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Dynamics retrievals in rain from Ka-W dual-wavelength Doppler spectra

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Outline

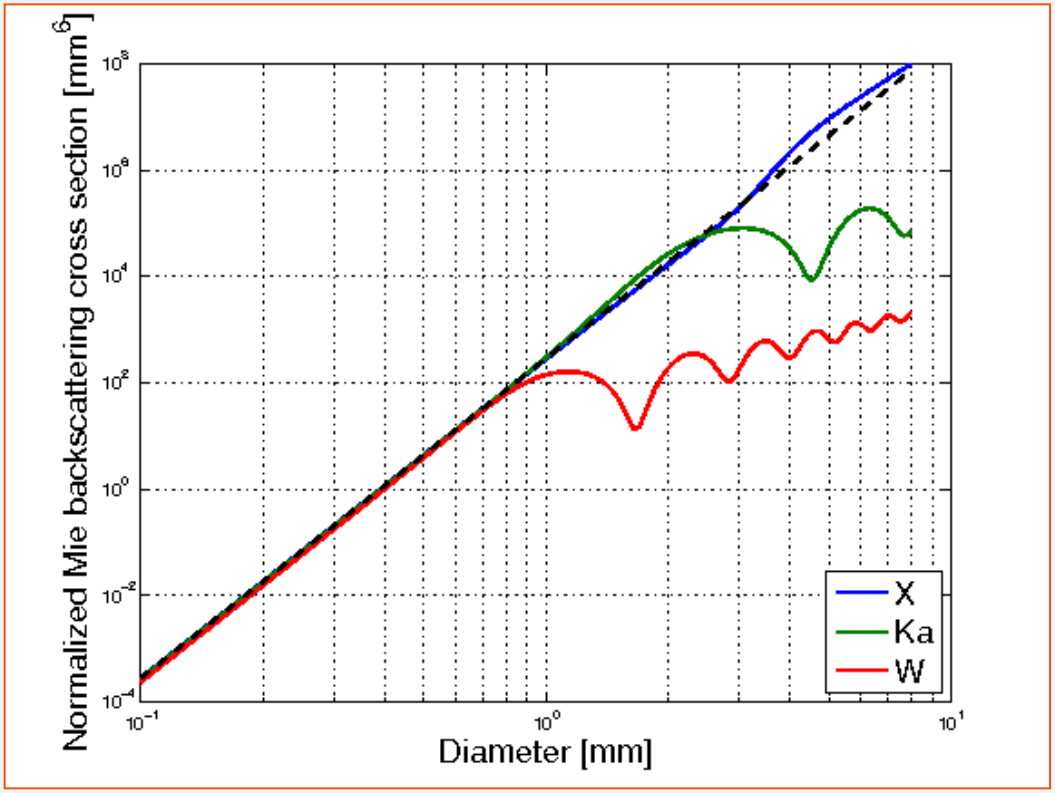
- Why multi-wavelength radar techniques? Why Doppler spectra?
- Retrieval of vertical velocity **in rain** from dual-wavelength Doppler spectra
- Retrieval of turbulence and rain drop size distribution

Work in progress

Multi-wavelength radar techniques

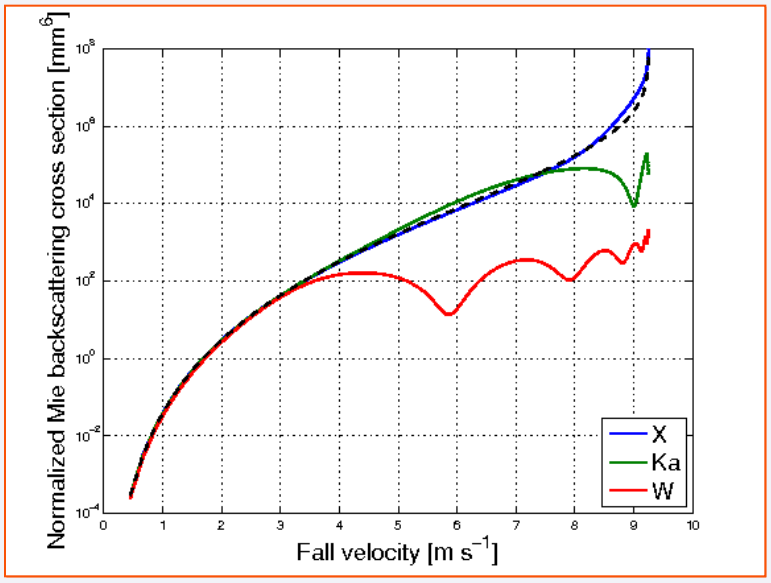
- Wavelength dependence of scattering and attenuation properties
  - Example: X-, K_a- and W-bands for liquid phase
  - Rayleigh approx.: $\sigma_b = \frac{\pi^5}{\lambda^4} D^6 |K_W|^2$

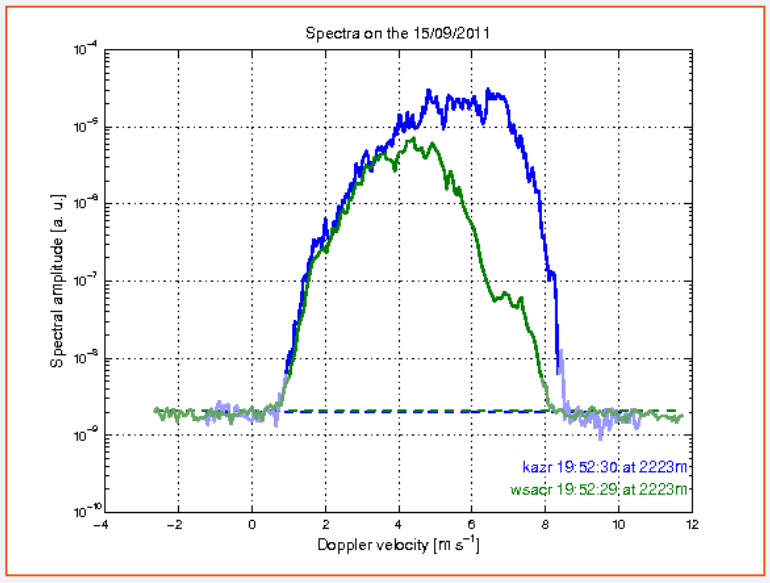
Band	f [GHz]	λ [mm]
X	10	30
K_a	35	8.6
W	94	3.2



Vertical velocity retrievals in rain with W-band radars

- Doppler spectra: reflectivity per Doppler velocity bin
- Fall velocity – diameter relation for rain drops: $V_t=f(D)$ (Atlas et al., 1973)
- Take advantage of the Mie resonance signatures in Doppler spectra of rain drops (Kollias et al., 2002, Giangrande et al., 2012)
  - Detection of the Mie notch at D = 1.65 mm, i.e. V_{fall} ~= 5.8 m s^{-1}
- Limits of application:
  - Minimum raindrop size threshold (~1.8 mm)
  - Very pronounced drop modes → possible confusion with Mie resonance

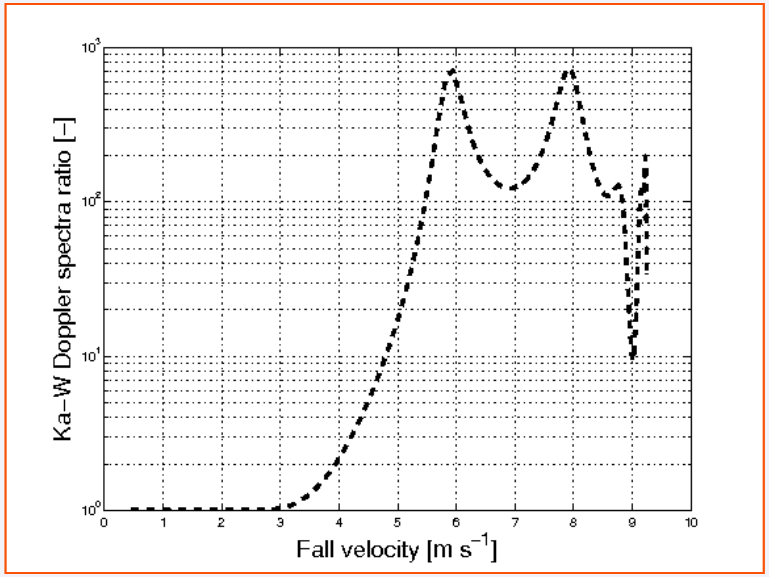


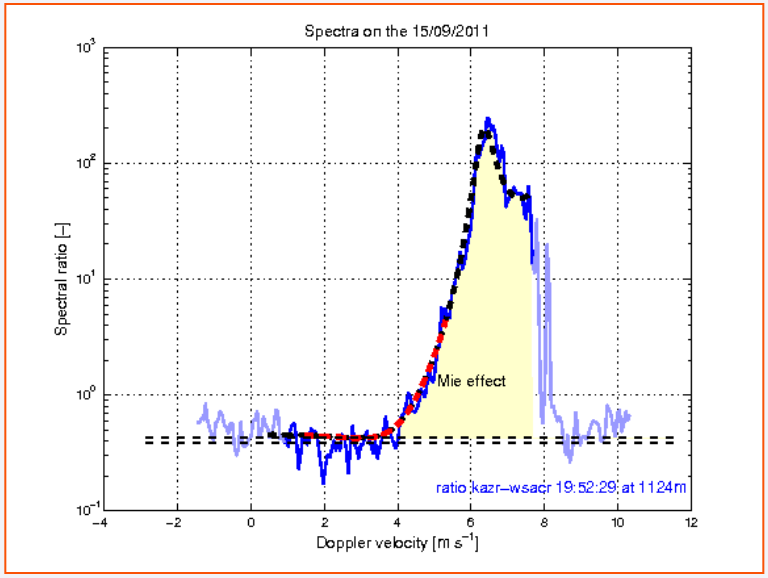


Dual-wavelength: the Doppler Spectra Ratio (DSR)

$$S_\lambda(v) = N(D)\sigma_\lambda(D)\frac{dD}{dv}$$

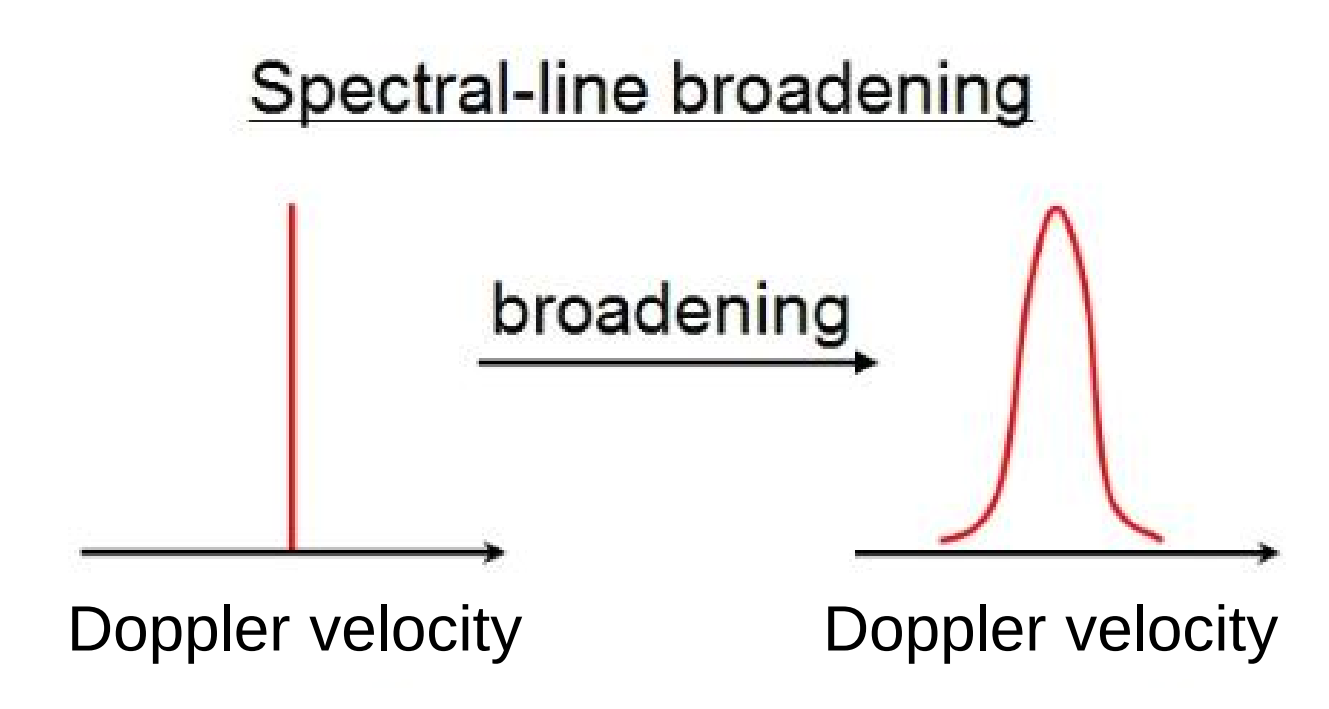
- The DSR is almost independent of the Drop Size Distribution (DSD)
- With the DSR, the Mie effects are obvious for drop diameter smaller than the first Mie notch → extension of the retrievals to lower rainfall rates (need drops of only around 1.2 mm)





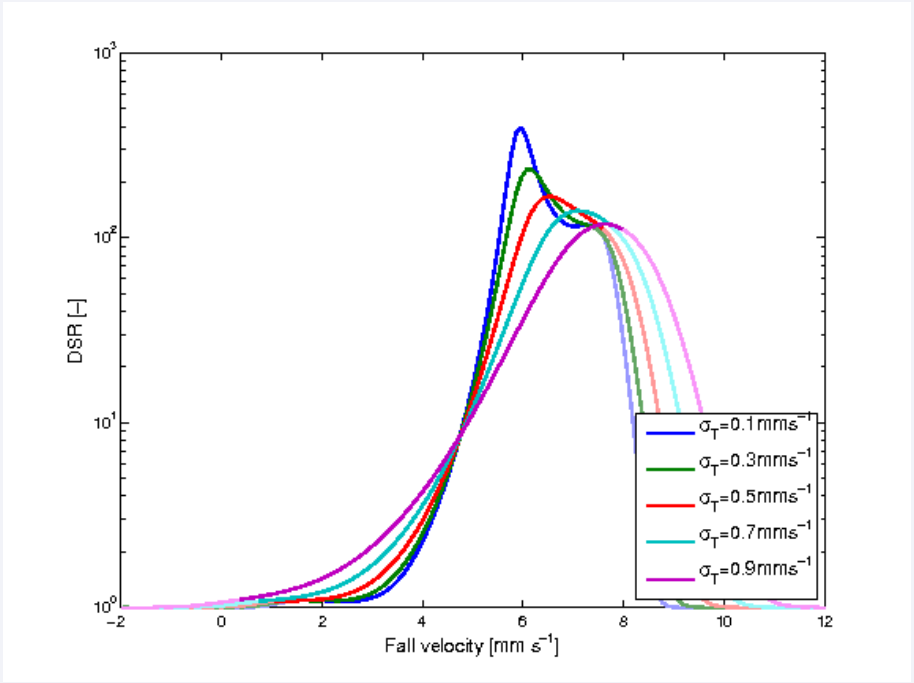
Doppler spectra widening due to turbulence

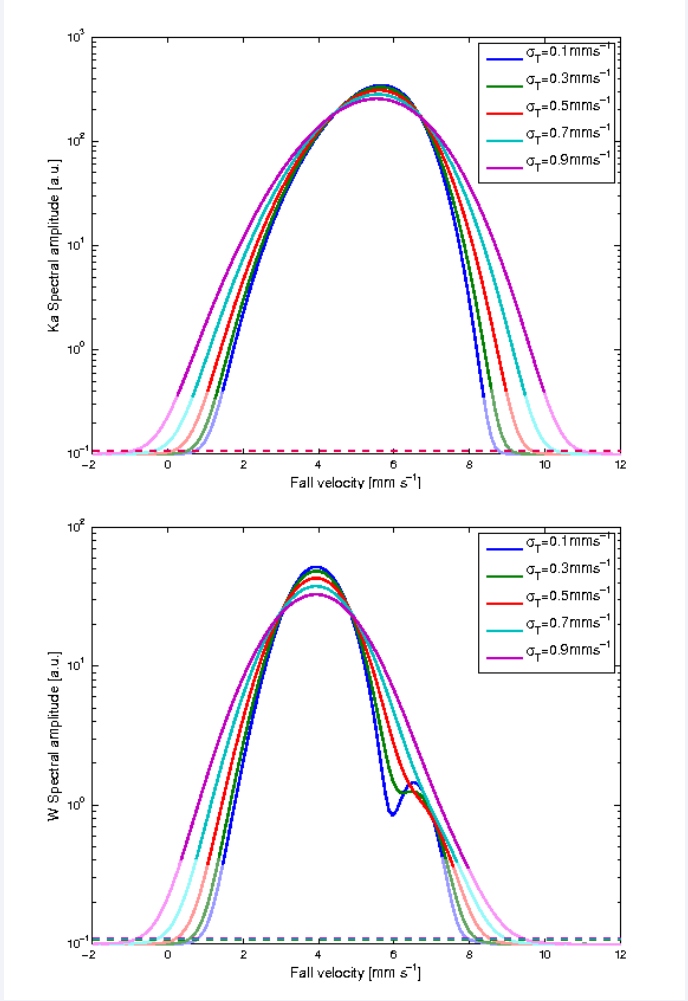
- By random movement of the hydrometeors, turbulence is known to broaden the Doppler spectra (simulated using a to a convolution with a Gaussian shaped spectrum of width σ_T)



Doppler spectra widening due to turbulence

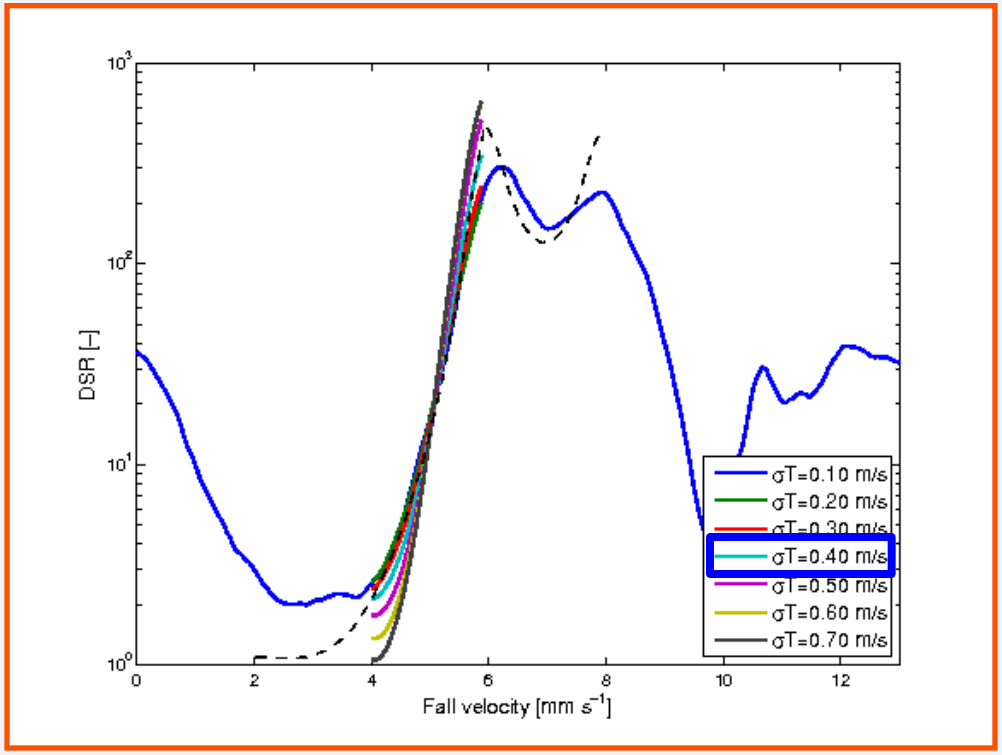
- The broadening effect depends on the spectrum shape and on the DSD
- The DSR shape depends slightly on the turbulence and DSD
  - Additional difficulty to retrieve the vertical wind
  - Possibility of retrieving the turbulence





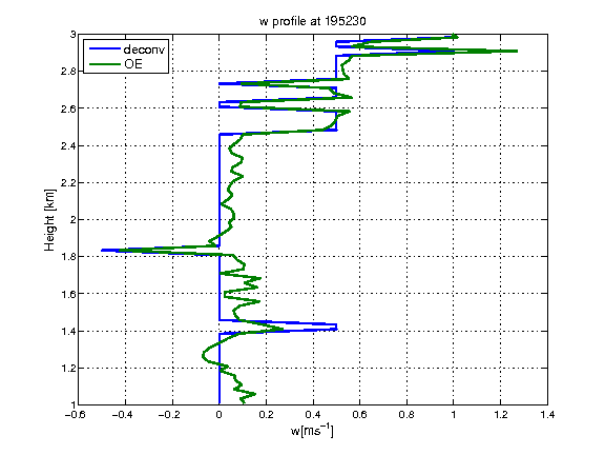
Turbulence de-convolution

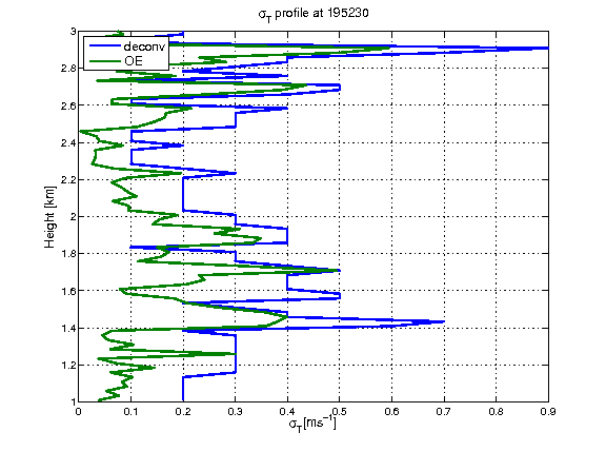
- Iterative de-convolution (Lucy, 1974) of the DSD with a set of possible turbulence intensities
  - Retrieval of the turbulence spectrum width σ_T → eddy dissipation rate ε
  - Direct correspondence between Doppler spectra and DSD → Estimate of the bin DSD
- Tricky process → Simulations have shown that the de-convolution technique generally overestimates the retrieval of σ_T

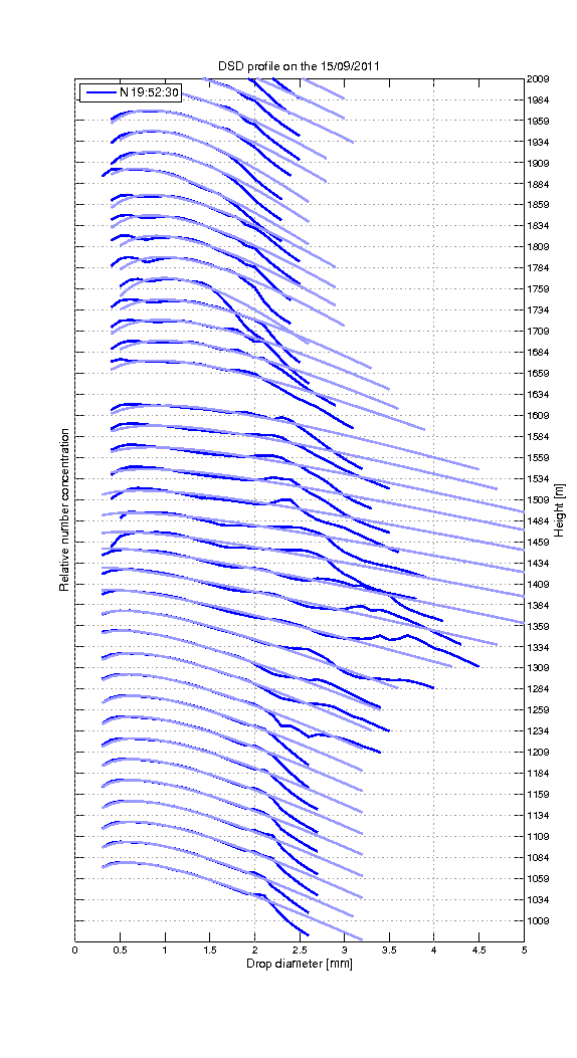


Optimal estimation of w, σ_T and DSD

- Forward model of Ka and W-band radar Doppler spectra
  - Bin DSD, vertical velocity w, turbulence spectrum width σ_T, air density ρ, differential attenuation







Conclusion

- Exploratory research – Work in progress
- New vertical velocity product in light rain
- Product combining vertical velocity, turbulence and bin DSD
- Time-height evolution of the DSD, influence of the dynamics on the collision-coalescence process
- How to guide this product? Are we ready for bin DSD comparison in models?

Thanks for your attention

Questions?