Applied Workshop: Doppler Lidars for Wind Energy

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Publication date: 2018

Document Version
Peer reviewed version

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Applied Workshop: Doppler Lidars for Wind Energy

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Vrije Universiteit Brussel
September 19, 2018 @ 9AM
How and what does a Doppler lidar measure?

- Doppler lidars measure motion, unlike ranging lidars (which can only measure distance).

Simplified measurement process:
- Laser light (near infrared, 1.5 μm) is emitted.
- Beam interacts with aerosols (particles) suspended in the air.
- The light frequency (wavelength) is shifted by the apparent speed.
- The backscatter signal is received and digitized.
- The dominant frequency is found by spectral analysis.
- Using the Doppler shift and speed of light, the radial velocity is obtained:
  \[ \Delta f = \frac{v_r}{c} f_0; \text{where } \Delta f = f - f_0 \]

- True wind speed & radial wind speed relationship:
  \[ v_r = v \cdot \cos(\theta) \]

  \( \theta \) = beam alignment relative to the wind direction.
  When parallel: \( v_r = \) true wind speed; when perpendicular \( v_r = 0 \) speed.

Figure source: Vasiljevic (2015)
Two varieties: Pulsed vs. continuous wave (CW)

**Pulsed**
- Collimated beam (parallel rays)
- Measures all distances at once
- Uses time of flight to differentiate ranges
- Probe volume is constant with distance
- Blind zone exist close to telescope

**Continuous Wave**
- Focused beam
- Measures one distance at a time
- Must refocus to measure at another point
- Probe volume is a $4^{th}$ power function of focus range
- Can measure very close to telescope

Figure source: Photonics.com

Figure source: Simley et.al. 2018
Doppler lidar applications in wind energy

- Wind resource assessment (e.g. wind profiles, big picture over complex terrain)
- Validation of other sensors and as an independent observation
- Power performance assessment (ensure turbine performs as expected)
- Validation of models (e.g. wind atlases, LES)
- Turbine wake and inflow measurements (e.g. validating wake and load models)
- Wind turbine & wind farm control
- Forecasting (either data assimilation into NWP or using statistical models)
## Common commercial systems

<table>
<thead>
<tr>
<th>Ground based profilers</th>
<th>Nacelle</th>
<th>Scanning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leosphere WindCube V2</td>
<td>Zephir Dual Mode</td>
<td>Leosphere WindCube 1/2/400S</td>
</tr>
<tr>
<td>Zephir 300</td>
<td>Avent (Leosphere) WindIris (4 beam)</td>
<td>Halo StreamLine XR</td>
</tr>
<tr>
<td>Pentalum SpiDAR</td>
<td>Windar Wind Eye/Vision (2/4 beam)</td>
<td>Lockheed Martin WindTracer</td>
</tr>
<tr>
<td>Mitsubishi CWL</td>
<td>Mitsubishi NL (9 beam)</td>
<td>Galion Lidar</td>
</tr>
</tbody>
</table>

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2018 EAWE PhD Seminar - Practical lidar workshop

11 September 2018

DTU Wind Energy (RISØ), Technical University of Denmark
Common measurement techniques

- Line of sight (LOS)
- Doppler beam swing (DBS)
- Velocity azimuth display (VAD)
- Plan position indicator (PPI)
- Range height indicator (RHI)
- Others
  - Dual Doppler
  - Triple Doppler
  - Adaptive
  - Complex
Sizing up

Strengths

• Portable / relatively fast to deploy and move
• Spatial measurement
• Measures remotely (no tower, no flow distortion)
• Configurable ranges
• Scanning lidar trajectories are configurable (point/area/volume)
• Validation history against calibrated sensors

Challenges

• Only radial measurements
• Measurements are spatially averaged (probe volume)
• Limited by low backscatter signal in certain conditions (availability)
• Eye/laser safety
• Power consumption
• Beam blockage
• Requires expert knowledge
• Limited inclusion in standards
• Limited “bankability” (acceptance)
Data formats

• Most devices output measurements in CSV text format, 1 file per 10 minutes

• Community isn’t united yet, but we are starting to get there!

• FAIR data principles (Findable, Accessible, Interoperable, Reusable)

• e-WindLidar: standardization group
  – Metadata cards
  – Lidaco: modular converter to netCDF4 format
  – Data catalogue (citable with DOI, permissions system)
  – Common tools and data products: spectra > radial speeds > vector > flow parameters
  – Upcoming workshop: October 3rd @ DTU Risø
Closing remarks

• DTU PhD summer school on Remote Sensing for Wind Energy
  – June 24-28, 2019 @ Risø (1 week, 2.5 ECTS)

• Questions?

• Let’s begin the exercise!
• If you want to follow/play along on your own computer:
  – Download Python Anaconda distribution (3.6.x version) - add to PATH env. variable
    https://www.anaconda.com/download/
  – Clone repository, or download files from GitHub page:
  – Navigate to where you saved the files (file explorer or shell)
    • If file explorer on windows: Shift + Right Click > Open command window here
    • “jupyter notebook” will launch a browser window
    • Open the .ipynb file