Reducing Uncertainty of Near-shore wind resource Estimates (RUNE) using wind lidars and mesoscale models

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Reducing Uncertainty of Near-shore wind resource Estimates (RUNE) using wind lidars and mesoscale models

EMS 2015, Sofia, Bulgaria, Coastal meteorology session

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Department of Wind Energy
Motivation

• Many offshore windfarms planned in near-coastal waters due to high winds and good grid connectivity
• Big uncertainty in coastal wind climate due to change in roughness and stability conditions
• Wind lidars and mesoscale models became reliable tools to study wind development
• Are mesoscale able to capture flow with sufficient accuracy in coastal areas?
**Options for measurements in coastal areas**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesoscale models</td>
<td>Cheap</td>
<td>Uncertainty of prediction up to 10%</td>
</tr>
<tr>
<td>Mesoscale models + local measurements</td>
<td>Uncertainty reduced to 3%</td>
<td></td>
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Which measurement solution is most cost-effective (cost vs. accuracy)?

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First attempt to answer the question: One or two lidars?
Lidar measurement background

A lidar can only measure a portion of the wind vector!!!
Two independent LOS measurements
Low elevation angles => neglect vertical component
With two lidars it is possible to measure:
- Horizontal wind speed
- Wind direction
Sector scan

Flow horizontally homogenous
Vertical component low  ■ Neglect vertical component
Low elevation angle
Sector scan => estimate horizontal wind speed and wind direction

\[ <V_{LOS}> = a \cos(\theta - b) \]
\[ V_{horizontal} = a \]
\[ Wind\_direction = b \]
Measurement set-up RUNE, sector scan vs. Dual-Doppler

• Measurement campaign: locations chosen
• Period: October-December 2015
• Sea surface temperatures / wave parameters available (important to evaluate mesoscale model)
• Offshore floating lidar
• Onshore vertical shooting long-range lidar (wind profile 0-2000 m)
• Dual doppler setup scanning pattern from approximately 5 km up to shoreline
• Scanning lidar over same distance (range gates 50 m)
Pre-RUNE experiment, April-May 2014

- **Used filters**
  - Horizontal wind speeds from 4 to 25 m/s
  - Hard targets removal
  - Wake free sectors
  - Signal quality (-27dB < CNR < -8dB)
  - All LOS measurements for sector scan
  - 75% of samples per each LOS of sector scan

- 90 hours
- 23 hours averaging
- 140 samples
Horizontal wind speed

Cup anemometer

Two lidars (Dual-Doppler)

One lidar (Sector Scan 60°)
Horizontal wind speed

One lidar (Sector Scan 60°)

$$\sigma_{\text{dif}} = 0.32 \text{ m s}^{-1}; y = 0.99x$$

Two lidars (Dual-Doppler)

$$\sigma_{\text{dif}} = 0.1 \text{ m s}^{-1}; y = 1.0x$$

<table>
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<tr>
<th></th>
<th>Cup</th>
<th>One lidar</th>
<th>Two lidars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples</td>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Mean wind speed [m/s]</td>
<td>7.07</td>
<td>7.04</td>
<td>7.04</td>
</tr>
<tr>
<td>$R^2$</td>
<td>/</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td>Difference [m/s]</td>
<td>/</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Difference [%]</td>
<td>/</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Standard deviation of the difference [m/s]</td>
<td>/</td>
<td>0.32</td>
<td>0.10</td>
</tr>
</tbody>
</table>
What is the best azimuthal angle for scanning?

- Compromise between having a very large angle giving a large part of the sinusoidal and therefore certain wind speed, but homogeneity is questionable.
- Small angle gives less certain wind speed but confined to a smaller spatial area.

Cup anemometer
Scanning lidar
Results of comparison cup anemometer@80 m vs. scanning lidar at same point for different scanning angles
Comparing the measurements and mesoscale models

- 4 months measurements from wind lidar
- Same period as RUNE experiment
- Results from 5 grid points from the WRF model
Conclusions

• One lidar will provide necessary local measurements, scanning with azimuthal angle of +/- 45 degrees seems to give good results

• If you have sufficient funds there are merits of using two lidars:
  - Higher measurement rate
  - Small portion of area sampled
  - More measurement points
  - If the flow is not horizontally homogeneous

• A high pointing accuracy is crucial in achieving reliable measurements

• Unique data set for evaluating mesoscale models

Thank you for your attention