Validation of the MMCR based retrievals of rainfall rate profiles

Traditional non-polarimetric radar measurements of rainfall

1. Based on Z_e – R relations
2. Attenuation in rain is considered an interfering factor
3. Special approaches are used to reconstruct profiles of non-attenuated Z_e if attenuation is appreciable

S- band (λ~10 cm) – attenuation is negligible
C-band (λ~ 5 cm) - attenuation is negligible to small
X-band (λ~ 3 cm) - attenuation is small to moderate
K_u-band (λ~ 1.8 cm) - attenuation is moderate to strong
K_a-band (λ~ 0.8 cm) - attenuation is strong to very strong
W-band (λ~ 0.3 cm) - attenuation is very strong

At K_a and W-bands attenuation in rain is often becoming a dominant factor which is responsible for changes of reflectivity along the vertical beam

At the same time at K_a and W-bands, "non-attenuated" Z_e values (due to non-Rayleigh effects) change with R much slower than at cm-wavelengths resulting in less pronounced Z_e-R relations

The attenuation-based approach to retrieve rainfall rate vertical profiles is based on the vertical range derivatives (i.e., gradients) of reflectivity ($\partial Z_e/\partial h$) not on reconstructed estimates of "nonattenuated" absolute values of Z_e.

Main features of the approach:

Attenuation is a dominant factor responsible for changes of measured Z_e in vertical
[this assumption generally becomes more valid as the vertical resolution of the approach (i.e., the vertical interval at which changes of reflectivity is considered) becomes larger]

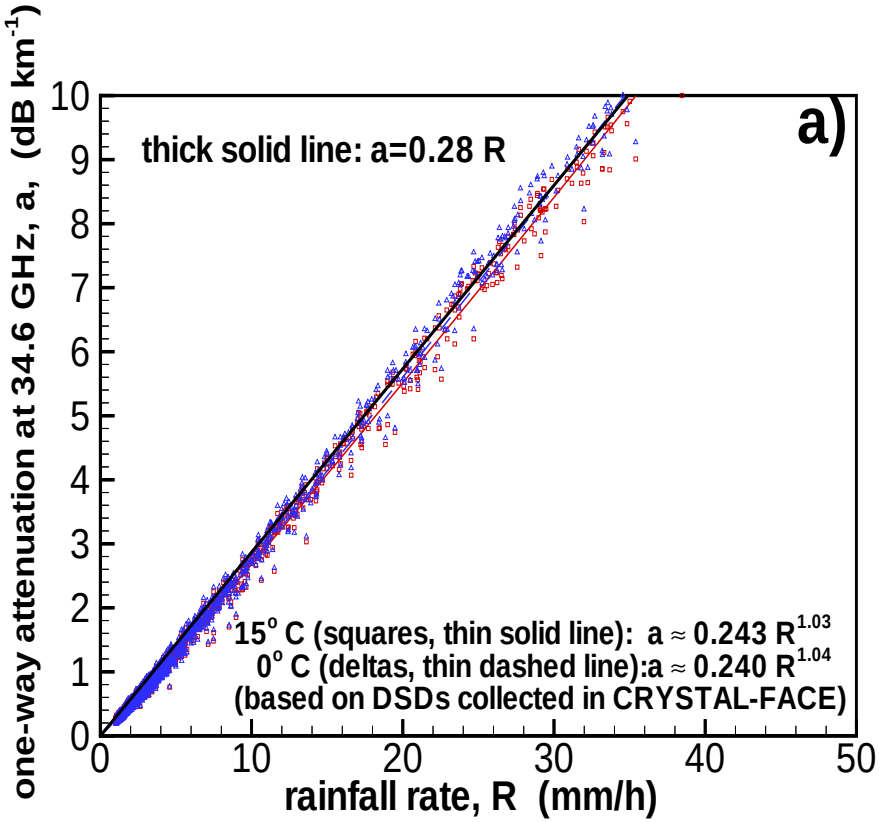
Estimates of ($\partial Z_e/\partial h$) are the proxy for the attenuation coefficient α in rain

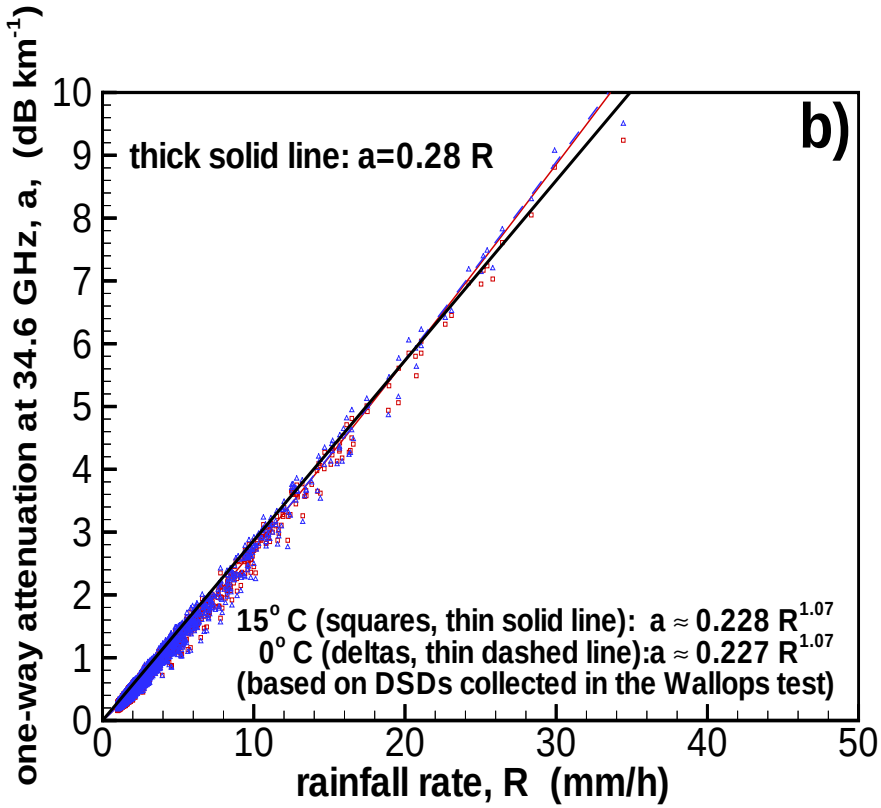
Statistical methods are used to get ($\partial Z_e/\partial h$) estimates because of meassurment noise

Vertical variability of "non-attenuated" reflectivity is considered as a limiting factor, which contributes to the uncertainty of the attenuation based retrievals

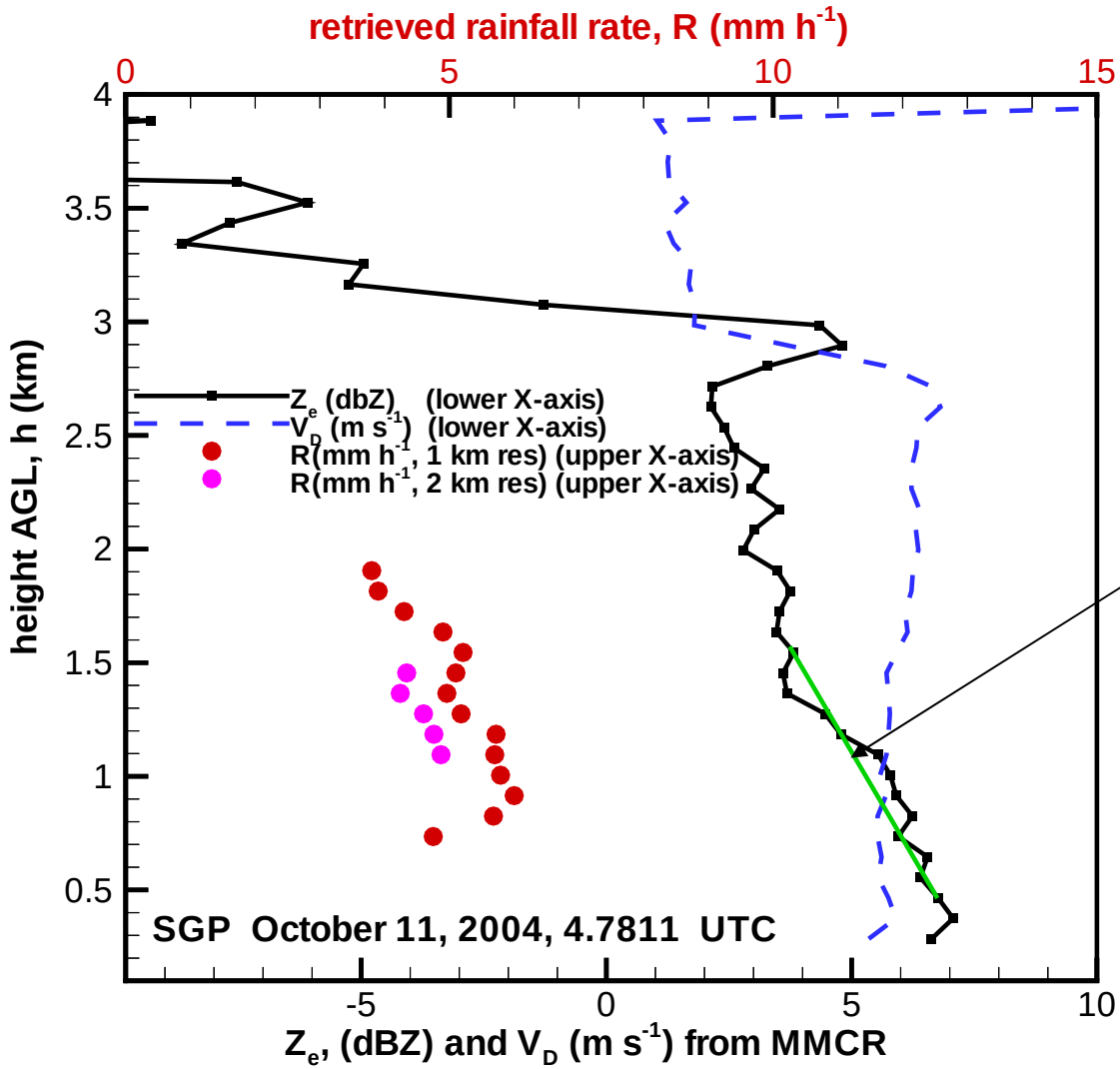
Linear dependence between R and α at K_a-band:

The variability around the best fit (α=0.28 R or R=3.62 α is less than 10%)
The best fit is not sensitive to the DSD details and temperature





An example of the rainfall rate profile retrieval: MMCR ARM SGP site



Rainfall rate is estimated as a slope of the best LMS fit through the attenuated reflectivity data points at the resolution interval

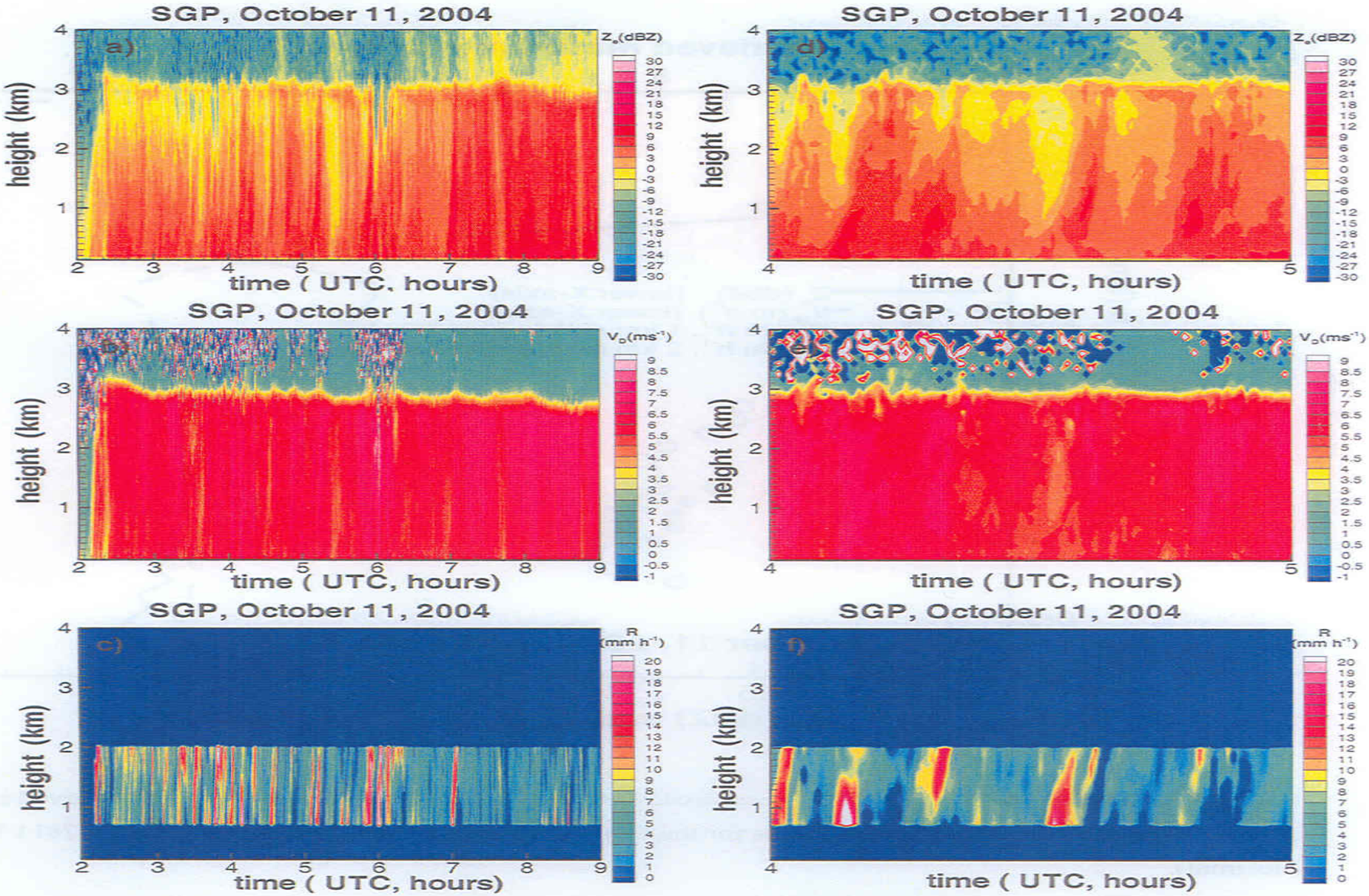
An example of the LSM routine is shown by the green line: it corresponds to 1 km resolution centered at 1 km height (1±0.5km)

An example of rain rate profile retrievals in stratiform rain at the SGP site

upper frames – measured (i.e., attenuated) MMCR reflectivity

middle frames – Doppler velocity

lower frames – retrieved rainfall rates



Errors of the attenuation-based retrievals of rainfall rate profiles

Two sources to retrieval errors:

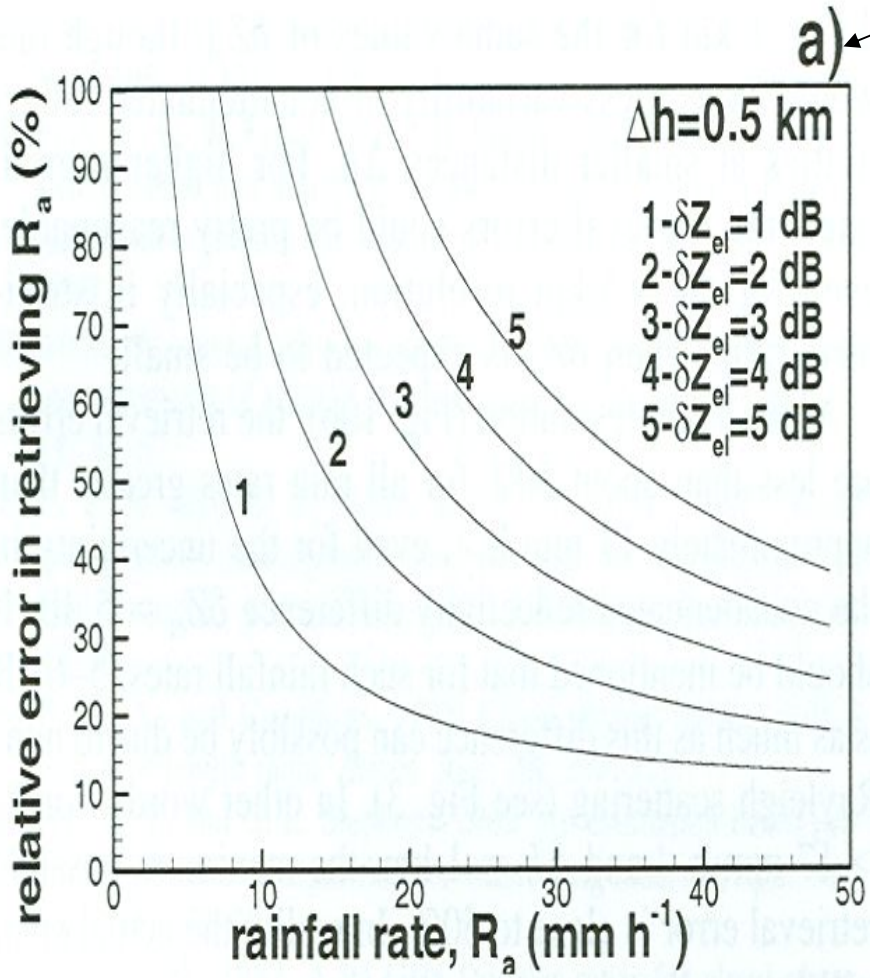
1. Uncertainty of relating R from the extinction coefficient α
   (i.e., the uncertainty of the $R = \beta\,\alpha$ relation (~10%)

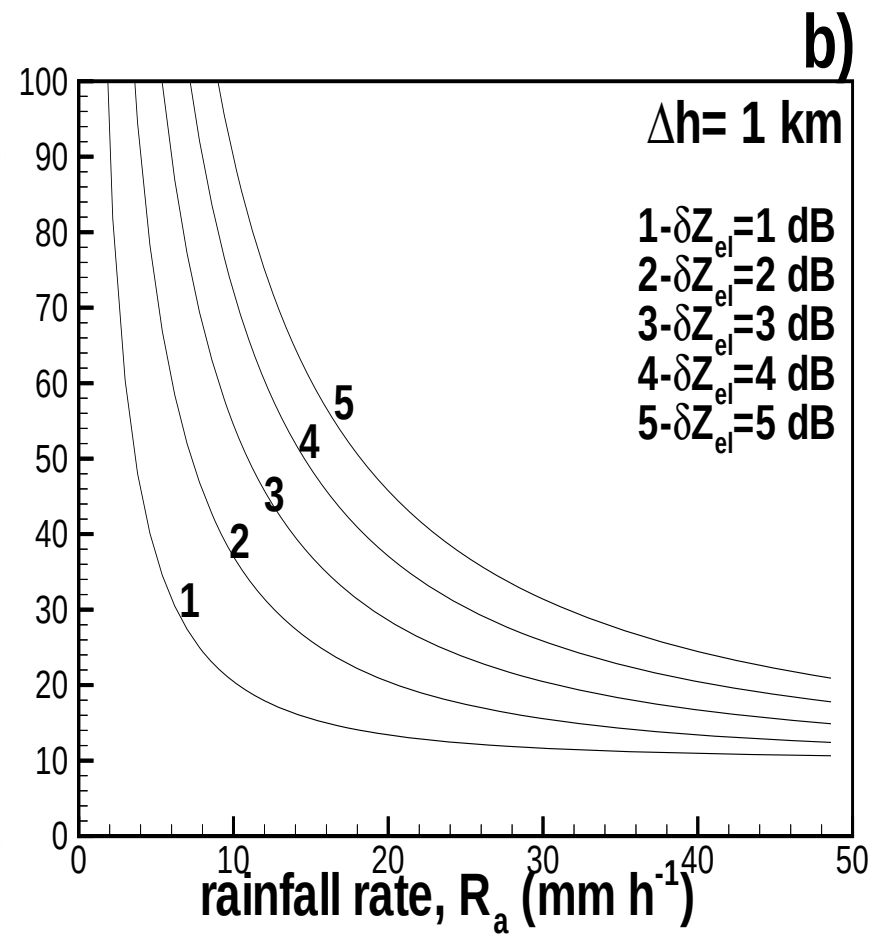
2. Variability of non-attenuated reflectivities (δZ) at the interval Δh used for estimating the height derivative $\partial Z_e/\partial h$
   $\sim \delta Z/(2\,\beta^{-1}\,\Delta h\,R)$

These two sources can be assumed to be independent (source 2 typically dominates source 1 for $R < 10$ mm h^{-1})

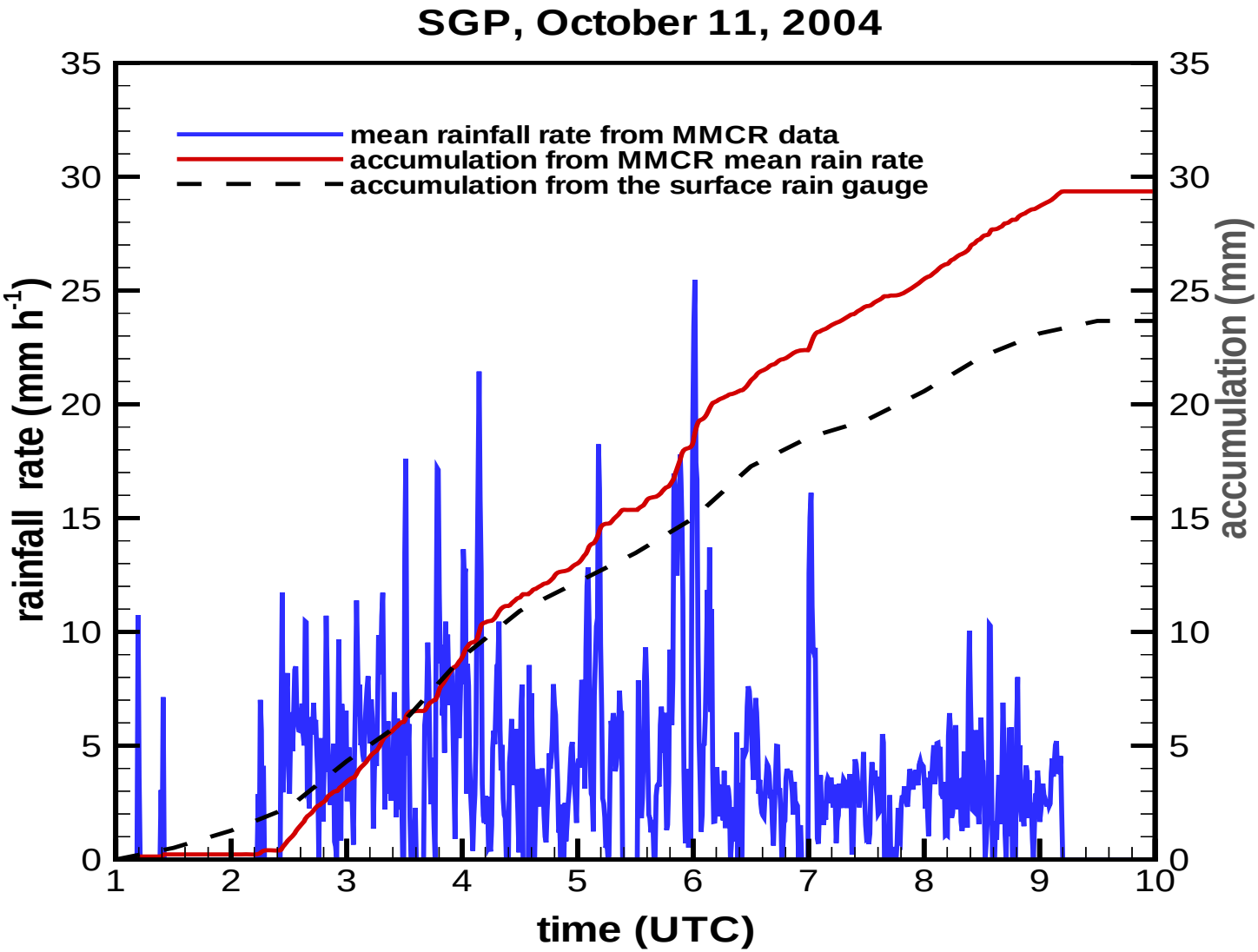
There are no error contributions from uncertainties of the MMCR absolute calibration and from the wet radome issues

Expected errors of attenuation – based retrievals of rainfall rate at K_a-band at resolution effective resolutions of 0.5 km and 1 km





Time series of the MMCR retrievals at the middle of the rain layer (~1.2 km)

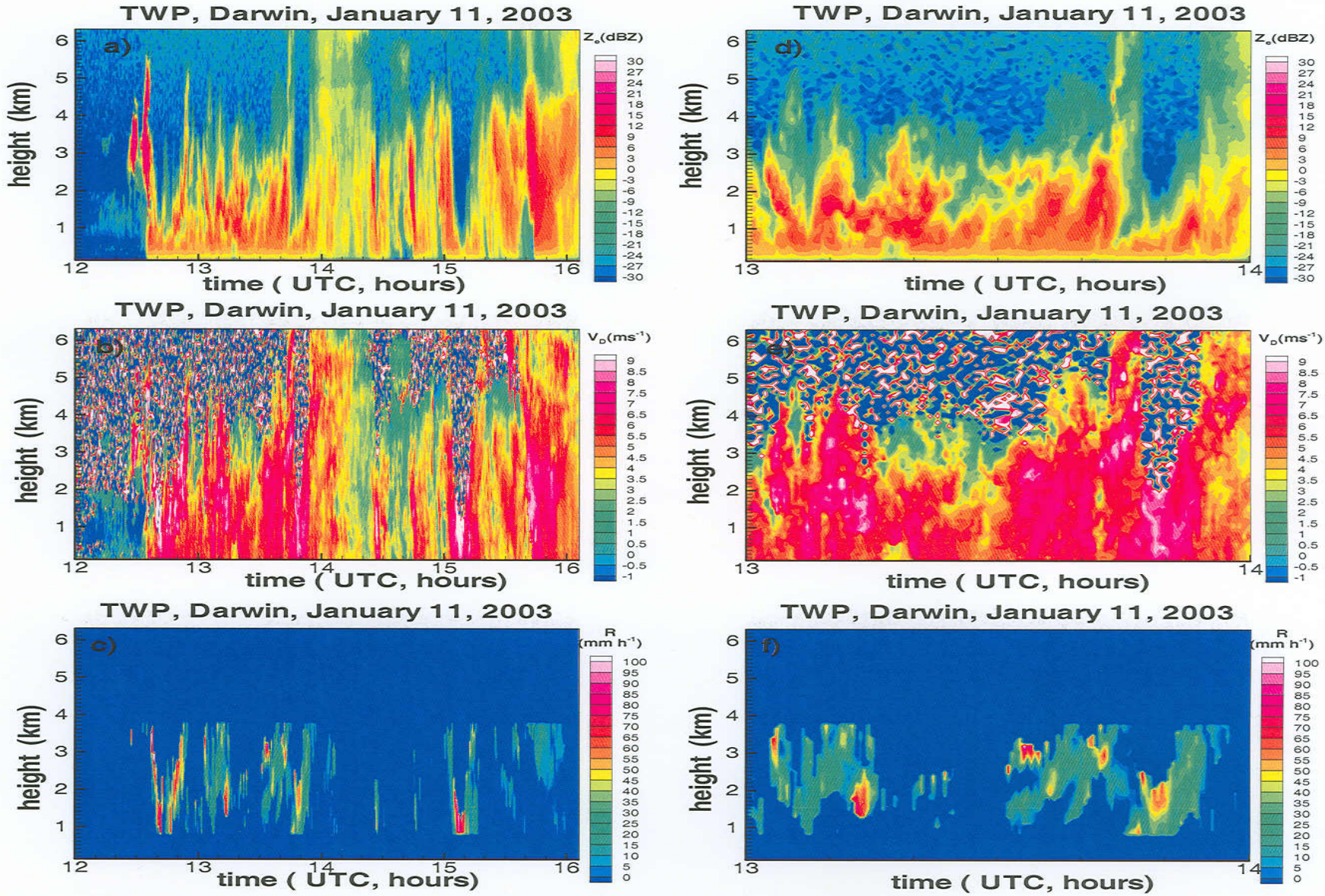


An example of rain rate profile retrievals in convective rain at the TWP site

upper frames – measured (i.e., attenuated) MMCR reflectivity

middle frames – Doppler velocity

lower frames – retrieved rainfall rates

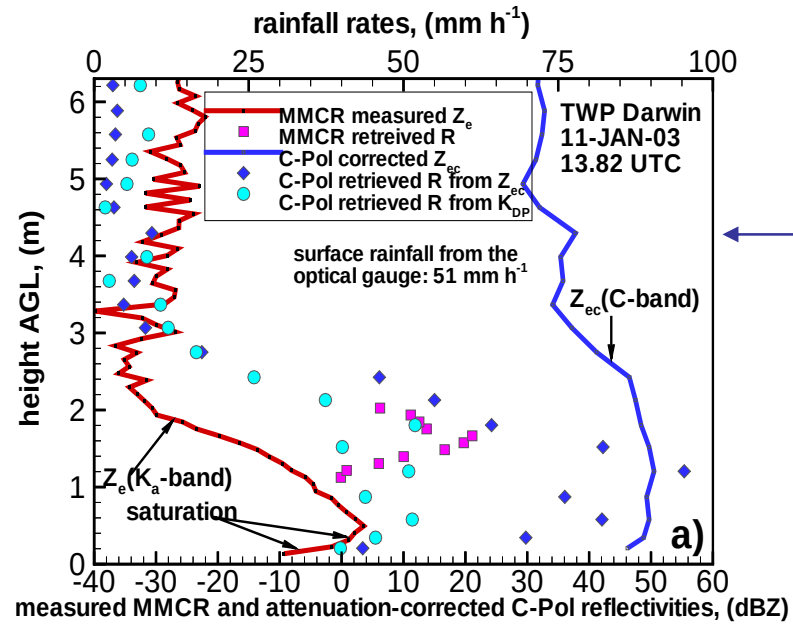


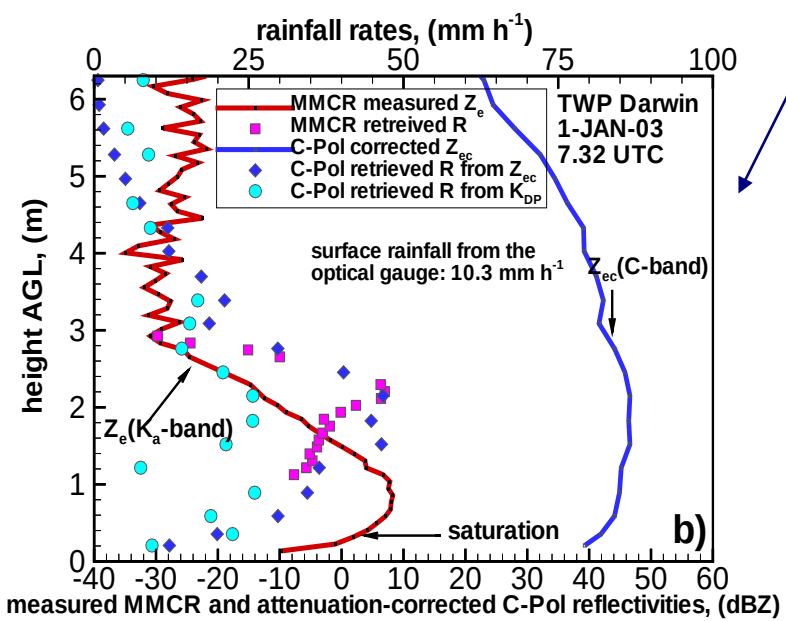
Comparisons of attenuated-based rainfall rate retrievals from MMCR (K_a-band) with polarimetric precipitation radar C-Pol (C-band)

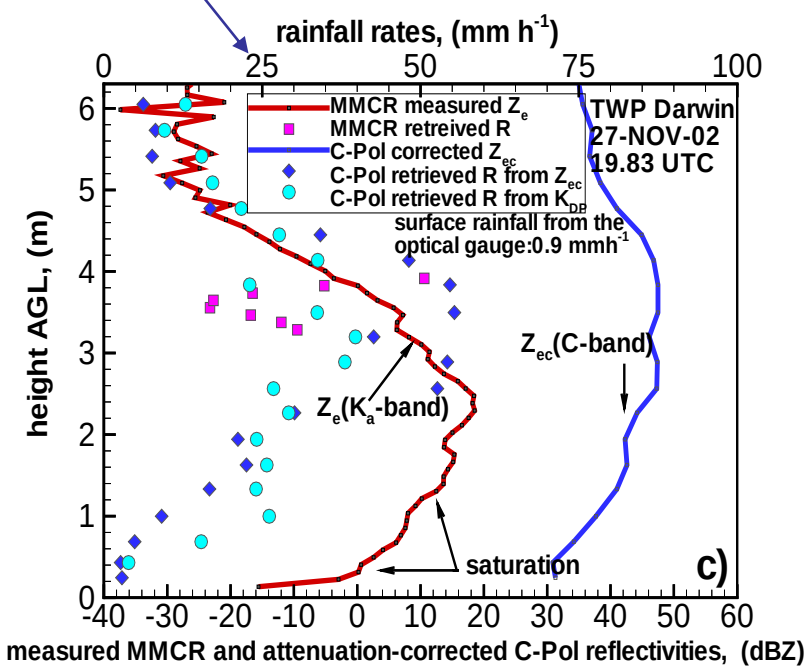
Low vertical variability in R

Moderate vertical variability in R

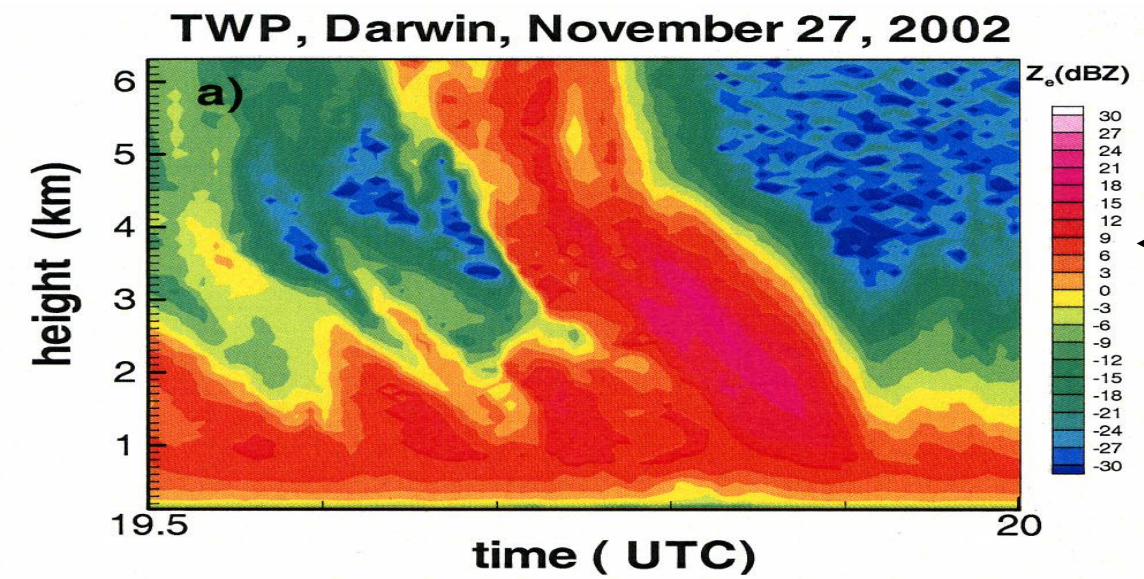
High vertical variability in R



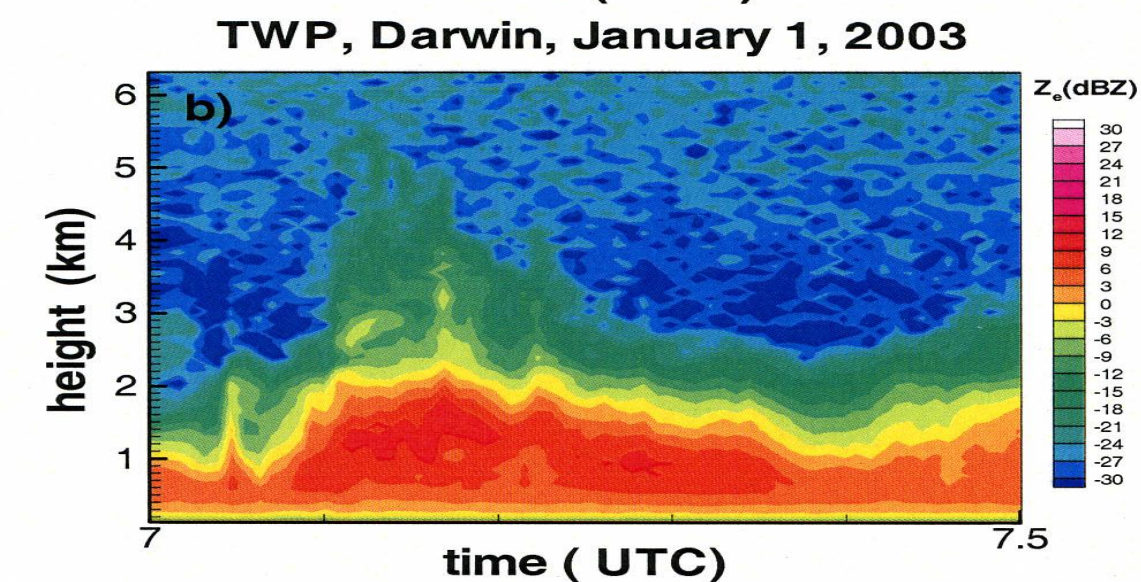




Possibilities of distinguishing between cases with high and low vertical variability of non-attenuated reflectivity



High variability of non-attenuated reflectivity (slanted Z_e patterns)



Low variability of non-attenuated reflectivity (not slanted Z_e patterns)

Conclusions:

attenuation-based retrievals of rainfall rate profiles from MMCR radars provide encouraging results

retrieval accuracies are expected to be better for heavier rains

comparisons with precipitation radars indicate the robustness of the attenuation-based approach

Attenuation-based retrievals use relative (not absolute) radar measurements thus absolute radar calibration is not an issue here

additional information on vertical profiles of non-attenuated reflectivity can improve the retrieval accuracy

retrievals of rainfall information provides a more complete characterization of the atmospheric column above ARM sites