First lightship-based wind lidar measurement in the North Sea

OffshoreWind2018 –Topic: 6. Beurteilung von Ressourcen

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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.

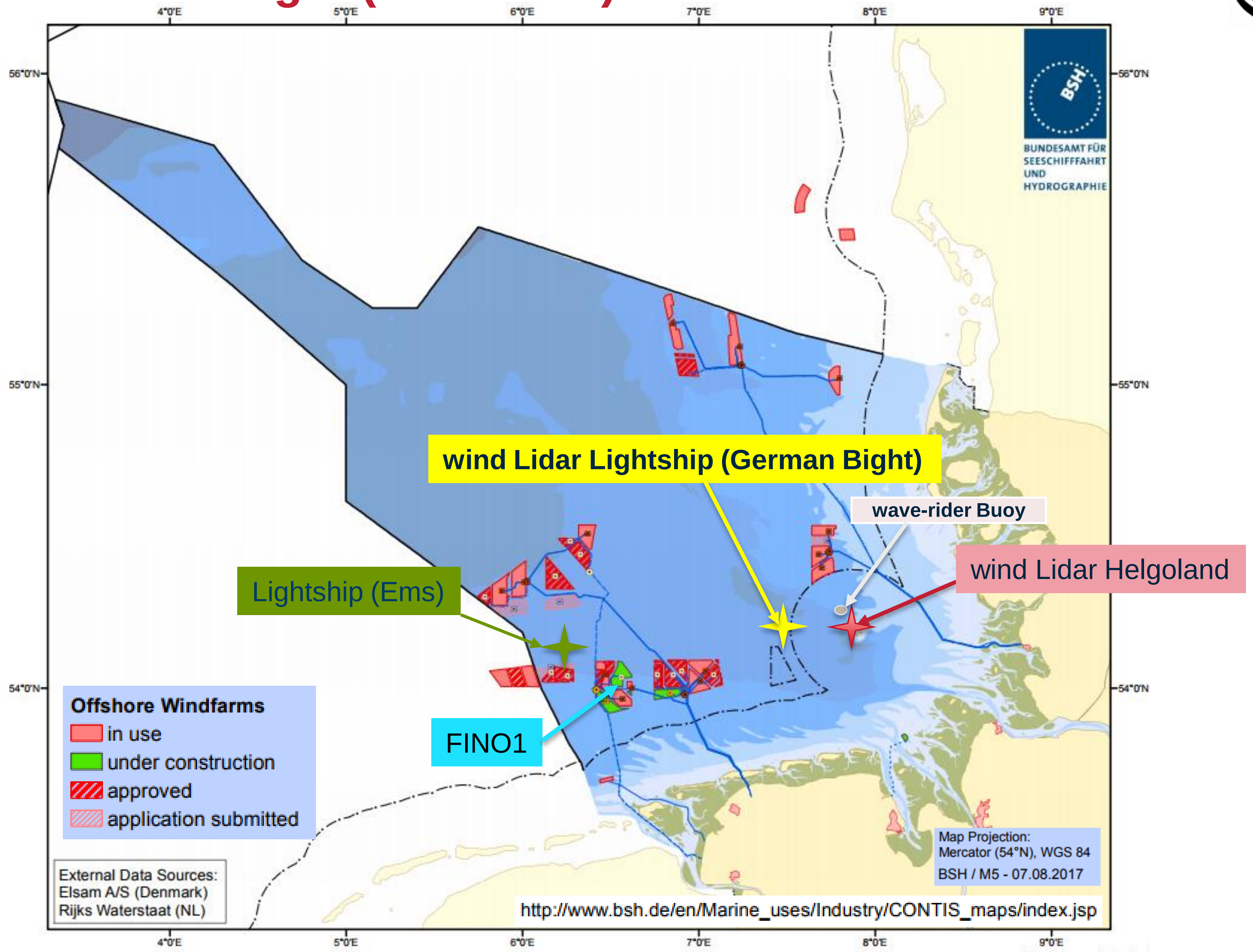
- Evaluation of vessel** movement effects on the wind lidar measurements, system stability, and performance in different weather conditions.

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.

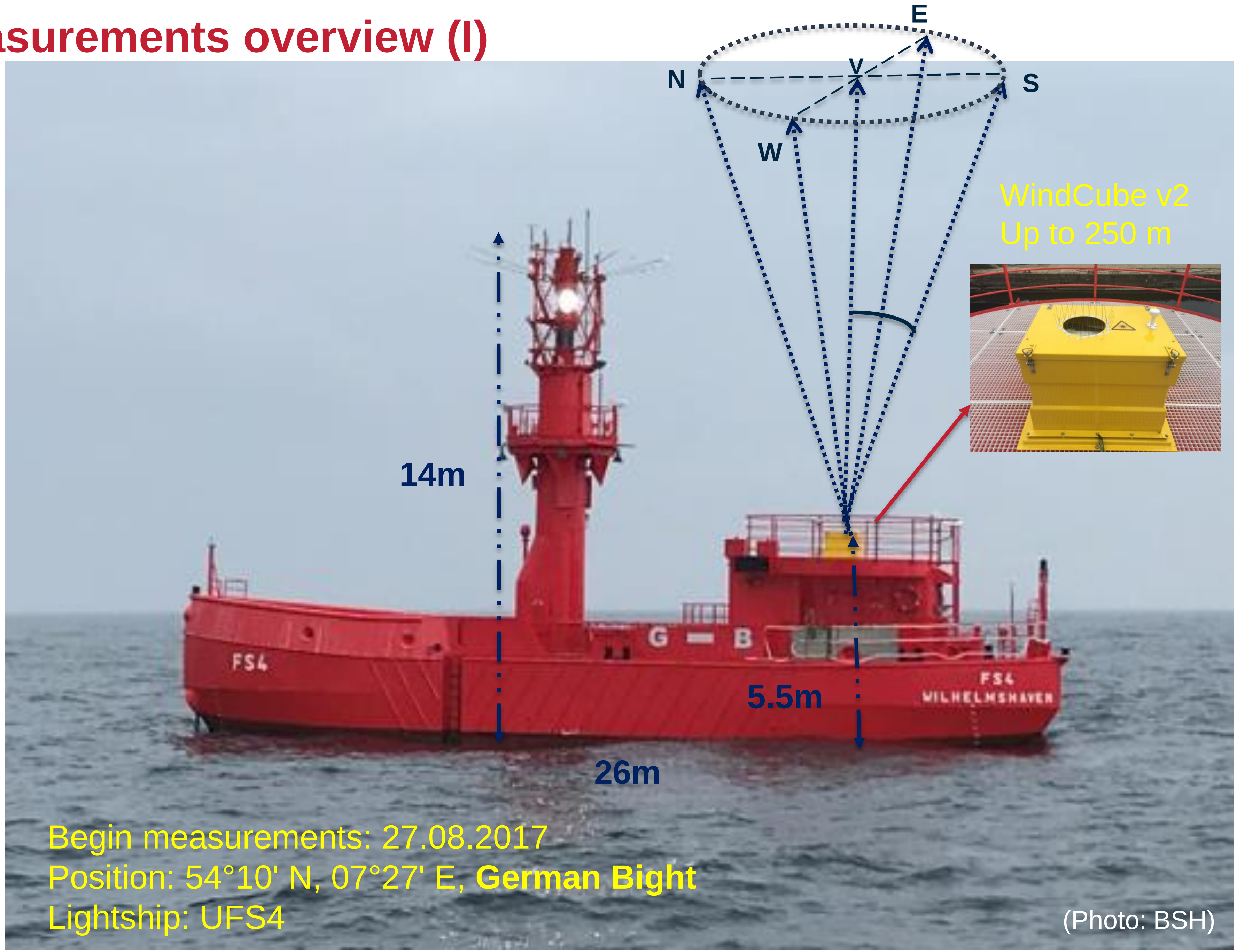
The WIPAFF project is funded by the German Federal Ministry of Economic Affairs and Energy (grant number: FKZ0325783) on the basis of a decision by the German Bundestag.

***The lightship is operated by the Wasser und Schiffahrtsamt (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)



3. Measurements overview (II)

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

3. Measurements overview (III)

Sensor type	Parameters	Time Resolution	Height above mean sea level [m]	Photos
PTH sensor	Air temperature, humidity, pressure	~ 1Hz /10-min	6	
Thies Anemometer & Wind vane	Wind Speed & Direction		15	
PT100, 1/3 DIN B	Air temperature		8	
Vaisala HMP45D	Air humidity	1min	8	
Vaisala PTB220	Air pressure		0	
PT100, 1/3 DIN B	SST		-1.5	
Wave-rider Buoy (Station Helgoland North)	Met-Ocean parameters (e.g. wave spectra, significant wave height, peak wave period, current speed and direction, SST)	30min	0	 (Photo: BSH)

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

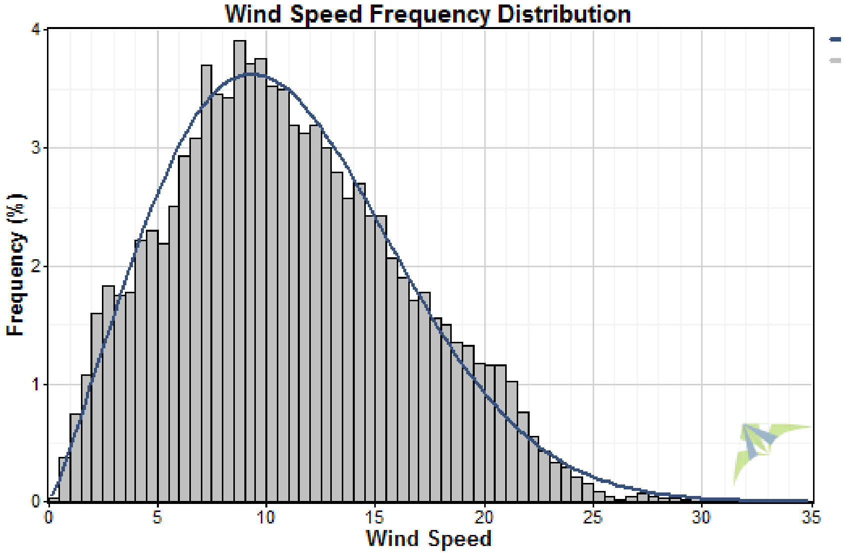
- Daily monitoring via TeamViewer
- Approx. monthly maintenance will be conducted by BSH Team (e.g. fill-up water container, exchange SSD, visual inspection,…)

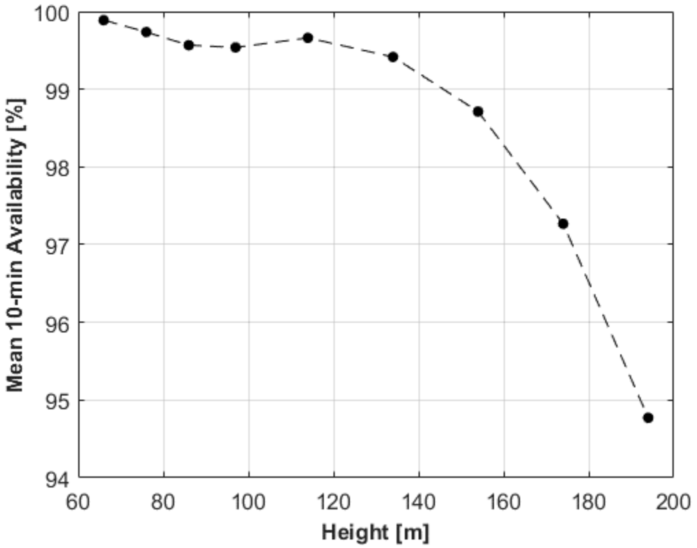
Time-synchronization

- 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





Data coverage

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

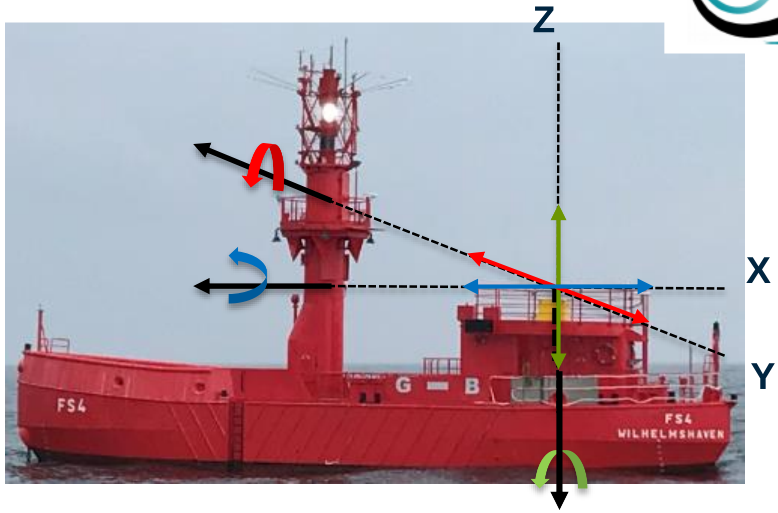
5. Ship-movements: influences on wind lidar measurements

Rotation motions:

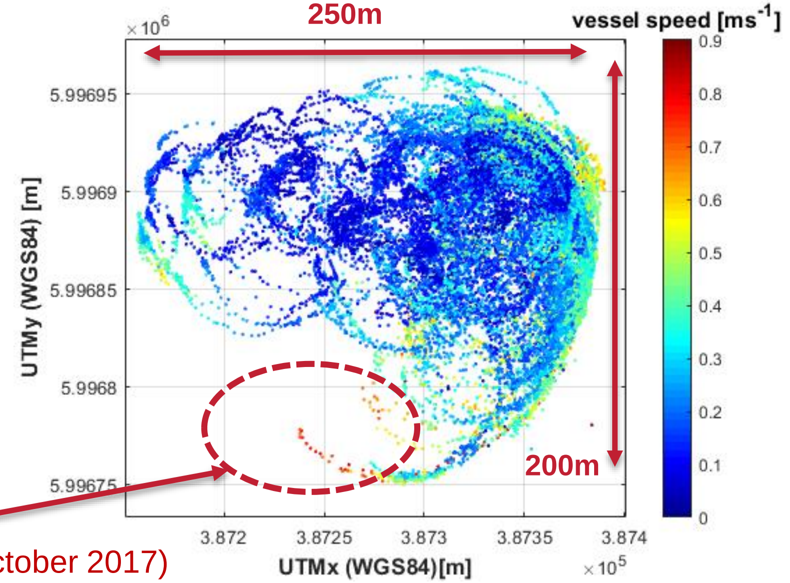
- Roll (φ): transverse (side-to-side) axis→ forward
- Pitch (θ): longitudinal (front/back) axis→ starboard
- Yaw (ψ): about the vertical axis→ downward

Linear motions:

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



Definition of Vessel Motions in Six Degrees of Freedom (Photo: BSH)



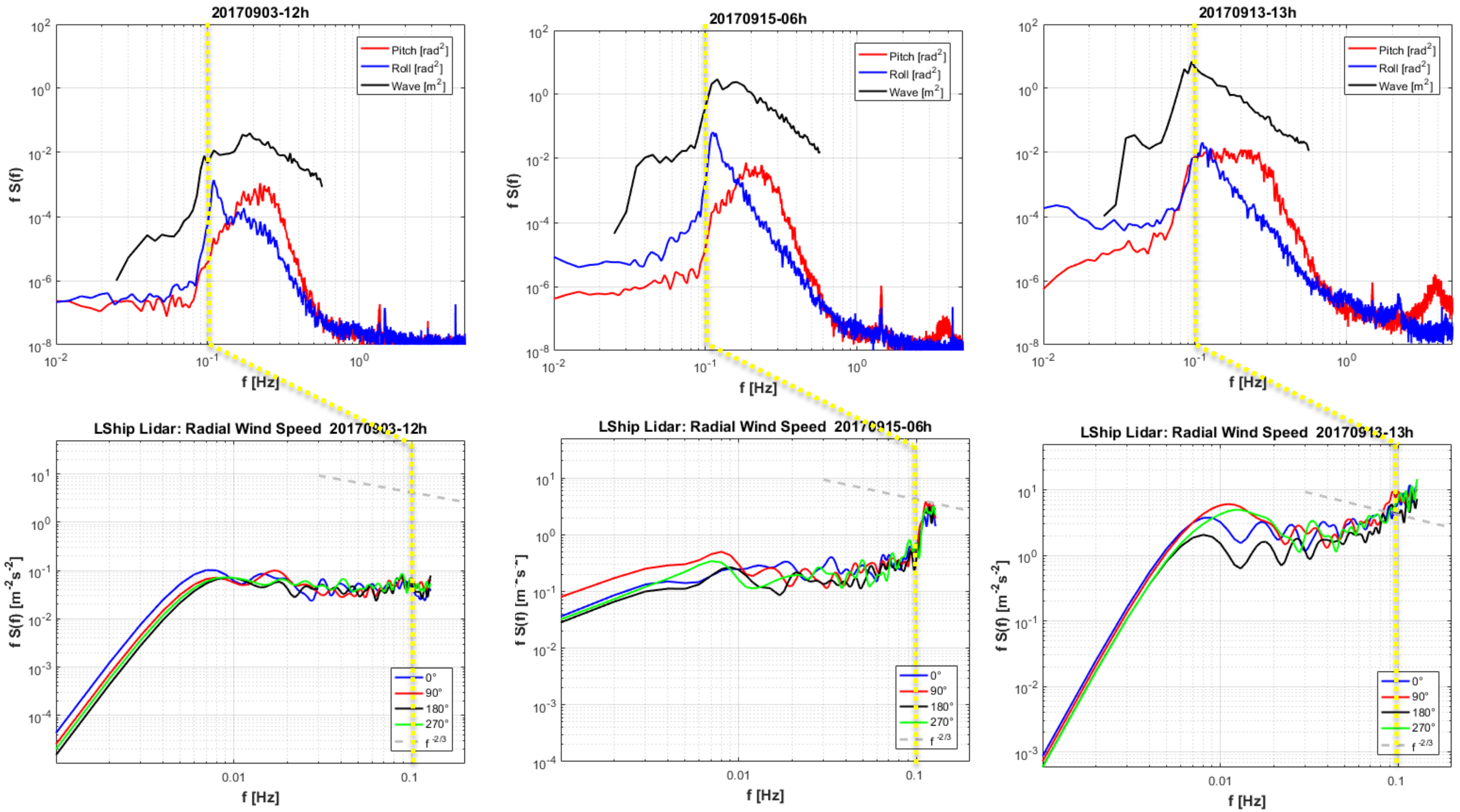
Storm HERWART (28./29. October 2017)
Δroll=±20°, Δpitch=±10°

5. Vessel-movements: influences on wind lidar measurements

Low Motion:
WS~3 m/s, Hs=0.6 m

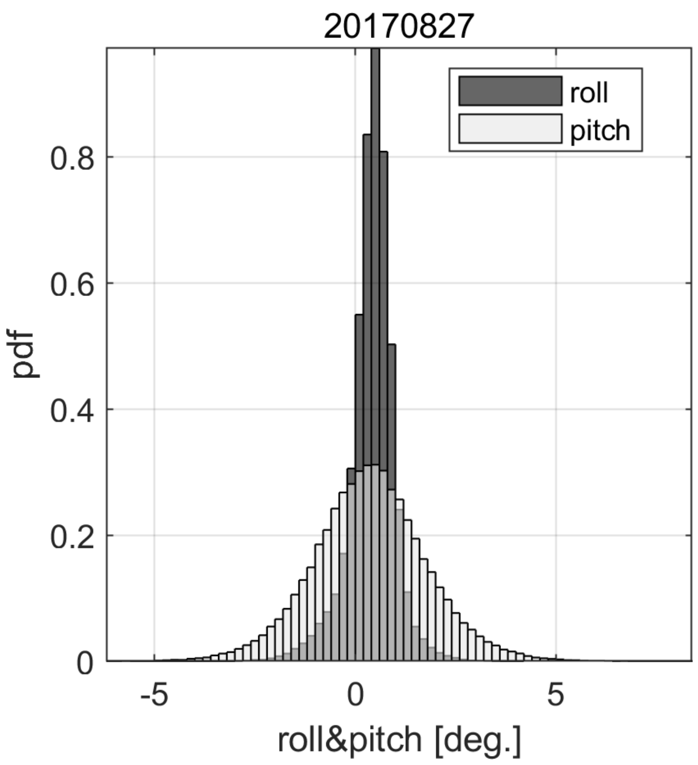
Moderate Motion:
WS~12 m/s, Hs=2.1 m

High Motion:
WS~30 m/s, Hs=6.2 m

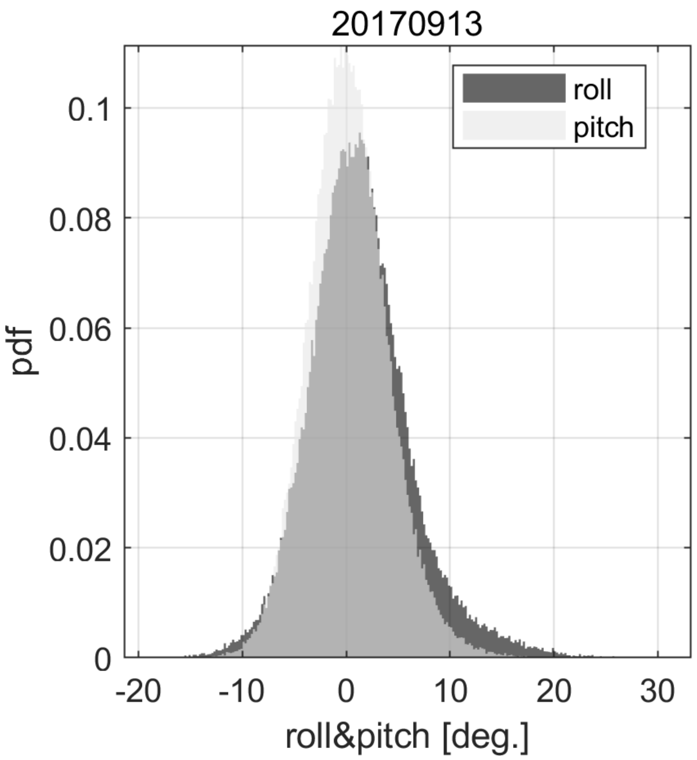


5. Example: Two different vessel-movement conditions

low ship motion

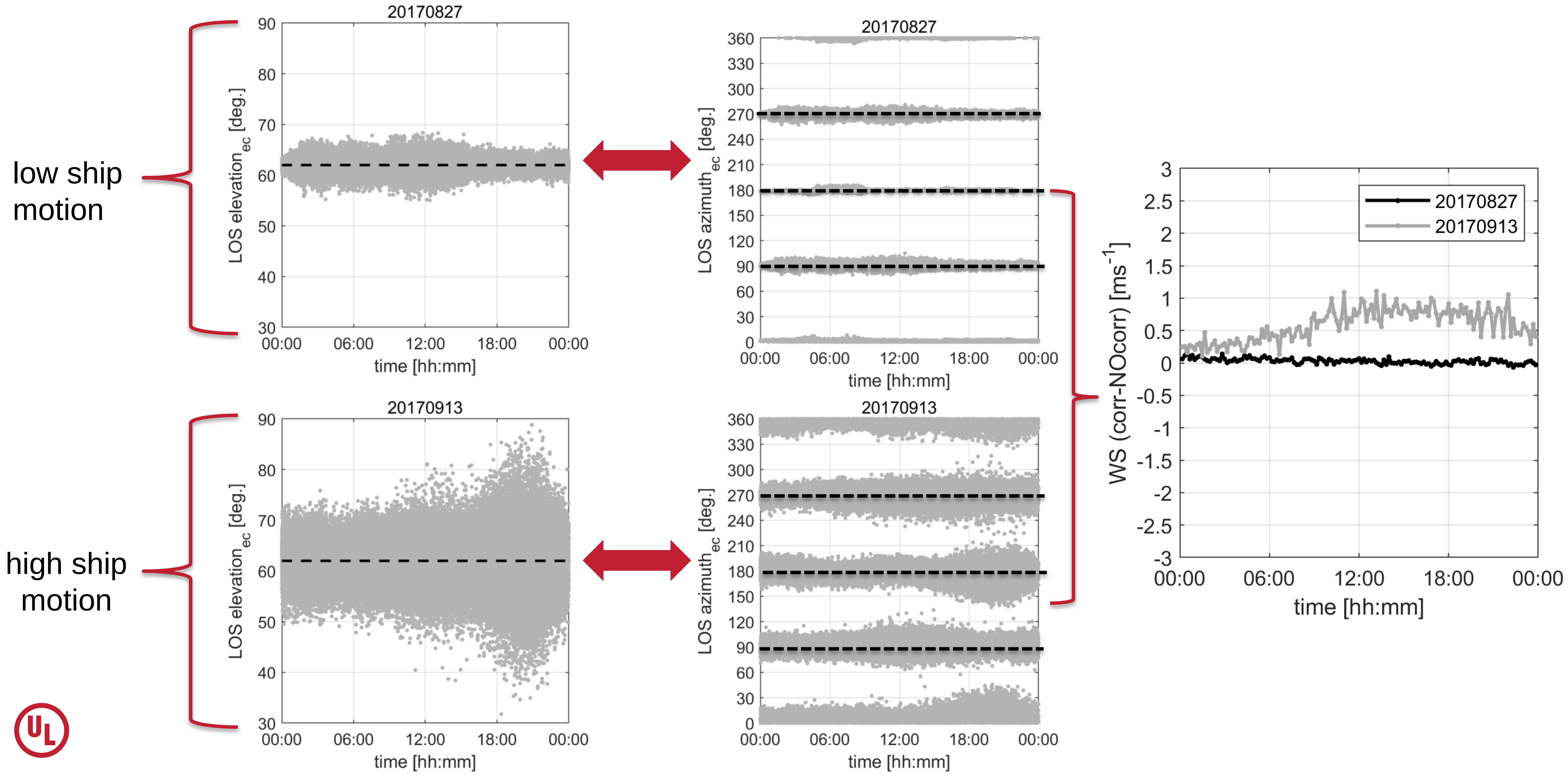


high ship motion



Definition of „high sea state“: angles exceeding ± 10°

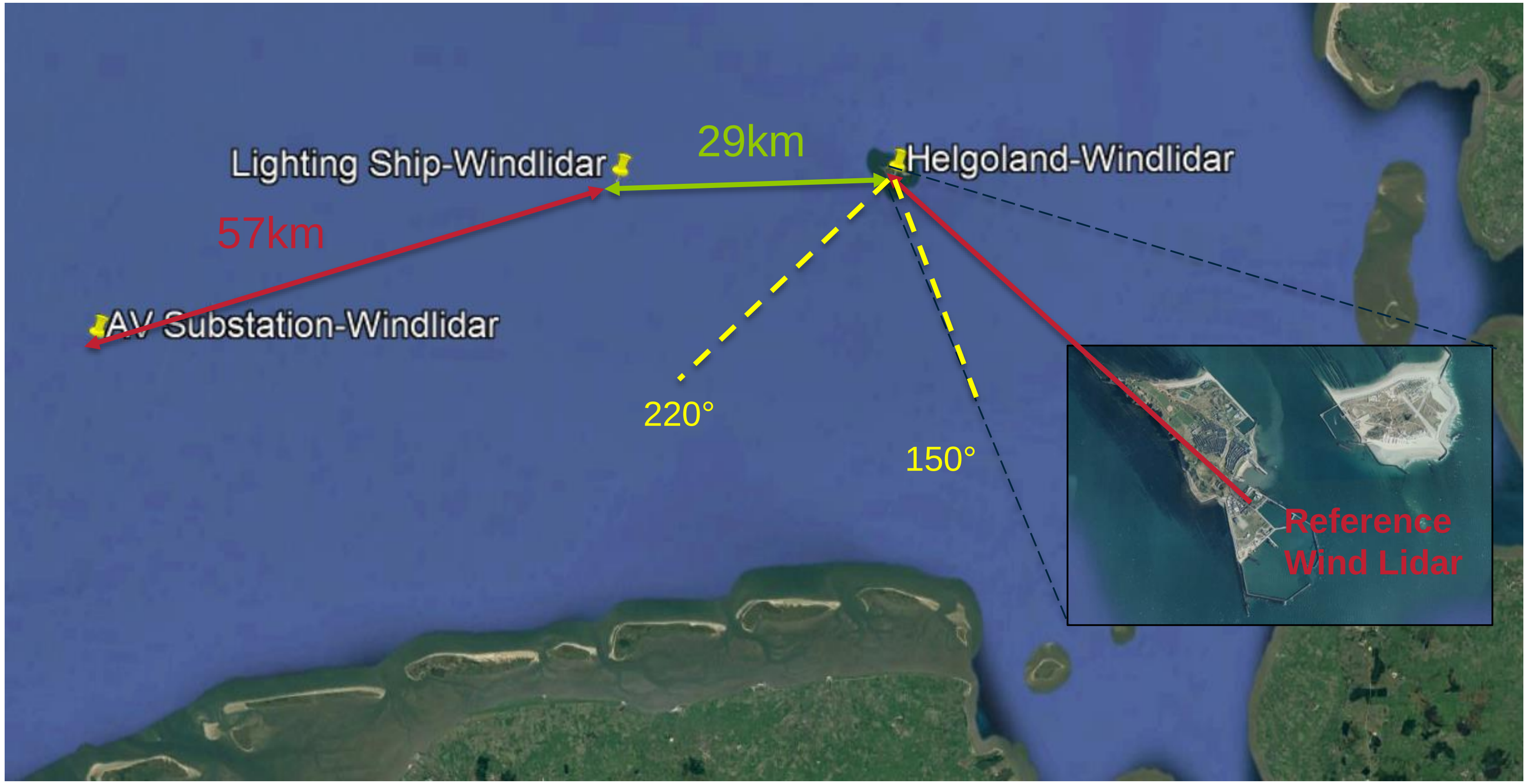
5. Example: Two different vessel-movement conditions → Effects



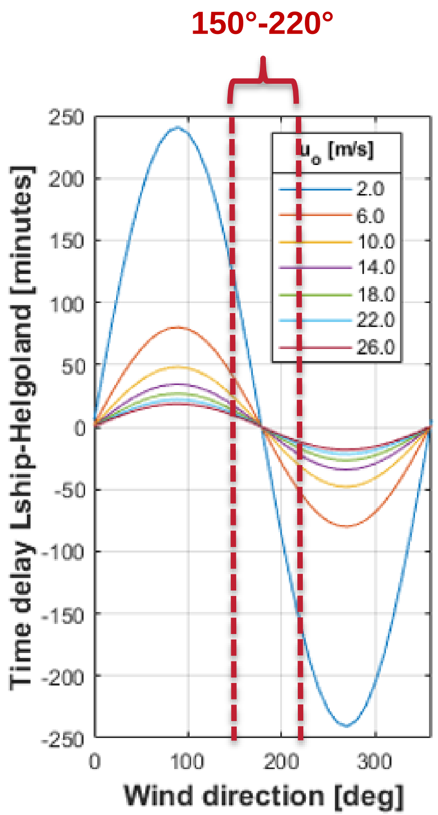
6. 10-min comparisons with Helgoland wind lidar (I)

Spatial-Variation*	
Location	**Scaling factors**
LShip/ Helgoland	**1.008**
LShip/AV Sub-station	**1.003**

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



Source: Google maps



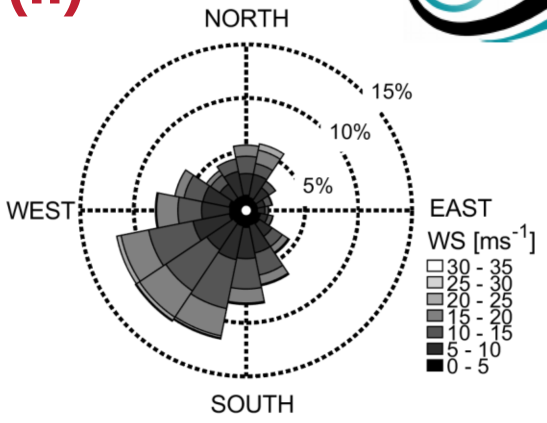
Theoretical time-delay for a stationary flow

6. 10-min comparisons with Helgoland wind lidar (II)

Reference data: WindLidar Helgoland (WindCube WLS8-8)

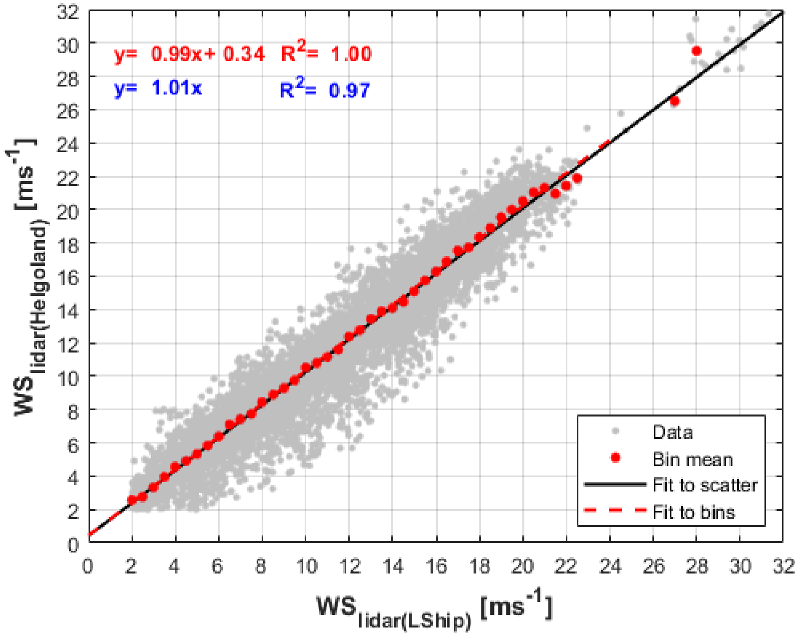
Experimental data: WindLidar Lightship (WindCube v2)

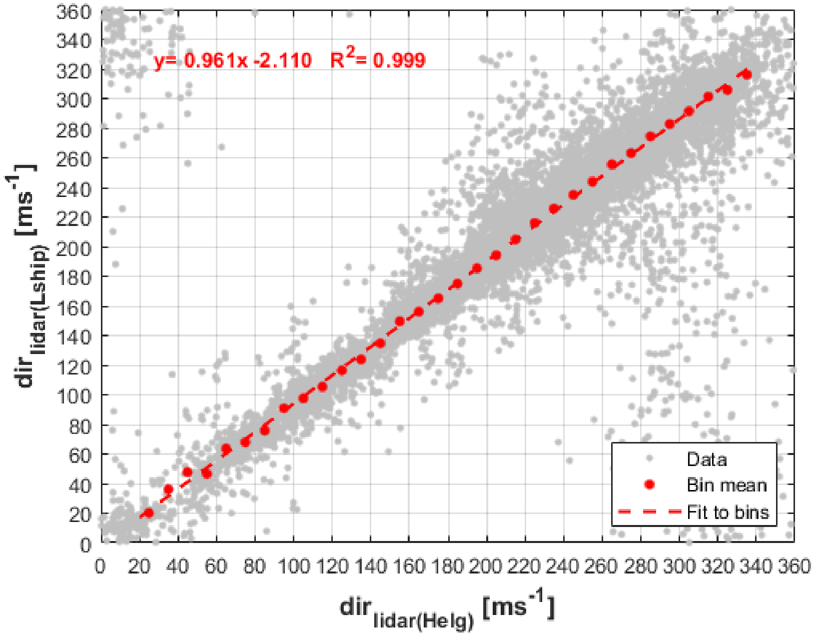
Measurement Period: 2017/08/27 00:10 - 2018/03/22 23:50



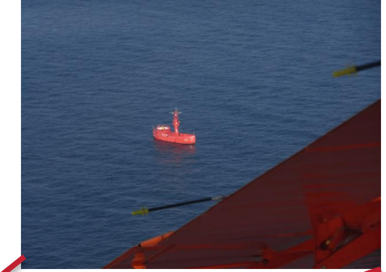
Dir $_{\text{lidar(LShip)}}$=lidar(Lship) wind direction + Ship heading

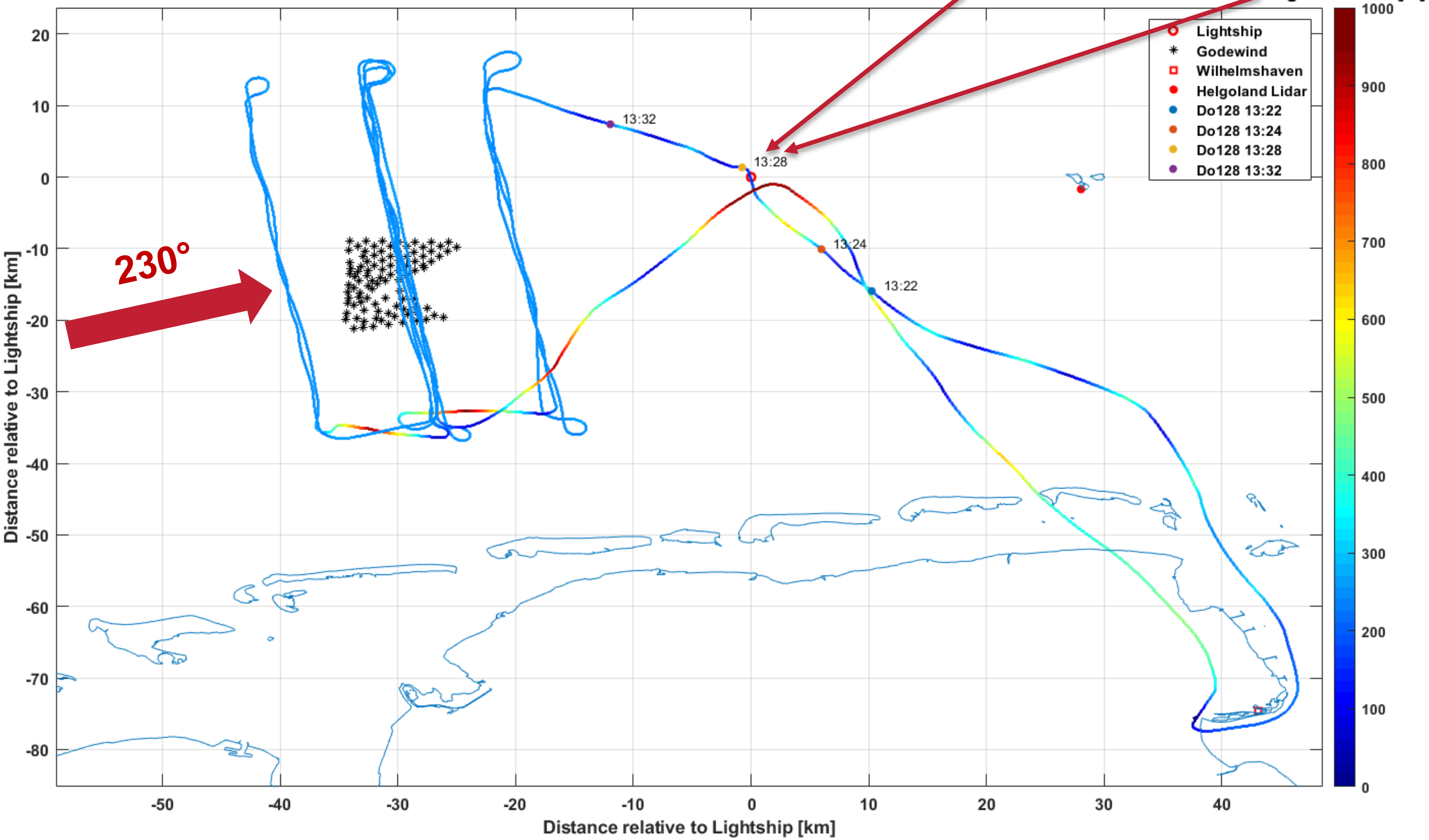
Wind sector selected: 150°-220°





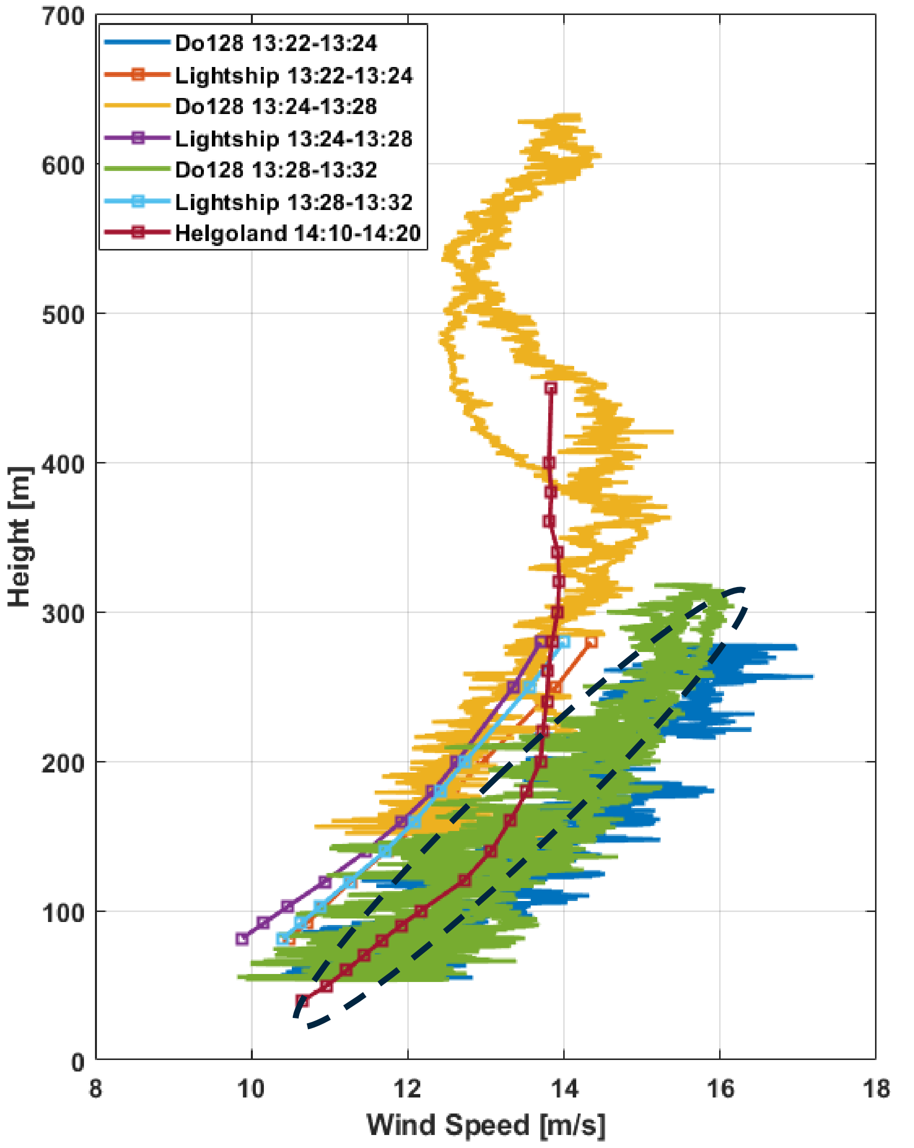
7. Comparison with airborne measurements (I)





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°
- Δroll=±1.5°, Δpitch=±4°

8. Summary

- Reliable long-term (>1year) 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 to 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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