Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Comparison of wind profiler radar measurements with Doppler wind lidar profiles measurements at the Lindenberg GRUAN site

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Outline

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- Motivation
- Radar wind profiler (RWP) - technical specification
- Doppler wind lidars - technical specifications
- Comparison Doppler wind lidars vs. RWP, Radiosonde (RS) and COSMO-EU NWP model
  - Campaign setup
  - Results
- Conclusions

Motivation

- Since 2 years commercial Doppler wind lidars available at the market
- providing vertical profiles in of the horizontal wind the boundary layer at high temporal and vertical resolution

- Questions:
  - What potential do Doppler lidars have for operational wind profile measurements ?
  - Can wind lidars complement / replace existing instruments ?

- For evaluation of Doppler wind lidars a comparison with (a well-established) radar wind profiler was done

Radar wind profiler (DWD)

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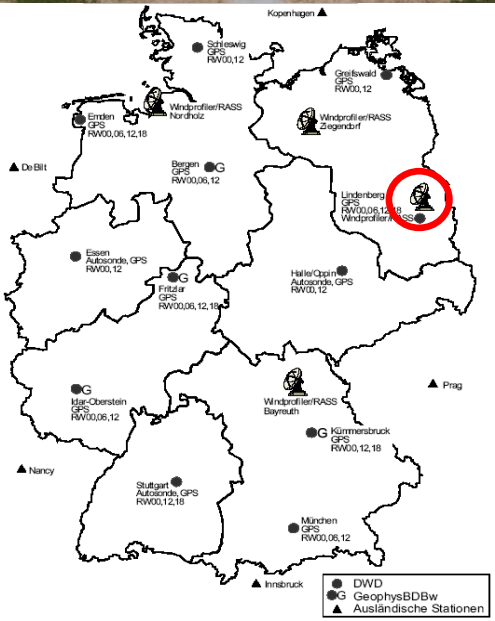

WP-Lindenberg:

- Frequency: 482 MHz
- WMO No.: 10394
- Latitude: 52,21° N
  Longitude: 14,10° E
- Height: 104 m
- Vertical resolution:
  - 150 m for low mode - Pulse width: 1000ns
  - 330 m for high mode - Pulse width: 2175ns
- Range:
  - 500 m to 9 km for low mode, 96 range gates
  - 4 km to 16,5 km for high mode, 40 range gates
- Beam angle: 15,2°
- Averaging period: 27 minutes for wind, 3 minutes for RASS
- Horizontal wind vector: Doppler beam swinging (4 beams)

Calculation of horizontal wind field

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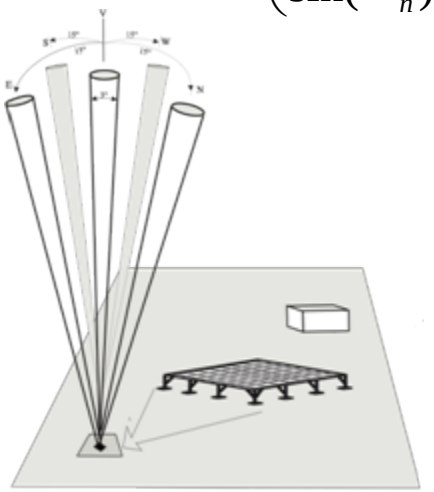
For (horizontally) homogeneous wind field :

$$\begin{pmatrix} \sin(\Phi_1)\sin(\Theta_1) & \cos(\Phi_1)\sin(\Theta_1) & \cos(\Phi_1) \\ \sin(\Phi_2)\sin(\Theta_2) & \cos(\Phi_2)\sin(\Theta_2) & \cos(\Phi_2) \\ \sin(\Phi_3)\sin(\Theta_3) & \cos(\Phi_3)\sin(\Theta_3) & \cos(\Phi_3) \\ \sin(\Phi_4)\sin(\Theta_4) & \cos(\Phi_4)\sin(\Theta_4) & \cos(\Phi_4) \\ \vdots & \vdots & \vdots \\ \sin(\Phi_n)\sin(\Theta_n) & \cos(\Phi_n)\sin(\Theta_n) & \cos(\Phi_n) \end{pmatrix} \begin{pmatrix} u \\ v \\ w \end{pmatrix} = \begin{pmatrix} v_{r1} \\ v_{r2} \\ v_{r3} \\ v_{r4} \\ \\ v_{rn} \end{pmatrix}$$



$$\mathrm{A}\,v = v_r$$

$$v = \left(\mathrm{A}^{\mathsf{T}}\mathrm{A}\right)^{-1}\mathrm{A}^{\mathsf{T}}v_r$$

Calculation of horizontal wind field

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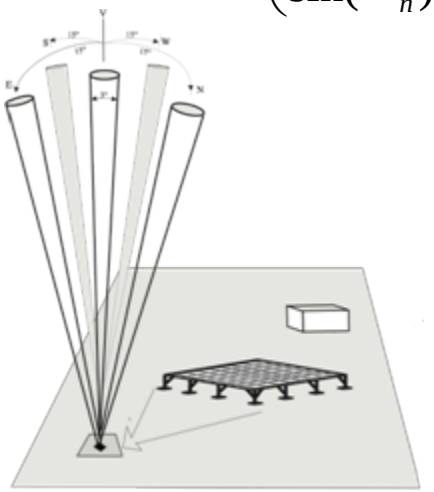

$$\mathrm{A}\,v = v_r$$

$$v = \left(\mathrm{A}^{\mathsf{T}}\mathrm{A}\right)^{-1}\mathrm{A}^{\mathsf{T}}v_r$$

singular value decomposition of A : $\mathrm{A} = \mathrm{U}\Sigma\mathrm{V}^{\mathsf{T}}$

$$v = \mathrm{V}\Sigma^{-1}\mathrm{U}^{\mathsf{T}}v_r$$

Doppler wind lidars

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Type	Streamline Lidar	Windcube WLS 70/200	Windcube WLS 200S
			
Manufactured by	HALO photonics	Leosphere	Leosphere
Provided by	Karlsruhe Institute of Technology (KIT)	GWU-Umwelt-technik GmbH	Leosphere
Wavelength	1,5 µm	1,5 µm	1,55 µm
Max. range	3 km	2 km / 6 km	6 km
Beam configuration	scanner	Four fixed beams	scanner
Scan modes	stare, VAD, DBS …	---	stare, VAD, DBS …

Campaign setup

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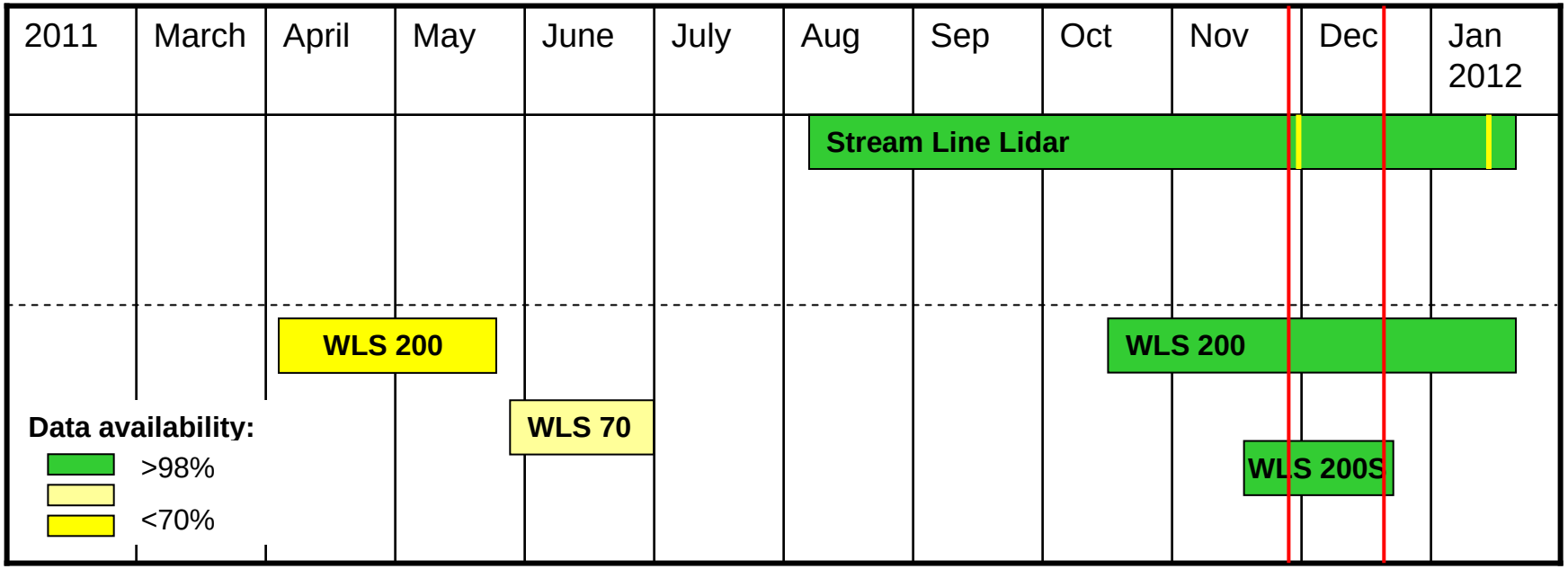

- Problems: Leosphere - Insufficient air conditioning (Spring)
- All three Lidars available in December with good data quality (3 weeks)
- Comparison for period 29. Nov. 2011 - 20. Dec. 2011 (red markers)

Campaign setup

- Three different Doppler Lidars next to LIN 482MHz wind profiler
- Data availability for all lidars good for a period of 3 weeks (28.11.2011 - 20.12.2011)
- Comparison Doppler wind lidar against:
  - Radar wind Profiler (RWP)
  - Launched radiosondes (RS)
  - NWP COSMO-EU model outputs
- Temporal resolution (wind speed/direction):
  - RWP 27min
  - WLS 200 10min
  - WLS 200S 2min scan
  - StreamLine 3min scan
  - RS 6h
  - COSMO-EU 1h (00UTC and 12UTC forecast)
- **For comparison all datasets were interpolated to the vertical and temporal resolution of the radar wind profiler**

Results - StreamLine

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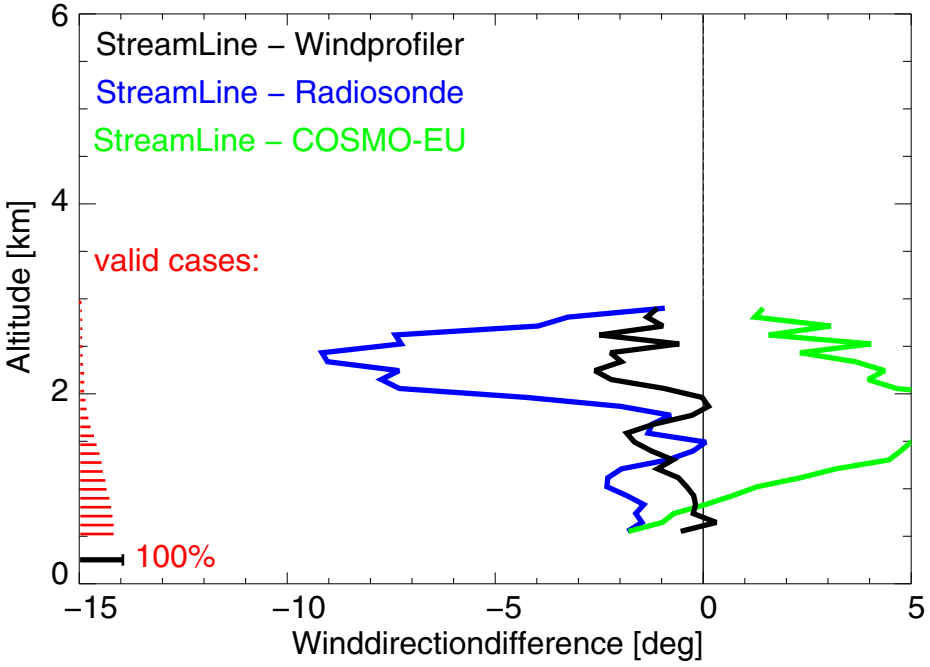

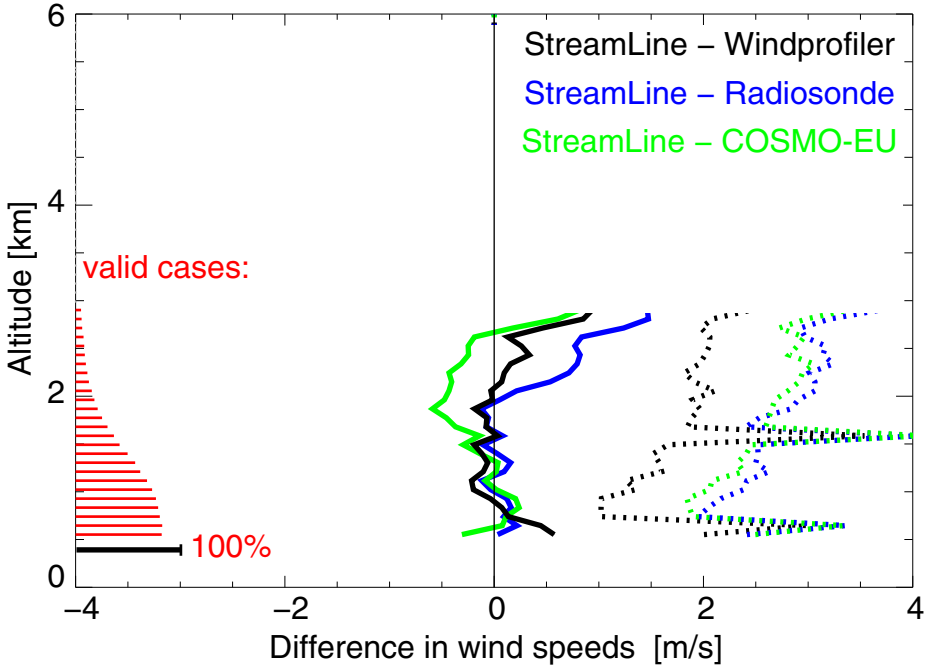

-Period 29.11.2011 - 20.12.2011 (3 weeks)

-Differences in WD <2.0° and WS <0.25m/s to RWP

-Data availability: 90%

Results - WLS 200s

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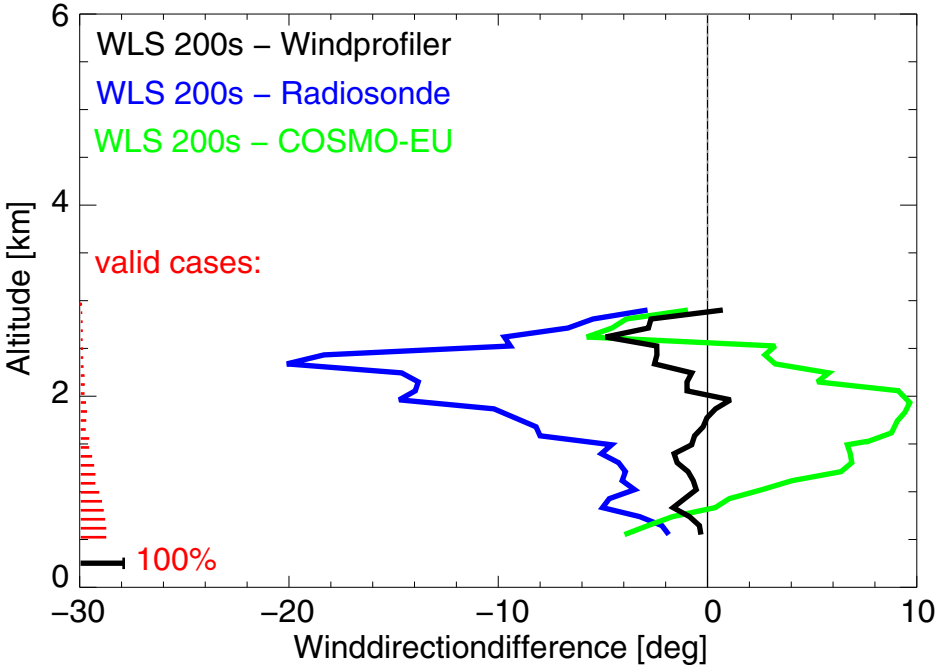
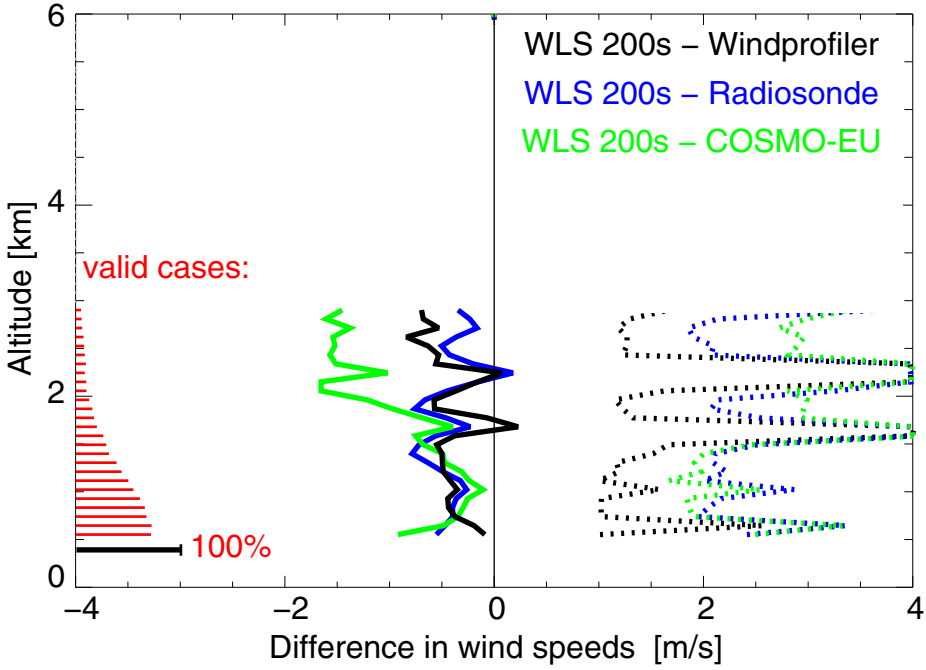
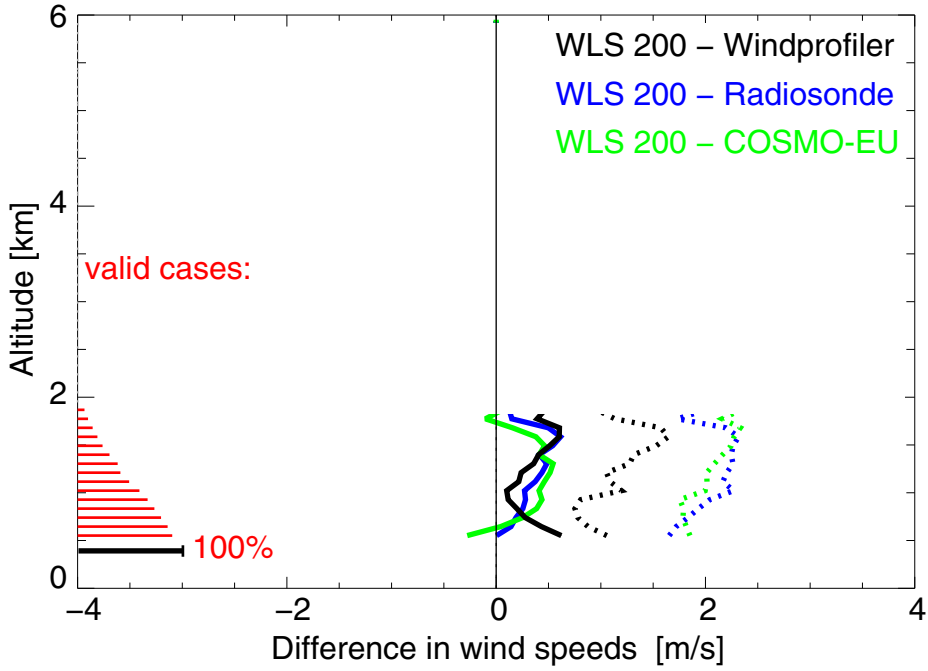




-Period 29.11.2011 - 20.12.2011 (3 weeks)

-Differences in WD <2.0° and WS <0.5m/s to RWP

Results - WLS 200



-Period 29.11.2011 - 20.12.2011 (3 weeks)

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Results

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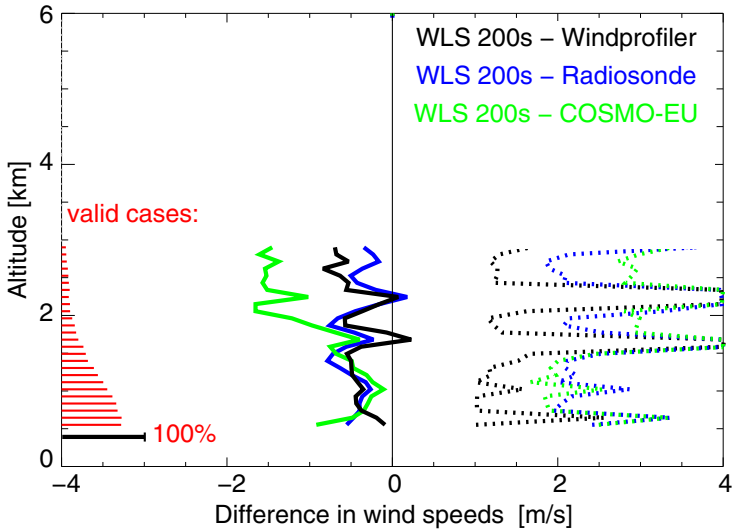

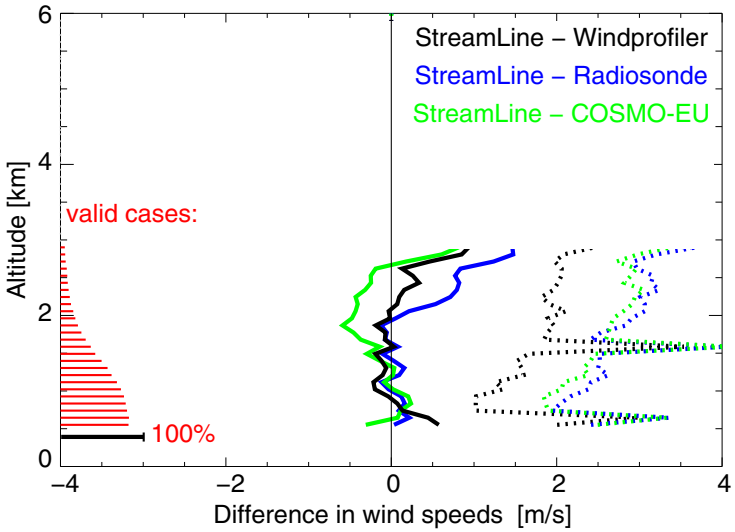

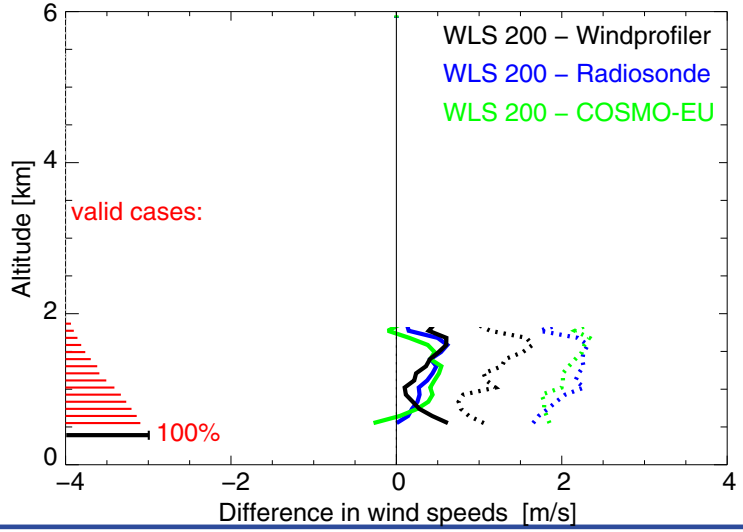

Results

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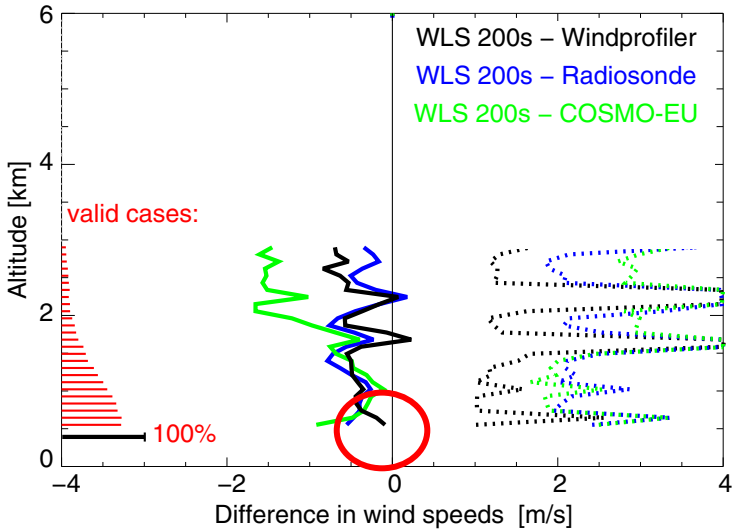

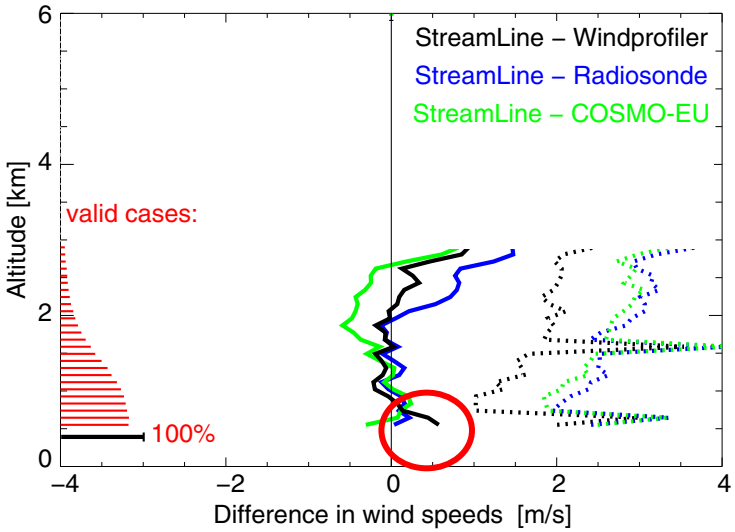

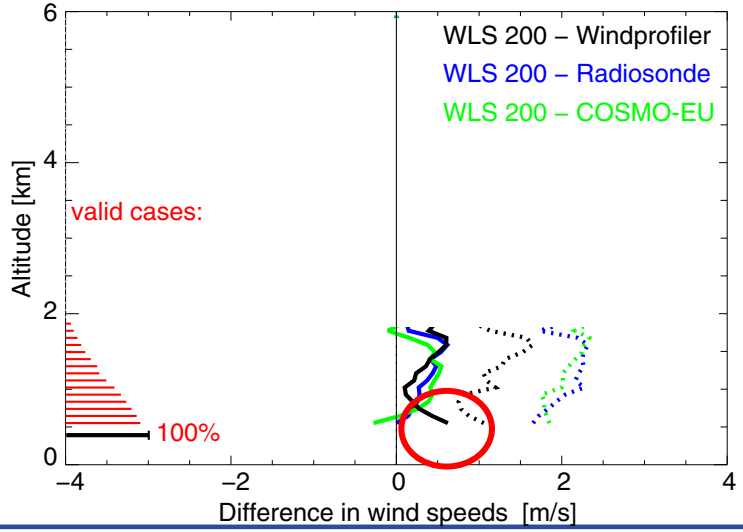

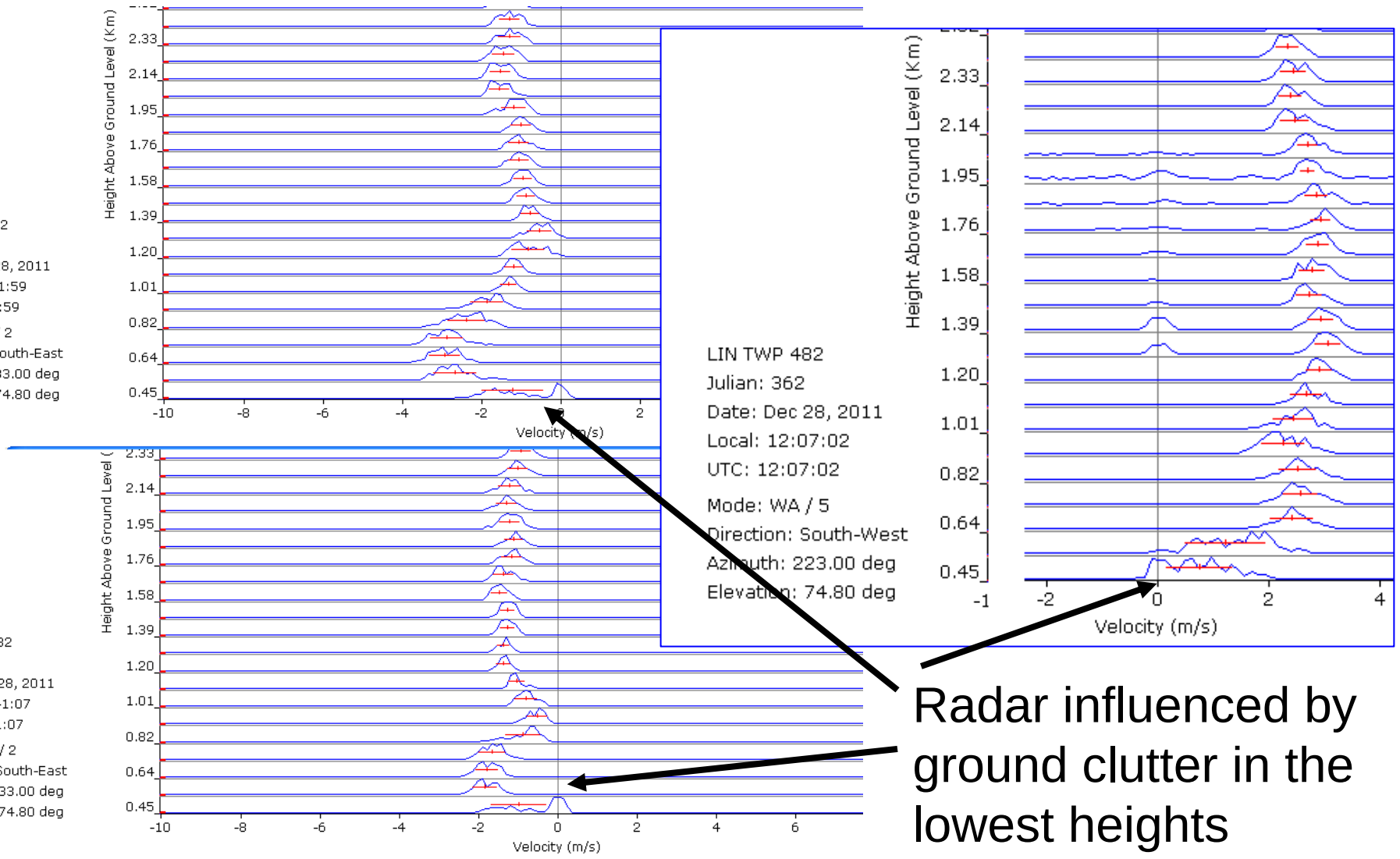

Radar influenced by ground clutter in the lowest heights

Results - profiles

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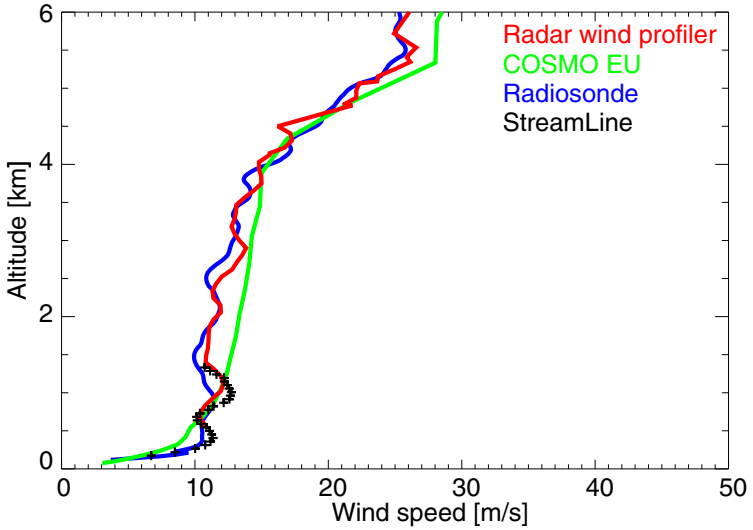

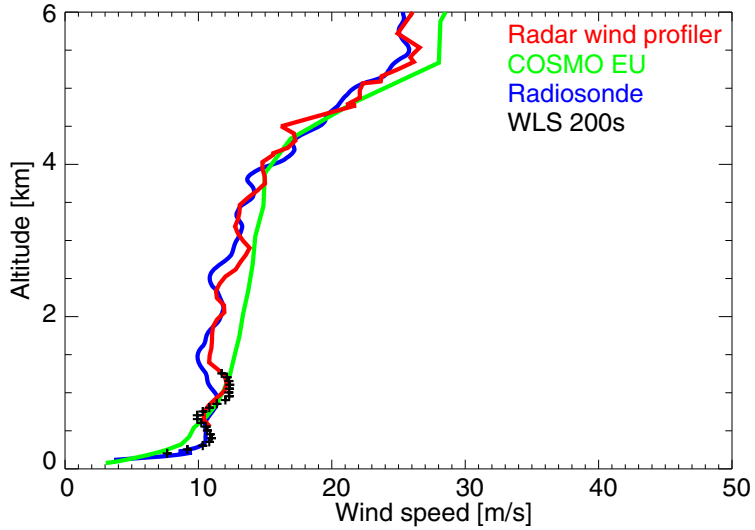

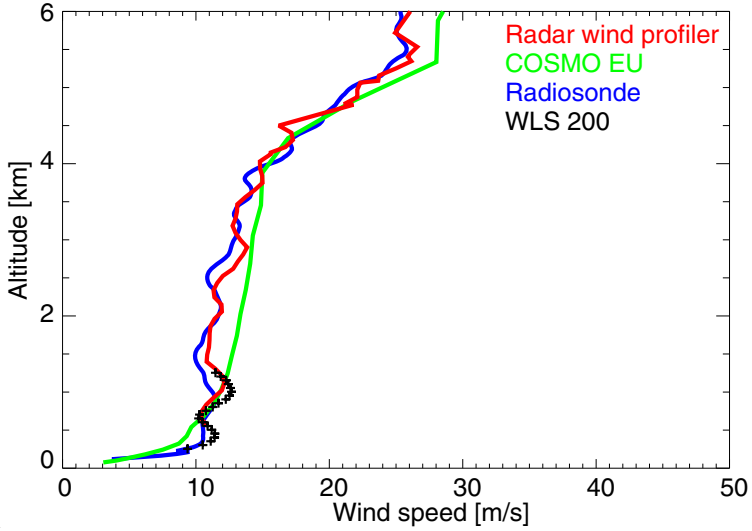

30. Nov. 2011 16:44 UTC

Results - time series

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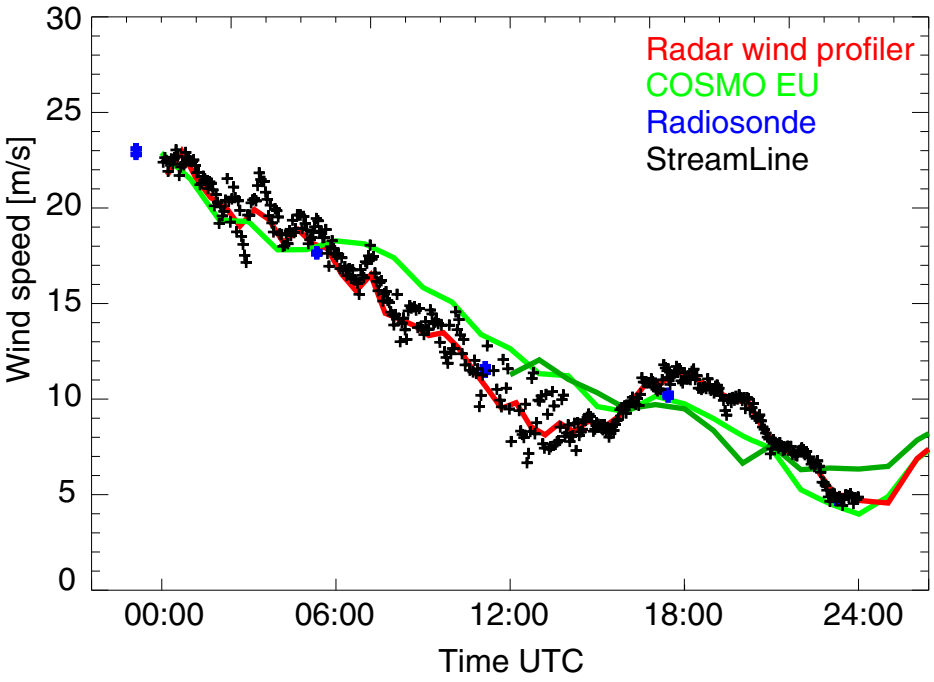

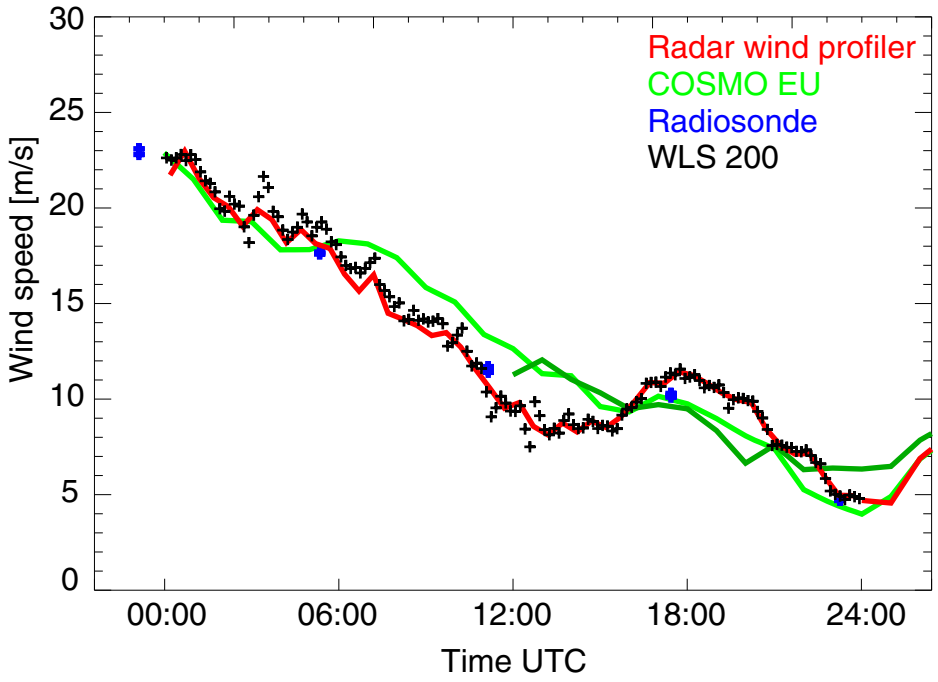

30. Nov. 2011, Altitude: 552m

Conclusion

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- All Doppler wind lidars are in a good agreement with the radar wind profiler
  - differences in **wind speed** of **0.2m/s** are observable
  - differences of **2°** are observable for **wind direction**
    IMPORTANT: accurate alignment of lidar is required !!
  - Large differences occur in the lowermost and uppermost altitude levels (ground clutter in RWP measurements / weak CNR)

- Data availability of wind lidars more than 90% up to 500 m → complement the wind profile retrieved by radar wind profilers
- **Doppler wind lidars are promising instruments for operational and scientific wind measurements in the boundary layer**

Thank You!