First lightship-based wind lidar measurement in the North Sea


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Photo: Astrid Lampert, TU Braunschweig
1. Project Motivation

Main motivation: As a part of the ongoing project WIPAFF* (Wind Park Far Field), this measurement campaign aims to collect long-term wind profiles under both, free and wind farm far-wake conditions.

• Evaluation of vessel** movement effects on the wind lidar measurements, system stability, and performance in different weather conditions.

Side topic: To assess the extent to which existing offshore infrastructure can be used for continuous monitoring of the marine boundary layer as supplement to bespoke monitoring infrastructure such as the FINO platforms.

*The WIPAFF project is funded by the German Federal Ministry of Economic Affairs and Energy (grant number: FKZ0325783) on the basis of a decision by the German Bundestag.

**The lightship is operated by the Wasser und Schifffahrtsamt (WSA) Wilhelmshaven and is also used by the Federal Maritime Agency (BSH) as a part of the Marnet monitoring network.
2. Location: German Bight (North Sea)
3. Measurements overview (I)

Begin measurements: 27.08.2017
Position: 54°10’ N, 07°27’ E, **German Bight**
Lightship: UFS4

(Photo: BSH)
### 3. Measurements overview (II)

<table>
<thead>
<tr>
<th>Sensor type</th>
<th>Parameters</th>
<th>Time Resolution</th>
<th>Height above mean sea level [m]</th>
<th>Photos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind lidar (WindCube v2, WLS7-576)</td>
<td>Wind Speed &amp; Direction, internal status parameters (e.g. availability, CNR, ...)</td>
<td>~ 1Hz /10-min</td>
<td>71.5, 81.5, 91.5, 102.5, 119.5, 139.5, 159.5, 179.5, 199.5, 249.5, 279.5, 295.5</td>
<td><img src="image" alt="Wind lidar" /></td>
</tr>
<tr>
<td>IMU Sensor (3DM-GX3-35 Microstrain)</td>
<td>Euler angles (Pitch, Roll, Yaw) &amp; angular rates ($\Omega_x$, $\Omega_y$, $\Omega_z$)</td>
<td>10Hz</td>
<td>5.5</td>
<td><img src="image" alt="IMU Sensor" /></td>
</tr>
<tr>
<td>Thales 3011 Dual-GPS</td>
<td>Ship position &amp; Heading</td>
<td>1Hz</td>
<td>6</td>
<td><img src="image" alt="Thales 3011 Dual-GPS" /></td>
</tr>
<tr>
<td>HS-50 Gill-Sonic anemometer</td>
<td>$u$, $v$, $w$, $T_s$</td>
<td>10Hz</td>
<td>6</td>
<td><img src="image" alt="HS-50 Gill-Sonic anemometer" /></td>
</tr>
</tbody>
</table>
### 3. Measurements overview (III)

<table>
<thead>
<tr>
<th>Sensor type</th>
<th>Parameters</th>
<th>Time Resolution</th>
<th>Height above mean sea level [m]</th>
<th>Photos</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTH sensor</td>
<td>Air temperature, humidity, pressure</td>
<td>~ 1Hz /10-min</td>
<td>6</td>
<td><img src="image1" alt="" /></td>
</tr>
<tr>
<td>Thies Anemometer &amp; Wind vane</td>
<td>Wind Speed &amp; Direction</td>
<td></td>
<td>15</td>
<td><img src="image2" alt="" /></td>
</tr>
<tr>
<td>PT100, 1/3 DIN B</td>
<td>Air temperature</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Vaisala HMP45D</td>
<td>Air humidity</td>
<td>1min</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Vaisala PTB220</td>
<td>Air pressure</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>PT100, 1/3 DIN B</td>
<td>SST</td>
<td></td>
<td>-1.5</td>
<td></td>
</tr>
<tr>
<td>Wave-rider Buoy (Station Helgoland North)</td>
<td>Met-Ocean parameters (e.g. wave spectra, significant wave height, peak wave period, current speed and direction, SST)</td>
<td>30min</td>
<td>0</td>
<td><img src="image3" alt="" /></td>
</tr>
</tbody>
</table>
3. Measurements overview (IV)

**Data communication**
- Mobile radio modem (3G cell network connection)
- BSH Iridium satellite phone: Daily Status Signals (Back-up)

**Data logging system**
- Central Industrial PC with external hard disk drive (SSD)

**Power Supply**
- Diesel Generators
- UPS (Batteries): 2 hours time (Back-up)

**Maintenance**
- Daily monitoring via TeamViewer
- Approx. monthly maintenance will be conducted by BSH Team (e.g. fill-up water container, exchange SSD, visual inspection,...)

**Time-synchronization**
- All datasets are based on GPS time
4. Overall system availability/reliability

Period analyzed: **27.08.17 to 26.08.18** (campaign ongoing)
Excluded CNR values < -22dB and NaN values

Number of system failures: 0
Number of maintenances (lightship): 4
  - Cleaning lidar window
  - Refilling water tank
Number of Unscheduled Outages: 2
  - 23-28 February 2018 Failure power supply
  - 28.03.18-04.04.18 Failure power supply
  - 05.04.18-07.06.18 in port for maintenance

Data coverage
5. Ship-movements: influences on wind lidar measurements

Rotation motions:
- Roll ($\phi$): transverse (side-to-side) axis $\rightarrow$ forward
- Pitch ($\theta$): longitudinal (front/back) axis $\rightarrow$ starboard
- Yaw ($\psi$): about the vertical axis $\rightarrow$ downward

Linear motions:
- Sway: lateral (side-to-side) motion
- Surge: longitudinal (front-back) motion
- Heave: vertical (up/down) motion

Storm HERWART (28./29. October 2017)
$\Delta$roll=$\pm 20^\circ$, $\Delta$pitch=$\pm 10^\circ$
5. Vessel-movements: influences on wind lidar measurements
5. Example: Two different vessel-movement conditions

Definition of „high sea state“: angles exceeding ± 10°
5. Example: Two different vessel-movement conditions → Effects
6. 10-min comparisons with Helgoland wind lidar (I)

<table>
<thead>
<tr>
<th>Spatial-Variation*</th>
<th>Location</th>
<th>Scaling factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LShip/ Helgoland</td>
<td>1.008</td>
</tr>
<tr>
<td></td>
<td>LShip/AV Sub-station</td>
<td>1.003</td>
</tr>
</tbody>
</table>

* Based on 4-Years (2007-2010) In-House Mesoscale simulations at 90m

Theoretical time-delay for a stationary flow
6. 10-min comparisons with Helgoland wind lidar (II)

Reference data: WindLidar Helgoland (WindCube WLS8-8)

Experimental data: WindLidar Lightship (WindCube v2)

Measurement Period: 2017/08/27 00:10 - 2018/03/22 23:50

Wind sector selected: 150°-220°

$\text{Dir}_{\text{Lidar(LShip)}} = \text{Dir}_{\text{Lidar(Lship)}} + \text{Ship heading}$
7. Comparison with airborne measurements (I)

Flight track on 14 October 2017 (aircraft Dornier 128-6, operated by the TU Braunschweig)
7. Comparison with airborne measurements (II)

14.10.2017

- Wind direction = 230°
- $\Delta$roll=$\pm 1.5^\circ$, $\Delta$pitch=$\pm 4^\circ$
8. Summary

- Reliable long-term (>1 year) wind lidar measurements can be performed on a lightship.
- Very good availability
- Movement correction important for pitch/roll angles > 8-10°
- Useful dataset for wind data/model validation

9. Next steps

- Analysis of wind lidar turbulence
- Development of a method to detect long wakes
- New lightship (UFS03) wind lidar measurements by the end November 2018
Acknowledgements

• We would like to thank our colleagues Hauke Decker and Christian Krüger for the system installation, the teams of K. Herklotz from the "Federal Maritime and Hydrographic Agency, BSH", H. Kleta from "German Weather Service, DWD" and M. Bredow from "Wasserstraßen- und Schifffahrtsamt, Wilhelmshaven" for their technical/logistic support during the first stage of the measurement set up on the lightship.
Thank you for your attention!

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