Energy Islands – Floating LiDAR Measurements

Motion correction of turbulence intensity. WP4: Baltic Sea campaign data

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Document Control

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Abbreviations

Abbreviation	Definition
com	Motion compensated
CW	Continuous wave
FLS	Floating LiDAR system
LiDAR	Light detection and ranging
MSL	Mean sea level
NaN	Not-a-number
PDV	Pre-deployment verification
RLL	Reference Land LiDAR
SWLB	Seawatch Wind LiDAR Buoy
TI	Turbulence intensity
unc	Not motion compensated (uncompensated)
UTC	Universal time coordinated
VAD	Velocity–azimuth display

Conventions

Convention	Description
Directions	Directions are given in degrees (°) increasing clockwise from North. The direction is defined as incoming: 0° means wind blowing from North, 90° from East etc. Directions are relative to true north.
Turbulence intensity	Turbulence intensity is defined as the standard deviation of horizontal wind velocity fluctuations divided by the horizontal mean wind velocity during 10-minute long averaging intervals.
Time	All times are UTC and timestamps mean the beginning of an averaging interval.

1. Introduction

Estimates of turbulence intensity (TI) from floating LiDAR systems (FLS) are influenced by motion. Rotational and translational motion in all six degrees-of-freedom leads to an overestimation of TI measured by an FLS when compared to values acquired by a collocated fixed LiDAR system of the same type. Energinet has asked Fugro to correct the TI measurements from the SEAWATCH Wind LiDAR Buoys (SWLB) deployed in the Baltic Sea for buoy motions. The correction of measured TI for buoy motions is split in two (2) work packages:

- WP3: Correction of TI measured during PDV
- WP4: Correction of TI measured during campaign (this report)

This report describes results of processing FLS measurement data from six deployments.

1. First deployment of SWLB WS199 at LOT3 (LOT 3, Deployment 1),
2. Second deployment of SWLB WS199 at LOT3 (LOT 3, Deployment 2),
3. First deployment of SWLB044 at LOT 4 (LOT 4, Deployment 1),
4. Second deployment of SWLB044 at LOT 4 (LOT 4, Deployment 2),
5. Third deployment of SWLB044 at LOT 4 (LOT 4, Deployment 3), and
6. Fourth deployment of SWLB044 at LOT 4 (LOT4, Deployment 4)

The ZX 300 used on the buoys are continuous-wave (CW) velocity-azimuth-display (VAD) scanning profiling wind LiDARs. For each of the six deployments one data file is provided, that each contains two datasets:

- FLS data, uncompensated (TI_FLS_unc)
- FLS data, motion-compensated (TI_FLS_com)

Table 1.1 gives information about the LiDAR units used on both SWLB units during the six deployments.

Both FLS have been pre-deployment validated at Fugro's test site at Frøya, Norway. Beside of the mean wind speed and direction assessment reported in [1] and [2], Fugro has performed an assessment of the accuracy of motion-compensated TI estimates in document number C75486-TI1-R-02. We refer to this document for details on the motion-compensation processing and its accuracy.

System	Location	LiDAR unit	Firmware
FLS1	WS199	898	v2.202
FLS2	SWLB044	993	v2.2029

Table 1.1: Details of LiDAR units

2. Data format

2.1 Data file description

Files: *LOT3_Deployment1_TIdata.csv*
LOT4_Deployment2_TIdata.csv
LOT3_Deployment1_TIdata.csv
LOT4_Deployment2_TIdata.csv
LOT4_Deployment3_TIdata.csv
LOT4_Deployment4_TIdata.csv

These files contain TI estimates without motion compensation (TI_FLS_unc) and with motion compensation (TI_FLS_com). For each of these values one data column represents data from one measurement elevation. Eleven numbered columns represent the eleven configured measurement elevations used for all deployments at both LOTs in ascending order. The measurement elevations are 30, 40, 60, 90, 100, 120, 150, 180, 200, 240, and 270 meters above mean sea level (MSL).

2.2 Data filtering

The data sets are unfiltered. That means that all successfully processed TI data are included. Missing data is marked as "NaN" in the data files.

2.3 Data availability

Figure 2.1 shows the daily mean data availability of motion-compensated TI data for all measurement elevations. The data availability is overall good. Unfortunately, for LOT 3, Deployment 1, *lidar1hz* files are available only until 01.03.2022. These files are the only ones that contain information about the first phase angle of the lidar prism for each scanning cycle, which is required for the applied method of motion compensation. Thus, data processing was only possible for data recorded until this date. Starting 26.11.2022, the lidar unit used for LOT4, Deployment 2 (unit 993) worked only intermittently, so that the data availability was reduced after that date.

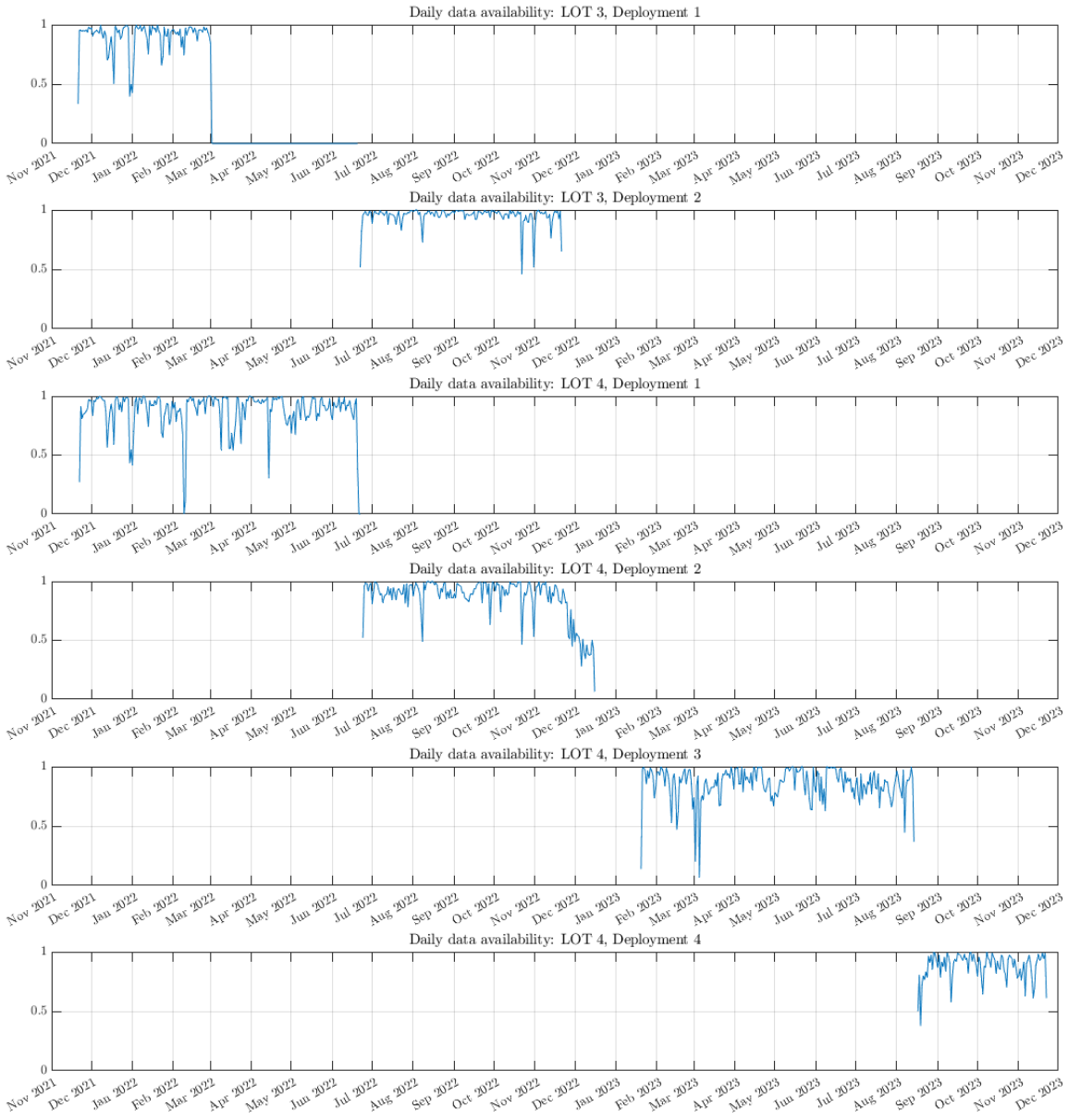

Figure 2.1: Daily availability of motion-compensated TI data for all six processed deployments

3. Conclusion

This report finalizes the work on motion correction of turbulence intensity values for data acquired during the SWLB deployments at LOT3 and LOT4 of the Baltic Sea measurement campaign.

The data processing worked out well and we refer to the corresponding PDV report [3] for an estimate of the TI data accuracy.

4. References

[1] DNV, "WS199 Independent performance verification of Seawatch Wind Lidar Buoy at Frøya, Norway. 10281716-R-11, Rev. A," 2021.

[2] DNV, "SWLB044 Independent performance verification of Seawatch Wind Lidar Buoy at Frøya, Norway. 10281716-R-12, Rev. B," 2021.

[3] Fugro, "Energy Islands – Floating LiDAR Measurements Motion correction of turbulence intensity. WP3: Baltic Sea pre-deployment verification tests," 2023.