Attribution of riming and aggregation to the evolution of hydrometeor shape and orientation in mixed-phase clouds with SLDR-mode scanning cloud radar

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SLDR…slanted linear depolarization ratio

PROM All-hands meeting
25-26 July 2022

Leibniz Gemeinschaft

DACAPO PESO
Dynamics, Aerosol, Cloud and Precipitation Observations in the Pristine Environment of the Southern Ocean

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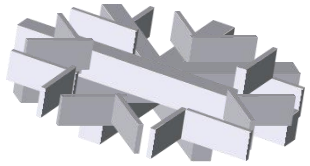
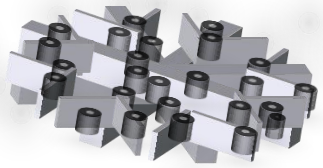
Leibniz-Institut für Troposphärenforschung

Microphysical growth processes in mixed-phase clouds

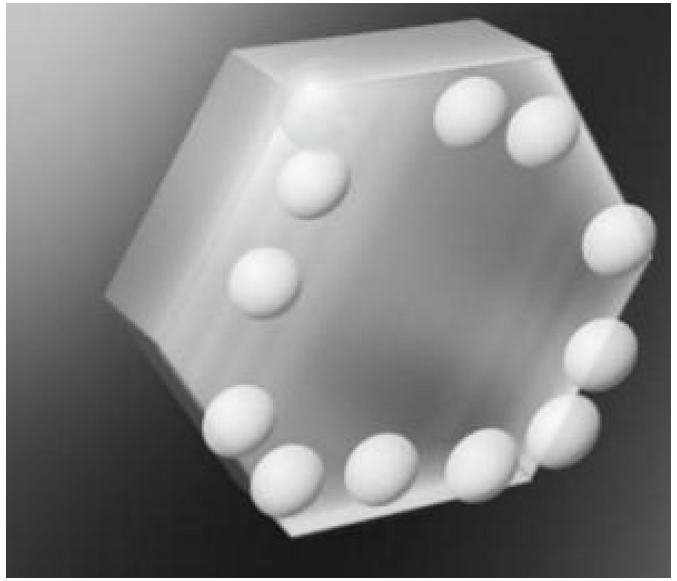
Riming process :

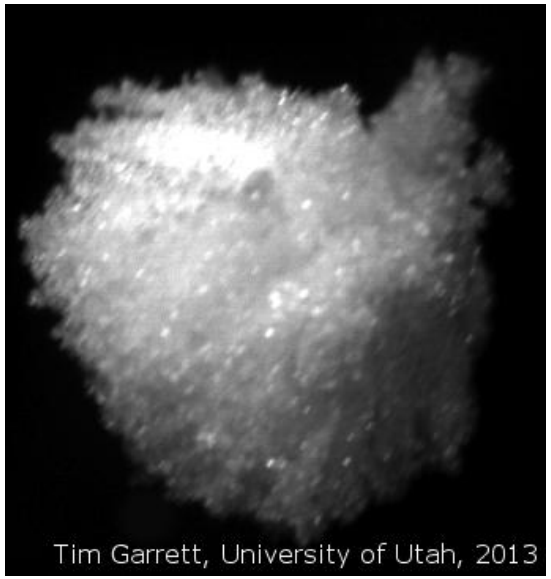


Dendritic layer



Liquid water layer





Riming

→ collision and accretion of **supercooled liquid water** onto ice particles

Spherical particle
High density → falling fast

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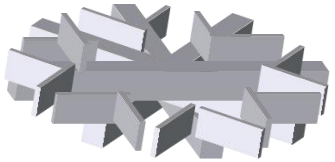
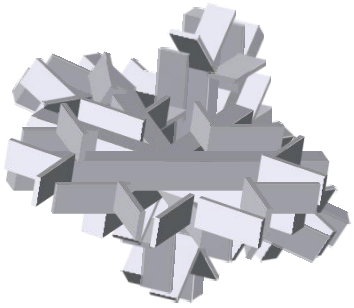
Microphysical growth processes in mixed-phase clouds

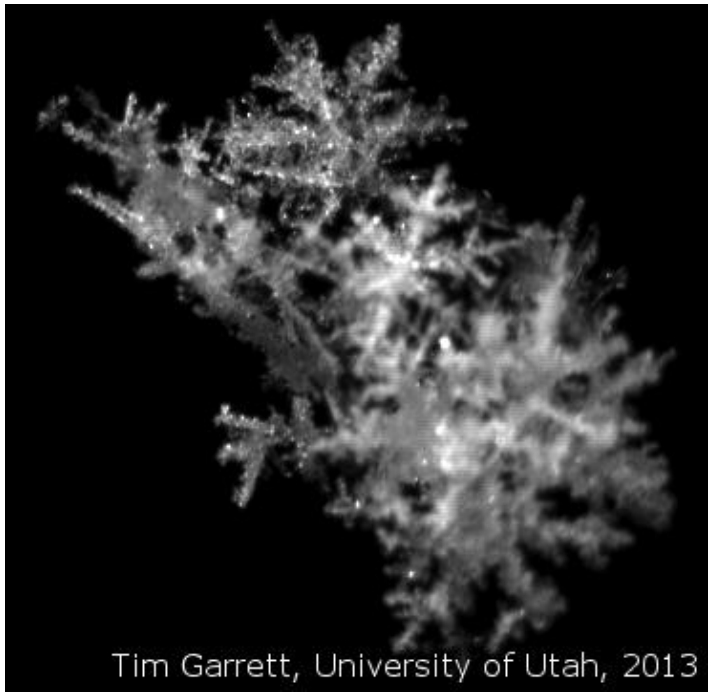
Aggregation process :



Dendritic layer



Snow flake layer



Aggregation

→ *Aggregation* occurs when several ice particles stick together, forming one larger particle

Spherical particle
Low density → falling slowly

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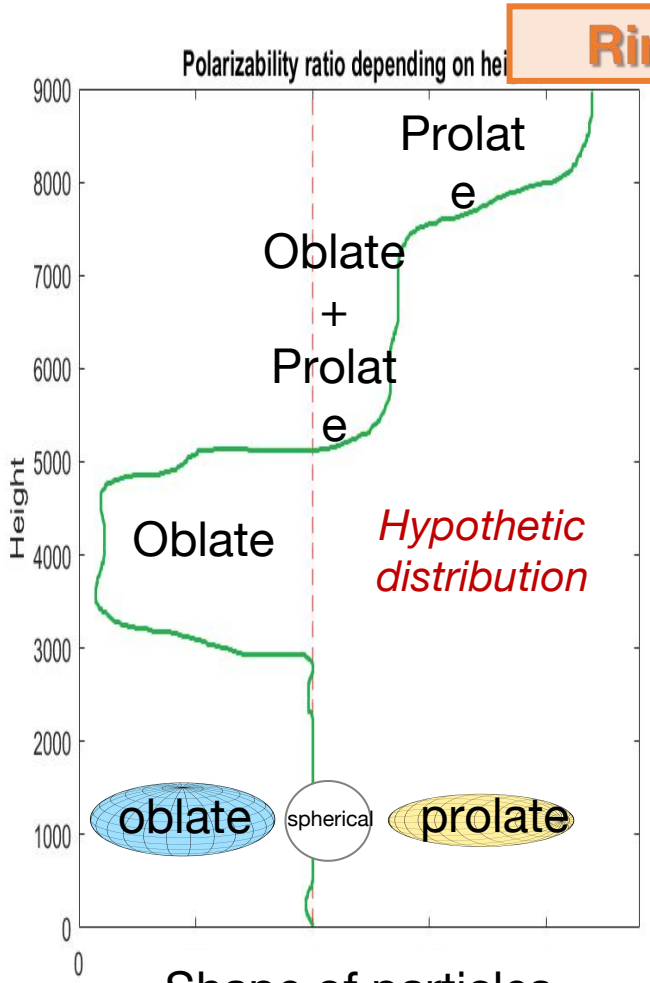
How to differentiate riming and aggregation?

ice -37°C

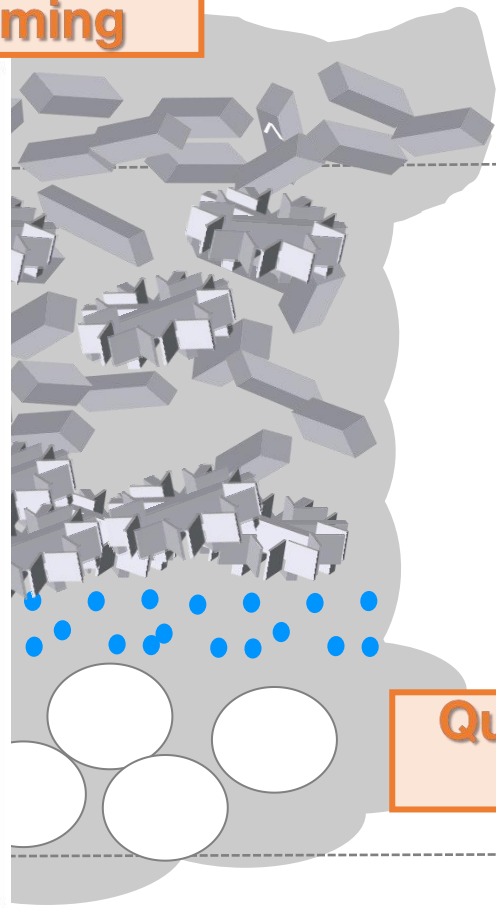
mixed-phas

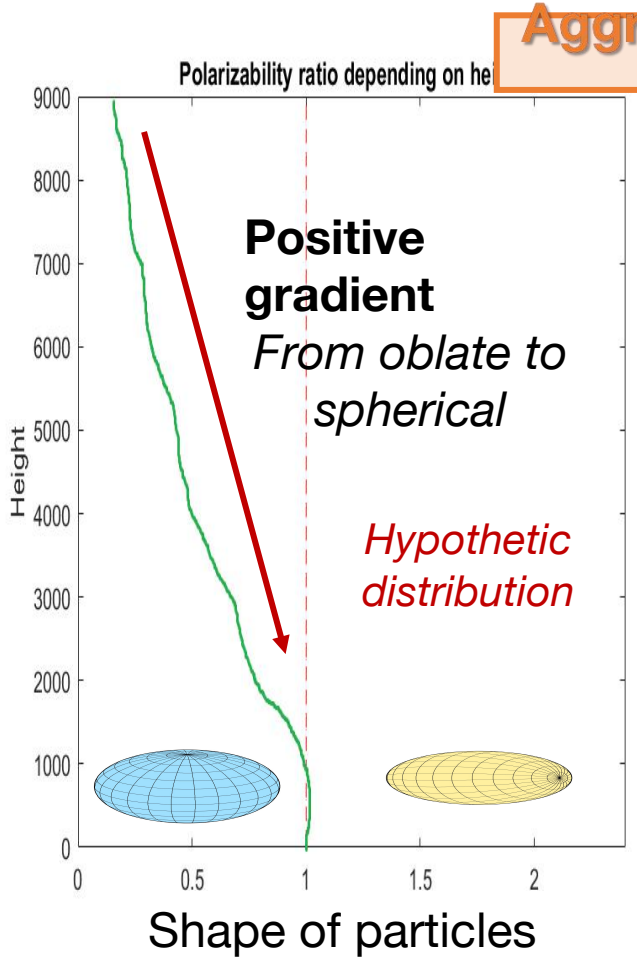
0°C

warm

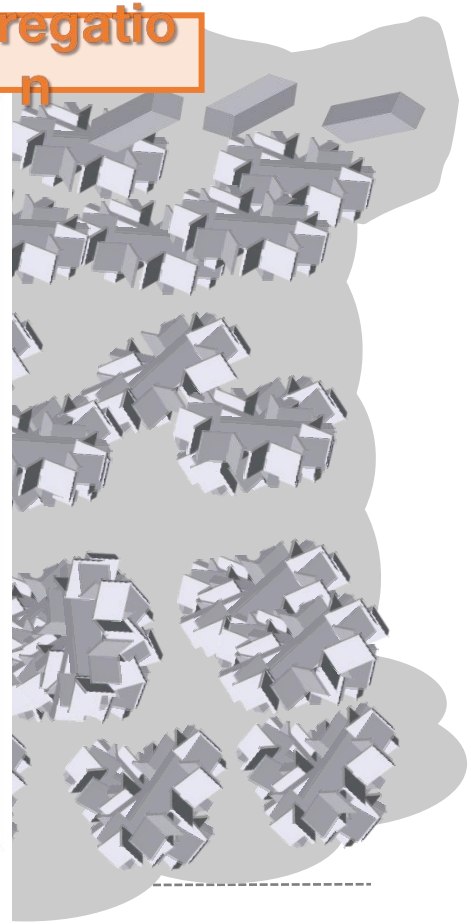


Riming





Aggregation



Polarizability ratio: measure of the density-weighted axis ratio (*Myagkov et al., 2016a, AMT*)

Legend :

Graupel | Supercooled liquid droplets | Dendrite | Column | Aggregate

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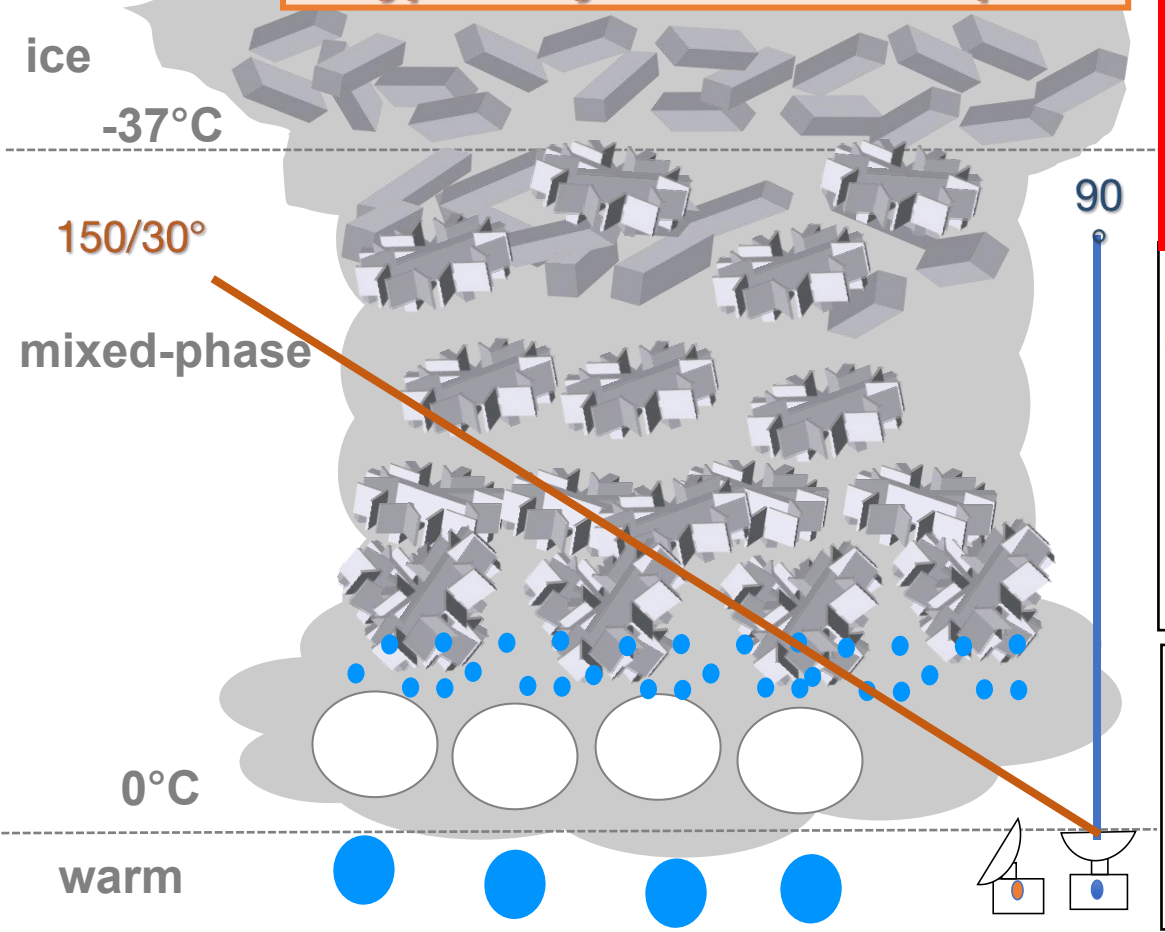
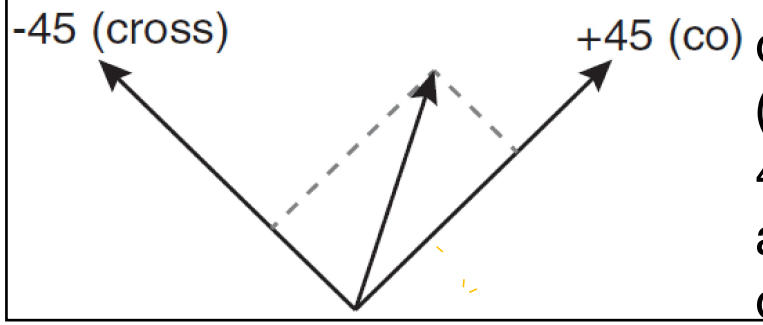
How to discriminate the manifold hydrometeor habits in clouds?

Typical hydrometeor shapes



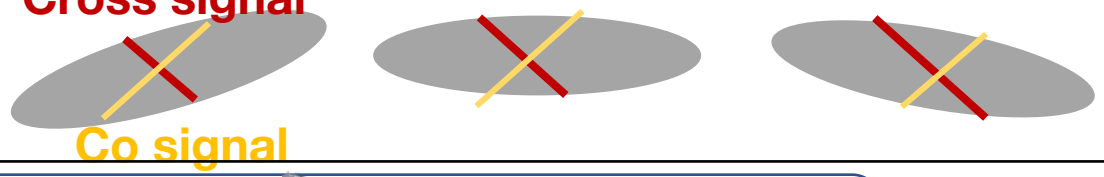
Approach:

Characterization of the vertical distribution hydrometeor shapes with a SLDR-scanning polarimetric cloud radar (MIRA-35 GHz)



Slanted linear depolarization ratio (**SLDR**)-**cloud radar:** 45° rotation of receiver antenna around direction of emission *[Myagkov et al., 2016, AMT]*

SLDR-mode minimizes wobbling effects of hydrometors on the measurements!



Legend :

Graupel · Supercooled liquid droplets · Dendrite · Column · Aggregate · Rain

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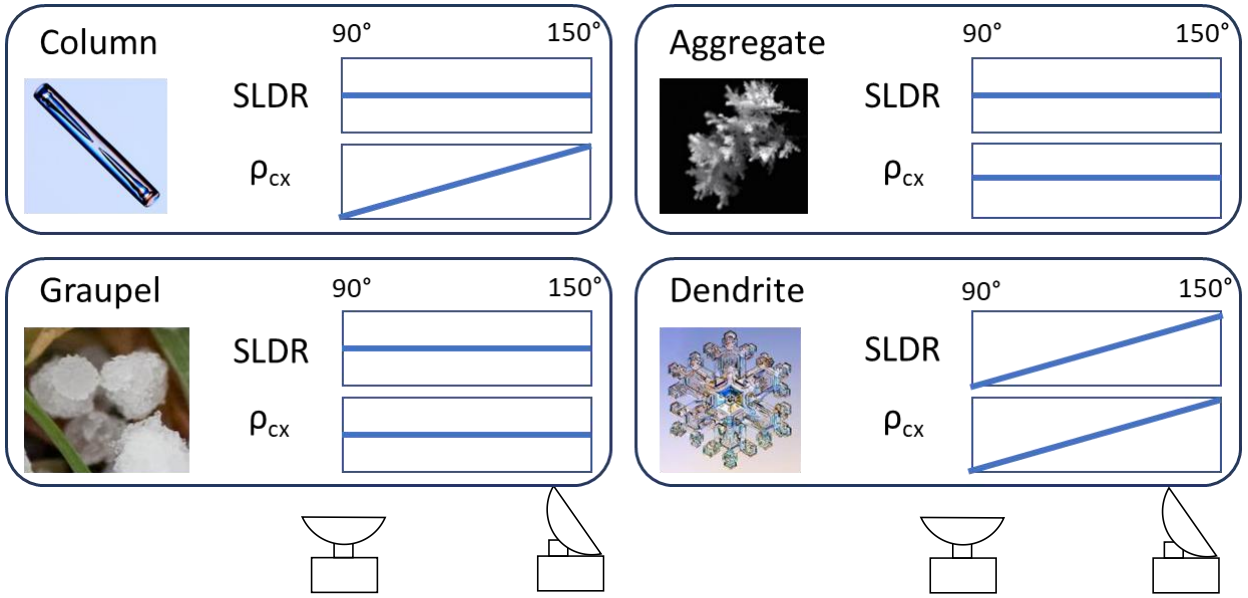
Shape estimation of particles

Exploit the unique relationship between: SLDR, ρ_{cx} (cross-correlation coefficient), antenna elevation angle and particle shape (in obs. + sim)

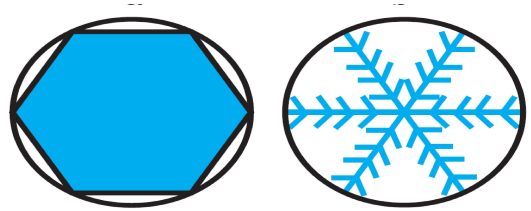


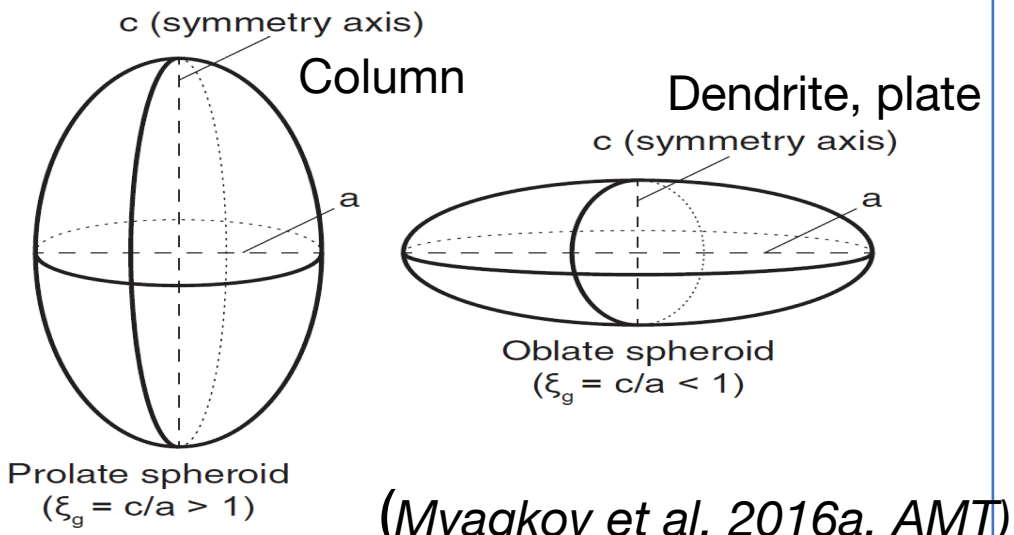
→ For our method we will assume that particles are horizontally oriented

→ Compare observations of elevation angle dependency of SLDR and ρ_{cx} to the scatt. model simulations to infer best-fitting hydrometeor shape

Spheroidal pol. scattering model is suitable to simula
relation between SLDR and ρ_{cx} as function of elev ang

Particle shape assumed to be spheroidal





(*Myagkov et al, 2016a, AMT*)

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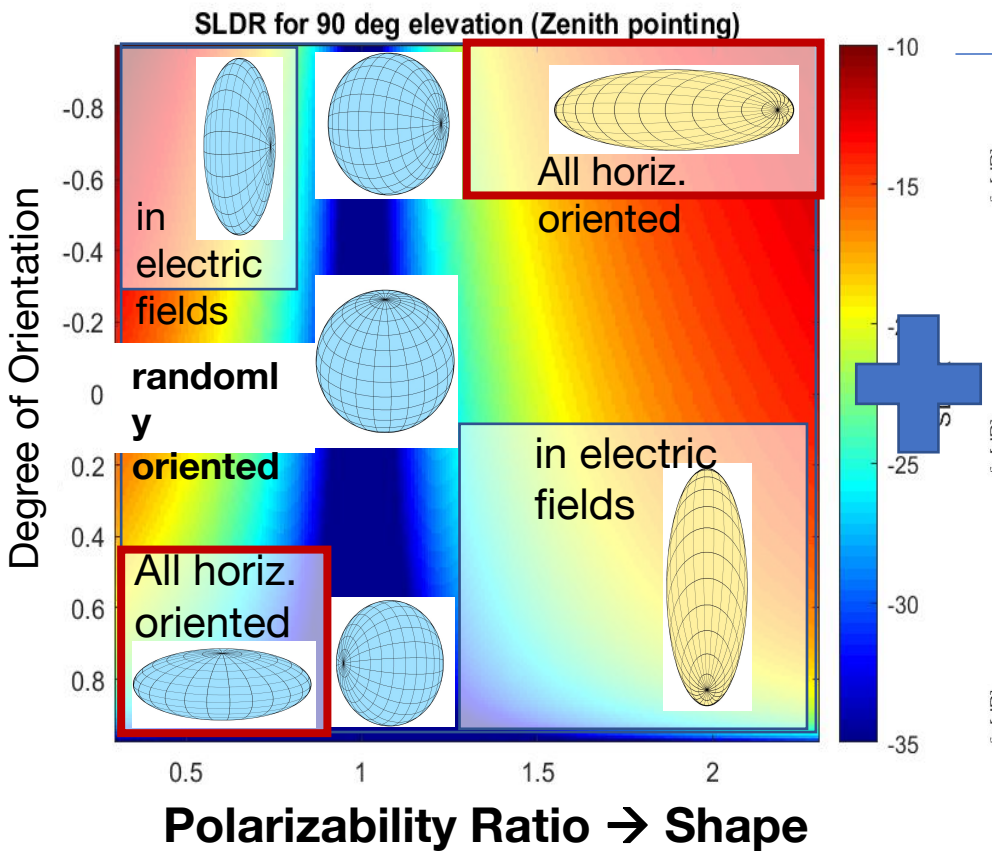
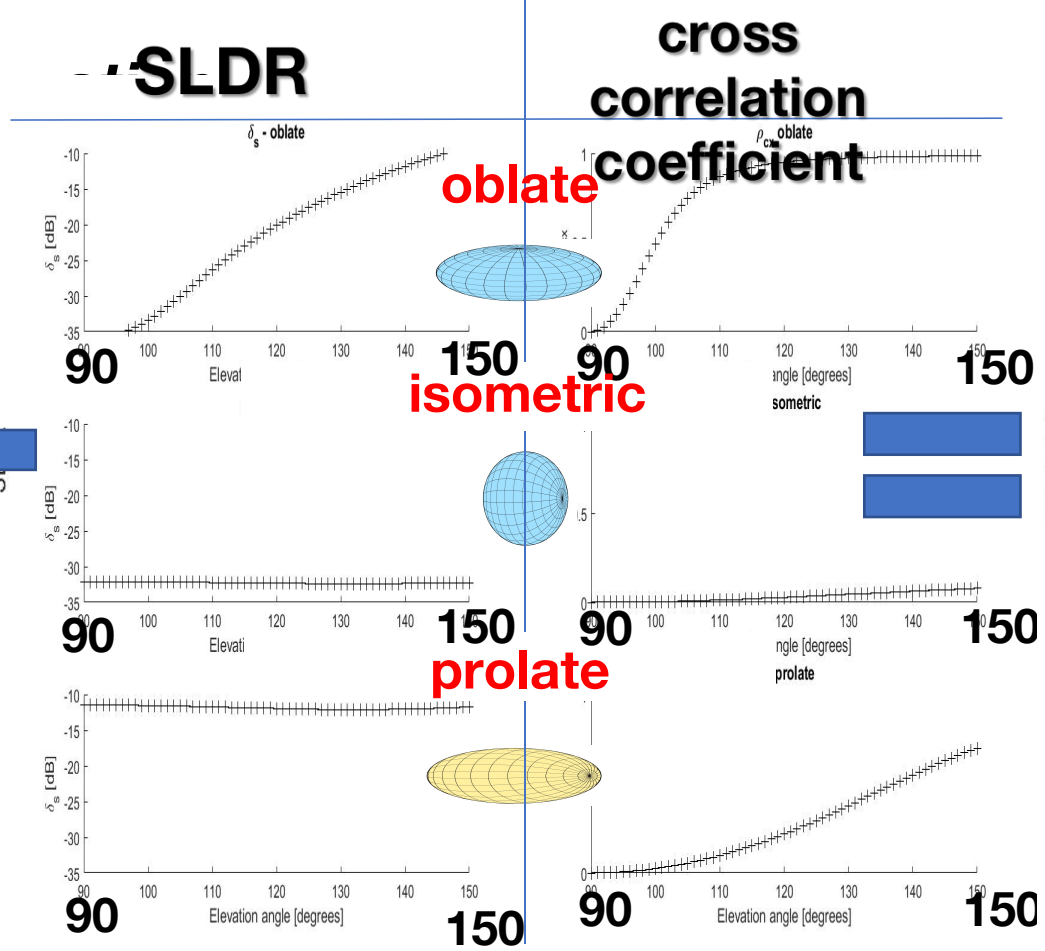
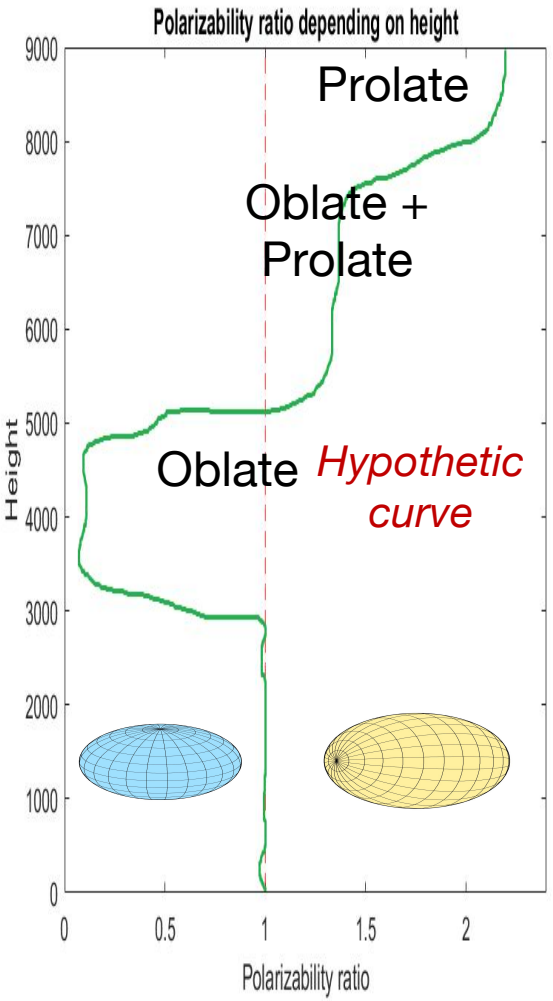
New method to estimate the vertical distribution of particle shape

Combination of spheroidal scattering model and scanning SLDR cloud radar observations







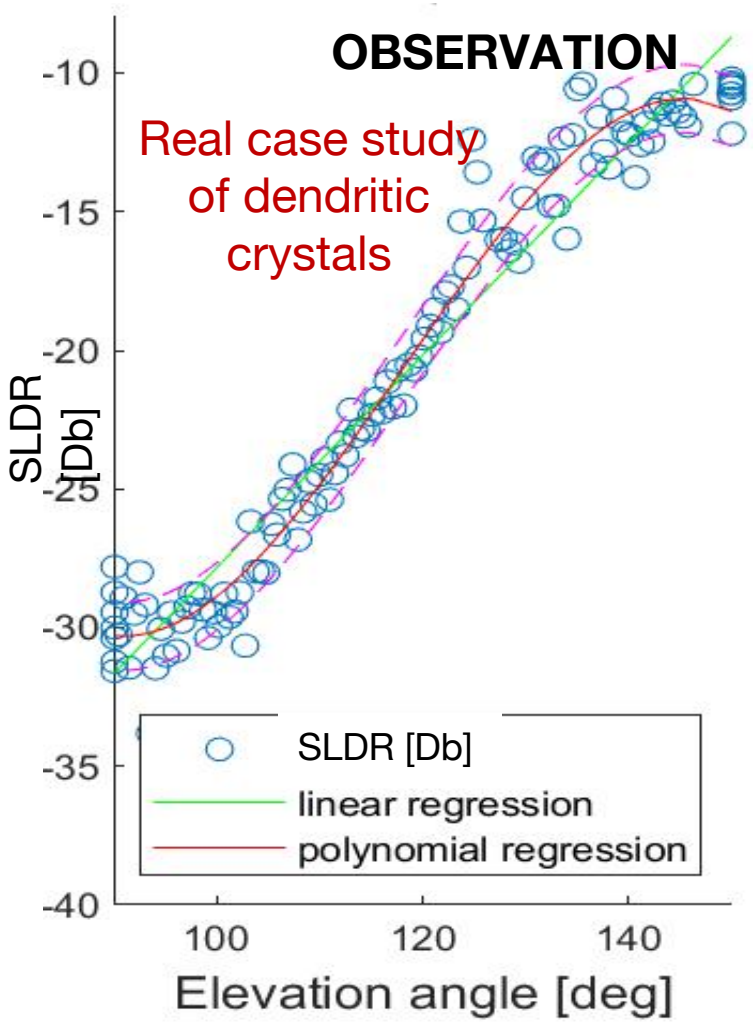
Myagkov et al., 2016a, AMT

Illustration of retrieval : SLDR(90°) = -32 dB and SLDR(150°) = -11dB

→ We will illustrate the new method with typical hypothetic dendritic values of SLDR at 90 and 150 degree elevation angle, based on a real case study.

OBSERVATION

Real case study of dendritic crystals



MODEL

Simulation of dendritic crystals

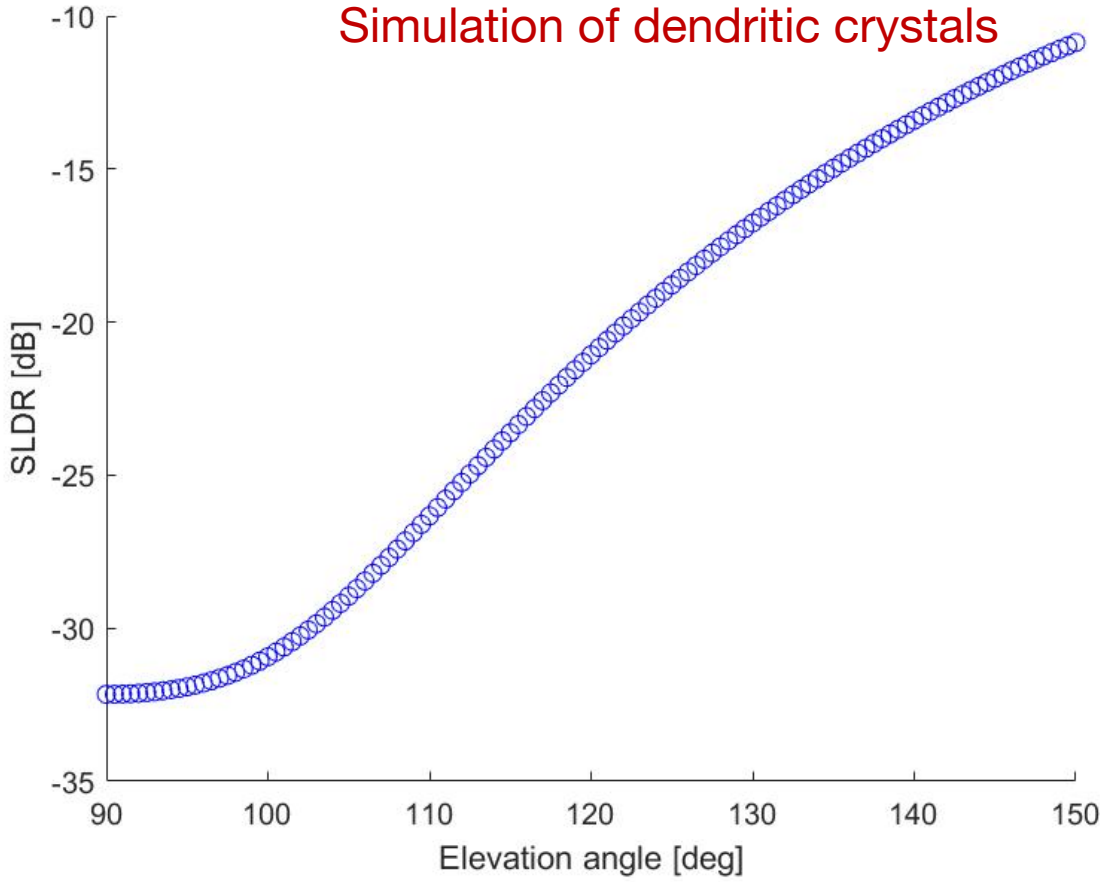
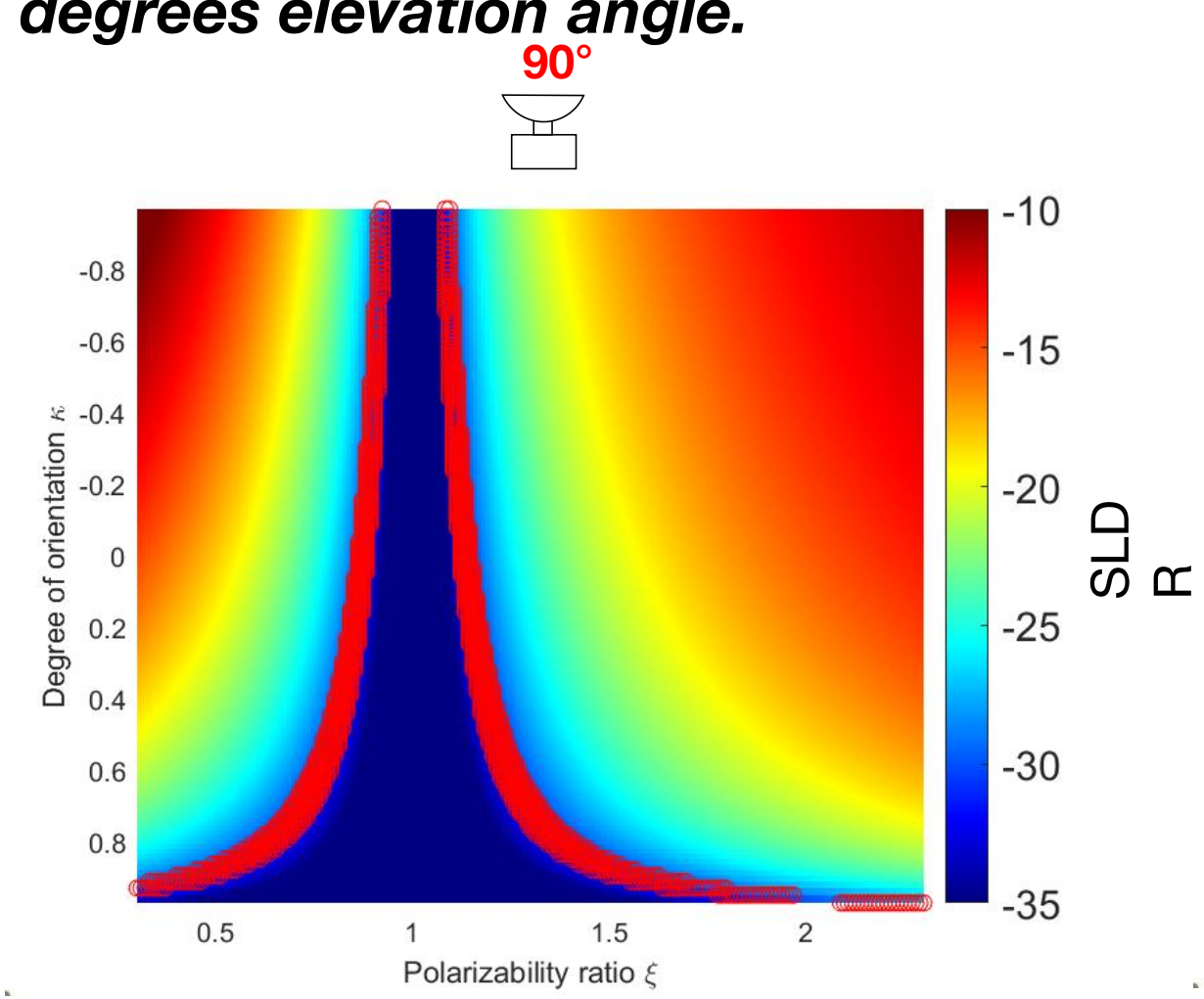


Illustration of retrieval : SLDR(90°) = -32 dB and SLDR(150°) = -11dB

Modeled SLDR dependency on shape and orientation of particles at 90 and 150 degrees elevation angle.



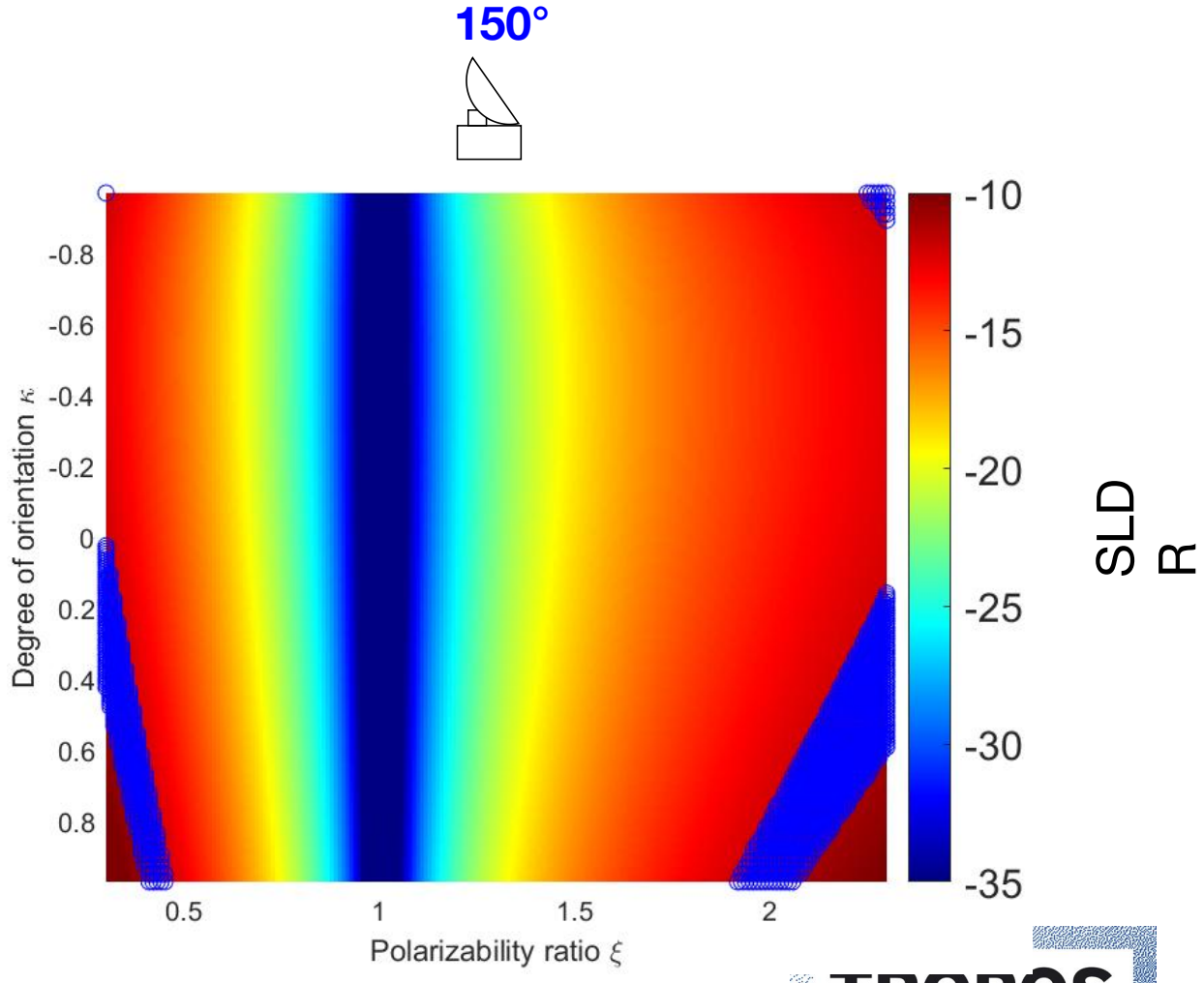


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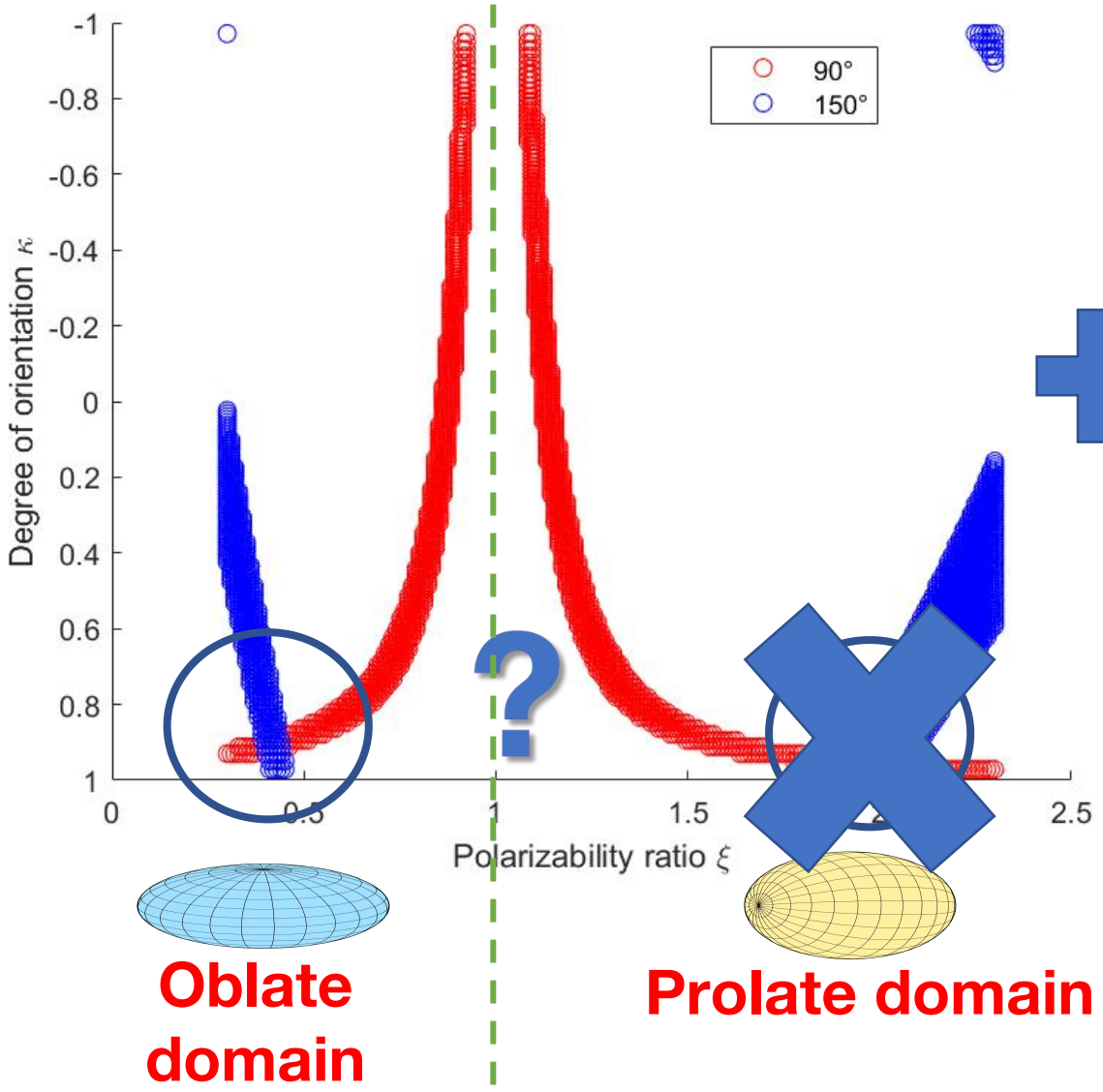
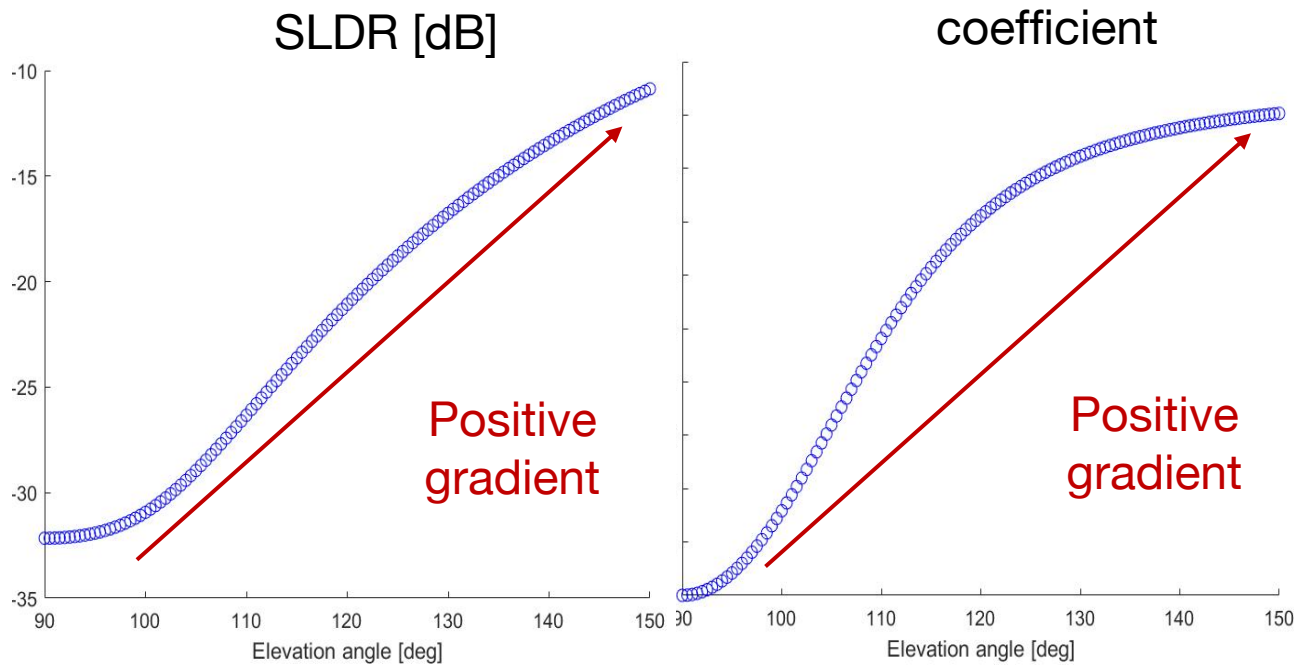
Illustration of retrieval : SLDR(90°) = -32 dB and SLDR(150°) = -11dB

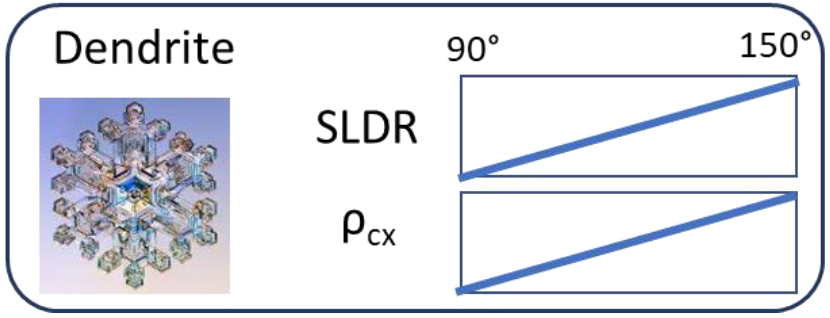


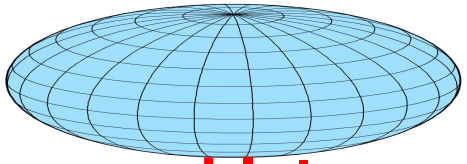
Oblate domain

Prolate domain

Analyze vertical gradients







oblate

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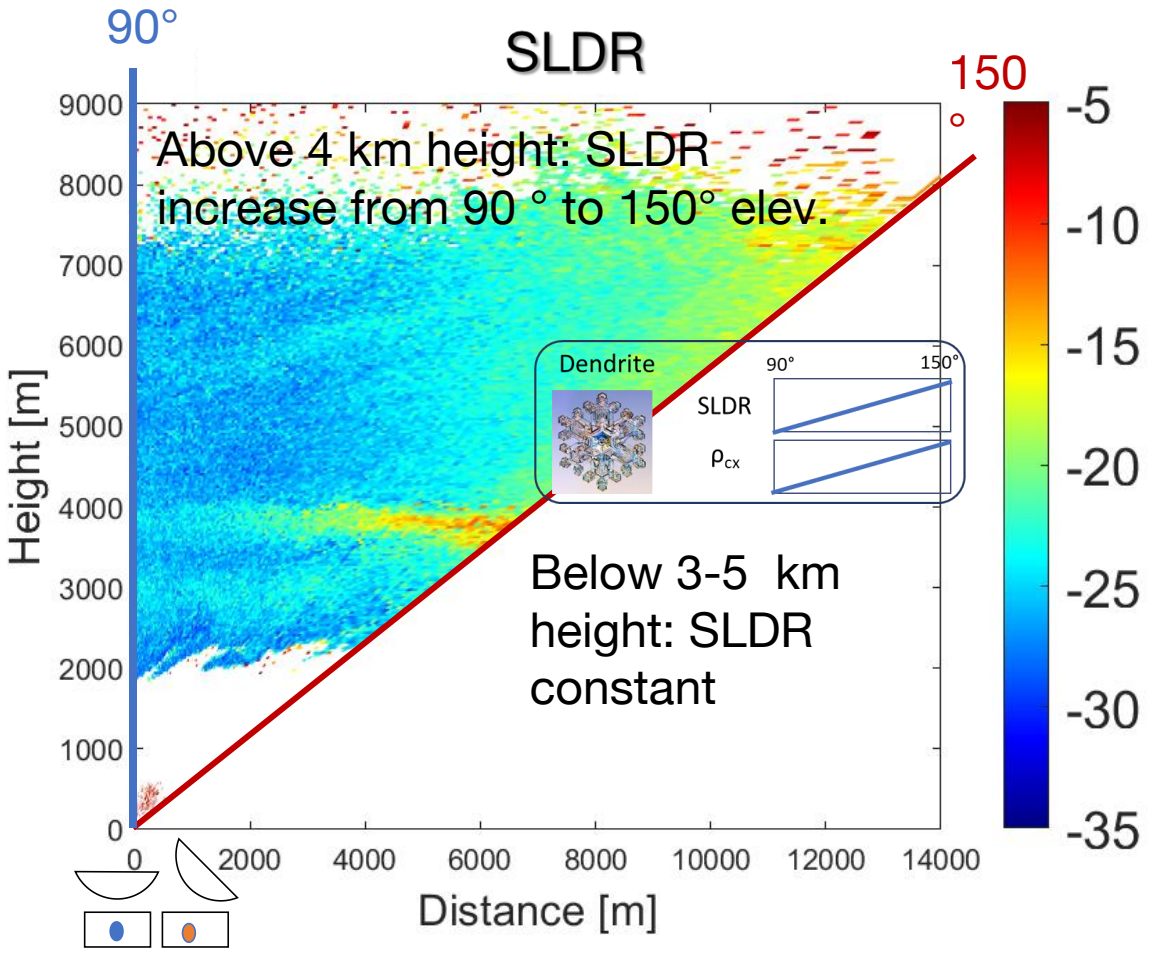
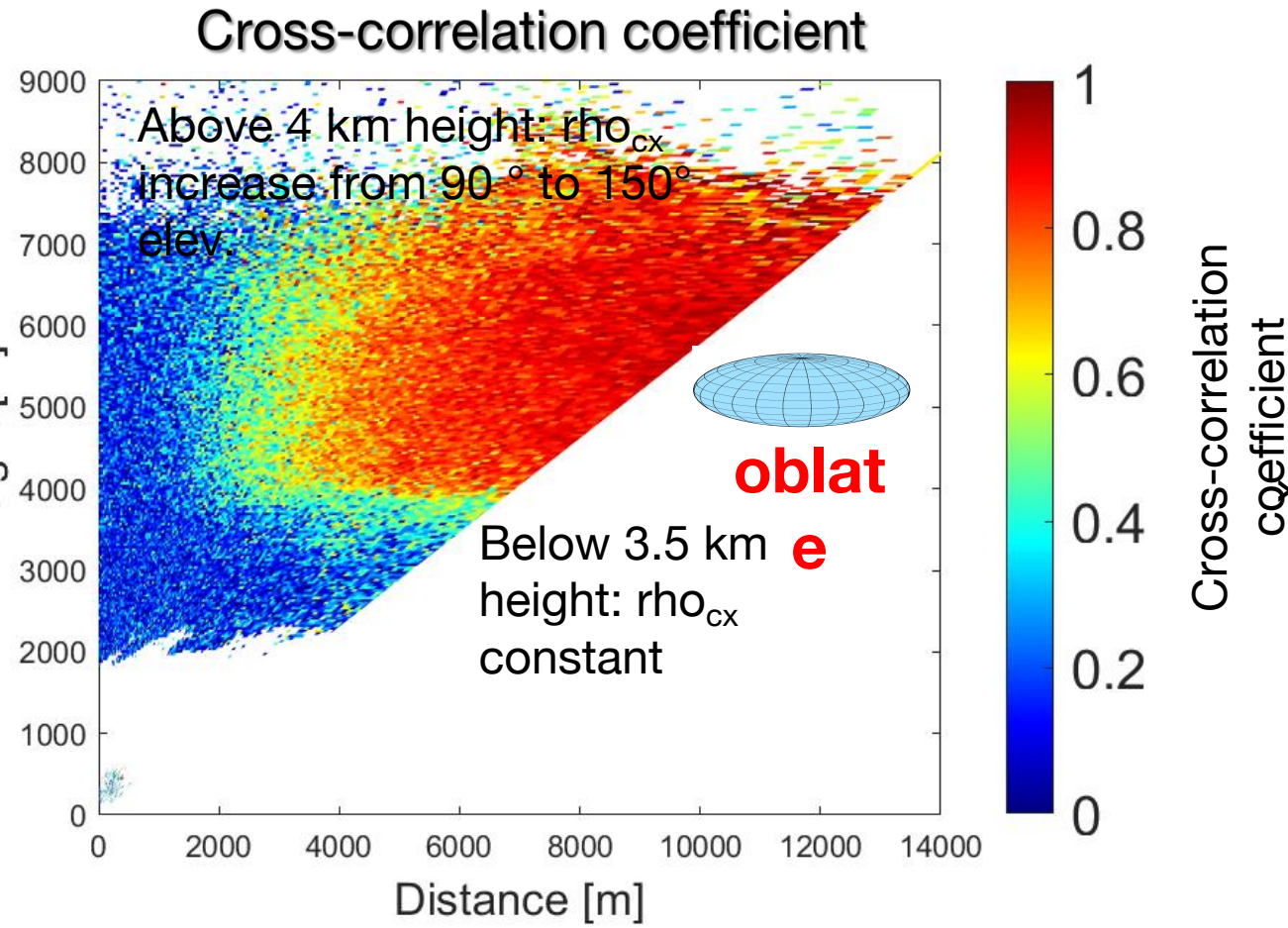
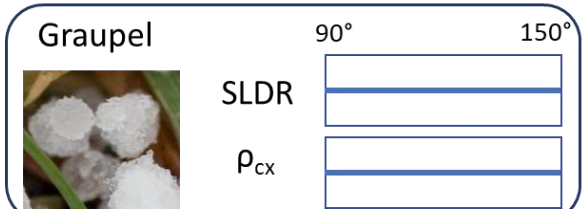
Case study, 26 August 2019, 06:30 UTC, Punta Arenas, Chile

RHI-scan of SLDR and ρ_{cx} during the DACAPO-PESO campaign

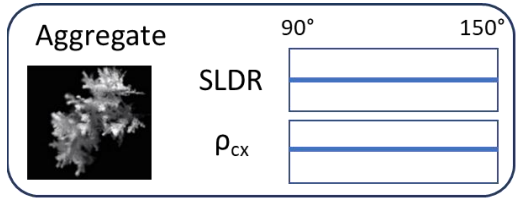




Below 4 km:

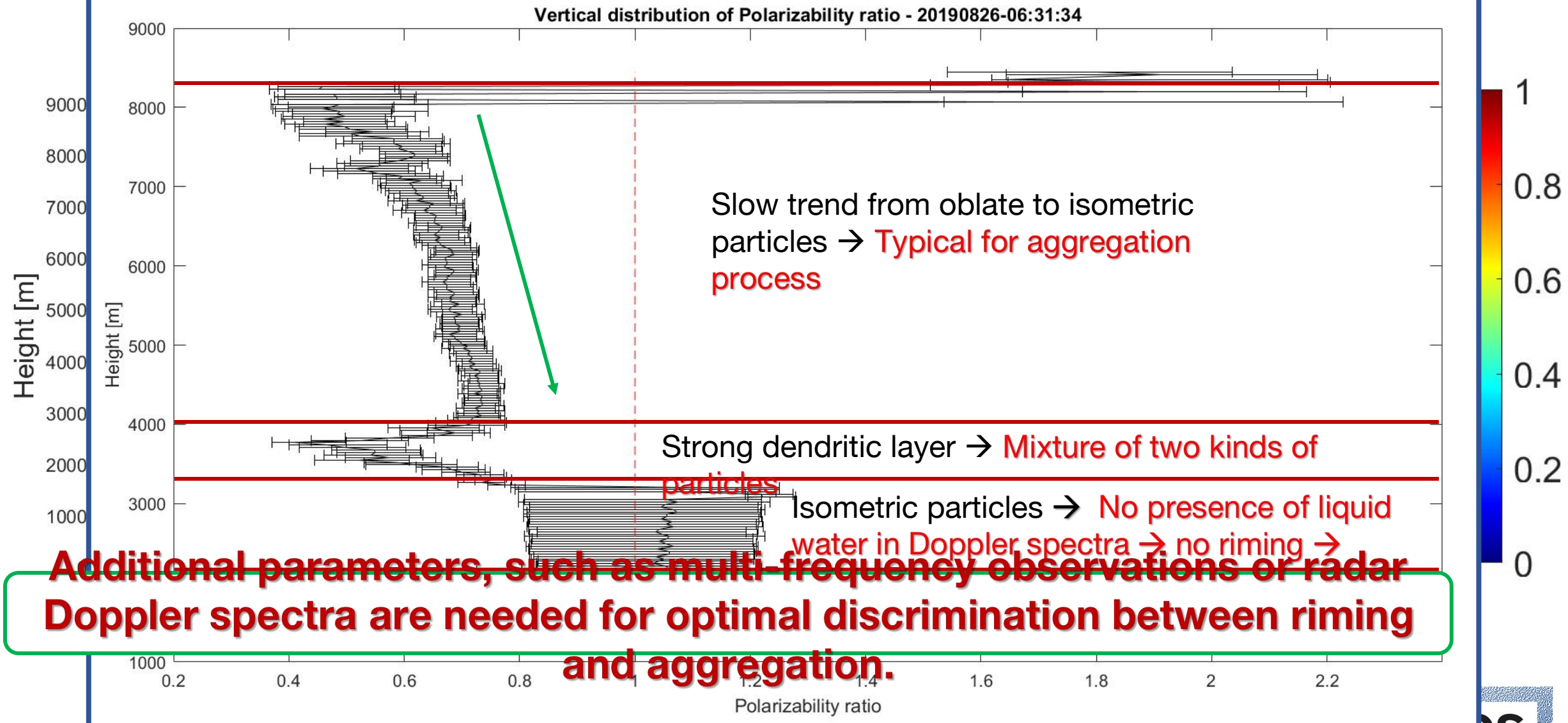


or



TROPOS

Case study, 26 August 2019, 06:30 UTC, Punta Arenas, Chile



Additional parameters, such as multi-frequency observations or radar Doppler spectra are needed for optimal discrimination between riming and aggregation.

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Summary

→ Scanning cloud Radar in SLDR-mode is a new technology which is highly sensitive to determine the shape of particles

→ The new approach allows to obtain the vertical gradient of polarizability ratio, describing the particle shape, which contains certain characteristic features for either riming or aggregation processes :

- ❖ Aggregation → progressive process: Particles will change slowly from oblate/prolate to spherical particles
- ❖ Riming → spontaneaous/abrupt process: Particles will change quickly from oblate/prolate to spherical particles, at the contact with supercooled liquid droplets

→ The VDPS method is validated and promising combined with the new configuration of MIRA-35

VDPS: Vertical Distribution of Particle Shape

→ Audrey is on PICNICC break (parental leave) → Phd Project is extended until 0

Study in preparation for PROM special issue:
https://acp.copernicus.org/articles/special_issue1154.html
Title: „Determination of the vertical distribution of particle shape in a cloud using a SLDR-mode 35GHz scanning cloud radar"
→ Finished. To be submitted by August 2021

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