Triple-frequency radar observations: What can they really tell us about snowfall properties?

Microphysics

- Initial particle shape and depositional growth
- Aggregation
- Riming, (Splintering, Melting)

Impact on snow properties

- particle density
- particle size distribution
- terminal velocity
- scattering properties (large uncertainties of single frequency radar retrievals)
Multi-frequency approach - Constraining the particle size distribution (PSD) utilizing different scattering regimes

- Particle scattering properties change from Rayleigh to Mie depending on size/mass and frequency
Multi-frequency approach - Constraining the particle size distribution (PSD) utilizing different scattering regimes

- Particle scattering properties change from Rayleigh to Mie depending on size/mass and frequency
- Reflectivity is scattering integrated over all particle sizes (or masses)
- Dual wavelength ratio: $DWR_{Ku,W} = Z_{e_{Ku}} - Z_{e_{W}}$ constrains PSD (rainfall, cirrus)
Dual frequency approach – A sufficient solution also for snow particles?

- Snow particle scattering depends also on particle shape
Dual frequency approach – A sufficient solution also for snow particles?

- Snow particle scattering depends also on particle shape
- => In order to constrain PSD we also have to constrain the shape
- Can we achieve improvement if we combine 3 radar frequencies?
Triple-frequency approach based on scattering models

Kneifel et al., JGR, 2011

Tyynelä and Chandrasekar, JGR, 2014

Influence of riming on scattering properties: See Poster 1.55 by Jussi Leinonen!
Comparison of triple-frequency radar signatures with ground-based in-situ data

Field Campaign: Biogenic Aerosols Effects on Clouds and Climate (BAECC), Hyytiälä, Finland, 2014
Comparison of lowest 200m from radar to in-situ at ground

Kneifel et al., JGR, 2015
Comparison of lowest 200m from radar to in-situ at ground

Triple-frequency signatures are related to characteristic size of PSD and bulk density of particles

Kneifel et al., JGR, 2015
TRIPEX: First German triple frequency radar experiment
Winter 2015/16, Collaboration between U. Köln, U. Bonn and KIT
Overall Vision:

Combine polarimetric, multi-frequency, and Doppler spectra view and explore their synergistic potential!
Descending warm front (24.11.2015)

- Vertically pointing X, Ka, and W-band
- Ze difference (DWR) between Ka and W band increases quickly below 4km
- No liquid water (MWR), no enhanced Doppler velocity
- Hence, signature is most likely caused by aggregation

- What exactly happens when DWR increases? Let’s have a look at the vertical evolution of the Doppler spectra at 10:40 UTC!
Vertical evolution of Doppler spectra
RED: Ka-Band, BLUE: W-Band
(positive velocities towards radar)

- No differential scattering above 5km (spectra well matched)
- Upwind area with new small (slow) particle mode at 4.5km (T=-15°C, dendritic growth region)
- New particle mode “speeds” up and merges with aggregate mode around 1 m/s
- Increasing differential scattering clearly attributable to right (fast) side of the spectrum (aggregates) and consistent with DWR from moments
Vertical evolution of Doppler spectra

**RED: Ka-Band**
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How to use triple-frequency Doppler spectra to evaluate scattering models?

-> Poster P.1.53
JuXPOL in 4km distance to JOYCE provided RHI every 2min

Around 10:40 UTC we find slightly enhanced ZDR (1-1.5 dB) at 4km (decreasing towards lower altitudes)

This is the height where small mode in the spectra starts to grow and DWR start to increase
Conclusions

- Triple-frequency signatures are found to be related to bulk snowfall density and the characteristic size of the PSD

- This opens new opportunities to study riming and aggregation inside clouds

- The combination of multi-frequency, Doppler spectra, and polarimetry bears a large and widely underexplored potential for studying microphysical processes in ice and snow clouds

- Ground-based multi-wavelength, multi-instrument datasets together with scattering databases and forward operators are very valuable to develop new satellite snow retrievals, to validate existing products, and to achieve closure!
Thank you!
Backup slides
List of References


Based on these first combined observations (3 case studies) we can draw a first conceptional picture:

Kneifel et al., JGR, 2015
Radar systems

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<tr>
<th>Specifications</th>
<th>XSACR</th>
<th>KaSACR</th>
<th>MWACR</th>
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<td>Frequency (GHz)</td>
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<td>Temporal Sampling (s)</td>
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Ground-based in-situ observations used for comparison

**PIP:**
- Particle Size Distribution
- Velocity-size relation
- Particle habit/structure
- Area Ratio

**Pluvio:**
- Snowfall rate

**Spotlight**

**Video Camera (PIP)**

**Pluvio weighing gauge**

**Bulk snow density**
Triple-frequency signatures based on other scattering datasets

ALL aggregates (based on dendrites, needles or rosettes) show the bending up and even slightly backwards! Note: Graupel signature! Also oriented crystals are now more separating from aggregates!