PROM – IMPRINT

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

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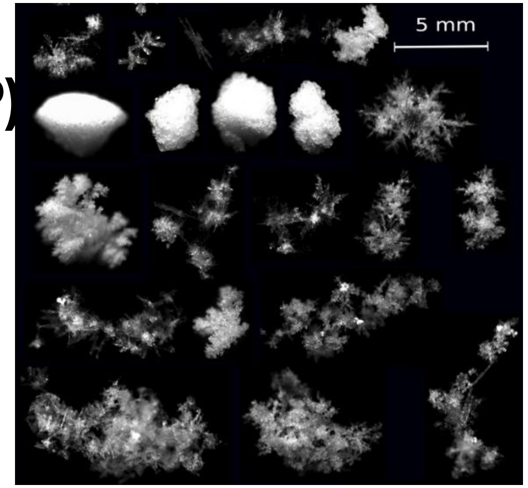
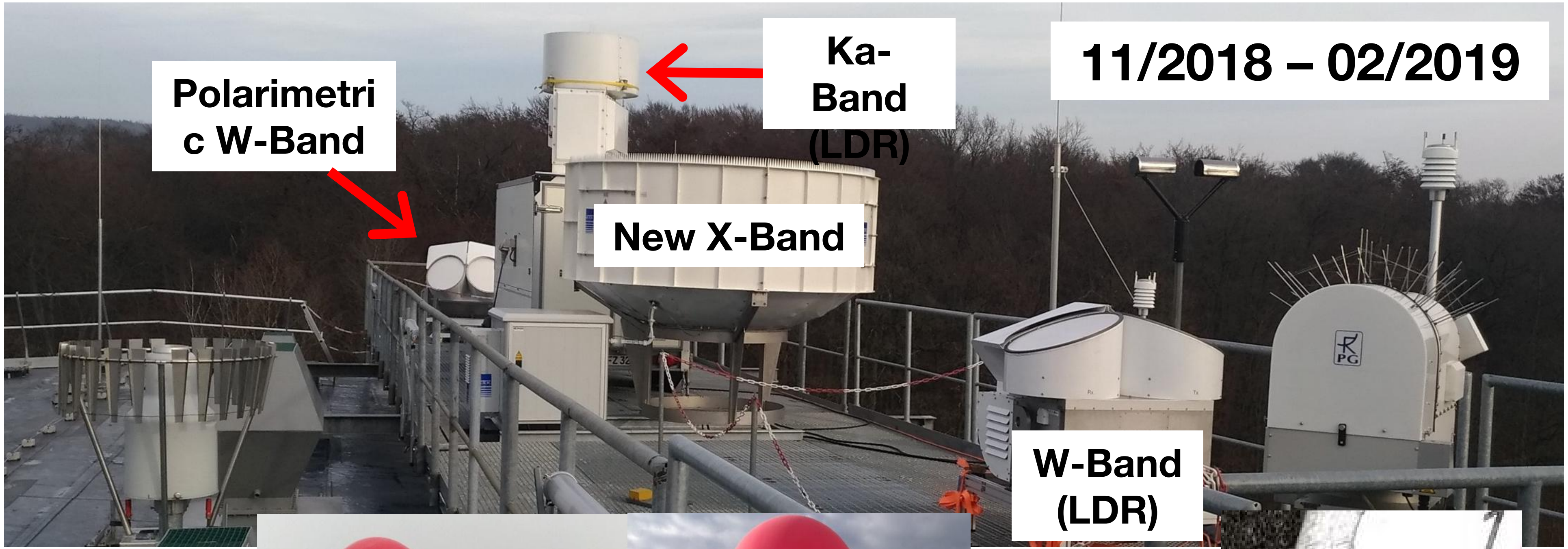
Motivation and Objectives

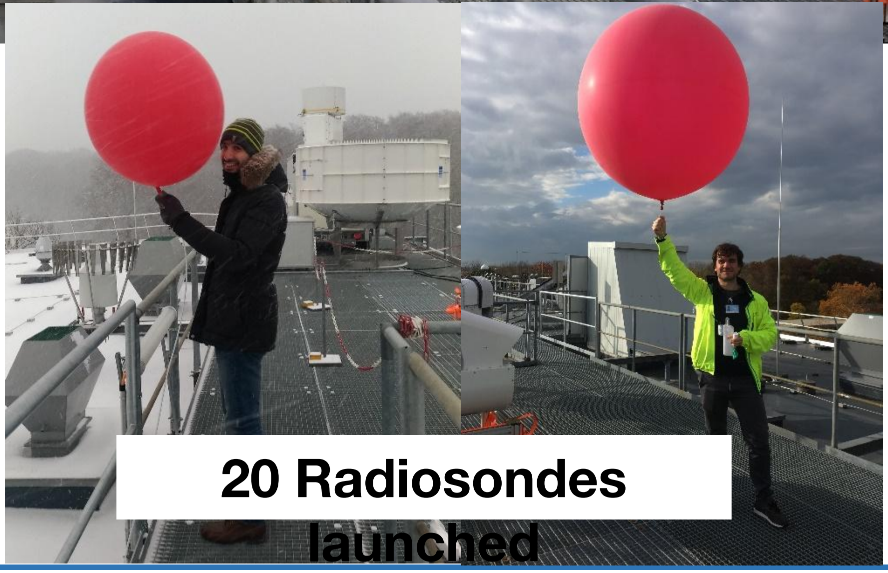
- Increase understanding of key **ice microphysical process (IMP)**
  - **Aggregation**
  - **Riming**
  - **Secondary Ice**
- **Observational approach:** Combined observations using spectral Polarimetry and Multi-frequency radar
- **Modelling approach:**
  - McSnow (1D): Lagrangian super-particle model allows to implement very detailed ice microphysics (**habit prediction, riming, aggregation, fragmentation**)
  - Simulation of synthetic observations using pyTmatrix



T. Garret, U. Utah

1st Winter Campaign: Tripex-pol



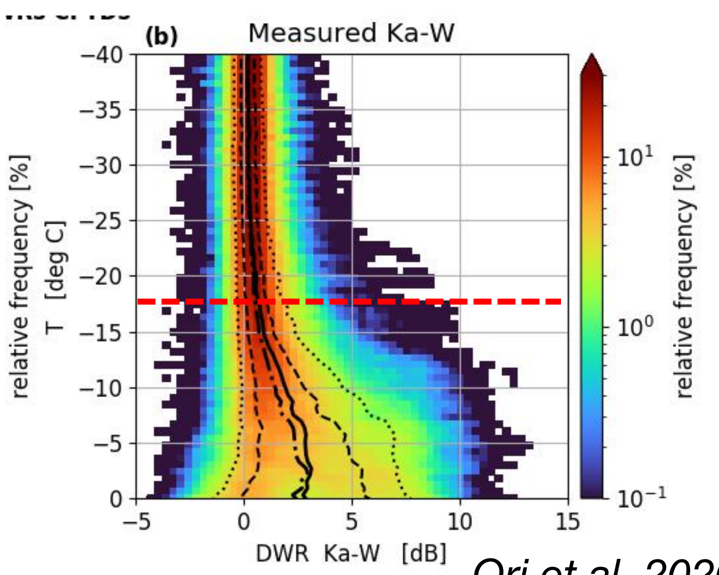


Previous work on aggregation

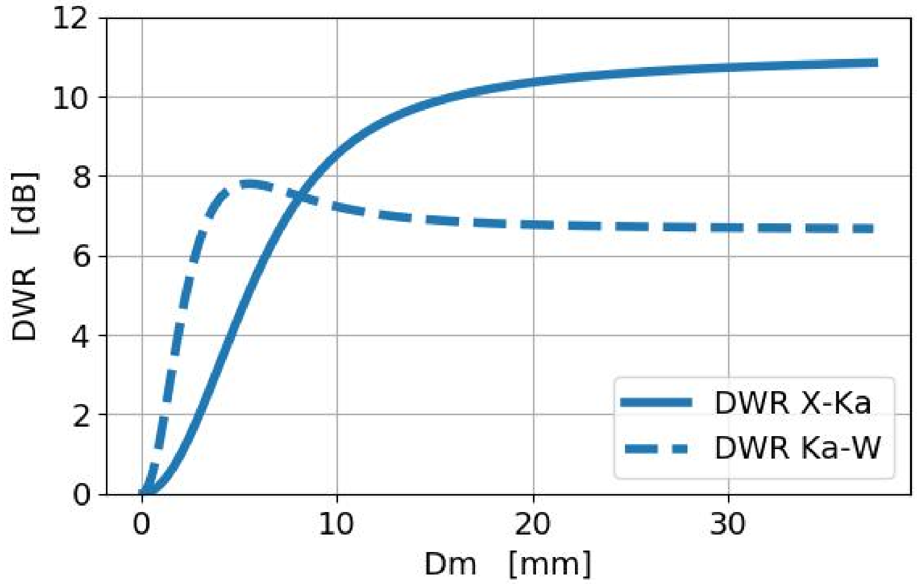
- $DWR_{\lambda_1\lambda_2} = Ze_{\lambda_1} - Ze_{\lambda_2}$
- DWR is dependent on mean size of particle distribution
  → indication of aggregation

We know already:

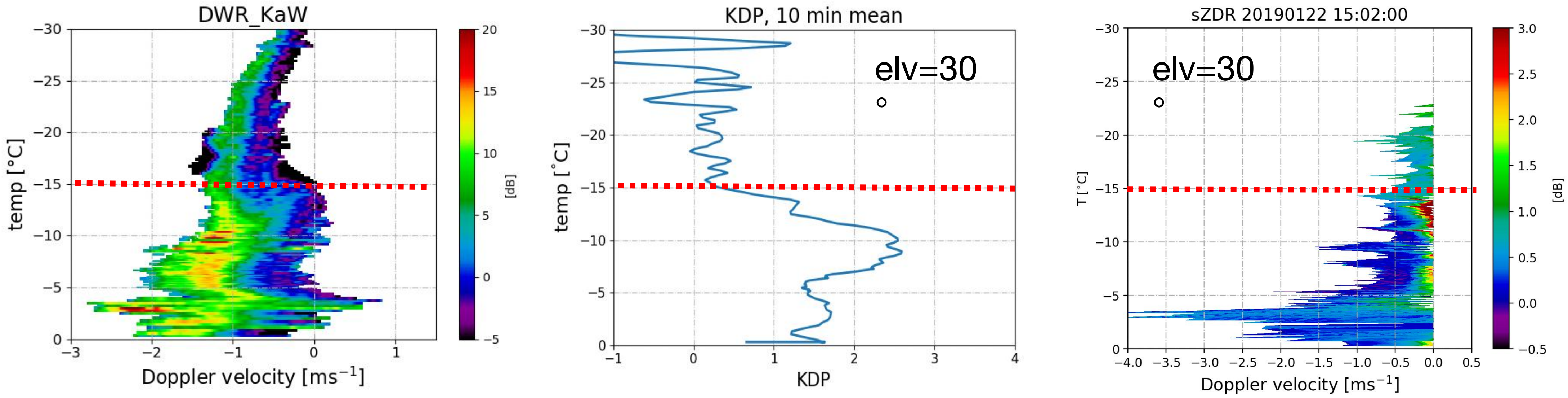
- Enhanced aggregation starting at around -17°C (widening of distribution in DWR_{KaW} statistics)
- Dendritic growth zone (DGZ) between -17 and -12°C well known to favor aggregation (dendritic arms can interlock)



Ori et al. 2020



Combined view on DGZ: combining DWR, spectra, and polarimetry



- Spectral ZDR strongly increases where spectra become bimodal
- KDP is increasing starting at -15°C, but reaches max. at -10°C
- DWR reaches max. at -10°C (coincident with max. of KDP)

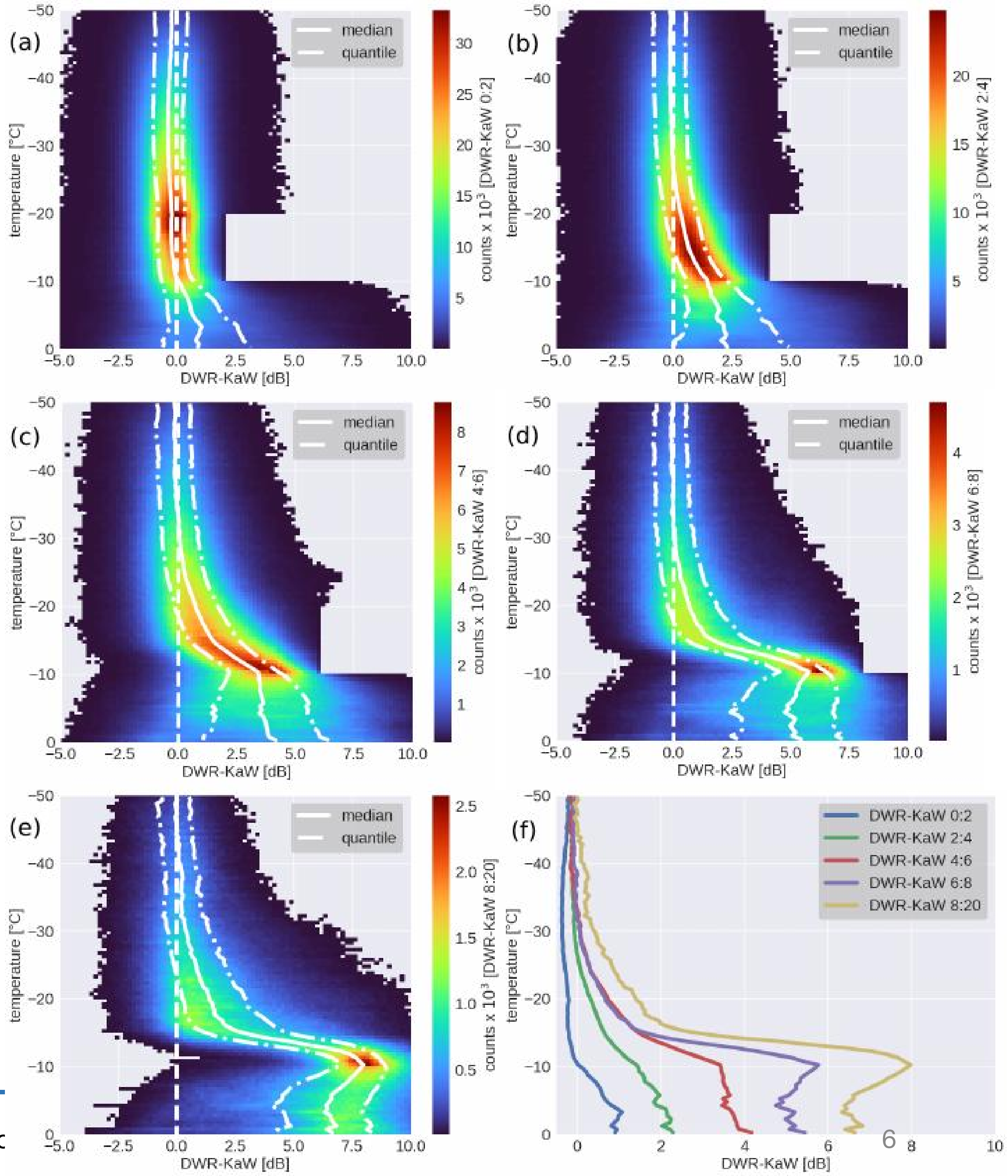
→With increasing aggregation, the number of small particles should decrease

→ so why is KDP increasing down to -10°C?

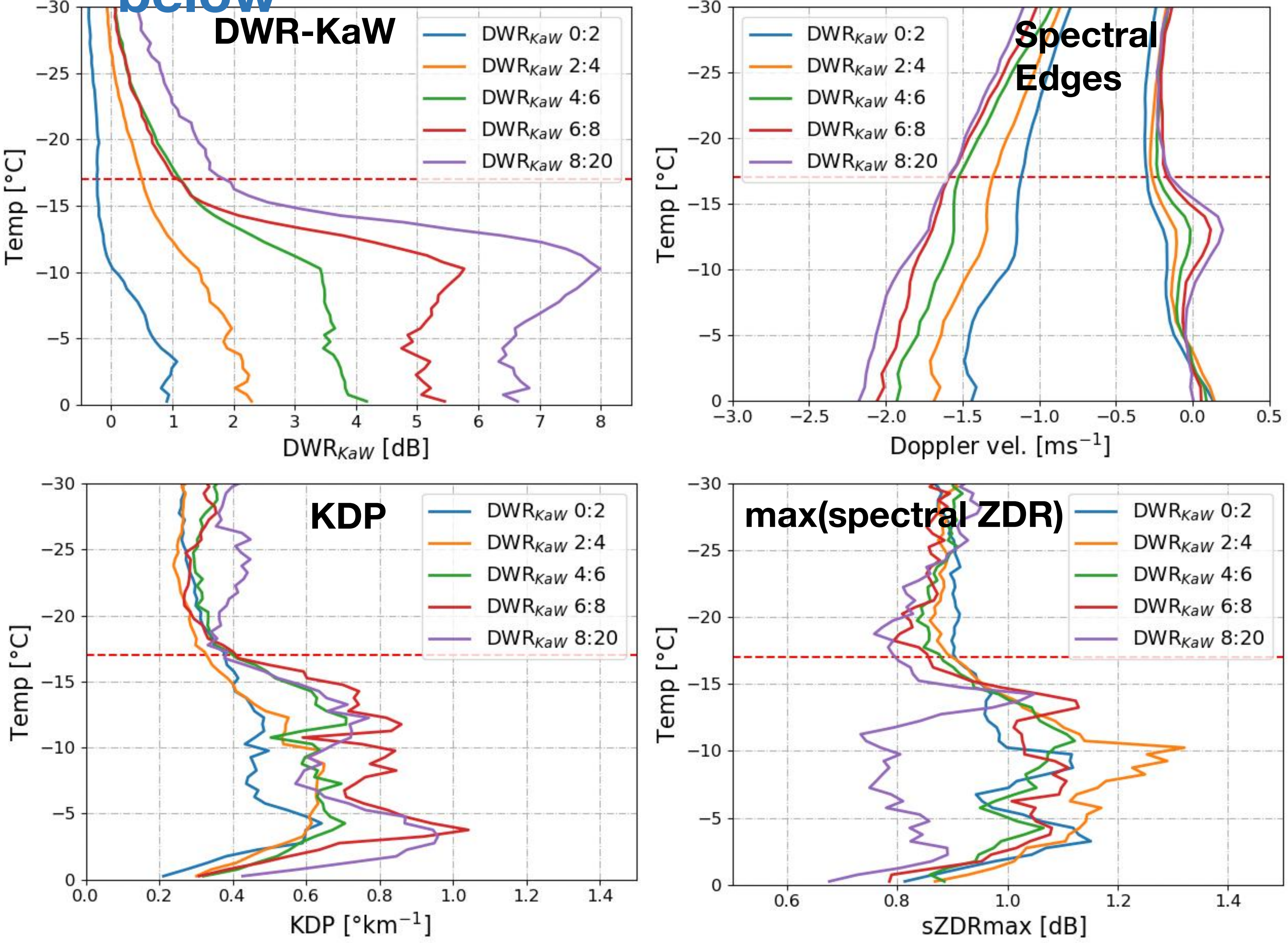
How strongly are aggregation and small particle mode linked?

→ Use multi-month dataset to explore this dependency in more detail

→ Separate dataset into DWR-classes defined by max(DWR_{KaW}) in DGZ (between -20 and -10°C)



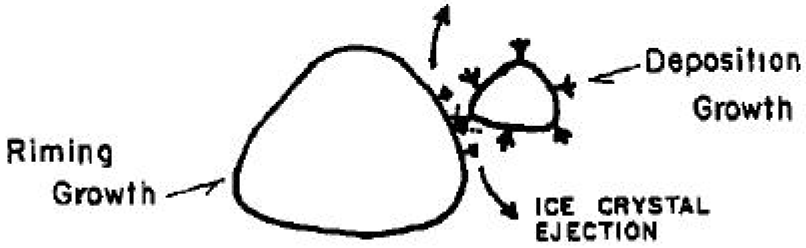
Small particles change at -17°C, aggregation maximized below



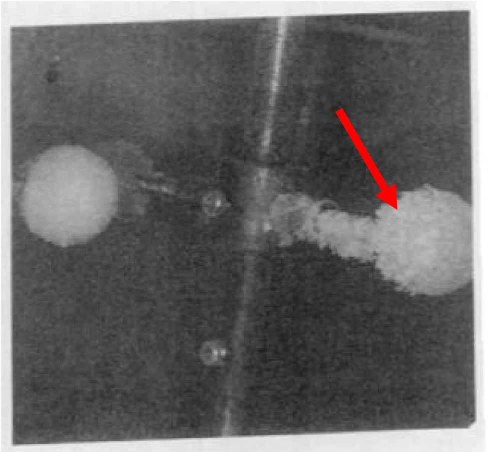
- → Largest aggregates at -10°C
- → Small particle mode at slow edge of spectra is increasingly slowing down with larger DWRs
- → Slow-down starts at -17°C; mostly microphysical feature

- → KDP also increases at -17°C
- → Weakly correlated with DWR class
- → KDP relatively constant down to -3°C -> what is the source?
- → Particles with largest ZDR similar for all DWR classes

Collision-fragmentation found in laboratory studies



Takahashi et al. 1993



Takahashi et al. 1995

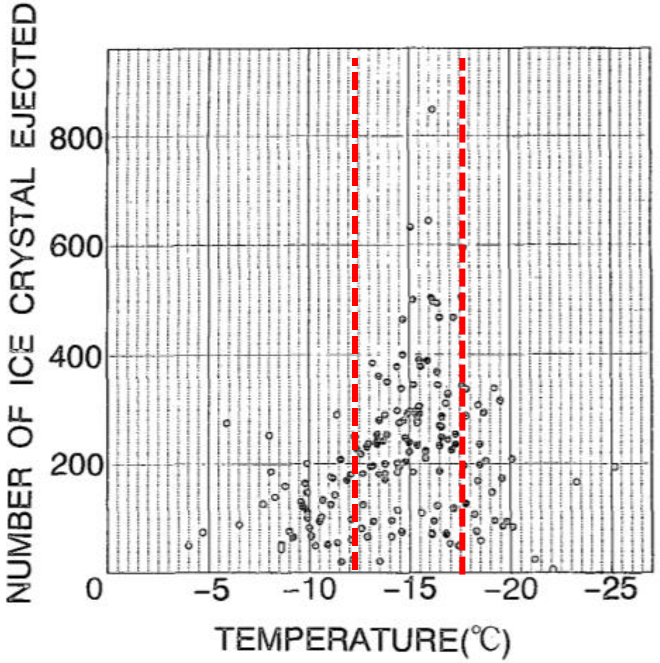


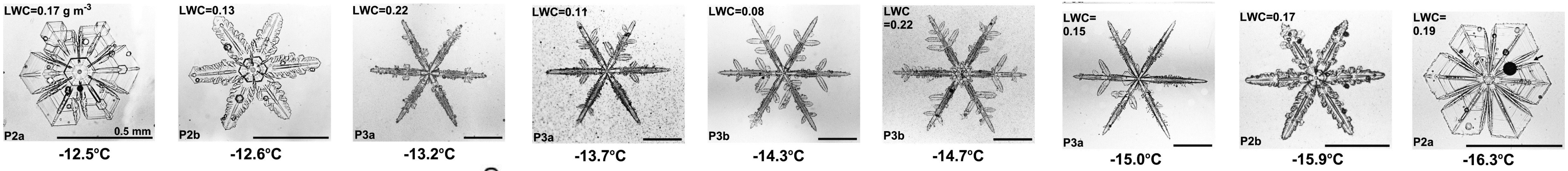
FIG. 4. Total number of ejected ice particles as a function of chamber temperature. The number of ice crystals collected by the main plate was simply multiplied by 4. The total number is therefore approximate. Cases of various collision forces were all included. Collision force was on the order of 500 dyn.

Takahashi et al. 1995: Graupel-Graupel collision, where maximum number of particles where ejected at -17°C

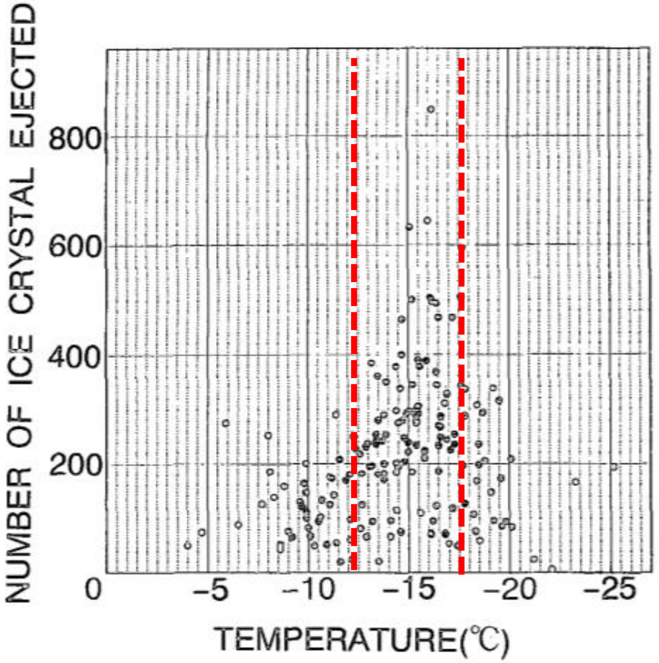
→Small arms are growing on ice-sphere which are easily fragmented of

→Could this also happen on aggregates at -17°C?

Collision-fragmentation indicated in laboratory studies



Takahashi 2014



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Takahashi et al. 1995

The temperature region where fragile, thin arms are growing coincides remarkably well with temperature region of stronger fragmentation (splinter production)

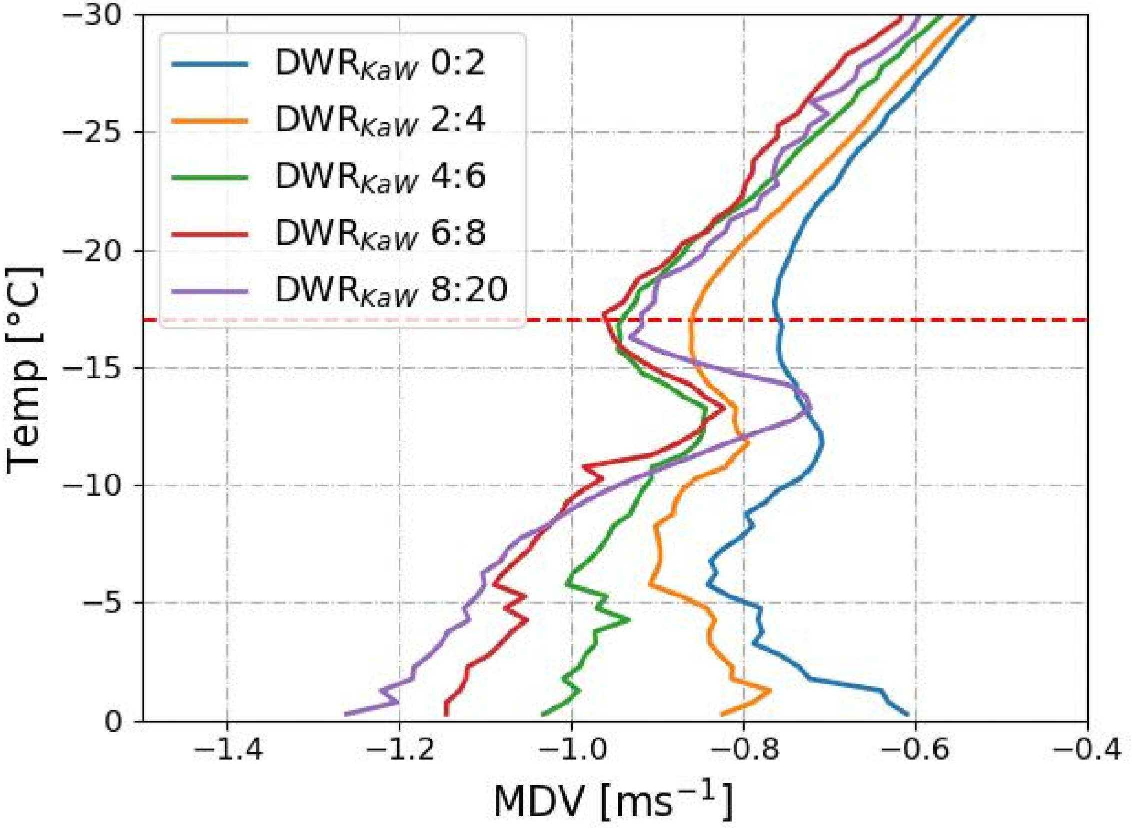
Conclusions

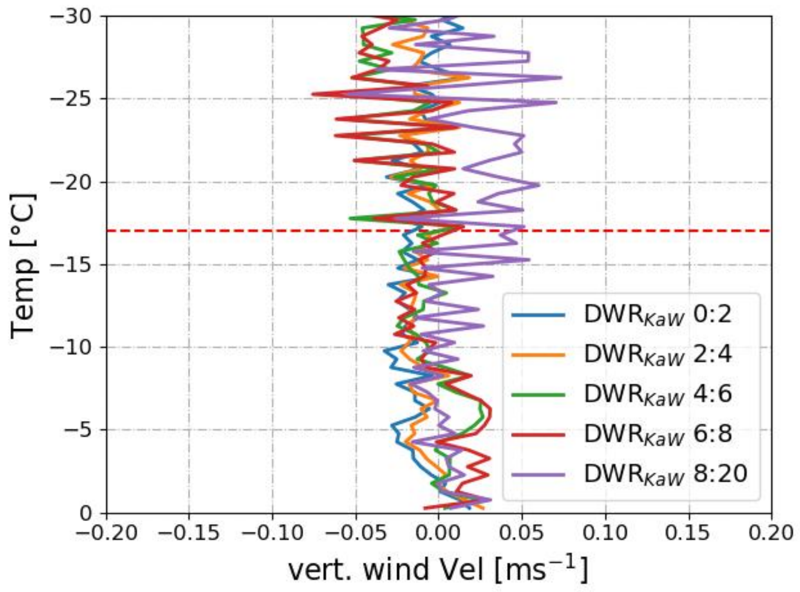
- Elevated KDP, sZDR, slow down in spectral edges, spectral multi-modality
  → **Observations indicate growth of a new mode of small particles**
- KDP is not enhanced yet at -20°C although plate-like regime starts there
  → **KDP producing particles first become visible at -17 °C**
- **Larger aggregation at lower levels is connected to larger KDP (more small particles)**
- KDP remains enhanced until -3°C
  → given aggregation as a sink, **a source for small particles is needed**

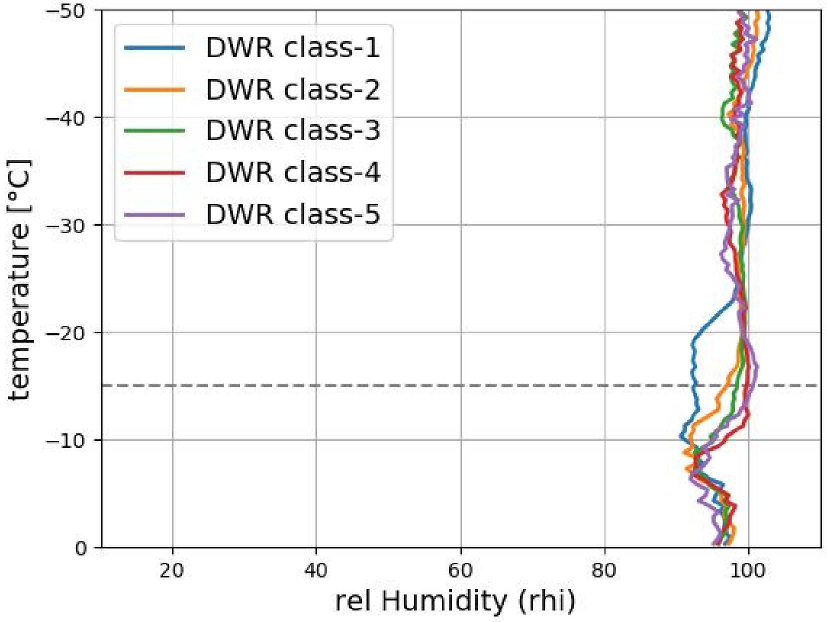
Question: How important is fragmentation for the aggregation process at the DGZ?

- for a definite answer we need
  → model with detailed ice-microphysics **(habit prediction, fragmentation in McSnow)**
  → in-situ measurements: **HALO-overflights in next campaign?**
  → potential laboratory studies: **cloud-chamber in Mainz? possible PROM-phase II ?**

All other profiles:







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