Multifrequency radar retrievals of rain microphysics

Evaluation of the rain representation in the WRF Model

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2-parts paper accepted in MWR

Introduction

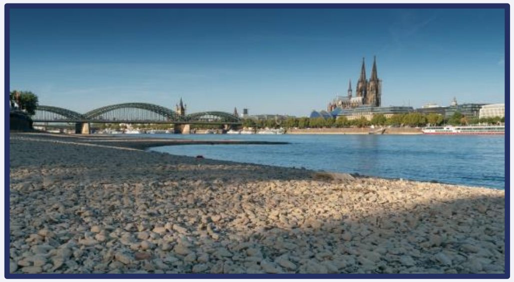
► Why study precipitation?

- forecast at regional scale (flood, drought,…)
- quantify its impact at the climate scale via the latent heat associated with condensation and evaporation

► Method?

- better represent the microphysics processes of precipitation: evaporation, breakup, self-collection…
- investigate the vertical profile of the Drop Size Distribution (DSD)

Paris - January 2018



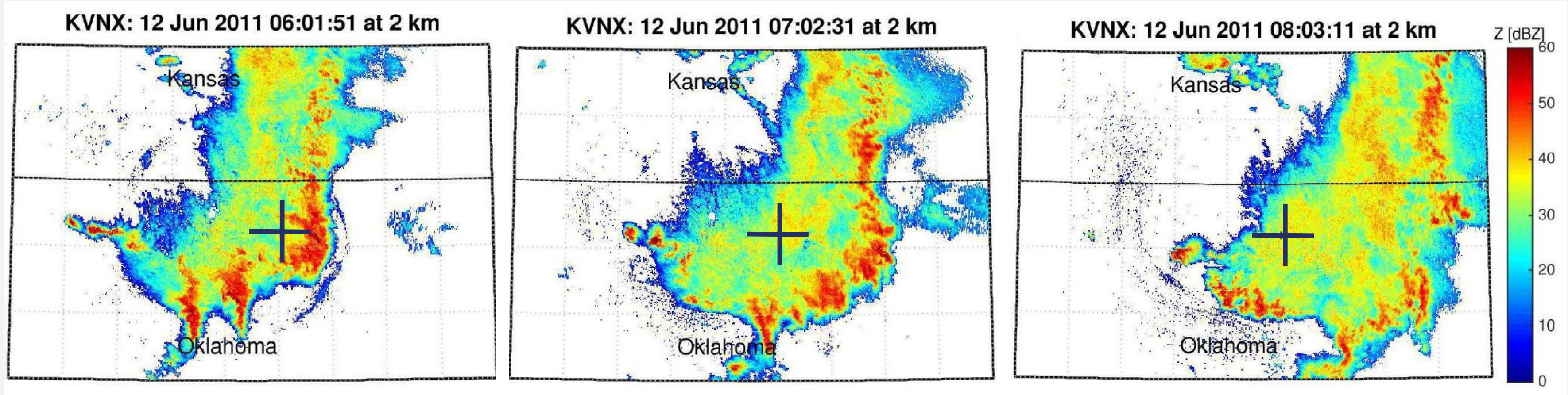
Cologne - November 2018

Artist's view of a Drop Size Distribution

Courtesy of NASA's Goddard Space Flight Center

► Objective: Evaluate the DSD representation in mesoscale models thanks to heavily instrumented observation site

Squall line case – 12 June 2011 (Oklahoma)



S-band
radar reflectivity
at the ARM SGP

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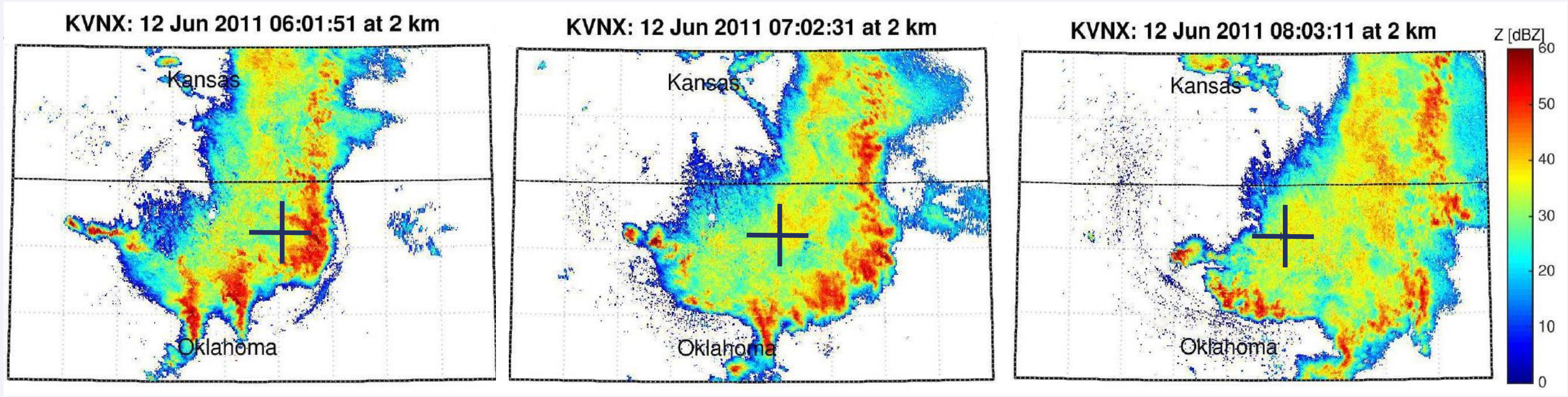
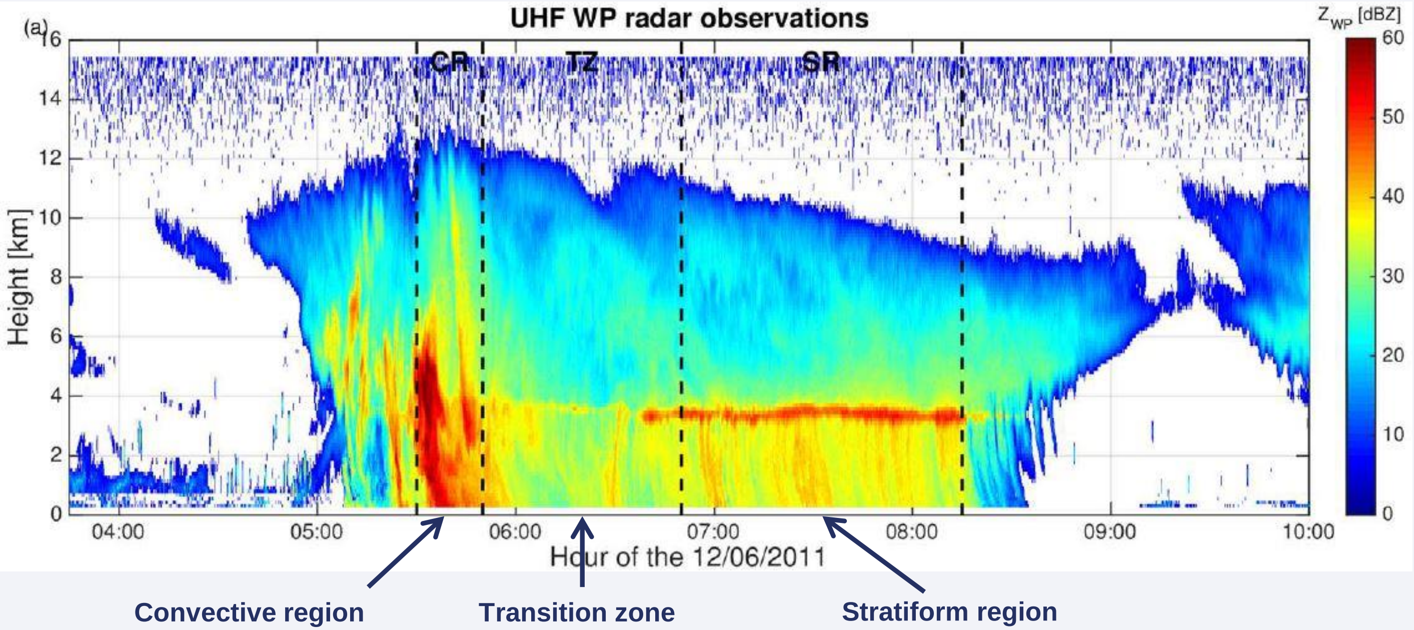


S-band and UHF radar reflectivity at the ARM SGP



K_a (35 GHz) and W-band (94 GHz) radar observations at ARM SGP site

Photo courtesy of S. Collis

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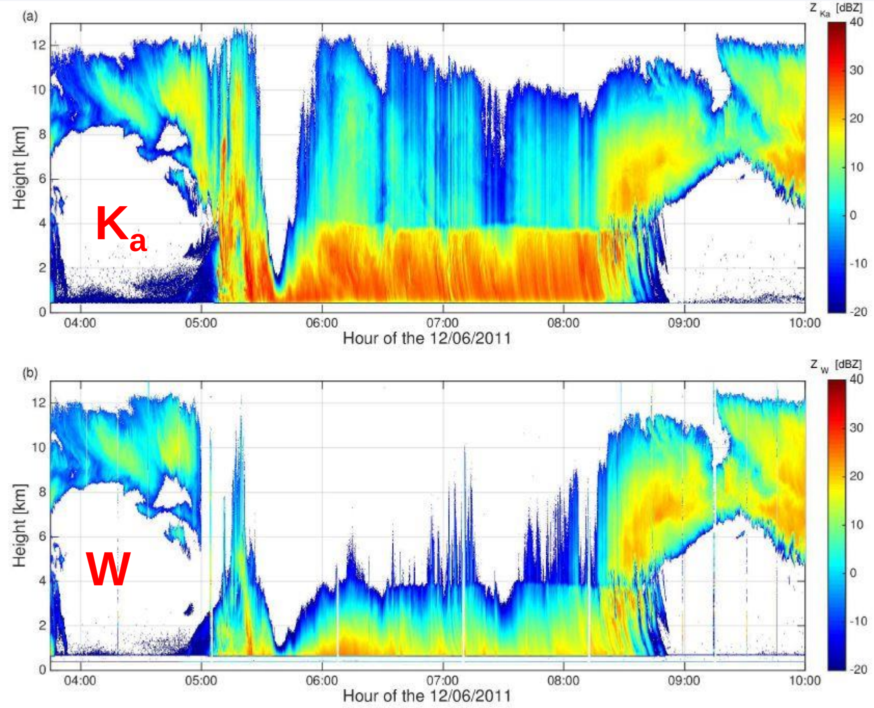

Radar reflectivity:
Z_{Ka} & Z_W

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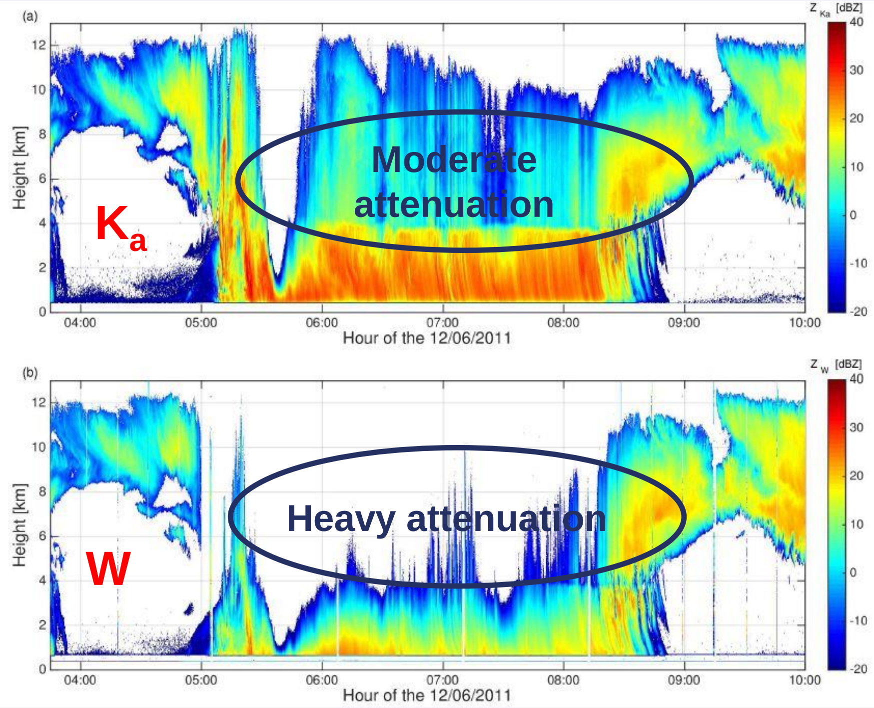

Radar reflectivity:
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Differential atten.:
ΔA

Diff. scattering:
Δ non-Rayleigh

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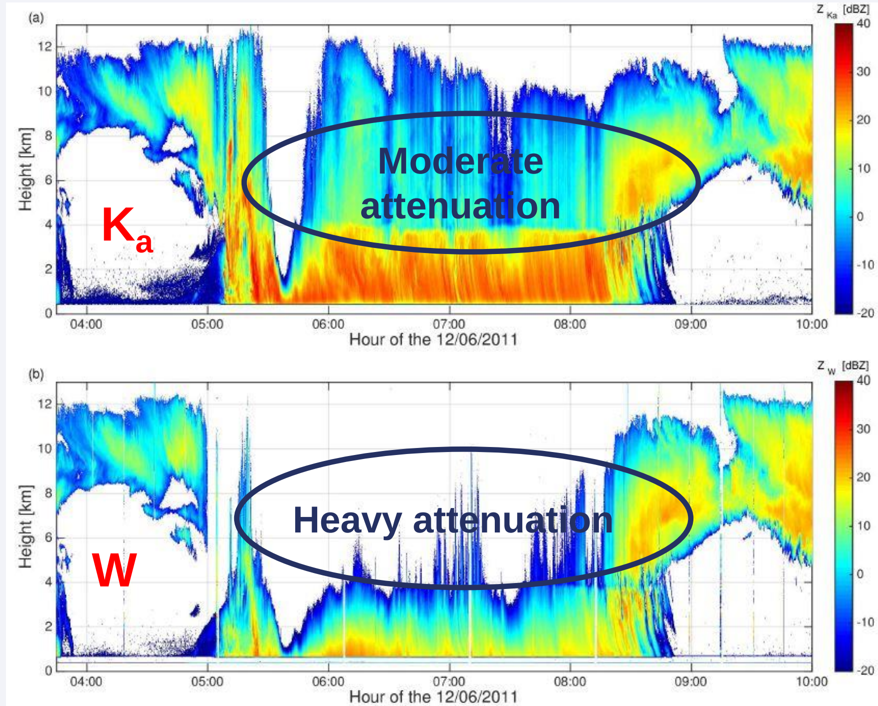
ARM CLIMATE RESEARCH FACILITY SGP

Photo courtesy of S. Collis



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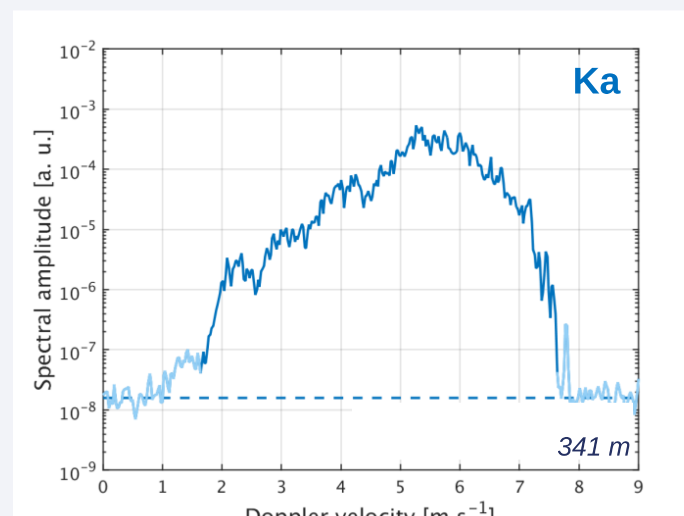

Tridon et al. 2017 (QJRMS)

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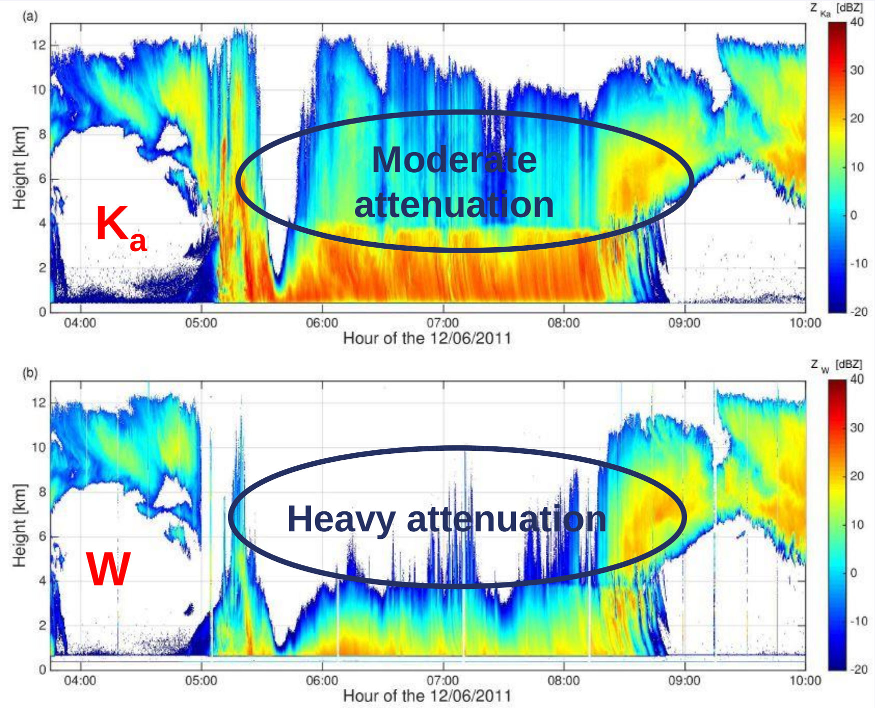

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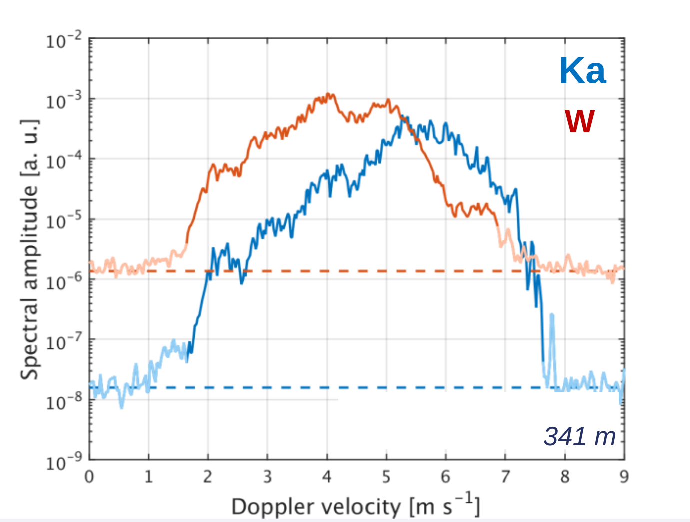

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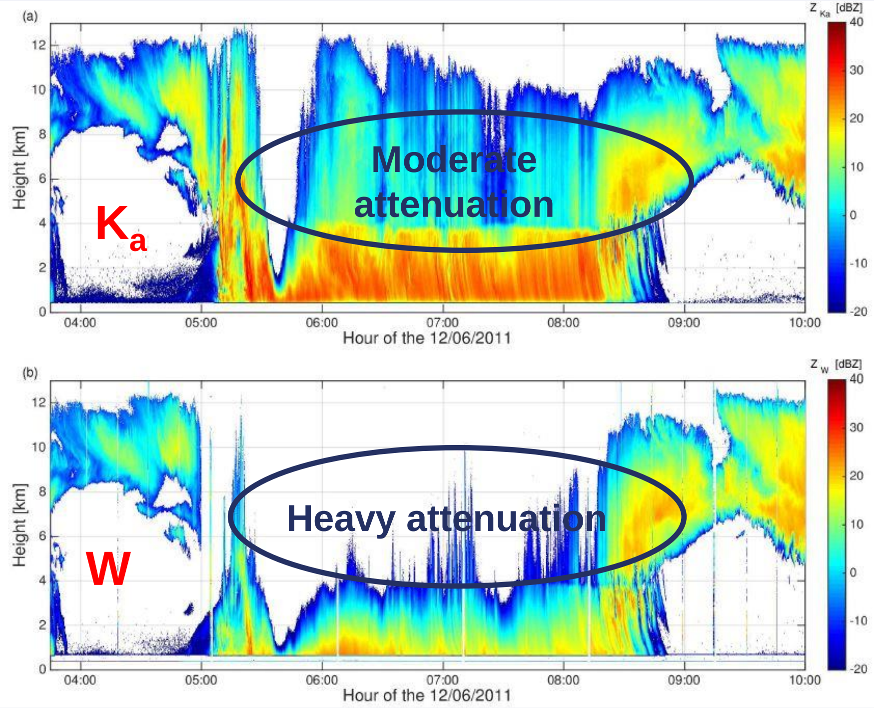

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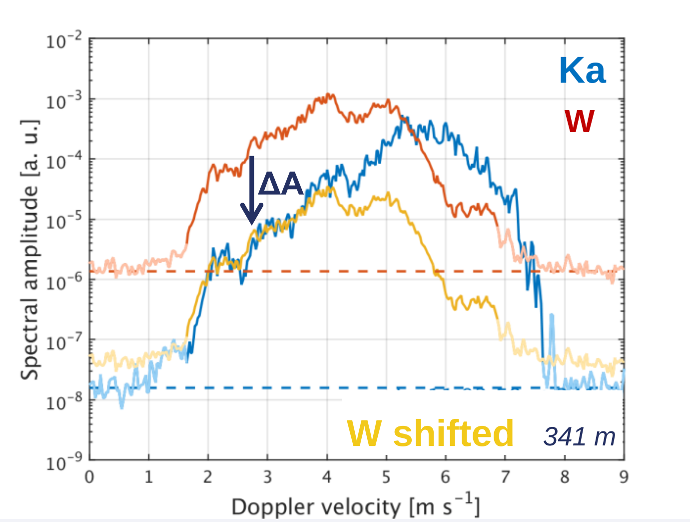

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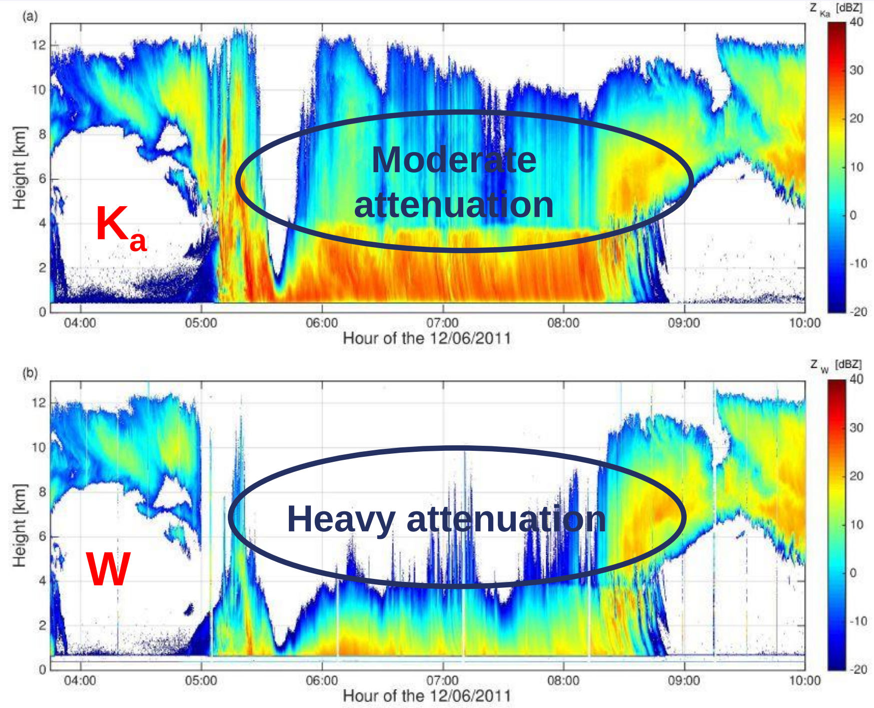

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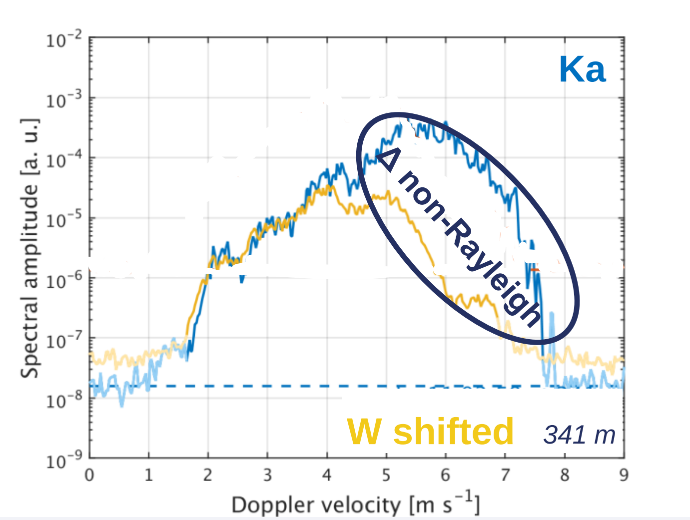
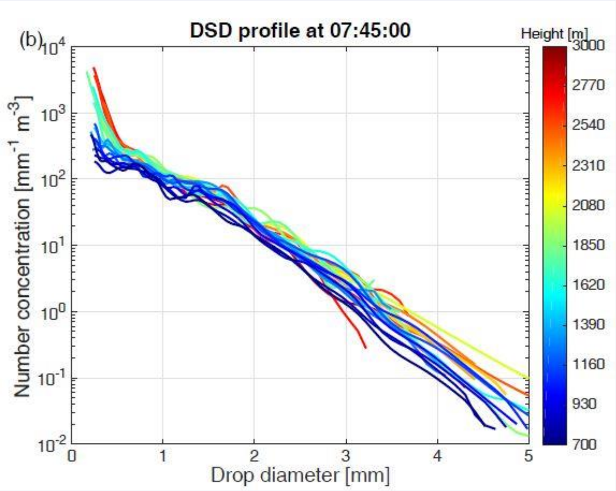
variational approach

→ Retrieval of the vertical wind w and drop concentration per diameter bin (DSD) at high resolution (2 sec., 50 m)



Tridon et al. 2017 (QJRMS)

Ka and W-band radar retrieval of DSD profiles: Validation



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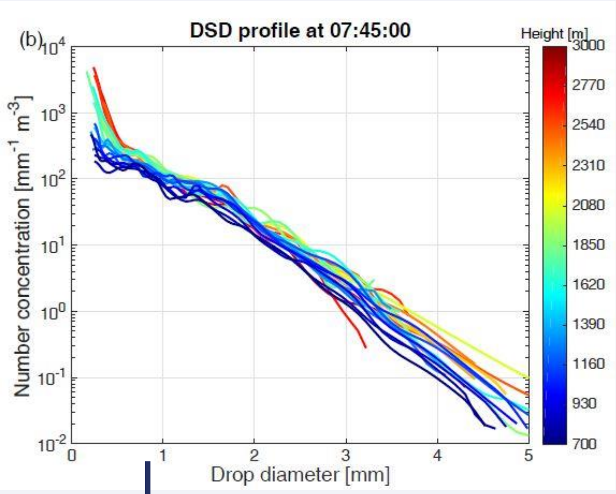

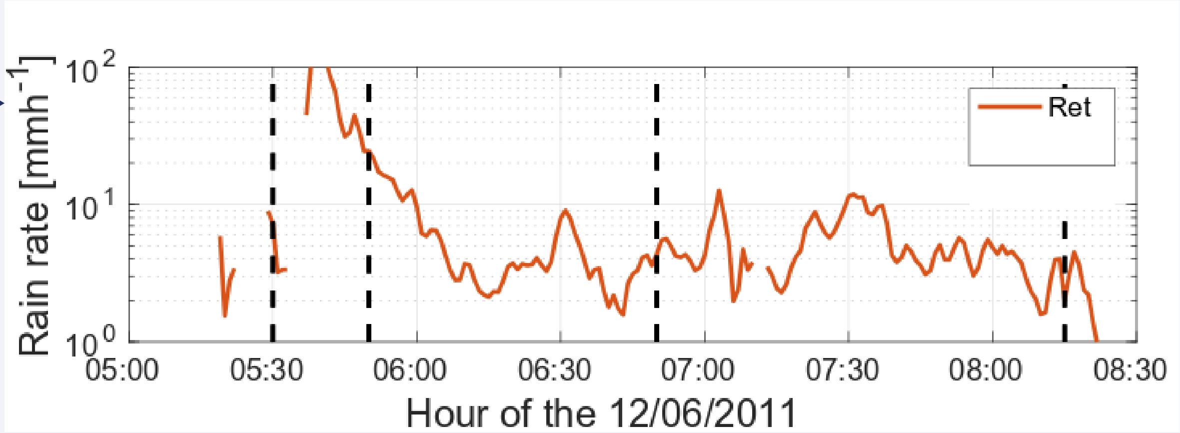

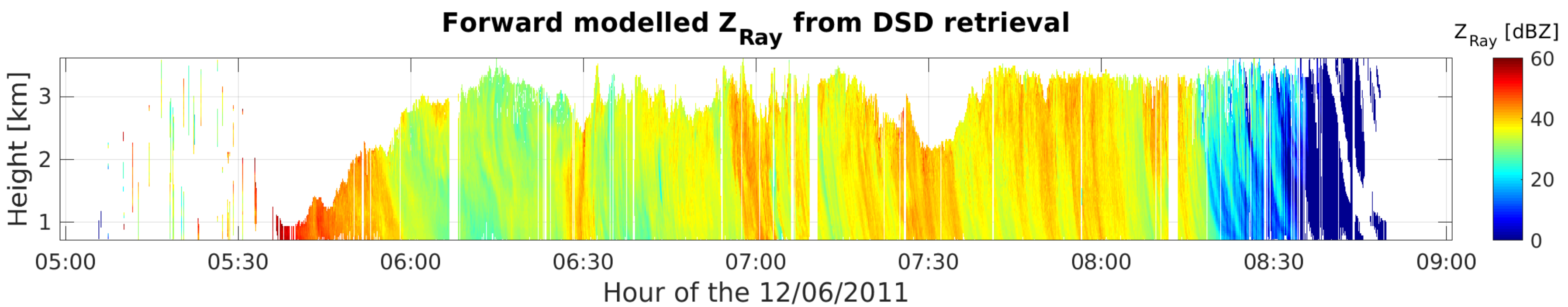

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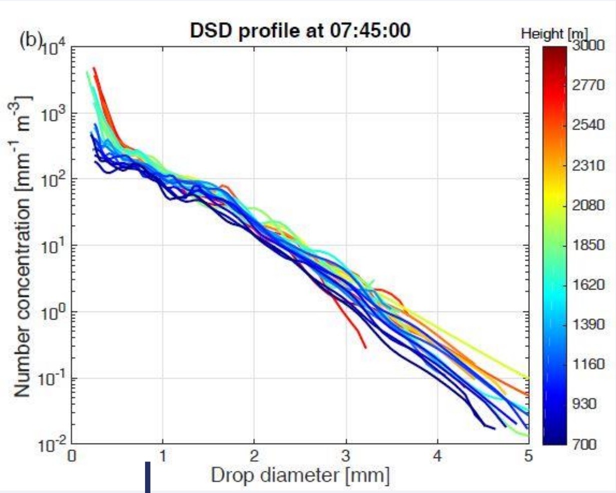
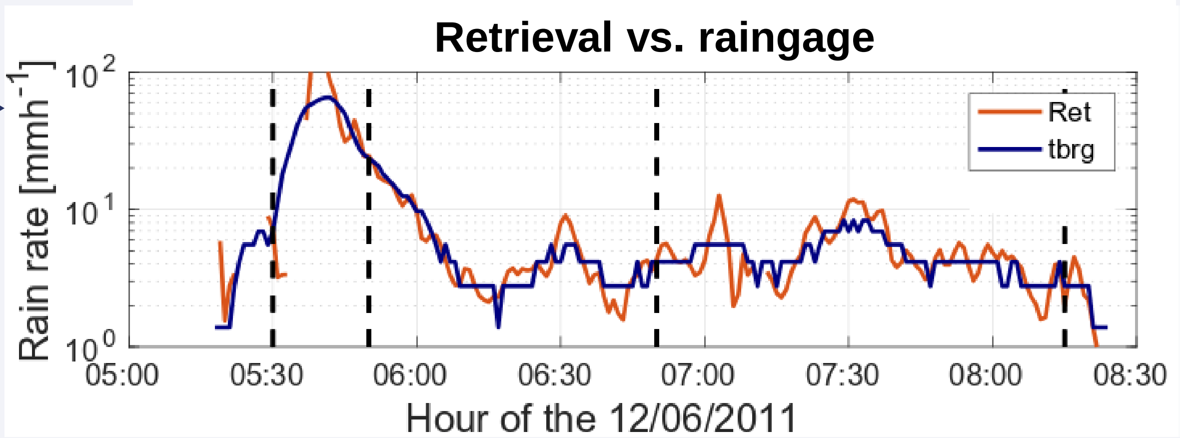
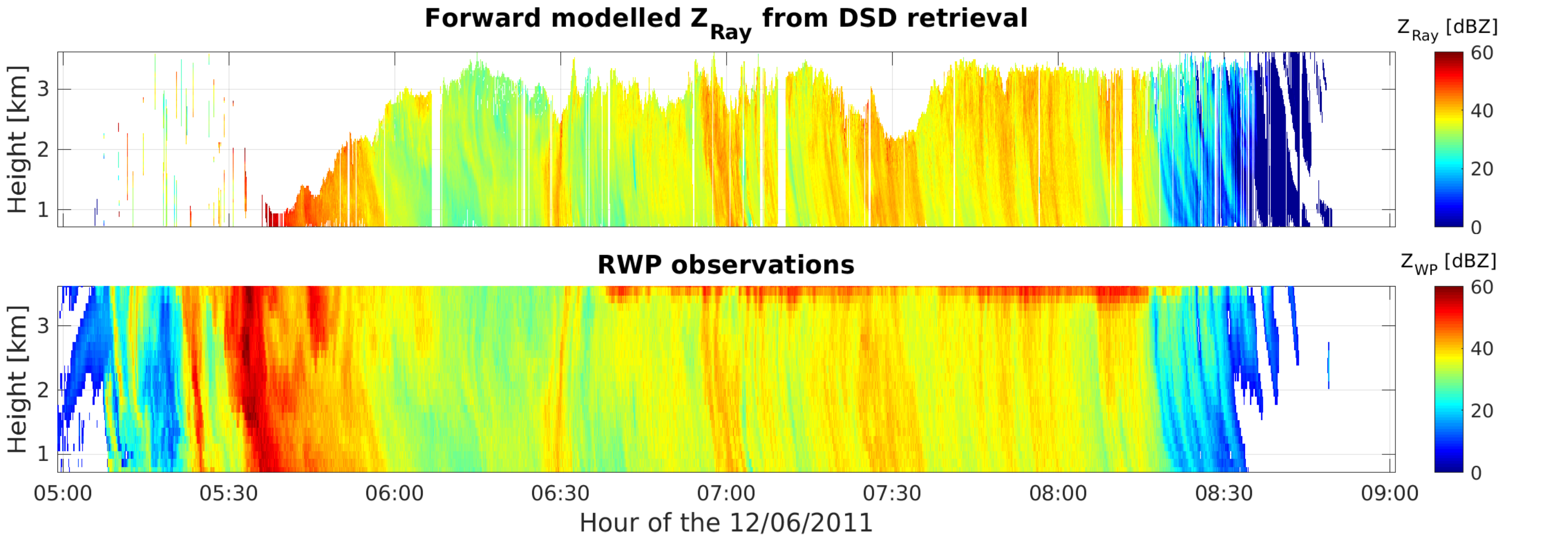
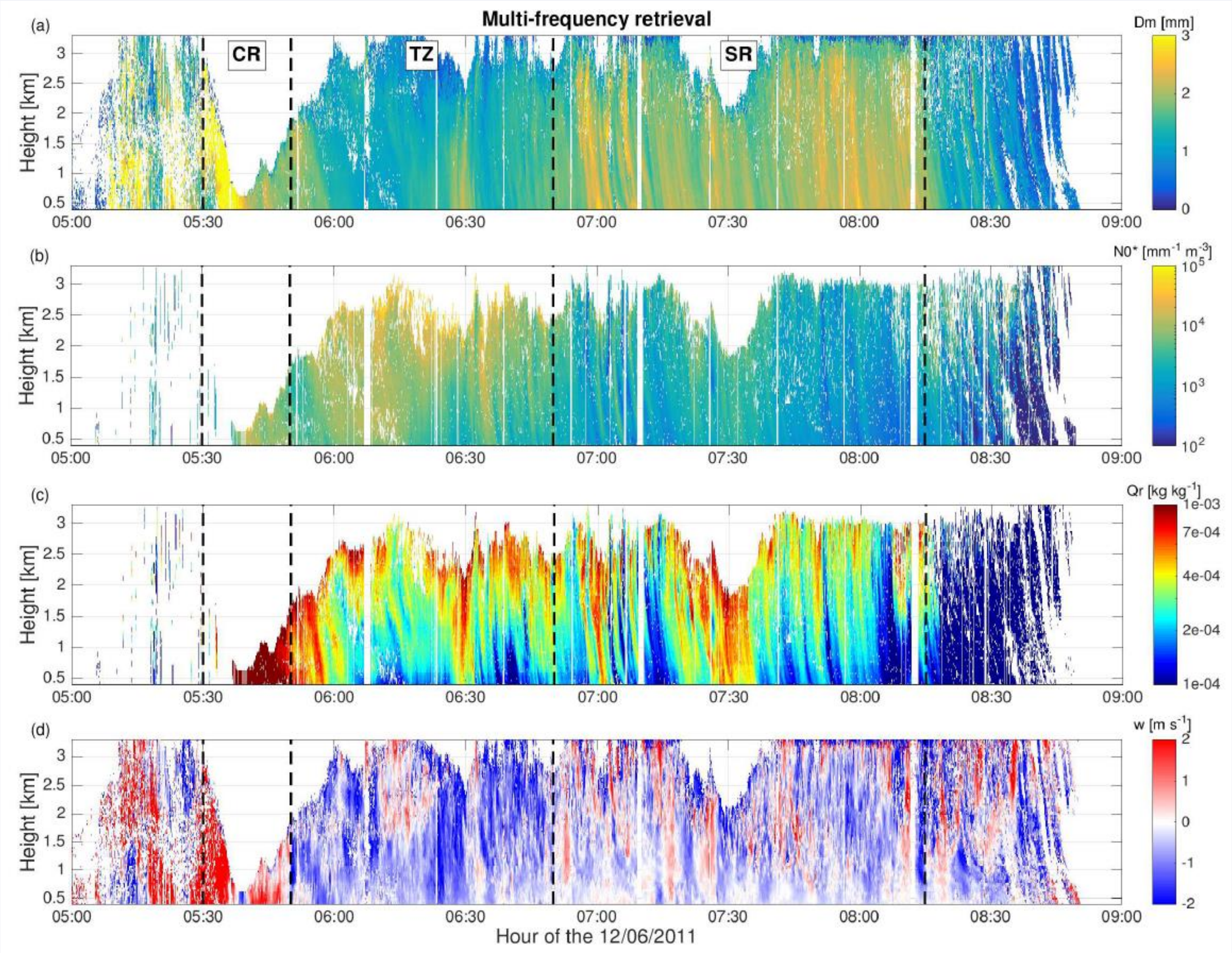






K_a and W-band radar retrieval of DSD profiles: DSD moments



D_m

N_0^*

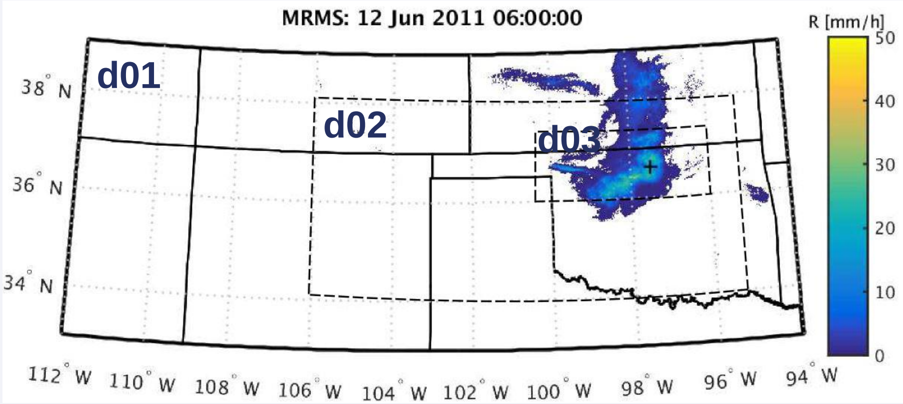
Q

w

Homogeneous properties within the SR

→ Investigate the vertical variability and comparison with models possible

Model setup and initiation



► **WRF** simulation

- 3 nested domains:
  d01: 136 x 50 pts & Δx = Δy = 12 km
  d02: 252 x 114 pts & Δx = Δy = 4 km
  d03: 384 x 152 pts & Δx = Δy = 1 km
- 72 levels in the vertical coordinate: Δz ≈ 250 m
- Initiation: ERA-Interim reanalyzes data (ECMWF) at 00:00 UTC on 11 Jun. 2011

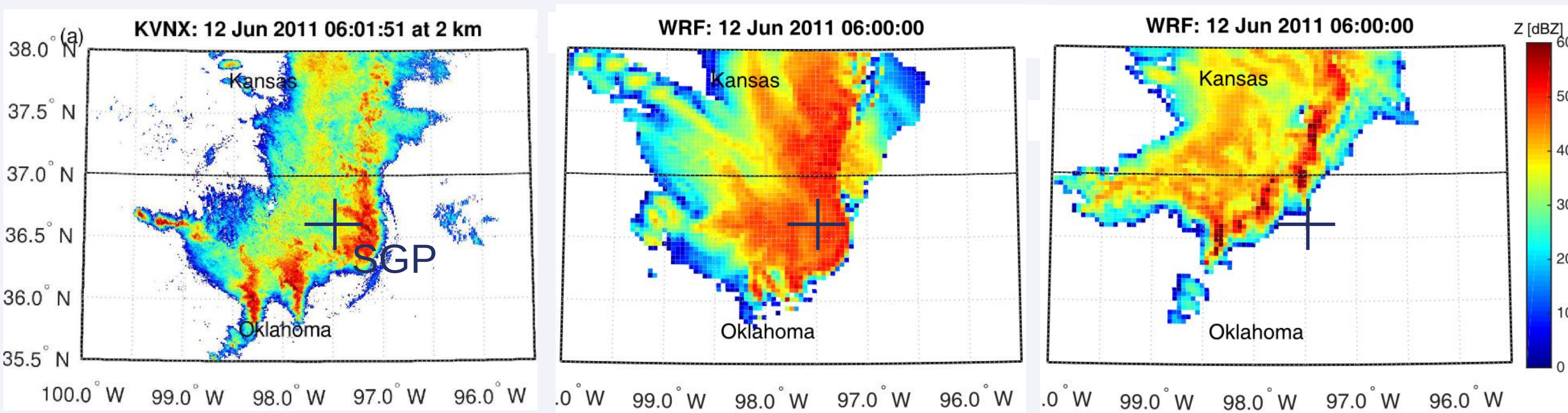
► Simulations performed using two different microphysics schemes:
Morrison et al. (2009)
Thompson et al. (2008)

Thompson scheme	Morrison scheme
Q_c, Q_r, Q_i, Q_s, Q_g	Q_c, Q_r, Q_i, Q_s, Q_g
N_r, N_i	N_r, N_i, N_s, N_g
THOM-CTL	MORR-CTL

Simulations vs. observations

Radar reflectivity at 06:00 UTC

Observations | WRF-MORR | WRF-THOM

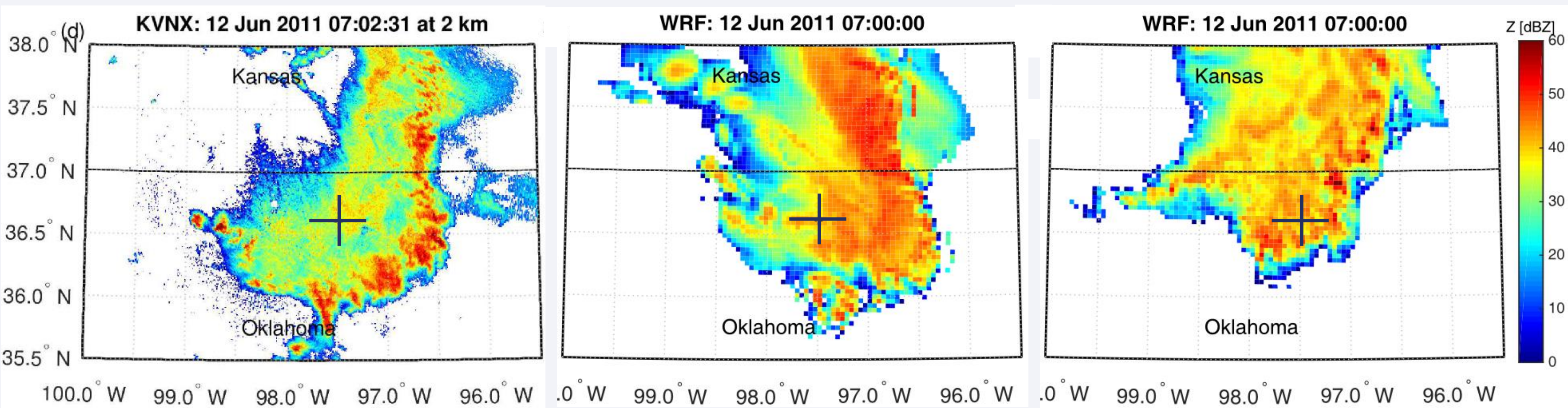


- ► Reasonable agreement for the location between the measured and simulated radar reflectivity.
- ► Simulated radar reflectivity is over-estimated using both schemes.

Simulations vs. observations

Radar reflectivity at 07:00 UTC

Observations   WRF-MORR   WRF-THOM



- ► Reasonable agreement for the location between the measured and simulated radar reflectivity.
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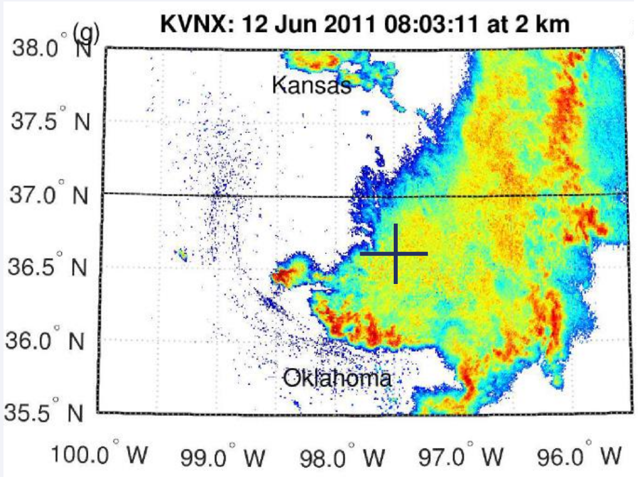
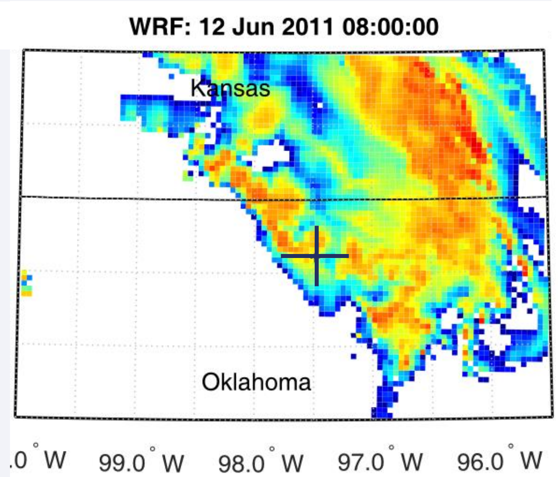
Simulations vs. observations

Radar reflectivity at 08:00 UTC

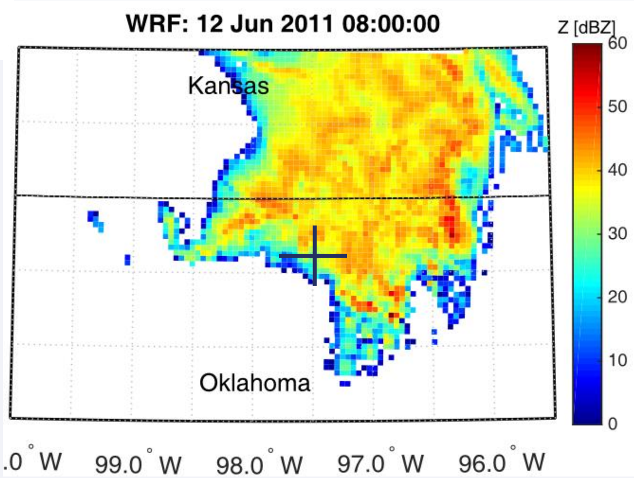
Observations



WRF-MORR



WRF-THOM

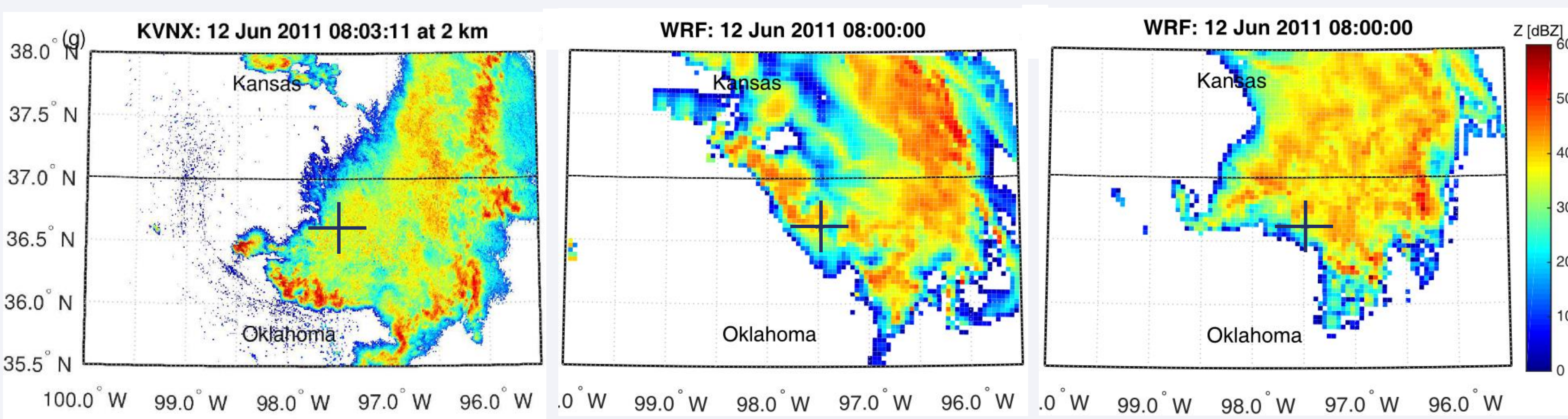


- ► Reasonable agreement for the location between the measured and simulated radar reflectivity.
- ► Simulated radar reflectivity is over-estimated using both schemes.
- ► Model reproduces quite well the evolution of the squall line system.
- ► But, both schemes fail to reproduce the Transition Zone.

Simulations vs. observations

Radar reflectivity at 08:00 UTC

Observations | WRF-MORR | WRF-THOM



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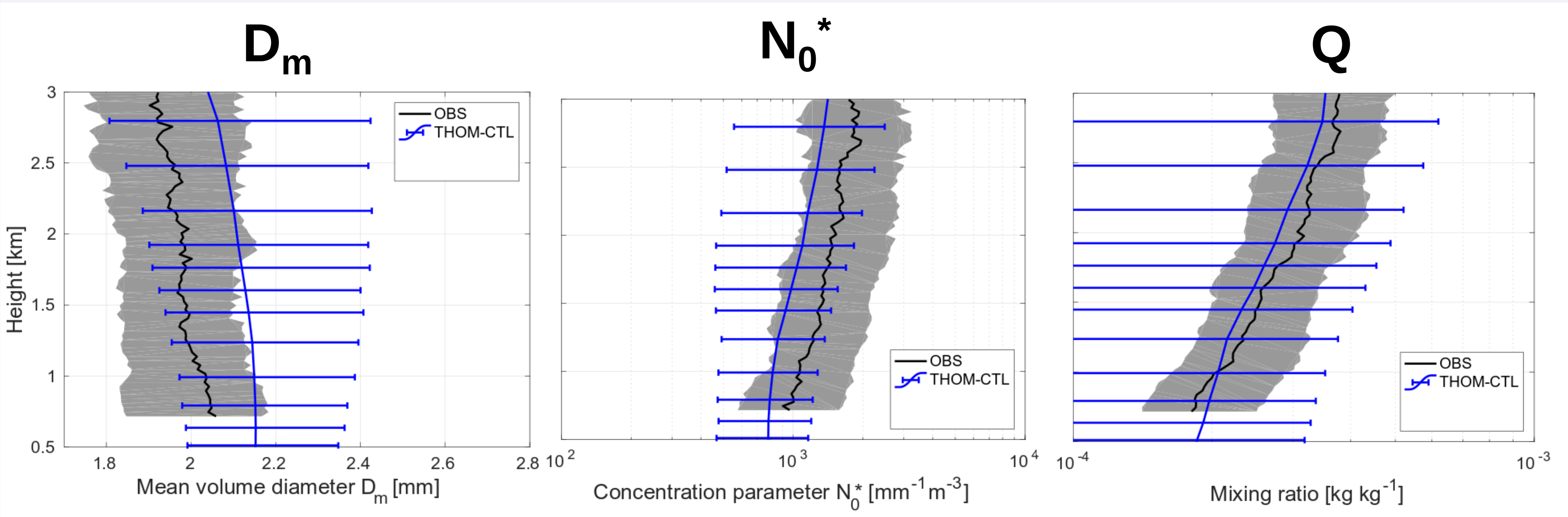
► Statistical approach for profiles comparison

DSD properties

within the Stratiform Region

THOM-CTL



► Reasonable agreement between DSD profiles and THOM-CTL simulation

DSD properties

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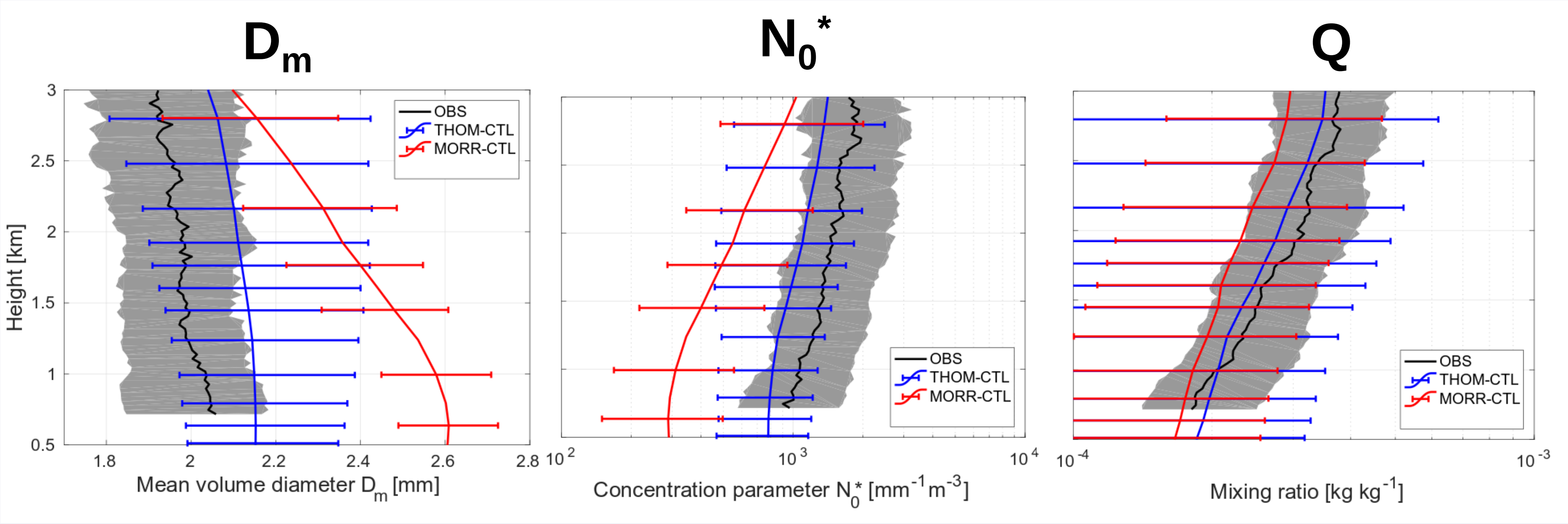
THOM-CTL

MORR-CTL



- ▶ Reasonable agreement between DSD profiles and THOM-CTL simulation
- ▶ Excessive size-sorting in MORR-CTL simulation

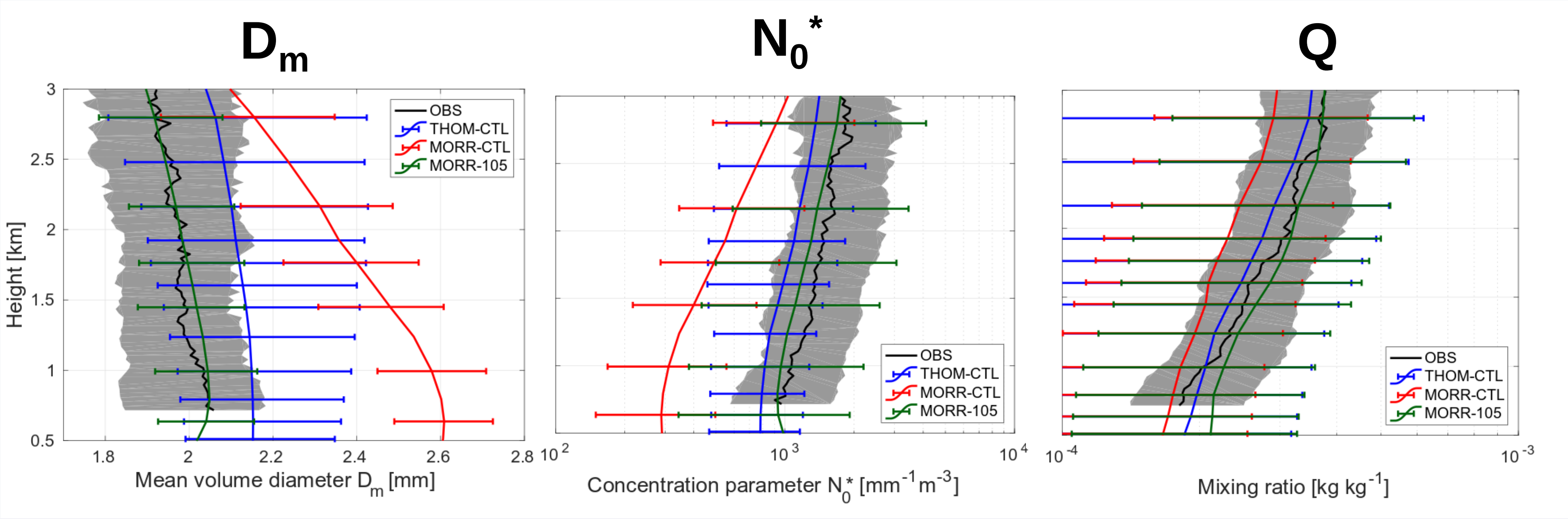
DSD properties

within the Stratiform Region

THOM-CTL

MORR-CTL

MORR-105



- ▶ Reasonable agreement between DSD profiles and THOM-CTL simulation
- ▶ Excessive size-sorting in MORR-CTL simulation
- ▶ Better agreement when the breakup efficiency is increased (as in Morrison et al., 2012)

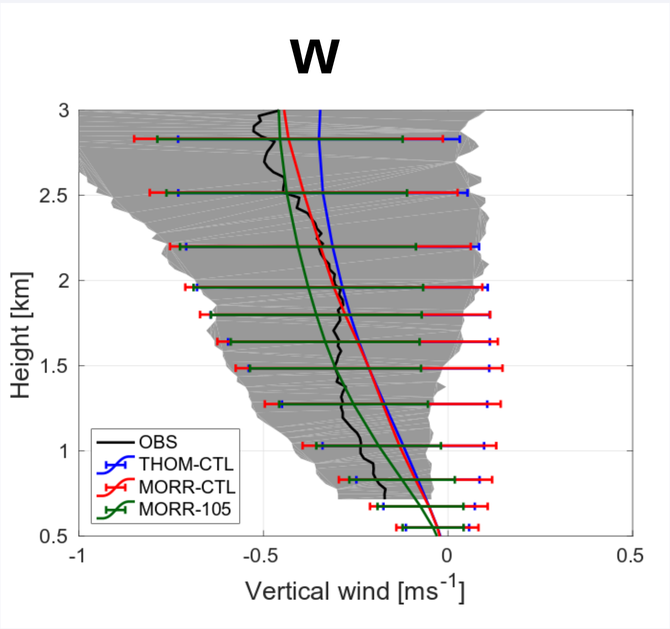
Evaporation rate

within the Stratiform Region

THOM-CTL

MORR-CTL

MORR-105



OBS from radar retrieval

► Simulations resonably reproduce the meso-scale downdraft associated with evaporation

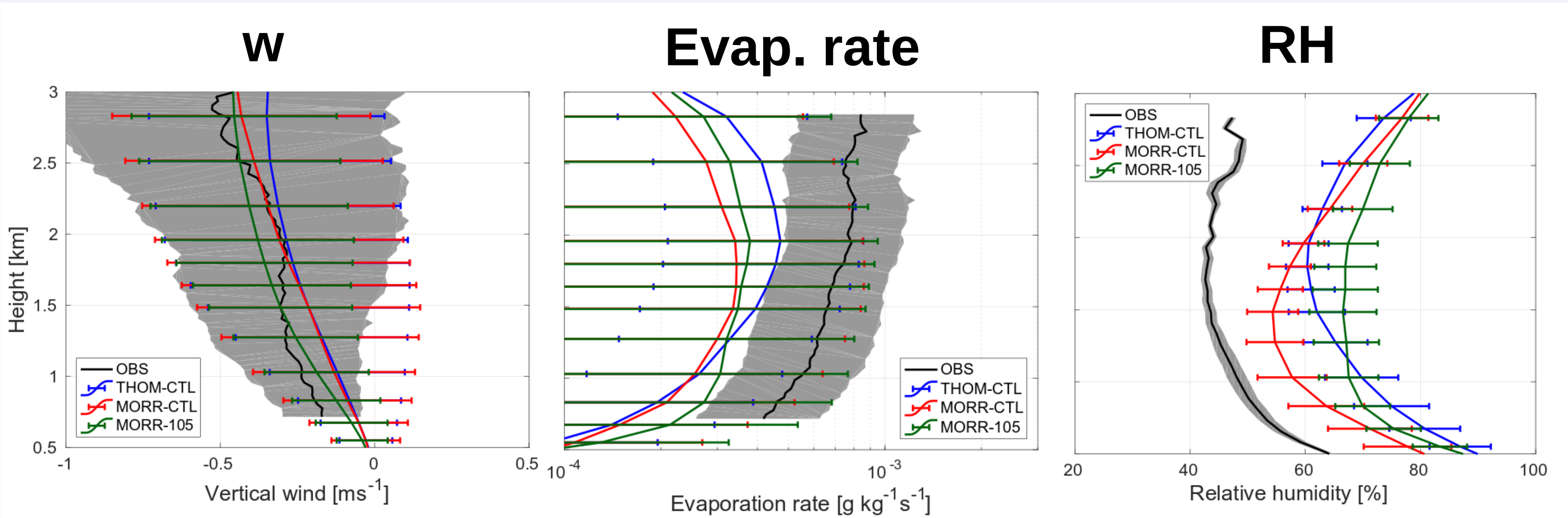
Evaporation rate

within the Stratiform Region

THOM-CTL

MORR-CTL

MORR-105



OBS from radar retrieval

OBS from Raman lidar (Turner et al., 2002)

► Simulations resonably reproduce the meso-scale downdraft associated with evaporation

► However, even if DSD profiles are well reproduced, evaporation is underestimated because RH is overestimated in the model

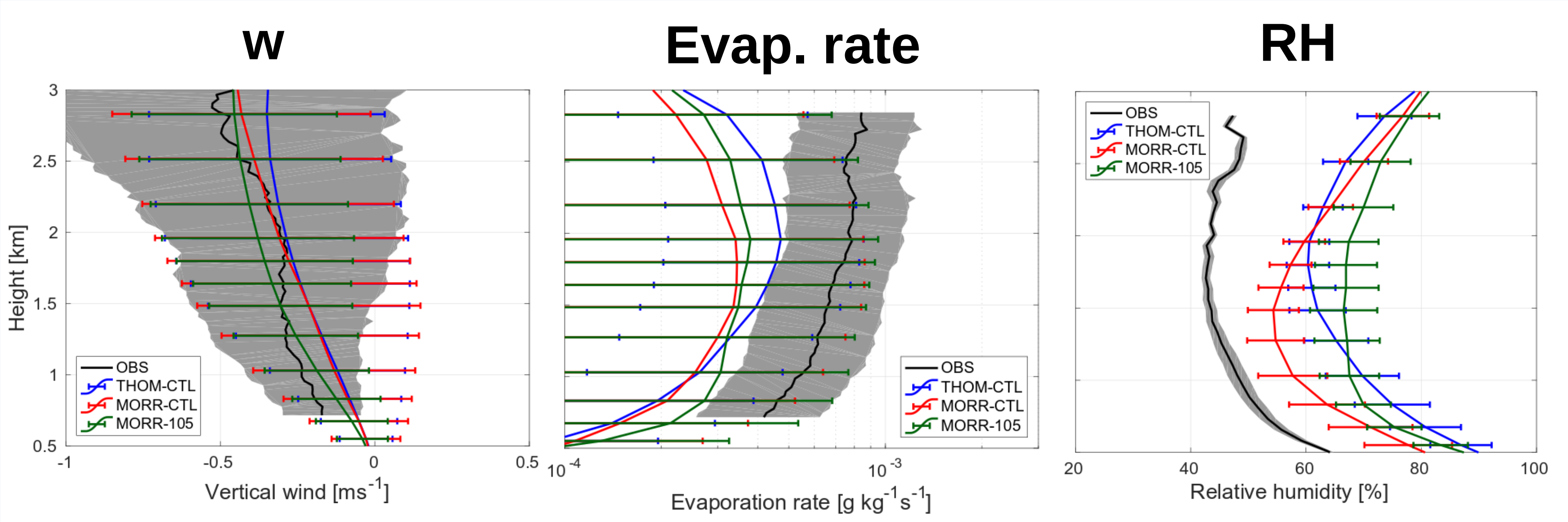
Evaporation rate

within the Stratiform Region

THOM-CTL

MORR-CTL

MORR-105



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► Simulations resonably reproduce the meso-scale downdraft associated with evaporation

► However, even if DSD profiles are well reproduced, evaporation is underestimated because RH is overestimated in the model

► Could impact the buoyancy of the atmosphere, cold pool intensity or the dynamics of the system → future work

Conclusions

Tridon et al., 2019, MWR
Planche et al., 2019, MWR

► Difficulties to reproduce the transition zone with WRF using either the Morrison or the Thompson scheme

► Recently developed retrieval technique providing both N0* and Dm at high resolution

→ overall reasonable agreement in the DSD profiles

► in the Morrison scheme, the breakup efficiency had to be increased in order to get better agreement with the observations for this case study

► Despite the small DSD discrepancies, the evaporation rate is significantly underestimated in the model because it cannot reproduce the especially low observed RH

→ How can this impact the buoyancy of the atmosphere, cold pool intensity or the dynamics of the system?

► We need more, and more persistent profiling observations with multi-frequency cloud radars

Thanks for your attention

Questions?