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A new approach for the estimation of rain-drop size-distributions using Doppler lidar and cloud radar

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1 Introduction

New commercially available scanning lidar and radar systems allow new combined measurement approaches. Due to the different wavelengths, the instruments are sensible to atmospheric scatterers of different sizes. We present an idea for an advanced application of these measurement differences.

During COPS campaign (Wulfmeyer et al., 2008) a 2 µm Doppler lidar (Windtracer) and a 35.5 GHz cloud radar (Mira 36-S) were collocated and performing a synchronized scan pattern. Here we show results from vertical stare measurements during rain episodes.

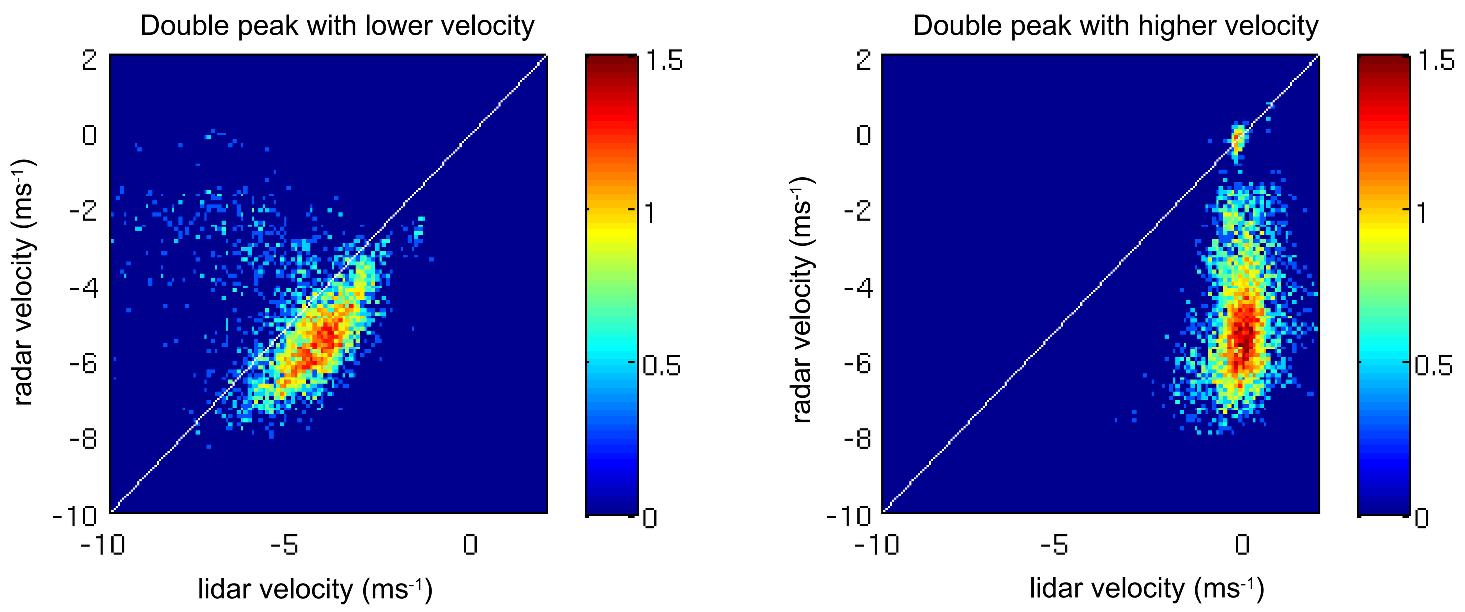

Fig. 1: Comparison of approx. 10.000 simultaneously measured vertical velocities. The lidar is able to detect 2 peaks (Fig. 2) in the Doppler spectra, a rain peak (left) and an air peak (right); the colour scale is in logarithmic units.

2 Methode

Intervals with rain were detected using a Joss-Waldvogel Disdrometer, which was collocated to the instruments. Occuring double peaks in the lidar power spectra were detected using a two component Gauss model (Figs. 1 and 2). Applying a Rayleigh scattering weighted velocity distribution to the radar (Eq. 1 with velocity v, droplet radius D and number of droplets N) and an optical scattering weighted velocity distribution to the lidar (Eq. 2), it is possible to explain the differences in the two detected velocities (Fig. 1 left). Using the two velocities from radar (v_{radar}) and lidar (v_{lidar}) and the approach of Atlas et al. (1973) for the terminal fall velocity (Eq. 3), it is straight forward to estimate parameters μ and λ from a Gamma distribution of the rain-drop size (Eq. 4).

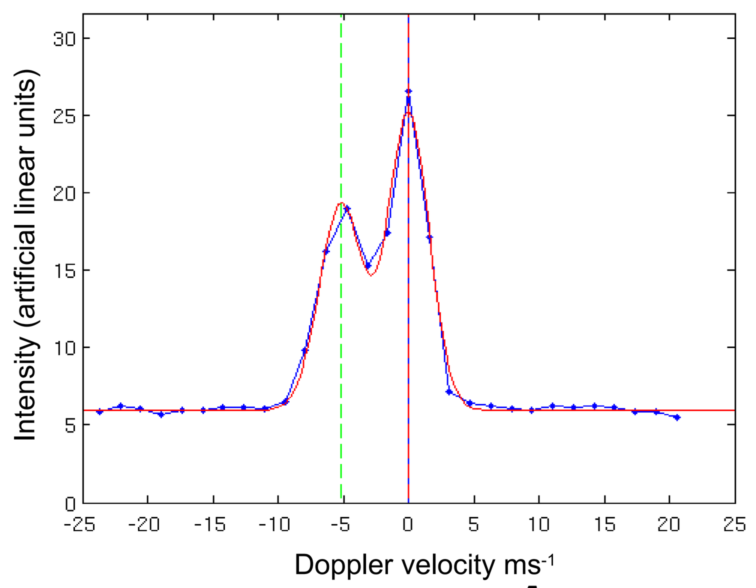

Fig. 2: Double peaks in the lidar Doppler spectra during rain: measured spectra (blue), Gauss fit (red) and two maxima indicated by vertical green and red line. One peak has always a velocity lower than zero, the other approx. zero.

$$v_{radar} = \frac{\int v(D)dZ}{\int dZ} = \frac{\int v(D)\cdot N(D)\cdot D^6 dD}{\int N(D)\cdot D^6 dD} \qquad [1]$$

$$v_{lidar} = \frac{\int v(D)dB}{\int dB} = \frac{\int v(D)\cdot N(D)\cdot D^2 dD}{\int N(D)\cdot D^2 dD} \qquad [2]$$

$$v(D) = 9.65 - 10.3\exp(-0.6\cdot D) \qquad [3]$$

$$N = N_0 D^{\mu}\exp(-\lambda D) \qquad [4]$$

3 Results

From 361 examined one minute rain intervals 111 fulfilled hard criteria, concerning distinguishability of the lidar double peaks and low velocity fluctuations over the considered range gates and time interval.

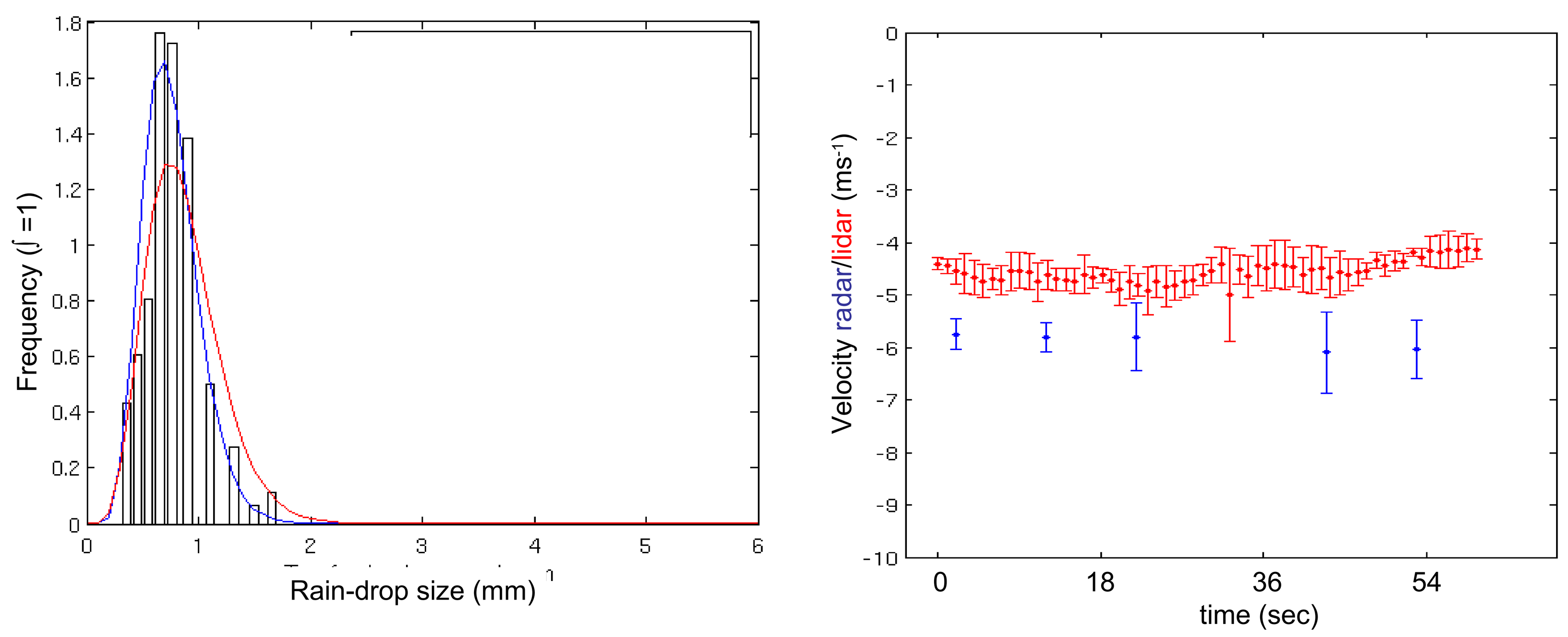

Fig. 3 (left): Rain-drop size-distribution from Disdrometer (bars), estimated distribution from moments of the Disdrometer measurement (blue) and from estimation using the radar and lidar velocities (red). Fig. 3 (right): vertical velocities associated to the spectra.

A comparison to the rain distribution measured at the ground using the Disdrometer (regarding a time difference of 2 minutes) shows, that

- in 52% is the difference between the first moments less than 0.2 mm
- in 89% is the difference between the second moments less than 0.1 mm²
- in 50% both criteria are fulfilled

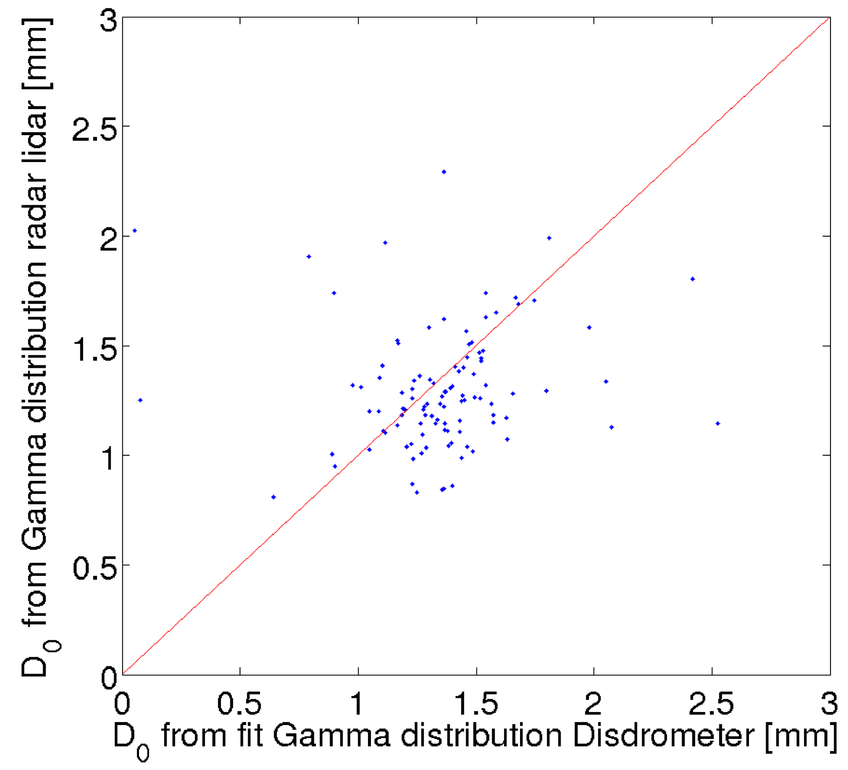

Fig. 4: Comparison between $D_0 = \frac{\mu+4}{\lambda}$ from Disdrometer and estimated from the radar lidar combination.

4 Discussion

Considering the uncertainties in measuring vertical velocities using remote techniques like radar and lidar, the results from the comparison of estimated rain-drop size-distributions with an in-situ method are satisfying. For Gamma distributed rain-drop sizes the spectra behave quite similar (Fig. 3). The described approach is promising to provide an easy way to measure rain-drop size-distributions in greater altitudes and even of rain, that doesn't reach ground.

References:
D. Atlas et al. Doppler Radar Characteristics of Precipitation at Vertical Incidence, *Rev. Geophys. Space Phys.* 11, 1–35, 1973.
V. Wulfmeyer et al. The convective and orographically-induced precipitation study. *Bull. Amer. Meteor.Soc.*, 2008.

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