Constraining fall speed of unrimed particles by cloud radar observations and novel modeling techniques

M. **Karrer**[1], J. Dias Neto[1], S. Kneifel[1], D. Ori[1], V. Schemann[1], A. Seifert[2], C. Siewert[2]
[1]University of Cologne, Institute for Geophysics and Meteorology
[2]German Weather Service (DWD)

1. Motivation

Ice particle **sedimentation** and **aggregation** are key processes for precipitation development. However, poorly constrained parameters (e.g. **terminal velocity of ice particle**) and bulk scheme limitations (e.g. **categorization**) hamper a more realistic representation of these processes.

We utilize **LES (ICON-LEM)** simulations (forced by a NWP model), **cloud radar** observations, a **Lagrangian Particle model** and **aggregation model** to constrain assumptions and parameters in **bulk schemes**.

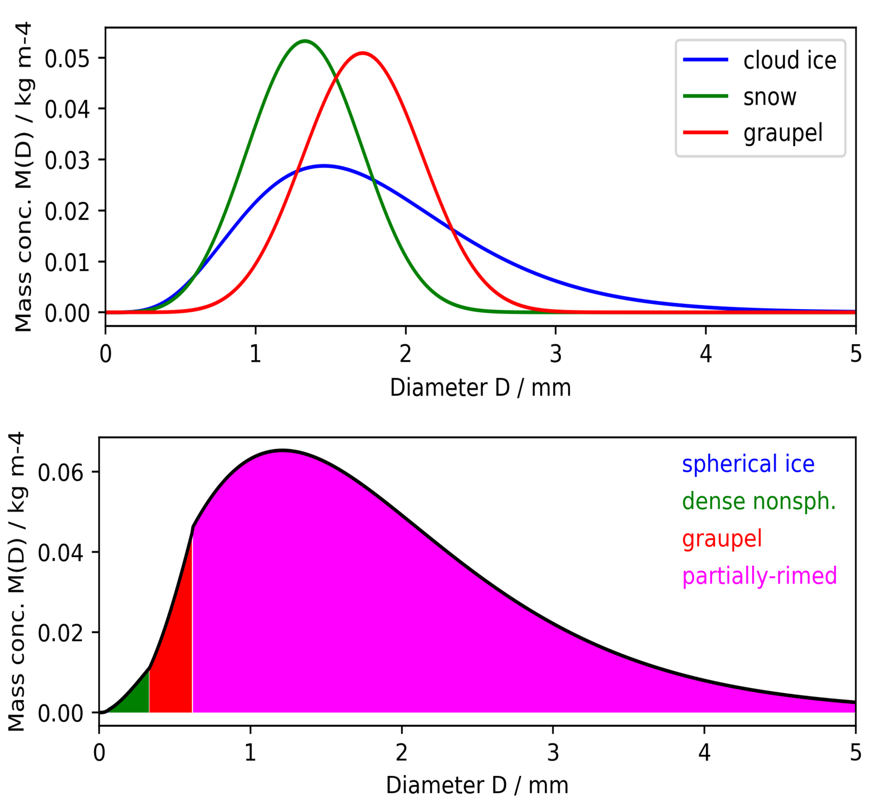
2. Methods: Bulk microphysics schemes and a Lagrangian Particle Model

Bulk schemes:	***Representation of the ice phase***
Seifert-Beheng two-moment scheme **(SB) [1]**	4 ice categories (**cloud ice, snow**, graupel, hail) with 2 predicted moments of the particle size distribution (PSD); fixed properties (e.g. terminal velocity size relation) for each category.
Predicted Particle Properties **(P3) [2]**	**Single ice category**; Predicted particle properties (rime volume and rime density) along with 2 predicted moments of the PSD.

Lagrangian Particle Model:

Monte-Carlo Particle Model **McSnow [3]**	Modeling of superparticles and their interactions; **Size distribution evolves freely**; 5 predicted properties for each superparticle (see Box 4).

We focus on **aggregation and sedimentation**, where we find **discrepancies** when **compared to cloud radar observations** (Box 3), which we further investigate in **idealized 1D-simulations** (Box 4) and by analyzing **simulated aggregates** (Box 5).



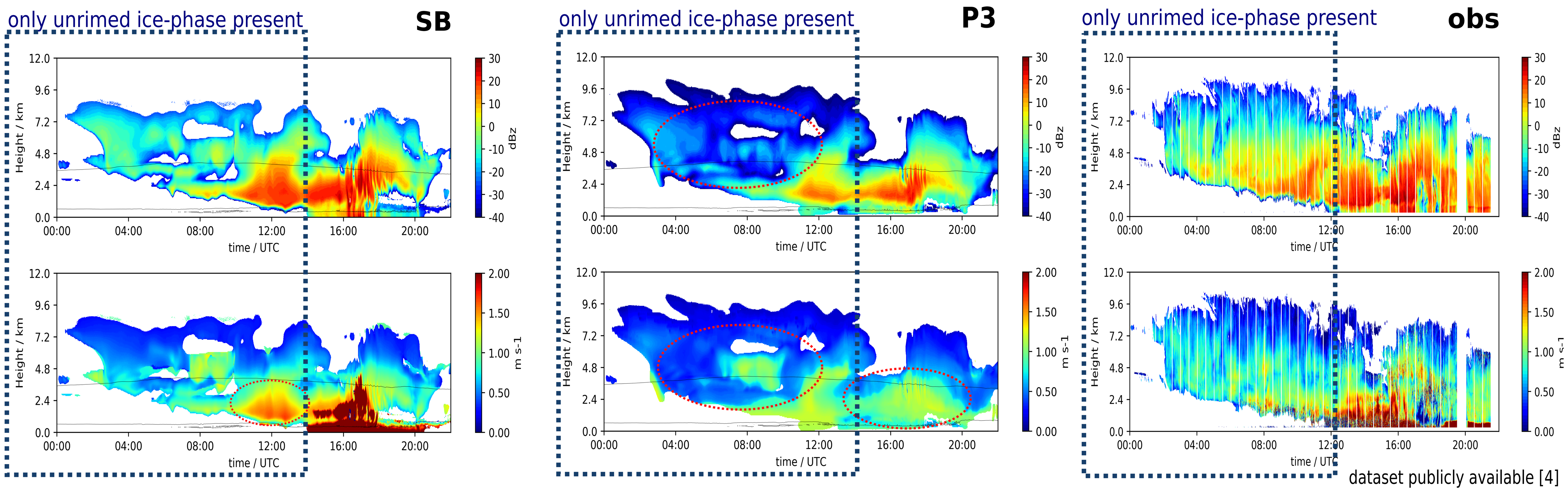
Example of size distributions in the bulk schemes: grid box containing rimed and unrimed particles (top for SB; bottom for P3)

3. Bulk scheme evaluation: Case study (24th November 2015, Jülich)

Radar observable

Reflectivity (Ka-Band): Correlated to mean mass and number concentration

Doppler velocity: Reflectiv. weighted terminal velocity + vertical air motion



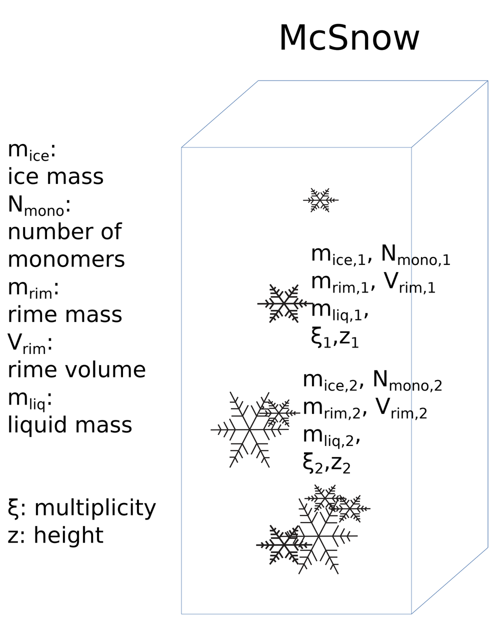
dataset publicly available [4]

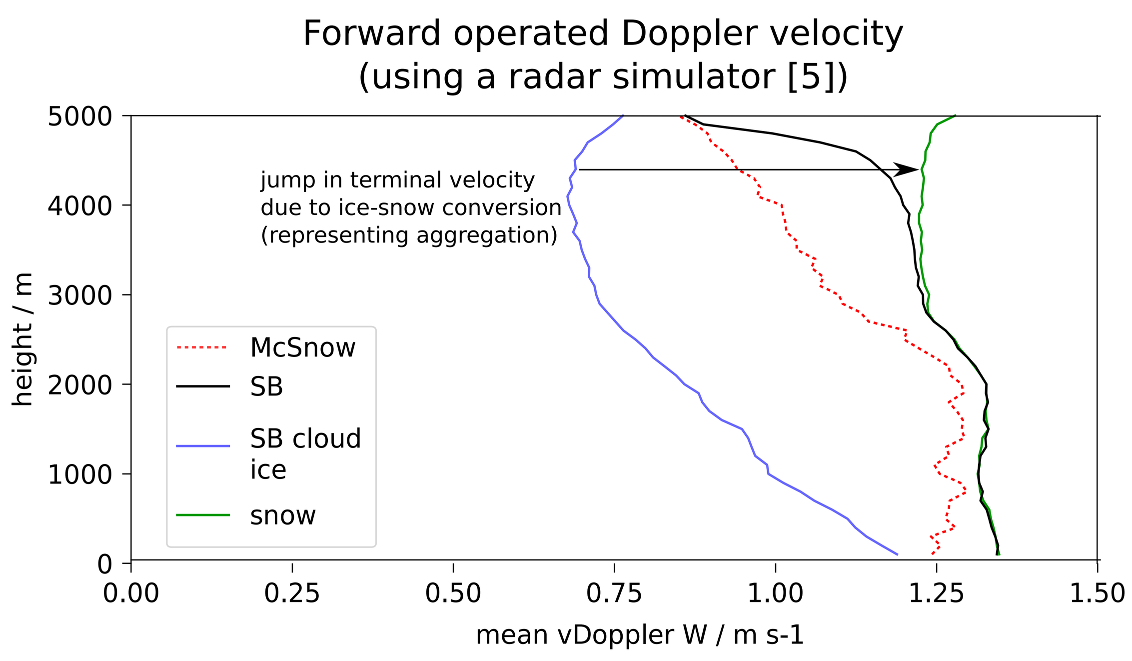
Interpretation:

Good match of cloud structure by both schemes; Underestimated reflectivity in the morning by P3.

SB: **Overestimated terminal velocity** by large **snow**; sharp increase (see Box 4).
P3: **Underestimated terminal velocity** (unrimed/rimed).

4. Bulk and Lagrangian model in observational space (idealized 1D-simulations)

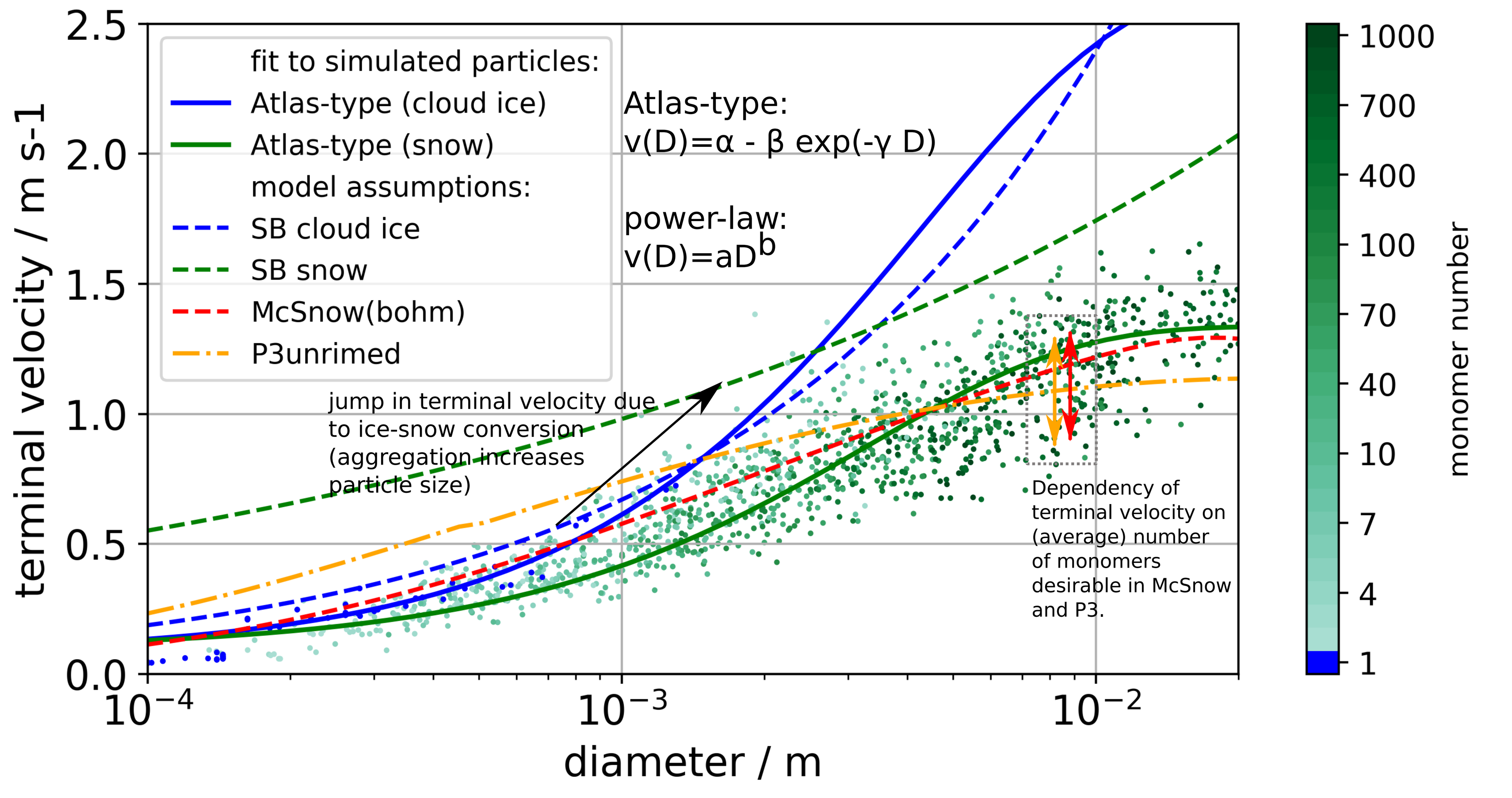




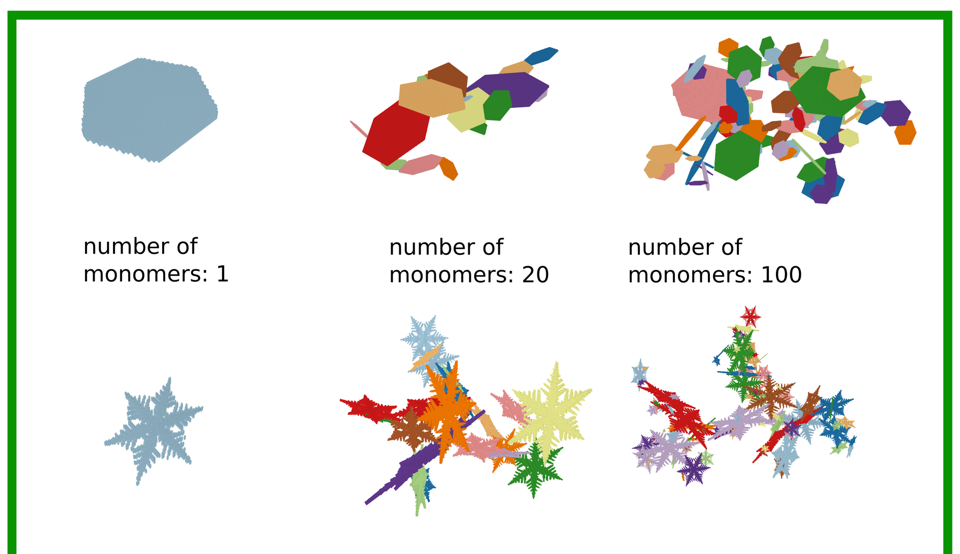
Left: Schematic of McSnow; Right: Vertical profiles of synthetic mean Doppler velocity based on idealized simulations (linear temperature profile: -30°C to 0°C; constant supersaturation over ice: 1%

- **Continuous increase** of Doppler velocity in **McSnow** due to explicit modeling of PSD and terminal velocity relation (see Box 5).
- **Sharp increase** of Doppler velocity in **SB** due to **conversion** of cloud ice (blue) to snow (green). → Evaluate assumptions by aggregation model (Box 5)

5. Comparison of terminal velocity parameterizations with simulated aggregates



Top: Terminal velocity as assumed by the different models and calculated from the simulated aggregates of plates (using the hydrodynamic model of [6])
Bottom: Examples of a aggregates of plates and dendrites simulated with the aggregate model from [7]



Aggregation model [7]

1. Aggregation model shows **continuous transition between monomers and aggregates**.
2. Terminal velocity of large particles **saturates** (in contrast to power-law relation).
3. **Atlas-type** velocity approach [8] **matches** terminal velocity of **small and large particles.**

6. Conclusion & Outlook

- Radar simulator **allows to compare** different **models** with **observations** in observational space.
- Aggregation model shows **smooth transition** and **saturation at large sizes** of the terminal velocity.
- Particle geometries from aggregation model and **Atlas-type** velocity ansatz could **overcome** current **discrepancies**.

- **Derive particle properties** (e.g. fall speed) as a function of the **number of monomers** using an aggregation model [5] and hydrodynamic theory.
- Use newly derived particle properties in SB (including Atlas-type fits) and McSnow and **evaluate impact of changes on aggregation and precipitation**.

[1] Seifert, A., and Beheng K.D. (2006). "A two-moment cloud microphysics parameterization for mixed-phase clouds. Part 1: Model description." MAP
[2] Morrison, H. and Milbrandt J. (2015). "Parameterization of cloud microphysics based on the prediction of bulk ice particle properties. Part I: Scheme description and idealized tests". JAMES
[3] Brdar, S., and Seifert A. (2018). "McSnow: A Monte-Carlo Particle Model for Riming and Aggregation of Ice Particles in a Multidimensional Microphysical Phase Space." JAMES
[4] Dias Neto, J. et. al. (2018). "The TRIple-frequency and Polarimetric radar Experiment for improving process observation of winter precipitation." ESSD, under review
[5] Maahn M. (2015). "Exploiting vertically pointing Doppler radar for advancing sniw and ice cloud observations" PhD thesis
[6] Böhm J. (1992). "A general hydrodynamic theory for mixed-phase microphysics. part i: Drag and fall speed of hydrometeors." AR
[7] Leinonen, J. (2013). "Impact of the microstructure of precipitation and hydrometeors on multi-frequency radar observations." PhD thesis
[8] Seifert, A. et. al. (2014). "On the anaytic approximation of bulk collision rates of non-spherical hydrometeors" GMD

Workshop on Eulerian vs. Lagrangian methods for cloud microphysics, Cracow, 2019

Contact: markus.karrer@uni-koeln.de