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Signal post-processing and reflectivity calibration of the ARM UHF wind profilers

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Introduction

- Cloud radars adequately detect clouds and precipitation → good characterization of transition from clouds to precipitation

- Rain rate retrieval with ARM 35 GHz radars (Matrosov et al. 2005, 2006):
  - Close relation between rain attenuation and rain rate: a (dB km^{-1}) = 0.28 R (mm h^{-1})
  - Attenuation estimation assuming vertically constant reflectivity within layers of 1 or 2 km
  - But, strong assumption, not valid in case of convection or wind shear

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Introduction

- Non-attenuated reference reflectivity profile from a cm wavelength radar like 915 MHz wind profiler (WP)
- WP reconfigured in a vertically pointing mode for the observation of precipitation (Giangrande et al. 2009):
  - Increase of temporal and vertical resolution
  - Increase of Nyquist velocity
- WP has rarely been used for its reflectivity measurements → need of a careful quality control:
  - Estimation of noise floor
  - Quantification of saturation level
  - Absolute calibration of the instrument

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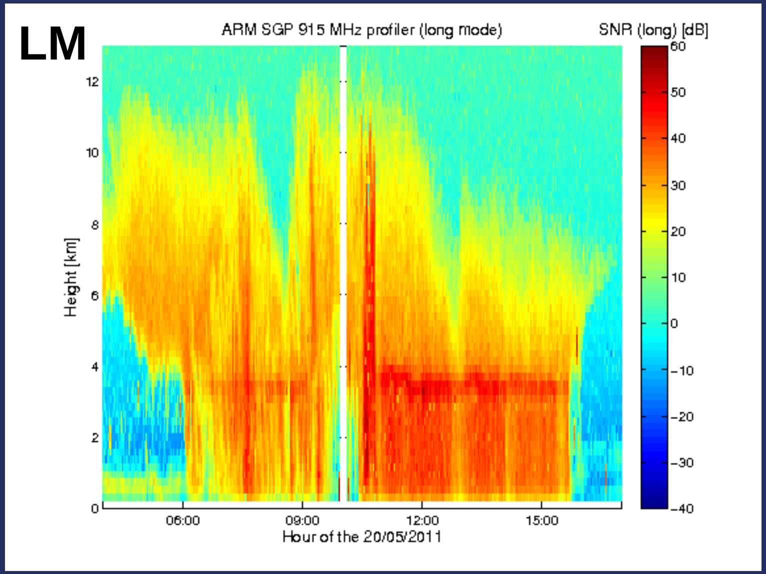
ARM wind profiler

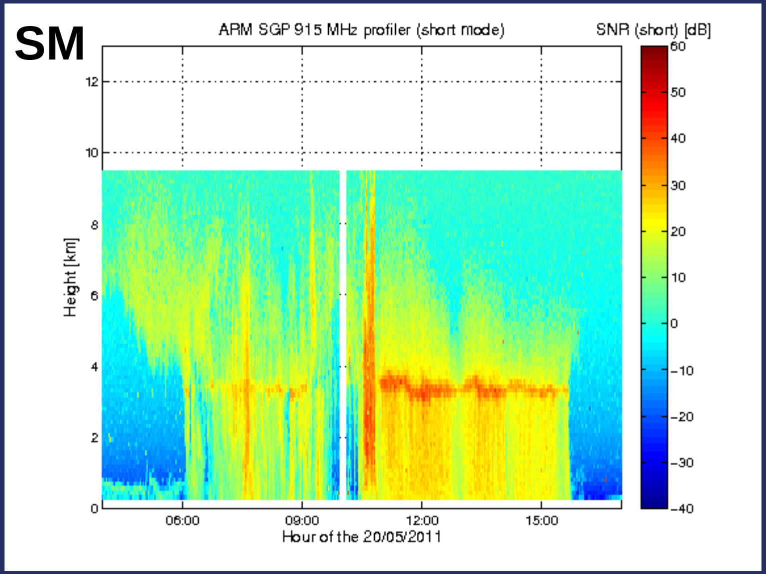
- Cycle in 8 s through two interlaced and complementary modes:
  - Long pulse mode (LM): 213 m resolution from 0.3 to 16 km
  - Short pulse mode (SM): 125 m resolution from 0.3 to 9.5 km
- Objective: the two modes will be merged in order to combine their advantages in single profile, and provide the required reference reflectivity profile
- Large beam width of 9º: not optimal for precipitation measurements in case of important inhomogeneity

Dataset: SGP in April-May 2011

- Midlatitude Convective Clouds Experiment (GPM)
- The suit of instruments involved provide an unprecedented opportunity for the characterization of clouds and precipitation
- Specifically, 2DVD and NOAA profilers collocated with the wind profiler
- Whole dataset studied, but illustration with a single rain event

20th May squall line Signal to Noise Ratio (SNR)





- Better sensitivity of long mode:
  - $SNR_{LM} > SNR_{SM}$
  - SNR_{SM} becomes undiscernible from noise at lower altitude

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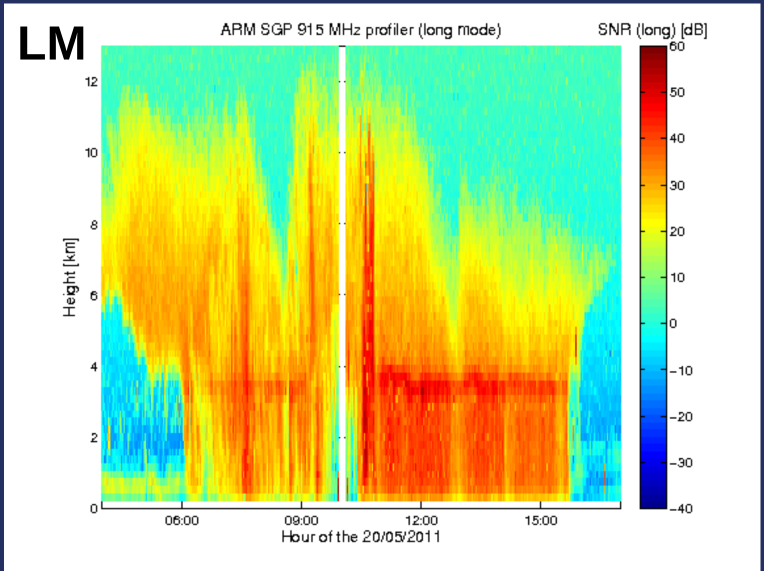
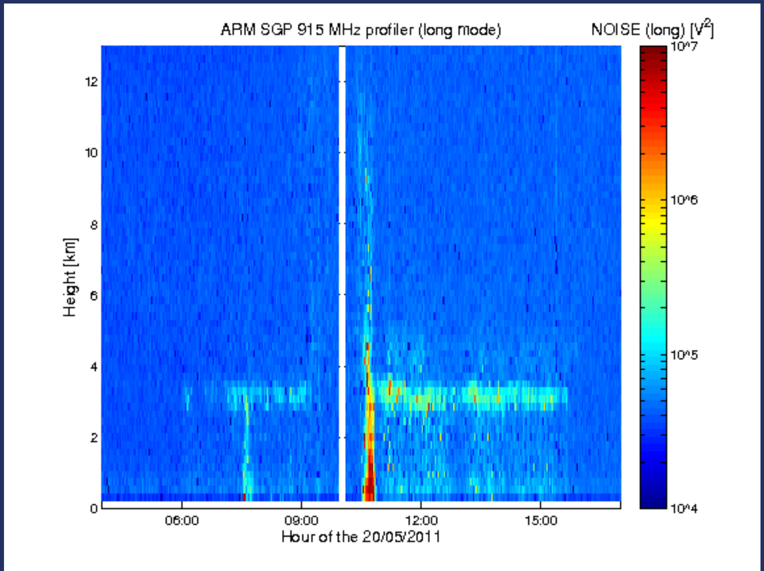
Routine estimation of noise level





- Unattended strong variability of noise level in bright band and convection
  - Significant spectrum widening because of turbulence and variable vertical wind → noise floor not visible → overestimation

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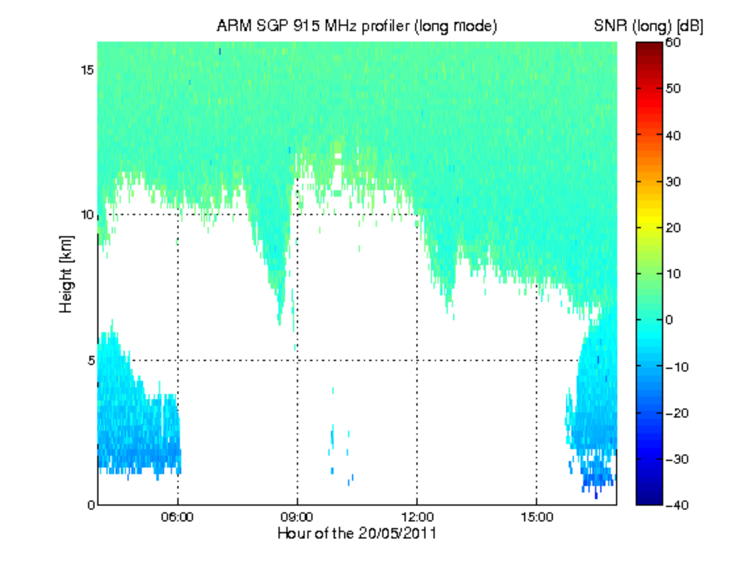
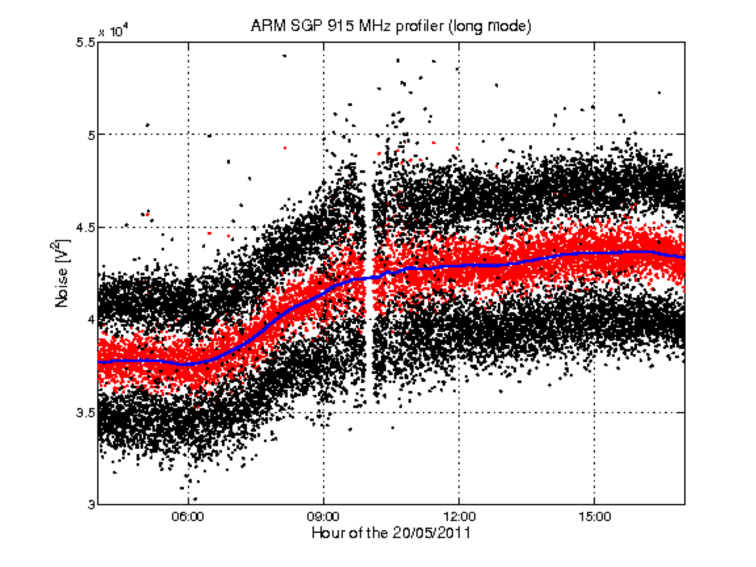
Noise estimation from clear air echoes





- For each profile: mean noise level determined from estimation in clear air gates
- Running average keeping natural variability of noise level

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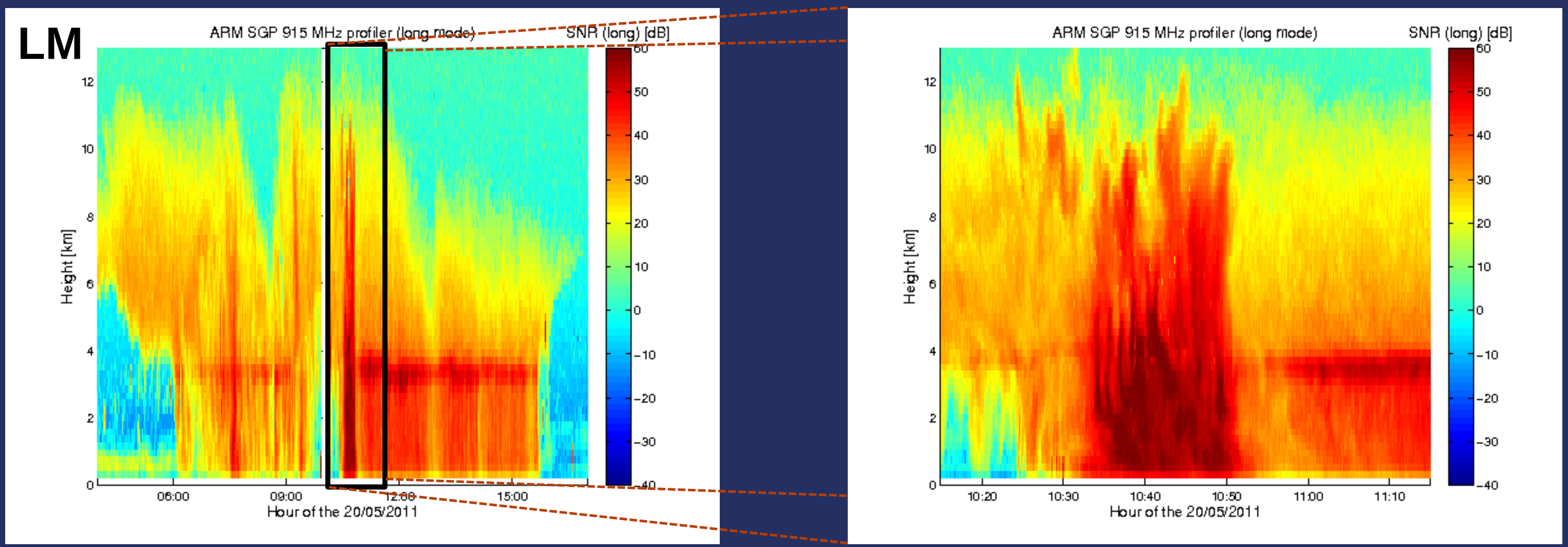
Strong effect on SNR



- Overestimation of noise level → underestimation of SNR mostly in bright band and convective cores
- Zoom: the underestimation can be very large (20 dB) → precipitation features were totally missed

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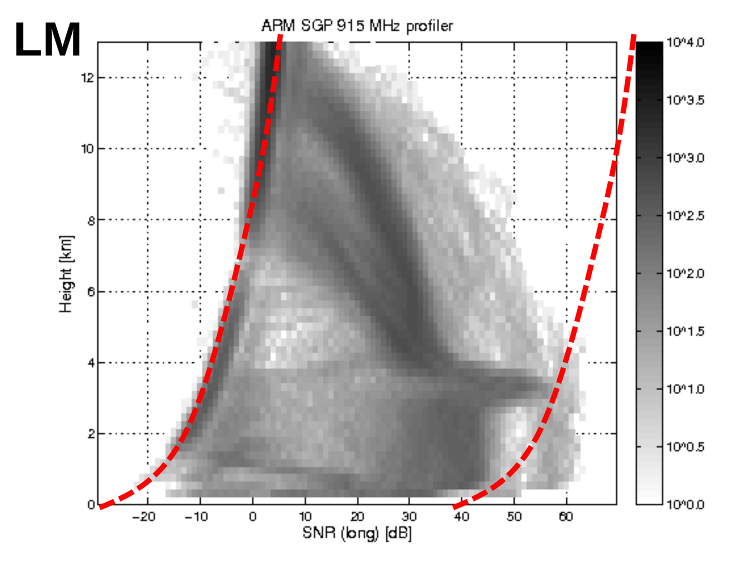
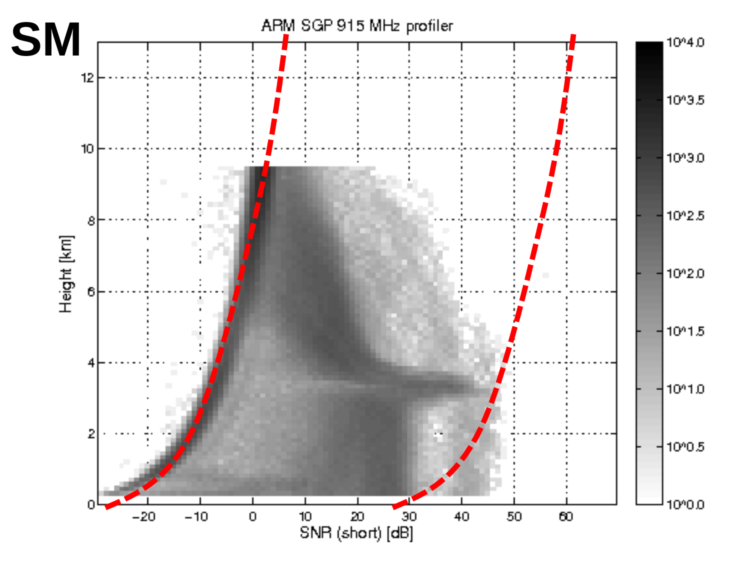
Effect visible on 2DFD: no saturation



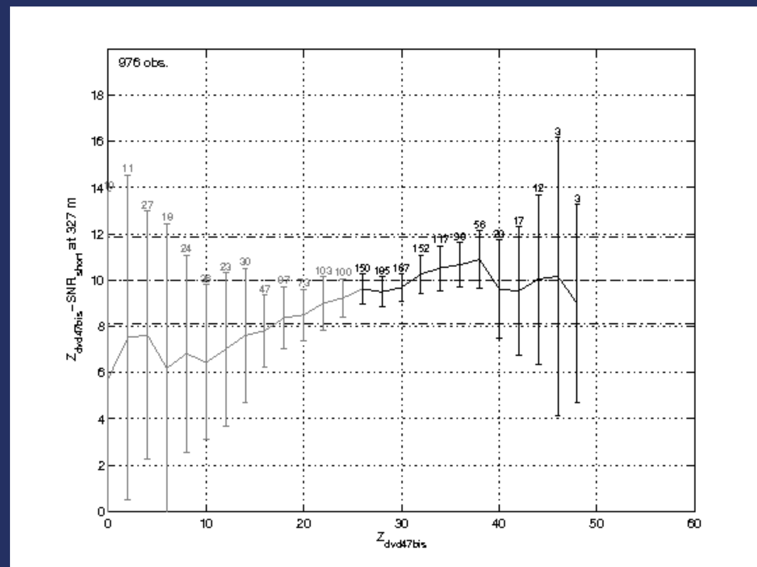


- Distributions of LM (and surprisingly SM) are bounded by two thresholds increasing proportionally to r^2: noise and saturation levels
- Saturation feature was actually due to bad noise level

Calibration

- Comparison of WP measurements in lowest gates with reflectivity computed from the DSD measured by a collocated 2DVD
- Method known to work well (Gage et al., 2000 ; Williams et al. 2005), 2 factors affect the goodness:
  - mismatch in sampling volume size
  - height/time differences between the samples
- Lowest reliable measurements of LM at 750 m:
  - SM calibrated with 2DVD comparison
  - LM calibrated with SM inter-comparison

Calibration of short mode



- Difference Z_{2DVD}-SNR_{SM} in dB normally distributed
- Difference and confidence intervals by Z_{2DVD} intervals:
  - Bragg scattering up to 25 dBZ
  - 25 < Z < 50 dBZ → calibration constant of 10 dB
  - σ = 2 dB (sampling volume, height and principle)

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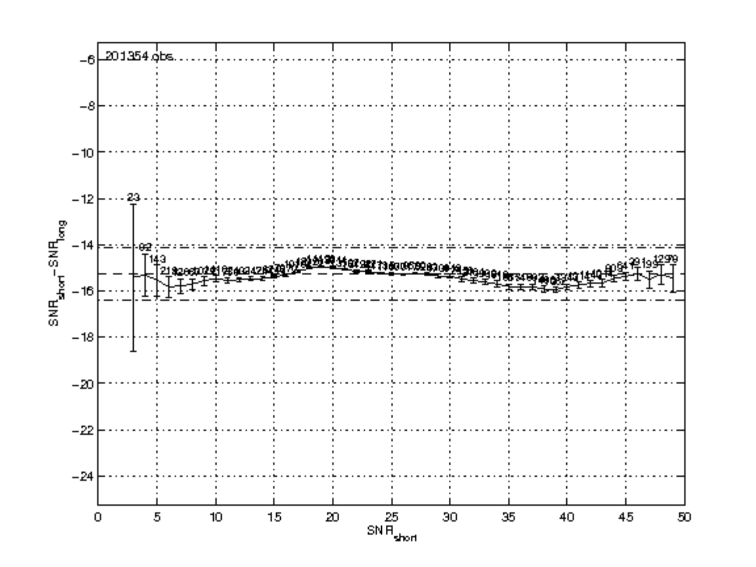
Inter-calibration of long mode



- Difference SNR_{SM}-SNR_{LM} between 1 and 5 km:
  - very good correspondence with σ = 1 dB
  - comparison possible in the Bragg scattering range
  - Inter-calibration constant: 15.6 dB → absolute C_{LM} = -5.9 dB

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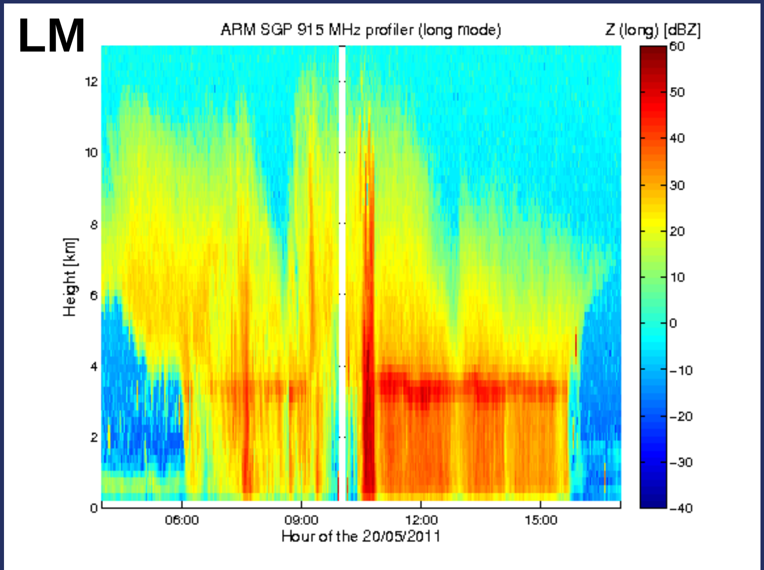
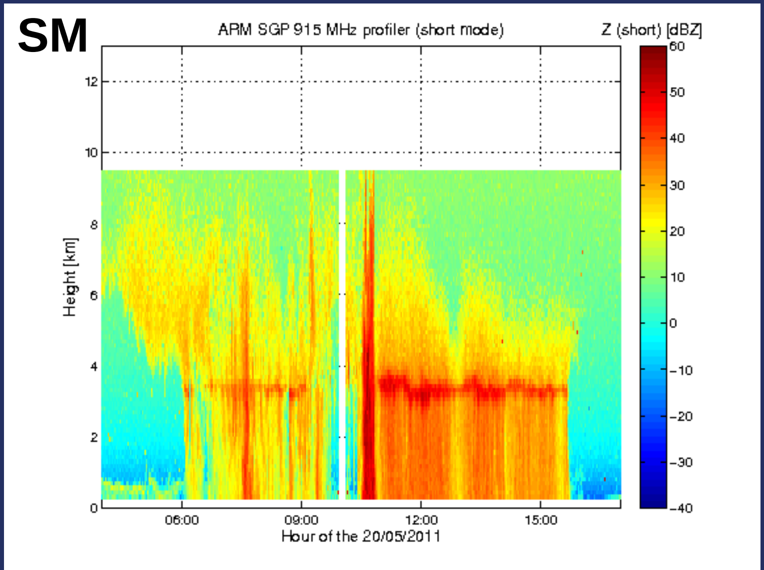
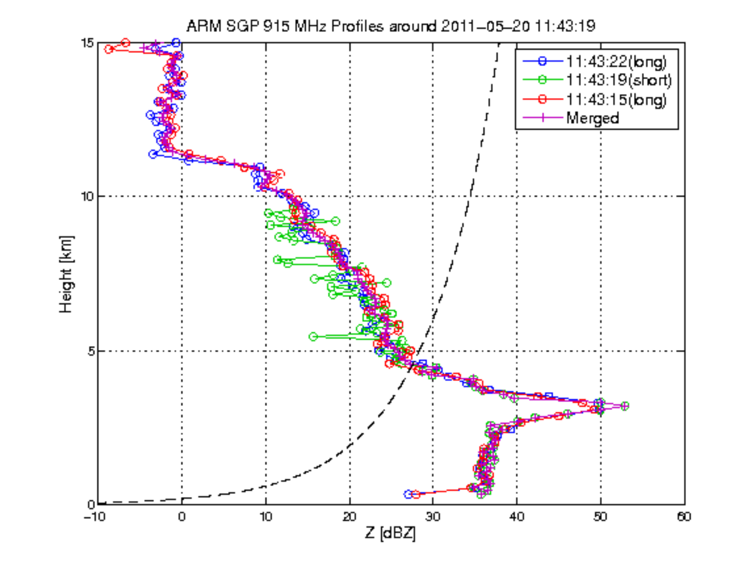
Calibrated reflectivities





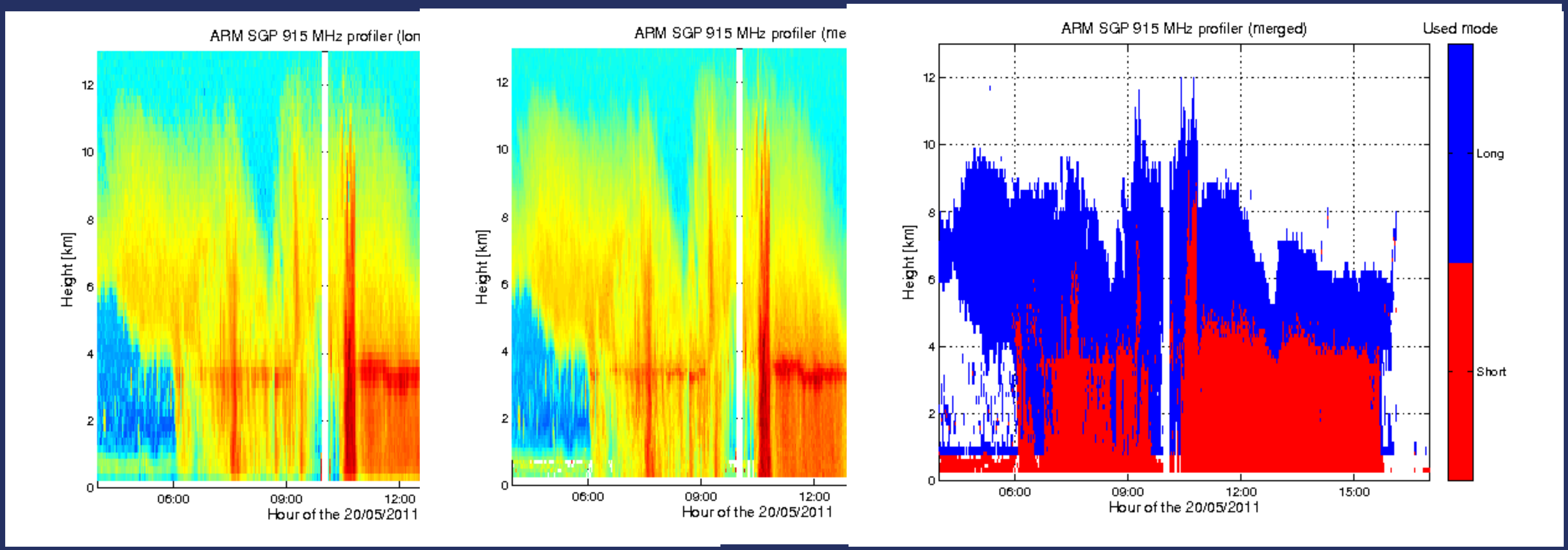
- Z_{SM} and Z_{LM} correspond well, but some differences:
  - Z_{SM} fall in noise level at low height (about 6 km)
  - bright band better resolved by higher resolution of SM
- Merging of modes to combine the advantages of both

Merging of the modes: methodology



- An interpolation of Z_{LM} at SM height resolution would only produce a smoother version of Z_{SM}
- The merged product is defined as:
  - equal to Z_{SM} when $SNR_{SM} > 5$ dB
  - Z_{LM} otherwise

Merging of the modes: results



- Merged Z has the high resolution of SM at low and medium range and long range of LM
- The maximum height at which Z_{SM} can be used is varying and can be as high as 8 km in convective portion

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Conclusions

- The reconfiguration of WP made them adapted to the measurements of precipitation
- Their wide beam is not optimal and can lead to a significant widening of spectra → overestimation of noise level → underestimation of SNR
- The proposed method makes use of the noise estimates from clear air gates and leads to a considerable improvement of SNR in strong portions of the signal

Conclusions

- Good comparison of WP measurements with 2DVD computed reflectivity → calibration of the WP
- Method proposed to merge the two modes and keep their both advantages: high resolution and long range

Future work

- Differential attenuation between K_a and WP
- Application of the dual frequency technique for rain rate retrieval

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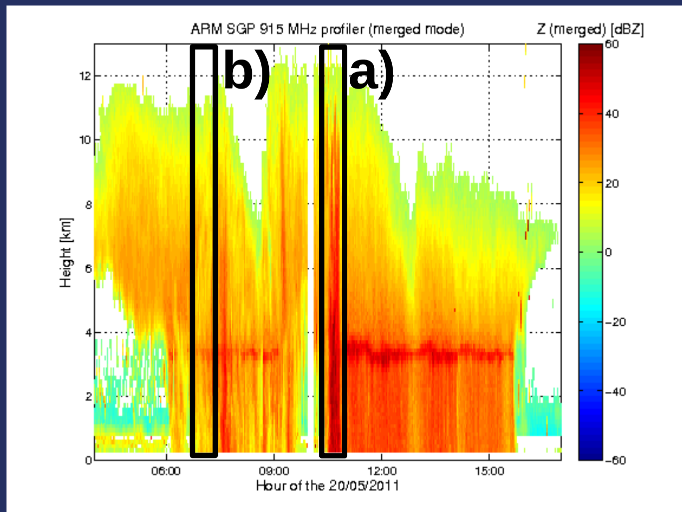
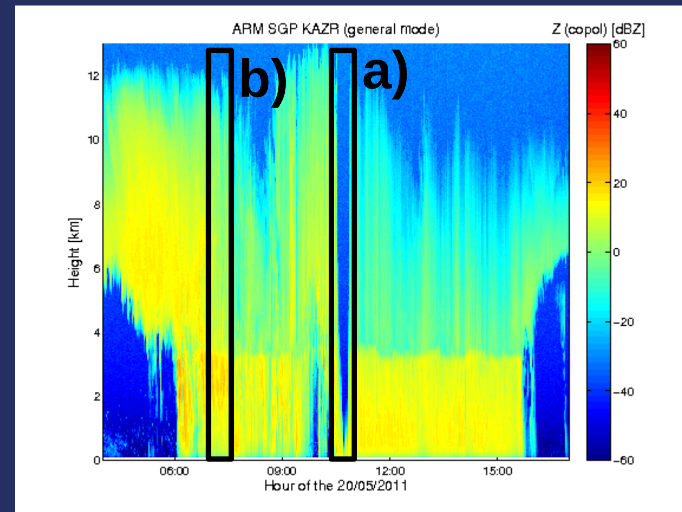
Thanks for your attention

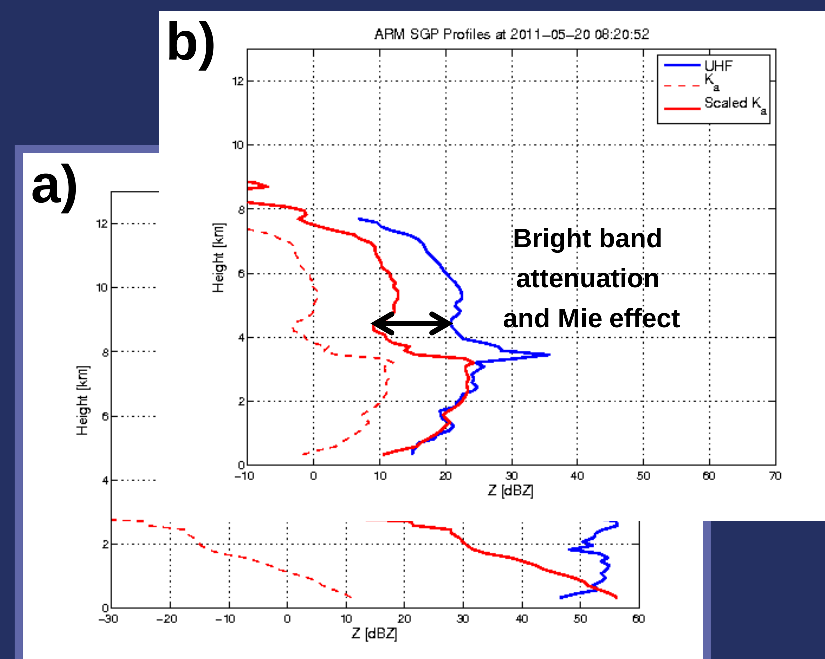
Future work



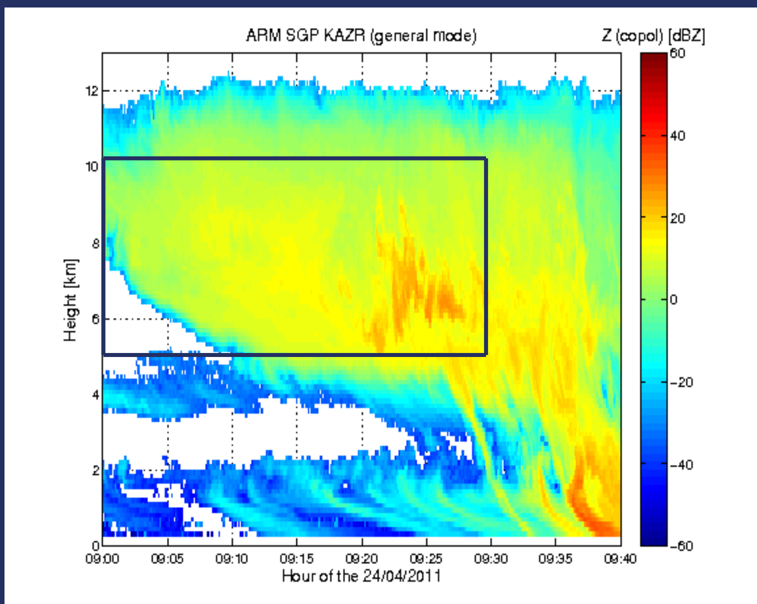


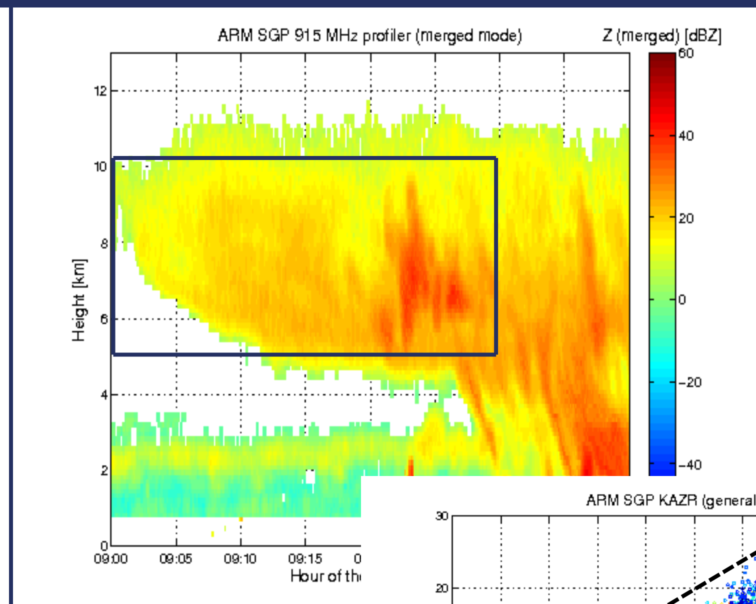
Application of the dual frequency technique for:

- rain studies
- bright band studies
- Ice studies
- Radome attenuation estimation



35 GHz radar calibration?





- 10 dB difference due to non Rayleigh effect in ice cloud?