EVALUATION OF TWO MICROPHYSICS SCHEMES IN THE AROME MODEL USING AN OBJECT- BASED APPROACH APPLIED ON DUAL-POLARISATION RADAR DATA

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INTRODUCTION

Thunderstorms are one of the most destructive weather phenomena due to the considerable damage they can cause. Despite significant progress made with numerical weather prediction models, forecasting thunderstorms remains challenging. **Dual-polarization radars**, which provide data at a fine temporal and spatial resolution, can highlight specific storm areas within storms [1]. Regions of enhanced differential reflectivity (Z_{DR}) above the environmental freezing level, are known as **Z_{DR} columns**. These columns are proxies of storm updrafts[2,3]. Recent studies have shown interest in Z_{DR} columns as a potential predictor of storm severity and as an aid for the warning decision process[4,5]. Simulations showed that such columns were associated with wet growth regime within the updraft[10].

The main goal of this work is to enhance storm forecasting. One possible way is to improve cloud representation. To do so, an algorithm to **detect and track Z_{DR} columns**, as well as convective core objects, has been implemented. This algorithm has been applied to both dual-polarisation French radar data and to forecasts issued by **AROME NWP**[12], coupled either with **ICE3**[13] **or LIMA**[14] **microphysics** schemes. Synthetic polarimetric fields are obtained thanks to the Augros et al. (2016)[16] radar forward operator. To (1) compare observed and modelled storms with their associated polarimetric signatures and (2) studied the influence of the microphysics on simulated polarimetric data, **a statistic evaluation has been performed on 34 convective days**. We first evaluated precipitations and reflectivities with a global approach (scores computation, distributions of maximum values, etc). Then, we investigated the characteristics of storms and their associated Z_{DR} columns in an object-based framework. The **results presented here are focused on the Z_{DR} columns.**

RADAR DATA

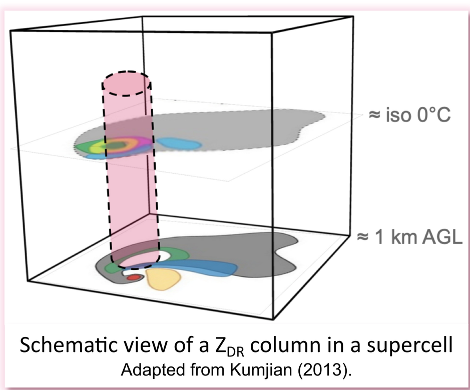
Advantages of dual polarised radars :

- ✓ High spatial and temporal resolution data
- ✓ New vision of storms thanks to polarimetric signatures[1]
- ✓ Provide information on hydrometeor contents

About the French radar network :

- ✓ Complete coverage over France (mostly C bands)
- ✓ Full scan each 5 min, 250 m gates
- ✓ Integrated hydrometeor classification algorithm[6,7] (using a fuzzy logic)

Z_{DR} COLUMNS DETECTION AND TRACKING



Schematic view of a Z_{DR} column in a supercell
Adapted from Kumjian (2013).

➢ Z_{DR} column

- region of enhanced Z_{DR} above the iso 0°C
- proxy of storm's updrafts[2,3]
- linked to storms severity[4,5]

A wider column may result in more abundant hail production, but larger hailstones appear to be linked with a deeper and narrower column[10,11].

➢ Detection and tracking algorithm

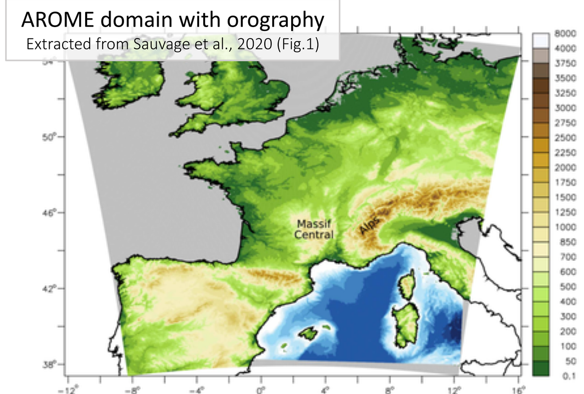
1. Z_{DR} column depth field computation
   - Thresholds (Z_H ≥ 25 dBZ and Z_{DR} ≥ 2 dB)
   - Continuity verification
2. Automated detection of features (storm cells and Z_{DR} columns) using *tobac*[8].
3. Features tracking : *tobac* relies on *Linkpy*[9] which is able to predict the object motion within a specified search radius.
4. Assignment of each column to its corresponding cell

SIMULATIONS

➢ AROME convective NWP

- non-hydrostatic and limited area
- 1.3 km horizontal resolution
- deep convection resolving
- 13 prognostic variables
- 90 vertical level

AROME domain with orography
Extracted from Sauvage et al., 2020 (Fig.1)



➢ About ICE3 microphysics

- 1 moment bulk scheme
- three-class ice parametrization (ice crystals, snow, graupel)
- warm phase (rain, cloud water) described by a Kessler scheme
- contents (r) are prognostics and number concentrations (N) diagnostics
- PSD : generalized gamma distribution
- implicit adjustment of r_{cloud} and r_{ice} within clouds (strict saturation criterion)

➢ Radar forward operator (Augros et al., 2016)[16]

- simulates dual-pol variables from model hydrometeor contents, T, P, etc
- mixed-phase representation (if coexistence of rain with graupel or hail)
- T-matrix scattering (oblate spheroids)

➢ About LIMA microphysics

- quasi 2 moments bulk scheme
- prognostic representation of aerosols
- number concentration for rain, ice crystals and cloud water are prognostic
- inherits most of the ICE3 characteristics but :
  - supersaturation over ice can evolve freely
  - ICE3 modified processes : evaporation, homogeneous freezing, etc
  - new processes : self collection of cloud droplets, raindrops breakup, etc

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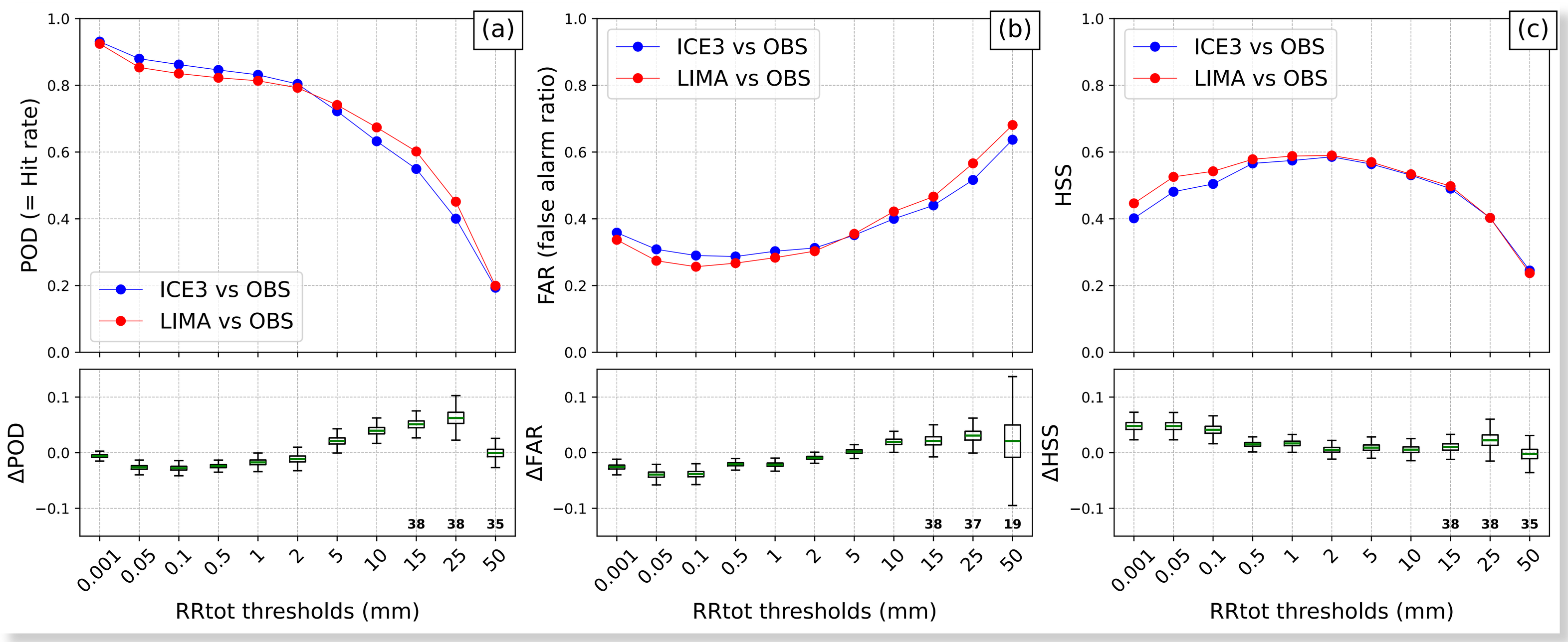
RESULTS

➢ **Fig.1** – POD **(a)**, FAR **(b)** and HSS **(c)** scores for precipitation accumulations (RRtot). Observations are compared to simulations with ICE3 (blue) or LIMA microphysics (red). Bootstraps on the RRtot differences between LIMA and ICE3 are shown below with boxplots.



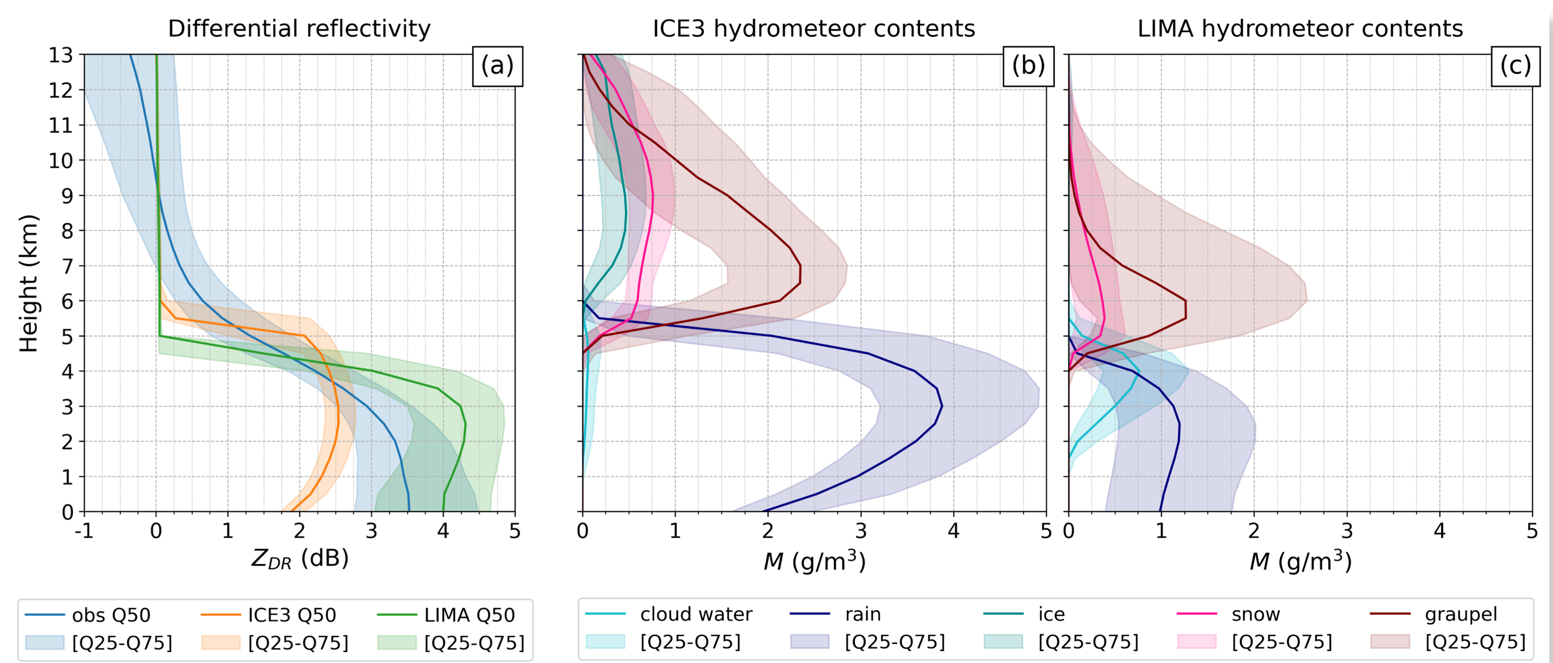
METHOD

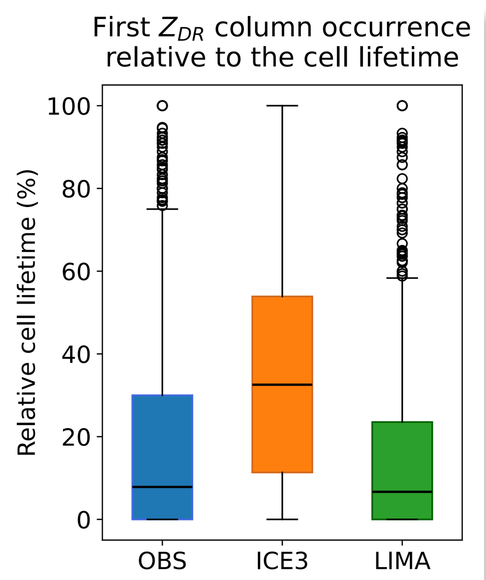
- ✓ ANTILOPE QPEs[15] are used as reference for RRtot obs data
- ✓ Division of French metropolitan domain into 50 x 50 km boxes
- ✓ Contingency tables : use of the Q99 value within each box
- ✓ Accumulated precipitations over each convective day

CLASSICAL MODEL EVALUATION : PRECIPITATIONS

OBJECT-BASED APPROACH : FOCUS ON Z_{DR} COLUMNS

➢ **Fig.2** – CFADs of Z_{DR} values **(a)**, and hydrometeor contents in forecasts with ICE3 **(b)** or LIMA **(c)** inside all detected Z_{DR} columns. Plain lines correspond the the median of the distribution. The 25th and 75th percentiles are displayed in lighter colours behind each curve.

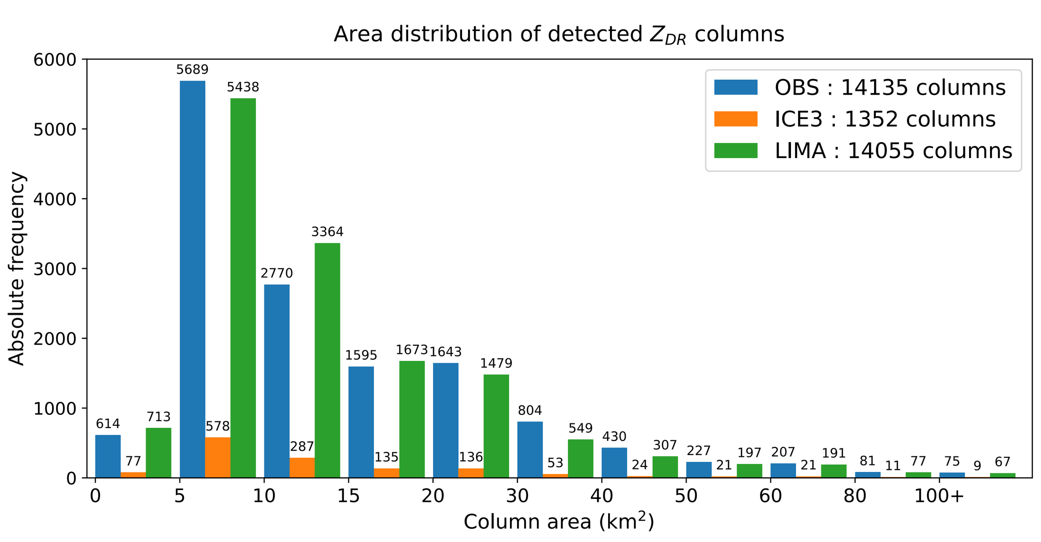




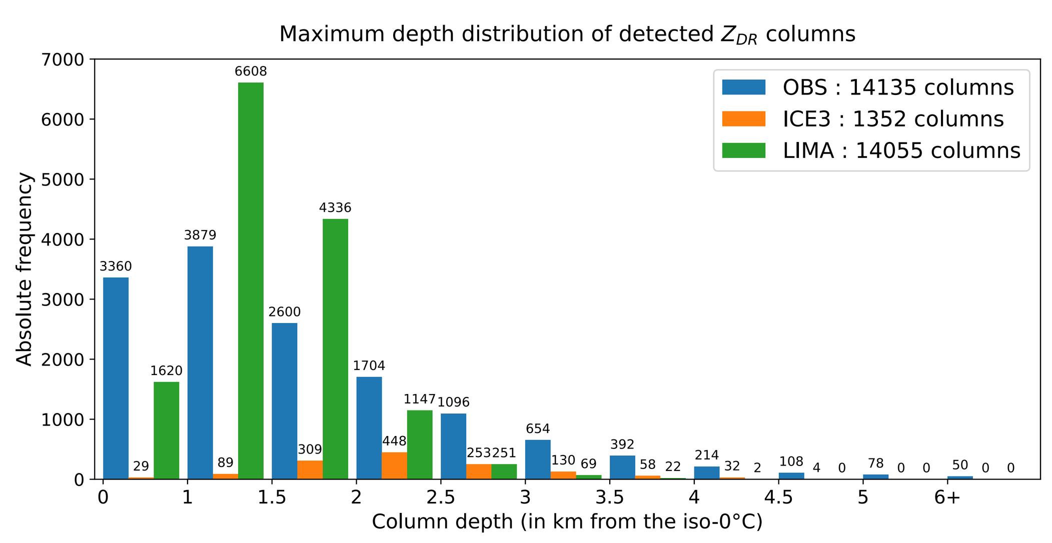
➢ **Table 1** – Comparisons of cells and Z_{DR} columns characteristics.

	OBS	ICE3	LIMA
Total number of convective cells	3177	1506	1776
Mean cell lifetime (min)	75'20''	83'45''	82'21''
Mean column lifetime (min)	18'33''	23'14''	19'50''
Proportion of cells with a Z_{DR} column	43.8 %	26.8 %	44.5 %

➢ **Fig.3** – First occurrence of the Z_{DR} column in relation to its belonging cell, expressed in terms of relative cell lifetime (0% meaning the birth of the convective core and 100% its death). Results are presented in boxplots for observations (blue), forecasts with ICE3 (orange) and with LIMA microphysics schemes (green). The bold line is the median and whiskers are the 5th and 95th percentiles.



➢ **Fig.4a** – Area distribution of detected Z_{DR} columns over all time steps, for observations (blue bars), and forecasts with ICE3 (orange) or LIMA microphysics (green).



➢ **Fig.4b** – Distribution of the maximum depth of detected Z_{DR} columns over all time steps, for observations (blue bars), and forecasts with ICE3 (orange) or LIMA scheme (green).

KEY POINTS

Dual polarisation observations have been compared to simulations with either ICE3 or LIMA microphysics schemes over 34 convective days. This poster is focused on the Z_{DR} column, a polarimetric signature which has raised interest in the scientific community. Complete results will be submitted soon in a paper. Key points about the contribution of LIMA to our results and more specifically Z_{DR} columns are summarized hereafter.

Z_{DR} columns

- Only ICE3 succeed to simulate high Z_{DR} columns (**Fig.4b**) as raindrops are lofted at higher altitudes compared to LIMA (**Fig.2b,c**)
- Z_{DR} values inside the columns (**Fig.2a**) hardly exceed 2 dB in rain with ICE3 → detected columns are only the strongest ones which can explain they are associated with powerful updrafts and thus higher Z_{DR} columns
- The width of the updrafts and the number of columns are particularly well simulated by LIMA (**Fig.4a**)
- The temporality of the column regarding the cell evolution is more realistic with forecasts relying on LIMA microphysics (**Fig.3**)

Other results

- no major improvement of precipitation scores with LIMA
- LIMA is better at simulating high Z_H, Z_{DR}, and K_{DP} under the environmental freezing level
- the model struggle to simulate small and/or short-lived convective structures regardless of the microphysics used