A comparison of selected vertical wind measurement techniques on basis of the EUCAARI IMPACT observations

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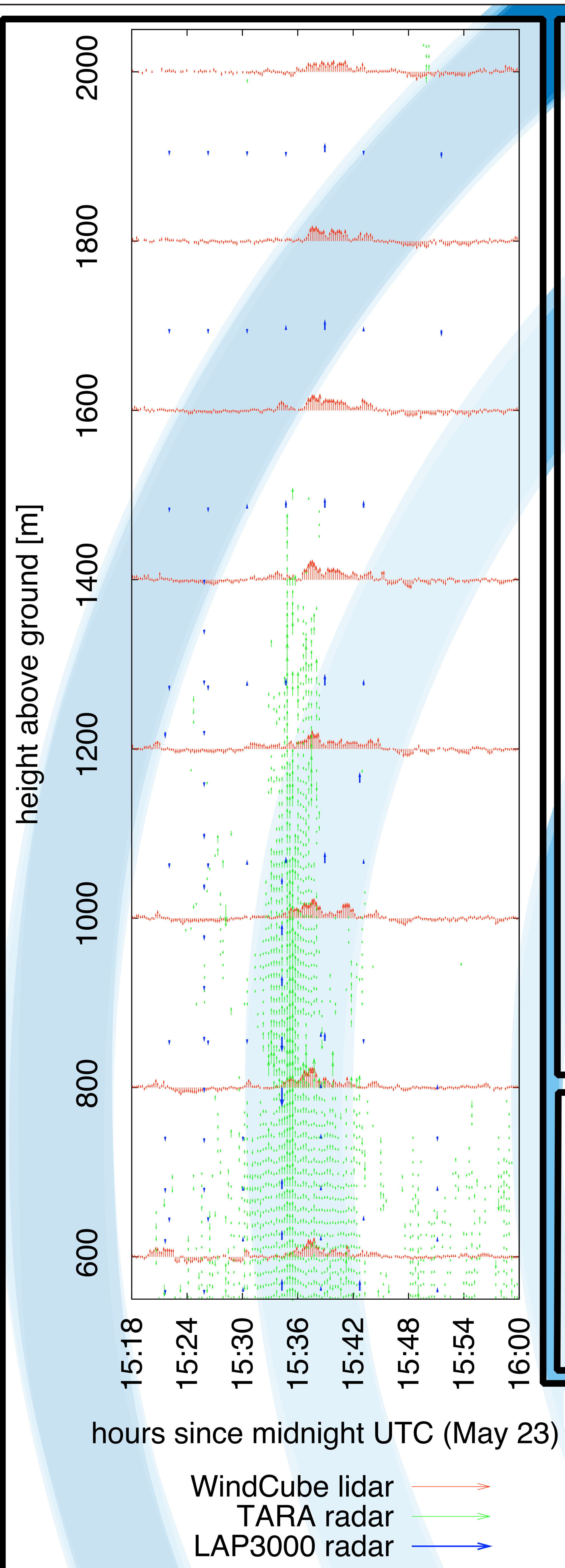

	TUDelft TARA S-band TRansportable RAdar	Vaisala LAP-3000 radar profiler (KNMI)	Leosphere WindCube WLS70 lidar	Cabauw Tower Gill R3 sonic anemometers (KNMI)	ACTOS platform Solent HS sonic anemometer (IfT)	SAFIRE ATR-42 radome 5-hole pressure probe
						
principle of operation	active remote sensing using radar (S-band 9.1 *cm*/3.3 *GHz* and UHF 23 *cm*/1.29 *GHz* for TARA and LAP3000, respectively), vertical velocity estimation based on analysis of Doppler shift caused by the displacement of spatial irregularities of atmospheric refractive index (related to variations in air temperature and humidity)		active remote sensing using infrared laser pulses (1.55 μm); vertical wind estimated using Doppler shift analysis of the signal back-scattered by particles suspended in the air (bigger in size than 500*nm*)	determination of the effect of the wind on transit times of acoustic pulses transmitted in opposite directions from two arms of the instrument		five pressure sensors on the radome of the aircraft nose measure the air velocity in the aircraft reference frame; the wind vector is estimated by subtracting the aircraft velocity with reference to the ground (from navigation system)
resolution and range	raw data have 3 *s* resolution, in the current study averaged over 18 *s*, altitude range: 200–15000 *m* (function of atmospheric conditions), sample volume increases quadratically with height	vertical mode measurement every 6 minutes (lasting about 20 *s*), two modes of operation: low and high, weighting the vertical velocity over 100 *m* and 400 *m*, respectively	one value per 10 *s* (IMPACT: 20 *s*) – average over 1 *s* (1.5 *s*), altitude range: 100–2000 *m* (400–2200 *m*) with 50 *m* (200 *m*) step, sample volume of 250 cm^3	10 *Hz* raw data, anemometers mounted at: 3, 60, 100 and 180 *m*, sample volume of 1000 cm^3	one value per 0.1 *s* (averaged from the raw 100 *Hz* data), with typical ACTOS speed this corresponds to 1.5 *m* spatial resolution	limited to 25 *Hz* by the frequency of the inertial navigation system, 10 *Hz* data used for the current study (corresponding to $\sim$ 10 *m* spatial resolution)
accuracy	0.3–0.8 *m*/*s* (estimate for the IMPACT data)	$<$ 1 *m*/*s* (manufacturer figure for horizontal wind)	$<$ 0.2 *m*/*s* (estimated from sample volume length)	$<$ 0.02 *m*/*s* (not counting tower-mounting sourced effects)	determined by the accuracy of the aicraft navigation system (GPS/INS) which amounts to 0.2–0.5 *m*/*s* (significant for time scales larger than the shortest mode of the aicraft motion)	
weather dependency	in presence of precipitation only hydrometeor fall speed is measurable (ie. no information on vertical wind), altitude range depends on atmospheric conditions, no information under very calm conditions (the technique relies on presence of inhomogenities of the air thermodynamic parameters)		hydrometeor fall speed is reported when precipitation is present, no data when the air is void of particles (eg. couple of hours after hard rainfall)	no data for rain events, results generally valid in fog/cloud	ACTOS is restricted to low wind ($<$ 5 *Bft*) and no overcast cloud conditions	no data under severe icing conditions or high water contents (system is equipped with a drainage allowing in-cloud operation),
other remarks	no information when the velocity is in range $\pm$0.2 *m*/*s* due to Doppler filtering strategy, vertical wind retrieved for the first time during IMPACT	the instrument and data processing techniques are based on NOAA design, the instrument is equipped with a radio-acoustic system capable of measuring temperature profile as well	prototype, IMPACT was the first deployment, the parameters of the final design might differ	redundant instrument needed on another mast arm to prevent discontinuities in dataset due to mast-caused airflow distortions, sonic anemometers/thermometers can measure (sonic) temperature as well	mounting on a helicopter-underhung platform results in a pendulum motion of the platform (filtering is feasible only for constant-altitude legs)	
typical applications	precipitation, cloud and boundary layer profiling (research)	monitoring (over hundred installations worldwide)	monitoring & research	monitoring of fluxes in the boundary layer	airborne boundary layer research	airborne research (200–7500 *m*)
references	Heijnen et al. (2000); Unal (2008)	Carter et al. (1995)	see poster XY75	Van Ulden and Wieringa (1996); Casso-Torralba et al. (2008)	Siebert and Muschinski (2001)	Lenschow (1986)

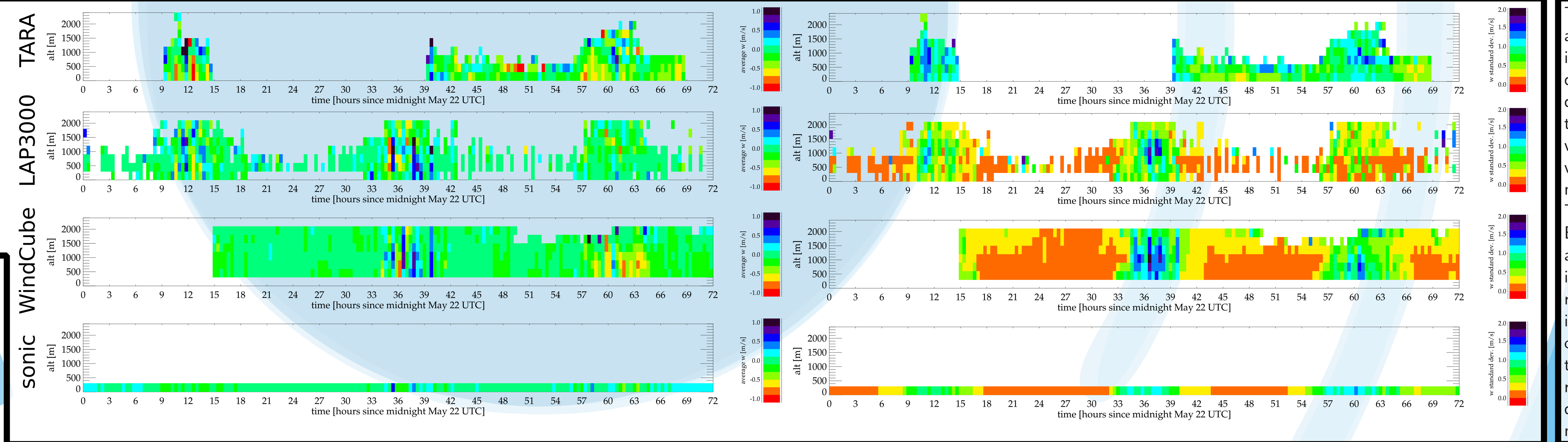

Figure 2

Mean vertical wind and wind standard deviation measured by: TARA & LAP3000 radars, WindCube lidar and the tower-mounted (180 m) sonic anemometer. Data are plotted as a function of height and time. Colour scale represent values of the parameters calculated from 24-minutes by 300-meters data subsets.

Figure 1

An example of the data used for calculating the statistics shown in Figure 2. Arrows represent vertical velocity (5 *m* on the height scale corresponds to 1 *m*/*s*).

The goal of the EUCAARI project is to study the aerosol - cloud - climate - air-quality interactions. The transformation of atmospheric aerosol particles into cloud droplets (activation) is a process linking aerosol characteristics, air dynamics and cloud microphysical properties. The spectrum of activated droplets depends on aerosol size and composition, and the supersaturation in the air. In convective clouds, the supersaturation is a consequence of the vertical motion of the air. Detailed knowledge of the spatial and temporal variability of the vertical wind (especially close to the cloud base) is therefore needed to accurately describe the activation process.

The techniques used for measurement of the vertical wind during the EUCAARI IMPACT campaign (May 2008, The Netherlands) are summarised above. Figure 2. presents a comparison of the results from four selected instruments. It covers statistics of the vertical velocity over a 0–2.4 *km* height range for a 72h long period of the month-long campaign. All considered instruments were located at the Cabauw site, less than 350 *m* apart from each other. An example of the data shown at the resolution used for calculation of the statistics is presented in Figure 1. The general consistency of the presented results confirms validity of the measurements while revealing hints on how the different temporal/spatial resolutions, and different principles of the measurement influence the results.

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