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

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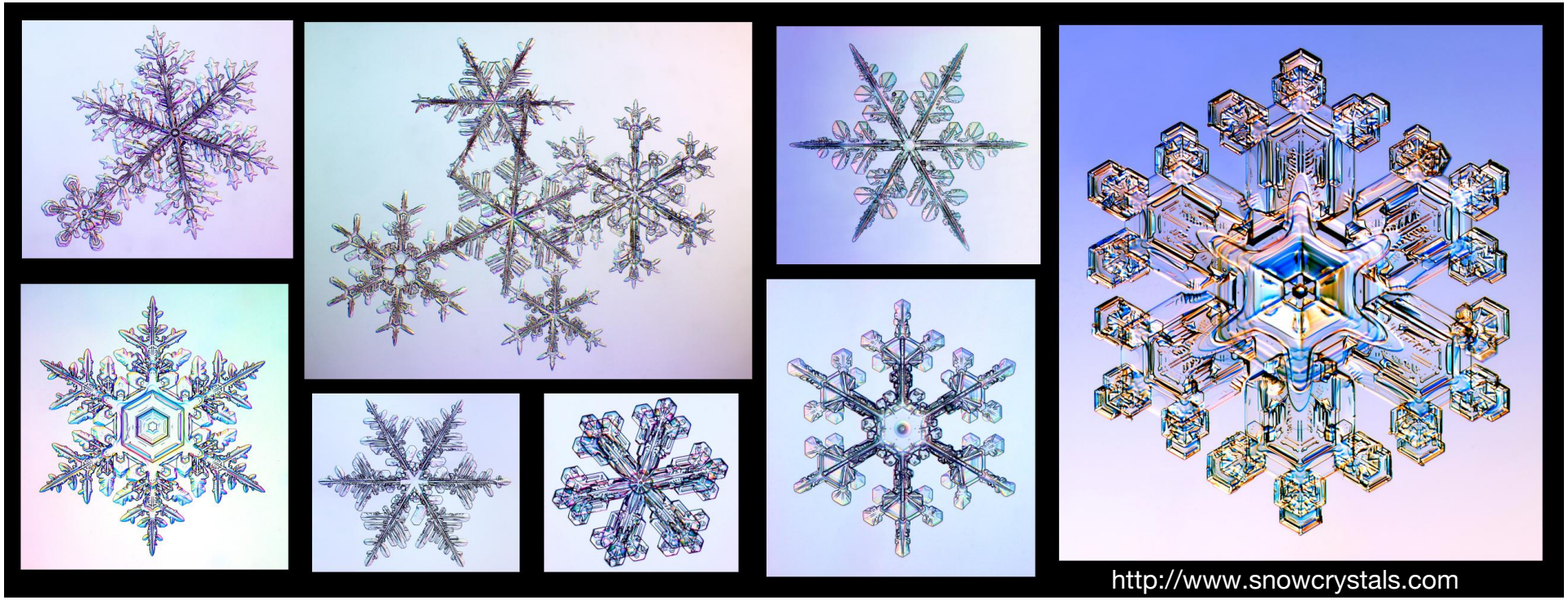
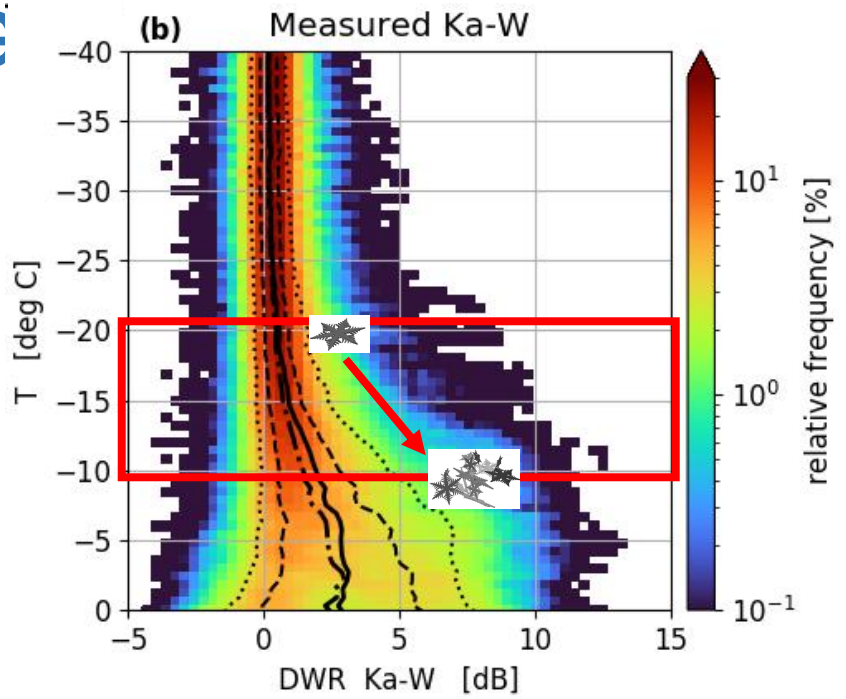


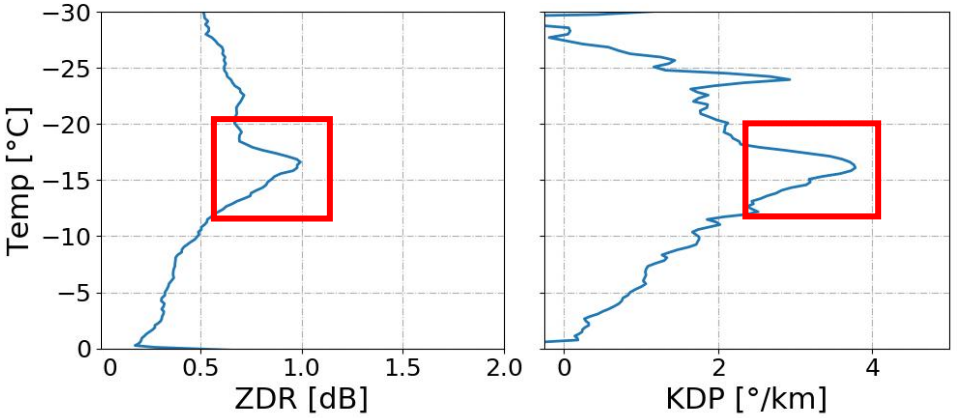
# Importance of Dendritic Growth Layer (DG

- First region with enhanced aggregation:
  - Differential scattering at different wavelengths (λ)
  - $DWR_{\lambda\ \ 1\lambda\ \ 2} = Ze_{\lambda g_1} - Ze_{\lambda\ 2}$
  - **DWR is indication of aggregation**




*Dias-Neto et al. 2019 ESSD, Ori et al. 2020 QJRMS*

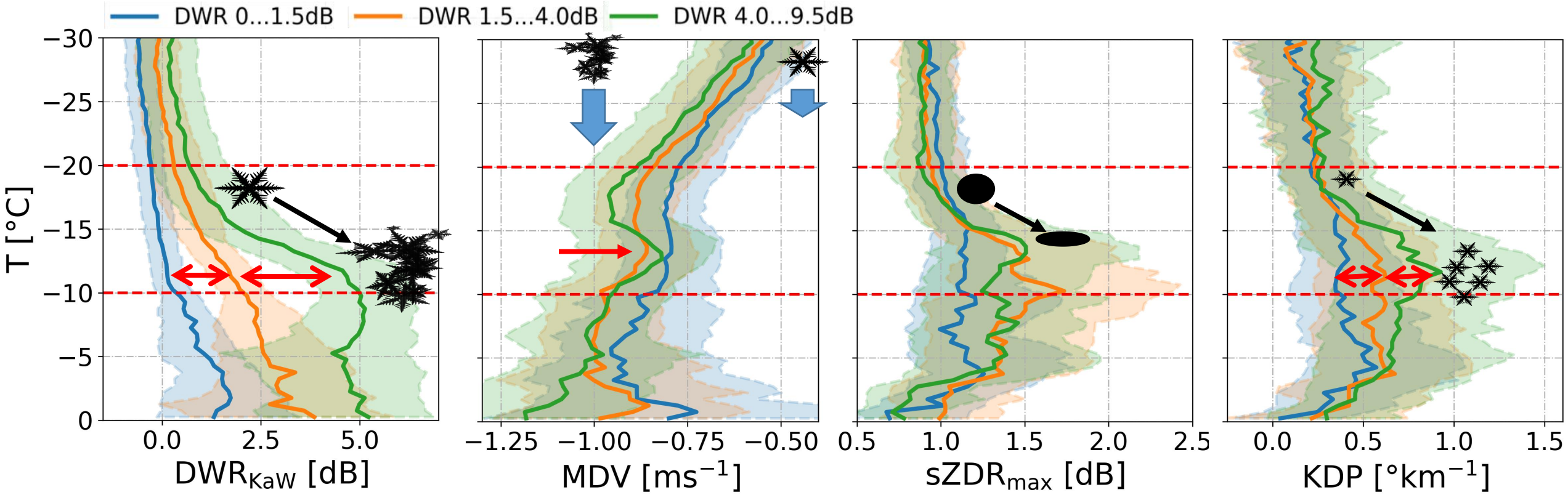
- Growth of oblate (plate-like) particles:
  - Enhanced ZDR and KDP layers around -15°C




**How are aggregation and ice crystal growth related?**
→ Statistical analysis of DGL combining multi-frequency Doppler radar observations with polarimetric Doppler cloud radar observations

# How are aggregation and growth of dendritic particles related?

→Classify dataset by maximum DWR within DGL (size of aggregates)




Increasing aggregate size with increasing DWR-KaW class

MDV reduction → combination of **new mode of small particles** and updraft

Increasing aspect ratio at -15°C → increase in crystal size

Concentration of crystals increases, stronger increase for larger aggregates

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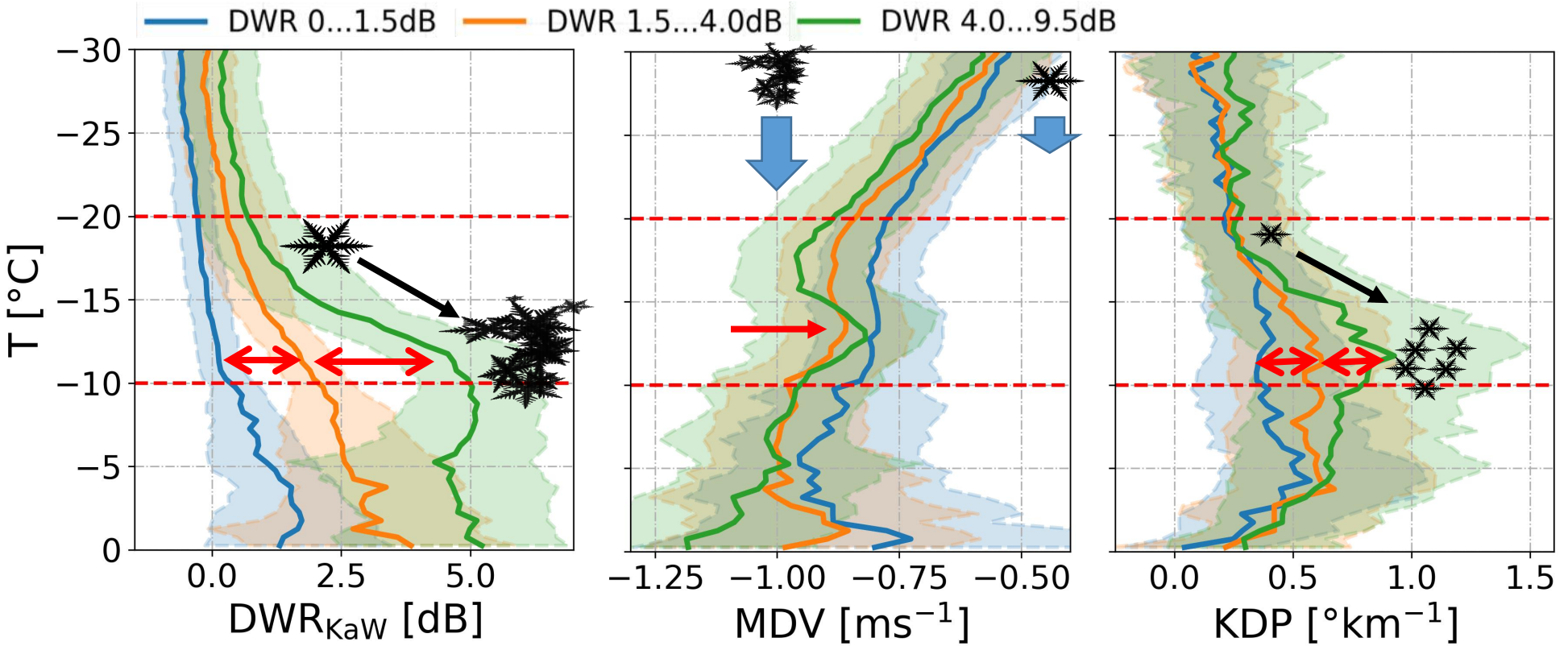
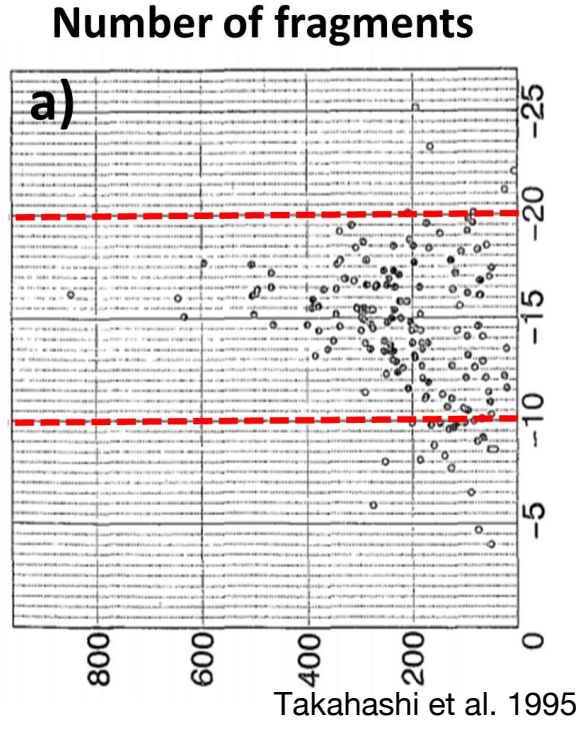



Takahashi et al. 1995

- Why is KDP increasing, aggregation should consume ice particles?

→ **Hypothesis: Fragmentation during aggregation process**

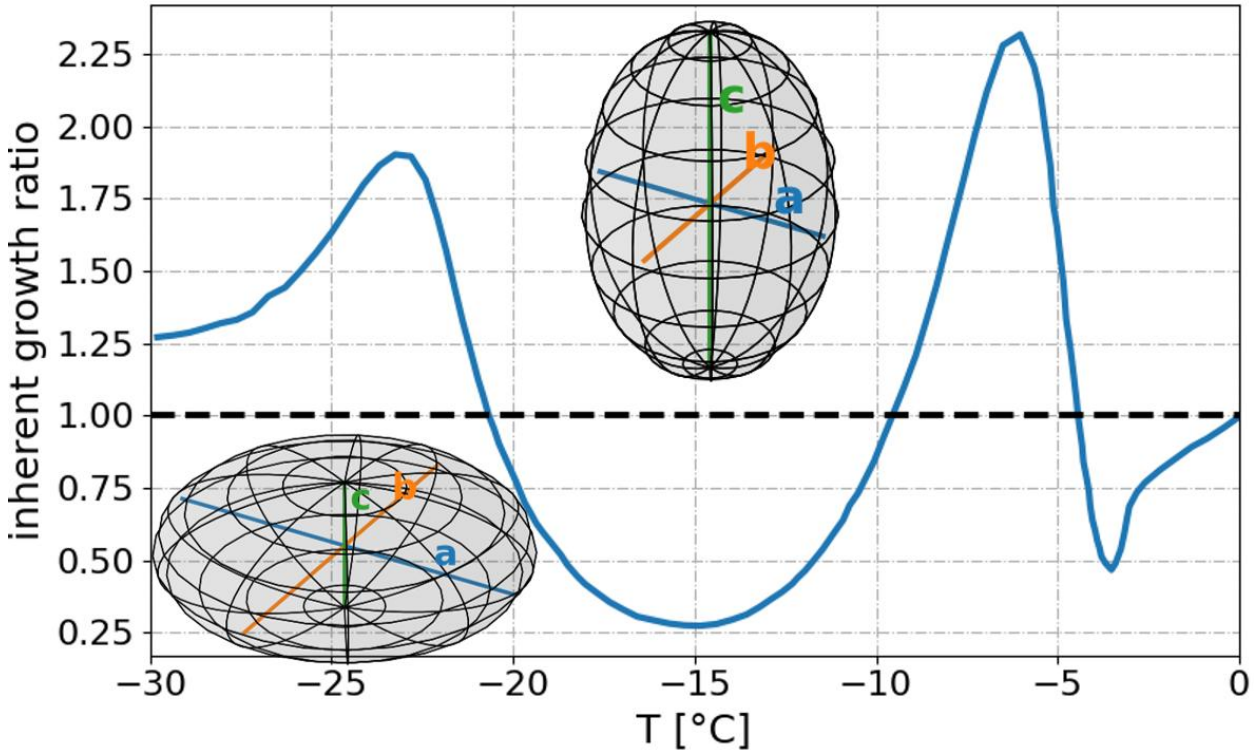
- Takahashi et al. 1993,1995: fragile arms growing on ice spheres were broken of during collision

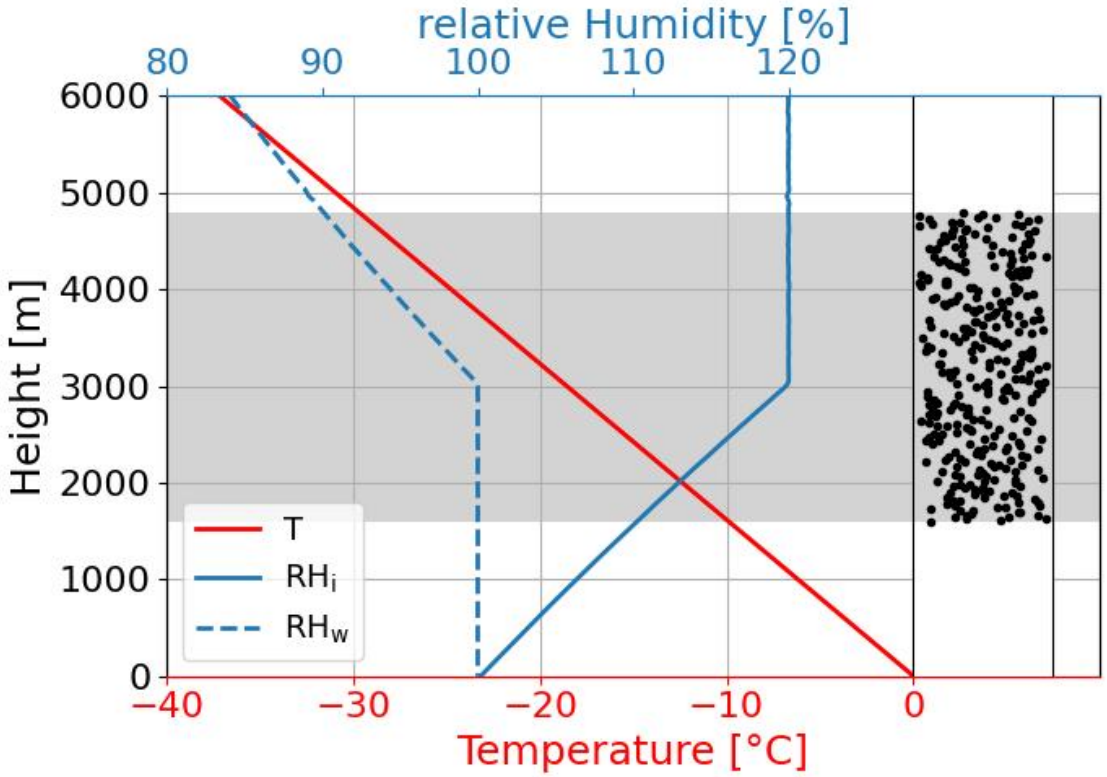
→ Hypothesis can be studied with Monte-Carlo particle model McSnow, Laboratory or in-situ obs

# Where do particles producing ZDR and KDP in the DGL come from?

- Seeding particles from above (e.g. Moisseev et al. 2015; Griffin et al. 2018)?
- Particles formed locally through SIP?

→ McSnow simulations with habit prediction (McSnow: Monte-Carlo particle model)

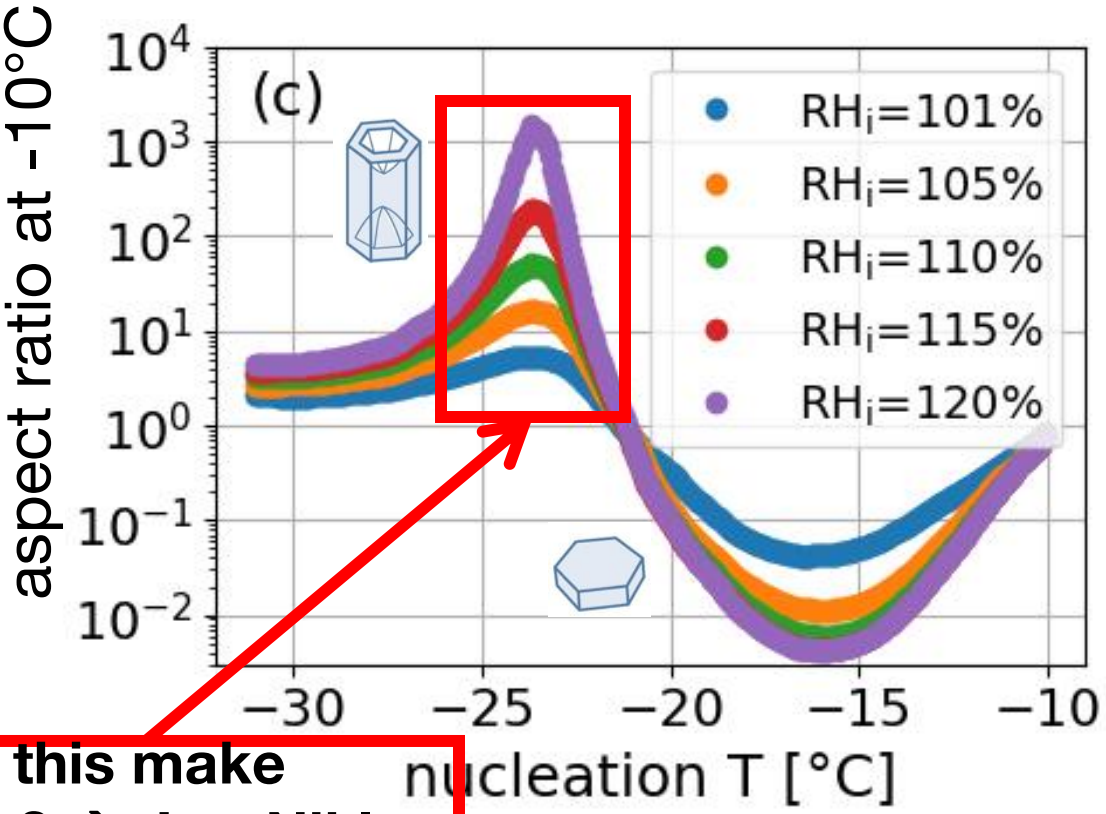


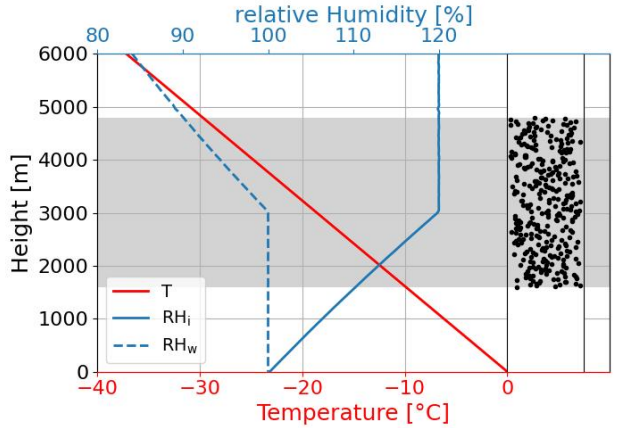



# Where do particles producing ZDR and KDP in the DGL come from?

→McSnow simulations with habit prediction

→ Particles grow through deposition while sedimenting




- **Particles nucleated at T<-21°C do not grow into plates**
- Particles nucleated at -16°C grow most efficiently into plates

→ Most likely: **particles are generated locally in DGL**

**Does this make sense? → Jan-Niklas talk**

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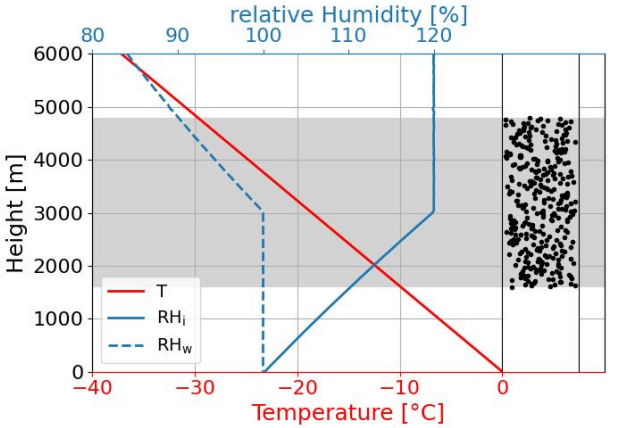


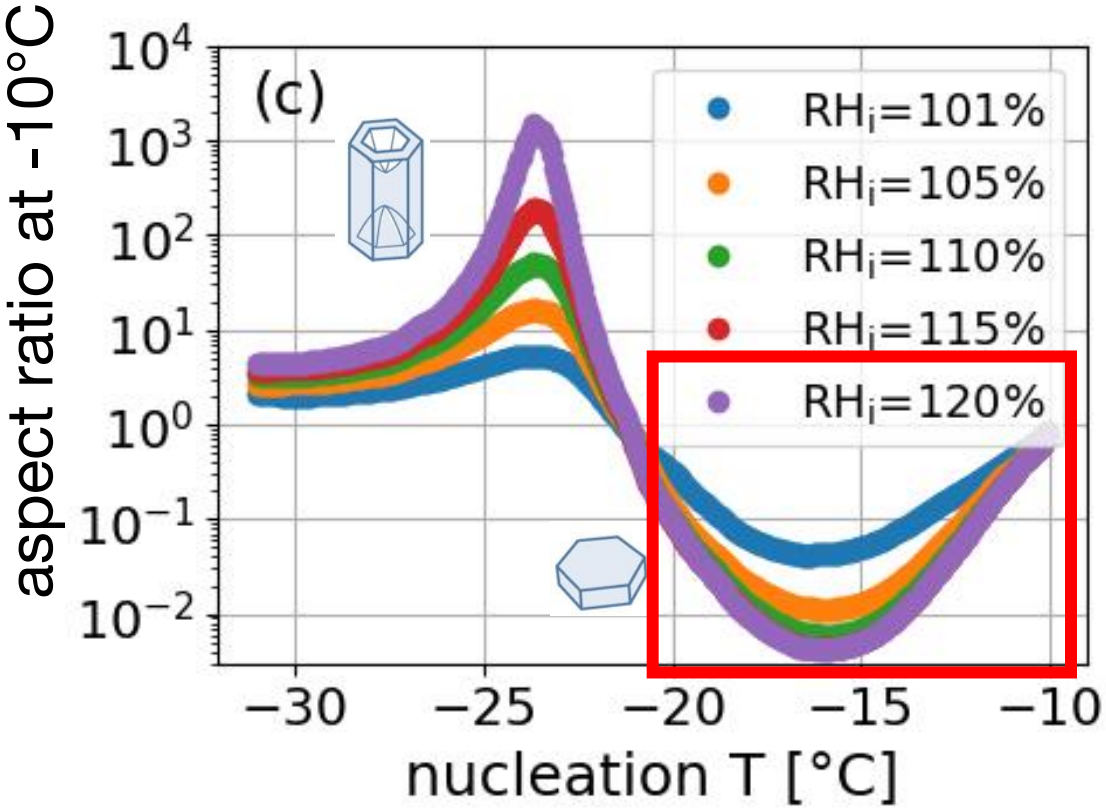


What does crystal growth look like in radar space? → forward simulation

# Where do particles producing ZDR and KDP in the DGL come from?

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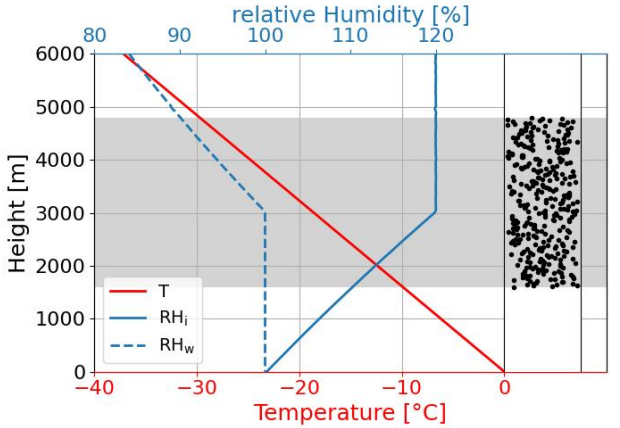
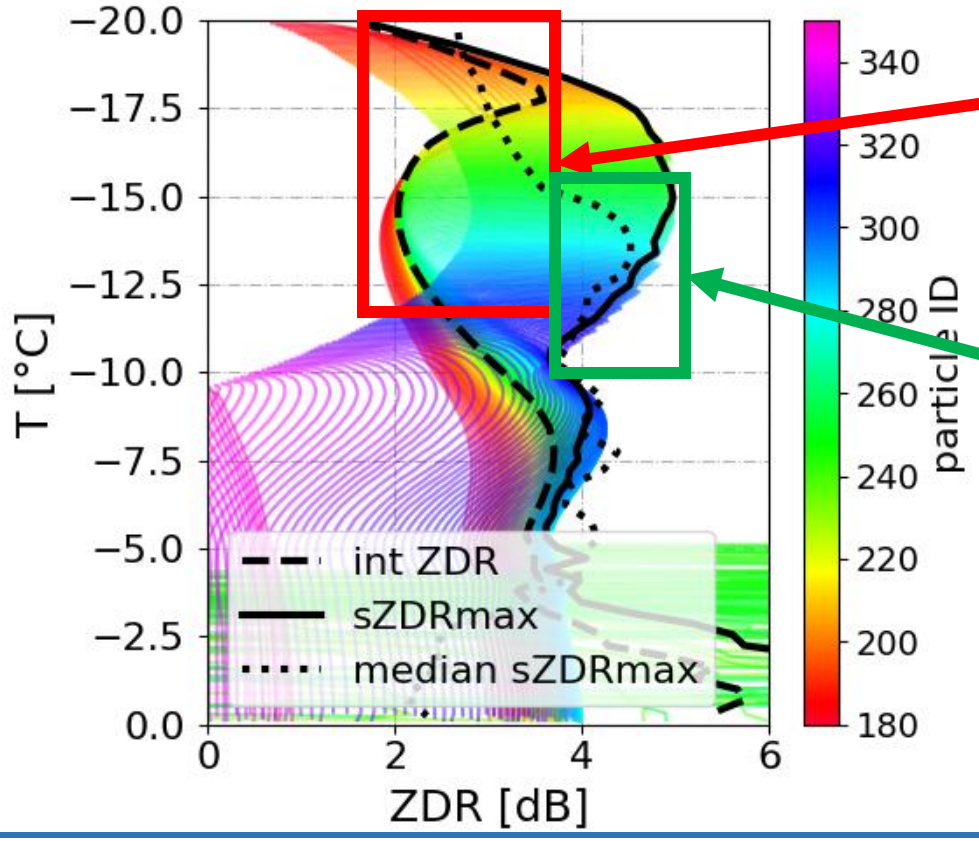
→Single particle scattering calculation with T-matrix




ZDR decreases due to branching

**To continuously increase ZDR below -15°C, particles have to be nucleated continuously**

# Conclusions

- Aggregation is linked to
  - Increase of ice crystal size (sZDRmax)
  - Increase of ice crystals concentration (KDP)
- Why does crystal concentration increase? Aggregation should decrease concentration!
- McSnow simulations revealed
  - Plate-like particles have to be nucleated within DGL
- Can fragmentation explain the observed radar signals?

→**FRAGILE: Laboratory studies**

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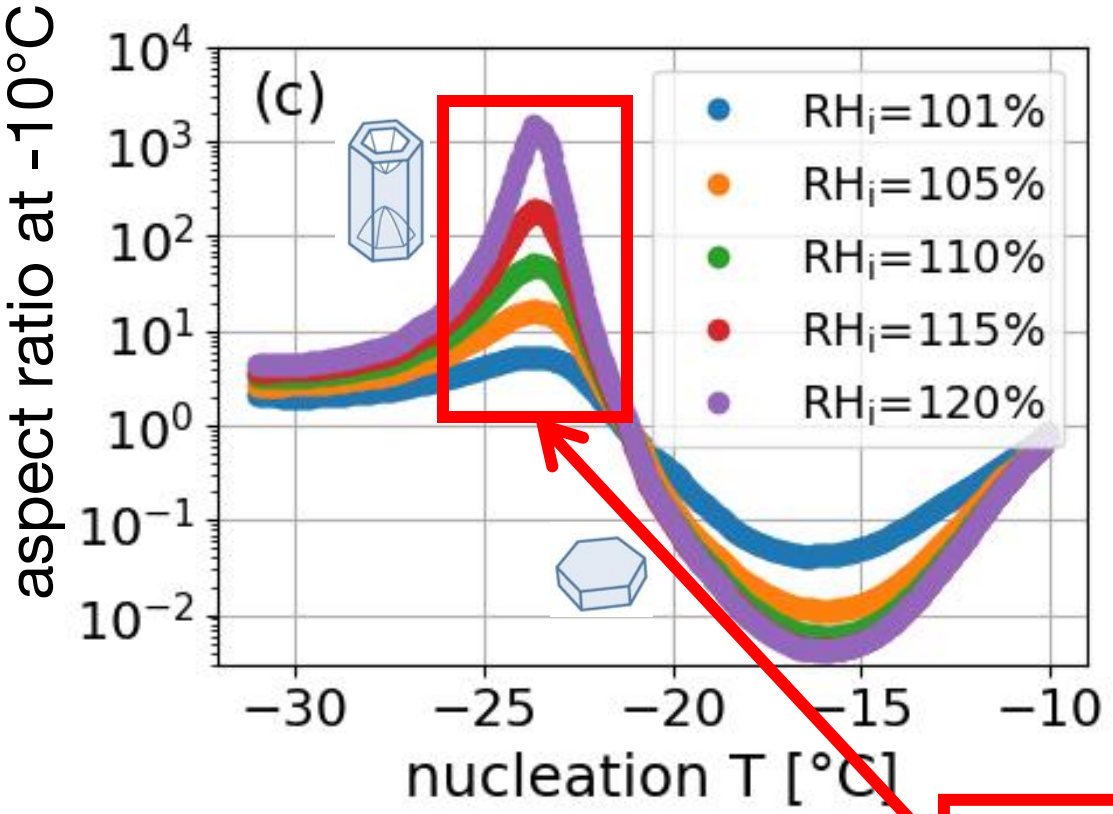
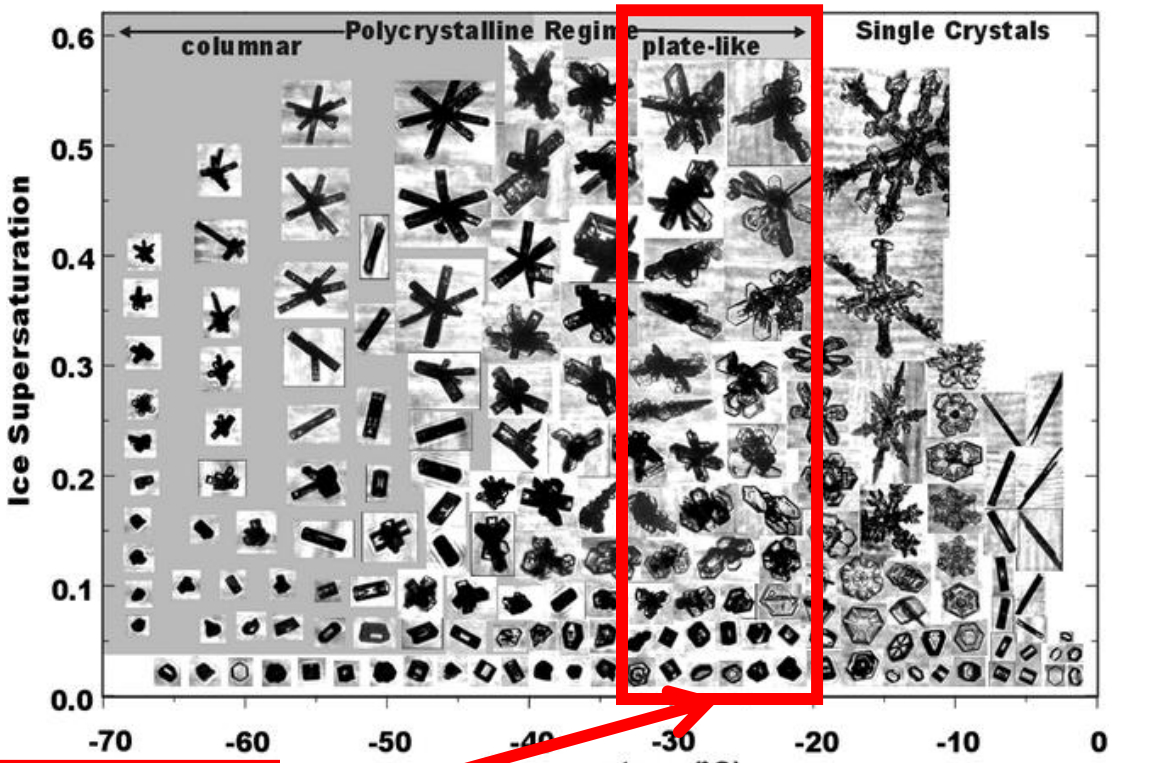


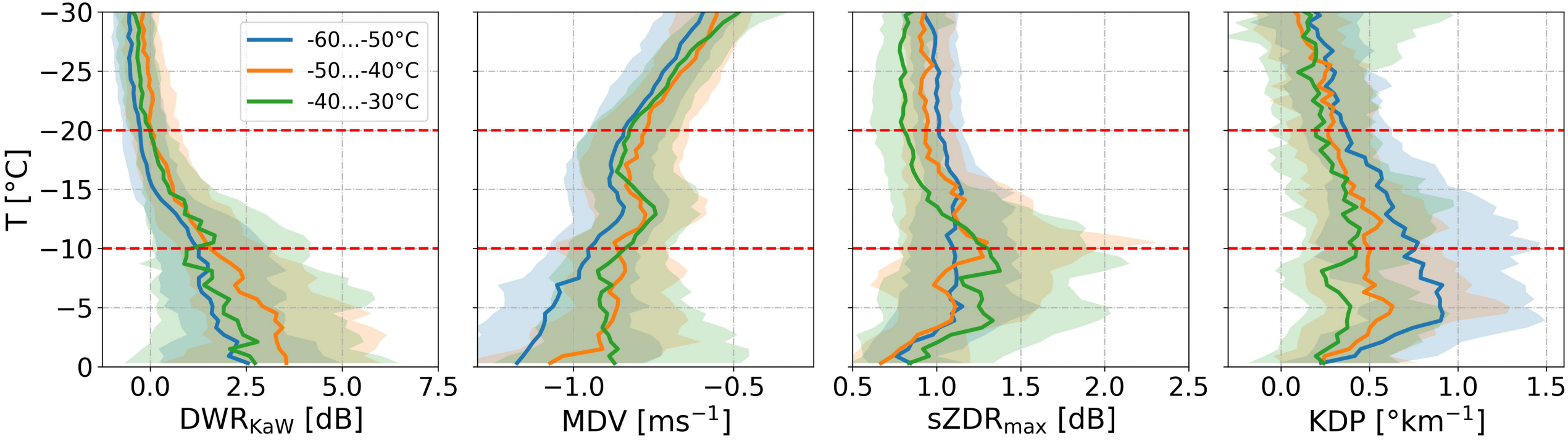




Bailey and Hallett 2009

**Jan-Niklas talk**

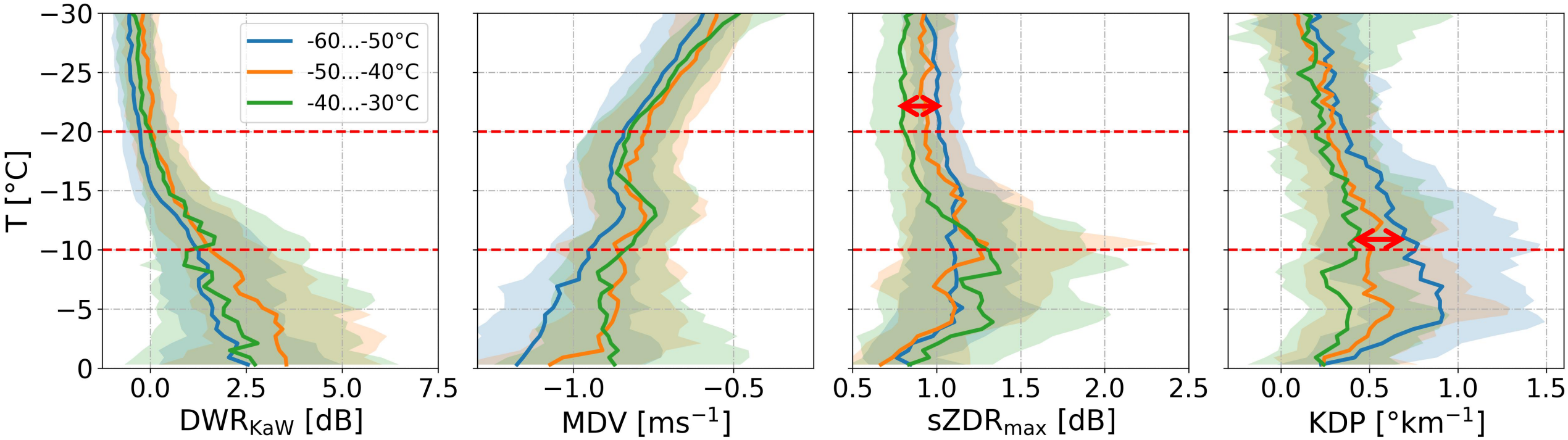
# How important are processes happening within DGL?

- Previous studies:
  - **correlation between cloud-top temperature (CTT) and KDP/ZDR**
  - Increase of ZDR and KDP due to seeding particles from above
- Classify by CTT



# How important are processes happening within DGL?

→Classify dataset by CTT




- Slightly larger crystals for colder CTT
- Concentration in DGL of crystals slightly larger for colder CTT

→ **Overall: much less dependent on CTT than on DWR**

→ **Processes in DGL seem to be important**