

Understanding the Complementarity of Wind Measurements from Co-located X-band Weather Radar and Doppler Lidar

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INTRODUCTION

- The measurement campaign took place in Vantaa, Finland from May 1st to November 30, 2021
- Objectives:
 - Compare agreement of co-located X-band radar and lidar Doppler velocity measurements
 - Quantify differences in Doppler velocity measurement performance in different weather conditions from surface measurements:
 - Horizontal visibility (FS11P)
 - Cloud base height (CL31)
 - Precipitation intensity (FS11P)

MAIN FINDINGS

- When Doppler velocity is available from both instruments, the measurements agree well ($R^2 = 0.96$)
- In clear air, Doppler lidar has good availability up to horizontal visibility of approximately 50km, after which availability reduces due to insufficient aerosol concentration
- In cloudy conditions, Doppler lidar beam cannot measure past cloud base
- X-band radar has good data availability in precipitation, while Doppler lidar signal is attenuated strongly beyond 2km in range
- In clear air, X-band radar exhibits seasonality in data availability, with good availability in summer due to insects

Figure: X-band radar and Doppler lidar at the measurement site. Photo by Raisa Lehtinen.



DATA AVAILABILITY AND HORIZONTAL VISIBILITY

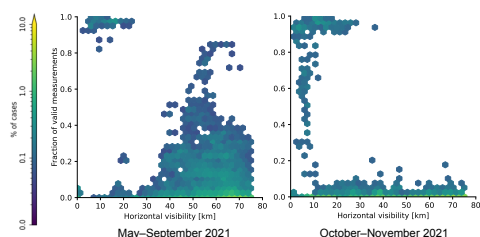


Figure: Availability of X-band radar Doppler velocity measurements against horizontal visibility. During summer, insect echo increases availability for radar in high visibility conditions.

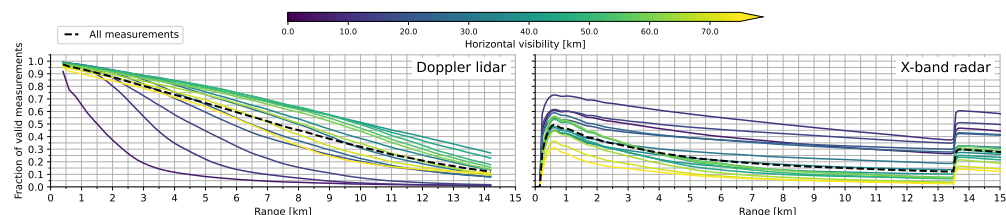


Figure: Availability of Doppler lidar and X-band radar Doppler velocity measurements as function of range, binned according to horizontal visibility.

Doppler lidar has low availability in low visibility conditions, and highest availability when horizontal visibility is 40-50km.

X-band radar has high availability in conditions with low horizontal visibility.

CASE EXAMPLES

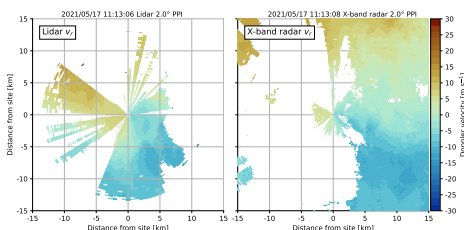


Figure: Thunderstorm and precipitation. X-band radar has measurements in rain, and Doppler lidar measures in clear air.

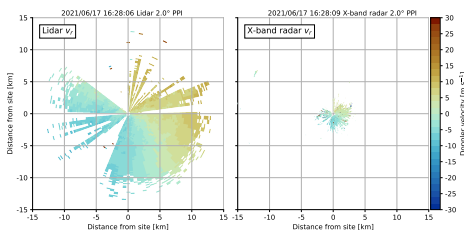


Figure: Clear air, no insects, horizontal visibility over 60km. X-band radar has very few measurements. Doppler lidar measures consistently up to approximately 10km.

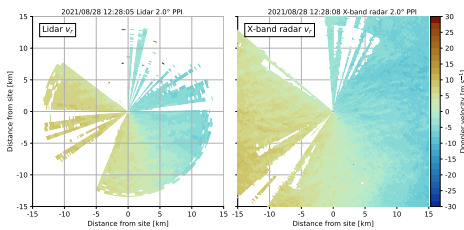


Figure: Clear air, insects, horizontal visibility appr. 45km. Both instruments measure consistently in the entire area.

DATA AVAILABILITY AND CLOUD BASE HEIGHT

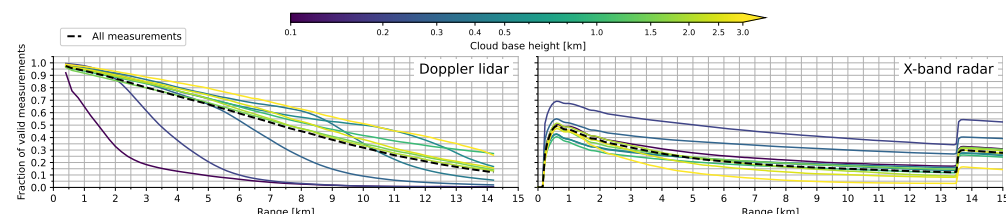


Figure: Availability of Doppler lidar and X-band radar Doppler velocity measurements as function of range, binned according to cloud base height.

Doppler lidar cannot measure past cloud base.

X-band radar has best data availability in low cloud base height conditions.

DATA AVAILABILITY AND PRECIPITATION

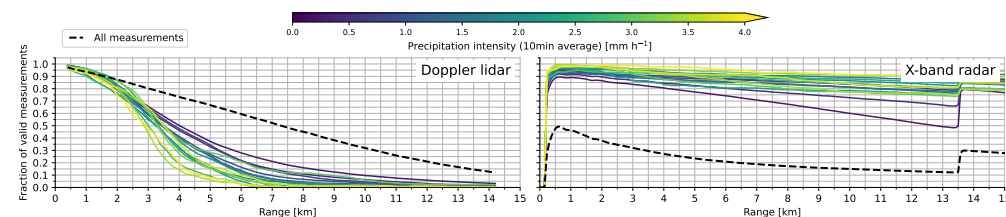


Figure: Availability of Doppler lidar and X-band radar Doppler velocity measurements as function of range, binned according to horizontal visibility.

Doppler lidar: any precipitation indicates low data availability beyond first kilometers in range.

X-band radar: any precipitation indicates high data availability.

INSTRUMENTS

Vaisala WRS400 X-band weather radar			
Radar Frequency	9.65 GHz	Pulsing scheme	dual-PRF
Half Power Beam width	0.95°	High/low PRF	2100/1400 Hz
Peak power (per channel)	400 W	Max. unambiguous velocity	32.66 m s ⁻¹
Pulse length, long	44 μs	Range resolution	75 m
Pulse length, short	1 μs	Max. unambiguous range	65 km
Noise reflectivity @ 1 km	-36.5 dBZ (long pulse) -21.9 dBZ (short pulse)	Number of pulses	64
		Elevation angle	2.0°

Vaisala WindCube400S Doppler wind lidar			
Lidar wavelength	1.54 μm	Range resolution	200 m
Laser divergence	33 μrad	Maximum range	14.3 km
Pulse duration	800 ns	Number of pulses	1000
Pulse repetition rate	10 kHz	Elevation angle	2.0°
Max. unambiguous velocity	30.4 m s ⁻¹	Ray angle resolution	3.0°

QUALITY CONTROL

- X-band radar: GMAP Doppler filter, dual-PRF correction and median filter.
- Doppler lidar: Instrument quality flag and CNR > -30 dB filter.

SURFACE MEASUREMENTS

- Surface measurements taken from FMI AWS at Helsinki Airport (WMO code 02974)
- Horizontal visibility from Vaisala FS11P sensor as 1 minute average
- Cloud base height from Vaisala CL31 ceilometer as 1 min average
- Precipitation intensity from Vaisala FS11P sensor as 10 min average

ACKNOWLEDGMENTS

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Read more about the results in article in Atmospheric Measurement Techniques Discussions