12B.5 TOWARDS A RADAR-BASED PRECIPITATION CLIMATOLOGY FOR GERMANY FIRST RESULTS AND FUTURE PERSPECTIVES

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1. INDRODUCTION

Lately, the number of fire brigade operations linked to flash floods seems to increase in Germany. Especially small-scaled heavy rain events, for example in July 2014 in the City of Münster (North Rhine-Westphalia), issue more and more challenges to policymakers of cities. Such events often occur short-dated, allow only short response times and need a fairly good preparation. The preparation includes a carefully considered urban planning and infrastructure design, as well as an elaborate strategy of civil protection. For its cross-cutting character, four federal institutes (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe – BBK, Bundesinstitut für Bau-, Stadt- und Raumforschung – BBSR, Umweltbundesamt – UBA, Technisches Hilfswerk – THW) and the Deutscher Wetterdienst (DWD) started a joint project. The main goal of the project is to perform a homogeneous and quality-controlled high-resolution precipitation reanalysis to evaluate the recent changes in extreme precipitation patterns in Germany since 2001.
Compared to station-based measurements, radar measurements provide a higher spatial resolution, which is needed to perform a detailed investigation of heavy precipitation events. Meanwhile, a database, containing 15 years of radar data, has been accumulated, which provides valuable information on short-term climatological questions. In a first step, all radar data were homogeneously re-processed with the RADOLAN (Radar Online Adjustment) algorithm. In this first version of the radar-based precipitation reanalysis some well-known radar artifacts, for example residual clutter or partial beam blockage, still remained uncorrected. In the next step, we aim to pre-process the raw radar data with the new POLARA (Polarimetric Radar Algorithms) software framework comprising a set of about 35 detection and correction algorithms primarily designed for real-time application that can also partly be used on single-polarization data in the reanalysis mode.
After reprocessing, the time series will be examined by descriptive and extreme value statistical approaches. In addition, case studies of particularly hazardous events will be performed blending precipitation data with users' data like water levels of rivers, the number of operations of civil protection units or runoff paths in urban regions. All in all, the project enables a nationwide risk analysis as well as a classification of individual extreme events in terms of the climatological return period and the specific damage potential. Additionally, potential users of the project's results are already involved during early project stages to ensure an ideal application-specific processing of the scientific results.
This paper will give an overview of the project, starting with the re-processing which leads to the data basis for statistical investigations. Thereby, the correction approaches will be presented more detailed.

2. DATA SET AND METHODS

Two types of precipitation observation were used: weather radar and rain gauge data.
The German radar network has been completed in the year 2000 and since this year it covers about 98% of the German territory. Until the year 2004, non-doppler and doppler single-polarization radar devices were used site-by-site (figure 1). Since 2011 DWD started to replace all radar devices with modern simultaneous dual-polarization and doppler technology. Today it consists of 17 C-band radar systems and only one single-polarization radar remains, namely radar Emden.

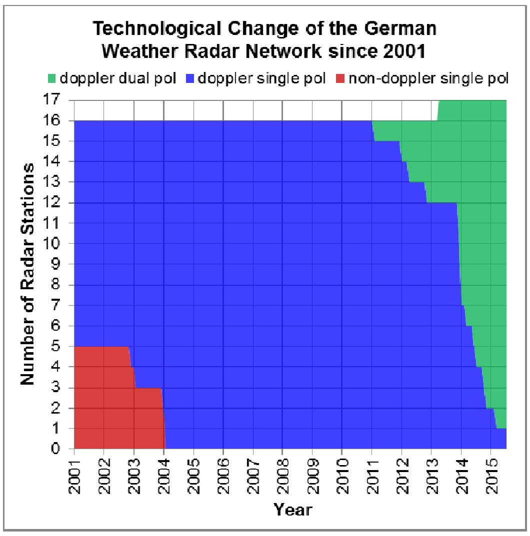

Figure 1: Technological change of the German weather radar network since the year 2001. The figure shows the number and the type of the operated radar devices. Red: non-doppler single polarization radar, blue: doppler single polarization radar, green: doppler dual polarization radar.

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Additionally, DWD operates a rain gauge network which is supported by stations from state authorities. The number of stations decreased from about 4000 stations to about 2000 in the year 2007 and since then it remains constant (figure 2).

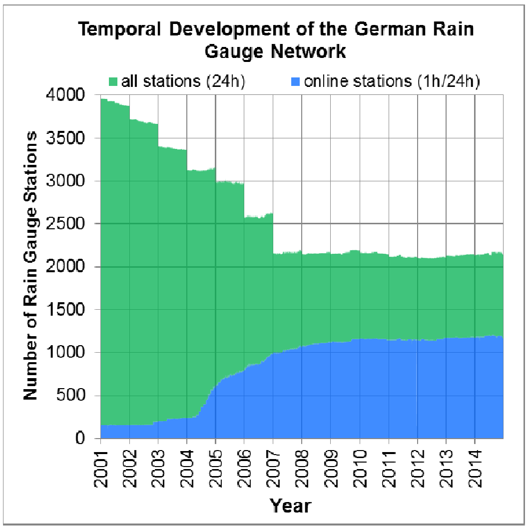

Figure 2: Temporal development of the German rain gauge network. The figure shows the number of conventional (green) and automated (blue) rain gauges.

Most of the rain gauge stations are operated conventionally and only provide daily precipitation data. Since 2001 DWD started to automate a lot of stations, which provides hourly data and an online precipitation observation.
To combine both types of precipitation observation, DWD operates an online precipitation analysis algorithm called RADOLAN (Winterrath et al., 2012). Low terrain-following precipitation scans with a temporal resolution of 5 min are used as input (DX-product). In a first step radar data passes a pre-processing, which includes a correction of partial shaded radar beams caused by the orography, the transformation of the reflectivity into a rain rate with a refined Z/R-relation, the compositing of all local radar data to one regular grid and the accumulation to an hourly radar data set. A statistical clutter filter is applied, which check the allocation of each grid pixel about 72 h back in time. If a pixel is too often allocated with a precipitation signal without interruption, it is rated as a clutter pixel.
After pre-processing, the hourly radar data set is adjusted with the hourly rain gauge data. Therefore two methods are used. On the one hand the algorithm calculates the difference between radar and rain gauge data and on the other hand the algorithm calculates the ratio between rain gauge and radar data. Both methods are applied separately and validated by a randomly chosen control group of 20% of the available rain gauge stations. The best method is determined at the stations of the control group and the results are interpolated as a weighted mean of the two methods. After the adjustment an external texture-based filter removes remaining clutter.

The derived data are quality-controlled, high-resolution quantitative precipitation estimation (QPE) products for real-time hydrological applications like flood forecast or water resources management. To perform our radar reanalysis we adapted the RADOLAN algorithm.

3. RESULTS OF THE FIRST REANALYSE

A first reanalysis of the period 2001 - 2014 was completed in January 2015. A server cluster with more than 180 CPUs was used and the processing took about 1.5 months.

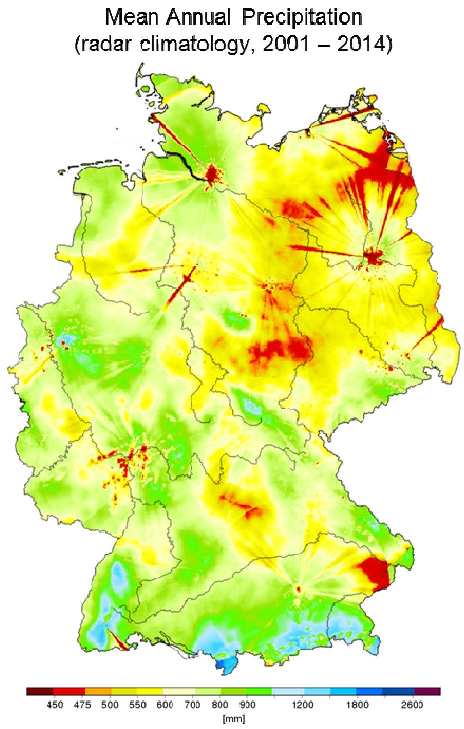

Figure 3: Mean annual precipitation of the investigation period 2001 – 2014.

The first results (figure 3) show an expected spatial distribution of precipitation in Germany. There is more precipitation in the German Uplands and the Alps and less precipitation in the German Lowlands. But, of cause, there are many radar artefacts left, like negative spikes caused by beam blockage, reverse speckles caused by clutter filtering artefacts and other effects like the cone of silence and overshooting.

4. IMPLICATIONS FOR THE NEXT REANALYSIS

4.1 *Additional Rain Gauge Data*

The results of the first version of the reanalysis show that the number of stations with hourly observation is too small for a good quantitative estimation in the first years of the investigation period (2001 – 2005, cf. figure 2).
To solve this problem, hourly data of about 200 analog rain gauge recorders are currently processed for the project. Additionally, methods are developed to include daily data. Therefore, two approaches are in discussion: (1) the disaggregation of daily data to synthetic hourly data and (2) the additional adjustment of the radar-based daily precipitation.

4.2 *Improved Radar Data Pre-Processing with POLARA*

POLARA is DWD's new and advanced software environment for radar data pre-processing (Helmert et al., 2014). It comprises a set of about 35 detection and correction algorithms which are largely not included in RADOLAN. POLARA is primarily designed for real-time application but can also be used in a re-calculation mode. However, the strength of POLARA lies on the usage of polarimetric radar data and this leads to a greater relevance of POLARA in the future years.

4.3 *Long-Term Correction Function*

The first reanalysis also provides information about long-term behavior of the signal path for each radar station. We investigated the terrain-following precipitation scans (DX-product) for radar Dresden (WMO-ID 10488) with a modified approach by Wagner et al. (2012). Dresden is located in the middle east of Germany and the Radar is operated close to the airport.

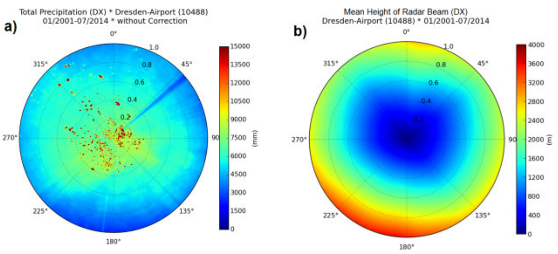

Figure 4: (a) Total precipitation (01/2001 – 07/2014) in millimeter calculated with the Z-R-relation by Marshall and Palmer (1948) for radar Dresden, (b) Mean height of the radar beam (01/2001 – 07/2014) in meter above sea level.

Figure 4a shows the total precipitation between January 2001 and July 2014. It should be noted that the data are not corrected with regards to clutter. Moreover we can see that the amount of precipitation is decreasing with increasing distance from the radar site due to the increasing height of the radar beam (figure 4b). This problem is known as the overshooting effect.

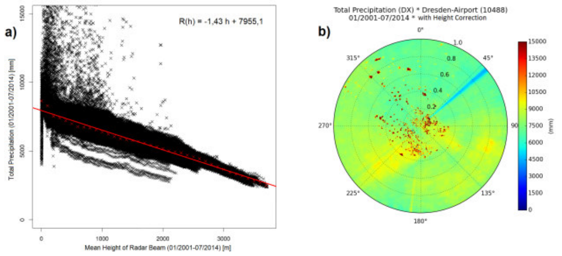

Figure 5: (a) Scatter plot of the amount of precipitation and the corresponding heights of the radar beam (figure 4), (b) Height-corrected total precipitation (01/2001 – 07/2014) for radar Dresden.

For the total precipitation of our investigated time period (01/2001 – 07/2014) the relation between the height of the radar beam and the amount of precipitation can be described with a linear function (equation 4.1):

$$R(h) = m \cdot h + n \qquad (4.1)$$

with m = -1.43 and n = 7955.1 (figure 5a).
To normalize the precipitation amounts to the ground level we used a height-depended correction factor (equation 4.2):

$$F_{\text{height}}(h) = \frac{n}{m \cdot h + n} \qquad (4.2)$$

The result shows a more homogeneous precipitation distribution but the climatological elements are retained (figure 5b). There is more precipitation in the uplands like the Ore Mountains in the southwest or the Zittau Mountains in the southeast of Radar Dresden. On the contrary there is less precipitation in the Eger Graben in the south and the lowlands north of Radar Dresden.

In a next step, we corrected the partial beam blockage to the northeast. Therefore we used a modification of the approach by Jacobi et al. (2014). First we defined the affected sector with an azimuthal center at 49° and a width of ± 3 ° (figure 6a). Then we calculated the median values of all affected beams and the first unaffected beam on the left (45 °) and the right (53 °) border of the sector in a range interval between 30 and 100 km (figure 6b). Next, the medians of the two unaffected beams are interpolated for all sector beams.

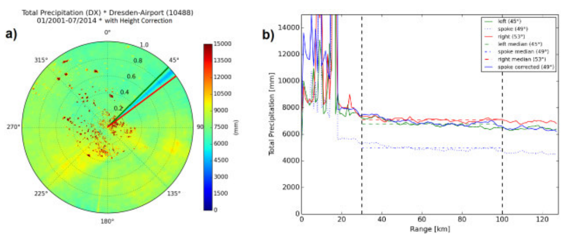

Figure 6: (a) Height-corrected total precipitation (01/2001 – 07/2014) for radar Dresden with partially blocked sector, (b) signal path most affected beam (49 °, blue dotted line) and first left (45 °, green line) and right (53 °, red line) unaffected beams.

The correction factors are calculated for each beam by the ratio between interpolated unaffected and corresponding affected median value (equation 4.3):

$$F_{\text{blockage}} = \frac{\tilde{R}_{\text{ipol, unaffected}}}{\tilde{R}_{\text{affected}}} \tag{4.3}$$

Every correction factor is valid for a whole beam. For example, the factor for the most affected beam (49 °) is 1.28. Finally, every value within an affected beam is amplified by the corresponding correction factor (figure 7b).

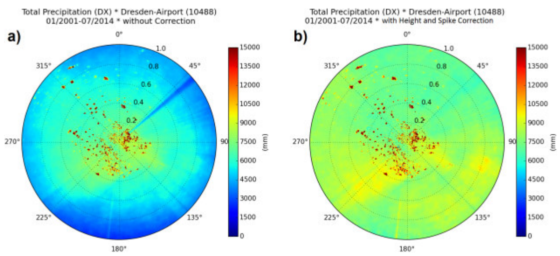

Figure 7: Total precipitation (01/2001 – 07/2014) for radar Dresden: (a) uncorrected values, (b) Height- and blockage-corrected values.

This method offers the possibility to correct a partially blocked sector without losing the information of the signal path along a beam. However, in this case study the first unaffected beams were selected subjectively. Currently, we work on an objective and automated version of this method.

5. CONCLUSIONS

A 14-years record of radar data provides us with the opportunity to learn more about the development and distribution of heavy precipitation events in Germany. To produce a high-resolution precipitation data set we used a combination of radar data and rain gauge data which is implemented in the RADOLAN algorithm. The results of the first version of a radar-based precipitation reanalysis shows a good spatial precipitation distribution but also a lot of radar artifacts. These problems have to be solved by an improved radar data pre-processing, for example by using the POLARA software environment. Additionally, we have to improve the quantitative estimation by adding more rain gauge data, especially in the first years of the investigation period. However, the results of the first version of the reanalysis lead to information about the long-term behavior of the radar data. We can derive correction functions for a height correction and correction factors for a correction of beam blockage. Both will be used to produce a more homogeneous precipitation reanalysis version in future.

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