

A close-up, high-magnification photograph of numerous small, white, irregular ice crystals or snowflakes scattered across a dark, textured fabric surface. The crystals vary in size and shape, some appearing as small clusters and others as individual flakes. The background fabric has a fine, woven texture.

Assessing the ice microphysics parameterization in the ICON model using triple-frequency Doppler cloud radar observations

Davide Ori

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Markus Karrer, Axel Seifert**

Example Ice: model vs reality

Example from Seifert and Beheng 2006



CLOUD "ICE"

aggregation

riming

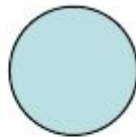
$$N(x) = N_0 x^\mu \exp(-\Lambda x^\gamma)$$

➡ **ASSUMPTIONS**



"SNOW"

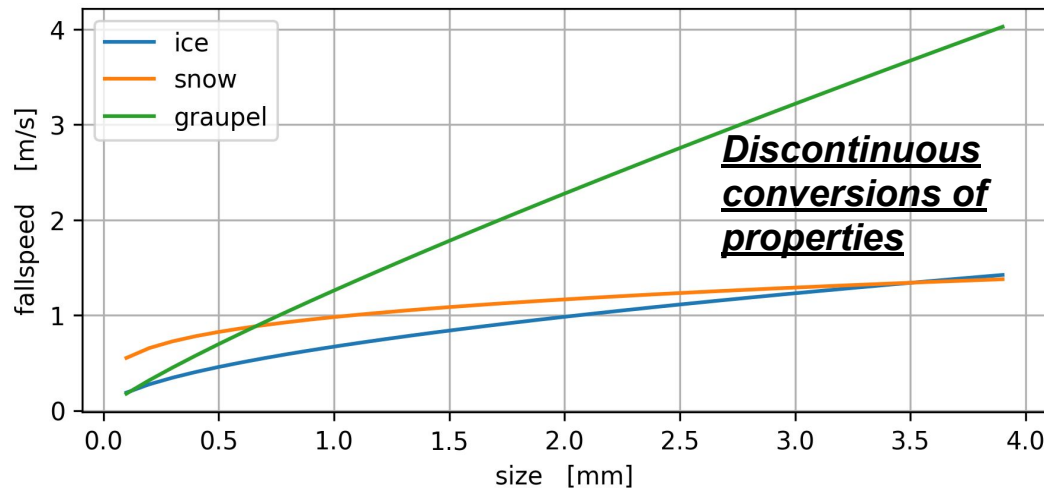
riming



GRAUPEL

q_i N_i

➡ **Prognostic variables**



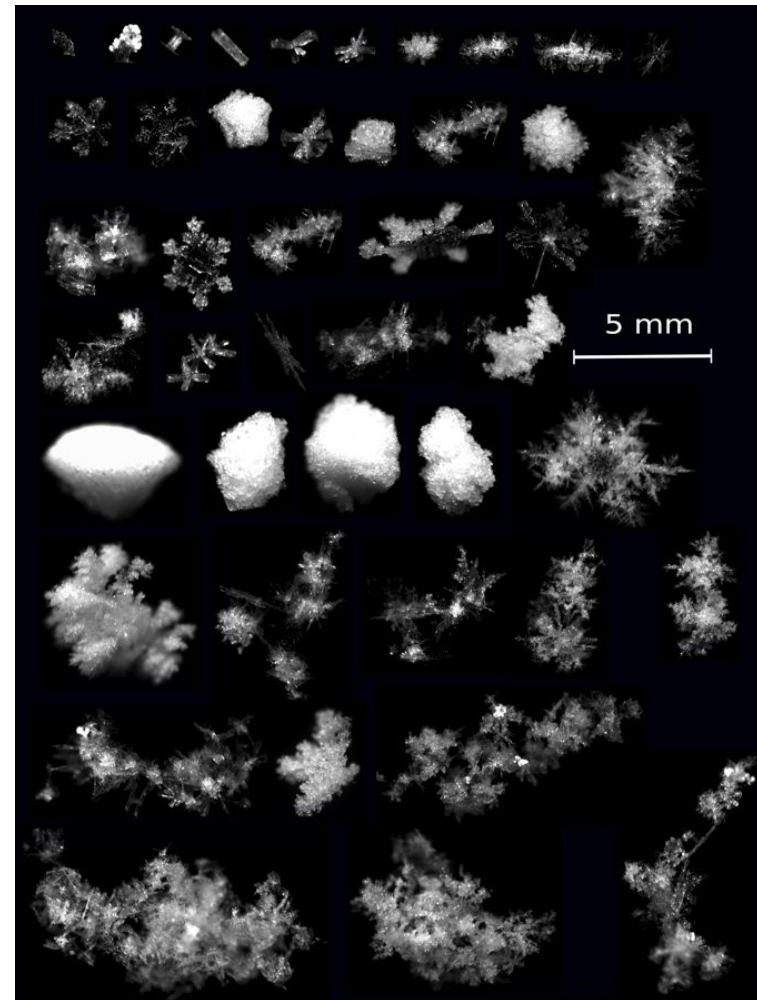
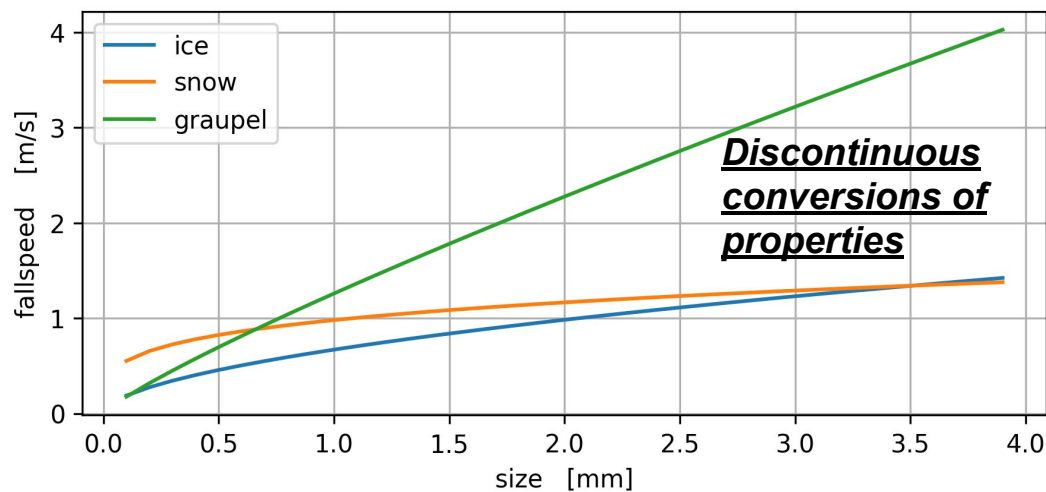
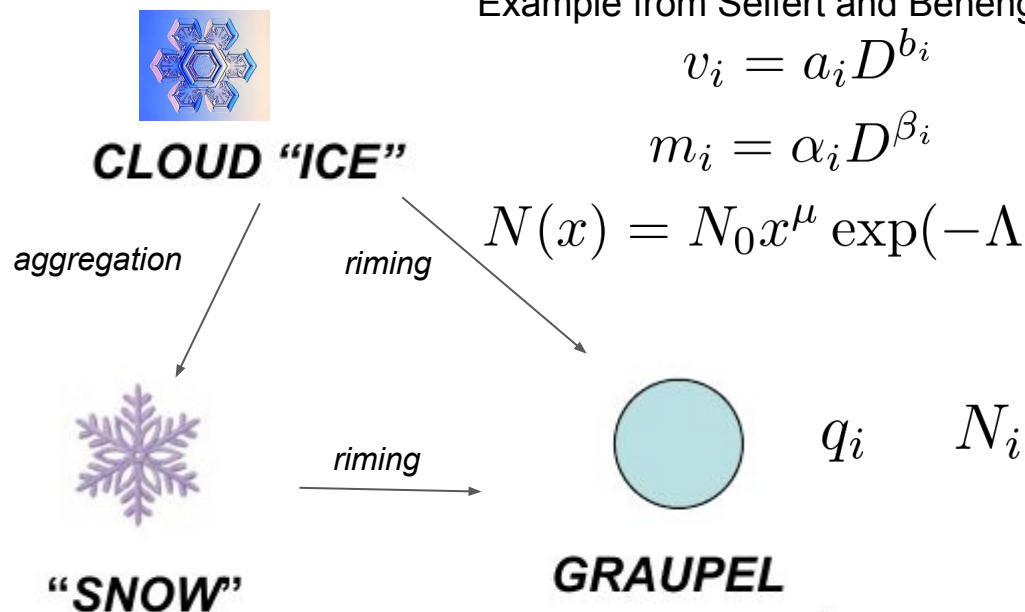
Example Ice: model vs reality

Example from Seifert and Beheng 2006

$$v_i = a_i D^{b_i}$$

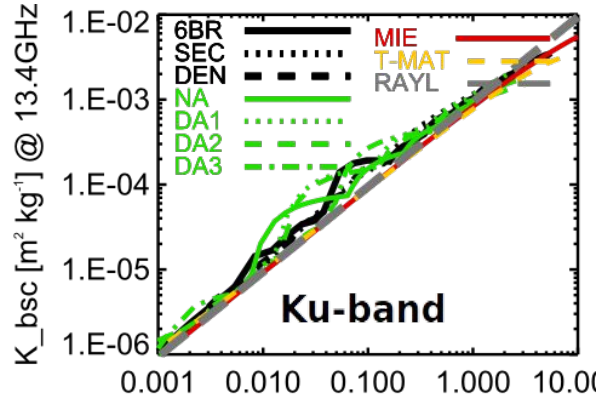
$$m_i = \alpha_i D^{\beta_i}$$

$$N(x) = N_0 x^\mu \exp(-\Lambda x^\gamma)$$

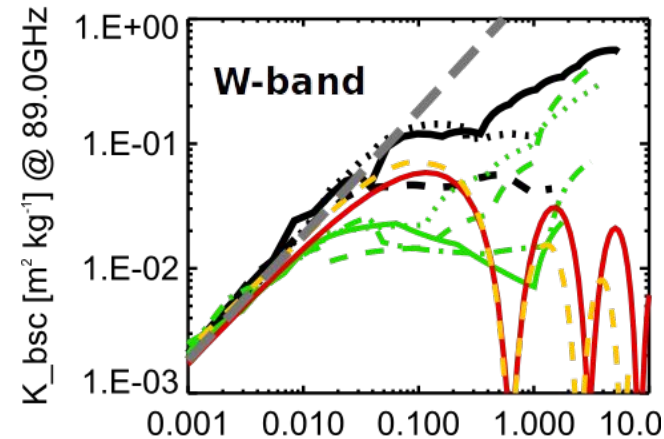


Garrett et al. 2012 AMT

Radars are sensitive to hydrometeor properties



Kneifel et al. 2011 JGR



Scattering depends on particle size, shape, density and electromagnetic frequency

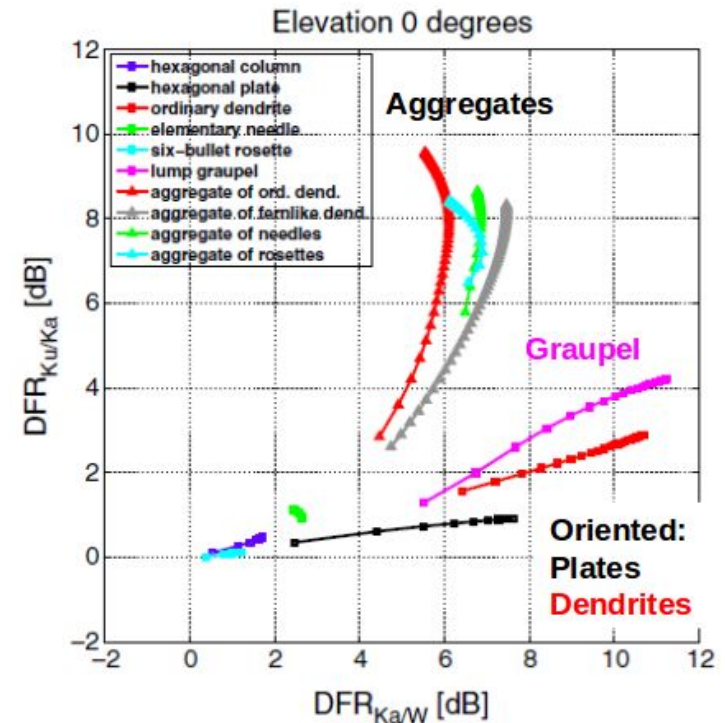
=> Combine **multiple frequencies** to constrain snow precipitation properties

$$DWR_{XK_a}[dB] = Z_X[dBZ] - Z_{K_a}[dBZ]$$

$$DWR_{K_aW}[dB] = Z_{K_a}[dBZ] - Z_W[dBZ]$$

=> and **Doppler spectral analysis** gives information on hydrometeor fallspeed

Constrain model microphysical parametrizations



Tyynela and Chandrasekar 2014 JGR

The TRIPEX observation campaign

Winter 2015/16 - 2 months dataset

Collaboration between U. Köln, U. Bonn, FZJ and KIT

3 co-located vertically pointing radars

(X, Ka and W band)

polarimetric and Doppler

[Dias Neto et al. 2019 ESSD](#)

Processed dataset publicly available

- Radar volume matching
- Offset correction
- Clutter removal
- Attenuation correction
- Cross-radar calibration
- Quality control



The Model

High resolution ICOSahedral Nonhydrostatic model (**ICON**)
nested simulations on “selected” weather events (26 days)

Heinze et al. 2016 QJRMS

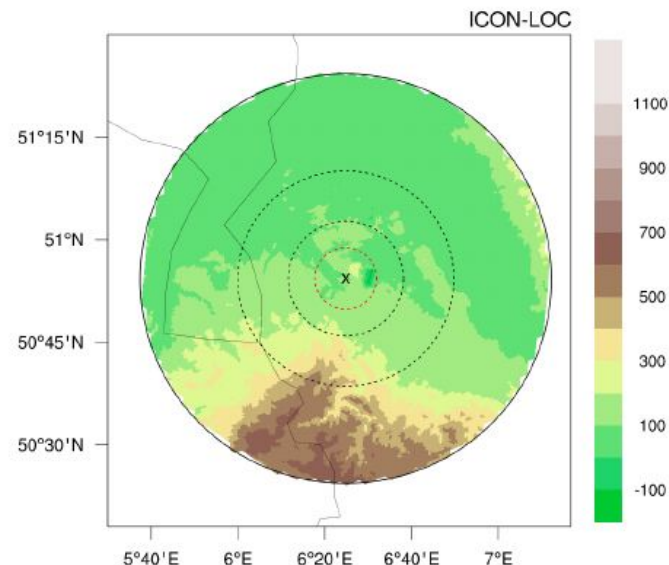
ICON-LEM

- Horizontal resolution 600m
- 110 km domain
- 2-moments microphysics (Seifert Beheng)
- Topography

Forward simulation with Passive and Active Microwave TRAnsfer tool (**PAMTRA**)

- Passive and active instrument simulator
- Instrument noise and sensitivity
- Innovative scattering properties **Self-Similar Rayleigh Gans**
 - > matching ICON assumptions about hydrometeor properties

MAP MODEL VARIABLES INTO THE OBSERVATION DOMAIN

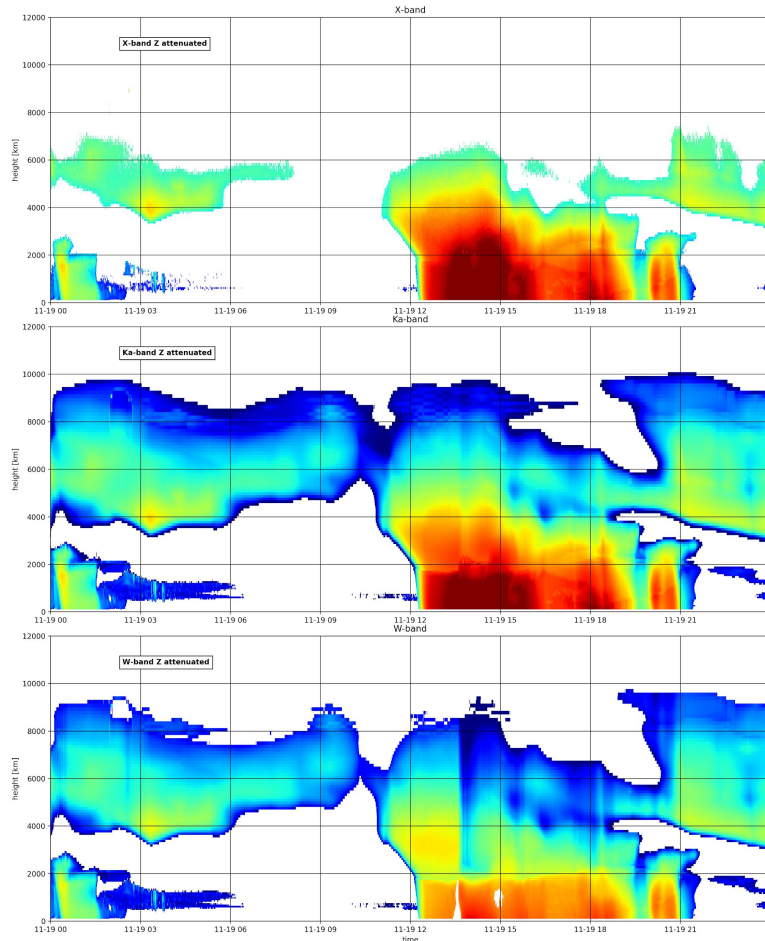


Maahn et al. 2015 JTECH

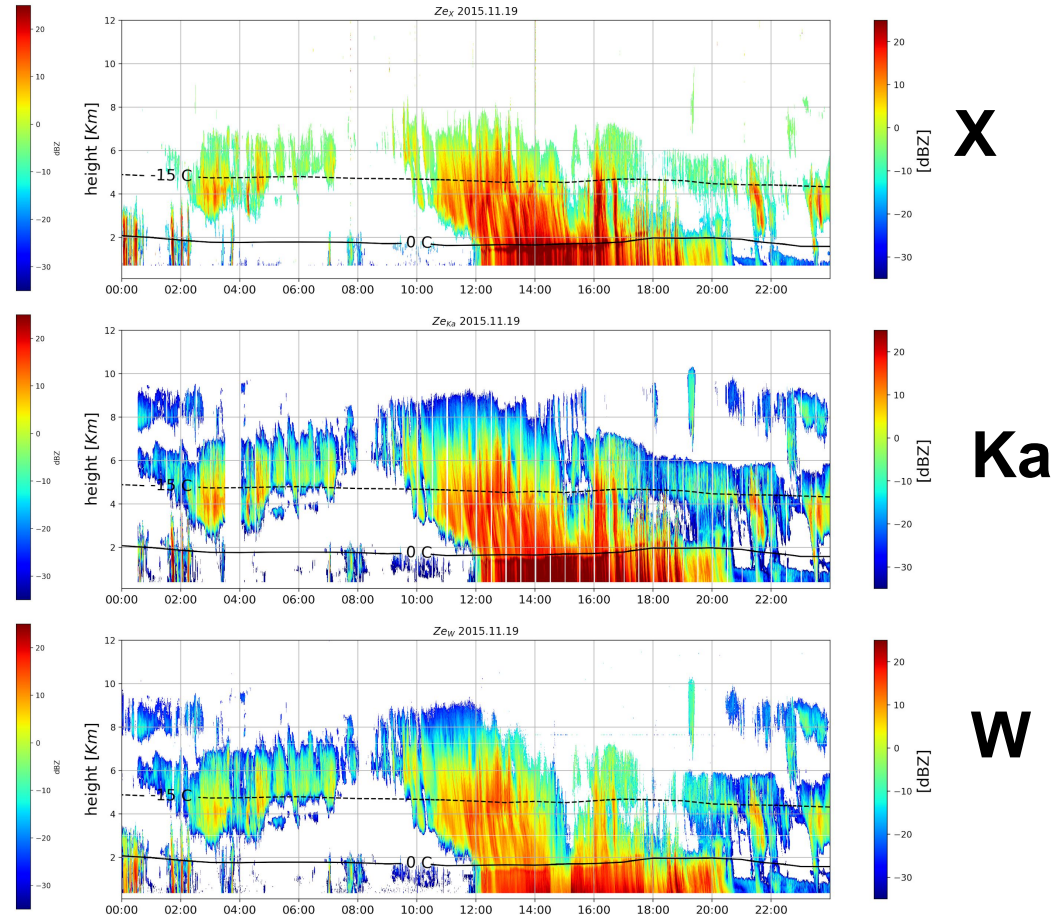
Hogan et al. 2017 QJRMS

How do model and observations compare?

MODEL



OBSERVATIONS



Quite well ...

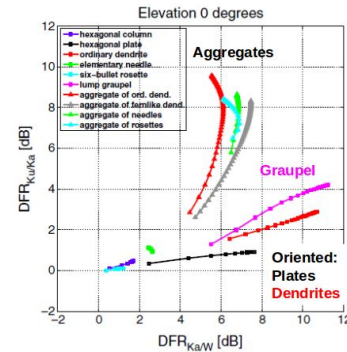
Although if we just compare point measurements with columns extracted from the larger model domain we have to face the “double penalty” and resolution problem

Triple frequency characteristics

2D Histograms DWRs

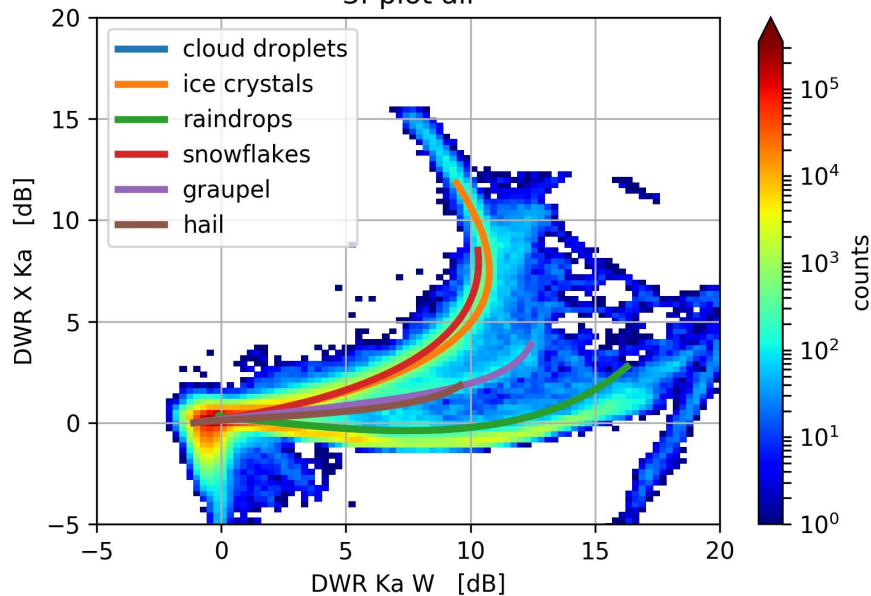
$$DWR_{XK_a}[dB] = Z_X[dBZ] - Z_{K_a}[dBZ]$$

$$DWR_{K_aW}[dB] = Z_{K_a}[dBZ] - Z_W[dBZ]$$



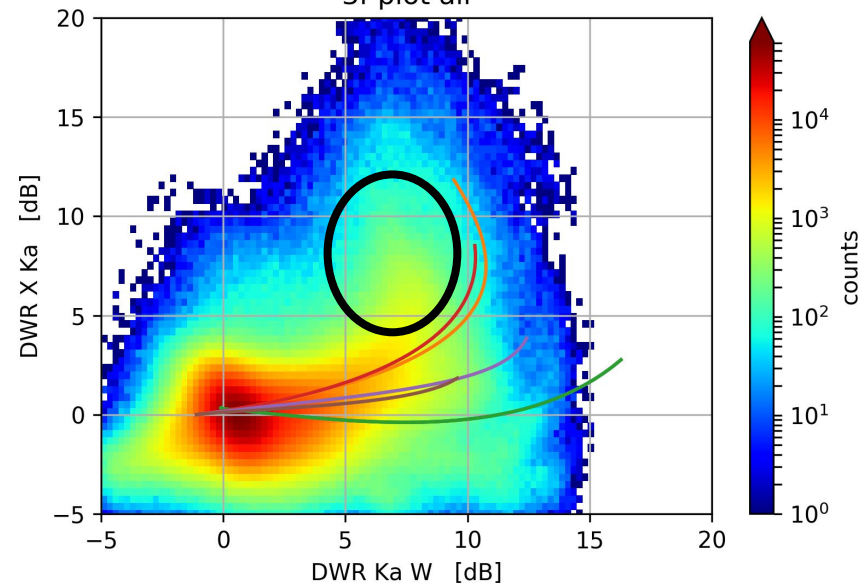
MODEL

3f plot all



OBSERVATIONS

3f plot all



Because of the predefined hydrometeor properties it is possible to determine the characteristics curves defined by each hydrometeor class

Models produce too large extreme values of DWR Ka-W

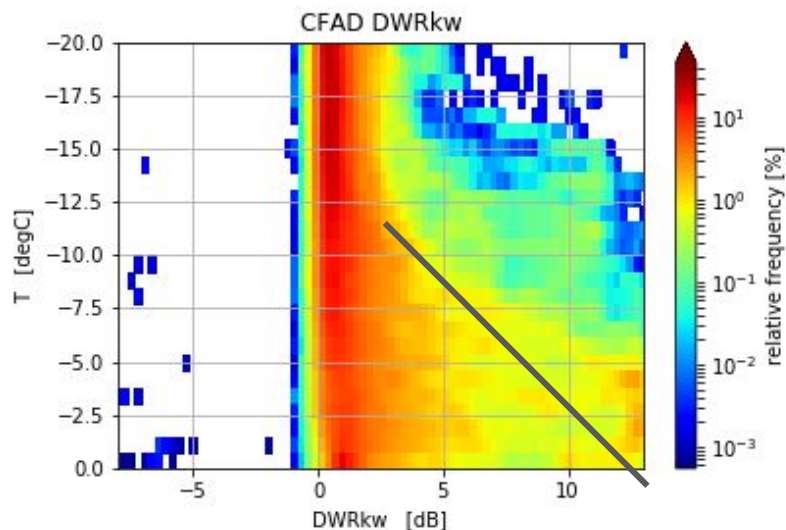
Triple-frequency properties of rimed particles are very well represented

The model can just “mix” hydrometeors, in reality we have smooth transition between “classes”

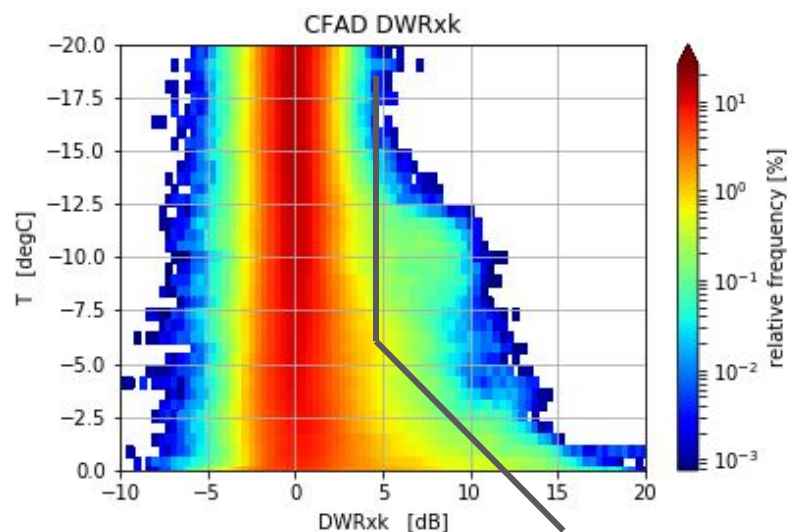
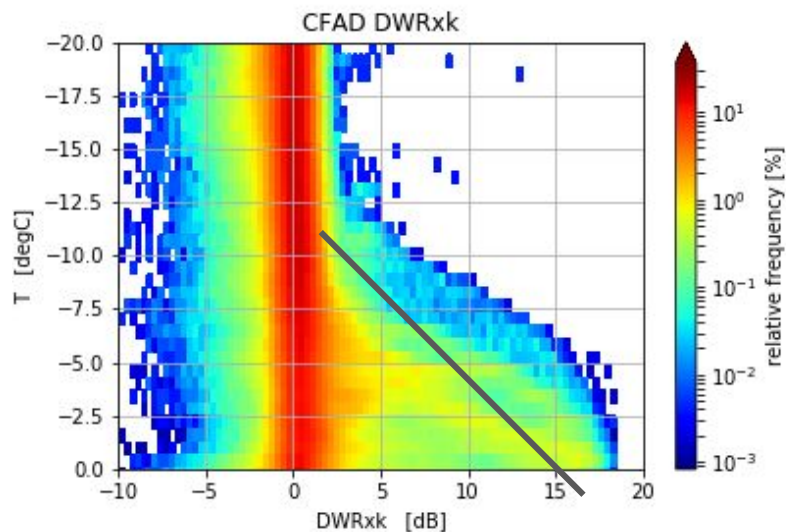
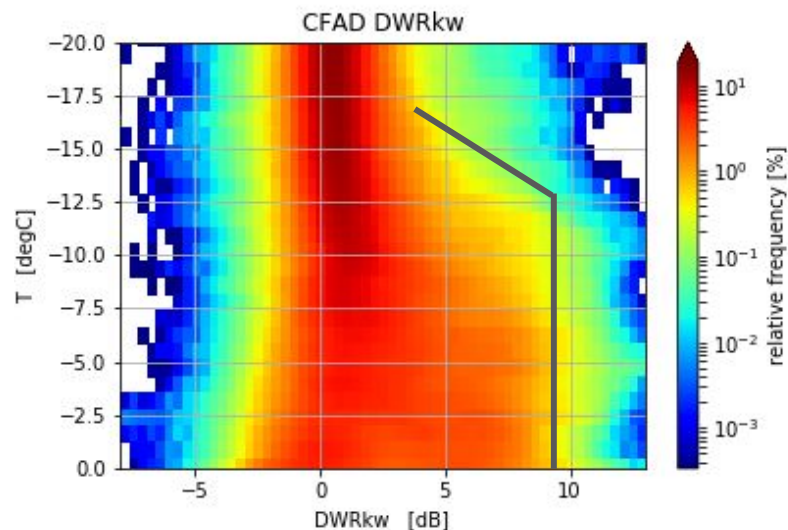
DWR vs temperature

Contoured Frequency Altitude (temperature)
Diagrams - CFAD

MODEL

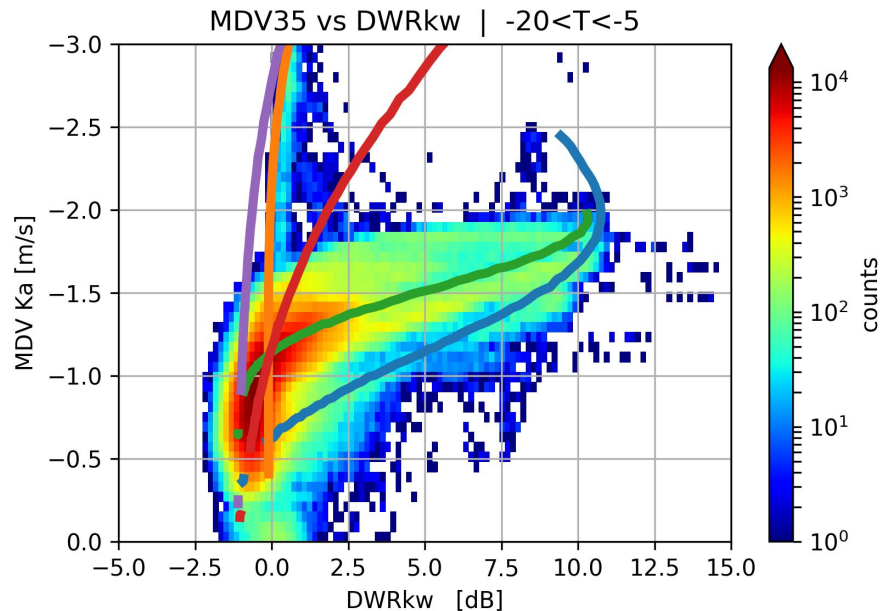


OBSERVATIONS

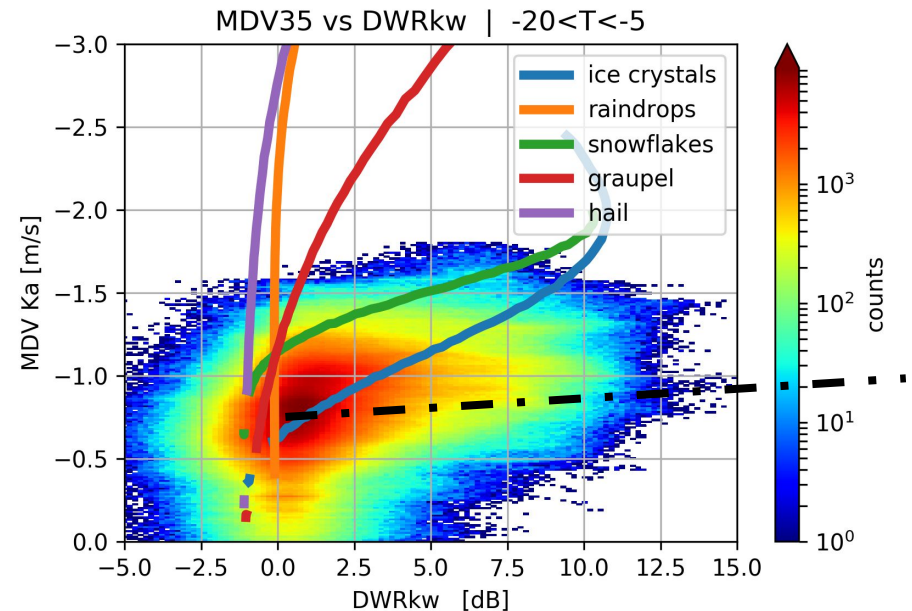


MDV vs DWR $-10 < T < -5 \Rightarrow$ ice particles

MODEL



OBSERVATIONS



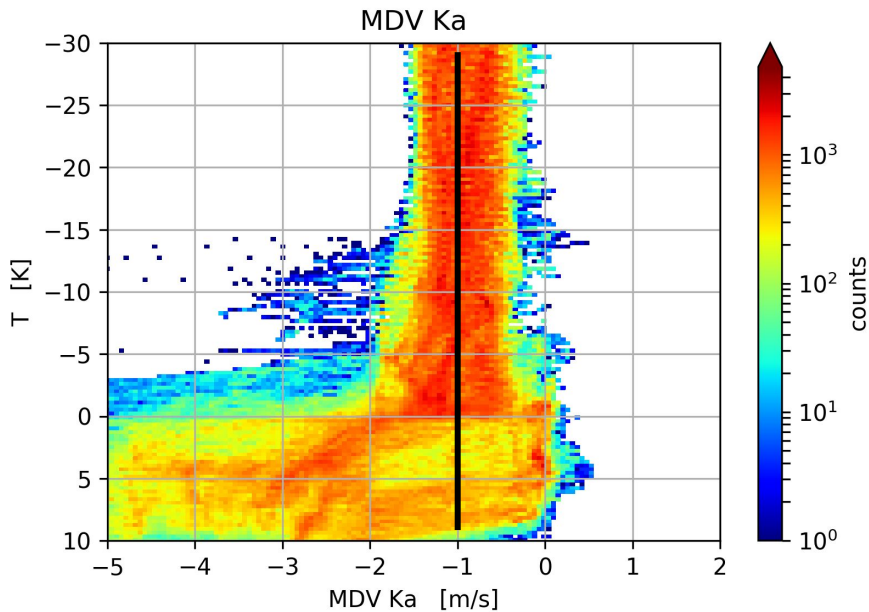
At low temperatures we exclude some of the rimed particles and larger snow

The power-laws used by the model for the v-D relations of ice particles are too high and especially too steep

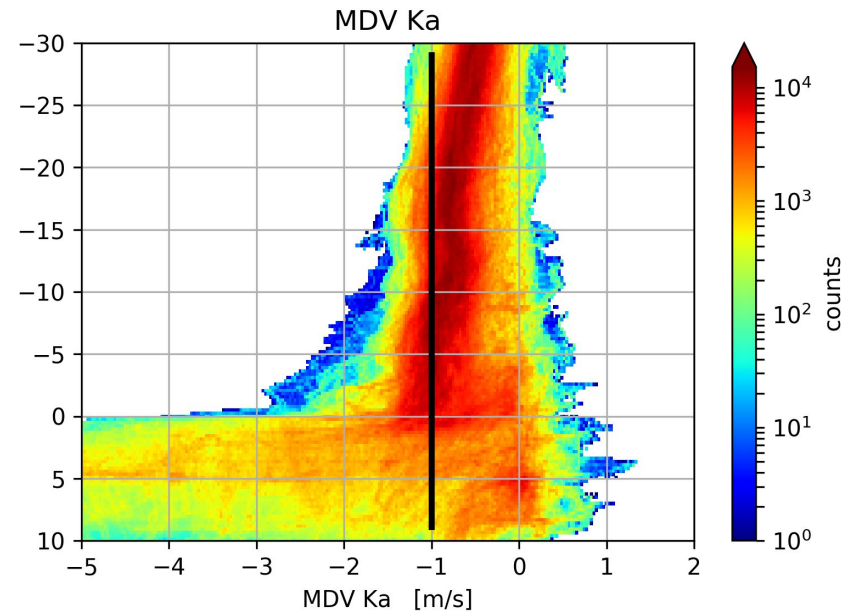
MDV vs Temperature

2D Histograms DWRs

MODEL

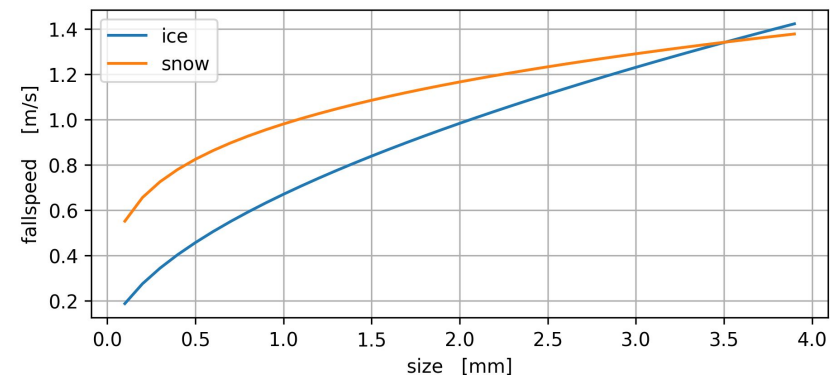


OBSERVATIONS



(model) High fallspeed at lower temperatures

Sharp transition between ice and snow category, properties and fast conversion (aggregation) of ice into snow



Summary and conclusions

1. The multifrequency Doppler radar observation are a great tool for the study of cloud microphysics.
2. Forward simulations can be used to map the model variable domain into the observation space effectively
3. No “Golden Case” but representative statistics
4. We have already identified some inconsistencies (snow density, sticking efficiency and fallspeed) with ICON hydrometeor assumptions

Follow-on campaign: TRIPEX-POL

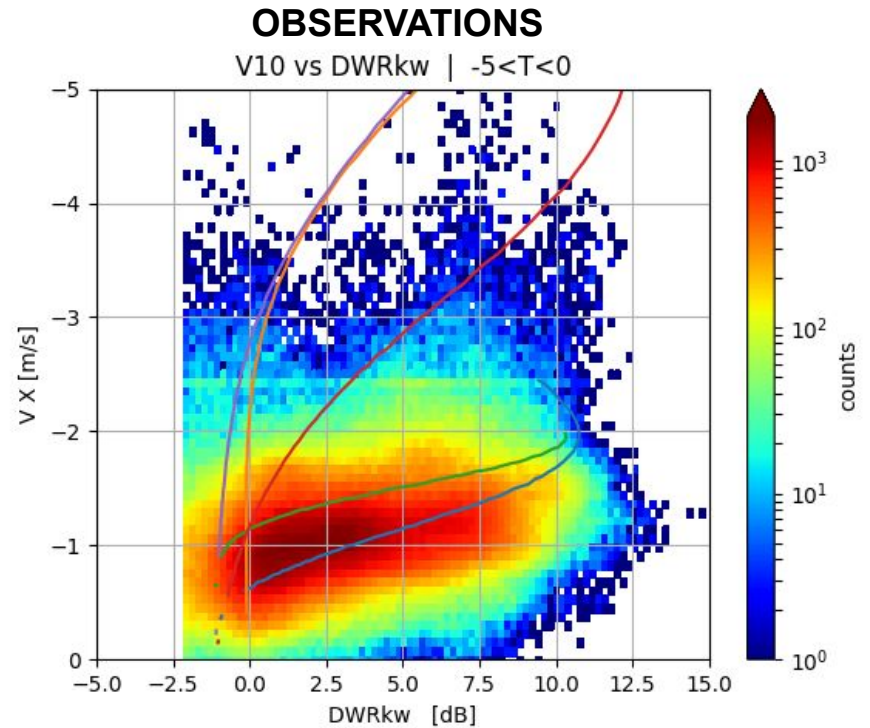
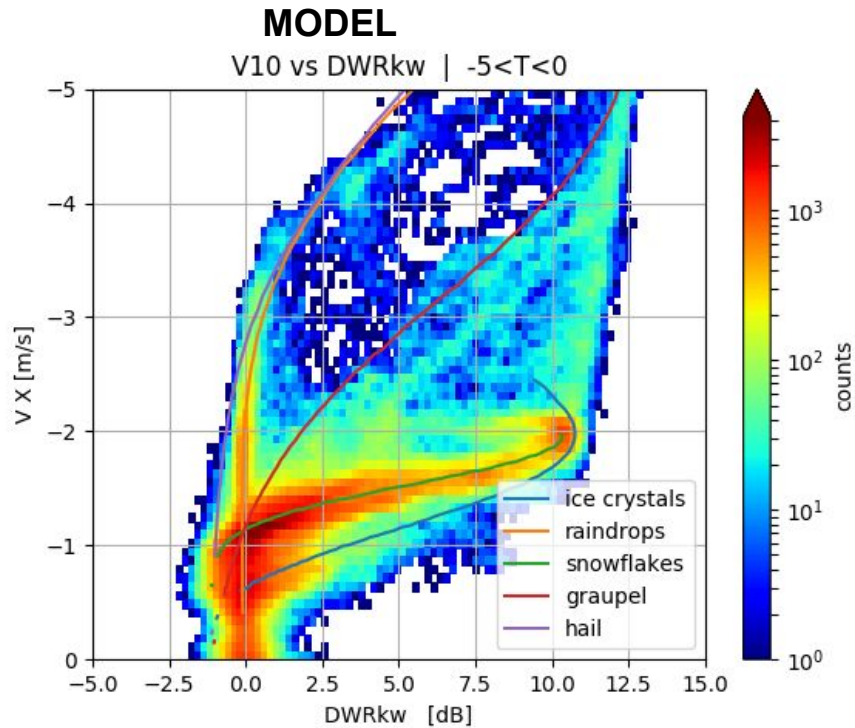
3-frequencies vertically pointing + additional W-band polarimetric Doppler scanning

4 months dataset

Measurement under processing for upcoming dataset publication



MDV vs DWR -5<T<0 => large snowflakes



The fallspeed of snow is overestimated

The observed data are closer to the predefined properties of ice crystals

The signature of hail and graupel is very weak in the observations