Nowcasting Using Dual-Polarization Radar In Southeast Brazil

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(Dated: 17 July 2014)

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1 Introduction

This study has objective to develop nowcasting tools from information collected by 9.375 GHz X-band Gematronik radar from CHUVA project. The CHUVA, meaning "rain" in Portuguese, is the acronym for the C*loud processes of tHe main precipitation systems in Brazil: A contribUtion to cloud resolVing modeling and to the GPM (GlobAl Precipitation Measurement)*. The fourth campaign took place in the Vale do Paraiba region between the Serra do Mar and Serra da Mantiqueira Mountain far 100 km from the ocean, with the radar situated in coordinates 23.2°S, 45.95°W. CHUVA's main scientific motivation is to contribute to the understanding of cloud processes, which represent one of the least understood components of the weather and climate (Machado et al., 2014). The *Forecast and Tracking the Evolution of Cloud Clusters* (ForTraCC, Vila, 2008) algorithm was used for tracking the convective cell for lagrangian time derivation, as well the evaluation of diverse nowcasting tools as polarimetric variables and vertical integrated parameters. The parameters are calculated for a hail event to obtain signatures of severity at the initial stage of the cell before it has an intense convective feature. Signatures are obtained by evaluating parameters in view of the potential predictability of severe short-term event in southeastern Brazil.

2 Methodology

2.1 Hail Event and Radar Data Processing

A hail-related storm event was selected for this study. Hail was reported at the ground at 17:12 UTC (15:12 local time) in Guarulhos, São Paulo state in november 29, 2011. The 3 km reflectivity Cappi of the storm is presented in Figure 1, where the storm is centered in the figure. The radar is located northeast of the cell.

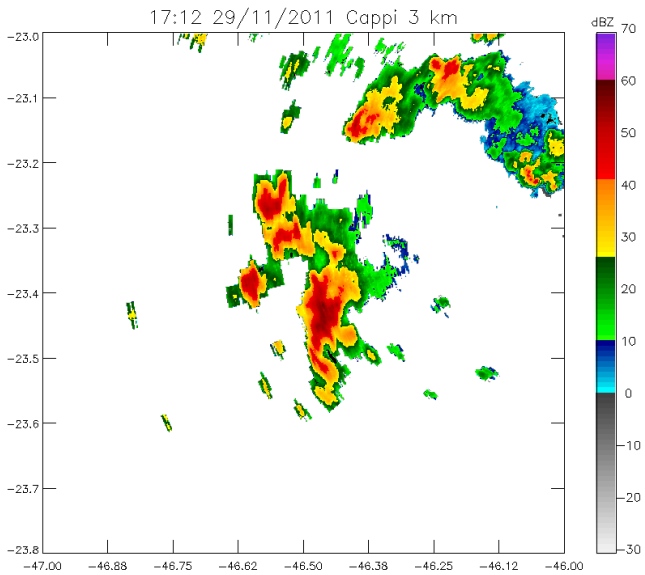

Figure 1: 3 km reflectivity Cappi of hail event with storm centered.

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Due to the radar high frequency attenuation, reflectivity and differential reflectivity data were corrected. ZPHI algorithm was used for attenuation correction of reflectivity (See details in Testud et al., 2000). Wet radome attenuation correction due precipitation over radar was also applied (Bechini et al., 2010). For differential reflectivity attenuation correction, linear Φ_{DP} technique was used (Bringi et al., 2007), as well as correction after vertical pointing presented in radar scan strategy (Sakuragi and Biscaro, 2012).

2.2 Cluster Tracking and Volumetric Calculations

For tracking and identification of clusters, ForTraCC-Radar algorithm (hereafter ForTraCC) was used (Queiroz, 2008) with 40 dBZ and 0,2 km^2 thresholds for 3 km Cappi data. This 2D-ForTraCC output was converted to 1 km x 1 km horizontal grid where, if a cluster pixel is present in a 1 km^2 area, this area is considered completely filled.

The radar data, originally in polar coordinates, were converted to 1 km x 1 km x 0.5 km volumetric grid, where the beam maximum dBZ, Z_{DR} and K_{DP} was obtained, as well as minimum values, mean, median, 10th and 90th percentiles, and Z_{DR} and K_{DP} values associated with maximum dbz beam. The horizontal 1 km^2 grid was compared with ForTraCC output for volumetric calculations. Vertically, the data were filled linearly in a case of volume without beams.

Predictor parameters were choosed, using K_{DP} and Z_{DR} polarimetric variables, as well as reflectivity. K_{DP} greater than 1°/km and Z_{DR} greater than 1 dB in different layers below -15°C isotherm was chosen for verify high precipitation rates in low levels and presence of supercooled water in mixed-phase layer. K_{DP} less than 0°/km and Z_{DR} less than 0 dB above 0°C isotherm was obtained in order to verify freeze hydrometeors in mixed-phase layer and above. Different high values of reflectivity above 0°C isotherm was obtained for verify system severity and presence of hail.

3 Results

Figure 2 shows the variation of volume of K_{DP} greater than 1°/km and Z_{DR} greater than 1 dB over entire volume for warmer temperature than -15°C. Hail time occurs at 0 in x-axis. The color represents: maximum (black), 90th percentile (light blue), beam with maximum dBZ (red), mean (yellow), median (green) and minimum (blue). As can be seen, an increase of supercooled water volume occurs 18 minutes before hail event. The increase of volume in this time step was 30.4 km^3/min. Woodard et al. (2012) also observed a Z_{DR} column feature in the mixed-phase layer before first lightning occurrence. Precipitation rate increasing can be seen minutes before hail.

The right panel of figure 2 shows volume of K_{DP} greater than 1°/km and Z_{DR} greater than 1 dB in melting layer over total volume of melting layer. It can be noticed a fall 6 minutes before hail event, indicating loss of supercooled water in this layer by freezing of hydrometeors.

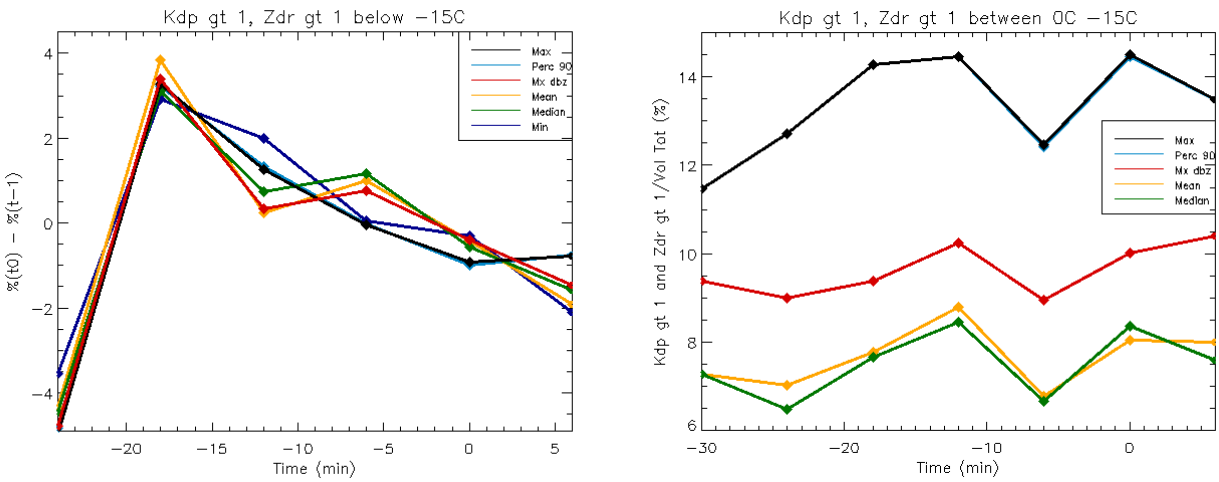

Figure 2: Left: variation of volume of specific differential phase greater than 1°/km and differential reflectivity greater than 1 dB below -15°C isotherm. Right: volume of specific differential phase greater than 1°/km and differential reflectivity greater than 1 dB in melting layer over total volume.

Figure 3 presents variation of volume with reflectivity greater than 45 dBZ above 0°C isotherm over the entire volume above 0°C. Eighteen minutes before hail event, it can be noticed an increase of volume of high reflectivity, indicating greater probability of hail in ice and mixed-phase layer. With a 12 minutes lead-time, minimum beam values of K_{DP} and Z_{DR} increase substantially in mixed-phase layer (Figure 3, right panel). This behavior indicates presence of freezing hydrometeors in this layer with a subsequently lower increase.

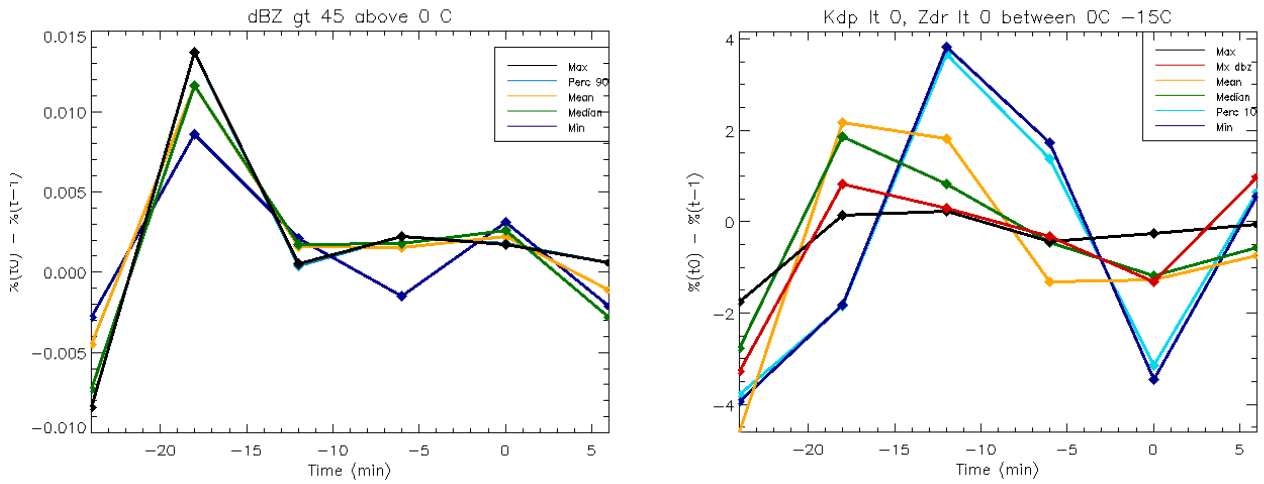

Figure 3: Left: variation of reflectivity greater than 45 above 0°C isotherm. Right: variation of specific differential phase and differential reflectivity less than 0 in melting layer.

4 Conclusion

This study presents important features observed before a typical convective event associated with hail. Initially, updrafts contributes to increase content of liquid water and supercooled water until in mixed-phase layer. An increase of high values of reflectivity above mixed-phase layer represents the beginning of maturation phase of storm life cycle. Six minutes after, ice content in mixed-phase layer increase considerably, representing freezing of liquid water, as well as the decrease of liquid content in this layer 6 minutes before hail in surface.

A substantial lead-time from 6 to 18 minutes is observed from different features by polarimetric radar. The understanding of micro-physical features and local convective characteristics are critical for short-term forecasting in vulnerable areas.

Acknowledgement

We would like to thank to CHUVA project supported by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) grant number 2009/15235-8. The first author was financed with a graduate fellowship from CNPq agency during the mater's degree in Meteorology at INPE.

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