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Identification of spurious precipitation signals in radar data

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1 Introduction

With the development of a new kilometer-scale numerical weather prediction system (LMK) for very short range forecasts at the German Weather Service (DWD), the availability of high quality radar data has become more important than ever. Other users of radar data such as hydrologists or water managers also need quality assessed pre-processed radar data at high temporal resolution. In Germany, a suitable precipitation scan supplies reflectivity as a basis for precipitation calculations near the surface every five minutes and therefore meets the latter requirement. But this fact also sets the limit for the maximum running time of data quality check algorithm. In order to take this into account the newly developed algorithm for quality control is based on simple but nevertheless effective data checks for corrupt images, spikes caused by beam blockage or external transmitters, and remnants of ground clutter, signals of ships, anaprop or wind parks. All of those belong to the most pressing radar data quality issues in Northern Europe (Saltikoff et al., 2004).

2 Data

The developed algorithm is based on data of precipitation scans of all 16 German weather radar systems. Those scans are performed at the lowest possible elevation following the horizon line and therefore are strongly dependent on the horizon line. They are available in polar coordinates with a spatial resolution of 1°x1 km (azimuth and range) and a temporal resolution of five minutes.

Measurements in the described data fields represent reflectivity values expressed in 8 Bit numbers with a resolution of 0.5 dB, between –31.5 dBZ and +95.5 dBZ whereas pixels set to zero show that the data has been thresholded.

3 Data problems considered and identification method

The algorithm developed here offers identification solutions for several problems. The identified pixels are written in a quality index field which has the same format as the original precipitation scan data field. There are different bit values reserved for every problem which allows an individual bit combination of the quality index field for various applications, such as assimilation in LMK (for more detail see: Helmert and Hassler (2006)).

In a first step of the algorithm, the data is searched for problems that affect the whole data set and are impossible to be assigned to single pixels. One of those problems is known as ‘the German pancake’, caused either by special meteorological conditions, for example rising warm air packages, or many insects flying at the same time or dust particles in the vicinity of big cities (Hassler et al., (2005)). Characteristics of German Pancakes (GP) are: they appear preferably at radar sites of big cities (e.g. Hamburg or Berlin), mostly during daytime and spring/summer/fall season, the vertical extension of the reflectivity echoes is confined to the lowest two to three kilometres, many pixels close to the radar sites contain a value of low reflectivity (figure 1, left), and the histograms of reflectivity show a narrow Gaussian distribution. Since vertical information (like volume scans) is available only every 15 minutes and the time of day and the month of appearance are weak identification criteria, the basis for the German Pancake identification algorithm is the histogram of reflectivities. More than 100 GP cases were analysed and a ‘standard German Pancake reflectivity distribution’ was established. Now, histograms of every new radar data set are calculated and compared to the GP ‘standard’. If the histogram of the analysed data set lies beyond defined thresholds and the total amount of pixels with values other than zero exceeds 30%, the whole data field is termed as ‘problematical’. Another example where a whole data set is affected is called ‘corrupt image’. One source for corrupt images (CI) can be problems caused by the radar itself. CIs are mainly selected because of

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their appearance, not of radar information or their physical characteristics. In those cases more than 65% of all pixels contain values with a small mean intensity, and they are evenly distributed over all ranges and azimuths (figure 1, right). Especially, more than 3/4 of the most distant range kilometre contain values. CI are identified by thresholds concerning the mentioned characteristics and then flagged.

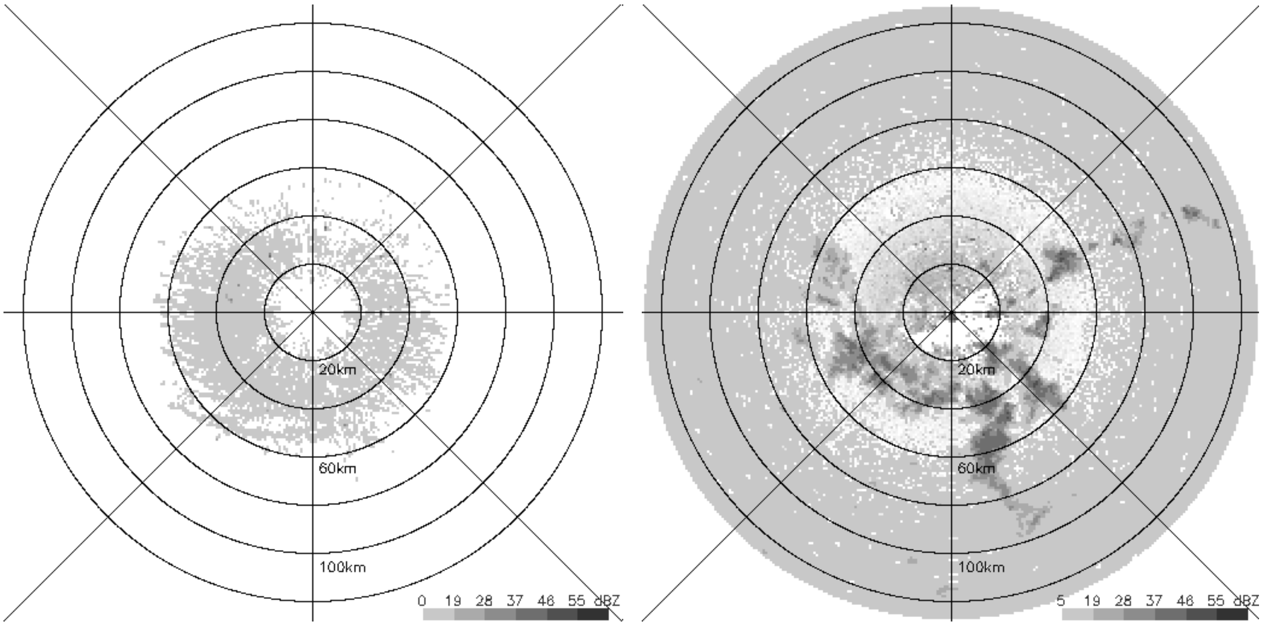

Fig. 1. German Pancake (GP, left) and corrupt image (CI, right) cases within data sets of a precipitation scan of a German Weather radar. In both cases the whole data set is flagged and normally not used for the assimilation process.

In the second part of the algorithm individual pixels are marked. Presently, radial spikes, concentric ring sectors and clusters of speckles such as remnants of clutter, aircraft or ships can be identified. For spikes and concentric rings, the special characteristics of data sets with polar coordinates are used. In polar coordinates obstacles produce shadows for one (or more) horizontal scan angles and some measured ranges at best, or external transmitters interfere in a small horizontal scan angle range (see figure 2). In both cases the limited extension over the azimuth angles and the (normally) sharp edge towards the surrounding pixel values are the most important features for identifying spikes. Thresholds for the minimum range distance at an affected azimuth angle and a minimum intensity difference between spike and surrounding pixel values are set to state the identification more precisely. Once identified, the whole range of the ‘spike’ azimuth angle is flagged. As opposed to spikes, rings affect just one (or more) measured ranges over a certain azimuth sector. In a B-scan (range over azimuth) the developed algorithm for detecting spikes is in principle also valid for rings. Slightly different thresholds for minimum affected azimuth angles are necessary. However, the quality indices for spikes and rings are identical.

Even though there is a Doppler clutter remover applied to most data sets of the German weather radars (Seltmann (2000)) there can still be clutter remnants left in the data dependent on the threshold setting. Especially windparks and ships cannot be detected with a Doppler filter since those reflectivity sources are moving. The developed algorithm has two different methods to identify this clutter depending on its appearance. Pixels containing values which show up in almost every data set at the same location (for example windparks) are marked by a so called blacklist. The blacklist for each individual radar site was developed by analysing over 200 precipitation-free data sets. Pixels with a probability over a certain threshold were written in the blacklist with the exact pixel ID. Only in cases where the ID of a pixel with a value in a data field coincides with an ID of the blacklist, that pixel is marked as ‘clutter’. Since new windparks or other echo sources are built continuously, it is necessary to renew the blacklists automatically on a regular basis. Therefore new precipitation-free data sets are stored in a ring archive as a basis for creation of the new blacklist. The second part of the clutter detection algorithm deals with clusters of speckles, e.g. remnants of ground clutter or ships (figure 2). Those signals are more or less randomly distributed over all ranges and azimuth angles and their detection is based on the fact that real precipitation normally has a certain spatial extension. Every pixel(group) of the data set is tested against two thresholds: First the size of the pixel(group) and second the number of non-zero pixels in the surrounding of the pixel(group). The size of this surrounding is range dependent since in polar coordinates pixels get larger with increasing distance. Only if both criteria are met the pixel(group) is flagged.

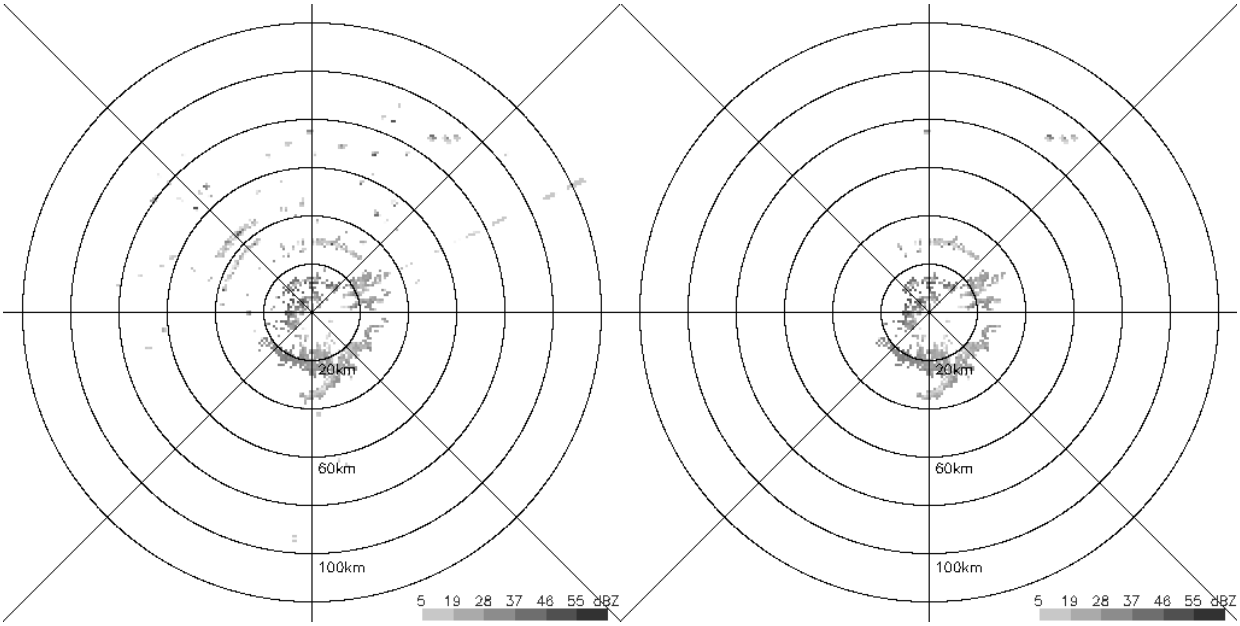

Fig. 2. Example of a data set with ring fragments (~315°), spike fragments (~65°) and remnants of ground clutter (left). After the identification algorithm was applied, most of the clutter as well as the ring and spike fragments are removed (right).

4 Summary and conclusion

The narrow temporal frame for transmission and processing of the radar data for the assimilation in LMK makes it necessary to find identification algorithms as simple but as fast as possible. Furthermore, the supply and processing of additional information which is not available in the same temporal resolution, like satellite images or data from radar volume scans, are at that stage too time consuming to be taken into account. The described algorithm consists of two main parts which are combined to a chain of identification steps. First the data fields are searched for problems which affect the whole data set like "German pancakes" or corrupt images. In a second step single pixels or pixel groups are checked if they belong to spikes or circles or to stand-alone clusters of speckles.

Applying this algorithm ins quasi-operational real.time test mode throughout the German network the amount of spurious precipitation signals in radar data from precipitation scans could be reduced significantly. About 90% of all corrupt images (CI), about 70% of all German pancake cases (GP), roughly 75% of all spikes and rings and about 60% of stand-alone pixel(groups) could be identified. But there are also some cases where small cells of real precipitation were marked wrongly. The algorithm is therefore still being improved and is presently tested at all 16 German weather radar sites. In a next step, further development of the algorithm might include a correction of the marked values and hence offer the opportunity to use them rather than just ignoring those pixel(groups).

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