UFO
ULTRA FAST WIND SENSORS

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DWD

DLR Deutsches Zentrum für Luft- und Raumfahrt

Performance and Application of X-band Radar and 1.6 µm Lidar

Low Level Wind Measurement at Frankfurt and Munich Airports

UFO Dissemination Workshop
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NLR Amsterdam

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6) Outlook
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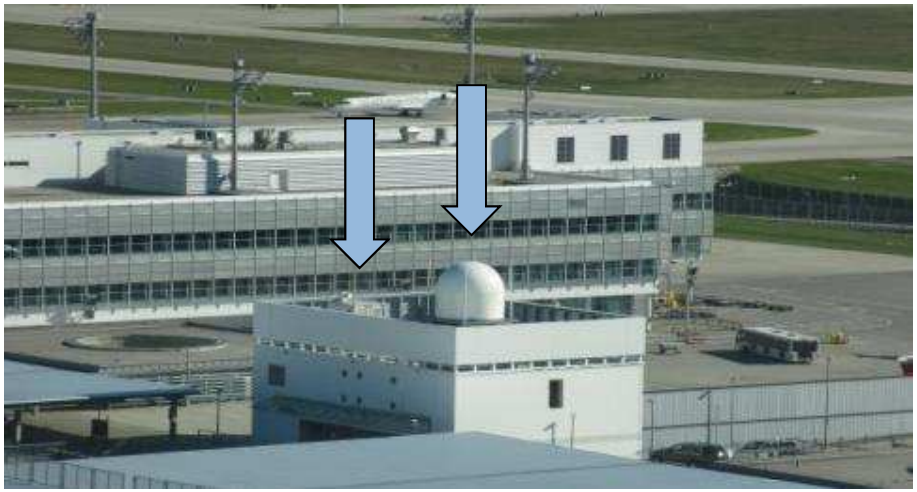


Lidar (left) and radar (right) at MUC

1 Introduction

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

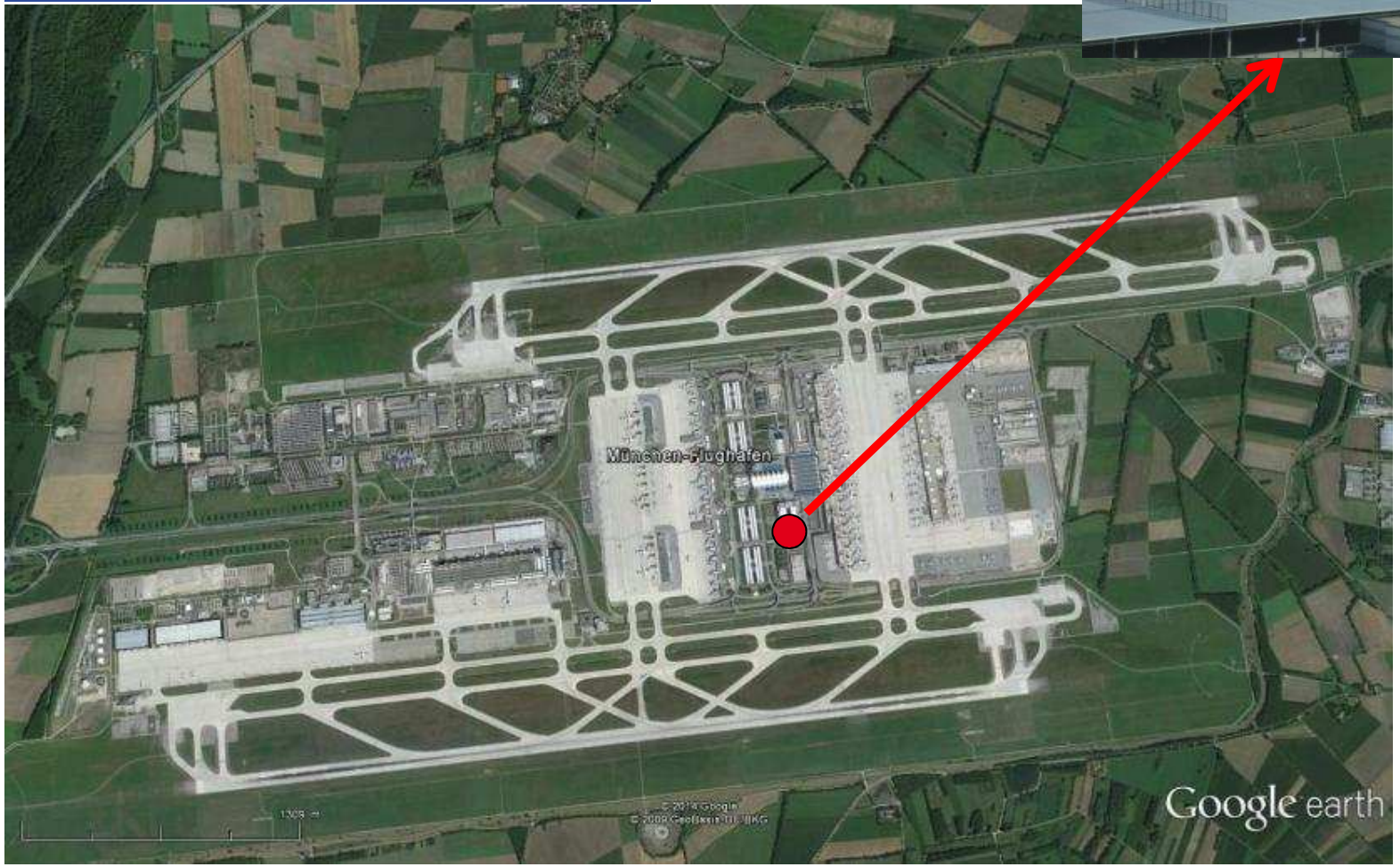
- Low-level Wind shear Alert System (LLWAS)
  based on X-band Doppler polarimetric radar and 1.6 µm Doppler lidar
  - Detection, quantification and alert on the presence of low-level wind shear
  - Independent on most weather situations
  - Automatic generation of warnings concerning ICAO every minute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

Main purpose: Increase of air traffic safety.

2 System overview

Location

Munich Airport (MUC)



2 System overview

Location

Frankfurt Airport (FRA)

2 System overview

Characteristics

Parameter	Radar (SELEX Meteor 50DX)	Lidar (Lockheed Martin WTX WindTracer)
Wavelength	3.2 cm (X-band)	1.6 µm
Measurement tracer	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.

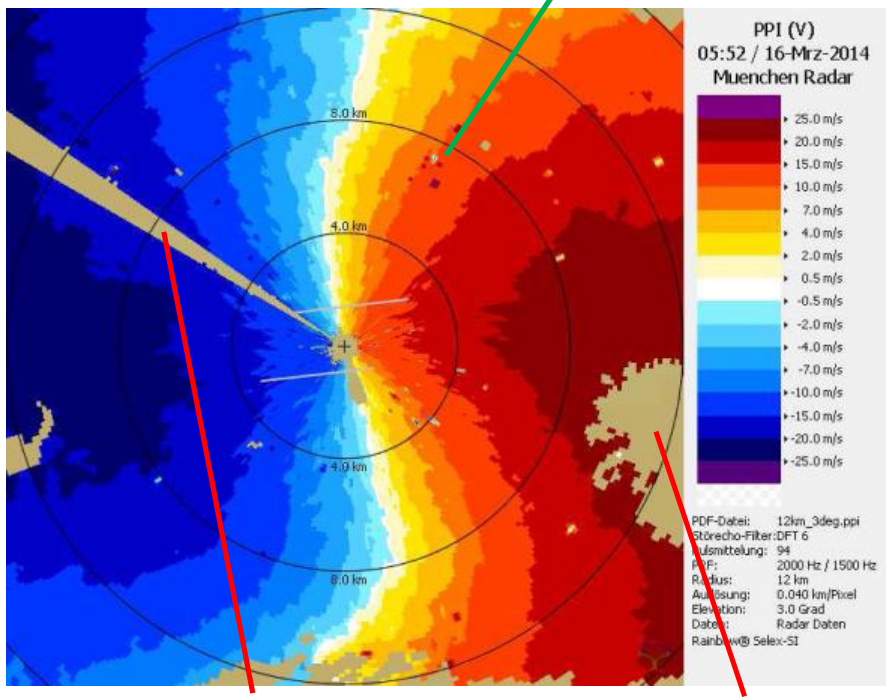
2 System overview

Data processing

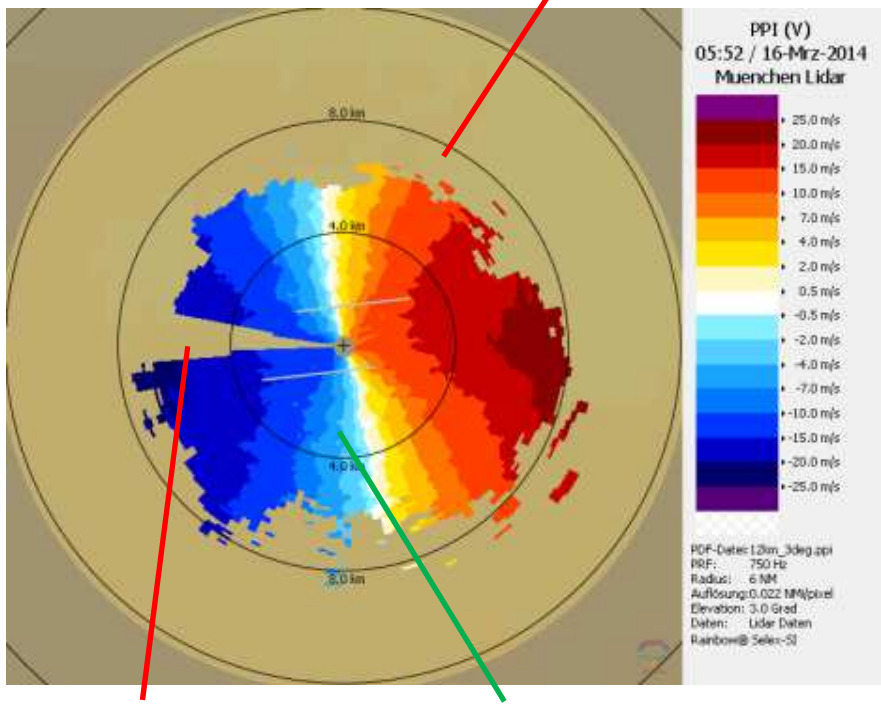
1) Filtering:

- 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



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2a) Vertical wind shear 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
- Thresholds:
  - 5 kt/100 ft (moderate), 9 kt/100 ft (severe) until 1600 ft (ICAO)
  - adaption will be based on absolut wind speed

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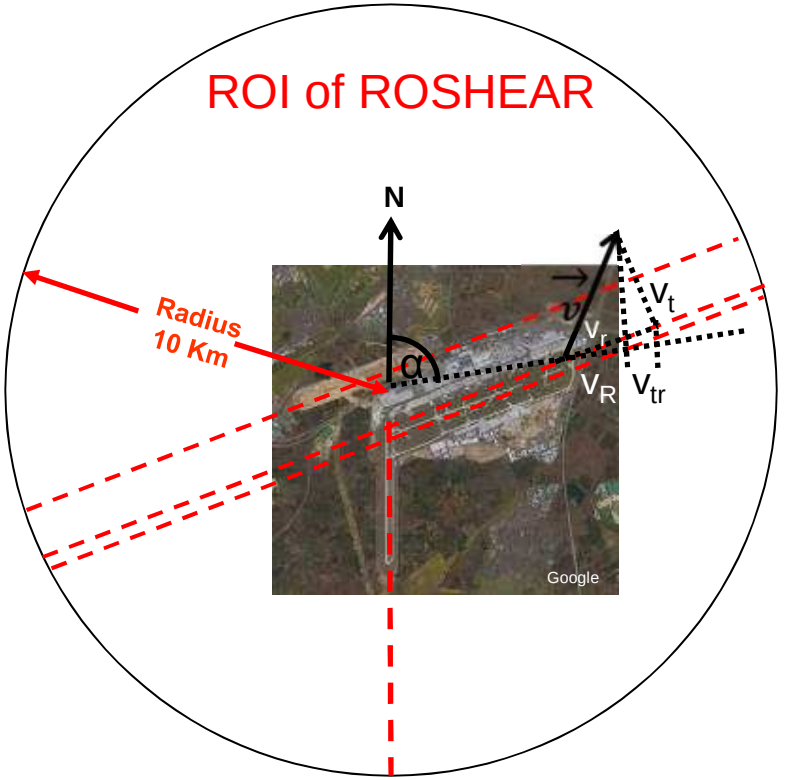
2b) Horizontal wind shear processing

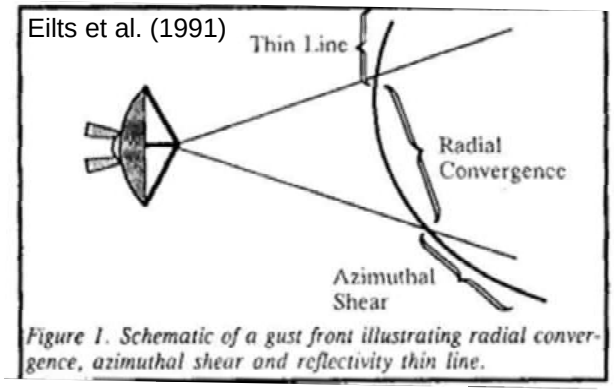
- Runway-oriented wind shear (ROSHEAR):

loss and gain of aircraft lift when approaching / departing, Δt = 1 min



- Gust front detection similar to Eilts et al. (1991):

Radial velocities variations from azimuth to azimuth, reflectivity / backscatter thin lines, Δt = 5 min



- Microburst detection based on Campbell (1989):

Radial velocity depending on height (divergence, convergence and rotation), reflectivity levels, Δt = 5 min

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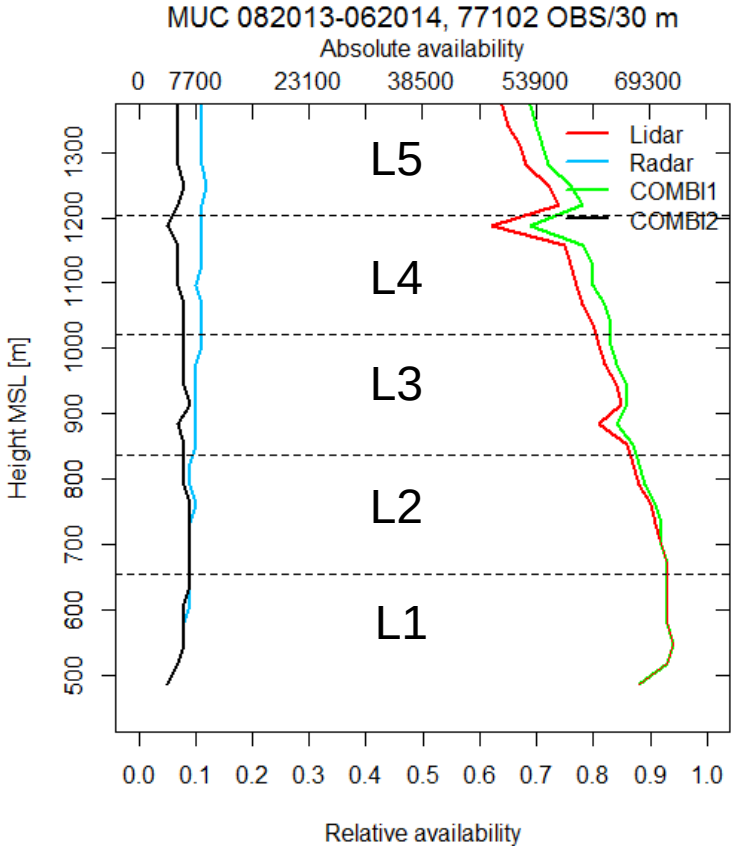
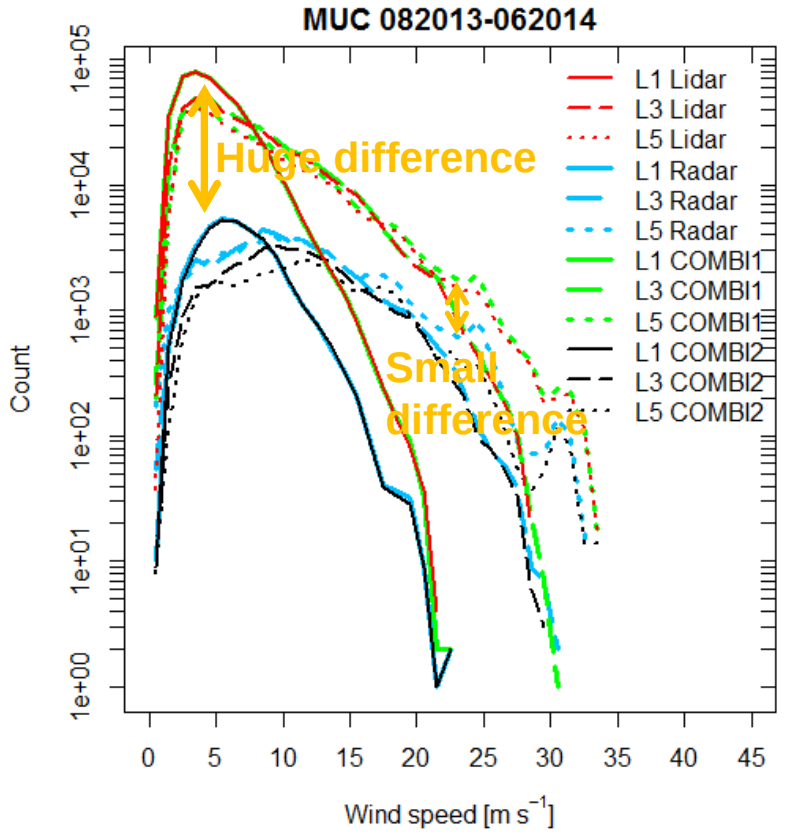
- PPI: Radar data are available at 10 % of the time, independent of range;
  lidar data are available at > 90 % at 3 km distance and < 50 % at 10 km distance (Weipert et al. 2014)
- VVP: Up to 500 m AGL lidar data are available in about 80 % – 90 % on average (left panel);
  the fraction of radar retrievals increases significantly with increasing wind speed (right)





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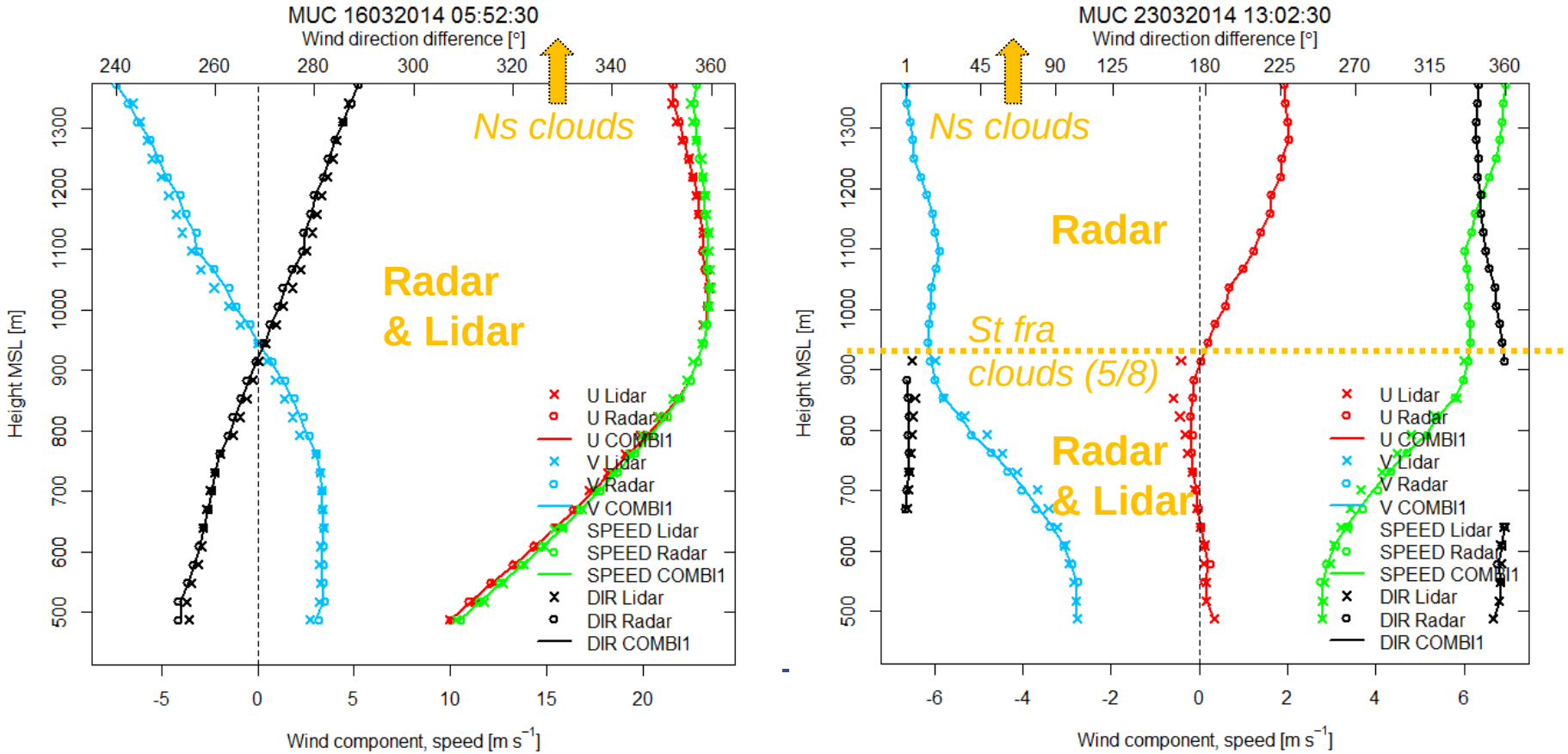
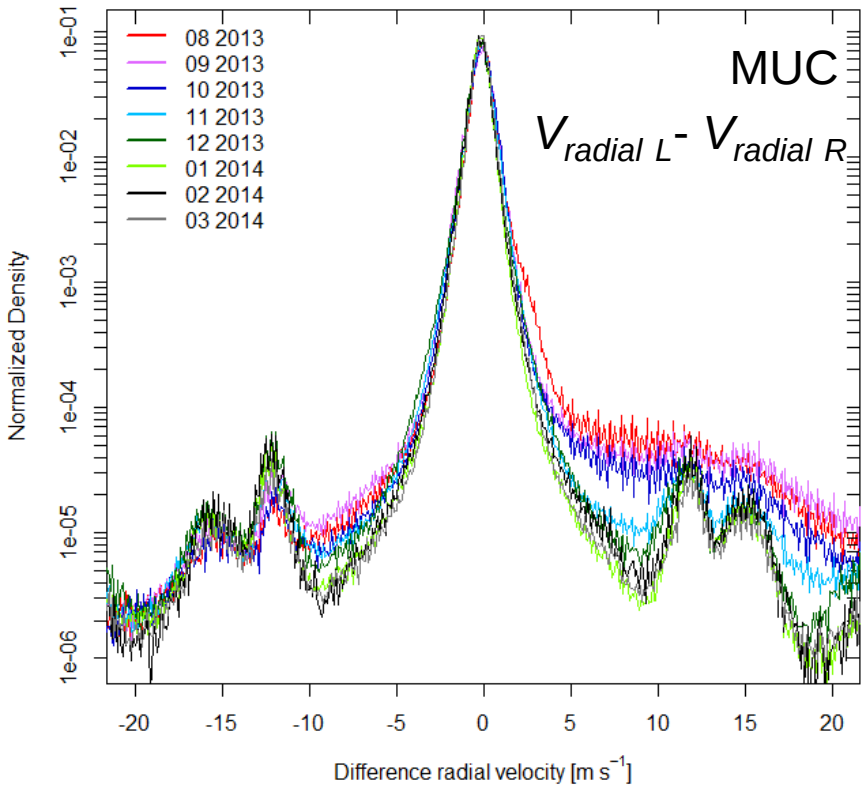
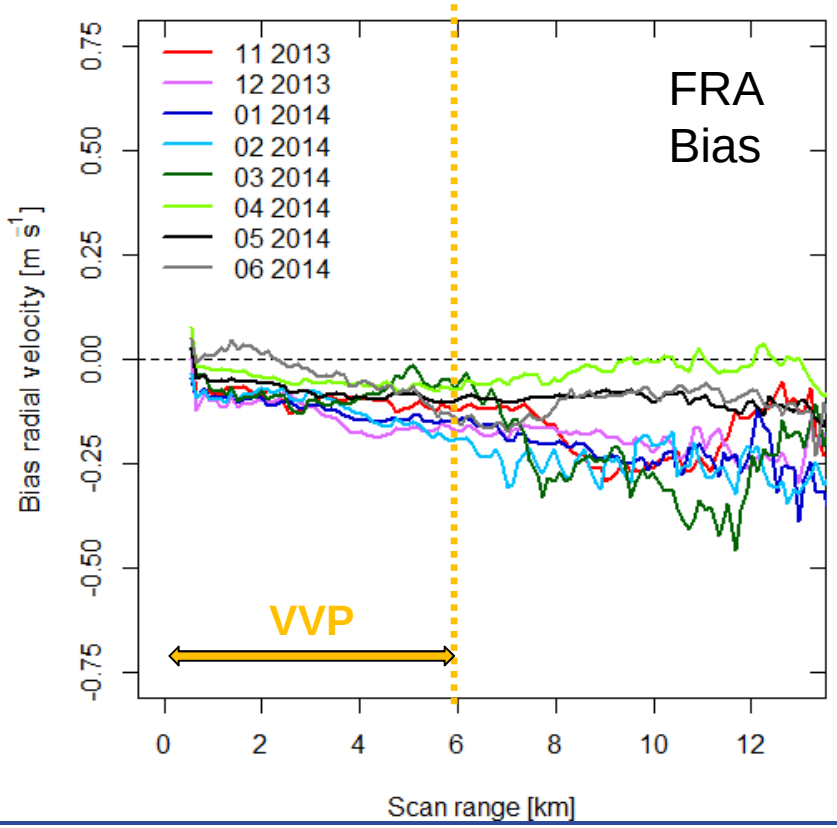
Baseline of quality control, verification: Overlapping between radar and lidar wind measurements.

- 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)



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





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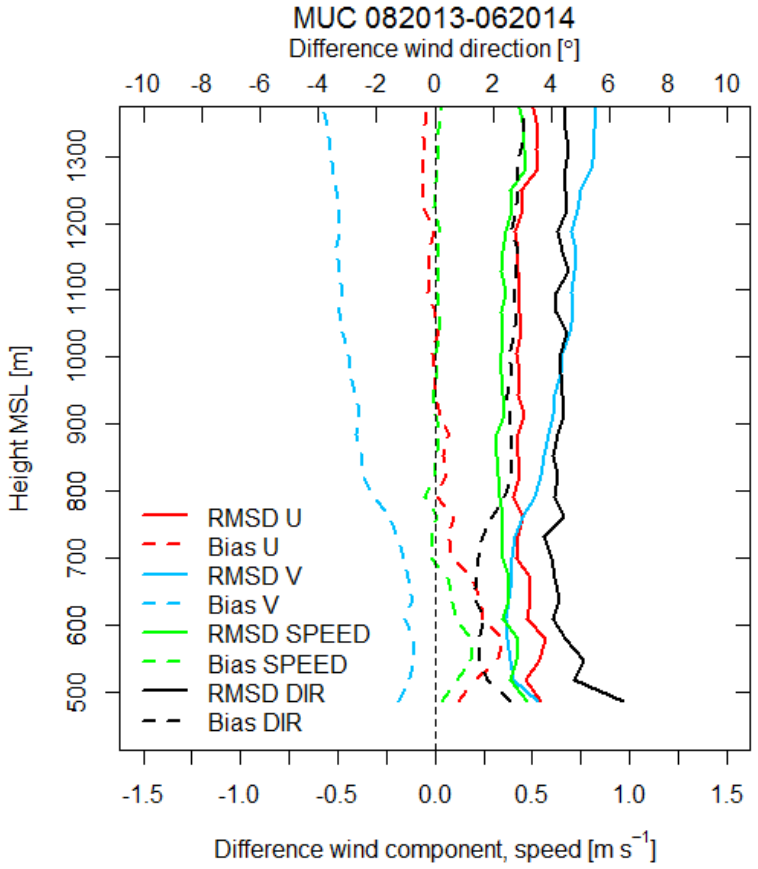
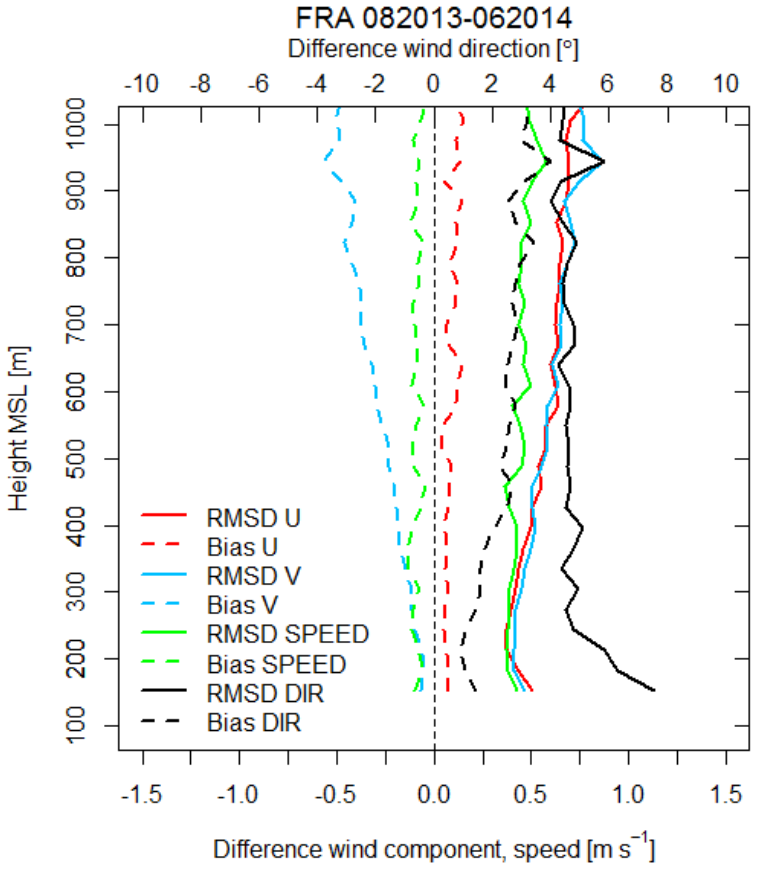
VVP wind profile

- Mean bias of wind speed & u: approx. 0 m/s, 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



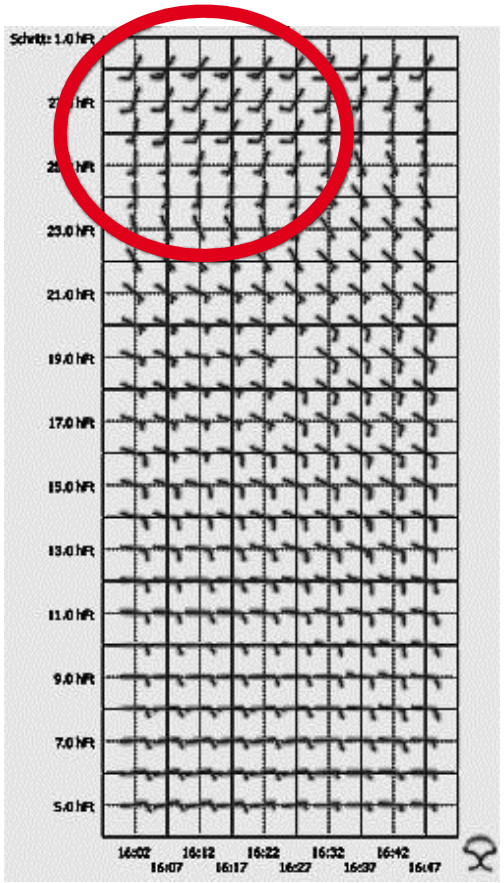


4 Wind shear events

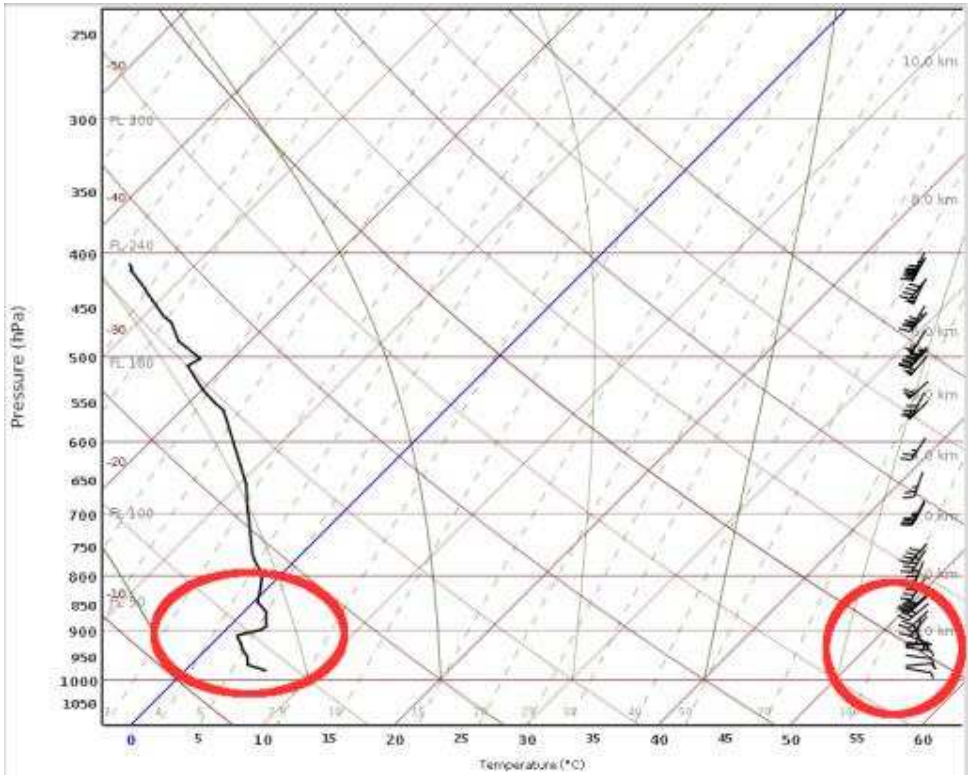
Vertical wind shear

1) Vertical wind shear event: free inversion at MUC (17 February 2014)

High resolution LLWAS VVP wind profiles



AMDAR temperature and wind profile



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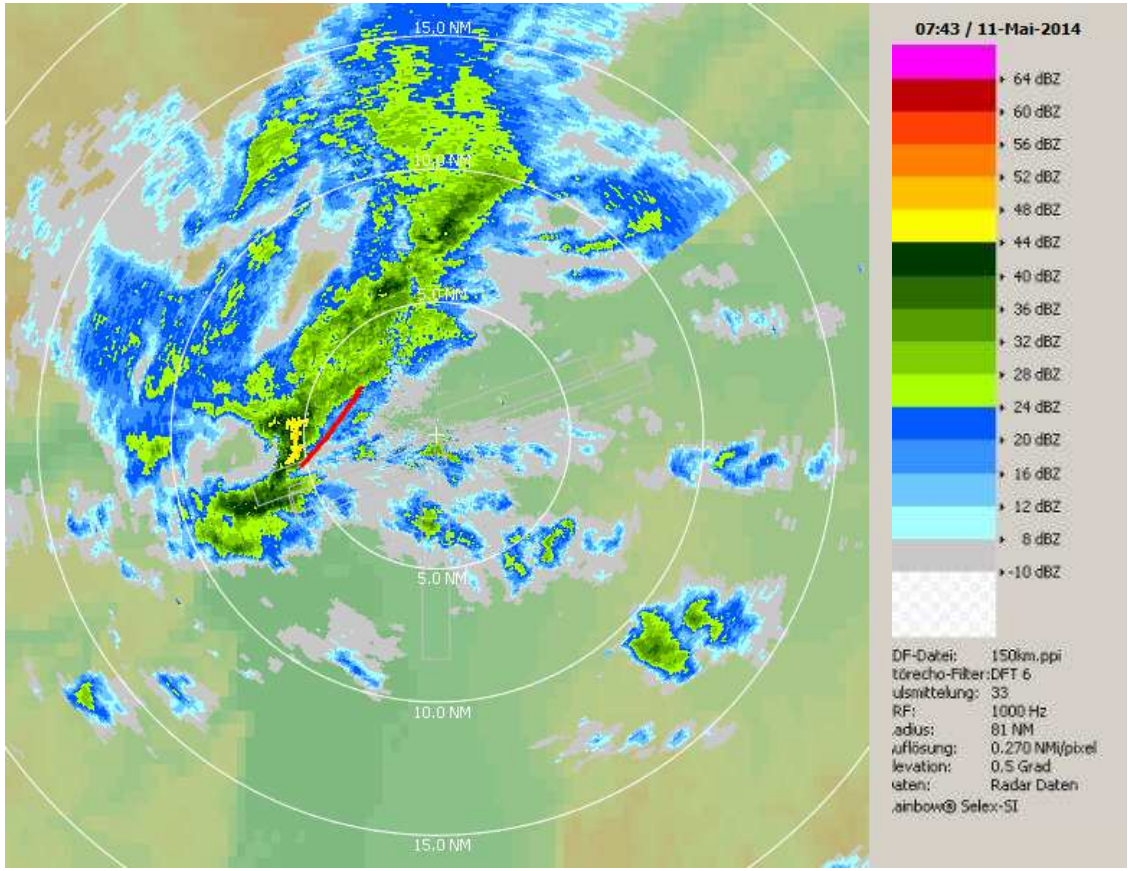
2) Gust front event: Frontal system at FRA (11 May 2014)

LLWAS radar reflectivity and gust front line



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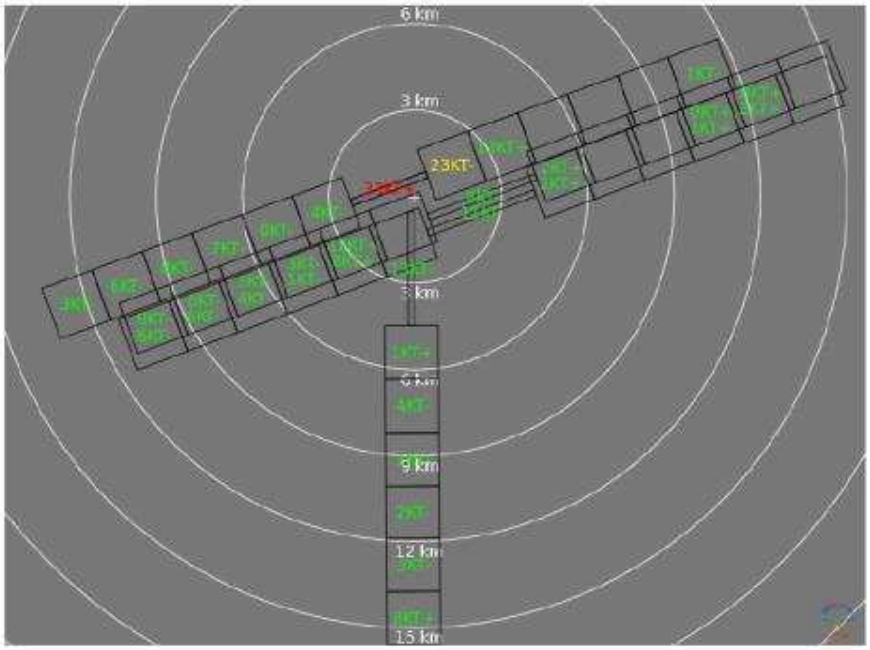
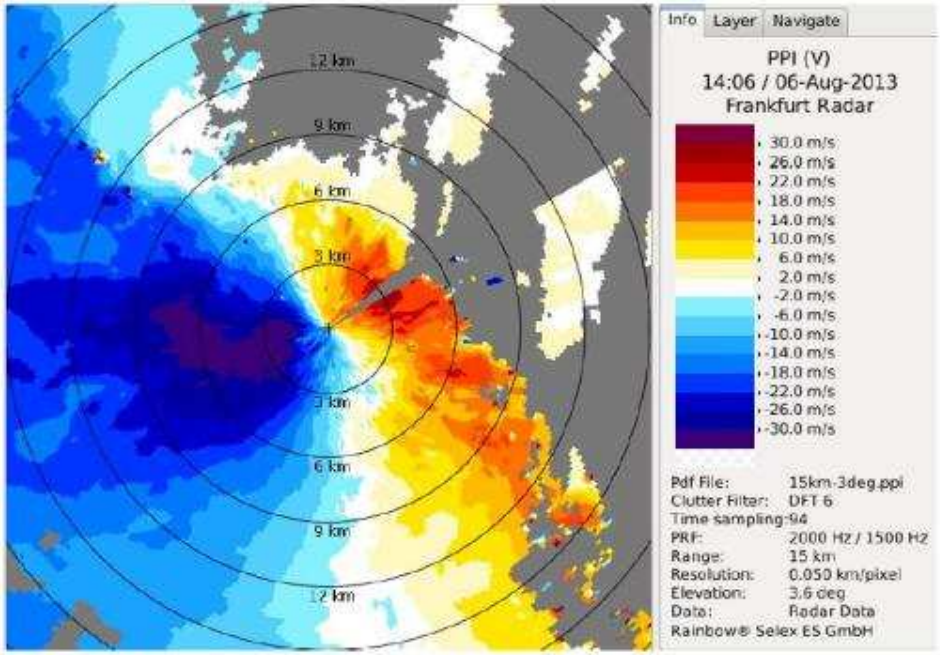
3) ROSHEAR event: Frontal passage connected with thunderstorm at FRA (06 August 2013)

ROSHEAR



Radar radial velocity



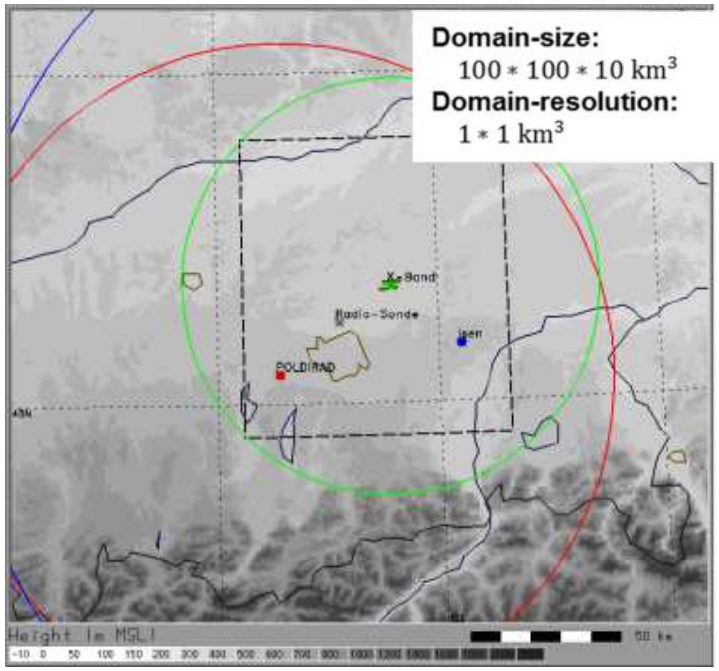
Weipert et al. (2014)

5 Enhanced studies

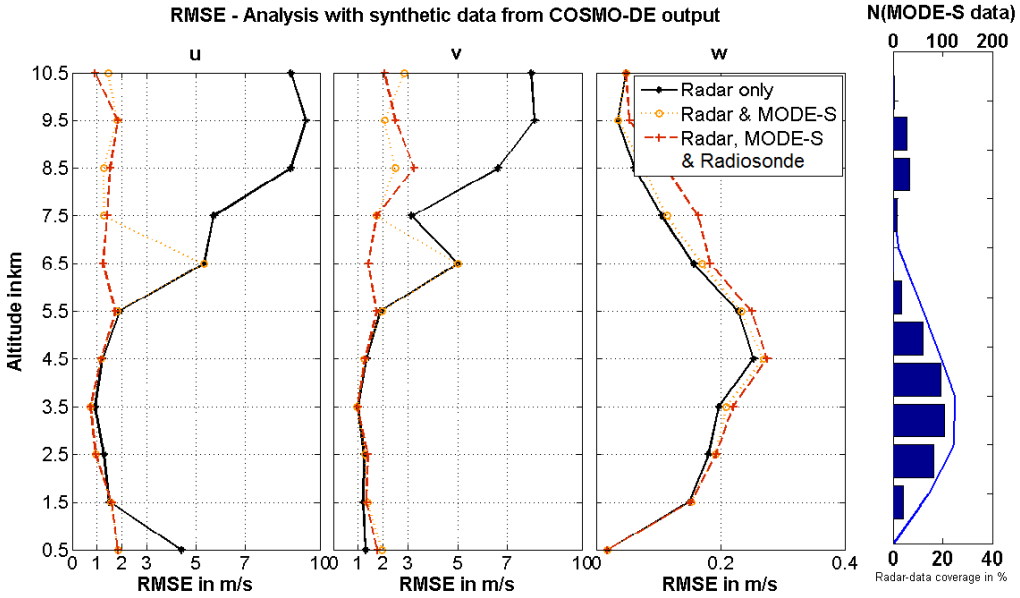
3D wind field

Development of a 3D wind field retrieval system for the region of MUC from measurements of

- 3 radar systems: LLWAS, Isen (DWD), POLDIRAD (DLR)
- 1 lidar system: LLWAS (DWD)
- Radiosondes (DWD) and
- Mode-S EHS flight data (KNMI)



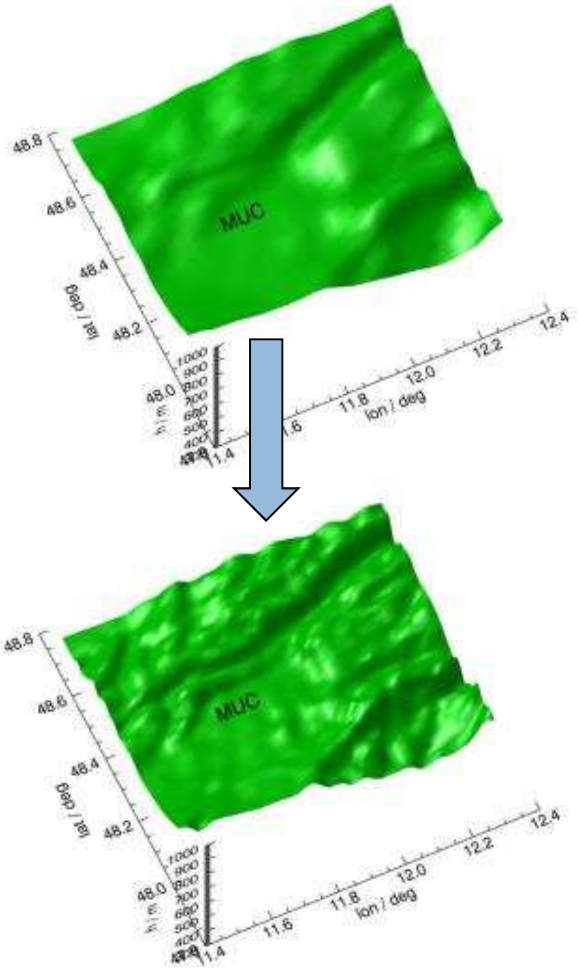
Method: 3D variational analysis



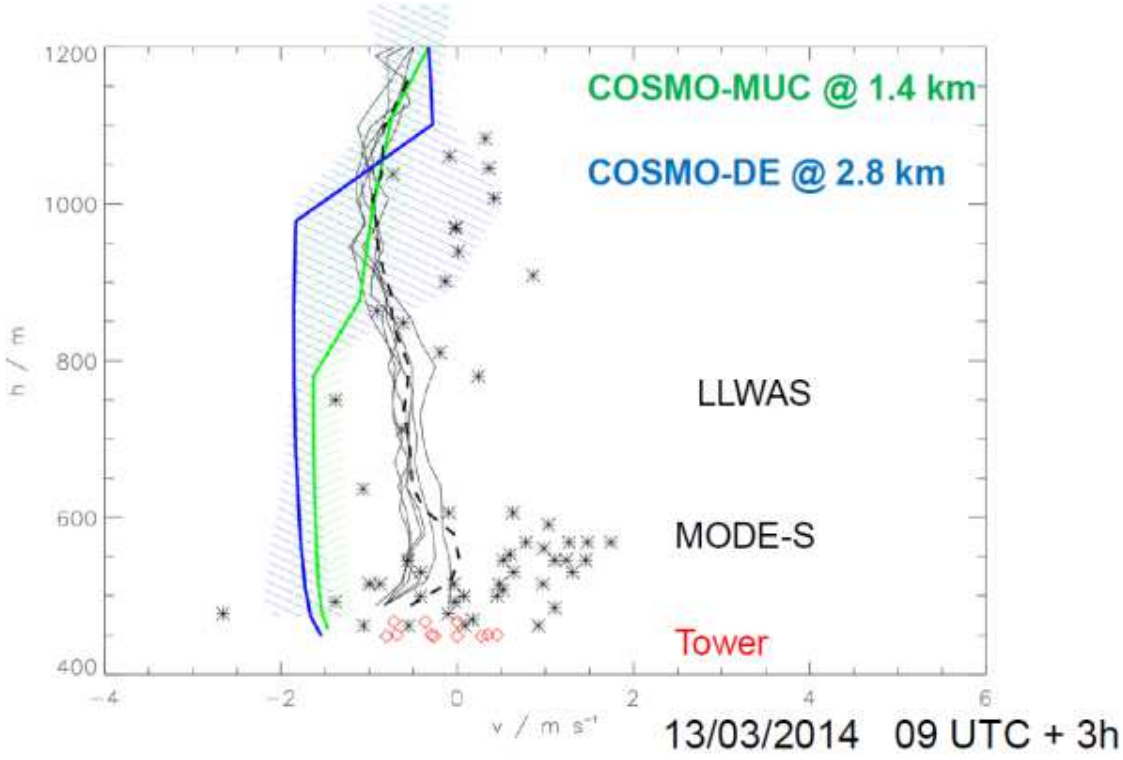
5 Enhanced studies

COSMO-MUC

- COSMO-MUC is a highly regionalised version of COSMO-DE model (1.4 km) in order to improve the prediction quality for very-short range weather forecasts at Munich Airport.
- Assimilation of new data: LLWAS, Mode-S EHS.



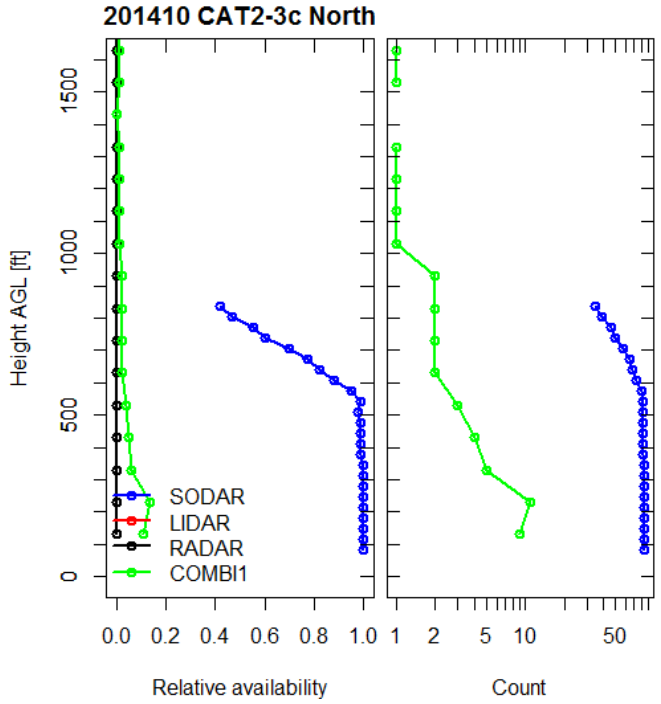
Verification of forecast skill

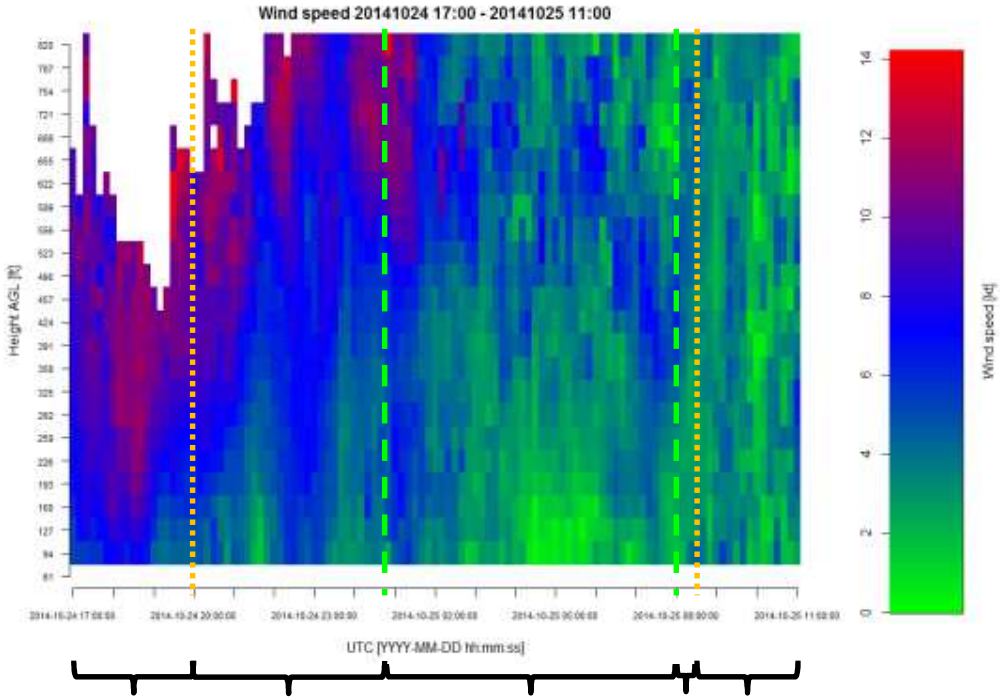


5 Enhanced studies

SODAR profiles

- Fog gap closure by SODAR measurements (left panel)
- Benefit for prediction of fog (right)





MOR > 1000 m
CAT = 1

MOR < 1000 m
CAT = 1

MOR < 1000 m
CAT >1

MOR < 1000 m
CAT = 1

MOR > 1000 m
CAT = 1

Further investigations and applications

- Adaption of wind shear thresholds for ATC (vertical)
- Back-up of operational C-band radar measurements
- Processing of head wind component for time based separation (resolution: 100 m – 150 m, 1 min)

http://www.nats.aero (2015)

- Hydrometeor and low cloud (stratus) detection / classification
- Calculation of horizontal wind components
- Assimilation into high-resolution NWP models
- Gap closure by SODAR measurements (fog)
- Investigation of the benefit of wind measurements for fog prediction

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Thank you!

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