# Ice processes in Antarctica (DOE-FOA-0001638)

## Triple frequency radar characterization of cloud microphysics at McMurdo during AWARE

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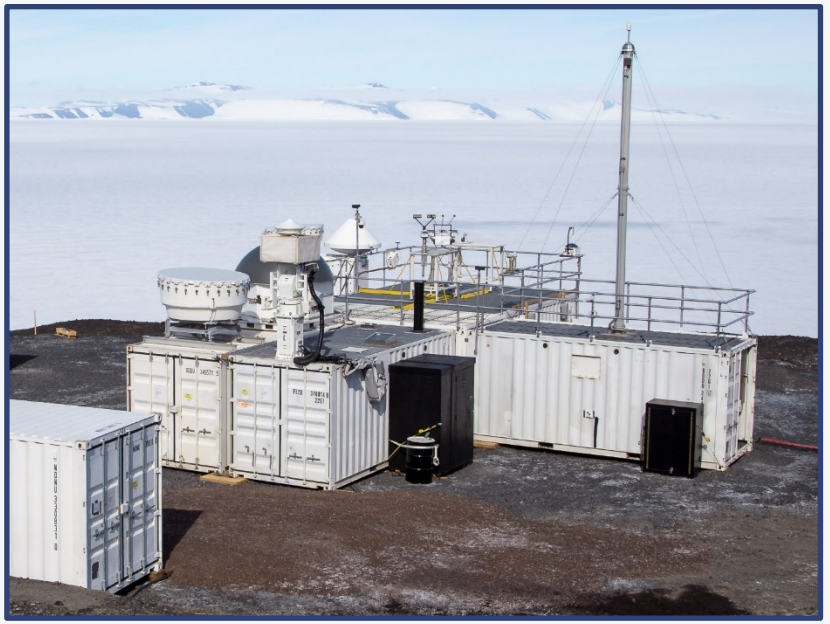
# Motivation

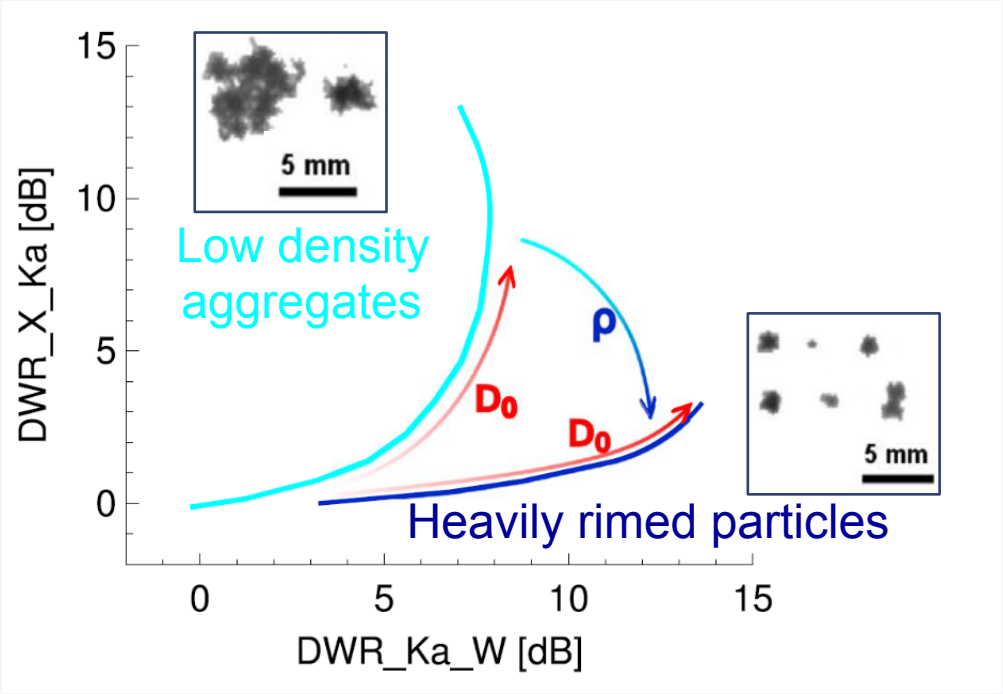
- How different aggregation and riming are for mid-latitude vs. high-latitude clouds?
- 3-frequency radar measurements provide constraints to particle sizes and bulk density
- During AWARE, triple-frequency radar observations have been collected for the first time in Antarctica (KAZR, XKa-SACR, MWACR).
- → Unique opportunity to evaluate the importance of aggregation and riming in such a cold and pristine environment



# Why triple-frequency radar?

- For large particles, scattering depend on radar frequency
- DWR can be used for sizing ice particles (Matrosov et al., 1993)
- Triple-frequency space for 2 pairs of DWRs
- Aggregates separate from rimed particles in the triple frequency space

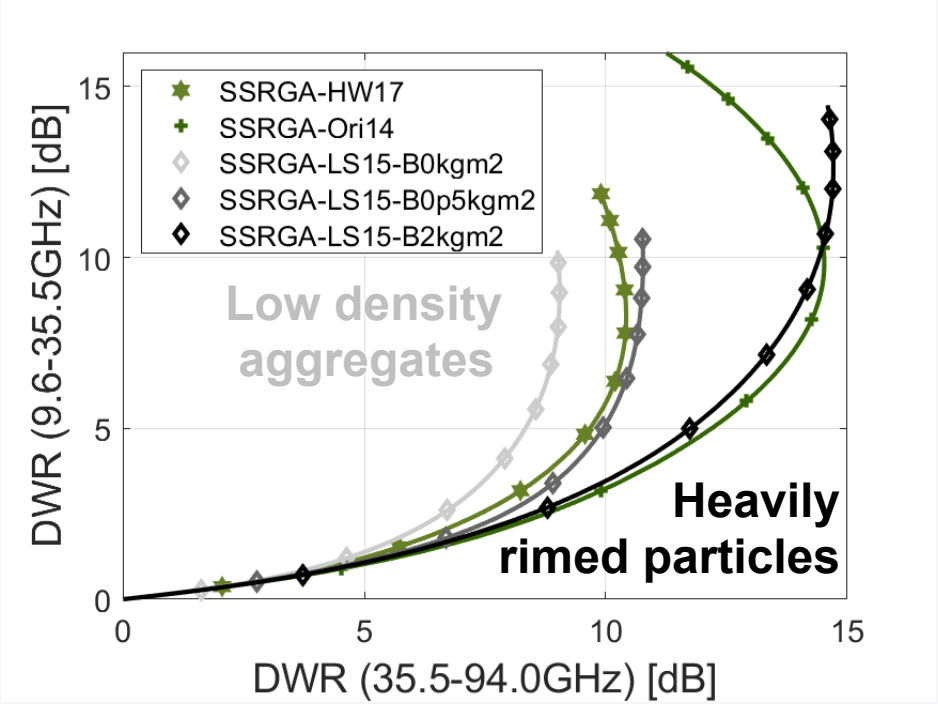
$$DWR_{Ka,W} = Z_{e,Ka} - Z_{e,W}$$




Kneifel et al. (2015)

# Scattering models

- Large number of scattering models developed in recent years
- Focus on the Self-Similar Rayleigh-Gans approximation (SSRGA, Hogan et al., 2017)
- Scattering cross section of a series of increasingly rimed aggregates obtained from an aggregation and riming model (Leinonen and Szyrmer, 2015)
- Definition of various SCAT-MIC models



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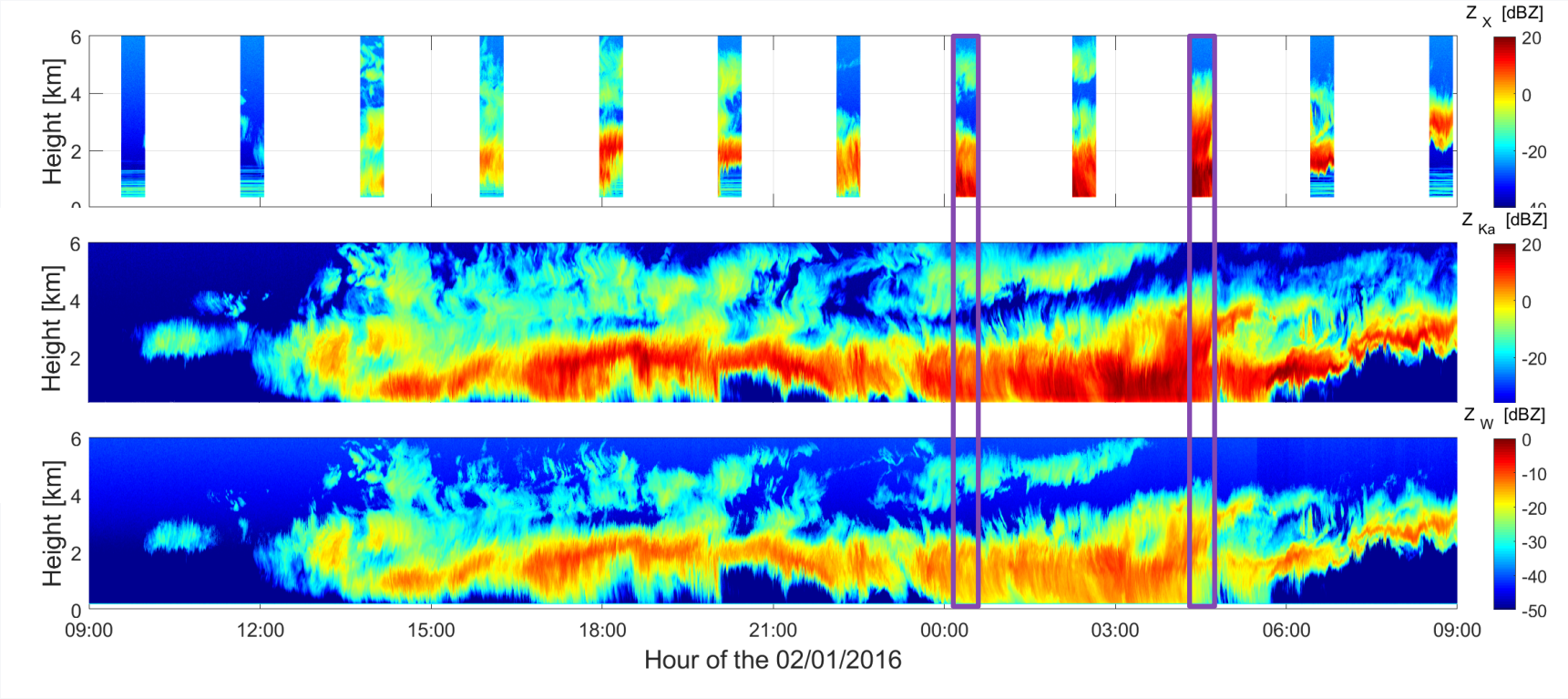
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Z Ka [dBZ]
Z W [dBZ]
Height [km]
Hour of the 02/01/2016
09:00
12:00
15:00
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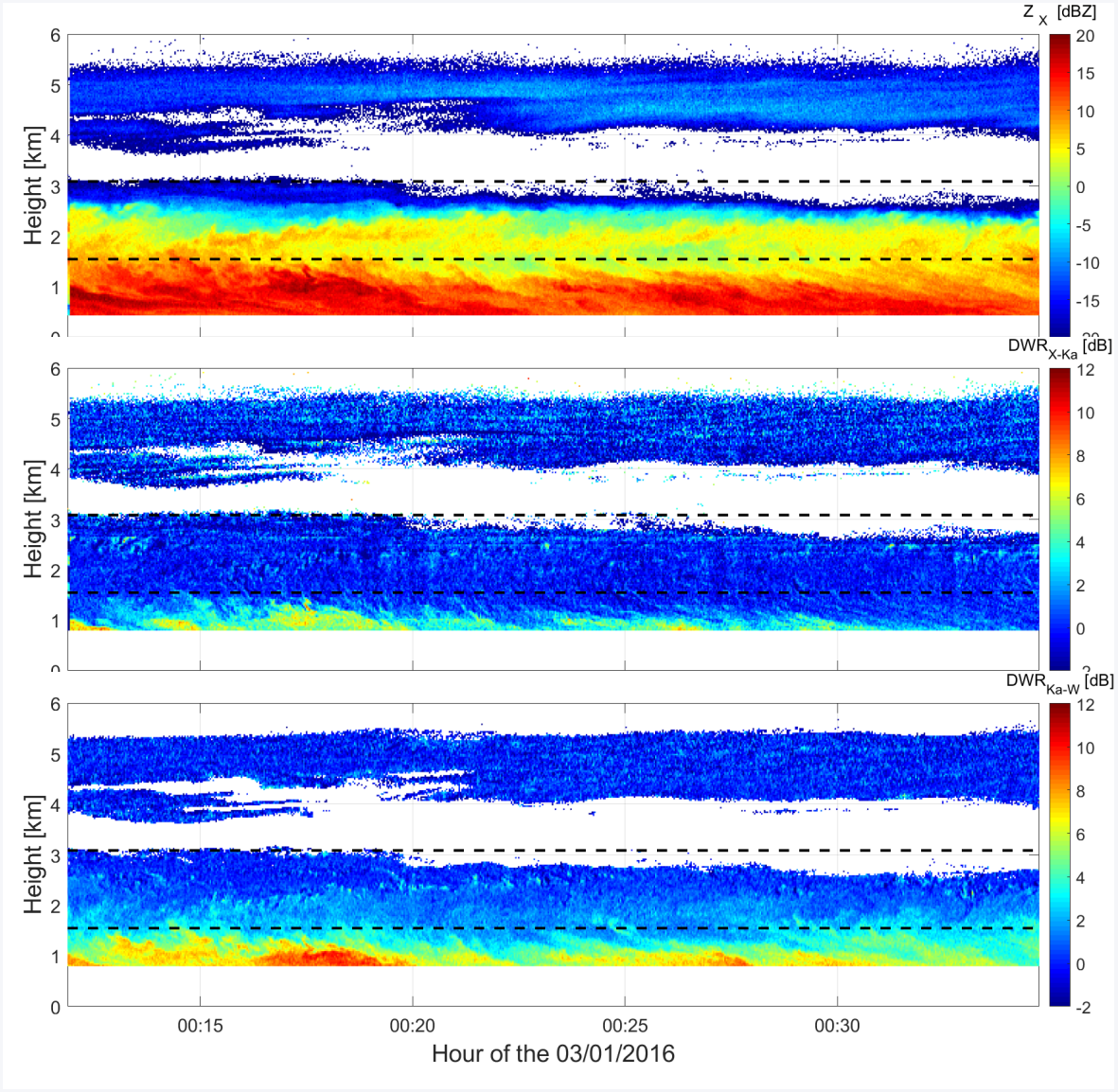
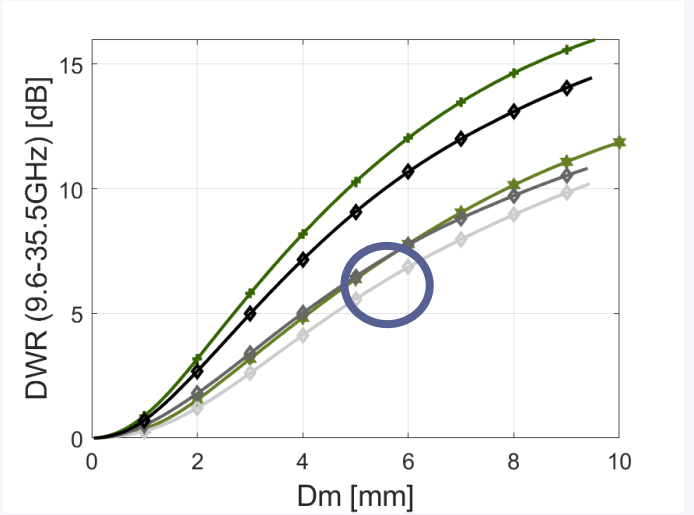
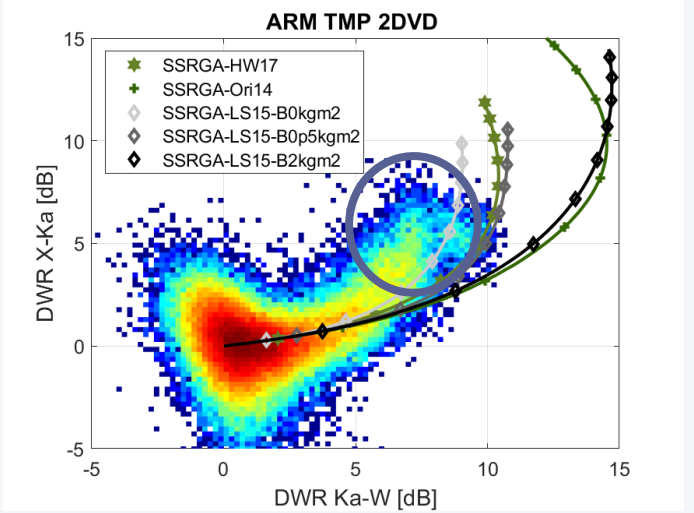
09:00

# 2-3 Jan. 2016 00:11:52-00:34:45

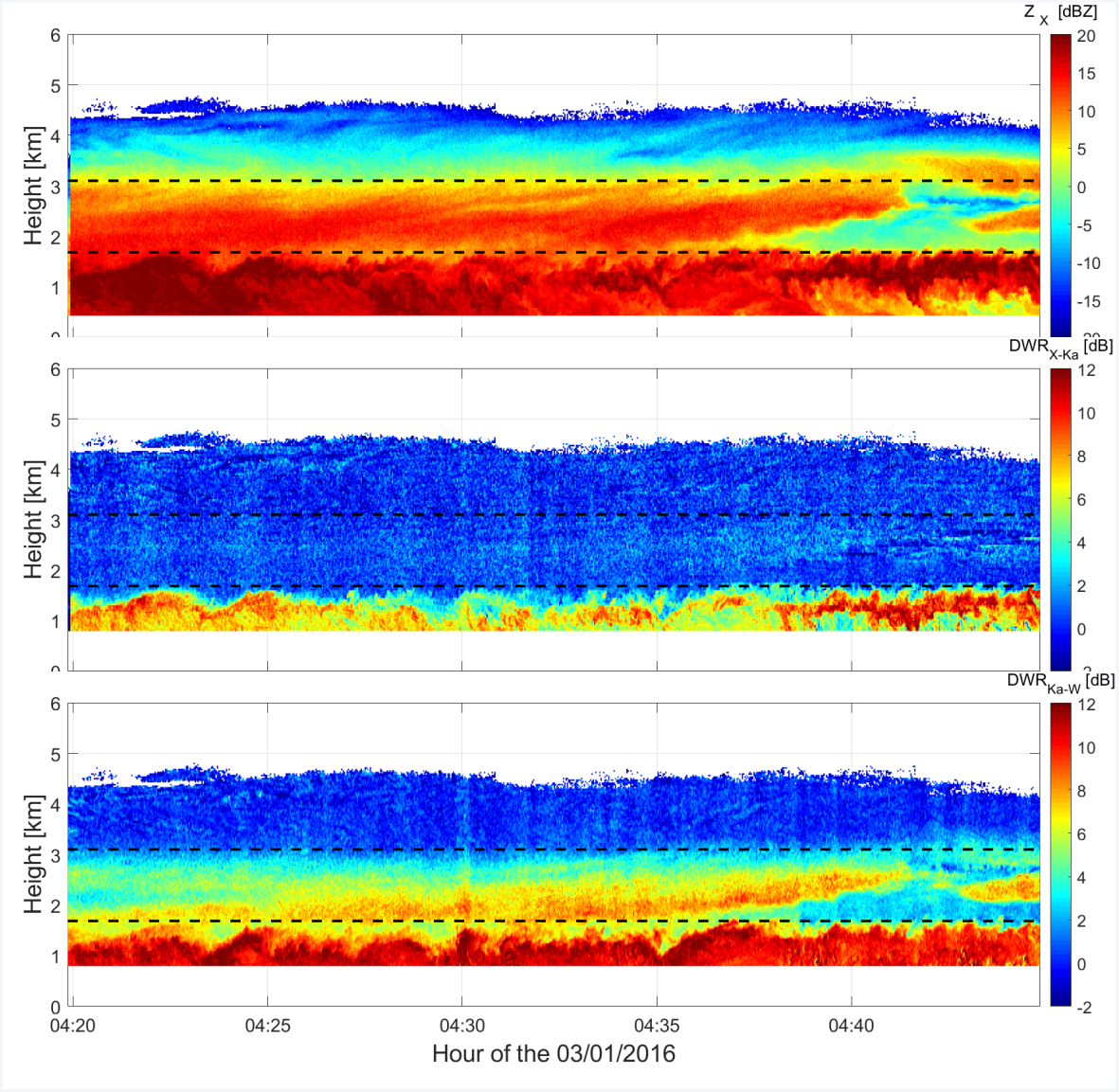


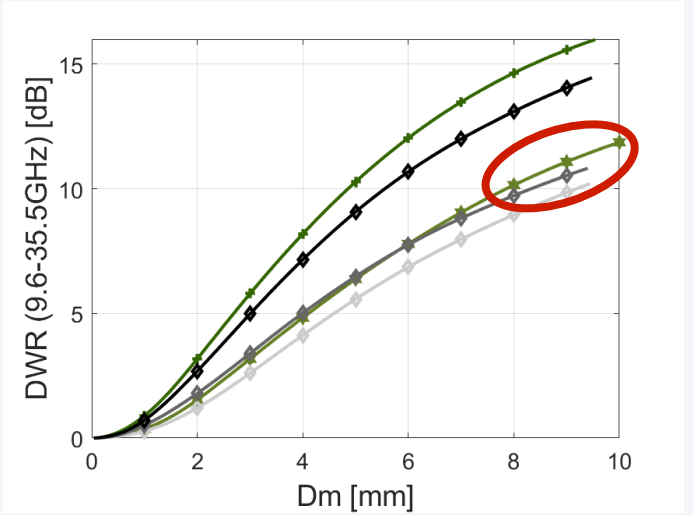



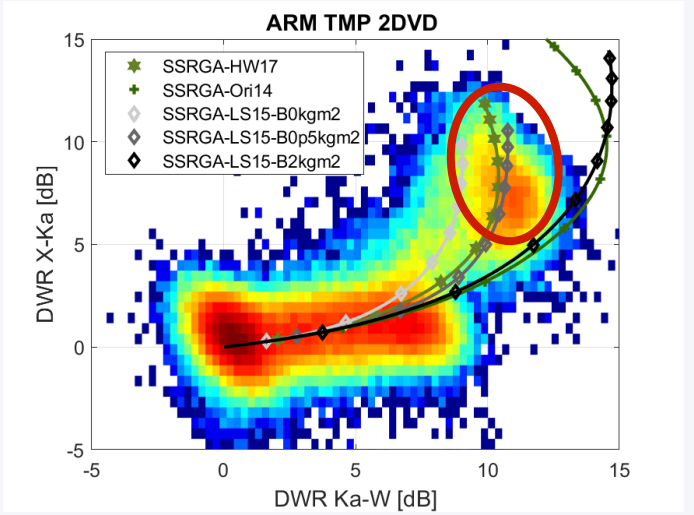




Clear signature of aggregation with $D_m$ up to 5 mm

# 2-3 Jan. 2016 04:19:51-04:44:50



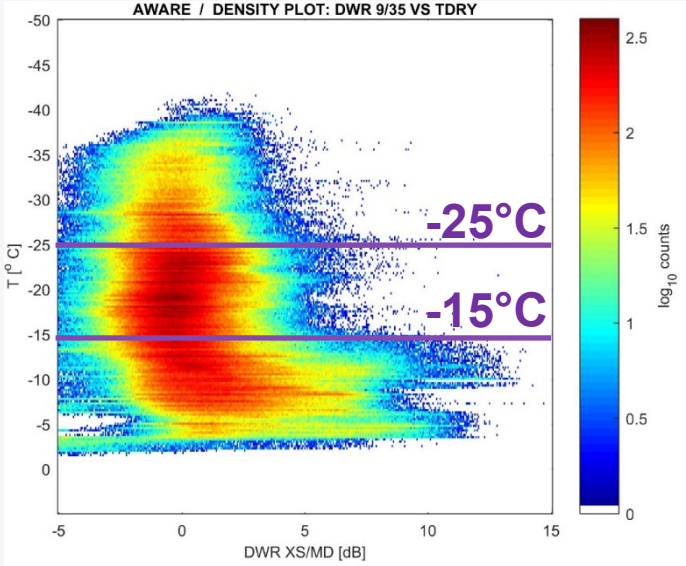




Clear signature of riming with $D_m$ up to 9 mm

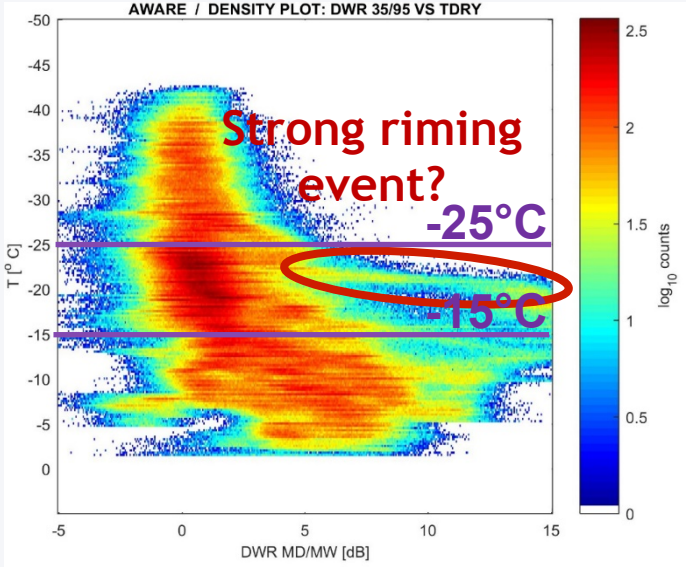
# Comparing statistics of dominant ice processes

**AWARE (18h)**

**$DWR_{XKa}$**




**$DWR_{KaW}$**



# Comparing statistics of dominant ice processes

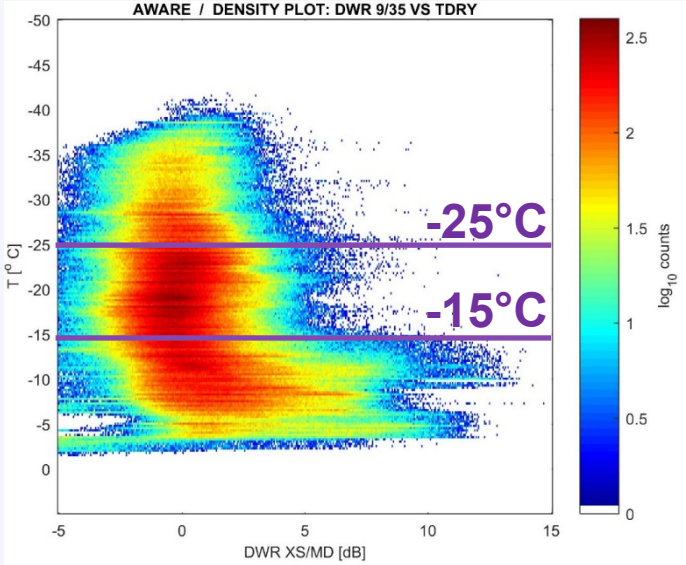
**AWARE (18h)**

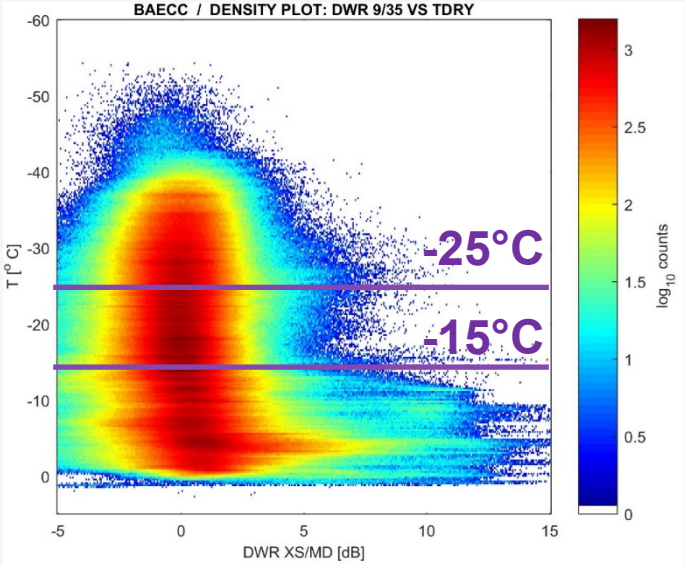
**BAECC (35h)**

**$DWR_{XKa}$**

Overall similarity quite surprising!

Significant increase of DWRs at -15°C (dendritic growth)

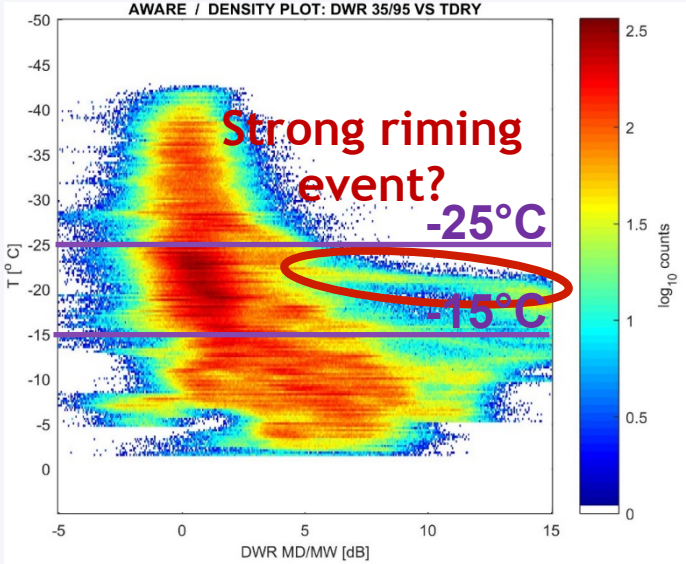


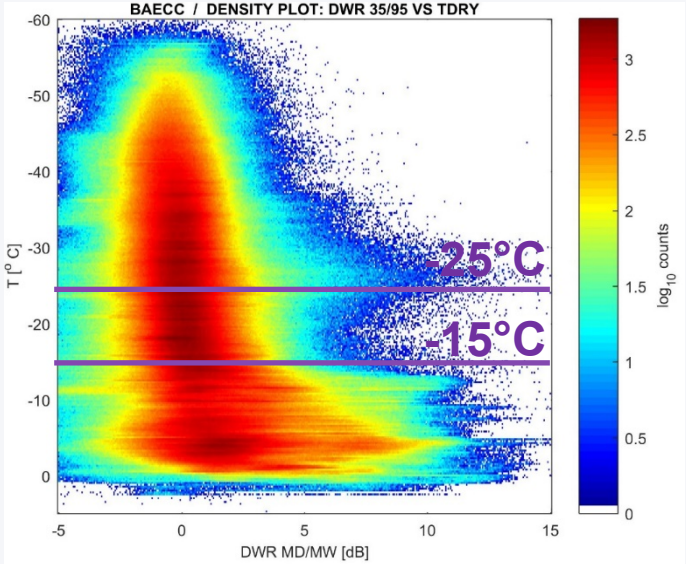




**$DWR_{KaW}$**

But also significant differences

Overall increase close to the ground and strong increase at -25°C



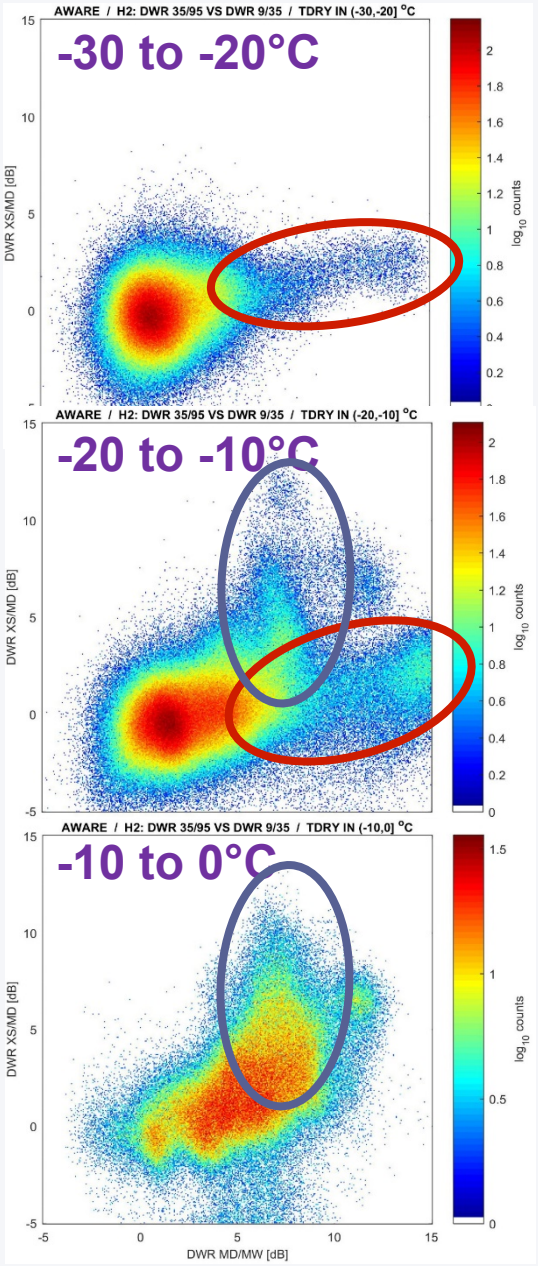



# Comparing statistics of dominant ice processes

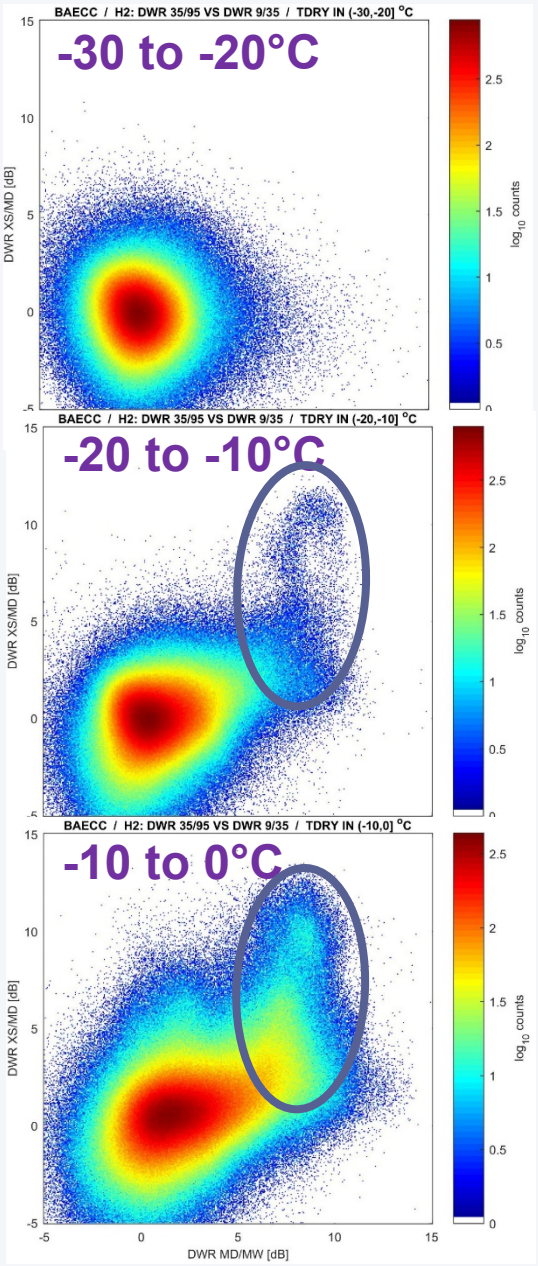
**Low density aggregates**

**Heavily rimed particles**

## AWARE

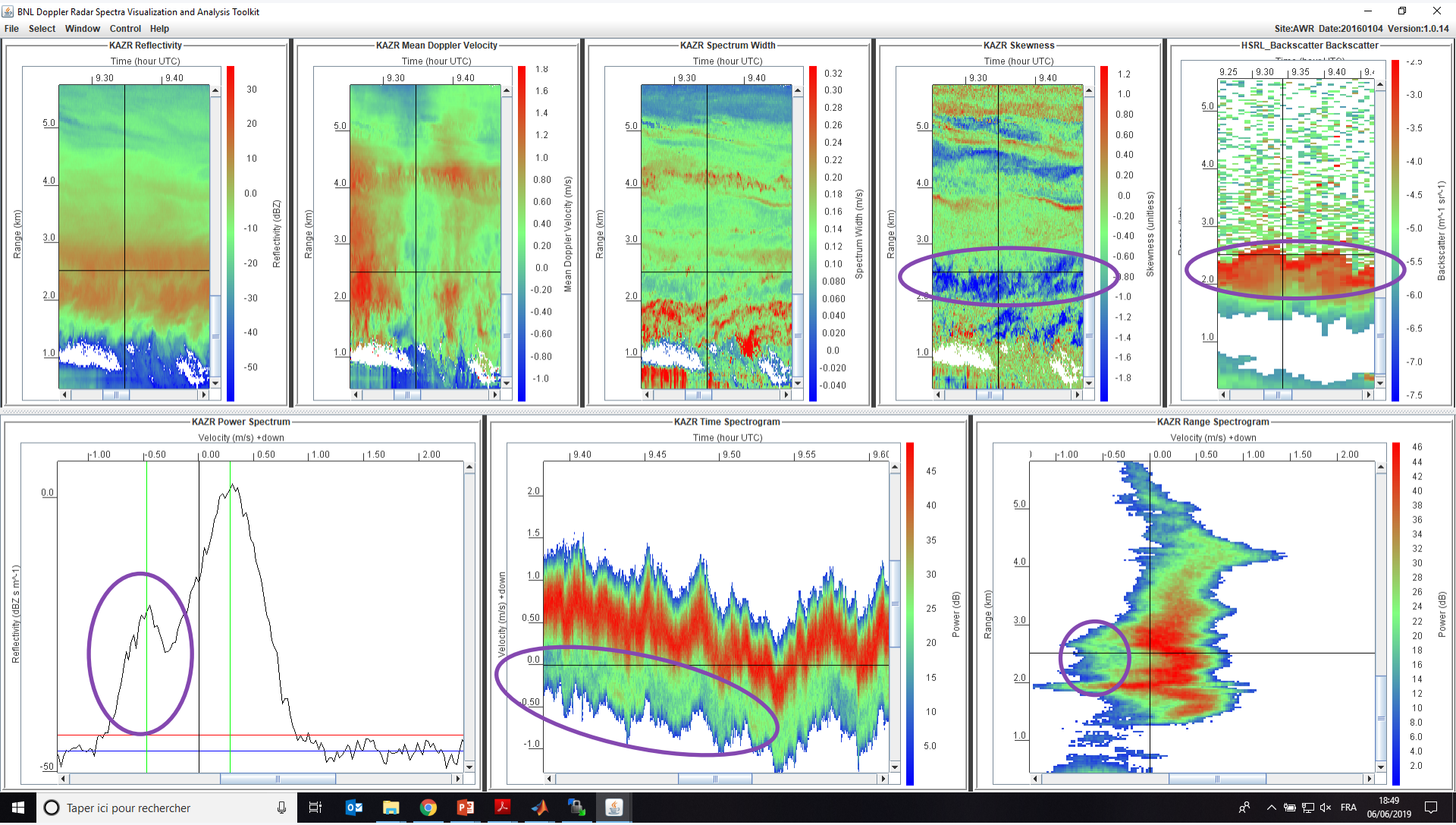



## BAECC



# Another example 2016-01-04 9h to 10h

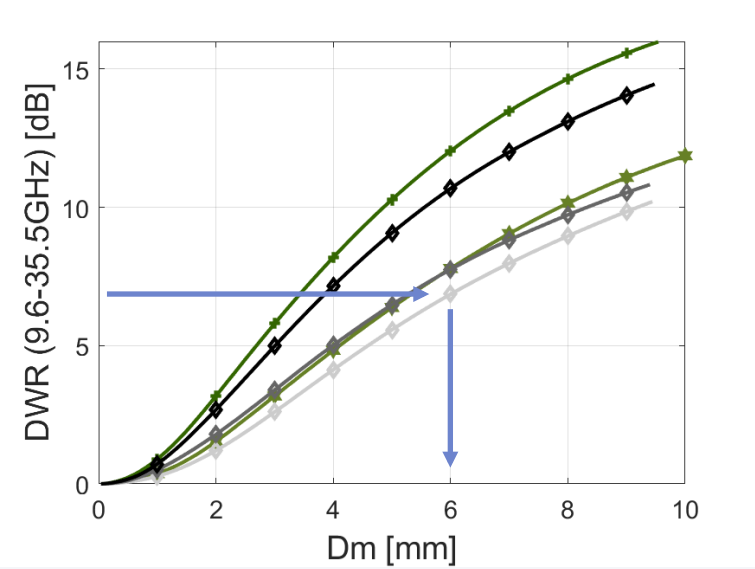
## Consistent layer of $DWR_{KaW}$ > 12dB between 1.5 and 2.5 km (T < 15°C)



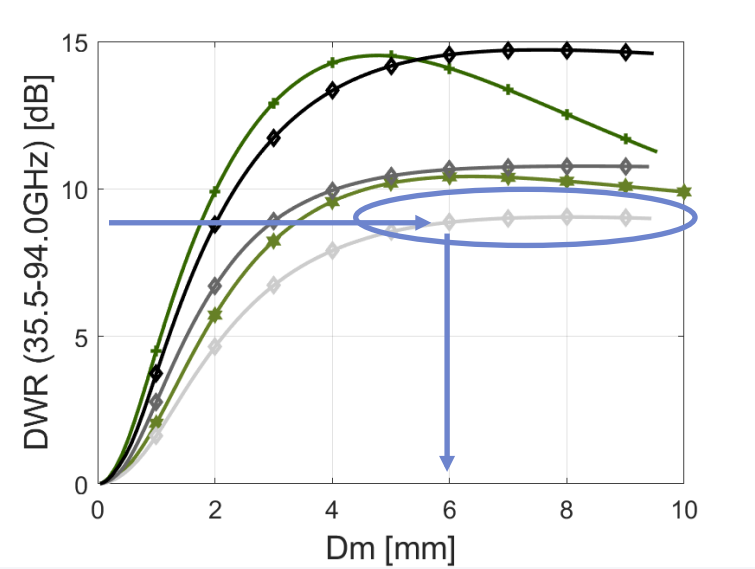

## Clearly, the high $DWR_{KaW}$ layer is associated with a long-lasting cloud liquid layer seen in the Doppler spectra and by the lidar

# Complementarity of the radar pairs

**$DWR_{XKa}$**




**$DWR_{KaW}$**




- Each radar pair has an optimum regime for sizing particles
- When both pairs have skills, they can be used in synergy in order to get the best accuracy
- → Optimal Estimation

# Complementarity of the radar pairs

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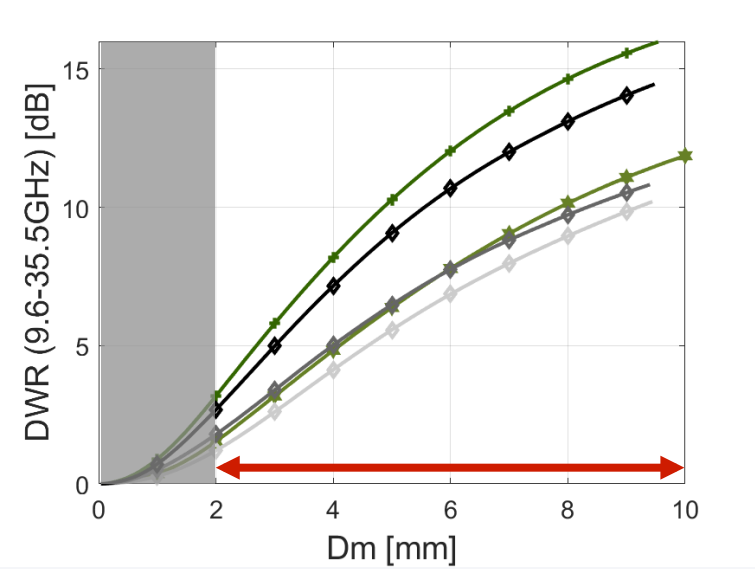
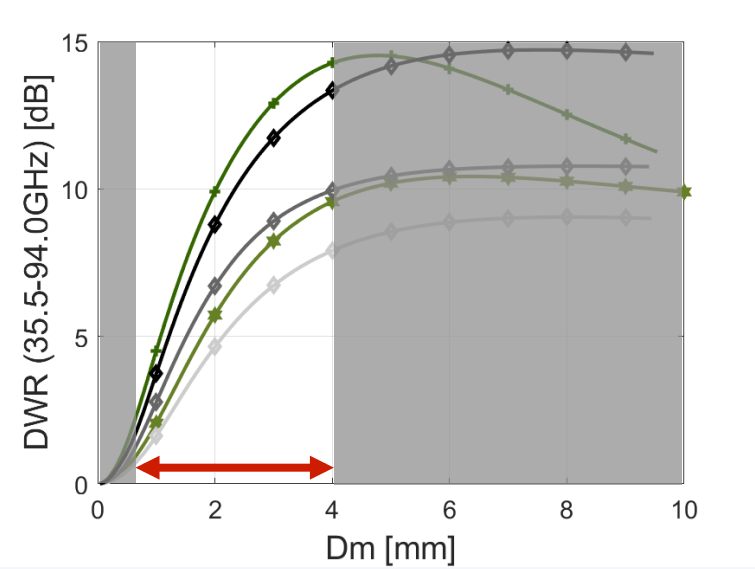



**$DWR_{KaW}$**

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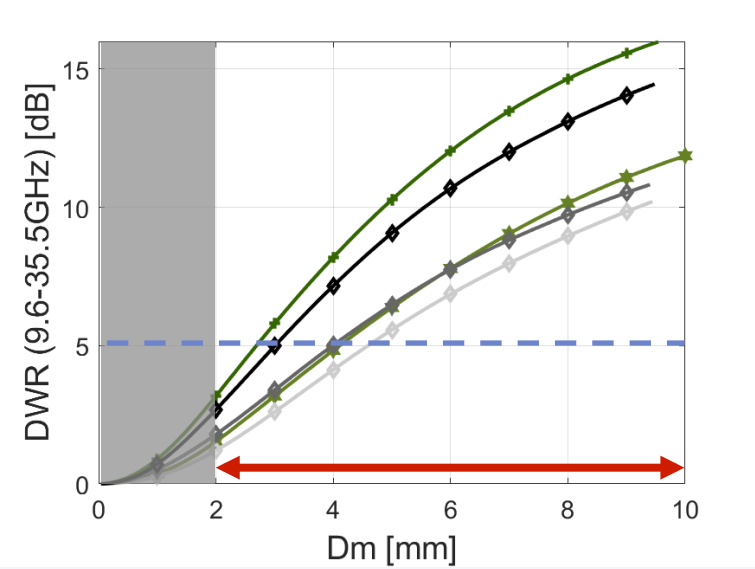
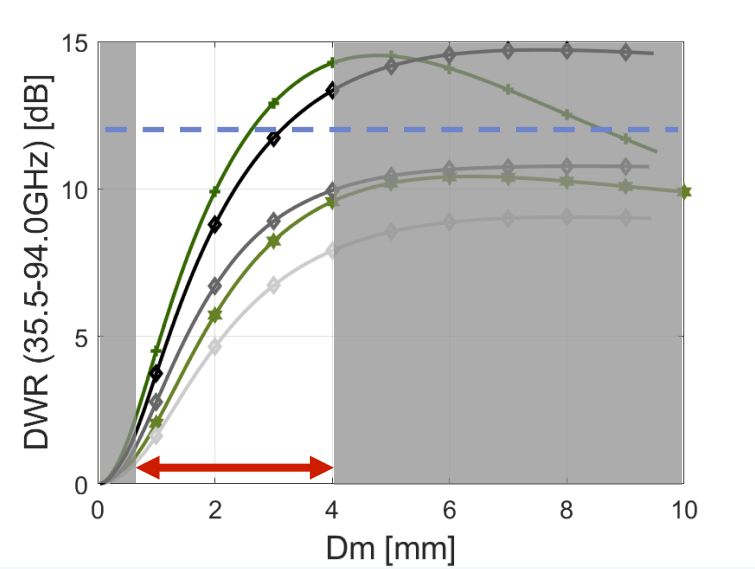



**$DWR_{KaW}$**

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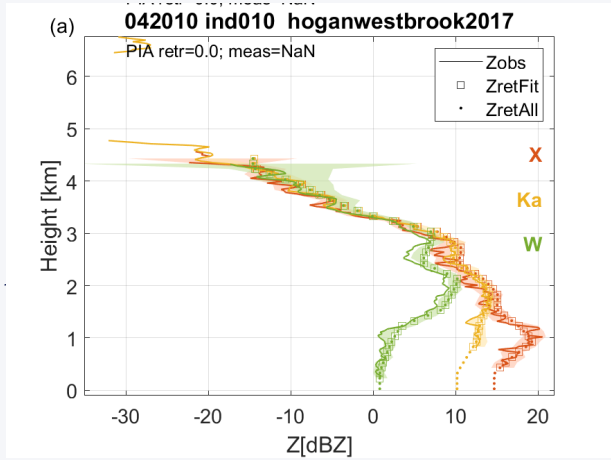
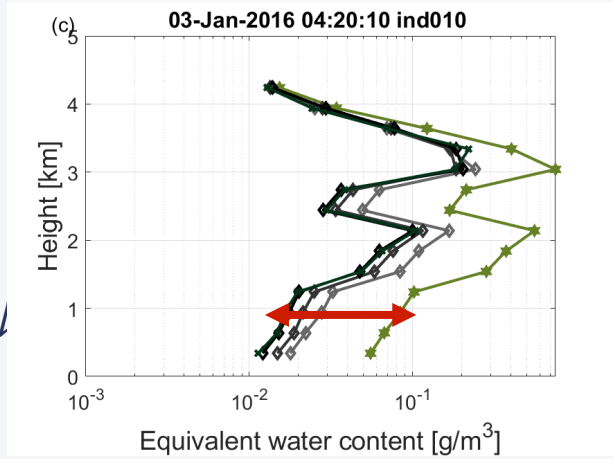
# Ongoing development of a 3-frequency radar retrieval

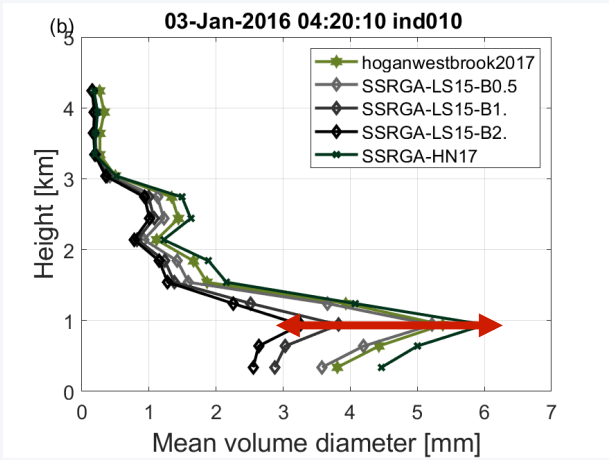
- We reverted the variational retrieval of Tridon et al. (2019) so that it can be applied to ground-based radars
- Optimal matching of X-Ka-W profiles for the retrieval of $D_m$ and WC, using each SCAT-MIC model to forward model the reflectivity profiles

$\boldsymbol{x}=[\blacksquare\blacksquare WC\downarrow$ $@D\downarrow m$

$\boldsymbol{y}=[\blacksquare\blacksquare Z\downarrow X\downarrow 1$
$@:@Z\downarrow X\downarrow m$
$@\blacksquare Z\downarrow Ka\downarrow 1$
$@:@Z\downarrow Ka\downarrow m$
$@\blacksquare Z\downarrow W\downarrow 1$
$@:@Z\downarrow W\downarrow m$

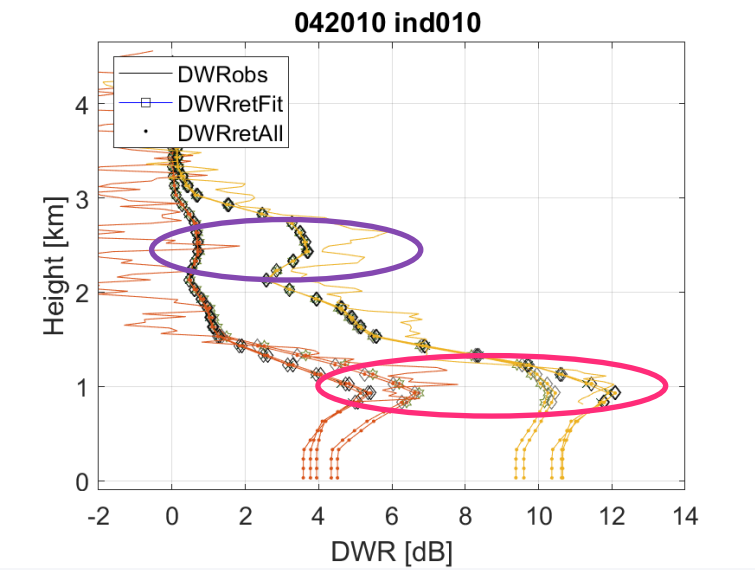


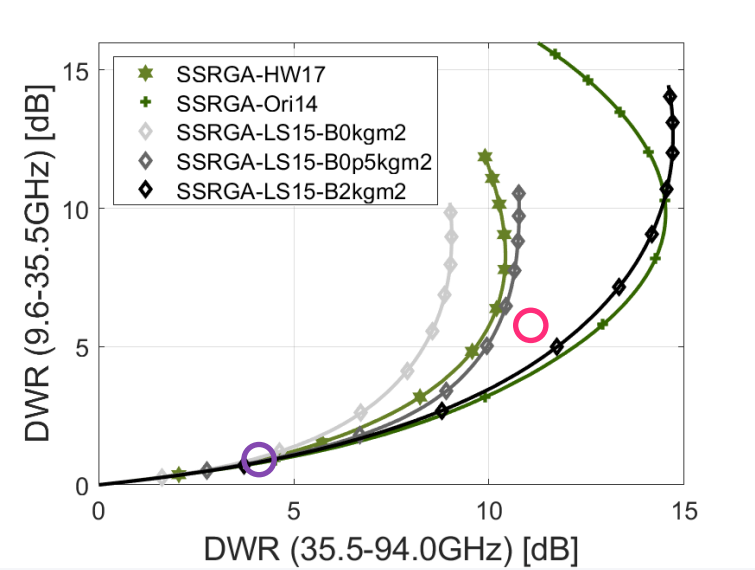




- For this profile, only the SCAT-MIC models corresponding to rimed aggregates are compatible with 3-f radar profiles

# Ongoing development of a 3-frequency radar retrieval

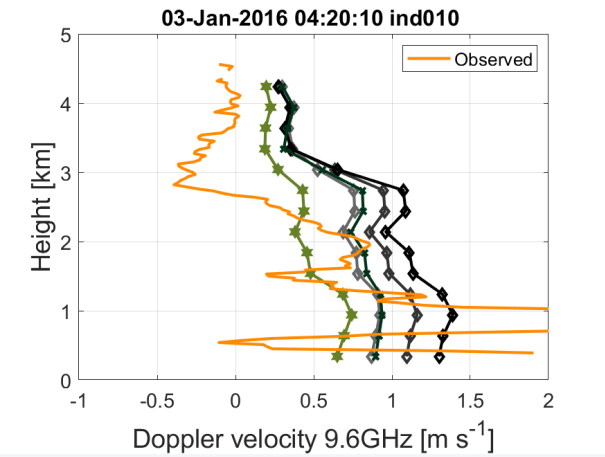


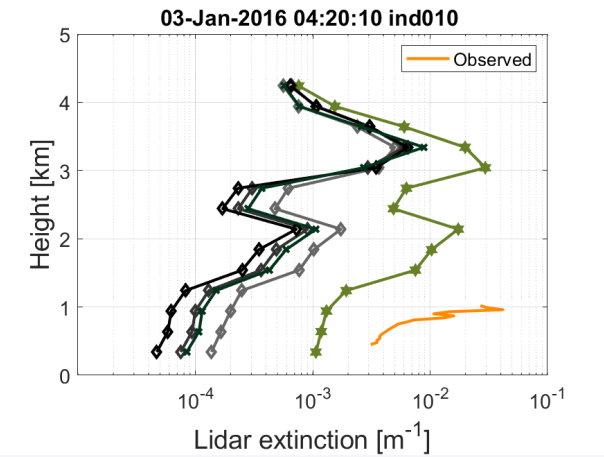



# Conclusions and ways forward

- AWARE reveals for the first time:
  - Intense aggregation and riming seem to be common in clouds around McMurdo
  - 3-frequency radar measurements can improve retrievals of Dm and IWC
  - → Statistics provide constraint for model microphysics

- There is still a variety of scattering-microphysics models which are compatible with **3-f radar observations**
  - Further selection of the SCAT-MIC models with instrument synergy: liquid water path from MWR, lidar extinction from HSRL, Doppler velocity



# Thanks for your attention

Questions?