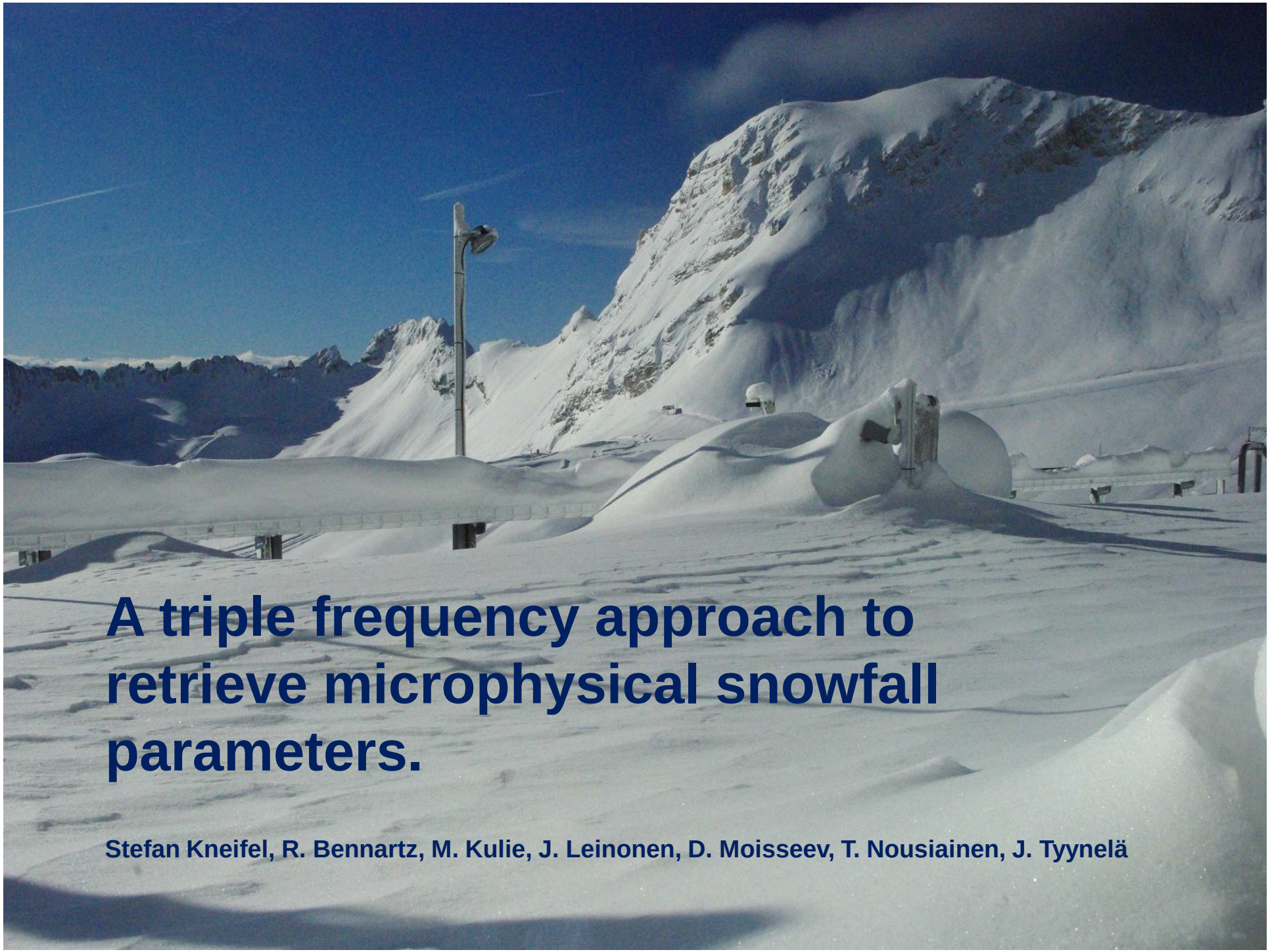


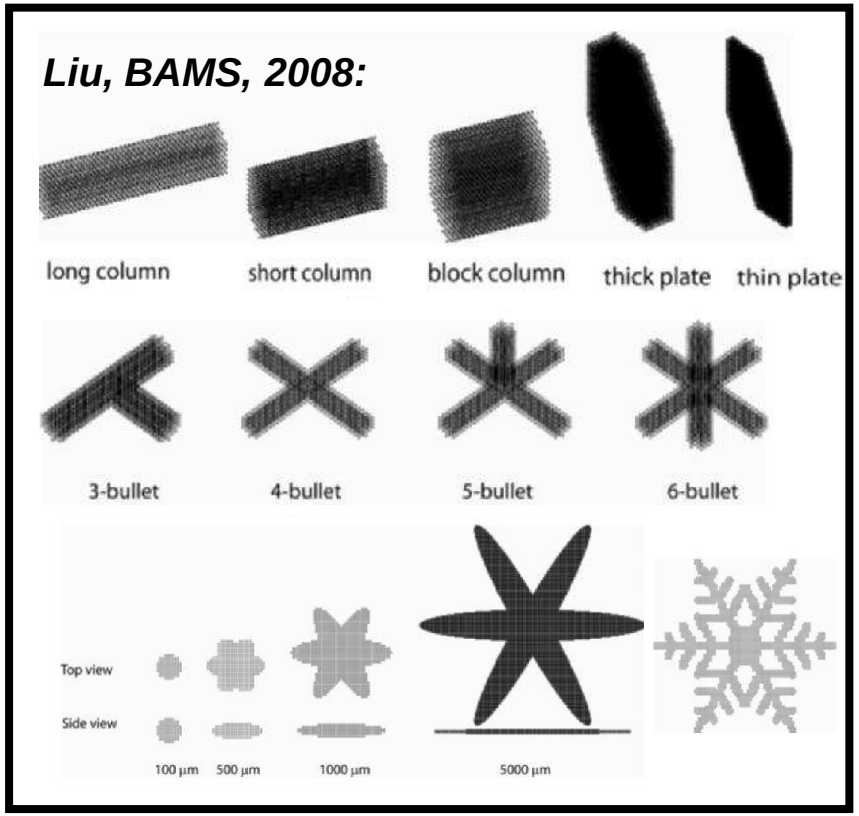
A triple frequency approach to retrieve microphysical snowfall parameters.

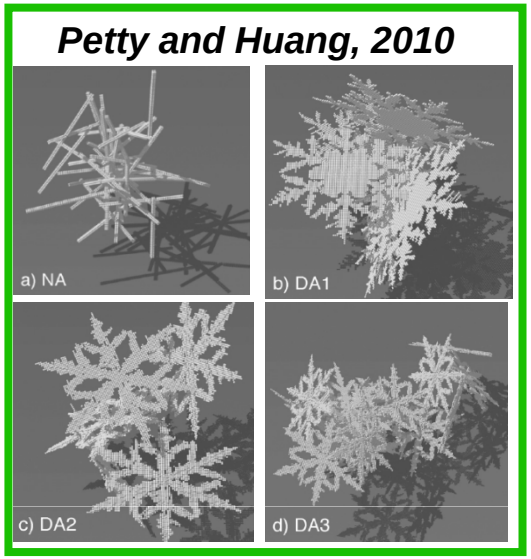
Stefan Kneifel, R. Bennartz, M. Kulie, J. Leinonen, D. Moisseev, T. Nousiainen, J. Tyynelä

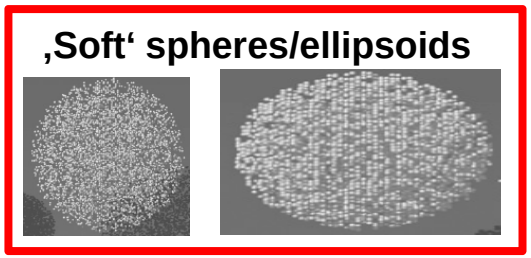
Outline

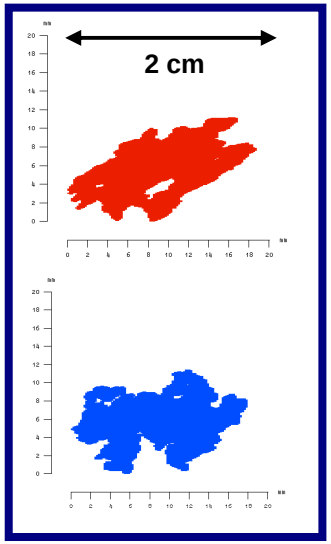
1. Single scattering properties of various snow habits
2. Single and Dual frequency approach
3. Triple frequency approach
4. Analysis of triple frequency data from Wakasa Bay experiment

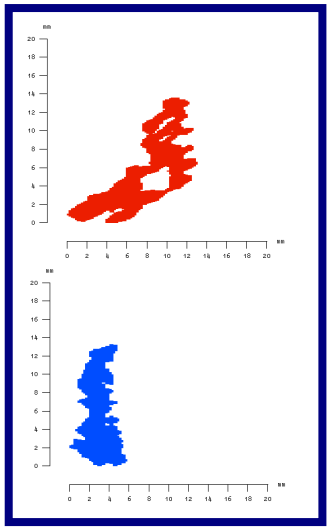
Databases of single scattering properties





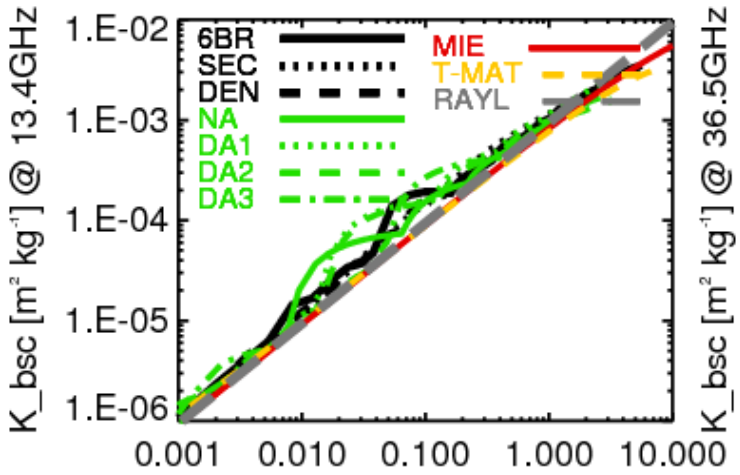


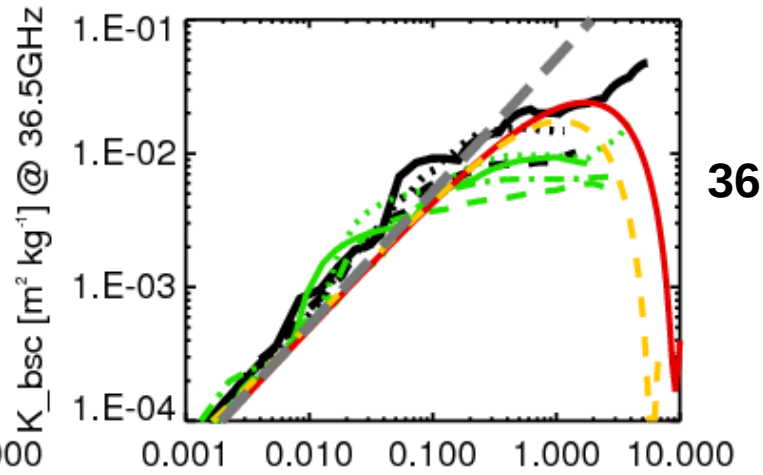




Backscattering of single particles (related to part.mass)

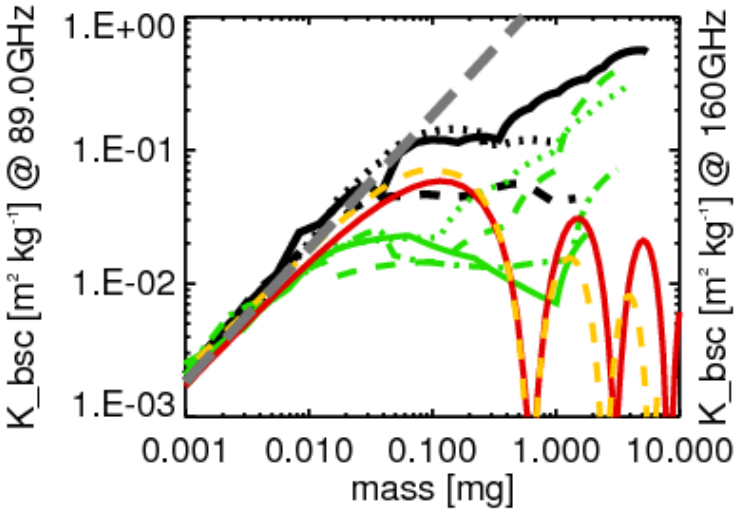
13.4 GHz

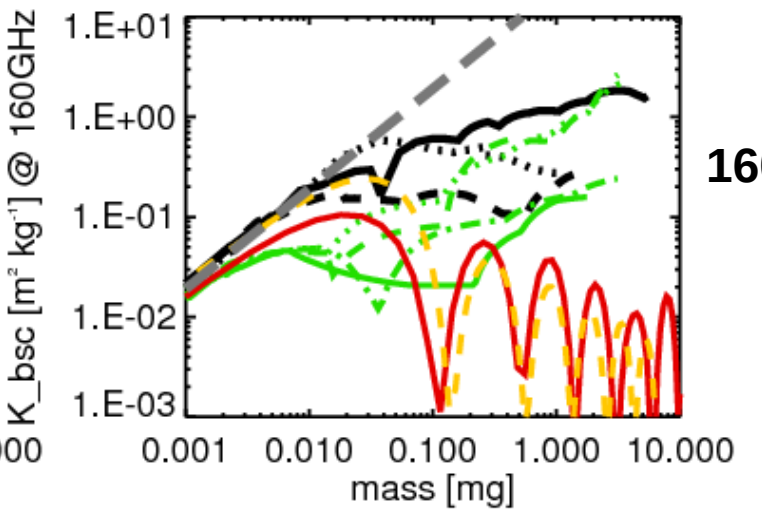




36.5 GHz

89 GHz





160 GHz

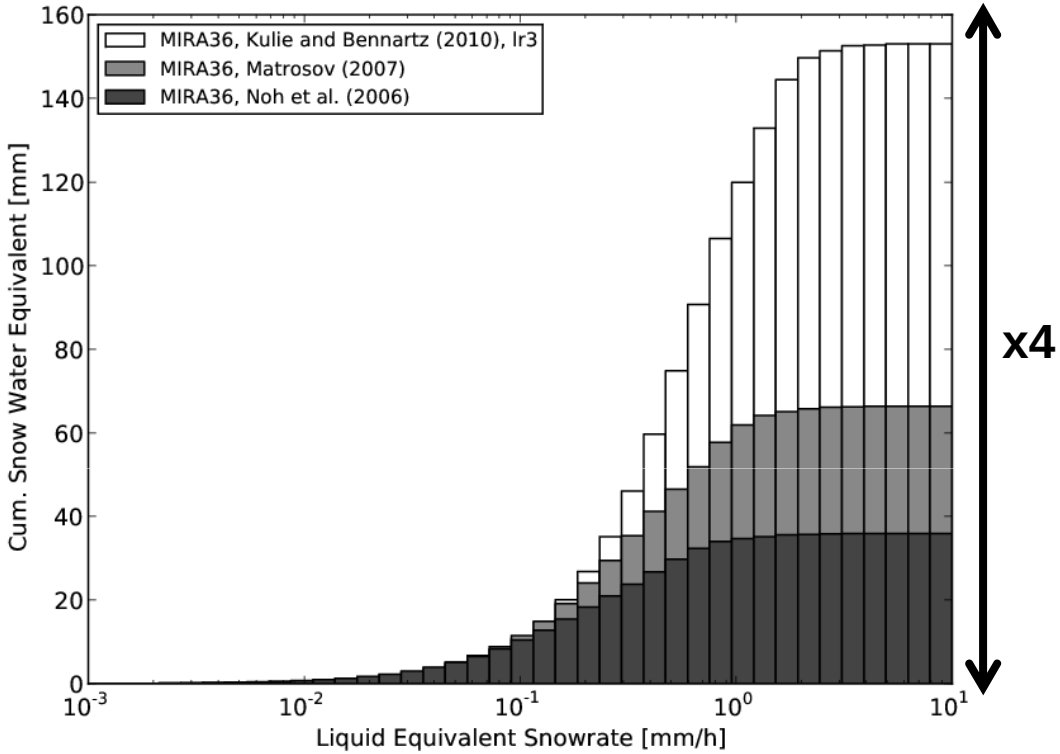
From single particle properties to volume properties

Single frequency technique

- Derivation of snowfall properties like snowfall rate (SR):

$$Z_e = a \cdot SR^b$$

- Three different published relations have exemplarily been applied to a 6-months snowfall dataset (TOSCA campaign) of 35.5 GHz cloud radar observations.



Problem: Rather different realizations of snowfall (habit, size distribution, mass-size relation) can produce the same Z_e.

Dual frequency approach assuming ‚soft' spheres

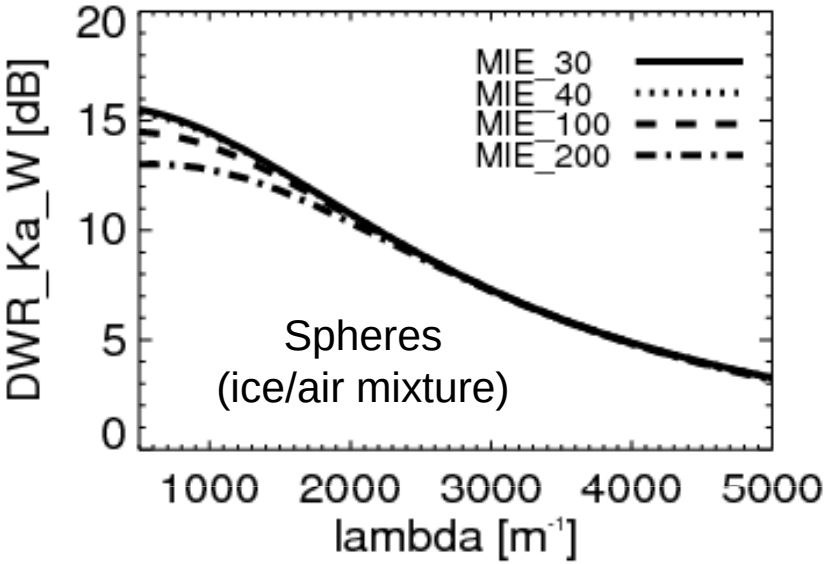
- Dual Wavelength Ratio DWR:

$$DWR_{\lambda_1,\lambda_2} = 10 \cdot \log\left(\frac{Z_{e,\lambda_1}}{Z_{e,\lambda_2}}\right)$$

- Instead of λ: K_u (13.4 GHz), K_a (36.5 GHz), W (94 GHz)

- DWR is independent of the intercept parameter N_0 of the assumed exponential snow size distribution:

$$N(D) = N_0 \cdot \exp(-\Lambda D)$$

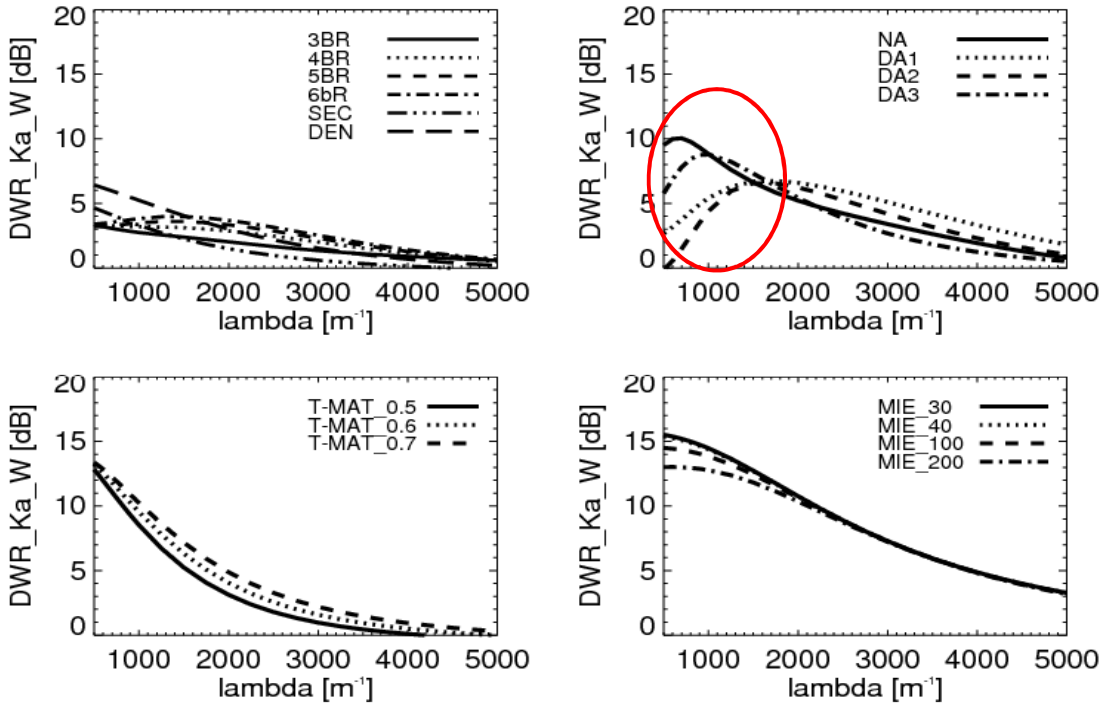


- DWR is almost independent of the sphere's density. Λ can be directly derived by measuring DWR.

- The derived Λ can be used to constrain Ze-SWC relations and to reduce the uncertainty range.

Dual frequency approach with various habits

- If non-spherical particles are considered and if particle sizes increase (i.e. Λ decreases) the “habit – independence” of DWR becomes invalid.



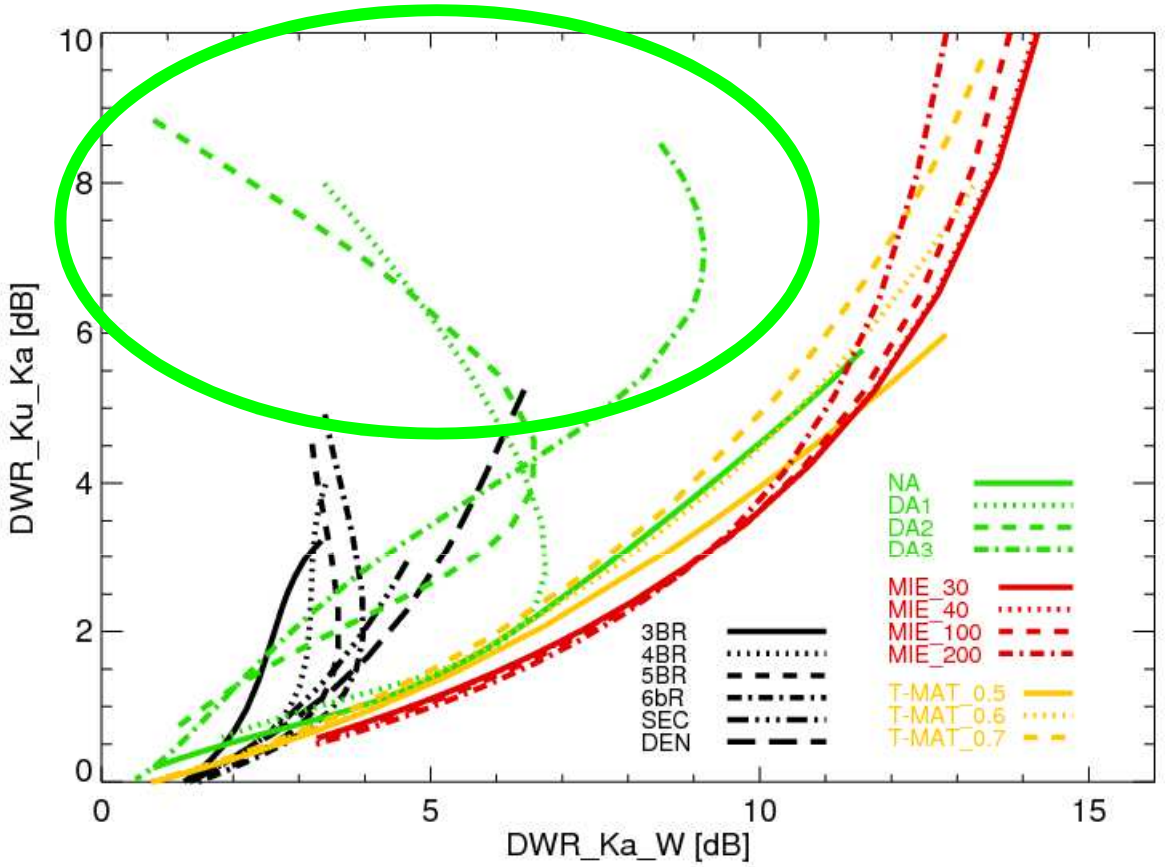
Kneifel et al., JGR, 2011

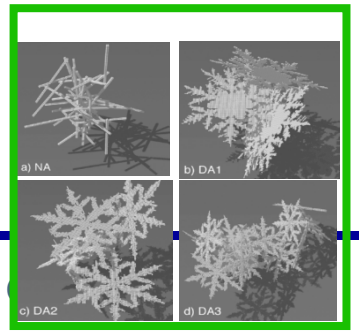
Possible solution: Combination of three frequencies (K_u, K_a and W-band) to distinguish between different particle habit classes.

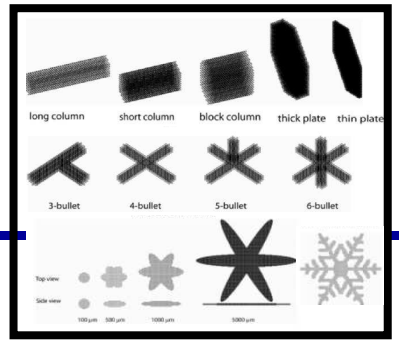
Triple frequency approach

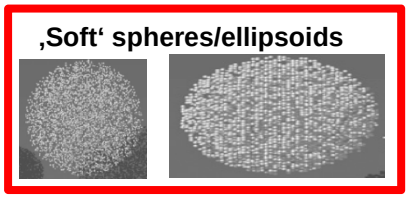
Kneifel et al., JGR, 2011

- The third frequency can provide information on particle habit class and helps to further constrain the derivation of Λ.
- Attenuation due to snow and liquid water has to be considered.

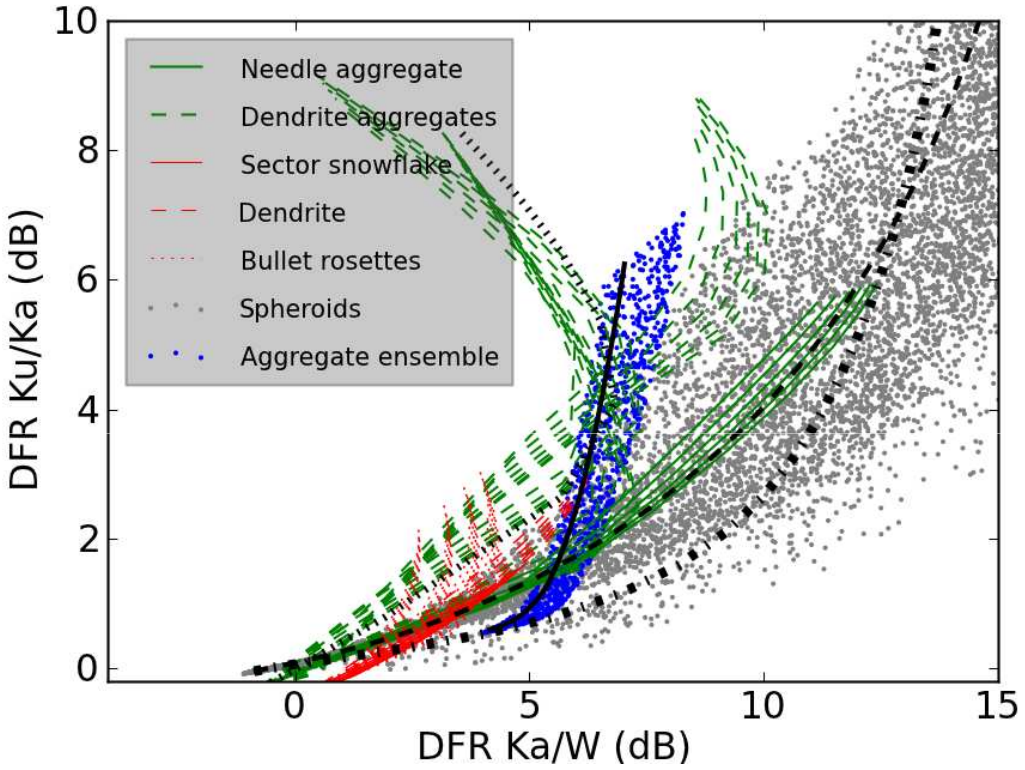




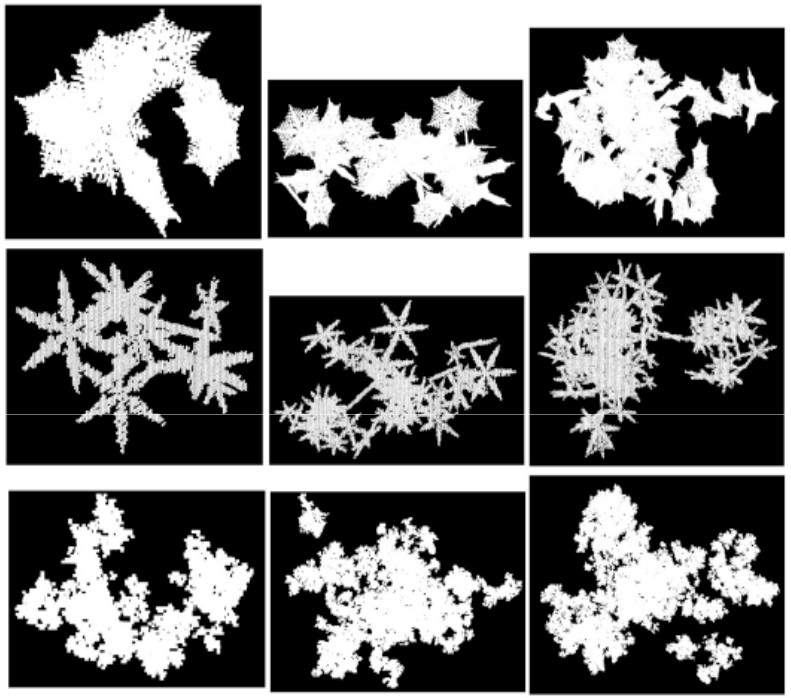




Triple frequency approach – different aggregate models



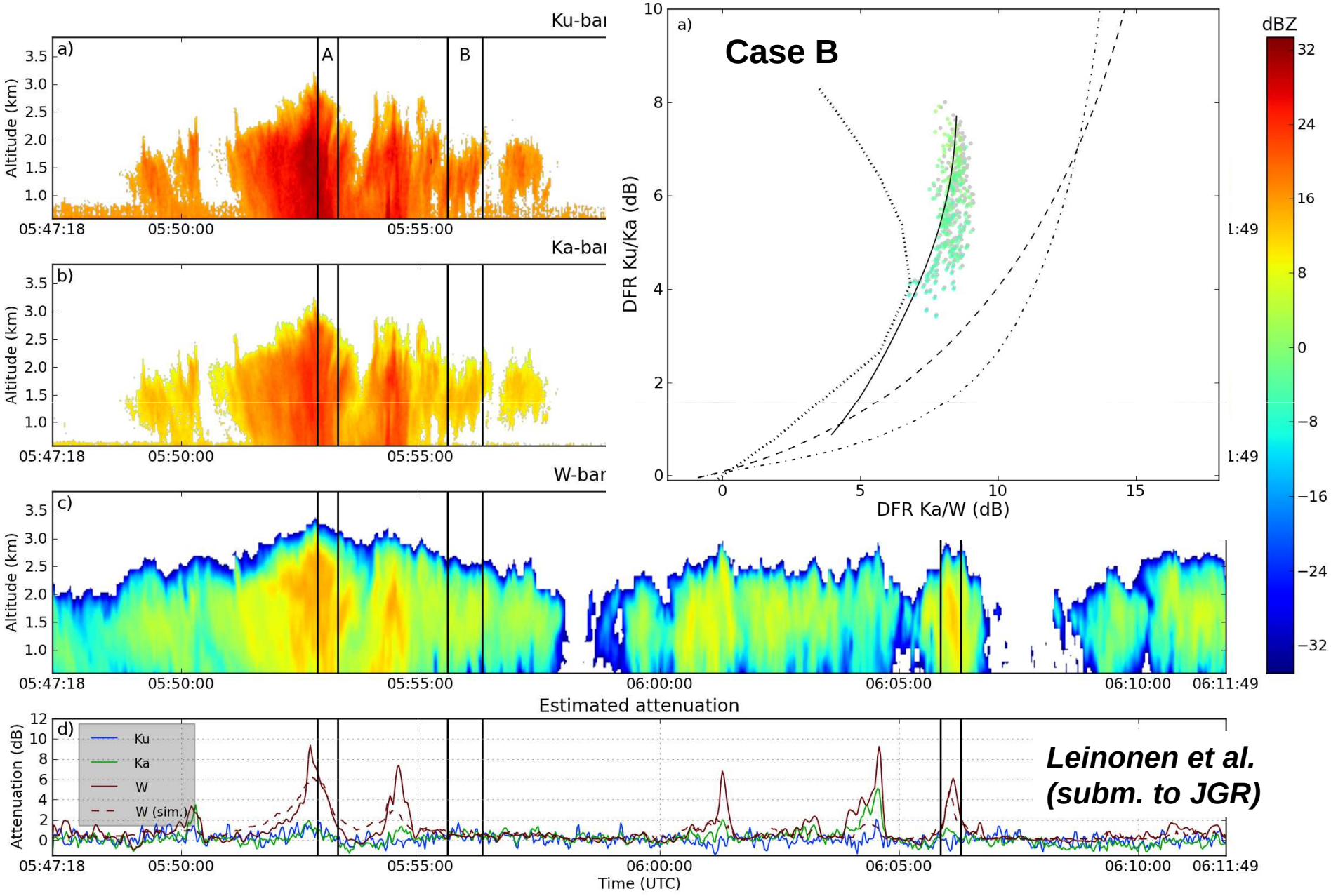
Leinonen et al. (subm. to JGR): Analysis of Wakasa Bay data (airborne triple freq. radar)



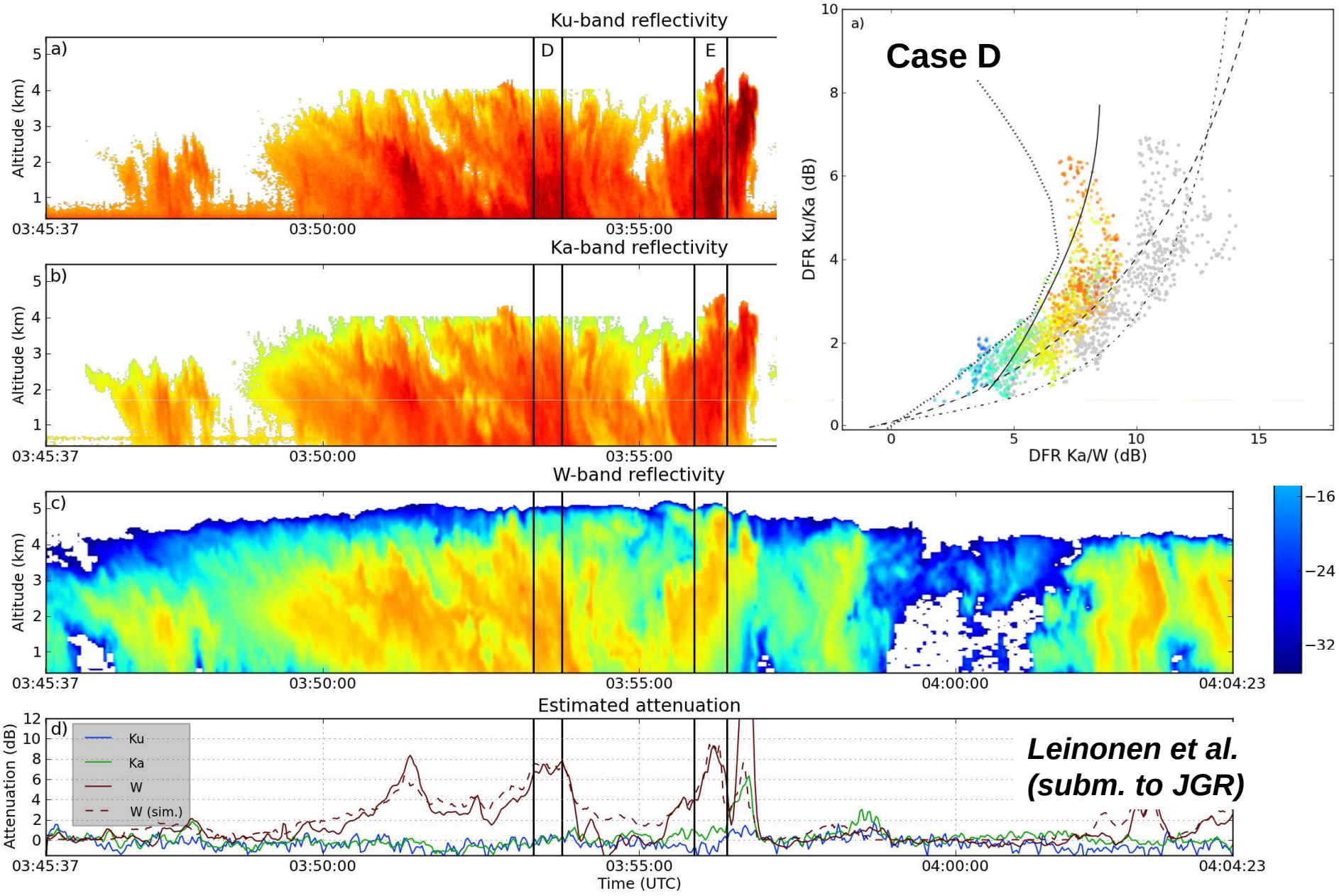
Tyynelä et al., JAOT, 2011: Comparison of fractal, aggregate and soft spheroids.

Do such signatures really exist?

Triple frequency observations from Wakasa Bay experiment



Triple frequency observations from Wakasa Bay experiment



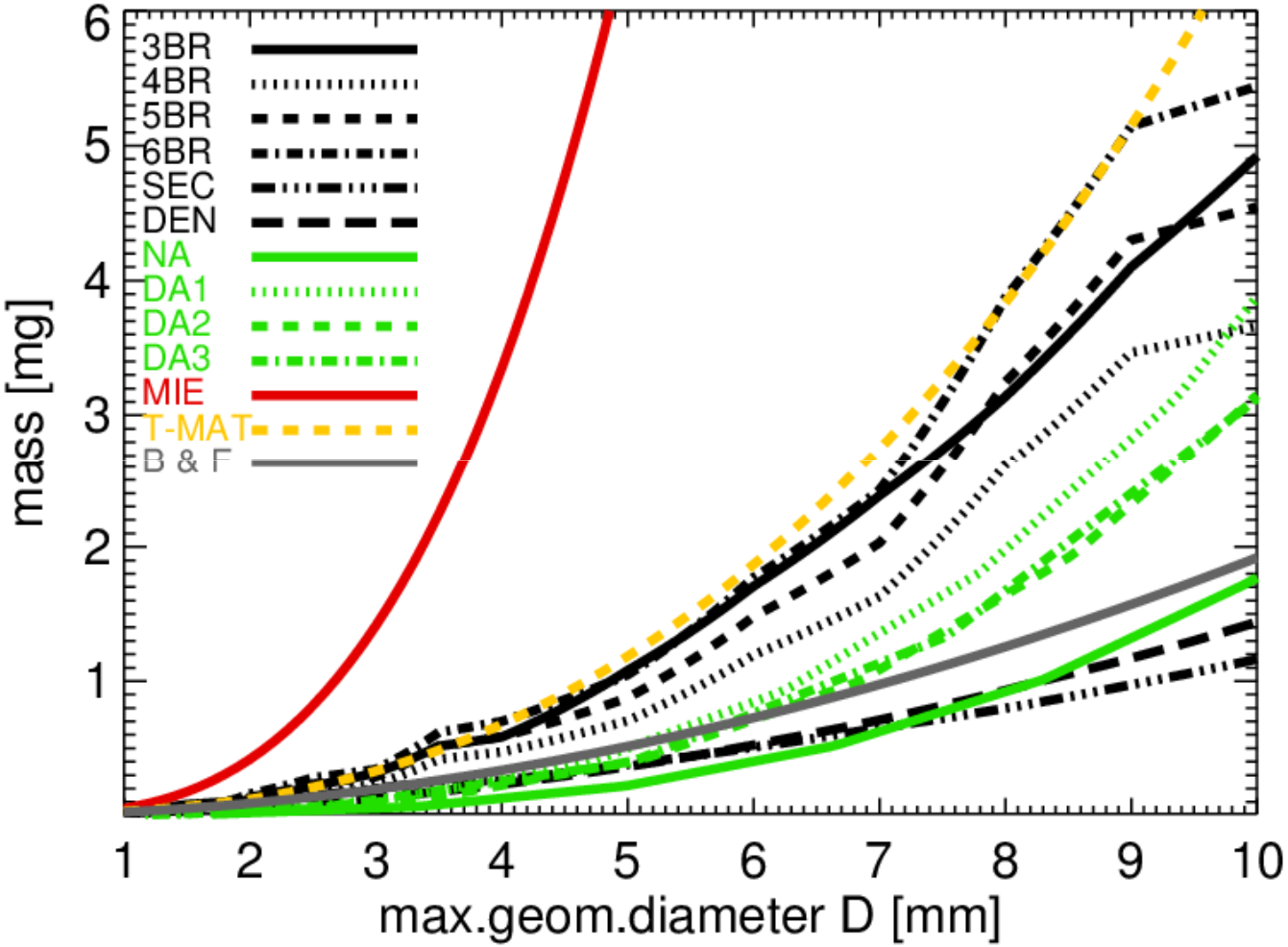
Conclusions

- Scattering datasets for various snow habits allow to study influence of microphyics on radar variables.
- Dual-frequency technique (K_a/W) is habit/density dependent for ‚large' particles (D_0>2mm or Λ<1500 m^{-1})
- A triple-frequency combination of K_u, K_a and W band reveals different behavior for spherical and aggregates snow.
- First triple-frequency observations reveal consistent features which have still to be prooven with in-situ observations.

Thank you!

Backup slides

Snow particle properties: m-D relation



Extinction of single particles (related to part.mass)