Radar-based Hail Statistics Over Belgium

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1. Introduction

The Royal Meteorological Institute (RMI) of Belgium has been operating a single-polarization C-band Doppler weather radar for more than ten years (2001 - 2012). The high resolution volumetric reflectivity measurements of the radar are archived since 2002. Next to many other applications those data are also used for operational hail detection, performed by the hail detection algorithm based on the method of Waldvogel et al. (1979).

In this study the Probability of Hail (POH) estimated by the operational hail detection algorithm is used to derive statistics on the occurrence of hail events in ten years period from 2003 to 2012. In addition to the operational POH algorithm, the possibility of severe hail is estimated using the Severe Hail Index (SHI) algorithm introduced by Witt et. al. (1998). The Probability of Severe Hail (POSH) and the Maximum Expected Size of Hail (MESH), derived from SHI algorithm allowed to produce statistics on the severity of hail storm over Belgium.

2. Observations

As most of the methods of hail detection for single-polarization radars, POH and SHI algorithms explore the relationship between the vertical profile radar reflectivity factor and hail occurrence on the ground. Estimation of the reflectivity profiles is based on the volumetric data generated by scanning at multiple elevations. For the best spatial resolution ten-elevation scan of the Wideumont radar was used. With this scan reflectivity data from 10 elevation angles between 0.5° and 17.5° are collected every 15 minutes .

Both algorithms POH and SHI combine the reflectivity data of single-polarization radar with the historical temperature profiles, obtained by dynamical downscaling of the ERA-Interim re-analysis. ALARO-0, the current operational Numerical Weather Prediction (NWP) model of RMI was used for this. A double nesting technique is applied for the achievement of the final high resolution grid.

3.1 Probability of Hail (POH)

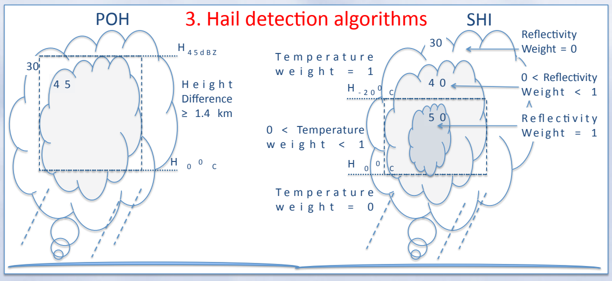
is in linear relation with the height difference between 0-isotherm and the highest point where a reflectivity value ≥ 45 dBZ was measured:

$$POH = 0.319 + 0.133\,(H_{45\,dBZ} - H_{0\text{-}isotherm})$$

This relation differs from the original one introduced in Waldvogel et.al. but was obtained from a verification study carried out by KNMI in the summer 2000 (Holleman, 2001).

The algorithm was successfully tested on the territory of Belgium and the Netherlands over summer periods of 2002 – 2006.

3. Hail detection algorithms



3.2 Severe Hail Index (SHI)

is calculated by vertical integration of the product of the hail kinetic energy *E(Z(h))* with the temperature-based function $W_T(h)$ and a reflectivity-based function *W(Z(h))*:

$$SHI = 0.1 \int_0^{H^T} W(Z(h))\, W_T(h)\, E(Z(h))\, dh,$$

where *Z(h)* is reflectivity at the height *h* and H^T is the highest point were a reflectivity ≥ 40 dBZ is measured.

Maximum Expected Size of Hail (MESH) is derived as:

$$MESH = 2.54\,(SHI)^{0.5}.$$

Probability of Severe Hail (POSH) is given by:

$$POSH = 29\,\ln(SHI/WT) + 50,$$

where $WT = 57.5\,H_0 - 121$ is a warning threshold of selection model.

4. Results

Figure 1: Average daily relative total extent (% of radars domain area) with **POH > 90**.

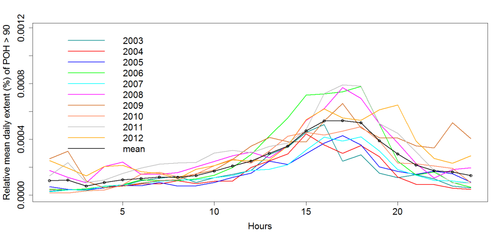


Fig. 1 and Fig. 2 show diurnal distribution of the relative total extend from the POH and SHI algorithms correspondently. The mean over ten years curve shows a clear peak between 16:00 and 18:00 UTC for the both methods of hail detection.

From Fig. 3 with relative total extent it is clear that the Hail-Season (HS) for Belgium lasts from April to September. Based on this conclusion a further statistical analysis in Fig. 2 and 4-6 are made for the six month period (April-September) of each year.

A distribution of number of hail days per month with hail and severe hail (≥ 20 mm in diameter) within the HS is shown by Fig. 5 and Fig. 6 correspondently. The mean number of days per month curve shows a pronounced peak in June for hail detected by POH and in May for severe hail detected by SHI algorithm.

The dynamics of total number of severe hail-days in HS per year detected by POSH (red) and detected by POH (blue) algorithm can be found in Fig. 4.

The spatial analysis as on Fig. 7, requires inclusion of some additional quality information. That will allow to exclude artifacts related to scanning geometry and non-weather targets (ground echoes, airplanes and interferences) from the statistical analysis.

Figure 2. Average hourly relative total extent (% of radars domain area) with **POSH > 60**.

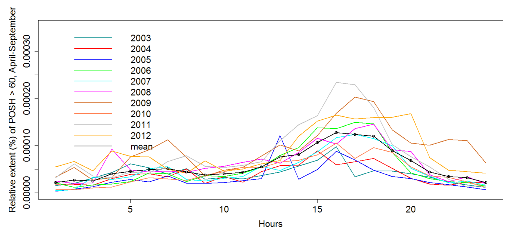


Figure 3. Annual distribution of hail storm relative total extents.

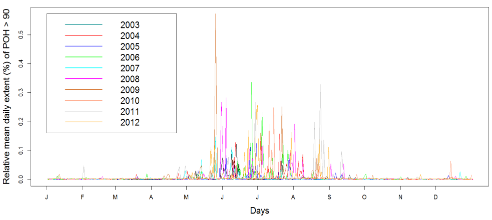


Figure 4. Total number of hail days in HS with POH > 90 (blue) and POSH > 60 (red).

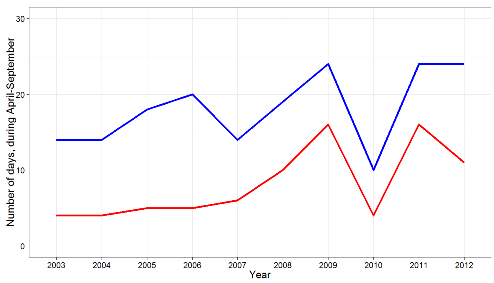


Figure 5: Distribution of hail days in HS (with **POH > 90**).

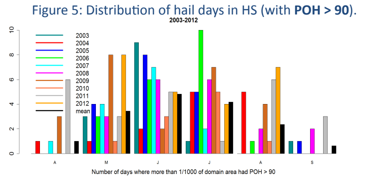


Figure 6: Distribution of severe hail days in HS (with **POSH > 60**).

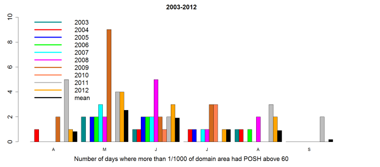


Figure 7. Relative frequency of hail, Wideumont radar, 2003 – 2012.

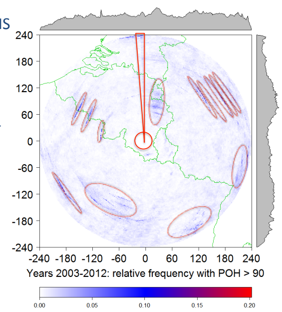
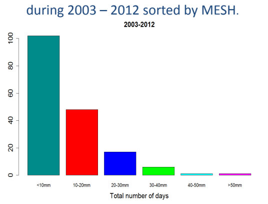


Figure 8. Total number of hail days during 2003 – 2012 sorted by MESH.



5. Conclusions

From the analysis of the single-polarization C-band Wideumont radar data of years 2003-2012 can be concluded that:

1) hail storms with the largest spatial extension are most often detected by both algorithms around 16:00 – 18:00 UTC;
2) most hail storms occur in the period between April and September;
3) hail is highly sporadic event and for each month the number of hail days vary dramatically from one year to another;
4) in total at least one out of four hail events is severe and this proportion varies from year to year;
5) hail stones of ≥ 30mm in the diameter are rare (Fig. 8);
6) in average hail storms more often occur in June, but the severe hail is frequently detected in May;
7) for a better spatial statistical analysis the quality information of the radar data is required.

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7. References

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