Evaluation of the 2 moment microphysical scheme LIMA based on HyMeX observations

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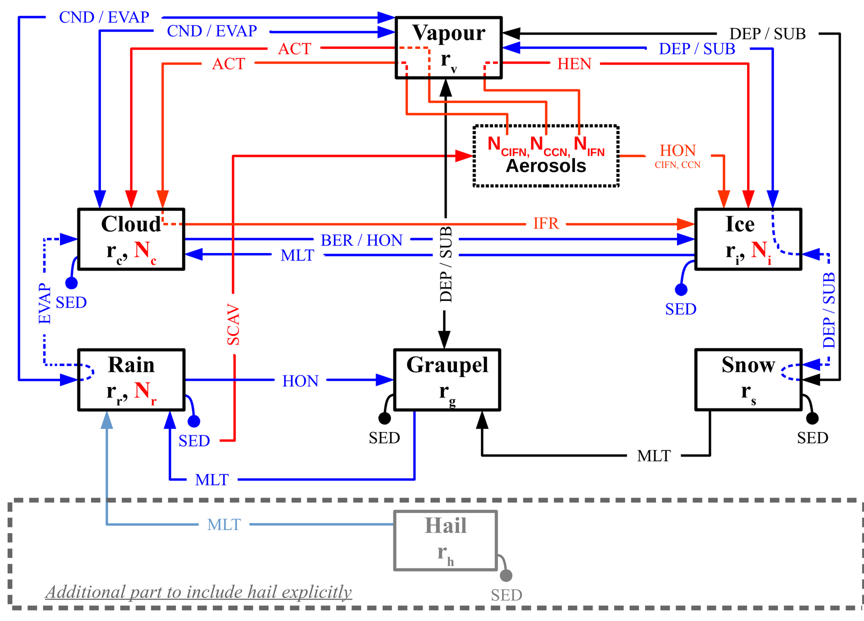
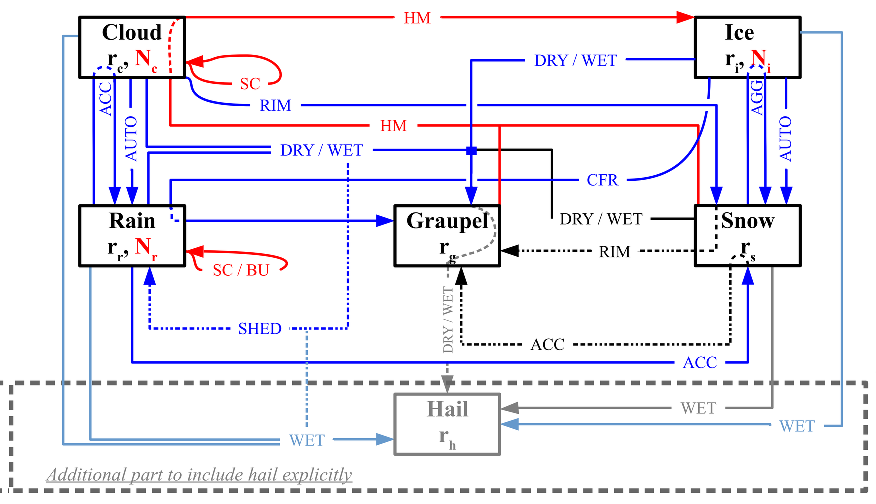
INTRODUCTION

The new **LIMA (Liquid Ice Multiple Aerosols)** microphysical scheme *(Vié et al. 2016)* predicts six water species (water vapor, cloud water, rainwater, primary ice crystals, snow aggregates, and graupel). LIMA uses a two-moment parameterization for three hydrometeor species (ice crystals, cloud droplets, and raindrops *(Cohard et al. 2000)*), and is derived from the one-moment scheme ICE3 used daily in the AROME cloud resolving operational model at Météo-France. In addition, it integrates a prognostic representation of the aerosol population. The Cloud Condensation Nuclei (CCN) activation is parametrized following *Cohard et al. (1998)* and was extended to handle competition between several CCN modes. Ice Freezing Nuclei (IFN) nucleation is parametrized according to *Phillips et al. (2008)*.

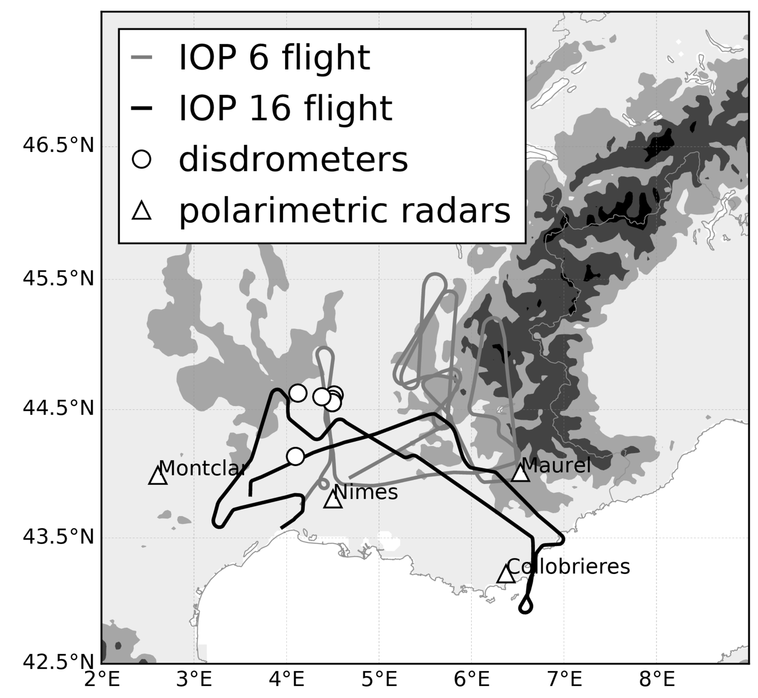




Diagrams of the microphysical processes of ICE3 and LIMA: (left) All the processes except collection; (right) Collection processes. Blue arrows represent existing processes in ICE3 modified in LIMA, red arrows are new processes in LIMA, and black arrows are identical processes in ICE3 and LIMA. When hail is a full sixth category, processes are in muted colours. Prognostic variables are written in the boxes: mixing ratio (r) and concentration (N). (Lac et al. 2018)

METHODS

The French anelastic research model Meso-NH (Mesoscale Non-Hydrostatic, Lac et al. 2018) is used to simulate two well-documented Heavy Precipitation Events from the HyMeX campaign. **The simulations are compared to a large variety of IOP 6 and 16a observations** (rain gauges, disdrometers, in-situ airborne measurements and dual-polarisation radars).

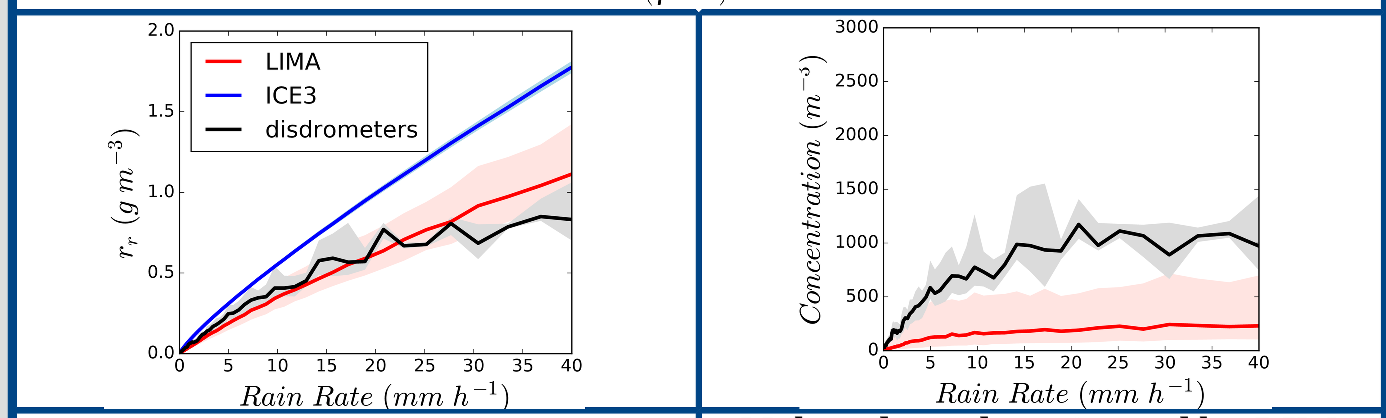


➔CCN concentration: constant between 0 and 1000m and above 1000m: concentration decreases to 0.01 cm^{-3} exponentially up to 10,000m.
➔IFN concentration: homogeneous.

ONE-MOMENT VERSUS TWO-MOMENT PARAMETERIZATION

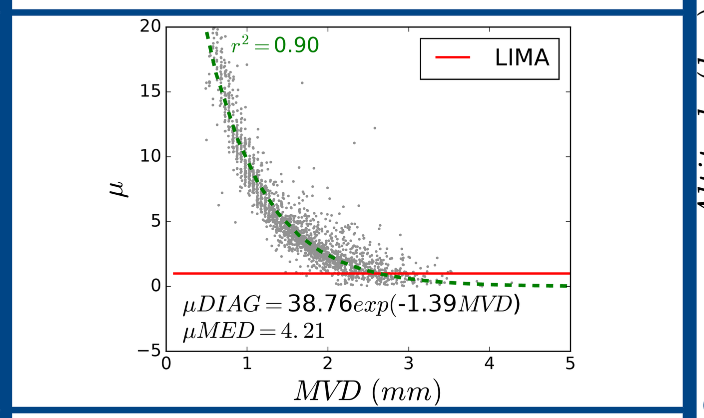
Rain mixing ratio (r_r) and number concentration (N_r) medians (lines) and interquartile ranges (shaded contours) as a function of rain rate simulated or derived from the observed rain drop size distribution:

$$n(D)\,dD = N\frac{\lambda^{\mu+1}}{\Gamma(\mu+1)}D^{\mu}\exp(-\lambda D)\,dD$$



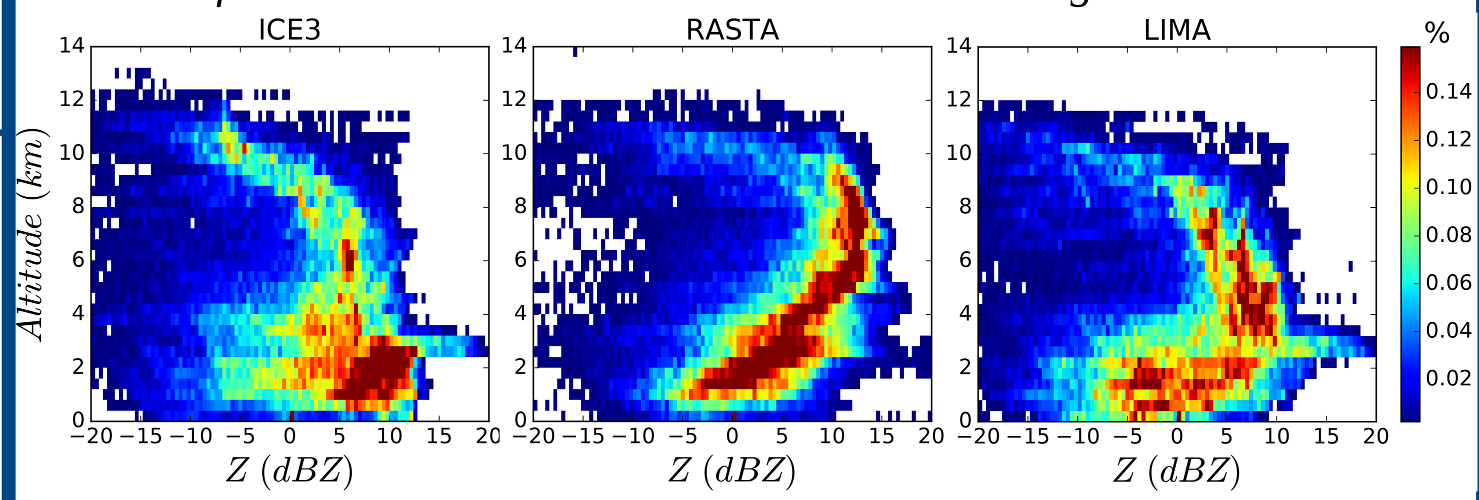
- r_r better estimated by LIMA than it is by ICE3
- N_r largely underestimated by LIMA → overestimation of the rain drops mean volume diameter
- microphysical variability (interquartile range) predicted by LIMA

Two months disdrometer measurement period scatter plot of μ parameter vs Mean Volume Diameter (MVD)



- median value (μMED=4.21)
- correlation between μ and D_m (μDIAG) (green dashed line)

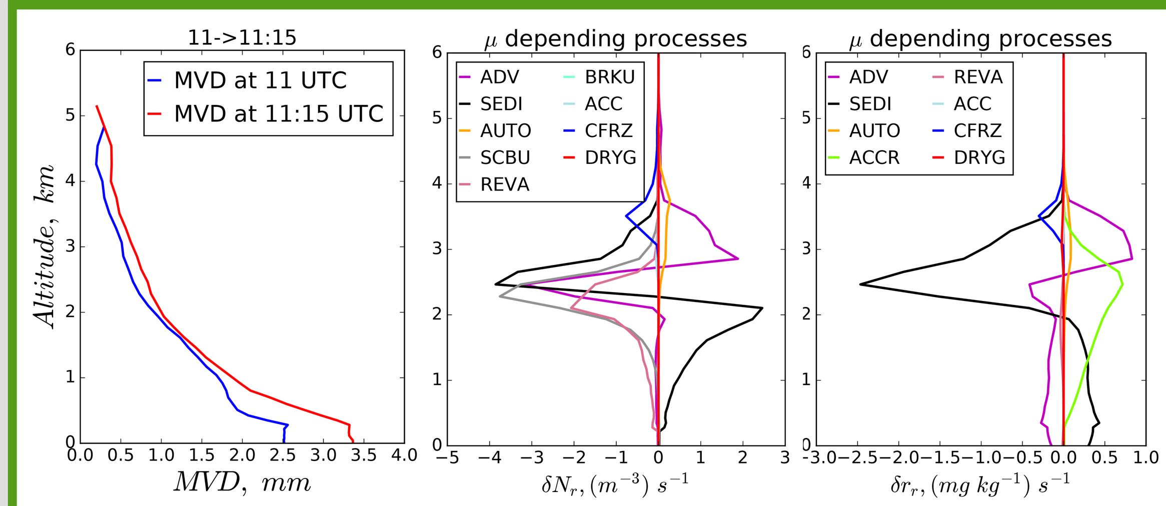
Contoured Frequency by Altitude Diagrams with airborne RASTA radar reflectivities measured and simulated combining both IOPs.



- Cloud top (~ upper part of the highest frequencies): observed to be near 10 km as with the LIMA simulation and overestimated near 12 km by ICE3.
- Around 3 km above the ground : more continuous profile with the LIMA scheme → better transition between ice and liquid water.

More results are presented in *Taufour et al. (2018)*

SENSITIVITY TO SIZE DISTRIBUTION SHAPE



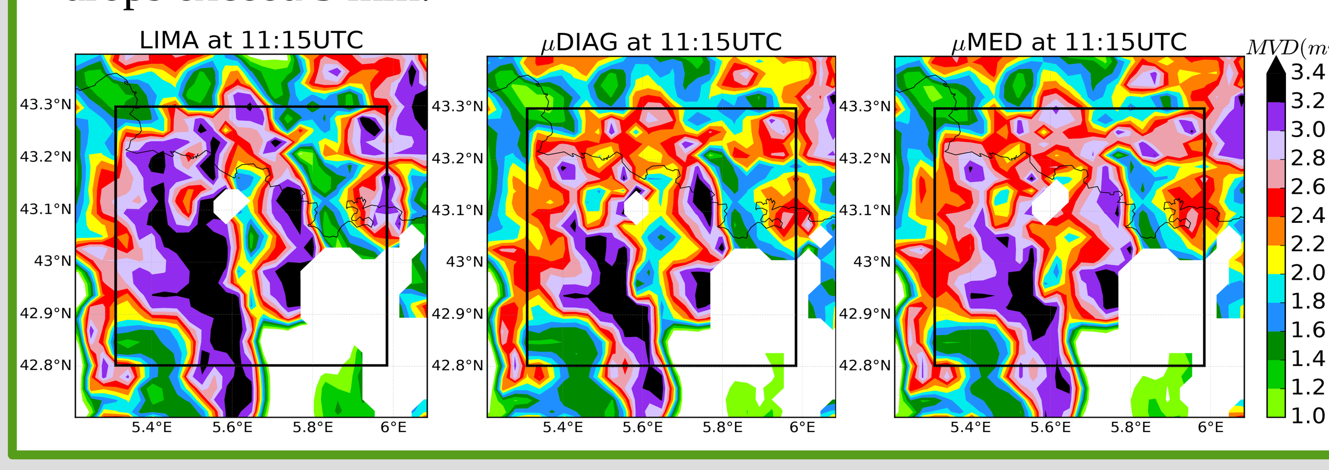
Rain drops MVD mean vertical profile (left), rain drops N_r (middle) and r_r (right) budget calculated over the box between 11 and 11:15 UTC.

15 minutes mean processes which lead to overpredict rain drops diameters:

- MVD profile increases in the mean
- Sedimentation (SEDI) process affect significantly r_r and N_r
- Rain evaporation (REVA) and Self-collection / break-up (SCBU) reduce N_r vertical profile
- Rain accretion (ACCR) increase r_r profile

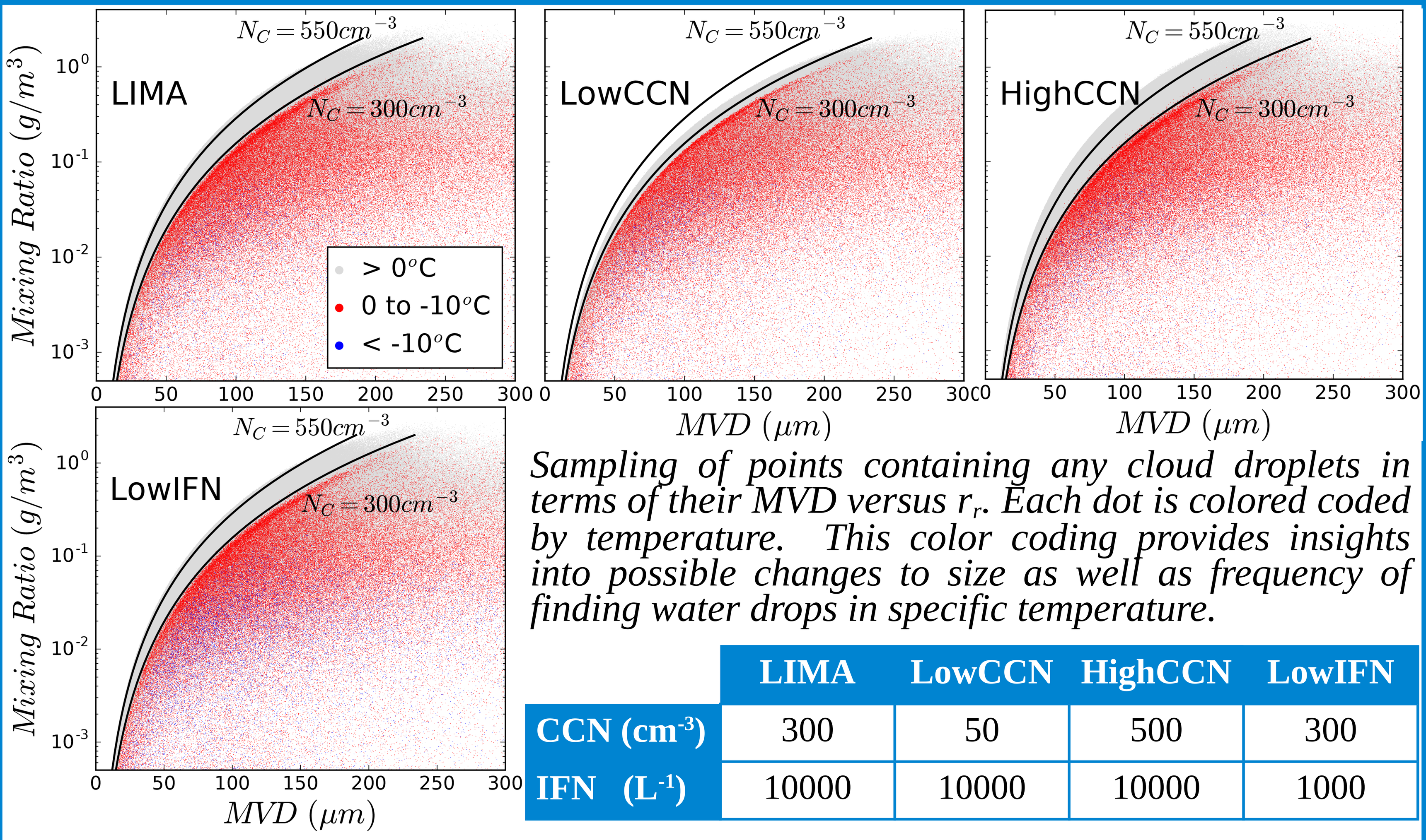
In the previous section, the rain drops size distribution μ parameter was identify as a possible driver of action on number concentration.

- Both new μ-parameterization lead to reduce the area where median diameters of rain drops exceed 3 mm:



Exemple of LIMA (μ=1) large MVD near the ground at 11:15 UTC (left). 15 minutes μMED (middle) and μDIAG (right) simulations using LIMA 11 UTC run as initial conditions

SENSITIVITY TO AEROSOLS LOADING



Sampling of points containing any cloud droplets in terms of their MVD versus r_c. Each dot is colored coded by temperature. This color coding provides insights into possible changes to size as well as frequency of finding water drops in specific temperature.

	LIMA	LowCCN	HighCCN	LowIFN
CCN (cm^{-3})	300	50	500	300
IFN (L^{-1})	10000	10000	10000	1000

- LIMA parameterization: nearly all points containing cloud water lie under the bound of cloud droplet concentration N_c=550 cm^{-3} and under the bound of N_c=300 cm^{-3} for negative temperatures.
- Cloud droplets distribution shifts to the right (resp. left) of the N_c=300 cm^{-3} line for higher (resp. lower) CCN concentration → **Increasing CCN concentration leads to more numerous, but smaller, droplets for a given liquid water content**.
- Reducing IFN concentration increase the frequency of cloud droplets at temperatures below -10°C.

CONCLUSION

2 moment vs 1 moment parameterization:

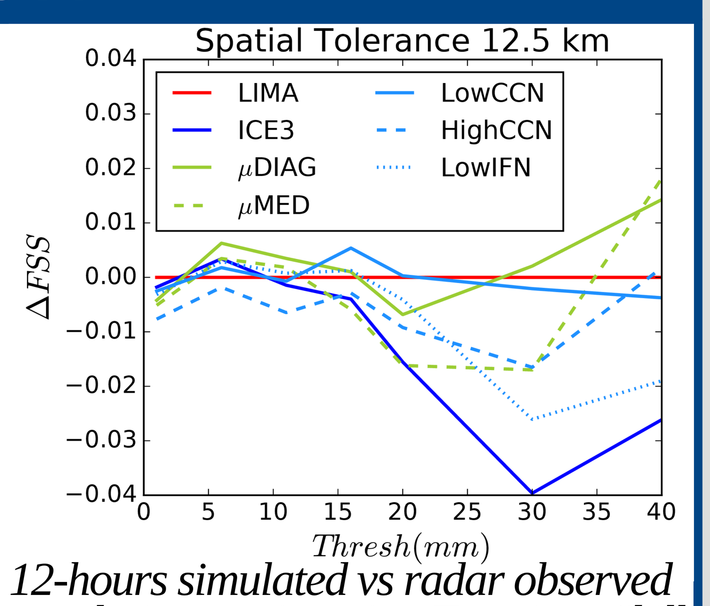
✔water content estimation
✔microphysical variability
✔convective system vertical structures
✗ rain number concentration overestimate → μ
✔cumulative precipitation > *15 mm h^{-1}*

Size distribution shape parameter μ:

➔*μ=1* → large MVD
➔reduction using other constant or diagnostic *μ*-parameter
➔diagnostic *μ*-parameter improve cumulative precipitation > *30 mm h^{-1}*

Aerosols loading:

➔CCN concentration → impact MVD
➔IFN concentration → frequency of water drops below *-10°C*



12-hours simulated vs radar observed cumulative precipitation Fractions Skill Score (FSS) against accumulation thresholds, using a neighborhood square of length 12.5 km. Lines represent the difference with LIMA simulation: positive values reflect an improvement.

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