Multi-frequency radar signatures of ice and snow from the AWARE campaign

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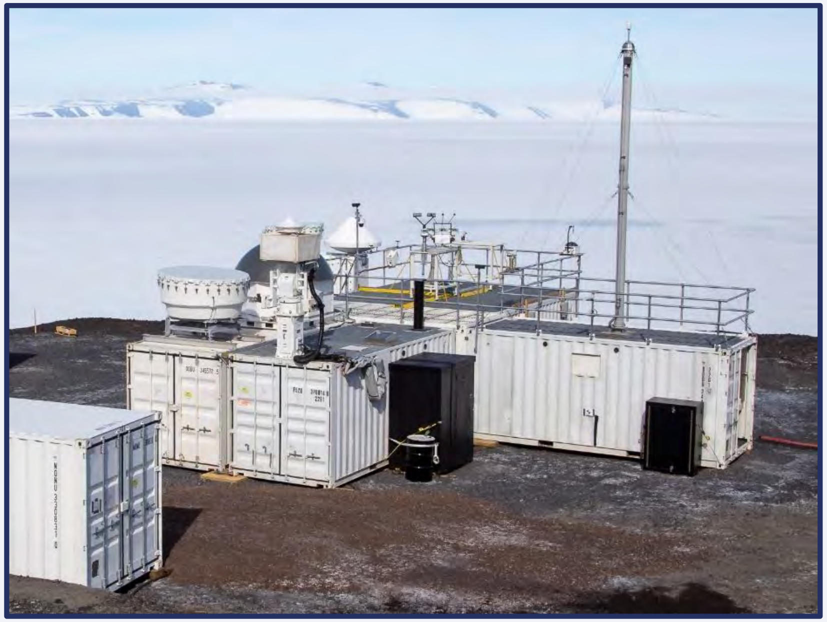
Motivation

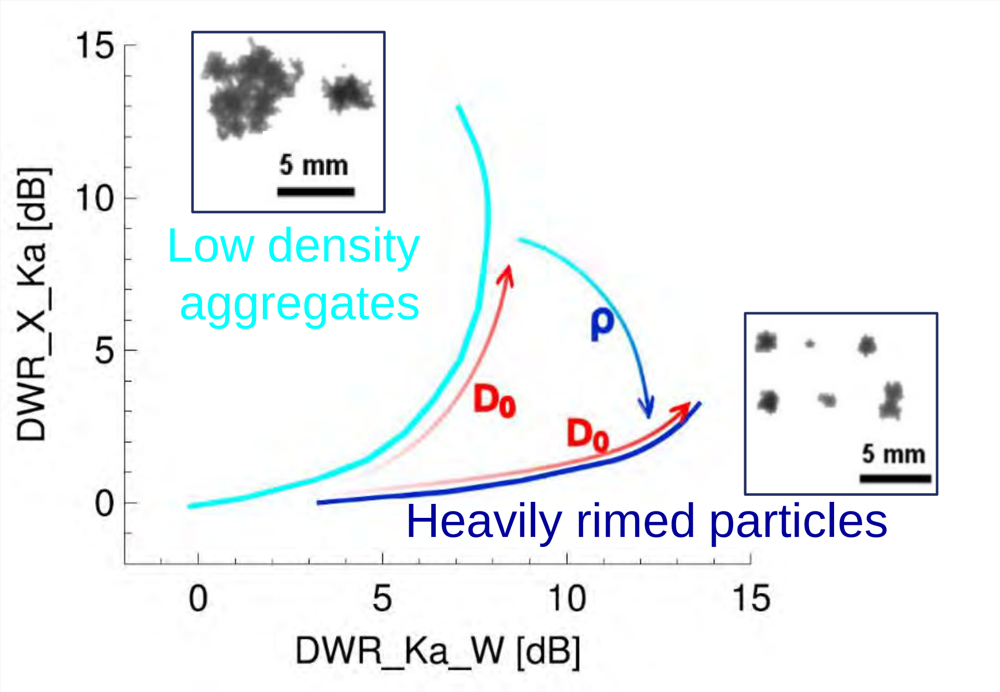
- How different aggregation and riming are for mid-latitude vs. high-latitude clouds?
- 3-frequency radar measurements provide constraints to particle sizes and bulk density
- During AWARE, triple-frequency radar observations have been collected for the first time in Antarctica
- → Unique opportunity 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)

→ New grasp on the scattering of aggregates thanks to ARM radars during the BAECC field campaign (Finland, 2014): first triple-frequency dataset

Comparing statistics of ice processes

Overall similarity is quite surprising!

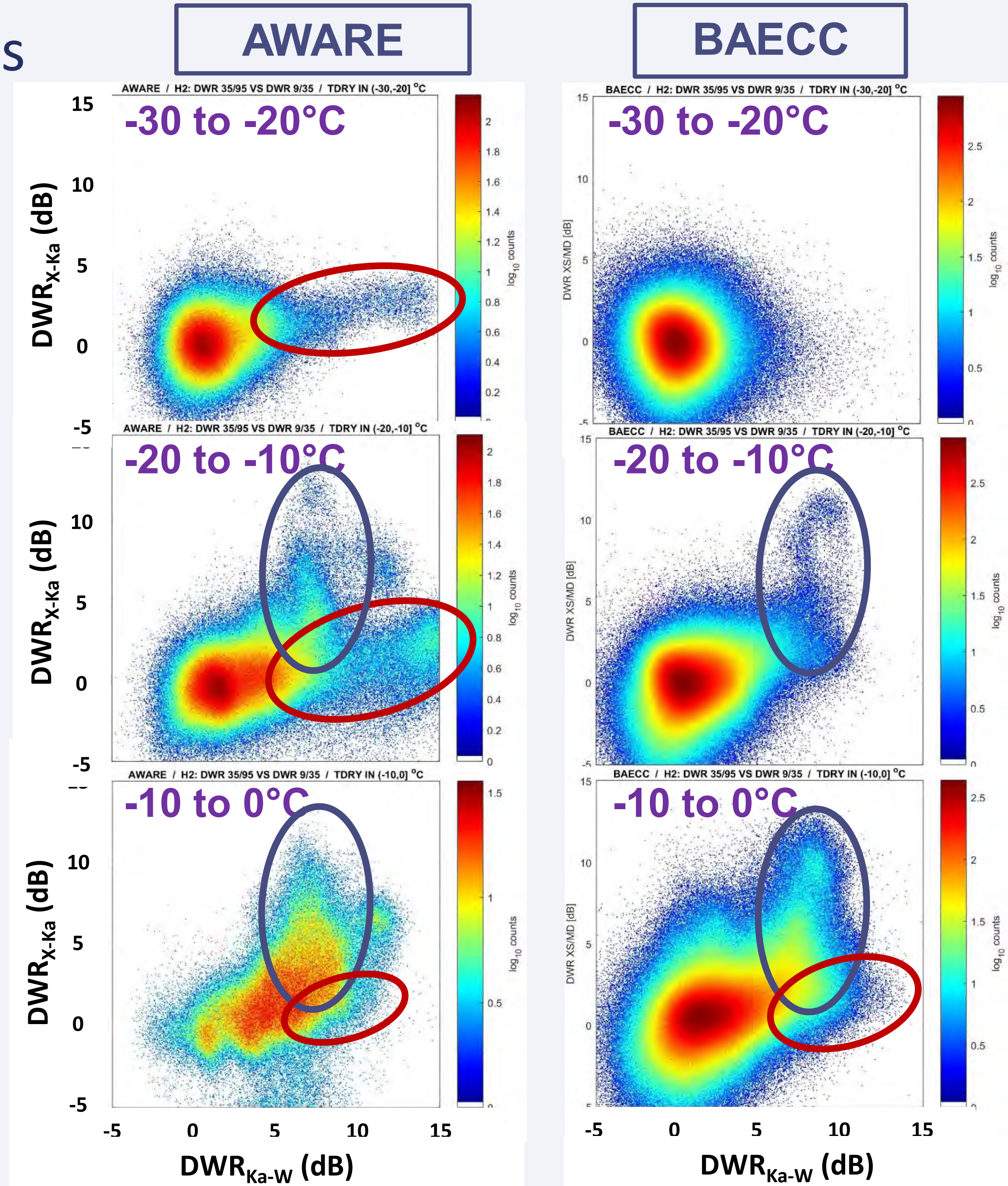
But also significant differences

Dendritic growth

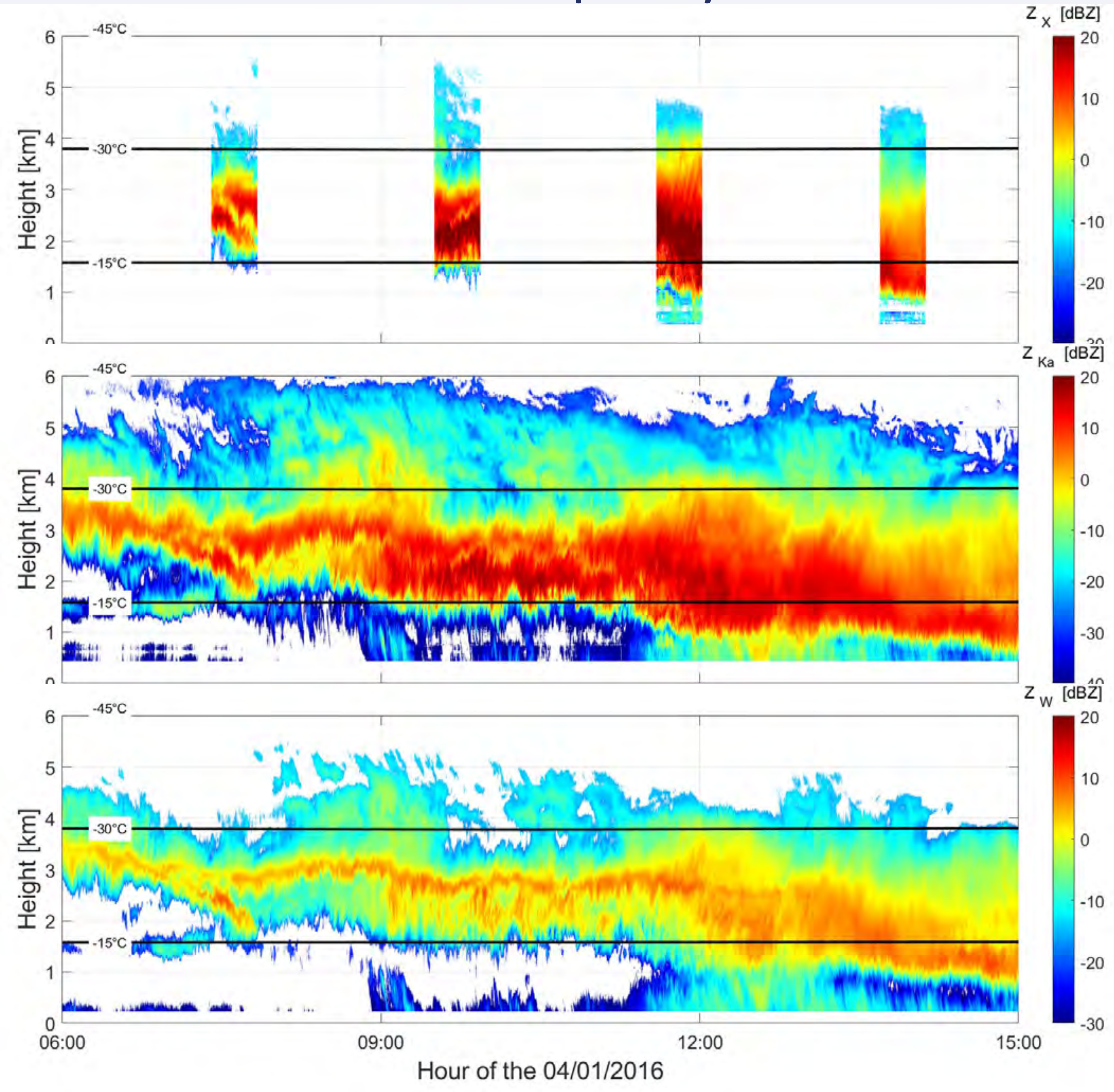
Riming

Unexpected that riming happens at colder temperatures during AWARE

→ Further look at a case study



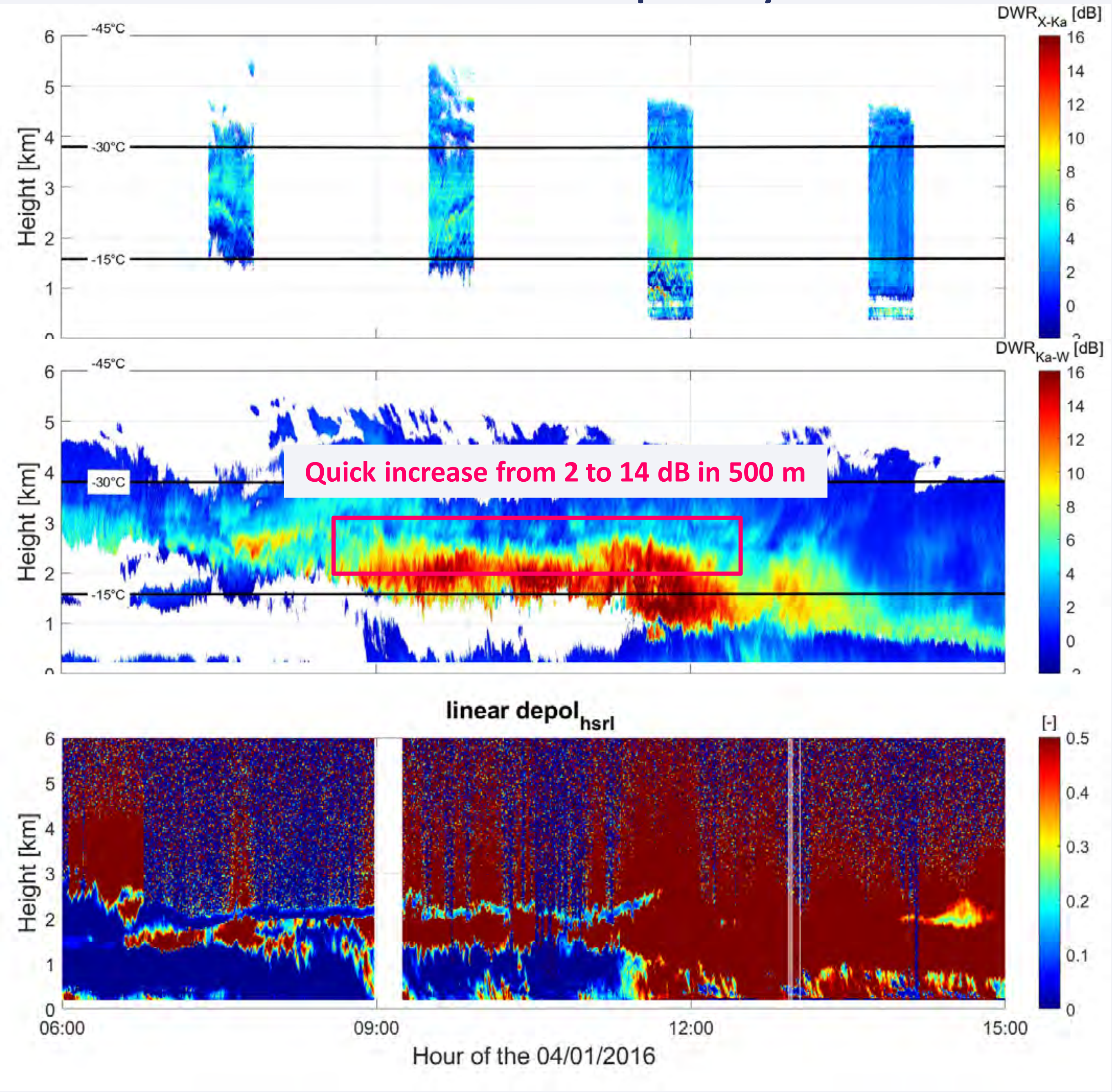
AWR 2016-01-04: quality-controlled radar reflectivity



- Correction of gas attenuation
- Correction of time and height offsets
- Relative calibration from Rayleigh targets at cloud top

} Z_W significantly lower than Z_{Ka}

AWR 2016-01-04: quality-controlled DWRs



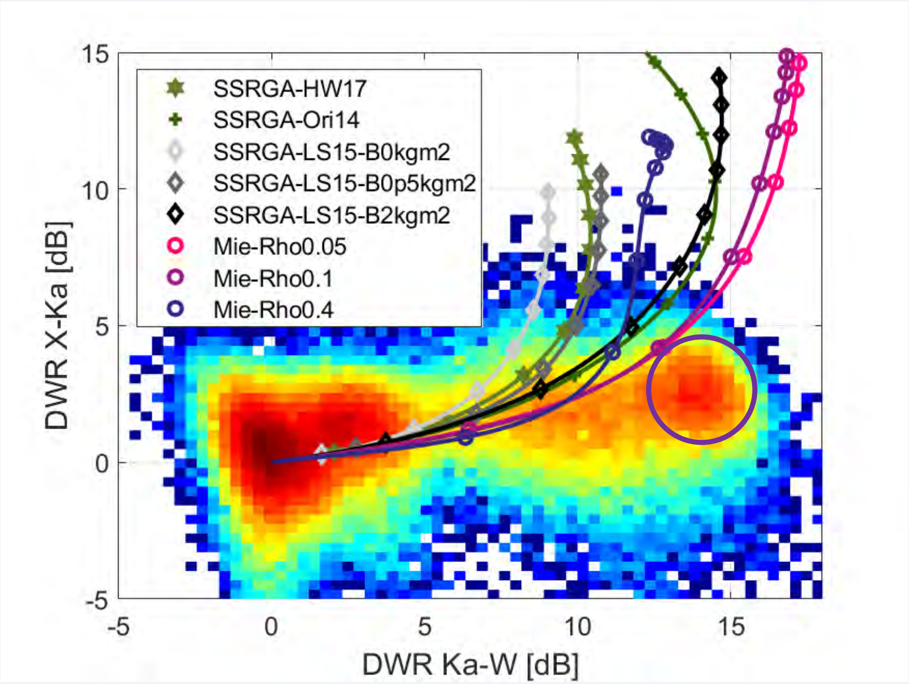
DWR$_{XKa}$ remains relatively small

Strong DWR$_{KaW}$ between 1.8 and 2.3 km

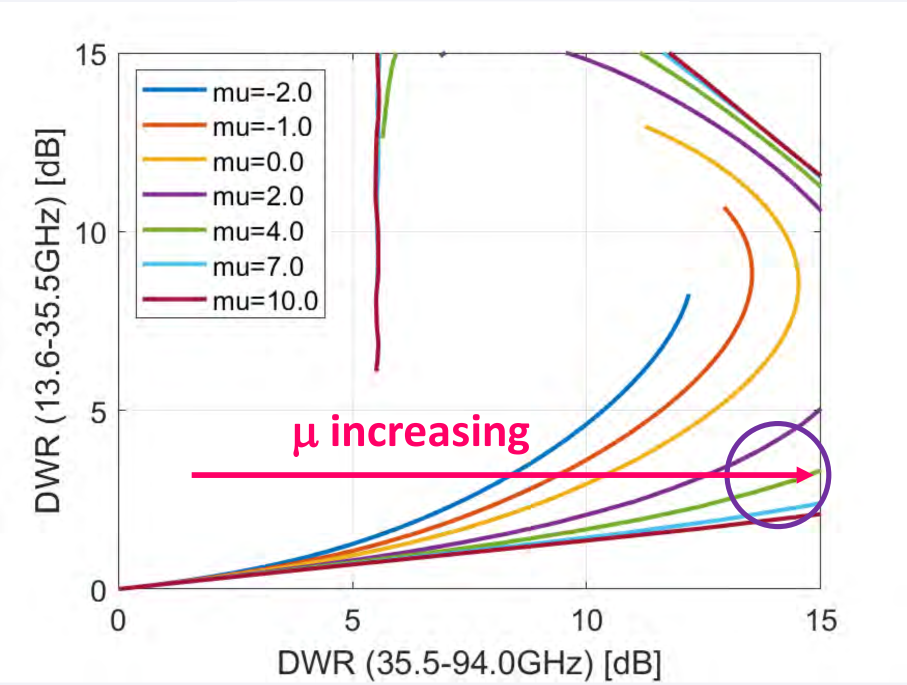
Liquid layer from 2 km

AWR 2016-01-04: Statistics vs. scattering models

Various models using exp PSDs



Effect of using a gamma PSD

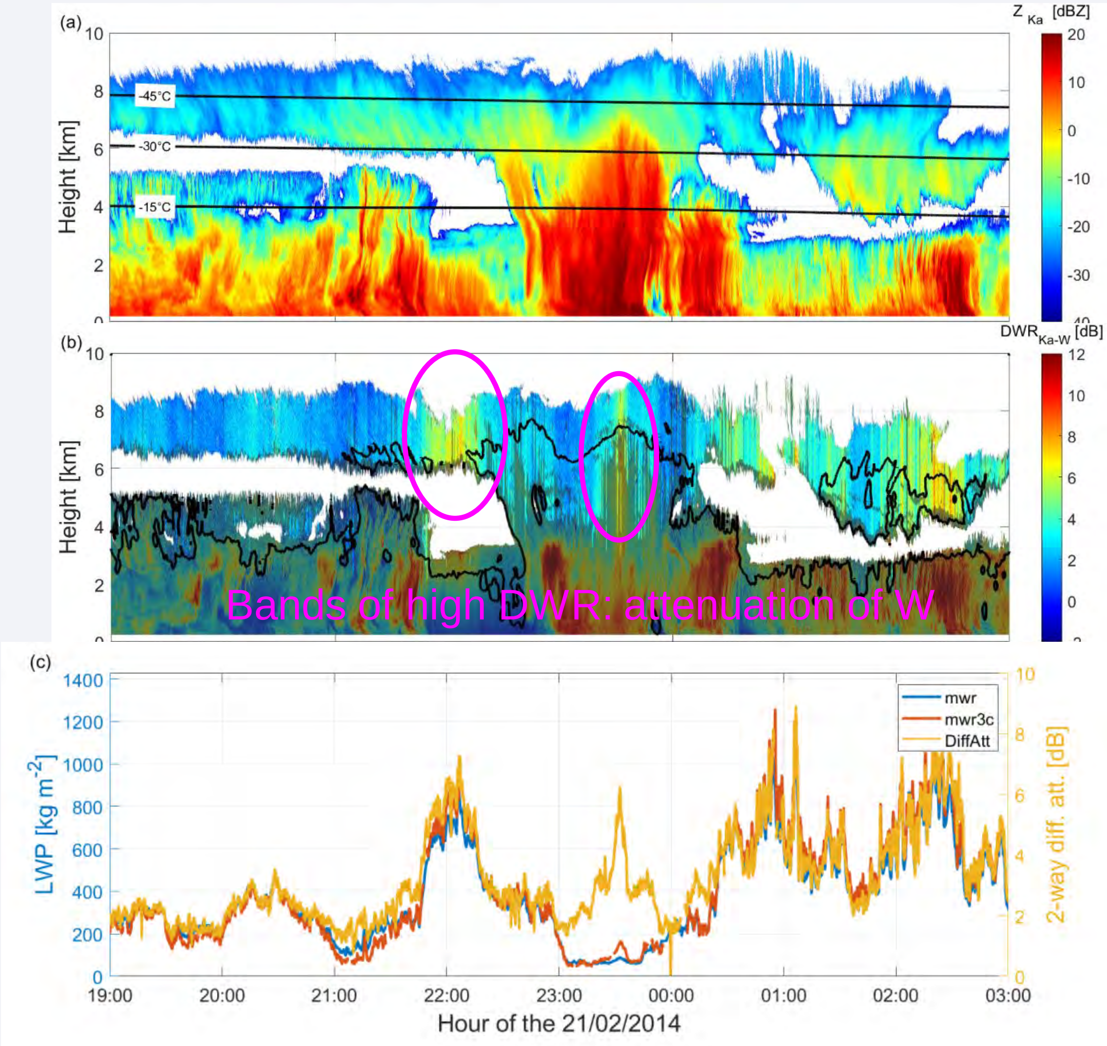


Mason et al. (2019)

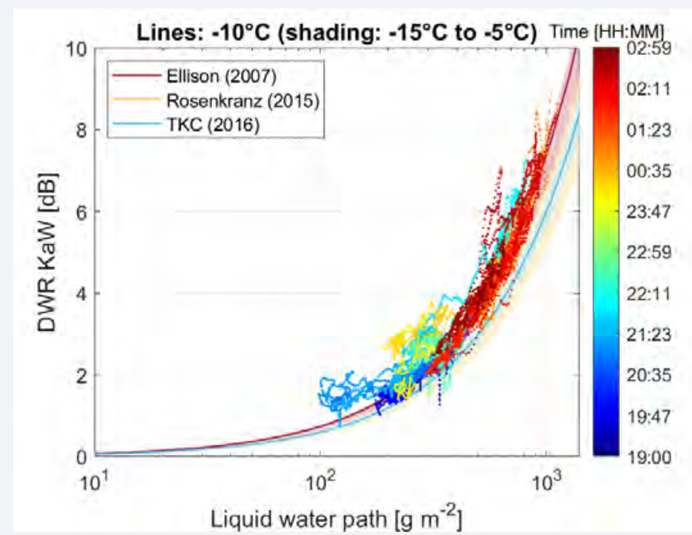
→ 3-f signature which looks like riming but cannot be explained by exp PSDs

→ rimed and unrimed ice are both possible (but with large μ)

LWP estimate from cloud top $DWR_{Ka\text{-}W}$ (BAECC example)

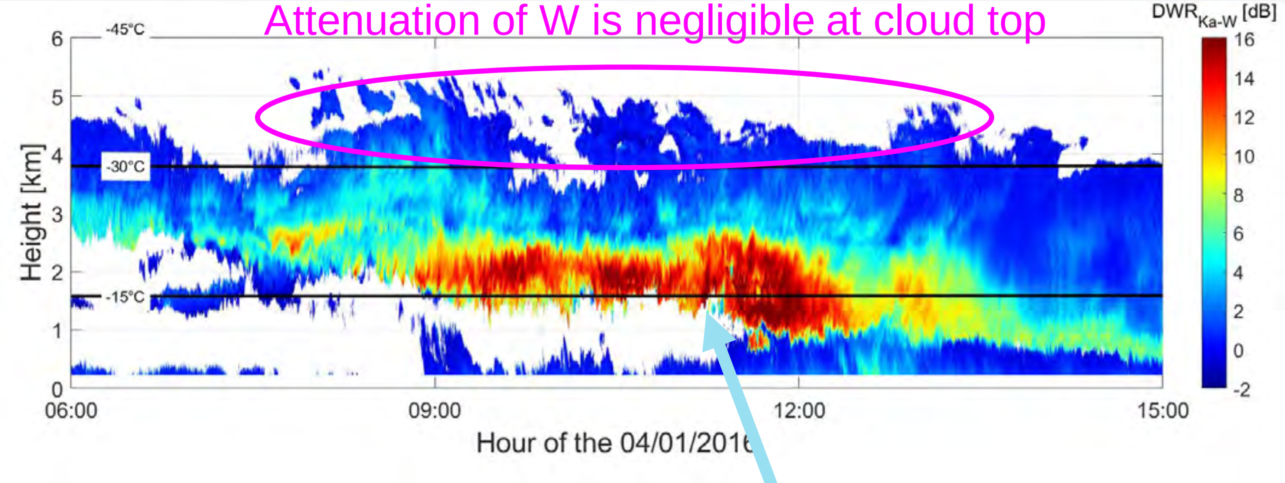


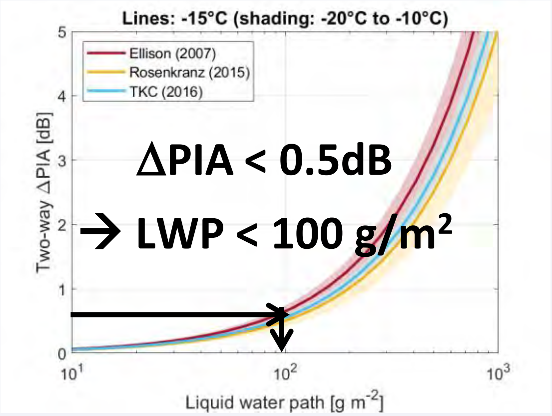
- New technique developed and tested on BAECC dataset
- Cloud top $DWR_{Ka\text{-}W}$ provides
  - Estimate of LWP when MWR radiometer is not available
  - Estimate of snow attenuation when combined with MWR



Tridon et al., How to estimate total differential attenuation due to hydrometeors with ground-based multi-frequency radars? AMTD, under review.

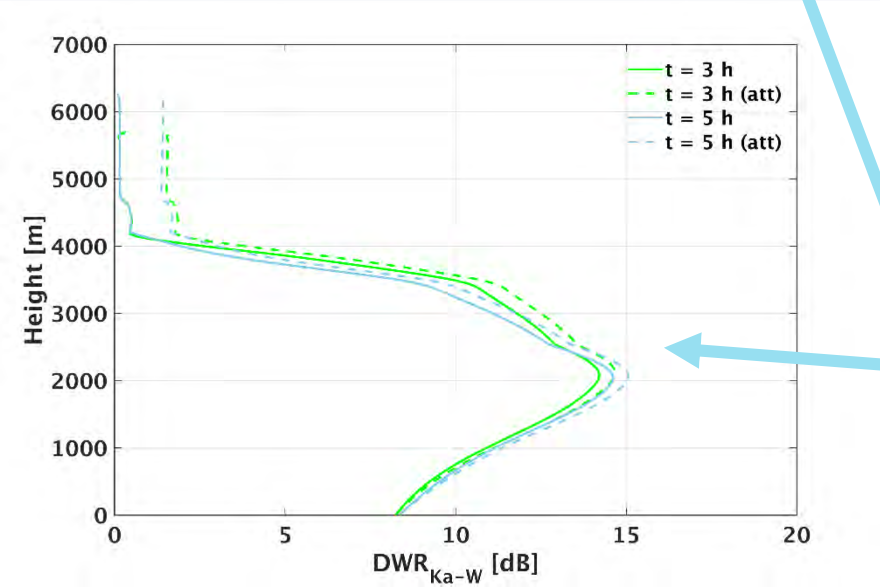
AWR 2016-01-04: LWP estimate from cloud top $DWR_{Ka\text{-}W}$





Ongoing work: 1D LES bin simulation with DHARMA

Israel Silber and Ann Fridlind



The bin model is able to reproduce the large $DWR_{Ka\text{-}W}$

Conclusions and next steps

- Installing 3-f radars in Antarctica was worth the effort!
- AWARE reveals for the first time:
  - Intense aggregation/riming seems to be common in clouds around McMurdo
  - 3-frequency radar measurements can improve retrievals of D_m and IWC
  - → Statistics provide constraint for model microphysics
- 04/01/2016: case study with striking 3-f signature
  - Can be explained by both heavily rimed or unrimed ice but with narrow PSDs ($\mu > 4$)
  - Less than 0.5 dB total attenuation at W-band → LWP < 100 g/m^2
- Current work: 1D LES bin simulations with DHARMA
  - It seems that the model can reproduce the narrow PSDs
  - Can we produce heavily rimed aggregates with such a little amount of LWP?
  - Effect of complex local orography?

Thanks for your attention

Questions?