3rd Calibration and Monitoring Workshop, Toulouse, France, 17-19 Nov 2021

EVALUATION OF DWD RADAR CALIBRATION BASED ON COLLOCATED SPECTRAL POLARIMETRIC OBSERVATIONS FROM W-BAND CLOUD RADAR

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ROHDE&SCHWARZ
Make ideas real

CONVENTIONAL DISDROMETER-BASED CALIBRATION

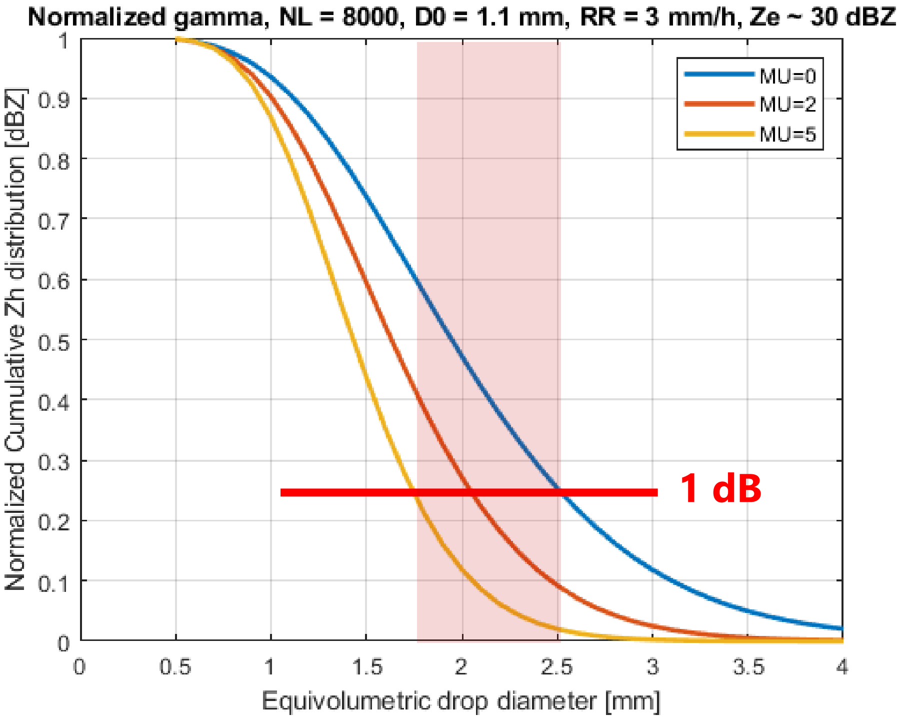
Freq: C-band (5.6 GHz)
Min. Range: 1 km
Res. Vol: **15000 m^3**

Surface
Samp. Area: **~50cm^2**

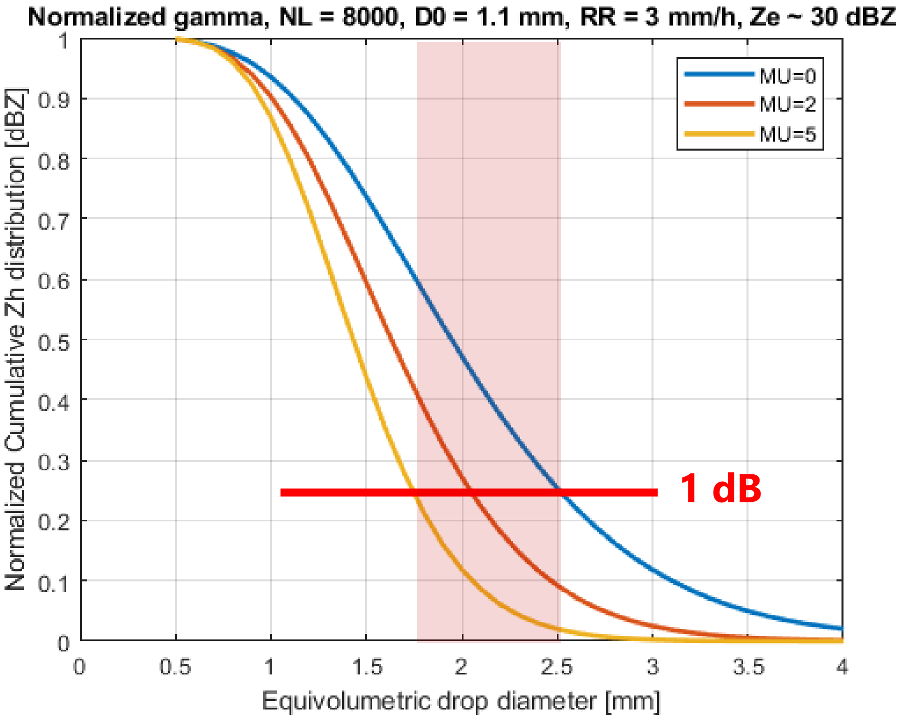
High short-term uncertainty due to sampling effects:

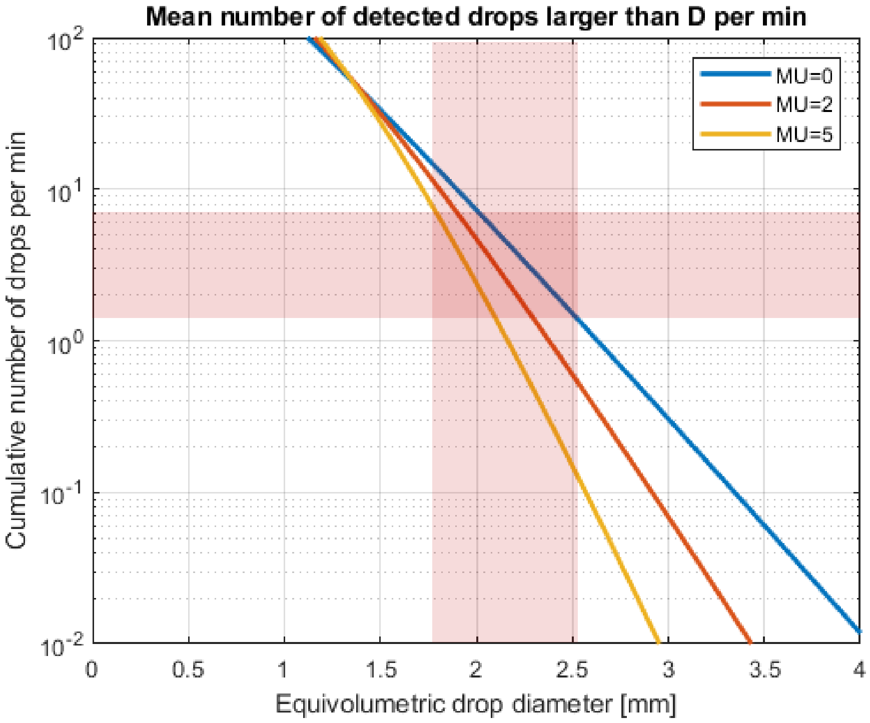
- ➢ Spatial and temporal DSD variability
- ➢ Different sampling volumes

CONTRIBUTION OF LARGE DROPS TO C-BAND REFLECTIVITY



CONTRIBUTION OF LARGE DROPS TO C-BAND REFLECTIVITY





1 dB accuracy relies on a few drops per minute observed by a typical disdrometer (50 cm^2)

0.5 dB accuracy 0.1 - 1 drop per minute

Coarse size-velocity grid

CONVENTIONAL DISDROMETER-BASED CALIBRATION

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Res. Vol: **15000 m³**

Surface
Samp. Area: ~**50cm²**

High short-term uncertainty due to:

- Sampling effects
- Spatial and temporal DSD variability

In order to reduce the uncertainty

- **> 20 h** averaging of **vertical** observations in stratiform rain are needed (Frech et al. 2017)

Is there a reliable reference for:

- ***shorter time scales***
- ***applicable to low elevations***

?

INTERMEDIATE REFERENCE: MM-WAVELENGTH RADAR

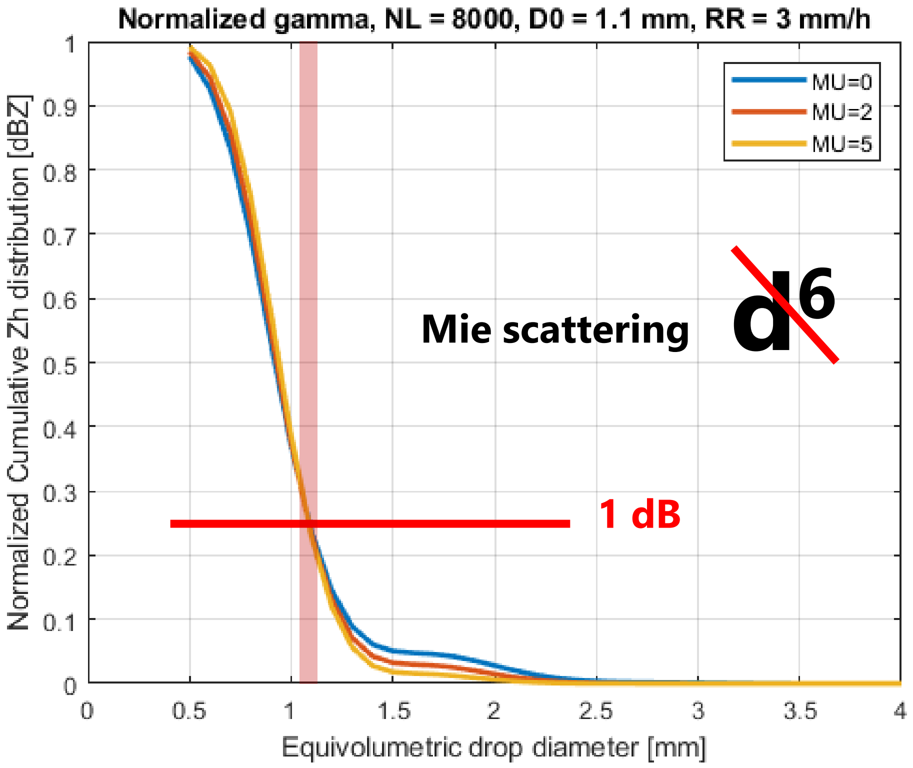
Freq: W-band (94 GHz)
Min. Range: 250 m
Res. Vol: 140 m^3

Surface
Samp. Area: ~50 cm^2

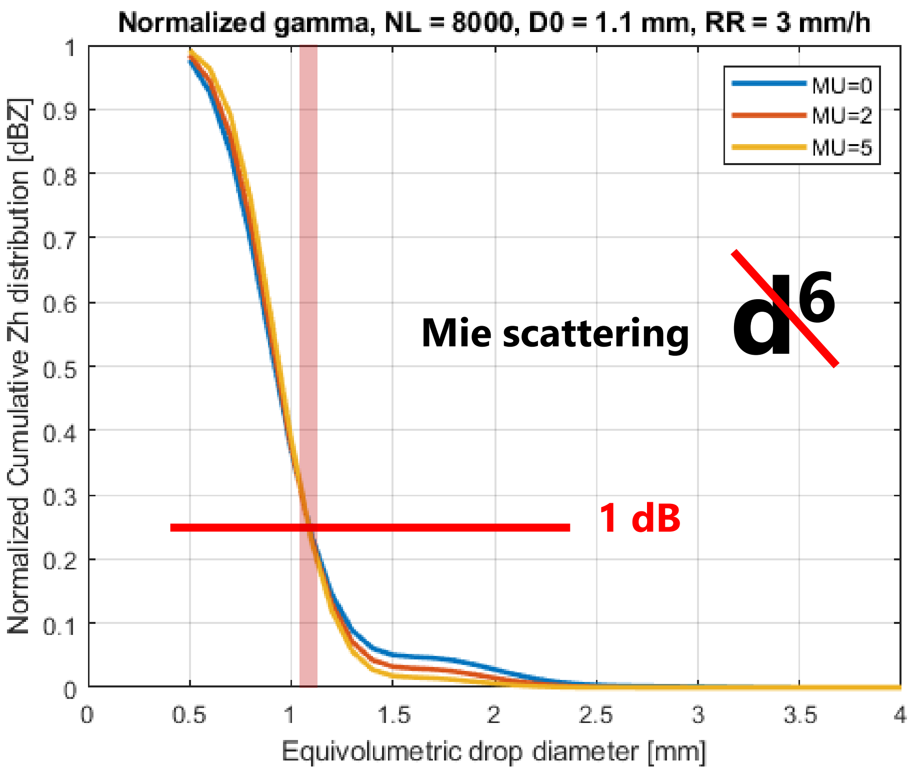
Sampling effects are of less importance due to:

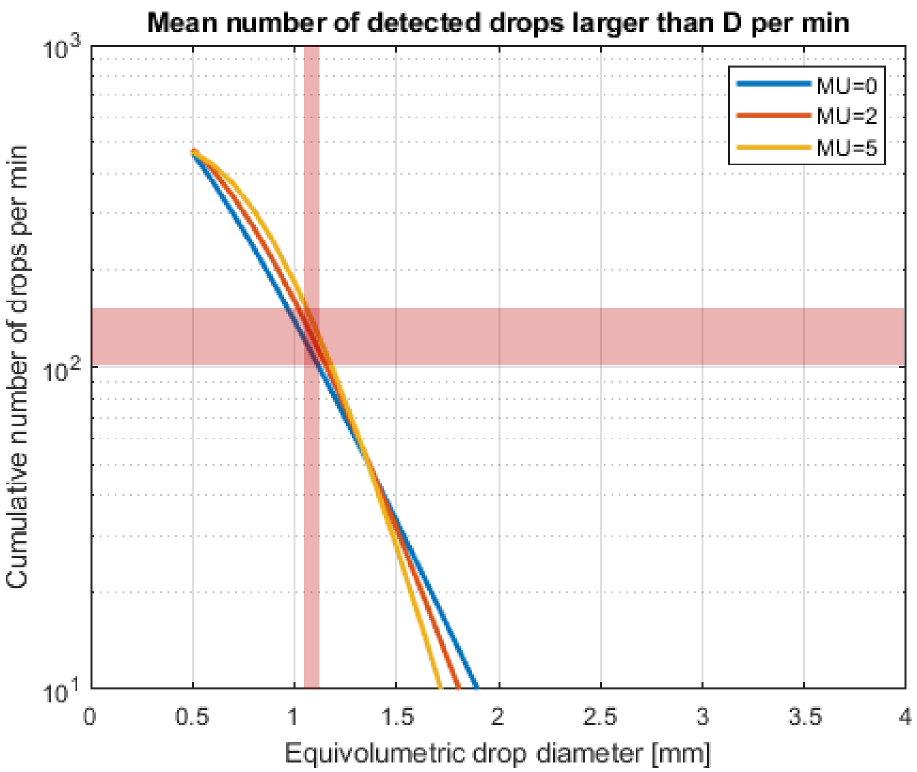
1. Smaller distance in between
2. Smaller resolution volume relative to a weather radar
3. Longer averaging and high SNR (up to 70 dB even in low intensity rain)

LARGE DROPS AT 94 GHZ



LARGE DROPS AT 94 GHZ





Disdrometer observations are much more representative for W-band

INTERMEDIATE REFERENCE: MM-WAVELENGTH RADAR

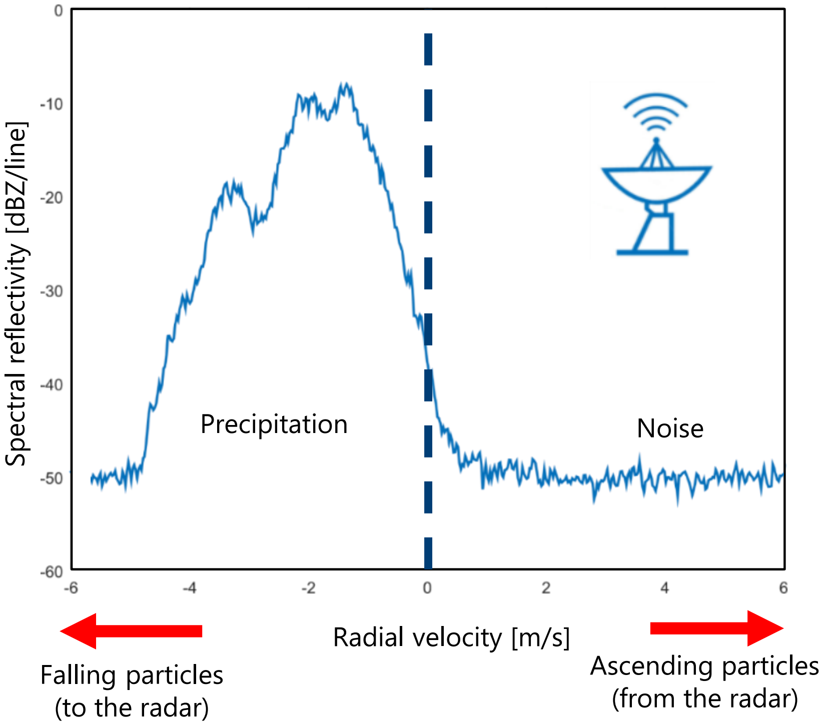
Freq: C-band (5.6 GHz)
Min. Range: 1 km
Res. Vol: 15000 m^3

Freq: W-band (94 GHz)
Min. Range: 250 m
Res. Vol: 140 m^3

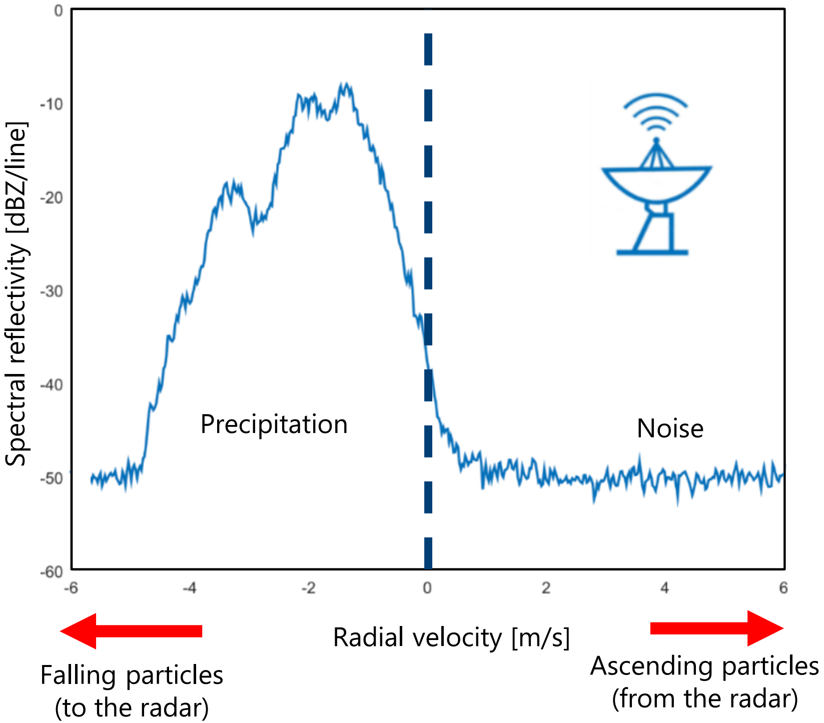
- Accurate calibration (Myagkov et al, 2020)
- More representative observations than a disdrometer (large particles are detected)
- Scanning unit. Profiles from operational weather radar scans can be used.
- A number of range bins can be compared

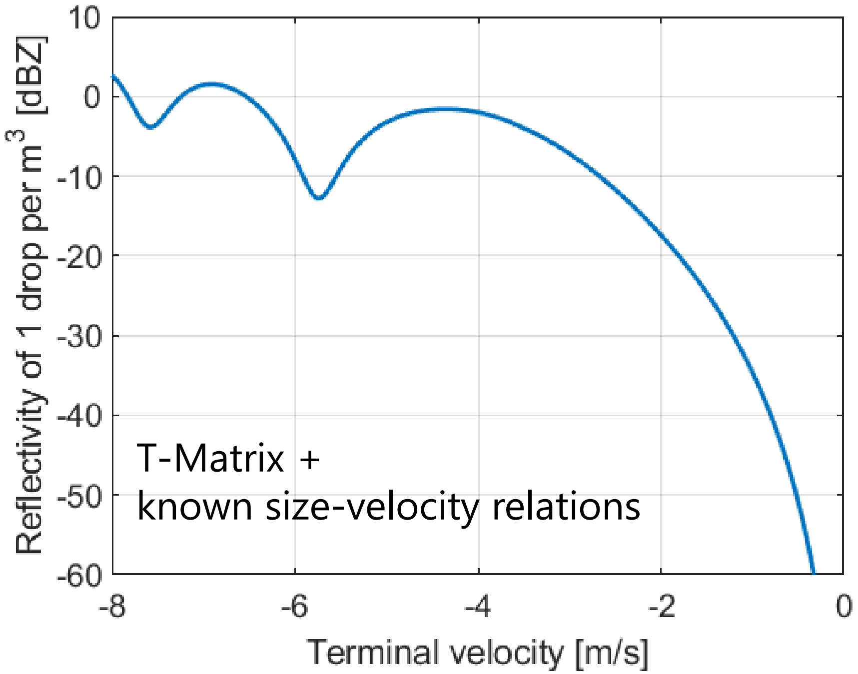
Problem: How to derive the reference 5.6-GHz reflectivity for low elevation from the cloud radar?

DSD RETRIEVAL USING DOPPLER SPECTRA



DSD RETRIEVAL USING DOPPLER SPECTRA

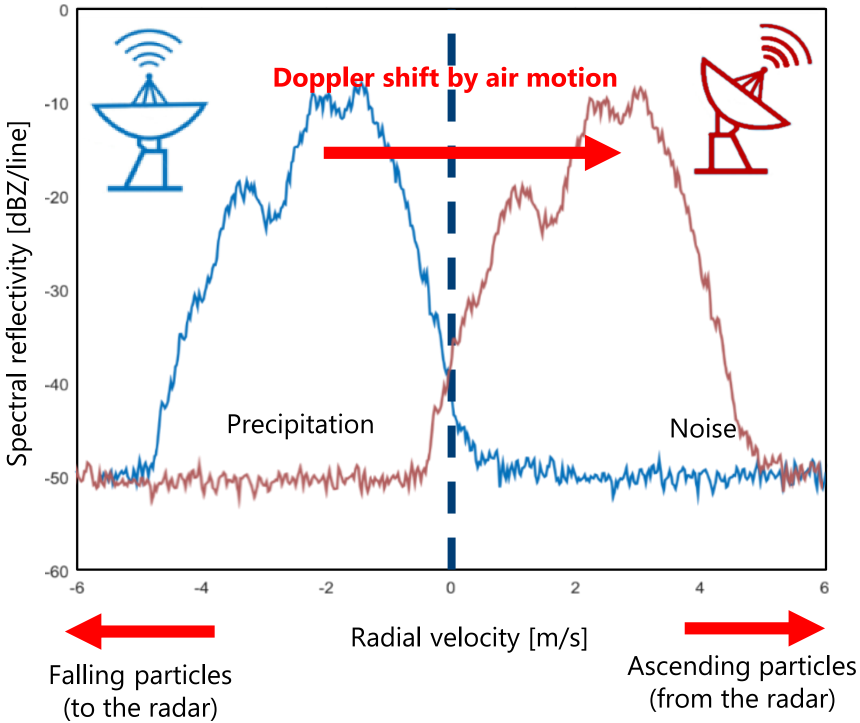




Uncertainties related to air motions (up/down + turbulence broadening)

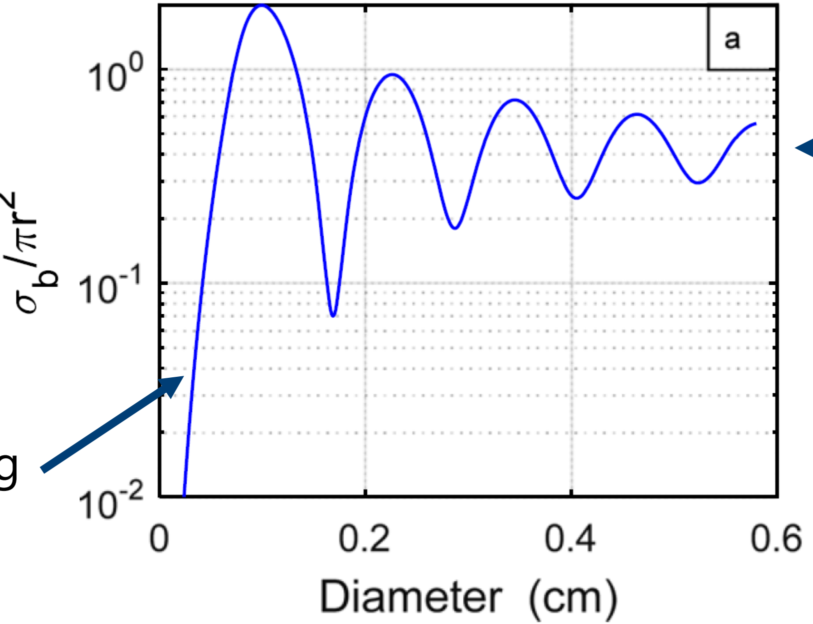
Is this also applicable to slanted observations?

SLANT OBSERVATIONS



Precise correction for air motions is needed

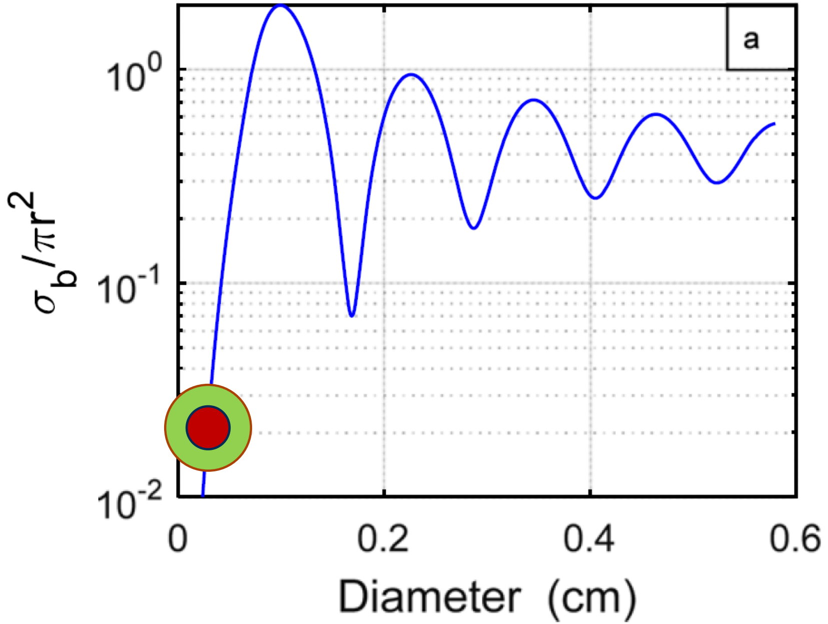
WATER DROP BACKSCATTERING @ 94 GHZ



Mie oscillations (resonance effect, scatterer comparable to wavelength)

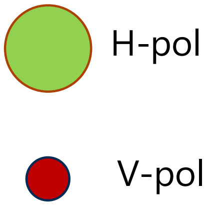
Rayleigh scattering (scatterer smaller than wavelength)

WATER DROP BACKSCATTERING @ 94 GHZ

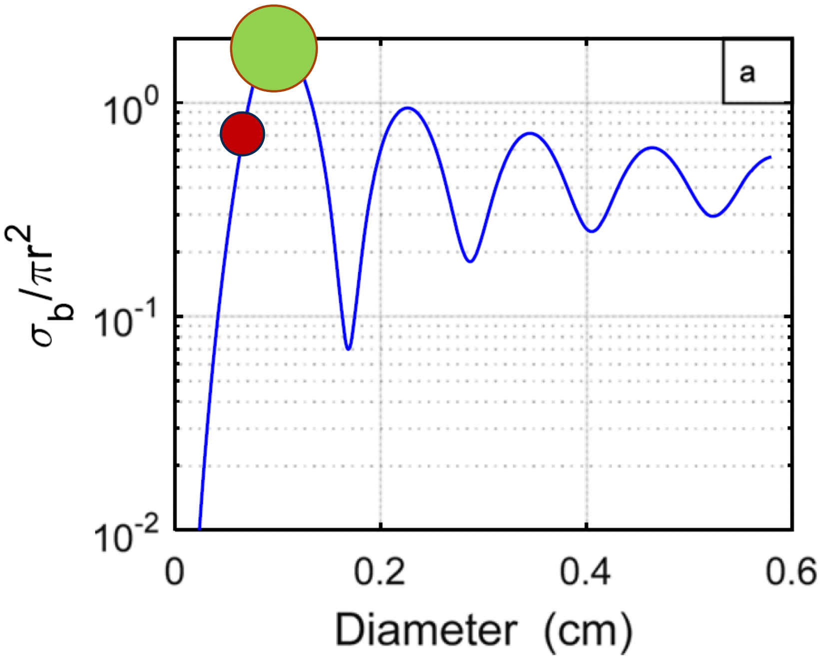


D_e = 0.2 mm

Z_{DR} ~ 0 dB

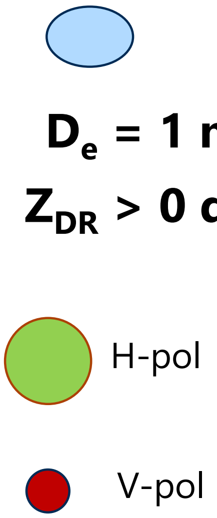


WATER DROP BACKSCATTERING @ 94 GHZ



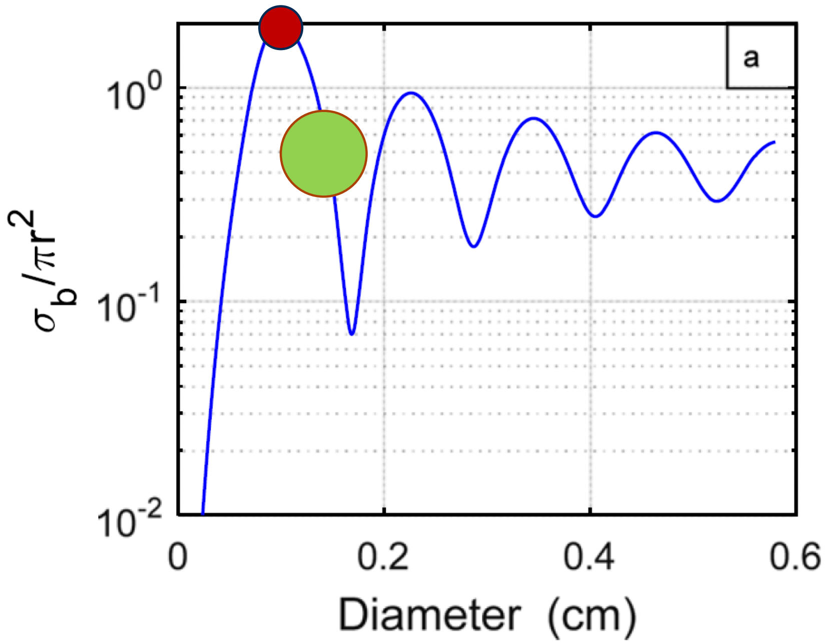
D_e = 1 mm

Z_{DR} > 0 dB



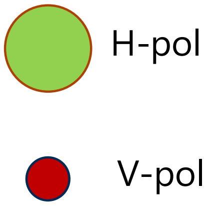
What happens next?

WATER DROP BACKSCATTERING @ 94 GHZ



D_e = 1.5 mm

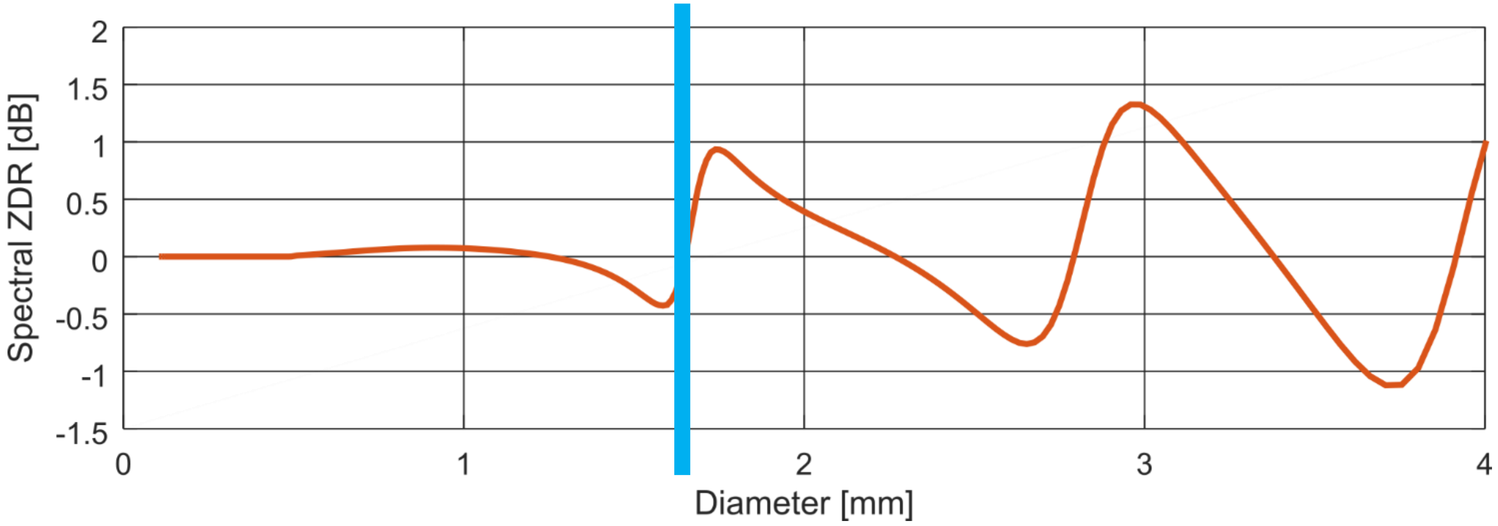
Z_{DR} < 0 dB



Polarimetric "oscillations"

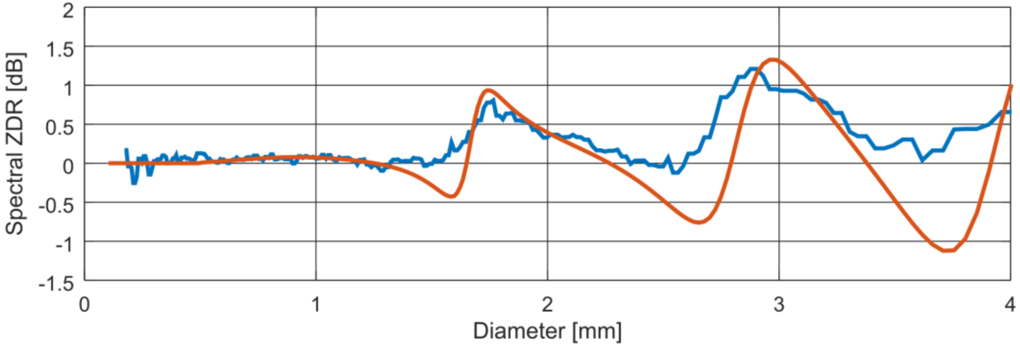
POLARIMETRIC OSCILLATIONS

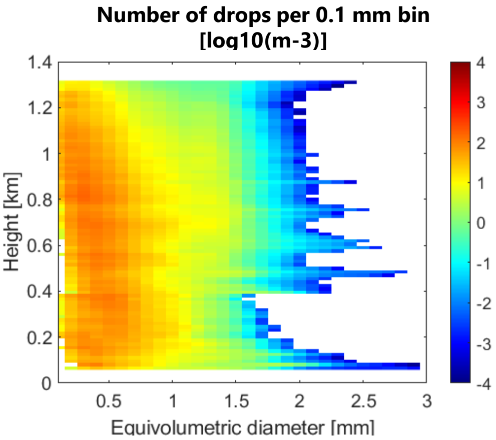
~5.5 m/s terminal velocity

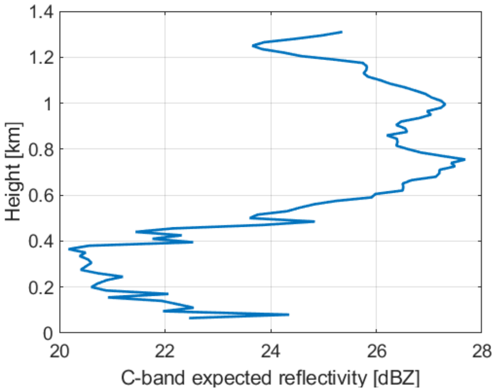


Oscillations can be used for mitigation of air motions

MODEL FIT





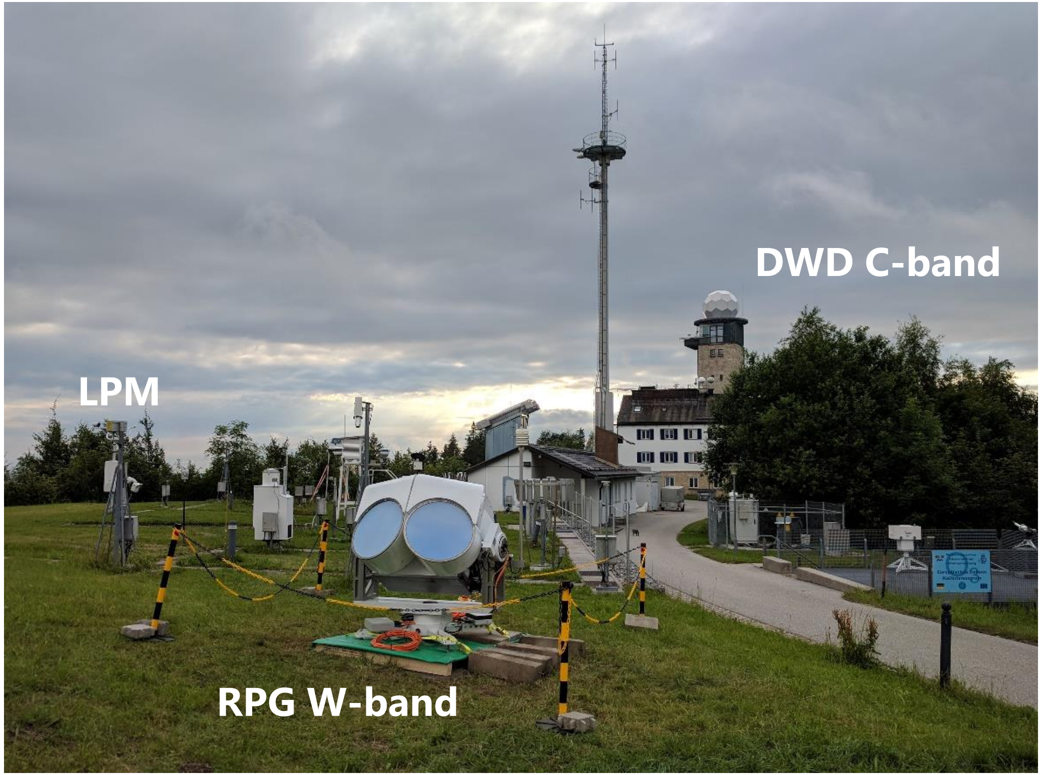


Variational retrieval similar to Tridon and Battaglia, 2015 (dual frequency spectra)

- Shift due to horizontal wind
- Turbulence
- Calibration of polarimetric variables
- Attenuation by liquid
- Attenuation by gas
- Air density effects
- Error covariance matrix (Myagkov and Ori, 2021, under revision in AMTD)

Derived profiles of DSD can be used to derive expected profiles of C-band reflectivity

PROOF-OF-CONCEPT CAMPAIGN HOHENPEIßENBERG, GERMANY, SUMMER 2021

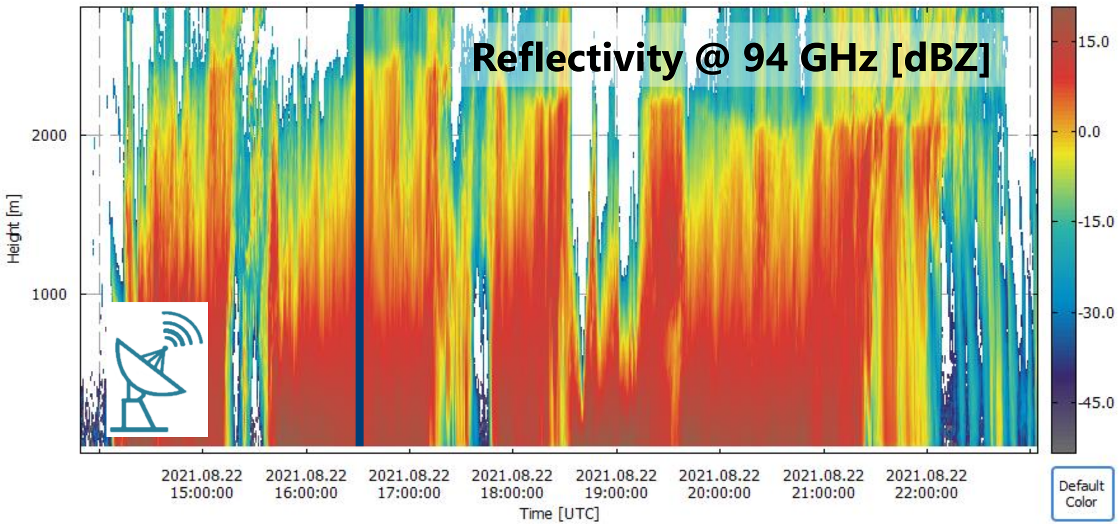


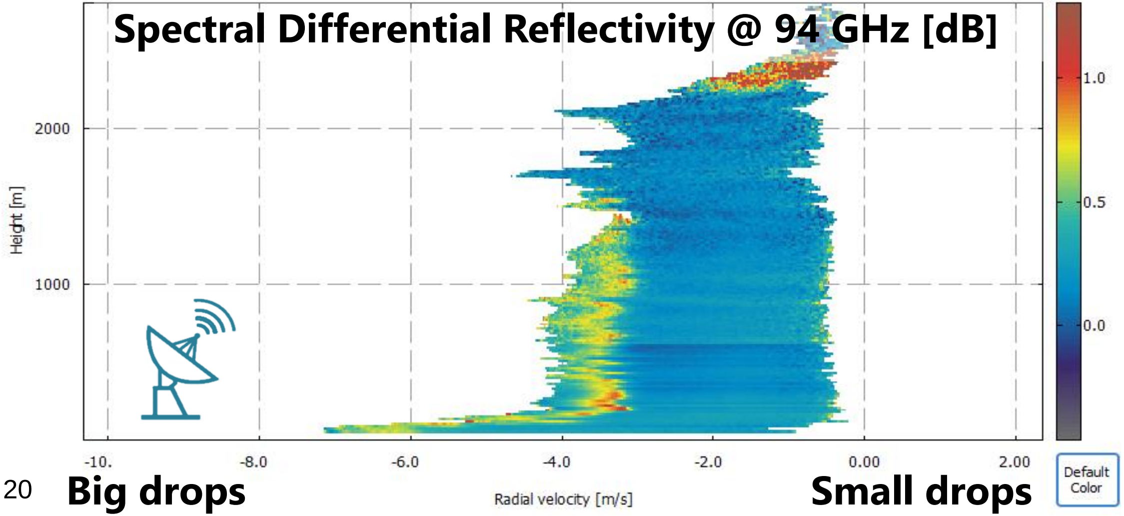
Cloud radar:

- Calibrated at RPG as described in Myagkov et al. 2020
- Rain mitigation system to keep cloud radar radomes dry
- Continuous observations at 30 deg elevation
- 5.5 s sampling, 30 m resolution
- Accurate leveling and pointing

Weather radar:

- Every hour the same direction for 5 min
- 25 m resolution, ~0.2 s sampling



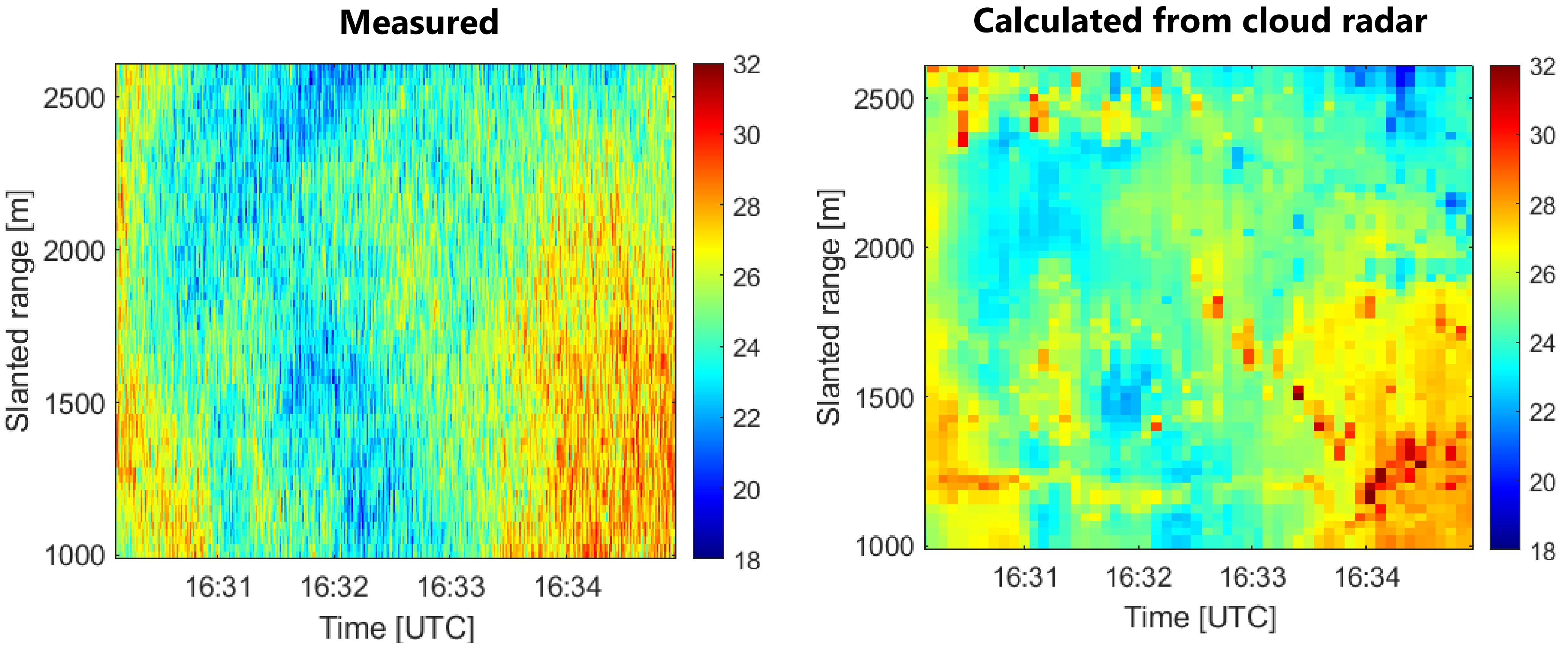


Big drops **Small drops**

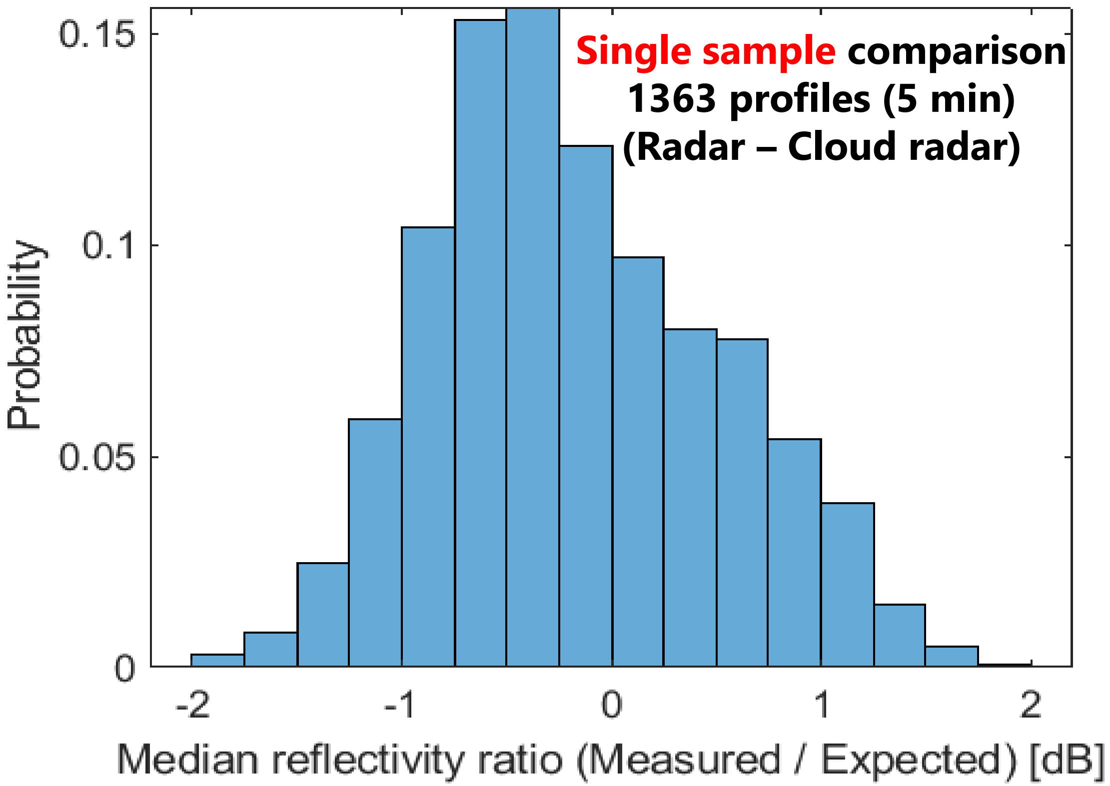
Case study 22 Aug 2021

- 30 deg elevation
- 16:30-16:35 C-band looked to the same direction
- Stratiform precipitation
- Low turbulence
- Rain rate 2-10 mm/h
- W-band Zh ~16-18 dBZ
- Melting layer at 2.3 km
- ZDR oscillation below 1.3 km

COMPARISON: PART 1



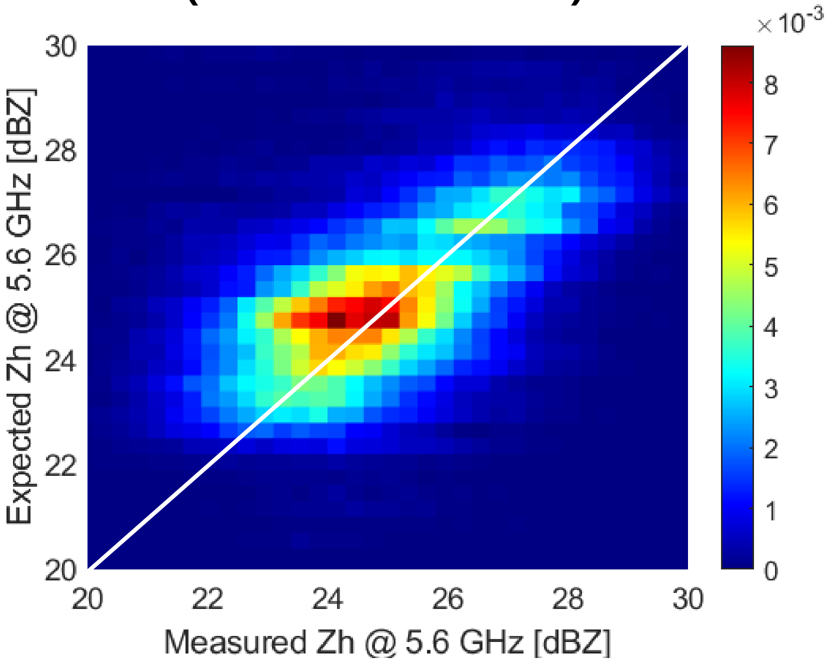
COMPARISON: PART 2



Percentile	Offset [dB]
5	-1.2
25	-0.7
50	-0.3
75	0.3
95	1.0

COMPARISON: PART 3

Single sample (~0.2 s) comparison
Total 5 min
(Radar – Cloud radar)



COMPARISON: PART 3

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Total 5 min
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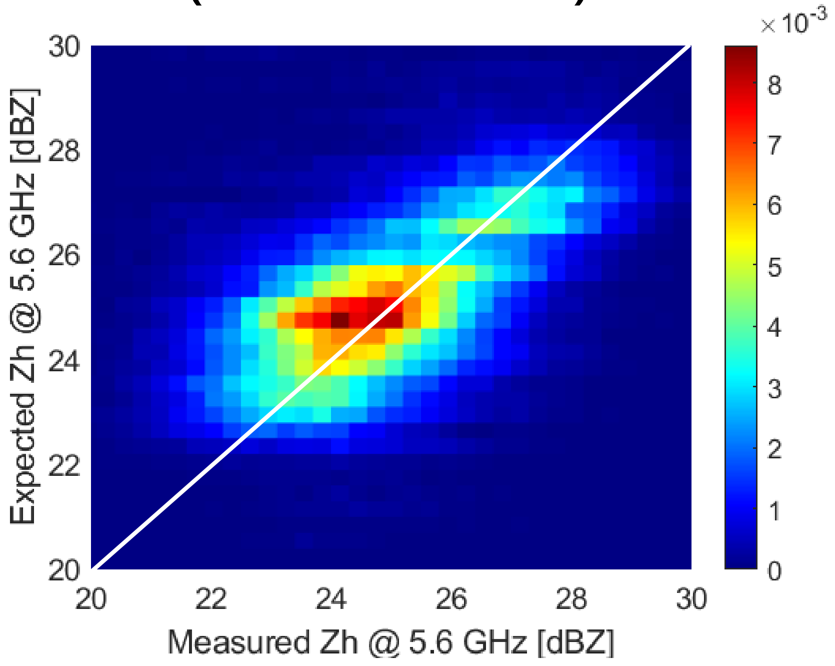
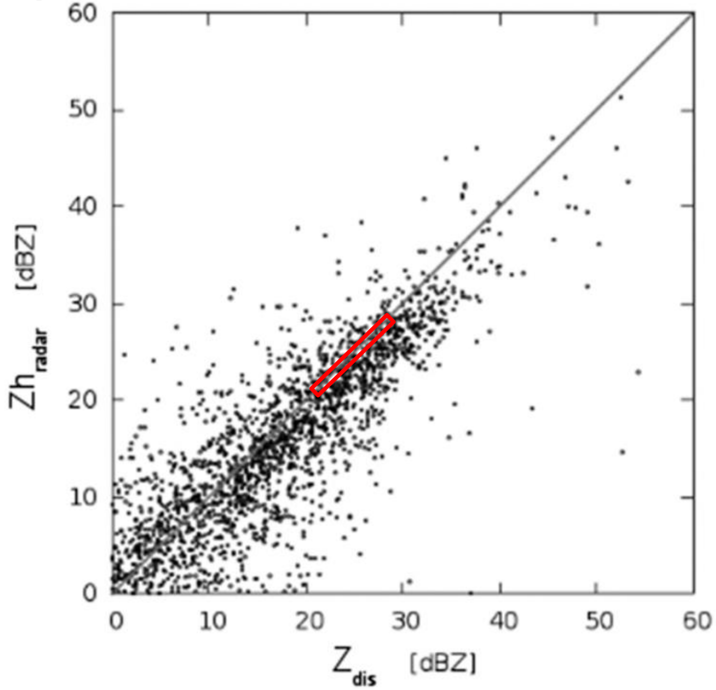


1-min averaged comparison
Total ~182 h (within 3 months)
(Radar – disdrometer, Frech et al, 2017)



SUMMARY AND OUTLOOK

- Novel approach to evaluate weather radar reflectivity using a cloud radar as an intermediate reference

- Applicable to a low number of samples at elevations from 20 to 45 deg

- Reachable accuracy within ±1 dB from a few radar samples

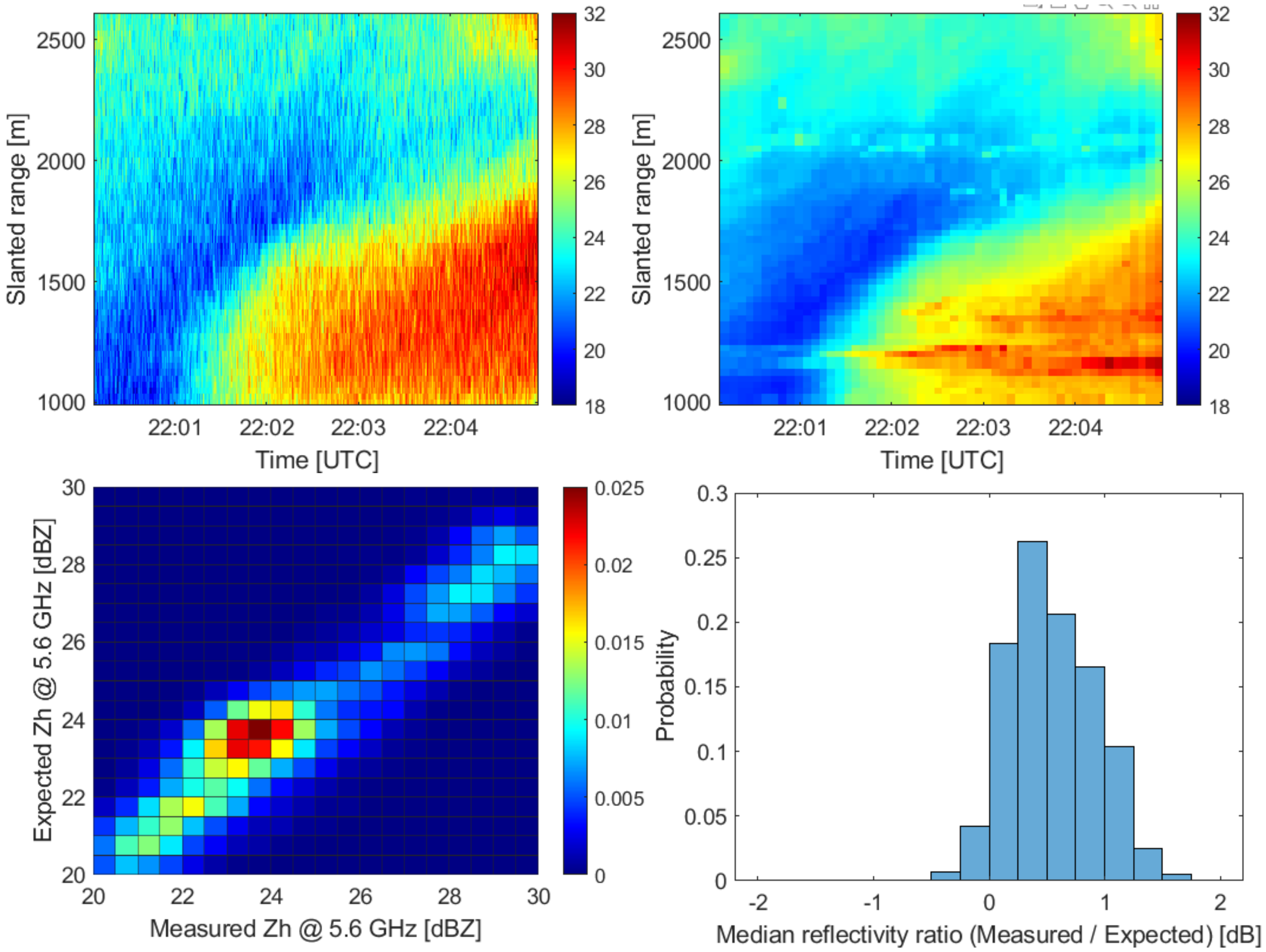
- More data to be analyzed

THANKS FOR YOUR ATTENTION

Contacts: alexander.myagkov@radiometer-physics.de

References:

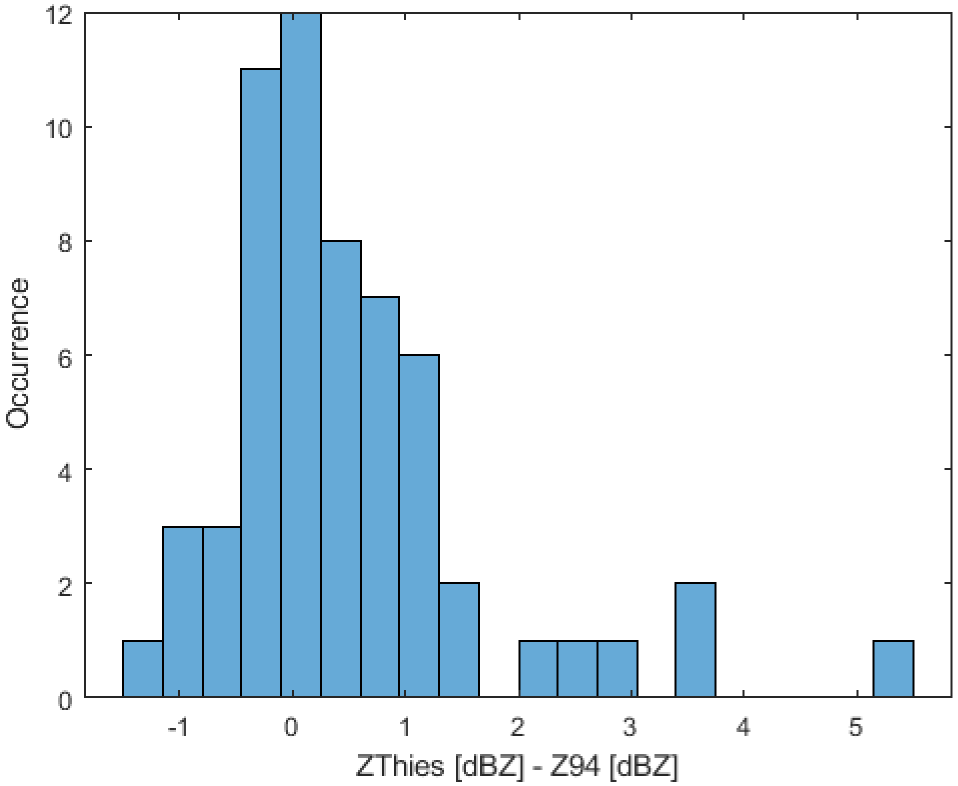
- Evaluation of the reflectivity calibration of W-band radars based on observations in rain, Myagkov et al, 2020, AMT
- Analytic characterization of random errors in spectral dual-polarized cloud radar observations, Myagkov and Ori, 2021, AMTD (under revision)
- Monitoring the Absolute Calibration of a Polarimetric Weather Radar, Frech et al, 2017, JTECH
- Dual-frequency radar Doppler spectral retrieval of rain drop size distributions and entangled dynamics variables, Tridon and Battaglia, 2015, JGR



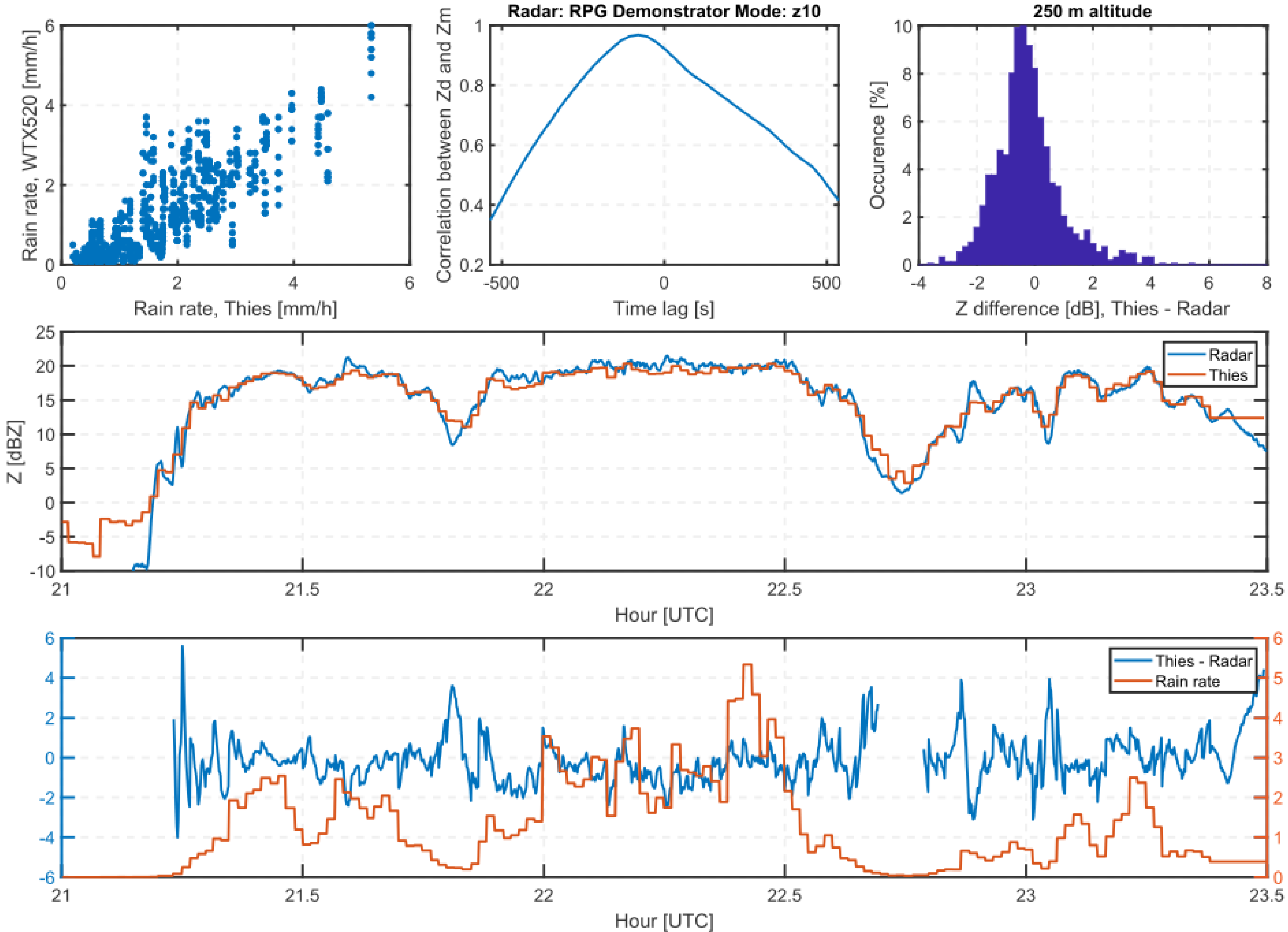
Slanted range [m]
2500
2000
1500
1000
22:01
22:02
22:03
22:04
Time [UTC]
32
30
28
26
24
22
20
18
Slanted range [m]
2500
2000
1500
1000
22:01
22:02
22:03
22:04
Time [UTC]
32
30
28
26
24
22
20
18
Expected Zh @ 5.6 GHz [dBZ]
30
28
26
24
22
20
20
22
24
26
28
30
Measured Zh @ 5.6 GHz [dBZ]
0.025
0.02
0.015
0.01
0.005
0
Probability
0.3
0.25
0.2
0.15
0.1
0.05
0
-2
-1
0
1
2
Median reflectivity ratio (Measured / Expected) [dB]

26 Sep 2021

CLOUD RADAR EVALUATION DURING THE CAMPAIGN

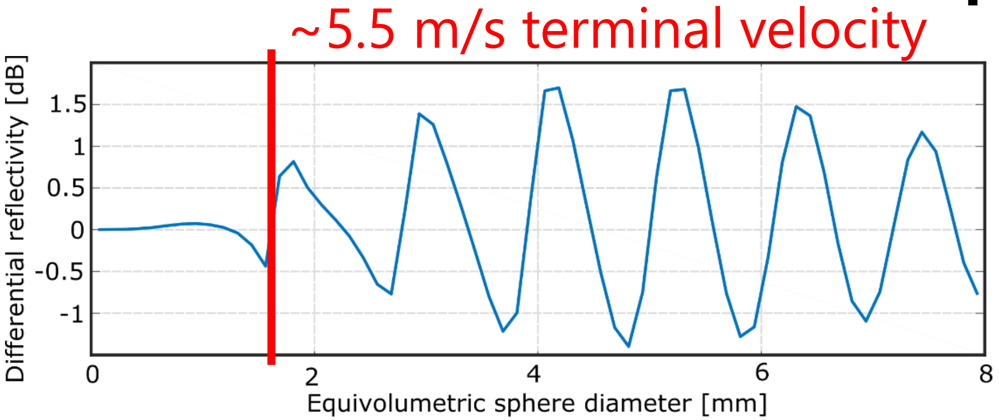


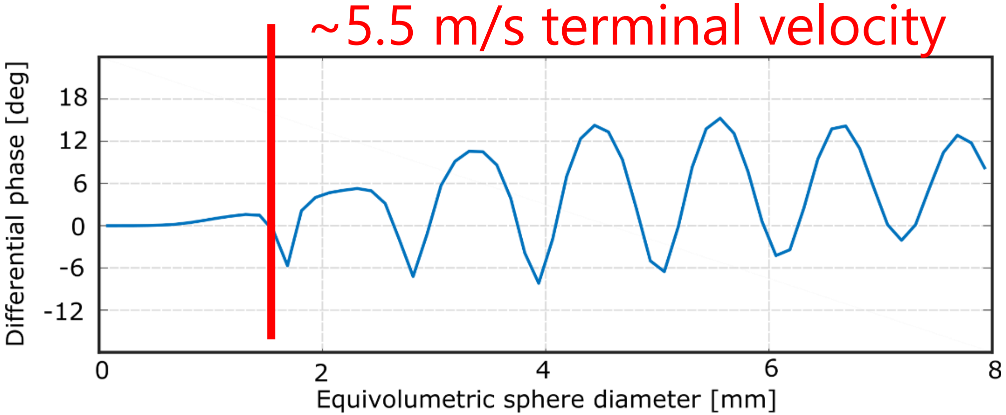
17.08.2021

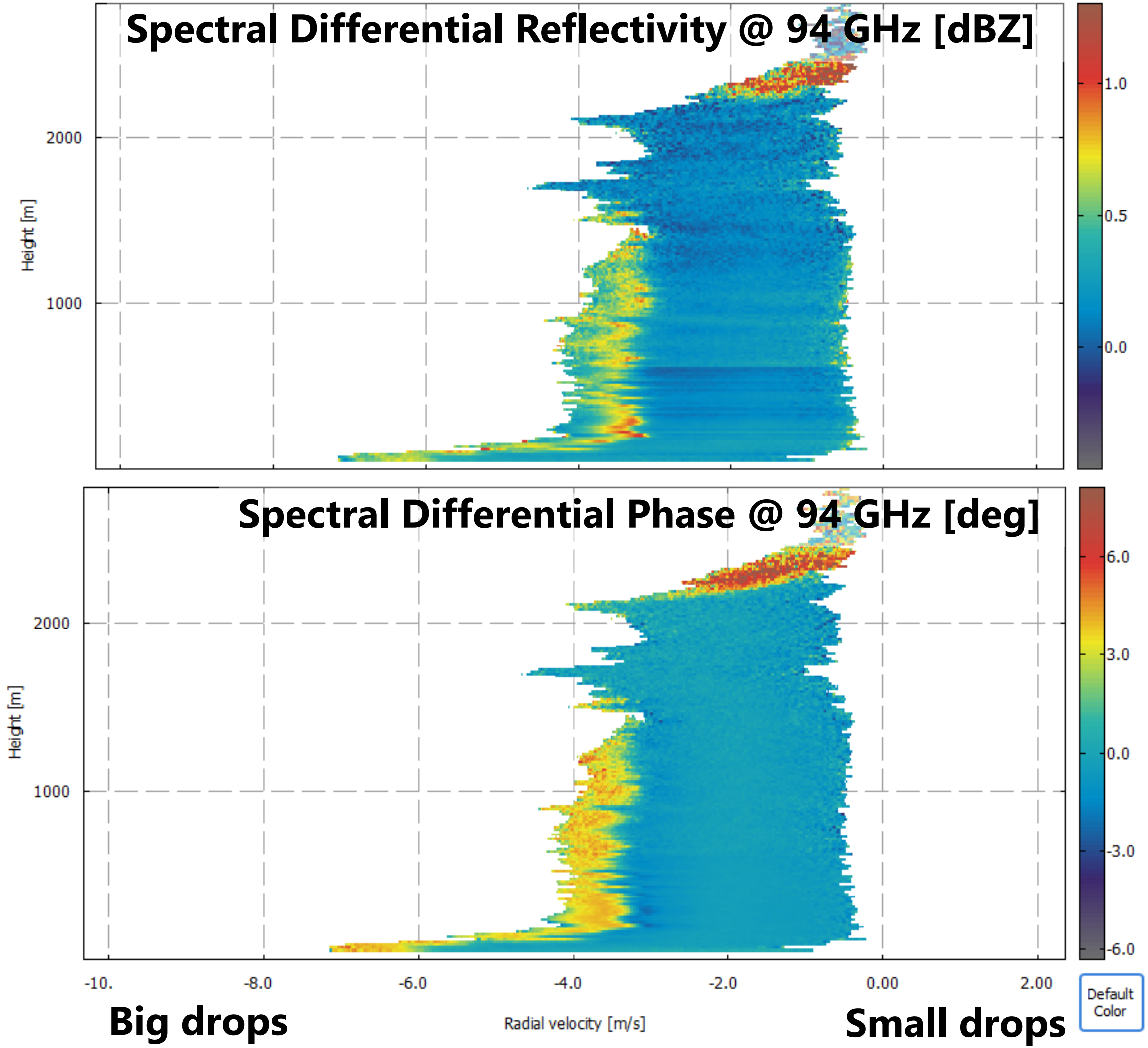


Radar: RPG Demonstrator Mode: z10
250 m altitude
Rain rate, WTX520 [mm/h]
Rain rate, Thies [mm/h]
Correlation between Zd and Zm
Time lag [s]
Occurence [%]
Z difference [dB], Thies - Radar
Z [dBZ]
Radar
Thies
Hour [UTC]
Thies - Radar
Rain rate
Hour [UTC]

Polarimetric oscillations for a water spheroid







Spectral Differential Reflectivity @ 94 GHz [dBZ]
Spectral Differential Phase @ 94 GHz [deg]
Height [m]
2000
1000
1.0
0.5
0.0
6.0
3.0
0.0
-3.0
-6.0
-10.
-8.0
-6.0
-4.0
-2.0
0.00
2.00
Radial velocity [m/s]
Big drops
Small drops
Default Color

DSD VARIATIONAL RETRIEVAL

$$\text{COST FUNCTION} = (\mathbf{y}-\mathbf{F}[\mathbf{x}])^{T}\, \mathbf{E}^{-1}\, (\mathbf{y}-\mathbf{F}[\mathbf{x}])$$

State vector **x**:

- Number of drops for each spectral bin
- Spectral shift due to air motions
- Spectral broadening due to turbulence

Observation vector **y**:

- Reflectivity spectrum H
- Reflectivity spectrum V
- Real covariance spectrum
- Imaginary covariance spectrum

Forward model **F**:

- Scattering model
- Size-shape-velocity relations
- Air motions and turbulence
- Signal-to-noise ratio

Observation error covariance matrix **E**:

- Calculated as shown in Myagkov and Ori, 2021