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Long-term Variability of the Wind Speed over Land, in Coastal and in Marine Areas

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Outline.

- Lidar Measurements
- Sensitivity to CNR (Carrier to Noise Ratio)
- Profile of Weibull distribution parameters (land, coastal and marine)
Figur af lidar princippet

\[ v_r = v_t + \frac{2V_r}{\lambda} \]
Comparison lidar cups/vanes

Høvsøre coastal

Fino3 marine

Cup 106 m vs WLS 122 m

Vane 100 m vs WLS rec 122 m
Tall Wind project
Høvsøre  
Hamburg
Table 1 Number of measurements and measuring periods at each site. The numbers in brackets represent the number of wind lidar measurements relative to the total number of cup anemometer measurements.

<table>
<thead>
<tr>
<th>Site</th>
<th>Wind lidar 100m/600m</th>
<th>Wind lidar and cup anemometer measurements; concurrent and full profiles up to 600 m</th>
<th>Cup anemometer</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Høvsøre-land</td>
<td>9885/8876 (84%)/(75%)</td>
<td>8754 (74%)</td>
<td>11758</td>
<td>25 April 2010 – 31 March 2011</td>
</tr>
<tr>
<td>Høvsøre-coastal</td>
<td>12618/11616 (73%)/(67%)</td>
<td>11383 (66%)</td>
<td>17377</td>
<td>15 June 2011 – 23 March 2012</td>
</tr>
<tr>
<td>Hamburg</td>
<td>34692/27504 (88%)/(70%)</td>
<td>26403 (67%)</td>
<td>39374</td>
<td></td>
</tr>
<tr>
<td>Fino3</td>
<td>40685/34487 (100%)/(85%)</td>
<td>32425 (80%)</td>
<td>40541</td>
<td>29 August 2013– 26 June 2014</td>
</tr>
</tbody>
</table>
Data availability

![Graph showing data availability for different locations: Hamburg, Høvsøre land, Høvsøre coastal, and Fino3. The graph plots CNR threshold against availability (%).]
The two-parameter Weibull distribution can be expressed as:

$$f(u) = \frac{k}{A} \left(\frac{u}{A}\right)^{k-1} \exp \left(-\left(\frac{u}{A}\right)^k\right)$$

where:
- $f(u)$ is the probability density function
- $u$ is Wind speed
- $\langle u \rangle$ is Mean wind speed
- $A$ is Scale factor
- $k$ is Shape factor

The expected value of wind speed is:

$$\langle u \rangle = A \Gamma(1 + 1/k)$$
Left: the wind profile at Hamburg; circles represent observations by the wind lidar and triangles from cup anemometers.
Right: mean wind speed at 100 m as function of the CNR when full profiles up to 600 m are used. The full lines are wind lidar measurements, triangles concurrent wind speed from the cup anemometer. The dashed lines represent the CNR dependency when only the measurements at 100 m are used (no height filter).
Generally good agreement between mast (triangles) and lidar (circles) for estimates of $k$. It is especially visible at Hamburg because of the height of the mast – illustrated here.
Full line parametrization suggested by Gryning et al. (2014)
Høvsøre coastal

Fino3

Mean wind speed (m s⁻¹)

Time of day (hour)
Wieringa (1989): \[ k = k_s + c_k (z - z_s) \exp \left( -\frac{z - z_s}{z_r - z_s} \right) \]

Gryning et al. (2014)

\[ k = k_s + c \frac{z - z_s}{z_r - z_s} \exp \left( -\frac{z - z_s}{z_r - z_s} \right) - (k_s - k_t) \exp \left( -\frac{z_t - z_s}{z - z_s} \right). \]

where \( k_s \) is the value of the shape parameter at the height \( z_s \) near the ground, \( z_r \) is the height of the shape parameter maximum (reversal height) and \( k_t \) is related to the synoptic value at height \( z_t \).
Thanks for your attention