Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Testing the Performance of Radar and Lidar Vertical Wind Shear Detection at Frankfurt and Munich Airports

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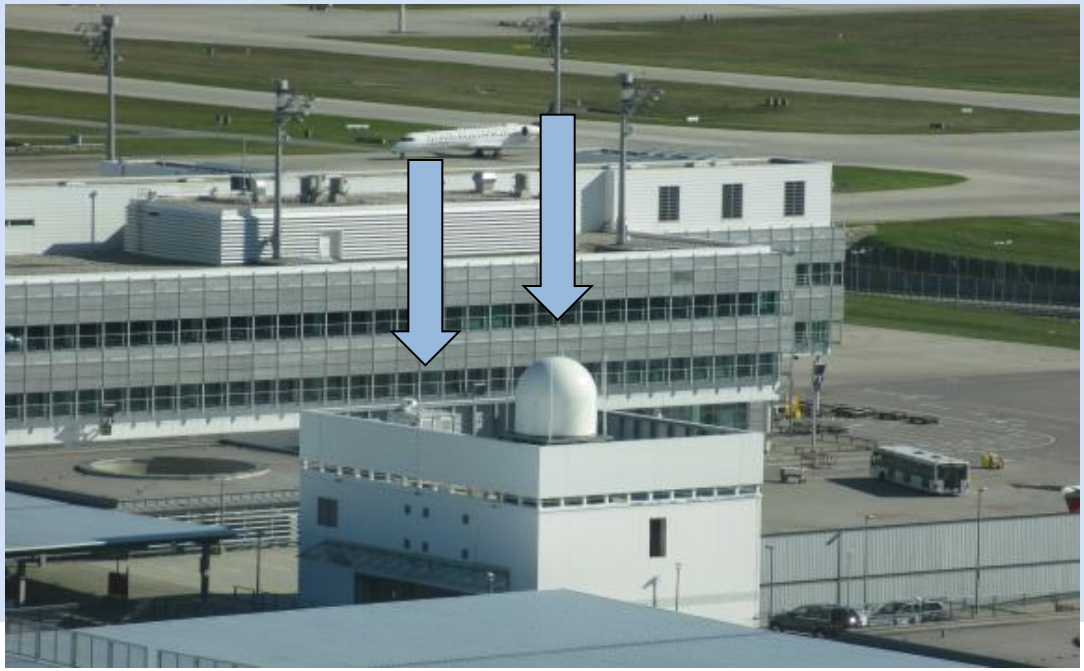
(Deutscher Wetterdienst / German Weather Service)



Lidar (left) and radar (right), Munich airport

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Wind shear present a great danger during aircraft landing and take-off

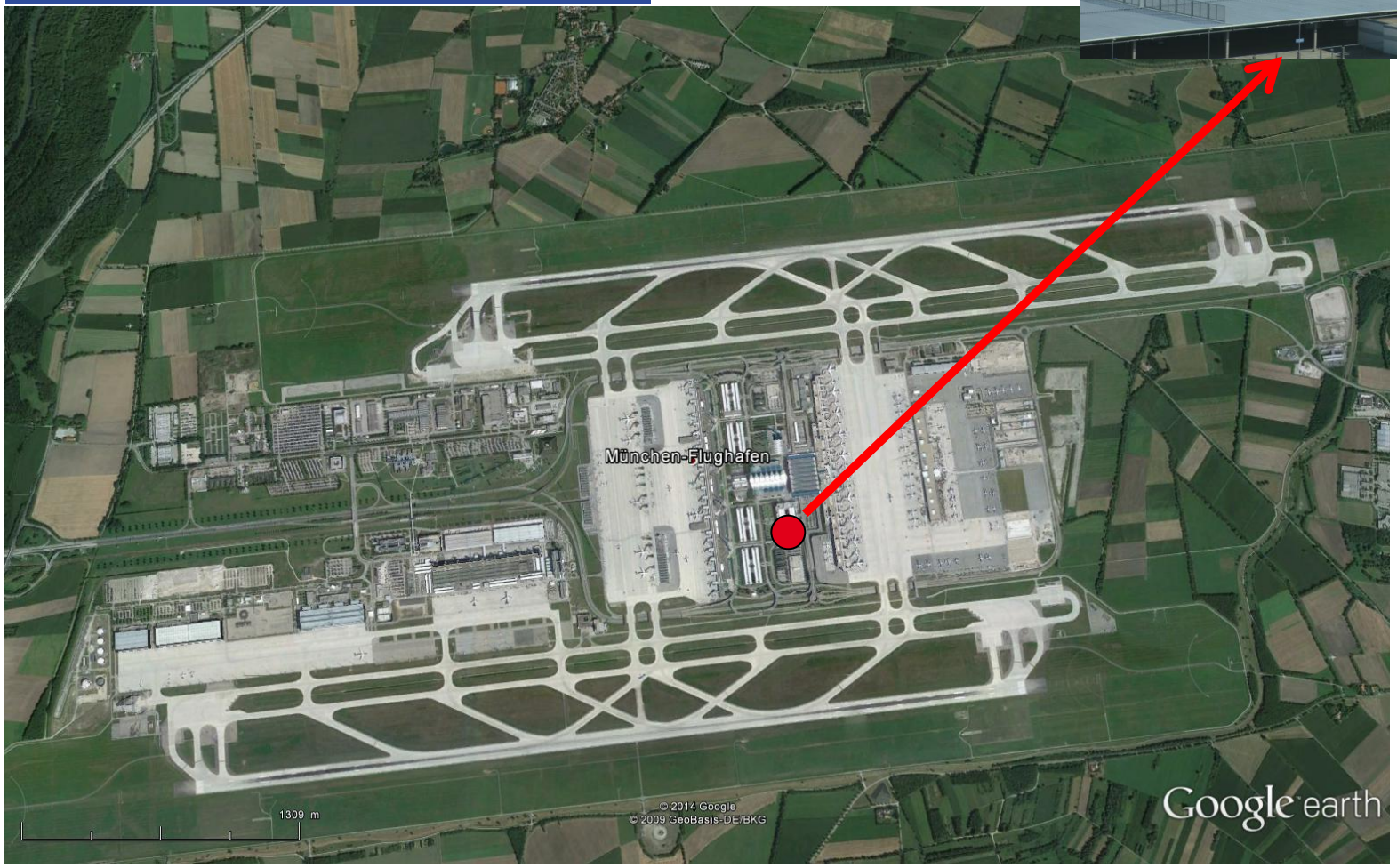
- Low-level Wind shear Alert System (LLWAS)
  based on X-band Doppler polarimetric radar and 1.6 µm Doppler lidar
  - Detection, quantification and alert on the presence of low-level wind shear
  - Independent on most weather situations
  - Automatic generation of warnings concerning ICAO every minute
  - Optimizing of aircraft staggering

Main purpose: Increase of air traffic safety.

2 System overview

Location

Munich Airport (MUC)



2 System overview

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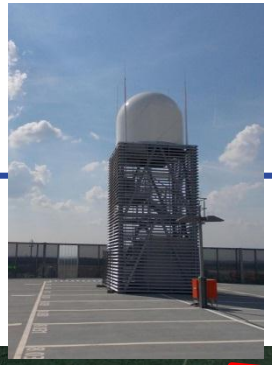


Frankfurt Airport (FRA)

Characteristics

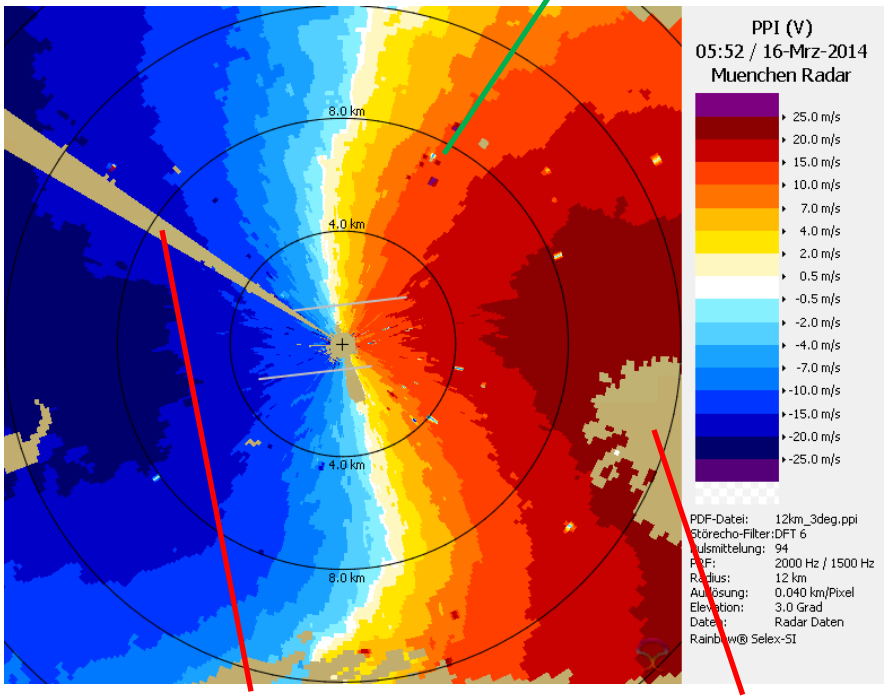
Parameter	Radar (SELEX Meteor 50DX)	Lidar (Lockheed Martin WTX WindTracer)
Wavelength	3.2 cm (X-band)	1.6 µm
Measurement indicator	Hydrometeors	Aerosols
Polarisation	Dual	Linear
PRF	2000:1600 Hz	750 Hz
Scan speed	18 deg/sec (3D scan up to 36 deg/sec)	14 deg/sec
Scan range	75 km	12-15 km
Radial resolution	0.15 km	0.10-0.12 km
Azimuthal resolution	1 deg	≈2.5 deg
Scan per minute	PPI @ 3 deg	PPI @ 3 deg
Scan once per 5 minutes	3D scan (11 PPIs 1.0-60.0 deg) PPI scan @ 150 km range @ 0.5 deg	3D scan (5 PPIs 1.5-20.0 deg) 1-2 RHI scans

Configuration in order to detect horizontal and vertical wind shear.

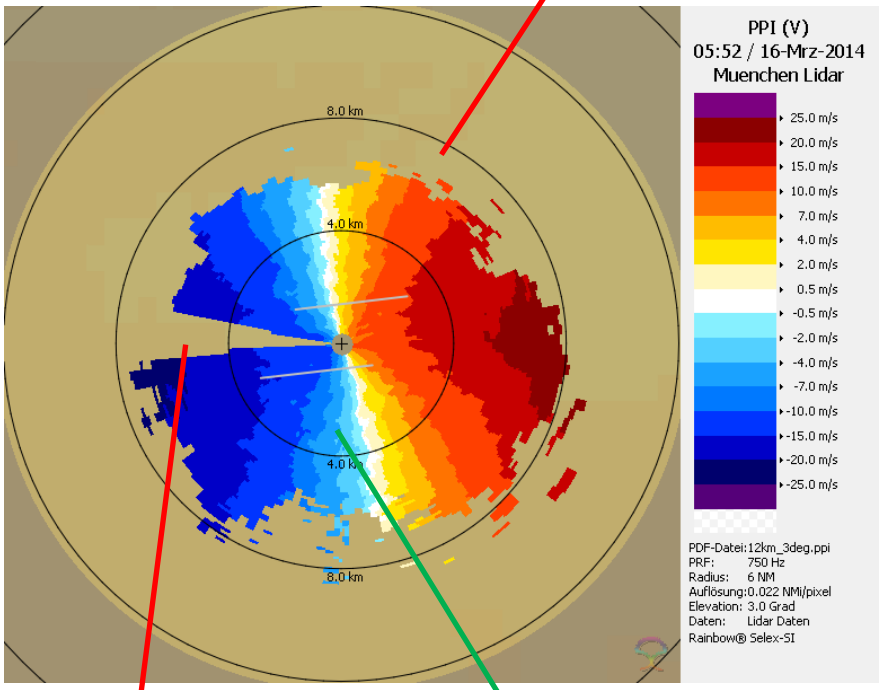
1) Filtering:

- Radar: ECLASS using DFT clutter filter, multi-trip-echo filter, interference filter
- Lidar: Modified wind standard deviation and SNR

Radar radial velocity



Lidar radial velocity



2) Vertical wind profile processing

- Volume Velocity Processing (VVP): Multivariate regression which fits a simple wind model to the observed radial velocities (Waldteufel & Corbin, 1979):

$$U(x,y,z) = u_0 + x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} + (z - z_0)\frac{\partial u}{\partial z}$$

$$V(x,y,z) = u_0 + x\frac{\partial v}{\partial x} + y\frac{\partial v}{\partial y} + (z - z_0)\frac{\partial v}{\partial z}$$

$$V_r = (w_0 + W_{final})\sin\theta + u_0\cos\theta\sin\Phi + v_0\cos\theta\cos\Phi$$

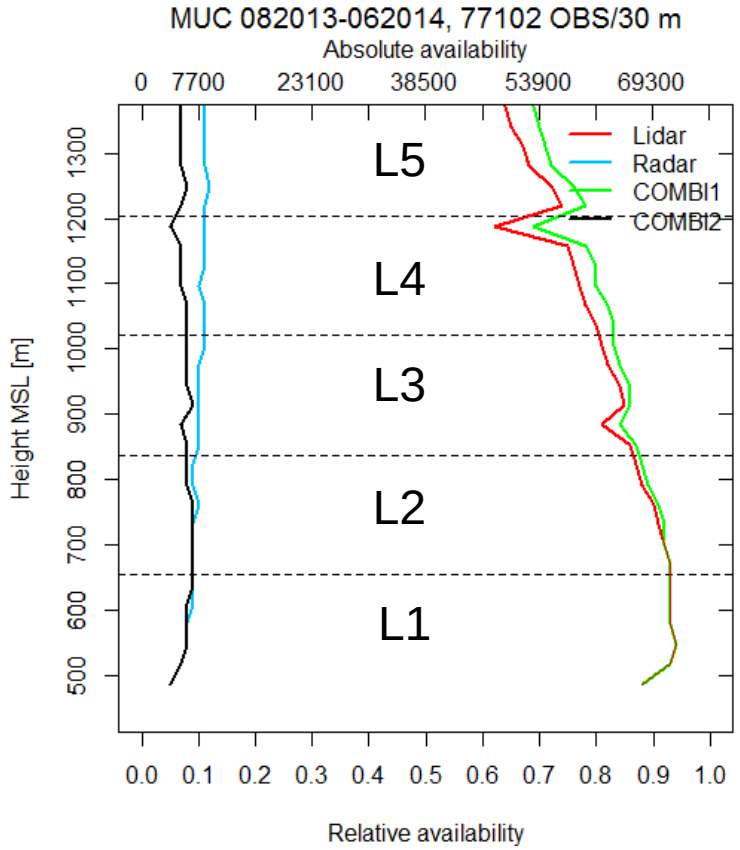
U,V,W: local wind components, u_0,v_0: wind components at the radar/lidar center, du/dx: partial derivates of the wind field at the center, z_0: height of interest, Φ: azimuth angle, θ: elevation angle

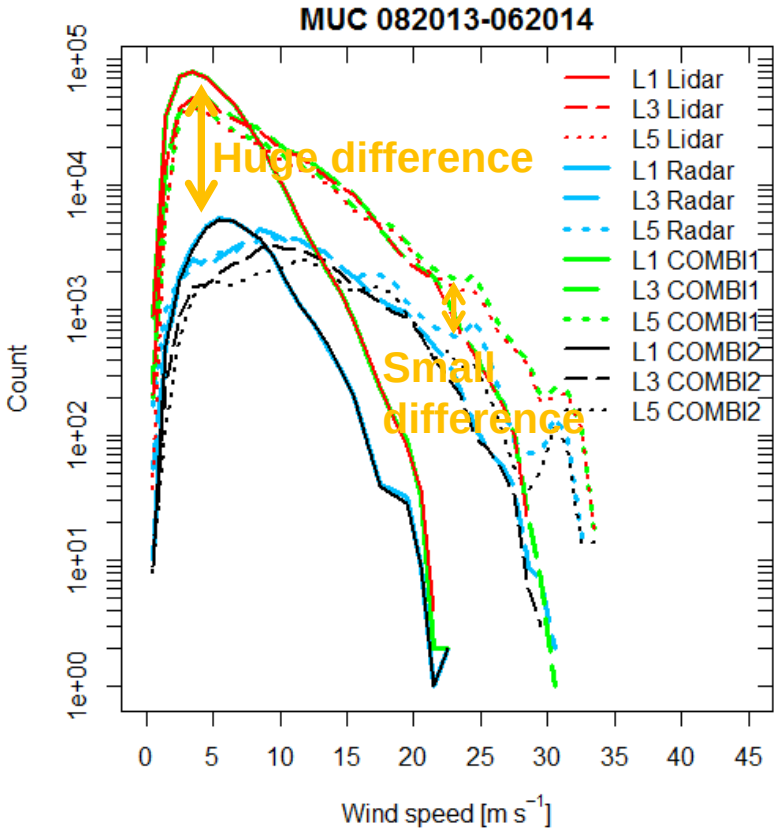
- Wind information Δz = 100 ft (approx. 30 m), Δt = 5 min
- Merging: depending on the count and variance of single measurements

3) Vertical wind shear detection

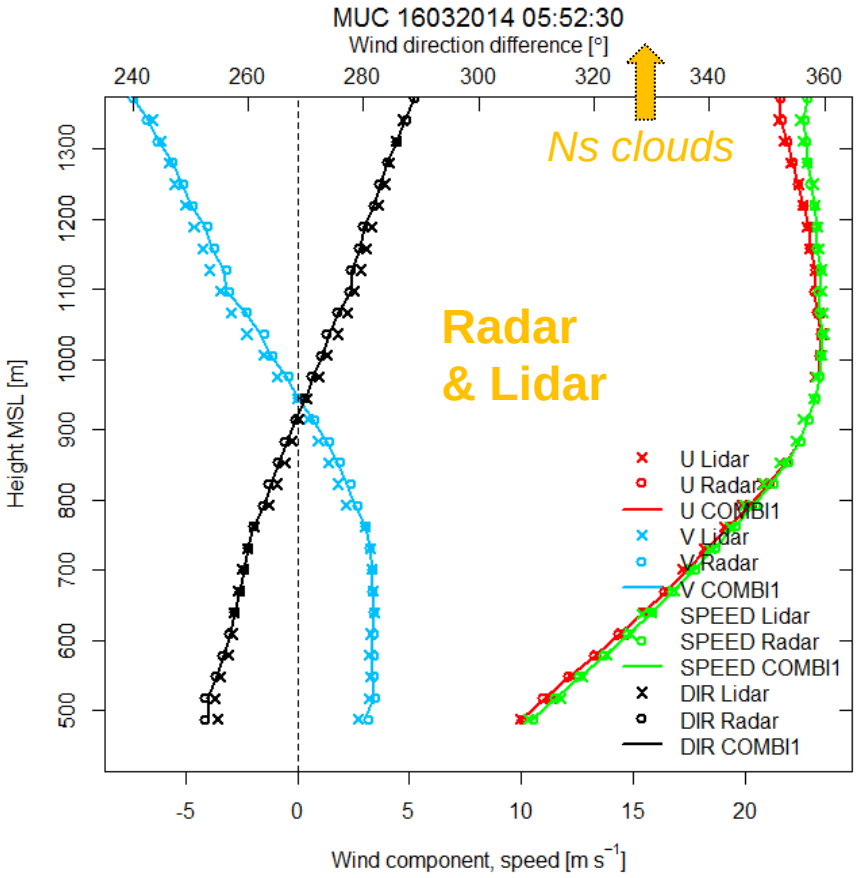
- Thresholds:
  - 5 kt/100 ft (moderate), 9 kt/100 ft (severe) until 1600 ft (ICAO)
  - adaption will be based on absolut wind speed
- Events Aug 2013 - June 2014: 344 (832) moderate, 2 (6) severe for FRA (MUC)

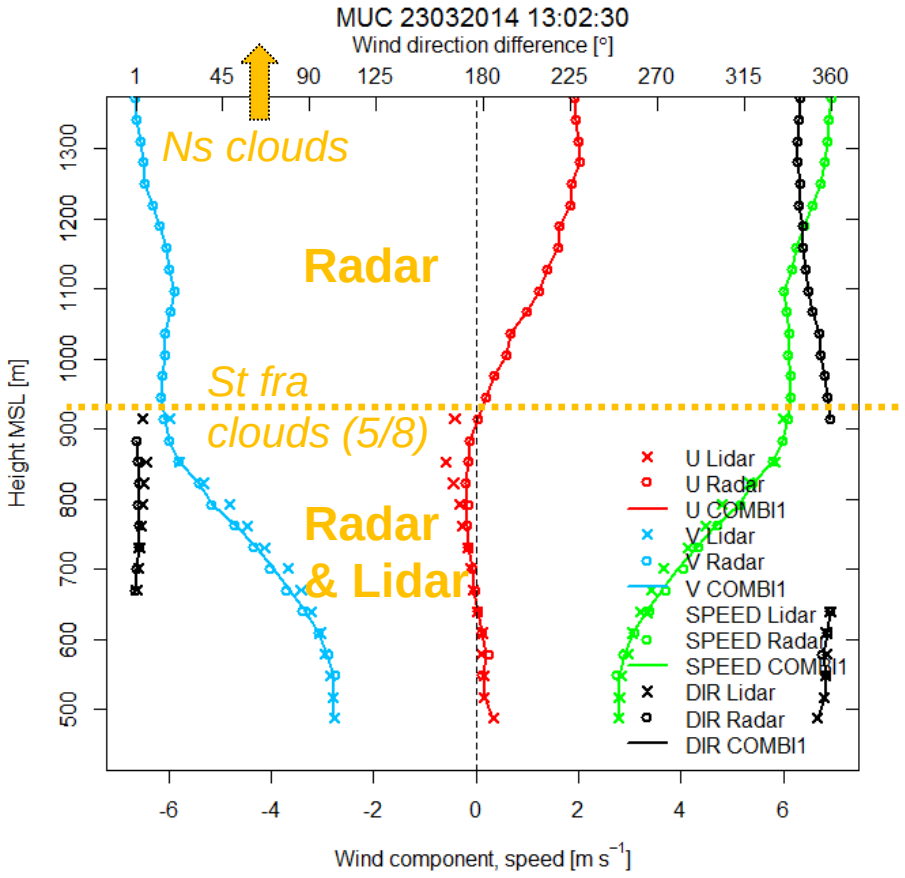
- Up to 500 m AGL lidar data are available in about 80%-90% on average (left panel)
- The fraction of radar retrievals increases significantly with increasing wind speed (right)





- Drizzle lead to radar and lidar wind detectivity within the whole profile (left panel)
- As a fact of St fra clouds lidar impulse do not transmit about 950 m MSL (right)





Baseline of quality control, verification: Overlapping between radar and lidar wind measurements.

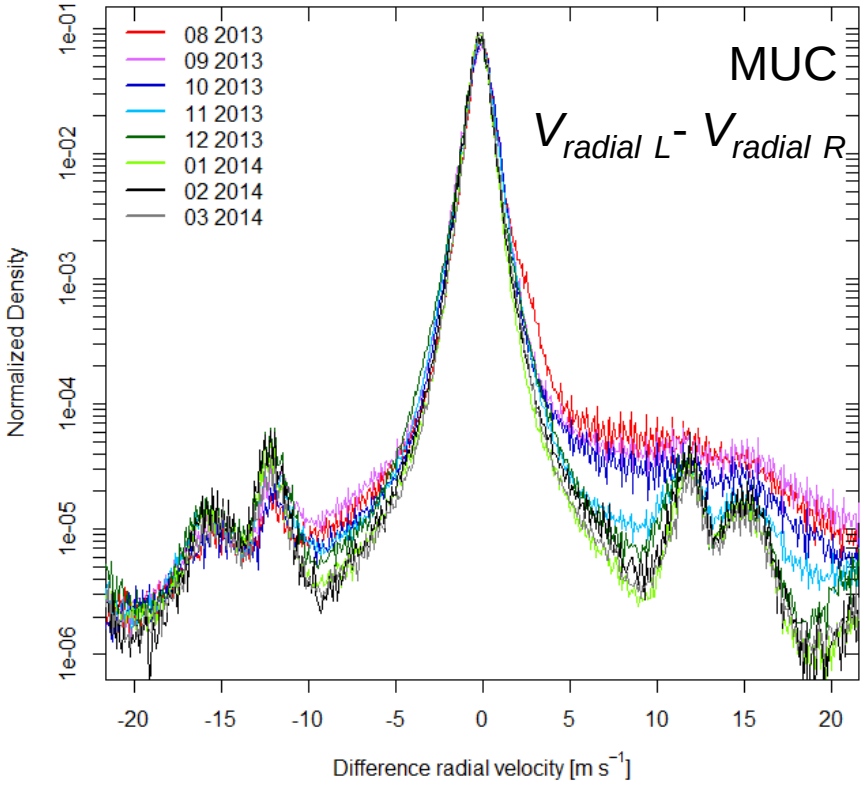
		Intensity of returned signal	
		high	small
Velocity standard deviation	high	Lidar or Radar	Neither Lidar nor Radar
	small	Lidar or Radar	**Lidar and Radar**

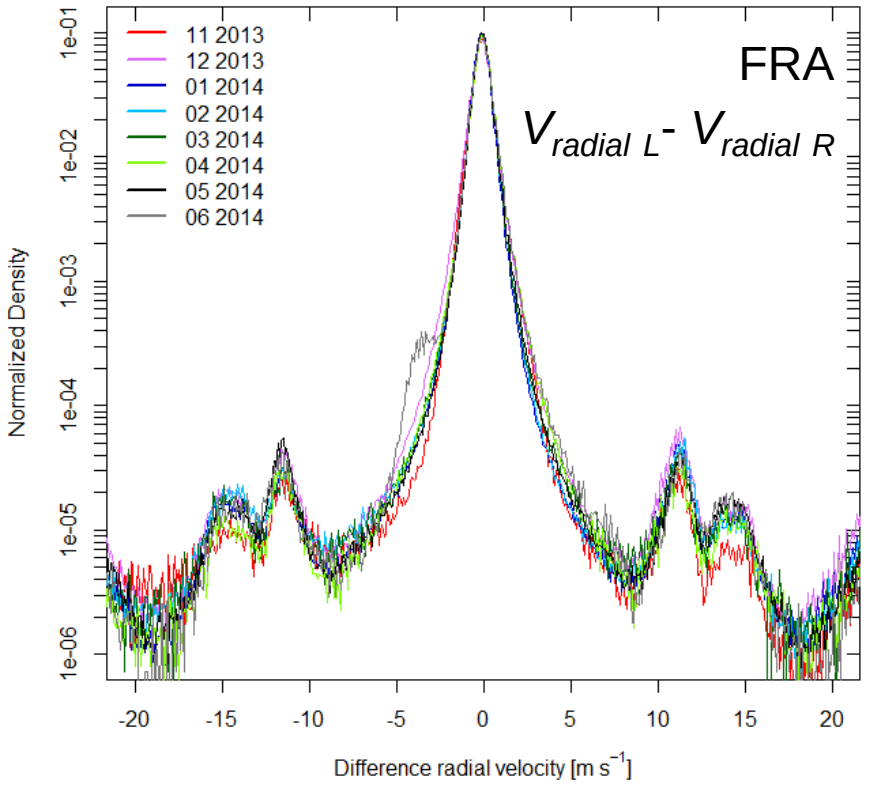
At Frankfurt and Munich airports about 5 % to 8 % of the measurements on average vertical wind data retrievals combine both sensors.

5 Verification

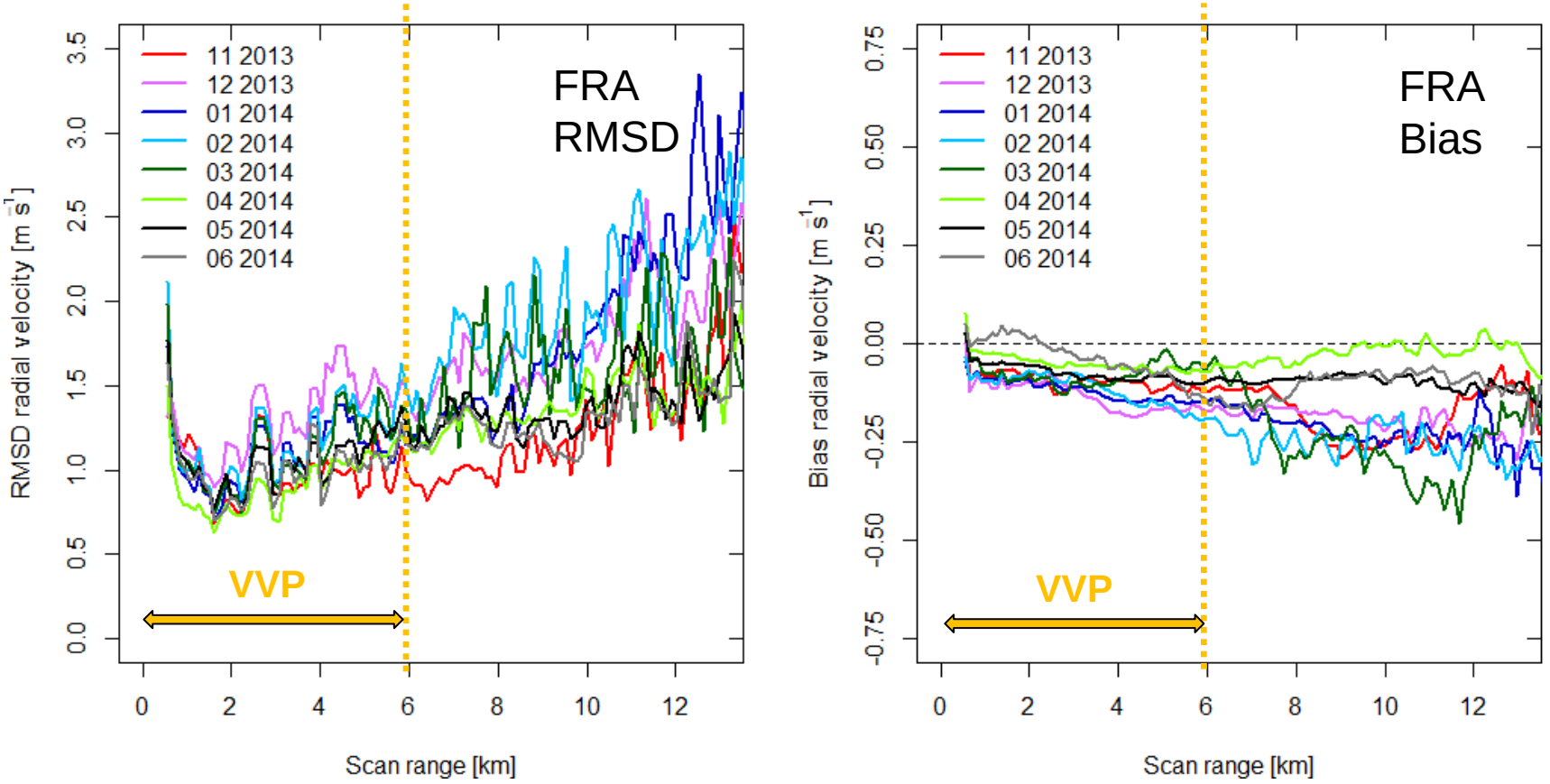
Radial velocity

- Monthly mean bias (lidar-radar) about 0 m/s, RMSD: 1.0 m/s to 1.4 m/s
- Decrease of bias at MUC Nov. 2013 (left panel): removal of speckles (after noise scan)
- Peaks at +-16, +-12 m/s: unambiguous velocities of single radar PRF (2000, 1600 Hz)



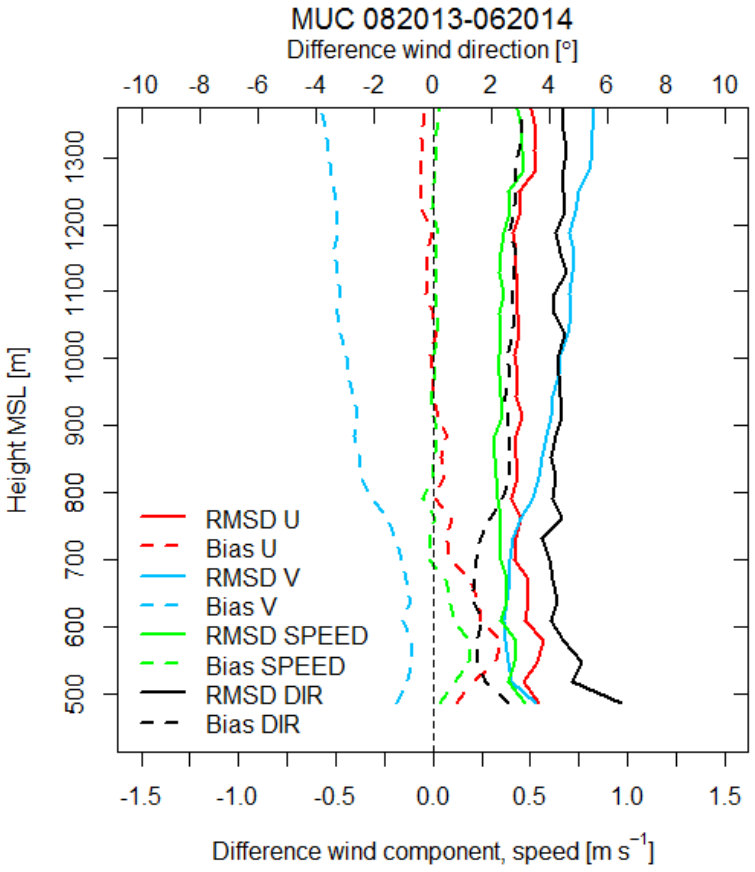


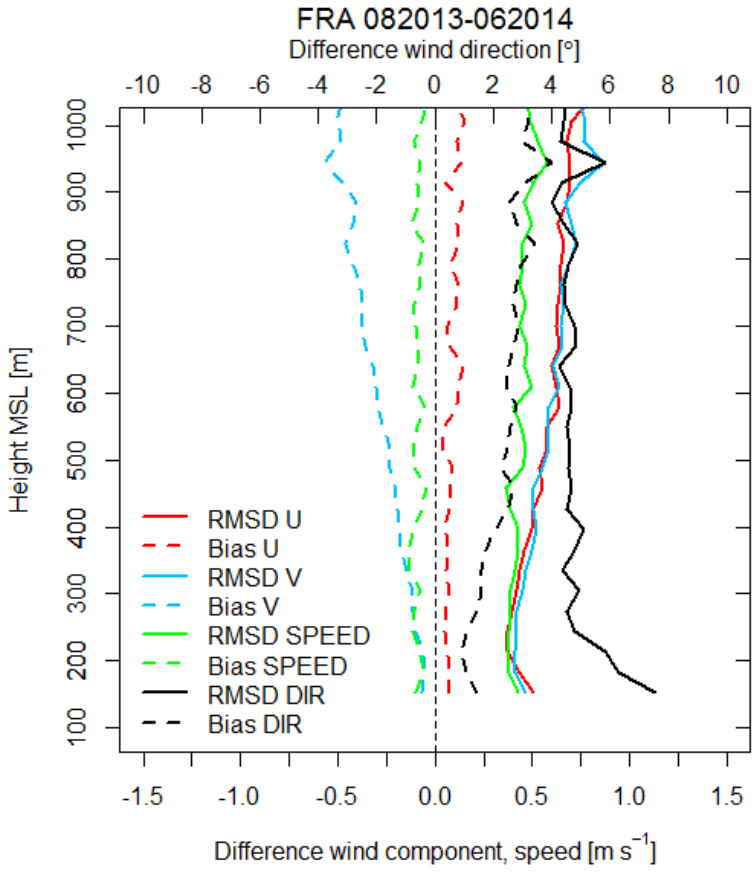
- Monthly mean RMSD (left panel) and bias (right panel) increase with increasing scan range up to 2.5 m/s respectively -0.4 m/s at 12 km range



VVP wind profile

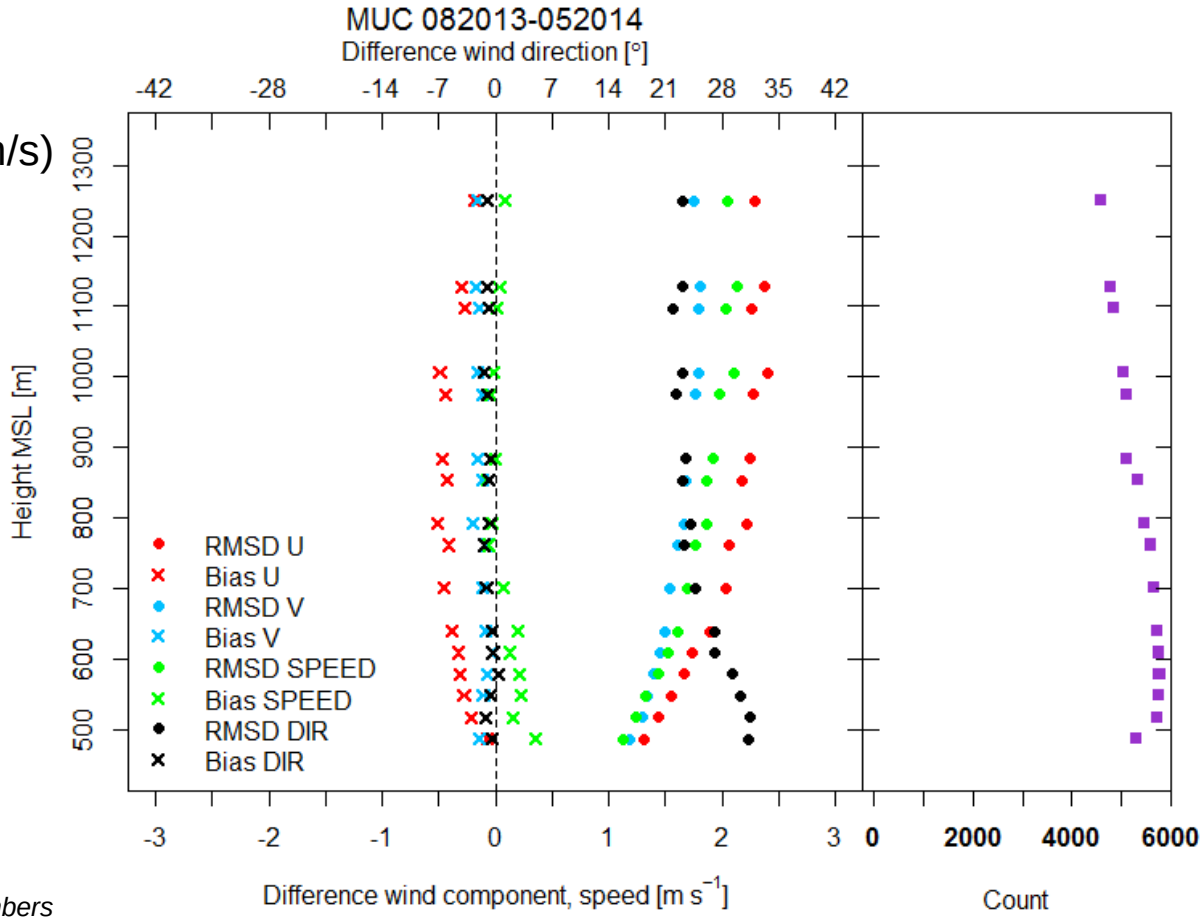
- Mean bias of wind speed & u: approx. 0, RMSD: 0.5 m/s within the whole profile
- Mean bias of wind direction & v increase with increasing height up to 4°, 0.5 m/s





Comparison with COSMO-DE model analyses (2.8 km, 2 h)

- Mean bias: < 2°, < 0.5 m/s (EUCOS* requirement: 5 m/s)
- Mean RMSD increases with increasing wind speed (height) up to approx. 23°, 2 m/s



**EUCOS is the ground-based or non-satellite observing system designed for EUMETNET Members*

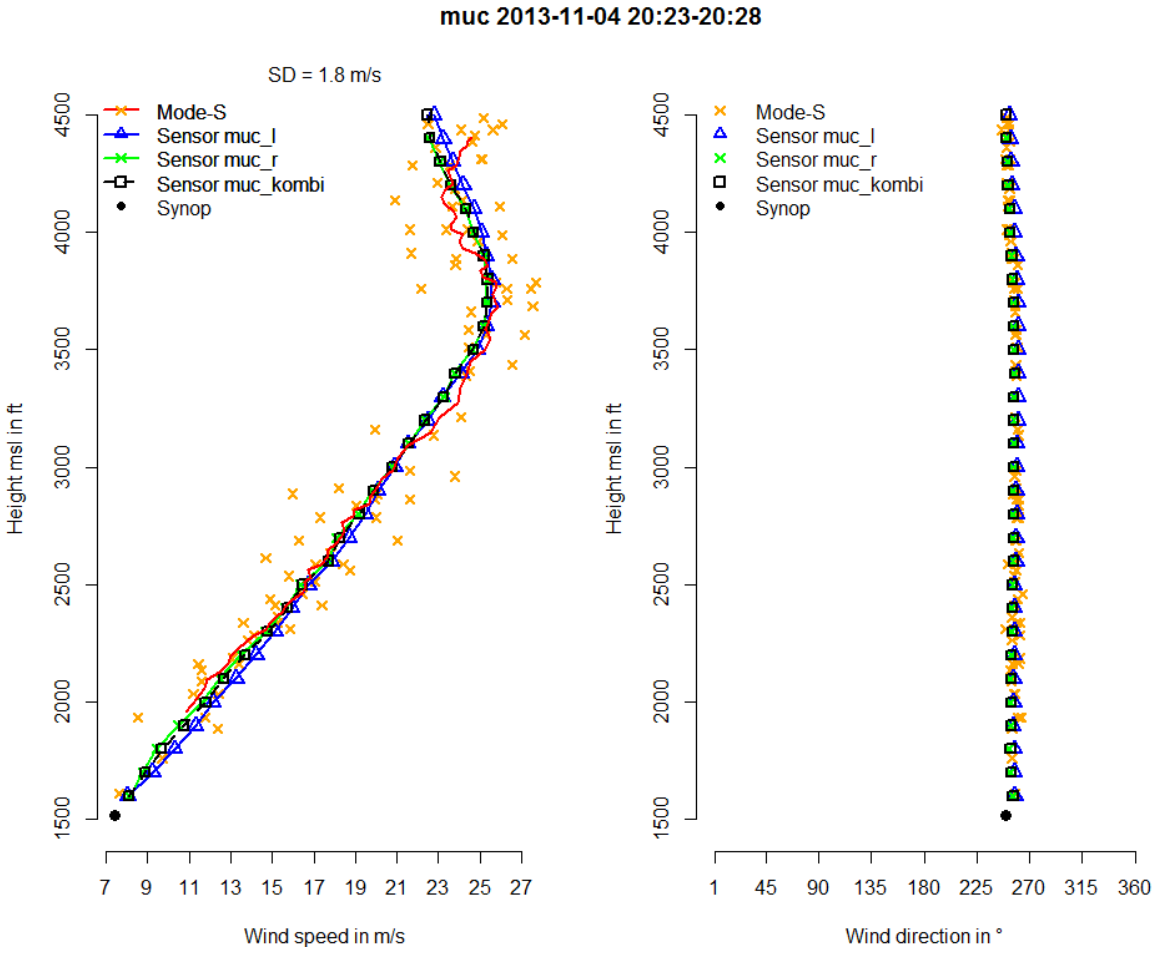
Excursus: Comparison with processed wind of Mode-S EHS flight data (source: KNMI)

Requirements for verification:

- high data coverage (depending on number of flight movements)
- stationary, uniform wind field

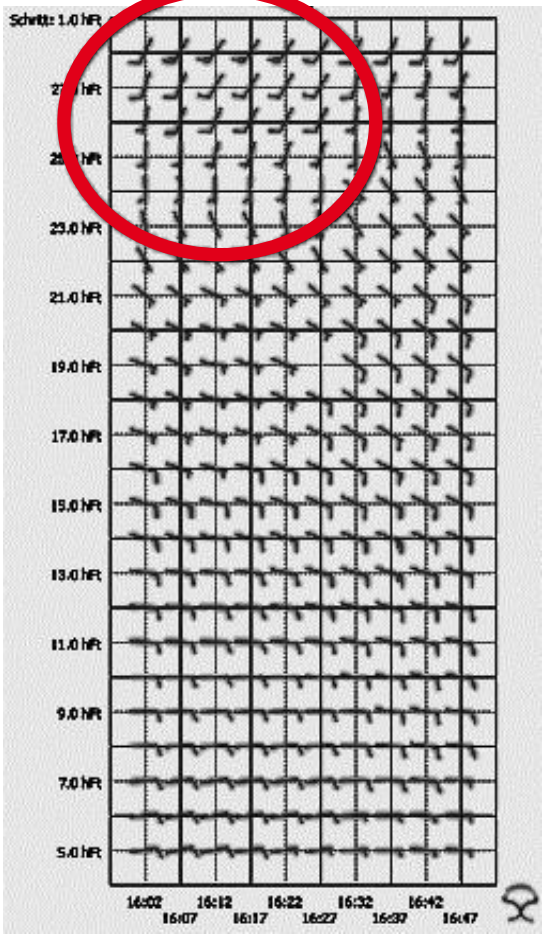
Example (right panel):

- 130 comparisons
- correlation coef. 0.95
- standard deviation 1.8 m/s

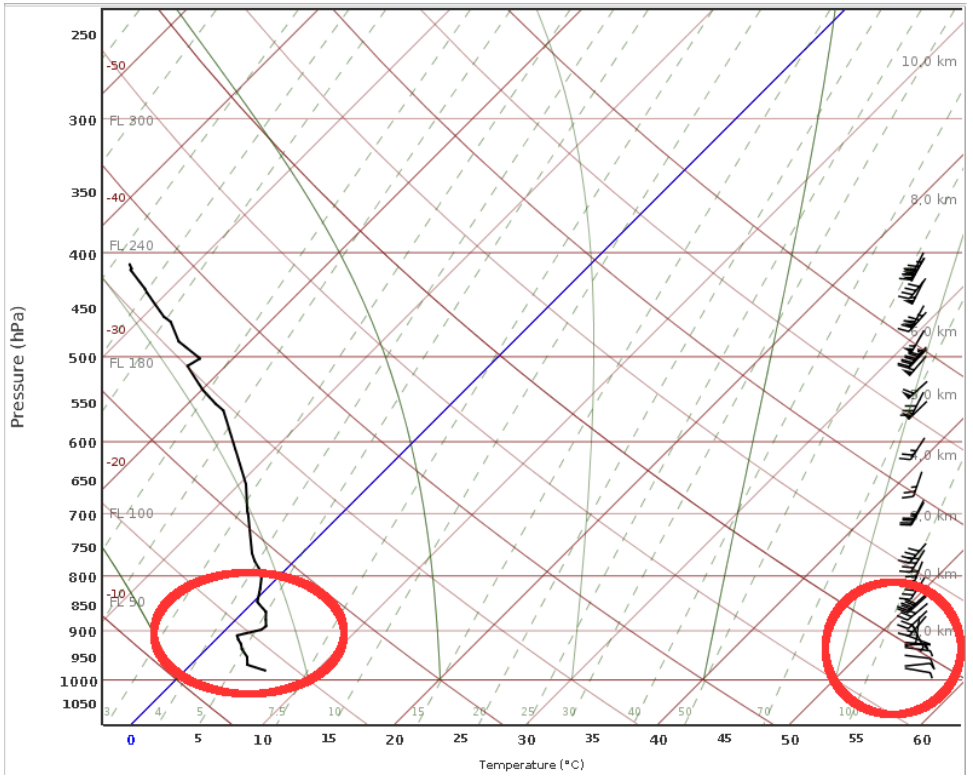


Example of vertical wind shear event: free inversion at MUC (17 February 2014, 16:47 UTC)

LLWAS VVP wind profiles



AMDAR temperature and wind profile



Summary

- X-band radar and lidar together measure wind in most weather situations (exception: fog).
- In general radar and lidar low-level wind show higher coverage than conventional wind measurements (by aircrafts: AMDAR, Mode-S; radiosondes).
- Small wind differences show high quality of lidar and radar measurements.
- Wind shear events are captured.
- VVP wind profiles show inversion and cloud heights.

Outlook

- Wind shear thresholds are foreseen to be adapted for the use of ATC.
- The quality controlled low-level wind data are foreseen to assimilate in high-resolution NWP models.
- LLWAS X-band radar can be used as back-up of operational radars.
- Development of further products are possible (e.g. EDR [wake vortices, turbulences]).

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Thank you!

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SEVENTH FRAMEWORK PROGRAMME

European Commission

UFO
ULTRA FAST WIND SENSORS