Westerduinweg 3
1755 LE Petten
P.O. Box 15
1755 ZG Petten
The Netherlands

www.tno.nl

T +31 88 866 50 65

TNO report

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Europlatform LiDAR measurement campaign; Instrumentation Report 2022

Date	24 October 2022
Author(s)	G. Bergman J.P. Verhoef P.A. van der Werff
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Summary

In order to better understand the wind conditions at the North Sea for future offshore wind farms a ZX300 LiDAR from ZXLidars was installed at the Europlatform (EPL) platform in 2016. This report describes the Europlatform, used LiDAR system, installation, configuration, data handling and operational aspects. This report is an updated version of earlier released instrumentation reports.

Contents

1 Introduction

1.1 Offshore wind energy deployment

Europe aims to become the first carbon neutral continent by 2050. To reach this goal, wind energy will play a fundamental role in the roll-out of renewable electricity and in the success of the Energy Transition in Europe (A European Green Deal). The North Sea has become a centre for industrial exploration of this technology, and is key for future transformation of the industry, since over 70% of existing and planned European offshore wind farms will be located in this area. Recently, in May 2022 the Netherlands together with three other European countries, Denmark, Belgium and Germany has signed the Esbjerg Offshore Wind Declaration, agreeing to reach together an install capacity of 65 GW by 2030 and of 150GW by 2050 [1]

The Offshore Wind Energy Act gives the government the option of issuing lots for the development of offshore wind farms. Recently the Dutch Government has planned to open 5 new areas for offshore wind farm development to accommodate these revised ambitions and targets [2], see Figure 1.

Figure 1 Locations of existing and planned wind farms (grey) and new designated zones for offshore wind farms (orange) to reach 21.5 GW over the Dutch North Sea by 2030, updated in June 2022 [2].

1.2 TNO leading role on offshore measuring campaigns

Before the integration of LiDARs in offshore wind resource assessments, meteorological masts (met mast) have been widely used by TNO. Notable examples include the met mast IJmuiden (MMIJ), as well as the met mast at Offshore Wind farm Egmond aan Zee (OWEZ).

Onshore measurement campaigns are also part of the activities of TNO for more than 20 years, including independent ISO17025 and IECRE based measurements (Power performance / Mechanical loads / Meteorological measurements / Remote sensing device verification and floating LiDAR verification) to support wind turbine prototype certification from small (330 kW) to larger turbines (13MW). During the measurement campaign, TNO is responsible for the entire life cycle: from the installation plan at the platform; to the purchase and selection of the instrumentation, installation, analysing, reporting and dissemination of the data.

Since 2014, TNO is performing for the Dutch Ministry of Economic Affairs and Climate Policy measurement campaigns with LiDARs at three strategically locations in the North Sea. These campaigns are part of the *'2022 Wind Conditions @ North Sea"* project to support the Dutch wind offshore roadmap. These three locations are: Lichteiland Goeree (LEG), Europlatform (EPL) and K13a (Figure 2).

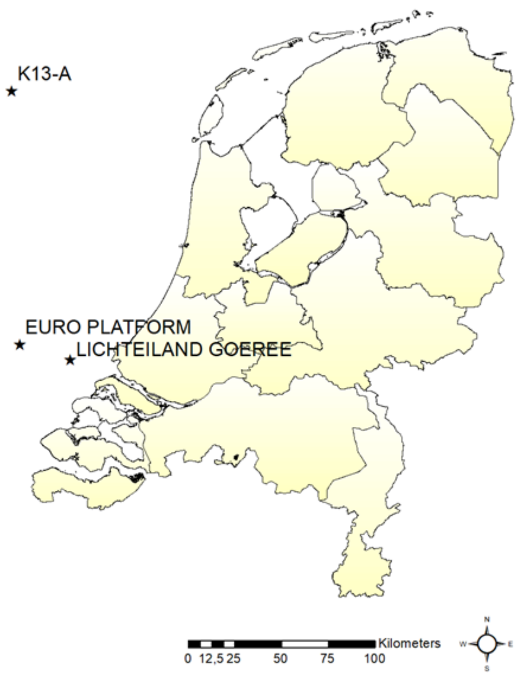

Figure 2 TNO locations of long term measurement campaigns for the wind resource at Lichteiland Goeree (LEG), Europlatform (EPL) and K13a.

This report focusses on the instrumentation on Europlatform (EPL). A description of the EPL platform is found in Chapter 2 and in Chapter 3 detailed information is found about ZX300 LiDAR. The installation is elaborated on in Chapter 4 and Chapter 5 focusses on the data handling. Finally, Chapter 6 covers the operation and maintenance aspects.

1.3 Open-access and public datasets

Since 2020 TNO has published annually reports on the wind conditions for each measurement campaign location. These reports are available at https://www.windopzee.net/en/ [5]. Via this website data sets starting from 2016 are available also.

2 Europlatform (EPL)

The Europlatform is a platform located at a distance of about 60 km west from Hoek van Holland. The location of the platform can be seen in Figure 3.

Figure 3 Location of Europlatform

The platform serves as a measurement station for among others water level and wave height measurements. Also, meteorological measurements are being performed on the platform. A picture of the platform can be seen in Figure 4.

Figure 4 Europlatform

Some specific data concerning the Europlatform are:

Coordinates : N51.99792° E3.27481° / 51°59'52.5"N 3°16'29.3"E
Water depth : 32 meter (MSL)
References for this information can be found in [3] and [4] .

The platform consists of a helicopter deck on a height of 19 meter above MSL, with an accommodation deck below. The floor of this accommodation deck is on 16.2 meter above MSL.

A top view of the platform can be seen in Figure 5.

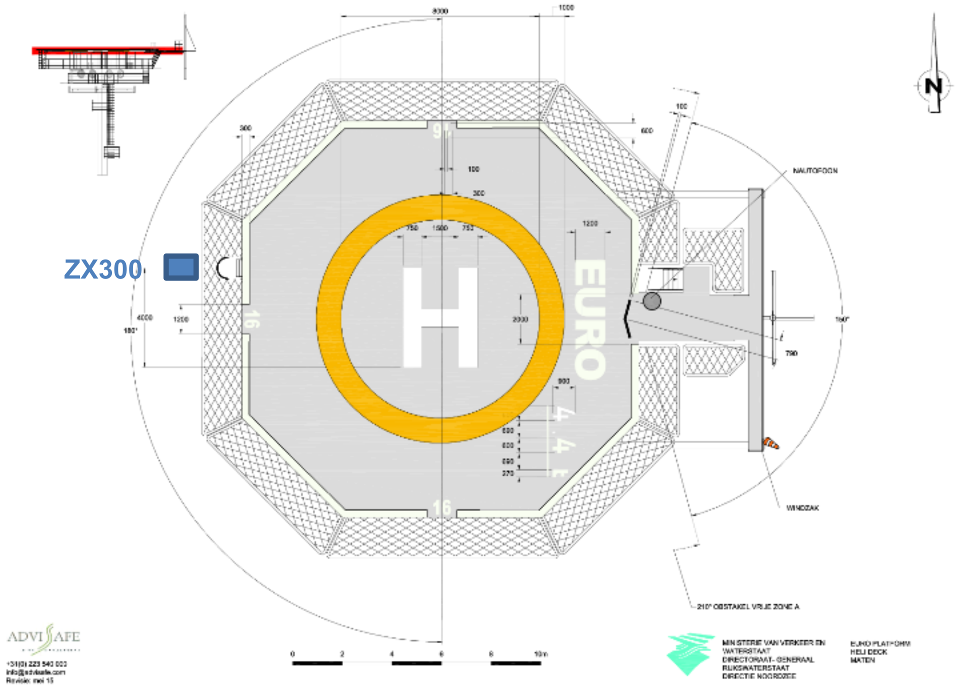

Figure 5 Top view of the Europlatform

3 ZXLidars ZX300

The ZXLidars ZX300 LiDAR consists of a tripod-shaped housing, with dimensions of ca. 90 x 90 x 90 cm. The inclined top of the housing contains the lens through which the laser beam comes out.

A picture of the system can be seen in Figure 6.

Figure 6 ZXLidars ZX300 LiDAR

The laser beam of this LiDAR points up with an angle of 30 degrees with respect to the vertical, and rotates to describe full circles, as can be seen in Figure 9.

A big advantage of this way of measuring is that an object blocking the laser beam in a certain position does not obstruct the data-acquisition. As long as sufficient data points are measured around the circle, the LiDAR is able to determine the wind speed.

4 Installation ZXLidars ZX300 LiDAR

Since May 2016 a ZX300 LiDAR is installed at EPL on an extension platform at the West side of the accommodation deck, just below the helideck, see Figure 7. Although an extended platform of ca. 1.75 x 1.75 meter is installed for the LiDAR, the laser scanning circle is still partially blocked by the helicopter deck netting. The mounting platform height is 16.2 meters above MSL.

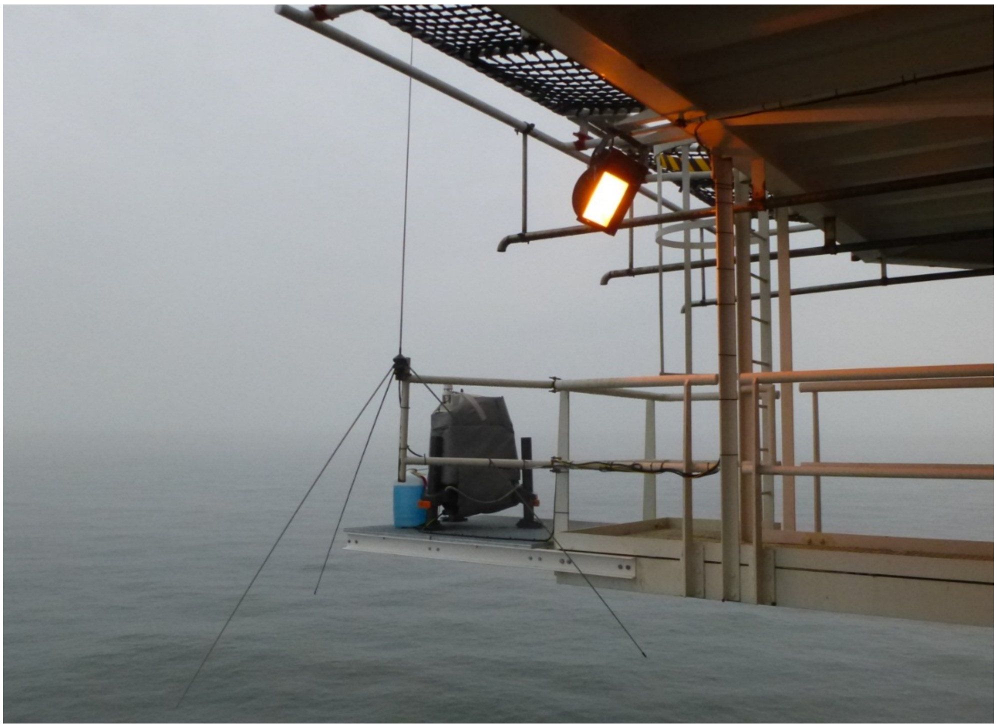

Figure 7 ZX300 LiDAR installed on the extension of the accommodation deck

Figure 8 Installed LIDAR. North maker pointing to the right

4.1 Electrical installation

4.1.1 Power supply

The power requirements of the LiDAR in standard climate conditions is between the 69 and 111 Watt, see Appendix B. The LiDAR is powered with 230VAC coming from the computer room. The 230VAC is converted to 12VDC by a converter located at the bottom of the LiDAR.

4.1.2 Communication

To be able to transfer the data measured by the LiDAR to TNO, a 3G/4G TNO VPN router is installed inside the computer room. From this router an ethernet cable has been routed to the LiDAR along the installed power cable. The router is connected to the internet using the KPN 4G network.

4.2 Orientation of the LiDAR

The LiDAR has been installed with the 'North' marker of the LiDAR pointing towards the platform North which is aligned to true North, see Figure 5. The LiDAR North marker is pointed to the right when looking at the LiDAR whilst standing on the existing accommodation deck extension, see Figure 8.

4.3 Obstacles

As the LiDAR has been installed quite close to the helicopter platform and the LiDAR beam has an opening angle of 30 degrees with respect to the vertical, the view of the LiDAR upwards is not totally free from obstacles.

The lens of the LiDAR is situated about 1 meter away from the netting of the helicopter deck in horizontal direction. The lens is situated at about 2 meters below the netting, resulting in a beam radius of about 1.15 meters at the netting height. This means that a small part of the scanning circle is obstructed by the netting.

Moreover, an exhaust of one of the Diesel motors of the platform is situated near the LiDAR, and can obstruct or deflect the scanning beam for a part of the scanning circle.

The ZX300 LiDAR is equipped with a sonic wind direction sensor. This measurement is used by the LiDAR to more reliably determine the wind direction. Because the platform blocks the wind at the measurement height of this sensor the wind direction of the sensor is not always reliable. In some cases this results in an 180 degrees offset on the LiDAR wind directions.

4.4 LiDAR settings

4.4.1 Measuring heights

We have chosen to measure wind speeds on the Europlatform on the same height as we are measuring wind speeds on the Licht Eiland Goeree platform, which are based on the meteorological mast (MMIJ) measurement height configuration, mentioned in chapter 1.

The lens of the LiDAR is around 17 meters above sea level (MSL). The measuring heights as configured in LiDAR can be seen in Figure 9 and Table 1 gives also the corresponding measurement heights above MSL.

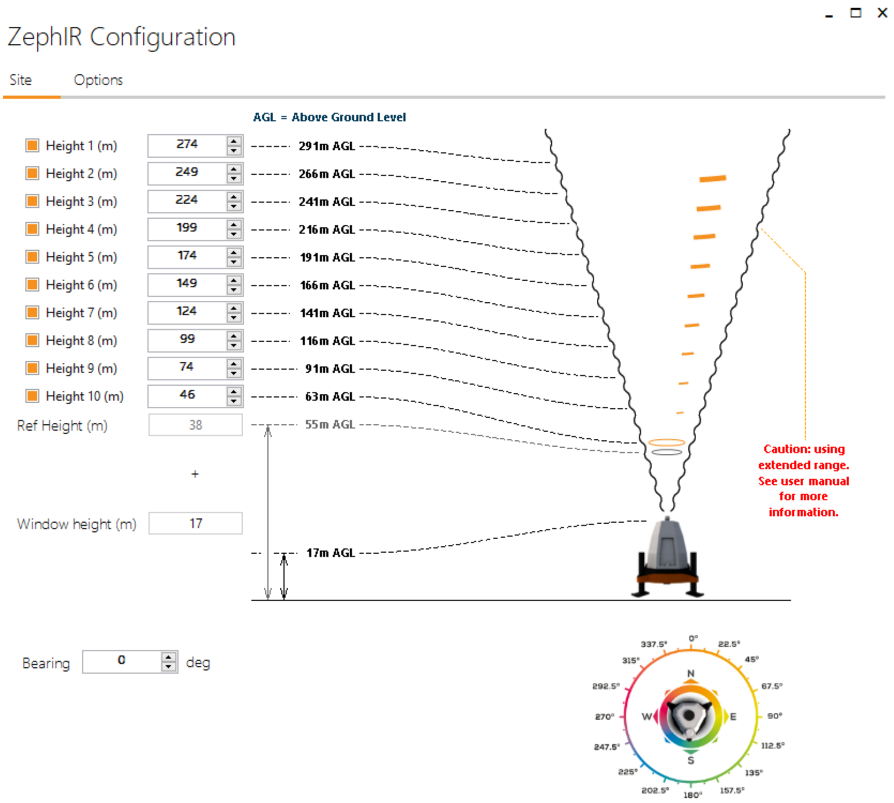

Figure 9 Height configuration of the ZX300 LiDAR

Table 1 LiDAR configuration and measurement height to MSL

No	LiDAR height configuration (m)	measurement height to MSL (m)
1	46	63
2	74	91
3	99	116
4	124	141
5	149	166
6	174	191
7	199	216
8	224	241
9	249	266
10	274	291

Note: according the specs the maximum measuring height is 200m so the measurements at the 3 top levels are for indication only.

5 Data handling

In this chapter we will consider the three TNO data sources / flow as well as the additional available data sources, namely:

- Standard produced ZXLidars ZX300 data files, 10-minute statistical data and 1-second (per configured measurement height) data;
- TNO database handling, checking, correction and filtering;
- TNO data export via https://www.windopzee.net/en/;
- Additional EPL data from RWS and KNMI.

5.1 ZXLidars ZX300 data files

The ZX300 LiDAR delivers data files in binary format(.ZPH) as well as in CSV format. The data is imported into the database using the 10-minute statistical CSV output files.
Two different CSV files are created by the LiDAR on a daily basis, one file with the 10-minute statistical data, recognised from the prefix “Wind10_” and one file with the 1-second (per configure measurement height) data with prefix “Wind_”.

The complete filename is build up as described below:

Wind10_”ID”@Yyyyy_Mmm_Ddd.CSV (Wind_”ID”… in case of 1-second data file)
- ID: ZX300 serial number
- yyyy: year of data
- mm: month of data
- dd: day of data

For an overview of the outputted signals see Appendix A.

All the produced CSV files are transferred on a daily bases from the LiDAR to the data server at TNO.

5.2 TNO database

After data transfer, the data is imported into the TNO database. Shortly after a “daily-plot” is automatically created and sent by email to the team members. The lead engineer will evaluate the “daily-plot”, see Figure 10. If needed the Lead Engineer performs a post-validation on the data in the database such that a specific data period is marked as invalid and no longer visible.

In the database is also an automated wind direction correction active as explained in Chapter 5.5.

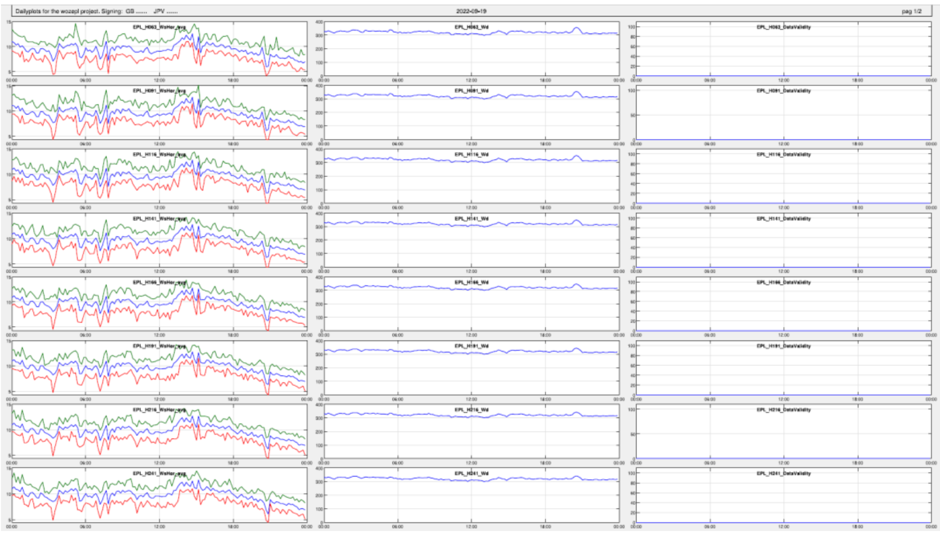

Figure 10 Daily plot for the EPL measurement campaign

5.3 Data export Europlatform

At the beginning of each calendar month TNO makes the 10 minute statistical data available via the https://www.windopzee.net/en/ website [5]. Here you can find the historical data of the LiDAR measurement campaign.

The order for export and presentation on the website will be as follows:
EPL-yyyy-mm.CSV for the previous month(s).

After a quarter is completed the monthly files will be replaced by:
EPL-yyyy-Qx.CSV (where x stands for the actual quarter)

After the year is completed the quarterly files will be replaced by a yearly file:
EPL-yyyy.CSV

5.4 Additional data sets

Besides the TNO LiDAR measurements, both KNMI and Rijkswaterstaat also perform measurements on EPL. Those measurements can be divided into Meteorological Measurements (KNMI) and Oceanographic measurements (Rijkswaterstaat), summarized in Table 2.

Table 2 Measurement Parameters from other organizations

Parameter	Meteorological (KNMI)	Oceanographic (Rijkwaterstaat)
Air pressure	X	
Wind speed / Wind direction	X	
Air temperature	X	
Relative humidity	X	
Visibility	X	
Water level		X
Water temperature		X
Wave height		X
Wave period		X

The oceanographic parameters are measured with a Radac WaveGuide Radar F08 free space type which is installed on the jacket construction.

The measurements are not carried out by TNO but they are important reference measurements and therefore imported into the project database. Together with the LiDAR data the availability and plausibility is checked on a daily basis.

5.5 Wind direction correction

The ZX300 is based on the continues wave technology. It changes focus point for every measurement height and per height is takes about 1 second to complete one 360 degree scan. Depending on the configured heights, it can take between 10 and 15 seconds to complete the measurements of all configured heights. Using the doppler shift in the backscattered data the wind speed can be determined but the direction of the doppler shift cannot be determined, which can result in a 180 degree offset shift. For this the ZX300 is equipped with a sonic anemometer mounted at a pole at the side of the LiDAR used as a reference wind direction. However when installed at the side of a platform like the LiDAR at the EPL platform, the sonic wind direction measurement is highly disturbed. This results in periods where the wind direction determination of the LiDAR fails and the wind direction is shifted 180 degrees.

This 180 degrees shift of course can only be identified by having a secondary wind direction signal for comparison, which is available in the additional EPL platform data set from KNMI. In short the correction is done as follows:

- Take the difference of the two wind direction timeseries;
- Remove solitary spikes from this difference signal;
- Identify the periods where the ZX300 wind direction is clearly reversed;
- These periods can be extended under certain circumstances.

The complete description of the wind direction correction method is found in Appendix C.

6 Operation and maintenance aspects

The ZXLidars ZX300 was first installed on May 10th, 2016. According to TNO quality system [8] the LiDAR is replaced every two years and will be serviced every year. All operational aspects with respect to installing and maintaining the LiDAR are recorded in the Logbook.

In the following table, an overview is given of the used LiDAR's and the period that they were operational. It should be noted that before the LiDAR is installed at the EPL platform it is first verified at the TNO RSD Verification Location near meteorological mast 6 at the EWTW test site in the Wieringermeer in the Netherlands [6,7] .

Table 3 Overview of applied LiDAR @ EPL

LiDAR	TNO code	Period	Reason for replacement
308	94012680	10-05-2016 to 10-08-2018	Periodically replacement
315	94012681	10-08-2018 to 23-10-2019	Power failure
308	94012680	23-10-2019 to 22-03-2022	Periodically replacement
315	94012681	22-03-2022 to ……………	

Using the manufacturers software Waltz we can connect to the LiDAR at EPL and the status of components can be monitored, see Figure 11.

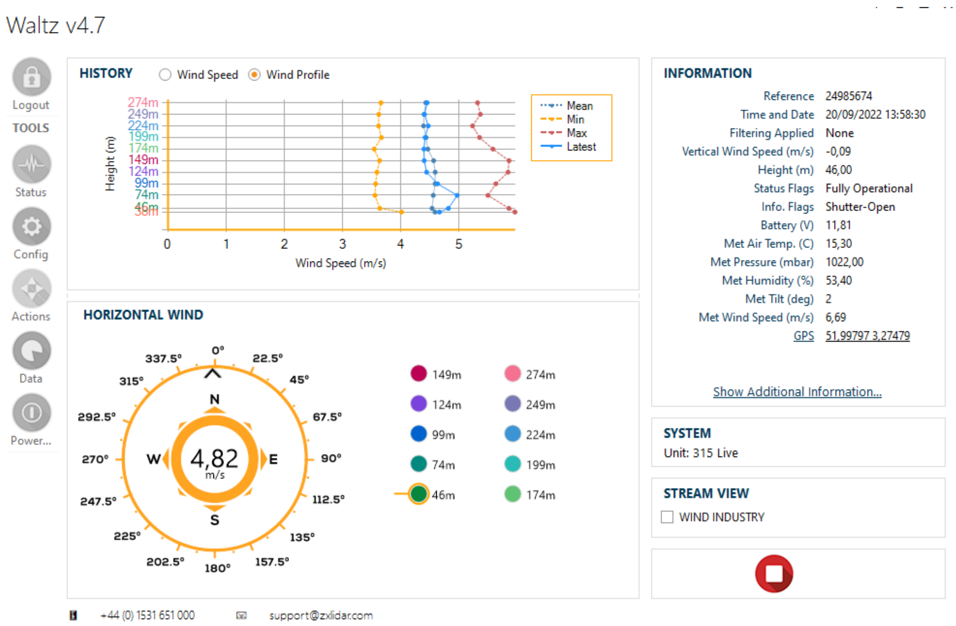

Figure 11 Screenshot of ZXLidars software Waltz

7 References

[1] Rijksoverheid, "THE ESBJERG DECLARATION on The North Sea as a Green Power Plant of Europe," Rijksoverheid, 18 May 2022.
[2] Kamerbrief aanvullende routekaart windenergy op zee 2030, Den Haag, Kamerbrief 10 juni 2022, kenmerk DGKE-E / 22235501.
[3] C. Gautier and M. v. d. Boomgaard. *Rapportage veldmetingen Westerschelde september 1997 t/m december 2002*. Document reference: RIKZ/2003.052. Ministerie van Verkeer en Waterstaat - Rijksinstituut voor Kust en Zee, Dec. 18, 2003.
[4] M. C. Kwanten. *Noordzee reductiematrix 2006*. Ministerie van Defensie - Koninklijke Marine - Dienst Hydrografie, Apr. 2007.
[5] https://www.WindOpZee.net.
[6] G. Bergman and J.P. Verhoef, *TNO ground based RSD Verification Facility at EWTW*, TNO – Wind Energy, TNO 2020 R10781, June 2020.
[7] G. Bergman, *Verification of the TNO ZX300 LiDAR system unit 315 at the EWTW test site*, TNO – Wind Energy, TNO 2021 R11643, March 2021
[8] *Procedure for LiDAR Calibration & Characterization*, TNO – Wind Energy, IN-810-060, November 2019.

A Signal list EPL ZX300 LiDAR

Name	Location	Short name (Signal name)	Sensor	Unit	installed	Freq (Hz)	Campaign
LiDAR, Zephir300							
Battery Voltage		EPL_VBat		V			
Max temperature inside Lidar		EPL_LowPodTemp		deg C			
Min temperature inside Lidar		EPL_UpPodTemp		deg C			
CPU temperature in Lidar		EPL_Tcpu		deg C			
Relative humidity inside Lidar		EPL_Hpod		%			
Lidar bearing		EPL_Bearing		deg			
Lidar tilt angle		EPL_Tilt		deg			
Air temperature at Lidar position		EPL_Tair2		deg C			
Air pressure at Lidar position	EPL	EPL_Pair2	ZXLidars ZX300	hPa	TNO	stat	Wind@Sea
Relative humidity at Lidar position		EPL_Hair2		%			
Wind speed measured by Lidar meteo station		EPL_WsMet		m/s			
Wind direction measured by Lidar meteo station		EPL_WdMet		deg			
Precipitation measured by Lidar meteo station		EPL_Rain		%			
Measuring height		EPL_Altitude		m/s			
External supply voltage		EPL_VGen		V			
Error flags		EPL_ErrorFlagsZP300		-			
GPS Lat.		EPL_ZPHS_GPSDataFloatLatitude		-			
GPS Lon.		EPL_ZPHS_GPSDataFloatLongitude		-			
For every measuring height (m):		xxx : 63, 91, 116, 141, 166, 191, 216, 241, 266, 291					
Horizontal wind speed average		EPL_Hxxx_WsHor_avg		-			
Horizontal wind speed std deviation		EPL_Hxxx_WsHor_std		-			
Horizontal wind speed minimum		EPL_Hxxx_WsHor_min		-			
Horizontal wind speed maximum		EPL_Hxxx_WsHor_max		deg			
Vertical wind speed average		EPL_Hxxx_WsVer_avg		m/s			
Wind direction		EPL_Hxxx_Wd		m/s			
Signal to noise ration	EPL	EPL_Hxxx_BackScatter	ZXLidars ZX300	m/s	TNO	stat	Wind@Sea
HorizontalConfidence		EPL_Hxxx_HorizontalConfidence		m/s			
Data package valid or invalid (only time series)		EPL_Hxxx_DataValidity		m/s			
# packets in fit		EPL_Hxxx_npackets		-			
# measuring points		EPL_Hxxx_npts		-			
# missed points		EPL_Hxxx_Missed					
# packets in fit		EPL_Hxxx_npackets					
CS, diagnostic use only		EPL_Hxxx_CS					

Figure 12 Signal list EPL ZX300 LiDAR

B Specifications of the ZXLidars ZX300 LiDAR

ZX300 Specification

Measurements

Range	10 - 200 metres (Lidar measurement) 0 - 10 metres (onboard met weather station)
Probe length	± 0.07 metres @ 10 metres ± 7.70 metres @ 100 metres
Heights measured	10 User configurable 1 Additional met weather station measurement
Sampling rate	50Hz (up to 50 measurement points every second)
Averaging rate	True 1-second averaging 10 Minute averaging
Accuracy wind speed	0.1 m/s*
Direction variation	< 0.5°
Speed Range	< 1 m/s to 80 m/s

Product

Service interval	36 months from new
Size	900 x 900 x 1001mm
Weight	55kg
IP Rating	IP 67
Power consumption	69W
Power input	12V
Temperature range	-40 + 50°C
Warranty	3 years
Maintenance	No annual maintenance or calibration in this period

Figure B.13 ZXLidars ZX300 LiDAR specifications

C Wind direction correction method ZX300 LiDAR

Short description:

- Take the difference of the two wind direction timeseries.
- Remove solitary spikes from this difference signal.
- Identify the periods where the ZX300 wind direction is clearly reversed.
- These periods can be extended under certain circumstances

Assumptions:

- Only 180 wind direction offsets are to be corrected;
- $WD_{corrected} = WD_{measured}$ + Offset | Offset is 0° or Offset =180°;
- The offset can only change at the start of 10 minute time frame;
- Wind direction is only reliable measured above a wind speed of 1 m/s;
- The offset changes occur longer then 20 minutes;
- Reference platform wind vane data available (KNMI).

Method:

1. Extract the wind direction and wind speed data from the Lidar at the lowest measuring height;
2. Acquire the wind direction data from the reference data source (KNMI);
3. Remove (set to NaN) all samples from the Lidar time series where the wind speed > 100 m/s;
4. Calculate the wind direction difference between Lidar and reference time series and take care of the north gap;
5. Derive 2 signals (timeseries): A and B
   A: True; if wind speed is > 1 m/s and |wind direction difference| < 30° ➔ Offset =0°
   B: True; if wind speed is > 1 m/s and 150°< |wind direction difference| < 210° ➔Offset = 180°
   In this way the timeseries is divided into intervals (‘sure‘ intervals) where it is sure whether the signal is switched or not switched, the intervals in between are the ‘unsure’ intervals. In a more mathematical way ‘sure’ interval mean signal A or signal B is true , ‘unsure’ interval mean signal A and signal B are both false;
6. Remove spikes from signal B.(remove solitary true or false values);
7. Intervals where signal B is true are investigated and extended as long as: |wind direction difference| > 90°, solitary missing data points are skipped. In this way the ‘sure’ intervals where the signal is switched, can grow into the ‘unsure’ intervals until it is more likely that the signal is ‘not switched’;
8. In case two adjacent intervals where B is true are separated by a period where the wind direction difference signal was missing, the two intervals are combined to one;
9. The moments where the Offset changes from 0° to 180° and reverse are found there where signal B shows rising or falling edges.