QUALITY OF ECHOTOP PRODUCTS AND DERIVED PROBABILITY OF HAIL AS A FUNCTION OF RANGE

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Abstract

Operational hail detection products at KNMI (Netherlands) and RMI (Belgium) are derived from the height of the freezing level and the 45-dBZ echotop values provided by single-polarization C-band weather radars. Echotop products are not only affected by errors on the measured reflectivity itself but also by errors on the height assigned to the measured reflectivities. In this study, we evaluate the relative importance of these errors as a function of range.

The method is based on the comparison between the reflectivity field observed by the radar of Wideumont in Belgium and the radar of De Bilt in The Netherlands on a vertical cross section extending between the two radars. Our results show that the measurement quality of maximum reflectivity and echotop values are not affected by range effects up to a distance of about 150 km. Within this range height assignment errors are generally less than 1 km and the impact of these errors on the derived probability of hail is small compared with the impact of calibration errors.

1. INTRODUCTION

Most hail detection algorithms for single polarization radars are based on the analysis of the vertical profiles of reflectivity. At KNMI (The Netherlands) and RMI (Belgium), the operational hail detection product is based on the difference (ΔH) between the height of the freezing level and the maximum height at which a reflectivity of 45 dBZ is observed (echotop 45 dBZ). The probability of hail (POH) is derived from $\Delta H(km)$ using $POH = 0.319 + 0.133\ \Delta H$. A detailed description and evaluation of this product can be found in Holleman (2001) and Delobbe et al. (2003).

Radar reflectivity measurements are affected by various sources of error which tend to increase with the distance from the radar. Attenuation, overshooting and the increasing size of the sampled volume are the most important ones. Beside these errors affecting the measured reflectivity itself, errors on the height assigned to the measured reflectivities arise due to the uncertainties in the trajectories of the radar beams. These uncertainties are related to inaccurate antenna pointing and to variations of the atmospheric propagation conditions. Height assignment errors affect the echotop product and the derived probability of hail. The aim of this study is to investigate how reflectivity measurements and derived products deteriorate with the distance from the radar.

The methodology is based on the comparison between reflectivity data from the radar of De Bilt in The Netherlands and the radar of Wideumont in Belgium. Usually, comparisons of reflectivity data measured by two or more radars are based on PPI or CAPPI products which does not allow to identify errors related to height assignment as a function of range (e.g. Huuskonen, 2001; Tabary, 2003). In this study, the comparison of reflectivity data is made on a vertical cross section extending from one radar to the other one. The reflectivity field observed at short distance by one radar is considered as reliable and the comparison with the field observed at the same time by the other radar allows to point out the shortcomings of the long-range observation.

2. METHOD

The radar of Wideumont in Belgium and the radar of De Bilt in The Netherlands are both Gematronik C-band Doppler radars. They perform a volumic scan every 15 minutes. It includes 10 elevations between 0.5 and 17.5 degrees for the radar of Wideumont and 14 elevations between 0.3 and 12 degrees for the radar of De Bilt. The beam width is 1 degree for both radars. The distance between the two radars is 244 km. For each radar, the reflectivity field on a vertical cross section drawn in the direction of the other radar can be extracted from the volumic data every 15 minutes.

First comparisons of vertical cross sections have been presented in Delobbe and Holleman (2003). In the present study, a more quantitative analysis of these comparisons has been carried out. Three thunderstorm episodes observed on July 30 2002, August 3 2002 and June 6 2003 were considered and a total of 40 cross sections were extracted from the volume data of each radar.

Figure 1 shows one of the 40 cross section pairs as an example. The cross section from Wideumont starts at 585 m above sea level, which is the altitude of the radar antenna. Three distinct cells are found between the two radars. The vertical extensions and the reflectivity levels are very similar in both data sets. One of the three cells exhibits reflectivity values higher than 45 dBZ. Some differences in the vertical structure of that cell can be observed but in the present case the difference in the echotop 45 dBZ does not exceed 1 km. The impact on the derived probability of hail is limited to 13 %.

As can be seen on Figure 1, data from the radar of De Bilt are only available up to a distance of 200 km and significant ground clutter is present up to a distance of about 40 km. Besides, the radars do not scan the whole tropospheric column at short ranges. For this reason, we have limited the comparison of the reflectivity data to ranges between 44 and 200 km. This range domain which is symmetric around the middle point between the two radars has been divided into 15 range intervals. All intervals are 10-km wide except the two extreme ones which are 13-km wide. For each interval, the maximum reflectivity from both data sets were compared for the 40 cross sections. Only maximum reflectivities higher than 7 dBZ in both datasets have been considered. The time difference between two corresponding volume data sets never exceeds 3 minutes.

3. RESULTS

Figure 2 shows a scatter plot giving the maximum reflectivity measured by the radar of De Bilt versus the maximum reflectivity of Wideumont. The scattering of the data is relatively limited and a significant bias between the two radars is observed. The effect of the distance on the mean difference between the maximum reflectivity of the two radars is shown in Figure 3. The standard deviation of this difference is about 1 dBZ for all ranges. At short ranges from Wideumont, the maximum reflectivity measured by the radar Wideumont significantly exceeds the maximum reflectivity from De Bilt. The mean difference is 10 dBZ at 44 km with a standard deviation of about 1 dBZ. At long ranges, the opposite behavior is observed with reflectivities from De Bilt exceeding those from Wideumont by about 5 dBZ at 200 km from Wideumont (44 km from De Bilt). At intermediatee ranges, the mean difference Z_{Wid} -Z_{Deb} does not depend on the distance. A significant bias of 5 dBZ is obtained between the two radars. This result shows that the quantitative comparison of cross sections is an effective method to point out a bias between two radars. Such a calibration difference is certainly a matter of concern. A careful re-examination of the hardware calibration of the two radars is being performed.

Near Wideumont, the slope of the mean difference is about 5 dBZ/40 km while the slope is about 10 dBZ/40 km near De Bilt. It means that the degradation of the reflectivity measurements with the distance is more pronounced for the radar of Wideumont than for the radar of De Bilt. This is probably related to the scan strategies of the two radars. The number of elevations is larger for the radar of De Bilt and the lowest scanned elevation is 0.5 degree for Wideumont while it is 0.3 degree for De Bilt. As a consequence, overshooting effects are likely to occur at shorter ranges for the radar of Wideumont. The orography amplifies this effect since the radar of Wideumont is located near the top of the Ardennes ridge at 585 m asl while the radar of De Bilt is almost at sea level. The distance from which a deterioration of the measurements appears is about 140 km for the radar of Wideumont and 155 km for the radar of De Bilt.

Echotop products are sensitive to reflectivity levels measured by the radar but also to the heights assigned to the measured reflectivities. In order to identify height assignment errors, the height where the maximum reflectivity is observed has been extracted for each range bin from both radars and the mean value for each of the 15 range intervals has been determined. To eliminate maximum reflectivity heights corresponding to low reflectivity levels, only range intervals with maximum reflectivity values higher than a given threshold are considered. The comparisons were made for three different thresholds: 7 dBZ, 20 dBZ, and 30 dBZ. With a higher threshold, only the heights of high reflectivity cores are compared which means that the comparisons are based on a smaller number of valid pairs. The comparison was not made for a 45 dBZ threshold because the number of valid pairs is too small. Figure 4 shows the number of valid pairs as a function of the distance. With a 7 dBZ threshold, the number of valid pairs is around 25 per range interval. It drops to a value around 10 for a 30 dBZ threshold. Figure 5 shows, for each threshold, the mean difference between the heights of the maximum reflectivity values from the radars of Wideumont and De Bilt. With a 7 dBZ threshold, the mean height difference is less than 500 m up to a distance of 140 km from the radar of Wideumont. Except at very short ranges, the radar of Wideumont tends to assign larger heights than the radar of De Bilt. At long ranges, the height differences increase rapidly. At 190 km from Wideumont, the maximum reflectivity heights seen by the radar of Wideumont exceed those seen by the radar of De Bilt by about 2 km. At this range, the difference in altitude of the lowest beams of the two radars reaches 4 km. In many cases, the radar of Wideumont overshoots the maximum reflectivity core observed by the radar of De Bilt. For larger thresholds, the height differences obtained up to a range of 140 km are larger but remain generally smaller than 1 km. Larger height differences are obtained at long ranges, especially with a 30 dBZ threshold where the height difference reaches 3 km at 180-km range. Note that for all thresholds and for all ranges, the standard deviation of the maximum reflectivity height differences is close to 0.3 km.

Based upon the results presented here, we can conclude that the radar of Wideumont generally tends to measure higher reflectivities and to assign higher altitudes to the measured reflectivities than the radar of De Bilt. Besides, the difference in the scanned elevations angles of the two radars significantly affects the performances at long ranges. Using a lowest elevation angle of 0.3 degree instead of 0.5 degree allows a significant increase of the effective range where reliable measurements of the vertical structure of the reflectivity field can be obtained.

The horizontal profiles Wideumont-De Bilt of echotop values have been calculated for three thresholds: 7 dBZ, 20 dBZ, and 30 dBZ. For each range interval, only RHI pairs where the maximum reflectivity exceeds the threshold in both data sets are included in the calculation of the mean difference. The mean difference of the echotop values between Wideumont and De Bilt is shown in figures 6. The standard deviation of these differences is less than 0.5 km for all thresholds and all ranges. Differences in echotop values are caused by differences in the measured reflectivities and in the heights assigned to these reflectivities, which makes the interpretation of the echotop discrepancies more difficult. It must be stressed that very small differences in the measured reflectivity values may induce very large differences in echotop values especially if the maximum measured reflectivities are close to the echotop threshold. If the maximum reflectivity exceeds the 45-dBZ thresold in only one of the two radar datasets, the difference in the derived probability of hail can reach 100 %. This effect has not been examined in the present study since the number of cases is too limited.

4. CONCLUSION

Reflectivity data on a vertical cross section extending from the radar of Wideumont in Belgium and the radar of De Bilt in The Netherlands have been compared and the differences have been analysed. Three thunderstorm episodes have been considered and 40 cross sections have been extracted from both radar volumic data. These comparisons appear as a valuable tool to point out calibration differences between radars as well as differences in the heights assigned to the measured reflectivities.

The quantitative analysis of the results shows that the measurement quality of maximum reflectivity and echotop values are not affected by range up to a distance of about 150 km. Within this range, the mean maximum reflectivity difference between the two radars is about 5 dBZ while the mean difference of the height assigned to the maximum reflectivity is less than 1 km. This suggests that height assignment errors have a relatively low impact on the probability of hail estimated by the hail detection algorithm used at KNMI and RMI. In contrast, small errors in the reflectivity measurements may strongly affect the derived probability of hail especially if the measured maximum reflectivity are close to the 45 dBZ threshold. Our results show that calibration errors dominate errors arising form inaccuracies in the antenna pointing and from variations in the atmospheric propagation conditions. Nevertheless, the relative importance of the different sources of errors will be further investigated using a larger number of thunderstorm episodes.

Acknowledgements

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FIGURE CAPTIONS

Figure 1: Reflectivity (dBZ) on a vertical cross section De Bilt-Wideumont observed by the radar of Wideumont (upper panel) and by de radar of De Bilt (lower panel). The distance between the two radars is 244 km.

Figure 2: Maximum reflectivity measured by the radar of De Bilt versus maximum reflectivity measured by the radar of Wideumont.

Figure 3: Mean difference between the maximum reflectivity measured by the radars of Wideumont and De Bilt as a function of the distance from Wideumont.

Figure 4: Number of valid pairs per 10-km range interval as a function of the distance from the radar of Wideumont for reflectivity thresholds of 7 dBZ (solid line), 20 dBZ (dashed line) and 30 dBZ (dash dot line). Only RHI pairs with maximum. reflectivity higher than the threshold in both data sets are considered as valid.

Figure 5: Mean difference of the maximum reflectivity height as a function of the distance from the radar of Wideumont for reflectivity thresholds of 7 dBZ (solid line), 20 dBZ (dashed line) and 30 dBZ (dash dot line).

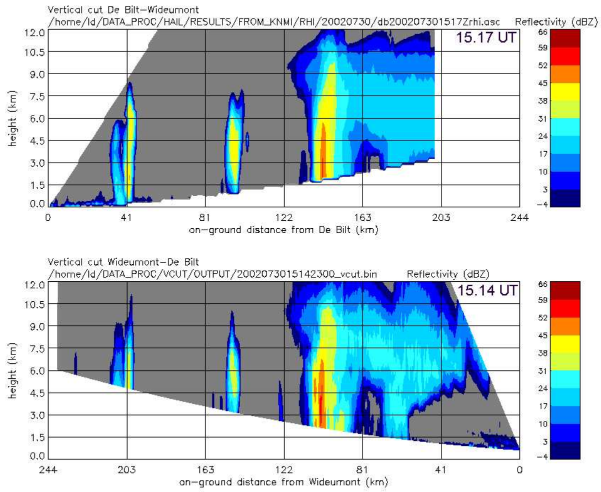
Figure 6: Mean difference of the echotop 7 dBZ (solid line), 20 dBZ (dashed line) and 30 dBZ (dash dot line).

Note for the production:

1) The upper and lower panels of Figure 1 are in the files ERAD04_P_00025F1A and ERAD04_P_00025F1B respectively. Figures 1A and 1B are provided in eps and png format as well. Take the best !

2) All the figures can be displayed on one column with an approximate width of 8 cm. However, if possible, Figure 1 will be nicer on two columns.

3) Many thanks !



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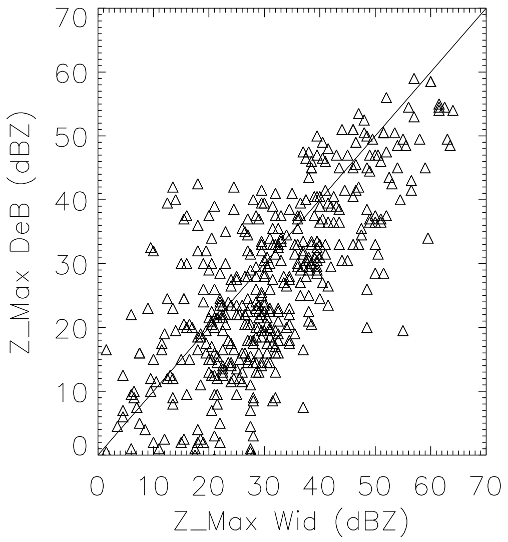
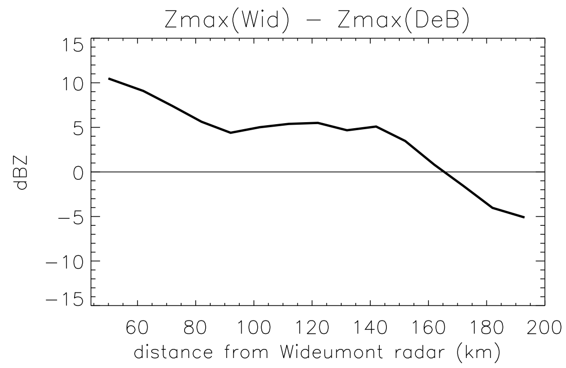


Figure 2:



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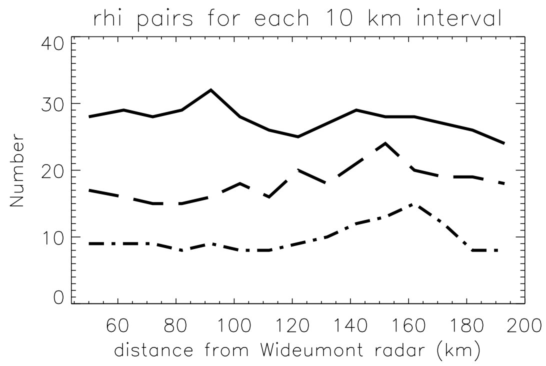

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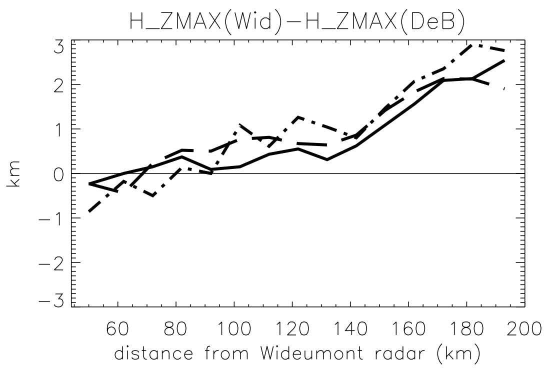

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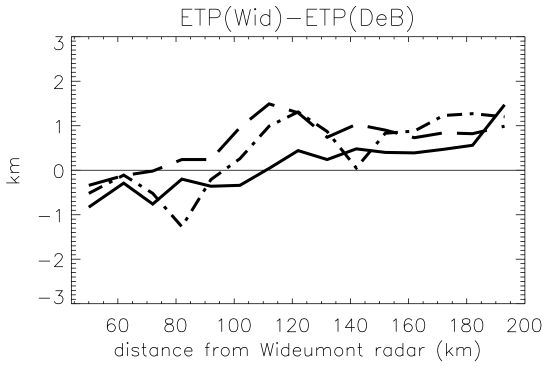
ETP(Wid)−ETP(DeB)
km
3
2
1
0
−1
−2
−3
60
80
100
120
140
160
180
200
distance from Wideumont radar (km)

Figure 6: