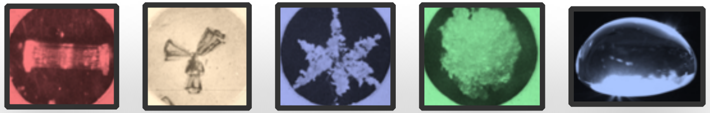
Motivation for a new modeling approach

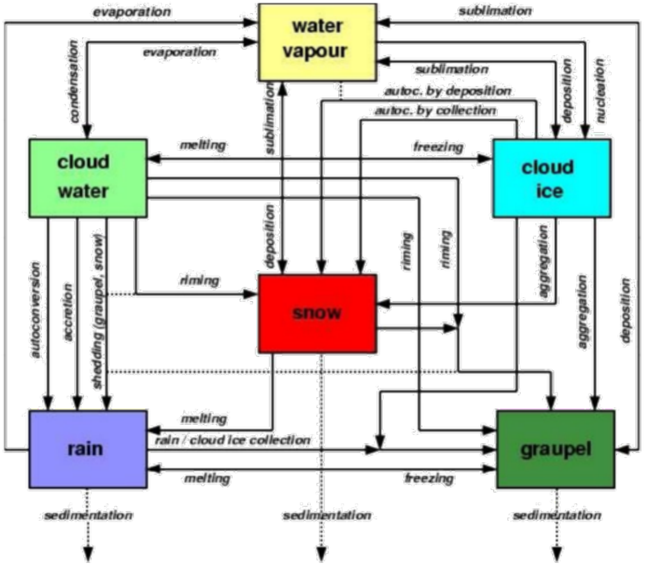
- Most microphysical models use categories like snow, graupel, hail etc.



Locatelli & Hobbs 74

Monte-Carlo Lagrangian models like our McSnow can avoid such a priori assumption.

- Similar as spectral bin schemes, McSnow can predict the PSD, but provides more detailed information about the particle growth and history.



T. Reinhardt, A. Seifert 2005

McSnow particles

Processes

nucleation

vapor diffusion

sedimentation

coalescence

riming

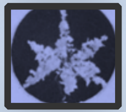
rime splintering

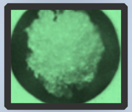
riming

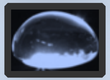
melting & shedding

hydrodynamic breakup

collision breakup







Locatelli & Hobbs 74

Prognostic Variables

ice mass m_i

number of monomers N_m

rime mass m_r

rime density ρ_r

liquid mass m_w

Diagnose geometry and fall speeds based on predicted particle properties.

Limiting cases are

- aggregates $m \sim D^2$
- graupel $m \sim D^3$
- rain $m \sim D^3$

but the transitions are continuous.

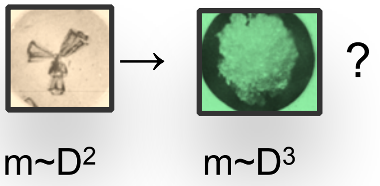
Fall velocity uses Best number approach, i.e.

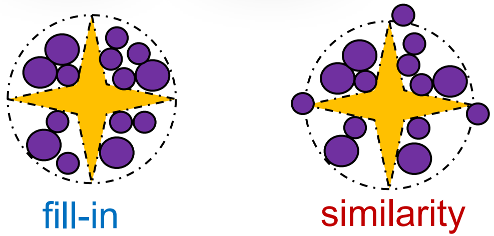
$$Re = f(X_{Best}) = f(m, D, A)$$

S. Brdar and A. Seifert 2017, *McSnow – A Monte-Carlo particle model for riming and aggregation of ice particles in a multidimensional microphysical phase space*, Journal of Advances in Modeling Earth Systems 10, 10.1002/2017MS001167

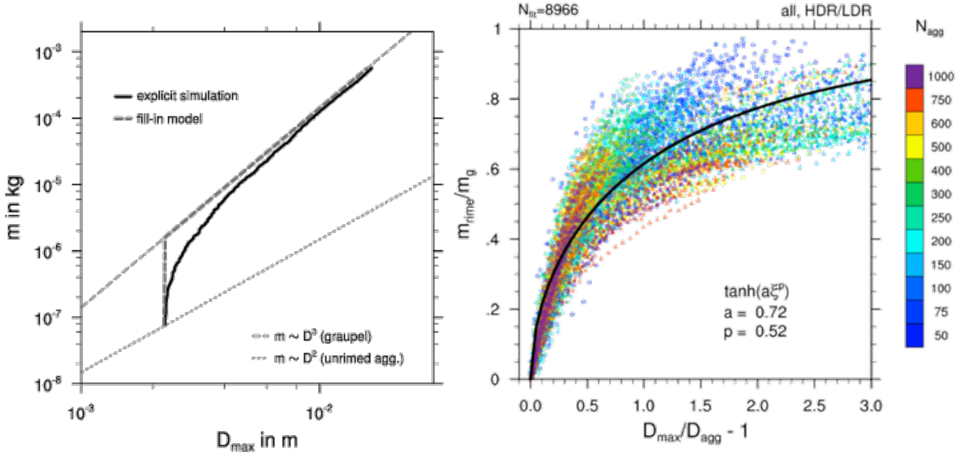
Geometry of rimed snow and transition to graupel

Most microphysical models use the simple ‚fill-in‘ approach. With McSnow we can overcome the simplification:





Results of aggregation-riming model



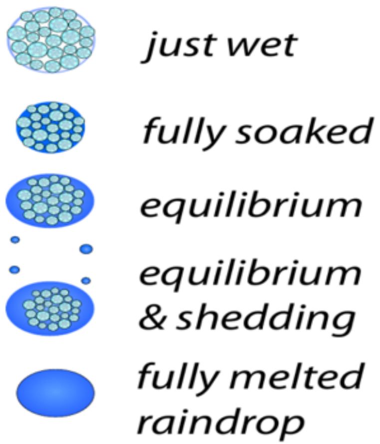
Simulations with McSnow show large effect on riming rate!

Axel Seifert, Jussi Leinonen, Christoph Siewert, Stefan Kneifel 2018, *The geometry of rimed aggregate snowflakes: A modeling study,* submitted to JAMES.

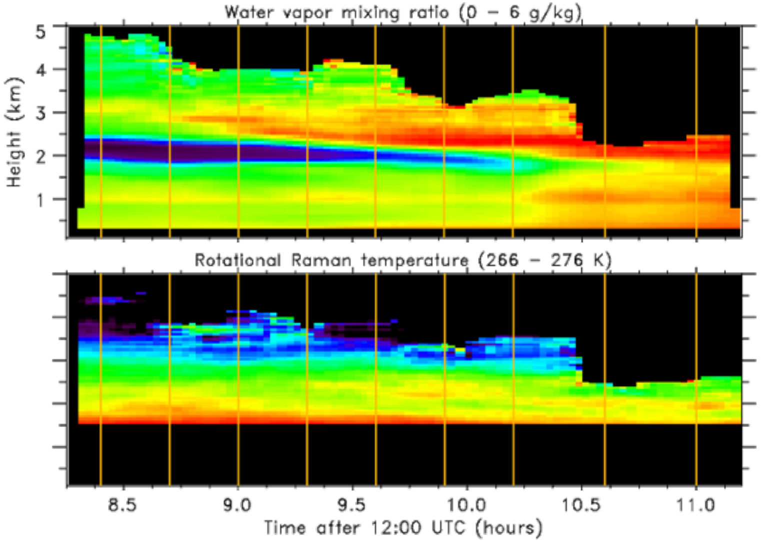
Example of a melting layer:

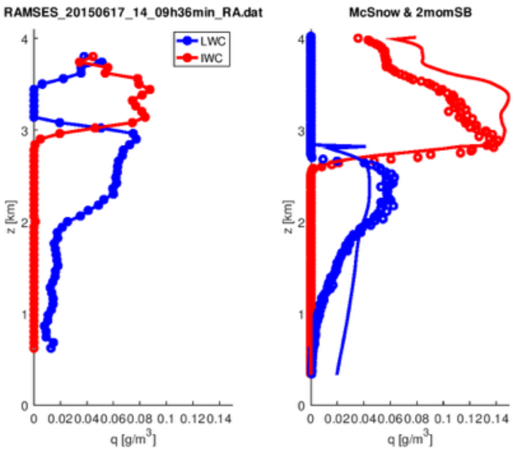
Measurement comparison

- $q_v(z)$, $T(z)$ → IWC, LWC



Vivek & Seifert 2015





RAMSES Raman Lidar (Lindenberg) 17.06.2015 21:36

Science topics of IMPRINT:

1. Depositional growth and particle habits of pristine crystals. For this McSnow will be extended with a habit prediction scheme.
2. Secondary ice production by Hallett-Mossop, fragmentation of snow, and freezing-shattering of drizzle drops.
3. Aggregation and riming processes and their importance for the PSD and the particle fall speeds. What are the conditions for strong aggregation?
4. Melting and re-freezing. Current implementation needs to be refined and completed.

Science topics of IMPRINT:

- For this research we will rely heavily on a comparison of the model results with polarimetric radar signatures, multi-wavelength radar data and Doppler spectra. The focus will be on wintertime stratiform cases.

- The science topics are rather broadly formulated. This gives us some flexibility to pick the most interesting cases from the observations.

- We will mostly work with 1d simulations, but 3d ICON simulations with McSnow are also planned.

Looking forward to a fruitful cooperation in SPP 2115

PROM - IMPRINT
Understanding Ice Microphysical Processes by combining multi-frequency and spectral Radar polarImetry aNd super-parTicle modelling

Stefan Kneifel (Uni Köln), Axel Seifert (DWD),
Alexander Myagkov (RPG)

Universität zu Köln

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Main Goal:

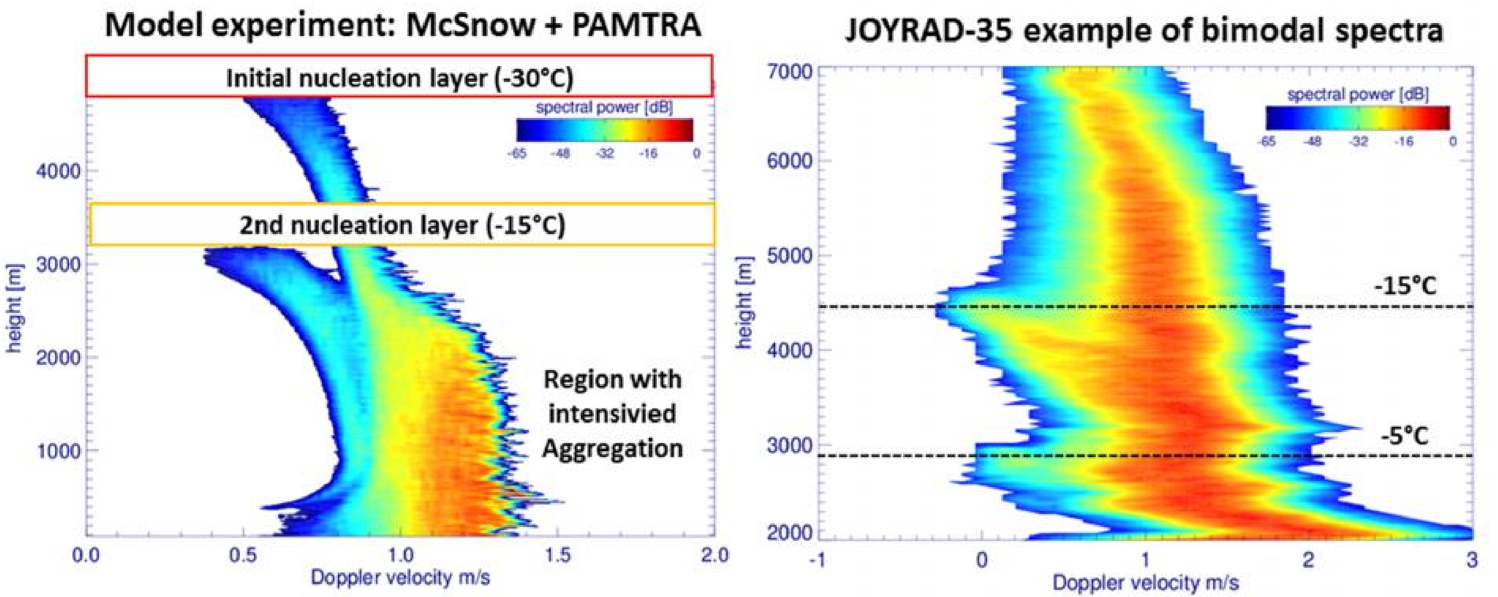
Develop strategy to improve understanding of key **ice microphysical process** (Depositional Growth, Secondary Ice Production, Riming, Aggregation) using rich information provided by polarimetric observations

Strategy and Working Areas:

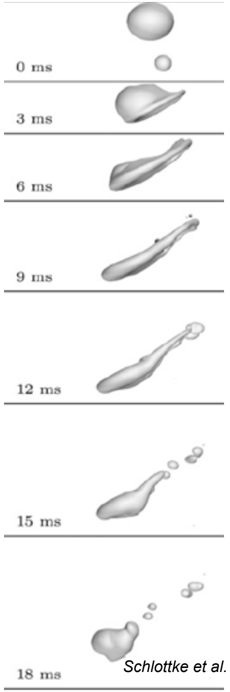
- **WA 1: Novel Polarimetric Observations**
- **WA 2: Monte-Carlo Lagrangian Particle Model (McSnow)**
- **WA 3: Polarimetric 1D Radar Forward Operator (PAMTRA-pol)**

Team: 1 PostDoc (DWD), 1 PhD (Uni Cologne)

Example of comparison of Doppler spectra:



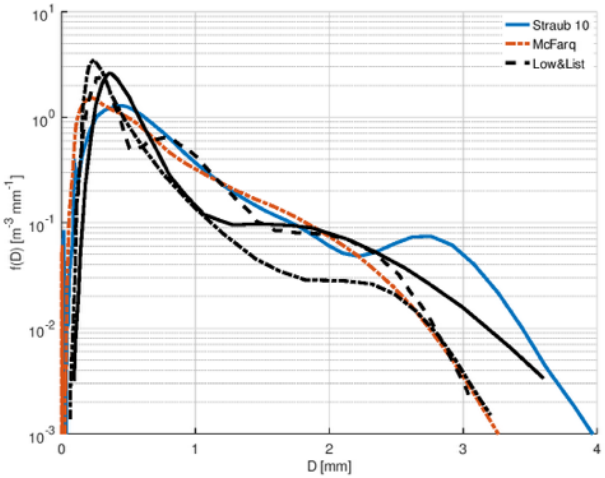
Drop break-up



Schlottke et al. 2010

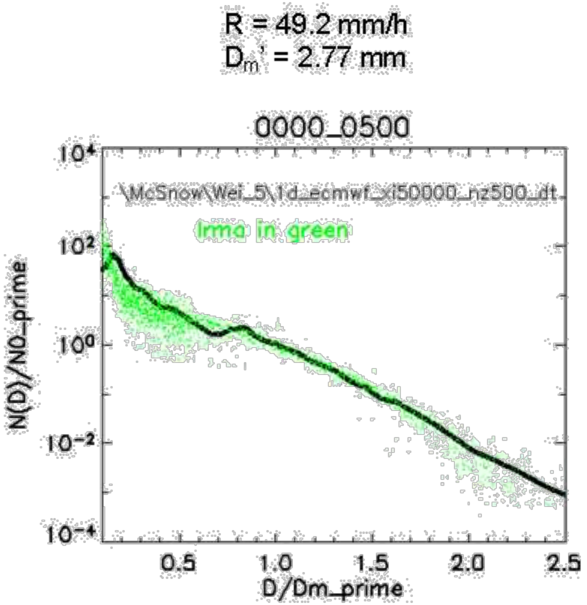
mass conservation every collision

- 0D comparison to bin model



Hurricane Irma

- 1D McSnow vs. measurement

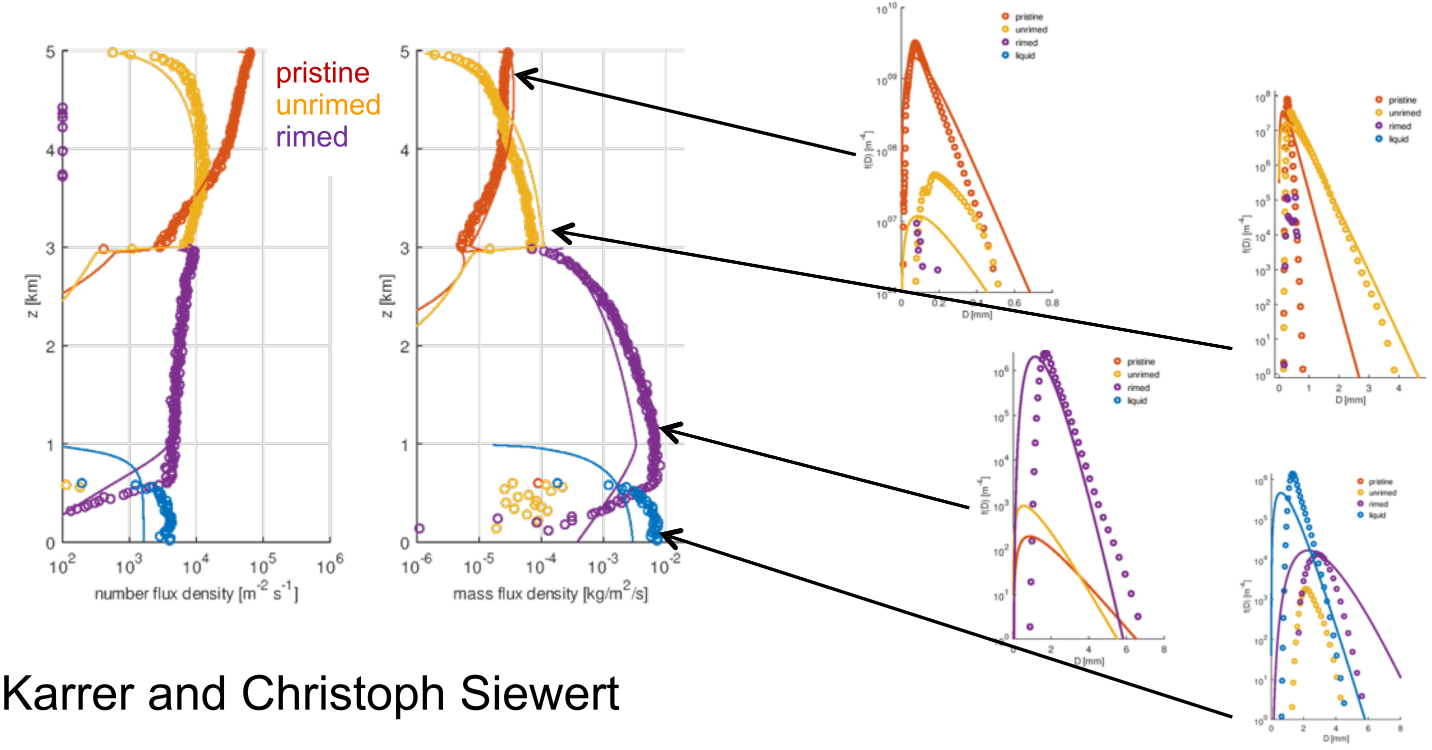


Merhala Thurai-Rajasingam & Viswanathan Bringi,, Colorado State University
Wei Wu & Greg McFarquhar, University of Oklahoma

Universität zu Köln

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

A comparison of McSnow with 2mom bulk scheme



by Markus Karrer and Christoph Siewert

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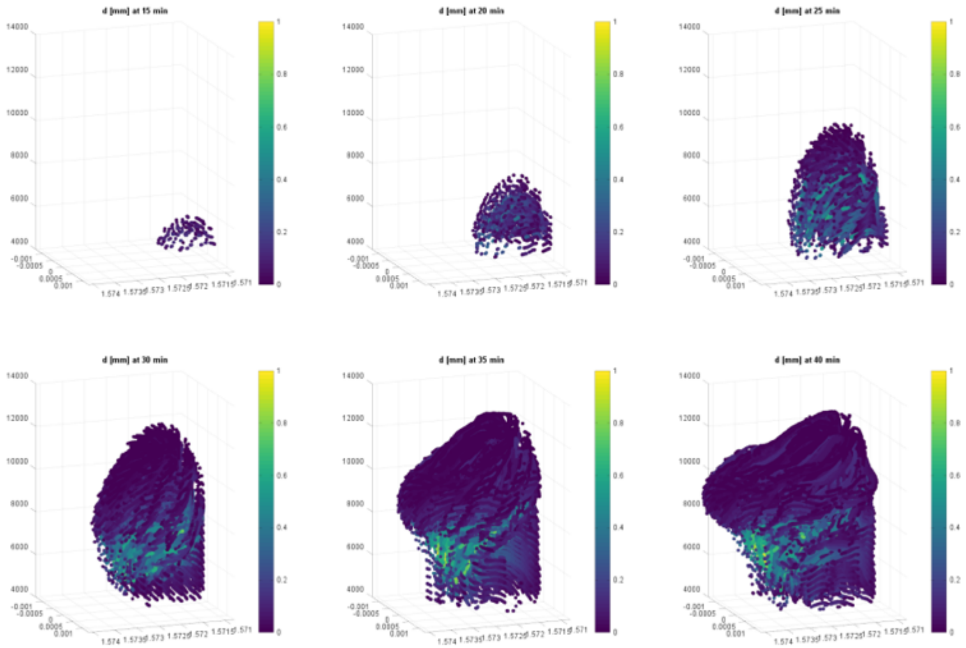


ICON-LEM R2B13 + McSnow

Weisman-Klemp warm bubble + wind

→ 200 Mio. super-particles

Again gelation (D_{max} > 1 m)
Difference 3D/1D:
- dynamic situation
- feedback from 2mom

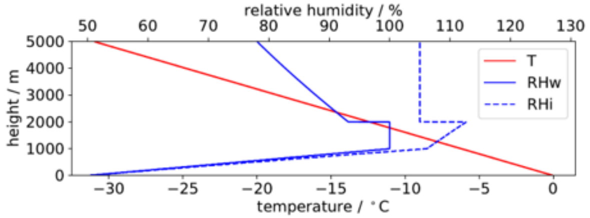
→ compare to 2mom in 1D

Comparison with 2-Moment scheme in 1D

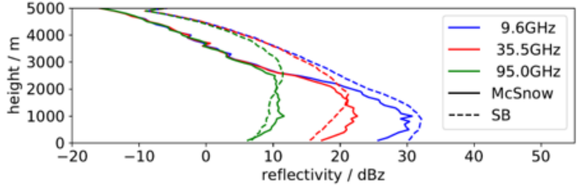
- Markus Karrer, Stefan Kneifel (Uni Köln): *multi-frequency radar*

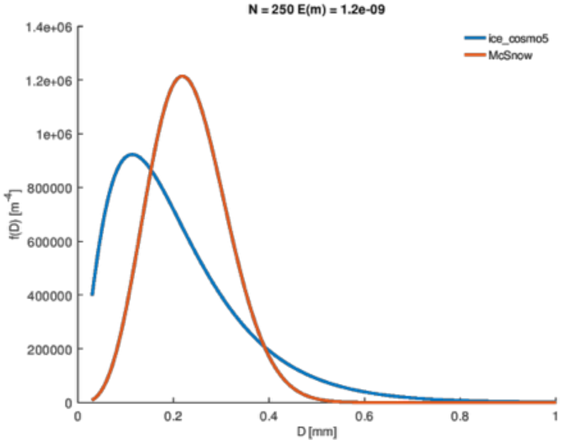
Reflectivity ~ D^4

Brdar & Seifert 2017 Setup

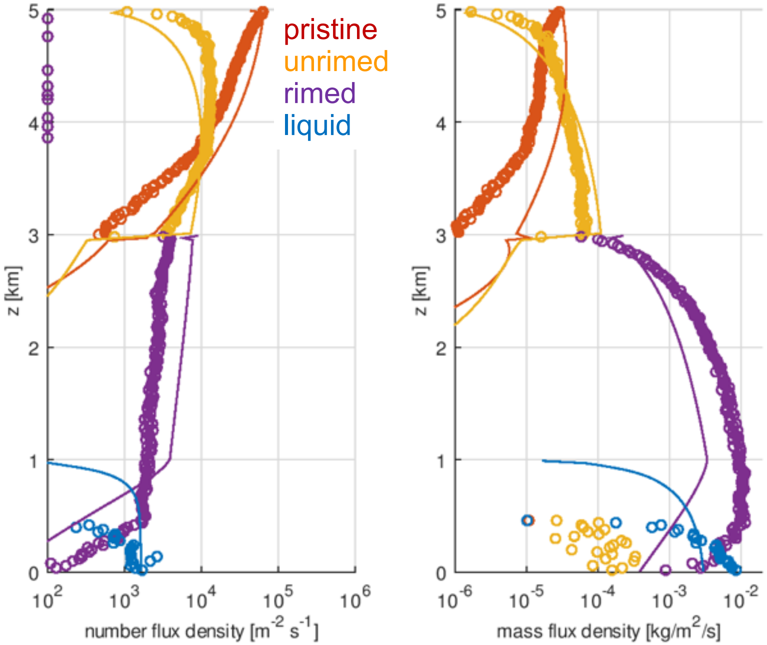


Radar forward operator PAMTRA





→ new boundary conditions needed



Sensitivities:

Sticking efficiency

- Conversion ice → snow

Rimming geometry

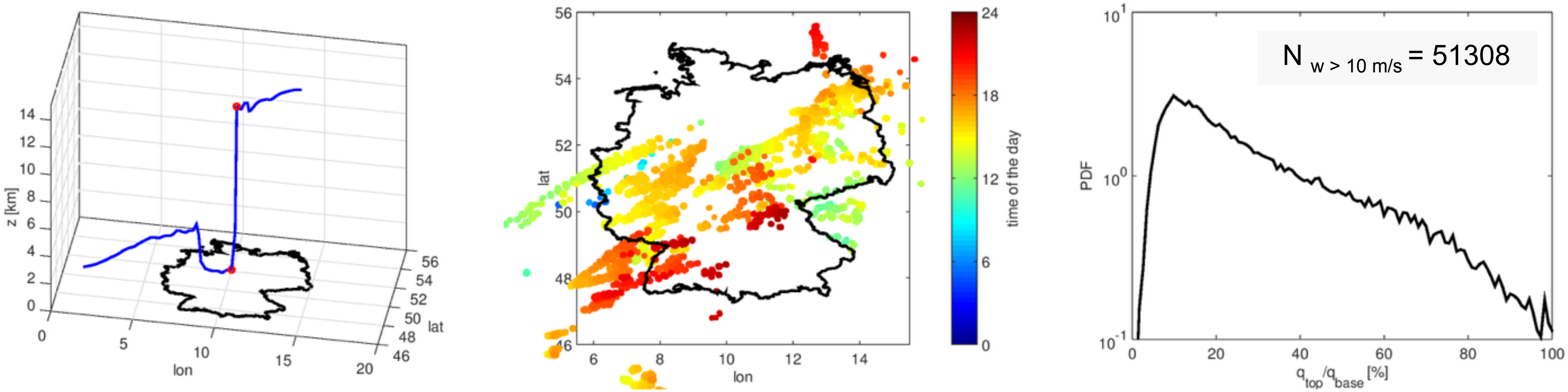
- Conversion snow → graupel

→ improve 2mom

→ large quantitative differences, but still qualitatively similar

New trajectories model for ICON

05.07.2015 ICON-D2 (Harald)
+ 46 Mio. trajectories/parcels



Validation with experiments

- Raman Lidar, Jens Reichardt (Lindenberg)

Improve 2-moment microphysics scheme

- Riming geometry
- Sticking efficiency

Run McSnow in 3D

- Dynamic in 1D (updrafts)
- Couple with new trajectory model

Future

DFG Priority Program 2115: Polarimetric Radar Observations meet Atmospheric Modelling (PROM)

- Multi-frequency and polarimetric radar, Stefan Kneifel (Köln)

e.g. cooperation with Viswanathan Bringi (Colorado State) & Greg McFarquhar (Oklahoma)