Energy Islands – Floating LiDAR Measurements

Bat monitor data evaluation report for Lot 1, November 2021 – May 2023

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Abbreviations

Abbreviation	Definition
CTD	Conductivity, temperature, depth
DD	day of month 2 digits
DGPS	Dual GPS
GNSS	Global Navigation Satellite System
GPS	Global positioning system
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
LiDAR (or lidar)	Light Detection and Ranging
MM	month 2 digits
MSL	Mean Sea Level
MWL	Mean Water Level
NaN (Not a Number)	Label indicating data as invalid/missing
PEP	Project Execution Plan
PPE	Personal Protective Equipment
QHSSE	Quality, Health, Safety, Security and Environment
QA/QC	Quality Assurance / Quality Control
SI	Système International
SWLB	Seawatch Wind Lidar Buoy
SWMini	Seawatch Mini Wave Buoy
UTC	Universal Time Coordinated
WMO	World Meteorological Organization
WS	Seawatch Wavescan buoy
YYYY	year 4 digits
MYONAT	Myotis nattereri
PIPNAT	Nathusius's pipistrelle
PIPKUH	Pipistrellus kuhlii
RHIHIP	Rhinolophus hipposideros
PIPPIP	Pipistrellus pipistrellus
PIPPYG	Pipistrellus pygmaeus
TADTEN	Tadarida teniotis

Conventions

Convention	Description
Time	All times are UTC
Directions	Directions are given in degrees (°) increasing clockwise from north. For wind and waves the direction is defined as incoming: 0° means wind/waves from the north, 90° from the east etc. For current velocity, the vector or flow direction is used: 0° means current flowing toward the north, 90° toward the east etc. The directions are subject to the source of heading, which is either compass - relative to magnetic north, or GNSS - relative to true north. Magnetic compass is used for wind directions from Gill, waves and currents, while GNSS is the main heading source for lidar wind directions. Compass data is available (stored in the data logger) as backup heading source for lidar wind directions. At Lot 1 the deviation between magnetic and true north is approximately 2.4°(E). This deviation applies to wave direction orientation and external compass heading data. [1] https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#declination

Executive Summary

Fugro Norway (OCEANOR) AS entered into an agreement with ENERGINET, Denmark for the project "Floating LiDAR Measurements Energy Island Offshore Wind Farm - Lot 1-4" for initially 12 months. Lots 1, 2 and 4 were extended for an additional 12 months each. The purpose of the assignment is to provide met ocean data obtained through real time measurements at the two (2) energy islands: Energioe Nordsoen and Energioe Bornholm. The results of the atmospheric and oceanographic measurements should be used for verification of the wind energy potential, as basis for derivation of metocean design parameters and as a supplement to the environmental baseline description.

For Lot 1 the following instruments were deployed: a LiDAR buoy (SWLB) together with a bottom mounted Thelma water level sensor and a bottom mounted upward-looking Nortek Signature500 current profiler. The buoy was equipped with a Wildlife Acoustics Song Meter bat monitoring system. The collected bat data was stored on the instrument, collected at every service and stored associated with the SWLB ID.

This report covers an initial analysis of the collected bat data at Lot 1 in the North Sea and includes general information on the measurement campaign, as well as a summary of the measurement configuration and automatic data analysis of the bat data between November 2021 and May 2023. For each set of sound recordings per buoy, deployment and SD card, the Auto-ID option was enabled with the classifier library set to "*Germany*" (Bats_of_Europe_5.4.0).

Bat calls were detected mainly in November and December 2021 and May 2022.

The detections in in November and December 2021 appear to be influenced by wind and wave noise, noise from any of the other systems on the buoys, or bird sounds and are likely false positives. During periods of high sea states, especially in the winter months, both high motion of the buoy and high winds and waves can act as several sources of noise which the automatic algorithm falsely interprets as matches.

The detections in May 2022 are more likely to be actual bat call identifications. During this time, sea state and wind conditions were calm and less wind and wave noise is expected in the sound recordings.

However, these results should be verified by doing a thorough analysis of the respective sound recordings.

1. Introduction

1.1 Energioe Nordsoen project area

The Energioe Nordsoen project area (**Figure 1-1**) is located approximately 90 km west of Thyborøn, Denmark. The water depth in the 1,100 km^2 large project area varies between 25 m LAT and 50 m LAT (Admiralty Chart).

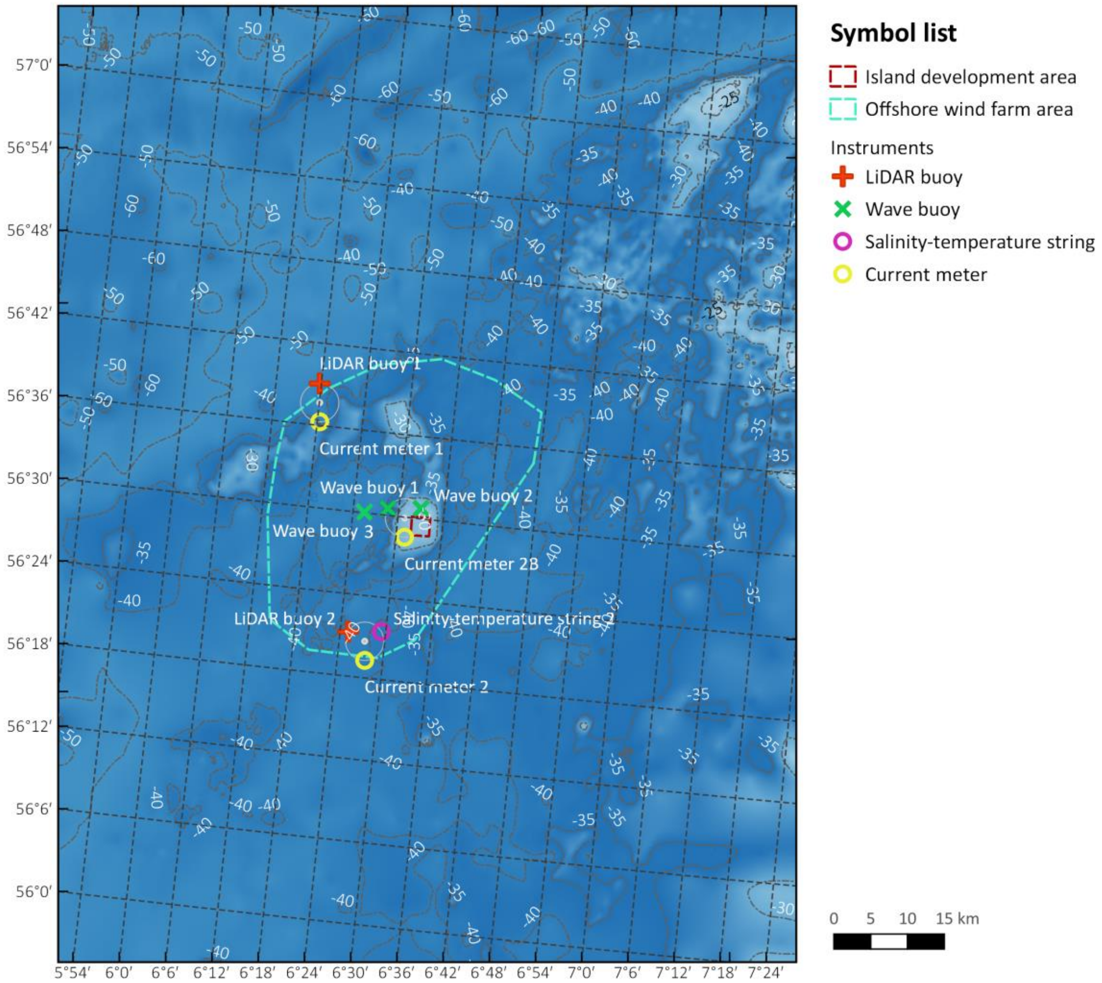

Figure 1-1 Instrument locations in the Energioe Nordsoen project area

The aim of the measurement campaign is to provide a set of continuous meteorological and oceanographic (metocean) data with excellent quality and high availability. The measurement campaign lasted 12 months and was extended for an additional 12 months. The results of the atmospheric and oceanographic measurements are to be used for verification of wind energy potential, as basis for derivation of metocean design parameters and as a supplement to the environmental baseline description.

1.2 Lot 1

During the campaign, 2 LiDAR buoys were used at Lot 1: WS170 and WS191. The buoys were deployed on the same mooring and swapped as needed. Both LiDAR buoys were equipped with an ultrasonic Wildlife Acoustics Song Meter SM 4BAT FS recorder.

The position of the bottom mooring weight is listed in **Table 1-1**. The buoys are free to float around the mooring point within a radius of about 110 m.

LiDAR buoy WS170 was deployed at Lot 1 on 15 November 2021 at 09:30 UTC. On 20 May 2022, WS170 was recovered for maintenance and the spare buoy WS191 was deployed on the same mooring. WS191 was recovered for maintenance on 01 December 2022, serviced offshore onboard the service vessel, and redeployed on the same day on the same mooring. WS191 was recovered on 22 April 2023 at 18:50 UTC and replaced by WS170 at 20:10 UTC. On 13 June 2023, WS170 was recovered at 09:40 UTC and, at 13:00 UTC, WS191 was re-deployed on the Lot 1 mooring. The campaign ended on 15 November 2023 but was extended further until 24 February 2024. WS191 was finally recovered on 26 April 2024.

Table 1-2 shows a log of the deployments at Lot 1. This table should be consulted when using the bat data, as only data collected during times when the buoys were offshore should be considered.

For this report, sound recordings until May 2023 were analysed.

Table 1-1 Buoy location and water depth

Buoy	Location	Latitude [°N]	Longitude [°E]	Water Depth [m MWL]
LiDAR Buoy 1 (SWLB)	North Sea/Lot 1	56.6280	6.3007	46.4

Table 1-2 Deployments at Lot 1

Deployment	Station	Buoy S. no.	LiDAR #	Start time (UTC)	End time (UTC)	Status
D01-SWLB	Lot 1	WS170	ZX585	2021-11-15 09:30	2022-05-20 07:00	Recovered for service
D02-SWLB	Lot 1	WS191	ZX862	2022-05-20 07:50	2022-12-01 08:10	Recovered for service
D03-SWLB	Lot 1	WS191	ZX862	2022-12-01 14:30	2023-04-22 18:50	Recovered for service
D04-SWLB	Lot 1	WS170	ZX585	2023-04-22 20:10	2023-06-13 09:40	Recovered for service
D05-SWLB	Lot 1	WS191	ZX862	2023-06-13 13:00	2024-02-24 23:50	End of campaign

2. Measurement configuration, data analysis, and post-processing

2.1 Measurement configurations

The general measurement setup, sensors, configurations, and measurement scheme of the whole campaign are described in the measurement plan [1].

Bat activity was recorded using a weatherproof, single channel, full-spectrum, ultrasonic Wildlife Acoustics Song Meter SM 4BAT FS recorder. Firmware algorithms attempt to detect and count individual echolocation pulses from bats and sequences of bat pulses based on configured parameters. A "bat pass" refers to a series of pulses recorded as a bat passes by the microphone. A bat pass begins with the first detected pulse and ends when either no pulses have been detected after the maximum time between pulses has occurred, or when the maximum trigger duration has been reached.

The SM 4BAT FS recorder was placed inside the central cylinder of the buoy where it was protected from any water intrusion. The SMM-U2 microphone was placed on the secondary mast in ca. 4 m height and connected with the recorder via a cable. On WS170, the power supply system was air-cooled using air-intake pipes, while WS191 was water-cooled. **Figure 2-1** shows the mounting arrangement for WS170 and **Figure 2-2** shows the mounting arrangement for WS191.

Table 2-1 summarizes the measurement configuration of the SM 4BAT FS recorders. The recorders were set to record all.

A Gill Windsonic M acoustic wind sensor was mounted at 4 m height on the main mast on each buoy. The buoy also recorded sea state data with a Wavesense 3 directional wave sensor. The wind and wave measurements were averaged every 10 minutes and reported monthly. **Table 2-2** summarizes the measurement configuration of the Wavesense 3 directional wave sensor and Gill Windsonic M acoustic wind sensor.

At the end of each deployment, the SD cards were recovered from the bat recorders and replaced with new cards. The sound recordings were downloaded and stored under the Lot number and buoy designation.

Table 2-3 summarizes the high-level folder structure. Each subdirectory includes a "Data" directory which contains the .w4v recordings.

Please note that all recordings have been provided, also those taken while the buoy was still on land, and **Table 1-2** should be consulted to ensure that only data when the buoys were offshore is considered.

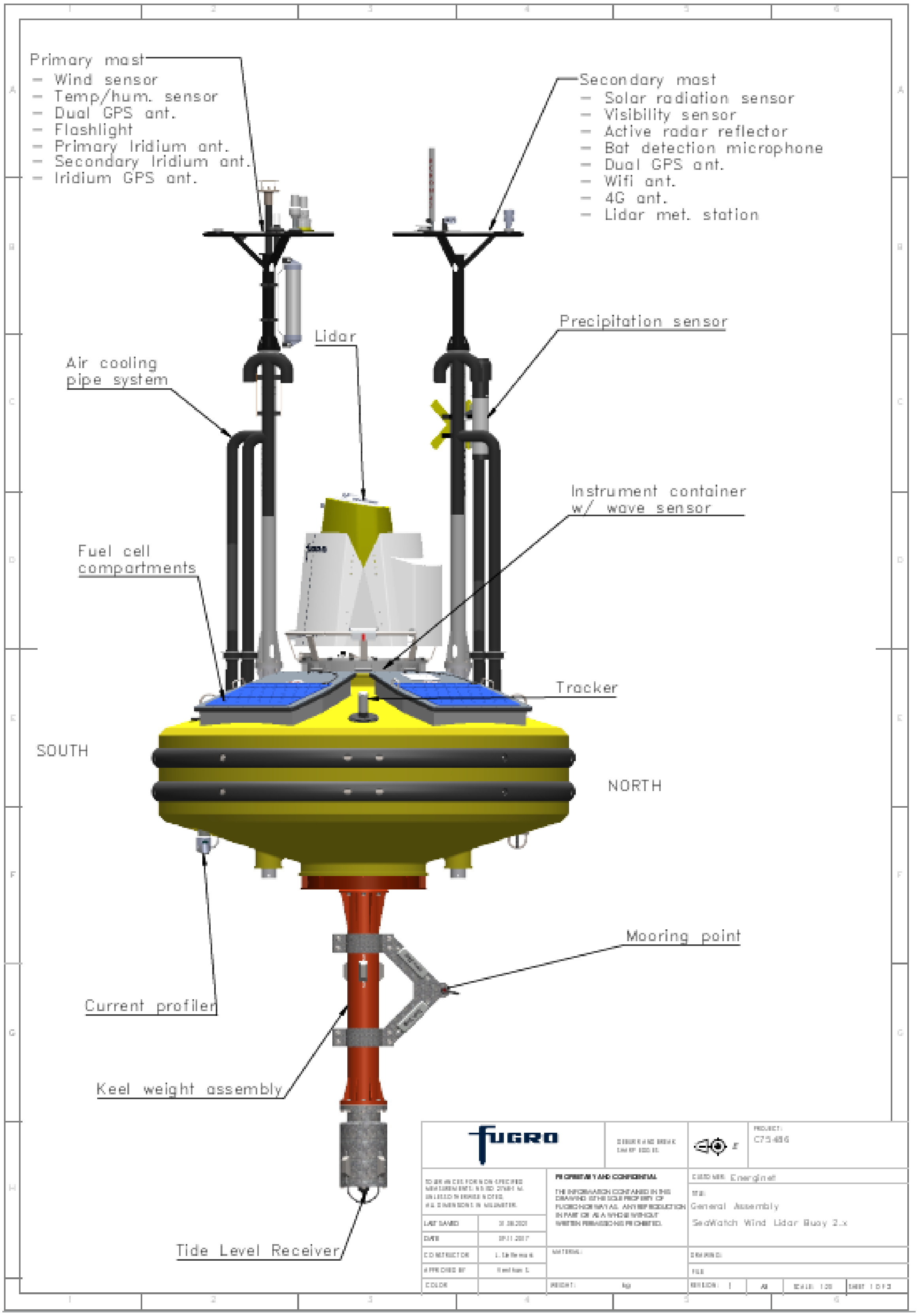

Figure 2-1 SWLB Mounting arrangement (air cooling)

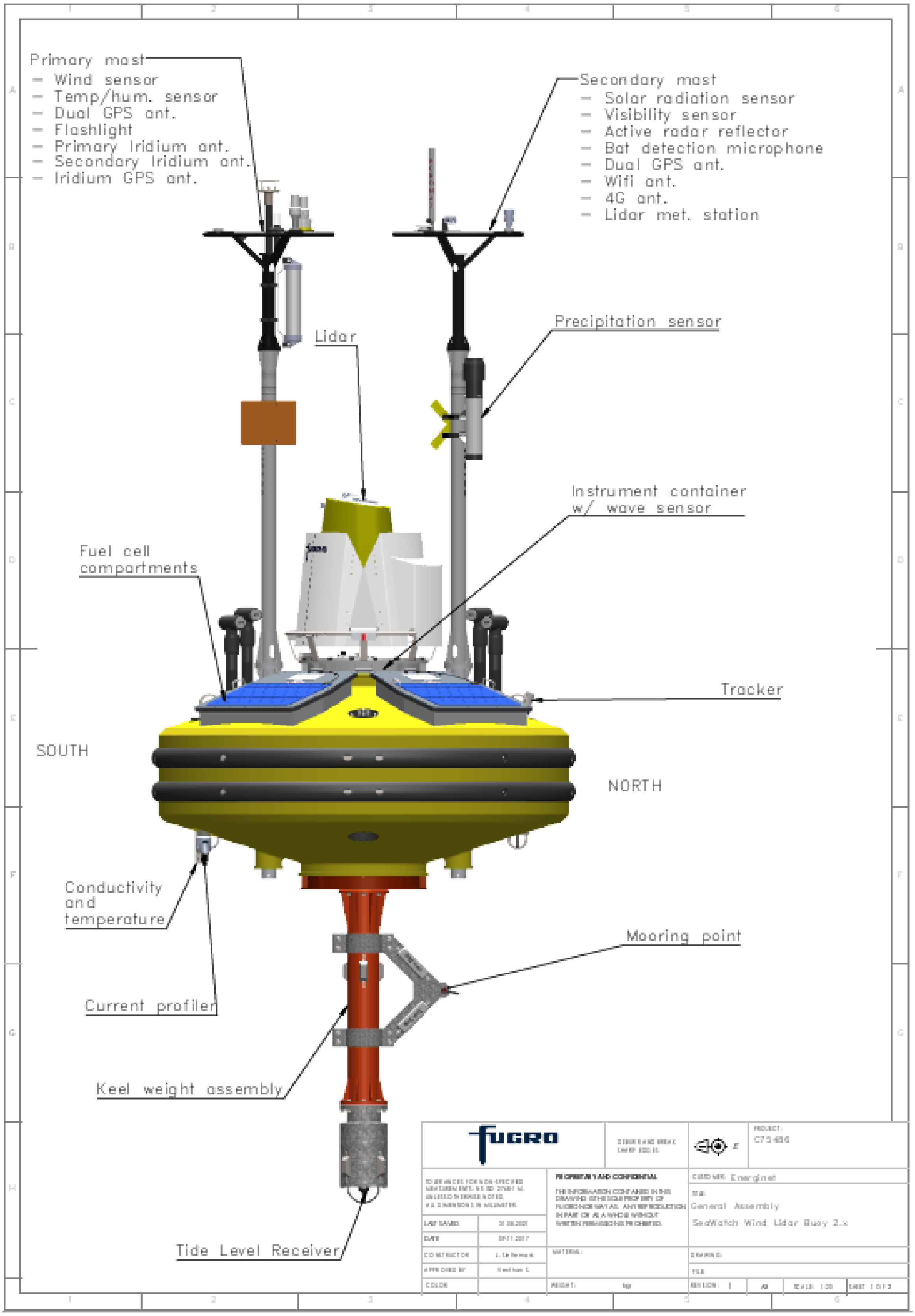

Figure 2-2 SWLB Mounting arrangement (water cooling)

Table 2-1 Configuration of the SM 4BAT FS recorder

Parameter	Unit	Setting
SD cards (slots 1 & 2)	GB	512
Mic 0	-	SMM-U2
Trig Ratio	%	10
Gain	dB	12
16kHz high filter	-	off
Sample rate	kHz	256
Min duration	mxs	1.5
Max duration	-	None
Min trig frequency	kHz	16
Trigger level	dB	6
Trigger window	s	3.0
Max length	(mm:ss)	00:15
Compression	-	W4V-8
Record	-	always

Table 2-2 Configuration of the wave and wind sensors

Instrument Type	Sensor Height [m]	Parameter Measured	Sample Height[1] [m]	Sampling Interval [s]	Averaging Period [s]	Burst Interval [s] [2]	Measurement Resolution
Wavesense 3	0	Heave, pitch, roll, heading	0	0.5	Time series duration: 1024 s	1024	0.1m, 0.2°, 0.2° 0.5°
		Sea state parameters[3]	0	600	1024	1024	0.1m, 0.2°, 0.1s
Gill Windsonic M	4.1	Wind speed and direction	4.1	1	600	600	0.01m/s 1°

Notes

[1] = Height relative to actual sea surface.

[2] = A burst of measurements is the raw data time series used to calculate the average parameters. The burst interval is the time from the beginning of one burst to the beginning of the next burst, and equal to the interval between writing of raw data to disk and transmissions.

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Table 2-3 Data files - Sound recordings

Lot and buoy	Deployment subdirectory
Energinet_Lot1_WS170_D1_A	No subfolder
Lot1_WS191	D1_Lot1_D02_May2022_Dec2022
Lot1_WS191	D2_Lot1_D03_Dec2022_Apr2023
Lot1_WS170	D2_Lot1_D04_Apr2023_Jun2023

2.2 Post processing

The general data flow, post-processing and quality control applied to the buoy data before they are delivered to the client is described in the measurement plan [1].

This chapter outlines the analysis of the bat recordings using the Wildlife Acoustics Kaleidoscope Pro software with the automatic identification algorithm enabled.

According to the Kaleidoscope Pro Manual [2], Auto-ID for Bats is an automated batch process analysis where the input files are separated into segments according to any split to max duration setting. Then full-spectrum files are converted to zero-crossing format. By default, full-spectrum to zero-crossing format conversion is enhanced with advanced signal processing. Files are then analysed for the presence of bat calls. Initial analysis is based on the signal parameter settings summarized in **Table 2-4**. Files which do not meet the described signal parameters are designated as Noise files. Input file segments which meet the signal parameter settings are passed to the Auto-ID function [2].

Table 2-4 Signal parameters

Parameter	Unit	Setting
Minimum frequency	kHz	8
Maximum frequency	kHz	120
Minimum pulse length	ms	2
Maximum pulse length	ms	500
Maximum inter-syllable gap	ms	500
Minimum number of pulses	int	2
CF noise filter maximum frequency	kHz	0
CF noise filter maximum bandwidth	kHz	0

For each set of sound recordings per buoy, deployment and SD card, the Auto-ID option was enabled with the classifier library set to "*Germany*" (Bats_of_Europe_5.4.0). The classifier library contains multiple individual Species Classifiers which are used to comparing recordings of bat calls to a known Species Classifier.

Statistical analysis is then performed on the detected bat calls. Statistical information includes the number of detected calls and average call characteristics. Identified bat calls are compared to enabled Species Classifiers within a classifier library. If a detected call in the file matches any reference call in the enabled Species Classifiers, the individual call is identified with a species type. If a detected call does not match calls in any enabled Species Classifier, the call is labelled No ID. Sequences of identified pulses are analysed to create a file-level AUTO-ID designation. If multiple species are detected within a single file, Alternate IDs are created [2].

Table 2-5 summarizes the content of the output files of the AUTO-ID analysis mode.

Table 2-5 Output files of the Auto-ID process

Output file	Description
settings.ini	This file is a snapshot of every setting in Kaleidoscope Pro at the time of the Auto-ID for Bats batch process. The settings.ini file is additionally useful because it provides a record of any custom Button Labels in the Viewer
idsummary.csv	This file provides a summary of which species were detected in the analysis. The total number of files labelled with an Auto-ID tag are listed for each species. Likelihood of presence probability is provided for each Species Classifier which was enabled in the batch process.
id.csv	This file contains the analysis results for each file or file segment in the input batch. The id.csv file contains extensive statistical information regarding the content of the input files. The main output parameters are: - AUTO-ID - This field shows the file-level automatic species identification. - PULSES - This is the number of total pulses detected in the file or file segment. The number of pulses is based on usable detections. - MATCHING - The number of detected pulses which match the AUTO-ID. - MATCH RATIO - The ratio of MATCHING over PULSES.
meta.csv	The meta.csv file contains a record of the input files used in the batch process.
db-batch.wdb	This file contains a record of the cluster analysis batch process in the form a file which can be uploaded to a database.
log.txt	Log file

For each deployment, the id.csv files were used to create time series of pulses and match ratio were plotted.

The AUTO-ID results were summarized in tabular form.

For comparison, significant wave height (hm0), mean wave direction (mdir), and wind speed and direction from the Gill Windsonic M acoustic wind sensor at 4 m height are also presented in **Section 0**.

Only very few spot checks (< 10) of the sound recordings versus the AUTO-ID results were done to gain an indication whether the detections are trustworthy or are dominated by false positives. **Section 4** summarizes caveats to be considered when using the results of the automatic analysis.

3. Presentation of the Auto-ID results

During deployment 1, the recordings cover the period from November 2021 until May 2022. Most pulses were found in December 2021. **Table 3-1** summarizes the number of Auto ID detections. **Figure 3-1** shows timeseries of pulses, matches and match ratio during the period from November 2021 until May 2022.

Table 3-1 Lot 1 D01 WS170 Auto ID summary Nov 2021 – May 2022

Auto ID	Species	Number of detections	Timeframe detected
PIPNAT	*Nathusius's pipistrelle*	1336	Nov and Dec 2021
PIPKUH	*Pipistrellus kuhlii*	45	Nov and Dec 2021
RHIHIP	*Rhinolophus hipposideros*	11	Dec 2021
PIPPIP	*Pipistrellus pipistrellus*	10	May 2022
TADTEN**	*Tadarida teniotis*	4	Dec 2021
PIPPYG	*Pipistrellus pygmaeus*	1	Dec 2021
MYONAT	*Myotis nattereri*	1	Dec 2021
** This is likely a false identification since this species is generally distributed from the Canary Islands and Madeira through the whole Mediterranean area.			

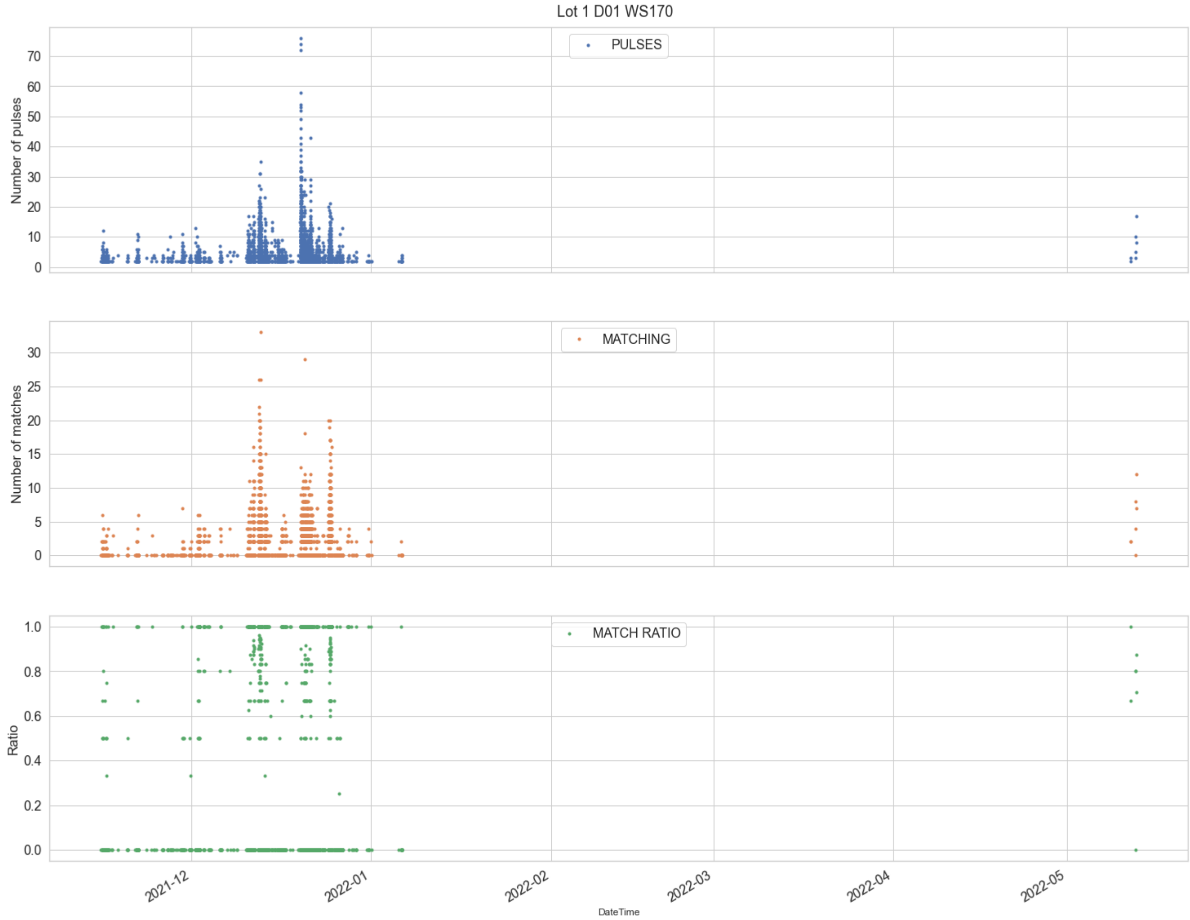

Figure 3-1 Pulses, matches and match ratio during the period from November 2021 until May 2022

During deployment 2, most sound recordings were taken when the buoy was on land. After deployment, the recordings only cover part of May and June 2022. Some matches were found in May 2022 with the main ID assigned as PIPNAT (**Table 3-2**). **Figure 3-2** shows timeseries of pulses, matches and match ratio in May 2022.

Table 3-2 Lot 1 D02 WS191 Auto ID matches in May 2022

Date	Pulses	Matching	Match ratio	AUTO ID	Species	Alternate ID	File
30.05.2022 23:23:44	3	3	1	PIPNAT	*Nathusius's pipistrelle*	PIPKUH	S4U11183_20220530_232344.w4v
30.05.2022 23:40:45	2	2	1	PIPNAT	*Nathusius's pipistrelle*	PIPKUH	S4U11183_20220530_234045.w4v
31.05.2022 16:12:57	2	2	1	PIPNAT	*Nathusius's pipistrelle*	PIPKUH	S4U11183_20220531_161257.w4v

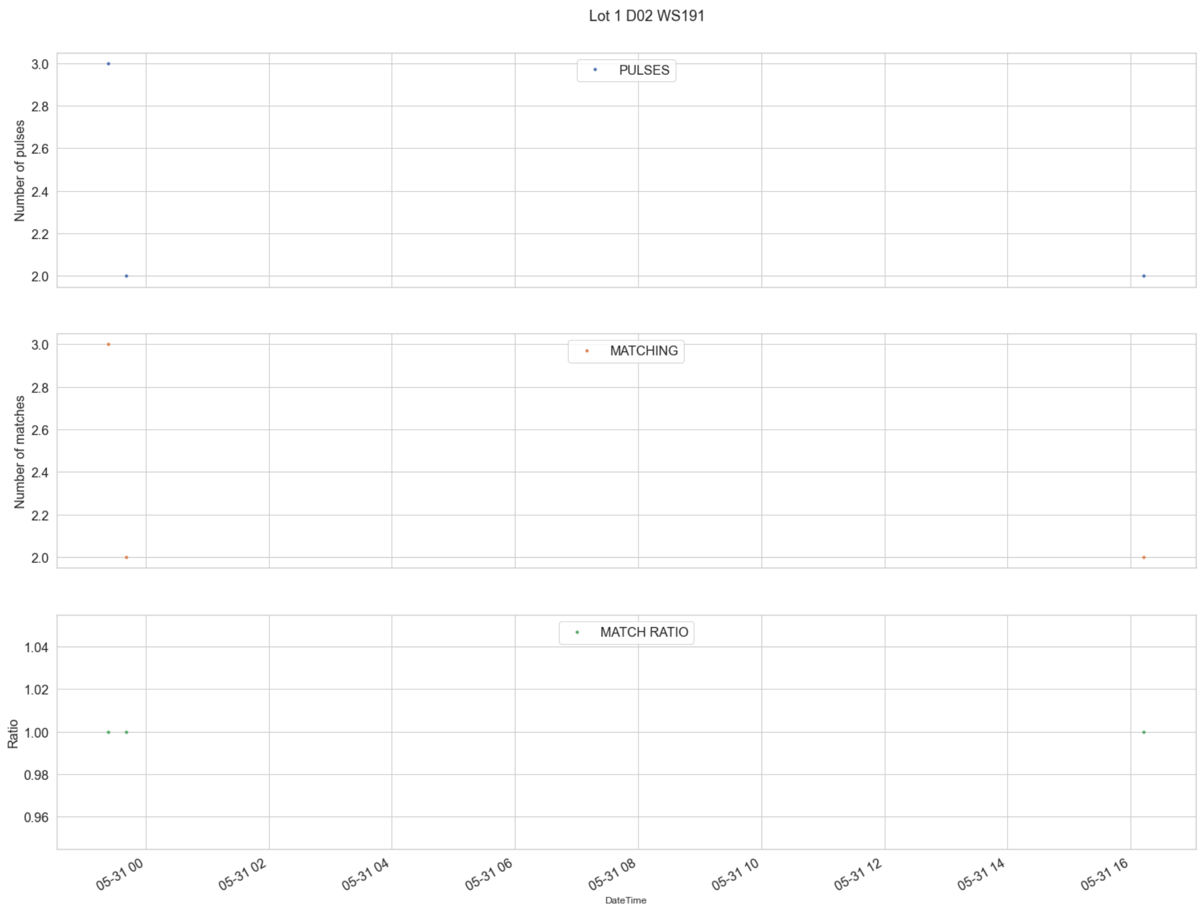

Figure 3-2 Pulses, matches and match ratio during deployment D02, WS191, in May 2022.

There were no valid pulses detected in deployment 3 (WS191, Dec 2022 – Apr 2023).

There were no valid pulses detected in deployment 4 (WS170, Apr 2023 – Jun 2023).

4. Discussion

4.1 Comparison with sea state

During deployment 1, most pulses were found in December 2021 and a separate set of pulses was found in May 2022. During November and December 2021, the buoys experienced winter storm conditions (**Figure 4-1**). Wind speeds measured at 4 m mast height exceeded 15 m/s and wave heights reached 6 m. Motion of both the buoy and the masts was high. Since the microphone was mounted on top of the secondary mast, it must be considered that the recordings are influenced by noise from wind and waves during this time. In addition, the recordings could also be dominated by bird sounds.

The separate set of detected pulses in May 2022, appears more likely to be bat passes, with PIPPIP as the main species identifier. The sea state and wind conditions were much calmer and less wind and wave noise is expected.

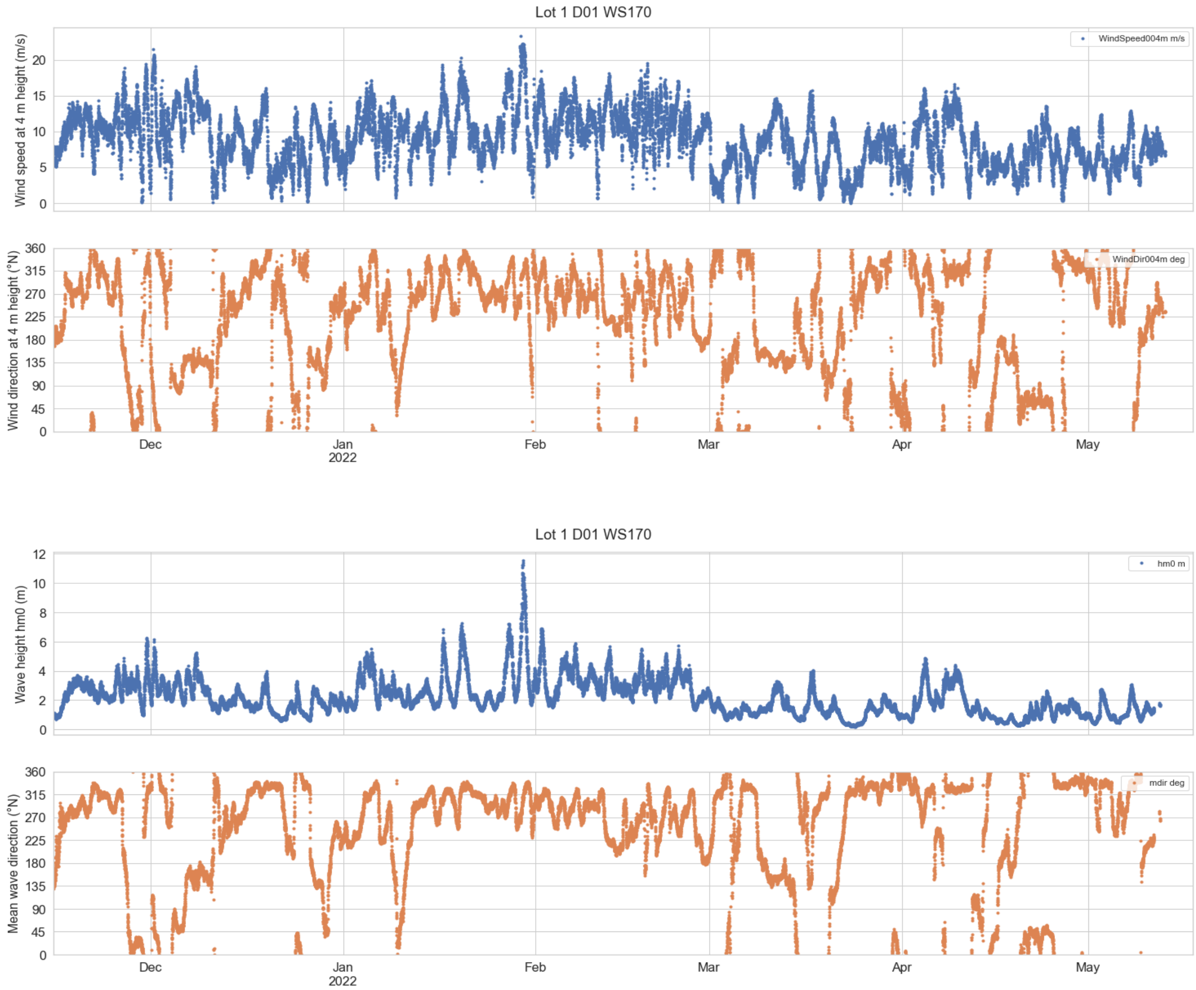

Figure 4-1 Wind speed and direction at 4 m height (top) and significant wave height and wave direction (bottom) from November 2021 until May 2022.

During deployment 2, some matches were found in May 2022 with the main ID assigned as PIPNAT. During this time, sea state and wind conditions were calm (**Figure 4-2**) and less wind and wave noise is expected.

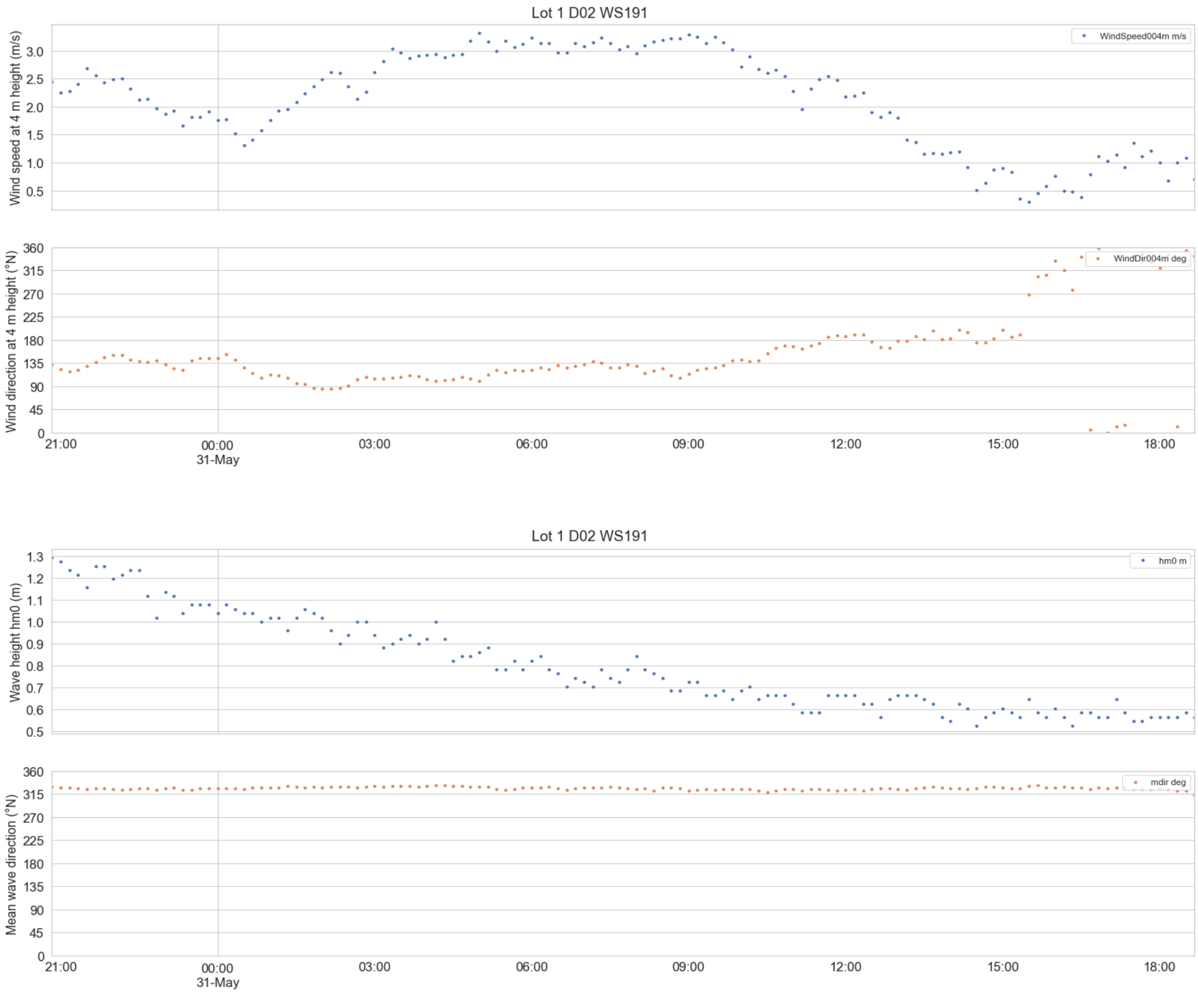

Figure 4-2 Wind speed and direction at 4 m height (top) and significant wave height and wave direction in May 2022.

Only very few spot checks (< 10) of the sound recordings versus the AUTO-ID results were done. A check of a recording from December 2021 indicates a continuous repeating signal pattern which seems connected to machine-generated sound. In addition, there are faint larger patterns, which could be related to wind, waves or birds.

A spot check of a recording in May 2022 revealed a sound pattern that was likely correctly identified as *Nathusius's pipistrelle* (PIPNAT).

4.2 Limitations in the applied methodology

There are a number of caveats that should be considered when using this dataset.

1. Placement of the microphone and recorder:
    a. The microphone was mounted on top the secondary mast at 4 m height. The masts are somewhat flexible and can move with the wind. The buoy itself moves with the waves and the masts move with the buoy. During periods of high sea states, especially in the winter months but also at other times, both high motion of the buoy and high winds and waves can act as several sources of noise.
    b. There is a possibility that additional noise from the air-intake pipes on WS170 could distort the recordings.
    c. There is a possibility that noise from the buoy's power supply system or sounds from other sensors could distort the recorded signals or introduce repetitive sound patterns.
    d. The recorder was mounted inside the buoy's cylinder where it was kept waterproof. However, this location is difficult to access. The instrument was thus left on to record at all times which used up disk space.
2. Measurement configuration:
    a. The instrument was configured to detect all sounds at all times with only the default cut-offs activated. The scheduling option was not activated and thus the recordings were not targeted to exclude background noise and winter storms.
    b. The instrument was configured with the default frequency cut-offs.
3. Automatic processing and species identification:
    a. The signal processing was run with the default parameters and frequency cut-offs.
    b. There is a possibility that the recordings could include bird sounds that distort the shape of the bat calls and could lead to misidentifications.
    c. Bats use echolocation for navigation and hunting, they adapt their calls in real time to respond to their situation. Individual species of bats can display extremely variable repertoires of call types [2] which may not all be captured in the species classifier library.
    d. Classifiers are generally built using recordings of individual bats in free flight, in low clutter environments. Background noise (e.g. wind, waves, buoy's power supply system) can obscure the call shape and influence the automatic ID accuracy [2].
    e. A thorough analysis of all single sound recordings was not done.

5. Conclusion

Background noise, clutter or echo can obscure the bat calls. Thus, it should be expected that there will be false positive and false negative identifications [2].

The detections in November and December 2021 appear to be influenced by wind and wave noise, noise from any of the other systems on the buoys, or bird sounds and are likely false positives. During periods of high sea states, especially in the winter months, both high motion of the buoy and high winds and waves can act as several sources of noise which the automatic algorithm falsely interprets as matches.

The detections in May 2022 are more likely to be actual bat call identifications. During this time, sea state and wind conditions were calm and less wind and wave noise is expected in the sound recordings. .

However, these results should be verified by doing a thorough analysis of the respective sound recordings.

6. References

[1] Fugro, "SWLB measurements at Energy Islands Project Measurement Plan, All Lots," Fugro, 2022.

[2] Wildlife Acoustics, Inc., "Kaleidoscope Use Guide," 12/16/2022.