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Microphysical Evolution of a Convective Event retrieved from Two Operational Polarimetric C-Band Radars

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1 Introduction

The analysis of the evolution of convective clouds and their correspondent microphysics vertical distribution will contribute to a better understanding of convective processes and will improve the representation of cloud evolution and latent heat formation for assimilation in NWP models.

The use of polarimetric radar measurements allows us to identify the prevailing hydrometeor type and their spatial distribution within a meteorological event.

The study is carried out using two polarimetric C-band radars located 90 km apart in the Po Valley of Northern Italy, the S. Pietro Capofiume and the Gattatico radars, both managed by ARPA Emilia-Romagna.

The radar observations are collected during the transition of a severe evolving storm occurred on the afternoon of 20 may 2003, moving across the region explored by the two radars, and the microphysical properties are obtained by using an hydrometeor classification scheme developed at the National Severe Storms Laboratory, NSSL, (Zrnic et al., 2001) and recently extended from S-band to C-band radar data (Marzano et al., 2006).

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The aim of the work is the reconstruction of the 3-D storm structure vertical evolution to understand how the microphysical properties change during the different stages of the storm formation and development (from the early to the mature and then dissipative stage of the cloud system).

Further "storm representative" vertical hydrometeor profiles will be discussed in order to elucidate the microphysical processes occurring during the storm's lifetime and their consequence on the ground rainfall field estimation.

A next step of this kind of analysis will be the comparison with NWP simulated profiles, to check if they are able to reproduce the reference hydrometeor vertical profiles seen by the radars.

2 The hydrometeor classification algorithm

The hydrometeor classification algorithm used for the analysis belongs to the fuzzy logic family and is a further implementation of the scheme developed at the National Severe Storms Laboratory (NSSL), with a reduced set of polarimetric variables collected at C-band: reflectivity (Z) and differential reflectivity (ZDR).

The fuzzy logic-based methodology was applied in the first place for implementing capabilities of distinguishing between several classes/types of hydrometeors. The crucial point of the classification scheme is the partitioning of the multidimensional space generated by the polarimetric variables in subsets related to specific particle classes. The scheme is based on a combination of weighting functions that map the Z-ZDR space and that are associated with a particular type of hydrometeor.

The environmental temperature is used to remove ambiguities in the decision process by introducing the additional constraint that every class of hydrometeors can only be found in cloud within a certain range of temperatures (e.g., dry snow or ice crystals are not found at temperatures above zero). The scheme makes use of a standard atmospheric profile of 6.5 km^{-1} starting from the surface temperature measured by local groundstation.

Ten hydrometeor classes are discriminated by the algorithm: light rain (LR, < 5 mm h^{-1}), moderate rain (MR, 5-30 mm h^{-1}), heavy rain (HR, > 30 mm h^{-1}), large drops (LD, when the raindrop size distribution is dominated by a very low concentration of large drops), rain-hail mixture (RH), graupel-small hail (GSH), hail (HA), dry snow (DS), wet snow (WS), and ice crystals (IC).

The radar considered in this study are operational C-band systems located in the Po valley: the S.Pietro Capofiume (SPC hereafter) and the Gattatico (GAT) radars.

A combined scanning strategy of these two instruments was conducted in order to try to correct the attenuation effects (of which the C band radars are strongly affected) and their consequences on the rainfall field estimation for a deep convection episode occurred on 20 may 2003. For further details the reader should refer to Celano et al. 2006. In brief the composite (SPC + GAT) map is made by taking the highest values of Z and ZDR for each image. The matching of the two radar data is a critical step, depending on the position of the storm with respect to the radars.

The radar data are then remapped on a 1x1 km grid at all available elevations, and the classified volume is geo-located in the 3D space, assuming atmosphere standard conditions.

3 Case study

In the afternoon of 20 May 2003 a severe hailstorm with very large hail hit the area monitored by the two radars. This deep convection episode was monitored from about 16:00 to 22:00 UTC, when this evolving storm moved across the region between the two radars.

For this analysis the whole lat-lon grid domain is divided in 3x3 km regions, which are previously considered only if they are homogeneous for the type of the precipitation at the ground and then we consider the vertical profile of the hydrometeor distribution.

That is for each type of surface precipitation (namely, light, moderate and heavy rain, ice precipitation and so on) it is investigated how the above hydrometeors are distributed with the height, to try to detect the typical vertical particles profile for each kind of ground precipitation and how they evolve during the storm lifetime. This vertical profile analysis has been carried on by considering small areas, instead of single grid pixels, to try to remove possible no-rain pixel (e.g. clutter signal).

In order to follow the evolution of the storm it is possible to choose different approaches, selecting a fixed region to analyse the microphysical property of the event moving across it or following the event by considering a box with variable dimension and spatial location. For the analysis of this event we have used the fixed-box approach.

Fig. 1 displays the RHI hydrometeor classification through the storm for the composite of the GAT and SPC radar data, along the reference line connecting the two instruments, for different life stages of the storm, from the early stage of the convective cell (displayed in the top of Fig.1) to the dissipative stage (showed in the bottom of Fig. 1), where the event becomes quite stratiform.

The core of the storm moves towards the SPC radar and the mature stage (until 18:00 UTC) presents the typical concentric structure of a convective event. The presence of hail and rain-hail mixture are well detected in the core of the storm, with graupel around them. Ahead and behind the core there is rain (light, medium, heavy and large drops) close to the ground, and dry snow and ice crystals above the melting layer (where wet snow is correctly detected).

Fig. 2 shows the first elevation PPI of the hydrometeor classification at 17:19 UTC and the location of the selected box for the analysis. The storm moves towards the N-E crossing the area, that is interested by all the life stages of the storm: from the early, to the maturation and then to the decay stage.

The ground hydrometeors (in terms of 3 x3 homogeneous areas number detected for different kind of ground precipitation) from 15:49 to 21:49 UTC (see Fig. 3) shows that from 16:00 to 18:00 (the more active part of the event) heavy (only few areas), moderate and light rain areas, with ice particles too (mostly GSH), are present. Further just at the beginning of the convection it is possible to note the significant presence of the large drop class (LD).

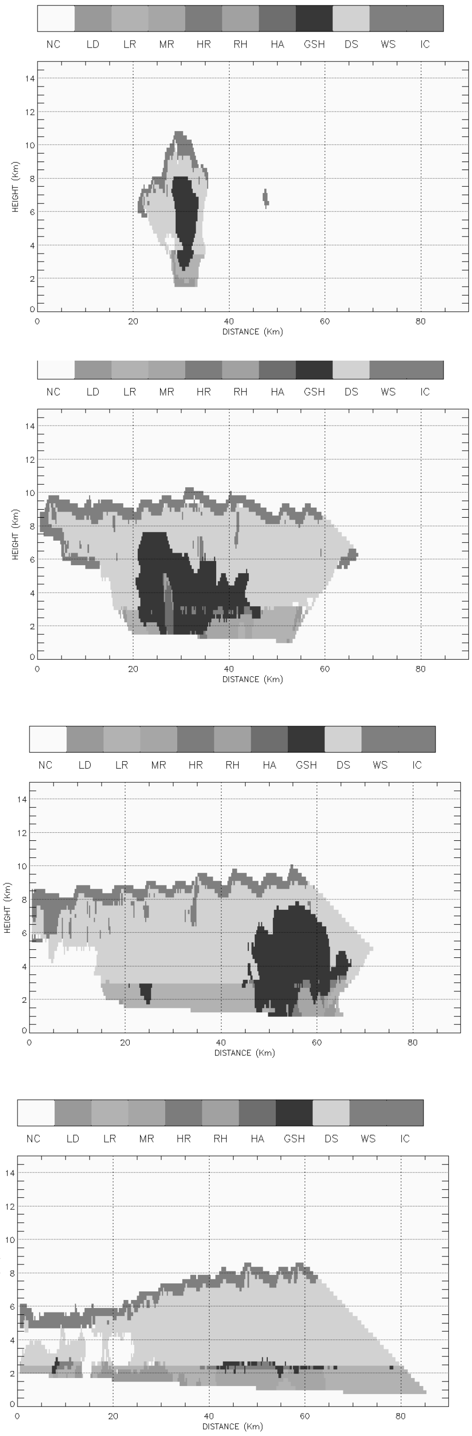

Fig.1. 20 May 2003; Composite RHI hydrometeors classification at (from the right to the bottom) 15:49, 17:04, 17:49 and 19:34 UTC.

From 18:00 UTC the more stratiform part of the event begins, with a greater number of areas of only liquid hydrometeors (wide region of medium and light rain) and no LD class is detected.

Fig. 4 displays, starting from the top to the bottom, the mean hydrometeor vertical profiles, respectively, for heavy (HR), moderate (MR) and light rain (LR) detected at the ground during the storm evolution.

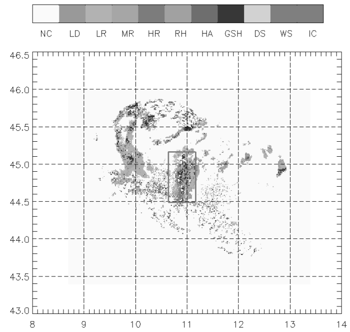

Fig. 2. 20 May 2003; First elevation PPI hydrometeor classification map.

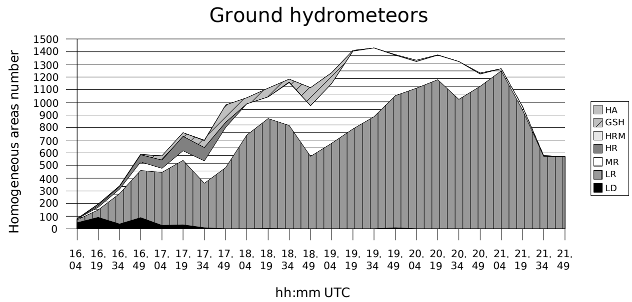

Fig. 3. 20 May 2003; Number of homogeneous areas for different ground hydrometeors from 16:04 to 21:49 UTC.

The HR profile indicates, above the heavy rain pixels, the presence of many graupels mostly around 2 km, whereas dry snow and a few ice crystals at higher altitude, with a peak at about 6 Km. In the LR profile very small graupel is detected over the LR cells, with a larger DS peak respect to the HR profile and this layer is thicker and particularly abundant when the convective activity is more intense. For the MR class, the profile shows an intermediate behaviour between the heavy and the light precipitation, with a graupel amount greater then for the LR case, but less then for the HR profile.

Each type of surface precipitation profiles, which belongs to every particular kind of surface hydrometeor, present very similar characteristics during the all storm evolution, confirming that it seems to be possible to identify a typical profile behaviour that it presents the same characteristics during the whole evolution period of the storm.

Further these “reference profile” are also identified analysing the evolution of other convective episodes (see Fig. 5 for LR and HR profiles for a multicell storm occurred on 4 May 2004).

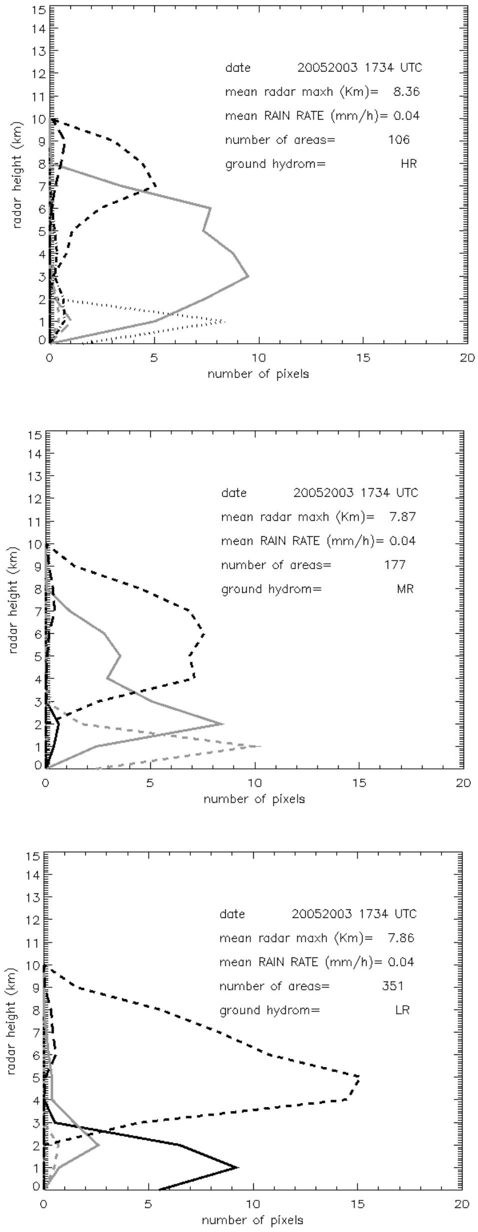

Fig. 4. 20 May 2003 17:34 UTC; Hydrometeor vertical profiles for HR (top), MR (middle) and LR (bottom) detected at the ground. In black: LR (solid line), HR (dotted line), HA (dash-dotted line), DS (dashed line), IC (long-dashed line). In grey: LD (dash-dotted line), MR (dashed line),HRM (long-dashed line), GSH (solid line), WS (dotted line).

4 Conclusions

Concernig the radar hydrometeor profiles, as general remark, they show a reliable sensitivity to the type of precipitation beneath, finding thicker ice layers over heavy precipitation and less ice water content over light and moderate rain. Moreover the graupel layer at intermediate levels is markedly thicker for the heavy rain than for the light rain.

The interesting peculiarity of the hydrometeor vertical profiles is that they presents different characteristics depending on the type of ground precipitation and that such behaviours are maintained during the evolution of the single event and also considering other convection episodes.

The future perspectives of this kind of analysis will deal with the comparison with hydrometeor profiles generated by LM to check their microphysical parametrization and with the future possibility to assimilate reliable latent heat at all tropospheric levels in Limited Area Models.

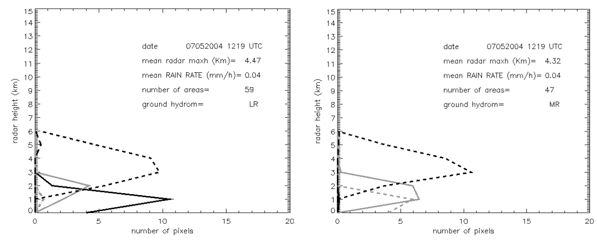

Fig. 5. 07 May 2004 12:19 UTC; Hydrometeor vertical profiles for LR (left) and MR (right) detected at the ground. Lines as in Fig. 4.

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