Long term evaluation of Aeolus wind profiles at Lindenberg observatory

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Meteorological Observatory Lindenberg
Ground based remote sensing capabilities

Active Remote Sensing

- Radar wind profiler/RASS **62 cm**
- Doppler wind LIDAR **1.5 µm**
- Raman-LIDAR RAMSES **355 nm**
- Ka-band „cloud” radar MIRA **8.6mm**
**UHF Windprofiler Radar / RASS LAP-16000**

- **main product:** vertical profiles of wind vector
- **data available 24/7 in both clear and cloudy atmosphere**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>482.0078 MHz (λ ~ 62 cm)</td>
</tr>
<tr>
<td>Vertical range</td>
<td>0.5 – 16 km</td>
</tr>
<tr>
<td>Vertical resolution</td>
<td>150 / 330 m</td>
</tr>
<tr>
<td>Averaging time</td>
<td>~10 – 30 min</td>
</tr>
</tbody>
</table>
Radar Wind Profiling: Doppler Beam Swinging

\[
\begin{pmatrix}
\sin(\alpha_1)\sin(\epsilon_1) & \cos(\alpha_1)\sin(\epsilon_1) & \cos(\epsilon_1) \\
\sin(\alpha_2)\sin(\epsilon_2) & \cos(\alpha_2)\sin(\epsilon_2) & \cos(\epsilon_2) \\
\sin(\alpha_3)\sin(\epsilon_3) & \cos(\alpha_3)\sin(\epsilon_3) & \cos(\epsilon_3) \\
\sin(\alpha_4)\sin(\epsilon_4) & \cos(\alpha_4)\sin(\epsilon_4) & \cos(\epsilon_4) \\
\sin(\alpha_5)\sin(\epsilon_5) & \cos(\alpha_5)\sin(\epsilon_5) & \cos(\epsilon_5)
\end{pmatrix}
\begin{pmatrix}
u \\
w
\end{pmatrix}
= \begin{pmatrix}
v_{r1} \\
v_{r2} \\
v_{r3} \\
v_{r4} \\
v_{r5}
\end{pmatrix}
\]

\[
v = (A^T A)^{-1} A^T v_r
\]
DWD Wind Profiler Network

Operational systems:
- Aug. 2003: 1st system: Ziegendorf
- May 2004: 2nd system: Nordholz
- Aug. 2005: 3rd system Bayreuth
- Nov. 2009: 4th system at MOL (completely new radar, prototype radar dismantled)

Projected lifetime of radars: 15 years
Co-operative network, no central funding for sites

- 42 RWP:
  - VHF: 16 (including 11 O-Q network radars)
  - UHF: 4 (Germany, 482 MHz)
  - L-Band: 22 (including La Reunion and Samoa)
- Additional 107 „weather radars“ (mostly C-Band): VAD, VVP wind data
- CWINDE Hub at UK MetO
- Technical support: Best endeavors under lead of MeteoSwiss
- Regular NWP monitoring information provided to operators (from 5 NWP Centers)
- Performance monitoring against simple and well-defined targets
Results from the following NWP centers are also available:

- DWD
- UK MetO
- MeteoFrance

Full line: OBS-FG
Dashed line: OBS-AN
Dotted line: Mean observation
(scale at the top of each plot)
**Performance monitoring**

**E-PROFILE RWP** and **W-RWP operational report**

**PROGRAMME:** E-PROFILE  
**REPORTING PERIOD:** December 2014  
**NETWORK MANAGER:** Maxime Hervo  
**DATE OF ISSUE:** 2015-01-15

<table>
<thead>
<tr>
<th>Target TUA023 01</th>
<th>Wind Profiler data, entering the hub and being processed within each minute averaged over the month, more than 98% of the time.</th>
<th>A) Incoming Data 100%</th>
<th>MET</th>
<th>B) Outgoing Data 100%</th>
</tr>
</thead>
</table>

1. **Availability, Timeliness and quality**

1.1 **Radar Wind Profiler (RWP)**

<table>
<thead>
<tr>
<th>WMO Code</th>
<th>WMO Name</th>
<th>WMO Mode</th>
<th>Availability</th>
<th>Timeliness</th>
<th>Quality</th>
<th>Root mean square vector difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10135</td>
<td>Nordholz</td>
<td>high</td>
<td>99</td>
<td>100</td>
<td></td>
<td>2.56</td>
</tr>
<tr>
<td>10266</td>
<td>Ziegendorf</td>
<td>high</td>
<td>99</td>
<td>100</td>
<td></td>
<td>2.74</td>
</tr>
<tr>
<td>10394</td>
<td>Lindenberg 482</td>
<td>high</td>
<td>100</td>
<td>100</td>
<td></td>
<td>2.75</td>
</tr>
<tr>
<td>10678</td>
<td>Bayreuth</td>
<td>high</td>
<td>99</td>
<td>100</td>
<td></td>
<td>4.03</td>
</tr>
<tr>
<td>10678</td>
<td>Bayreuth</td>
<td>low</td>
<td>99</td>
<td>100</td>
<td></td>
<td>4.03</td>
</tr>
</tbody>
</table>
Comparison statistics WR – RS (2010 - 2014)
Doppler wind LIDAR and Wind profiler colocation

1.5 µm Doppler-Lidar

482 MHz Doppler Radar
Wind:

• Operational vertical wind vector profiles from radar wind profilers and radiosondes
  → Horizontal wind vectors will be projected onto the HLOS direction of ALADIN
  → Long-term comparison statistics

• High resolution wind measurements in boundary layer from Doppler wind lidars

• Open question:
  • What is the optimal temporal averaging interval to minimize sampling error?
  → RWP data can be reprocessed with variable temporal resolution based on archived raw data

Aerosol and clouds:

• 35.5 GHz Ka-Band radar (Cloudnet products)
• AERONET sun-photometer (AOD @ 340, 380 nm)
• 1064 nm Ceilometer CHM-15 k (Cloudnet products)

Special campaigns
• 355 nm Raman lidar RAMSES (backscatter and extinction coefficient, depolarisation,...)
Lindenberg, Sep 03, 2011: Aerial view of 482 MHz RWP

Thank you!
Laser, transmitter:
• injection-seeded, frequency-tripled Nd:YAG laser
• PRF=30 Hz, > 400 mJ UV pulse energy (transmitted; $\lambda_L = 354.7$ nm)
• tenfold beam expansion (eye safety)

Receiver:
• 20-cm near-range telescope, fiber-coupled, 3-channel polychromator
• 80-cm far-range telescope, nonfiber-coupled, 9-channel polychromator
  OR 8-channel polychromator and water spectrometer (385-410 nm)
• fluorescence spectrometer (~370 – 770 nm)

Operation:
• autonomous, 24/7
• active beam stabilization (optional)

Measurement parameters (direct):
• $m$, $\alpha$, $\beta$, $S$, $\delta$, $\beta_{\text{ice}}$, $\beta_{\text{liq}}$, $T$, …
Measurement example
6-7 August 2014
Starting 22:30 UTC
Integration 1200 s
White areas:
Noise filtering applied

Raman Lidar products
## Ka-Band cloud radar MIRA 36

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavelength</strong></td>
<td>35.5 GHz (8 mm) Radar (Ka-Band)</td>
</tr>
<tr>
<td><strong>Manufacturer</strong></td>
<td>Metek GmbH</td>
</tr>
<tr>
<td><strong>Transmitter</strong></td>
<td>Magnetron, PEP 30 kW</td>
</tr>
<tr>
<td><strong>Antenna</strong></td>
<td>Cassegrain antenna with polarization filter</td>
</tr>
</tbody>
</table>
| **Receiver**             | - Coherent on receive  
- Dual linear polarization  
- Doppler moments in two RX channels                             |
| **Vertical range**       | 0.25 – 15km                                                            |
| **Vertical resolution**  | 30m                                                                     |
| **Averaging time**       | 10 s (2 s spectra)                                                     |
| **Sensitivity**          | - 55dBZ (5km, 10s)                                                     |
Cloudnet processed measurements from Lindenberg

http://www.cloud-net.org/
Radiosonde: Routine RS 92 + GRUAN

Daily launches: 00, 06, 12, 18 UTC

www.gruan.org
MOL providing data to AERONET since Aug 27, 2013

http://aeronet.gsfc.nasa.gov/cgi-bin/type_one_station_opera_v2_new?site=MetObs_Lindenberg&nachal=2&level=1
Wind vector:

→ 482 MHz Radar wind profiler ~ 0.5…. 15 km, 30 min
→ 1.5 µm Doppler lidar ~ 0.1…. 3 km, 30 min (10 min possible)
→ 4 Radiosonde launches (RS-92) per day

Note: fully operational is 2D wind - (u,v), vertical wind is still experimental

Optical parameters:

→ 355 nm Raman lidar RAMSES (backscatter, extinction, depol.ratio profiles)
→ 35.5 GHz Ka-Band radar (Cloudnet products)
→ CIMEL (AOD @ 340, 380 nm)
→ 1064 nm Ceilometer CHM-15 k (Cloudnet products)
Doppler wind LIDAR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>1.55 µm</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Halo Photonics</td>
</tr>
<tr>
<td>PRF</td>
<td>10 kHz</td>
</tr>
<tr>
<td>Max. range</td>
<td>9830 m</td>
</tr>
<tr>
<td>Range gates</td>
<td>200</td>
</tr>
<tr>
<td>Range resolution</td>
<td>48 m (16 pts)</td>
</tr>
<tr>
<td>Laser shots per ray</td>
<td>75,000</td>
</tr>
<tr>
<td>Nyquiste velocity</td>
<td>19.4 ms⁻¹</td>
</tr>
<tr>
<td>Velocity resolution</td>
<td>0.0382 ms⁻¹</td>
</tr>
<tr>
<td>Dwell time for one ray</td>
<td>5 s</td>
</tr>
<tr>
<td>Products</td>
<td>3D wind vector</td>
</tr>
</tbody>
</table>

Retrieval: Vertical profiles of horizontal wind (30 min average)
Doppler wind LIDAR and Wind profiler colocation

1.5 µm Doppler-Lidar

482 MHz Doppler Radar
UK MetOffice FSO estimate of RWP impact

Reduction of forecast error measured by global moist energy norm (u,v,T,p,q)

4 German TEMPs vs. 4 German RWP (482 MHz)

First results from UK MetO FSO-tool for the period
Aug 22 – Sep 29, 2010

Lindenberg RWP impact is 5 times bigger than the impact of a co-located Radiosonde!

Courtesy:
Richard Marriott
Catherine Gaffard
Ronny Leinweber
Long term evaluation of AEOLUS wind profiles at Lindenberg observatory

Ronny Leinweber

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