P8R.16 SPATIAL CLASSIFICATION OF PRECIPITATION FROM OPERATIONAL RADAR DATA

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Abstract

This research is intended to improve on existing rainfall estimation algorithms derived from operational radar data as well as to facilitate the study of spatial and temporal variability of rainfall. Using the C-band radar data of the KNMI at De Bilt (the Netherlands) several operational products with a grid of 256 by 256 pixels are produced with a resolution of 2.5km x 2.5km from which precipitation characteristics can be derived. Commonly a single Z-R relation is applied on CAPPI fields to create an estimate of rainfall. The proposed algorithm tries to make a distinction between convective and stratiform precipitation types and therefore will offer a chance to improve upon the estimation of precipitation. First an algorithm based on reflectivity intensity is to provide a first guess of convective and stratiform areas. Secondly separate reflectivity areas (RAs) are identified and tracked in consecutive images to follow their development. Within the first step CAPPI, lightning, echo-top height and Vertically Integrated Liquid (VIL) data can be used to identify more accurately different precipitating areas. Future plans also involve incorporating volume scans directly into the algorithm.

1. INTRODUCTION

Commonly radar reflectivity data is converted into precipitation intensities in a fairly straightforward way using a single Z-R relation, like the Marshall-Palmer relation (Marshall and Palmer, 1948), therefore not taking into account different precipitating cloud types and their associated different Z-R relations. Over the last decade numerous algorithms have been developed though to classify radar reflectivity data into different precipitation types (Steiner et al., 1995; Yuter and Houze, 1997; Lang et al., 2002; Biggerstaf et. al., 2000). These algorithms require the input of volume scan data or only take into account a CAPPI product. As volume data is not always available but only the operational end-products, an algorithm allowing as accurate as possible estimates of precipitation from not only CAPPI, but also other operational products like echo-top height and VIL, would be highly usable.

The proposed algorithm seeks to distinguish between convective and stratiform precipitation types from several of commonly available operational radar products and consequently improve precipitation estimates. The available operational products that can be used within this algorithm are CAPPI, echo-top height and Vertically Integrated Liquid (VIL) as well as a non-radar product, lightning intensity. The algorithm also offers the opportunity to investigate the relevance of using space-borne radar systems for measurement of precipitation at different spatial- and time scales; firstly through testing space-borne radar systems with the improved ground-based radar images created by the proposed algorithm and secondly by directly applying the algorithm to the space-borne radars. Another use would be its function as an operational now-casting product as it keeps track of the development of separate reflectivity areas (RA).

2. DATA

The radars used for this research are two C-band Doppler radar operating at 6 GHz and are located at KNMI in De Bilt and Den Helder (The Netherlands). The main radar is placed on top of a tower at KNMI and has little disturbance of nearby objects and has the advantage of being placed in the fairly flat region of the Netherlands. The radar scanning strategy produces data at two vertical resolutions. The first scans every 5 minutes on 4 low elevations and the second does a high resolution scan at 14 elevations every 15 minutes. Both have an angular spacing of 1 degree at each PPI. The spatial resolution of the volume scan is 1 kilometer. The scans of both radars are merged to produce a 5-minute CAPPI of 256 by 256 pixels at a resolution of 2.5km x 2.5km. From this

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data also an echo-top height and a hail product is produced operationally. Currently a VIL product is not available from KNMI. For the purpose of this research it is created from original volume data.

Lightning data are obtained from the SAFIR network operated by KNMI and in cooperation with the Belgian network of KMI. The network can detect both horizontal (cloud to cloud) as well as vertical (cloud to ground) discharges and the accuracy for the central part of the Netherlands has been shown to be within 2.6km for 80% of the detected discharges (Wessels, 2005).

The KNMI rain-gauge network collects 10-minute data at 35 automated weather stations in the Netherlands as well as daily data at 300 volunteer sites. Around the Cabauw-site a high-density rain-gauge network has been installed since March 2004 in a joined venture between Utrecht University and Wageningen University. The network has operated up to May 2005 with 30 rain-gauges spread over an area of maximally 10 kilometers distance from the Cabauw site. Since May 2005 the network has been thinned to 15 rain-gauges.

3. THE ALGORITHM

The algorithm consists of two main components. The first classifies CAPPI data above a threshold of 16 dBZ into stratiform or convective data. It can also use VIL, echo-top height and lightning operational data as additional sources of information. The second part is the tracking of the separate RAs to be able to extract meaningful statistics from these separate entities and make a more refined precipitation classification as well as follow the development of these RAs.

3.1 Part one of algorithm: Operational products for direct stratiform/convective precipitation classification

The first part of the algorithm uses the work of Steiner et al. (1995) and that of Yuter and Houze (1997) to make a first guess about convective and stratiform areas within the measured precipitation regions. The algorithm first assumes that values above 40dBZ will always be convective precipitation. Below 40 dBZ and above the threshold reflectivity (chosen as 16dBZ) a more accurate distinction has to be made. This happens by looking at the background reflectivity surrounding a current pixel. The background of a pixel is taken in a radius of 11 kilometers. If the average background value is much lower than the current pixel value it will be classified as convective along with a fixed area around it. The background to current pixel value ratio is dependent on the reflectivity value of the current pixel.

Currently the other operational products only have a very limited input in the algorithm. For the moment the echo-top height values above 9km and the lightning data areas with lightning discharges are identified as convective. Extensive research for the parameterization of the radius around an echo-top or lightning value that will be identified as convective will be performed in the future.

3.2 Part two of algorithm: Reflectivity area tracking

The RAs, or “precipitating clouds”, can be identified separately and tracked through time as has been done by other autors (e.g. Handwerker, 2001; Mukherjee and Acton, 2002; Leese and Novak, 1971). This is the same basic principle as used in Now-casting for predicting rainfall.

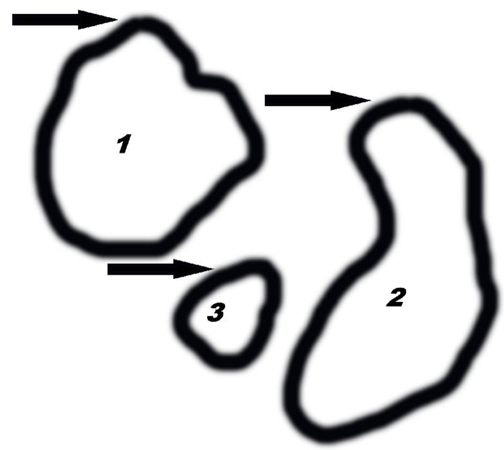

Figure 1. Moving along a row each pixel is assessed as a precipitating area or a clear area. If identified as a precipitating pixel all adjacent pixels within a radius of 3 pixels with a precipitation value are identified as part of the same RA until all pixels belonging to the RA have been found. As soon as the area has been identified the next pixels in the row are identified in search for the next RA.

The algorithm proposed here tries to track the RAs using a simple cross-correlation technique. Taking the precipitation map (values above 16dBZ) as input, separate RAs are identified by first scanning the map from the upper left corner to the lower right corner. As soon as a pixel value with a stratiform or convective value is encountered the adjacent pixels are also evaluated and if also identified as stratiform/convective added to the current RA ID number. To prevent single pixels, which are part of larger systems to be called separate RAs the algorithm scans in a radius of up to a maximum of three pixels. Pixels within this region will all get the same RA ID.

Next the last and current images are correlated using the identified RAs. This is done by taking a frame around a RA in the previous image and correlating this frame with a section of the current image. The frame size is dependent on the RA size. The smaller the RA is, the larger the frame will be. The size of the frame has to increase for smaller RA sizes as a RA of example one or two pixels with a frame of only one pixel surrounding it is very hard to correlate accurately. The section chosen in the current image for correlation are the coordinates of the frame in the previous image as well as an extra border, which is dependent in size on the maximum distance a RA can have moved in the time interval between the two images.

The characteristics of the separate RAs like direction, intensity and size are stored in a database for more detailed analyses. This database allows clouds to be tracked through time and their development can be analyzed to name RAs convective or stratiform. It also allows the possibility of keeping track of RAs that split or merge. Also see figures 1 and 2 for an illustration of the correlation technique and figure 3 for an example of the resulting image.

4. CONCLUSIONS AND OUTLOOK

Currently the basic algorithm is operational and the first impression of the first part of the algorithm is that it does indeed find the different precipitating areas. Comparisons with the high-density rain-gauge network will provide the accuracy and will offer opportunities to improve upon it. The only truly functional part at this moment is the algorithm based upon the work by Steiner 1995. As mentioned before the lightning and echo-top data are currently only implemented in a very crude way into the algorithm and still need an analysis using the raingauge and volume scan data to become fully functional within the algorithm. The VIL data also will be included into the algorithm as soon as the other operational products work accurately.

The tracking section of the algorithm is capable of identifying and tracking RAs with reasonable accuracy and looks promising. Even though the database of the tracked clouds is fully operational

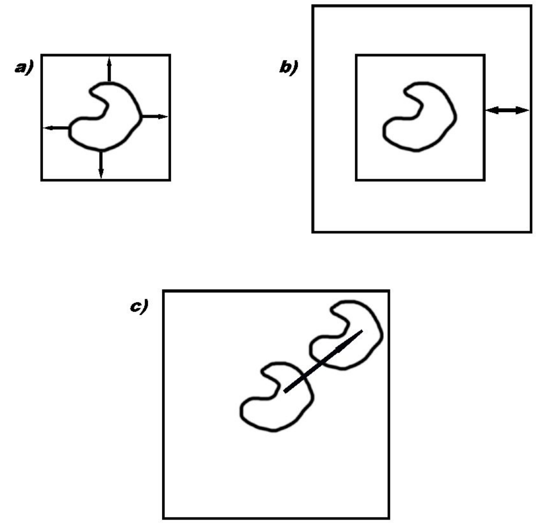

Figure 2. A frame is placed around identified RA of the CAPPI of the previous time step (see a). Around the coordinates of the area selected in a) another frame is selected which size depends on the time interval between the previous and current CAPPI (see b). The data of the RA within the previous RA is correlated with the frame of the current image to determine the motion vector (see c).

the opportunity it offers as an extra identifier for stratiform/convective precipitation is not yet in place. Like the precipitation identification algorithm more comparison with rain-gauge and volume data is needed to optimize the tracking and database features.

If there is a large precipitating system on the radar map cyclonality will begin to be an important factor and the currently straightforward cross-correlation tracking algorithm is not applicable anymore. Future research will have to reveal if dividing larger areas into smaller sections will offer a solution or that a completely different kind of tracking algorithm needs to be developed, as proposed by previously mentioned authors, that keeps track not only of direction but also of shape.

Another purpose of this algorithm is to assess its performance using different spatial- and time scales to see how the parameterization will have to change

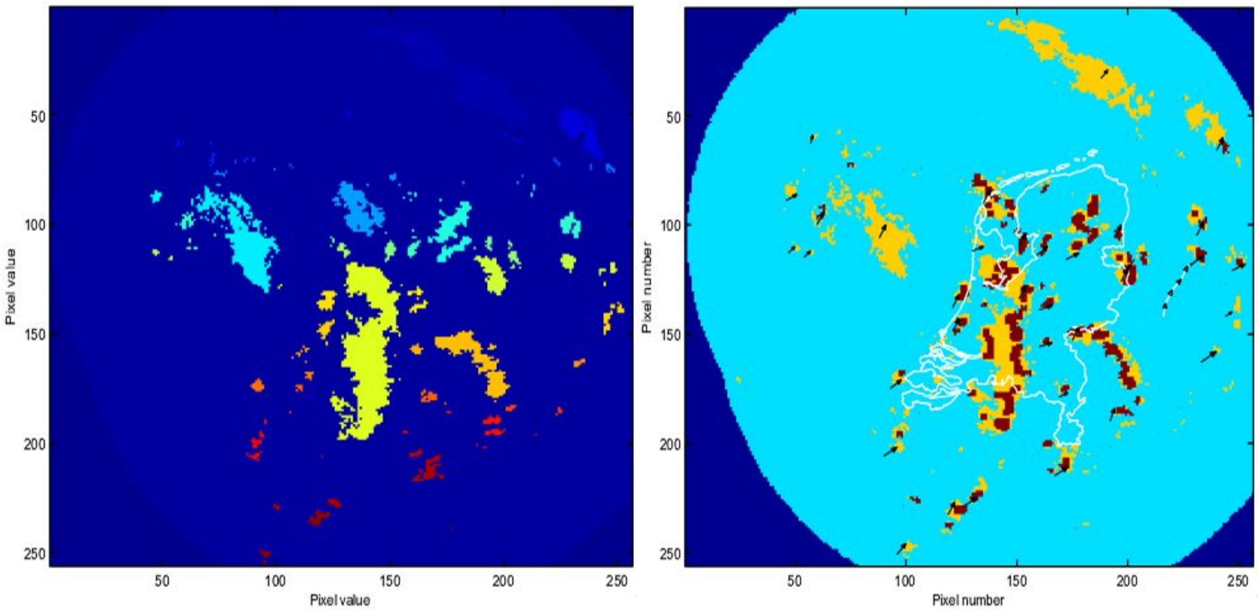

Figure 3. Example of the algorithm. In the left figure the RAs of the previous scan are shown and on the right side the convective/stratiform classification, where yellow is stratiform and red convective. The black arrows represent the movement of the tracked RAs and just east of the Dutch border an example is given of the tracking history with the white arrows.

depending on resolution for both ground based and space-borne radar systems. As soon as the algorithm is completely operational a full analysis will be performed.

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