P3C.6 RADAR-BASED HAIL DETECTION: IMPACT OF HEIGHT ASSIGNMENT ERRORS ON THE MEASURED VERTICAL PROFILES OF REFLECTIVITY

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1. INTRODUCTION

Most hail detection algorithms for single-polarization radars are based on the analysis of the vertical profiles of reflectivity. These profiles are estimated from the volumic data generated by a scanning at multiple elevations. Beside the usual sources of errors affecting the radar reflectivity, the estimated vertical profiles are also affected by the uncertainties in the trajectories of the radar beams. This results in uncertainties in the height assignment of the measured reflectivities, and thus introduces errors in the measured vertical profiles.

To get a first idea of the effect of these errors on the estimated probability of hail (POH), RMI (Belgium) and KNMI (The Netherlands) have started a study in which the volumic data from the radars of Wideumont and De Bilt are compared, as well as the derived probability of hail.

Both radars are 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 15 elevations between 0.3 and 12 degrees for the radar of De Bilt. The distance between the two radars is 244 km.

We here present first results concerning thunderstorm cases with hail observed between the two radars in the summer 2002. The experimental set-up is shown in Figure 1.

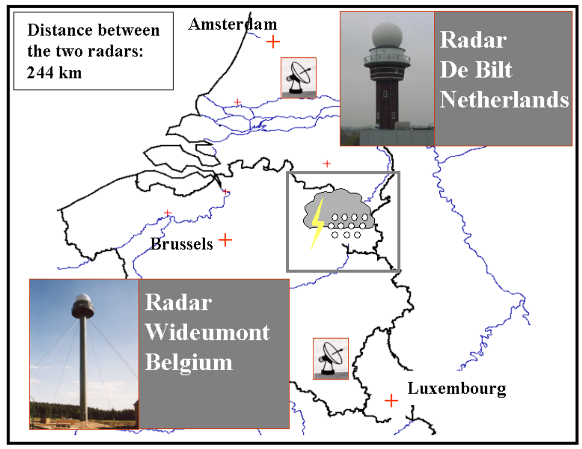

Figure 1: Experimental setup

2. HAIL DETECTION USING SINGLE POLARIZATION RADARS

We estimate the probability of hail following the method of Waldvogel et al. (1979) which is operationally used at KNMI. As shown in Figure 2, it is based on the difference ΔH (km) 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 calculated as follows:

$$POH = 0.319 + 0.133\ \Delta H \quad (1)$$

This expression has been obtained from a verification study carried out by KNMI in the summer 2000 (Holleman, 2001).

The method of Waldvogel combines an indicator for the presence of a substantial updraft, the height of the strong reflectivity core (45 dBZ), with that for a large amount of undercooled water and/or ice, the reflectivity core above the freezing level, to detect (developing) hail. The probability of the presence of hail increases with increasing height of this reflectivity core. The method of Waldvogel is currently also being used in the NEXRAD hail detection algorithm (Witt et al., 1998).

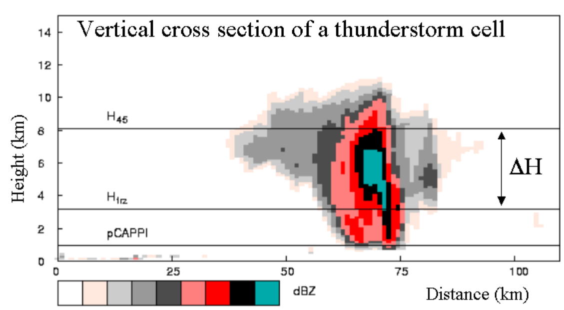

Figure 2: Hail detection method of Waldvogel.

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3. RESULTS

3.1 Max reflectivities

The max(imum) reflectivity product gives for each pixel the highest measured value along the vertical, which is thus unaffected by propagation effects. A thunderstorm case with hail was observed in the area of Hasselt-Maastricht on August 3, 2002. The comparison between the max products (in dBZ) from the two radars is given in Figure 3.

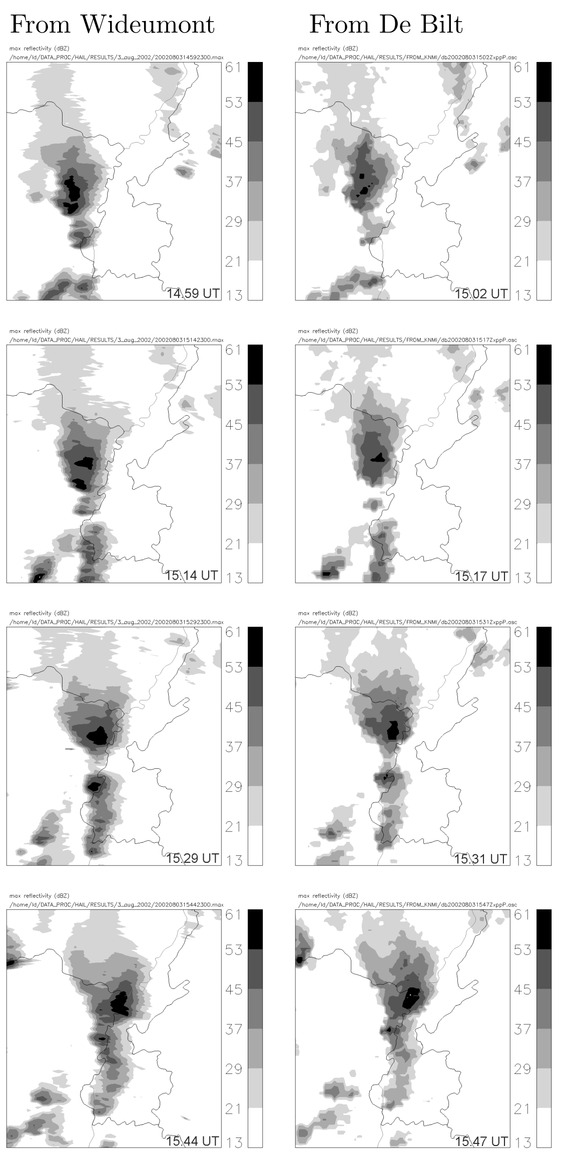

Figure 3: Comparison between the max reflectivities measured by the radars of Wideumont and De Bilt

Four images with a 15-min time interval are given for each radar. The visualisation domain is the 60x60 km^2 square drawn in Figure 1. There is a time shift of about 3 minutes between the corresponding snapshots. Taking into account that the two radars observe the situation from an opposite viewpoint, the agreement between the two observed evolutions of the thunderstorm spatial structure is remarkable.

3.2 Echotop 45 dBZ and derived POH

The highest values of echotop 45 dBZ and probability of hail (POH) are obtained around 15.30 UT. Again, the results obtained from the two radars are very similar (Figure 4). The spatial shift between the corresponding images is mainly due to the time difference between the snapshots. The differences in echotop values are limited to about 1 km, which corresponds to a difference in POH of about 13 %.

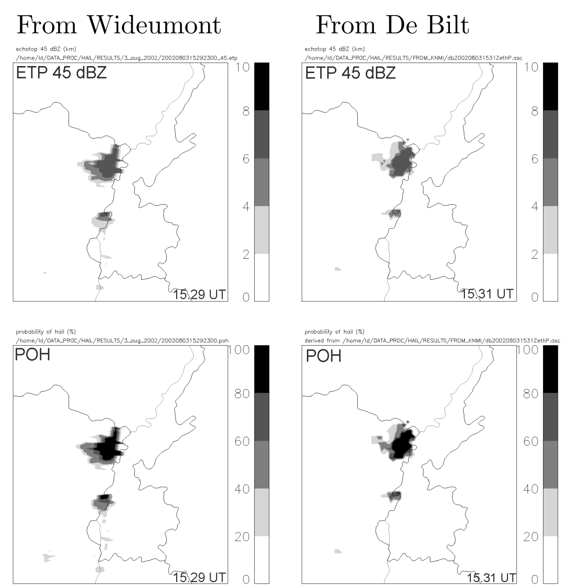

Figure 4: Comparison between the echotop 45 dBZ and probability of hail from the radars of Wideumont and De Bilt

A 1 km difference in the echotop values can be considered as a relatively small difference. At a distance of 120 km, the beamwidth for both radars is about 2 km and the height difference between the centres of two adjacent elevations is typically 1.5 km.

It seems that in this particular case the height assignment errors do not introduce significant discrepancies between the two estimated POH. It does, however, not mean that these errors are not affecting the results. If the atmospheric conditions are homogeneous in the area comprised between the two radars, the errors on the estimated beam trajectories will be similar for both radars. These errors will not be apparent when the thunderstorm is located at mid-distance from the two radars.

3.3 Vertical cross section De Bilt-Wideumont

An interesting way to point out the effect of the distance on the observed vertical structure of thunderstorm cells is to draw vertical cross sections extending from one radar to the other one. In a first step, two thunderstorm episodes observed on July 30 2002 and August 3 2002 have been analysed and a total of 26 cross sections have been extracted from the volumic data of each radar. The comparison for three representative situations is shown hereafter.

Figure 5 shows the first comparison. 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 the difference in the echotop 45 dBZ does not exceed 1 km which has a relatively low impact on the derived probability of hail.

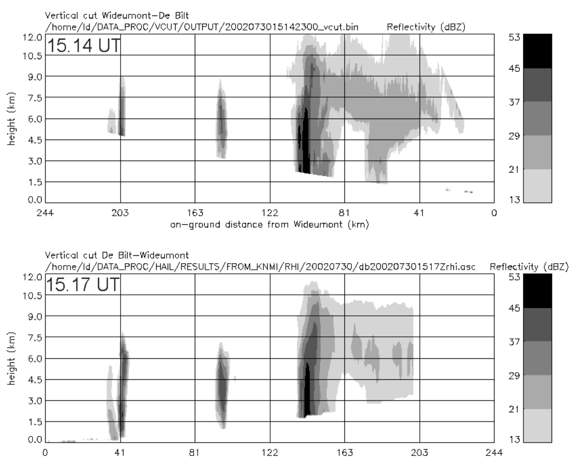

Figure 5: Reflectivity (dBZ) on a vertical cross section De Bilt-Wideumont from Wideumont (upper panel) and De Bilt (lower panel).

In the second case presented in Figure 6, the radar of Wideumont detects a thunderstorm cell at a 75-km range with a reflectivity core higher than 45 dBZ between 5 and 7.5 km above sea level. The radar of De Bilt, which is located at 170 km, detects the cell but with reflectivities lower than 45 dBZ which means that no hail will be associated to this cell. At 170 km, the 1-degree radar beam is 2.96 km wide and the relatively low reflectivities measured by the radar of De Bilt are probably due to a partial beam filling of the high reflectivity core. Unless the centre of the radar beam crosses the centre of the reflectivity core, in many cases the degradation of the spatial resolution with the distance leads to an underestimation of the maximum reflectivity of the thunderstorm cell.

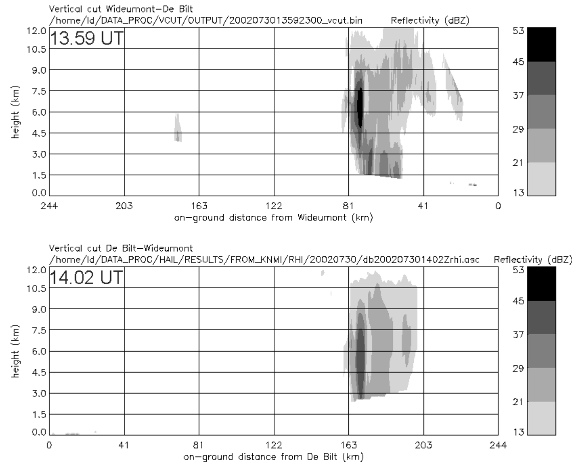

Figure 6: Reflectivity (dBZ) on a vertical cross section De Bilt-Wideumont from Wideumont (upper panel) and De Bilt (lower panel).

The last situation is characterized by a number of cells located between 110 and 180 km from the radar of Wideumont (Figure 7). On this cross section, the attenuation effect is clearly apparent. For example, the cell located near 122 km is much weaker in the data from de radar of De Bilt as a result of the attenuation by numerous cells located in-between. Attenuation effects also alter the apparent vertical extension of the thunderstorm cells which makes difficult to clearly identify the impact of height assignment errors. Further investigation of this effect will need to compare vertical cross sections in various thunderstorm situations where a single cell is present between the two radars.

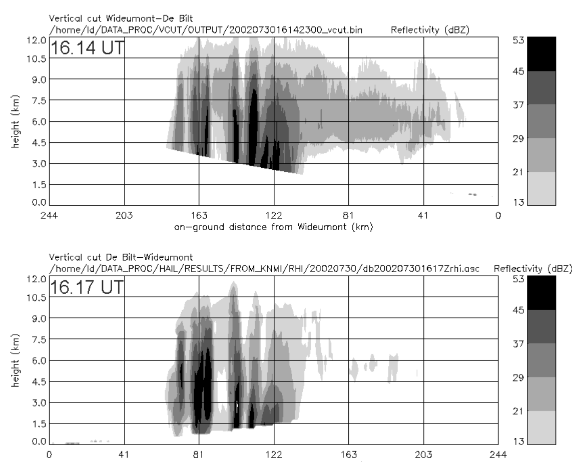

Figure 7: Reflectivity (dBZ) on a vertical cross section De Bilt-Wideumont from Wideumont (upper panel) and De Bilt (lower panel).

5. CONCLUSIONS AND PERSPECTIVES

For the particular cases we have analyzed here, the discrepancies between the max reflectivities, echotop 45 dBZ and probability of hail derived from the two radars are very limited. A very good agreement was found between the spatial structure of the thunderstorm complexes as seen by the two radars.

For both radars, the vertical cross section extending from one radar to the other one was extracted from the volume reflectivity data. This product appears as a powerful tool for identifying differences in the observed vertical structure of the thunderstorm cells. In particular, it allows to get a first estimate of the relative importance of the various sources of errors affecting the measured reflectivity field and the derived probability of hail.

For the particular situations tested in this study, it appears that height assignment errors do not have a major impact. Errors affecting the measured reflectivity itself, such as attenuation and partial beam filling play a more important role. By reducing the measured reflectivity levels, the maximum reflectivity inside a thunderstorm cell may drop under the reflectivity threshold used in the hail detection algorithm, which means that no hail will be detected. The effect of height assignment errors is only to modify the derived probability of hail. Based on the results presented here, we estimate that this effect does not exceed 20 %. However, a deeper investigation will require a larger number of cases with a special focus on situations where a single cell is present between the two radars in order to minimize the attenuation effects.

Acknowledgments

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