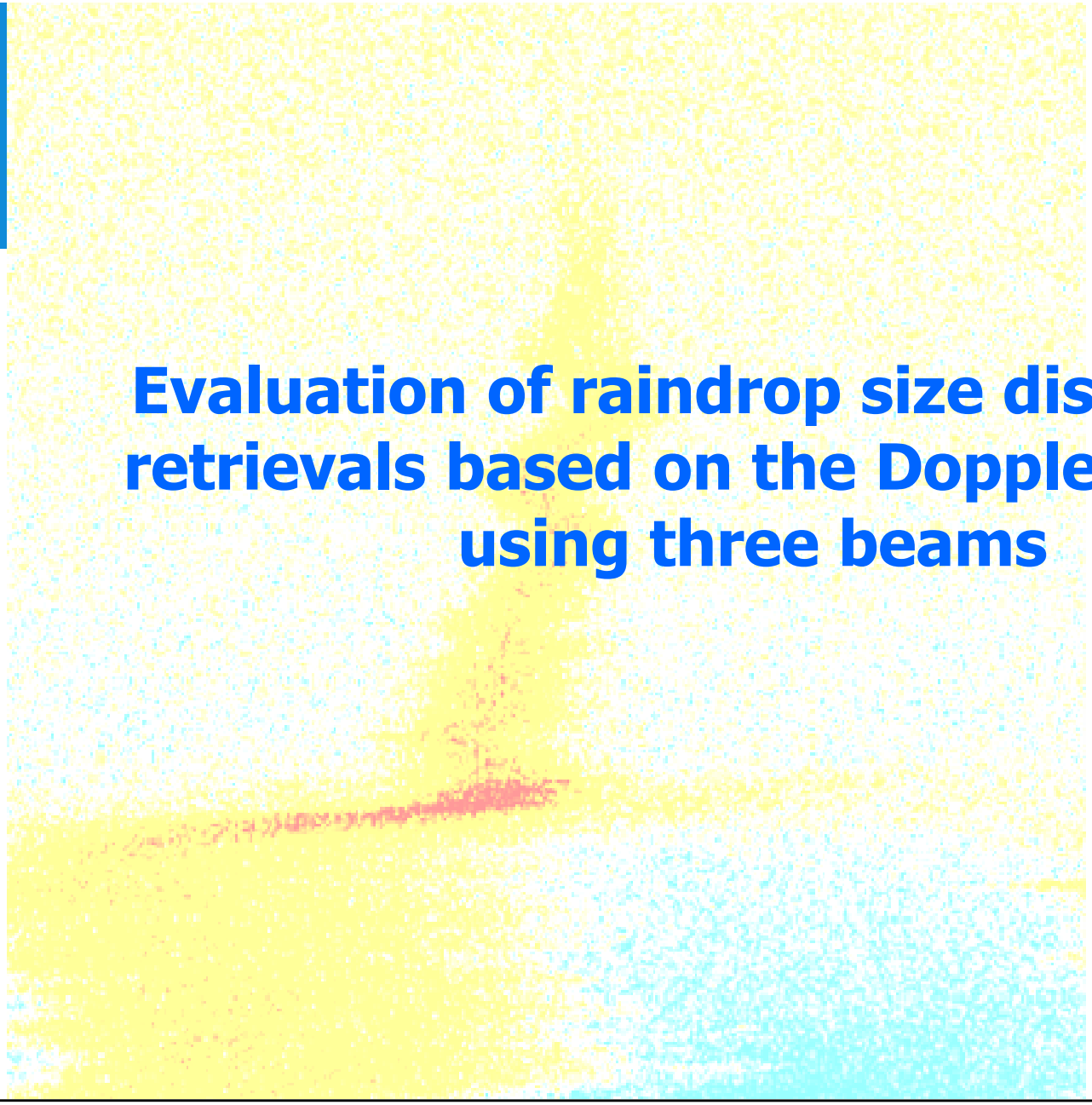
ATMOS

TU Delft

Delft University of Technology

Evaluation of raindrop size distribution retrievals based on the Doppler spectra using three beams



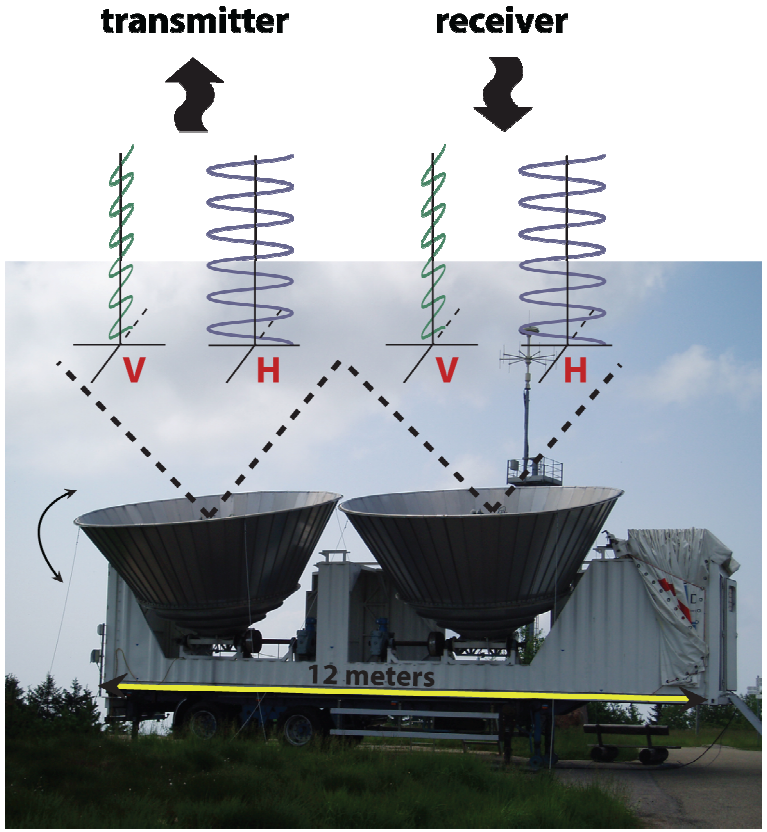
Christine Unal

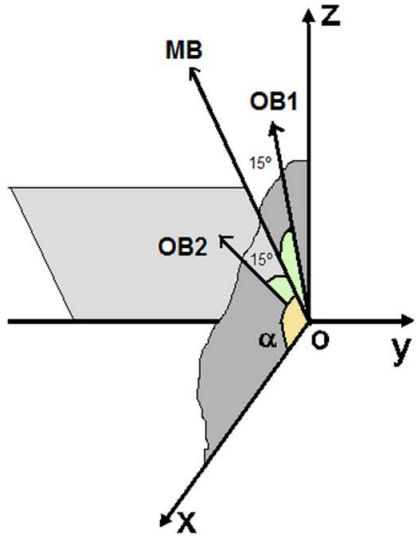
In this talk:

- Differential reflectivity Z_{dr} cannot be used (near-vertical profiling or light rain) → Doppler spectra
- first evaluation of rain Drop Size Distribution (DSD) comparing retrievals from the same radar resolution volume using two different polarizations
- second evaluation comparing DSD retrievals in different directions during stratiform light rain

→ **Influence of the radial wind on the DSD estimates**

FM-CW Doppler-polarimetric S-band TARA radar





wind measurement available

Doppler spectra model

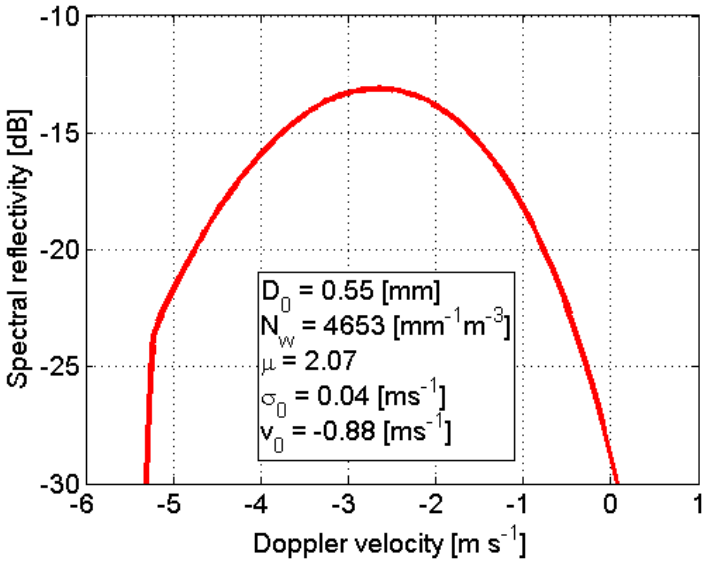
Based on

Moisseev, Chandrasekar, Unal and Russchenberg, 2006: Dual-polarization spectral analysis for retrieval of effective raindrop shapes

Input

- Drop Size Distribution (DSD) :
  - ❖ median volume diameter D_0
  - ❖ intercept parameter N_w
  - ❖ shape parameter μ
- Radial wind (v_0)
- Spectral broadening (σ_0)

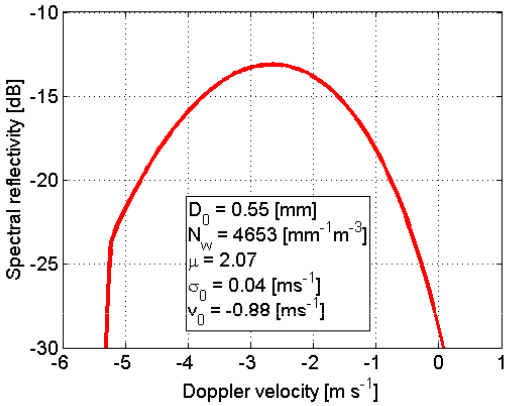
Output



Retrieval technique

Based on

Moisseev, Chandrasekar, Unal and Russchenberg, 2006: Dual-polarization spectral analysis for retrieval of effective raindrop shapes



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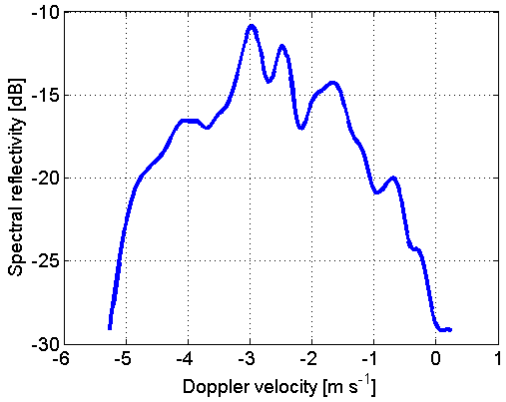

Non-linear optimization of D_0, μ, σ_0

+ estimation of N_w, v_0

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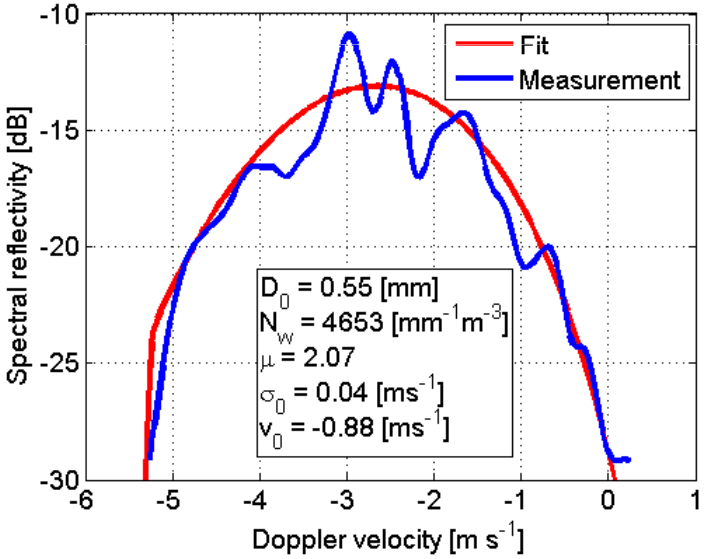


Sensitivity analysis

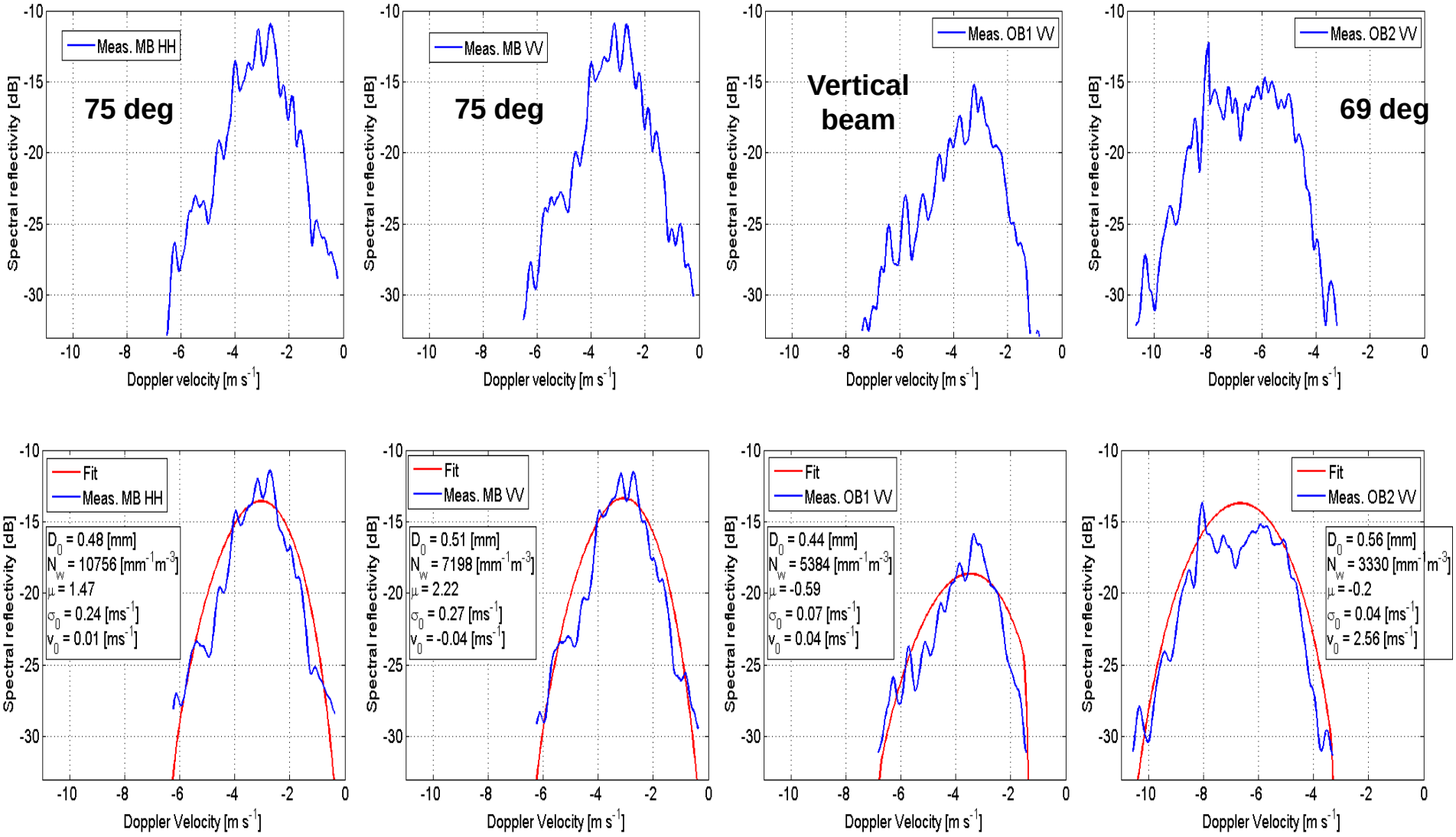
Simulation results on averaged Doppler spectra

(10-55 dBZ reflectivity, average:30)

Parameter	D_0	N_w	μ	σ_0	v_0
Region	0.2 – 3 mm	0 – 8000 $mm^{-1} m^{-3}$	-2 – 10	0.1 – 0.9 m s^{-1}	0 – 1.2 m s^{-1}
RMSD	0.12 mm	1350 $mm^{-1} m^{-3}$	0.67	0.04 m s^{-1}	0.18 m s^{-1}
CV(RMSD)	17%	54%		8.4%	28%

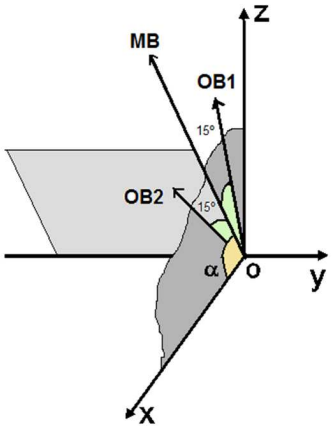
Parameter	Z	LWC	N_t
RMSD	0.30 dB	0.13 g m^{-3}	142 m^{-3}
CV(RMSD)	0.91%	22%	7.4%

Multi-beam retrieval example (non-averaged Doppler spectra)

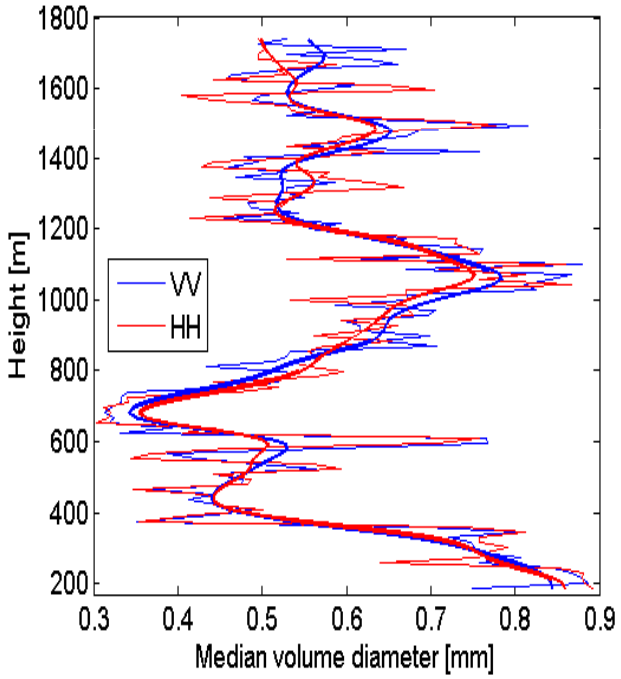


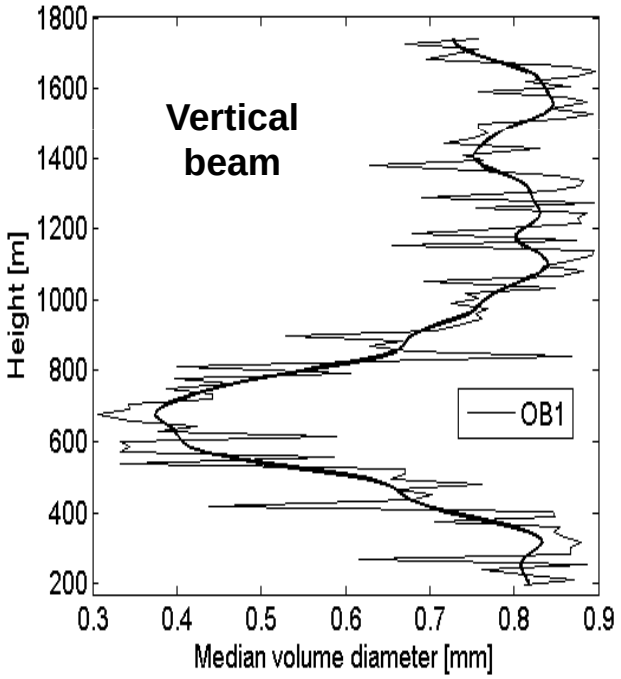
Multi-beam retrieval profile example

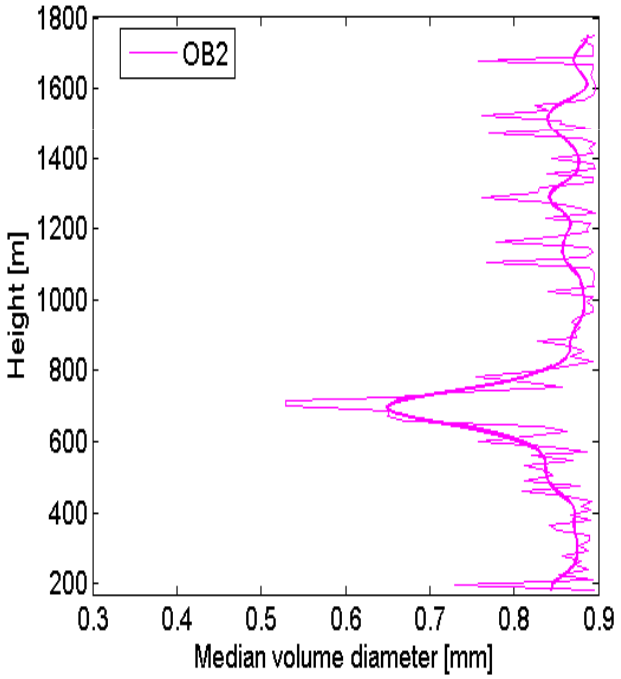
Median volume diameter D_0 profile in 3 different looking directions



Retrieval procedure + height-smoothing

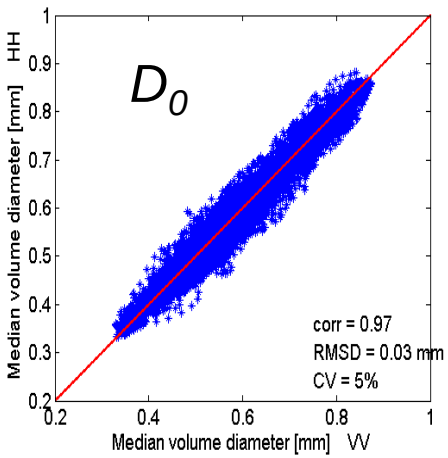


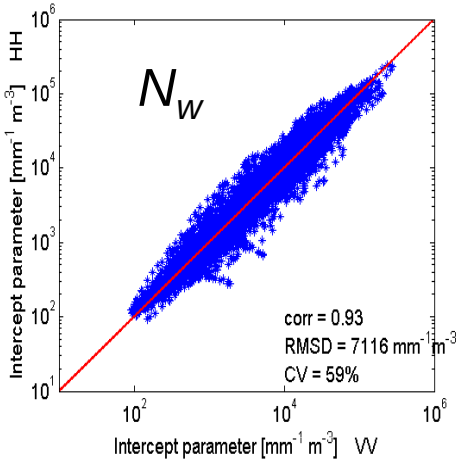


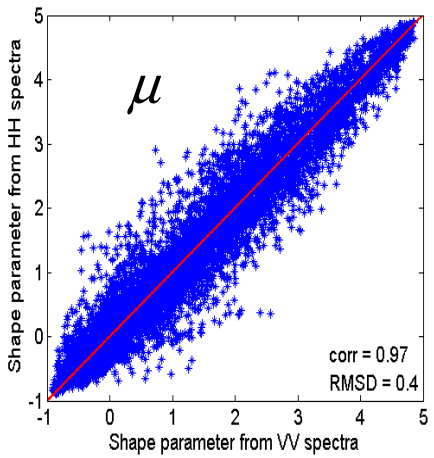


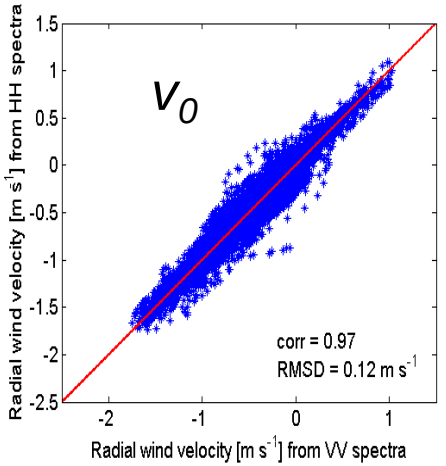
Retrievals comparison (light rain)

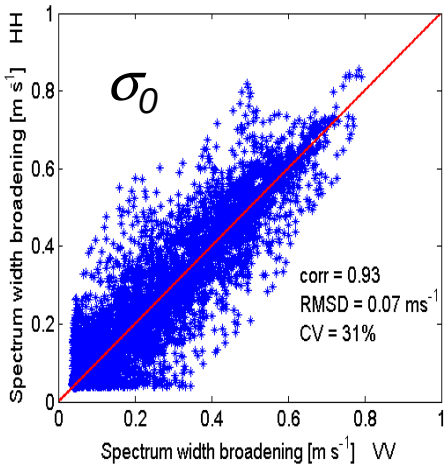
HH and VV non averaged Doppler spectra

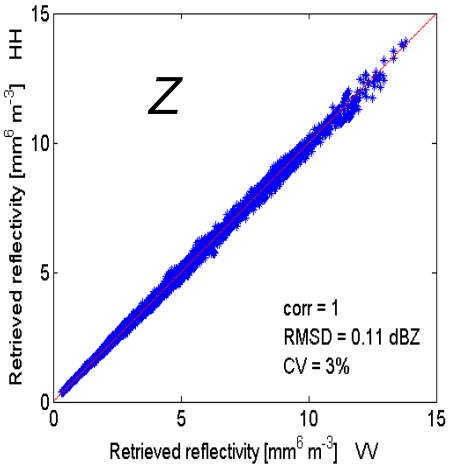


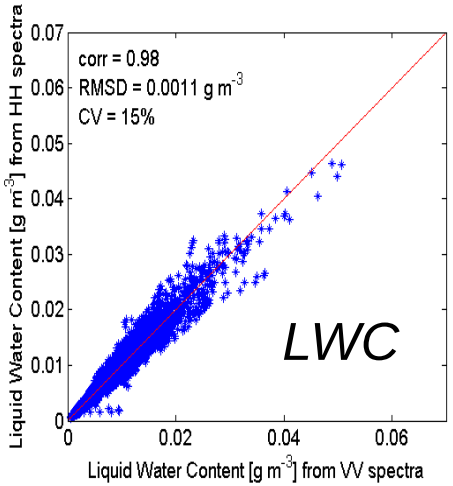


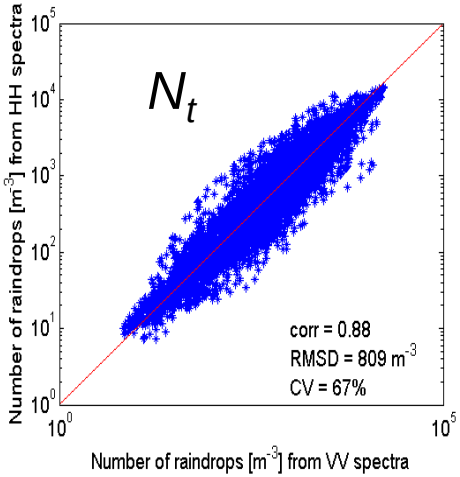






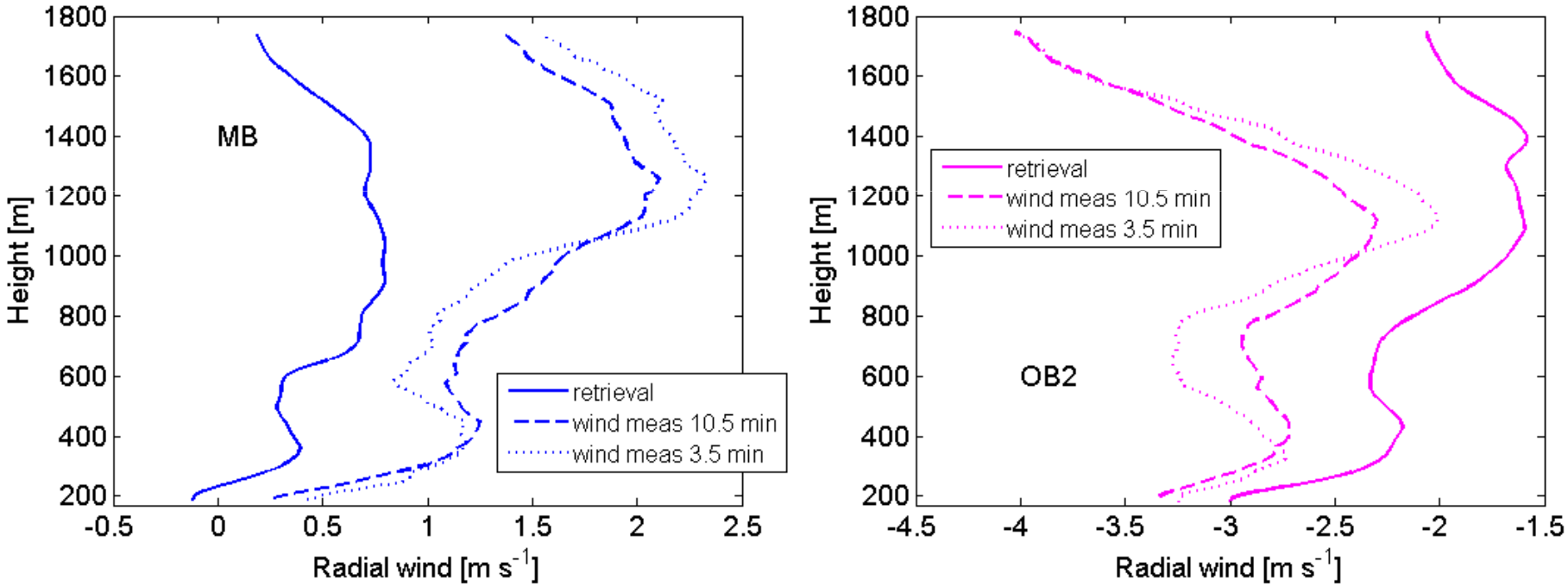




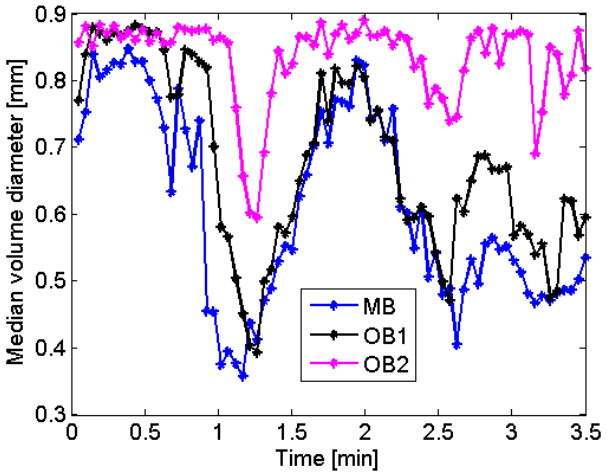


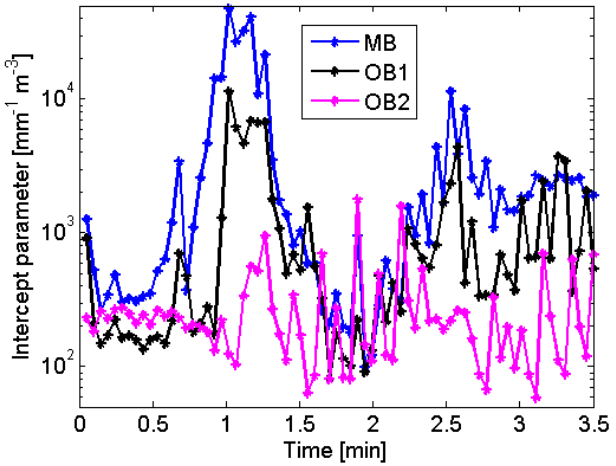
Dynamical retrieval v_0

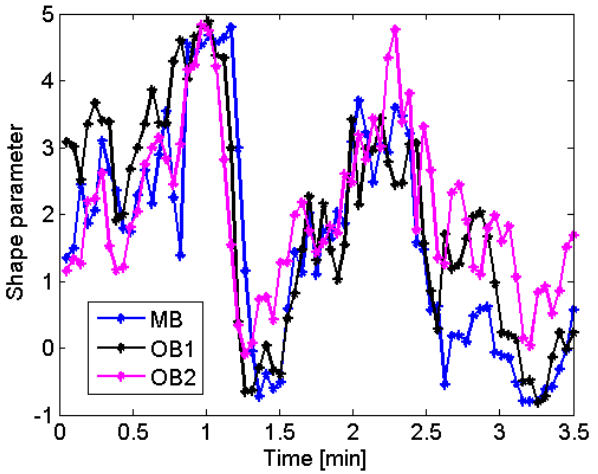
Comparison between retrieval of radial wind ($-v_0$) and radial component of mean horizontal wind measured by TARA



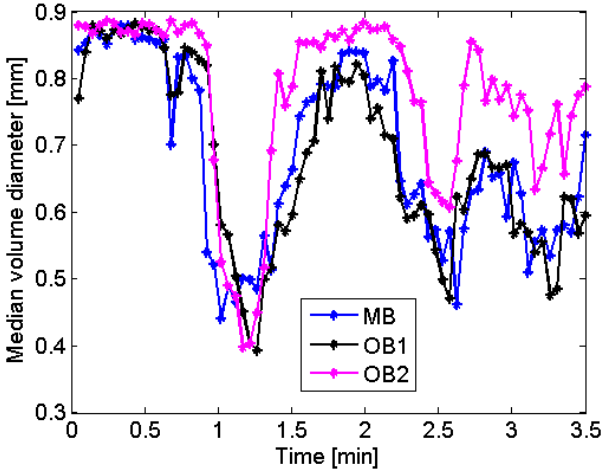
Influence of the error on v_0 on the DSD retrieval

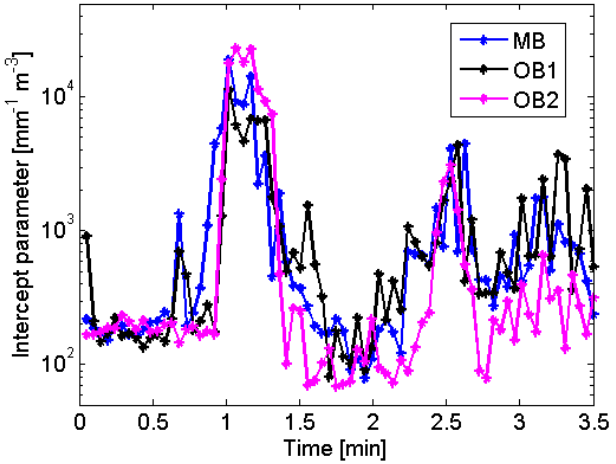


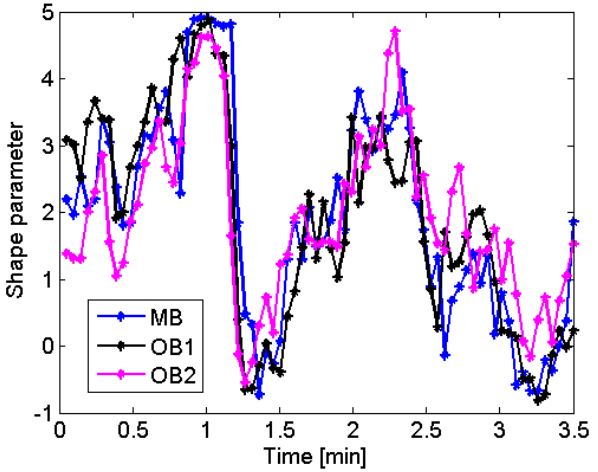




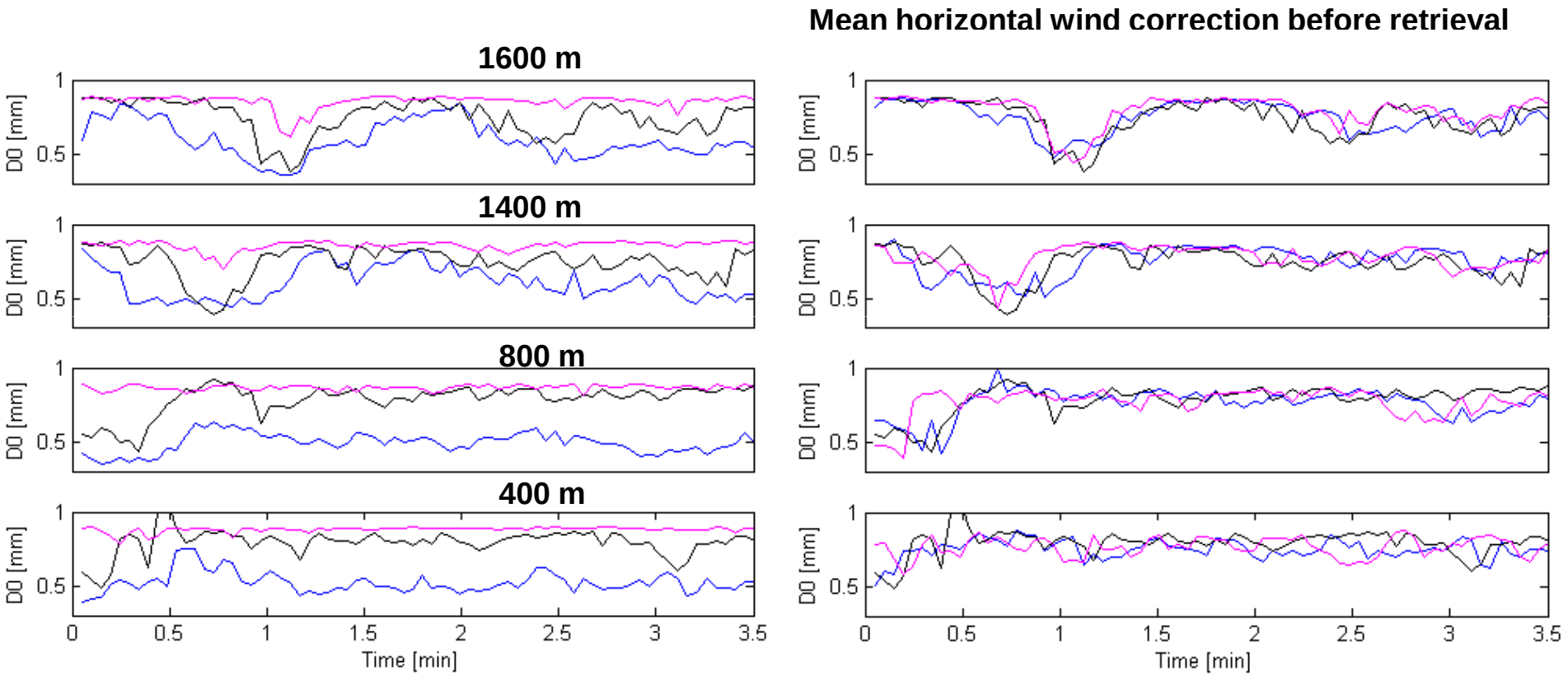
Doppler spectra are shifted using TARA mean horizontal wind measurement before retrieval







Influence of the error on v_0 on the median volume diameter (D_0)



Conclusions

- development of an automatic rain retrieval technique based on the complete Doppler spectrum (from drizzle to heavy rain)
- a tool for study cases
- consistency of the retrievals (D_0, μ, v_0, σ_0, LWC) representing the same radar resolution volume
- when Z_{dr} is too small (light precipitation, near-vertical profiling), it looks necessary to input the radial component of the mean horizontal wind to reduce the errors on (D_0, N_w, μ)
- adding two other looking directions (beams) to estimate the contribution of the radial wind may solve this problem

Moisseev, Chandrasekar, Unal and Russchenberg, 2006: Dual-polarization spectral analysis for retrieval of effective raindrop shapes

Simulation of the rain Doppler spectra (S-band, Rayleigh scattering)

Axial distributions (**Mardia** 1972, Bringi and Chandrasekar, 2001)

Canting angle and orientation due to wind and turbulence

Particle size distribution N(D)

Modified gamma distribution (Bringi and Chandrasekar, 2001)

Equivolumetric diameter D dependency.

Density 1 g cm^{-3}

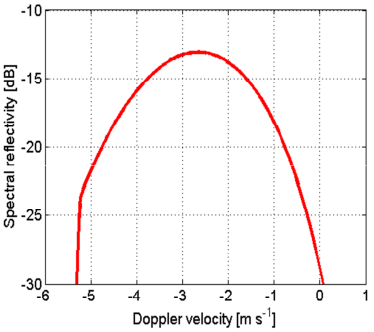
Relative permittivity ε_r=81

Radar Cross-section

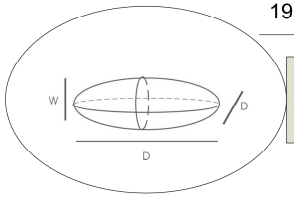
$$sZ_{IIII}(v) = N\left(D\{v\}\right)\sigma_{IIII}\left(D\{v\}\right)\left|\frac{dD}{dv}\right|dv$$

$$sZ_{HH,\mathrm{mod}}(v) = \frac{1}{\sqrt{2\pi\sigma_0}}\int \exp\left[-\frac{(v-\tilde{v})^2}{2\sigma_0^2}\right]\cdot sZ_{HH}(\tilde{v})\,d\tilde{v}$$

$$\sigma_{HH} = \frac{\pi^5}{9\lambda^4}\left|\varepsilon_r - 1\right|^2 D_e{}^6 q_{HH}$$



Oblate spheroids
1.1<D≤4.4 mm (Andsager, 1999)
D≤1.1 and D>4.4 mm (Beard and Chuang, 1987)

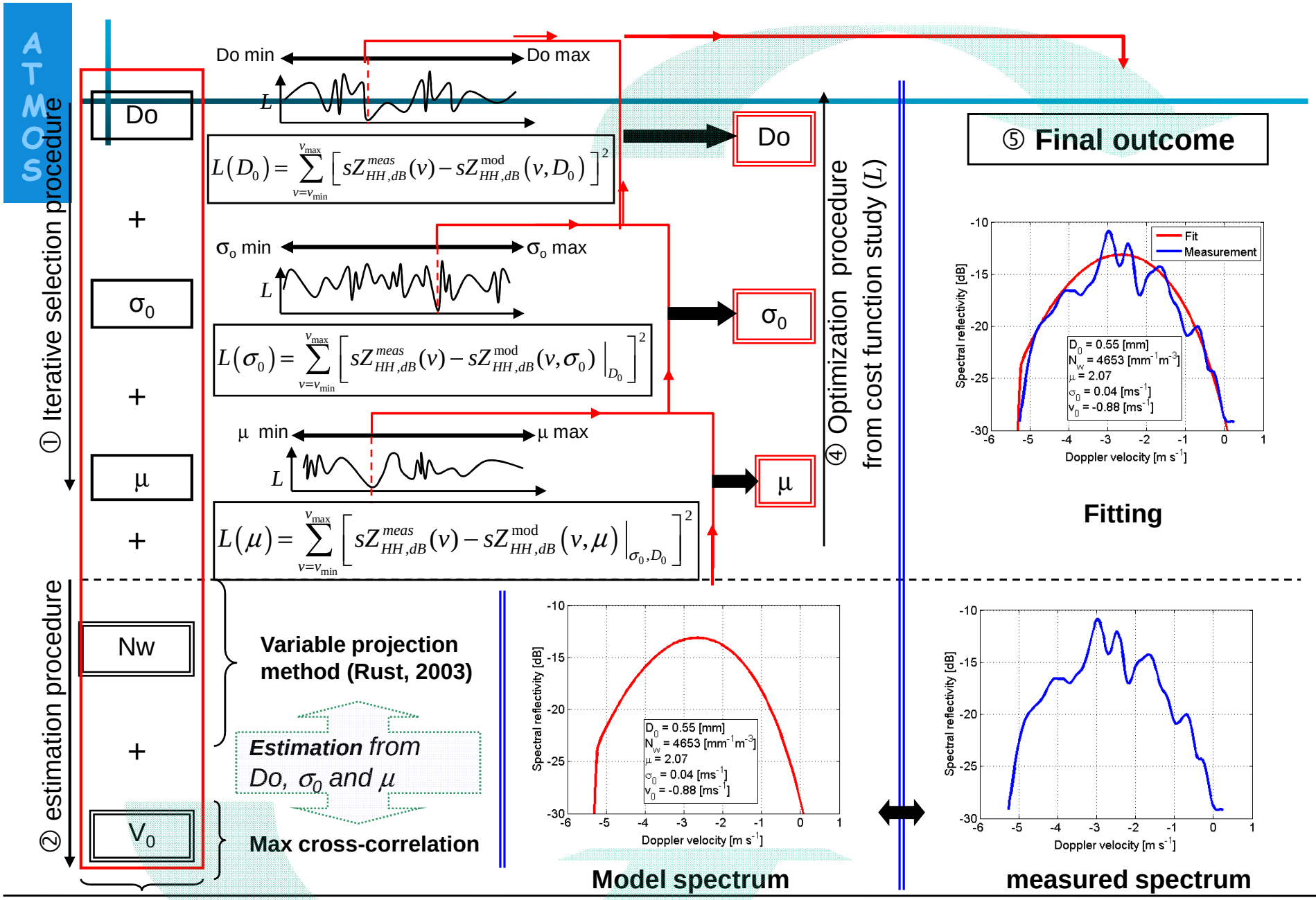


Shape of the raindrops

Relation radial velocity – diameter of the raindrop

$$v(D) = \left(\frac{\rho_0}{\rho}\right)^{0.4}\left[9.65 - 10.3\exp(-0.6D)\right]\sin\alpha$$

Model Input
Particle type: rain
+
Particle Size Distribution parameters (N_w, D_0 and μ)
+
Ambiant wind v_0 and spectral broadening width σ_0


ATMOS
① Iterative selection procedure
② estimation procedure
Do
σ0
μ
Nw
V0
+
Do min
Do max
L
$L(D_0) = \sum_{v=v_{min}}^{v_{max}} \left[sZ^{meas}_{HH,dB}(v) - sZ^{mod}_{HH,dB}(v, D_0) \right]^2$
σo min
σo max
$L(\sigma_0) = \sum_{v=v_{min}}^{v_{max}} \left[sZ^{meas}_{HH,dB}(v) - sZ^{mod}_{HH,dB}(v, \sigma_0) \Big|_{D_0} \right]^2$
μ min
μ max
$L(\mu) = \sum_{v=v_{min}}^{v_{max}} \left[sZ^{meas}_{HH,dB}(v) - sZ^{mod}_{HH,dB}(v, \mu) \Big|_{\sigma_0, D_0} \right]^2$
Variable projection method (Rust, 2003)
Estimation from Do, σ0 and μ
Max cross-correlation
③ Output of the model
④ Optimization procedure from cost function study (L)
⑤ Final outcome
Fit
Measurement
D0 = 0.55 [mm]
Nw = 4653 [mm-1m-3]
μ = 2.07
σ0 = 0.04 [ms-1]
v0 = -0.88 [ms-1]
Spectral reflectivity [dB]
Doppler velocity [m s-1]
Fitting
Model spectrum
measured spectrum
Error calculation
Non linear least-square algorithm
Remote sensing of the environment (RSE)
TU Delft
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15

Retrieval outputs: dsd, v_0 and σ_0

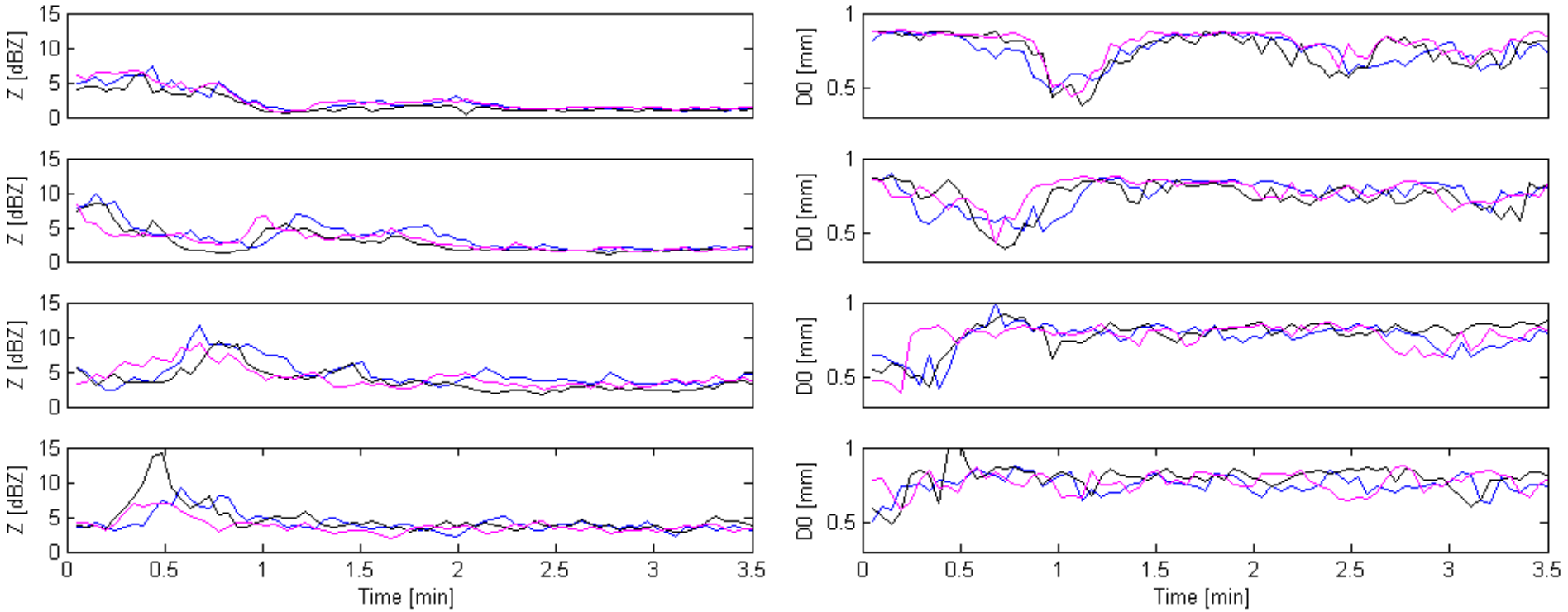
- median volume diameter D_0
- μ bounded [-1 5]
- spectral broadening σ_0 bounded [0 1] m s^{-1}
- intercept parameter N_w free
- radial wind v_0 free

→ crucial to get the actual D_0

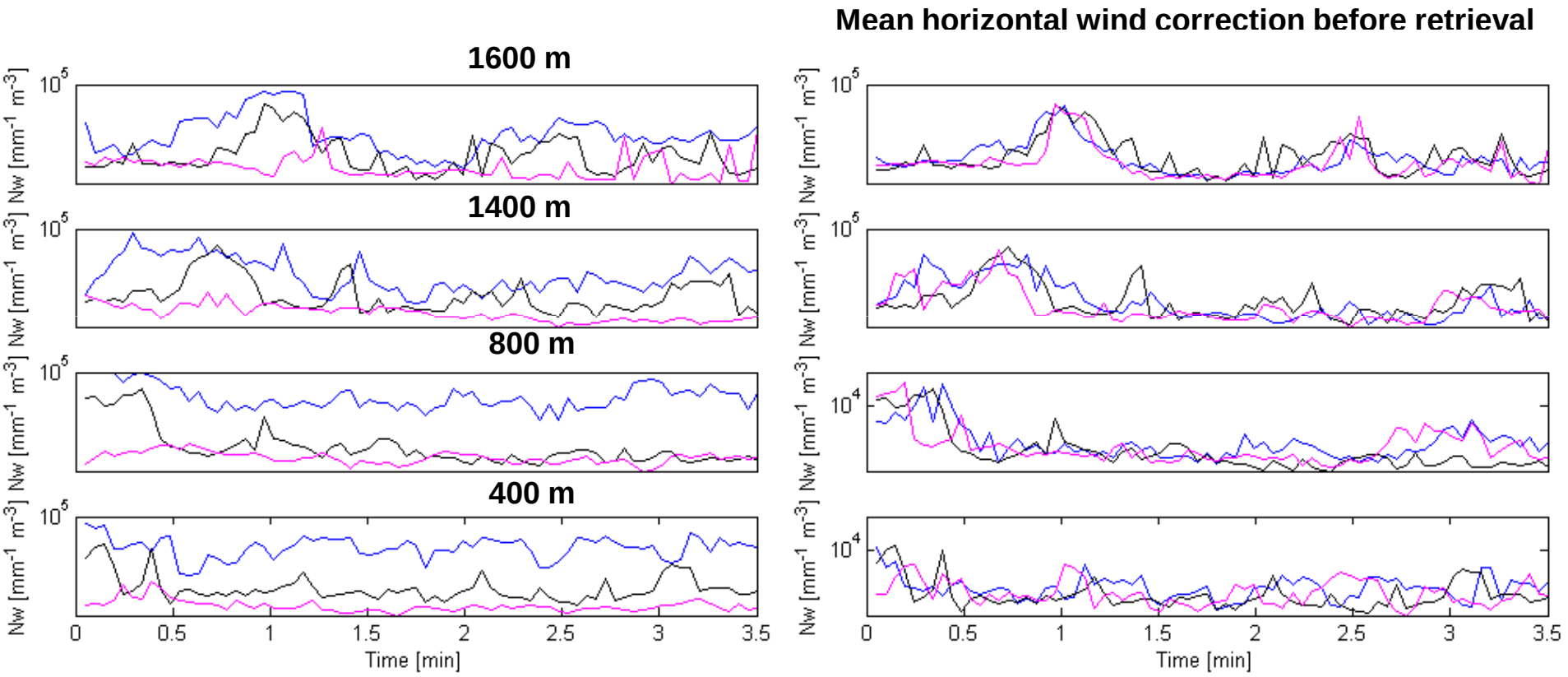
help → Polarimetry with Z_{dr}
help → Wind estimates with v_0
help → Reflectivity

Multi-beam raindrop size comparison (Z-D_0)

Mean horizontal wind correction before retrieval



Multi-beam raindrop size comparison (N_w)



Multi-beam raindrop size comparison (μ)

Mean horizontal wind correction before retrieval