



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

Bernd Stiller, Ronny Leinweber, Volker Lehmann

DWD - Deutscher Wetterdienst  
Meteorologisches Observatorium Lindenberg  
Germany  
[Ronny.Leinweber@dwd.de](mailto:Ronny.Leinweber@dwd.de)

# Outline

- 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



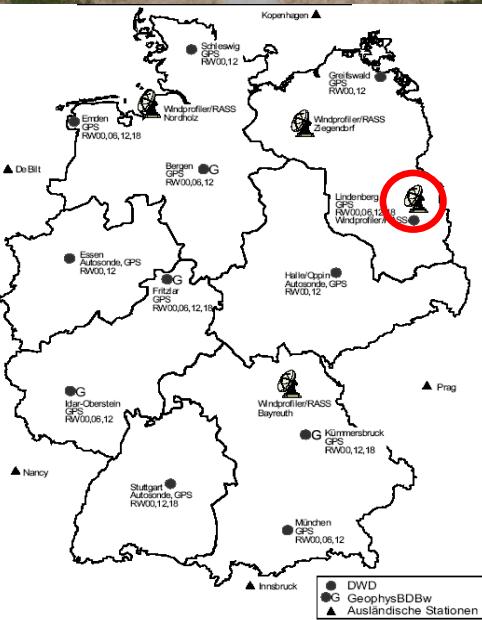
- Since 2 years commercial Doppler wind lidars available at the market
- providing vertical profiles in of the horizontal wind the boundary layer at high temporal and vertical resolution
- Questions:
  - What potential do Doppler lidars have for operational wind profile measurements ?
  - Can wind lidars 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)



## WP-Lindenberg:

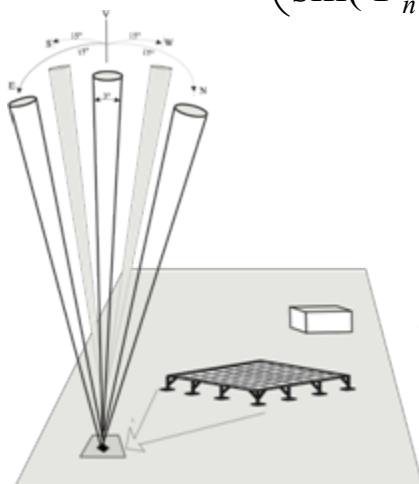
- Frequency: 482 MHz
- WMO No.: 10394
- Latitude: 52,21° N  
Longitude: 14,10° E
- Height: 104 m
- Vertical resolution:
  - 150 m for low mode - Pulse width: 1000ns
  - 330 m for high mode - Pulse width: 2175ns
- Range:
  - 500 m to 9 km for low mode, 96 range gates
  - 4 km to 16,5 km for high mode, 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

For (horizontally) homogeneous wind field :

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



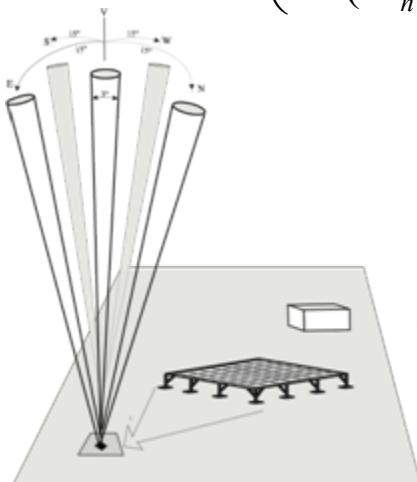
$$A v = v_r$$

$$v = (A^\top A)^{-1} A^\top v_r$$

# Calculation of horizontal wind field

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$$A v = v_r$$

$$v = (A^\top A)^{-1} A^\top v_r$$

singular value decomposition of  $A$  :  $A = U\Sigma V^\top$

$$v = V\Sigma^{-1}U^\top v_r$$

# Doppler wind lidars

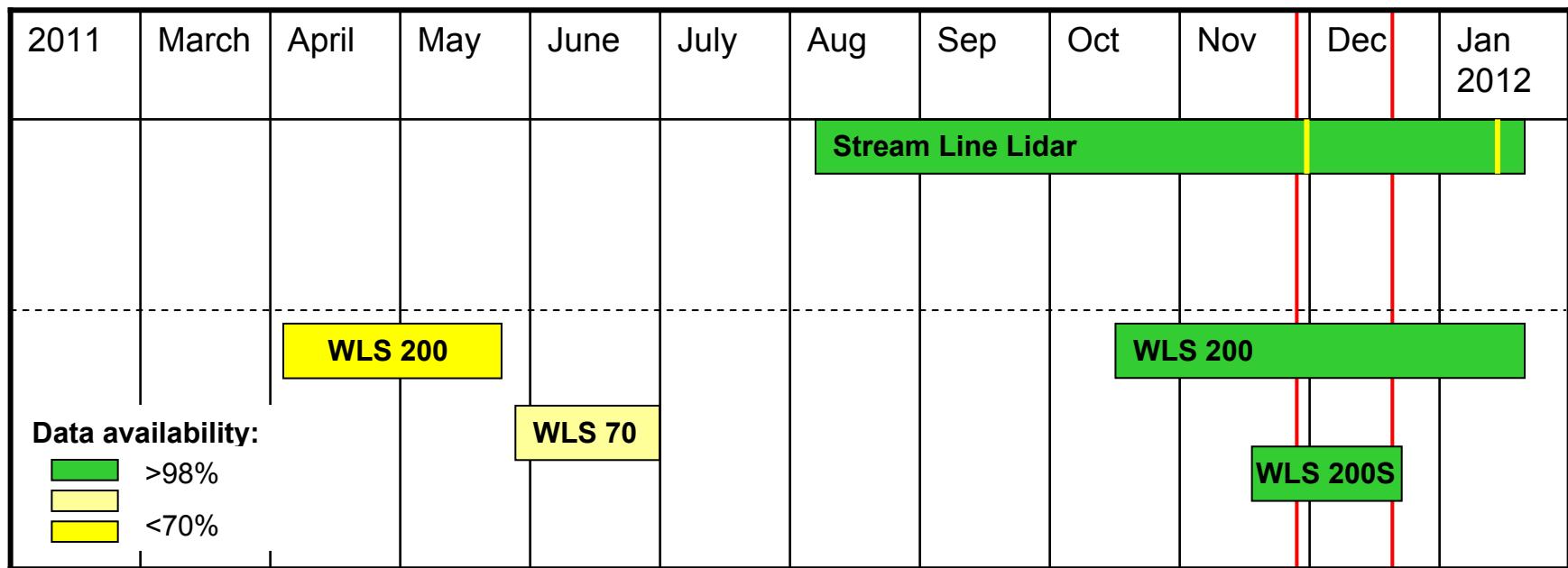
Deutscher Wetterdienst  
Wetter und Klima aus einer Hand



Type	Streamline Lidar	Windcube WLS 70/200	Windcube WLS 200S
	A compact, white Streamline Lidar unit mounted on a black tripod stand in a grassy field. It has a small circular sensor head on top and a control unit with cables at the bottom.	A white rectangular Windcube WLS 70/200 unit with four black fans on top, mounted on a black tripod stand in a grassy field.	A larger white rectangular Windcube WLS 200S unit with multiple ports and cables, mounted on a black tripod stand in a grassy field.
Manufactured by	HALO photonics	Leosphere	Leosphere
Provided by	Karlsruhe Institute of Technology (KIT)	GWU-Umwelttechnik 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



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

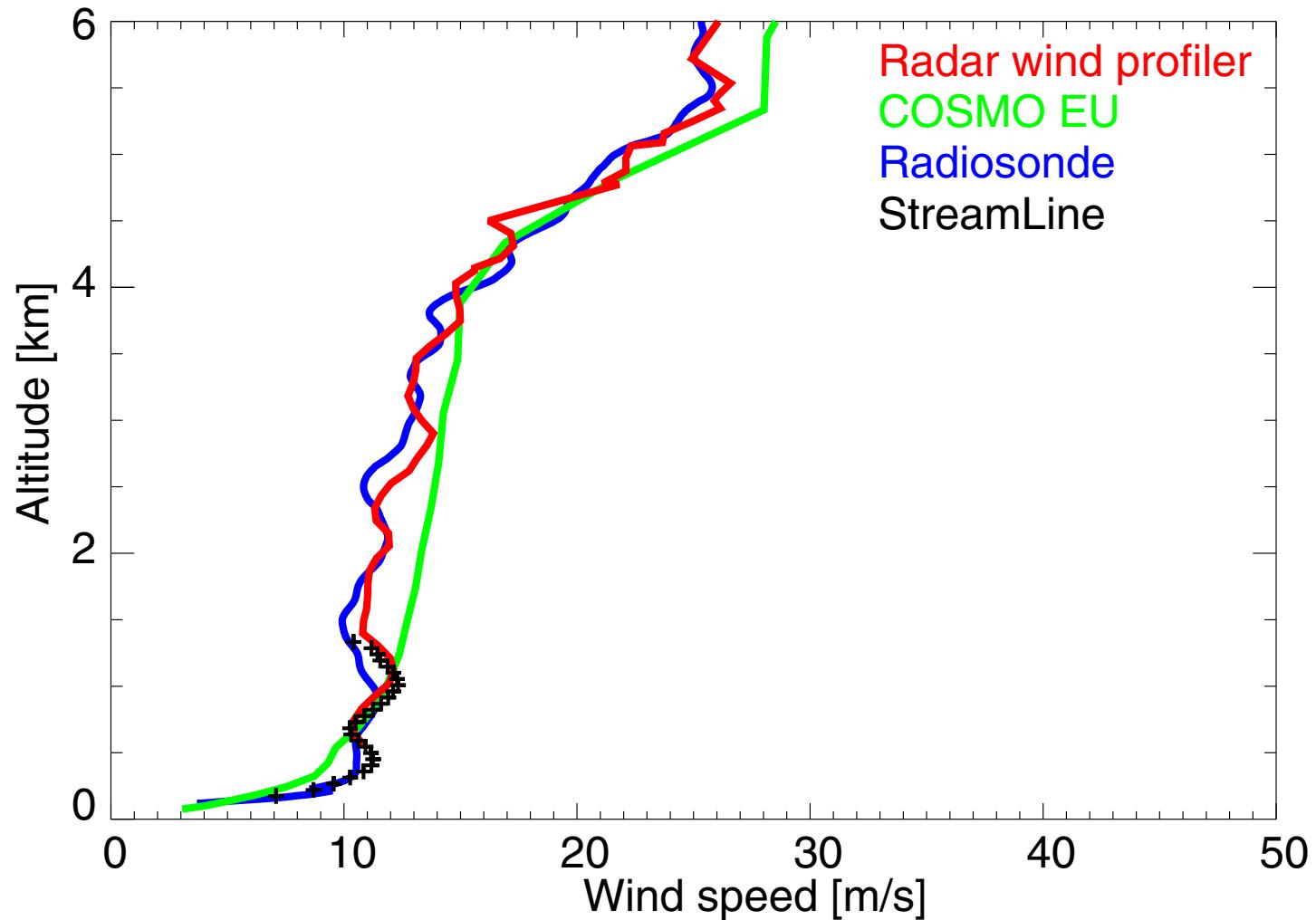
# Campaign setup



Three different Doppler Lidars next to LIN 482 MHz 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)
  - Radiosondes (RS)
  - NWP: DWD COSMO-EU model output
- Temporal and vertical resolution (wind speed/direction):
  - RWP            27min / 150m
  - WLS 200        10min / 50m
  - WLS 200S      2min / 50m
  - StreamLine     3min / 50m
  - RS              6h / 10-12m
  - COSMO-EU     1h (00UTC and 12UTC forecast) / ~130m
- **all datasets were interpolated to the vertical resolution (150m) and averaged to temporal resolution (27min) of the radar wind profiler**

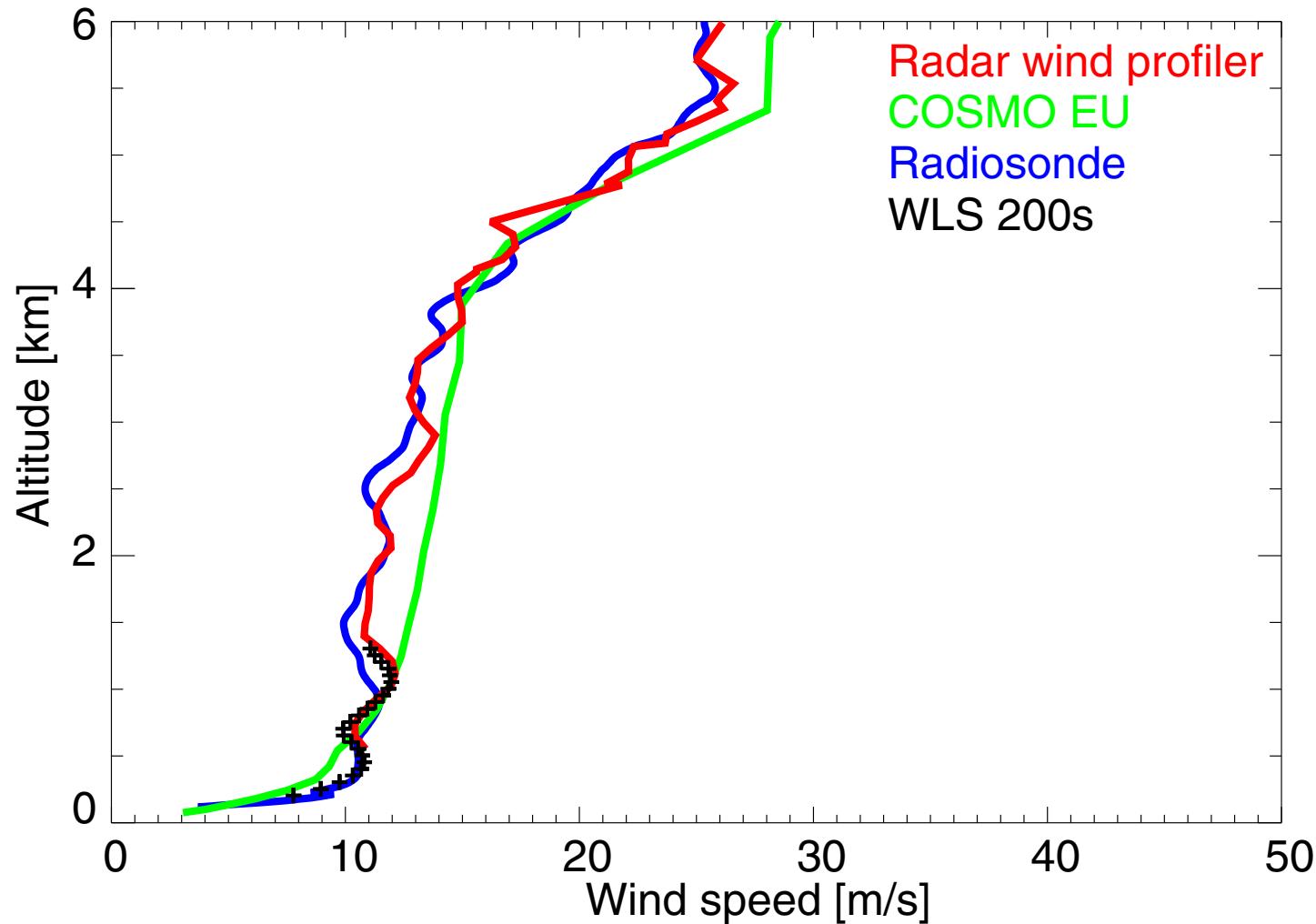
# Results - profiles



30.11.2011 16:30 – 17:00 UTC



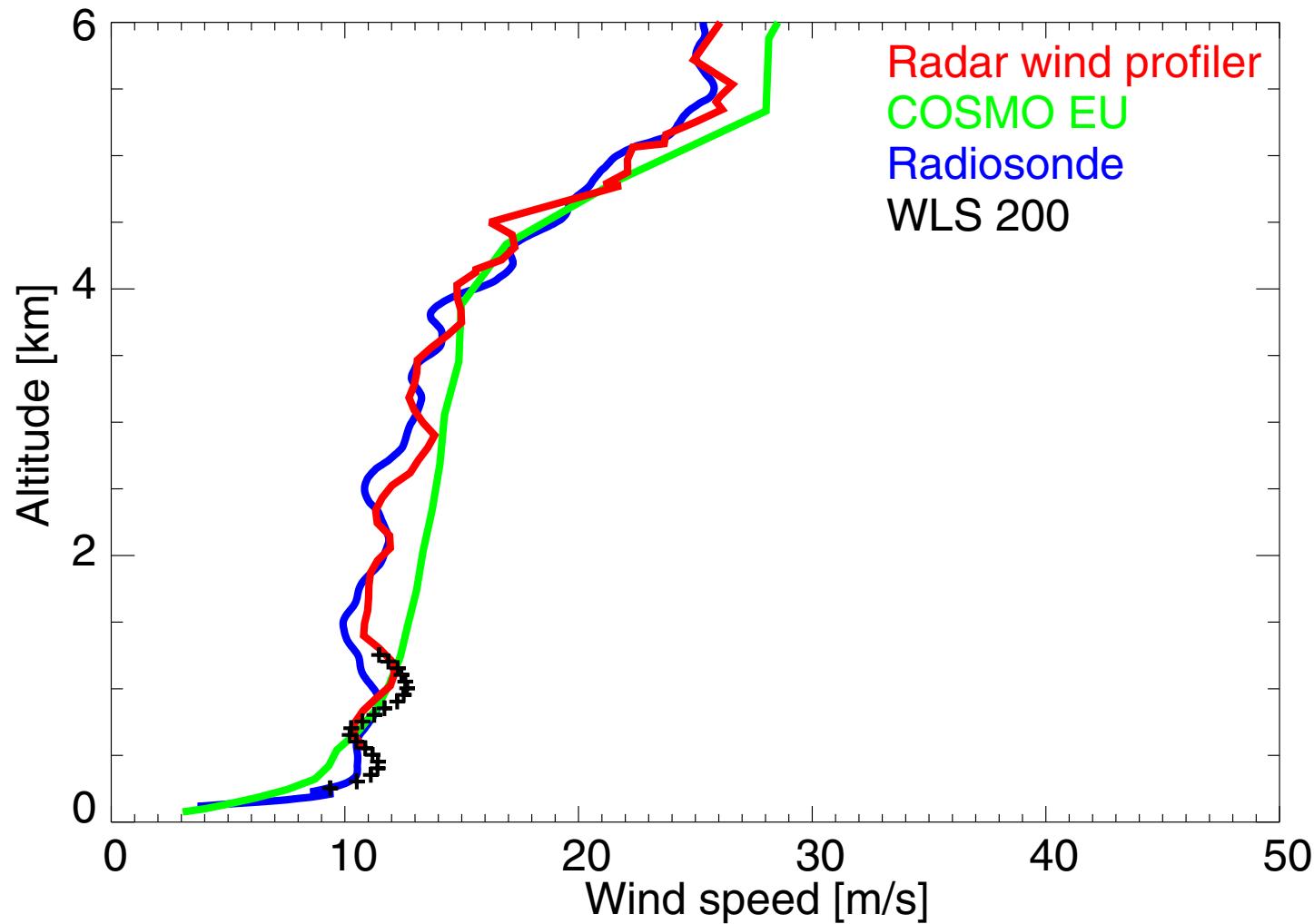
# Results - profiles



30.11.2011 16:30 – 17:00 UTC



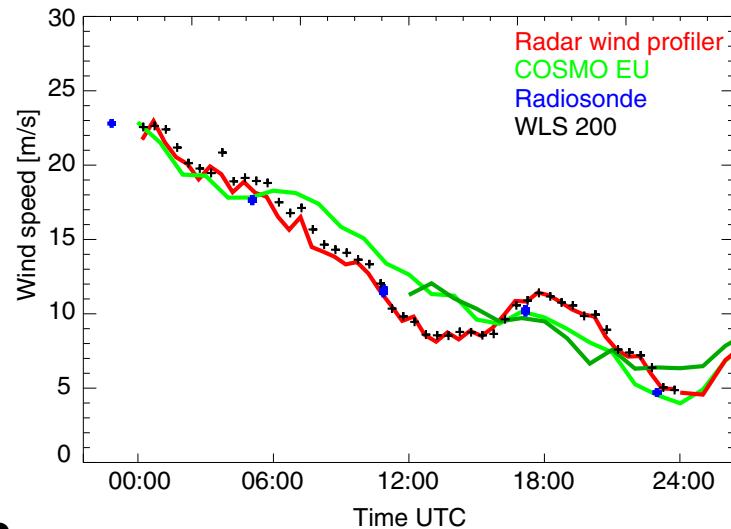
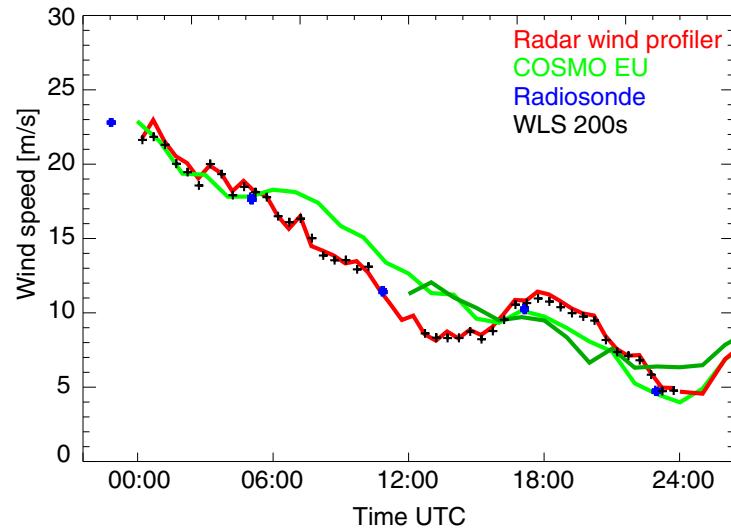
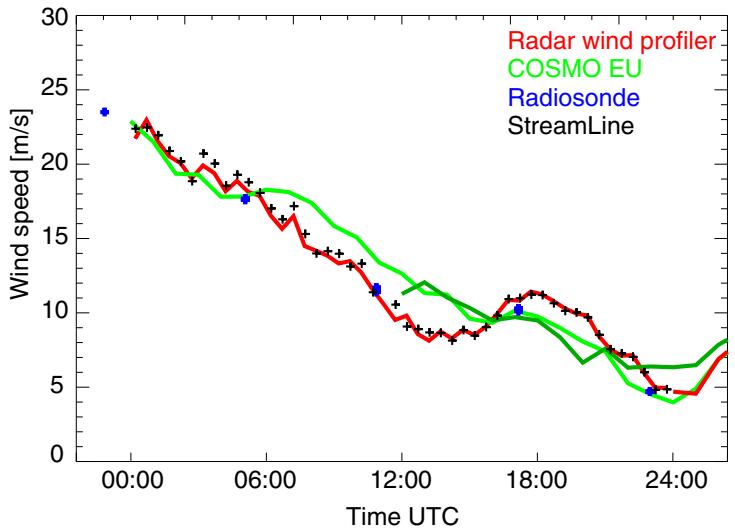
# Results - profiles



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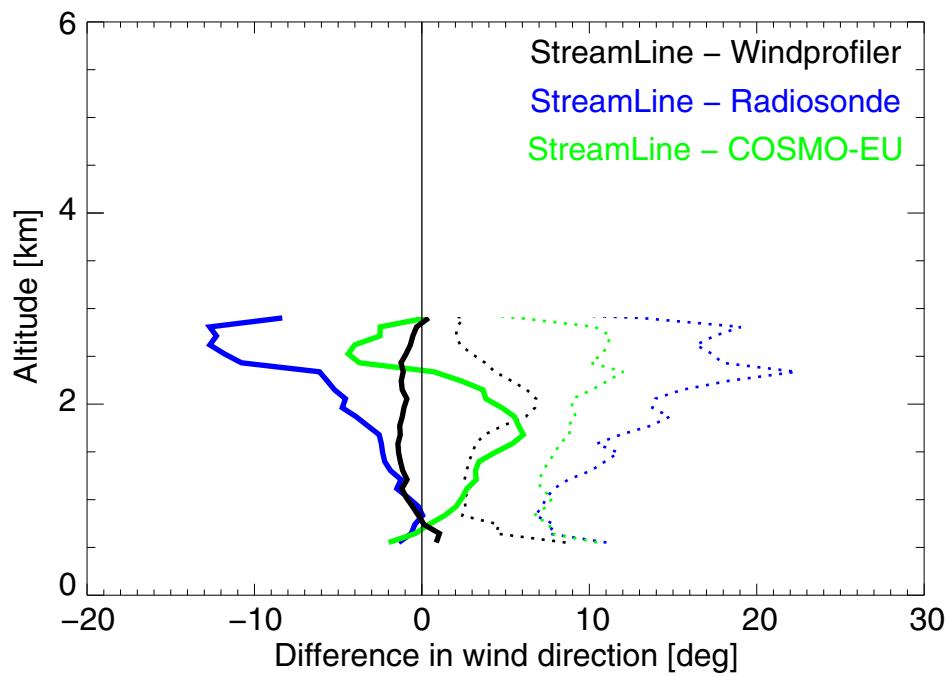
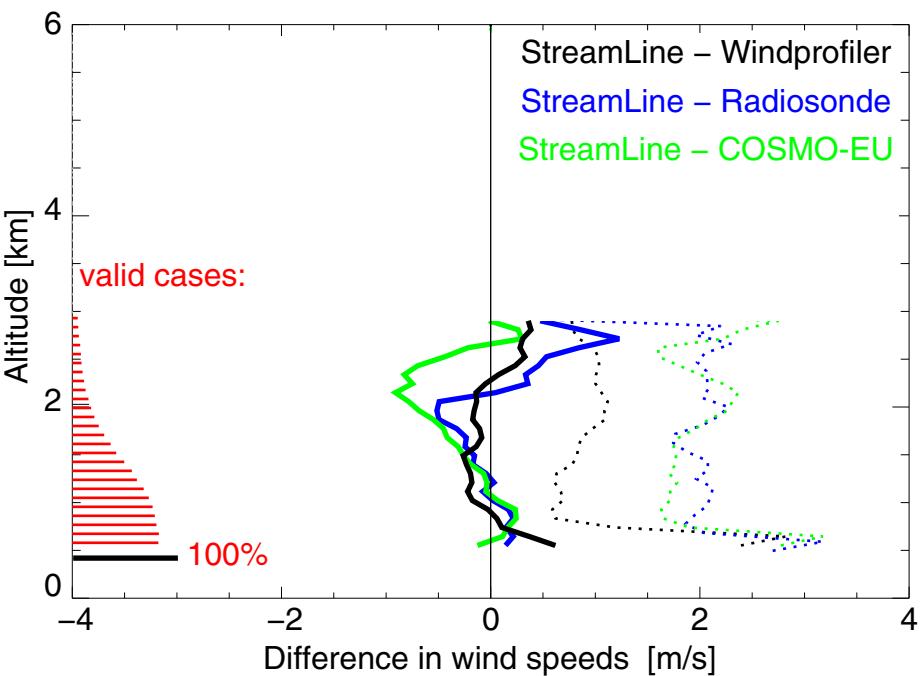
# Results - time series



30.11.2011, Altitude: 552m

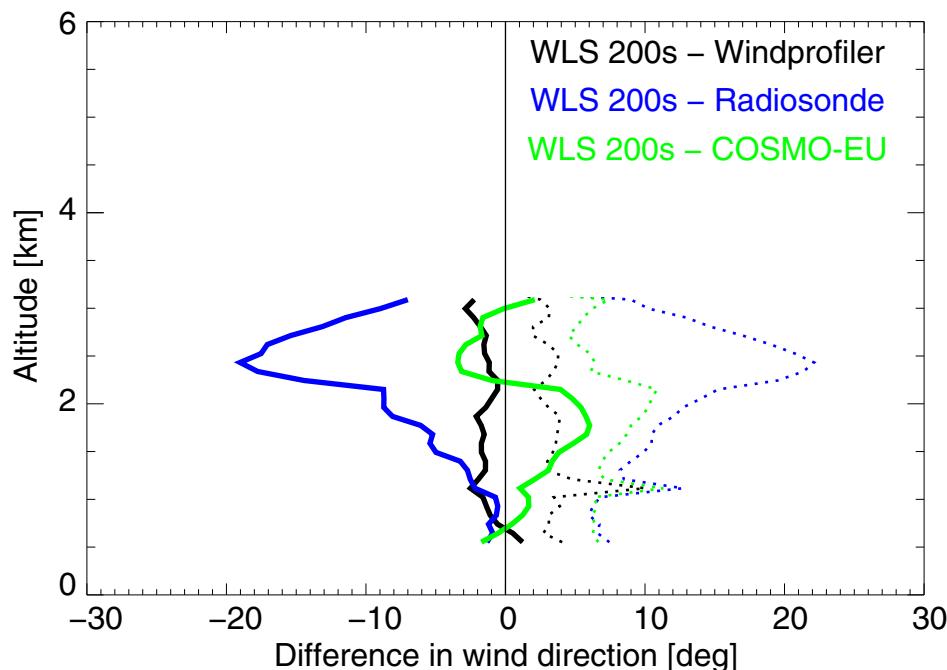
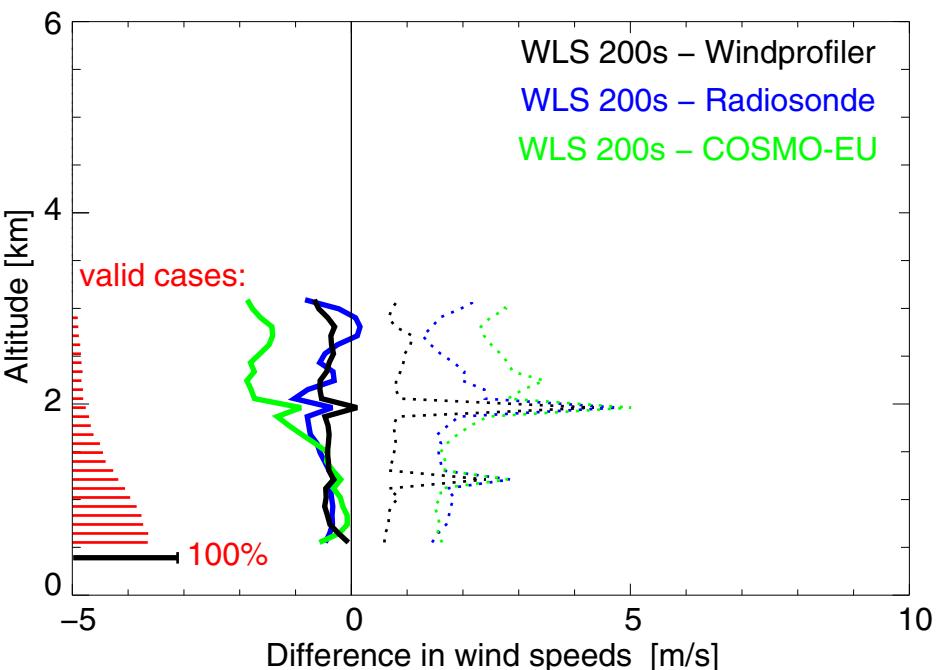


# Results - StreamLine



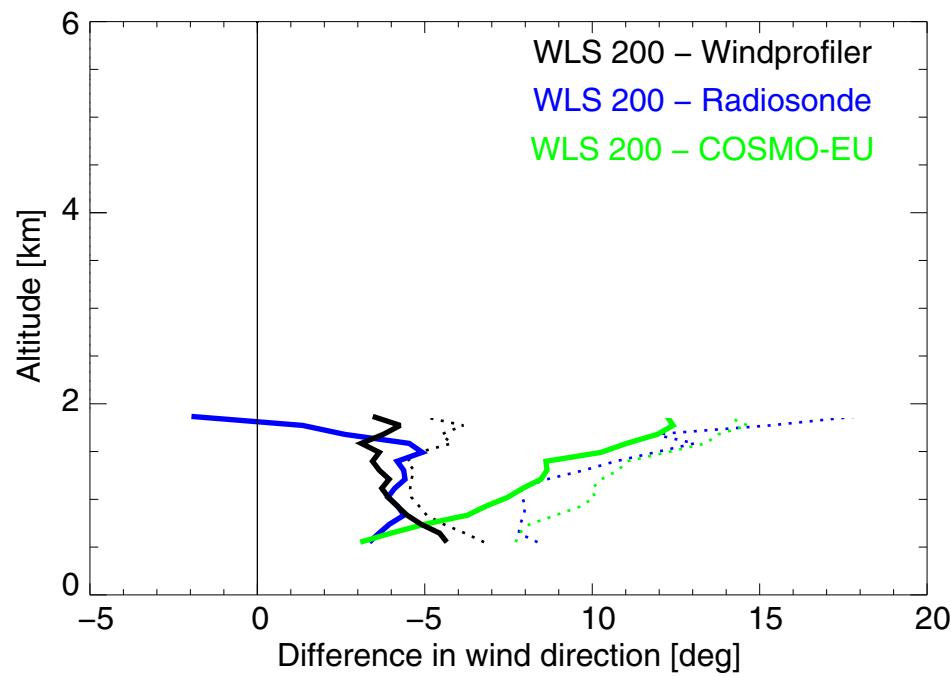
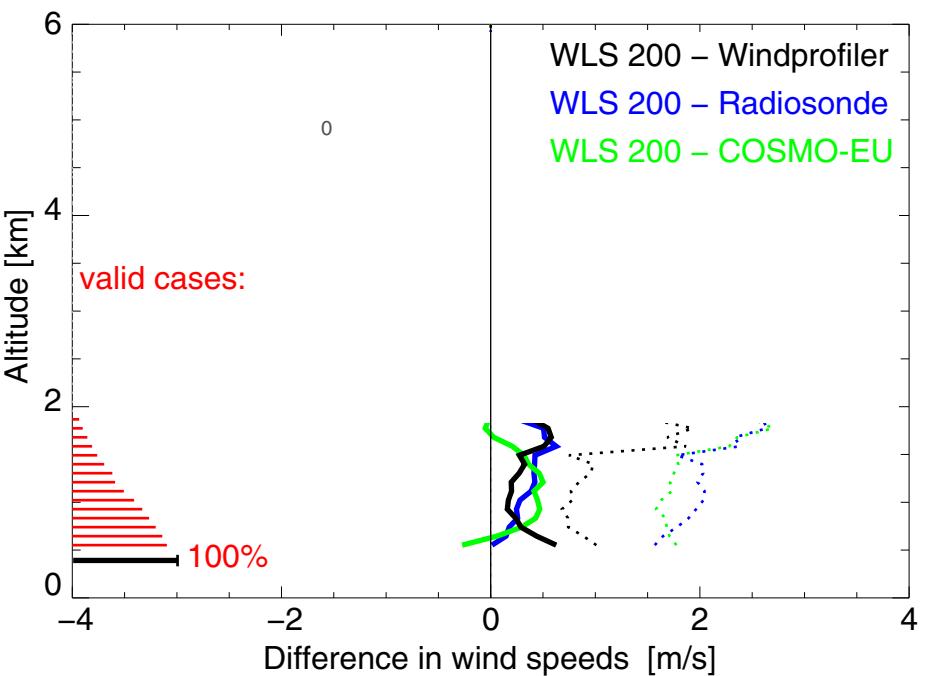
- Period 29.11.2011 - 20.12.2011 (3 weeks)
- Differences in WD  $<2^\circ$ ; WS  $<0.25\text{m/s}$  to RWP

# Results - WLS 200s



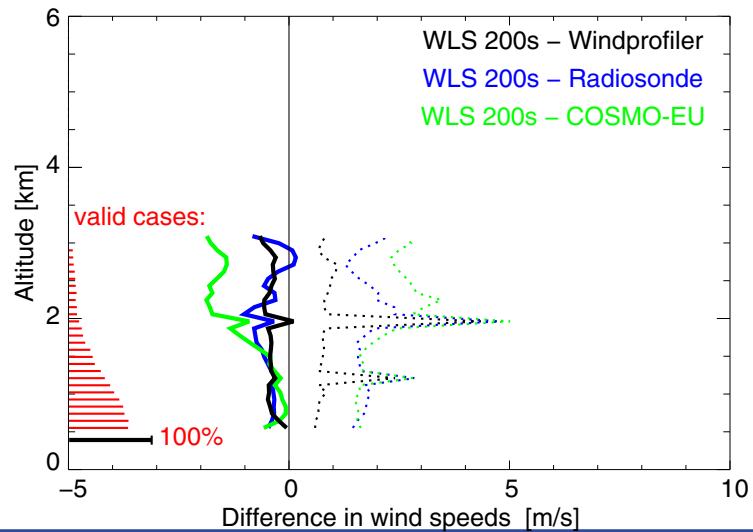
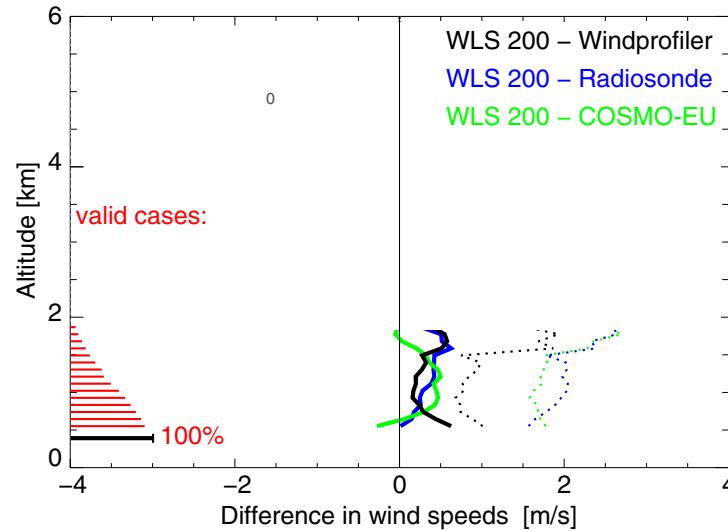
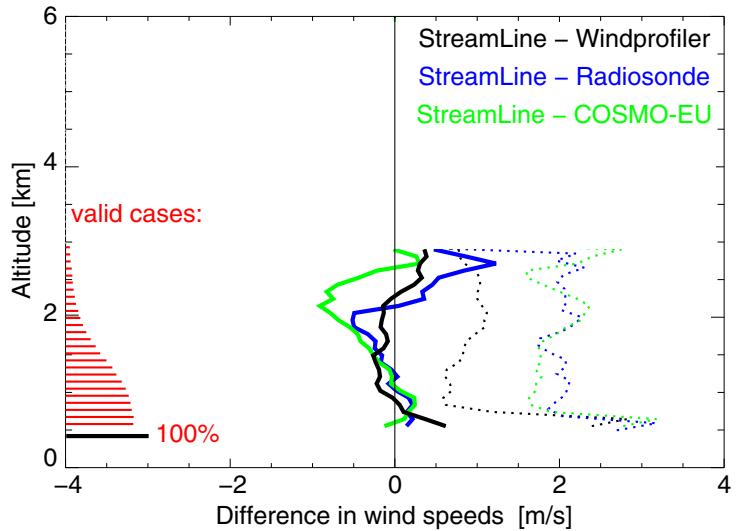
- Period 29.11.2011 - 20.12.2011 (3 weeks)
- Differences in WD <2.0° ; WS <0.5m/s to RWP

# Results - WLS 200

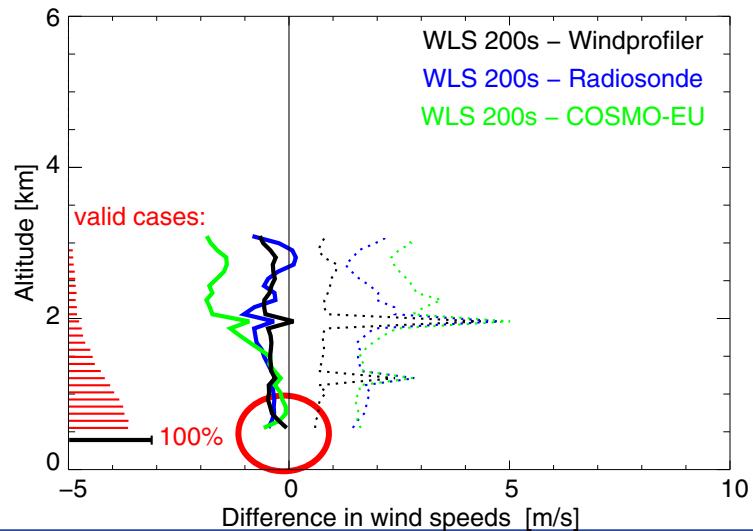
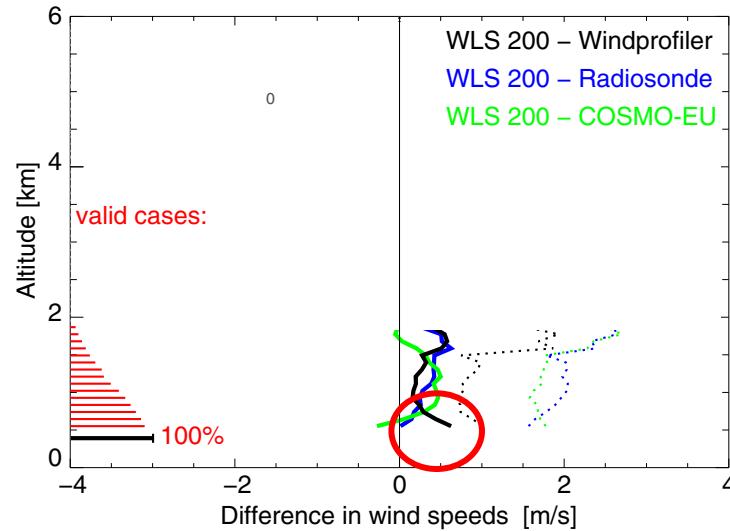
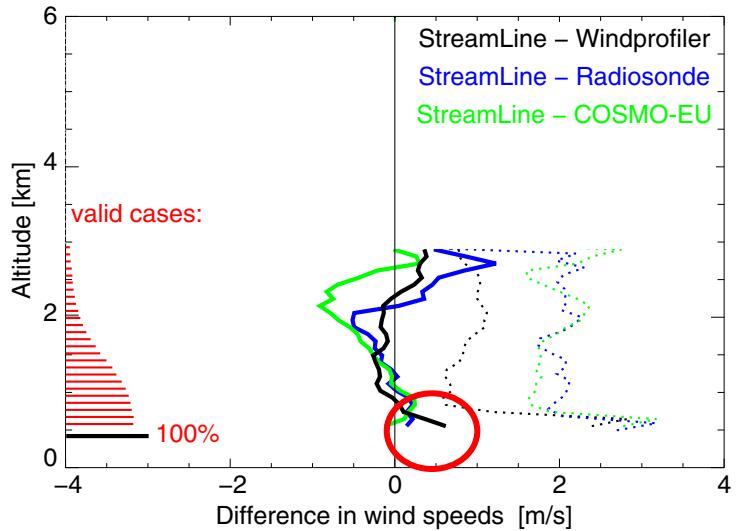


- Period 29.11.2011 - 20.12.2011 (3 weeks)
- Differences in WD <4.0° ; WS <0.25m/s to RWP

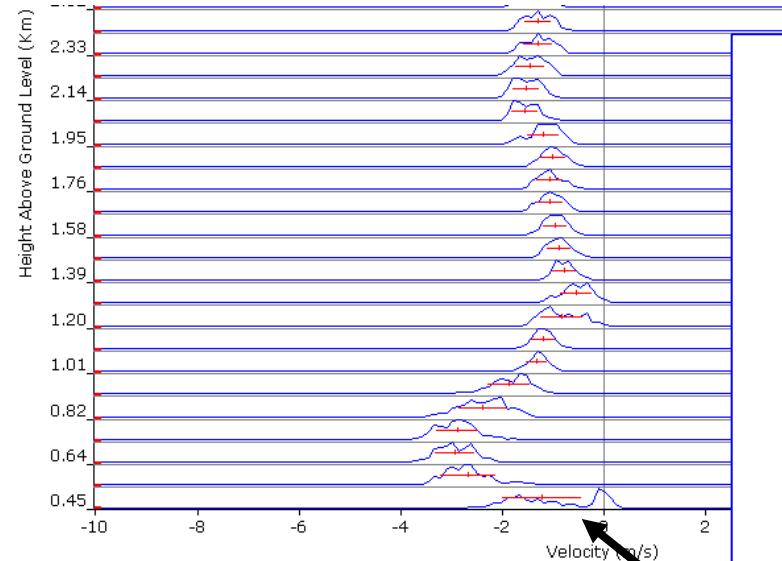
# Results



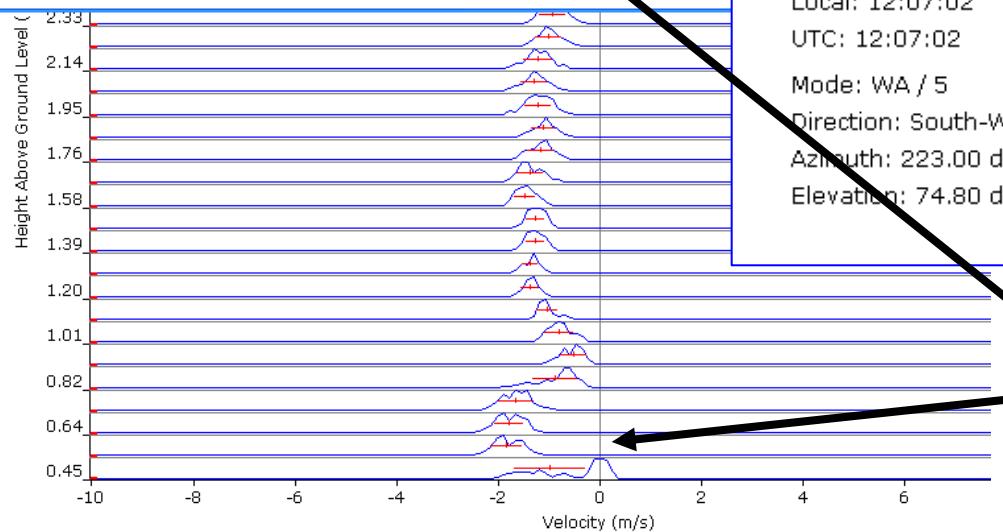
# Results



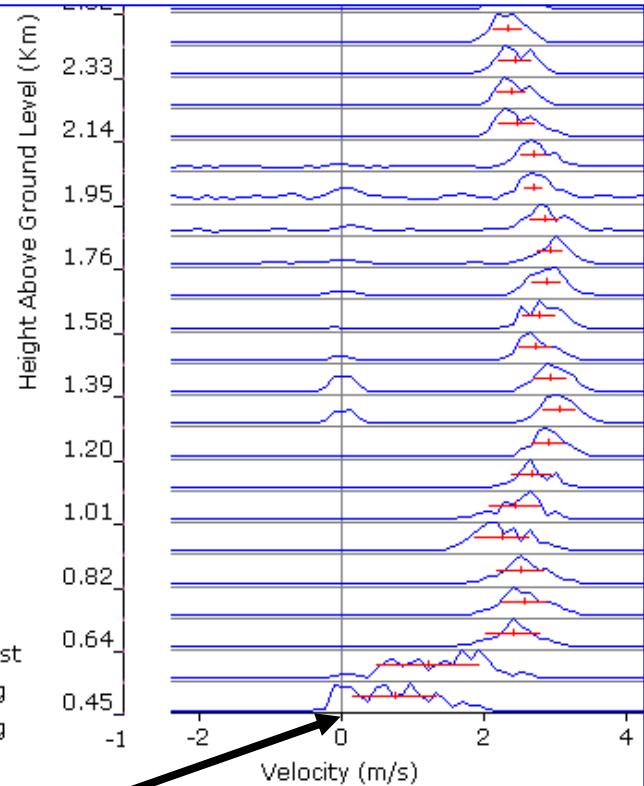
IN TWP 482  
 Julian: 362  
 Date: Dec 28, 2011  
 Local: 20:21:59  
 UTC: 20:21:59  
 Mode: WA / 2  
 Direction: South-East  
 Azimuth: 133.00 deg  
 Elevation: 74.80 deg



IN TWP 482  
 Julian: 362  
 Date: Dec 28, 2011  
 Local: 18:41:07  
 UTC: 18:41:07  
 Mode: WA / 2  
 Direction: South-East  
 Azimuth: 133.00 deg  
 Elevation: 74.80 deg



LIN TWP 482  
 Julian: 362  
 Date: Dec 28, 2011  
 Local: 12:07:02  
 UTC: 12:07:02  
 Mode: WA / 5  
 Direction: South-West  
 Azimuth: 223.00 deg  
 Elevation: 74.80 deg



Radar influenced by ground clutter in the lowest heights



# Conclusion

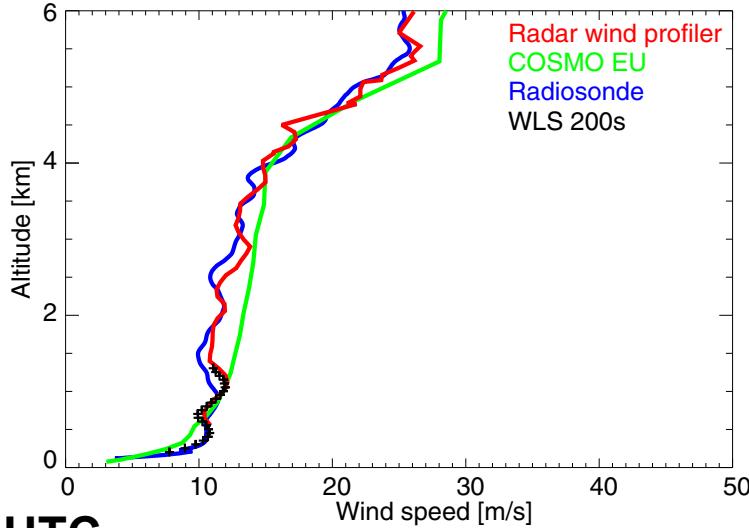
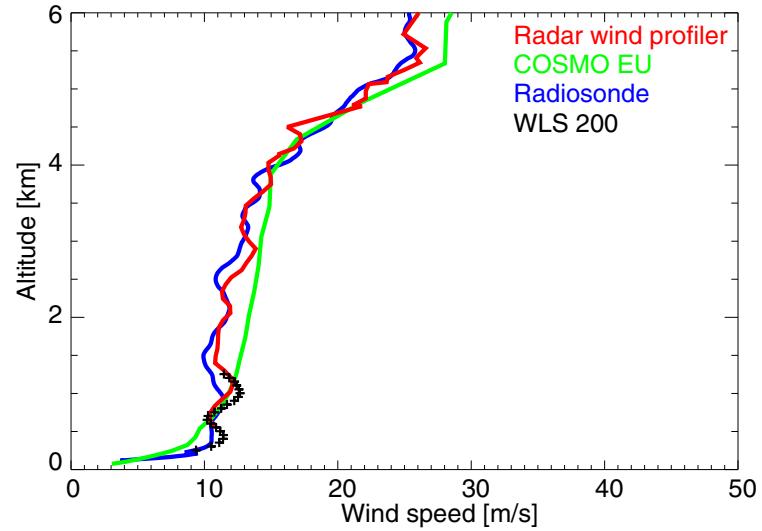
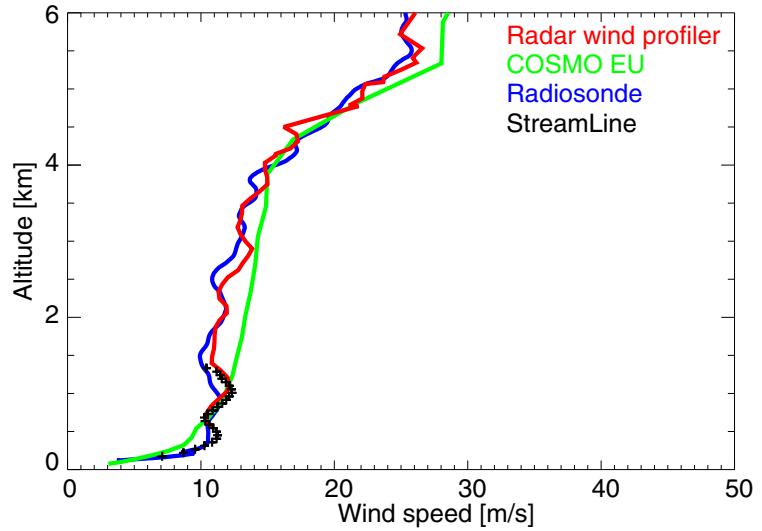
- All Doppler wind lidars are in a good agreement with the radar wind profiler for a period of 3 weeks
  - differences in **wind speed** of **0.25m/s** were observed
  - differences of **2°** were observed for **wind direction**  
IMPORTANT: accurate alignment of lidar is required !!
  - Large differences occur at 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 (UHF) radar wind profilers
- **Doppler wind lidars are promising instruments for operational and scientific wind measurements in the boundary layer**

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# Thank You!



# Results - profiles



30.11.2011 16:30 – 17:00 UTC

