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

\[ DWR_{Ka,W} = Z_{e,Ka} - Z_{e,W} \]

→ 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

Quick increase from 2 to 14 dB in 500 m

DWR_{X,Ka} remains relatively small

Strong DWR_{Ka,W} between 1.8 and 2.3 km

Liquid layer from 2 km
→ rimed and unrimed ice are both possible (but with large $\mu$)

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

Mason et al. (2019)
LWP estimate from cloud top $\text{DWR}_{\text{Ka-W}}$ (BAECC example)

- New technique developed and tested on BAECC dataset
- Cloud top $\text{DWR}_{\text{Ka-W}}$ 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 $DWR_{Ka-W}$

Attenuation of W is negligible at cloud top

$\Delta PIA < 0.5 \text{dB}$
$\rightarrow$ LWP < 100 g/m$^2$

Ongoing work: 1D LES bin simulation with DHARMA

*Israel Silber and Ann Fridlind*

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