Towards Improved Particle Properties of Cloud Ice and Snow in the Seifert-Beheng Two-Moment Microphysics Scheme

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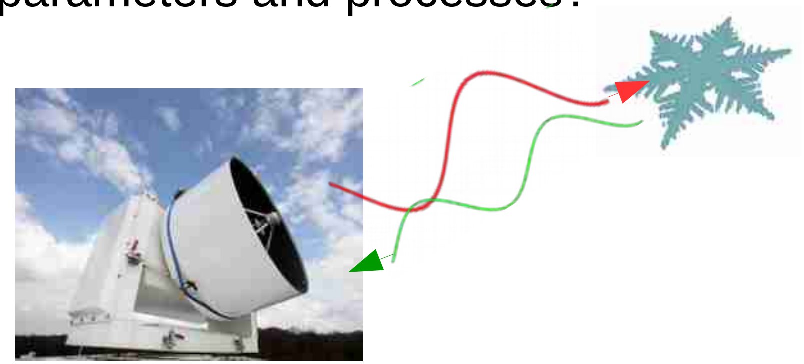
Motivation/ Research questions

- Microphysical processes are one of the main sources of uncertainty in atmospheric models [Boucher et al. 2013]

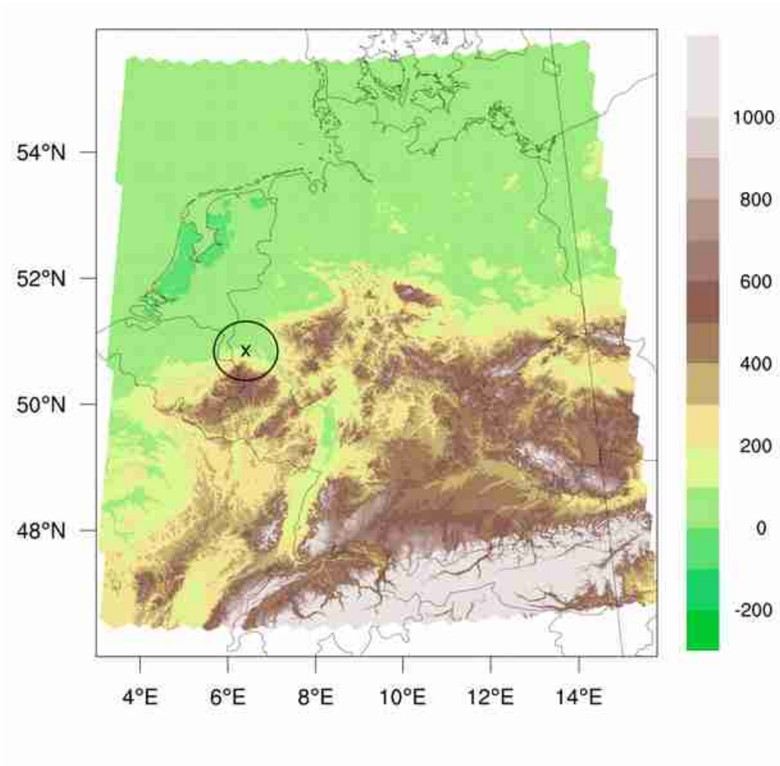
- Can we use cloud radars (Doppler, multi-frequency) to evaluate ice microphysical parameters and processes?



- How can we improve ice aggregation and sedimentation in ICON (Seifert-Beheng 2-moment scheme)?

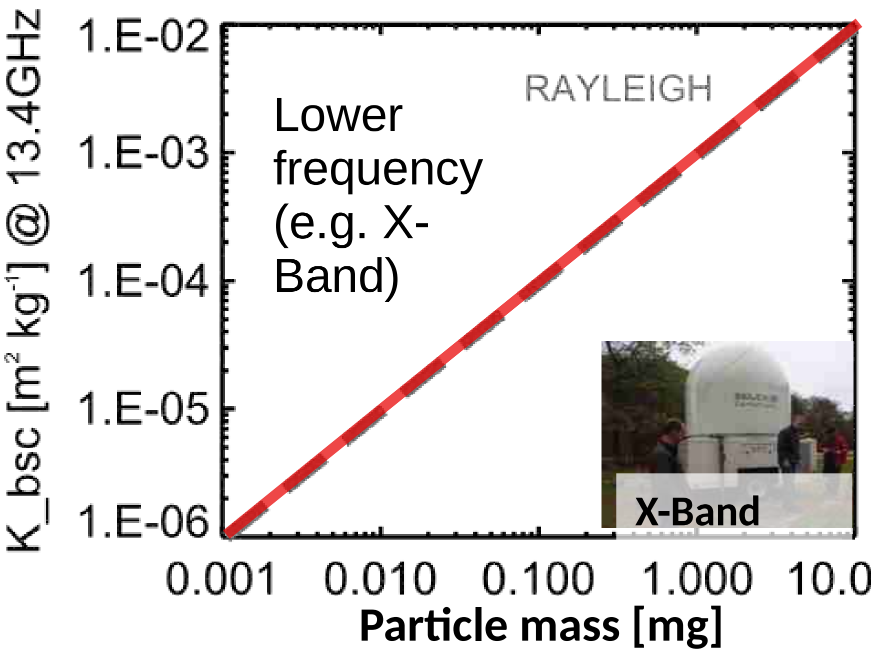
Model setup – ICON-LEM

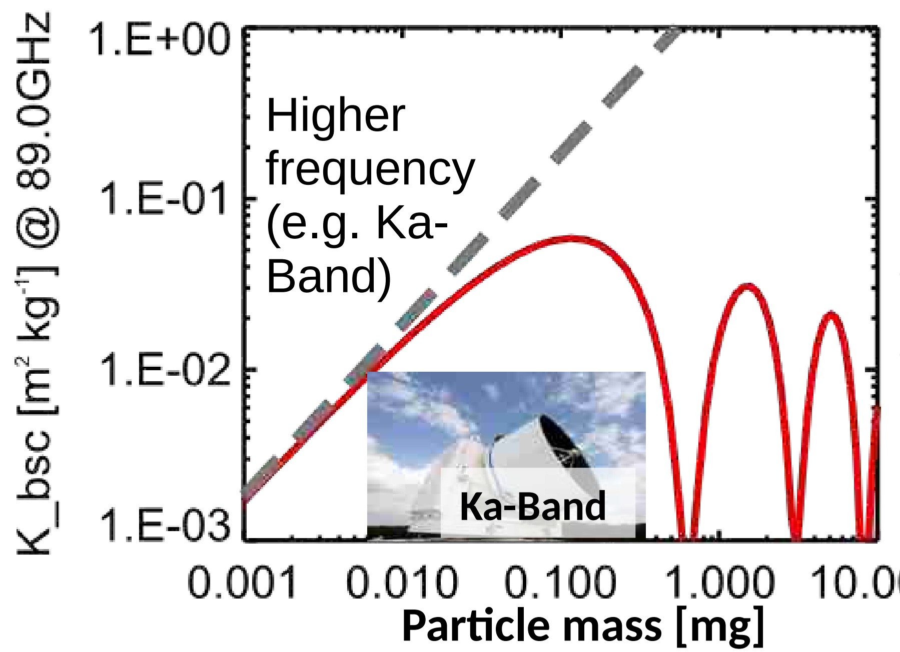
- 2-moment µ-physics *(Seifert&Beheng 2006)*
- Domain with diameter of 100km centered over JOYCE (measurement site with e.g. multi-frequency cloud radars)
- 600m horizontal resolution
- Two months in winter 2015/2016
- Initialized by IFS each day at 0 UTC
- Radar forward simulations with Passive and Active Radiative Transfer Tool (PAMTRA, Mech et al., submitted to GMD)



JOYCE: Jülich Observatory for Cloud Evolution

Observations - Why multi-frequency radars?





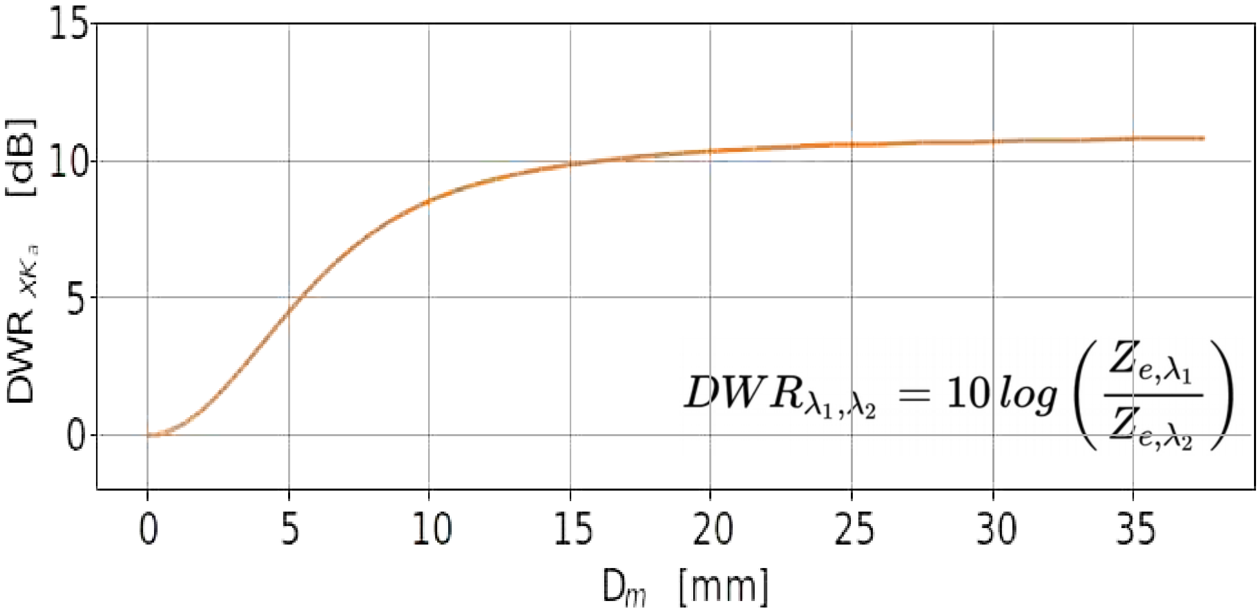
- Particle scattering properties change from Rayleigh to Mie depending on size/mass and frequency
- Dual wavelength ratio $DWR_{\lambda_1,\lambda_2} = 10\, log\left(\frac{Z_{e,\lambda_1}}{Z_{e,\lambda_2}}\right)$ is proportional to particle size

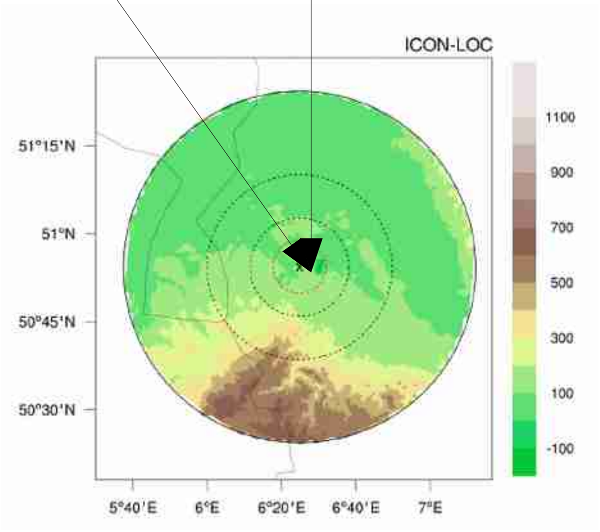
Observations - Why multi-frequency radars?

Dias Neto et al (2019)

- To which particle sizes are these combinations of radar frequencies sensitive?

  X-Ka Band: ~3-20mm

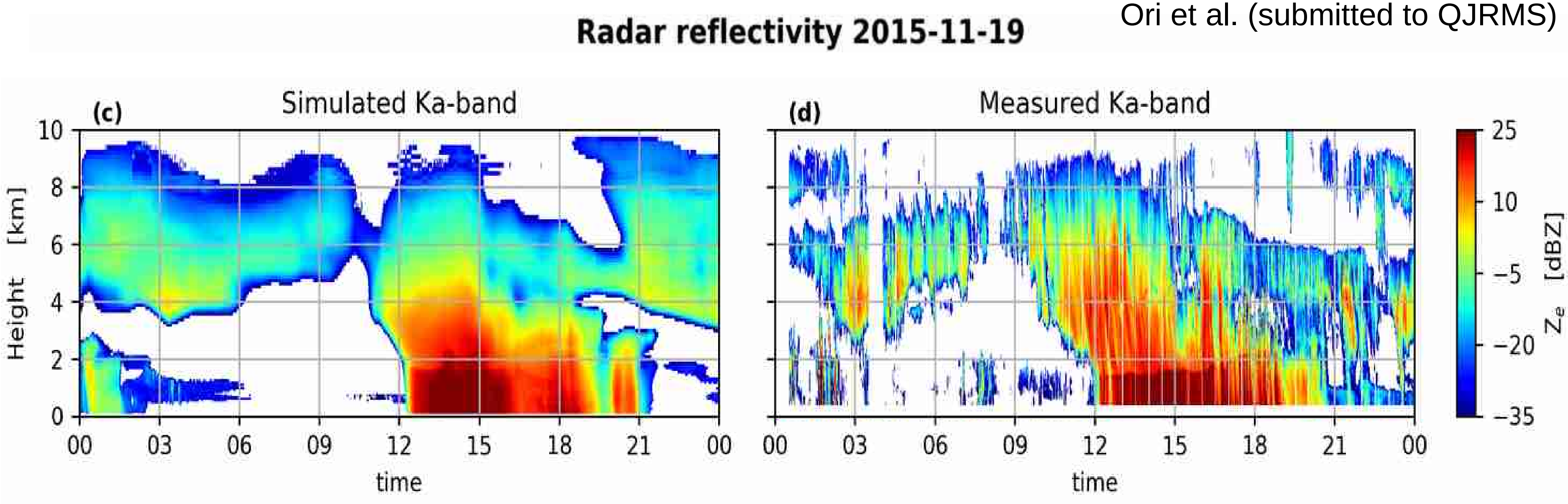




D_m: mean mass diameter

Model-observation comparison

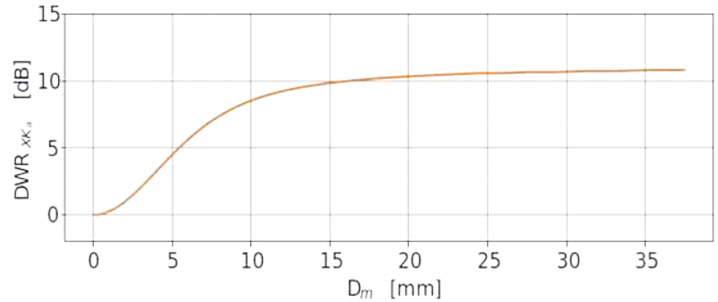
Ori et al. (submitted to QJRMS)

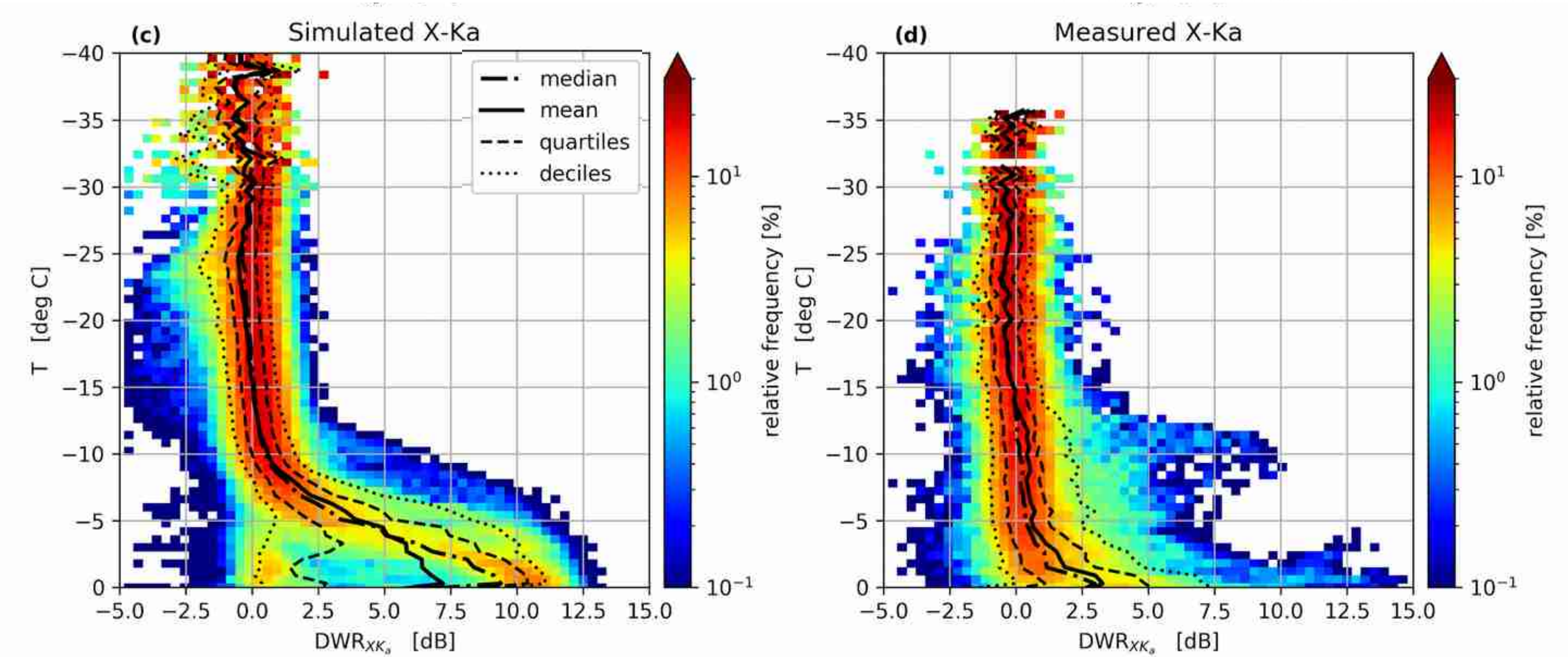


http://gop.meteo.uni-koeln.de/~Hatpro/dataBrowser/dataBrowser2.html?site=TRIPEX

- Good match of **cloud structure**
- Good match of **precipitation** (timing and strength)
- two-month dataset: case study → **statistical comparison** (mean size and velocity of particles)

Model-observation comparison - statistics



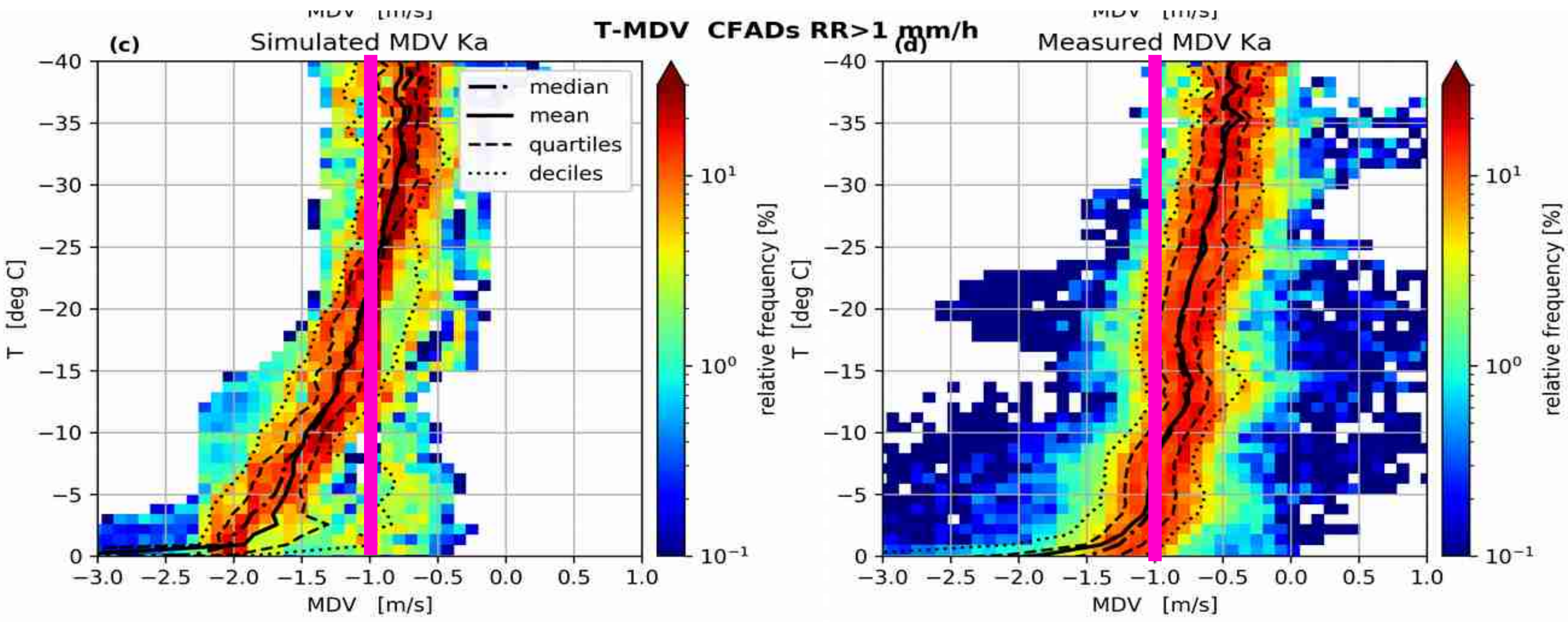


- CFADs of dual wavelength ratio (DWR) – 47 days – rain rate (RR) >1mm/h
- Overestimation of **particle sizes** for T>-7°C (too strong aggregation)

Ori et al. (submitted to QJRMS)

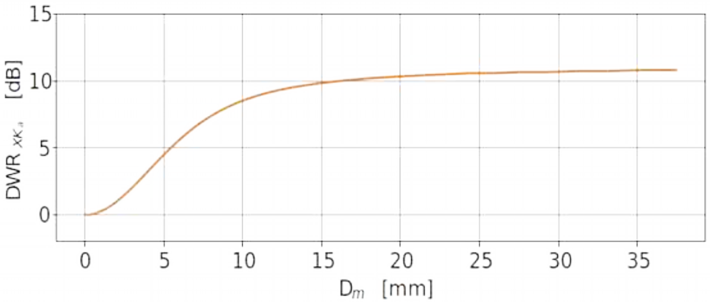
Model-observation comparison - statistics

Ori et al. (submitted to QJRMS)

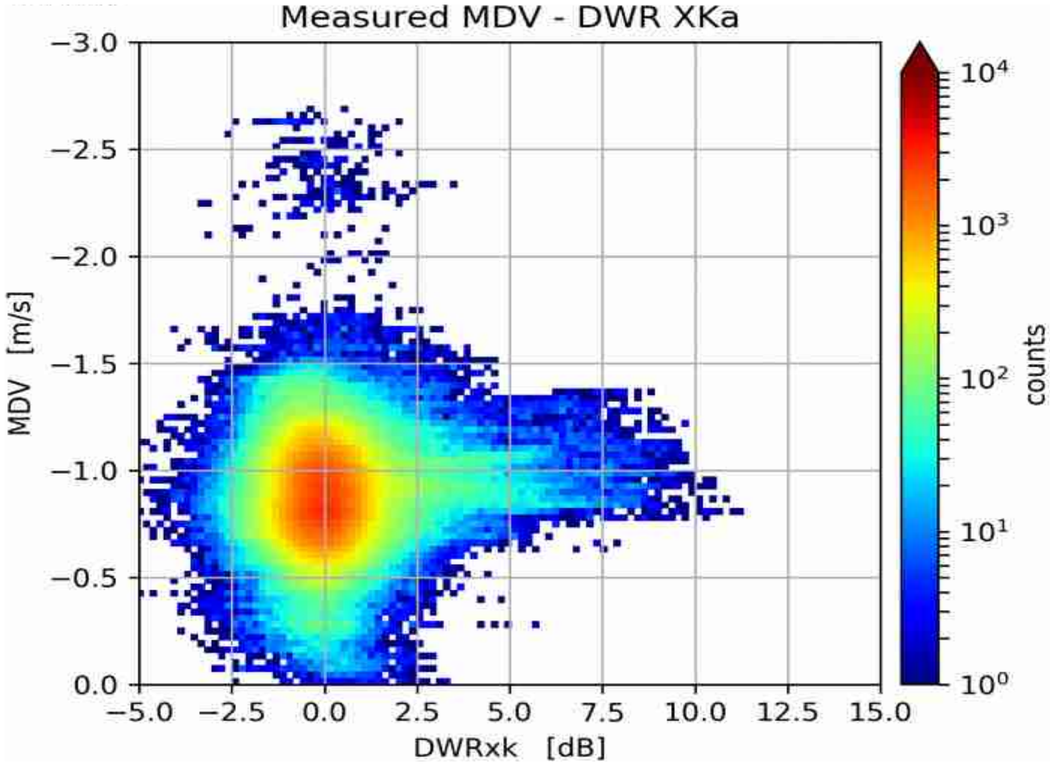


- CFADs of mean Doppler velocity (MDV) – 47 days – rain rate (RR) >1mm/h
- **Overestimation of Doppler velocity** at low and high temperatures

Model-observation comparison - statistics



Mean terminal velocity + air motion

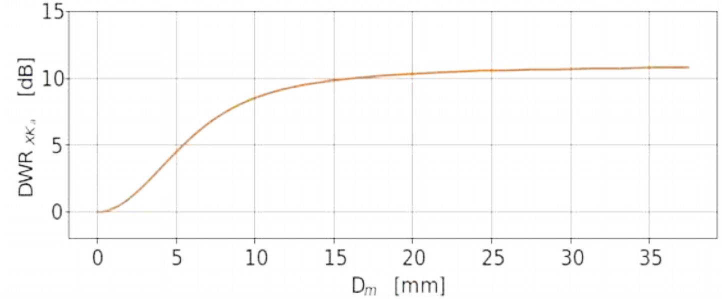


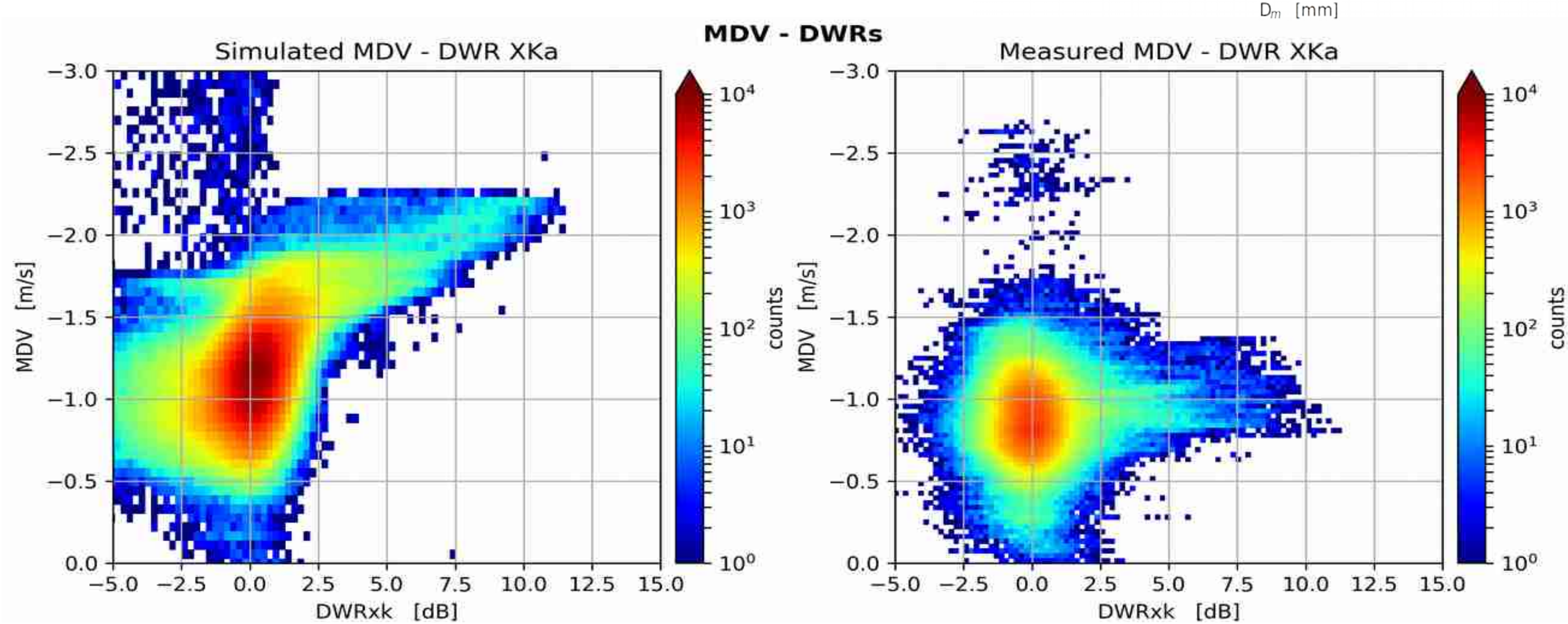
Mean size

- **Terminal velocity** stays **constant** („saturates“) with increasing size in **observations**

Ori et al. (submitted to QJRMS)

Model-observation comparison - statistics

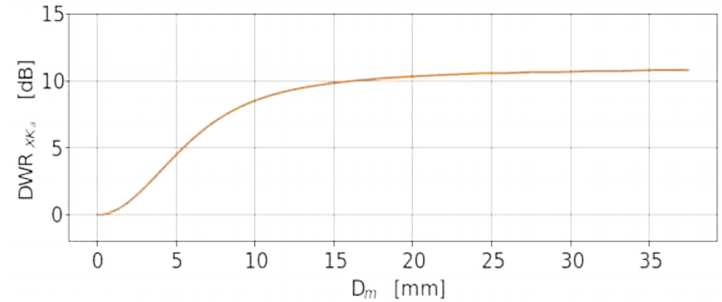


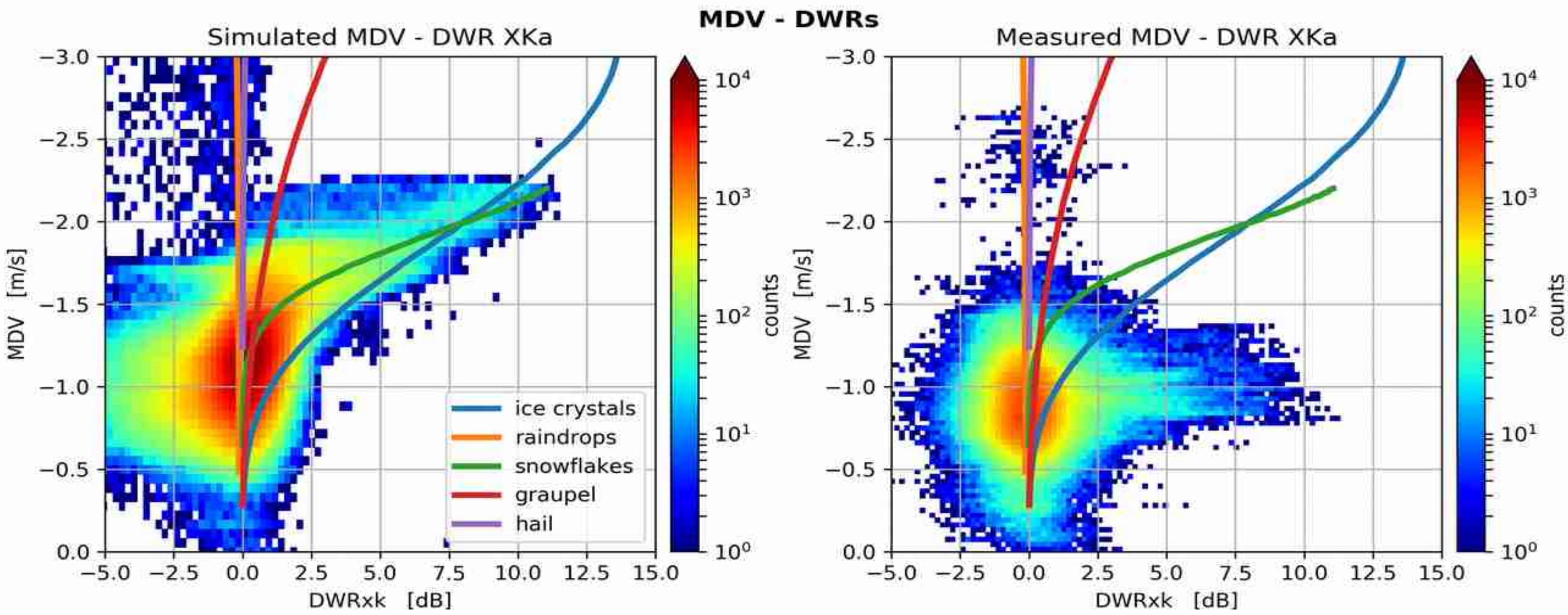


- **Terminal velocity** is **increasing in model** but is **constant** („saturating“) with increasing size in **observations**

Ori et al. (submitted to QJRMS)

Model-observation comparison - statistics





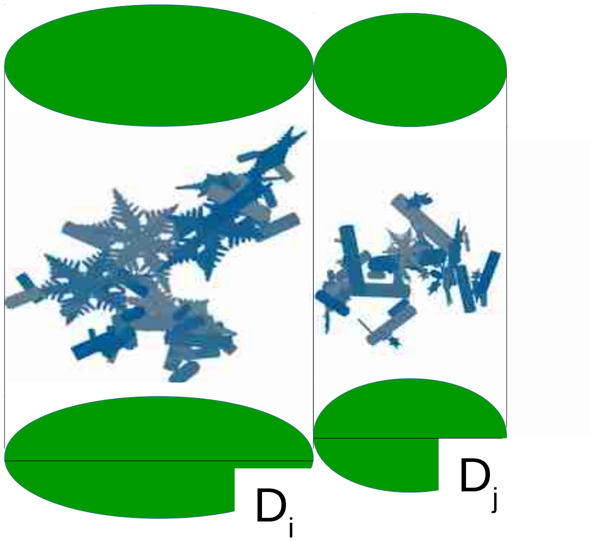
- Only snow reaches large particle sizes
- Are these model biases **(too large snow, too high velocity)** linked**?**

Ori et al. (submitted to QJRMS)

Too large and too fast particle – how is that connected?

Aggregation kernel:

$$K(i,j) = \frac{\pi}{4}(D_i + D_j)^2 |v_{term,i} - v_{term,j}| E_c E_s$$



- Large particles likely catch other particles

Too large and too fast particle – how is that connected?

Aggregation kernel:

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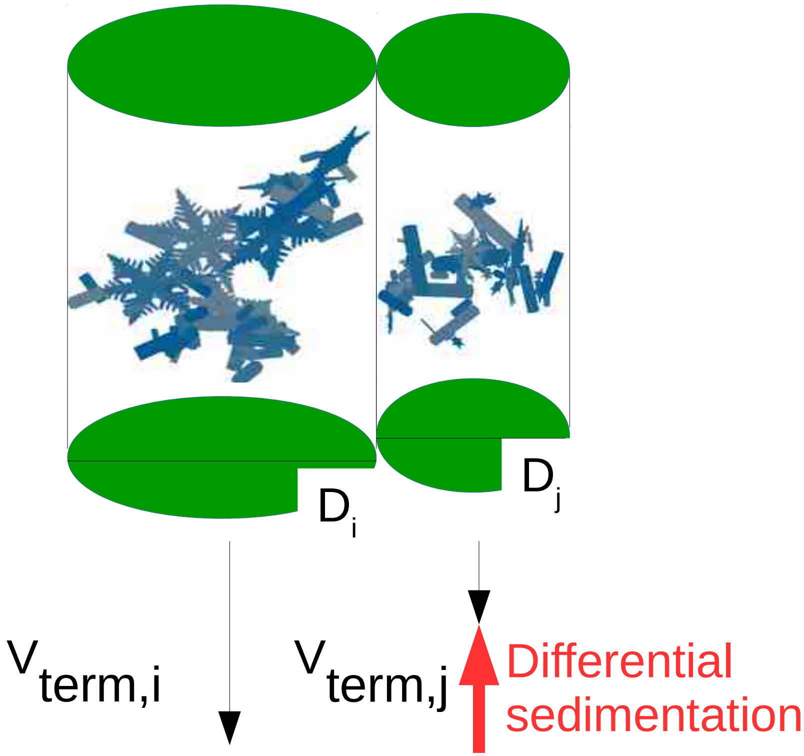

- Large particles likely catch other particles **if a velocity difference remains**

Too large and too fast particle – how is that connected?

Aggregation kernel:

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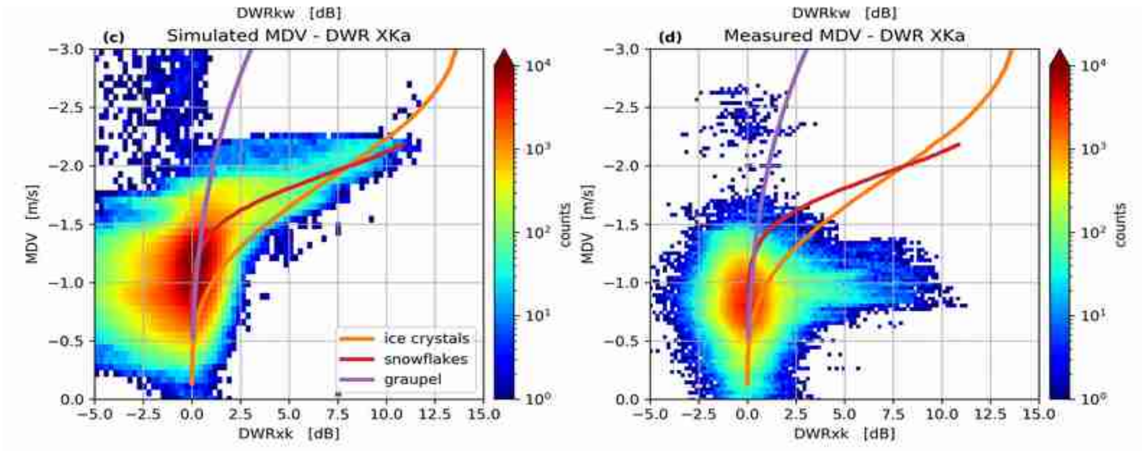

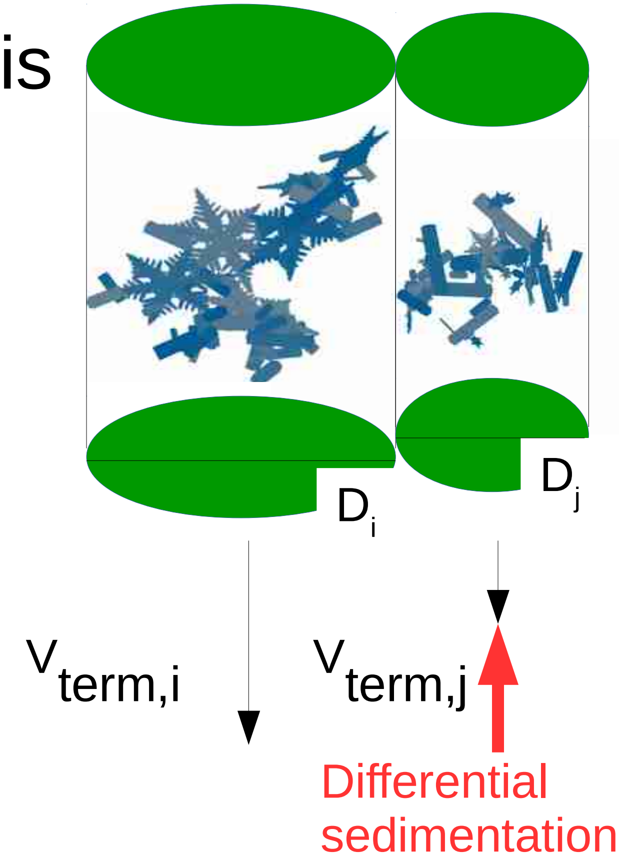

- Large particles likely catch other particles if a velocity difference remains
- **Saturation of terminal velocity** (suggested by observations, but not implemented in model) **dampens the aggregation process**.

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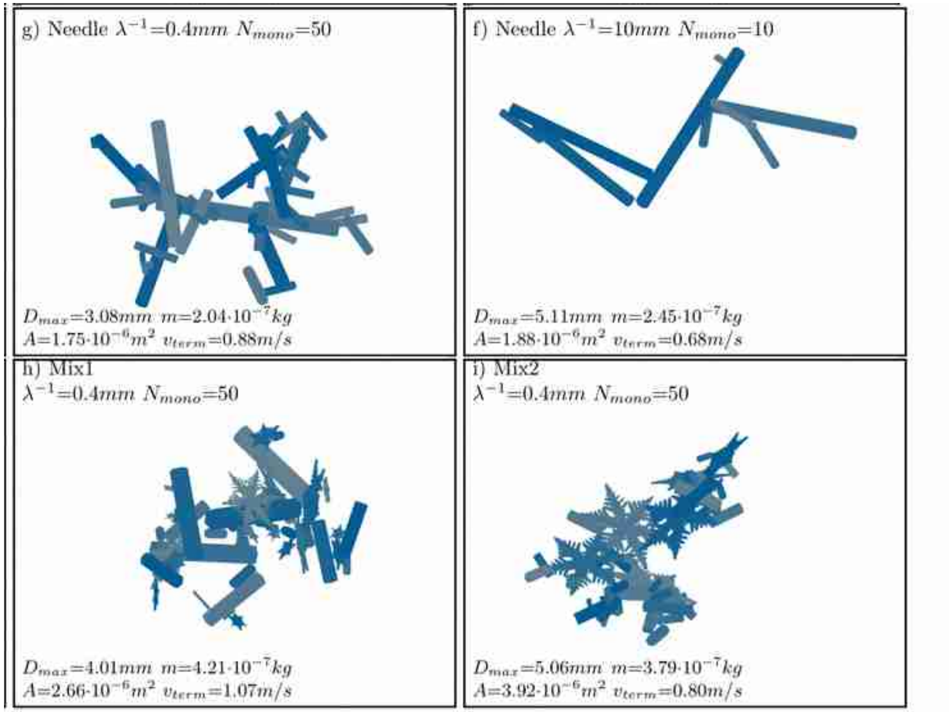
Improving ice microphysical description

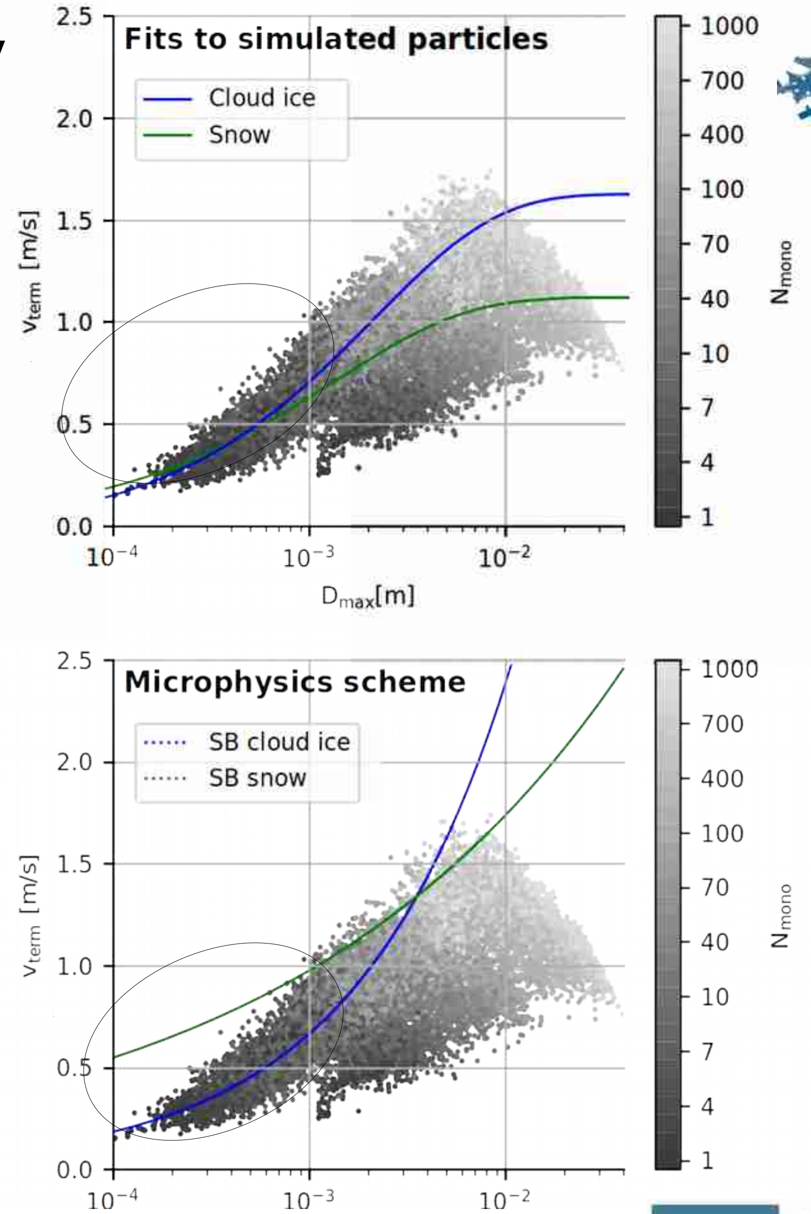
- Observations alone do not provide sufficient information to resolve biases
- We combine an aggregation model and hydrodynamic model to derive consistent
  - mass-size
  - projected area-size
  - velocity-size relations and
  - scattering properties



~100.000 simulated particles (various monomer shapes & monomer number)

Simulated terminal velocity

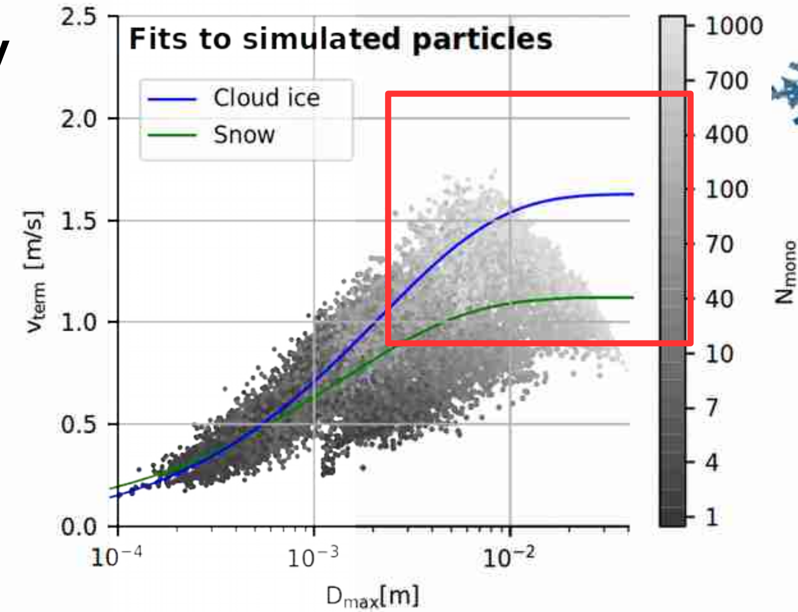
- At small sizes the terminal velocity of cloud ice and snow is similar
- In contrast the SB scheme currently assumes strongly different velocity at same sized cloud ice and snow particles

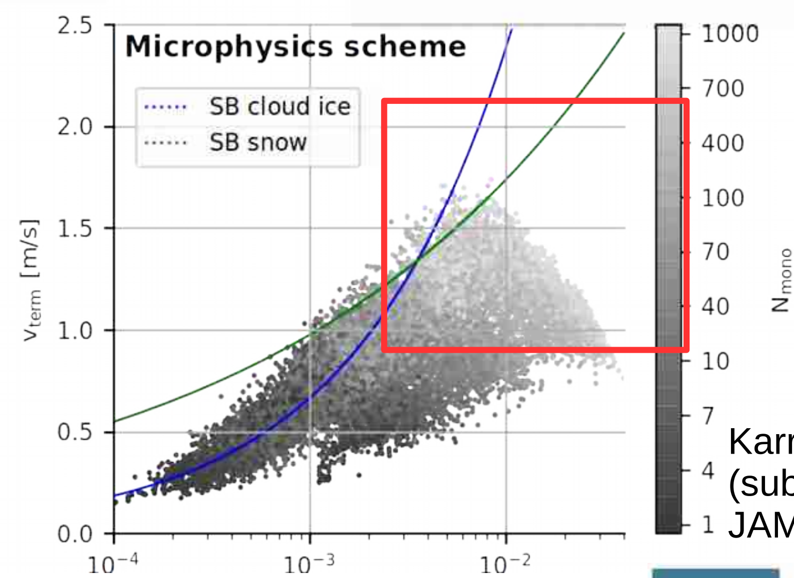


Karrer et al. (submitted to JAMES)

Simulated terminal velocity

- Terminal velocity saturates at large sizes.
- Power law fit, which is currently used in scheme can not represent this saturation



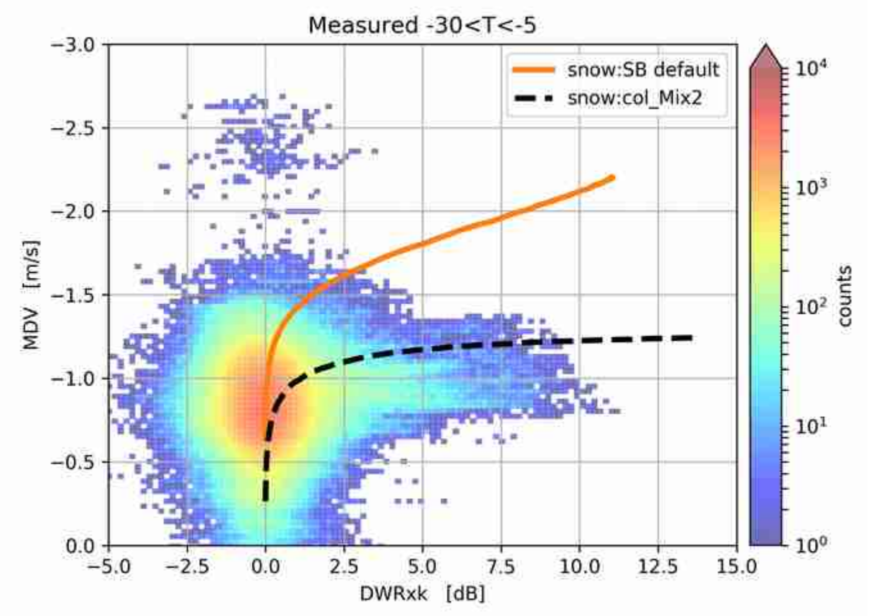


$$K(i,j) = \frac{\pi}{4}(D_i + D_j)^2 |v_{term,i} - v_{term,j}| E_c E_s$$

Karrer et al. (submitted to JAMES)

Summary

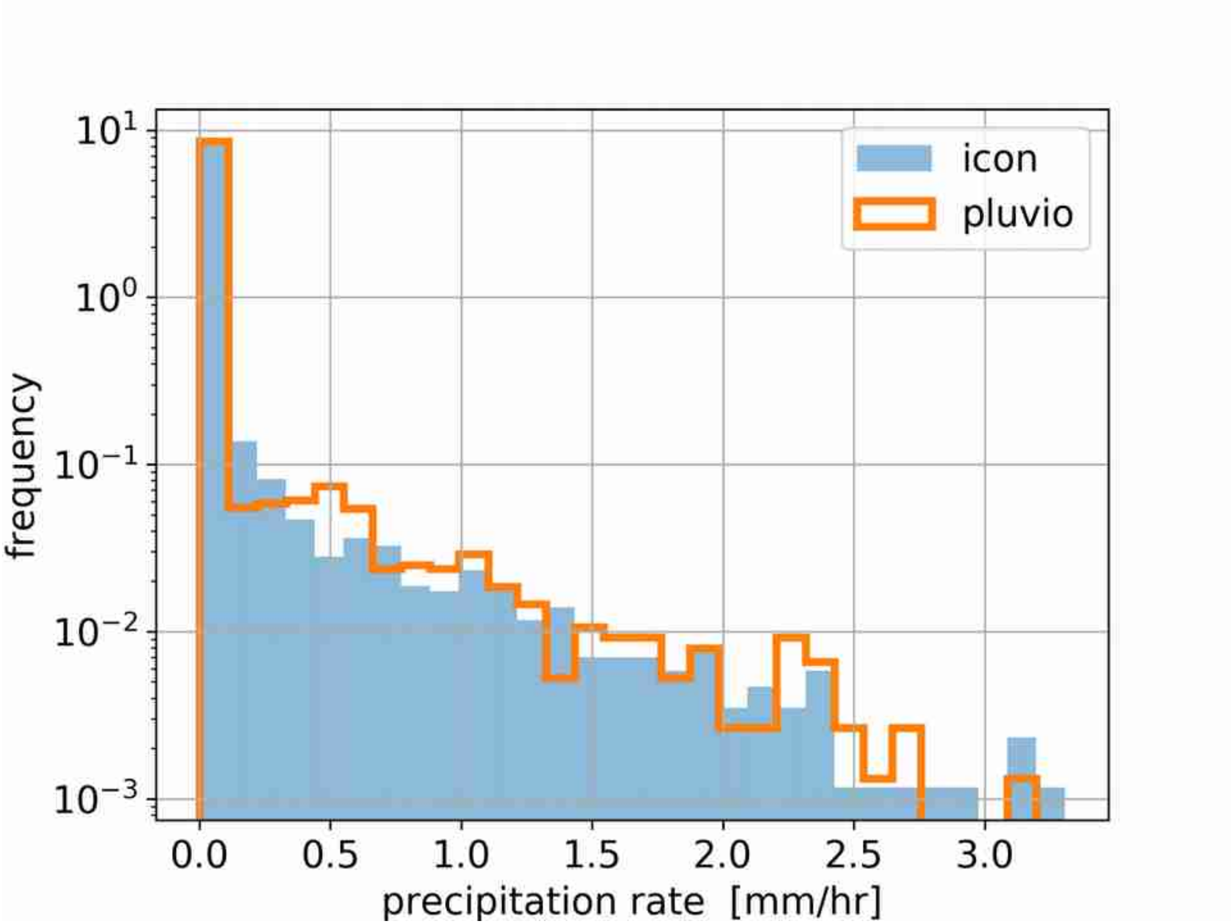
- Statistics of the **combination** of **Doppler** and **multi-frequency radars** revealed **discrepancies** in simulations of **ice sedimentation** and **aggregation**
- **Aggregation modeling** provides new **consistent particle properties** that match well with radar statistics



Next Steps

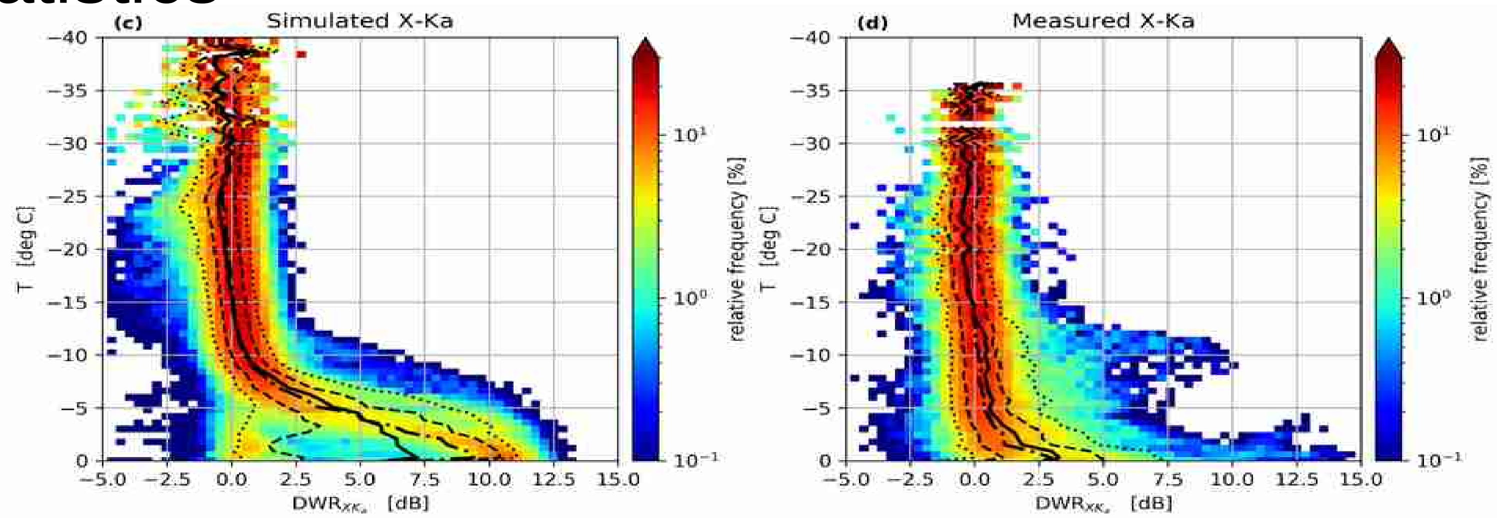
- Use and evaluate newly derived particle properties in ICON simulations
- Adjust additional parameters (e.g. sticking efficiency)
- Extend statistical analysis to rain

Precipitation statistics

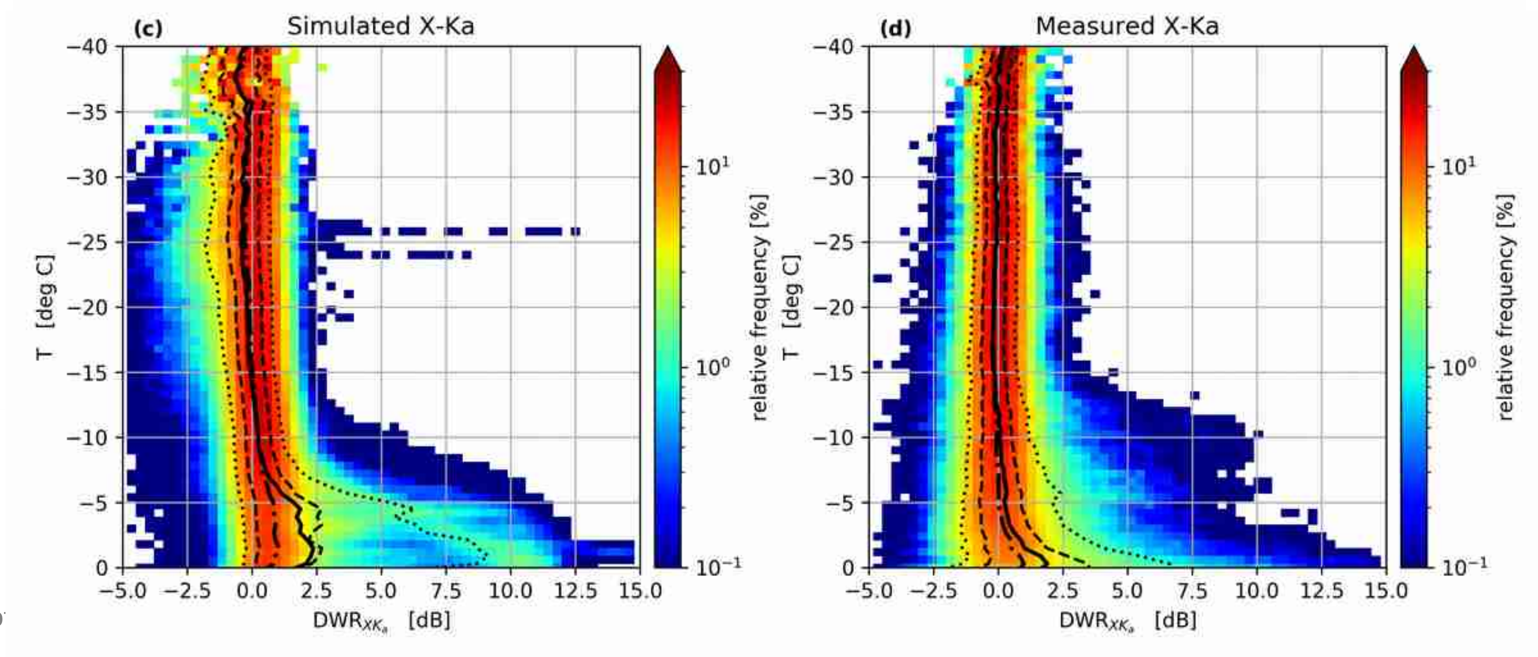


Model-observation comparison - statistics

RR> 1mm

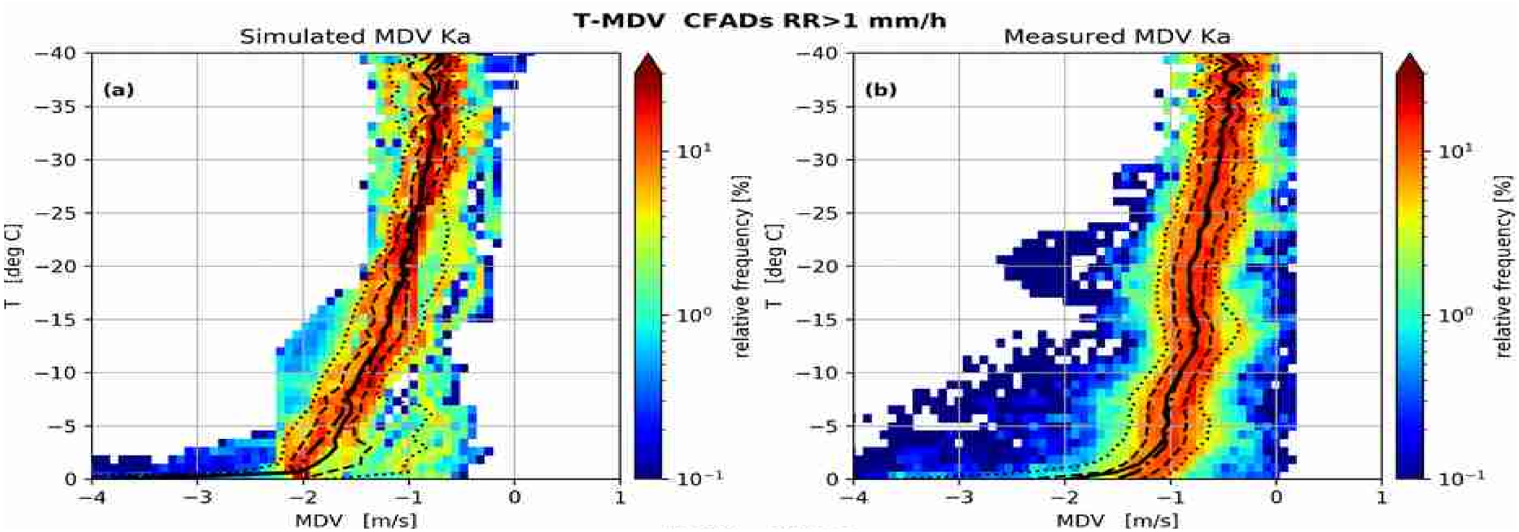


All RR



Model-observation comparison
- statistics

RR>
1mm



All RR