Comparison of Simulated Polarimetric Signatures Using ICE3 and LIMA Microphysics Scheme in Meso-NH

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Outline

★ Scientific Context

- Supercell Thunderstorms
- Dual-Polarization Radar Data
- Convective-Scale Models
- Dual-Polarization Signatures

★ Scientific Question

★ Methodology

- Idealized Supercell Simulations
- Radar Simulator

★ Results

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- Mid level Zdr ring
- Mid level ρHV ring
- Zdr arc

★ Conclusions

★ Perspectives

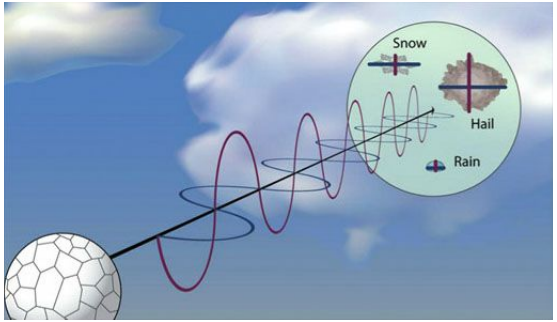
Scientific Context

★ Supercell-thunderstorms

- Visible dual-polarization radar signatures

★ Dual-Polarization Radar Data

- New standard for operational weather radars (S / C / X)
- Emit 2 electromagnetic waves simultaneously:
  - horizontal / vertical
- More information about microphysics:
  - Zh: concentration, size
  - Zdr: shape;
  - Kdp: concentration, shape
  - ρHV: homogeneity



Dual-polarization radar principle (source: NOAA)

★ Convective-Scale Models

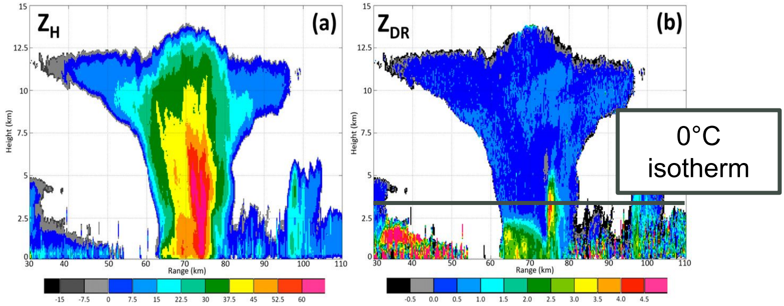
- New generation of Operational Numerical Weather Prediction Models
- Kilometer-scale horizontal resolution
- Detailed microphysics schemes
  - One moment: predicts the total mass concentration
  - Two-moment: includes the prediction of total number concentration
- Improved representation of atmospheric processes

Scientific Context

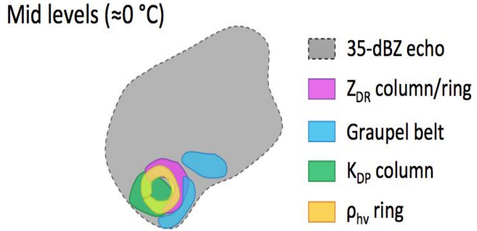
★ Dual-polarization signatures

○ Zdr column

- enhanced Zdr above the environment 0°C level
- represent the growth of large raindrops above the environment 0°C level (Kumjian et al. 2014)



Vertical cross sections of Zh and Zdr showing an example of Zdr column. Kumjian et al (2014).



Schematic of polarimetric signatures in supercells at low and middle levels. Source: Adapted from Kumjian (2013)

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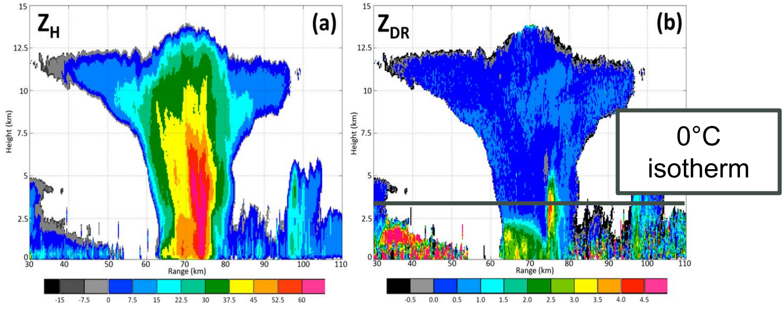

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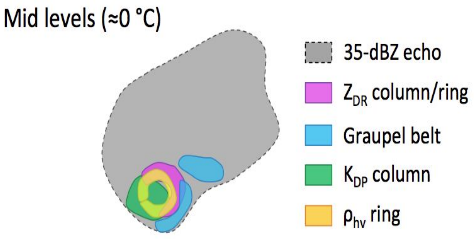

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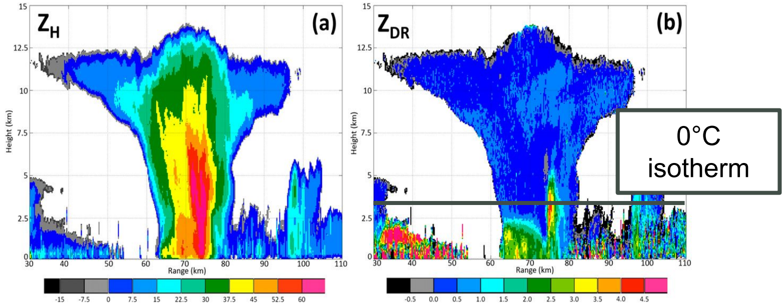
○ Mid level Zdr and ρHV ring

- enhanced Zdr and depressed ρHV
- visible in mid levels near the updraft



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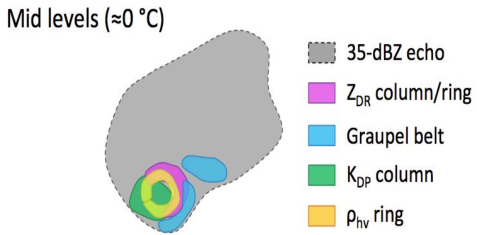

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○ Mid level Zdr and ρHV ring

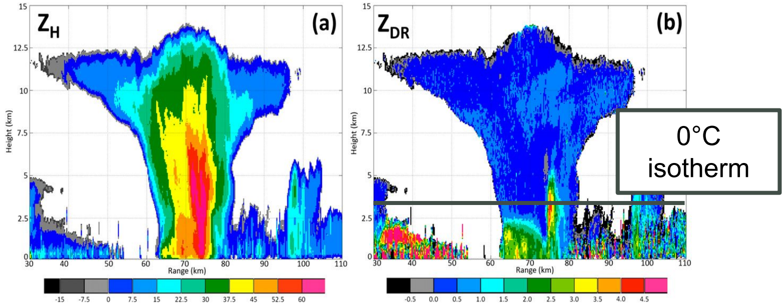
- enhanced Zdr and depressed ρHV
- visible in mid levels near the updraft

○ Zdr arc

- enhanced Zdr near the surface
- due to size sorting of rimed-ice and raindrops (high Zdr) and strong wind shear (Kumjian 2013)

○ Kdp foot

- enhanced Kdp near the surface
- possibly due to melting hail (Johnson et al. 2016)



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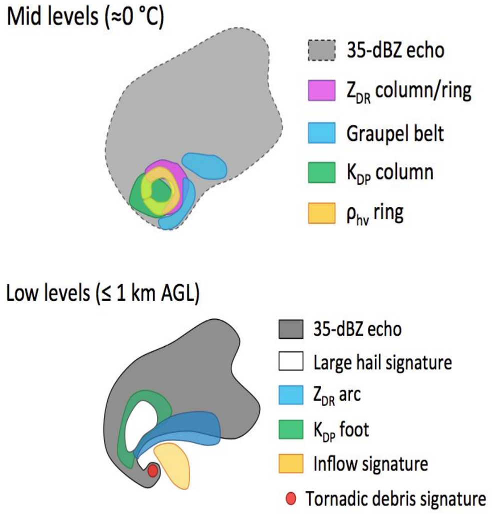


Schematic of polarimetric signatures in supercells at low and middle levels.
Source: Adapted from Kumjian (2013)

Scientific question

Are the latest numerical models and their microphysical schemes able to reproduce dual-polarization signatures observed in thunderstorms?

Methodology

Use of an ideal supercell simulation to evaluate the model's ability to represent dual-polarization radar signatures

★ Idealized Supercell Simulation

- Meso-NH model (Lac et al 2018)
  - **ICE3** (Pinty and Jabouille, 1998)
    1 moment microphysics scheme (mass mixing ratio)
  - **LIMA** (Vie et al. 2016)
    Quasi 2 moment microphysics scheme (mass mixing ratio and total number concentration)
- Convection initiation (Verrelle et al. 2015): Weisman and Klemp (1982) with thermal perturbation bubble of +2K
- Horizontal resolution of 500m
- 62 vertical levels
- S band

	ICE3	LIMA
Cloud droplets	r	r, Nt
Raindrops	r	r, Nt
Pristine ice cristals	r	r, Nt
Snow	r	r
Graupel	r	r
Hail	Na	Na

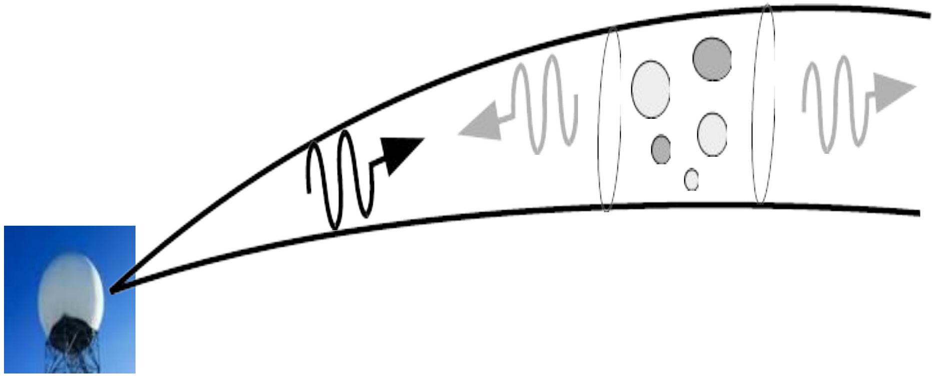
Methodology

★ Radar simulator

- Augros et al. (2016)
- Validated in real cases
- Scattering: T-matrix for oblate spheroids
- Melting model for graupel (Jung et al 2008)
    - for T > 0°C only
    - dielectric function varies with water fraction:

$$Fw = \frac{Mr}{(Mr+Mg)}$$

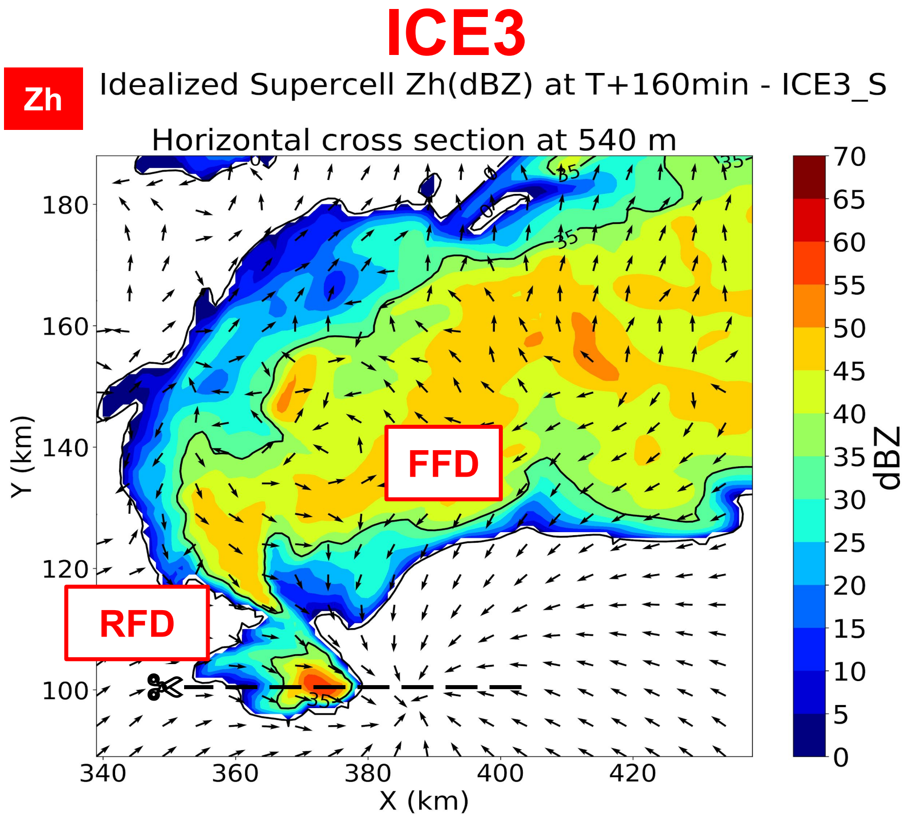
- Hydrometeor axis ratios:
    - Rain: Brandes et al (2002)
    - Pristine Ice: sphere
    - Dry snow: 0.75 for D≥8mm (1 → 0.75 linearly for D<8mm)
    - Dry graupel: 0.85 for D≥10mm (1 → 0.85 linearly for D<10mm)
    - Wet graupel: combination between rain and graupel axis ratios

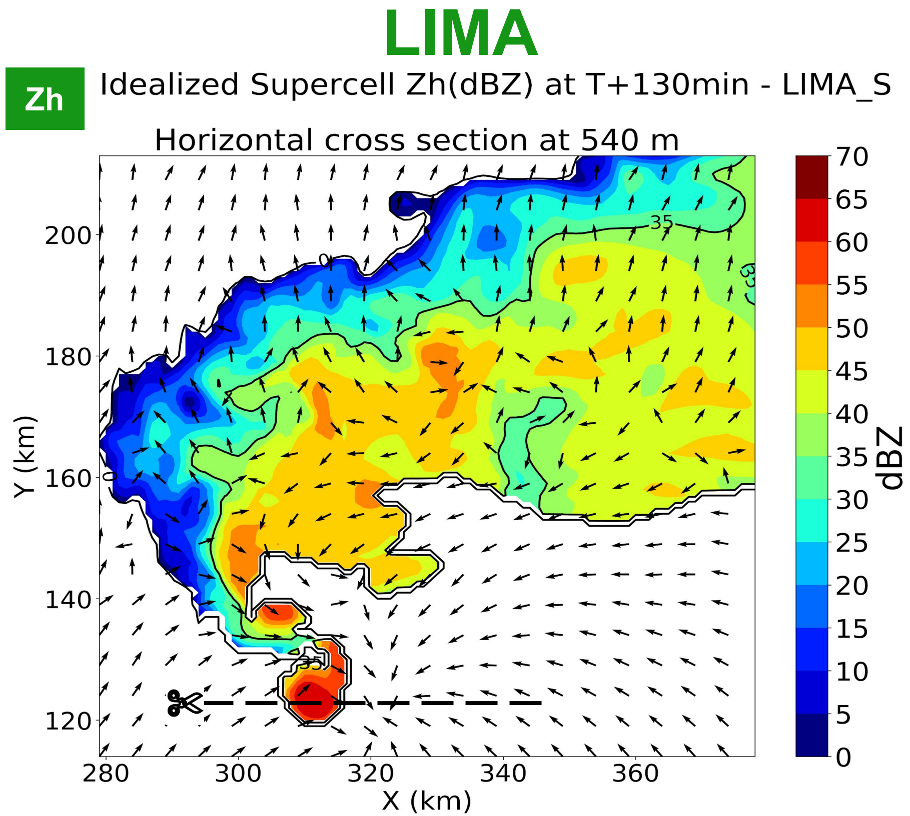


Mr, Ms, Mg, Mi, T, P ⇨ **Scattering** spheroids : T-matrix S, C or X band ⇨ Zh, Zdr, Kdp, ρHV

Scheme of the radar forward operator. Adapted from Augros et al (2016)

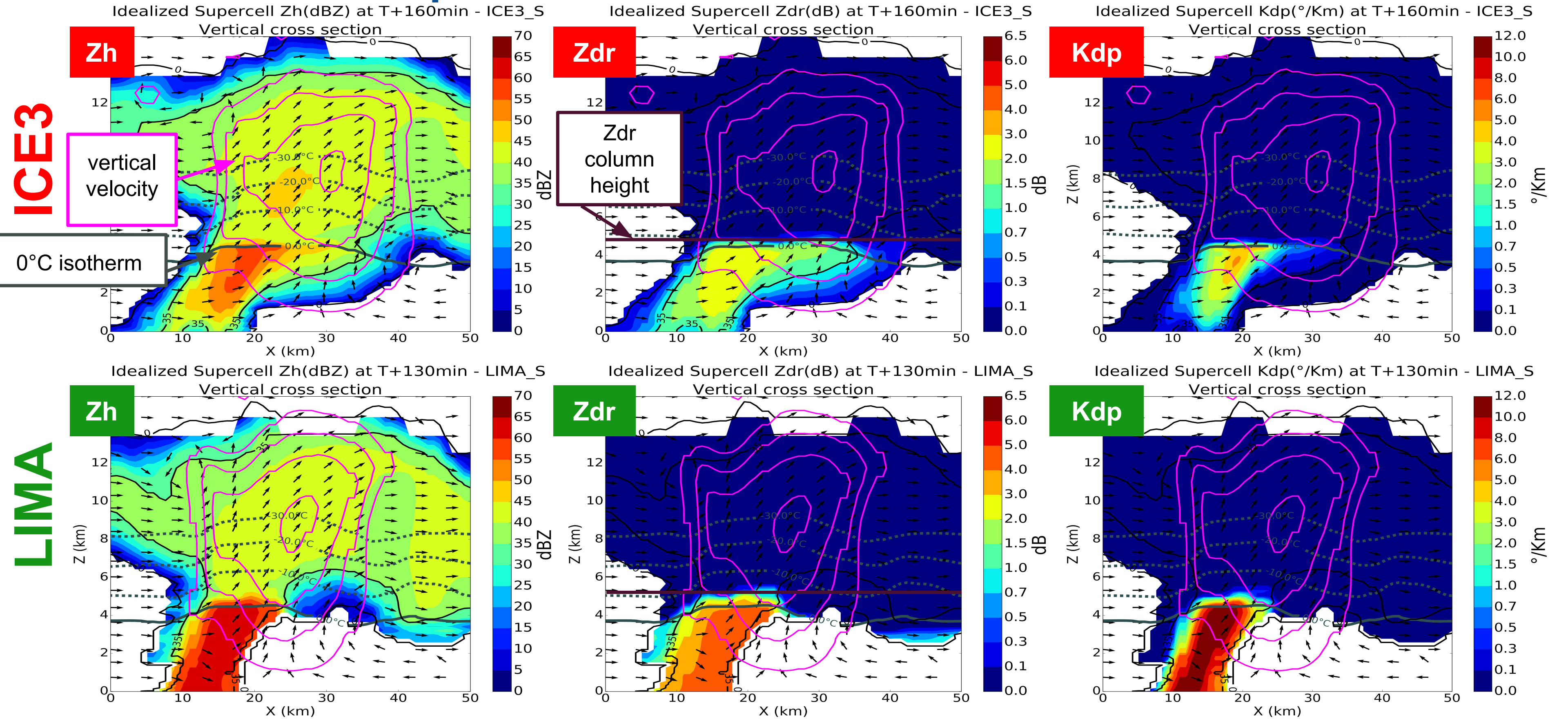
Results: Zh





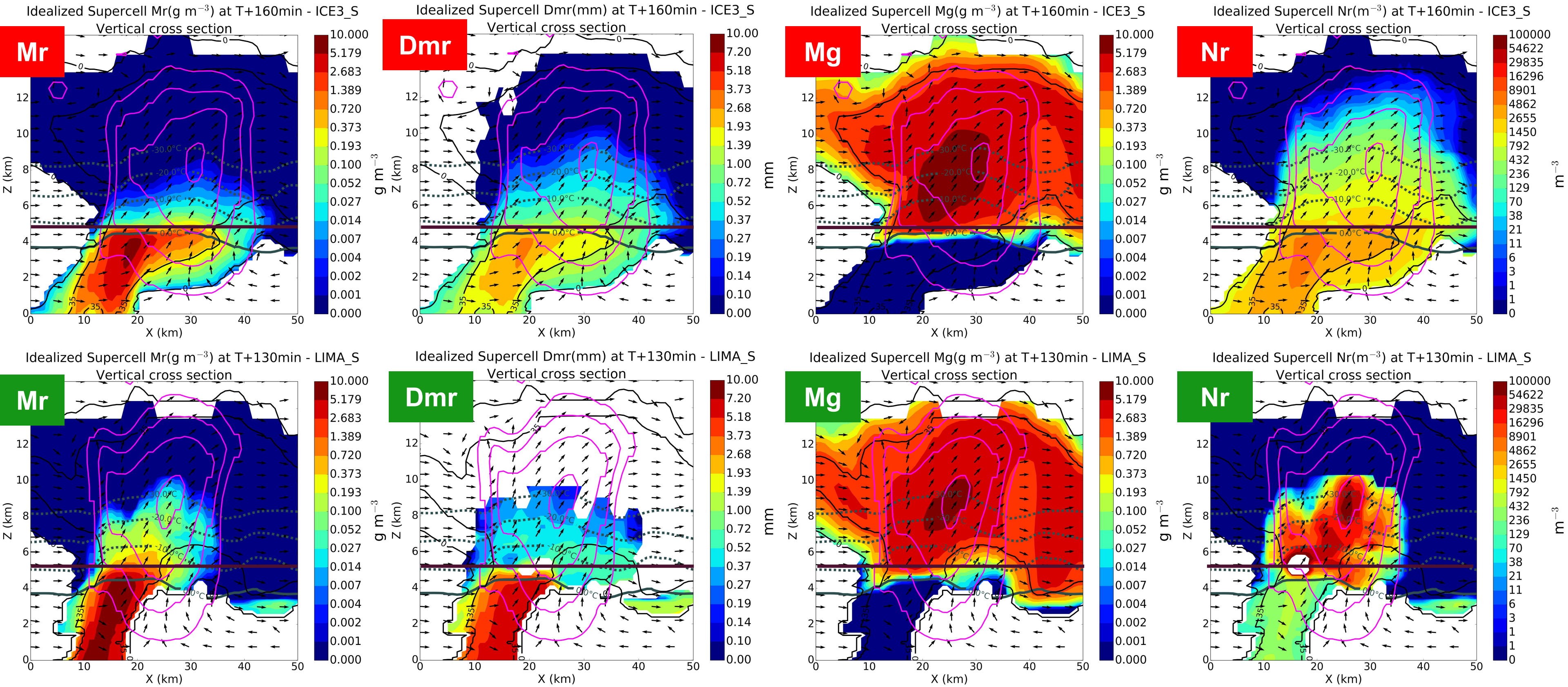
- ★ Both simulations were able to reproduce the supercell
- ★ Similar systems and timing in both simulations
- ★ LIMA presented higher values of horizontal reflectivity

Results: Zdr and Kdp column



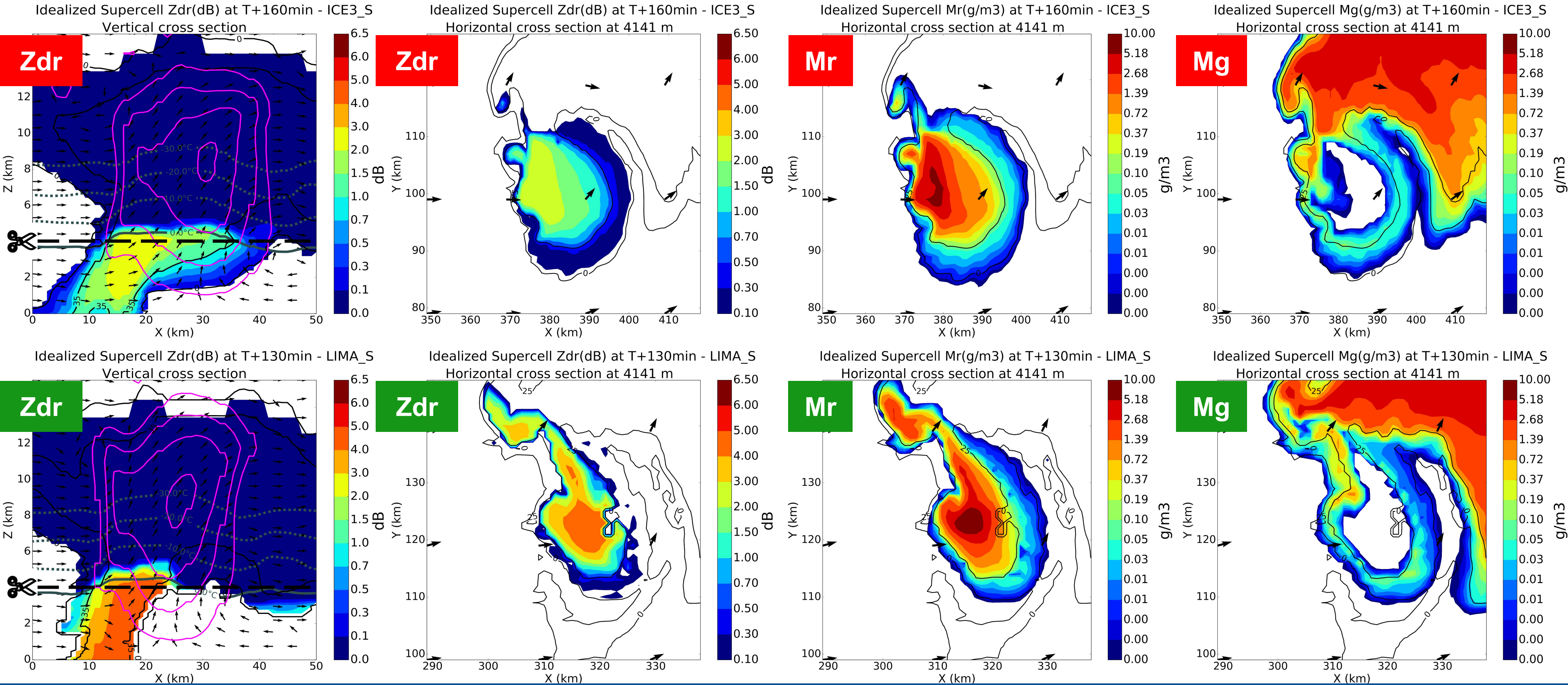
- ★ Both ICE3 and LIMA were able to reproduce the Zdr and Kdp columns
- ★ More realistic values for Zdr in LIMA but too large for Kdp

Results: Zdr and Kdp column



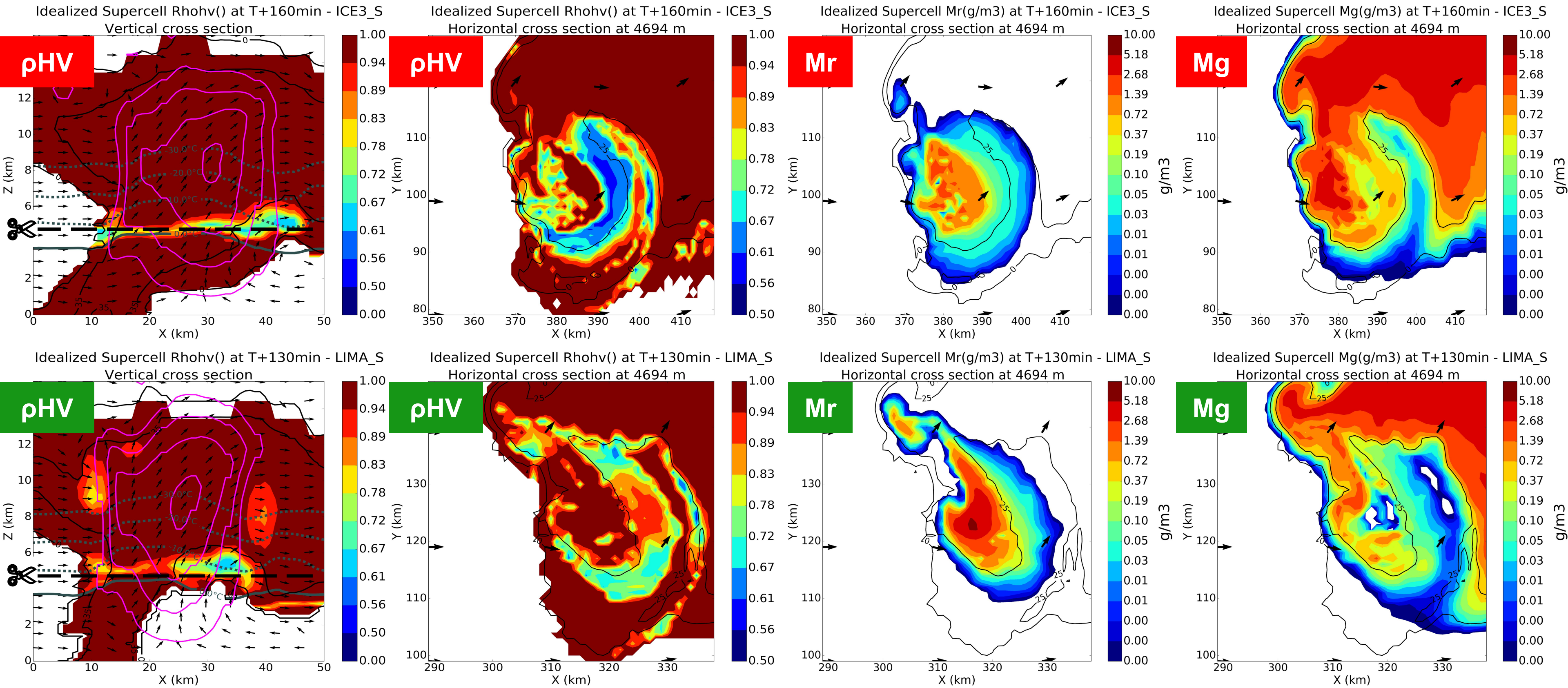
- ★ Higher Zdr and Kdp in LIMA due to higher rain content (Mr) and lower number concentration (Nr)
- ★ Liquid water content above melting layer

Results: Mid level Zdr ring



- ★ Zdr ring not correctly simulated in ICE3 or LIMA
- ★ But ring visible in graupel content (Mg): poor representation of scattering by melting graupel?
- ★ Strong Zdr in the middle due to large and oblate raindrops (instead of spherical hailstones)

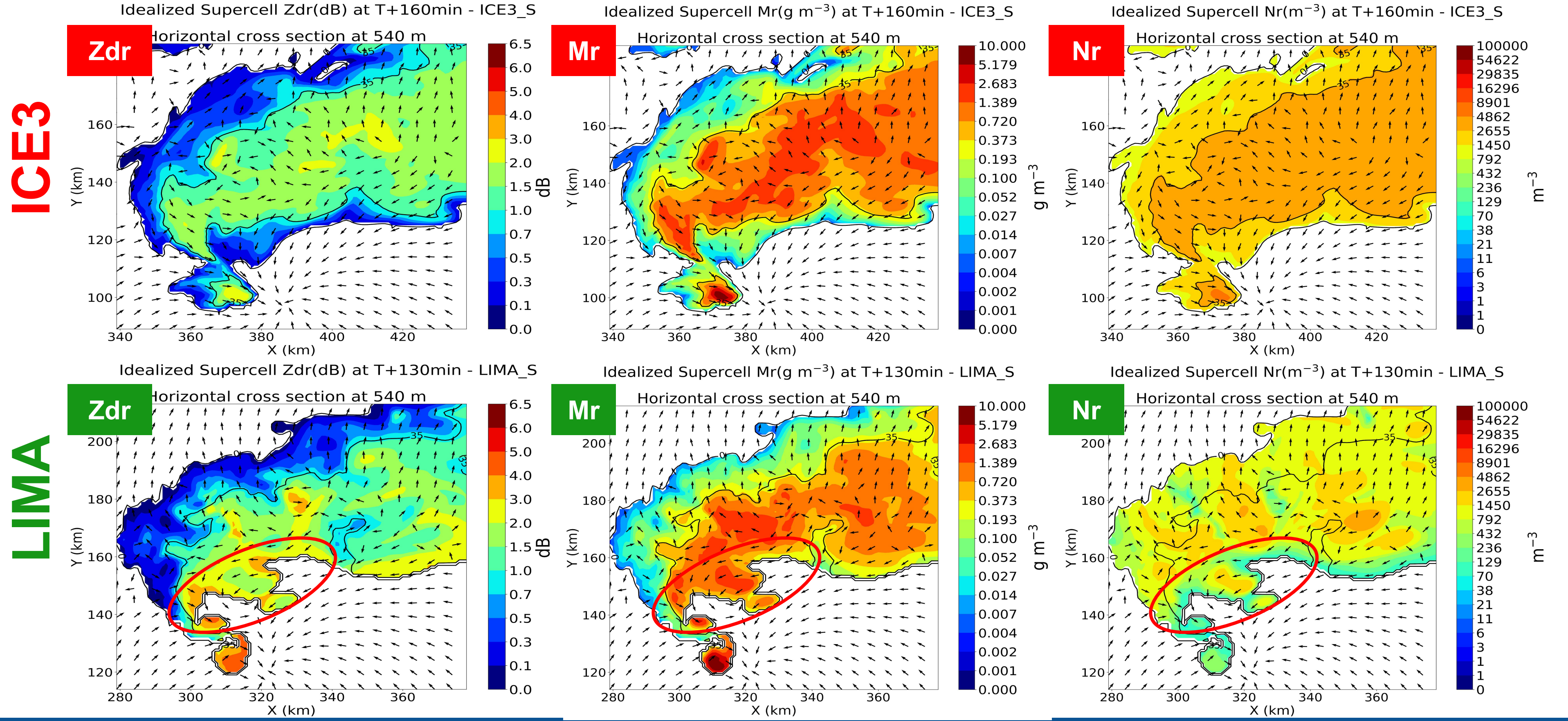
Results: Mid level ρHV ring



- ★ Visible in both ICE3 and LIMA
- ★ Signature is more marked in ICE3 than LIMA

Mr ~ Mg ⇒ ↘ ρHV
Mr >> Mg ⇒ ↗ ρHV

Results: Zdr arc



- ★ LIMA presented a well defined Zdr arc
- ★ Due to lower Nr and larger Mr in the southern part of the FFD

Conclusions

Zdr and Kdp columns

★ Both microphysics schemes are able to reproduce Zdr and Kdp columns
★ Higher Zdr and Kdp in LIMA due to higher rain content (Mr) and lower number concentration (Nr) below 0°C isotherm

Mid level Zdr ring

★ Zdr ring not correctly simulated in ICE3 or LIMA
★ But ring visible in graupel content
★ Strong Zdr in the middle due to large and oblate raindrops (instead of spherical hailstones)

Mid level ρHV ring

★ ρHV ring visible in both ICE3 and LIMA
★ Weak ρHV values above the 0°C isotherm (>0.6 for ICE3, >0.7 for LIMA) indicating a mixture of precipitation

Zdr arc

★ LIMA presented a well defined Zdr arc
★ Due to lower Nr and larger Mr in the southern part of the FFD

Perspectives

- ★ Investigate the sensitivity to the wavelength (S, C and X)

- ★ Modify the parametrization of melting graupel in the radar simulator to better represent the vertical extension of the Zdr and Kdp columns

- ★ Re-do the simulations with:
  - A better DSD representation in LIMA (Taufour et al 2018) → reduction of largest raindrops
  - More vertical levels (90 levels) → improve melting layer representation
  - Add hail → investigate Zdr ring and Kdp foot

- ★ Study real cases


Thank you for your attention
Any questions?
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Image: basehunterschasing