An overview of the new radar-based precipitation climatology of the Deutscher Wetterdienst – data, methods, products

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Abstract

Within the last years, heavy precipitation events followed by urban flooding and flash floods have caused significant damage and even fatalities in Germany, especially during the summer of 2016. The recent abundance of extreme precipitation events has raised the question, whether there are any geographical hot spots at high risk of being impacted by heavy precipitation or flash flooding expressing the need for high-resolution precipitation climatologies. Due to the small extent of convective precipitation events, sparse gauge networks are not well suited for monitoring heavy precipitation events. The Deutscher Wetterdienst has therefore reprocessed and analyzed gauge-adjusted radar-based precipitation estimates starting in 2001. The data allows the monitoring of heavy precipitation events in high temporal and spatial resolution. The results show distinct differences to solely gauge-based analyses. Although, the time series is still quite short, statistical precipitation analysis reveals that extreme precipitation events of short duration time are rather uniformly distributed over Germany loosing correlation to topography when exceeding the severe weather warning level. The radar-based precipitation climatology has been used in calculations by Fischer et al. (2018) showing an increase in mean annual erosivity compared to currently applied reference values based on historical gauge data.

1. Introduction

The focus of the presented work lies on local extreme events causing pluvial flooding. In contrast to fluvial events like the Elbe flood in 2002, where persistent precipitation over a wide area led to catastrophic flooding of large areas in Eastern Germany, pluvial floods are caused by intensive rainfalls that can even be restricted to rather small horizontal extents. These pluvial floods are characteristic of catchments with short response times, predominantly in regions with steep topography and in urban areas with infrastructure that is vulnerable to flooding. Local, small-scale events, however, are difficult to detect by classical ground-based gauges. With data resulting from area-covering radar monitoring all events become detectable. Within the last years, several studies have been performed on the climatological analysis of radar-based precipitation data (e.g. Bližňák et al., 2016; Goudenhoofdt und Delobbe, 2016; Marra and Morrin, 2015; Tabary et al., 2012; Overeem et al., 2009).

In the context of a joint research project of five German federal agencies, the Deutscher Wetterdienst (DWD) has established the technical and scientific basis for reprocessing the data of the German radar network beginning in 2001 leading to a quality-controlled, high-resolution precipitation data set suitable for analyzing extreme events in a climatological approach (RADKLIM). Data have been analyzed applying classical as well as extreme value statistics. As a first example of practical application, Fischer et al. (2018) used the RADKLIM data (Winterrath et al., 2018) to derive an updated erosivity map for Germany. An overview of the data, developed and applied methods, and a selection of products is given in the final report of the project (Winterrath et al., 2017). In the meantime, the data set has been extended by the year 2017. Here, we summarize the main information on the data set and present the most important results of the study.
2. Methods

The DWD operates a Germany-wide network of currently 17 C-Band Doppler radar systems. Reflectivity data of the complete network is available since 2001. New climatological correction methods for radar data have been defined and applied: improved detection of radar-specific errors like e.g. clutter; correction of signal reduction with height and distance caused by different effects like overshooting, attenuation, and increase of the measurement volume; and correction of spokes caused by partly shaded radar beams (Winterrath et al., 2017). Local reflectivity data with a maximum range of 128 km have been composed to a Germany-wide mosaic with a raster size of 1 km² in polar-stereographic projection. The radar-based precipitation estimates have been adjusted to hourly totals from in-situ gauge data according to the real-time RADOLAN method running in operational mode since June 2005 (Winterrath et al., 2012). In addition to automatic gauges typically used in real-time applications, daily gauge data have been disaggregated to hourly totals and incorporated into the reprocessing suite. In contrast to RADOLAN, however, in the case of missing radar data no interpolated gauge data are alternatively used in order not to influence the extreme value statistics. Five-minute radar data are quantified by application of a scaling factor derived from the ratio of adjusted to non-adjusted hourly totals.

Classical statistical analysis has been performed, yielding to several products like mean annual precipitation and antecedent precipitation indices. Focusing on extreme precipitation, we calculated threshold exceedances pixel-wise summing-up all hours with precipitation amounts exceeding at least one of the duration-dependent thresholds of the defined DWD warning levels for short-lasting as well as long-lasting precipitation. In this approach no independency of events is assumed. In addition, extreme value statistics using a peak-over-threshold approach and fitting by an exponential function has lead to estimates of statistical precipitation values for different durations and return periods. However, due to the still rather short time series, the results have to be considered preliminary and might be subject to changes when the time series will be extended.

3. Data

We have reprocessed and analyzed 17 years of precipitation data starting in 2001. Although the time series is still rather short for climatological statistics, for the first time the data set allows insight into e.g. the distribution, size, life cycle, and duration of extreme events that cannot be monitored by point measurements alone. The radar-based precipitation data of RADKLIM are freely available via the opendata server of DWD. Currently, gauge-adjusted hourly totals (RW product) as well as quasi-adjusted five-minute precipitation rates (YW product) can be downloaded in binary and ascii format, respectively. You can access the landing pages directly using the digital object identifier (Winterrath et al., 2018). Further information and document links are given on the DWD web page www.dwd.de/radarklimatologie.

4. Results

Figure 1a shows the mean annual precipitation in Germany scaled to the availability of radar data. The scaling is predominantly necessary in regions that have not been covered by radar data for a significant time period, i.e. during hardware exchange, when the DWD radar sites have been upgraded to modern dual-polarization technology. The areal pattern of annual precipitation is very similar to interpolated gauge-based data (not shown). Both the clear connection to Germany’s topography with high precipitation sums in the mountainous regions, e.g. the Alps and the Black Forest, as well as the rather dry areas in the North-Eastern part of Germany are reflected by the new radar-based product.

The data set has been further analyzed focusing on the occurrence of extreme events. Figures 1b shows the statistical precipitation depths derived from extreme value analysis for daily precipitation and a return period of one year. Figure 1c presents the corresponding results for one hour duration and 20 years return period – thus rare short-lasting events. It is evident that the occurrence of
common, long-lasting precipitation events is bound to topography and resembles the pattern of mean annual precipitation, while the probability for the occurrence of short-term extreme events is quite uniformly distributed over Germany and shows no obvious correlation to mountainous regions. This result stands in distinct contrast to extreme precipitation climatologies based on gauge data only, thus providing new insights into the heavy precipitation hazards across Germany. Due to the still short observation period, we compared the results to simple counting of threshold exceedances.

Figure 1: a) Mean annual precipitation (2001-2016), b) statistical precipitation depths for a return period of one year and a duration of 24 hours, c) same as b) but for 20 years and one hour; Figures taken from Wintertheth et al. (2017).

The observation is supported by Figure 2 giving the number of hours with exceedance of the DWD warning thresholds for long- (upper panel) and short-lasting (lower panel) extreme precipitation within the period from 2001 to 2016.

For longer durations of 12 to 72 hours the topographically influenced pattern can be found for all warning levels. The right map showing the exceedances of warning level 4, however, is largely influenced by single extreme events, e.g. the 2002 Elbe flood and the 2010 flooding in the area of Osnabrück in the North-Western part of Germany. This effect is strengthened by counting all hours without checking for independence, however, further analysis based on independent events shows very similar patterns.

For short duration times, the distribution of precipitation values exceeding 15 mm in one hour or 20 mm in six hours (warning level 2) is still very similar to the pattern for long duration times. It is interesting to note that with the change from level 2 to the extreme level 3 the occurrence of short-lasting extreme precipitation is less strongly bound to topography but tends to be more equally distributed over Germany. Due to the short observation period, the number of extreme events exceeding warning level 4 is too low for a statistical interpretation.

In addition, several new products have been designed for customers in water and risk management, urban planning, agriculture, soil erosion modeling, and for policy makers, e.g. the antecedent precipitation index – a weighted sum of the last 30-days’ precipitation – used as a proxy for soil moisture in hydrological applications. Fischer et al. (2018) calculated a new Germany-wide map of the R factor of the Universal Soil Loss Equation (Wischmeier, 1959) that gives the mean annual erosivity of rainfall. The results show a distinct rise in precipitation erosivity
over time that might be attributed to climate change. Lengfeld et al. (2018) analyzed the correlation length of precipitation events of different durations. The results can be found in this issue.

Figure 2: Total number of hours within the period 2001 to 2016 with precipitation values exceeding the given thresholds [hours] that serve as official warning levels (‘Stufe’) of DWD for long- (upper panel) and short-lasting (lower panel) heavy precipitation. The respective criterion is fulfilled, if at least one of the given thresholds is exceeded; Figures taken from Winterrath et al. (2017).
5. Conclusions and Outlook

With the 17-year radar-based precipitation climatology for Germany a new data set for monitoring, analyzing, and statistically processing extreme precipitation events is available. The data set is thoroughly quality-controlled, freely available, and will be extended on an annual basis. Analyses comprise classical statistics as well as derived products like the antecedent precipitation index and precipitation erosivity. Statistical analyses reveal that the distribution of extreme short-lasting precipitation events is not strictly related to topography but presenting a risk for all regions in Germany. Future applications of the data set comprise the support of risk analyses in combination with hydrological impact modeling as well as the validation of regional climate models. As climate projections indicate a shift of precipitation characteristics towards extreme events (e.g. ReKliEs-DE, 2017) the need for climate analyses of not only point-wise intensity but also distribution, size, and duration of precipitation events becomes evident to monitor climate change. The results of the climatological analysis of extreme precipitation events based on radar data constitute an important contribution to the German adaptation strategy to climate change.

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References

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