Energy Islands – Floating LiDAR Measurements

Motion correction of turbulence intensity. WP2: North Sea campaign data

C75486-TI1-R-04 03 | 20 March 2024
Final

ENERGINET

Document Control

Document Information

Project Title	Energy Islands – Floating LiDAR Measurements
Document Title	Motion correction of turbulence intensity. WP2: North Sea campaign data
Fugro Project No.	C75486
Fugro Document No.	C75486-TI1-R-04
Issue Number	03
Issue Status	Final

Client Information

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Revision History

Issue	Date	Status	Comments on Content	Prepared By	Checked By	Approved By
01	14 September 2023	Draft	First issue	Felix Kelberlau	Irene Pathirana	
02	4 December 2023	Draft	Second Issue	Felix Kelberlau	Irene Pathirana	
02	20 March 2024	Final	Final Issue	Irene Pathirana	Irene Pathirana	Arve Berg

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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 North Sea for buoy motions. The correction of measured TI for buoy motions is split in two (2) work packages:

- WP1: Correction of TI measured during PDV
- WP2: 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 WS170 at LOT 1 (LOT 1, Deployment 1),
2. Second deployment of SWLB WS191 at LOT 1 (LOT 1, Deployment 2),
3. Third deployment of SWLB WS191 at LOT 1 (LOT 1, Deployment 3),
4. First deployment of SWLB WS181 at LOT 2 (LOT 2, Deployment 1),
5. Second deployment of SWLB WS170 at LOT 2 (LOT 2, Deployment 2), and
6. Third deployment of SWLB WS181 at LOT 2 (LOT 2, Deployment 3)

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 the three SWLB units during the six deployments.

All three FLS units have been pre-deployment validated. WS181 and WS191 have been trialled at Fugro's test site at Frøya, Norway and WS170 has been tested at the LEG platform, Netherlands. Beside of the mean wind speed and direction assessment reported in [1], [2], and [3]. Fugro has performed an assessment of the accuracy of motion-compensated TI estimates in document number C75486-TI1-R-01. We refer to this document for details on the motion-compensation processing and its accuracy.

System	Name	LiDAR unit	Firmware
FLS1	WS170	585	v2.2034
FLS2	WS181	759	v2.2033
FLS3	WS191	862	v2.2034

Table 1.1: Details of LiDAR units

2. Data format

2.1 Data file description

Files: *LOT1_Deployment1_TIdata.csv*
LOT1_Deployment2_TIdata.csv
LOT1_Deployment3_TIdata.csv
LOT2_Deployment1_TIdata.csv
LOT2_Deployment2_TIdata.csv
LOT2_Deployment3_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 is 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 very good. Unfortunately, several periods could not have been processed due to missing data.

For LOT 1, Deployment 1, the lidar unit stopped operating on 10.04.2022. For LOT 1, Deployment 2, during the period from 02.06.2022 until 14.07.2022, no data from the Septentrio D-GPS system has been stored for unknown reasons. The Septentrio D-GPS data is required for the temporal synchronization between motion and lidar data. For LOT 1, Deployment 3, the

lidar unit was working intermittently after 24.02.2023 with increasing data loss towards the end of the deployment.

Only a fraction of the data of LOT 2, Deployment 1 could have been processed because Septentrio D-GPS is not available until 24.06.2022. We assume that the missing data are automatically overwritten by the system as consequence of the limited internal data storage of the Septentrio in combination with the extended memory requirement of storing more raw data. Then the lidar stopped measuring on 13.07.2022. For LOT 2, Deployment 2 *lidar1hz* files are available only until 22.11.2022. For LOT 2, Deployment 3, Septentrio data is available only from 18.12.2022 and starting on 08.03.2023, the lidar unit worked only intermittently, so that the data availability was reduced after that date.

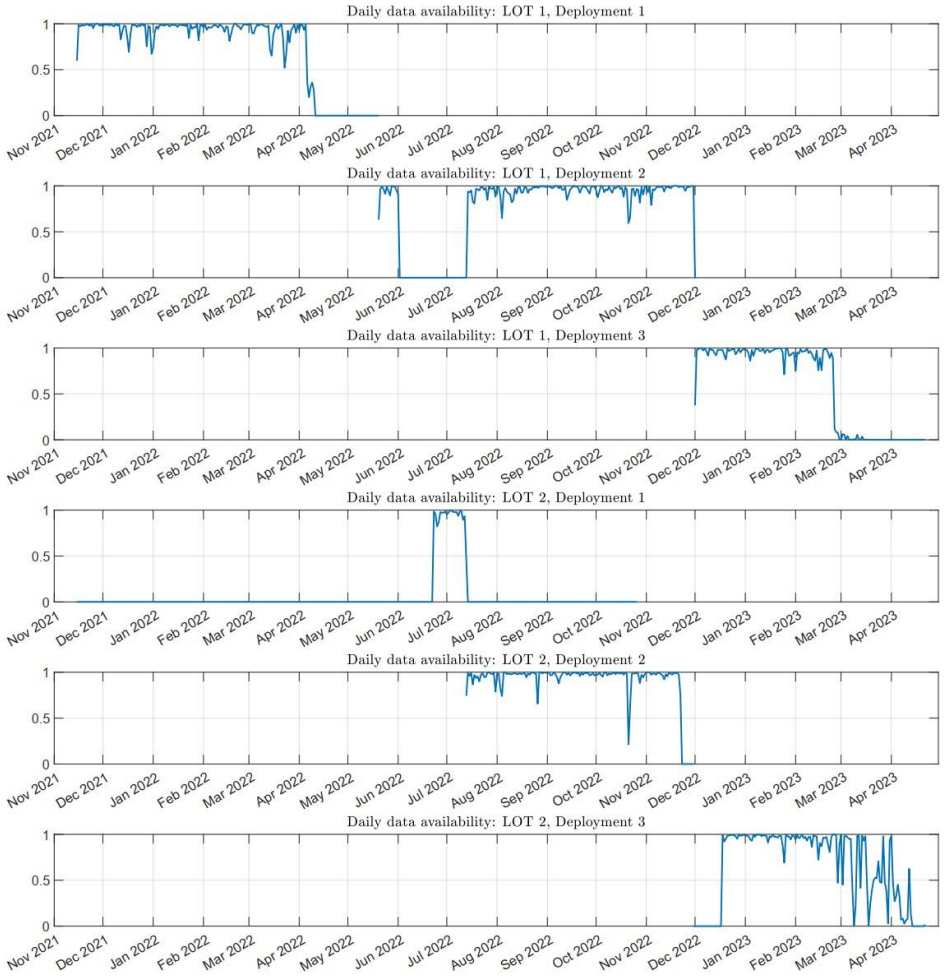

Figure 2.1: Daily availability of motion-compensated TI data for all six processed deployments

3. Conclusion

This report finalizes the work on motion correction of turbulence intensity values for data acquired during the first three SWLB deployments at LOT1 and LOT2 of the ongoing North Sea measurement campaign.

The data processing worked out well and we refer to the corresponding PDV reports for an estimate of the TI data accuracy [4]. Unfortunately, motion-compensation processing has not been possible for several periods as described above.

At LOT1, a fourth and fifth deployment and at LOT2, a fourth deployment are not covered in this report. They are scheduled to be concluded in November 2023 and data will be processed after recovery and results will be added when they are available.

4. References

[1] DNV, "WS181 Independent performance verification of Seawatch Wind Lidar Buoy at Frøya, Norway. 10281716-R-2, Rev. B," 2021.

[2] DNV, "WS191 Independent performance verification of Seawatch Wind Lidar Buoy at Frøya, Norway. 10332389-R-4, Rev. A," 2022.

[3] DNV, "WS170 Independent performance verification of Seawatch Wind Lidar Buoy at the LEG offshore platform. 10298247-R-1, Rev. A," 2021.

[4] Fugro, "Energy Islands – Floating LiDAR Measurements Motion correction of turbulence intensity. WP1: North Sea pre-deployment verification tests," 2023.