Capability of scanning polarimetric cloud radar measurements for identifying ice hydrometeor habits and shapes

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Traditional polarimetric radar approaches for hydrometeor ID

These approaches are typically applied with S-, C- and X-band polarimetric radars operating at H-V basis at low radar beam tilts

They use radar parameters in horizontal – vertical polarization basis (i.e., reflectivity Z_e, differential reflectivity Z_{DR}, copolar correlation ρ_{hv}, and specific differential phase shift K_{DP})

Hydrometeor classes such as: rain, snow, simple ice, hail, drizzle are distinguished using fuzzy logic techniques with Z_e, Z_{DR}, ρ_{hv}, K_{DP}

Complications:

Discrimination among different habits in the "simple ice" class remains uncertain (such discrimination is important for many applications).

Many polarimetric (K_a-, W-band) cloud radars measure a single polarimetric parameter, which is depolarization ratio (DR) (do not measure Z_{DR}, ρ_{hv}, K_{DP}).

A different polarimetric cloud radar approach for ice hydrometeor type identification and shape estimation

Ice hydrometeor type:

planar (e.g., single dendrites, plates, stellars, and aggregates of these types of crystals)

columnar (e.g., columns, bullets, needles)

quasi-spherical (e.g., ice pellets, graupel)

Ice hydrometeor shape: mean aspect ratio (for a dominant ice hydrometeor type)

This approach uses depolarization ratios (DRs) for the whole range of radar beam tilts [from 0^o to 90^o (zenith) – RHI scans]

$DR=10\log_{10}(Z_w/Z_s)$ (i.e., the ratio of power echoes in "weak" and) "strong" polarimetric channels)

could be used with ARM cloud radars (e.g., K_a, W-bands)

Some polarization bases (states) other than H-V are more beneficial for the purpose of particle type identification (i.e., planar vs. columnar vs. irregular vs. spherical) and estimating particle aspect ratio

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DR in the H-V polarization basis (HLDR) depends on particle density, aspect ratio and (strongly) orientation

DR in the circular polarization basis (CDR) depends on particle density, aspect ratio and (very weakly) orientation

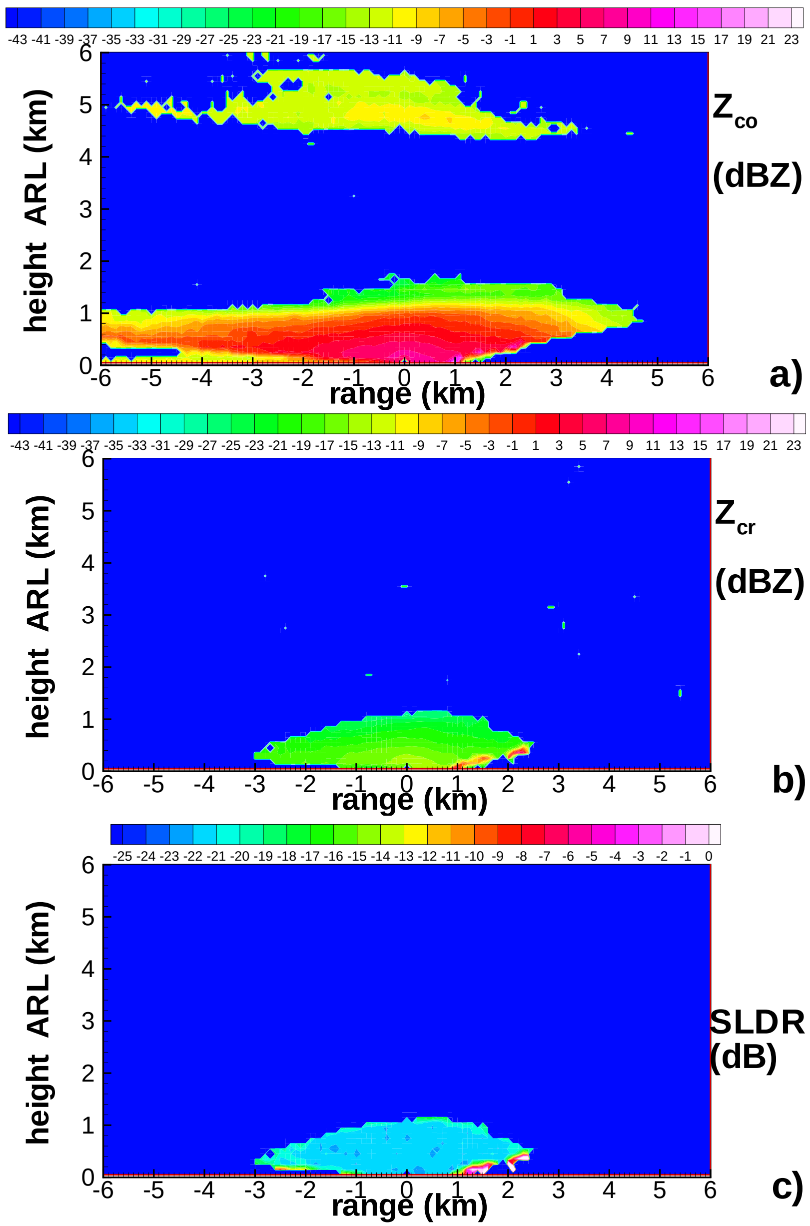
DR in the slant 45^o polarization basis (SLDR)depends on particle density, aspect ratio and (weakly) orientation

Besides: cross-polar signals when measuring CDR and SLDR are stronger than in HLDR (which is important for weaker targets)

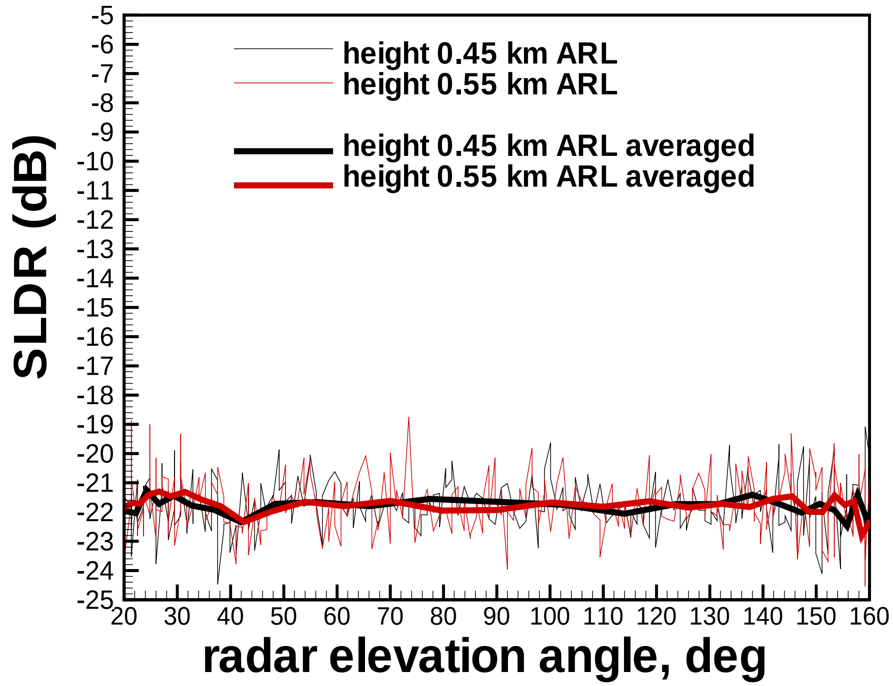
Polarimetric Scanning W-band ARM Cloud Radar (SWACR) data were used to evaluate SLDR measurements for the purpose of ice hydrometer type and shape estimations

Data were collected during the AMF2 deployment at the StormVEx IOP)

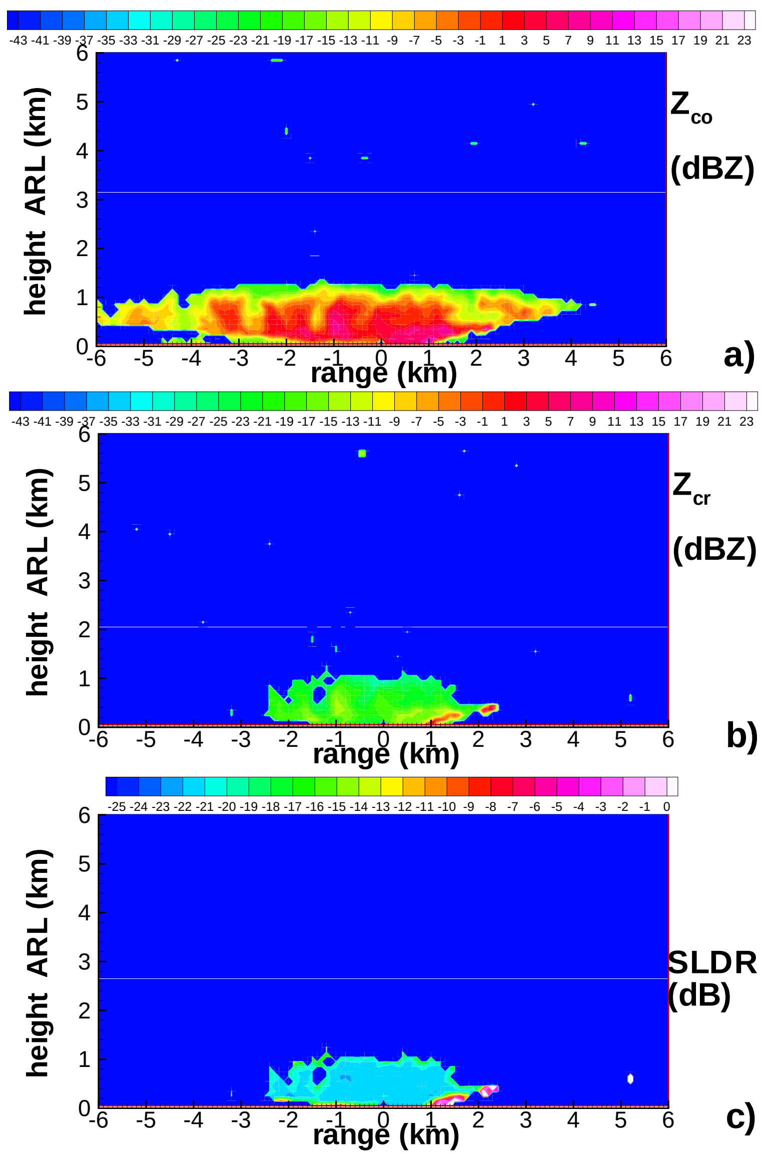
Calibrating SWACR when observing freezing drizzle

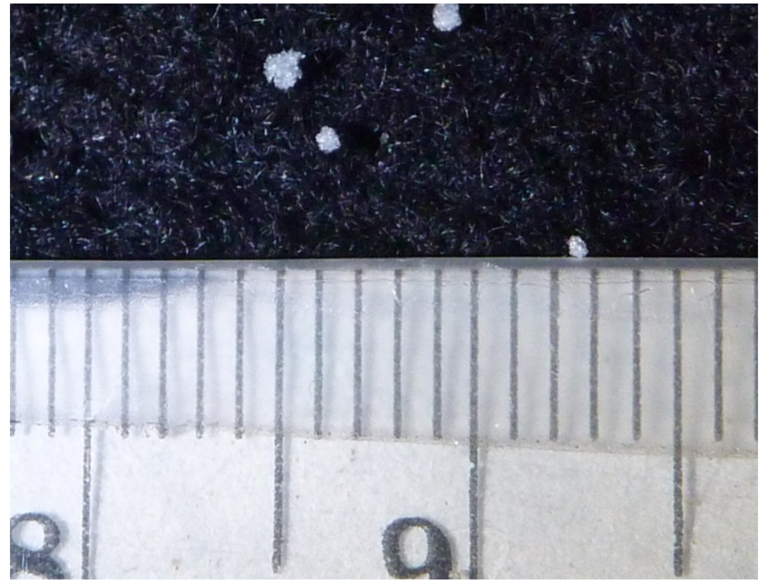


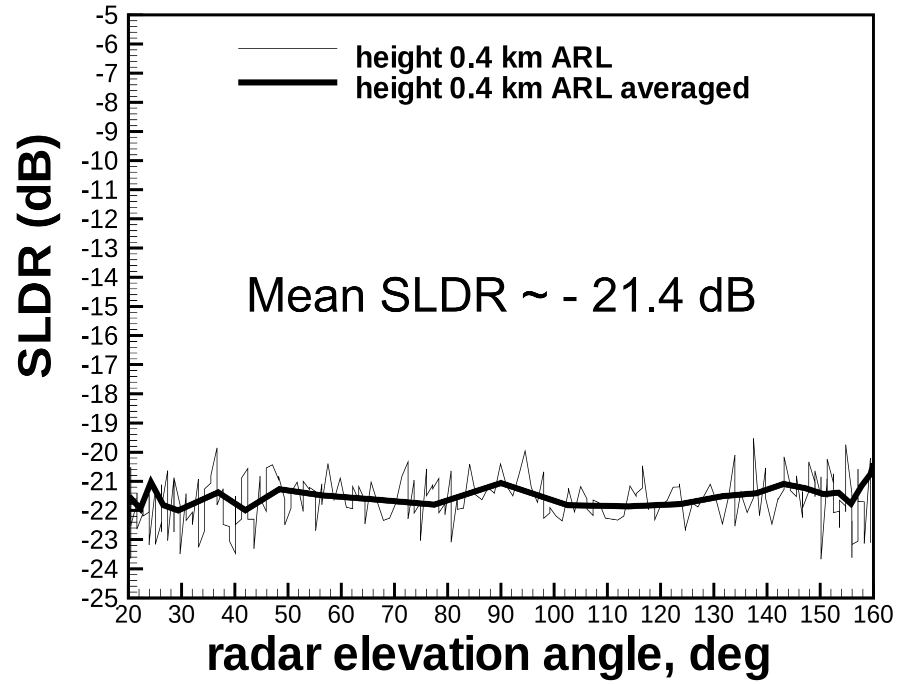
SLDR polarization cross-talk ~ -21.8 dB



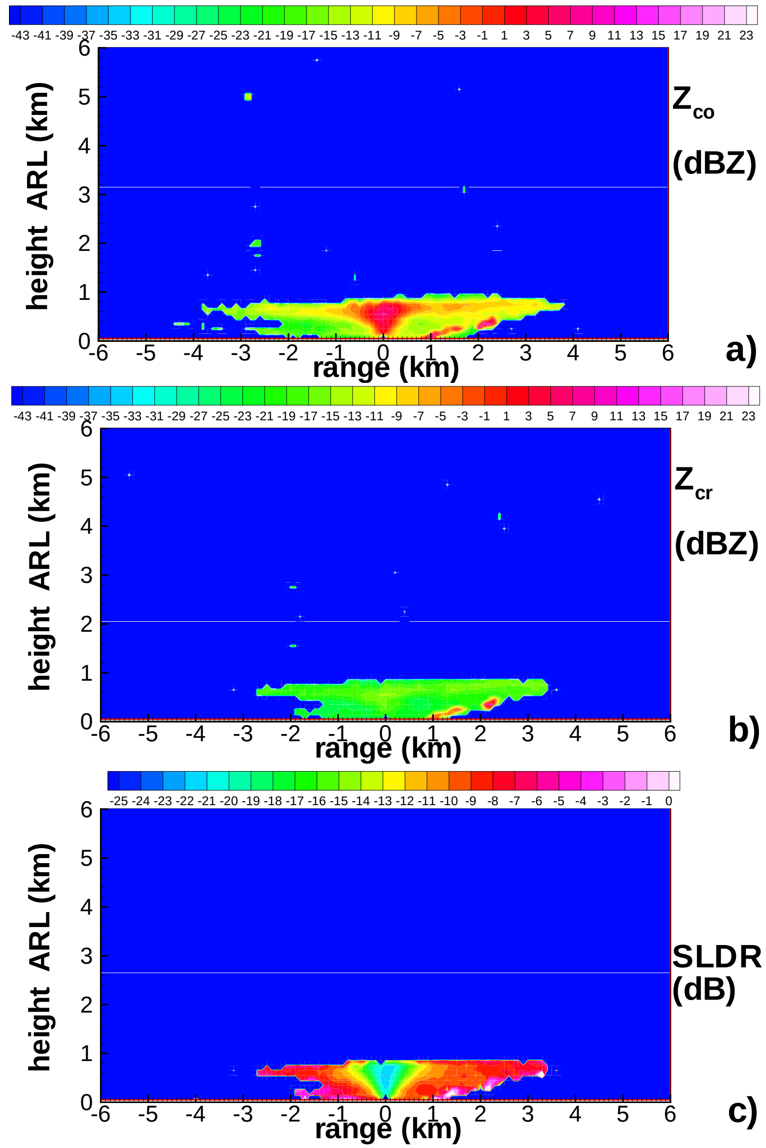
Observing round graupel with SWACR



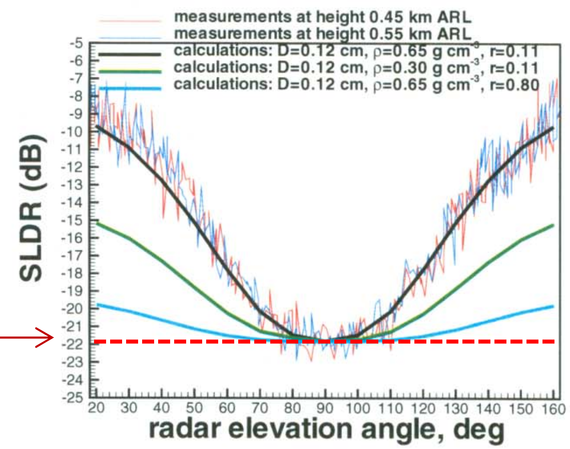


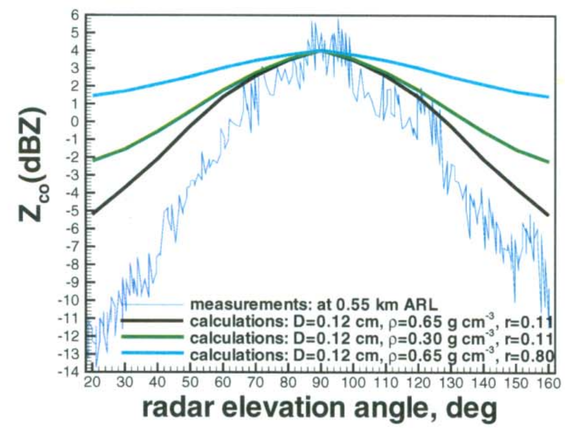


Observing pristine dendrites with SWACR

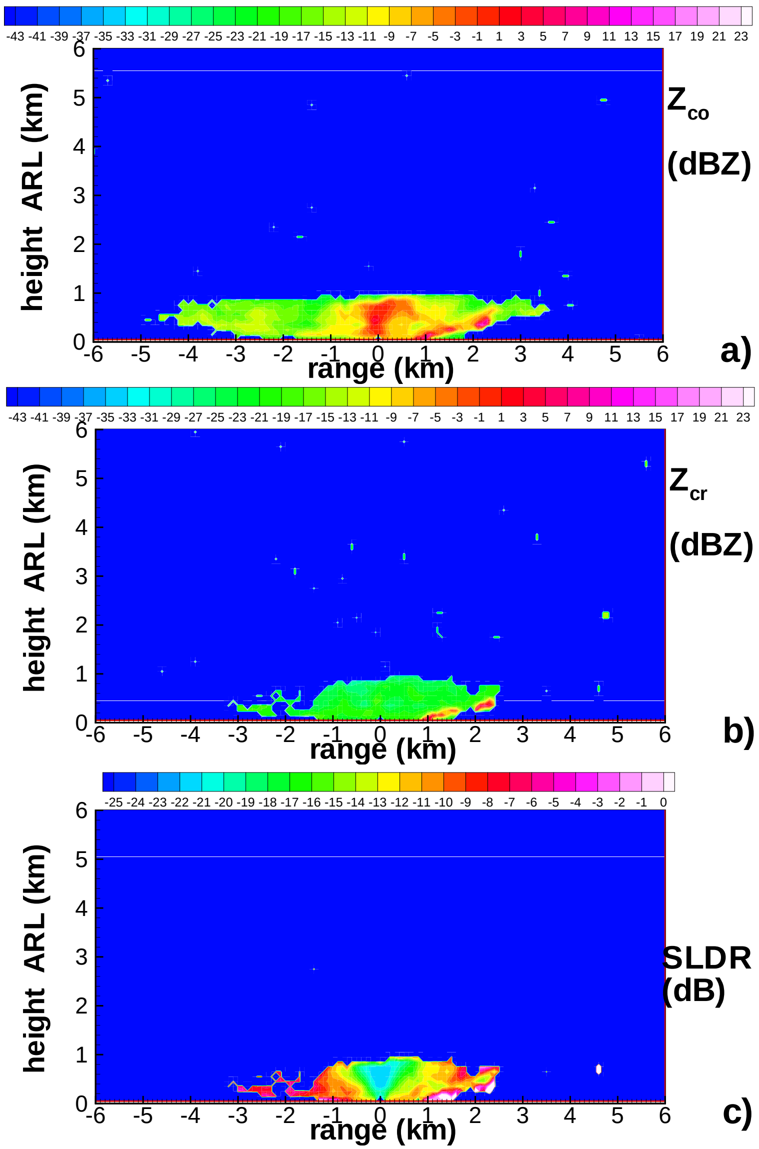


cross-talk

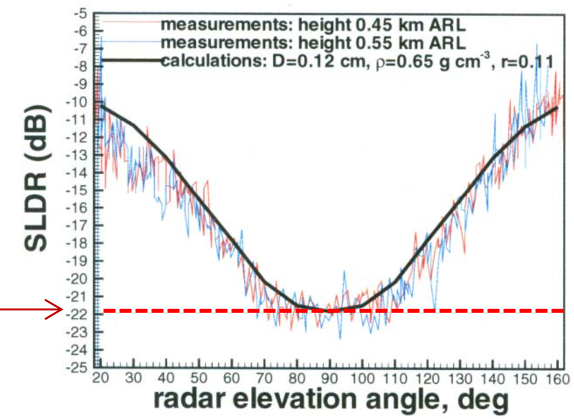


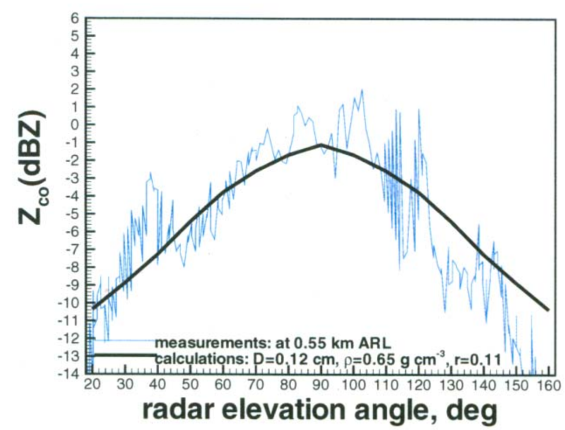


Observing lightly rimed dendrites

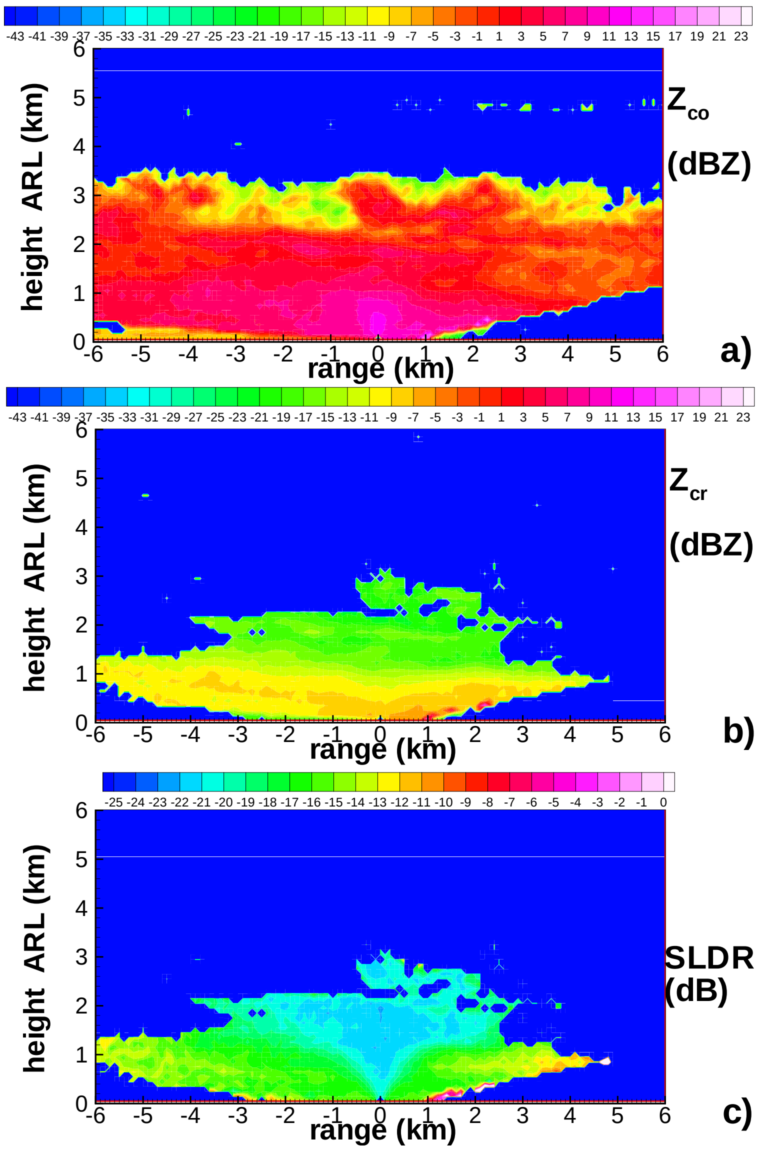


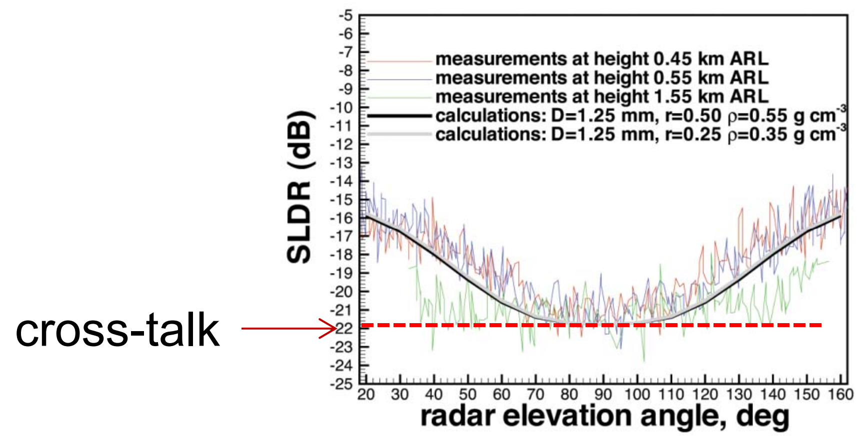
cross-talk

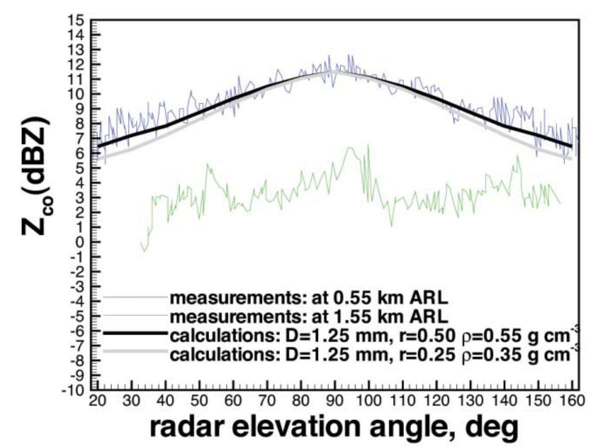


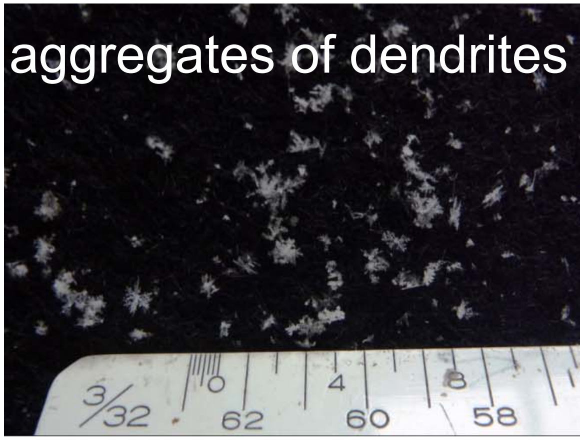


Observing moderately rimed dendrites

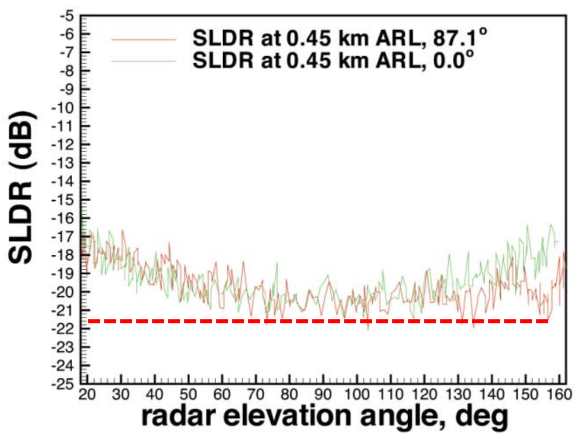




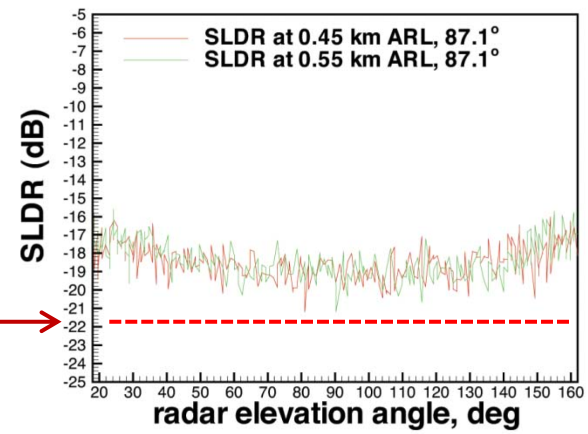


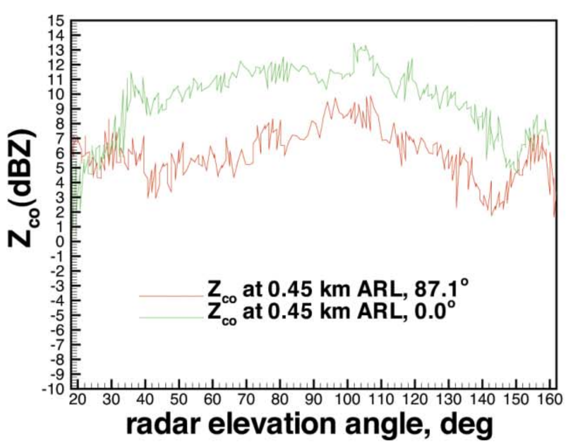

aggregates of dendrites

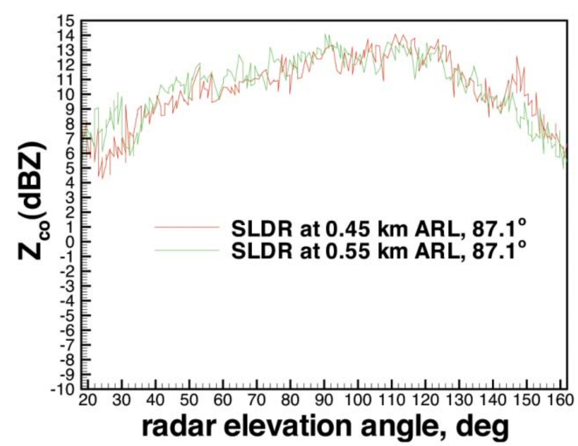

particle mixture including some columns


SLDR at 0.45 km ARL, 87.1°
SLDR at 0.45 km ARL, 0.0°
SLDR (dB)
radar elevation angle, deg

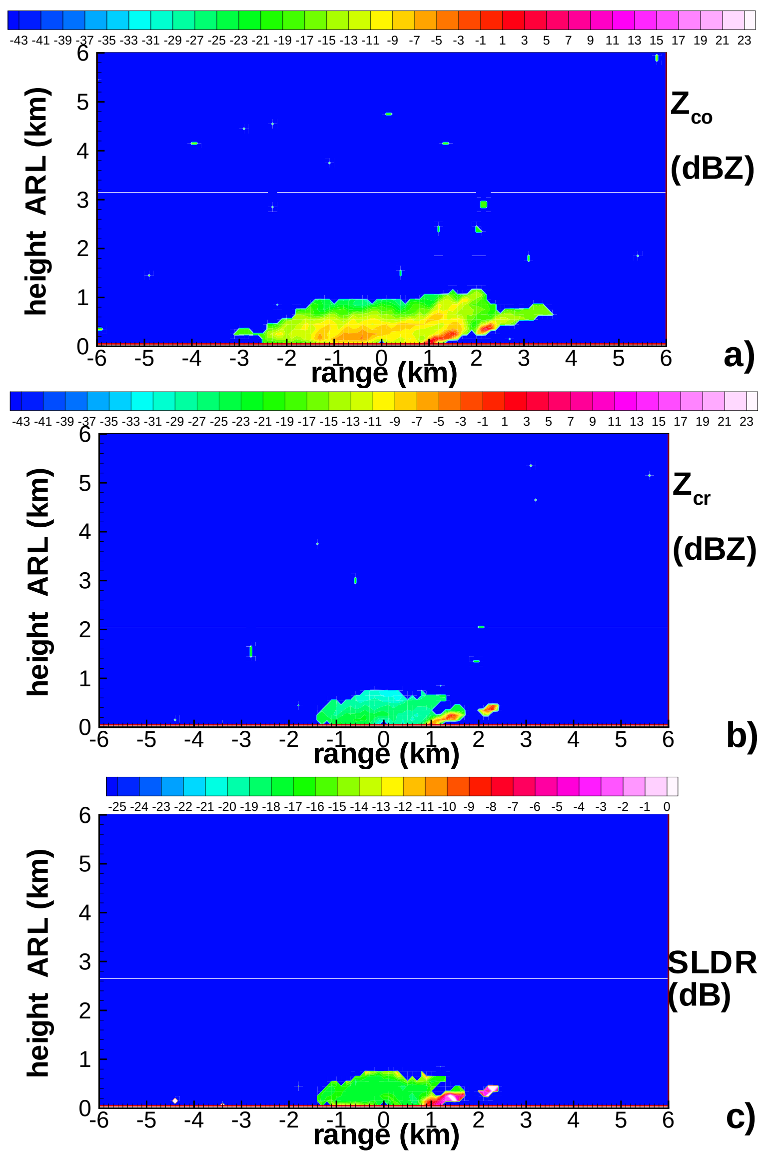
cross-talk

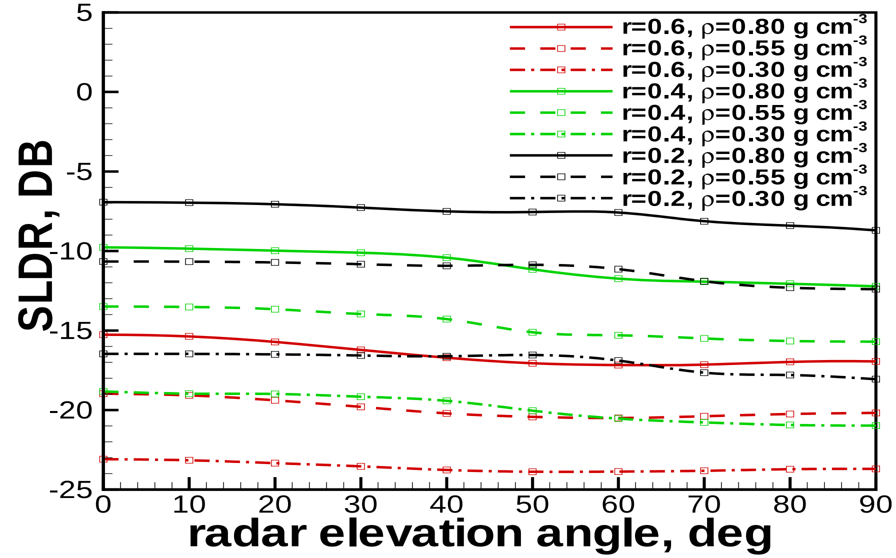

SLDR at 0.45 km ARL, 87.1°
SLDR at 0.55 km ARL, 87.1°
SLDR (dB)
radar elevation angle, deg

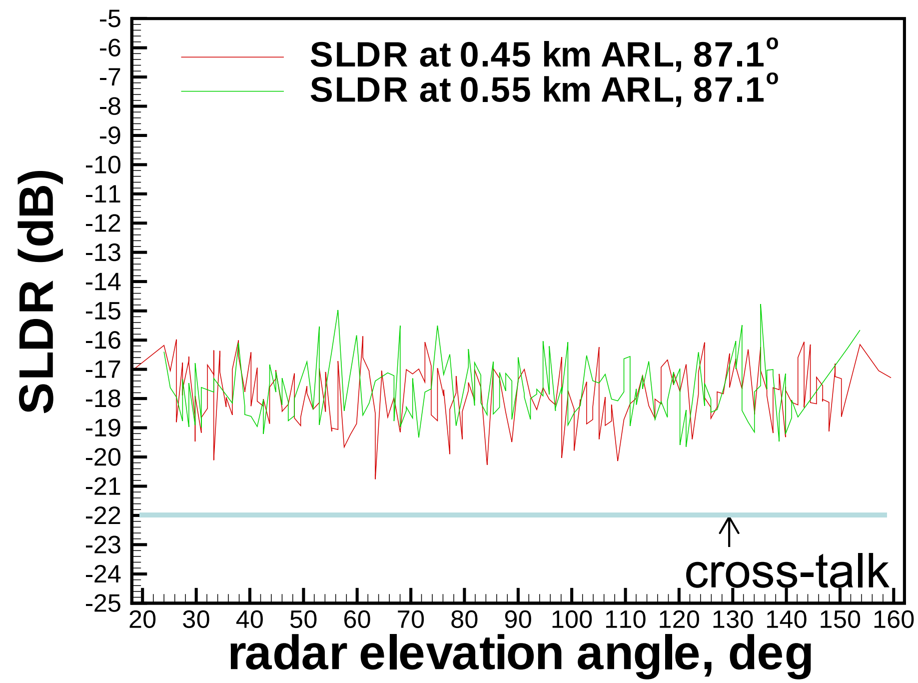

Zco at 0.45 km ARL, 87.1°
Zco at 0.45 km ARL, 0.0°
Zco(dBZ)
radar elevation angle, deg


SLDR at 0.45 km ARL, 87.1°
SLDR at 0.55 km ARL, 87.1°
Zco(dBZ)
radar elevation angle, deg

Observing columnar crystals with SWACR







Summary

Depolarization ratios (DR) from scanning polarimetric K_a and W-band cloud radar data can be used for ice particle identification and shape estimation

Slant 45^o degree linear and/or circular polarization bases (SLDR and CDR) are better than the traditional H-V basis (LDR) for ice particle ID and shape estimation because SLDR and CDR depends less on orientation the LDR

DR trends with radar elevation angle β are indicative of the predominant planar or columnar crystal habit in the radar resolution volume:
DRs for planar crystals increase when β changes from 90^o (zenith) to 0^o(horizontal beam)
DRs for columnar crystals show relatively little trend with radar elevation angle

As a dominant habit is deduced (i.e., planar vs columnar), shape (mean aspect ratio) estimations are possible from DR values at a radar elevation angle of about 45^o
(a bulk density assumption is needed for aspect ratio estimations)

In the absence of strong electrical fields and turbulence, ice crystals tend to be oriented with major dimensions close to horizontal. This results in reflectivity enhancement in the zenith (nadir) direction for planar crystals. This enhancement is stronger for W-band and can amount for several dB (up to 5-10 dB sometimes) in case of dendrites