Priority Program SPP 1167 of the DFG

Convective and Orographically Induced Precipitation Study

Karlsruhe Institute of Technology

Simultaneous Wind Measurements with Lidar and Cloud Radar: Complementarity and Quality Check

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IMK´s scanning ground based remote sensing instruments: Cloud radar MIRA36-S & Doppler lidar WindTracer

Fig. 1.1 MIRA36-S cloud radar

Wavelength:		8.44 mm (35.5 GHz)
Pulsewidth:		200 ns
Pulse repetition frequency:		5 kHz
Sampling rate:		50 MHz
Power (average/peak):		30 W / 30 kW
Rangegates:		512
Scanning:	azimuthal	-183 … 183°
	elevational	-45 … 45°
	velocity	up to 10°s^{-1}
Velocity (unambiguous) :		±10 ms^{-1}

Fig. 1.2 Doppler lidar WindTracer

Wavelength:		2.0225 µm
Pulsewidth:		425 ns
Pulse repetition frequency:		500 Hz
Sampling rate:		100 MHz
Average Power:		1 W
Peak Power:		4.5 kW
Rangegates:		100
Scanning:	azimuthal	0 … 360°
	elevational	-5 … 185°
	velocity	0.1 … 25°s^{-1}
Velocity bandwidth:		50 MHz (± 20 ms^{-1})
		100 MHz (± 40 ms^{-1})

Fig. 1.3a and b Instruments location during COPS campaign.

The Doppler lidar and the cloud radar were both located aside on Hornisgrinde mountain during the COPS campaign. Both participated in the coordinated scan strategy optimized to get best synergistic measurement data from all scanning remote sensing instruments at Supersite H.

The strategy offered also free time slots which were used to apply simultaneous scan patterns to Doppler lidar and cloud radar dynamically adapted to current wind situation. Apart from small coordination errors and problems with synchronous starting a common scan pattern was successfully tested.

Comparing VAD velocities

Suitable scanning for using VAD algorithm was performed by both instruments during 40 measurement days. Within intervals of 15 minutes synchronous measured VAD velocities for height steps of 50 m between ground and 8000 m were selected. Horizontal velocities were removed in case of large rms deviations (20 % or 1 ms^{-1} for velocities below 5 ms^{-1}) between the measured radial velocities and the fit. It can be shown, that the lidar typically delivers data of sufficient quality in the first 2000 m above ground, whereas the radar obtains data up to 8000 m.

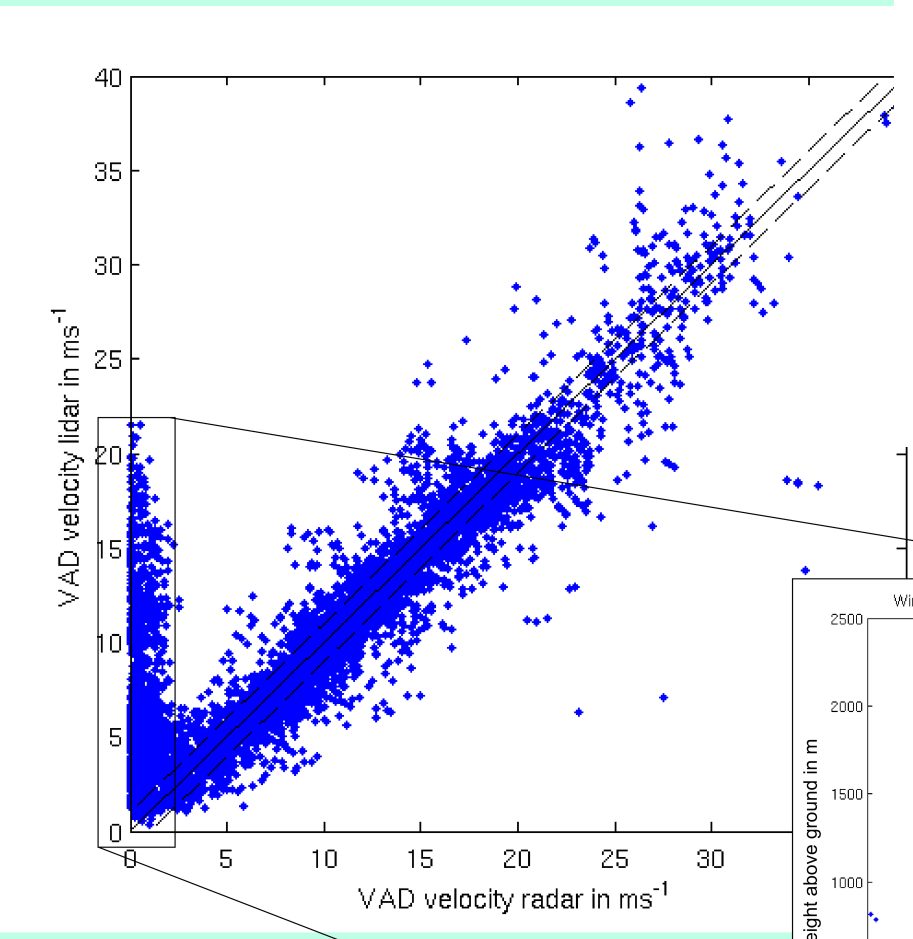

Fig. 2.1a (above) VAD velocities of spatial-time-intervals measured synchronous by both instruments (in total 1 % of the defined intervals).

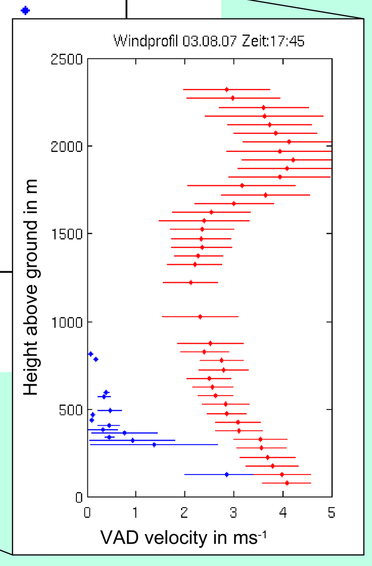

Fig. 2.1b Example of the radar ground clutter problem (blue), the lidar is able to measure the true wind profile (red).

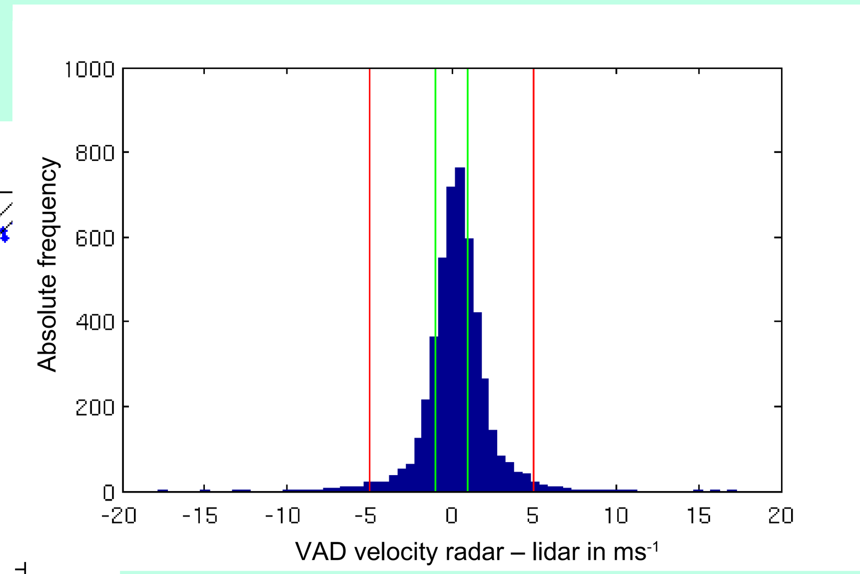

Fig. 2.2 (above) Distribution of the differences between VAD velocities determined by radar and lidar, ground clutter corrected. The distribution is not exactly symmetric, a median towards higher radar velocities of 0.33 ms^{-1} occurs.

43.3 % of the VAD velocities show differences below 1 ms^{-1}, 12.1 % differences above 5 ms^{-1}. The comparison of the VAD velocities can be used to find typical measurement problems, e.g. radar ground clutter.

The instruments have their optimal operation conditions under different atmospheric situations due to the two wavelengths used. During dry and cloudless situations or gentle cumulus clouds the lidar performs very well (Fig. 2.4 a). On the other hand, when there are deep clouds or fog the radar operates under optimal conditions (Fig. 2.4b). During seven days, selected for their representativeness, lidar measurements are available in 4.0 % of the total data (all spatial-temporal intervals), whereas radar measurements are available in 7.1 %.

Therefore combined VAD velocity profiles can lead to extended wind information in time and/or height. Fig. 2.3 shows an example for a day with dissolving clouds, Fig. 2.4d for a situation with stratocumulus clouds.

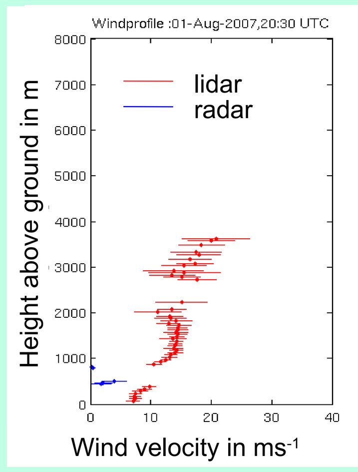

Fig. 2.4a dry, clear air – optimal lidar conditions

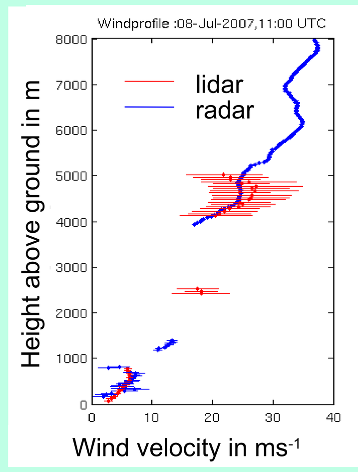

Fig. 2.4b measurements in clouds – optimal radar conditions, lidar signal is extinct soon

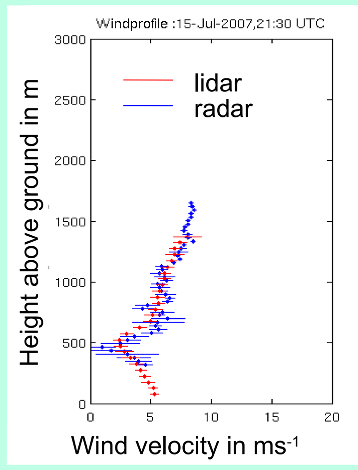

Fig. 2.4c good conditions for both instruments – profiles overlap

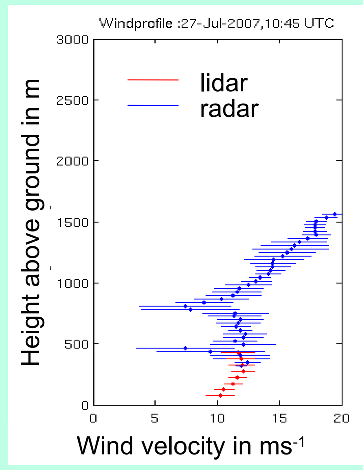

Fig. 2.4d complementary conditions

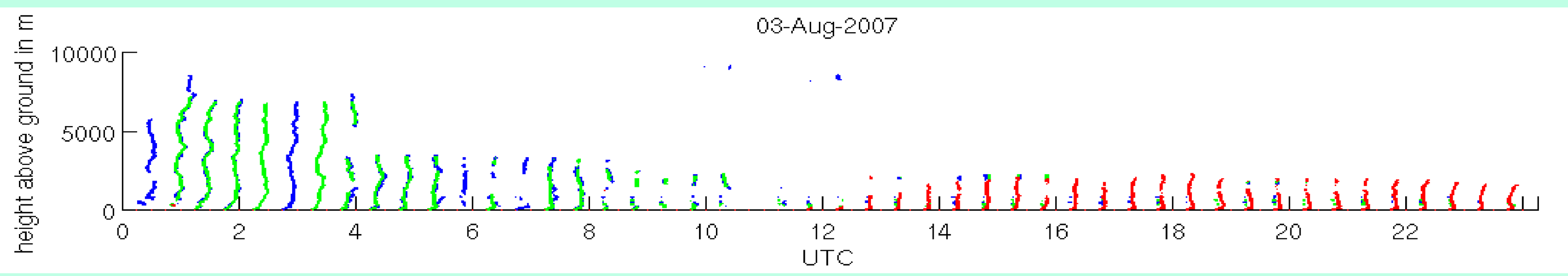

Fig. 2.3 Complementation of lidar (red) and radar (green and blue) wind velocity for a day with dissolving clouds. The figure shows calculated VAD profiles every 30 min.

Comparing direct measured vertical velocities

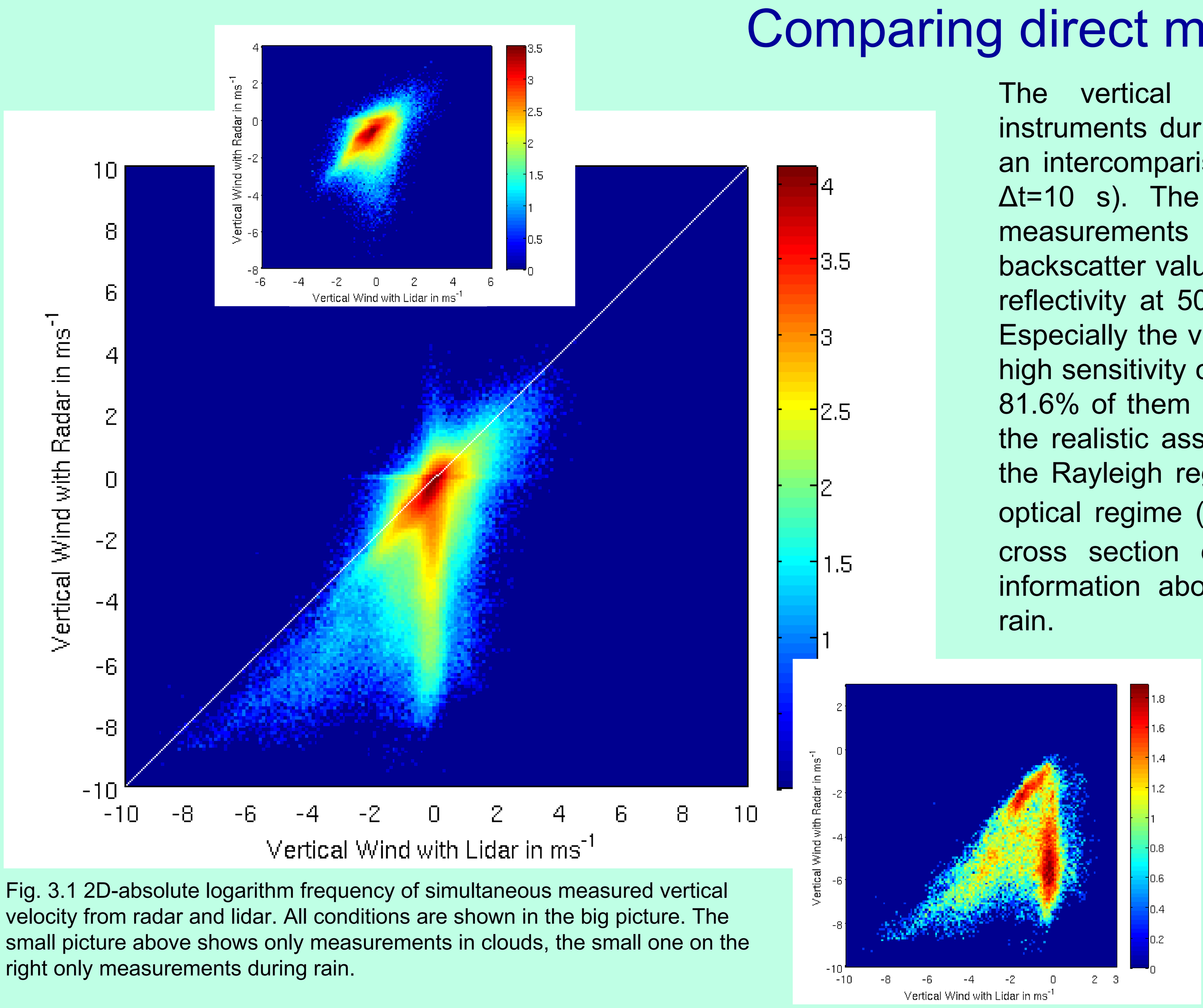

Fig. 3.1 2D-absolute logarithm frequency of simultaneous measured vertical velocity from radar and lidar. All conditions are shown in the big picture. The small picture above shows only measurements in clouds, the small one on the right only measurements during rain.

The vertical stare measurements from both instruments during 31 non continuous days, allows an intercomparison of vertical velocities (Δh=72 m, Δt=10 s). The data was distinguished between measurements in clouds (using a critical lidar backscatter value), during rain (using a critical radar reflectivity at 500 m above ground) or in clear air. Especially the velocity data during rain events show high sensitivity on the scatterers size (Fig. 3.1, right, 81.6% of them differ by more than 1 ms^{-1}). Using the realistic assumption, that the radar operates in the Rayleigh regime ($\lambda > r_{scatterer}$) and the lidar in the optical regime ($\lambda < r_{scatterer}$) one can use the different cross section dependencies to derive additional information about the dropsize distribution of the rain.

Combined variance profiles of vertical velocities are very useful in turbulence research but care has to be taken to avoid influence from atmospheric processes (e.g. falling scatterers like droplets) differently detected by lidar and radar (Fig. 3.2).

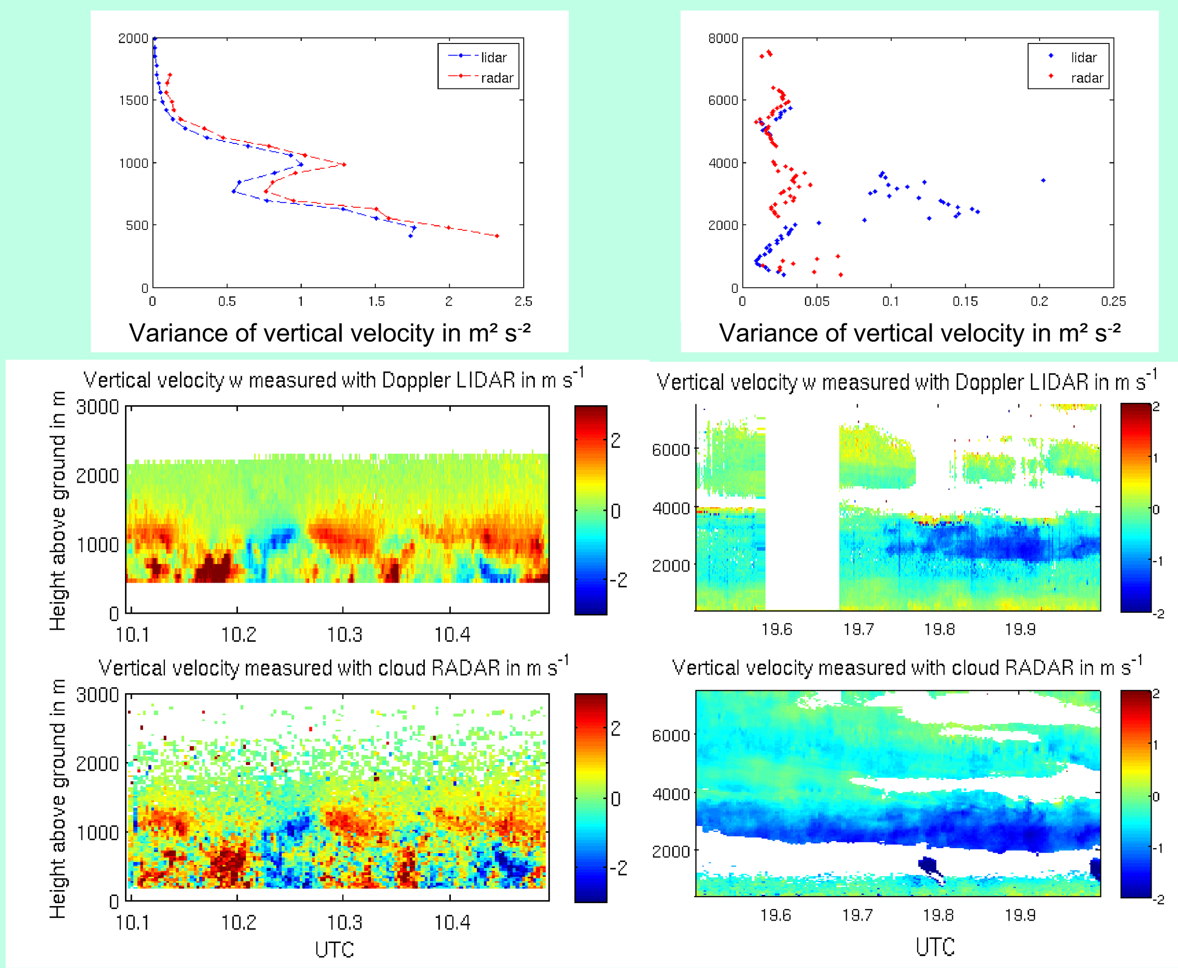

Fig. 3.2 a and b Variances of the vertical velocity measured by lidar (blue + middle) and radar (red + bottom). A coincident or complementary behaviour depends on the chosen interval. Fig. a (left) shows a turbulent boundary layer in which both instruments measure the same structures, Fig. b (right) shows a situation were the different scatters lead to different velocity measurements.