented for the location of Eitorf in North Rhine-Westphalia with the objective to determine the most realistic rainfield during this small scale heavy rainfall event.

2 Data base

Over the more general study, four radars (Essen, Flechtdorf, Neuheilenbach of DWD, C-band and Bonn of Bonn University, X-band) were used. Numerous raingauges from water agencies, cities and the DWD were also available. For the Eitorf case presented here, the three radar locations of the DWD (all C-Band) are the main subjects of investigation.

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3 Selected event

The Eitorf event produced over 100 mm of rainfall over an area of less than 15 km^2. The nearest raingauge collected 73,5 mm – the above estimation is from adjusted radar data. A village was partly flooded and a main road was partly washed away by a small creek fed by one of the strongest rainfields.

3.1 Estimation of small scale rainfall

Smale scale heavy rainfall is difficult to assess quantitatively. Raingauges are too sparse to give a reliable picture for areas below 15 km^2, and radar observations are suffering from a number of uncertainties. Besides attenuation effects which occur during heavy rainfall events, at this scale of observation other effects become also important:

- The difference of measurement at the radar beam level as compared to the ground,
- Drift effects as function of the radar beam height and of small scale wind,
- Problems with inhomogeneous beam filling,
- Time differences between the radar measurement and the arrival of the observed rainfall at the ground,
- The correct mapping of the radar coordinates to the ground coordinates.

The last point, of course, includes the correct coordinates for the raingauges that are selected for comparison to radar data.

3.2 Comparison of different radars

When working very carefully with radar data and raingauge data, one could assume to come close to a certain "rainfall truth".

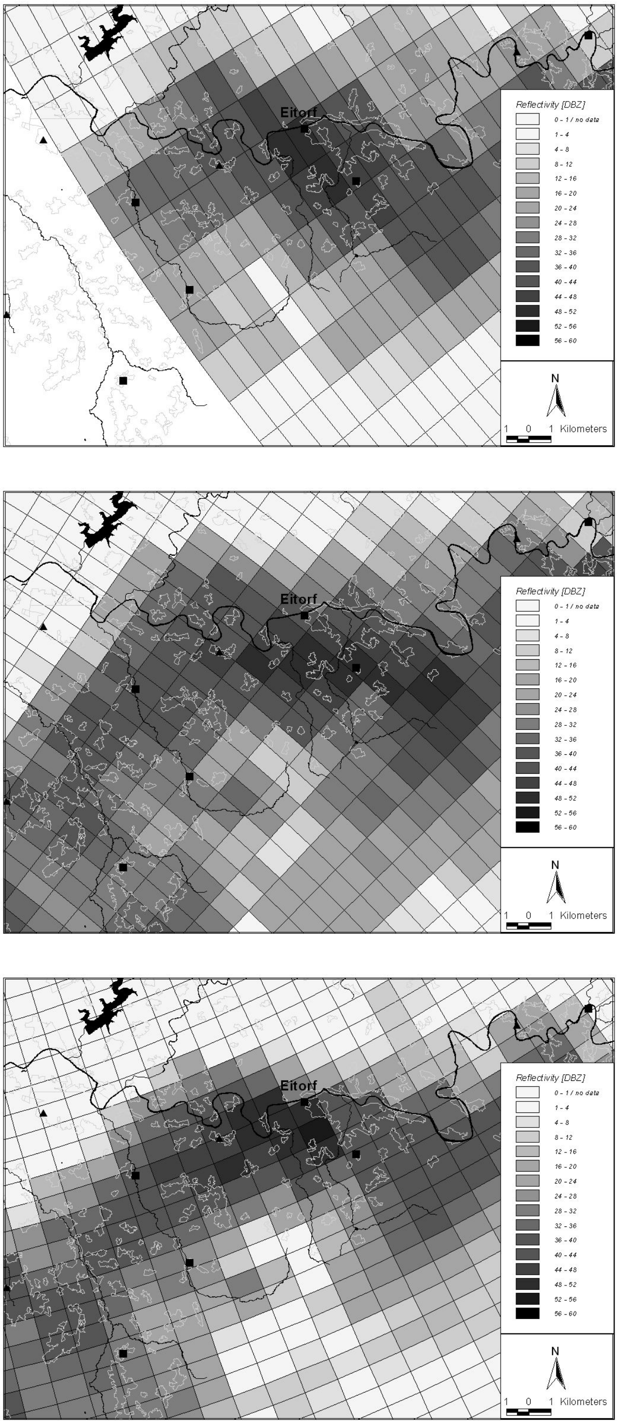

Fig. 1. Polar measurements of radars Flechtdorf, Neuheilenbach and Essen over Eitorf area.

However, having a look at three radars covering the same area gave some surprises. In Table 1 are shown the different measurement heights of the centre of the radar beam and the corresponding distances between radar and area of interest. A view across the area of interest at 15:00 UTC showed steep gradients of reflectivities and some differences between the radar observations, as well for polar data as for derived cartesian data. Figure 1 is showing this effect visually, Table 2 is showing the associated numbers.

All radars show extremely high values just south of Eitorf (in the middle of the radar images), while north of the location the precipitation is rapidly decreasing. The area with reflectivities above 48 dBZ is not larger than ten pixels – where the highest values appear on the Essen radar which is the closest to the location.

A comparison to cartesian data was performed because they are frequently the standard data format for applications. Except for the Essen data, the standard deviation inside the cartesian data of the same radar is smaller than the one of the polar data – this may be due to smoothing effects in the resampling process. On the other hand, the resampling to cartesian data may distort the spatial distribution of the pixel values as can be seen with the Essen data: the value in the centre is much lower than the corresponding polar value for the same location. This is due to Eitorf being situated right on the border of the polar grid.

A comparison for the location Eitorf of the radar measurements from the three radars becomes difficult – the measurement ranging between 41 and 49 dBZ for the polar data and between 29,5 and 49 dBZ for the cartesian data. This is even more troubling when considering the fact that the value of a radar grid cell is already an averaged value over the sampling volume. Thus, a comparison to measurements at the raingauge at Eitorf is containing a large bandwidth of uncertainties – the raingauge being located at the border of the grid cell for two of the radars.

4 Discussion

The above displayed behaviour is based on instantaneous radar measurements. However, the situation is similar for cumulated values of small scale heavy rainfall. Therefore we think that it can be generalised.

The comparison of three radars shows that some small scale, but discernable difference between viewing directions exist. For example, attenuation effects appear to be visible in Fig. 1 for the Flechtdorf and Essen radars.

It seems as if a more detailed view would be required – however some disturbances like the effects of attenuation, beam height, sampling volume and (unknown) drift effects will not disappear.

An adjustment of radar data to raingauge data under such conditions cannot be done in a completely automatic manner. Neither is averaging the radar data over the nine radar pixel neighbourhood a solution because the mean of the nine pixels does not properly represent the precipitation amount.

These findings for small scale heavy rainfall events seen by radar suggests that radar observations should be used in a non-deterministic way, leaving room to probabilistic evaluations of the observed uncertainties.

Table 1. Measurement height and distance from the radar (straight propagation conditions).

	Flechtdorf		Neuheilenbach		Essen	
	distance [km]	height [m asl]	distance [km]	height [m asl]	distance [km]	height [m asl]
Eitorf	120,2	2229	96,6	1933	77,1	1257

Table 2. Measurements in polar data (left) and cartesian data (right).

radar Neuheilenbach (polar data)				
range to radar [km]	pixel [km²]	angle [°] 52	51	50
98	1,67	17,5	32,0	40,5
97	1,68	32,5	41,5	45,0
96	1,70	44,0	47,5	50,5
		standard deviation		**10,2**

radar Neuheilenbach (cartesian data)				
y-axis	pixel [km²]	x-axis 189	190	191
55	1,00	41,5	32,0	42,0
54	1,00	47,5	45,0	40,5
53	1,00	47,5	50,5	45,0
		standard deviation		**5,4**

radar Flechtdorf (polar data)				
range to radar [km]	pixel [km²]	angle [°] 211	212	213
118	2,05	32,0	44,5	47,5
119	2,07	38,5	49	51,0
120	2,09	44,5	49	45,5
		standard deviation		**6,0**

radar Flechtdorf (cartesian data)				
y-axis	pixel [km²]	x-axis 26	27	28
189	1,00	44,5	38,5	44,5
190	1,00	49,0	49,0	44,5
191	1,00	41,5	49,0	51,0
		standard deviation		**4,1**

radar Essen (polar data)				
range to radar [km]	pixel [km²]	angle [°] 294	295	296
77	1,34	51,0	29,5	22,5
78	1,35	51,5	48,5	38,0
79	1,37	50,5	52,5	42,0
		standard deviation		**10,8**

radar Essen (cartesian data)				
y-axis	pixel [km²]	x-axis 160	161	162
197	1,00	35,0	22,5	22,5
198	1,00	51,0	29,5	48,5
199	1,00	51,5	51,5	52,5
		standard deviation		**13,0**

5 Conclusions

A more detailed view on small scale rainfall also raises more questions, particularly on:

- the height and the volume of the radar measurement
- the influence of polar to cartesian coordinate conversion
- the timing of the radar images
- the accuracy of raingauge coordinates and the correct allocation of the radar pixels to the raingauges
- the timing between high resolution raingauge data and radar data

The results of this project suggest:

- It is useful to work on the original polar data as long as possible.
- The more you measure the more different values (and views) for the same phenomenon you get.
- Also, the more detailed the spatial and temporal rainfall information is the more doubts become visible about the possible accuracy of the quantitative rainfall results at a point.

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