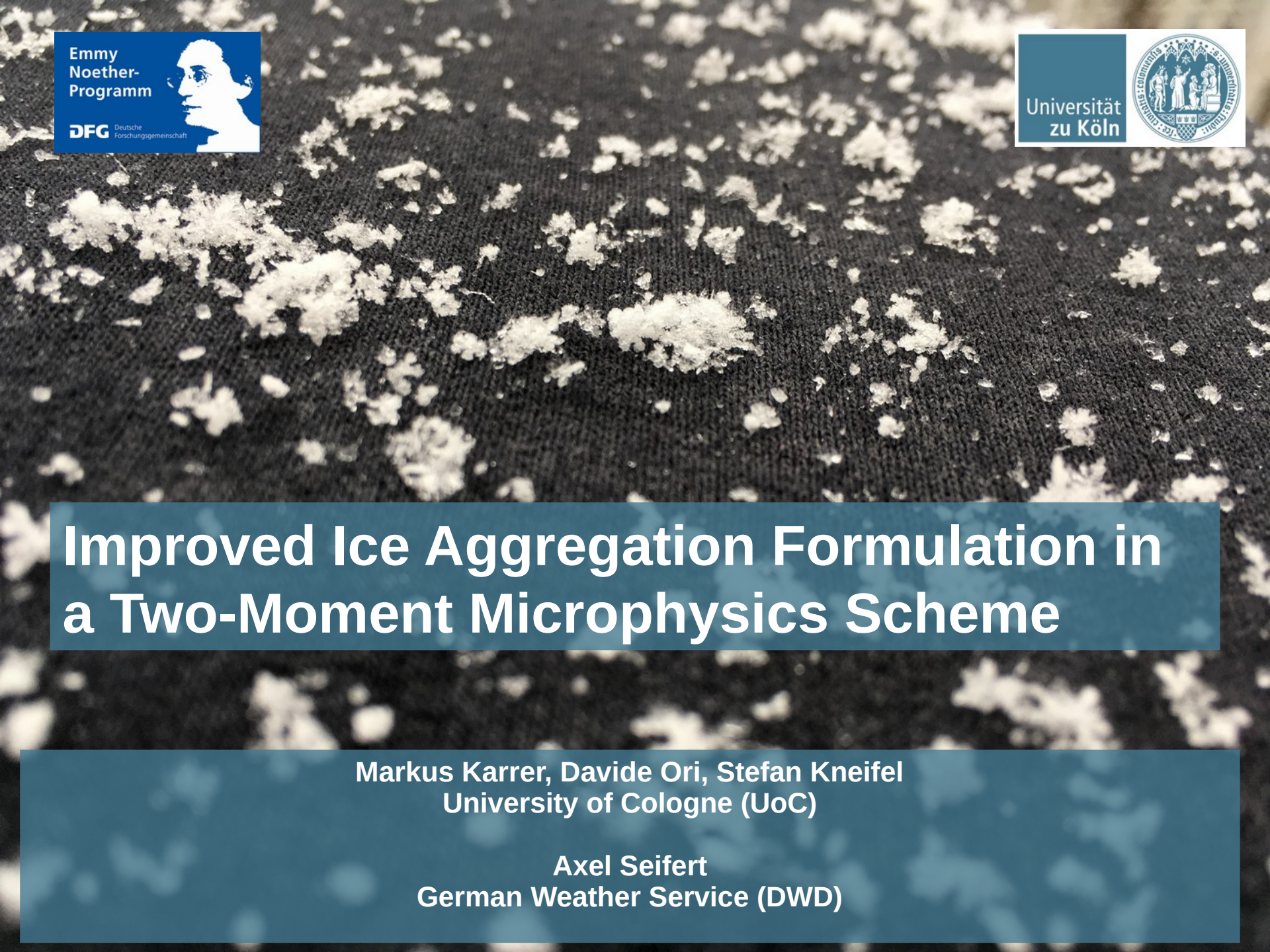


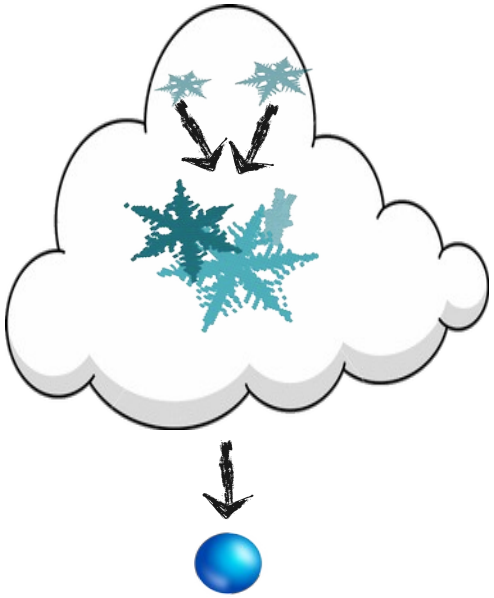
Improved Ice Aggregation Formulation in a Two-Moment Microphysics Scheme

Markus Karrer, Davide Ori, Stefan Kneifel
University of Cologne (UoC)

Axel Seifert
German Weather Service (DWD)

Motivation

- **Aggregation** is important for **precipitation** formation
- Aggregation is **difficult to simulate** because of:
  - not well-known parameters
  - simplified description necessary



Motivation

- **Aggregation** is important for **precipitation** formation
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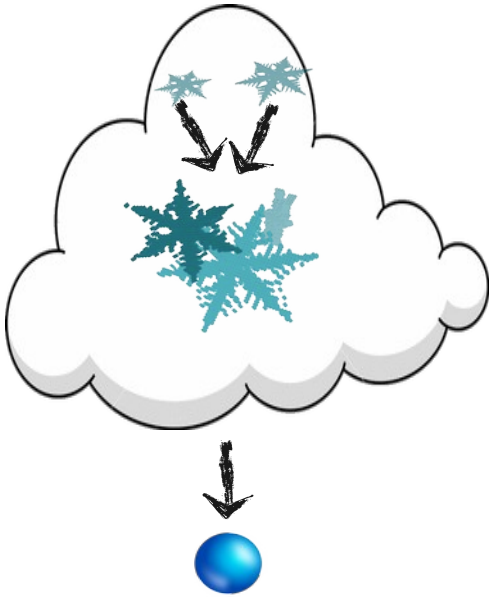
  - simplified description necessary

→ we need **cloud observations**



How can we use **cloud radar** observations to ...

1) **evaluate**

2) **improve**

… the **simulation of aggregation**?

Methods (1)

2-moment microphysics scheme *(Seifert&Beheng 2006)* as part of:

- **simple 1D model**
- **ICON-LEM** (LES version of the ICOsahedral Non-hydrostatic model)

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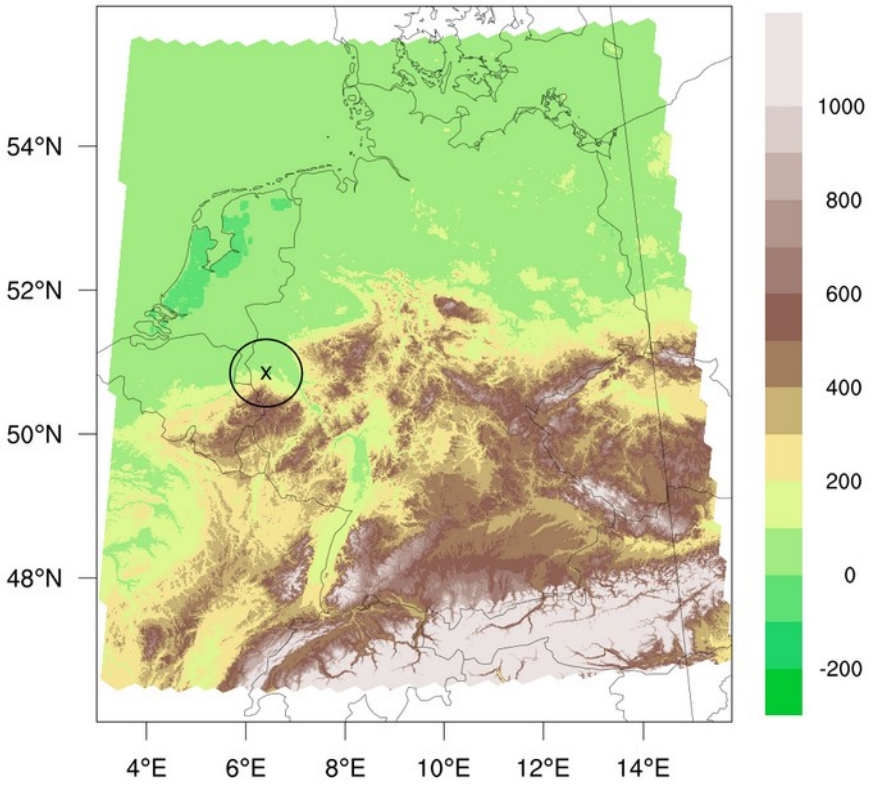

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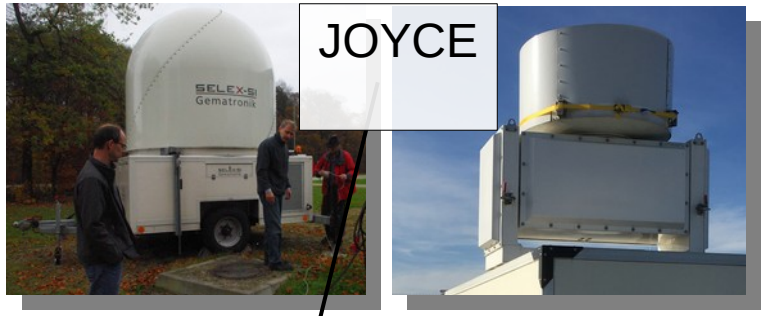
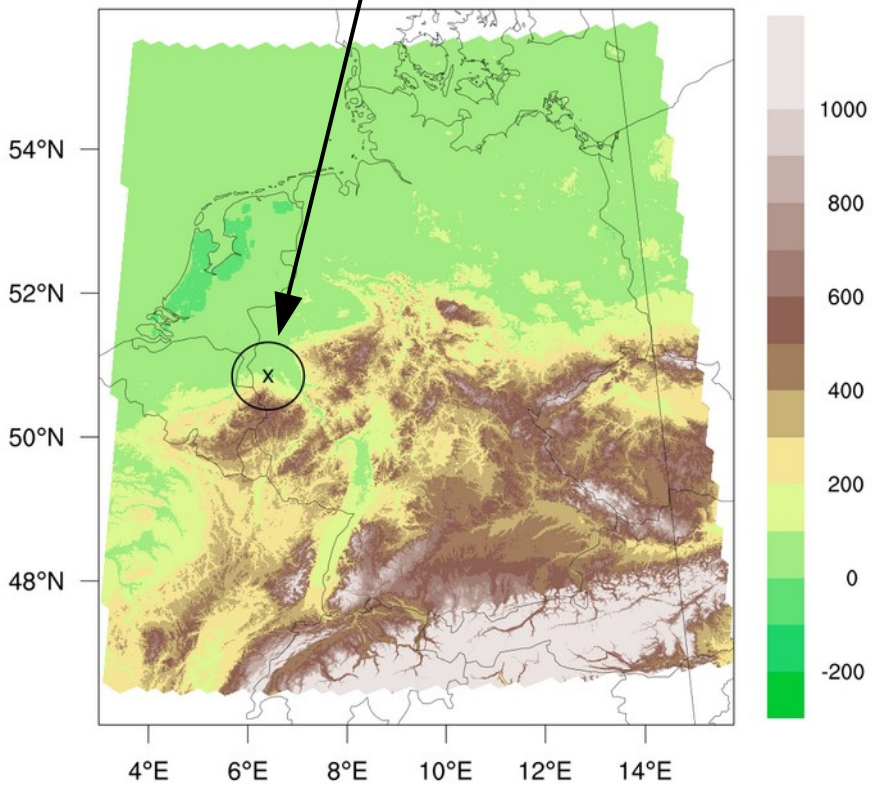
  - Radar forward simulations with **PAMTRA** *(Mech et al., 2020)*

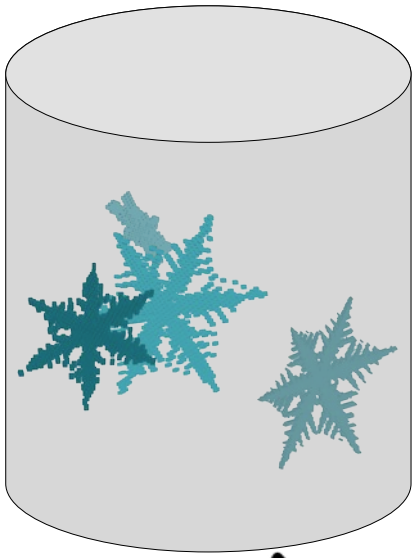




Methods (2): Multi-frequency Doppler Radars

- Mean Doppler velocity (MDV) ~ terminal velocity v_{term}

MDV ~ v_{term}



zenith-pointing

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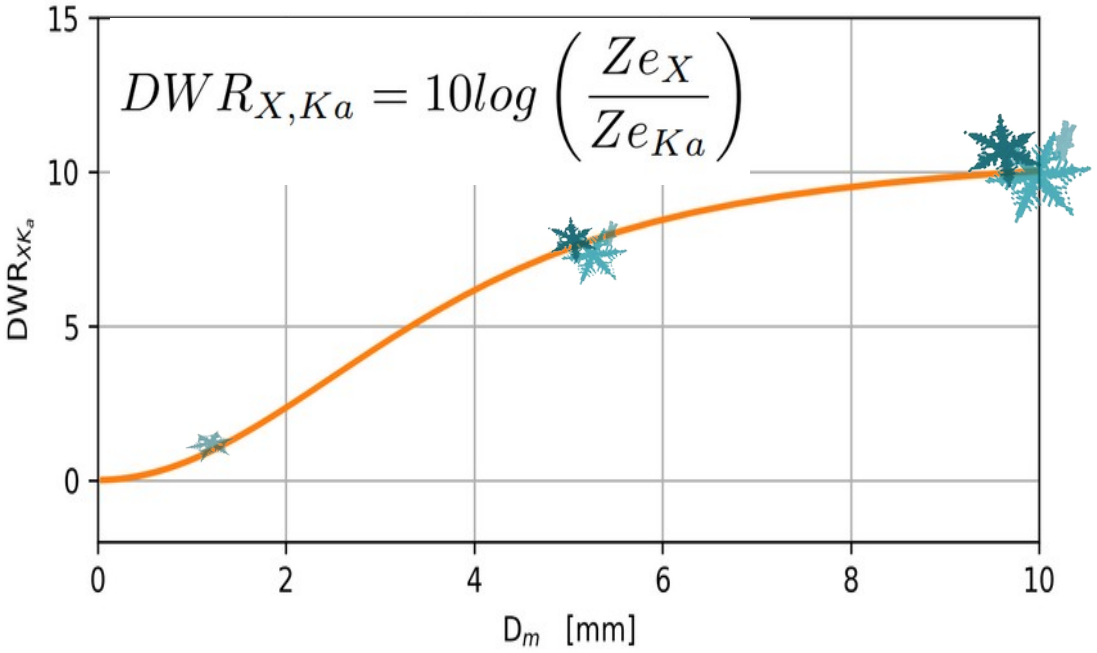
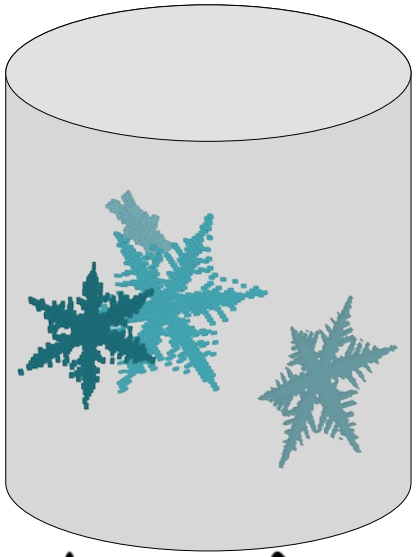
Methods (2): Multi-frequency Doppler Radars

- Mean Doppler velocity (MDV) ~ terminal velocity v_{term}
- Dual-wavelength ratio ~ mean particle size





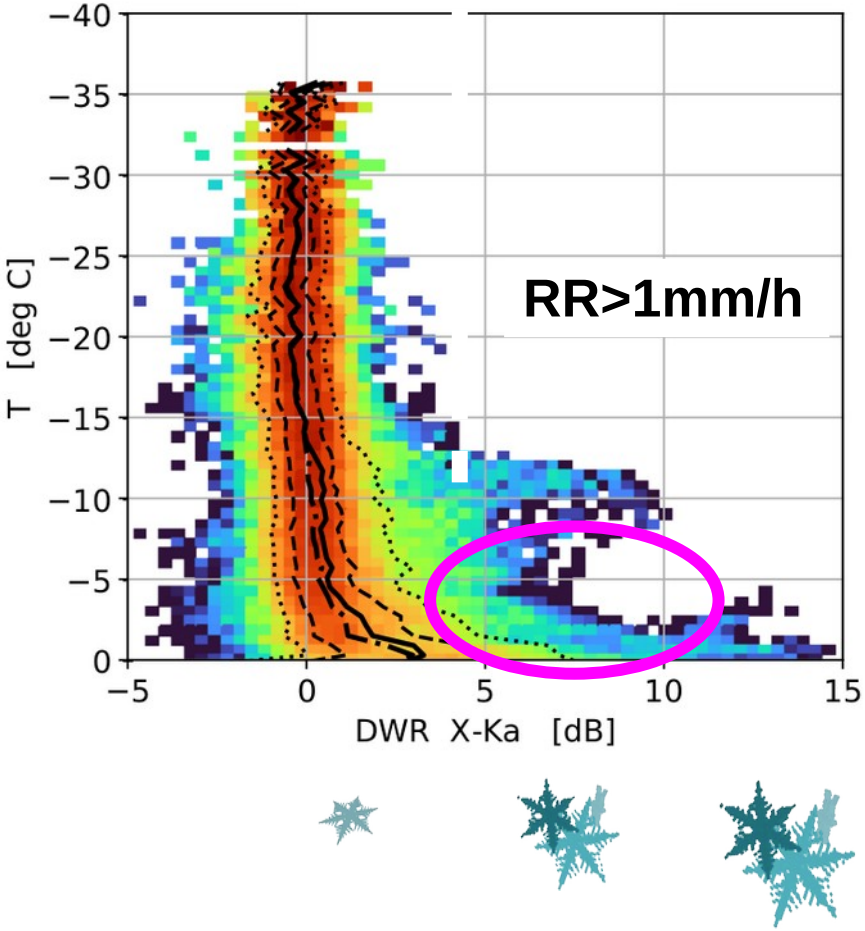
Statistical Comparison

Ori et al. (2020, QJRMS)

DWR ~ D_{mean}

DWR: dual-wavelength ratio
D_{mean}: mean diameter

Observation



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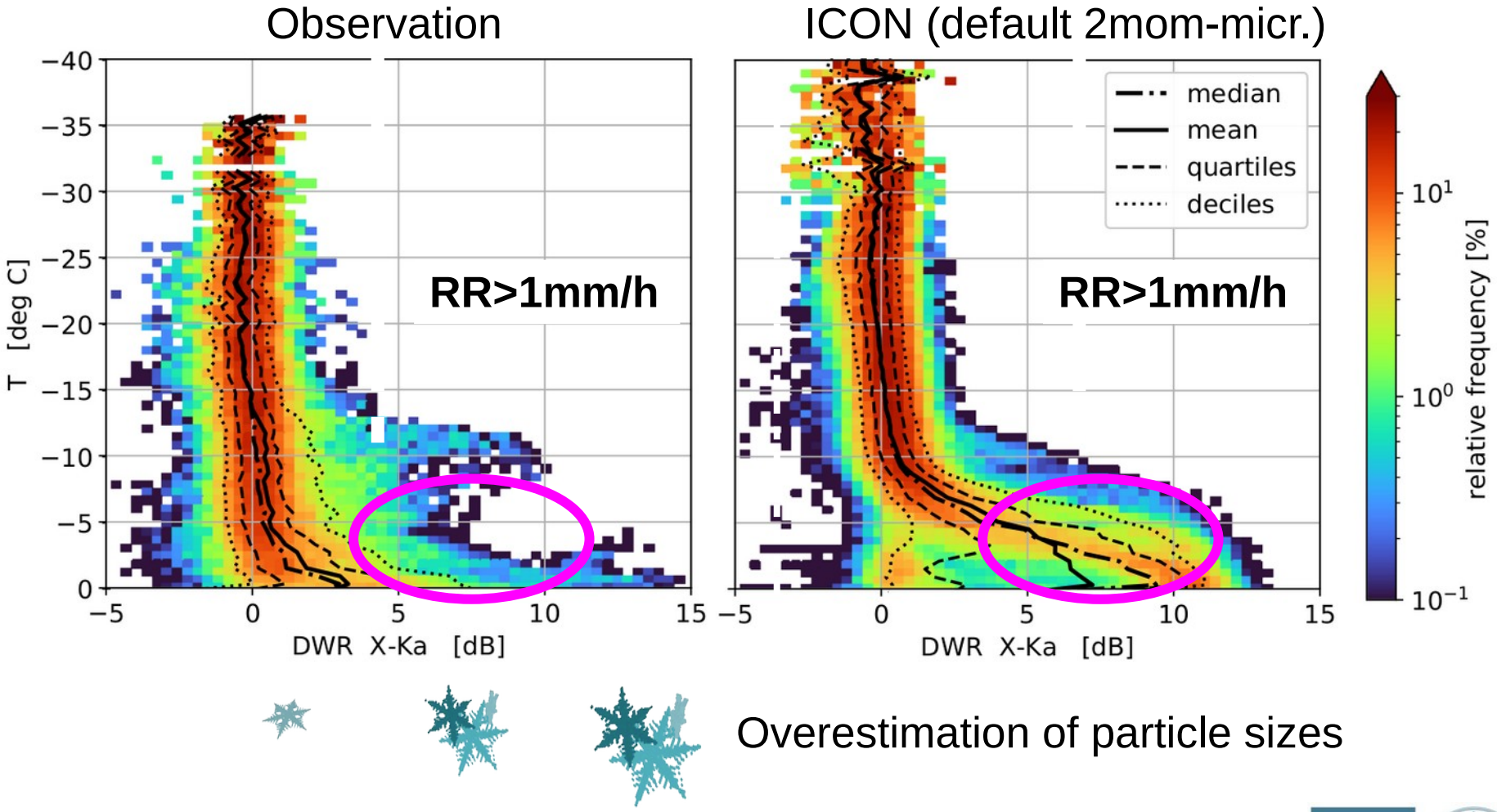

Overestimation of particle sizes

Statistical Comparison

MDV ~ v_{term}

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V_{term}: terminal velocity

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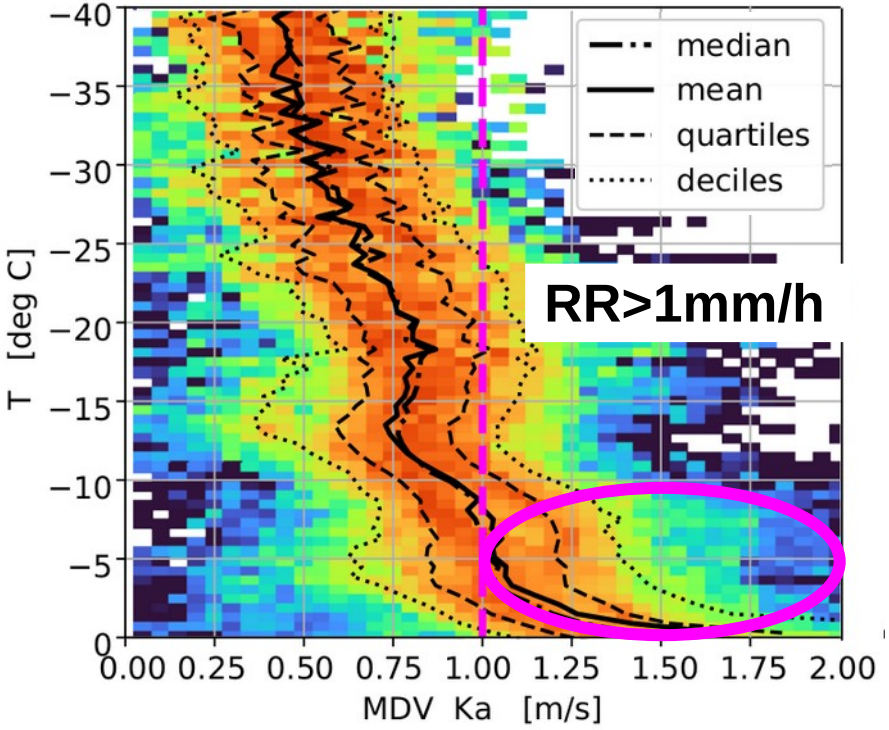

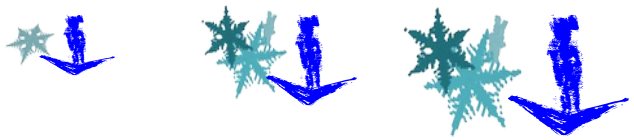

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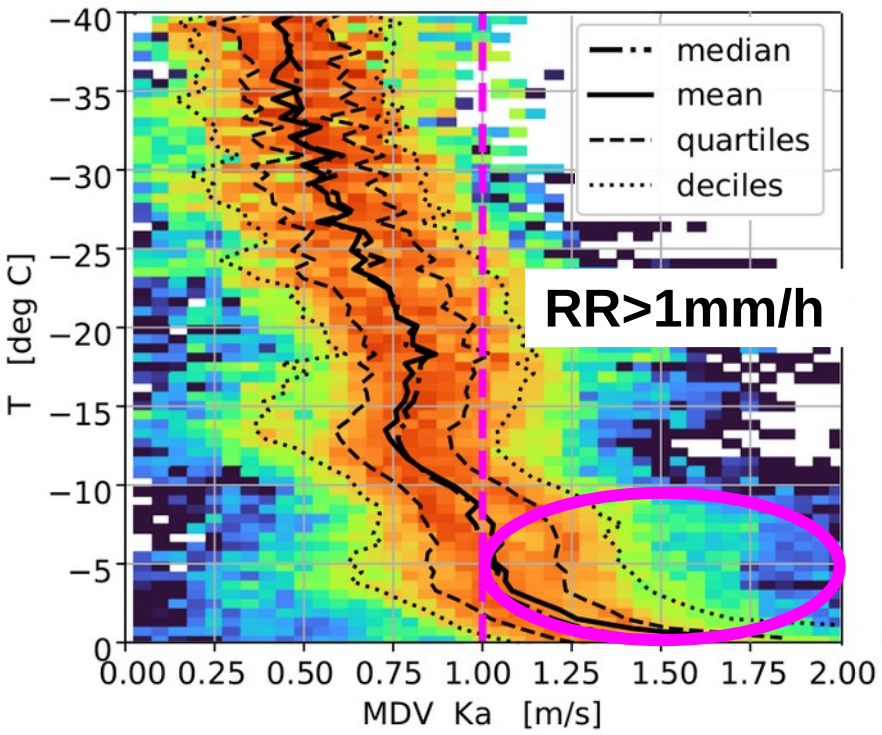
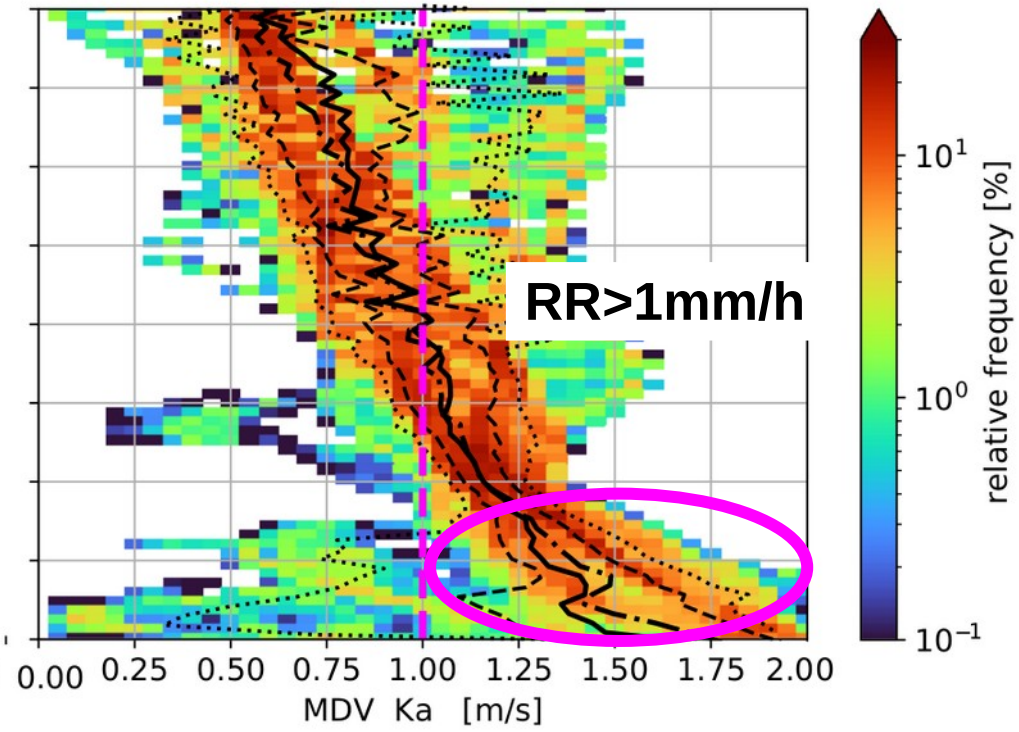
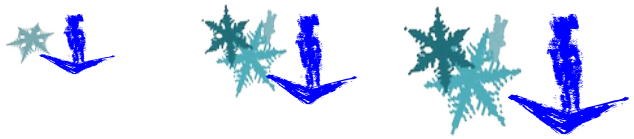


ICON (default 2mom-micr.)





Overestimation of Doppler velocity

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Wrap-up Part I: Evaluation

Evaluated aggregation in 2mom scheme by
statistics of **multi-frequency Doppler** radar observations:

overestimated particle **velocity** & **size**

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Part II: Improvements

How can we **improve** the simulation of aggregation?

Aggregation: what matters?

Aggregation rates:

f: size distribution
m_i, m_j: particle masses

$$\left.\frac{\partial f(m_i)}{\partial t}\right|_{aggregation} = -\int K_{i,j} f(m_i) f(m_j) dm_j$$

Aggregation kernel:

$K_{i,j}$: aggregation kernel
A_{coll}: collision cross-section
Δv_{term}:differential sedimentation
E_{stick}: sticking efficiency

$$K_{i.j} = A_{coll.} \Delta v_{term} E_{stick}$$

Sticking efficiency

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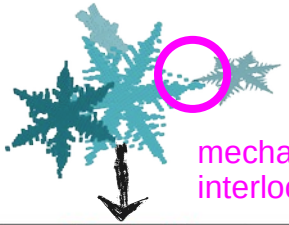
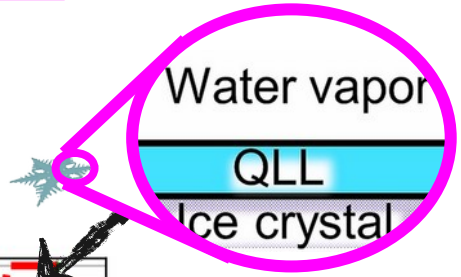
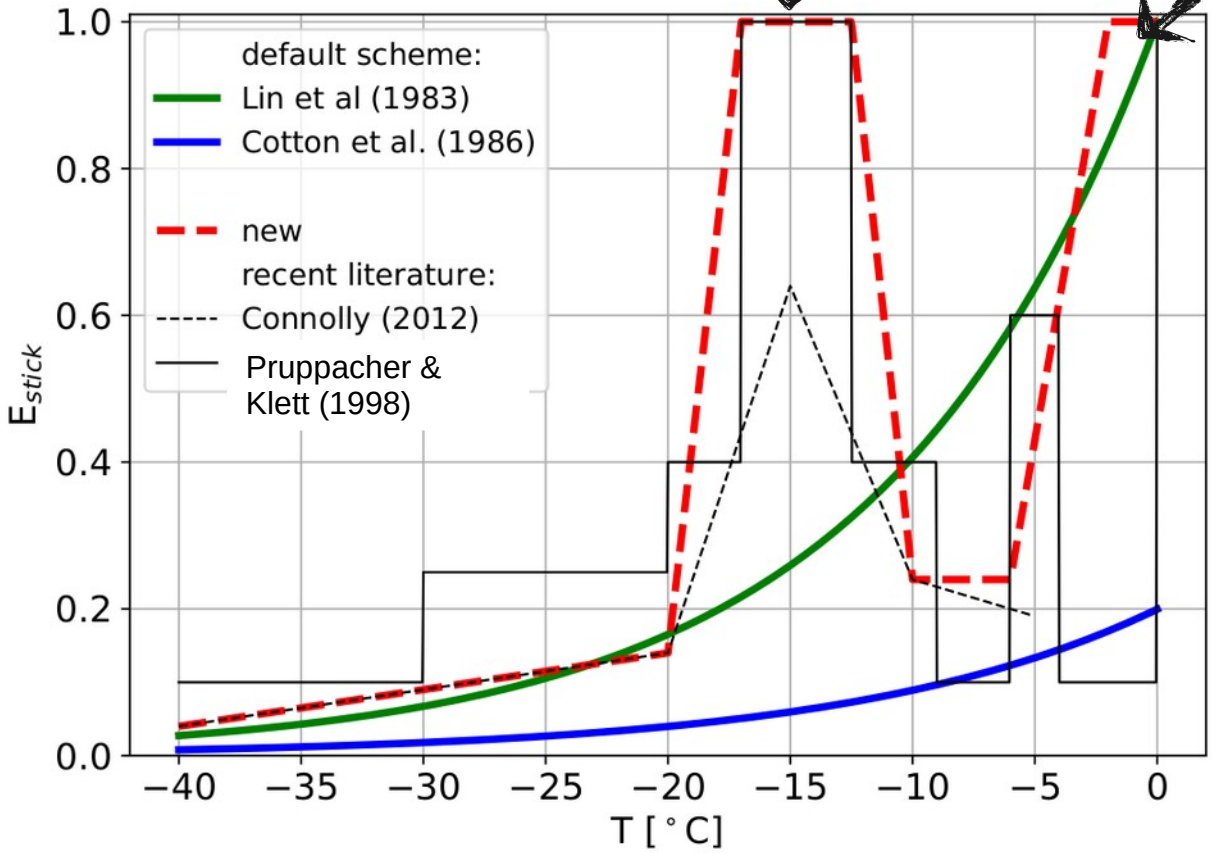


mechanical interlocking



quasi-liquid layer (QLL)



New $\mathbf{E_{stick}}$ formulation considers maximum at ~-15°C

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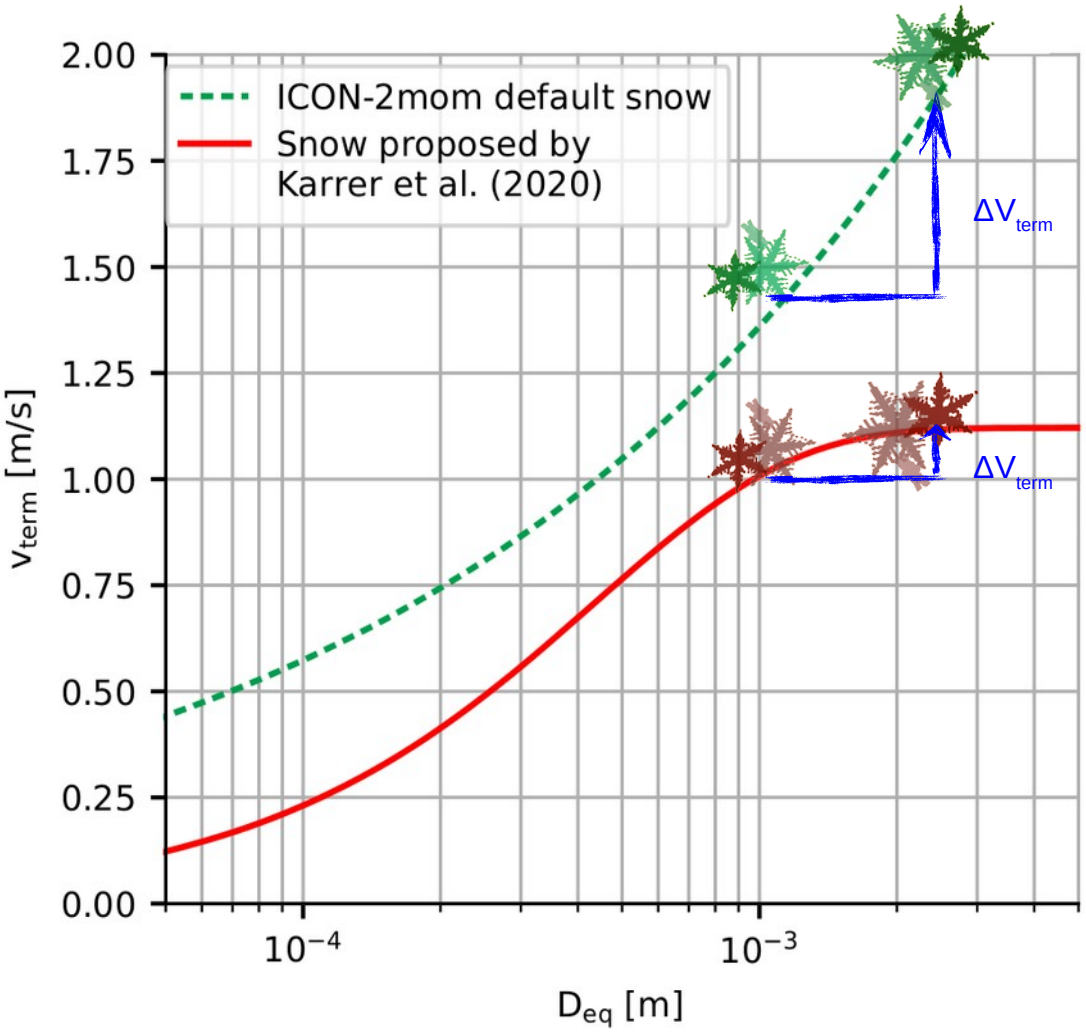
Terminal velocity

$K_{i,j}$: collection kernel
A_{coll}: collision cross-section
Δv_{term}:differential sedimentation
E_{stick}: sticking efficiency

$$K_{i,j} = A_{coll} \Delta v_{term} E_{stick}$$

Karrer et al. (2020, JAMES)



Smaller slope of v_{term} at large sizes reduces Δv_{term}

Collision cross-section

$K_{i,j}$: aggregation kernel
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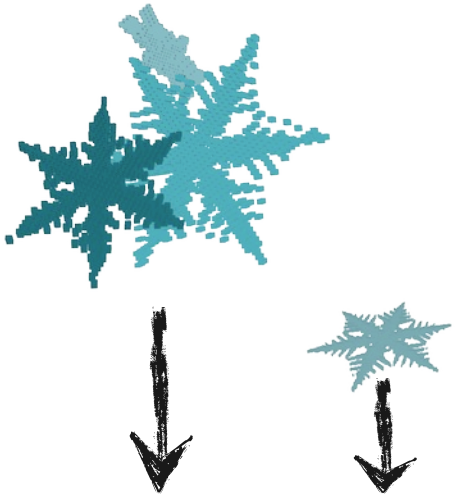
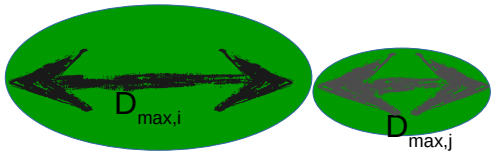
Δv_{term}:differential sedimentation
E_{stick}: sticking efficiency

$$K_{i,j} = A_{coll} \Delta v_{term} E_{stick}$$

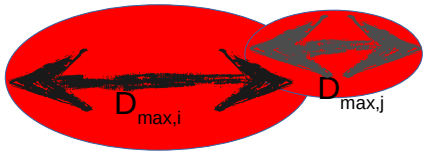


default



A_{coll}: collision cross section

new



Collision cross-section A_{coll} of snowflakes is smaller than circumscribing circles

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Size distribution shape

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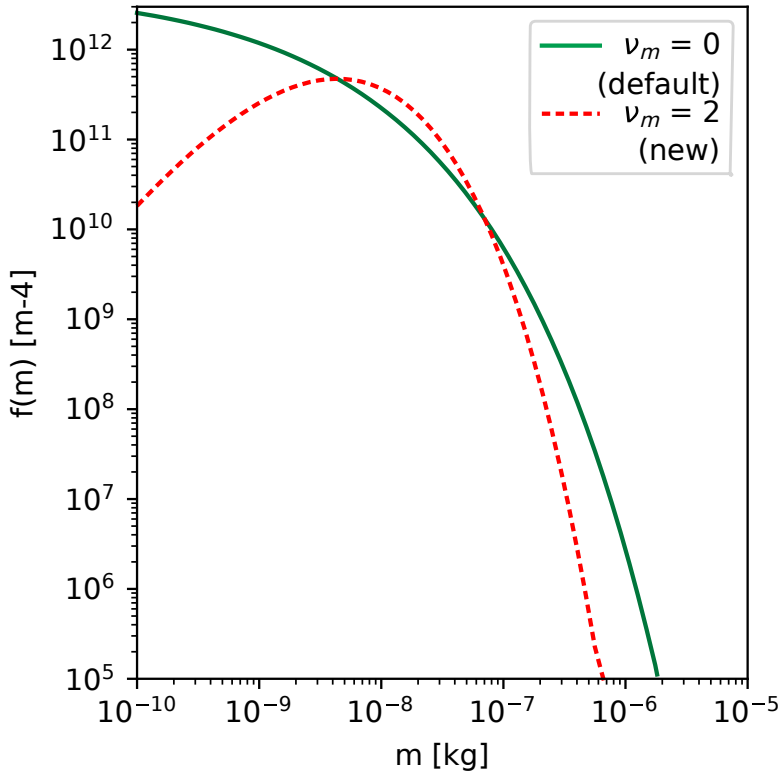

Narrower **size distribution**
→ less diversity
→ smaller Δv_{term}

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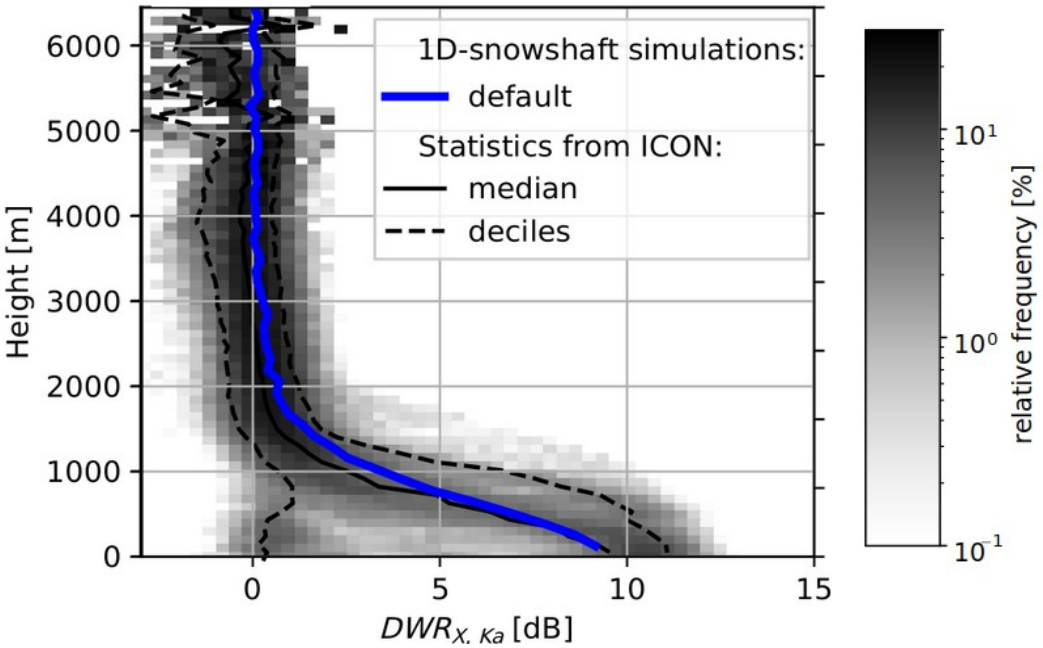
„Snowshaft“ simulations

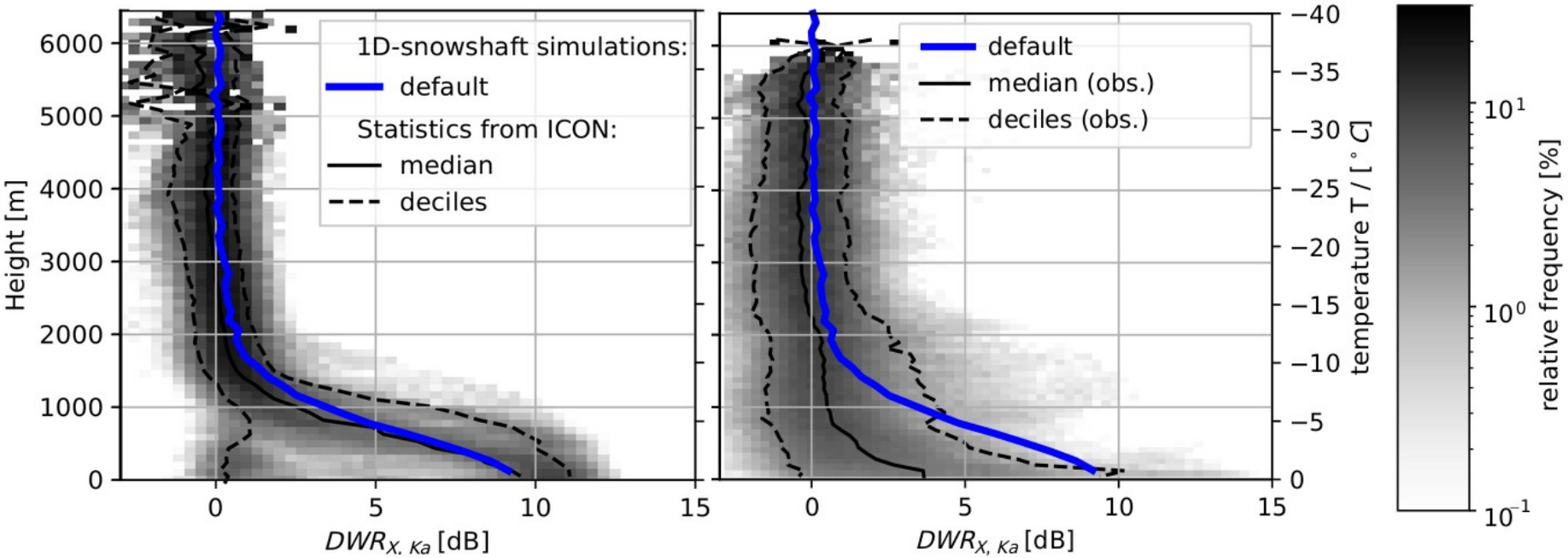
a) Setup idealized simulations (constant T,RH profile; no nucleation or advection)



„Snowshaft“ simulations can reproduce characteristics of ICON simulations

„Snowshaft“ simulations

a) Setup idealized simulations b) Compare with observed CFADs



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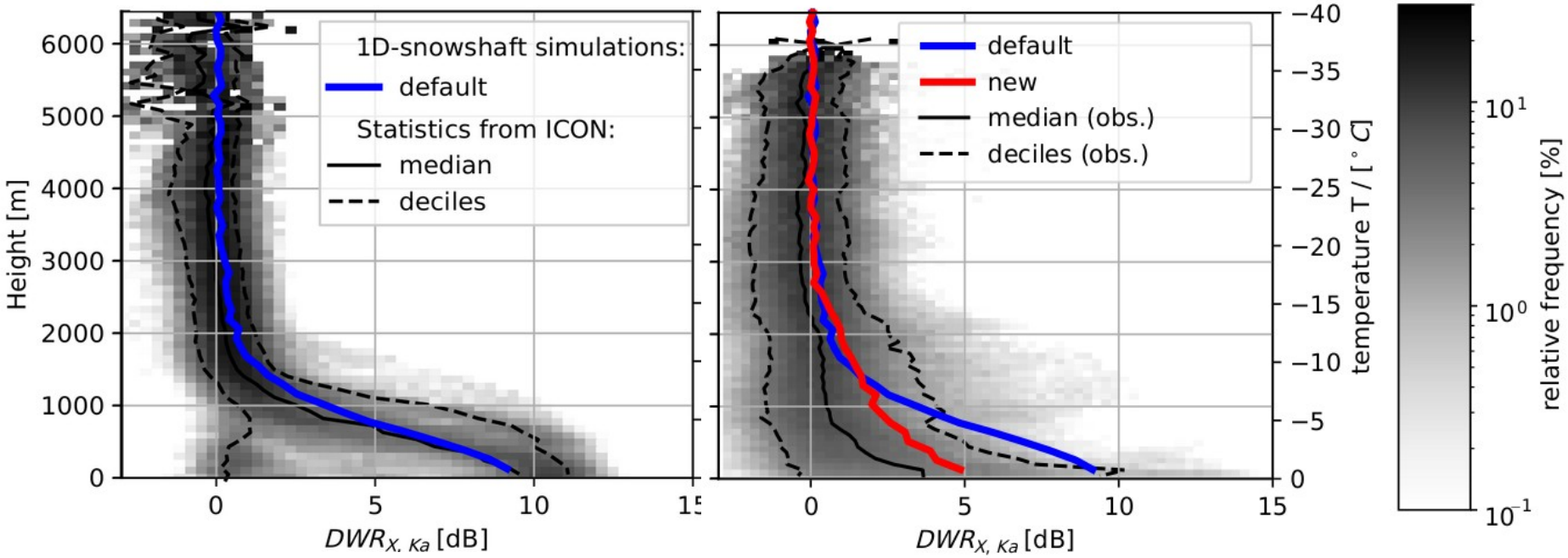


„Snowshaft“ simulations can reproduce characteristics of ICON simulations

New setup fits several observables (Ze, MDV, DWRs) well

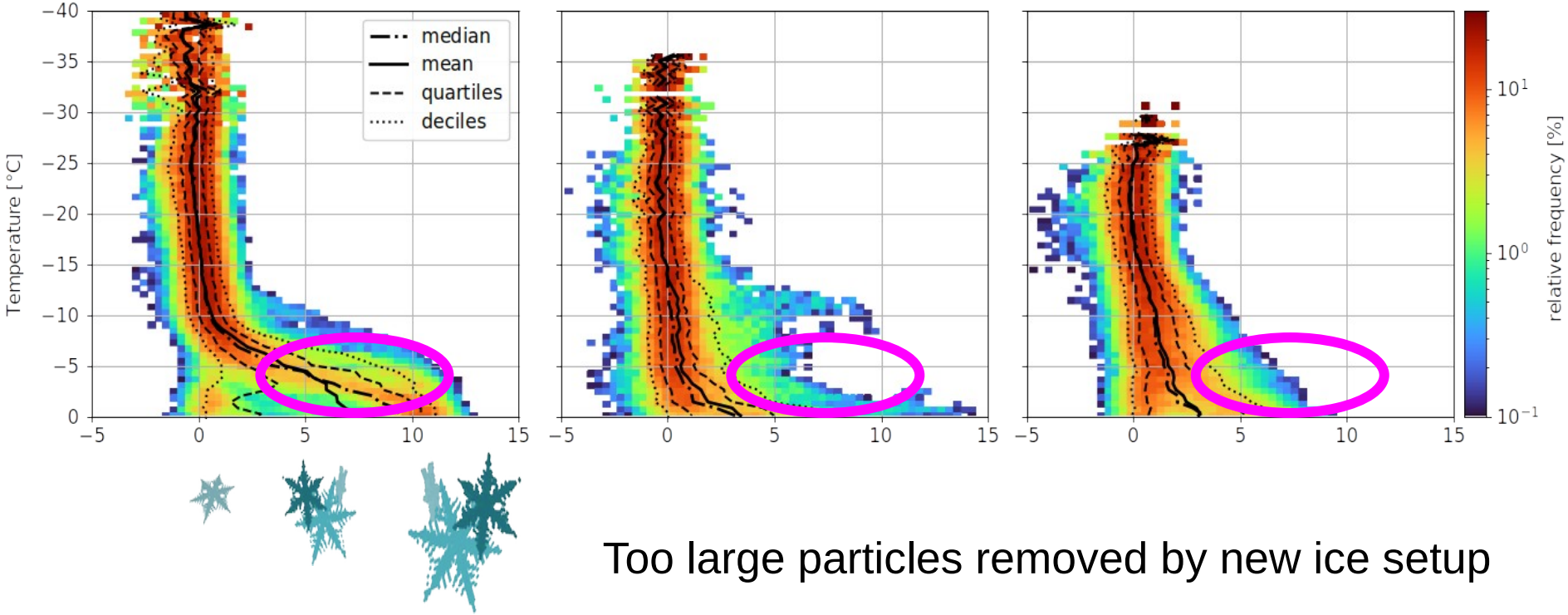
Statistical comparison including new setup

Karrer et al. (in preparation)

ICON (default 2mom-micr.)

Observation

ICON (new ice setup)



Too large particles removed by new ice setup

Statistical comparison in new setup

Karrer et al. (in preparation)

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Observation

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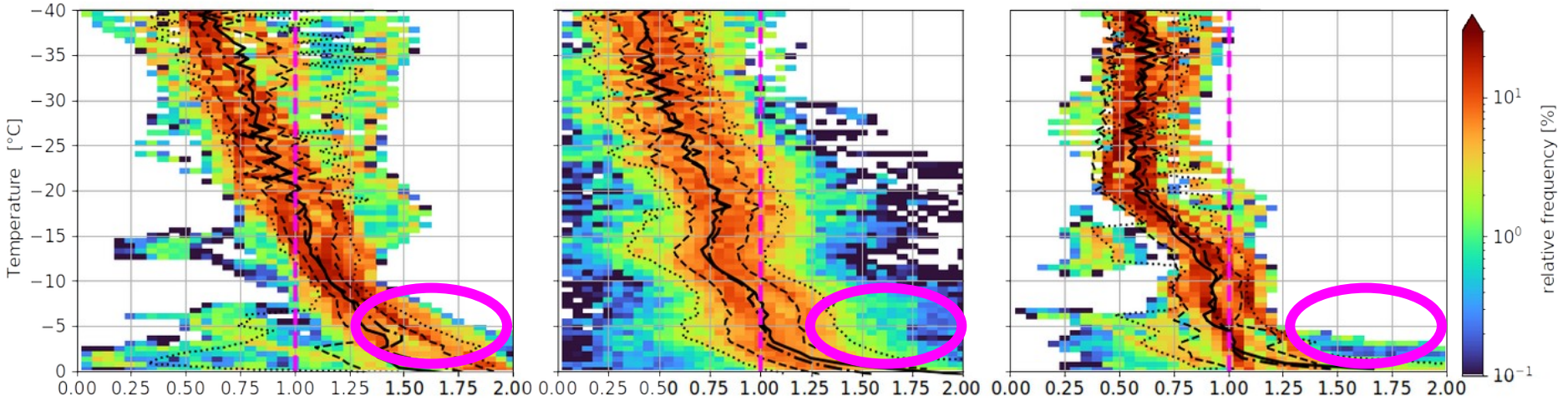
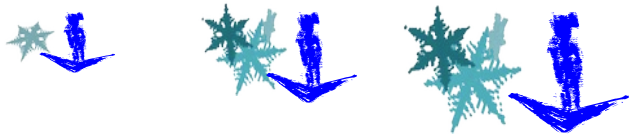




Too fast particles removed by new ice setup

Now slightly to slow (too weak riming?)

Summary

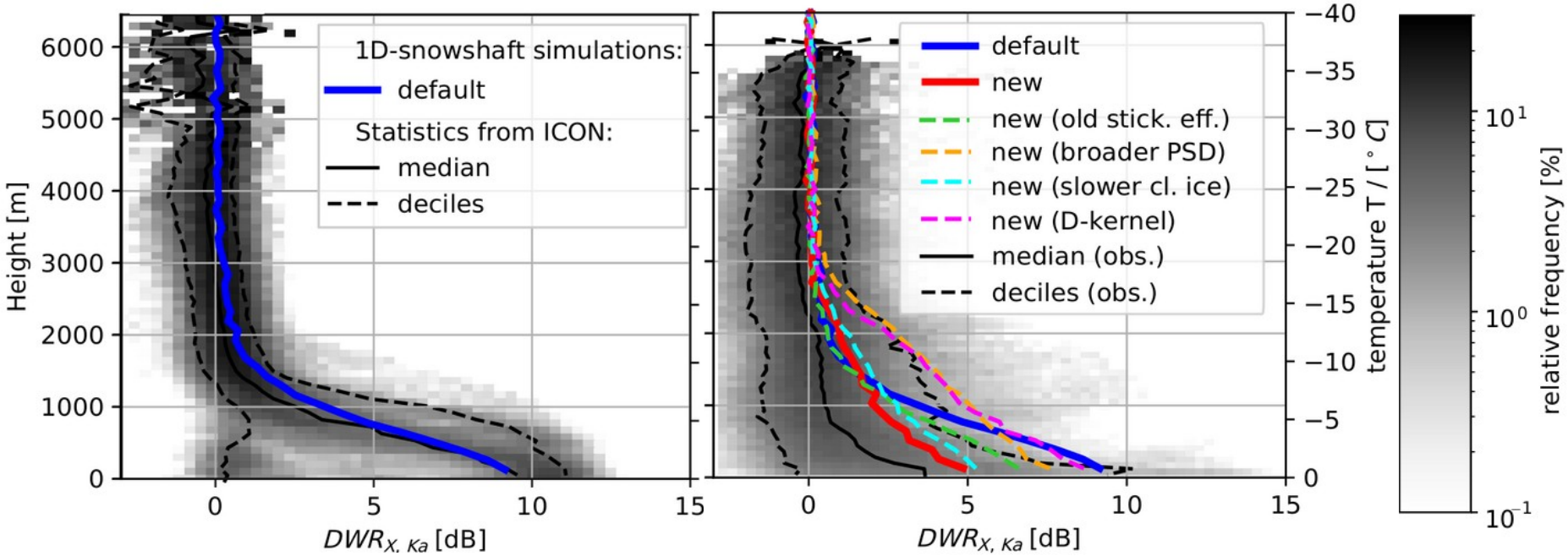
- **Evaluated** and **improved** the simulation of **aggregation with:**
  - **statistics** of **multi-frequency Doppler** radar observations
  - **simple 1D model** setup
- reduced biases in **particle velocity & size** in ICONs 2mom scheme

Outlook

- investigate connection of **ice** and **rain particle sizes**

„Snowshaft“ simulations

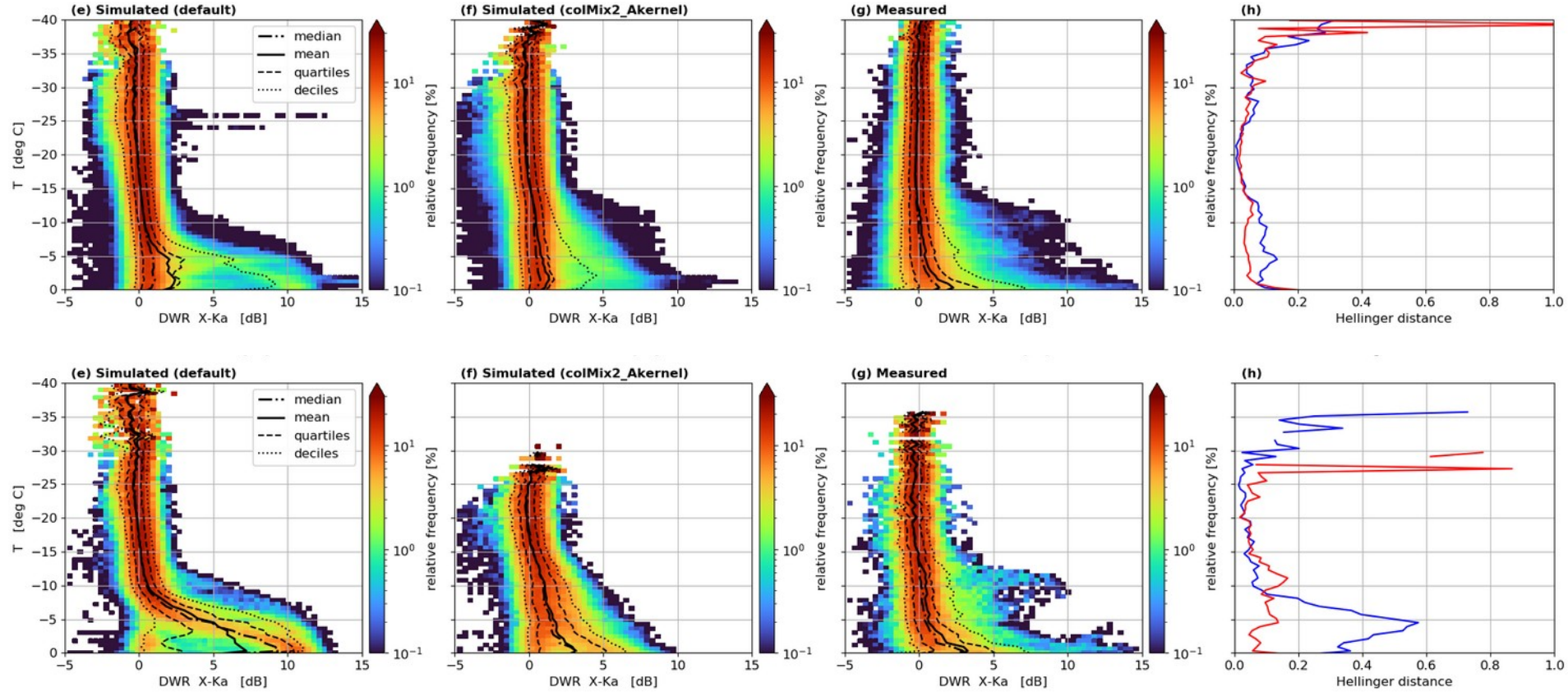
a) Setup idealized simulations b) Sensitivity analysis



„Snowshaft“ simulations can reproduce characteristics of ICON simulations

PSD width and A- vs. D-kernel matters must

DWRxk-T (top: full statistics, bottom: RR>1mm)



Precipitation statistics at JOYCE