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Hesselø South

Site Wind Conditions Assessment

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Hesselø South, Site Wind Conditions Assessment

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LIABILITIES

According to contract.

Executive Summary

Objective

The objective of this technical report is to present the findings of the Site Wind Conditions Assessment conducted by EMD International A/S for Energinet in relation to the Hesselø South offshore wind farm project in the Kattegat Sea.

Background

The Danish Energy Agency has tasked Energinet with undertaking site wind conditions assessments for the development of five Offshore Wind Farm (OWF) areas within the Danish Exclusive Economic Zone. The site wind conditions assessments are a part of the technical basis for future public tenders on the development of the projects. The OWF areas are divided into three lots, respectively in the Kattegat, Baltic and North Sea. In the Kattegat Sea, two OWF projects are considered, Hesselø South and Kattegat, the former being the subject of this report.

Methodology

The site wind condition assessment is based on 12 months of onsite measurements using floating LiDAR systems (FLS) in the Kattegat OWF areas and delivers the site wind condition parameters according to IEC 61400-1 [1], IEC 61400-3-1 [2] and in addition refers to Eurocode EN1991-1-4 [3] including the Danish annex [4], DS 472 ed.2 [5] and IEC 61400-15-1 [6].

The site wind conditions assessment is intended to serve as basis for:

- Preliminary site-suitability analysis of the Wind Turbine Generator (WTG) and Rotor Nacelle Assembly (RNA)
- Front-End Engineering and Design (FEED) of offshore support structures for WTGs and other structures.

The report includes a presentation and analysis of onsite data from two floating LiDAR buoys (SWLB059 and WS190) deployed on site as well as secondary measurements surrounding the site and sourced for this purpose. A wind model has been created for the site through long-term correction of 12 months of onsite LiDAR data with 22 years of EMD-WRF mesoscale data (labelled “Primary Wind Model”).

The Primary Wind Model has been backed up by three alternative models, based on data from the Kattegat floating LiDAR (KG-1-LB), Hesselø floating LiDAR (H1) and Læsø meteorological mast (M1). The three alternative models are in good agreement with the Primary Model on mean wind speed for the site, given the distance from the Hesselø South Wind Farm and the data quality.

Site condition parameters are supported by data from secondary sources.

Calculations are done in windPRO 4.1, developed by EMD International A/S.

Results

The site condition parameters are summarized in Table 1.

Table 1. Summary table of site wind condition parameters at the four selected positions for the Hesselø OWF area. All values refer to 150 m height above sea level (ASL).

Parameter	HS-1-LB	HS-A	HS-B	HS-C
Mean wind speed	9.66 m/s	9.73 m/s	9.65 m/s	9.72 m/s
Weibull distribution, A parameter (scale)	10.91 m/s	10.99 m/s	10.89 m/s	10.98 m/s
Weibull distribution, k parameter (shape)	2.23	2.24	2.23	2.23
Normal wind profile power law exponent	0.086	0.086	0.086	0.086
Turbulence intensity mean value (TI_μ) at a 10-min average wind speed of 15m/s*	4.9%	4.9%	4.9%	4.9%
Turbulence intensity standard deviation (TI_σ) at a 10-min average wind speed of 15m/s*	2.0%	2.0%	2.0%	2.0%
Turbulence intensity 90% quantile at a 10-min average wind speed of 15m/s*	7.5%	7.5%	7.5%	7.5%
Mean air density	1.23 kg/m^3	1.23 kg/m^3	1.23 kg/m^3	1.23 kg/m^3
Mean air temperature	9.0°C	9.0°C	9.0°C	9.0°C
50-year extreme wind speed	40.1 m/s	40.1 m/s	40.1 m/s	40.1 m/s
1-year extreme wind speed	31.5 m/s	31.5 m/s	31.5 m/s	31.5 m/s
Wind shear for extreme wind speed extrapolation	0.13	0.13	0.13	0.13
Characteristic turbulence intensity at 50-year extreme wind speed	12.0%	12.0%	12.0%	12.0%
Air density for extreme wind	1.25 kg/m3	1.25 kg/m3	1.25 kg/m3	1.25 kg/m3
Lightning	1.18 flash/year/km^2	1.18 flash/year/km^2	1.18 flash/year/km^2	1.18 flash/year/km^2
Solar radiation, mean	121 W/m^2	121 W/m^2	121 W/m^2	121 W/m^2
Solar radiation, peak	880 W/m^2	880 W/m^2	880 W/m^2	880 W/m^2
Relative Humidity, mean	82.8%	82.8%	82.8%	82.8%

*Turbulence values at other wind speeds can be found in Appendix F

The datasets produced by this study are available in a data package prepared for Energinet.

Climate change effects on the wind conditions assessed above has been investigated. From this investigation it appears that wind speed is likely unaffected, the models are inconclusive concerning extreme wind speed while there is clear indication of an up to 2˚C increase in temperature for the medium term (2041-2060), resulting in an 0.7% decrease in air density. An increase in precipitation is expected for both near and medium term.

Recommendations

EMD recommends supporting the turbulence assessment with additional local turbulence measurements from suitable sources, preferably cup anemometer measurements, in the Kattegat Sea.

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1 Introduction

EMD International A/S has been tasked by Energinet to provide a site wind condition assessment for the Hesselø South offshore wind farm.

The objectives of the site wind condition assessment are outlined in the Scope of Services Site Wind Conditions Assessment [7] provided by Energinet and aims for a site wind condition assessment adequate for a preliminary site-suitability analysis for the Wind Turbine Generator (WTG) and Rotor Nacelle Assembly as well as input for Front-End Engineering and Design (FEED) of offshore support structures for WTGs and other structures.

The parameters for the wind condition assessment are listed in Table 2 and are defined according to IEC61400-1 [1], IEC 61400-3-1 [2] and IEC 61400-15-1 [6].

Table 2. List of Site Wind Conditions Parameters.

SITE WIND PARAMETERS AT 150 M MSL	
Normal Conditions Parameters	**Extreme Conditions Parameters**
Mean wind speed	Maximum 10-minute mean wind speed for a 50-year (Extreme Wind Model)
Omni-directional Weibull wind speed distribution parameters	/
Wind profile for wind speed extrapolation with elevation	Wind shear for extreme wind speed extrapolation with elevation
Wind profile for Integrated Load Analysis, Normal Wind Profile (NWP)	Wind profile for integrated load analysis
Normal Turbulence Model (NTM)	Extreme Turbulence Model (ETM)
/	Turbulence intensity at extreme wind speed
Mean air density	Mean air density
Mean air temperature	/
Salinity	/
Solar radiation	/
Earthquake	/
Relative humidity	/

The site wind condition parameter list is populated through a wind condition and resource assessment based on onsite floating LiDAR data from one location and mesoscale WRF data. This model is supported by a selection of secondary stations located within meaningful distance to the Hesselø South wind farm zone.

Beside the present report, measurement data as well as mesoscale WRF and long-term corrected datasets are provided in the form of time series text files.

All elevations throughout are referred to as Above Sea Level (ASL) with the reference sea level being the mean sea level.

A naming convention is used for turbulence conditioned on wind speed where 'mean turbulence' is the mean of 10 min wind speed standard deviations (σ) within a wind speed bin. The 'standard deviation of turbulence' is the standard deviation across 10 min wind speed standard deviations ($\sigma\sigma$) in a wind speed bin. Both these quantities (mean and standard deviation of turbulence) may be normalized to the wind speed of the wind speed bin in question, in this case the normalized turbulence is referred to as Turbulence Intensity (TI), either mean or standard deviation.

2 Site Description

Hesselø South project area is located 40 km east of the Djursland peninsular, Denmark, protruding into Kattegat Sea and 33 km north of the Island of Zealand (Figure 1).

The Hesselø South OWF area is defined through a shape file provided by Energinet.

Closest distance to land from the OWF area is 33 km to the southeast (Zealand), although the small island of Hesselø is merely 13 km south of the OWF area.

The neighbouring wind farm, Anholt, is located adjacent to the Northen part of the neighbouring Kattegat OWF project and 26 km from the Hesselø South OWF area. Additional wind farms are planned in this part of the Kattegat Sea, such as the Kattegat OWF, planned about 15 km to the west.

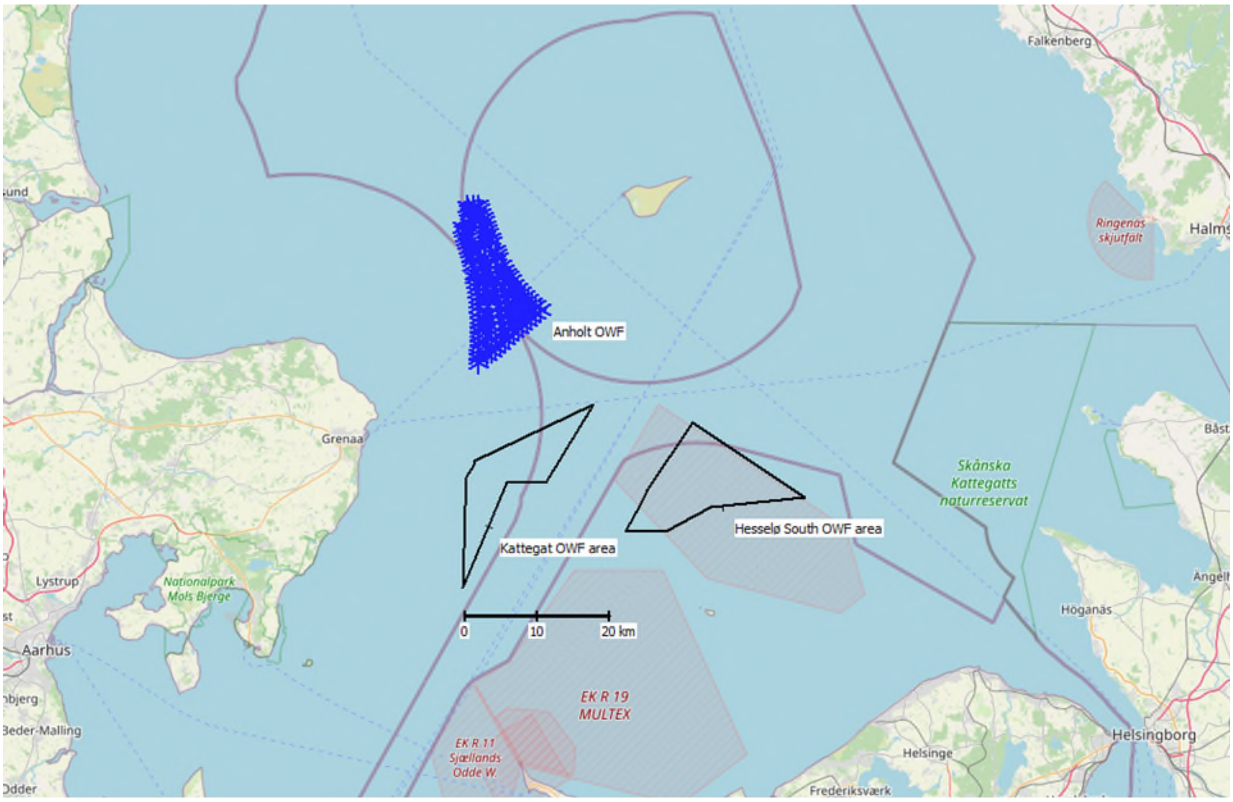


Figure 1. Regional map with location of the Hesselø South OWF area together with Kattegat OWF area and the existing Anholt OWF (in blue).

The wind farm zone is located in open water with sufficient distance to any shoreline (minimum 33 km). The effect of the shorelines on the wind speed gradient across the site will therefore be better represented by mesoscale effects. For this reason, no further terrain assessment has been conducted. The water depth within the OWF zone is between 18 m and 30 m.

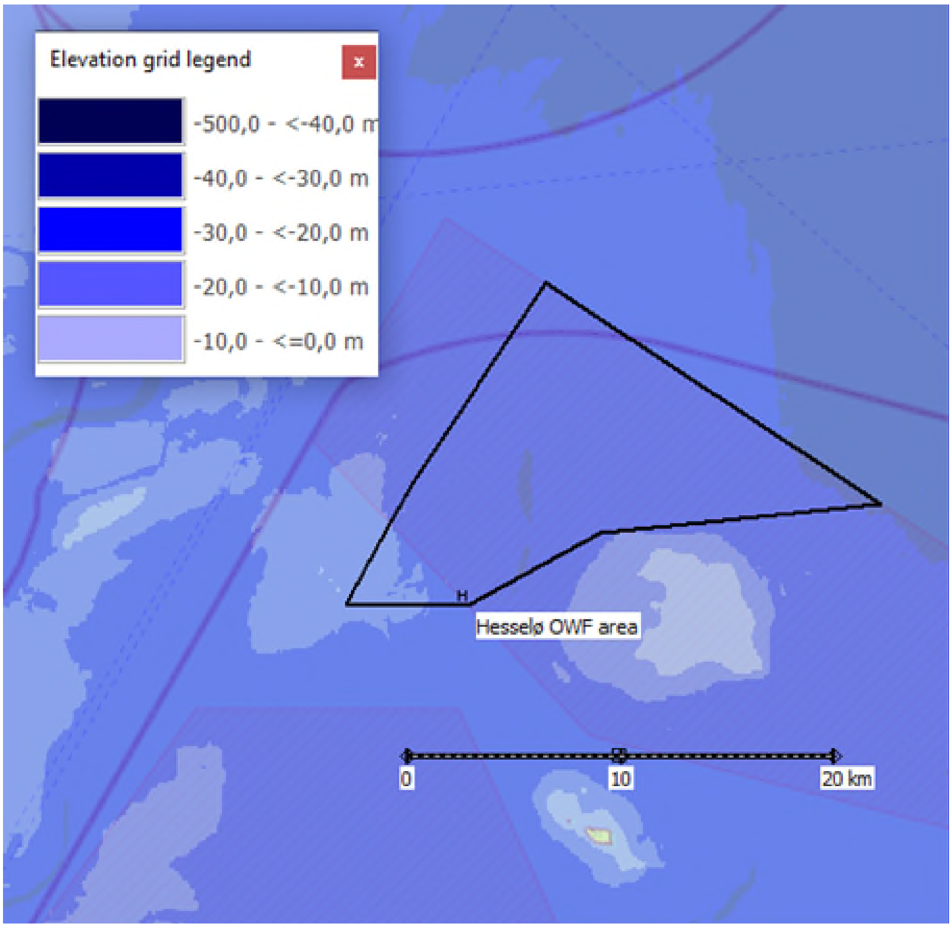


Figure 2. Bathymetric map of Hesselø South OWF zone (source: EMODnet – 115 m grid resolution)

3 Overview of Available Wind Data

A host of wind data measurements was considered for the wind condition and resource analysis. Each source is listed in Table 3 and Table 4 and considered in the following.

The onsite Floating LiDAR System (FLS), Hesselø South (HS-1-LB), commissioned by Energinet, is the primary source of information and is used for the primary wind model. The data are described in section 4.

For the validation of the primary wind model, data from Kattegat floating LiDAR (KG-1-LB), Hesselø floating LiDAR (H1), and Læsø met mast (M1) are used.

For the turbulence model, data from FINO2 and FINO3 offshore met masts are used.

Meteorological stations data from the Danish Meteorological Institute (DMI) [8] and the Swedish Meteorological and Hydrological Institute (SMHI) [9] are primarily used to verify the long-term variation in wind climate or the temperature profile for the site. Some of the stations included are done so with only limited contribution to the study as far as data quality permits.

A number of other meteorological stations were considered, but not used in this study as it was found that their data were of insufficient quality, not representative for the site or redundant.

Table 3 lists all the meteorological stations suggested by Energinet.

The measurement locations are plotted on a map in Figure 3.

All secondary data used in this study are presented in Appendix A.

Table 3.List of considered measurement stations, with measured heights and period. In bold are the used measurements stations.

NAME	TYPE	MEASUREMENT HEIGHT [M] ASL	MEASUREMENT PERIOD	LENGTH [YEARS]
Kattegat (KG-1-LB)	Floating LiDAR System	12 - 300	07/2023 – 07/2024	1
Hesselø South (HS-1-LB)	Floating LiDAR System	12 - 300	07/2023 – 07/2024	1
Hesselø (H1)	Floating LiDAR System	12 - 240	02/2021 - 02/2022	1
FINO2	Offshore Met-Mast	102.5	08/2008 - 08/2015	7
FINO3	Offshore Met-Mast	107, 101, 91, 81, 71, 61, 51, 41, 31	01/2010 - 12/2013	4
Læsø (M1)	Offshore Met-Mast	15, 30, 45, 58, 62	07/1999 - 07/2003	4
Anholt	Climate Met-Mast	10	05/2000 - 05/2024	24
Gniben	Climate Met-Mast	10	05/2003 - 05/2024	21
Nakkehoved Fyr	Climate Met-Mast	10	05/2001 - 05/2024	23
Hallands Väderö	Climate Met-Mast	2	01/1996 - 01/2024	28
Røsnæs Fyr	Climate Met-Mast	10	05/2002 - 05/2024	22
Sletterhage Fyr	Climate Met-Mast	10	05/2002 - 05/2024	22
Anholt OWF ANH	LiDAR System	Unknown	01/2013 - 01/2014	1
Anholt OWF	Unknown	Unknown	03/2010 - 05/2010	0.16
Anholt E	Unknown	Unknown	01/1983 -	-
Fladen Lighthouse	Climate Met-Mast	Unknown	01/1988 - 12/1999	11
Hamlstad Flygplats	Climate Met-Mast	Unknown	02/1945 -	-
L:A Middelgrund	Unknown	Unknown	01/1978 -	-
N14 Falkenberg	Unknown	Unknown	01/1996 -	-
P22	Unknown	Unknown	09/2021 - 03/2022	0.53
Ringhals	Climate Met-Mast	Unknown	01/1967 -	-
Stora Middelgrund	Unknown	Unknown	01/1978 -	-

Table 4. Coordinates and data provider of the considered measurement stations (geographic coordinates, datum WGS84).

NAME	LONGITUDE [° E]	LATITUDE [° N]	Z, A.S.L [m]	PROVIDER (CODE#)
Kattegat (KG-1-LB)	11.2010	56.3506	0	Energinet
Hesselø South (HS-1-LB)	11.7723	56.3340	0	Energinet
Hesselø (H1)	11.8351	56.4642	0	Energinet
FINO2	13.1542	55.0069	0	BHS
FINO3	7.1583	55.1950	0	BHS
Læsø (M1)	11.1232	57.0842	0	Energinet
Anholt Haven	11.5098	56.7169	1	DMI (#06079)
Gniben	11.2787	56.0083	14	DMI (#06169)
Nakkehoved Fyr	12.2580	56.1524	0	DMI (#06168)
Hallands Väderö	12.5453	56.4496	8	SMHI (#62260)
Røsnæs Fyr	10.8694	55.7435	1	DMI (#06159)
Sletterhage Fyr	10.5135	56.0955	2	DMI (#06073)
Anholt OWF ANH	11.1527	56.5957	25.6	Ørsted
Anholt OWF	11.1658	56.6925	0	Energinet
Anholt E	12.1167	56.6667	0	SMHI (#40009)
Fladen Lighthouse	11.8333	57.2167	0	SMHI (#35068)
Hamlstad Flygplats	12.8167	56.6863	21	SMHI (#62410)
L:A Middelgrund	11.7583	56.9583	0	SMHI (#40058)
N14 Falkenberg	12.2117	56.9400	0	SMHI (#40068)
P22	12.3360	56.2888	0	SMHI (#33037)
Ringhals	12.1125	57.2497	0	SMHI (#02105)
Stora Middelgrund	12.2167	56.5667	0	SMHI (#40087)

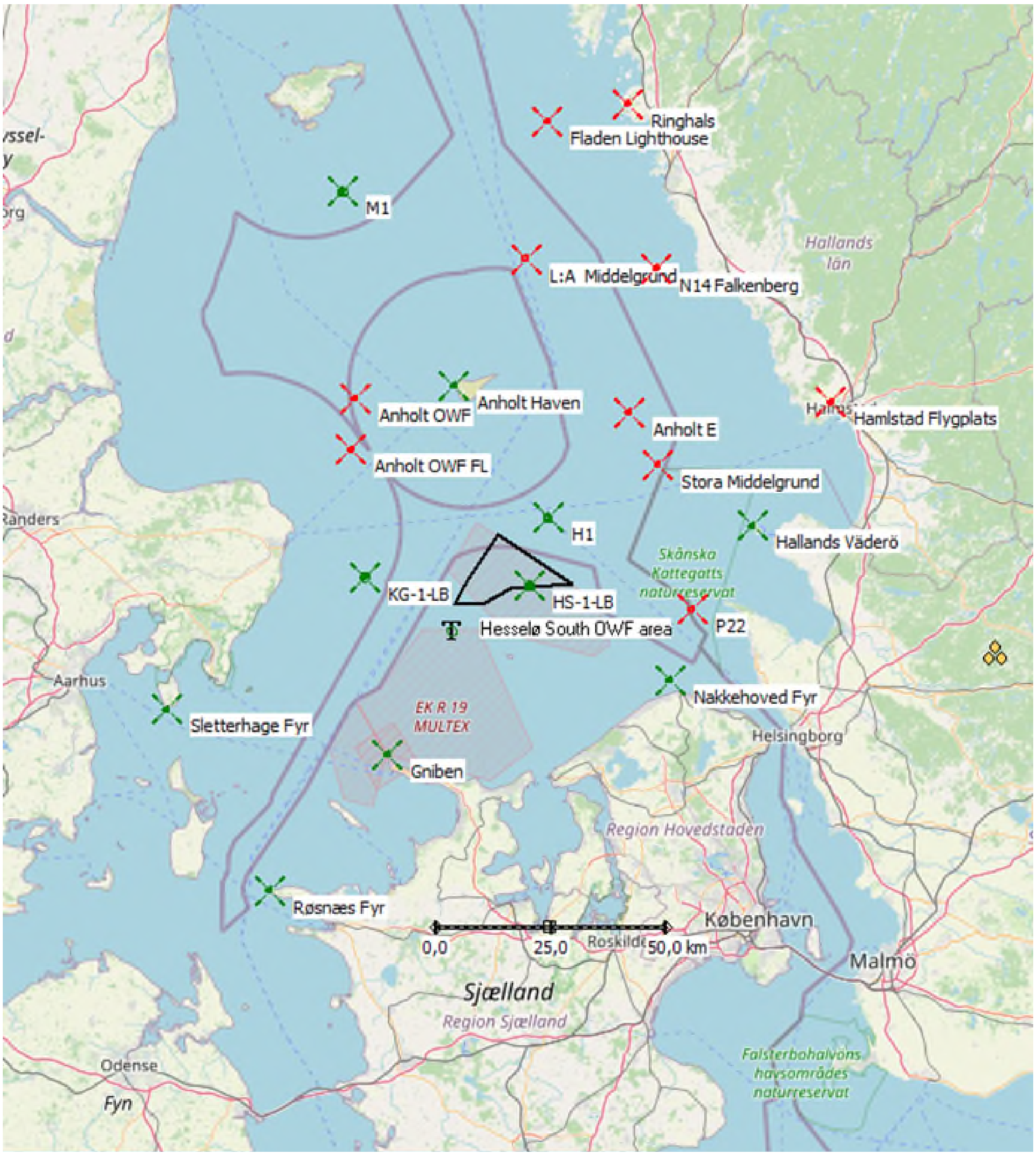


Figure 3. Location of considered measurement stations in Kattegat Sea, with used stations in green and discarded ones in red (black line: Hesselø South wind farm area).

Figure 4. Location of measurement stations finally used for siting parameters (black line: Hesselø South wind farm area).

4 On-Site Floating LiDAR Measurements

Energinet has commissioned floating LiDAR measurements on site, operated by Fugro Norway AS. The deployment location is labelled HS-1-LB. Two buoys have been in operation on this location: SWLB059 and WS190. The campaign commenced on 21/07/2023 and it ended on 04/08/2024.

EMD has received documentation as listed in Table 5.

EMD has received measurement data as monthly batches covering the period 21/07/2023 to 21/07/2024, hence covering consecutive 12 months.

No motion correction is applied. Averaging over 10 minutes is considered sufficient to remove motion effects on mean wind speed data. This was verified during pre-deployment verification. The detrimental effects of motion on the turbulence measurements remain.

EMD has received documentation and measurements beyond those mentioned here, but those are not used directly in this study.

Table 5. List of documentation received on the Floating LiDAR Systems (FLS).

TITLE	SOURCE	DATE	CONTENT	REFERENCE
SWLB measurements - Danish Offshore Wind 2030, Project Measurement Plan, All Lots	Fugro	25/11/2023	Project Measurement Plan	[10]
SWLB measurements at Danish Offshore Wind 2030 – Lot 1	Fugro	05/12/2023	Description of instrument deployment, data collection and processing.	[11]
Danish Offshore Wind 2030 – Floating LiDAR Measurements, Monthly report (11 instalments)	Fugro	19/01/2024 – 12/07/2024	11 monthly reports on operation and measurements. Reports available 21 July 2023 – 21 June 2024	[12]
Danish Offshore Wind 2030 – Floating LiDAR Measurements, Service Report, Kattegat and Hesselø South, (4 instalments)	Fugro	20/03/2024 – 30/04/2024	4 service reports describing preparation and deployment of the buoy and current profiler	[13]
ZX1277, Independent analysis and reporting of ZX LiDARs performance verification executed by Zephir Ltd. at the UK Remote Sensing Test Site	DNV	23/05/2023	LiDAR verification report for ZX1277, mounted on SWLB059	[14]
SWLB059, Independent performance verification of Seawatch Wind LiDAR Buoy at Frøya, Norway	DNV	13/07/2023	Pre-deployment verification document for SWLB059	[15]
ZX809, Independent analysis and reporting of ZX LiDARs performance verification executed by Zephir Ltd. at the UK Remote Sensing Test Site	DNV	22/10/2022	LiDAR verification report for ZX809, mounted on WS190	[16]
WS190, Independent performance verification of Seawatch Wind LiDAR Buoy at Frøya, Norway	DNV	15/08/2023	Pre-deployment verification document for WS190	[17]

4.1 Buoy Positions

The buoy deployment positions are reported by Fugro as listed in Table 6.

The buoys positions are recorded in the logged data series. EMD has plotted a section of these and can confirm that the drift of the buoys is within 100 m (Figure 5). For all practical purposes the buoys can be considered stationary.

On the 23/03/2024 the SWLB059 buoy was replaced by WS190 buoy. Figure 6 presents the logged positions after replacement and confirms that the general locations of measurement are unchanged.

Table 6. List of wind speed measurement locations.

STATION	UTM WGS84, Zone 32		GEOGRAPHICAL COORDINATES WGS84	
HS-1-LB	671,382	6,246,708	11.7723°	56.3340°

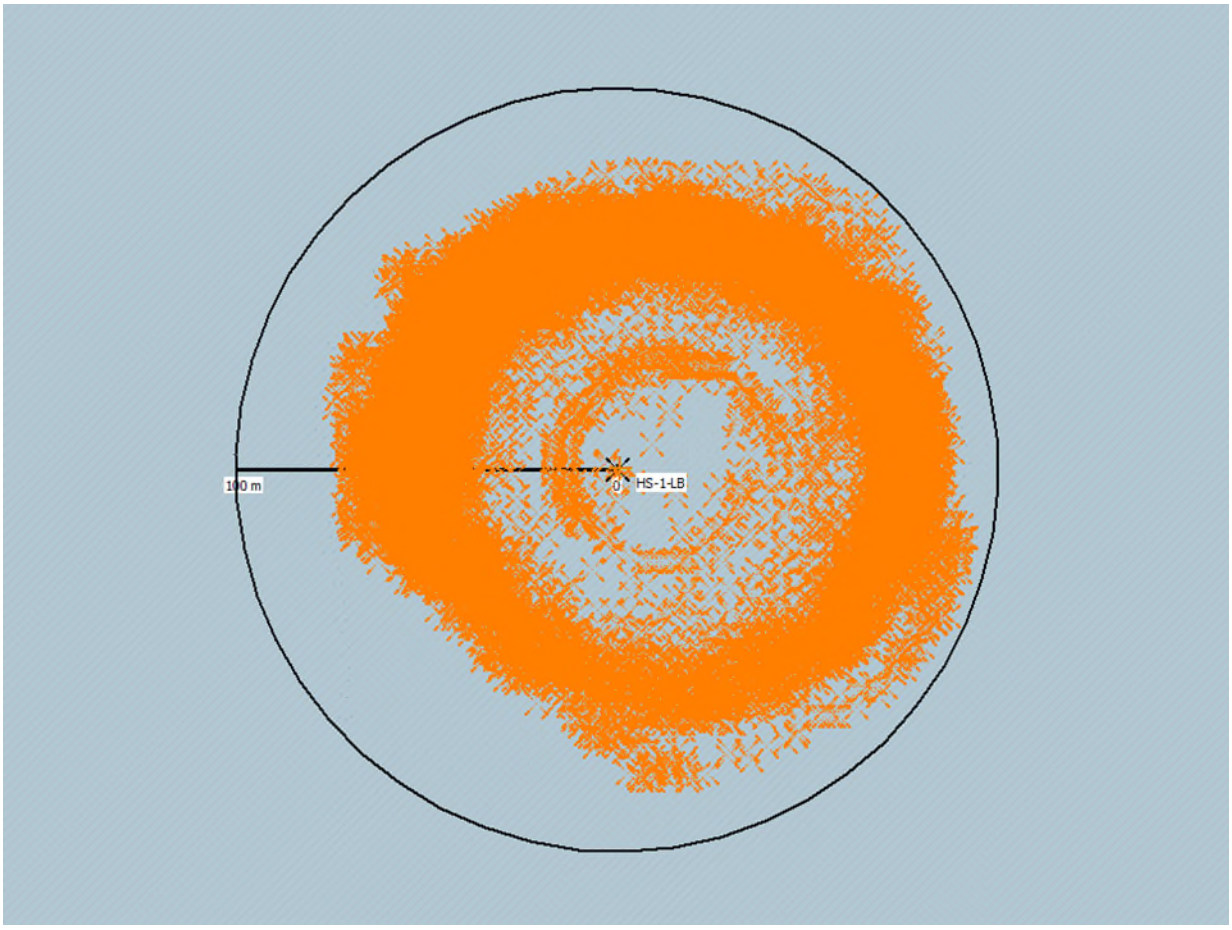


Figure 5. Position logs before recovering (23 March 2024) confirm a drift within 100 m (black circle) of stated location (black "X").

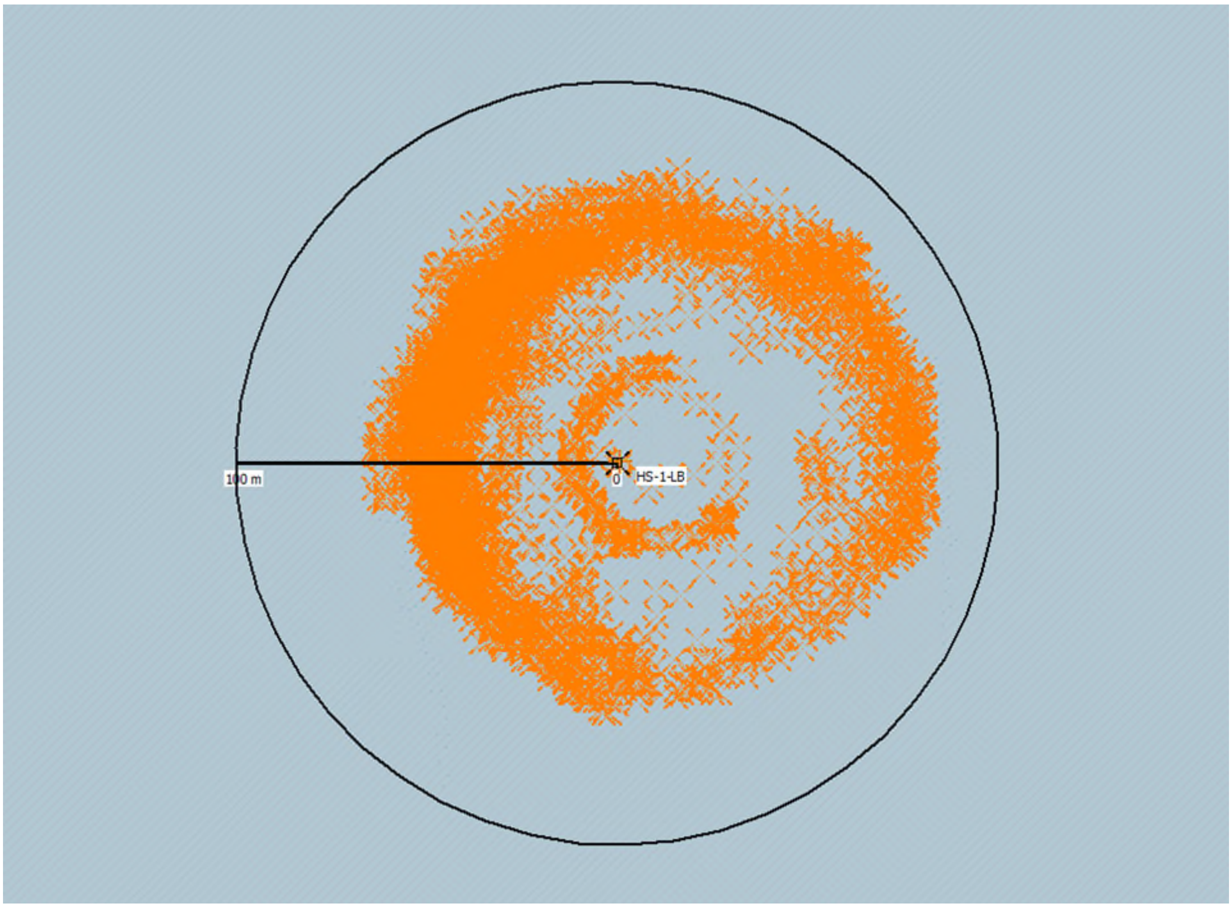


Figure 6. Position logs after redeployment (23 March 2024) confirm that the locations are unchanged (black "X").

4.2 Instrumentation

The SEAWATCH Wind LiDAR buoy (SWLB) and instrumentation is described in the measurement plan [11]. The instrumentation on the SWLB059 and WS190 is for all practical purposes identical. In the following, only instruments relevant for the analysis of the site wind conditions are described.

4.2.1 LiDAR

The LiDAR mounted on the buoy is a ZX300M LiDAR from ZX LiDAR Ltd. This LiDAR model is classified by DNV [18] and has reached Stage 3 maturity [19].

Both LiDARs (ZX1277 and ZX809) were verified at the Pershore, UK, an onshore test site operated by DNV-GL [14], [16].

Once mounted on the buoy, the LiDARs were verified again by DNV at Frøya Norway against a ground-mounted onshore LiDAR of the brand ZephIR ZX300 [15], [17].

The information from the classification and the verification is used to assess the measurement uncertainty of the LiDARs.

The LiDAR window is located at the top of the buoy and is as such elevated above sea level. This elevation difference is compensated for in the provided data files, so that the stated height is height above sea level, not height above buoy.

4.2.2 Wind Direction

The Fugro buoys are equipped with three different wind direction sensors:

- A magnetic compass that indicates the wind direction relative to magnetic north.
- The Differential GPS (DGPS) system that provides wind direction relative to true north.
- A wind direction signal from the LiDAR meteorological station.

The DGPS is the primary source for wind direction data. If the DGPS is unavailable, the magnetic compass is used as a backup. The LiDAR met station's signal serves as the third option for measuring wind direction. To ensure accuracy and resolve any potential 180-degree direction ambiguities, the data are compared with readings from the Gill WindSonic sensor. Consequently, the wind direction data from the buoys should be interpreted as relative to true north.

4.2.3 Additional Instrumentation

The Fugro buoys are equipped with additional meteorological instruments, including the Gill WindSonic ultrasonic package, a Vaisala PTB330A air pressure sensor, and a Vaisala HMP155 sensor for measuring air temperature and humidity. Details of these specifications are outlined in reference [10].

Air pressure readings are taken at actual sea level. Measurements of temperature, humidity, wind speed, and wind direction are conducted at a height of 4.1 meters above sea level. However, as they are not used for shear or wind model analysis, they are assigned a standard height of 4.0 m by EMD.

The air temperature data is used for the assessment of site temperature and air density.

4.3 Operation History

The measurement campaign started on 21/07/2023. Fugro has submitted event logs tracking faults and flaws of the buoys [12]. Of these, only two events have had impact on the LiDAR data:

- Since 24/02/2024, the lidar has intermittently been unavailable to measure wind data due to insufficient input power from an unhealthy fuel cell. This problem was resolved remotely on 02/03/2024 by adjusting the internal fuel cell process.
- On 23/03/2024 the SWLB059 was recovered and replaced by WS190.
- The buoy was decommissioned on 04/08/2024.

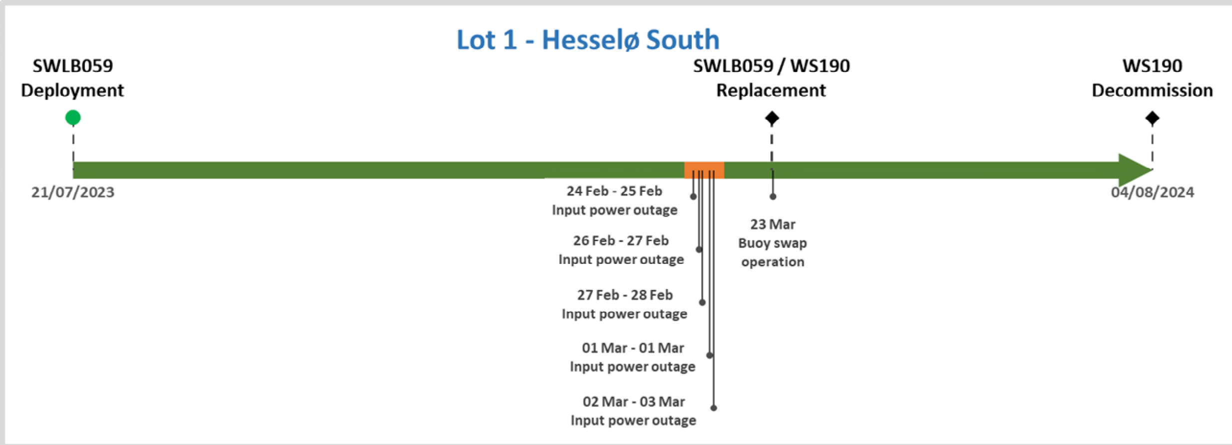


Figure 7. Timeline chart of buoy deployment on Hesselø South site (HS-1-LB). Buoy IDs (SWLB059 and WS190) are indicated, green color marks provided data, orange color marks data gaps.

4.4 Post-Processing of Data

4.4.1 Quality Control and Filtering Performed by Fugro

Fugro has provided some information on the post-processing of the LiDAR data [11]. ZX LiDARs typically equip their instruments with a standard data filter, known as industry filter, designed to ensure the acquisition of high-quality data by eliminating data points that have a low signal-to-noise ratio. Fugro has disabled the industry data filter on the LiDAR data and has implemented a simpler filtering algorithm [10]. The processing of the LiDAR data by Fugro involves the following steps:

- Removing values outside of those times where the system is deployed at the target position.
- Check that data was saved for all 10-min intervals. Out of the 36-37 data packages produced every 10 minutes, a minimum of 9 packages (25%) are required to qualify as a valid measurement.
- Check for duplicates measurements.
- Removing out of range values (e.g. speed below 0.001 m/s and above 58 m/s, wind direction above 360˚)
- Apply 180˚ ambiguity fix on LiDAR wind directions using Gill directions.

Beyond the 9-data-package filter already provided by Fugro, EMD has determined that increasing the threshold for the number of data packages does not enhance the quality of the data. Therefore, no additional filtering based on package count has been conducted.

The data from Fugro were organized into monthly files:

- Wind speed, wind direction and turbulence data were supplied in files named “HS-1-LB_Mxx_WindSpeedDirectionTI.csv”.
- The package counter information was supplied in files named “HS-1-LB_Mxx_WindStatus.csv”.
- Temperature, humidity and pressure data were supplied in files named “HS-1-LB_Mxx_MetOceanData.csv”.

It is understood that this filtering setup is identical to the one used during the verification procedure and that the verification is valid with these filter settings.

4.4.2 Quality Control and Filtering Performed by EMD

EMD has conducted a qualitative, manual filtering process by comparing the LiDAR data with several mesoscale-derived datasets (EMD-WRF and NORA3). Data points where wind speed and wind direction substantially differ from these datasets have been excluded. Although the industry-standard filter was disabled, which may have allowed some faulty data points to pass through Fugro's simpler filtering, EMD has found that the overall quality of the dataset is good, with only a few such discrepancies identified.

Typical anomalies identified in the dataset include instances of peak wind speeds at great heights (over 130 meters) that occur for very brief periods and are not consistent with the wind speed and shear observed at lower altitudes. These discrepancies were specifically targeted during the manual filtering process to ensure the reliability of the dataset (Figure 8).

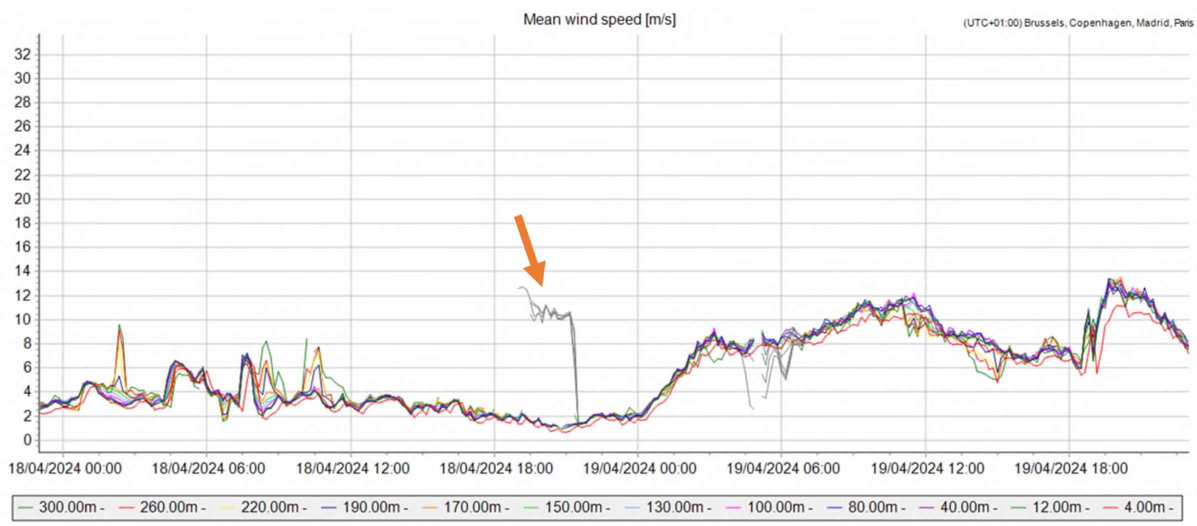


Figure 8. Example of short bursts of high wind speed at tall height disconnected from wind speed at lower height. Buoy WS190.

According to Fugro report [11], the primary sensor for wind direction is measuring relative to true north. EMD has compared the wind direction signal at 150 m height against a mesoscale derived dataset (EMD-WRF) and finds the average difference is 1.3˚ at equivalent heights. EMD therefore has applied a 1.3˚ offset on the wind direction data.

At very low wind speeds, some remnants of the 180-degree ambiguity in wind direction measurements persist. Given the high uncertainty of wind direction at these low speeds, EMD has decided not to make any corrections to these data.

A few cases were observed where wind speed at very tall heights (>200m) were lower than at medium heights (100-150m). In an isolated case, this would be considered erroneous, but the phenomenon was found at the same time on both the Kattegat (KG-1-LB) and the Hesselø South (HS-1-LB) LiDARs and it can therefore not be ruled out that it is natural and not instrument error. This could be linked to the phenomenon of low level jets.

4.4.3 Recovery Rate and Data Substitution

With the industry filter disabled, the data recovery rate for the LiDAR measurements is substantially higher than is sometimes seen with ZX LiDAR instruments. Notably, the data recovery rates decrease with increasing height above sea level (ASL), and these rates are detailed in Table 9. Additionally, a small data recovery loss is still experienced due to the applied filtering.

To address some of the data loss, data substitution procedures were implemented: one based on measured shear on the Hesselø South LiDAR (HS-1-LB), referred to as "shear repair" and another using data from Kattegat LiDAR (KG-1-LB), referred to as "horizontal repair". The shear repair procedure is prioritized over the horizontal repair due to its expected lower uncertainty.

The shear data substitution is based on a shear matrix created from the surrounding heights. Which heights are used to create the shear matrix for each repair are listed in Table 9. The shear matrix is applied to the source height, also listed in below tables, to produce a synthesized dataset. An example of a shear matrix is presented in Table 7.

The synthesized data fills in gaps and replaces disabled data for wind speed and wind direction in the recorded dataset. However, the Turbulence Intensity (TI) signal is not reconstructed; instead, it is simply copied from the data at a lower height.

The horizontal repair involves transferring data between the two LiDAR datasets (at KG-1-LB and HS-1-LB) at the same measurement heights using a sectorial linear regression function based solely on original data (data generated through the shear repair procedure are not used in these transfers). High correlation between datasets from the two buoy datasets increase confidence in the transferred data (Table 8). To prevent distortions due to thermal stability, data transfers occur only between the same heights.

For each data transfer, 360 transfer functions are created for each 1˚ direction bin, using data from a 30˚ sector window. The functions for wind speed are first-order, while those for direction are zero-order functions (constants). The process avoids residual resampling to prevent random scatter. Only wind speed and wind direction data are repaired, with turbulence intensity data missing in the repaired time steps.

Table 9 lists the results of each repair procedure. The 12 m and 40 m heights are repaired only using the horizontal repair procedure, and the outcome of those repairs are not included in the presented table.

Table 7. Example of shear matrix, here for 150 m height ASL at HS-1-LB. The values are the shear exponents α, which are calculated using data from three different heights: 130 m, 150 m and 170 m.

Hour	N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW
00-02	0.12	0.03	0.03	0.10	0.15	0.20	0.18	0.15	0.08	0.09	0.05	0.09
02-04	-0.02	0.03	-0.01	0.10	0.11	0.13	0.11	0.11	0.10	0.09	0.07	0.01
04-06	0.04	-0.07	-0.06	0.09	0.05	0.05	0.14	0.06	0.10	0.09	0.12	0.02
06-08	-0.01	-0.03	0.00	0.12	0.13	0.11	0.04	0.13	0.14	0.07	0.11	0.04
08-10	-0.02	0.00	0.00	0.06	0.04	0.18	0.08	0.12	0.06	0.07	0.02	0.06
10-12	0.00	-0.08	0.02	0.08	0.04	0.09	0.07	0.13	0.09	0.08	0.10	-0.01
12-14	0.11	0.14	0.06	0.13	0.10	0.16	0.07	0.12	0.10	0.12	-0.01	0.09
14-16	-0.02	0.23	-0.05	0.09	0.07	0.05	0.08	0.13	0.08	0.14	0.01	0.07
16-18	-0.03	-0.16	-0.10	0.09	0.08	0.05	0.08	0.15	0.11	0.15	0.13	0.01
18-20	0.02	-0.07	0.01	0.08	0.03	0.12	0.05	0.15	0.10	0.14	0.17	-0.01
20-22	-0.06	0.03	-0.05	0.13	0.08	0.11	0.17	0.17	0.11	0.07	0.09	0.05
22-24	-0.06	-0.02	-0.05	0.11	0.15	0.12	0.15	0.19	0.09	0.06	0.13	0.04
All	**0.00**	**-0.01**	**-0.03**	**0.10**	**0.09**	**0.11**	**0.11**	**0.14**	**0.09**	**0.10**	**0.07**	**0.04**

Table 8. Correlation coefficient, r, between HS-1-LB and KB-1-LB measurements at the equivalent height.

MEASUREMENT HEIGHT [m]	CORRELATION COEFFICIENT, r [%]
12	91.3
40	92.4
80	92.4
100	92.8
130	93.1
150	93.5
170	93.8
190	94.1
220	94.3
260	94.6
300	94.8

Table 9. Results of data repair at Hesselø South (HS-1-LB).

REPAIRED HEIGHT [m]	80	100	130	150	170	190	220	260	300
Source height [m]	40	80	100	130	150	170	190	220	260
Shear matrix heights [m]	40, 80, 100	80, 100, 130	100, 130, 150	130, 150, 170	150, 170, 190	170, 190, 220	190, 220, 260	220, 260, 300	220, 260, 300
Recovery rate before repair	97.1%	96.5%	96.1%	95.9%	95.8%	95.6%	95.4%	94.9%	94.8%
Recovery rate after shear repair	98.7%	97.2%	96.6%	96.2%	96.1%	95.9%	95.7%	95.5%	95.3%
Recovery rate after shear and horizontal repair	99.8%	99.1%	98.6%	98.4%	98.3%	98.2%	98.1%	98.0%	97.9%
Share of repaired data	2.7%	2.6%	2.5%	2.5%	2.5%	2.6%	2.8%	3.2%	3.2%

4.5 Data Analysis

EMD has combined the datafiles, forming time series of wind speed, wind direction, turbulence intensity and data package count for each measurement height. For 4 m height, temperature, relative humidity and pressure is added. The signals for maximum wind speed and vertical wind speed are only added to the 150 m height dataset.

4.5.1 Wind Speed

The mean wind speed on the LiDAR measurements is calculated both as arithmetic mean wind speed and as Weibull-derived mean wind speed through a Weibull fit. The Weibull fitting is done in windPRO using an energy conservation condition.

The following table summarizes the resulting wind speeds before and after data substitution.

Table 10. Weibull parameters of the repaired datasets at Hesselø South (HS-1-LB).

HEIGHT [m]	PERIODS [MONTHS]	BEFORE DATA SUBSTITUTION	AFTER DATA SUBSTITUTION			
		ARITHMETIC MEAN WIND SPEEDS [m/s]	ARITHMETIC MEAN WIND SPEEDS [m/s]	WEIBULL MEAN [m/s]	WEIBULL – A PARAMETER	WEIBULL – k PARAMETER
4	12	7.21	7.21	7.24	8.18	2.223
12	12	8.10	8.06	8.10	9.14	2.333
40	12	8.86	8.83	8.84	9.98	2.254
80	12	9.47	9.42	9.44	10.66	2.218
100	12	9.71	9.66	9.69	10.94	2.201
130	12	9.95	9.90	9.93	11.21	2.162
150	12	10.09	10.05	10.07	11.37	2.138
170	12	10.21	10.16	10.18	11.49	2.108
190	12	10.31	10.26	10.26	11.59	2.085
220	12	10.43	10.38	10.36	11.70	2.051
260	12	10.58	10.50	10.46	11.80	2.002
300	12	10.72	10.64	10.56	11.91	1.955

Further details on the directional wind speed and Weibull distribution can be found in Appendix C.

4.5.2 Turbulence Intensity

Standard deviation of wind speed and hence turbulence intensity from LiDAR measurements are not immediately comparable to those of cup anemomters. The standards reffered to in this study do not recognize turbulence intensity mesurements from LiDARs and the observed turbulence data from HS-1-LB are therefore not used or documented here. They are however included in the data package produced as part of the deliverables.

4.5.3 Wind Direction

The wind direction distribution for the 12 months of measurements is presented in Figure 9. There is a rotation of the wind direction clockwise with increasing height of 10.2 degrees from 40 m to 300 m, amounting to a rate of 0.039 degrees/m (Figure 10).

The direction distribution for each height can be found in Appendix C.

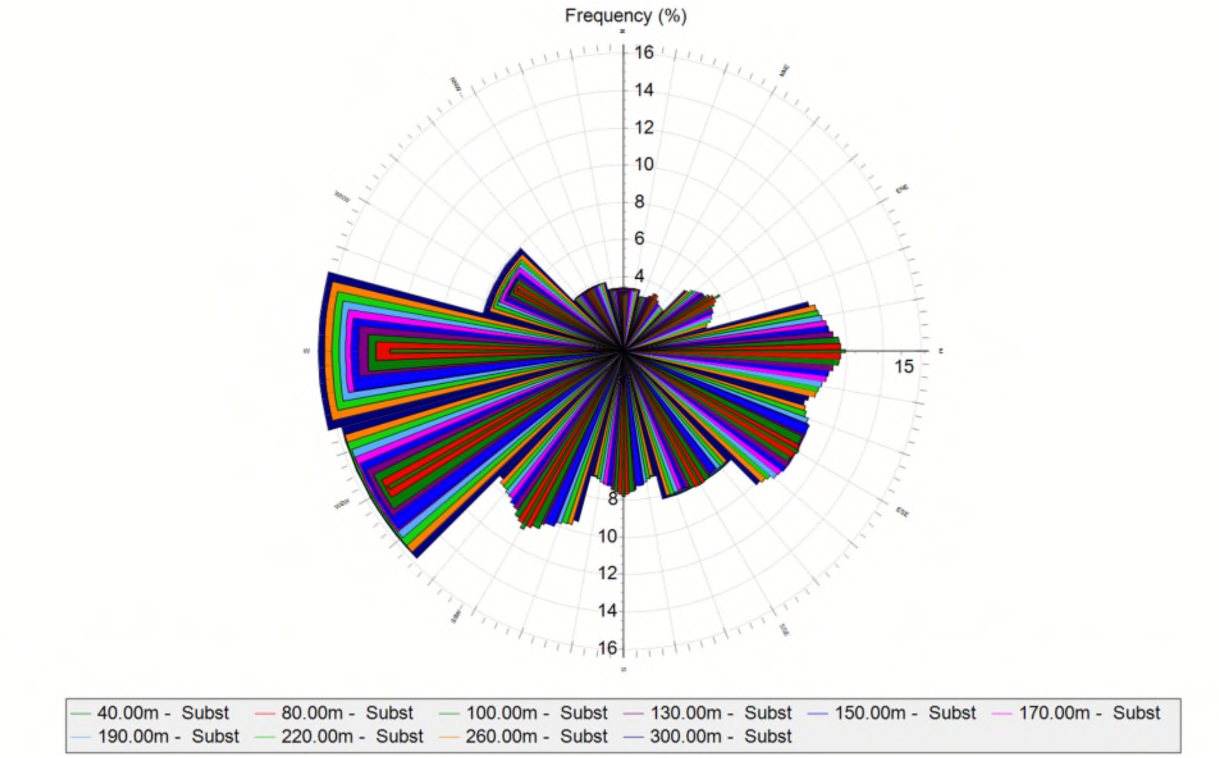


Figure 9. Directional distribution at selected heights of Hesselø South (HS-1-LB) LiDAR measurements.

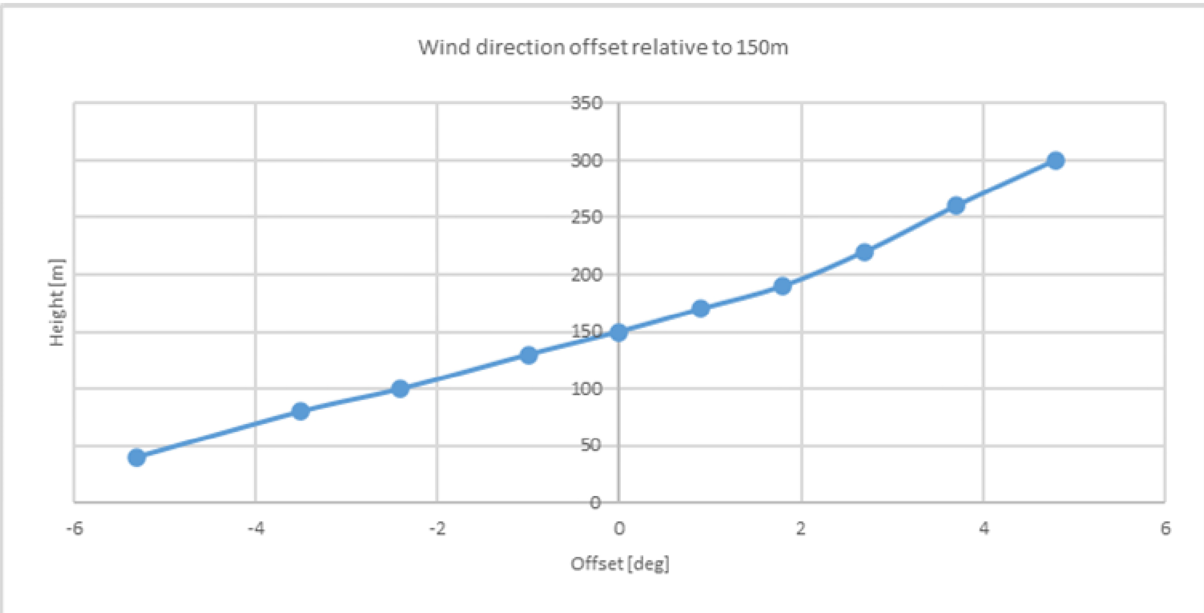


Figure 10. Rotation of wind direction relative to 150 m measurements at Hesselø South (HS-1-LB) LiDAR.

4.5.4 Diurnal Variations

There is a minor variation in wind speed across the day with marginally higher wind speed at night and lower wind speed at daytime.

The temperature at the buoy is almost uniform across the day.

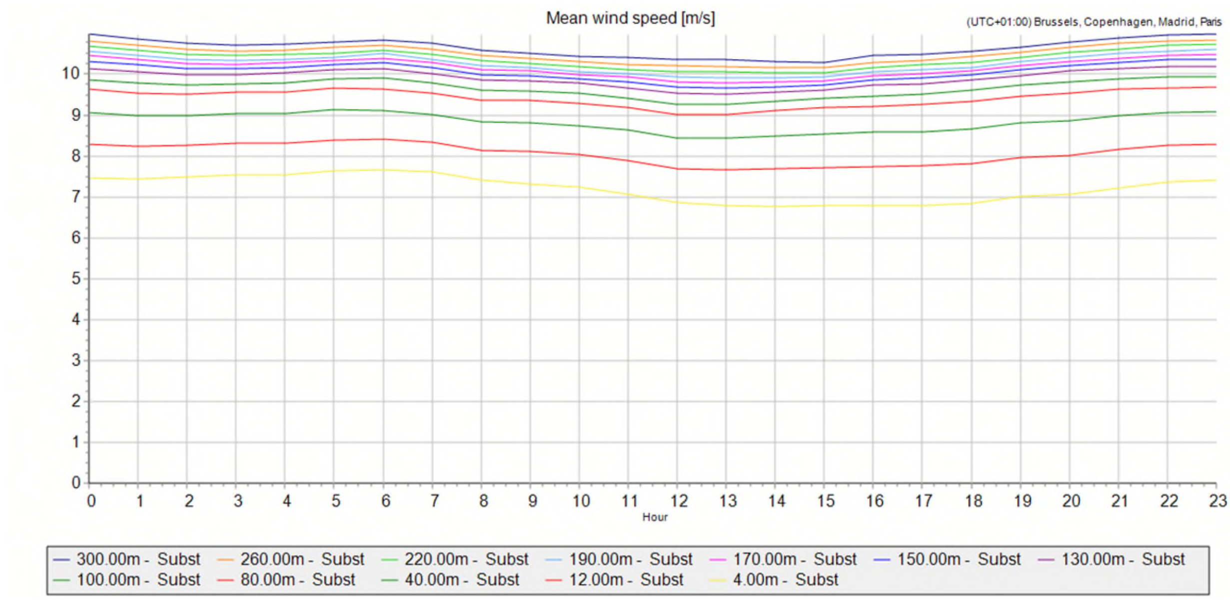


Figure 11. Diurnal wind speed variation at Hesselø South (HS-1-LB) LiDAR.

4.5.5 Seasonal Variations

The specific year of measurement has the typical pattern for the region with higher wind speed during winter than during summer.

The temperature at 4 m height varies across the year from a mean temperature in January of 1.4˚C to 17.5˚C in August.

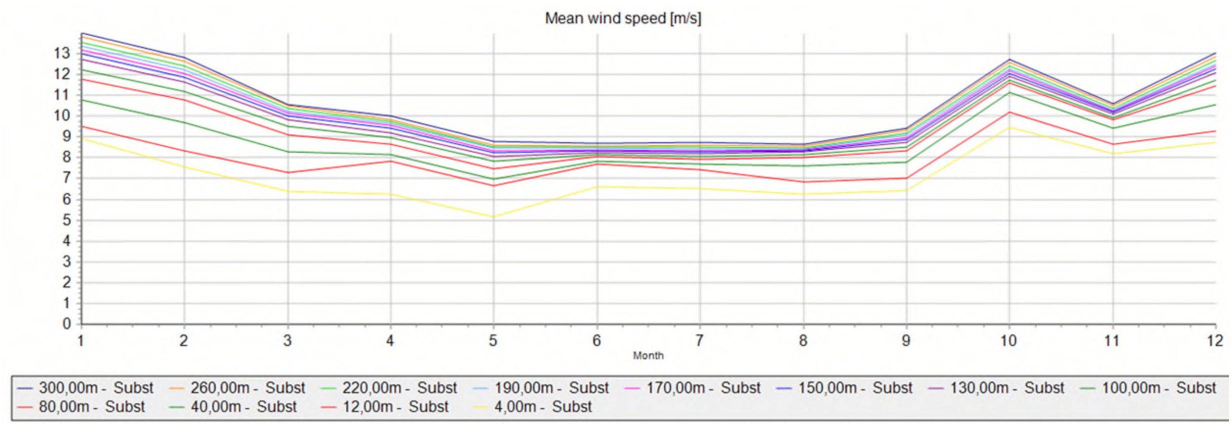


Figure 12. Monthly mean wind speed at Hesselø South (HS-1-LB) LiDAR.

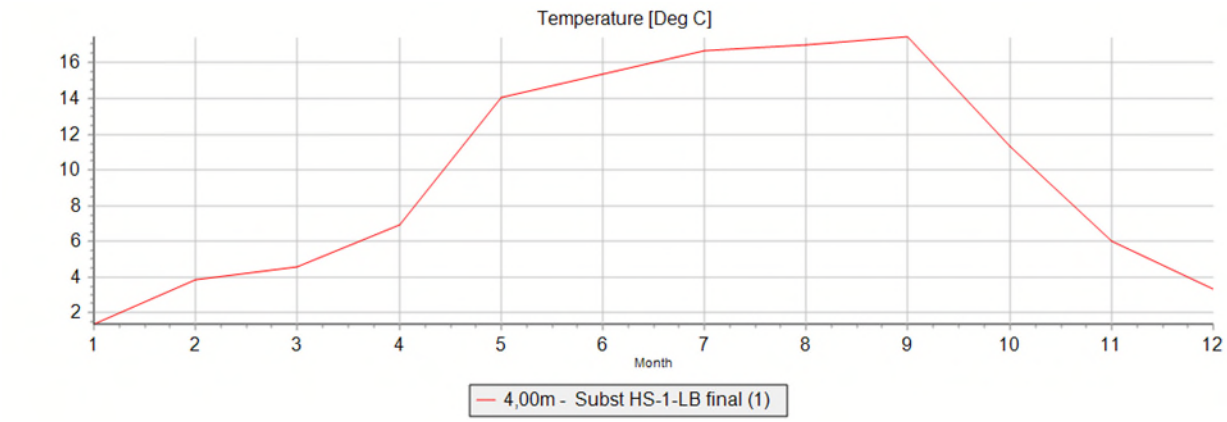


Figure 13. Monthly mean temperature at Hesselø South (HS-1-LB) LiDAR.

4.6 Measurement Uncertainty

Measurement uncertainty of the LiDAR measurement consists of three components:

- Classification uncertainty
- Verification uncertainty
- Data repair uncertainty

The classification uncertainty, giving the maximum expected uncertainty, is obtained from the ZX300 classification document [18] as 1.41% (average from 130 m and 135 m height). These heights are the tallest heights reported and are here considered representative of the 150 m measuring height. The classification table is included in Appendix B.

The verification of the SWLB059 and WS190 buoy-mounted LiDAR's was provided in [15], [17]. The test site was at the Frøya, Norway.

In these studies the Key Performance Indicators (KPI) according to the OWA Roadmap [20] are tested and the verification uncertainty is here calculated according to the method suggested by the CT/OWA LiDAR Uncertainty Standard Review [21]. All KPI's were successfully fulfilled.

The reference LiDAR at Frøya is also ZX Z300 LiDAR and both reference LiDAR and the buoy mounted LiDAR's were verified prior to the verification test at Pershore test site, in UK.

The verification uncertainties of the SWLB059 and WS190 buoy-mounted LiDAR's from the verification reports are included in Appendix B for 140 m and 160 m, the closest heights to 150 m. The average of the two uncertainty assessments is used. Verification uncertainty is calculated by frequency weighting the uncertainty at each wind speed. For the SWLB059 LiDAR this uncertainty is 1.87% and 1.83% at 140 m and 160 m height, respectively. For the WS190 LiDAR this uncertainty is 1.81% and 1.80% at 140 m and 160 m height, respectively. Hence the average of the two buoys is 1.83%.

The uncertainty from the vertical data repair is found by assuming a 20% uncertainty on the wind speed change from source to destination. With a 1.5% wind speed difference (from 130 m to 150 m), this results in an additional uncertainty of 0.3% on wind speed of the synthesized data. At 150 m, the vertically synthesized data contribute is 0.31% of the dataset at HS-1-LB. Resulting vertical data repair uncertainty is 0.001% at HS-1-LB.

For the horizontal data repair at 150 m, a linear regression method is used to transfer data from the KG-1-LB dataset to the HS-1-LB dataset (buoy SWLB059/WS190). The transfer function has a mean bias error of -0.10% and an RMS error on hourly basis of 15.9%. Using the same procedure as used for assessing LiDAR verification uncertainty (wind speed binned mean deviation), the transfer function uncertainty is assessed to 5.6%. This additional uncertainty applies to the horizontally synthesized part of the dataset at HS-1-LB (2.2%), resulting in an uncertainty component of 0.126%.

Combined, vertical and horizontal data repair contribute is 0.127% uncertainty to the measurement dataset at HS-1-LB at 150 m.

The verification, classification and data repair uncertainty are combined into a total uncertainty on the LiDAR measurements at 150 m (Table 11).

Table 11. Wind speed measurement uncertainty at 150 m ASL at Hesselø South (HS-1-LB) LiDAR.

DATASET	CLASSIFICATION UNCERTAINTY	VERIFICATION UNCERTAINTY	DATA REPAIR UNCERTAINTY	TOTAL MEASUREMENT UNCERTAINTY
HS-1-LB (SWLB059/WS190)	1.41%	1.83%	0.127%	2.31%

5 Reference Data

Mesoscale data have been obtained for the dual purpose of long-term correcting the onsite measurements and calculating a wind speed gradient across the wind farm zone. The period length is limited by the data availability and has afterwards, through a consistency analysis, been curtailed to an appropriate length.

Different mesoscale and re-analysis products have been used as long-term data sources:

- 34 years of ERA5 merged with the preliminary ERA5(T) [22] for the last 3 months, hourly data at a height of 100 m AGL have been obtained. ERA5 is a climate reanalysis dataset developed through the Copernicus Climate Change Service (C3S) and processed/delivered by ECMWF. ERA5(T) is the initial release of ERA5 with availability 5 days behind real time. ERA5 is final data with availability 2-3 months behind real time, hence the merging of ERA5(T) to the ERA5 data for the missing months of the period. The locations are the closest available data node to the buoy.
- 25 years of EMD-WRF On-Demand [23], high resolution mesoscale data have been obtained. The mesoscale model developed by EMD (http://www.emd.dk) has been run for the location of the Kattegat measurements. ERA5(T) data from ECMWF (http://www.ecmwf.int) has been used as the global boundary dataset. The temporal resolution is hourly. Similar datasets have been obtained for the locations of selected supporting datasets including the location of a third location for the site parameter analysis.
- 25 years and 3 months of NORA3 [24] data have been obtained. The NORA3 data have been sourced from the Norwegian Meteorological Institute. The NORA3 dataset uses a combination of ERA5 reanalysis data and an extensive surface model database. Instead of a WRF model, the NORA3 model is processed using the HARMONIE-AROME model. The model grid is 3 km, and the temporal resolution is hourly. The closest available node is used. The data is available until 31/03/2024.

The location of the mesoscale reference data around HS-1-LB is presented in Figure 14 and Table 12. All data are extracted through windPRO software.

Table 12. Reference datasets position and period length. Positions are given in Geographic degrees, WGS84.

	EMD-WRF	ERA5(T)	NORA3
Position/Node	11.772°E 56.334°N	11.250°E 56.750°N	11.754°E 56.316°N
Start (data used)	01/01/1999	01/01/1990	01/01/1999
Stop (data used)	31/07/2024	31/07/2024	31/03/2024

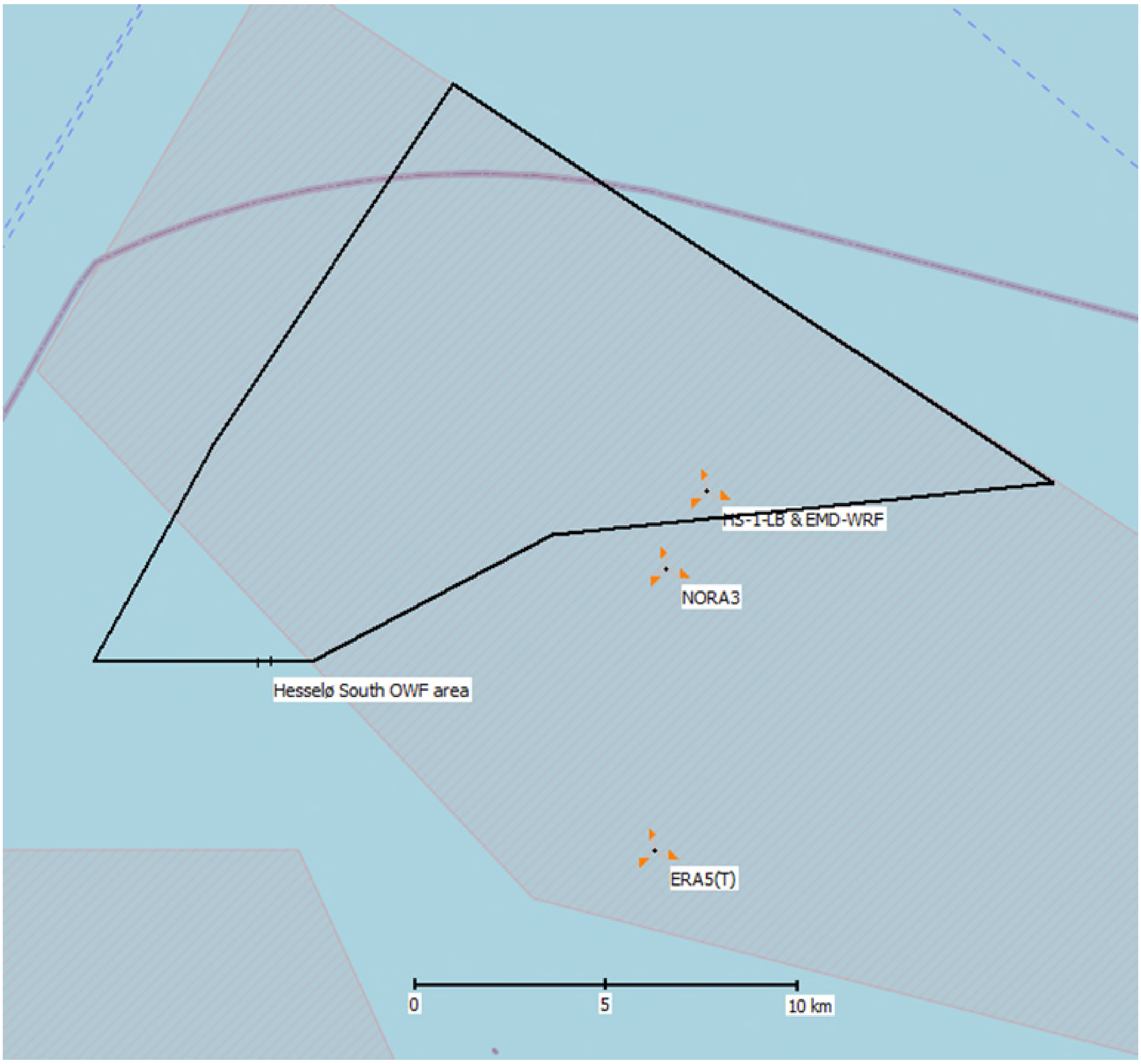


Figure 14. Location of reference datasets near HS-1-LB.

6 Long-term Correction

6.1 Review of Reference Data

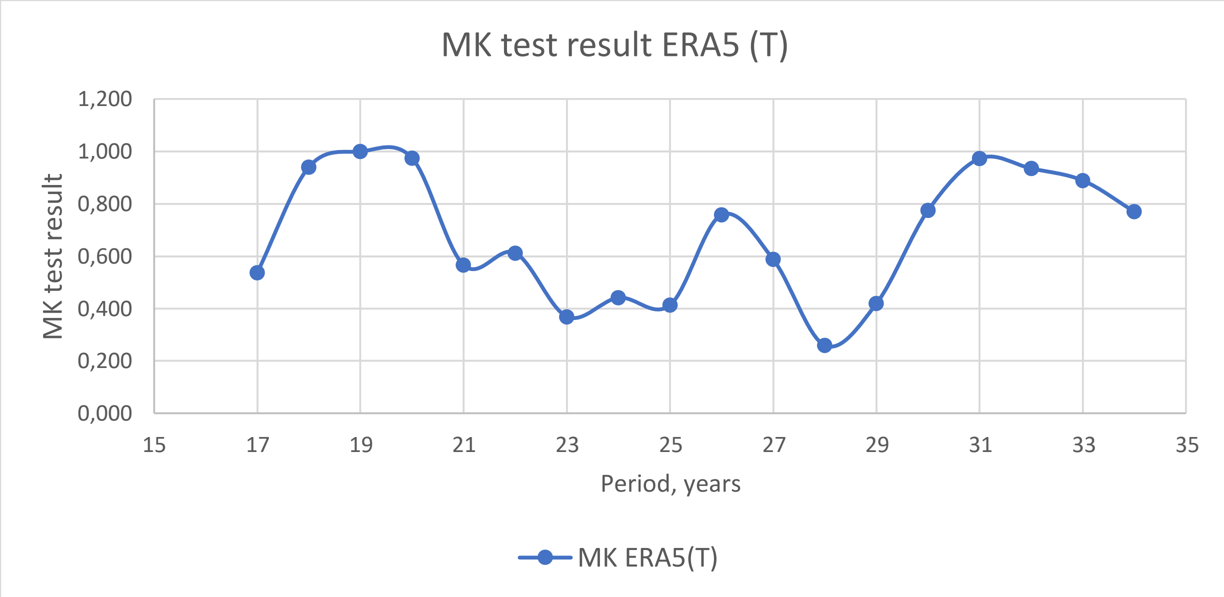
6.1.1 Long-term Consistency & Selection of Reference Period

The consistency of historical wind reference data is of vital importance when determining the long-term variation of wind speed. EMD has conducted consistency checks on the datasets in order to ensure that these would be suitable for use. These checks aim to identify trends and to establish a suitable baseline period. Two metrics have been used: The Mann-Kendall trend test and production indices.

To avoid trends in the dataset, EMD recommends, based on experience, a Mann-Kendall (MK) [25] test value above 0.4, but preferably higher. Analysis of the ERA5(T) dataset using the Mann-Kendall trend test [25] indicated the dataset back to 1993 (31 years) results in a high MK value (0.973) with close to no trend in the time series. The mean wind speed of the 31-year period 1993-2023 at 100 m of the ERA5(T) dataset is 8.86 m/s. Similar results of high MK value (0.935) and similar wind speed (8.86 m/s) can be observed with a 32-year period (1992-2023) or 33-year period (1991-2023) and their respective MK value of 0.935 and 0.889 and mean wind speed of 8.86 m/s and 8.86 m/s (Figure 15). Such periods can be qualified as long-term representative and consistent. Similar results of mean wind speed and good MK value (0.758) can be observed as well for a 26-year period (1998-2023).

A very close mean wind speed of 8.87 m/s is met for a 22-year period (2002-2023), allowing us to consider this period as a proper reference period as well. The 21-year period (2003-2023) has a mean wind speed of 8.86 m/s as the 31-year period. However, the 22-year period is preferred since it has a better MK value than the 21-year period (respectively 0.612 and 0.566). The 22-year period has a lower MK value than the 31-year period, but it is still considered adequate. Using a 22 year-period allows to include more datasets which would not have been available for a 26 or 31-year period, considering the available long-term datasets concurrent with the measured wind data from the floating LiDAR.

An alternative measure of considering consistency in long-term data is to compare the windiness index. A windiness index can be constructed by scaling the wind speed to the expected long-term wind speed at the site, applying a power curve to each record and dividing by the average of the records. The index value serves as an energy index value for each period considered. As a starting point, a windiness index was calculated using the period 1993-2023 as baseline, reflecting the long period of data available in the ERA5 dataset. This is plotted in Figure 15 as average index of period.



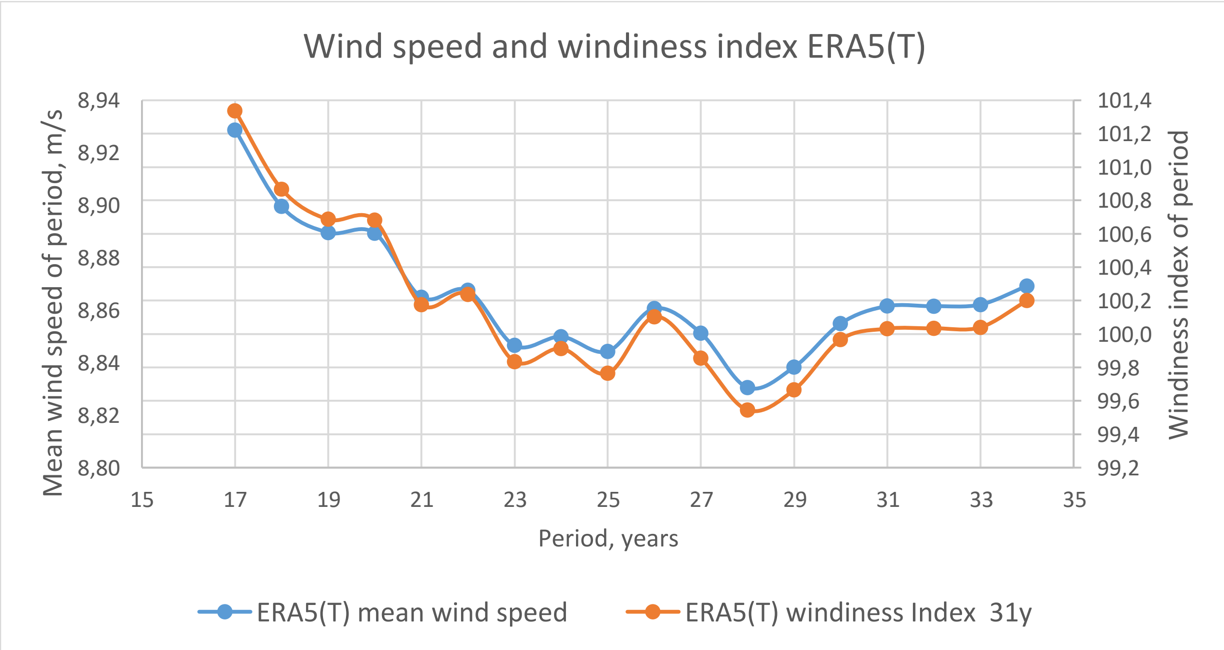


Figure 15. Consistency tests on ERA5(T) data. Period length in years dating back from January 1st, 2024, are analyzed for M-K trend test (top graph) and mean wind speed and windiness (energy) index of period (bottom graph). Baseline period 1993-2023.

Based on the 31-year baseline period, the index of different periods as plotted in Figure 15 varies between 99.5 and 101.4 with a median value of 100.1. The 31, 30-, 26- and 22-year periods have a relative index value of 100.0. 100.0, 100.1 and 100.2, which confirms that these periods are consistent with each other and are also representative of the long-term energy level.

It can be noted that the variations of mean wind speed and energy index of different periods is rather limited.

Finally, the 22-year period of 2002-2023 is selected as the base line period since it has proven to be consistent, based on wind speed comparison with the 26-year, 30- year and 31-year period, and for this shorter period the population of available reference data is larger. The 22-year period can therefore be considered representative to the long-term period for even longer periods than 22 years.

Since EMD-WRF data and to some extent NORA3 data are derived from ERA5/ERA5(T), these datasets can be expected to have similar consistency properties. A comparison of the ERA5(T)-based wind index with the EMD-WRF-based wind index confirms that the above conclusions based on ERA5 are also valid for EMD-WRF. The index of the ERA5 data for the period 2002-2023 is indeed perfectly correlating with the index of EMD-WRF data.

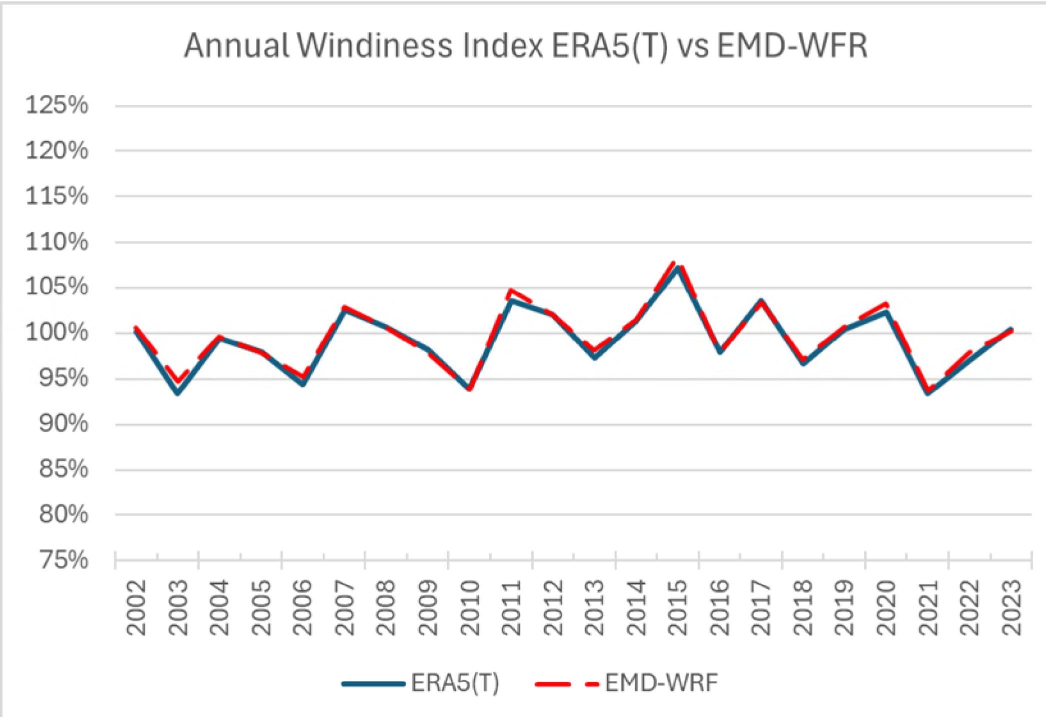


Figure 16. Annual windiness (energy) index for ERA5(T) and EMD-WRF data. Baseline period: 2002-2023.

Similar plots are made with six of the secondary ground stations described in Appendix A, where a long continuous time series are available. It is clear that Nakkehoved is very trended and unsuited to verify the trend at Kattegat. The Anholt data has similar problems. There are here three distinct periods: Until 1999, from 1999 to 2012 and after 2012 with large offsets between each period which could mean the Anholt mast may have been moved or significantly changed. In any case, it cannot be used to verify the trend at Kattegat. Data from Gniben and Røsnæs are of higher quality, consistency-wise, and while not giving a perfect match, go a long way to confirm the pattern seen in the ERA5(T) data. Data from Väderö show a good match as well, except for the years impacted by data recovery issues. Sletterhage shows a downward trend.

A diagram superimposing the windiness index of progressively longer periods (Figure 18), show the trends of ERA5 imitated by Gniben and Røsnæs.

The analysis of windiness indices from secondary data therefore confirms the selection of the period of 2003 to 2023 as long-term representative and consistent.

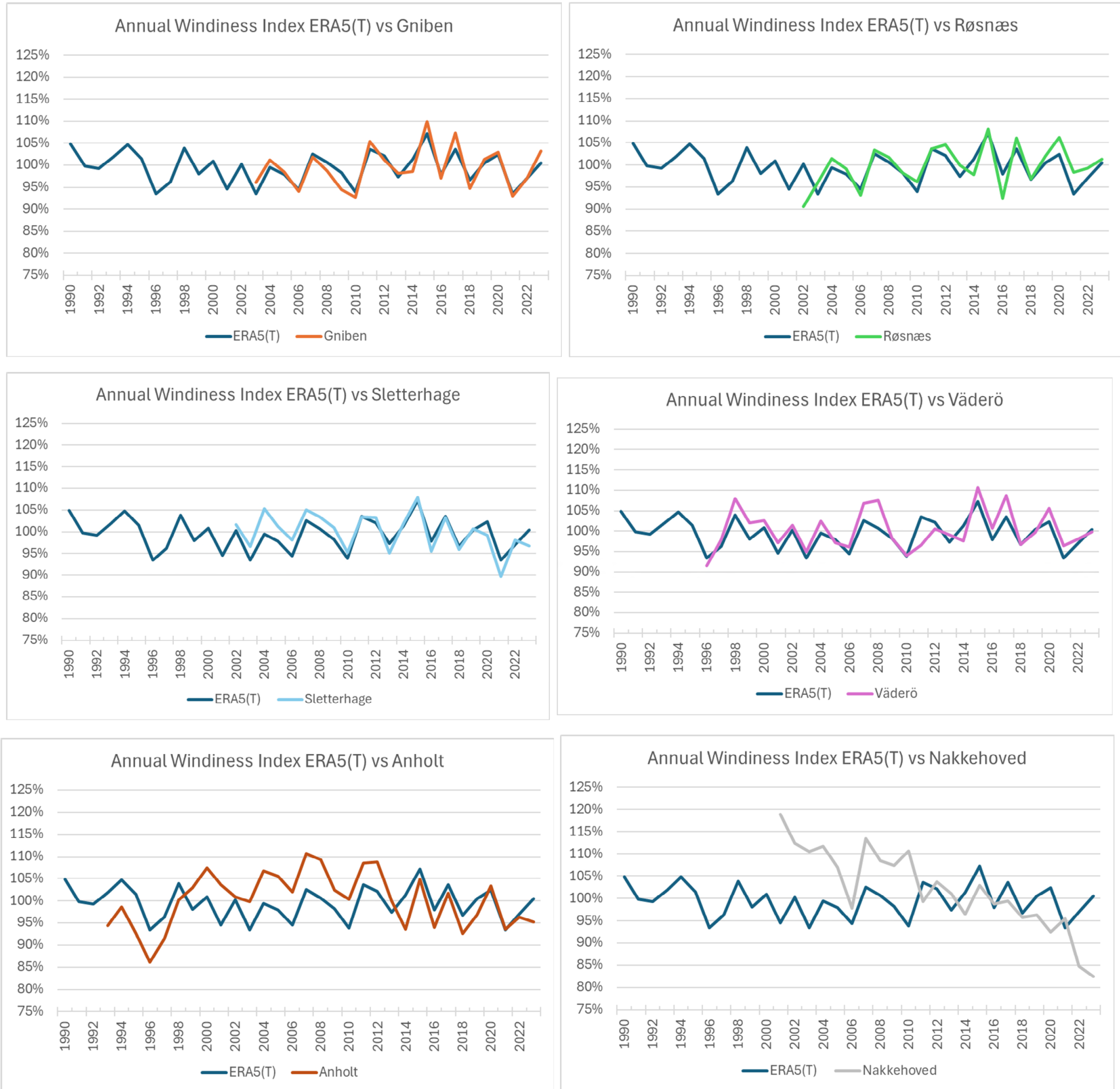


Figure 17. Annual windiness indices for a selection of secondary meteorological stations.

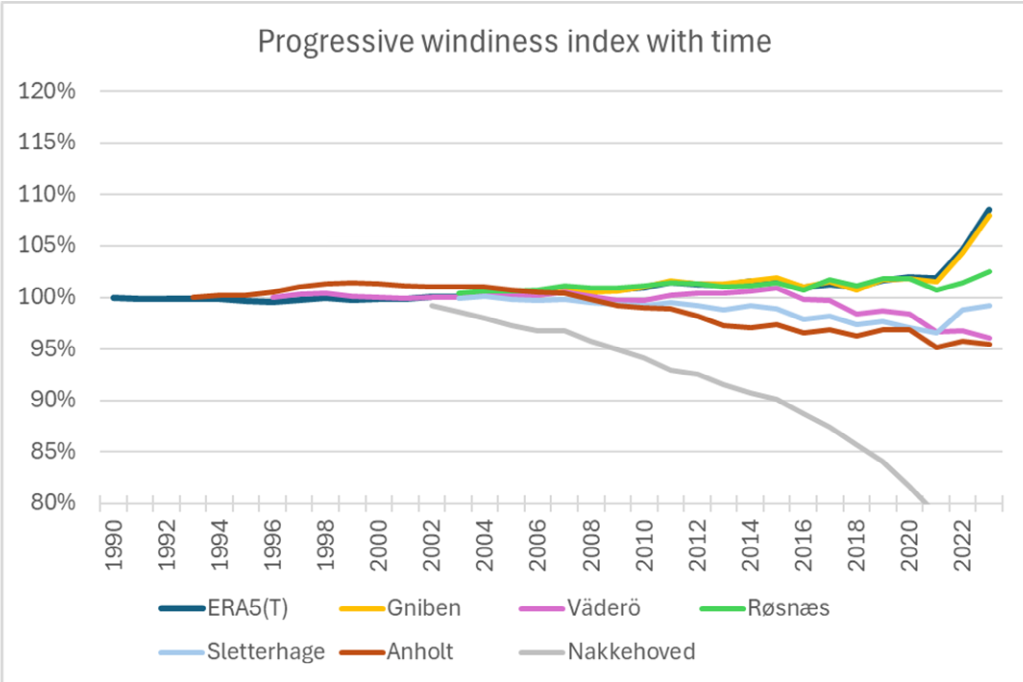


Figure 18. Progressive windiness index with time. The index of each year is the average of all following years.

6.1.2 Selection of Reference Data

Three potential reference datasets were considered for long-term correction of the LiDAR measurements from HS-1-LB. These are the three datasets described in section 5: EMD-WRF, ERA5(T) and NORA3. The data have all been successfully evaluated for use as long-term reference, passing all tests as described above. The correlation, r, of the datasets with the LiDAR data is equally high for all datasets. NORA3 does not cover the entire measurement period (8.3 concurrent months with the LiDAR). This places it for at a disadvantage compared to the other datasets which are covering the whole measurements period (12 months). Priority must be given to datasets allowing for the longest concurrency between the reference and the measured datasets. NORA3 remains useful though as validation of the long-term correction.

The standard deviation on the resulting long-term wind speed across all three references and three different methodologies is limited to 0.04 m/s on the 150 m height measurements. There is a good match in predicted long- term wind speed across the selection of reference data and the MCP methodologies. The overall best performances are obtained with EMD-WRF data together with the Matrix methodology as described in section 6.2. EMD has decided to proceed with EMD-WRF as reference.

The reference dataset is 22 years of EMD-WRF data at the HS-1-LB location, covering the period 01/01/2002 to 31/12/2023. The dataset is available in the data package where the entire 25-year dataset is submitted.

6.2 Correlation between Onsite and Reference Data

6.2.1 Wind Speed and Energy Correlation

The concurrent period of LiDAR data and EMD-WRF data is 12 months (21/07/2023 to 21/07/2024).

The correlation of the wind speed between LiDAR measurements and EMD-WRF data is high.

Correlation coefficient, r, is calculated without averaging. That means that the 10-minute data of the LiDAR measurements are correlated with the hourly value of the reference data with the assumption that the hourly reference data value represents the last 10-minute period of the hour. That may not actually be the case, but the observed scatter from the 10-minute measurements is important for the following long-term correction.

The wind energy dataset is calculated by applying a power curve (NREL IEA 15 MW reference turbine) to the measured and reference data time series and divide with the average production. This is a measure of what a turbine would produce in a given period relative to average. Correlation is calculated on monthly averages and represents the match in seasonal variation in production output between reference and local data.

Table 13. Correlation coefficient r between the reference data (EMD-WRF, 150 m) and the onsite floating LiDAR Hesselø South (HS-1-LB) at 150 m ASL.

REF: EMD-WRF	HS-1-LB
Wind Speed Correlation, r [%] hourly	95.0
Wind Energy Correlation, r [%] monthly	99.1

6.2.2 Wind Direction Correlation

According to the instrument description from Fugro [11], the wind direction of measurements is referenced to true north with a secondary compass oriented against magnetic north (see section 4.2.2). Upon verification with EMD-WRF data an average deviation in wind direction was found within -0.5˚, confirming that the measured wind direction is correct.

There is a good match of wind direction roses between the LiDAR (150 m) and EMD-WRF (150 m) on the concurrent data (Figure 19).

The measurement period does not seem perfectly representative of the long-term as shown on Figure 20. For example, the eastern and western sectors have been more frequent during the measurement periods than on the long-term. It must be expected that a long-term correction of data will change the observed directional distribution.

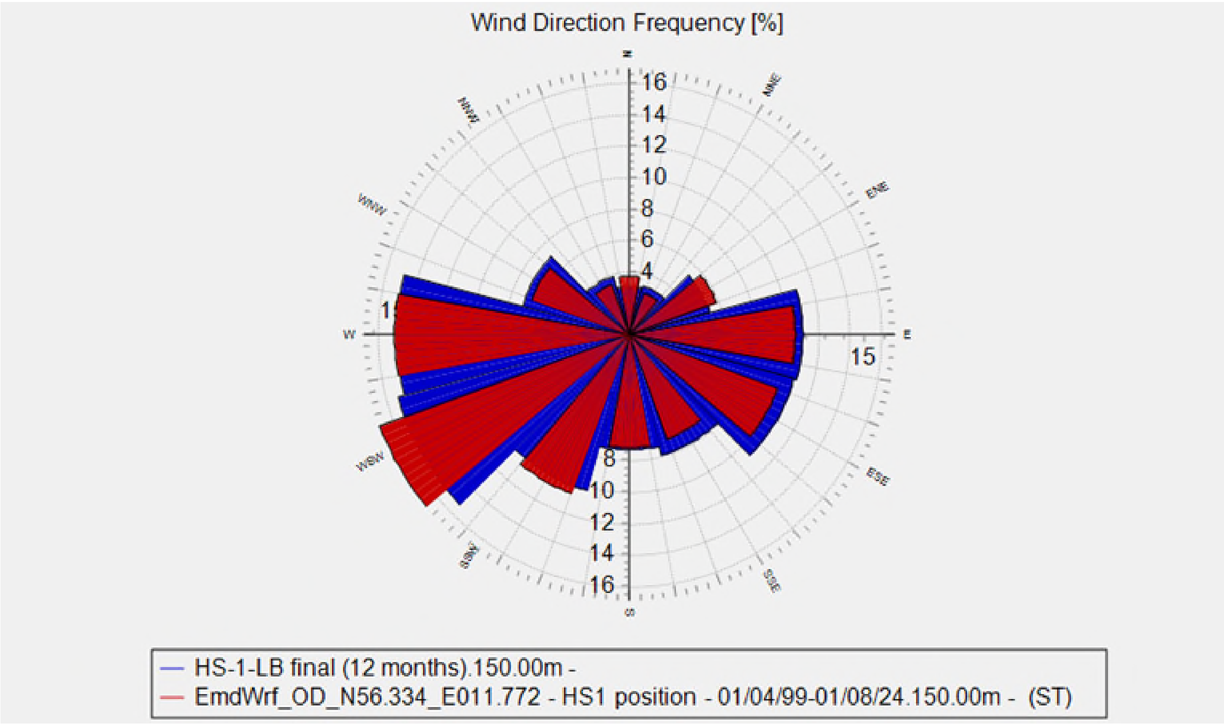


Figure 19. Wind direction roses for the concurrent period of Hesselø South (HS-1-LB) LiDAR (blue) and EMD-WRF (red) data.

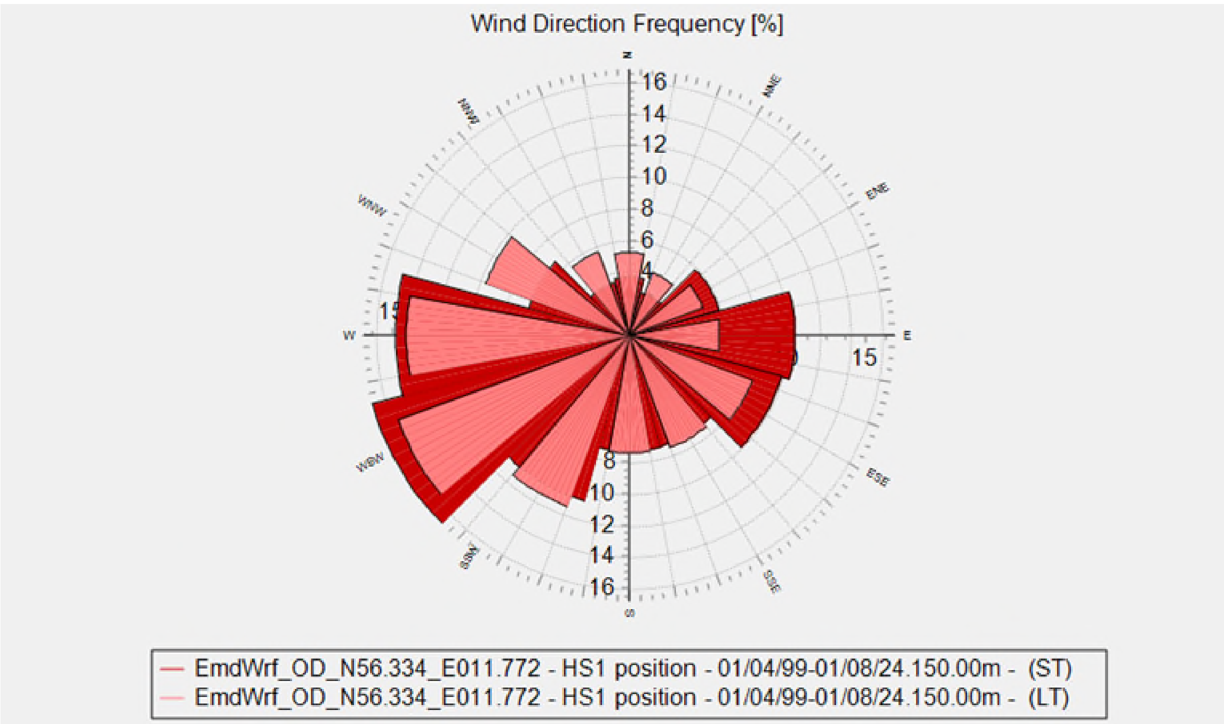


Figure 20. Wind direction roses for EMD-WRF data. Light red represents the entire long-term period (22 years) and deep red the period concurrent with Hesselø South (HS-1-LB) LiDAR measurements (1 year).

6.2.3 Long-term Correction and Validation

EMD has several long-term correction methodologies at disposal. A full description of these can be found in the windPRO reference document on Measure-Correlate-Predict (MCP) methods [26].

The relevant windPRO methodologies that will correct for the wind direction are linear regression, neural network and the matrix methods.

The performance of each method is tested through a 24-hour slicing test. In this test, the transfer function is trained on every second day of the dataset and used to predict a period consisting of every other day. The metric for comparison is the Mean Bias Error (MBE) on production output, which is comparable to the difference in turbine production in percentage between using measured or predicted data. The result of this test is presented in Table 14.

A similar test is done using the entire concurrent period for both training and testing, which amounts to a self-test.

Additionally, the Kolmogorov-Smirnov (K-S) test metrics using each method are presented in Table 14. The K-S test measures the maximum difference between measured and predicted wind distribution and is an expression of how well the observed wind distribution is captured by the prediction [26].

The Neural network methods is disqualified since it gives high MBE on the production output. The linear regression method generally produces the smallest error. The matrix method gives satisfying MBE and the best results in predicting the direction distribution and Weibull distribution shape (the K-S test). The matrix method provides the median predicted mean wind speed value.

The long-term correction has been performed using a wind speed/direction matrix. The windPRO matrix MCP method is described by developing a relationship matrix for the wind speed bins and direction bins between the wind data at the reference and a concurrent period of wind data from the local site and applying this relationship matrix to all the long-term wind data to determine the estimated site data wind climate. This method corrects for changes in both wind speed and wind direction.

Table 14. Prediction test using a 24-hour slicing method and a self-test using the entire concurrent period. The parameter presented is over-prediction of production in percent. (at Hesselø South (HS-1-LB) - 150 m data).

REFERENCE: EMD-WRF LOCAL DATA: HS-1-LB, 150M	LINEAR REGRESSION	NEURAL NETWORK	MATRIX
MBE, 24-hour slicing test, % production	0.41	-0.39	0.69
MBE, Concurrent period test, % production	0.02	2.11	-0.16
Kolmogorov-Smirnov test, %	2.52	3.62	0.80
Predicted long-term mean wind speed, m/s	9.52	9.64	9.55

The synthesized time series from EMD-WFR and matrix method represent the long-term wind climate. Time series are generated for all the heights of the Hesselø South (HS-1-LB) LiDAR (12 m to 300 m). The EMD-WFR data at the closest height of a given LiDAR height is used for the long-term correction. Similar to the 150 m data, the EMD-WFR data at 10, 25, 50, 75, 100 and 200 m give good correlation and performance indicators for the long-term correction.

The resulting artificial time series is presented in the following chapter, focusing on the 150 m results.

6.3 Long-Term Wind Climate

6.3.1 Long-term Wind Speed Distribution

The long-term wind speeds for the HS-1-LB buoy in Hesselø South OWF are summarized in the following tables. A detailed breakdown of the Weibull parameters can be found in Appendix D.

Table 15. Weibull parameters of the long-term wind data at HS-1-LB (all heights).

HEIGTH [m]	PERIOD [Y]	ARITHMETIC MEAN WIND SPEEDS [m/s]	WEIBULL MEAN [m/s]	WEIBULL - A PARAMETER [m/s]	WEIBULL - k PARAMETER
12	22	7.80	7.91	8.91	2.46
40	22	8.43	8.56	9.65	2.40
80	22	8.99	9.11	10.28	2.33
100	22	9.18	9.3	10.5	2.30
130	22	9.42	9.52	10.75	2.23
150	22	9.55	9.66	10.91	2.23
170	22	9.66	9.75	11.01	2.19
190	22	9.75	9.86	11.13	2.18
220	22	9.87	9.96	11.25	2.14
260	22	9.99	10.06	11.36	2.10
300	22	10.12	10.17	11.48	2.06

6.3.2 Long-term Wind Direction Distribution

The long-term frequency and energy distribution for the long-term corrected LiDAR data from HS-1-LB at 150 m ASL indicate a main wind direction from west-southwest, west and south-southwest.

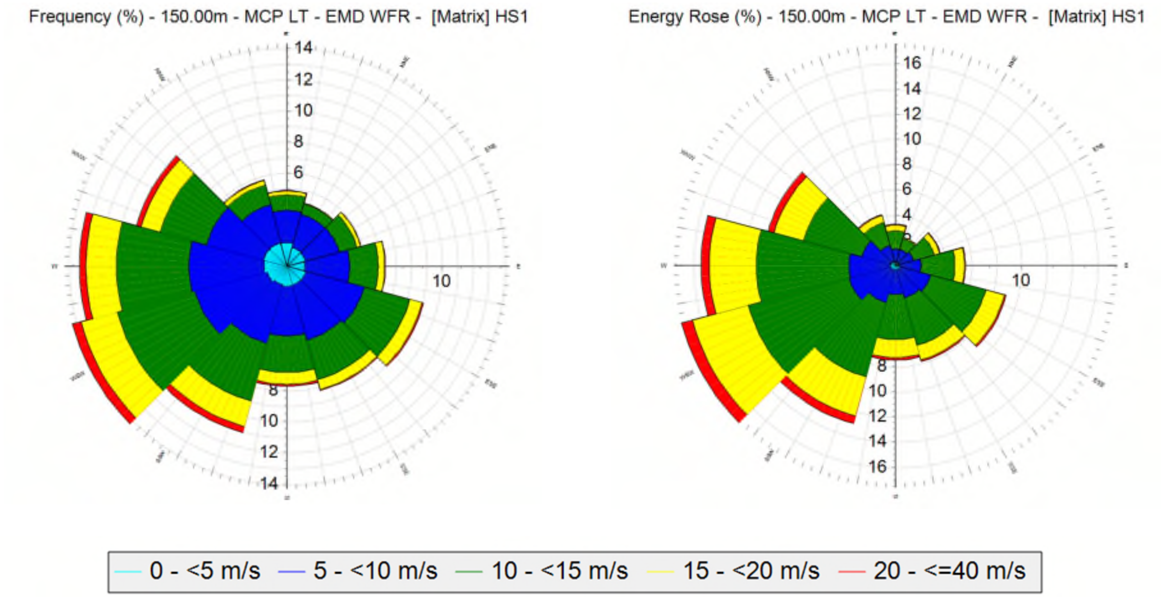


Figure 21. Left: Wind direction distribution of long-term corrected LiDAR data (HS-1-LB) at 150 m. Right: Energy distribution of long-term corrected LiDAR data (HS-1-LB) at 150 m, both divided in wind speed intervals.

6.3.3 Long-term Diurnal Variations

The diurnal long-term wind speed has similar variations with the measured mean wind speed but adjusted to a lower level for the long-term dataset (Figure 22).

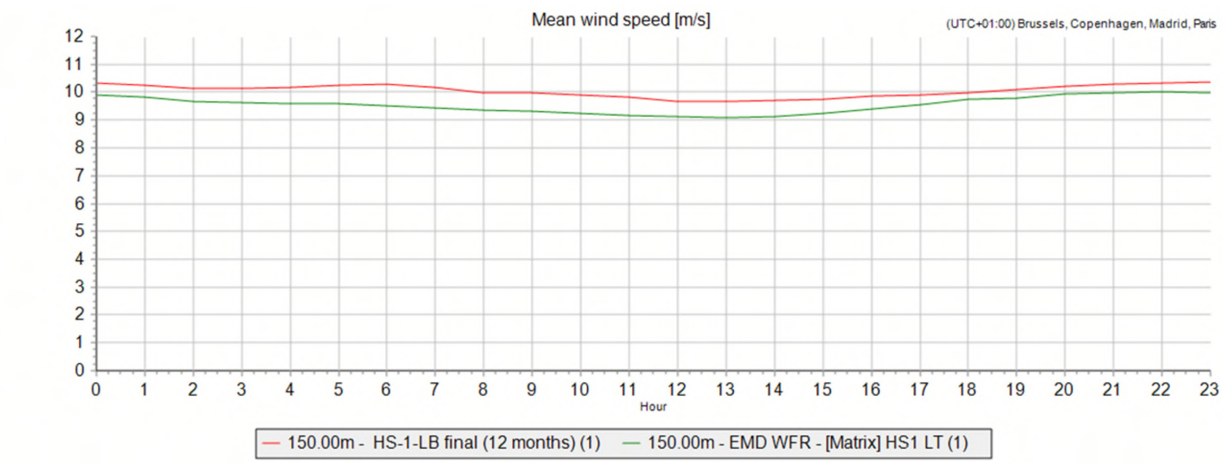


Figure 22. Diurnal wind speed, long-term corrected (green) and observed (red), at HS-1-LB LiDAR.

6.3.4 Long-term Seasonal Variations

The long-term seasonal variation of wind speed at 150 m is presented in Figure 23 and compared to the actual observations. Whereas the seasonal variation of the measurements is based on 12 months, the seasonal variation of the long-term timeseries is an average of 22 years of data and therefore predictably smoother.

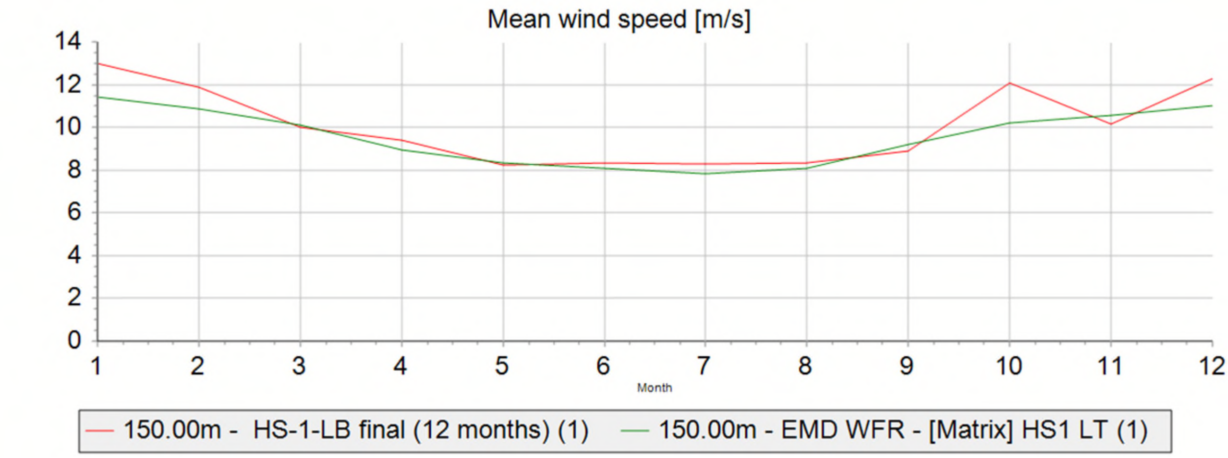


Figure 23. Seasonal variation of long-term corrected dataset (green) and observed dataset (red) at 150 m, at HS-1-LB LiDAR.

7 Validation of Wind Model

7.1 Secondary Models

The wind resource at Position HS-1-LB was assessed through long-term correction of measured LiDAR data. This remains the primary model for the site.

Three secondary models were tested, translating secondary measured data from Kattegat (KG-1-LB), Hesselø (H1) and Læsø (M1) to the site. The Hesselø (H1) and the Kattegat (KG-1-LB) datasets are located relatively close to HS-1-LB. The M1 mast is at a greater distance, north of HS-1-LB. These were used to validate the primary wind model at Hesselø South OWF. The locations of the secondary datasets are presented in Figure 24.

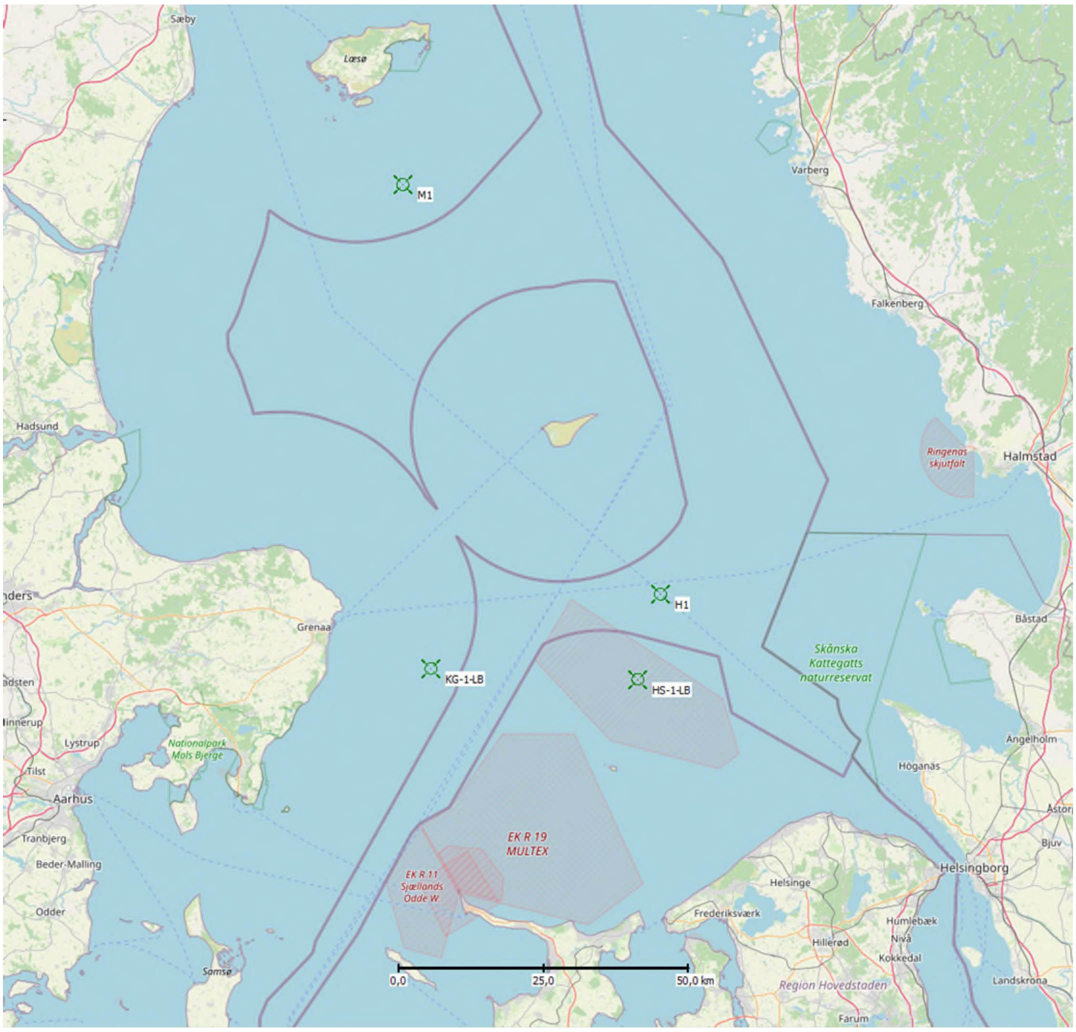


Figure 24. Location of KG-1-LB, H1 LiDAR buoys and Læsø meteorological mast M1 relative to HS-1-LB LiDAR buoy.

For the validation, the secondary datasets are transferred from their locations to HS-1-LB using the relative differences resulting from the comparison of mesoscale data. This transfer is based on the assumption that the difference between the two sites can be fully described by the difference observed in mesoscale data.

For each of the three onsite datasets, an EMD-WRF dataset was extracted (section 5). The correlation in terms of wind speed, energy content and wind direction has been analysed for sufficiency. If mismatches are identified, a transfer function has been developed to mitigate the differences.

The datasets are described and adjusted to long-term wind climate in Appendix A.

7.1.1 Kattegat Floating LiDAR (KG-1-LB)

Based on 12 months of LiDAR measurements on the buoy deployed for the Kattegat site (KG-1-LB), a 22-year dataset was produced with the same reference period as for HS-1-LB. The height of interest is at 150 m ASL.

The KG-1-LB buoy is located 35 km west of HS-1-LB buoy (Figure 24). The HS-1-LB and KG-1-LB buoys are exposed differently to the impact of land. Still the KG-1-LB buoy has the advantages of being relatively close to HS-1-LB, with concurrent wind data, same height of measurements and technology.

For the validation of the wind model at HS-1-LB, the long-term corrected dataset at KG-1-LB is transferred to the location and height of the buoy following the below-described methodology.

An EMD-WRF dataset was extracted at the KG-1-LB buoy location (section 5). The correlation between the KG-1-LB LiDAR data and EMD-WRF is very high, both on wind speed, monthly energy content and directional distribution. Although ERA5 was eventually the preferred long-term correction dataset for KG-1-LB (Appendix A.1.1a.i), EMD-WRF correlates well enough to be used for the data transfer between KG-1-LB and HS-1-LB.

Comparing the wind direction distribution between EMD-WRF data at KG-1-LB and EMD-WRF data at HS-1-LB, a difference in directional distribution and particularly energy distribution is noted (Figure 27). A transfer function is therefore required to transfer both the wind direction and the energy content in each direction.

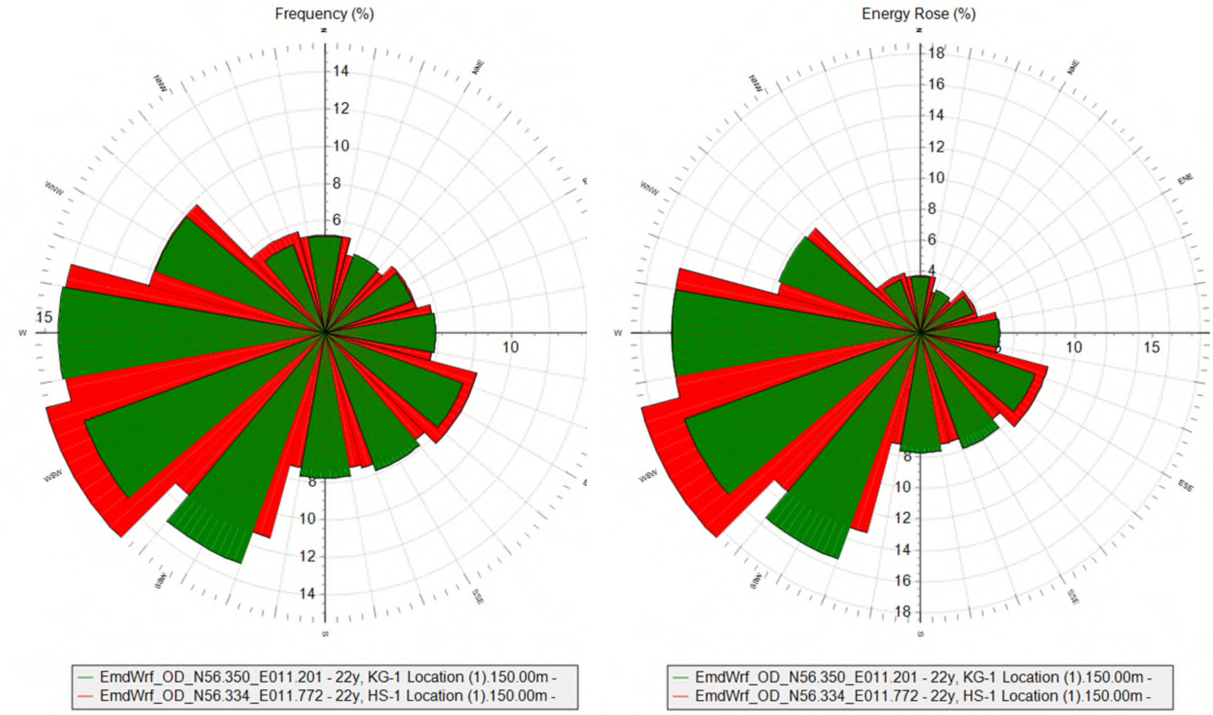


Figure 25. Left: Directional distribution between EMD-WRF at KG-1-LB (green) and EMD-WRF at HS-1-LB (red), 22 years. Right: Energy rose of same two datasets, 22 years.

A translation function is created using linear regression with a translation function for every 1° direction bin, using data in a +/-15° sector window, giving a scale and offset on wind speed as well as an offset on wind direction.

This translation function is then applied to the 22-year of long-term corrected 150 m KG-1-LB data, creating a 22-year dataset at HS-1-LB.

A comparison of directional distribution of transferred KG-1-LB data at 150 m with long-term corrected HS-1-LB data is presented in Figure 26. The match between the original HS-1-LB and the transfered data is good. A small discrepancy is noted on the energy rose, which can be attributed to the difference in EMD-WRF data from the two locations. Overall the data alignment remains robust.

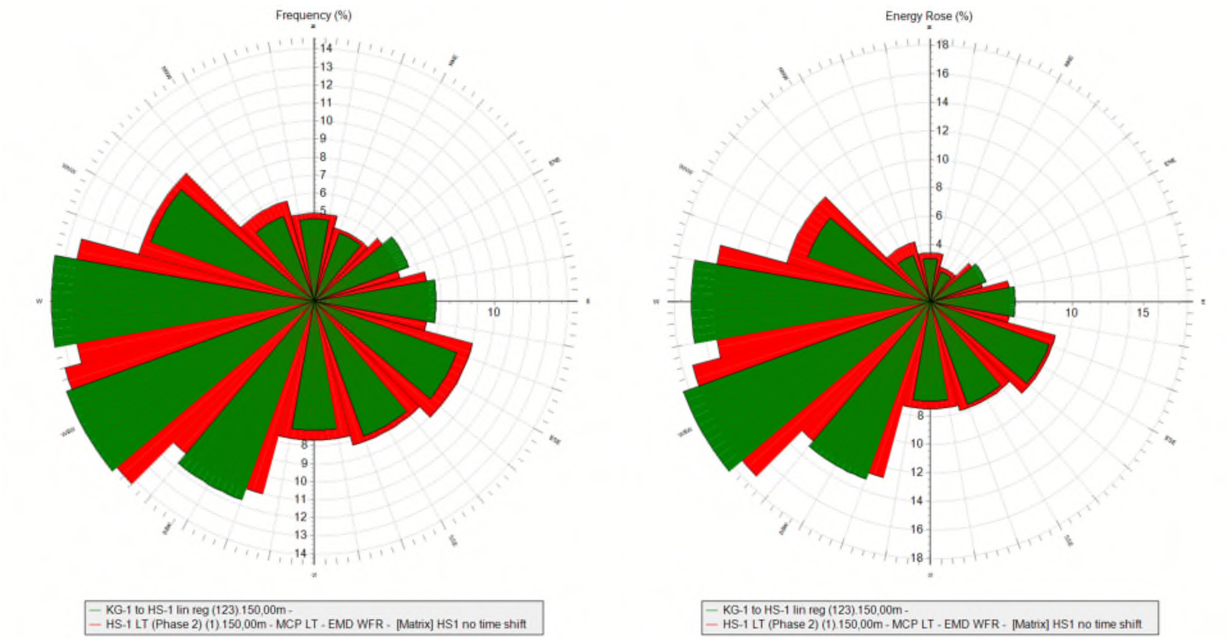


Figure 26. Comparison of directional distribution (left) and energy rose (right) of transferred KG-1-LB data (green) with HS-1-LB (red) (22 years).

The mean wind speed through the steps can be followed in Table 16. The wind distribution and Weibull fit can be found in detail in Appendix F.

Table 16. Mean wind speed through the transfer stages, at KG-1-LB data.

Stage	Arithmetic Mean Wind Speed [m/s]
12 months of measured, KG-1-LB, 150 m	10.00
22 years, long-term corrected HS-1, 150 m	9.51
22 years, transferred to KG-1-LB, 150 m	9.48

7.1.2 Hesselø Floating LiDAR (H1)

Based on 12 months of LiDAR measurements on the buoy deployed for the “Old” Hesselø site (H1), a 22-year dataset was produced with the same reference period as for HS-1-LB. The height of interest is at 150 m (shear extrapolated from measurement height 140 m).

The H1 buoy is located about 15 km north of HG-1-LB buoy (Figure 24). The buoys are similarly exposed to the impact of land and is relatively close to HS-1-LB, with similar heights of measurements and technology, but the dataset was recorded for a different year than that of HS-1-LB.

For the validation of the wind model for HS-1-LB, the long-term corrected dataset at H1 is transferred to the location and height of the HS-1-LB buoy following the below-described methodology.

An EMD-WRF dataset was extracted for the H1 buoy location (section 5). The correlation between the H1 LiDAR data and EMD-WRF is very high, both on wind speed, monthly energy content and directional distribution as discussed in Appendix A and the EMD-WRF data can therefore be said to capture the wind dynamics very well at H1.

Comparing the wind direction distribution between EMD-WRF data at HS-1-LB and EMD-WRF data at H1, the difference in directional distribution and energy distribution is very small (Figure 27).

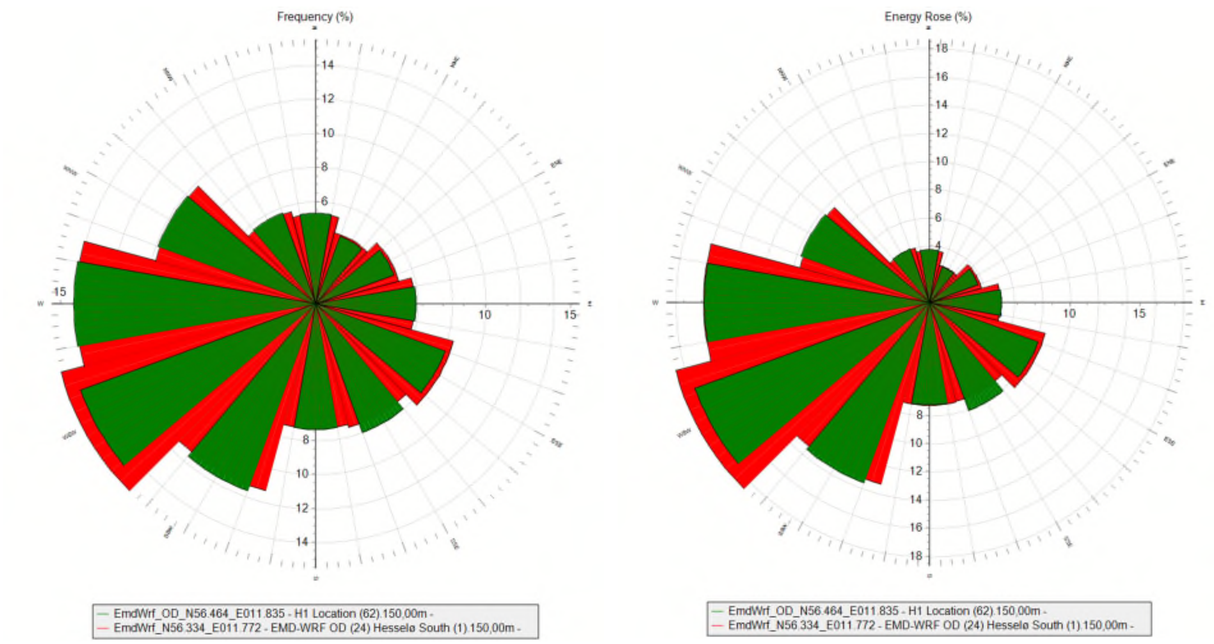


Figure 27. Left: Directional distribution between EMD-WRF at HS-1-LB (red) and EMD-WRF at H1(green), 22 years. Right: Energy rose of same two datasets, 22 years.

A transfer function is created using linear regression with a translation function for every 1° direction, used data in a +/-15° sector window, giving a scale and offset on wind speed as well as an offset on wind direction.

This translation function is then applied to the 22-year of long-term corrected 150 m H1 data, creating a 22-year dataset at HS-1-LB.

A comparison of directional distribution of transferred H1 data at 150 m with long-term corrected HS-1-LB data is presented in Figure 28. The match is very good with only minor deviation.

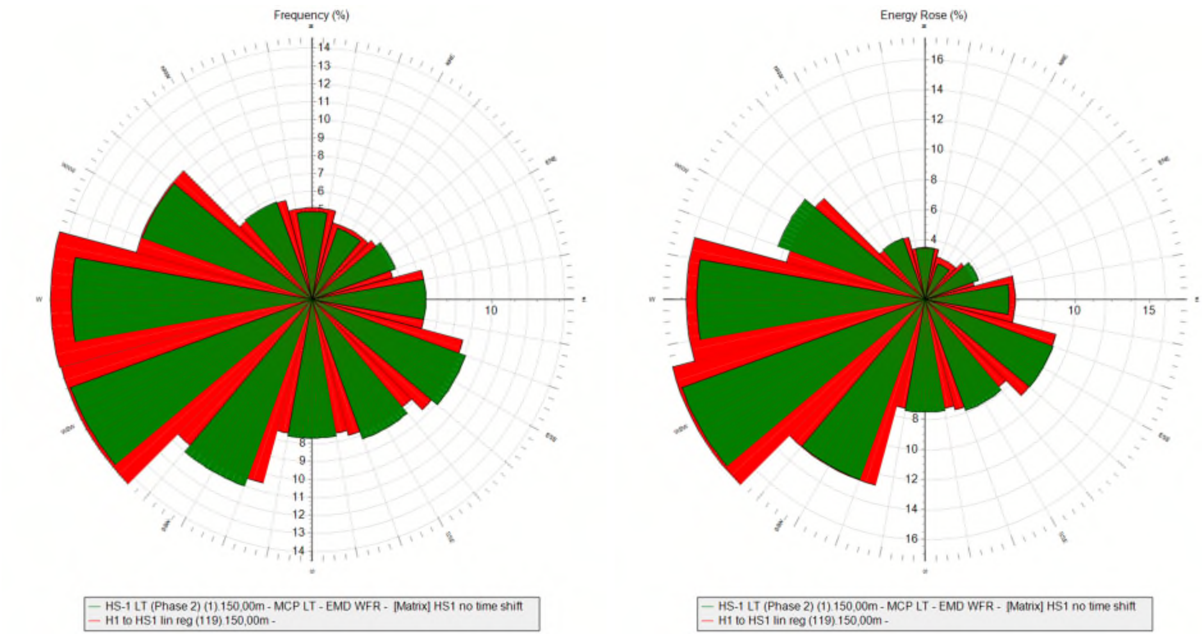


Figure 28. Comparison of directional distribution of transferred H1 data (red) with HS-1-LB (green) (22 years). Left: by frequency, right: by energy.

The mean wind speed through the steps can be followed in Table 17. The wind distribution and Weibull fit are presented in detail in Appendix F.

Table 17. Mean wind speed through the transfer stages, H1 data.

Stage	Arithmetic Mean Wind Speed [m/s]
12 months, measured, H1, 140 m	9.80
12 months, shear extrapolated, H1, 150 m	9.87
22 years, long-term corrected, H1, 150 m	9.73
22 years, transferred to HS-1-LB, 150 m	9.70

7.1.3 Læsø Mast (M1)

Based on 4 years of mast measurements at Læsø offshore met mast (M1), a 22-year dataset was produced with the same reference period as for HS-1-LB (Appendix A). The measurement height of interest is at 62 m ASL.

The location of the M1 mast is about 82 km north relative to the HS-1-LB buoy, as presented in Figure 24.

For the validation of the wind model for HS-1-LB, the long-term corrected dataset at M1, 62 m, is transferred to the location and height of the HS-1-LB buoy.

An EMD-WRF dataset was extracted for the M1 mast location (section 5). The correlation between the M1 data and EMD-WRF is very high, both on wind speed, monthly energy content and directional distribution as discussed in Appendix A and the EMD-WRF data can therefore be said to capture the wind dynamics very well at M1.

By comparing the wind direction distribution between EMD-WRF data at M1 and EMD-WRF data at HS-1-LB, a difference in directional distribution is noted (Figure 29). A transfer function is therefore required to transfer both the wind directions and the energy content in each direction.

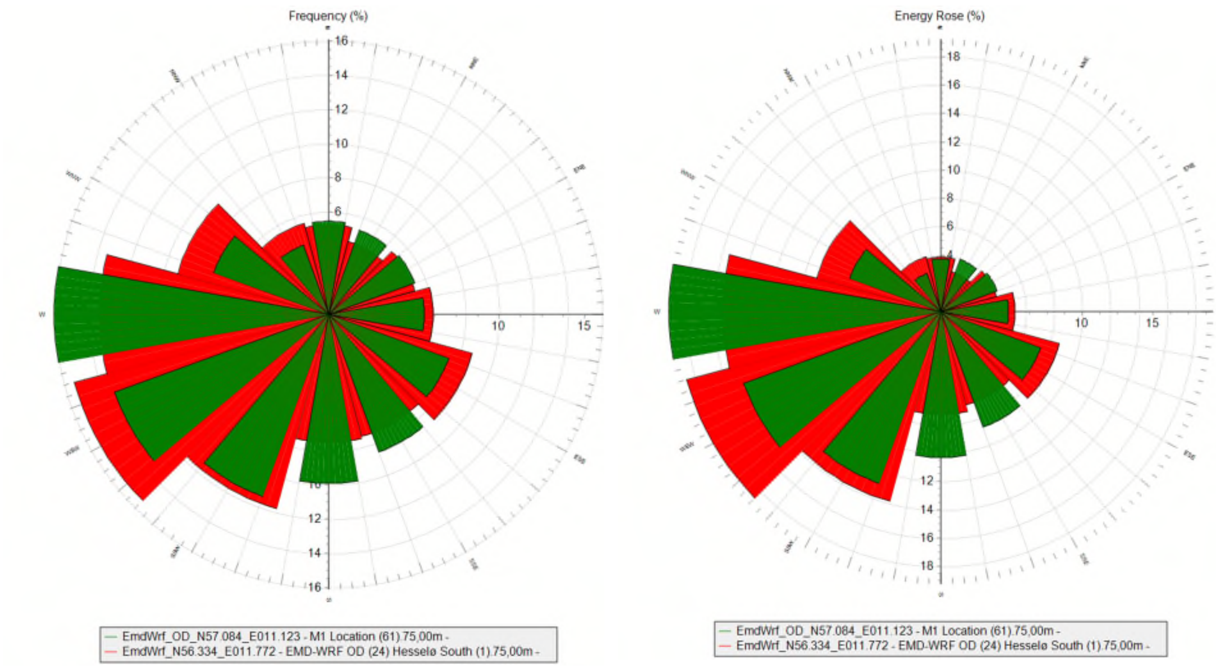


Figure 29. Left: directional distribution between EMD-WRF, 75 m at M1 (green) and EMD-WRF, 75 m at HS-1-LB (red). Right: Energy rose of same two datasets.

A translation function is thus created using linear regression with a translation function for every 1° direction, used data in a +/-15° window, giving a scale and offset on wind speed as well as an offset on wind direction. This transfer function is then applied to the 22 year of long-term corrected 62 m M1 data, creating a 22-year dataset at HS-1-LB.

A comparison of directional distribution of transferred M1 data at 62 m with long-term corrected HS-1-LB data at 80 m is presented in Figure 30. The match is reasonably good but with some deviation in the south-southwest and west sector.

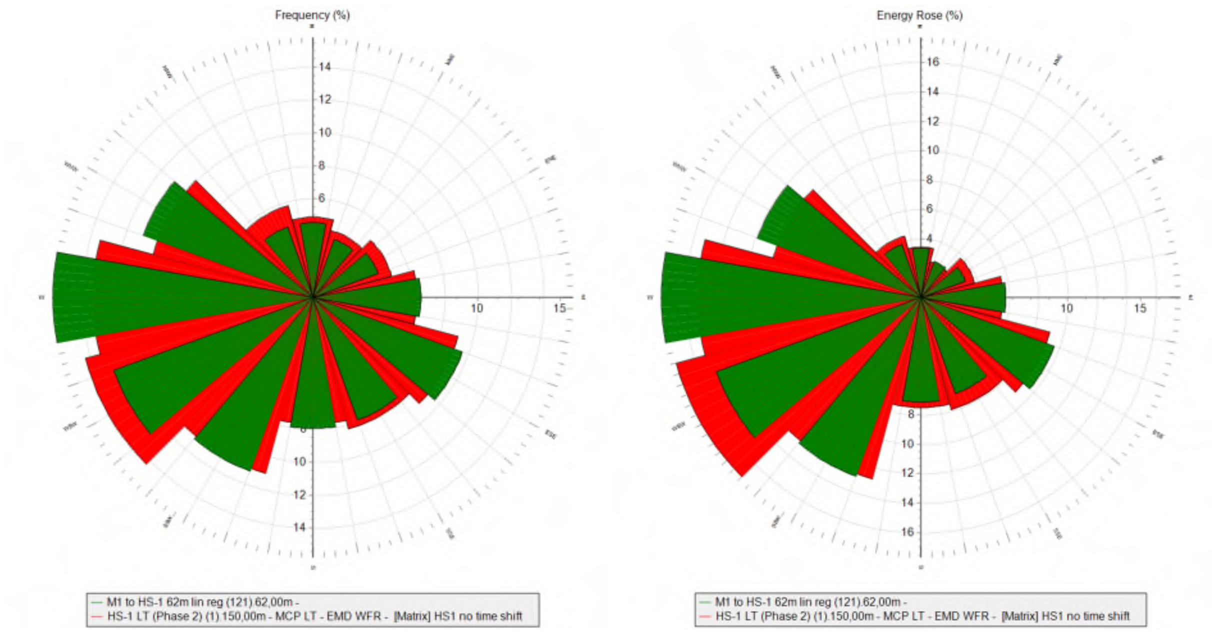


Figure 30. Comparison of directional distribution of transferred M1 data, 62 m (green) with HS-1-LB, 80 m (red) (22 years). Left: by frequency, right: by energy.

The transfered data at 62 m ASL at HS-1-LB had to be extrapolated to 150 m ASL. The obvious way to do this is through a shear extrapolation. This is however not trivial. A shear extrapolation from 62 m to 150 m is far outside the 2/3 ratio set by the MEASNET guideline ([28]).

The method applied is to use a shear based on 1 year of observations on HS-1-LB. This is the observed shear on the location where the transfer is taking place.

The shear used to extrapolate the 62 m M1 data translated to HS-1-LB from 62 m to 150 m is thus calculated from the long-term data at HS-1-LB from 100 m to 150 m (Table 18).

Table 18. Shear by season, based on measurements at HS-1-LB from 40 m to 150 m.

Direction /hour	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Shear	0.15	0.12	0.08	0.06	0.07	0.09

The mean wind speed through the steps can be followed in Table 19. The wind distribution and Weibull fit can be found in detail in Appendix F.

Table 19. Mean wind speed through the transfer stages atM1 data.

Stage	Arithmetic Mean Wind Speed [m/s]
4 years of measured mean wind speed, 62 m	8.80
22 years, long-term corrected at 62 m	8.98
22 years, transferred to HS-1-LB, 62 m	8.85
22 years, transferred to HS-1-LB, shear extrapolated to 150 m	9.61

7.2 Comparison of Primary Model with Secondary Models

The wind resource at HS-1-LB was assessed through long-term correction of measured LiDAR data. This remains the primary model for the site. Three secondary models were tested, translating measured data from Kattegat (KG-1-LB), Hesselø (H1) and Læsø (M1) to the site. They cover different directions and distances from the Hesselø South OWF and all have advantages and disadvantages as described previously.

The results of these tests are summed up in Table 20.

The long-term corrected mean wind speeds of the primary model are supported by the secondary models, with a maximum deviation of 1.6% on the mean wind speed at 150 m ASL, which is within the expected uncertainty.

The results from the M1 met mast deviate slightly more when looking at the wind speed distribution (Figure 31), mean wind speed per sector (Figure 32), frequency distribution (Figure 33) , diurnal and monthly variations (Figure 34, Figure 35). The difference may well be explained by the distance between M1 and the Hesselø OWF.

The secondary models support the primary wind model, but it is also clear that the primary model is stronger than any of the secondary models. Therefore, only the primary model is submitted in the data package. The frequency distributions and Weibull parameters of the secondary models are submitted below and Appendix E.

Table 20. Comparison of model results at HS-1-LB, 150 m ASL.

	PRIMARY MODEL	TRANSFERRED KG-1-LB MODEL	TRANSFERRED H1 MODEL	TRANSFERRED M1 MODEL
Wind speed [m/s]	9.55	9.48	9.70	9.61
Wind speed relative to primary model		99.3%	101.6%	100.6%

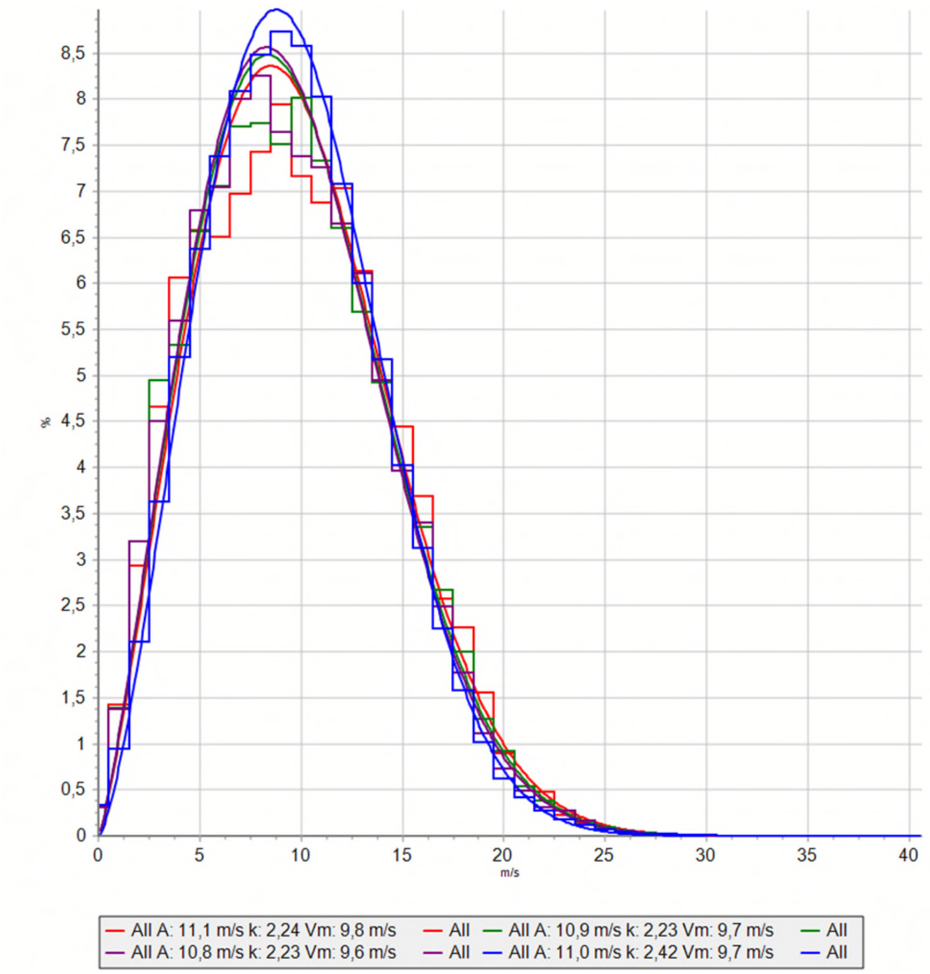


Figure 31. Wind speed probability function for the four datasets at HS-1-LB position. Primary model, HS-1-LB (green), KG-1-LB model (purple), H1 (red) and M1 (blue).

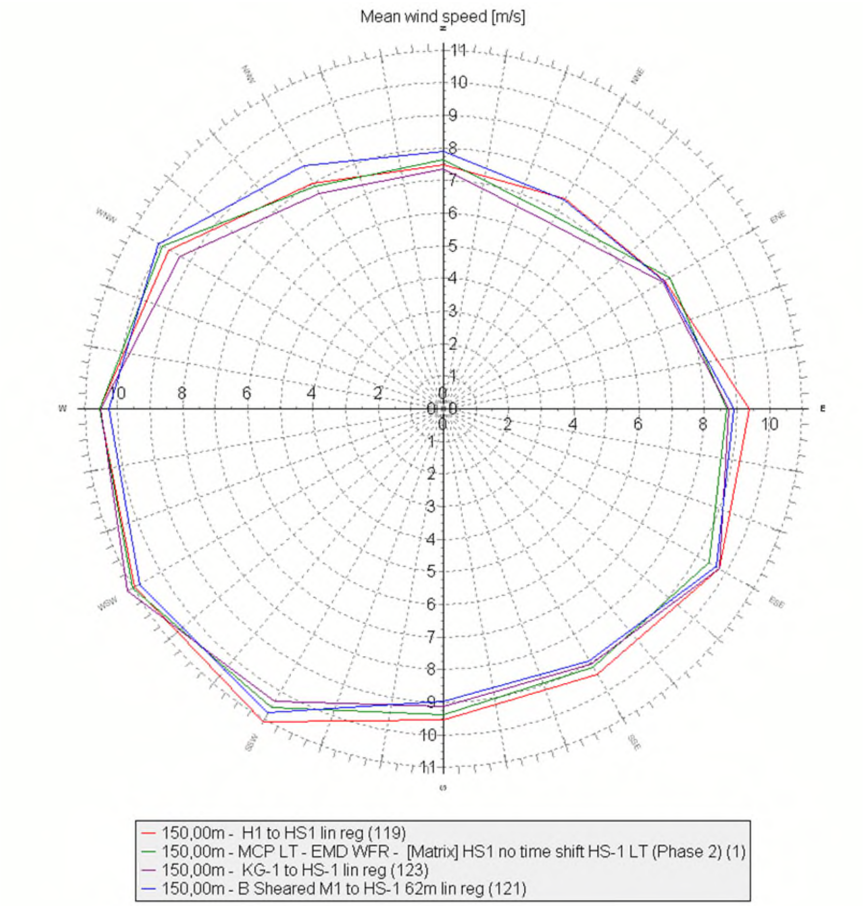


Figure 32. Mean wind speed per direction for the four datasets at HS-1-LB position. Primary model, HS-1-LB (green), KG-1-LB model (purple), H1 (red) and M1 (blue).

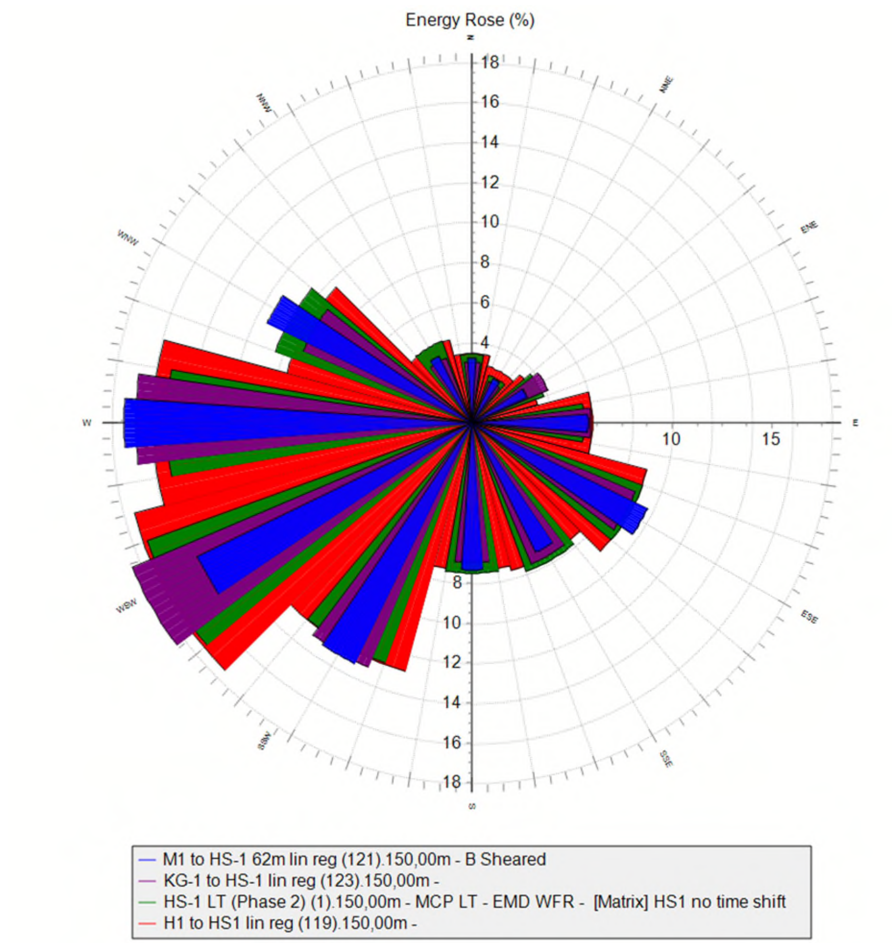


Figure 33. Directional distribution of the four long-term wind models at HS-1-LB position. Primary model, HS-1-LB (green), KG-1-LB model (purple), H1 (red) and M1 (blue).

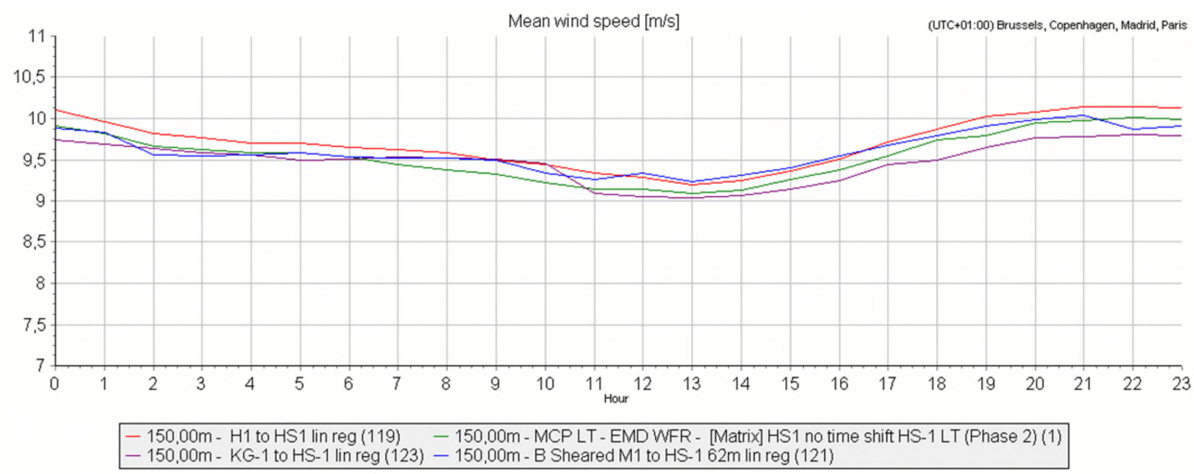


Figure 34. Diurnal wind speed of the four long-term wind models at HS-1-LB position. Primary model, HS-1-LB (green), KG-1-LB model (purple), H1 (red) and M1 (blue).

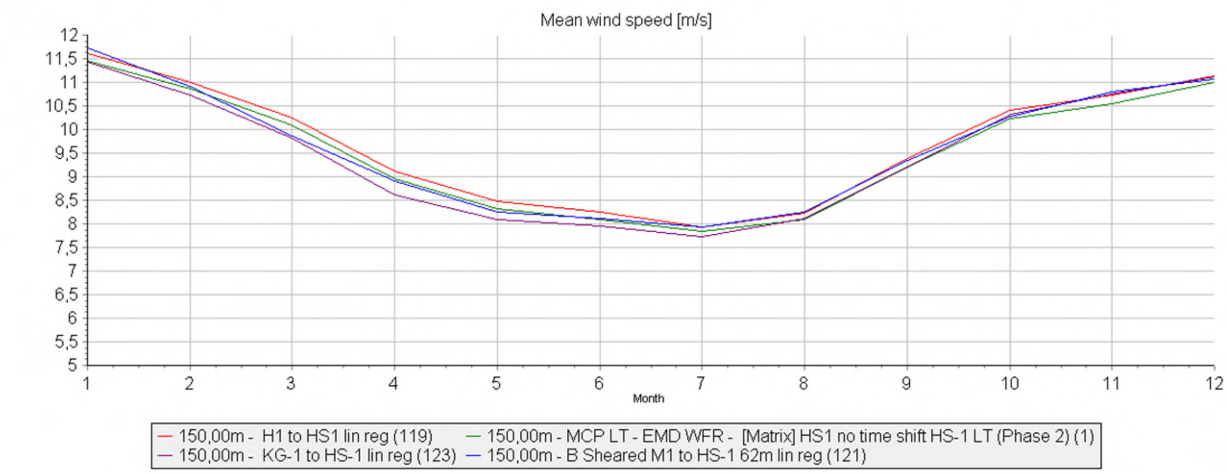


Figure 35. Seasonal variation of the four long-term wind models at HS-1-LB position. Primary model, HS-1-LB (green), HS-1 model (purple), H1 (red) and M1 (blue).

7.3 Uncertainty of Primary Wind Model

7.3.1 Measurement Uncertainty

Uncertainty on measurements was discussed in section 4.6. The results are summarized in Table 21.

Table 21. Measurement uncertainty.

BUOY	TOTAL MEASUREMENT UNCERTAINTY
HS-1-LB	2.31%

7.3.2 Long-term Correction Uncertainty

The long-term correction uncertainty consists of components with very low uncertainty (correlation, reference consistency, reference period length) and one component with moderate uncertainty, which is the measurement period of 12 month. This is therefore the dominant uncertainty with very minor contributions from other components.

Based on [28], the combined long-term correction uncertainty of a 12-month period will range between 1.5% and 4%.

For the long-term correction three different references (EMD-WRF, ERA5 and NORA3) were tested using four different methods in a sensitivity analysis. The standard deviation on predicted wind speed of these was 0.4%. Alternatively, the range from minimum to maximum resulting wind speed can be used as an indicator of the uncertainty. This range is 1.3% for HS-1-LB.

We therefore consider an uncertainty on long-term correction of 1.5% a reasonable value for long-term correction of the primary data from the buoy.

7.3.3 Very Long-term Uncertainty

The future climate uncertainty is the potential difference in mean wind speed of the next 20 years from the past period considered in the wind study. Northern Europe is subject to longwave oscillations meaning that a 20-year operation period can be quite different from the very long-term average. As suggested by [28], we estimate that for a 20-year dataset in this region this uncertainty is 1.5 % on wind speed.

This is supported by [29] who indicates a 20-year multidecadal variability amplitude of the Kattegat on yield around 3%. Given a yield to wind speed ratio near unity, this translates well to wind speed and results in an uncertainty of wind speed of 1.5%.

While the reference period applied in this study is 22 years, we do not consider this materially different when considering the conclusions above for a 20-year reference period.

7.3.4 Year-to-year Variability

Based on the annual variation on the EMD-WRF data the inter-annual variability is 4.1% at HS-1-LB. Over a 20-year lifetime this uncertainty is reduced to 0.9%.

7.3.5 Total Uncertainty

The uncertainty components are combined to a total wind speed uncertainty. A total is given for 1- and 20-year periods.

The results from the secondary data provide a standard deviation on the four reported wind speed results for the HS-1-LB location at 1.0%. Due to the horizontal extrapolation distortion and in some cases poorer measurement uncertainty than at the buoy, the uncertainty on the transferred secondary data should be considered higher than on the local data, however the standard deviation of the results from the four different models remain within the uncertainty of the total wind speed uncertainty of the primary model (Table 22) and therefore confirms the primary model.

Table 22. Combined uncertainty on long-term wind data. Uncertainty given as one standard deviation wind speed.

	HS-1-LB	
WIND DATA UNCERTAINTY	1 YEAR	20 YEARS
Measurement uncertainty	2.31%	2.31%
Long-term correction uncertainty	1.5%	1.5%
Very long-term uncertainty	1.5%	1.5%
Annual variability	4.1%	0.9%
Total	**5.16%**	**3.27%**

8 Flow Modelling

To calculate the wind resource for the whole Hesselø South OWF area from the primary wind model (long-term corrected LiDAR data), it is necessary to establish a flow model to account for the variation in wind speed distribution across the site. This modelling is used to calculate the wind resource at three additional positions (HS-A, HS-B and HS-C) within the Hesselø South OWF area and a wind resource map for the whole development area.

8.1 WFR Model

Due to the distance from the coast, a mesoscale modelling is most suitable for flow modelling on the Hesselø South OWF area. EMD has customized WRF model runs including the wake energy drain from the existing wind turbines at Anholt wind farm. This wind farm is located at the closest about 25 km from the northern boundary of the Hesselø South area, in northwest direction.

The wake influence of the planned Kattegat OWF has not been included in the model.

The WRF model used is version 4.5 with ERA5 data as the boundary data.

The wind turbines are represented in the WRF model using a Fitch scheme [30] with TKE advection.

A representative year is used as input data to reduce the calculation time, while to a sufficient degree maintaining the correct wind speed level and direction distribution.

The criteria for being a representative year is that the windiness index (production output index) must be close to unity and the wind direction distribution should be close to the long-term distribution. Windiness index is preferred to wind speed index as this ensures that the wind speed distribution in the range producing wakes is representative.

A twenty two-year period, 2002 to 2023 of EMD-WRF data was considered. From this period, 2012 to 2023 was excluded since it corresponds to the time where Anholt OWF was built and in operation. From the remaining period, the year 2004 was selected as representative with a windiness index of 99.4 and a direction distribution close to the 22-year average (Figure 36).

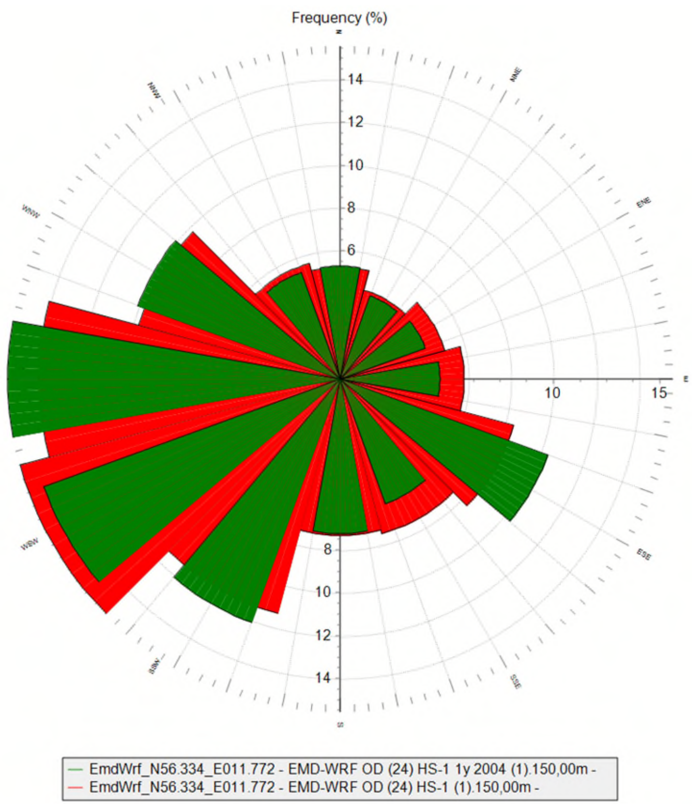


Figure 36. Direction distribution of EMD-WRF mesoscale data at HS-1-LB position in 2004 (green) compared to the 22-year period (red).

The WRF run is based on a domain of 200 by 200 km and produces a grid of time series with 1 km resolution, centered on the Hesselø South wind farm area.

The temporal resolution of the output time series is 1 hour (internal model steps are of the order of seconds to ensure numerical stability).

The simulation is run for two scenarios: a baseline scenario 1 with no wind turbines, and a scenario 2, with the currently operating wind farm of Anholt.

The relative change in wind speed between the two scenarios is presented in Figure 37, as the ratio on the average Weibull wind speed at 150 m height ASL between the two scenarios.

The impact of the Anholt wind farm on the wind resource is limited. Only the northwestern part of the Hesselø South OWF area is affected and that only mildly (<0.1%). The wind speed reduction in direct wake wind directions is higher, with a maximum of 0.4% reduction of mean wind speed along the northwestern edge of the wind farm zone. This direction is however not a main wind direction. It must be noted that the mentioned wind speed ratios consider all wind speed bins and arenot calculated per wind speed bins. It is expected that the impact of an operating wind farm is larger for the wind speed bins with high thrust curve values (5-20 m/s), and that the relative difference between the modeling with and without the Anholt turbine would then be wind speed dependent. Nevertheless, EMD has deemed that it was not necessary to generate mesoscale modelling by wind speed bin because the impact is small and concerns wind directions with low frequency.

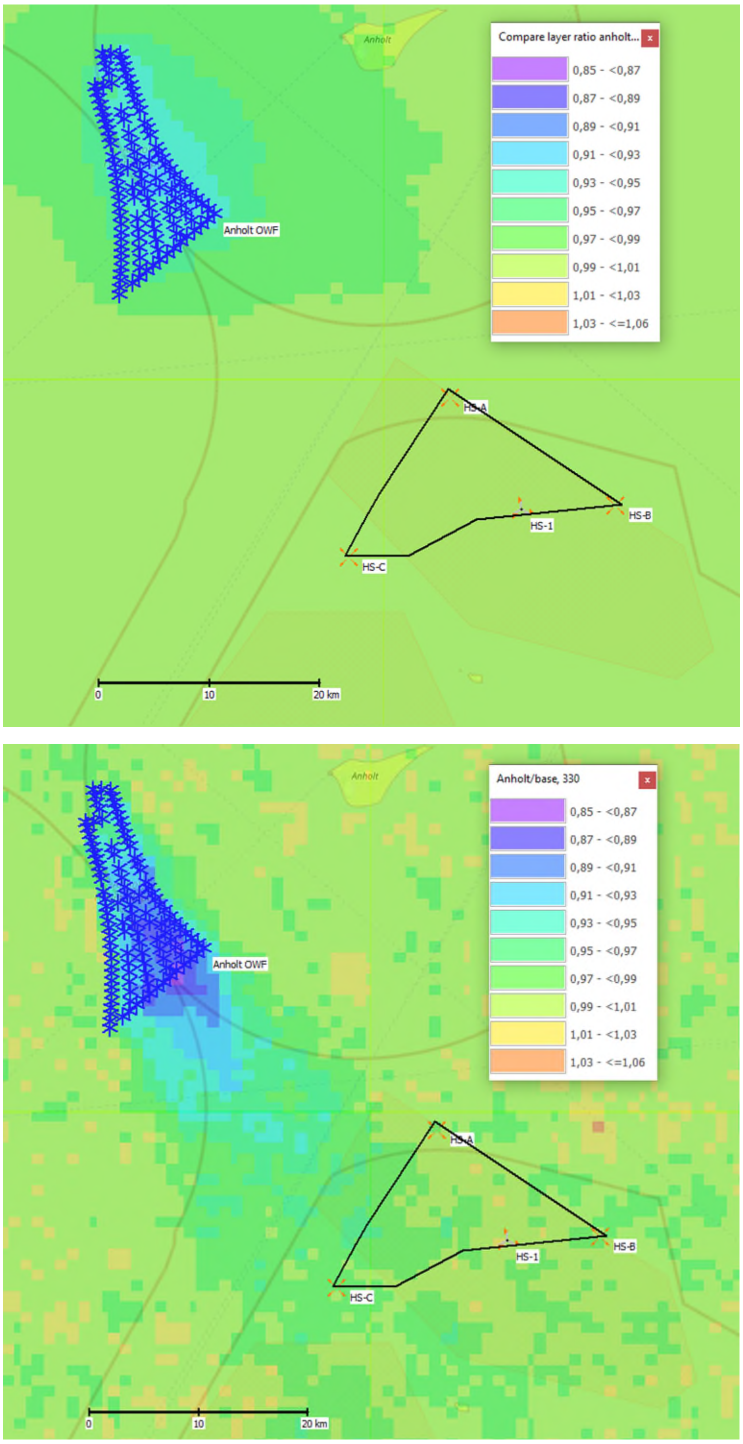


Figure 37. Map of the ratio between Weibull mean wind speed calculated by mesoscale modelling with and without Anholt OWF; top for all wind directions; bottom: for the most impacted wind direction (330 degrees).

Finally, the mesoscale gradient file including the Anholt OWF is the WFR model used to calculate the wind resource in the project area, as presented in the following sections.

8.2 Wind Resource for Positions HS-A, HS-B and HS-C

The location of three additional positions (HS-A, HS-B and HS-B) for siting parameters have been provided by Energinet. The coordinates are presented in Table 23. The three positions are located in the extreme locations of the triangle formed by the area.

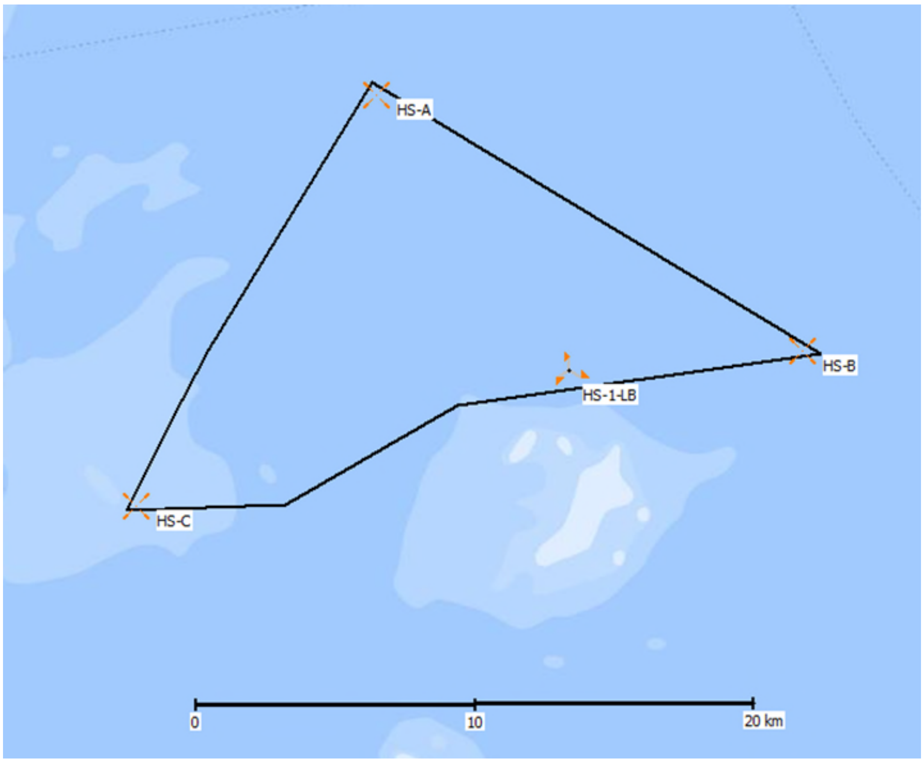


Figure 38. Location of the measurement point (HS-1-LB) and additional positions (HS-A, HS-B and HS-C) for siting parameters within the Hesselø South OWF boundaries.

Table 23. Coordinates for Additional Siting Parameters Positions

NAME	UTM WGS84 ZONE 32		GEOGRAPHICAL COORDINATES WGS84	
HS-A	664482	6256563	11.666997°	56.424910°
HS-B	679789	6247376	11.908553°	56.336895°
HS-C	655863	6241814	11.518653°	56.295454°

For HS-A, HS-B and HS-C, a long-term time series has been produced at 150 m ASL.

This is achieved through the gradient file method available in windPRO. With this method observed data are moved around the site using a mesoscale gradient file (section 8.1): Weibull A parameters of the Weibull distributions are read from the gradient map (the wind resource map) from the location of the observed data (HS-1-LB) and the prediction location (HS-A, HS-B and HS-C) and the ratio is applied to the observed time series. A specific ratio is found for each of 12 direction sectors. No change is made to the wind direction data.

The validity of this assumption is tested by comparing the long-term directional distribution of EMD-WRF data for the locations close to HS-1-LB, HS-A, HS-B and HS-C. There is a marginal difference in wind direction, but small enough to assume that a similar direction distribution is valid.

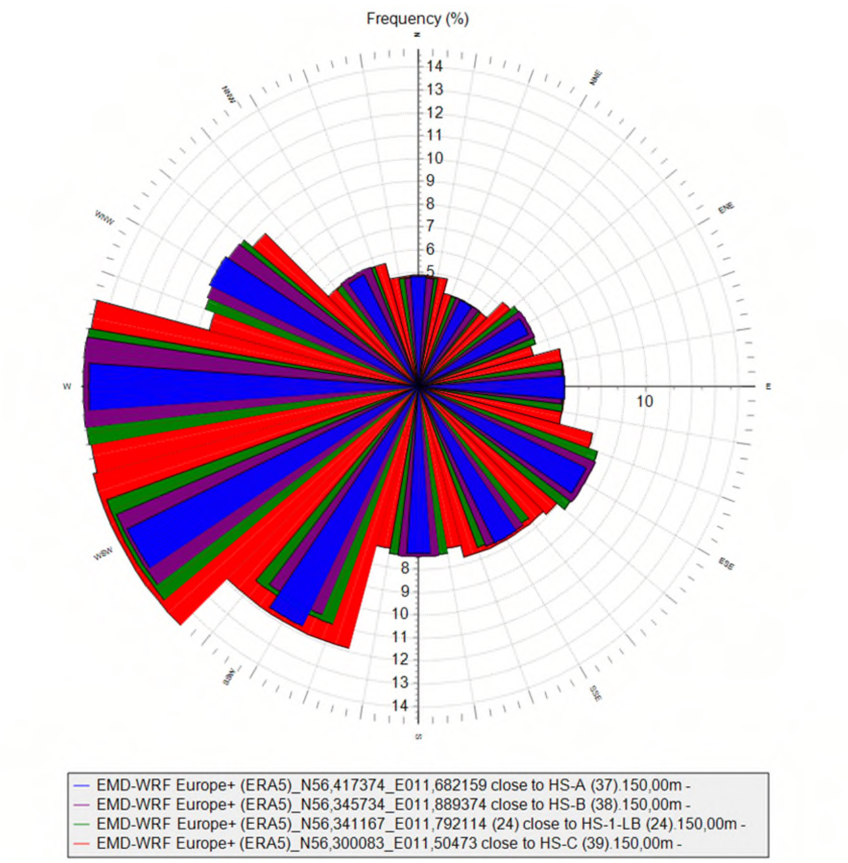


Figure 39. Comparison of 22 years direction distribution between EMD-WRF Europe + data for locations close to HS-1-LB (green), HS-A (blue), HS-B (purple) and HS-C (red).

For HS-A, HS-B and HS-C the resulting time series at 150 m was generated using the long-term corrected time series for HS-1-LB at 150 m and the mesoscale wind gradient.

With this method, a time series can be extracted for any location on the site using the wind data time series and the gradient file. The time series are included as deliverables. The time series for HS-A, HS-B and HS-C includes wind speed and wind direction for 22 years in an hourly resolution.

The arithmetic mean wind speed and Weibull parameters for HS-A, HS-B and HS-C are presented in Table 24. Details can be found in Appendix D.

Table 24. Weibull parameters of the long-term wind data, HS-A, HS-B and HS-C.

NAME	PERIOD [Y]	ARITHMETIC MEAN WIND SPEEDS [m/s]	WEIBULL MEAN [m/s]	WEIBULL - A PARAMETER [m/s]	WEIBULL - k PARAMETER
HS-A, 150 m	22	9.62	9.73	10.99	2.23
HS-B, 150 m	22	9.54	9.65	10.89	2.23
HS-C, 150 m	22	9.61	9.72	10.98	2.23

8.3 Wind Resource Map

The wind resource map for the Hesselø South area is calculated from the long-term corrected measurements at HS-1-LB and the mesoscale gradient calculated by the WFR modelling described above which includes the impact of Anholt OWF.

The resulting recalibrated wind resource map with 250 m resolution is presented in Figure 40 and provided as a deliverable.

As expected, the wind resource is increasing with the distance to the coast.

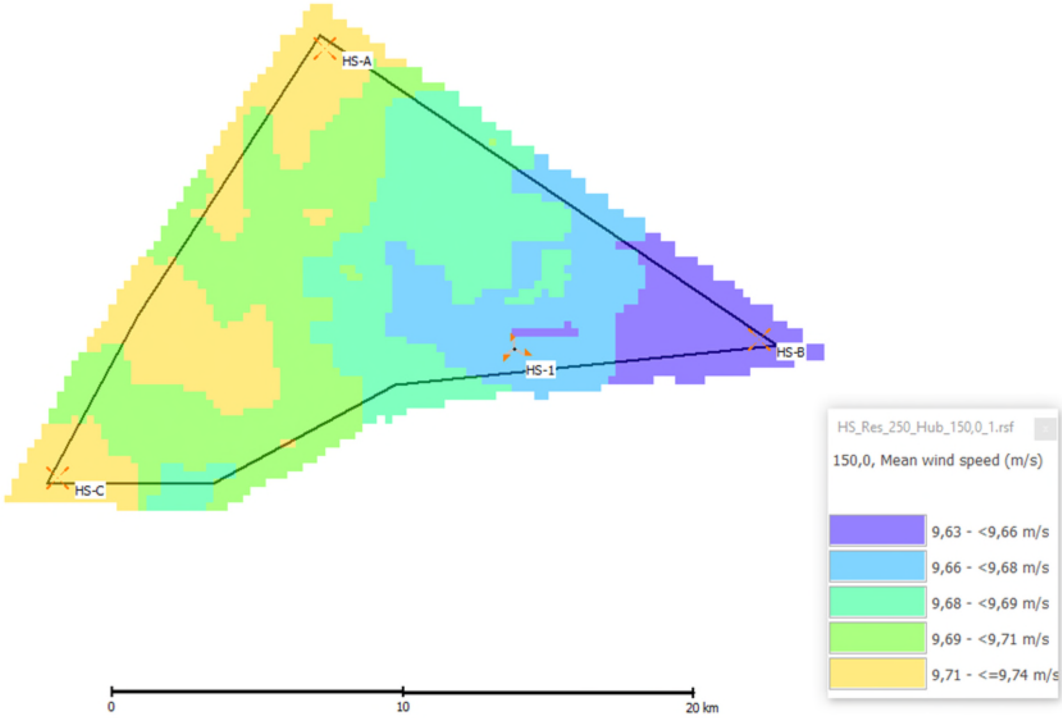


Figure 40. Wind resource map at 150 m for the Hesselø South OWF area.

9 Siting Parameters

This chapter outlines the requested siting parameters for assessment of structural integrity of wind turbines in accordance with the relevant design standards: IEC 61400-1 Ed. 4 [1], IEC 61400-3-1 Ed. 1 [2], IEC 61400-15-1 CD [6], DS 472 Ed 2. [5], and EN1991-1-4 including the Danish Annex DK NA EN1991-1-4 [3] [4].

For siting parameters that require turbine specific information, the following has been assumed.

Table 25. Turbine specific information used for siting parameters.

TURBINE SPECIFICATION	VALUE
Hub height	150 m
Rotor diameter	240 m
Cut-in wind speed	3 m/s
Cut-out wind speed	25 m/s
Wind turbine class	II

9.1 Normal Wind Conditions

Normal wind conditions have been derived in accordance with IEC 61400-3-1 Ed. 1 [2], IEC 61400-1 Ed. 4 [1] and IEC 61400-15-1 CD [6]. All parameters, except for the wind speed distribution, have been estimated as omnidirectional characteristic values. This is in line with the IEC 61400-3-1, which allows omnidirectional values to be considered for offshore sites that are far away from the coast where the environment generally exhibits little directional variation.

Due to the site location being offshore, the terrain is classified as “not complex” (terrain complexity factor is 1.0) and the wind flow is assumed without any inclination (flow inclination 0°).

9.1.1 Wind Speed Distribution

The 10-min mean wind speed probability distribution at hub height is modelled by a Weibull distribution for each direction [1]. The distributions are estimated based on long-term corrected data from the Hesselø South (HS-1-LB) LiDAR. Note that the temporal resolution of this data is 1 hour but according to IEC 61400-3-1 the long-term probability distribution of mean wind speed may be assumed to be independent of averaging periods between 10 minutes and 3 hours. The results are summarized in the table below. Mean wind speed is derived from the Weibull distribution. Details can be found in Appendix D.

Table 26. Weibull distribution parameters based on long-term corrected LiDAR data at 150 m ASL, HS-1-LB. Wind speeds are derived from the Weibull distribution.

SECTOR	A PARAMETER [m/s]	k PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [m/s]
Mean	10.91	2.23	100.00	9.66
0-N	8.53	1.84	4.88	7.58
1-NNE	7.86	2.29	4.22	6.97
2-ENE	9.08	2.10	4.94	8.04
3-E	9.95	2.35	6.33	8.82
4-ESE	10.76	2.50	9.10	9.55
5-SSE	10.44	2.46	8.26	9.26
6-S	10.68	2.26	7.71	9.46
7-SSW	12.18	2.44	11.05	10.80
8-WSW	12.57	2.54	14.31	11.16
9-W	12.01	2.44	13.38	10.65
10-WNW	11.33	2.17	10.05	10.04
11-NNW	8.93	1.98	5.77	7.92

Table 27. Weibull distribution parameters based on long-term corrected LiDAR data at 150 m ASL, transferred to HS-A. Wind speeds are derived from the Weibull distribution.

SECTOR	A PARAMETER [m/s]	k PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [m/s]
Mean	10.99	2.24	100.00	9.73
0-N	8.49	1.84	4.88	7.54
1-NNE	7.86	2.29	4.22	6.96
2-ENE	9.34	2.09	4.94	8.28
3-E	10.12	2.35	6.33	8.97
4-ESE	10.92	2.50	9.10	9.69
5-SSE	10.63	2.46	8.26	9.43
6-S	10.78	2.26	7.71	9.55
7-SSW	12.02	2.44	11.05	10.66
8-WSW	12.63	2.54	14.31	11.21
9-W	12.05	2.44	13.38	10.68
10-WNW	11.42	2.17	10.05	10.11
11-NNW	9.15	1.96	5.77	8.11

Table 28. Weibull distribution parameters based on long-term corrected LiDAR data at 150 m ASL, transferred to HS-B. Wind speeds are derived from the Weibull distribution.

SECTOR	A PARAMETER [m/s]	k PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [m/s]
Mean	10.89	2.23	100.00	9.65
0-N	8.55	1.84	4.88	7.60
1-NNE	7.88	2.29	4.22	6.98
2-ENE	9.12	2.10	4.94	8.08
3-E	9.76	2.34	6.33	8.65
4-ESE	10.62	2.49	9.10	9.42
5-SSE	10.56	2.46	8.26	9.36
6-S	10.64	2.26	7.71	9.42
7-SSW	12.22	2.44	11.05	10.84
8-WSW	12.52	2.53	14.31	11.11
9-W	11.91	2.44	13.38	10.56
10-WNW	11.50	2.17	10.05	10.19
11-NNW	8.85	1.97	5.77	7.85

Table 29. Weibull distribution parameters based on long-term corrected LiDAR data at 150 m ASL, transferred to HS-C. Wind speeds are derived from the Weibull distribution.

SECTOR	A PARAMETER [m/s]	k PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [m/s]
Mean	10.98	2.23	100.00	9.72
0-N	8.34	1.83	4.88	7.41
1-NNE	7.72	2.29	4.22	6.84
2-ENE	9.41	2.08	4.94	8.33
3-E	10.29	2.33	6.33	9.12
4-ESE	10.91	2.51	9.10	9.68
5-SSE	10.59	2.46	8.26	9.39
6-S	10.84	2.26	7.71	9.61
7-SSW	12.16	2.45	11.05	10.78
8-WSW	12.59	2.54	14.31	11.17
9-W	12.10	2.44	13.38	10.73
10-WNW	11.42	2.17	10.05	10.12
11-NNW	8.66	1.96	5.77	7.68

9.1.2 Normal Wind Profile (NWP)

The site-specific normal wind profile is characterised by the mean wind shear power law coefficient (α_c). According to IEC 61400-1 Ed. 4 [1] the site-specific omnidirectional characteristic wind shear should be evaluated as the energy-weighted average of the sector-wise values.

The repaired 12 months LiDAR dataset was used to calculate the characteristic shear. Two values are offered: A power law coefficient based on heights 130 m, 150 m, and 170 m, the expected hub height range, and, secondly, the shear across to expected rotor range, based on 40 m, 150 m, and 260 m height data. For comparison purposes a shear is calculated for the Hesselø floating LiDAR (H1). Here 12 months of data are available, though for a different year. Hub height range shear is calculated for 120 m, 140 m, 160 m and 180 m. Rotor range shear is based on 40 m, 140 m and 240 m measurement heights. The shear values are consistent with the Hesselø South (HS-1-LB) LiDAR measurements. The results are summarised in the table below.

For position HS-A, HS-B and HS-C, the shear from HS-1-LB can be assumed.

Table 30. Site specific omnidirectional wind shear exponent.

WIND SHEAR POWER LAW EXPONENT [-]	HESSELØ SOUTH HS-1-LB (12 months)	HESSELØ H1(12 MONTHS)
Hub height range 130 m to 170 m	0.083	0.094
Rotor range 40 m to 260 m	0.086	0.096

WIND PROFILE CHARACTERISTICS

The observed wind profile at Hesselø South is presented as a function of heat flux (Table 31). The heat flux is obtained from EMD-WRF data at buoy location. Three distinct zones can be found Figure 41:

1. Negative heat flux, typical for stable conditions, with a clear link between shear and heat flux,
2. A middle range, typical for neutral condition, with a well-defined shear
3. Positive heat flux with a substantial scatter in shear.

The different regimes are summarized in Table 31.

Table 31. Range of observed shear by heat flux, Hesselø South

Kattegat (HS-1-LB)	LOW HEAT FLUX	CENTRAL RANGE HEAT FLUX	HIGH HEAT FLUX
Heat flux range	<5 W/m^2	5 – 25 W/m^2	>25 W/m^2
Frequency of range	15%	53%	31%
Typical shear range	0.1 - 0.3	0.00 - 0.1	-0.15 - 0.20

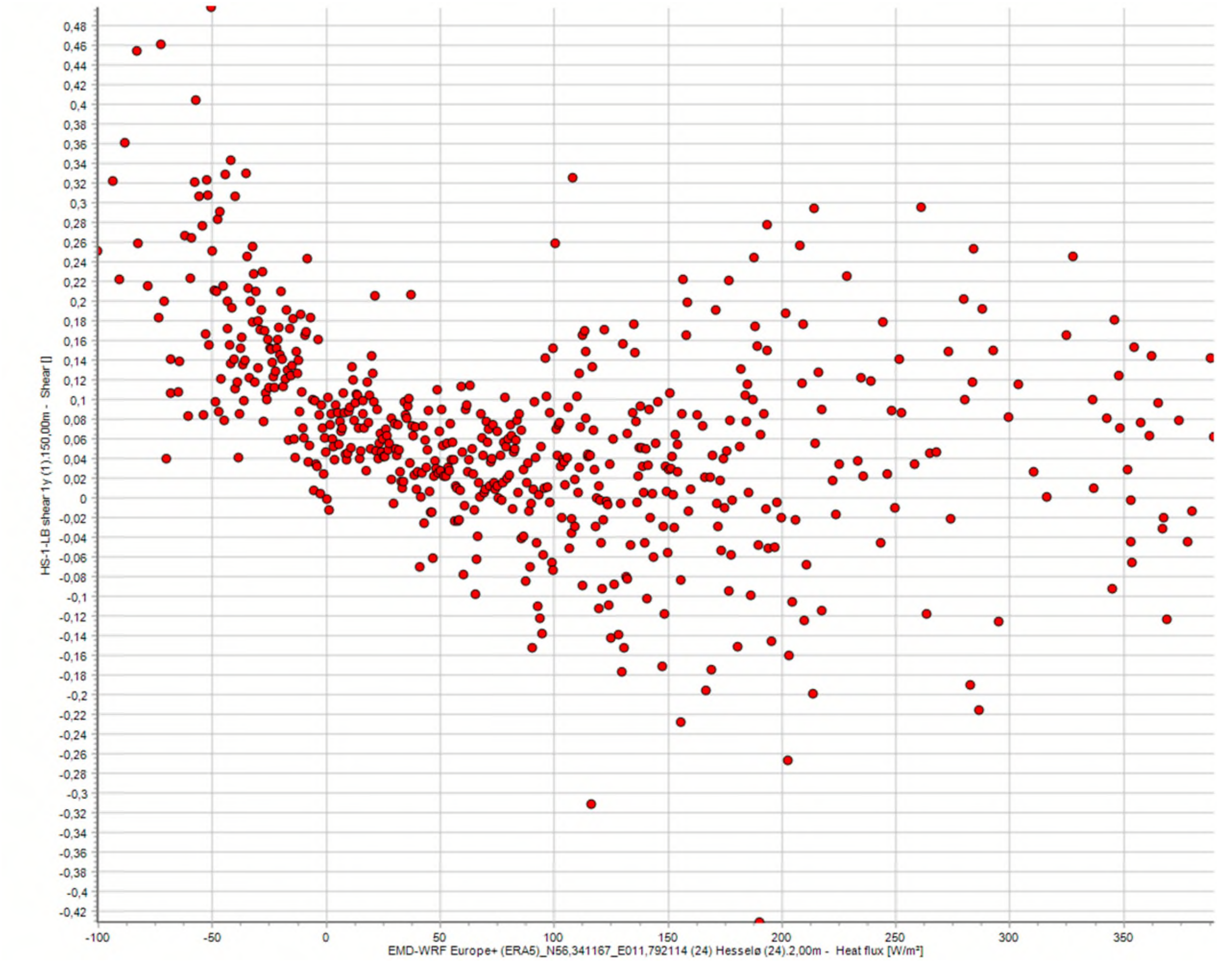


Figure 41. Shear power law coefficient as a function of heat flux at Hesselø South (HS-1-LB).

Stability classes are defined though the Monin Obukhov length, here using three categories as described in Table 32. The 1/L (rmol) signal in the EMD-WRF data is used to describe stability at Hesselø South in Figure 42. Stable conditions are fairly rare and typical for the spring months. Both stable and unstable conditions are suppressed at high wind speed. Note the difference in the prevalence of the stability classes based on heat flux and rmol. This is due to the strong dependency on friction velocity in the 1/L expression (used in the third power). For this reason, heat flux may be the better descriptor of stability conditions.

Table 32. Range of observed shear as a function of stability class at Hesselø South.

KG-1-LB	Stable	Neutral	Unstable
Inverse Monin-Obukhov length [m]	1/L > 0.005	-0.005 > 1/L > 0.005	1/L <- 0.005
Frequency	13%	29%	57%
Typical shear range	-1 - 1	-0.1 - 0.2	-1 - 1

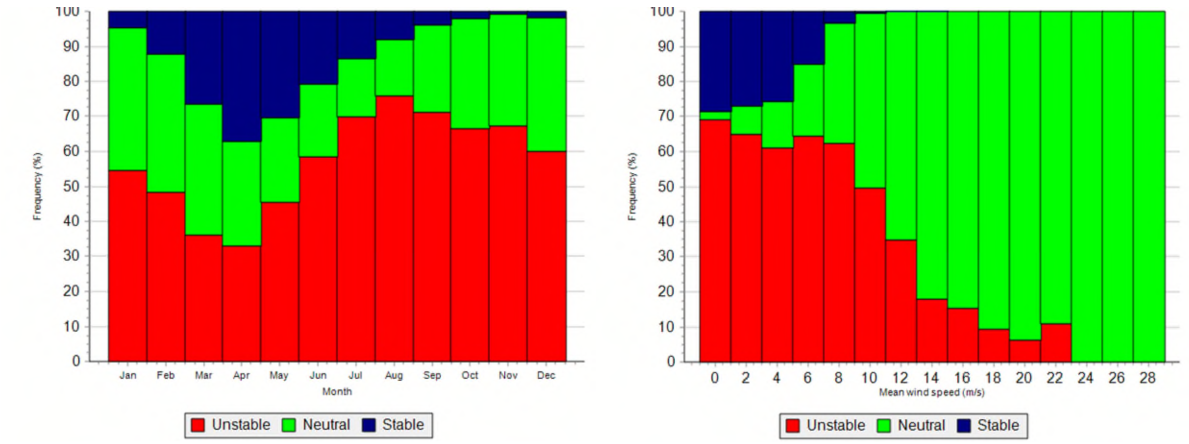


Figure 42. Frequency of stability classes as a function of month and wind speed, EMD-WRF at location of HS-1-LB.

Shear as a function of stability (1/L) at Hesselø South is presented in Figure 43. In this period, only in the neutral case is there a consistent shear. Both unstable and stable conditions are characterized by very large scatter in shear. This also demonstrates that 1/L has a weaker link to shear than heat flux does.

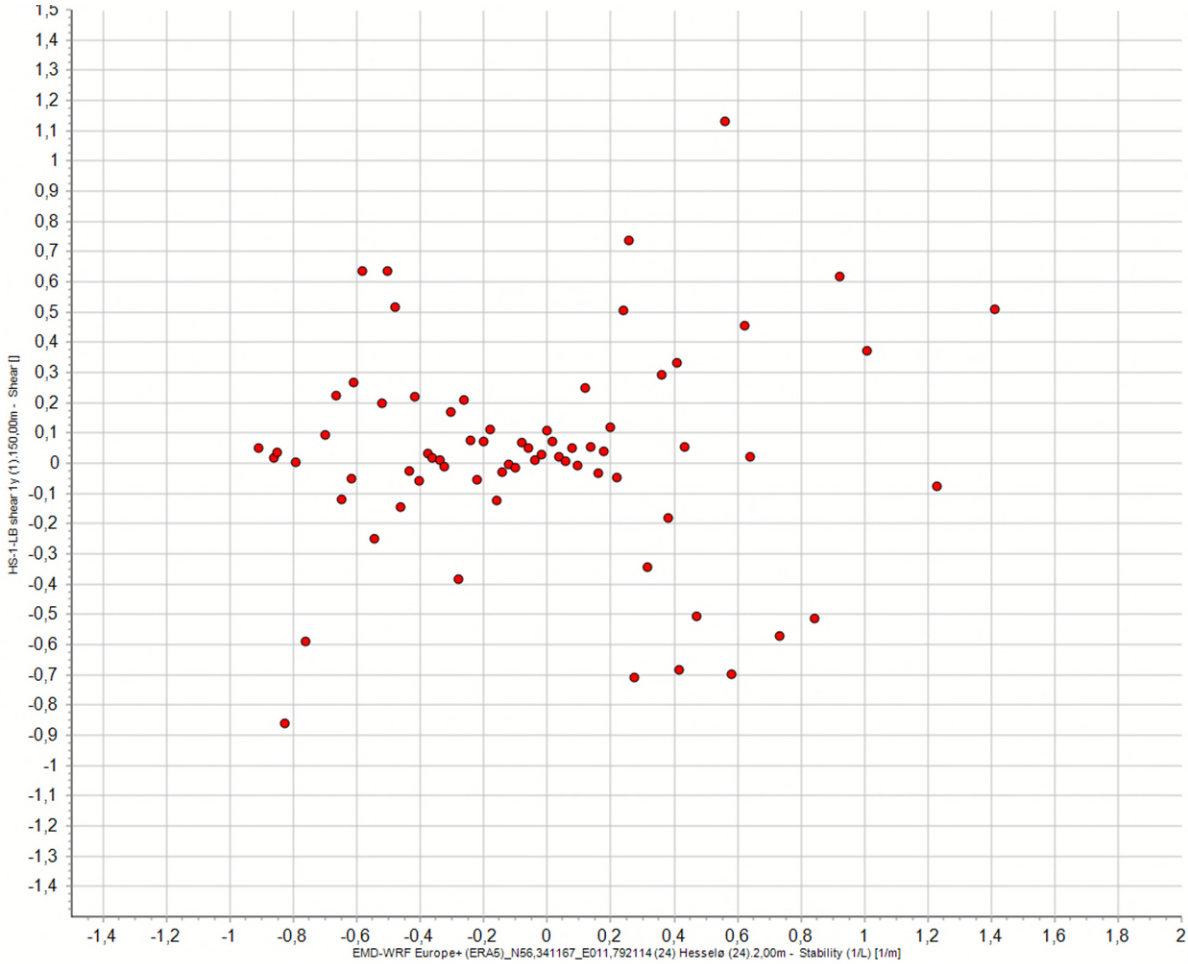


Figure 43. Shear coefficient as a function of stability (1/L), based on HS-1-LB and EMD-WRF data.

At offshore locations, the main driver of the shear coefficient is seasonal rather than diurnal and a plot of rotor radius shear as a function of month (Figure 44) fits well with distribution of stability over the year and shear for different stability regimes with higher shear and stability in spring months.

The monthly shear at Hesselø South (HS-1-LB) LiDAR is plotted against the monthly shear observed at the older Hesselø LiDAR buoy (H1). The H1 data was collected during a different year and while it demonstrates the expected difference in shear between summer and winter, it also shows that for individual months the shear can be quite different from year to year.

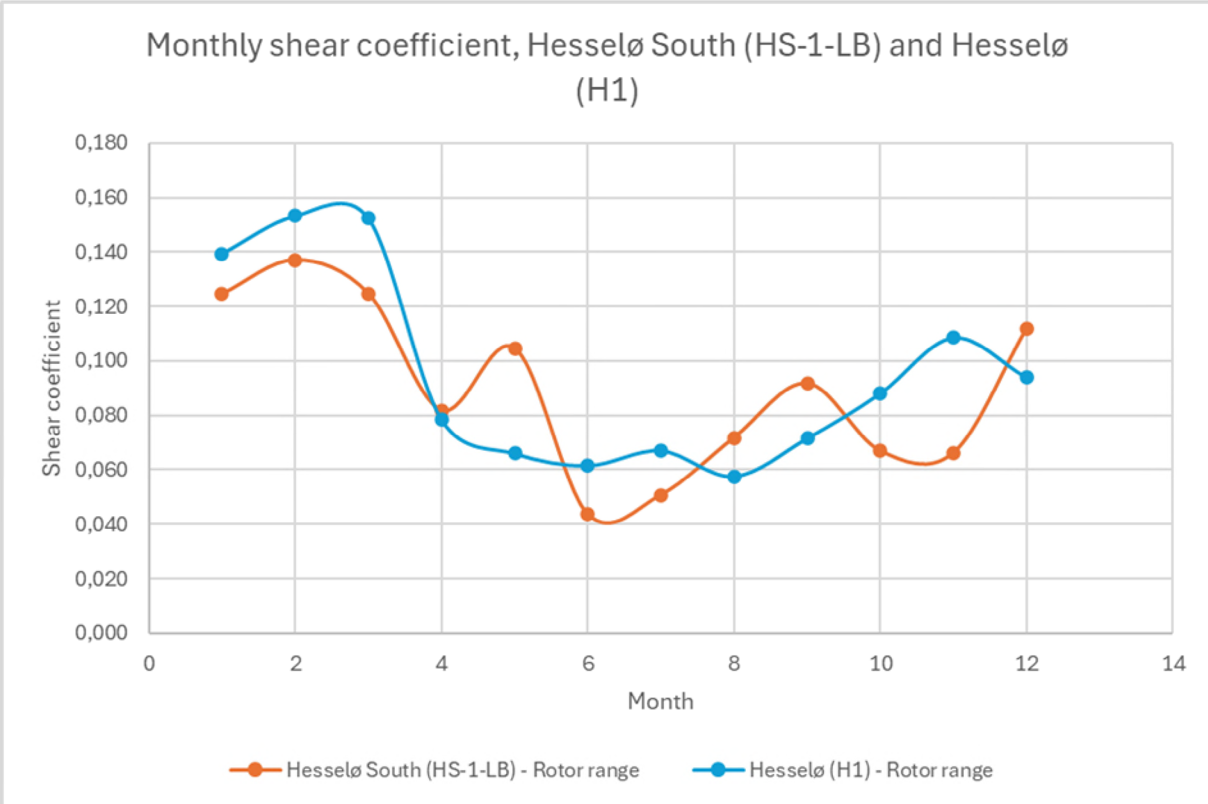


Figure 44. Monthly shear coefficient α across the rotor at Hesselø South (HS-1-LB) and Hesselø (H1).

9.1.3 Normal Turbulence Model (NTM)

TURBULENCE MODEL AND FIT

The normal turbulence model in the IEC 61400-1 [1] standard defines a linear relationship between the characteristic 90% quantile of turbulence ($\sigma_{c,90}$) and wind speed. For offshore sites, this is not representative, due to the Charnock effect, which adds a second order effect to the turbulence increase with wind speed [2]. A special purpose offshore model is therefore considered where the turbulence mean value (σ_μ) is modelled as a second order function of wind speed, and the turbulence standard deviation (σ_σ) is modelled as a linear function of wind speed. The models are outlined by the equations:

$$\sigma_\mu(u) = A_{\sigma_\mu} + B_{\sigma_\mu} u + C_{\sigma_\mu} u^2 \quad (1)$$

$$\sigma_\sigma(u) = A_{\sigma_\sigma} + B_{\sigma_\sigma} u \quad (2)$$

The characteristic turbulence required for structural design can be calculated by combining the two models as [1]:

$$\sigma_{c,90}(u) = \sigma_\mu(u) + 1.28\sigma_\sigma(u) \quad (3)$$

SELECTION OF TURBULENCE DATA

The models and safety factors forming the basis of the IEC 61400-1 and IEC 61400-3-1 are calibrated using turbulence measured by cup anemometers. LiDARs measure turbulence in a different way than cup anemometers, as they represent a volumetric average contrary to the point observation of a cup. No industry standard has yet been established to define corrections of LiDAR turbulence for use in site assessments and loads, although attempts are ongoing as e.g. CFARS. On top of this limitation floating LiDARs are exposed to wave movements which are amplified with increasing height. This movement appears as an additional contribution to the apparent turbulence seen by a floating LiDAR. As a consequence, floating LiDARs are not consistent with the requirements in IEC61400-1 or IEC61400-3 for assessment of turbulence and cannot be used to characterise the site turbulence.

Luckily, far offshore conditions are relatively uniform, at least regionally, which is documented in the highly relevant master thesis [31]. Causes of local variations are mainly due to coastal effects and changes in wave-seabed interaction in areas of shallow water affecting the waves. The closest alternative data sources based on cup anemometry, which are available to this study is the Læsø measurement mast. The Læsø mast is located 80 km north of the Hesselø South buoy at sufficient distance from shore, but at shallow water (5 m water depth) extending at least 10 km in all directions around the mast (Figure 45). EMD has investigated the turbulence data recorded at 62 m height ASL and find the turbulence conditions not representative to a deep-water site, like the Hesselø South site. For comparison, the Læsø turbulence data are presented in Appendix A.

EMD is in possession of more representative turbulence data for the Hesselø South site, but due to confidentiality these data cannot be disclosed.

Instead, a pragmatic solution is found by combining the turbulence model for the North Sea and the turbulence model for the Baltic Sea as reported by EMD for the Site Wind Conditions Assessment, Energy Island North Sea [32] and Site Wind Conditions Assessment, Energy Island Baltic Sea [33].

These two turbulence models are based on data from the FINO3 and FINO2 masts, both of which are located at similar water depth albeit in two different bodies of water(Figure 46 and Figure 47).

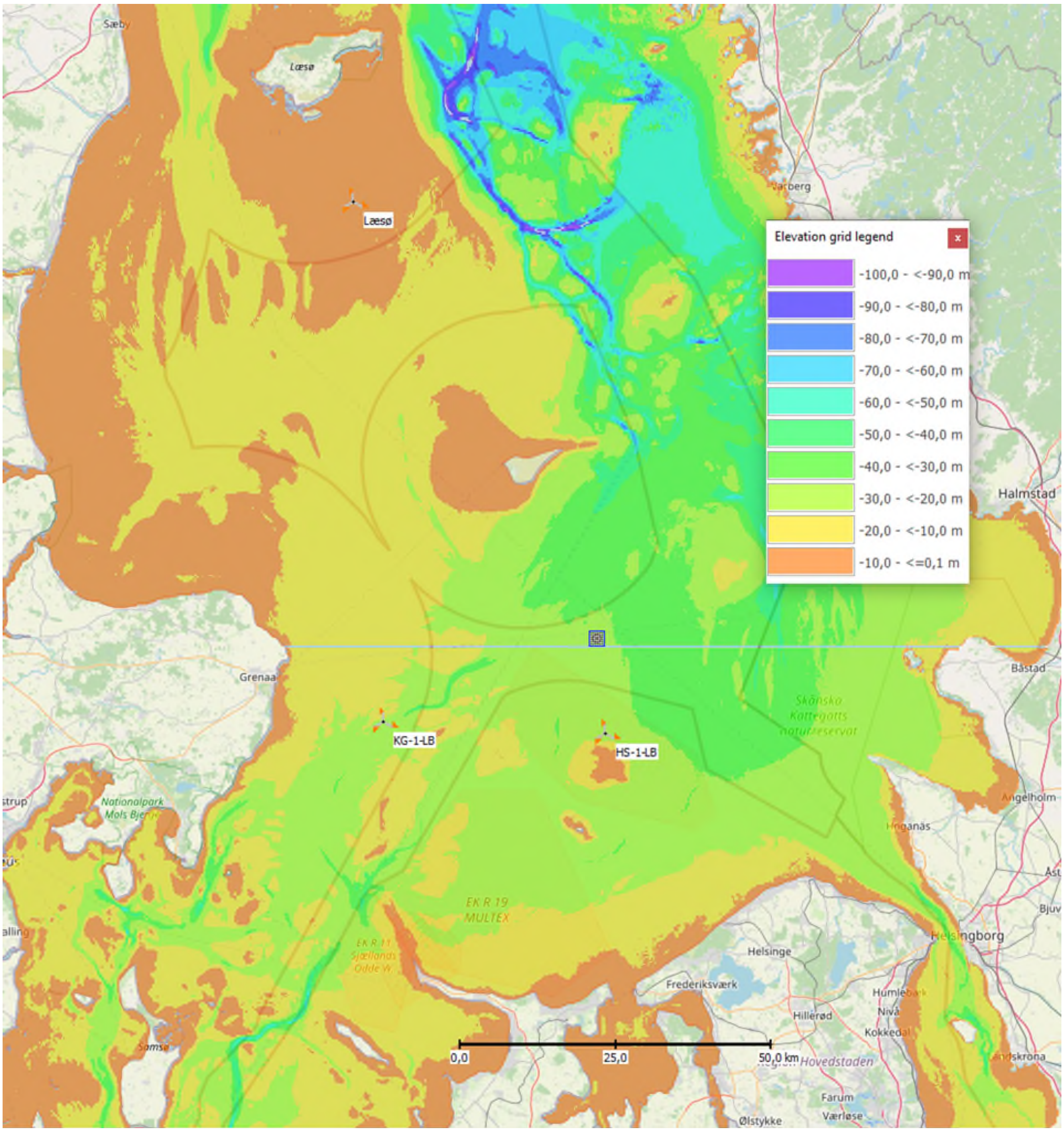


Figure 45. Plot showing the bathymetry of the Kattegat and the relative positions of the Læsø mast to the Kattegat (KG-1-LB) and Hesselø South (HS-1-LB) buoys.

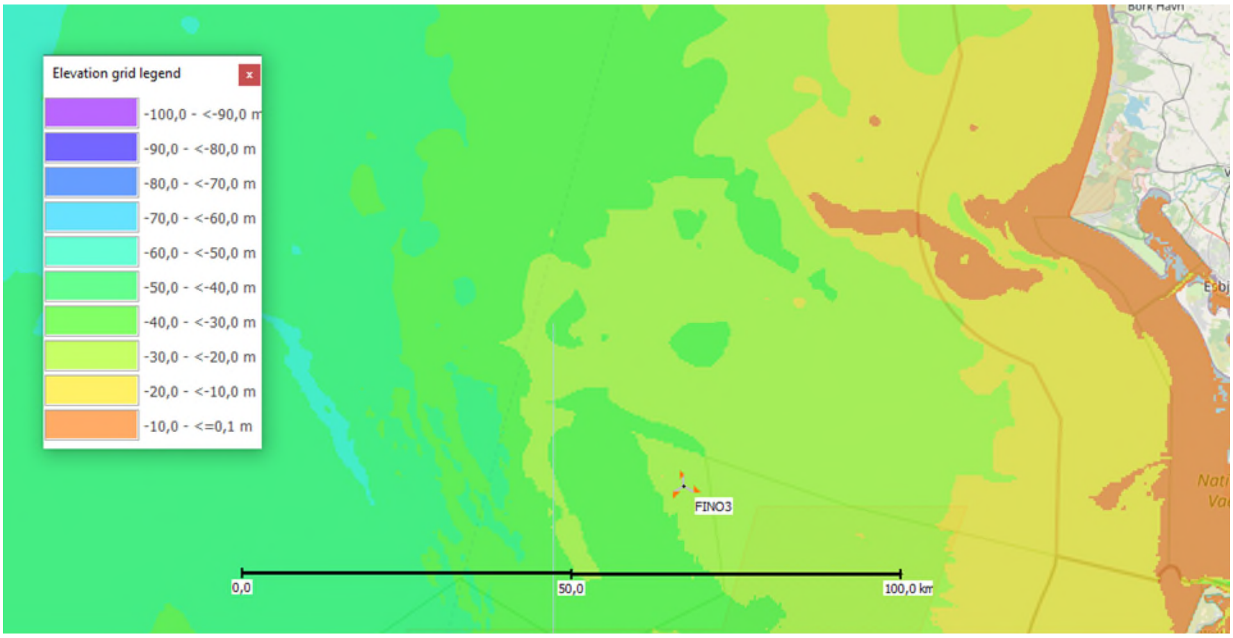


Figure 46. Water depth around the FINO3 mast.

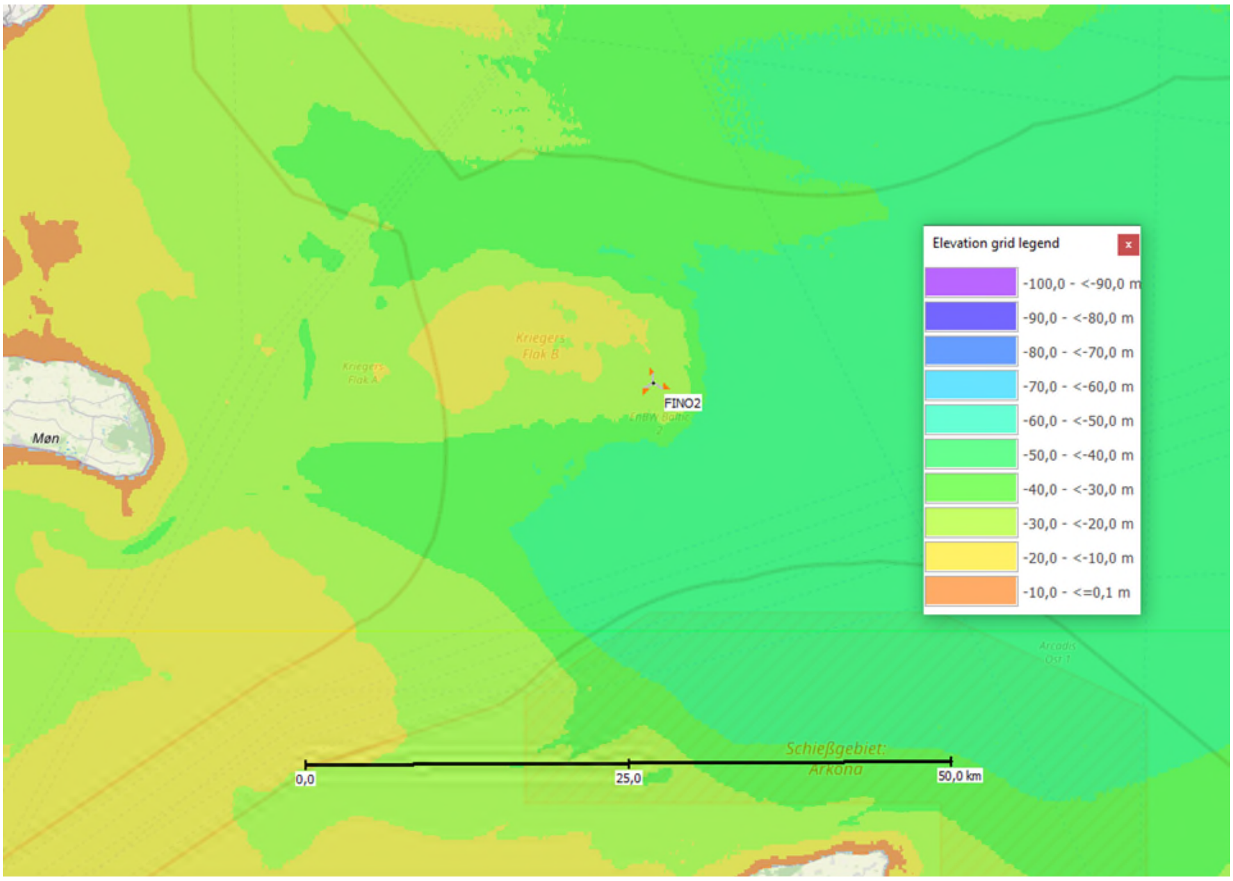


Figure 47. Water depth around the FINO2 mast.

The master thesis [31] documents that the turbulence level at a given height as a function of wind speed is surprisingly uniform and consistent across masts in the entire North Sea, even including the Irish Sea. While the two Site Wind Conditions Assessment reports document a difference between the North Sea and the Baltic Sea, it is a reasonable assumption that the turbulence conditions in Kattegat will form a gradient between the two bodies of water.

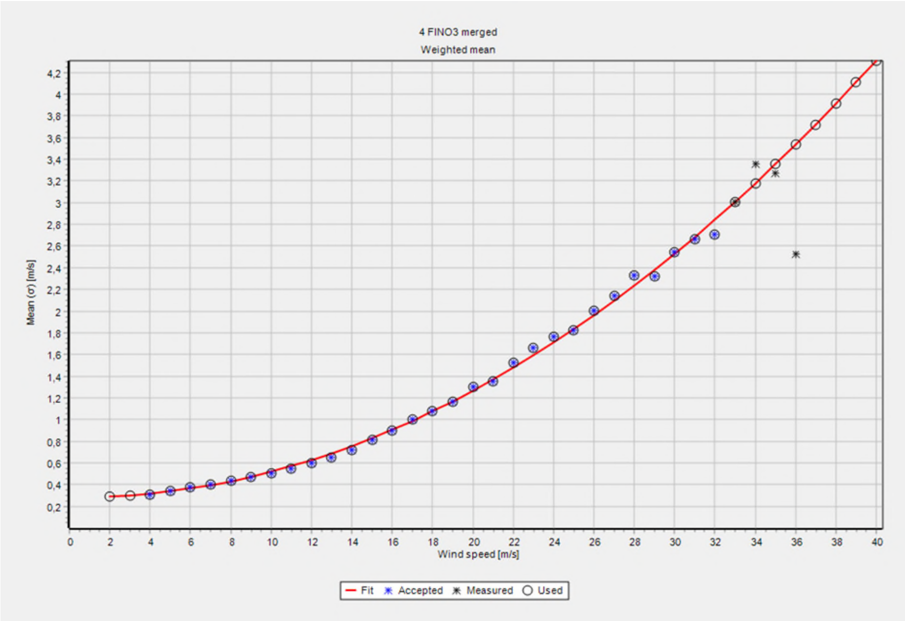
FINO3 was the primary source of turbulence information for the Site Wind Conditions Assessment, Energy Island North Sea where it was documented there that the FINO3 turbulence is representative of turbulence conditions in the North Sea. The measurements used for turbulence assessment is at 91 m height ASL. The FINO3 mast is described in Appendix A. The below presentation of turbulence at FINO3 summarized the findings of the Energy Island North Sea study [32].

FINO2 was the primary source of turbulence information for the Site Wind Conditions Assessment, Energy Island Baltic Sea where it was documented there that the FINO2 turbulence is representative of turbulence conditions in the Baltic Sea. The measurements used for turbulence assessment is at 102 m height AMSL. The FINO2 mast is described in Appendix A. The below presentation of turbulence at FINO2 summarizes the findings of the Energy Island Baltic Sea study [33].

FIT OF THE TURBULENCE AT FINO3

As described above, a second-order fit is required to fit the mean turbulence offshore whereas a linear fit is sufficient for the offshore standard deviation of turbulence. According to [2] turbulence may be considered omnidirectional far offshore, which is the setting for the FINO3 data and Hesselø South site, hence, the turbulence data are fitted independently of direction.

Figure 51 shows the turbulence observations and associated omnidirectional fits for the 91 m level at FINO3. Notice the clear non-linear effects for the mean turbulence due to wave interaction (i.e. the 'Charnock' effect).



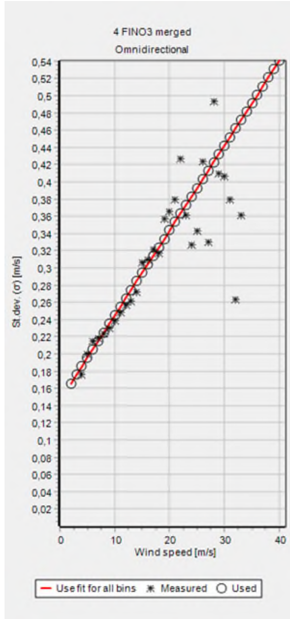


Figure 48. Left: observed mean turbulence versus wind speed at FINO3 91 m including the second order fit. Stars are observations and circles are model values. If the bin has enough samples the star is inside the circle and the bin will contribute to the fit. Right: observed standard deviation of the turbulence versus wind speed at FINO3 91 m including the first order fit.

VERTICAL EXTRAPOLATION AT FINO3

The target height of 150 m for the Hesselø South site means 64% extrapolation from the 91 m turbulence data at FINO3. Utilizing the variation of turbulence across the three measurement heights 51 m, 71 m, and 91 m has been considered for the vertical extrapolation model. Figure 49 shows the turbulence data (parameterized) at winds speeds from 5 m/s to 25 m/s as a function of height. For each wind speed a fit modelling the variation with height has been added as dashed lines. For the mean turbulence the best fit type is linear and shows as expected a decrease with height. The decrease with height increases with wind speed. For the standard deviation of turbulence, a second order fit is a better match, showing a slightly increasing positive gradient with wind speed but also an increasing nonlinearity.

Due to the large extrapolation, there is a high risk that turbulence gradients or fits for heights between 51 m and 91 m are not representative of the conditions from 91 m to 150 m. In particular, for the mean turbulence the fits predict a very strong decrease for large wind speeds, with an associated risk of non-conservatism for the resulting loads. Therefore, a simpler and more conservative vertical extrapolation model has been chosen for the mean turbulence. This model bases the extrapolation on the local wind shear as a function of wind speed ($\alpha(u)$) estimated at the Energy Island North Sea site. It reproduces the patterns of variation with height and wind speed seen in [31]. For the mean turbulence the wind speed in the expressions for mean and standard deviation of turbulence is scaled by the speed-up factor relative to 91 m due to the local wind speed dependent shear. This is consistent to assuming a constant wind speed standard deviation (i.e. turbulence mean) with height and assuming only the wind speed changes due to shear. This is in line with the proposal in IEC 61400-15-1 [6] that the wind speed standard deviation may be kept constant while wind speed is extrapolated upwards to hub height.

For the standard deviation of turbulence, the behaviour is opposite that for the mean as it increases with height, again showing stronger gradients at larger wind speeds. Hence, pragmatically the reverse model is adopted as it reproduces the general patterns in [31]. Both models lead to less adjustment of the original 91 m turbulence data and their expressions are given below, with *f(u)* representing the speed-up from 91 m to height *h* due to shear.

$$f(u) = \left(h/_{91m}\right)^{\alpha(u)} \tag{4}$$

$$\sigma_{\mu,h}(u) = A_{\sigma_\mu} + B_{\sigma_\mu}(u/f(u)) + C_{\sigma_\mu}(u/f(u))^2 \tag{5}$$

$$\sigma_{\sigma,h}(u) = A_{\sigma_\sigma} + B_{\sigma_\sigma} u\, f(u) \tag{6}$$

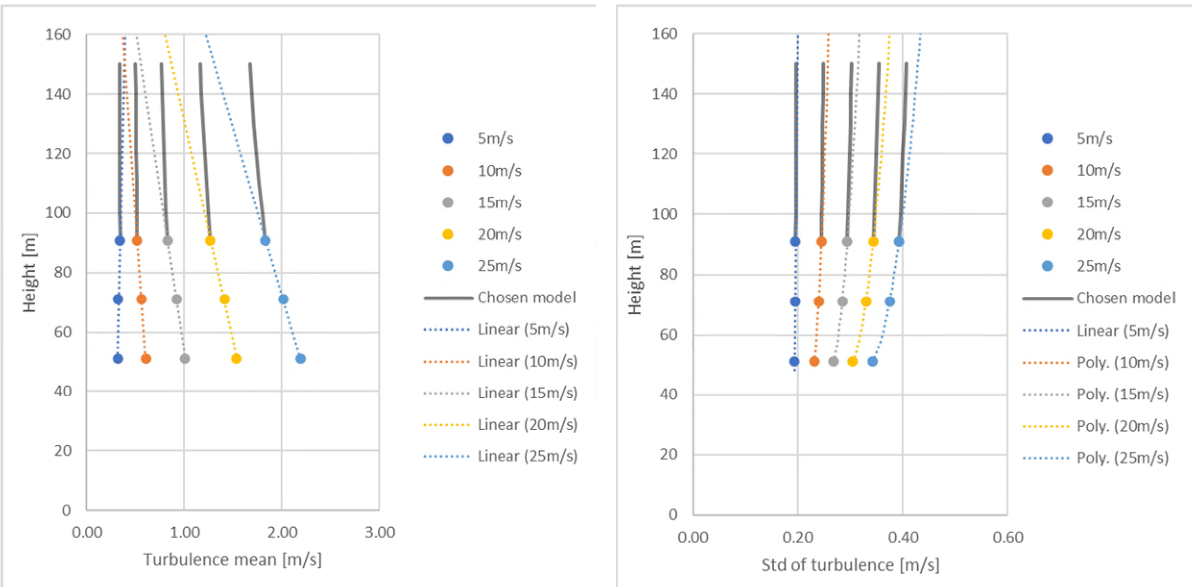


Figure 49. Variation of turbulence with height (y-axis) shown for wind speeds 5, 10, 15, 20 and 25 m/s. Turbulence mean (left) and standard deviation of turbulence (right), shown for the three heights at FINO3: 51 m, 71 m and 91 m, together with possible fits to extrapolate across heights as well as the chosen model based on scaling using the wind speed dependent shear.

The consequence of choice of vertical extrapolation model is shown in Table 33, which compares the mean, standard deviation and characteristic turbulence values at 15 m/s. As the table shows, the extrapolation based on the fitting of the height variation at lower heights ('extrapolation') leads to considerably lower turbulence levels than the shear scaling method described above. The shear scaling method is therefore preferred.

Table 33. Comparison of the extrapolation models at 150 m with observations at 91 m for the different turbulence values at a wind speed of 15 m/s at FINO3. The shear scaling is chosen as the final model for the North Sea.

at 15 m/s	TURBULENCE MEAN VALUE	STANDARD DEVIATION OF TURBULENCE	TURBULENCE CHARACTERISTIC VALUE
91 m observation	5.5%	2.0%	8.1%
150 m shear scaling	**5.1%**	**2.0%**	**7.7%**
150 m extrapolation through fitting of observations	3.7%	2.1%	6.4%

FIT OF THE TURBULENCE AT FINO2

As for FINO3, a second-order fit is required at FINO2 to fit the mean turbulence offshore whereas a linear fit is sufficient for the offshore standard deviation of turbulence. According to [2] turbulence may be considered omnidirectional far offshore, which is also the setting for the FINO2 data, hence, the turbulence data are fitted independently of direction. This also allows the exclusion of the wind direction interval from 340˚ to 40˚ where significant measurement disturbances were detected (see Appendix A).

Figure 50 shows the turbulence observations and associated omnidirectional fits for the 102 m level at FINO2. Notice the clear non-linear effects for the mean turbulence due to wave interaction (i.e. the 'Charnock' effect).

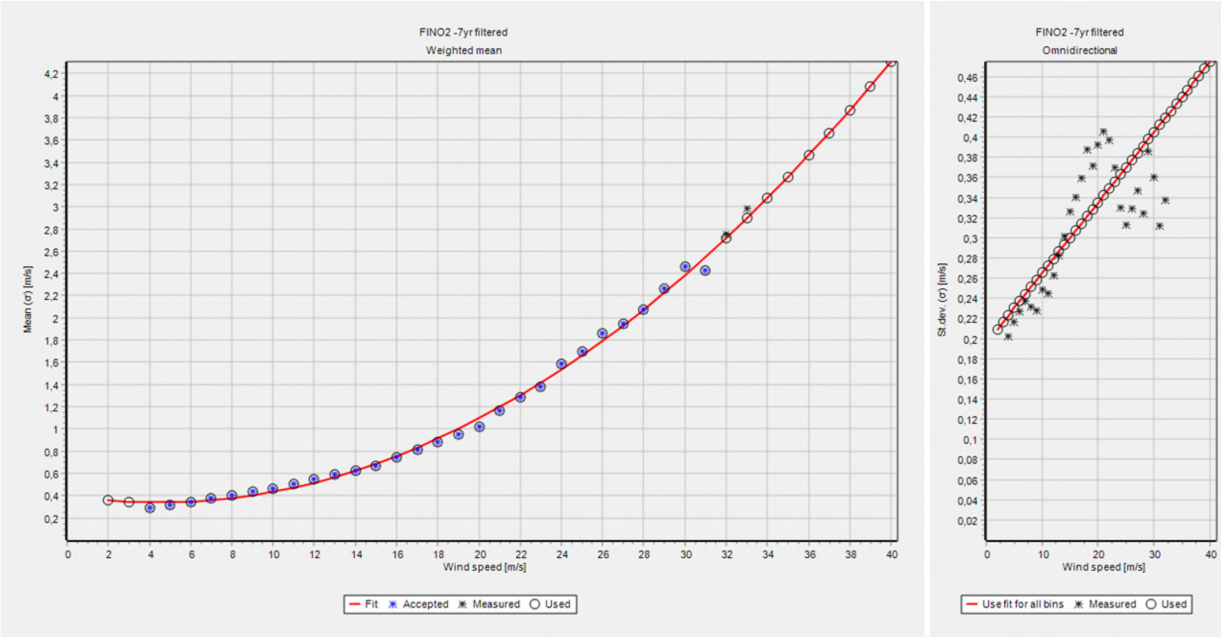


Figure 50. Left: observed mean turbulence versus wind speed at FINO2 102 m including the second order fit. Stars are observations and circles are model values. If the bin has enough samples the star is inside the circle and the bin will contribute to the fit. Right: observed standard deviation of the turbulence versus wind speed at FINO2 102 m including the first order fit.

VERTICAL EXTRAPOLATION AT FINO2

The target height of 150 m for the Hesselø South site means approximately 50% extrapolation from the 102 m turbulence data at FINO2. Utilizing the variation of turbulence across the eight measurement heights from 32 m to 102 m has been considered for the vertical extrapolation model. Figure 51 shows the turbulence data (parameterized) at winds speeds from 5 m/s to 25 m/s as a function of height. For each wind speed a fit modelling the variation with height has been added as dashed lines. For the mean turbulence the best fit type is linear and shows as expected a decrease with height. The decrease with height increases with wind speed. For the standard deviation of turbulence, a second order fit is a better match, showing a slightly increasing positive gradient with wind speed but also an increasing nonlinearity.

The extrapolation model used for FINO3 is also used on the FINO2 data. The local wind shear is here the observed shear at the Energy Island Baltic Sea.

It may also be noted that there is an odd jump from 92 m to 102 m on the standard deviation of turbulence curves. The jump results in a lower standard deviation of turbulence based on 102 m data than based on 92 m data and is consistent for all wind speed bins. Below 92 m results for all heights are consistent. The primary difference between the 102 m and the lower measurements is that 102 m anemometer is top mounted while at the lower heights they are side mounted on booms that are not long enough to be IEC compliant. Our understanding is therefore that the mounting of the side anemometers is the cause of a higher-than-expected standard deviation of turbulence and that the top mounted anemometer is correct. The extrapolation of standard deviation of turbulence is therefore based on the 102 m measurements.

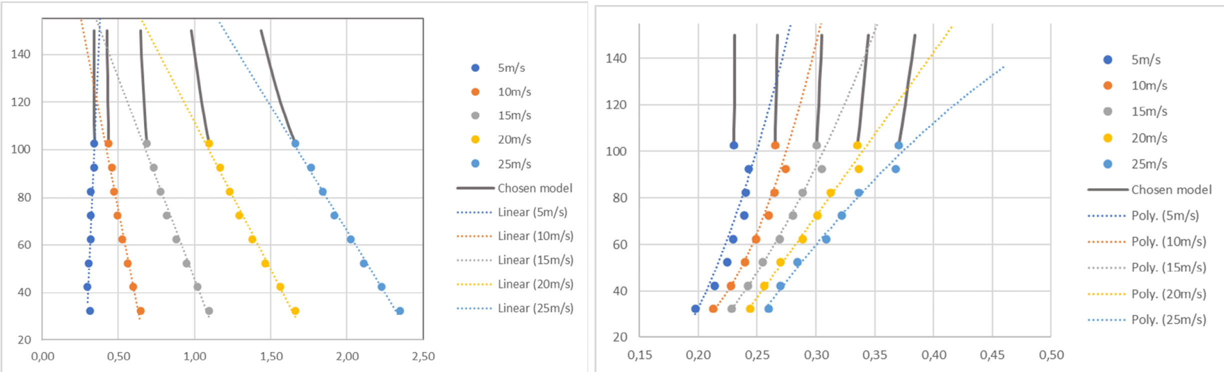


Figure 51. Variation of turbulence with height (y-axis) shown for wind speeds 5, 10, 15, 20 and 25 m/s. Turbulence mean (left) and standard deviation of turbulence (right), shown for the eight heights at FINO2: 32.4 m to 102.5 m together with possible fits to extrapolate across heights as well as the chosen model based on scaling using the wind speed dependent shear. Note the offset at 102.5 m for standard deviation of turbulence. The extrapolation is based on the top-mounted anemometer.

The consequence of the choice of vertical extrapolation model is shown in Table 34, which compares the mean, standard deviation and characteristic turbulence values at 15 m/s. As the table shows the extrapolation based on the fitting of the height variation at lower heights ('extrapolation') leads to considerably lower turbulence levels than the shear scaling method described above. The shear scaling method is therefore preferred.

Table 34. Comparison of the extrapolation models at 150 m with observations at 102 m for the different turbulence intensity values at a wind speed of 15 m/s at FINO2. The shear scaling is chosen as the final model for the Baltic Sea.

At 15 m/s	TURBULENCE MEAN VALUE	STANDARD DEVIATION OF TURBULENCE	TURBULENCE CHARACTERISTIC VALUE
102.5 m observation	4.6%	2.0%	7.1%
150 m shear scaling	**4.3%**	**2.0%**	**6.9%**
150 m extrapolation through fitting of observations	2.5%	2.3%	5.5%

COMBINED MODEL FOR KATTEGAT

As a pragmatic solution, the turbulence model suggested for the Kattegat body of water is an average of the North Sea and the Baltic Sea model.

The combination is done by averaging the turbulence model parameters (A, B and C) for mean turbulence and standard deviation of turbulence of the North Sea and the Baltic Sea models. The characteristic turbulence is then calculated from the resulting mean and standard deviation of turbulence.

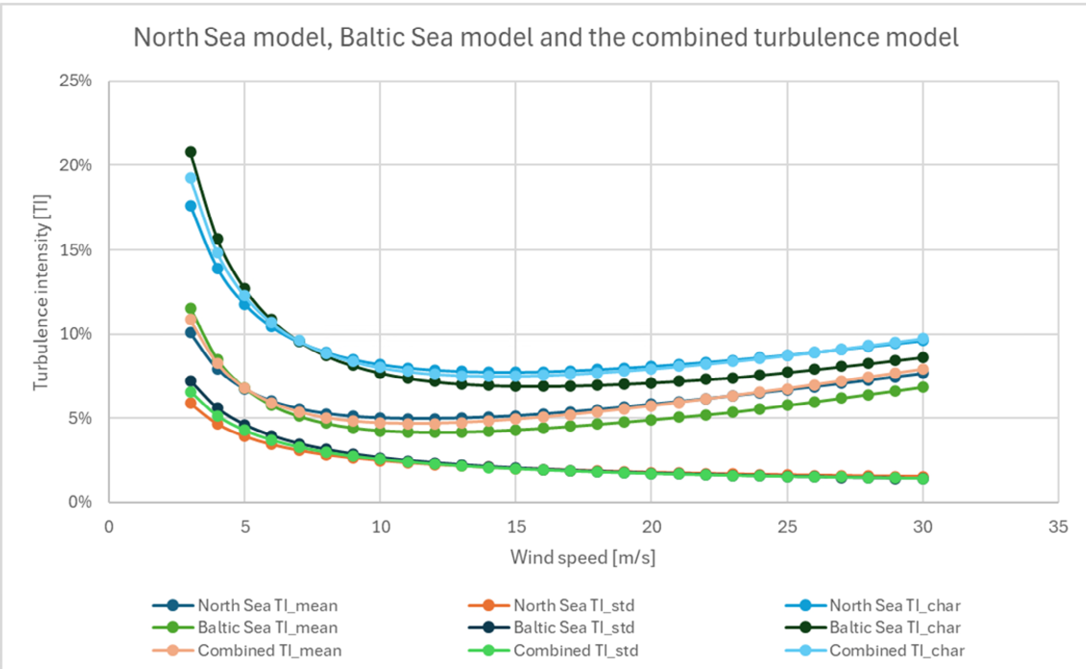


Figure 52. Turbulence intensity models for the North Sea and the Baltic Sea as well as the combined model for Kattegat, which is the average of the North Sea and Baltic Sea models. TI_mean signifies mean turbulence intensity, TI std is standard deviation of turbulence intensity and TI_char is the characteristic turbulence intensity.

EMD has verified the combined model for Kattegat with internally available data for the Kattegat region and finds a very good match with the combined model, especially on the characteristic turbulence intensity. The turbulence model should however be considered uncertain and EMD recommends obtaining local turbulence measurements from the Kattegat area.

Table 35. Turbulence intensity at 150 m for the North Sea model, the Balic Sea Model and the combined model for Kattegat.

at 15 m/s	TURBULENCE MEAN VALUE	STANDARD DEVIATION OF TURBULENCE	TURBULENCE CHARACTERISTIC VALUE
150 m North Sea model	5.1%	2.0%	7.7%
150 m Baltic Sea model	4.3%	2.0%	6.9%
150 m combined model	**4.9%**	**2.0%**	**7.5%**

Coefficients of the final turbulence model at the Hesselø South site are presented in Table 36. The chosen final model is based on the average of the North Sea and the Baltic Sea models. A, B and C represent the zeroth, first and second order terms, respectively.

Table 36. Turbulence model parameters at the Hesselø South site (150 m) for the chosen model. See equations (1), (2) and (3).

TURBULENCE MODEL PARAMETERS AT THE SITE	TURBULENCE MEAN VALUE	STANDARD DEVIATION OF TURBULENCE	TURBULENCE CHARACTERISTIC VALUE
A [m/s]	0.3446	0.1710	0.5634
B [-]	-0.0148	0.0086	-0.0038
C [s/m]	0.0027		0.0027

9.1.4 Air Density

Air density during normal wind conditions is characterised by its average value at hub height, which is here set to 150 m. Two sources for air density information have been used.

Based on long-term mean temperature found in section 9.1.5, air density is calculated at 150 m elevation assuming standard pressure at this height of 995 hPa. The resulting air density is for HS-1-LB is 1.229 kg/m^3. This is used as primary result.

Alternatively, the air density at 150 m elevation is estimated based on the recent Global Atlas and Siting Parameters (GASP). GASP is the outcome of an EUDP sponsored project by DTU and EMD [34] where site parameters such as air density are defined for the heights 50 m, 100 m and 150 m. The air density based on GASP data is found to be 1.227 kg/m^3 for position HS-1-LB, HS-A, HS-B and HS-C. This secondary result corroborates the primary result.

Hence the air density average value at 150 m ASL of 1.23 kg/m^3 is assumed.

Mean air density (150 m)	**1.23 kg/m^3**

9.1.5 Air Temperature

Air temperature was measured on the Hesselø South Buoy (4.1 m) throughout 12 months of operation. The average temperature measured during that period was 9.9°C. The temperature has been long-term corrected with EMD-WRF Europe+ data from the buoy location to 9.7°C. This temperature conforms with temperatures at surrounding meteorological stations Table 38.

The temperature at 150 m height has been found using the atmospheric lapse rate of -4.4 K/km derived from the EMD-WRF Europe+ data. The result is 9.0˚C at the Hesselø South buoy.

The EMD-WRF Europe+ time series at 150 m has been calibrated to represent the LiDAR position at 150 m height by applying and offset 0.7˚C (difference between EMD-WRF Europe+ and measurements). The resulting time series has then been used to estimate how many hours the temperature is outside the normal and extreme temperature ranges defined in the IEC 61400-3-1 as -10°C to 30°C and -15°C to 40°C, respectively. The results are summarized in Table 37. The probability of temperatures falling outside the defined ranges is assessed by Gaussian distributions fitted to either the 10% highest or lowest temperatures [35].

For HS-A, HS-B and HS-C, the same temperature as at HS-1-LB can be assumed.

Table 37. Temperature assessment at HS-1-LB – Hesselø South buoy (150 m).

CHECK	TMIN [°C]	TMAX [°C]	< TMIN [H/YEAR]	> TMAX [H/YEAR]	TOTAL HOURS OUTSIDE RANGE [H/YEAR]
Normal range	-10.0	30.0	2,892	0.400	3.29
Extreme range	-15.0	40.0	0.041	0.000	0.041
Mean air temperature				9.0°C	
Standard deviation air temperature				6.6°C	
Maximum temperature				29.2°C	
Minimum temperature				-10.2°C	

Table 38. Temperature measurements from surrounding stations.

STATION	HEIGHT ASL [M]	PERIOD LENGTH [Y]	TEMPERATURE [°C]
Anholt Harbour	10	24	9.7
Gniben	10	21	9.6
Hallands Väderö	2	28	9.3
Nakkehoved	10	23	9.2
Røsnæs Fyr	10	22	9.8
Sletterhage Fyr	10	22	9.5

9.2 Extreme Wind Conditions

9.2.1 Extreme Wind Speed Model (EWM)

The site-specific extreme wind speed model is characterized by the extreme wind speed with a 50-year return period [1], which for offshore conditions is supplemented by the extreme wind speed with a 1-year return period [2].

Typically, more onsite data is required to reliably estimate extreme events, than what is currently available to this project. The site-specific extreme wind speeds have therefore been estimated using the approach recommended by the Eurocode for wind loads on structures EN1991-1-4 [3] including its Danish Annex DK NA EN1991-1-4 [4] as well as the Danish Standard DS 472 [5]. This result is supplemented with alternative methods/data.

EN1991-1-4 [3] defines a fundamental value of the basic wind speed ($v_{b,0}$) which corresponds to a 50-year extreme wind speed at 10 m height, independent of direction and time of year and with a standard surface roughness length of $z_{0,II} = 0.05\ m$. Inland in Denmark this basic wind speed is set to 24 m/s [4]. It is specified that this value also covers the inner seas of Denmark where the current site is located.

Instead of the simplified method to vertically extrapolate extreme winds in EN 1991-1-4 [3], the dedicated flow model WAsP Engineering (WEng) has been used for this purpose. WEng includes the effects of waves, formulated by Charnock, including the effect of upstream fetch on wave development and resulting roughness and vertical speed-up. It is noted that atmospheric conditions are assumed neutral in WEng which matches with high wind speed conditions [36]. The analysis was performed through Site Compliance in windPRO with settings as shown below:

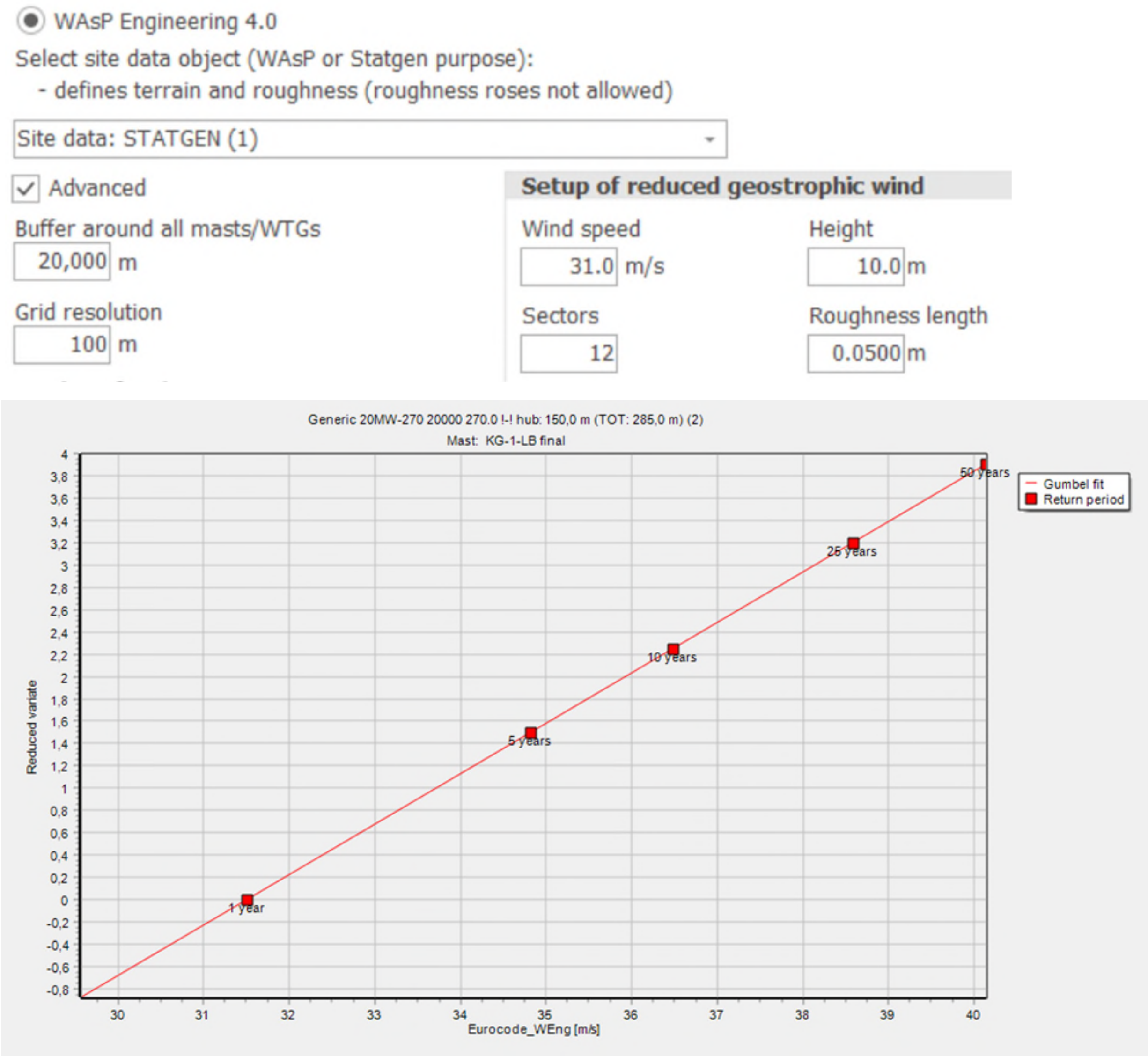


Figure 53. WAsP Engineering settings and output from modelling in windPRO, Site Compliance.

The resulting 1-year and 50-year extreme wind speeds are summarized in the table below:

Table 39. Extreme wind speed results at HS-1-LB (150 m).

TIME HORIZON	EXTREME WIND SPEED [m/s]
1-year	31.5
50-year	40.1

For comparison, we also include two alternative estimates of the onsite extreme wind speeds based on mesoscale data and the annual maximum method (AM) combined with a spectral correction to compensate for the use of mesoscale data, see e.g. [34]. For the method details of AM, see [37]. The spectral correction may be based either on a theoretical assumption about the slope of an undampened spectrum at high frequencies or on a site estimate of the actual spectral slope using onsite measurements. Below we include both spectral correction estimates, the theoretical and the site specific for the buoy.

Finally, as a fourth option the peak-over-threshold (POT) method is used based on the onsite buoy data.

Table 40. Extreme wind speed alternative results using different methods (150 m).

EXTREME WIND METHOD	50-YEAR EXTREME WIND SPEED [m/s]
EN1991-1-4 + WEng + DS472	40.1 (main result)
AM Mesoscale (20y) + Spectral correction (theoretical)	41.0
AM Mesoscale (20y) + Spectral correction (site specific)	41.3
POT (N=20, Δt_{min}=4 days)	40.0

It is noted that the alternative estimates are surprisingly consistent around 40 m/s even if they are based mostly on different data and statistical methods. However, using the Danish Standard [5] directly focused on offshore design conditions for wind turbines is still considered the best alternative as it is based on decades of building experience and knowledge of regional extremes condensed into the building codes.

9.2.2 Wind Shear at Extreme Wind Speed

The site-specific wind profile associated with extreme wind speed events has been estimated based on the on-site LiDAR data at the Kattegat and the Hesselø South buoys. The plot below shows the wind shear exponent versus wind speed at 150 m above sea level for the two buoys. The wind shear exponent is estimated for each time step and then averaged in 0.5 m/s bins. Notice the linear increase in shear from around 0.01 at 5 m/s, to 0.13 around 17 m/s. Above 17 m/s wind shear levels out at 0.17 but with a noticeable scatter.

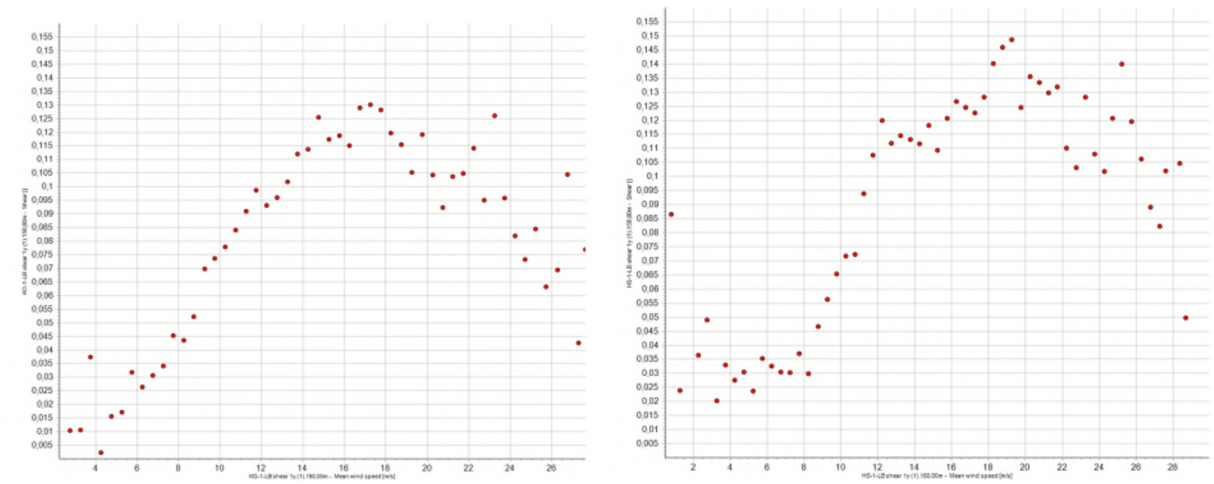


Figure 54. Observed wind shear versus wind speed (0.5 m/s bins) at the Kattegat KG-1-LB buoy (left) and the Hesselø South HS-1-LB buoy (right). For both buoys, the wind shear clearly levels off at around 0.13 for wind speeds above ca. 17m/s. At lower wind speeds the wind shear increases linearly.

Given these observations the expected wind shear at extreme wind speeds is summarized below.

Expected wind shear at extreme wind speeds	**0.13**

9.2.3 Extreme Wind Shear (EWS)

To estimate the site-specific extreme wind shear, it is recommended to use equations (27) and (28) in section 6.3.3.7 of the IEC 61400-1 [1] with site-specific values for the ambient turbulence standard deviation together with the site-specific wind shear exponent.

9.2.4 Turbulence at Extreme Wind speed

In addition to the extreme turbulence model, the IEC 61400-3-1 [2] requires that the site-specific turbulence for extreme wind speed is defined. Using the turbulence model defined in section 9.1.3 the turbulence is estimated at the site estimate of the 50-year extreme wind speed as shown below:

Table 41. Turbulence at extreme wind speed.

50-YEAR WINDSPEED (@HUB HEIGHT) [M/S]	TURBULENCE INTENSITY MEAN [%]	STD. DEV OF TURBULENCE INTENSITY [%]	TURBULENCE INTENSITY CHARACTERISTIC [%]
40.1	10.3	1.3	12.0

Wave development and growth is limited, such that, for a given wind speed, the significant wave height and peak wave lengths stop growing above a certain wind speed. In effect, this means that the sea surface roughness will eventually saturate as the wind speed becomes increasingly extreme, and the Charnock effect (second order effect) will cease to grow. In [38] and [39] it was reported that the 10 m wind speed required for saturation of the surface roughness is in the range 33-40 m/s while [40] indicates saturation at 35 m/s in 10 m height. In this work the latter saturation value of 35m/s at 10 m height is adopted. The saturation estimates correspond to a virtually infinite fetch, and prolonged wind duration for full wave development, it is therefore expected that the wind speed required for saturation at the real sites will be lower than 35 m/s, making this assumption conservative.

9.2.5 Extreme Turbulence Model (ETM)

The site-specific extreme turbulence model as function of wind speed (σ_{ETM}) is assessed using the peak factor method described in the IEC 61400-1 footnote 32 [1]:

$$\sigma_{ETM}(V_{hub}) = \sigma_{mean}(V_{hub}) + k_p(V_{hub}) \cdot \sigma_{stddev}(V_{hub}), \quad [7]$$

$$k_p = 0.01\left(\frac{V_{ave}}{(m/s)} - 21\right)\left(\frac{V_{hub}}{(m/s)} - 5\right) + 5 \quad [8]$$

Omnidirectional values are used for the mean wind speed (V_{ave}) as well as the mean and standard deviation of turbulence. The extreme turbulence values are plotted below:

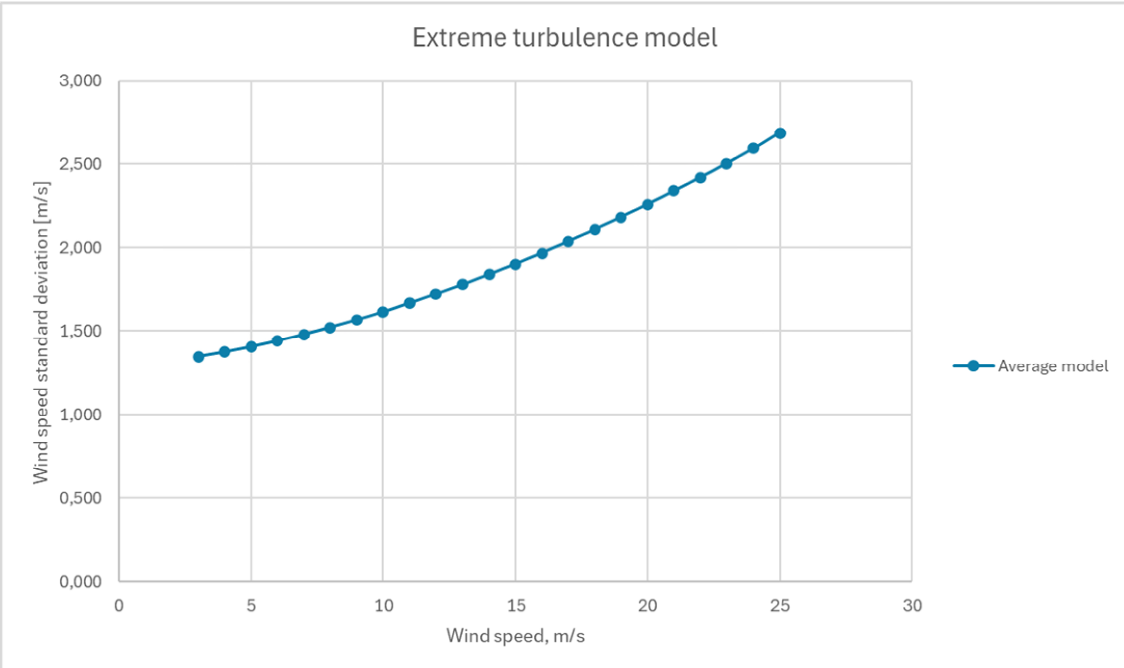


Figure 55. Extreme turbulence model. Turbulence is standard deviation of wind speed.

9.2.6 Air Density for Extreme Wind

The air density for extreme wind conditions is found based on average temperature at high wind speed events. This is calculated as 1.25 kg/m^3 for the position of HS-1-LB. Alternatively, the air density for extreme wind conditions can be taken from GASP [34], which results in a value of 1.22 kg/m^3.

It was decided to proceed with the air density for extreme wind speeds from the buoy.

Air density for extreme wind speeds (150 m)	**1.25 kg/m^3**

9.3 Additional Site parameters

9.3.1 Salinity

The IEC 61400-1 [1] does not specify details when assessing the salinity of the site. EMD proposes to use the salinity of the upper part of the water column as salinity figure. The water can form droplets at high wind speed which get in contact with the wind turbine structure.

The salinity is assessed though the Copernicus Marine Service [41]. The average salinity at surface level based on the period 2021-2024 is found to be 22.5 g/m2.

9.3.2 Lightning

The IEC 61400-1 [1] does not specify details when assessing the impact of lightning on the site. Based on data from NASA, Global Hydrology and Climate Center [42], the lightning frequency of the site is 1.18 flashes/year/km^2.

9.3.3 Solar Radiation

Based on Heliosat, SARAH3 data [43] the average solar irradiation during the period 2004 to 2024 is 121 W/m^2. Peak solar radiation does not exceed 880 W/m^2.

9.3.4 Earthquake

The site rates as Low Hazard with a peak ground acceleration of 0.22 m/s^2 [44]. With the low hazard rating, earthquakes need not be investigated further [2].

9.3.5 Relative Humidity

The HS-1-LB buoy measures the humidity near sea level. Based on 12 months of measurements the average relative humidity is 82.8% with a standard deviation of 9.6%.

9.4 Climate Change

In the context of this report, the impact of the climate change is consired relevant for the following signals types :

- Mean wind speed
- Extreme wind
- Temperature (and therefore air density)
- Rain (as being driver for blade degradation)

Of these parameters, all, except for extreme winds, are covered by the Copernicus Interactive Climate Atlas [45]. The atlas contains 25 models for each scenario. Two scenarios have been considered, SSP3-7.0 and SSP5-8.5, which are estimated to be the most realistic with the current development of emissions. The two terms which cover the operational period of the planned project are studied: near-term (2021-2040) and medium term (2041-2060).

For the relevant area in Hesselø South the Copernicus Interactive Climate Atlas finds no change of the annual mean wind speed signal or no robust signal for neither of the two scenarios under consideration. Also, the seasonal mean wind speed signals show no change or no robust signal. A robust signal is defined through the requirement that at least 80% of the models agree on the sign of change and at least 66% of the models show a change greater than the internal-variability threshold. Note that while the average annual mean wind speed might remain unaffected, there are indications of an increase in prolonged weather patterns [46]. These patterns may be characterized by extended periods of either low wind speeds, such as during high-pressure omega blocks, or high wind speeds.

Other studies [47] identify a significant correlation around 0.9 between equator-to-pole temperature gradient and wind speed reduction, which imply that the arctic amplification is a risk for European offshore wind energy. While the North Sea seems clearly affected, the project area does not indicate a significant correlation (Figure 56).

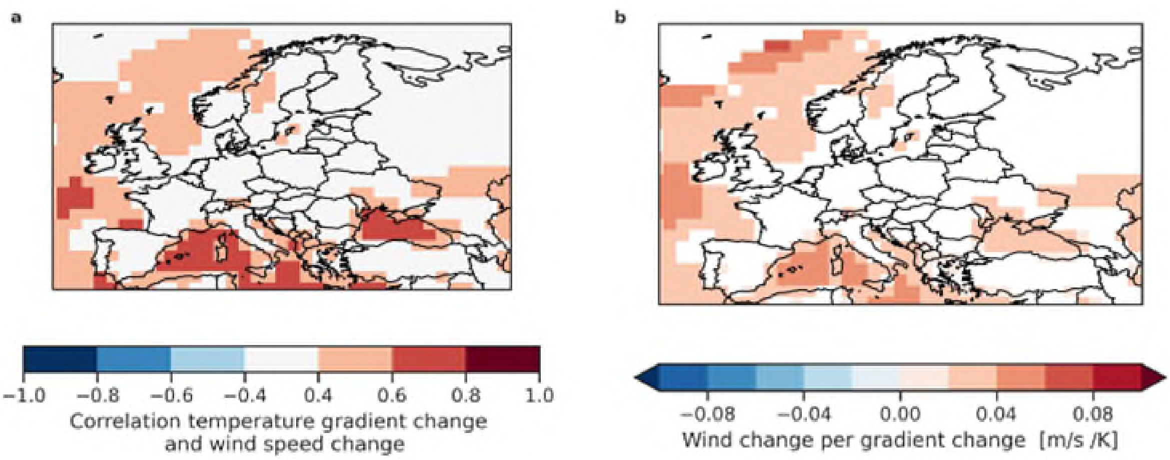


Figure 56. Relationship between changes in wind speed and the equator-to-pole gradient in Europe in the full CMIP6 ensemble. Correlations between changes (a) and the slope of a linear regression in locations where correlations exceed absolute values of 0.4 (b) [47]

Not only forcing like global warming affect mean wind speeds, but also natural variations, like Atlantic Multidecadal Oscillation (AMO). Some work indicates that CMIP6 shows weaknesses and does not capture the AMO sufficiently [48]. Therefore, it is advisable to investigate multidecadal oscillations separately.

Wohland et al [49] compares natural oscillations with forced wind speed changes: For the historic period the trends of the forced wind speed changes for the are at the order of 0.01m/s per decade (green histogram, Figure 57 a), while the observed trends are 1 order of magnitude larger (orange histogram). The trend in the forced wind speed changes increase for increased radiative forcing (green histogram in Figure 57 c and d) but stay still at below 1/4 of the natural changes.

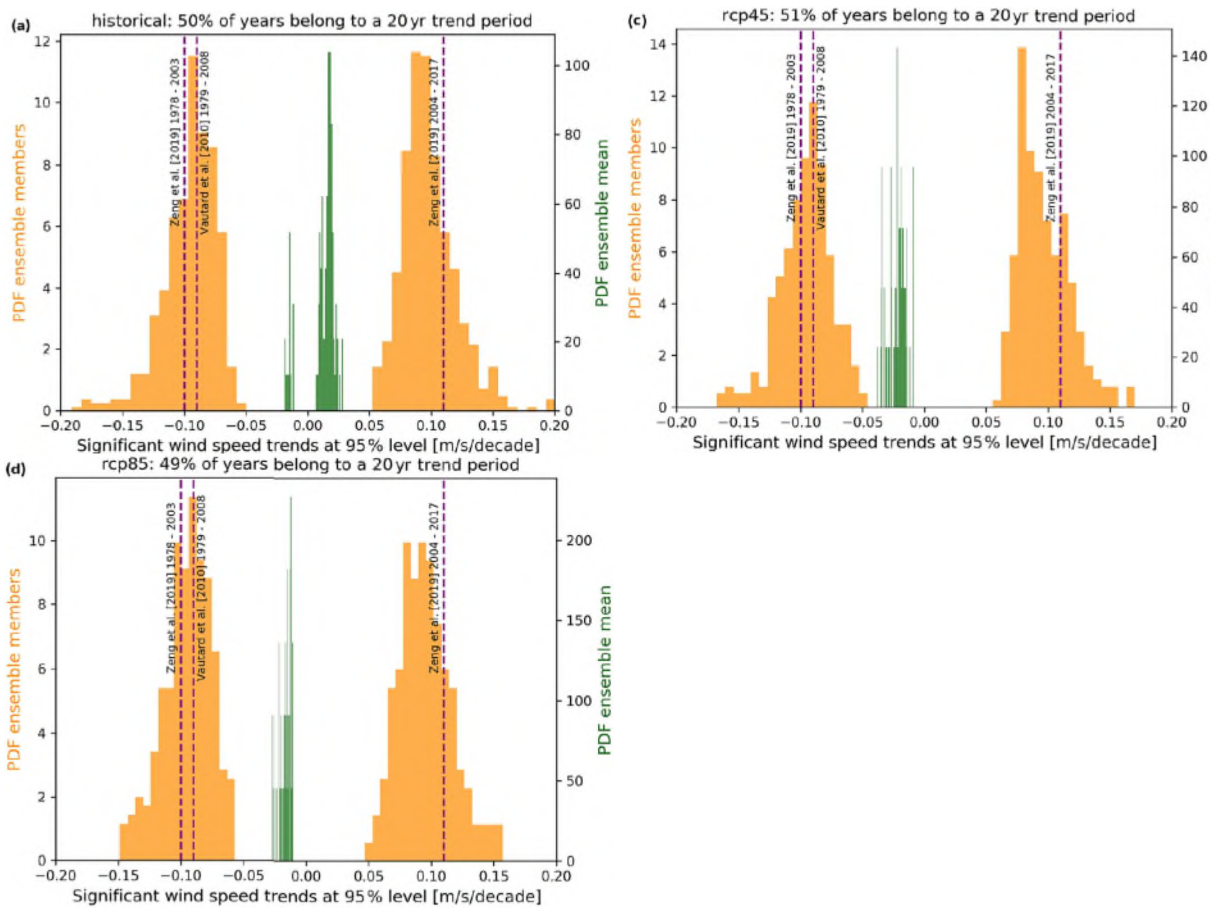


Figure 57. Twenty-year trends in European annual mean wind speed in Max Planck Institute - Grand Ensemble (MPI-GE) under historic (a) and future climate conditions (c) and (d). Trends are computed for each ensemble member after subtraction of ensemble mean (orange – representing internal variability) and for the ensemble mean (green – representing forced changes). Different subplots show different experiments. Trends are only shown if they are different from zero at a 95% significance level.

We conclude that the potential change of mean wind speed in the Baltic Sea is smaller than the natural variability. Other studies conclude the same [50].

Among many studies on climate change impact, the impact on extreme wind conditions is one of those that does not lead to clear conclusions. We refer to the recent work of Xiaoli Guo Larsén et al, DTU [51]. A selection of models from the SSP5 scenario were compared with reanalysis data (ERA5) and the offshore masts Fino 1-3. The near-term period from 2020 to 2049 was analysed, which overlaps well with the operational period of the planned projects. In contrast to the North Sea, Larsén finds no significant signal for most of the SSP5 ensemble models for the projected area in the Baltics. Other studies conclude the same [50].

For temperature, however, the Copernicus Interactive Climate Atlas [45] shows a robust signal when compared to the period 1991-2020. The absolute temperatures are illustrated in Figure 58. In the worst case (SSP5, medium term), the temperature will increase by 2˚C corresponding to 0.7% lower air density, which will impact the power production of wind turbines in the area.

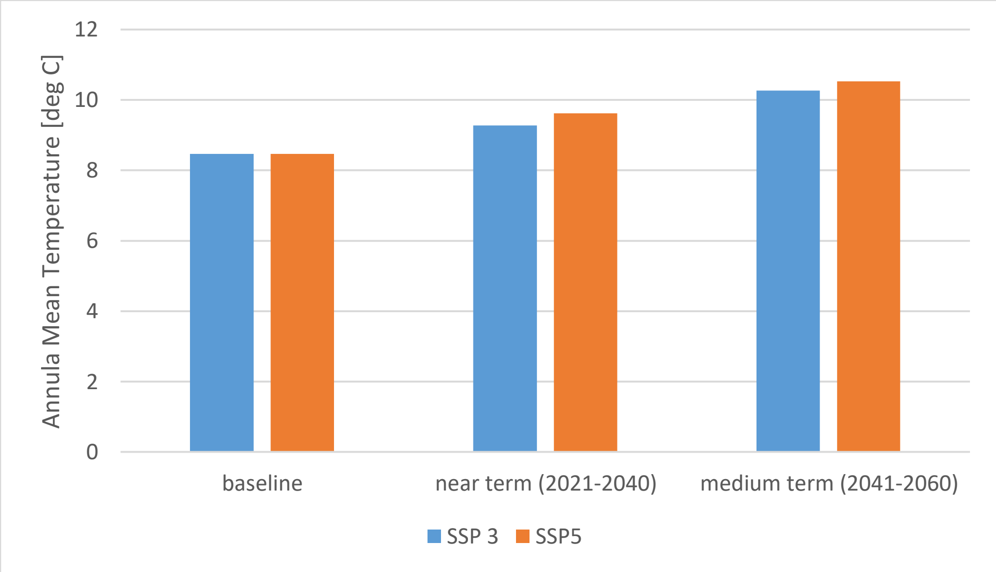


Figure 58. Development of the absolute annual temperature in the Hesselø South area.

To evaluate the changes of precipitation, the daily accumulated precipitation in mm/day was analysed from the Copernicus Interactive Climate Atlas [45]. Here SSP3 shows a robust signal showing an increase of precipitation, both for near and medium term. An increase of precipitation might lead to more blade degradation. SSP5 shows no signal or no robust signal.

9.5 Summary Table of Siting Parameters

The requested omnidirectional siting parameters are summarized in Table 42.

Table 42. Summary table of siting parameters (150 m) at Hesselø South.

Parameter	HS-1-LB	HS-A	HS-B	HS-C
Mean wind speed	9.66 m/s	9.73 m/s	9.65 m/s	9.72 m/s
Weibull distribution, A parameter (scale)	10.91 m/s	10.99 m/s	10.89 m/s	10.98 m/s
Weibull distribution, k parameter (shape)	2.23	2.24	2.23	2.23
Normal wind profile power law exponent	0.086	0.086	0.086	0.086
Turbulence intensity mean value (TI_{μ}) at a 10-min average wind speed of 15m/s*	4.9%	4.9%	4.9%	4.9%
Turbulence intensity standard deviation (TI_{σ}) at a 10-min average wind speed of 15m/s*	2.0%	2.0%	2.0%	2.0%
Turbulence intensity 90% quantile at a 10-min average wind speed of 15m/s*	7.5%	7.5%	7.5%	7.5%
Mean air density	1.23 kg/m^3	1.23 kg/m^3	1.23 kg/m^3	1.23 kg/m^3
Mean air temperature	9.0°C	9.0°C	9.0°C	9.0°C
50-year extreme wind speed	40.1 m/s	40.1 m/s	40.1 m/s	40.1 m/s
1-year extreme wind speed	31.5 m/s	31.5 m/s	31.5 m/s	31.5 m/s
Wind shear for extreme wind speed extrapolation	0.13	0.13	0.13	0.13
Characteristic turbulence intensity at 50-year extreme wind speed	12.0%	12.0%	12.0%	12.0%
Air density for extreme wind	1.25 kg/m3	1.25 kg/m3	1.25 kg/m3	1.25 kg/m3
Lightning	1.18 flash/year/km^2	1.18 flash/year/km^2	1.18 flash/year/km^2	1.18 flash/year/km^2
Solar radiation, mean	121 W/m^2	121 W/m^2	121 W/m^2	121 W/m^2
Solar radiation, peak	880 W/m^2	880 W/m^2	880 W/m^2	880 W/m^2
Relative Humidity, mean	82.8%	82.8%	82.8%	82.8%

**Turbulence values at other wind speeds can be found in Appendix H*

10 Data Package

EMD has submitted datasets in support of this study. These are as far as it is possible provided in accessible formats.

10.1 Filtered and Repaired LiDAR Data

Datasets for the filtered and repaired datasets are provided in folder "20 Analysis/22 Filtered time series". The filter and repair process is described in section 4.4.3. The dataset represents 12 months of data. The text file can be imported directly into windPRO, but as an open format, it is generally accessible.

- HS-1-LB_12 month.txt

The text file includes measurements at all heights. Measurements on the buoy (non-LiDAR data) are for practical reasons set at 4 m. The dataset is organized in columns, grouped by height. Data for a given height with Sample Status flagged as "1" is disabled by EMD.

The content of the columns is explained in Table 43.

The dataset is also included as windPRO Meteo objects in an Object export file

- HS-1-LB_12 months.wpobjects

The object export file can be imported into windPRO 4.1 by right-clicking in the Object list and select Import -> Import from windPRO object import file.

Table 43. Column explanation for data time series.

COLUMN LABEL	DESCRIPTION
TimeStamp	Date and time, dd/mm/yyyy hh.mm
MeanWindSpeedUID_xx,xm	Mean wind speed at height xx.x m, m/s
DirectionUID_xx,xm	Wind direction at height xx.x m, m/s
TurbIntUID_xx,xm	Turbulence intensity at height xx.x m
OtherUID_xx	Number of data packages received at height xx.x m, m/s
Comment_xx,xm	Comments for height xx.x m (not used)
TimeStampStatus_xx.xm	Internal setting for WindPRO
SampleStatus_xx.xm	Status flag on entire sample: 0: OK, 1: disabled, 2: below limit, 4: above limit, 8: duplicate, 16: null value, 32: missing, 128: other error
DataStatus_yyyy_xx,xm	Status flag for parameter yyyy flagged at height xx.x m. Settings as for Sample Status.
DataStatus…..	Data status for other parameters.
OtherUID_xx,xm	Info flag at height xx.x m
TemperatureUID_4.0m,xm	Temperature at 4m, ˚C
RelativeHumidity_UID_4.0m,xm	Relative humidity at 4m, %
PressureUID_4.0m,xm	Pressure at 4m, hPa

10.2 Long-term Corrected LiDAR data

The long-term corrected time series at the positions of HS-1-LB, HS-A, HS-B and HS-C are included in the data package in the folder "20 Analysis/23 Long-term time series". Position HS-1-LB includes all LiDAR measurement heights. Positions HS-A, HS-B and HS-C only include the 150 m height.

- HS-1-LB LTC.txt
- HS-A LTC.txt
- HS-B LTC.txt
- HS-C LTC.txt

Parameters included are wind speed and wind direction. Data format follows the format described above. The text file can be imported directly into windPRO, but as an open format, it is generally accessible.

All three datasets are included as windPRO Meteo objects in an Object export file.

- LTC Position HS-1-LB, HS-A, HS-B, HS-C.wpobjects

The object export file can be imported into windPRO 4.1 by right-clicking in the Object list and select Import -> Import from windPRO object import file.

10.3 EMD-WRF Dataset

The EMD-WRF dataset for the positions of HS-1-LB is included in the data package in the folder "10 Models" as a text file export with selected parameters:

- EMD-WRF Position HS-1-LB.txt

The data columns are described in Table 44.

The EMD-WRF datasets is included as windPRO Meteo objects in an Object export file.

- EMD-WRF HS-1-LB position.wpobjects

The object export file can be imported into windPRO 4.1 by right-clicking in the Object list and select Import -> Import from windPRO object import file. The object export file includes more parameters than presented in the text file.

Table 44. Column explanation for EMD-WRF data time series.

COLUMN LABEL	DESCRIPTION
TimeStamp	Date and time, dd/mm/yyyy hh.mm
MeanWindSpeedUID_xx,xm	Mean wind speed at height xx.x m, m/s
DirectionUID_xx,xm	Wind direction at height xx.x m, m/s
TurbIntUID_xx,xm	Turbulence intensity at height xx.x m
TemperatureUID_100,0m	Temperature at height xx.x m
Comment_xx,xm	Comments for height xx.x m (not used)
TimeStampStatus_xx.xm	Internal setting for WindPRO
SampleStatus_xx.xm	Status flag on entire sample: 0: OK, 1: disabled, 2: below limit, 4: above limit, 8: duplicate, 16: null value, 32: missing, 128: other error
DataStatus_yyyy_xx,xm	Status flag for parameter yyyy flagged at height xx.x m. Settings as for Sample Status.
DataStatus	Data status for other parameters.

10.4 Wind Resource Map

The wind resource map calculated in section 8.3 is provided as an .rsf file (recognized WAsP format) in in the folder “50 Wind resource maps”:

- HS_Res_250_Hub_150.0_1.rsf

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Appendix A. Supporting Data

Several data sources have been used to support the assessment of site wind conditions. These data are of different types and quality and have thus been used for different purposes. The description of the measurement setup, data quality check and processing are presented in section Appendix A.1. The Appendix A.2 section deals with data analysis of different parameters. Finally, the long-term correction of the relevant supporting data is described in Appendix A.3.

Appendix A.1. Available Data, Data Treatment and Quality Check

For an overview of the measurements station please refer to Table 3, Table 4, Figure 3 and Figure 4.

i. Kattegat Floating LiDAR (KG-1-LB)

The LiDAR was commissioned by Energinet and operated by Fugro Norway AS. The LiDAR was located in the Kattegat Sea, 20 km east of Djursland peninsula, in Denmark.

Instrumentation

The LiDAR is a ZX300M LiDAR from ZXLiDARs Ltd and is mounted on the WS199 buoy (Figure 59).

The general measurement setup, sensors, configurations, and measurement scheme are described in the measurement plan [10]. In the following, only instruments relevant for the site wind conditions are described.

Figure 59. ZXLidars – ZX300M, source: www.zxlidars.com

This LiDAR model is classified by DNV-GL [18]. The LiDAR buoy WS199 has been pre-validated and passed Best Practice Criteria for all wind speed and direction ranges at all heights, except wind speed slope at 40 m [52].

Table 45. LiDAR measurement height levels

Level	Measurement height [m]
11	300
10	260
9	220
8	190
7	170
6	150
5	130
4	100
3	80
2	40
1	12

The WS199 is equipped with two additional meteorological sensors. Vaisala PTB330A measuring air pressure, Vaisala HMP155 measuring air temperature and humidity.

Operation history

Wind LiDAR buoy WS199 was deployed at Kattegat on 21st of July 2023. Fugro has submitted event logs tracking faults and flaws of the buoy [53]. Of these, only two events have had impact on the LiDAR data:

- The LiDAR stopped data collection for two days starting on 24/01/2024 due to abrupt input power outage.
- The buoy had been recovered for repairs on 18/02/2024 and redeployed on 22/02/2024. Therefore, the dataset has a 2-day gap due to service. EMD has verified and confirmed that the buoy was redeployed to the same location.
- The buoy was decommissioned on 04/08/2024.

Fugro post-processing of Data

Fugro has provided some information on the post-processing of the LiDAR data [11]. ZX LiDARs typically equip their instruments with a standard data filter, known as industry filter, designed to ensure the acquisition of high-quality data by eliminating data points that have a low signal-to-noise ratio. Fugro has disabled the industry data filter on the LiDAR data and has implemented a simpler filtering algorithm [10]. The processing of the LiDAR data by Fugro involves the following steps:

- Removing values outside of those times where the system is deployed at the target position.
- Check that data was saved for all 10-min intervals. Out of the 36-37 data packages produced every 10 minutes, a minimum of 9 packages (25%) are required to qualify as a valid measurement.
- Check for duplicates measurements.
- Removing out of range values (e.g. speed below 0.001 m/s and above 58 m/s, degrees above 360)
- Apply 180˚ ambiguity fix on LiDAR wind directions using Gill directions.

Beyond the 9-data-package filter already provided by Fugro, EMD has determined that increasing the threshold for the number of data packets does not enhance the quality of the data. Therefore, no additional filtering based on packet count has been conducted.

EMD Filtering of LiDAR Data

EMD has conducted a qualitative, manual filtering process. EMD has found that the overall quality of the dataset is quite good, with very few discrepancies identified.

Typical anomalies identified in the dataset include instances of peak wind speeds at great heights (over 130 meters) that occur for very brief periods and are not consistent with the wind speed and shear observed at lower altitudes. These discrepancies were specifically targeted during the manual filtering process to ensure the reliability of the dataset.

According to Fugro reports [11], the primary sensor for wind direction is measuring relative to true north. EMD has compared the wind direction signal against mesoscale derived dataset (EMD-WRF) and finds the average difference within 1˚ at equivalent heights. EMD therefore finds the wind direction data correct with no need for adjustment.

However, at very low wind speeds, some remnants of the 180-degree ambiguity in wind direction measurements persist. Given the high uncertainty of wind direction at these low speeds, EMD has decided not to make any corrections to these data.

Recovery Rate and Data Substitution

With the industry filter disabled, the data recovery rate for the LiDAR measurements is substantially higher than is sometimes seen with ZX LiDAR instruments. Notably, the data recovery rates decrease with increasing height above sea level (ASL), and these rates are detailed in Table 46. Additionally, a small data recovery loss is still experienced due to the applied filtering.

To address some of the data loss, data substitution procedures were implemented: one based on measured shear on the Kattegat LiDAR (KG-1-LB), referred to as "shear repair" and another using data from Hesselø South LiDAR (HS-1-LB), referred to as "horizontal repair". The shear repair procedure is prioritized over the horizontal repair due to its expected lower uncertainty. The process is detailed in section 4.4.3

Table 46 lists the results of each repair procedure. The 12 m and 40 m heights are repaired only using the horizontal repair procedure, and the outcome of those repairs are not included in the mentioned table.

Table 46. Results of data repair.

REPAIRED HEIGHT [M]	80	100	130	150	170	190	220	260	300
Source height [m]	40	80	100	130	150	170	190	220	260
Shear matrix heights [m]	40, 80, 100	80, 100, 130	100, 130, 150	130, 150, 170	150, 170, 190	170, 190, 220	190, 220, 260	220, 260, 300	220, 260, 300
Recovery rate before repair	96.6%	96.1%	95.3%	95.1%	94.9%	94.8%	94.7%	94.5%	94.4%
Recovery rate after shear repair	98.2%	96.6%	96.2%	95.4%	95.2%	95.0%	94.9%	94.7%	94.6%
Recovery rate after shear and horizontal repair	100.0%	99.0%	98.6%	98.4%	98.3%	98.2%	98.1%	97.9%	97.9%
Share of repaired data	3.4%	2.9%	3.3%	3.4%	3.5%	3.5%	3.5%	3.5%	3.6%

Table 47. Treatment summary of the primary wind data source from HS-1 floating LiDAR.

Phase of treatment	Height [m]	Start	End	Period [Months]	Arithmetic mean wind speeds [m/s]	Recovery rate [%]
Raw	150	21/07/2023	21/07/2024	12	9.97	95.5
Filtered	150	21/07/2023	21/07/2024	12	9.99	95.1
Repaired	150	21/07/2023	21/07/2024	12	10.00	98.4

ii. Hesselø Floating LiDAR (H1)

The LiDAR was commissioned by Energinet and operated by EOLOS Floating LiDAR Solutions. The LiDAR was located in Kattegat Sea, between north of Zealand coastline and the island of Anholt, in Denmark.

Instrumentation

The LiDAR mounted on the Eolos FLS200-E01 is a ZX300M LiDAR from ZX LiDARs Ltd (Figure 59).

The instrumentation on the Eolos FLS200-E01 is described in [54]. In the following, only instruments relevant for the site wind conditions are described.

This LiDAR model is classified by DNV-GL [18]. A similar model, but not the same instrument was verified at the Pershore, UK, test site by DNV-GL [55]. The specific instrument deployed on the Eolos FLS200-E01 was verified by Multiversum at the TNO Lichteiland Goeree Offshore Test Site, NL [56].

The LiDAR window is located 1.6m above sea level. This should be compensated for when interpreting the measurement results together with an 0.4 m offset built into the tidal correction of the data processing by Eolos. This means a 2 m offset between the measurement height reported and the real heights. This results in measurement heights according to Final Data report [54].

Floating LIDAR Measurement heights	
Level	**Configured LIDAR height + offset (m)**
10	238+2 = 240
9	198+2 =200
8	178+2 = 180
7	158+2 = 160
6	138+2 =140
5	118+2 = 120
4	98+2 = 100
3	68+2 = 70
2	38+2 = 40 (ZX reference height)
1	10+2 = 12

Figure 60. LiDAR measurement height levels, source: [54].

The Eolos FLS200-E01 is equipped with two additional meteorological stations. These are a Vaisala WXT536 package and the second is an Aimar 200WX package. Both can measure standard parameters: Wind speed, wind direction, air pressure, temperature, humidity and rainfall.

The mounting of the instruments is 3.25 m above the , however as they are not used for shear or wind model analysis, they are by EMD assigned a generic height of 10 m.

In the datafiles provided by Eolos only one sensor signal for each parameter is reported and it is not clear which of the stations provide the input. Hence, the two weather stations are considered as a single unit called METEO by Eolos.

Operation history

The measurement campaign has run for a period of 12 months. EMD has received measurement data starting from 28/02/2021 to 28/02/2022.

Data gaps:

19/03/2021 - corrective maintenance

14/07/2021 -17/07/2021 - control box replacement

23/12/2021 – ADCP replacement

Eolos Post-processing of Data

Eolos has provided some information on the post-processing of the LiDAR data [57].

Wind direction data are corrected for the yaw of the buoy and the homodyne behaviour of the LiDAR. This is the 180-degree ambiguity in the LiDAR measurements. The METEO data are used for this correction.

No motion correction is applied. Eolos states that this is a valid approach.

Eolos corrects for tidal variations. It is understood that this makes the measurements comparable with a fixed structure, such as a mast or a wind turbine, but it also means that the actual measurement height above sea level is variable, within the range of tidal variations. The tidal correction includes a 0.4m offset to convert the 1.6 m window height to 2 m.

Data are filtered if:

- buoy location is outside maximum drift radius + 20 m (97 + 20 = 117 m)
- the LiDAR returns invalid values, such as N/A, 9998 or 9999, representing poor quality data.
- out of wind speed (V < 0 m/s or V > 50 m/s) or wind direction (Dir < 0° or Dir > 360°) range.

Eolos has applied a quality control algorithm to the raw measurement data and defines four states:

0 – System not available

1 – System available & post-processed data passing quality checks

2 – System available but data filtered for not passing quality checks

3 – System available & postprocessed data are passing quality checks for wind speed but not direction

State 0 and state 3 are not present in the datasets. EMD has disabled data records with state 2.

EMD Filtering of LiDAR Data

Eolos reports [57] that the wind direction sensor used in the datafiles is that of the ZX LiDAR. In a comparison with EMD-WRF data an average offset of -7.9 degrees is noted. In the validation study [56], Multiversum finds good agreement between reference station direction and the buoy main compass, but a -6.5-degree offset to the ZX LiDAR wind direction measurements. As these two offsets are in agreement, EMD has applied a 6.5 degree offset on the LiDAR wind direction measurements.

EMD has used the code setting 2 (section 3.2.5) to filter the data. This has effectively removed the inherent ZX error settings (n/a, 9998 and 9999).

No filtering has been done on the METEO data. They are provided as is.

Recovery Rate and Data Substitution

The LiDAR dataset suffers data loss as a result of above filtering. In order to recover some of this loss a data substitution procedure was done.

The recovery rate on the LiDAR is higher at lower heights than at taller heights. The substitution procedure transfers lower height measurements upwards in the profile with a shear transfer function.

The shear matrix transformation method is described in detail in the WindPRO manual, section 12.3.3.4.2.1 [35].

For each height repaired, the height one or two levels below was used as source. A shear matrix was built using the most relevant heights (immediately above or equal to the height and below the repaired height), including the source height. The binning for the matrix consists of 12 diurnal bins and 12 directional bins. No seasonal binning was used in order to increase the count of data records in each bin. Only data concurrent at all selected heights feed into the shear matrix. The shear value in each bin is calculated based on a Weibull derived mean wind speed for each selected height.

The synthesized data replaces gaps and disabled data in the recorded dataset (wind speed and direction). Table 48 lists the properties of each repair procedure.

Table 48. Results of data repair.

REPAIRED HEIGHT [M]	100	120	140	160	180	200	240
Source height [m]	70	100	100	120	140	160	180
Shear matrix heights [m]	70, 100, 120	100, 120, 140	100, 120, 140	120, 140, 160	140, 160, 180	160, 180, 200	180, 200, 240
Recovery rate before repair	92.6%	89.6%	88.2%	87.2%	84.6%	81.7%	80.0%
Recovery rate after shear repair	95.0%	93.0%	93.1%	90.4%	88.9%	87.7%	85.9%
Share of repaired data	2.40%	3.40%	4.90%	3.20%	4.30%	6.00%	5.90%

Finally, the repaired data at 140 m has been extrapolated to the height of interest for the model validation of 150 m. A shear matrix was built using the heights from 120, 140 and 160 m, with 12 diurnal bins and 12 directional bins.

Table 49. Shear matrix used to extrapolate 140 m data to 150 m height. Values are shear exponent α.

Hour	N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW
00-02	0.04	0.07	0.09	0.05	0.11	0.17	0.13	0.11	0.09	0.10	0.13	0.13
02-04	-0.06	0.00	0.08	0.07	0.11	0.08	0.16	0.07	0.10	0.13	0.09	0.05
04-06	0.00	0.06	0.07	0.09	0.10	0.10	0.10	0.13	0.11	0.13	0.12	0.10
06-08	0.09	0.08	0.20	0.08	0.07	0.01	0.03	0.11	0.13	0.13	0.14	0.04
08-10	0.07	0.26	0.00	0.07	0.12	0.07	0.07	0.18	0.14	0.11	0.09	0.09
10-12	0.06	0.10	0.01	0.01	0.06	0.08	0.11	0.13	0.08	0.13	0.07	0.09
12-14	-0.17	-0.01	0.04	0.12	0.09	0.11	0.18	0.07	0.11	0.14	0.11	0.07
14-16	-0.03	-0.06	0.07	-0.14	0.11	0.12	0.09	0.13	0.10	0.14	0.09	0.09
16-18	0.00	0.01	0.05	0.11	0.11	0.11	0.10	0.14	0.07	0.10	0.12	0.12
18-20	0.06	-0.07	0.11	0.00	0.07	0.11	0.13	0.13	0.10	0.11	0.09	0.09
20-22	0.05	-0.03	0.01	0.14	0.06	0.08	0.12	0.13	0.15	0.13	0.13	0.09
22-24	0.16	0.08	0.26	0.06	0.09	0.14	0.11	0.16	0.10	0.13	0.14	0.07
All	**0.05**	**0.04**	**0.06**	**0.06**	**0.09**	**0.10**	**0.12**	**0.13**	**0.10**	**0.12**	**0.11**	**0.09**

Table 50. Treatment summary of the primary wind data source from H1 floating LiDAR.

Phase of treatment	Height [m]	Start	End	Period [Months]	Arithmetic mean wind speeds [m/s]	Recovery rate [%]
Raw	140	28/02/2021	28/02/2022	12	9.75	93.7
Filtered	140	28/02/2021	28/02/2022	12	9.82	88.2
Repaired	140	28/02/2021	28/02/2022	12	9.80	93.1
Shear extrapolated	150	28/02/2021	28/02/2022	12	9.87	93.1

iii. Læsø Offshore Met Mast (M1)

Wind data from an offshore measurement mast has been provided by Energinet. The met mast was setup in Kattegat Sea about 17 km south of the island of Læsø. The distance to Danish and Swedish coast is about 45 km and 66 km. The available measurements used are shown in Table 51.

Table 51. Measurement data at Læsø met mast

Measurement type	Heights ASL [m]	Parameter	Averaging period
Wind speed	62, 58, 45, 45, 30, 30, 15, 15	mean, min, max and standard deviation	10-min
Wind direction	60, 58, 43, 28	mean, min, max and standard deviation	10-min
Absolute temperature	55, 13	mean, min, max, standard deviation	10-min

Besides the analysed data, the Læsø mast was also equipped with relative humidity, atmospheric pressure and solar radiation sensors.

The available data covers a period of 4 years and 8 months from 24/04/1999 until 09/12/2003. However, the wind speed data from the anemometer at 58 m ends on 18/04/2000. This data is therefore not considered further on in the analysis.

EMD had access to a wind resources report [58] analysing the measured data until November 2002 and describing the equipment installed and mast details. According to the documentation available [58] EMD has not received any calibration reports nor installation report describing the type of sensors and the detials of the mounting (boom orientation, length, distance to lightning finial). It has thus not been possible to check if the installation has been conducted according to the IEC standards [59]. The only information available comes from the csv files itself, from which the setup of the mast has been deducted and is presented in Table 52.

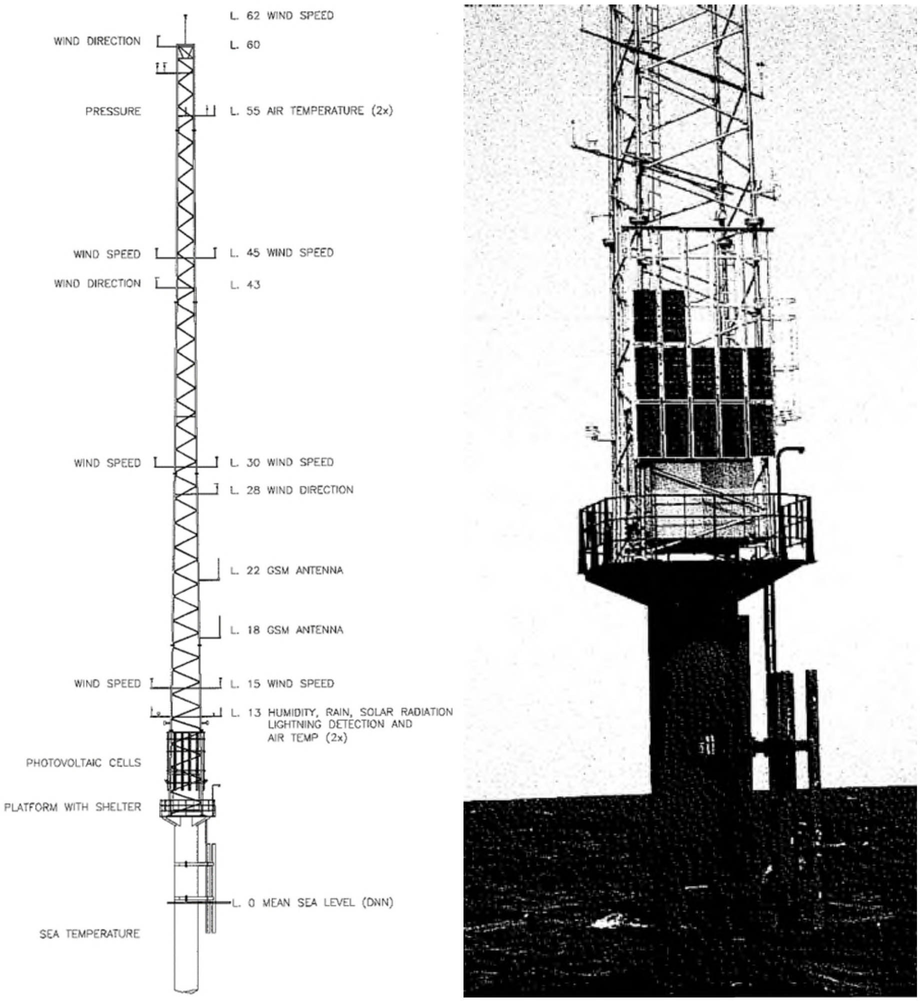

Figure 61. Pictures and details from Læsø met mast, source: [57]

Table 52. Mounting of sensors on the Læsø met mast

Height AGL [m]	Channel Name	Description	Mounting and Orientation	Horizontal boom	Vertical boom
62	CUP62M	Cup Anemomter Unknown type	Top mounted	Top mounted	Unknown
58	CUP58M	Cup Anemomter Unknown type	0°	Unknown	Unknown
45	CUP45SV	Cup Anemomter Unknown type	225°	4.35 m	Unknown
45	CUP45NO	Cup Anemomter Unknown type	45°	4.35 m	Unknown

Height AGL [m]	Channel Name	Description	Mounting and Orientation	Horizontal boom	Vertical boom
30	CUP30SV	Cup Anemomter Unknown type	225°	4.75 m	Unknown
30	CUP30NO	Cup Anemomter Unknown type	45°	4.75 m	Unknown
15	CUP15SV	Cup Anemomter Unknown type	225°	5.40 m	Unknown
15	CUP15NO	Cup Anemomter Unknown type	45°	5.40 m	Unknown
60	DIR60SV	Wind vane Unknown type	225°	4.20 m	Unknown
58	DIR58M	Wind vane Unknown type	0°	Unknown	Unknown
43	DIR43SV	Wind vane Unknown type	225°	4.40 m	Unknown
28	DIR28SV	Wind vane Unknown type	225°	4.80 m	Unknown
55	TEMPA55NO	Temperature sensor, absolute	45°	Unknown	Unknown
13	TEMPA13NO	Temperature sensor, absolute	45°	Unknown	Unknown

EMD has obtained access to the data as csv files. Therefore, the conversion of the raw data could not be verified.

A discrepancy between the documented boom direction (from the file) and the observed direction can be noticed on the wind speed difference graph between anemometers at same height. For example the booms for the 45 m anemometers seem to be orientated at 15 deg (instead of 45 deg) and 210 deg (instead of 225 deg), as seen on Figure *62*. No wind veer has been applied to the data since it correlates well with other data sources wind direction.

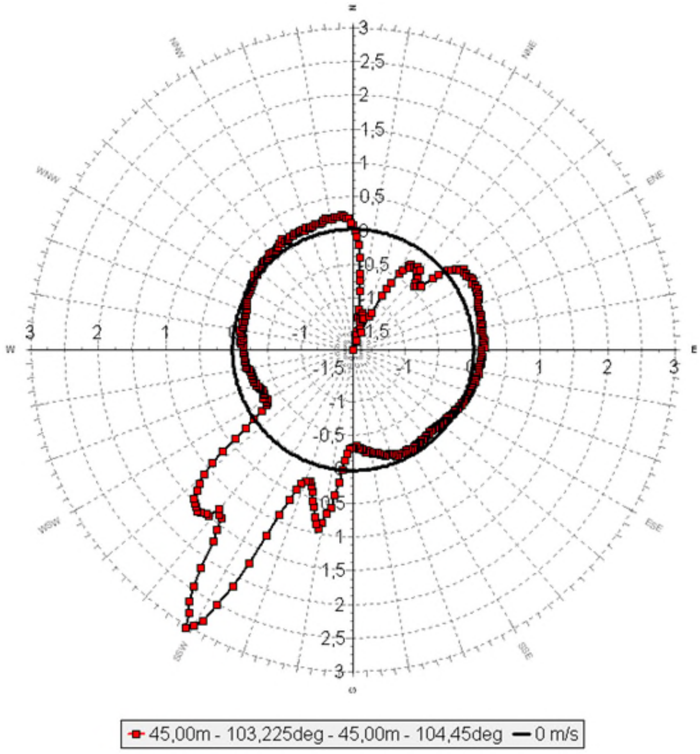

Figure 62. Wind speed difference between 45 m SV and 45 m NE, binned by direction at Læsø

The data at 45, 30 and 10 m have been merged to remove the tower shadowing, based on the observed distortions.

From Figure *62* it can also be observed that not only the shadowing of the mast creates a difference larger than 0. It could be due to the vicinity of the wind vane.

In general, the data quality is good. The correlation of the wind directions data and wind speed data at different heights is as expected. The data has been filtered for faulty equipment and failures.

A final of 4 full years, from 01/07/1999-01/07/2003, have been selected. The data from the 62 m anemometer is the primary data from the Læsø met mast considered in the study. The recovery rate of the data for this period (94.7%) complies with the minimum requirements of MEASNET [60]. The following major gaps (consecutive days with missing or erroneous data) in the wind data (wind speed at 62 m and wind direction at 58 m) can be noted:

- 35 days from 12/01/2000
- 25 days from 04/01/2002, gap concerning all channels
- 3 days from 01/11/2002

At this stage, the 62 m data has not been extrapolated to the height of interest 150 m. The shear determined from the available measured data at 62, 45 and 30 m would indeed not be representative of the expected shear at 150 m.

Table 53. Treatment of the primary wind data source from Læsø met mast.

Phase of treatment	Height [m]	Start	End	Period [Months]	Arithmetic mean wind speeds [m/s]	Recovery rate [%]
Raw	62	24/04/1999	09/12/2003	56	8.36	97.6
Filtered	62	24/04/1999	09/12/2003	56	8.85	93.2
Trimmed	62	01/07/1999	01/07/2003	48	8.94	94.7

iv. FINO2 Met Mast

Wind data from the FINO2 offshore measurement mast has been used to assess the expected turbulence conditions on the Hesselø South site.

The data was made available by the FINO (Forschungsplattformen in Nord- und Ostsee) initiative, which was funded by the German Federal Ministry of Economic Affairs and Climate Action (BMWK) on the basis of a decision by the German Bundestag, organised by the Projektträger Jülich (PTJ) and coordinated by the German Federal Maritime and Hydrographic Agency (BSH).

The FINO2 mast is mounted on a platform and is part of the FINO research project. The met mast was setup in the Baltic Sea about 38 km north of the German coast, 39 km east of the Danish coast and 40 km south of Swedish coast. The distance from the FINO2 mast to HS-1-LB is about 170 km Figure 4.

The collected measurements considered in this report are:

- wind speed from cup anemometers at 102.5, 92.4, 82.4, 72.4, 62.4, 52.4, 42.4, and 32.4 m above MSL as 10-minute values (mean, min, max and standard deviation)
- wind direction at 91.8, 71.8, 51.8 and 31.8 m above MSL as 10-minute values (mean, min, max and standard deviation)
- wind speed and wind direction from sonic anemometers at 82.1, 62.1 and 42.1 m above MSL as 10-minute values (mean, min, max and standard deviation)
- absolute temperature at 99.3, 70.3, 50.3, 40.3 and 30.3 m above MSL, as 10 minutes values (mean values)

Besides the data obtained, the FINO2 mast was also equipped with sonic anemometers, relative humidity, air pressure, precipitation, and global irradiance sensors.

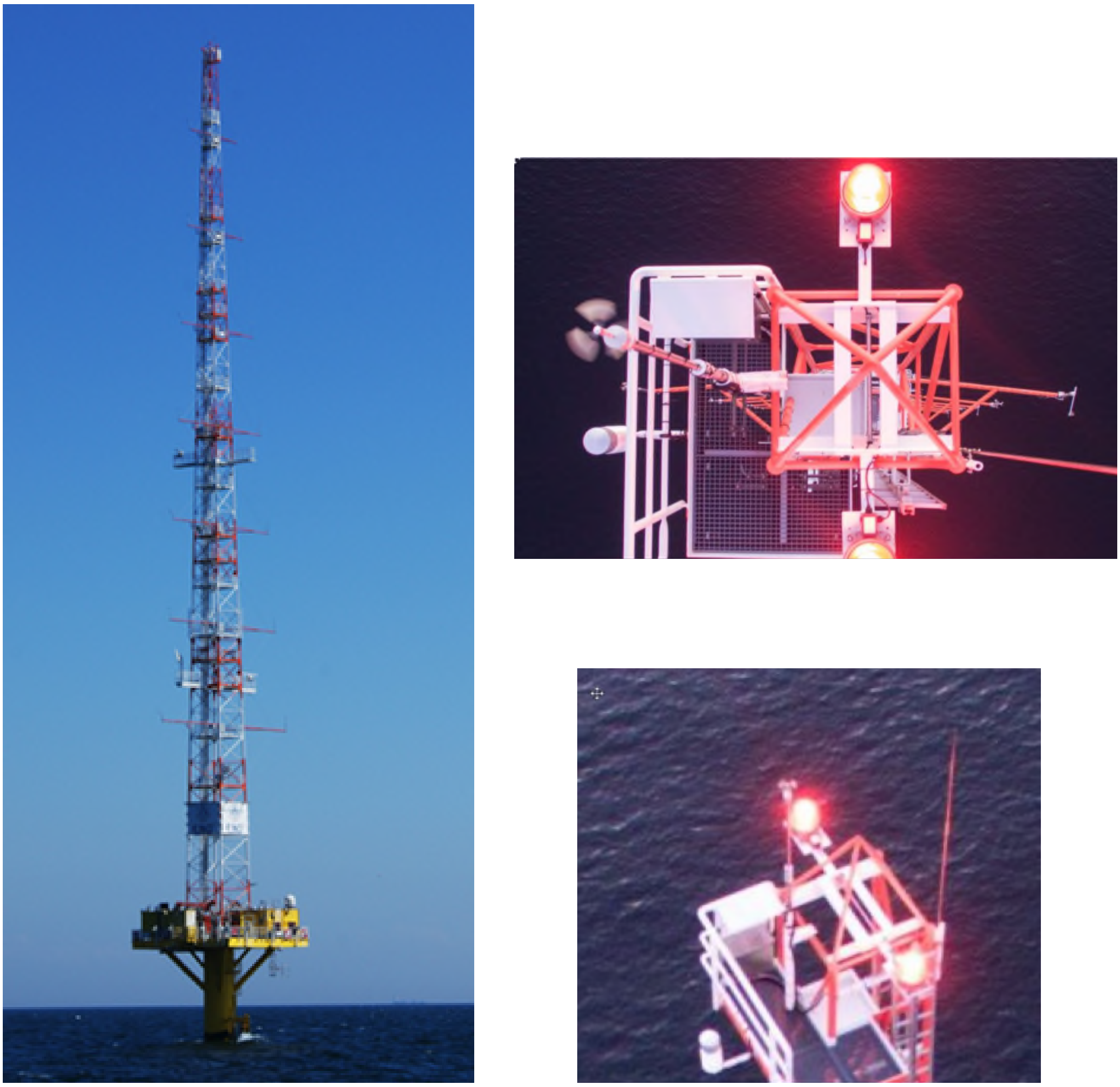

Figure 63. Picture of FINO2 met mast, and view on the top anemometer from top and southeast (source: [61]).

The available data covers a period of around 14.8 years, from April/2008 to February/2023. However, the series was trimmed to 7 full years, from 31/08/2008 to 31/08/2015, in order to avoid the influence of wakes from the neighbouring wind farm installed after September 2015 (EnBW Baltic 2/Kriegers Flak 1) (Figure 64).

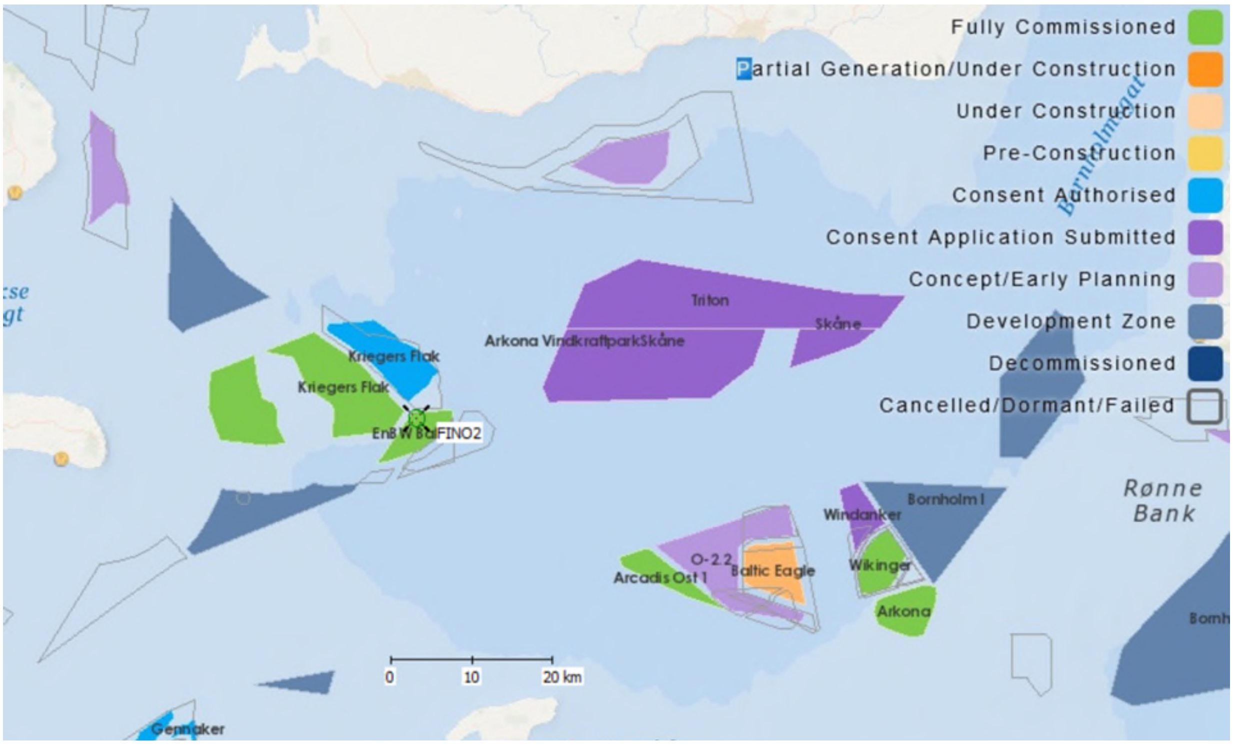

Figure 64. Indicative location map for FINO2 with existing wind farms in green (background map: 4C Offshore [62]).

EMD has access to a mast report [63] describing the equipment installed and mast details. EMD has not received any anemometer calibration reports. The data obtained was considered to be logged with the right calibration factors. EMD has obtained access to the data as csv files. Therefore, the conversion of the raw data could not be verified.

According to the documentation available [63], FINO2 design and installation has not been conducted fully according to the IEC standards [59], especially in relation to the sizes of the mast and booms for the side anemometers (92.4, 82.4, 72.4, 62.4, 52.4, 42.4, and 32.4 m).

Table 54. Mounting of sensors on the FINO2 mast.

HEIGHT AMSL[M]	DESCRIPTION	MOUNTING AND ORIENTATION	HORIZONTAL BOOM LENGTH [m]	VERTICAL BOOM LENGTH [m]
102.5	Cup anemometer – Vector A100L2	Top	-	-*
92.4	Cup anemometer – Vector A100L2	180°	2.92	1.5
82.4	Cup anemometer – Vector A100L2	180°	3.5	1.5
72.4	Cup anemometer – Vector A100L2	180°	4.5	1.5

HEIGHT AMSL[M]	DESCRIPTION	MOUNTING AND ORIENTATION	HORIZONTAL BOOM LENGTH [m]	VERTICAL BOOM LENGTH [m]
62.4	Cup anemometer – Vector A100L2	180°	5.0	1.5
52.4	Cup anemometer – Vector A100L2	180°	6.1	1.5
42.4	Cup anemometer – Vector A100L2	180°	6.5	1.5
32.4	Cup anemometer – Vector A100L2	180°	7.7	1.50
82.1	Ultrasonic anemometer – Thies 4.383021.400	0°	3.5	-
62.1	Ultrasonic anemometer – Thies 4.383021.400	0°	5.0	-
42.1	Ultrasonic anemometer – Thies 4.383021.400	0°	6.5	1.5
91.8	Wind vane – Thies 4.3120.22.012	0°	2.9	1.5
71.8	Wind vane – Thies 4.3120.22.012	0°	4.5	0.8
51.8	Wind vane – Thies 4.3120.22.012	0°	6.1	0.8
31.8	Wind vane – Thies 4.3120.22.012	0°	7.7	0.8
99.3	Thermometer – Thies 1.1005.50.015	180°	-	-
70.3	Thermometer – Thies 2.1260.00.000	180°	-	-
50.3	Thermometer – Thies 1.1005.50.015	180°	-	-
40.3	Thermometer – Thies 2.1260.00.000	180°	-	-
30.3	Thermometer – Thies 1.10005.54.241	180°	-	-

* Information not available

As FINO2 is a large offshore mast, the observed mast disturbance on the wind speed measurements is significant, especially for the anemometers mounted on horizontal booms. On Figure 65 it can be seen how the turbulence intensity is increasing with heights (except for the top anemometer at 102.5 m) in the sector where anemometers are affected by mast shadowing.

The top anemometer is not installed on the very top of the mast structure, but on the side facing south (Figure 63). The lightning finial (in the northwest corner) as well as the pyramidal top of the mast are expected to cause flow disturbance of the 102.5 m measurements. On Figure 66, the wind speed measured at 92.5 m is indeed greater than the wind speed measured 102.5 m in east northeast sector. It has not been possible to remove the tower shadowing from the data since no double nor triple cup anemometry has been available at the same heights.

Data from sonic anemometers has not been deemed reliable for the purpose of this analysis (low data availability) and couldn't be used to remove the shadowing either.

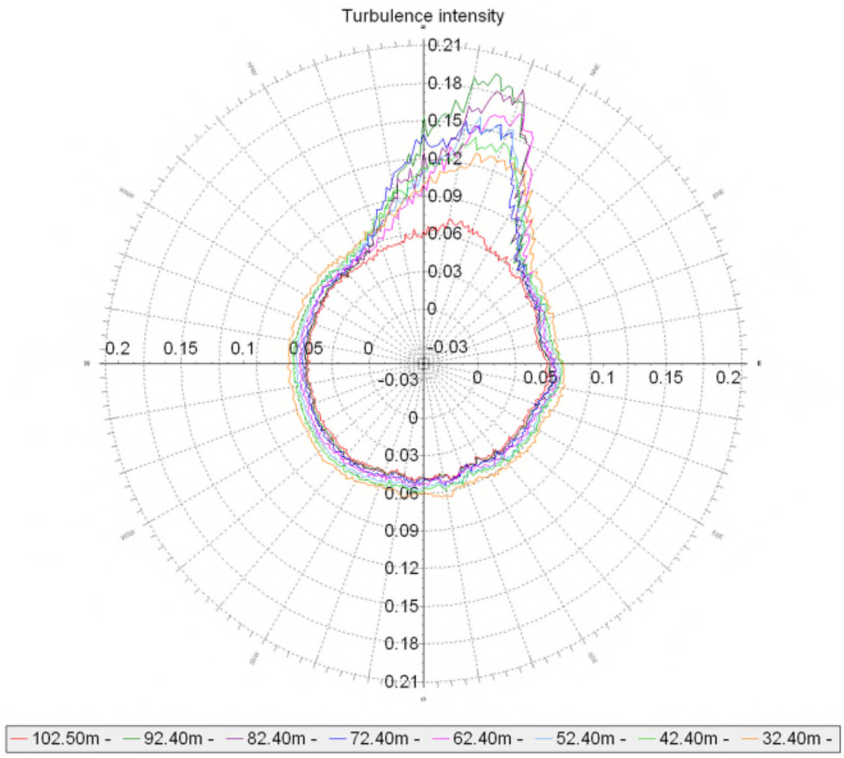

Figure 65. Directional Turbulence Intensity for the cup anemometers, FINO2.

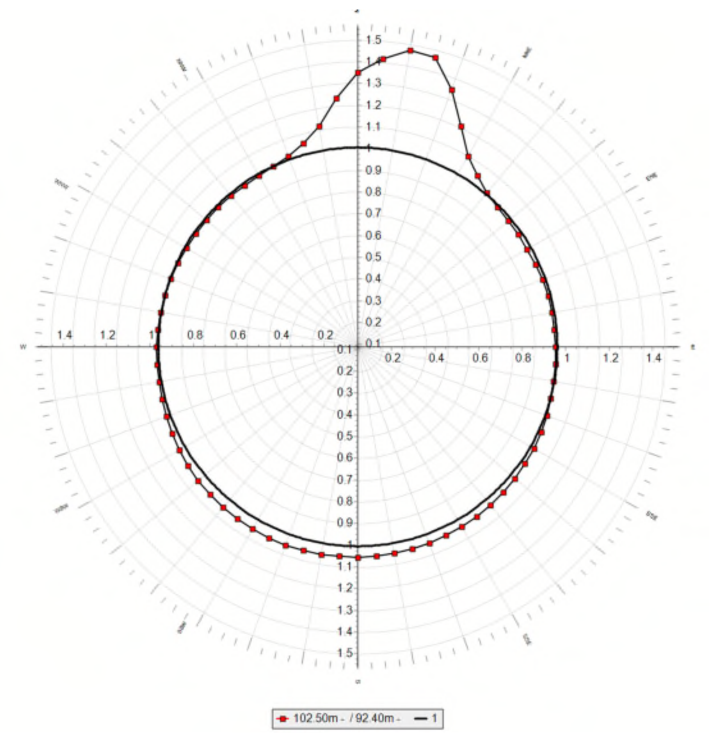

Figure 66. Directional wind speed ratio between 102.5 m and 92.5 m data, FINO2.

In general, the data quality is good. The wind directions and wind speed data at each height correlates well with the data at the other heights. The data has been filtered for faulty equipment and failures. Where possible, the missing direction data has been substituted with data from the available closest wind vanes.

7 full years have been selected from 01/09/2008 to 31/08/2015. The data from the 102.5 m anemometer is the primary data from the FINO2 met mast considered in the study. The recovery rate of the final data for the 7-year period is 93.3%.

For the turbulence intensity evaluation, the data heavily affected by shadowing has been excluded (340-40 degrees).

The following major gaps (consecutive days with missing or erroneous data) in the wind data (wind speed at 102.5 and wind direction at 91.8 m) can be noted:

- 15 days from 30/11/2009
- 7.5 days from 09/09/2010
- 20.5 days from 15/05/2011
- 11 days from 22/05/2012
- 11.5 days from 08/06/2012
- 16.5 days in January 2015 (divided in about 5 different periods)
- 10 days from 19/03/2015

Due to the unavailability of some information, as mast's maintenance and instrument certification, it was not possible to precisely assess an uncertainty on FINO2's measurements. The uncertainty on FINO2 measurements was estimated to be in the magnitude of 3.5%, taking into account the lack of information and the noncompliance to the standards [59].

v. FINO3 Met Mast

Wind data from the FINO3 offshore measurement mast has been used to assess the expected turbulence conditions on the Hesselø South site.

The data was made available by the FINO (Forschungsplattformen in Nord- und Ostsee) initiative, which was funded by the German Federal Ministry of Economic Affairs and Climate Action (BMWK) on the basis of a decision by the German Bundestag, organised by the Projektträger Jülich (PTJ) and coordinated by the German Federal Maritime and Hydrographic Agency (BSH).

The FINO3 mast is mounted on a platform and is part of the FINO research project. The met mast was setup in the North Sea about 84 km west of the island of Rømø, on the Danish coast. It is located at about 300 km southeast of the HS-1-LB buoy (Figure 4).

The collected measurements are:

- wind speed at 107, 101, 91, 81, 71, 61, 51, 41 and 31 m as 10-minute values (mean, min, max and standard deviation)
- wind direction at 101, 61 and 29 m as 10-minute values (mean, min, max and standard deviation)
- absolute temperature at 95 and 29 m, as 10 minutes values (mean values)

Besides the data obtained, the FINO3 mast was also equipped with relative humidity, air pressure, precipitation, and global irradiance sensors.

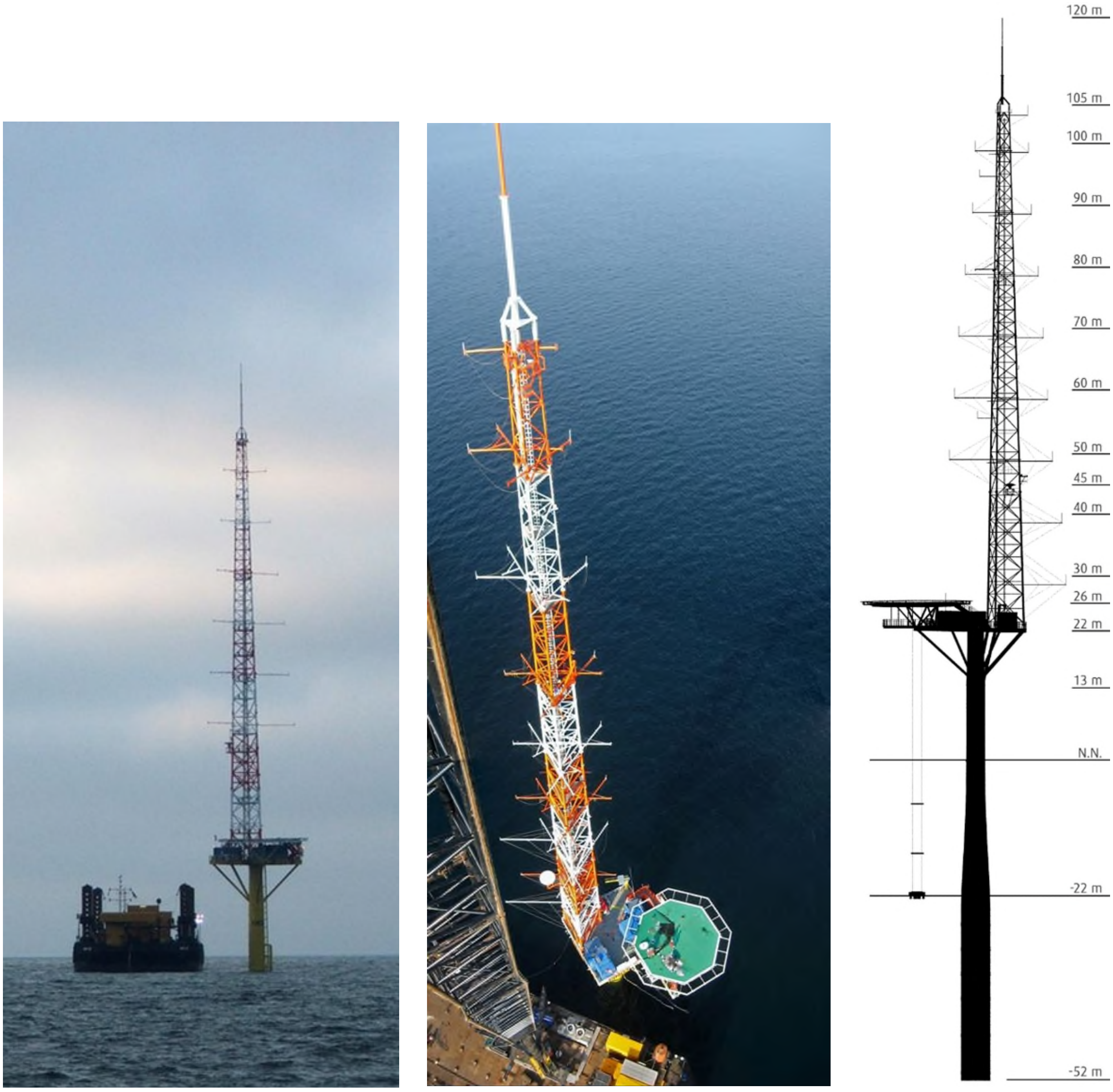

Figure 67. Pictures and details from FINO3, source: [64]

The available data covers a period of around 13.5 years, from September/2009 to February/2023. However, the series was trimmed to 4 full years, from 01/01/2010 to 31/12/2013, in order to avoid the influence of wakes from the neighbouring wind farm installed after 2014 (DanTysk OWF).

EMD had access to a mast report [63] describing the equipment installed and mast details. EMD has not received any anemometer calibration reports. The data obtained was considered to be logged with the right calibration factors. According to the documentation available [63], FINO3 design and installation has not been conducted according to the IEC standards [59], especially in relation to the sizes of the mast and booms.

Table 55. Mounting of sensors on the FINO3 mast

HEIGHT ASL [M]	INSTRUMENT IDENTIFICATION	DESCRIPTION	MOUNTING AND ORIENTATION	HORIZONTAL BOOM LENGTH [m]	VERTICAL BOOM LENGTH [m]
107	AN 107m - B	Cup anemometer - Vector A100L2	345°	3.5	1.75
101	AN 101m - B	Cup anemometer - Vector A100L2	345°	3.2	1.75
101	Sonic 101m - A	Ultrasonic anemometer - RM Young Mod 81000	225°	3.2	1.50
91	AN 91m - B	Cup anemometer - Vector A100L2	345°	3.9	1.75
91	AN 91m - A	Cup anemometer - Vector A100L2	225°	3.9	1.50
91	AN 91m - C	Cup anemometer - Vector A100L2	105°	3.9	2.00
81	AN 81m - B	Cup anemometer - Vector A100L2	345°	4.6	1.75
81	AN 81m - A	Cup anemometer - Vector A100L2	225°	4.6	1.50
71	AN 71m - B	Cup anemometer - Vector A100L2	345°	5.4	1.75
71	AN 71m - C	Cup anemometer - Vector A100L2	105°	5.4	2.00
71	AN 71m - A	Cup anemometer - Vector A100L2	225°	5.4	1.50
61	AN 61m - B	Cup anemometer - Vector A100L2	345°	6.2	1.75
61	Sonic 61m - A	Ultrasonic anemometer - RM Young Mod 81000	225°	6.2	1.50
51	AN 51m - C	Cup anemometer - Vector A100L2	105°	6.7	2.00

HEIGHT ASL [M]	INSTRUMENT IDENTIFICATION	DESCRIPTION	MOUNTING AND ORIENTATION	HORIZONTAL BOOM LENGTH [m]	VERTICAL BOOM LENGTH [m]
51	AN 51m - B	Cup anemometer - Vector A100L2	345°	6.7	1.75
51	AN 51m - A	Cup anemometer - Vector A100L2	225°	6.7	1.50
41	AN 41m - B	Cup anemometer - Vector A100L2	345°	7.5	1.75
31	AN 31m - B	Cup anemometer - Vector A100L2	345°	8.4	1.75
101	Dir 101m	Wind vane - Friedrichs 41211000	105°	3.2	2.00
81	Dir 81m*	Wind vane - Friedrichs 41211000	105°	4.6	2.00
61	Dir 61m*	Wind vane - Friedrichs 41211000	105°	6.2	2.00
29	Dir 29m	Wind vane - Vector W200P	180°	8.4	-
95	Temp 95m	Thermometer – Thies 1.10005.54.241	180°	3.9	-
55	Temp 55m	Thermometer – Thies 1.10005.54.241	180°	6.7	-
29	Temp 29m	Thermometer – Thies 1.10005.54.241	180°	8.4	-

*Although those instruments are listed on the mast description, they were not included in the data files EMD had access to.

EMD has obtained access to the data as csv files. Therefore, the conversion of the raw data could not be verified.

As FINO3 is a large offshore mast, the observed mast disturbance on the wind speed measurements is significantly. Only for the data at 91, 71 and 51 m it has been possible to remove most of the tower shadowing thanks to the 3 cup anemometers in different direction for each height, as shown in Table 54 and Figure 68. The data has been merged based on the detected distortions (Figures 65 and 70).

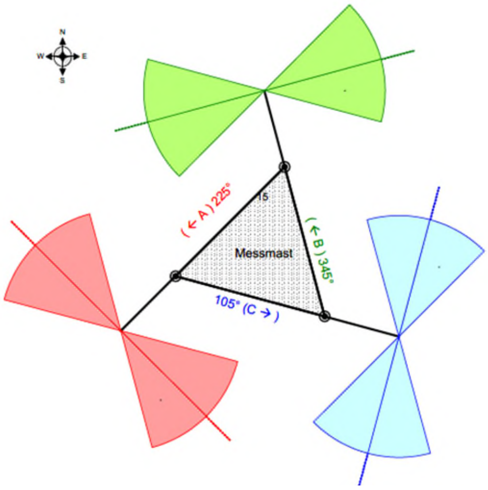

Figure 68. Representation of the boom's positioning in FINO3 and the undisturbed inflow directions, source: [63]

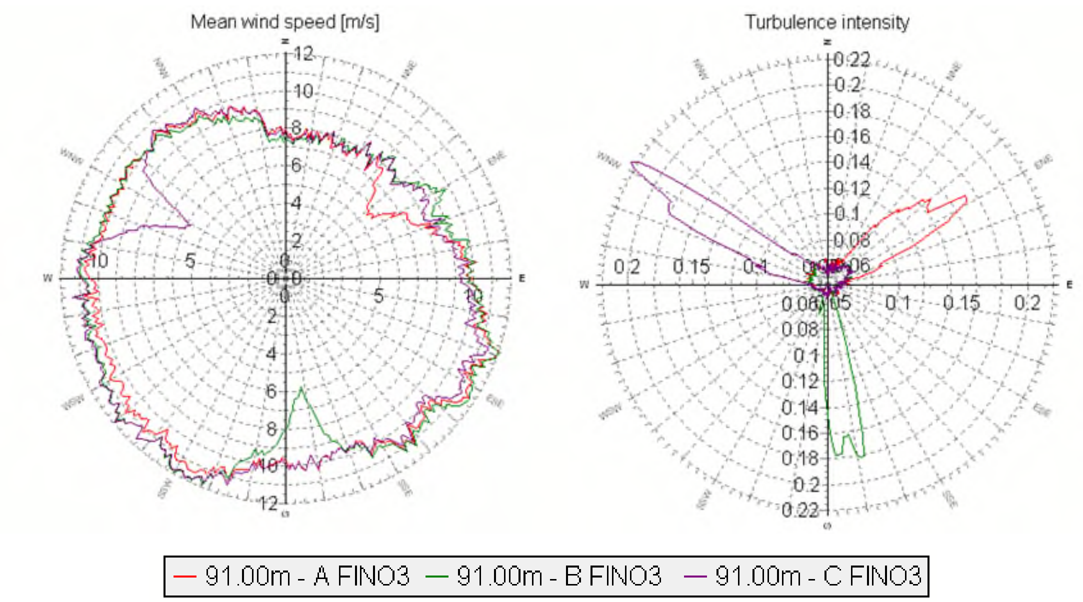

Figure 69. Directional Mean wind speed (left) and Turbulence Intensity (right) for the 3 cup anemometers at 91 m, before merging.

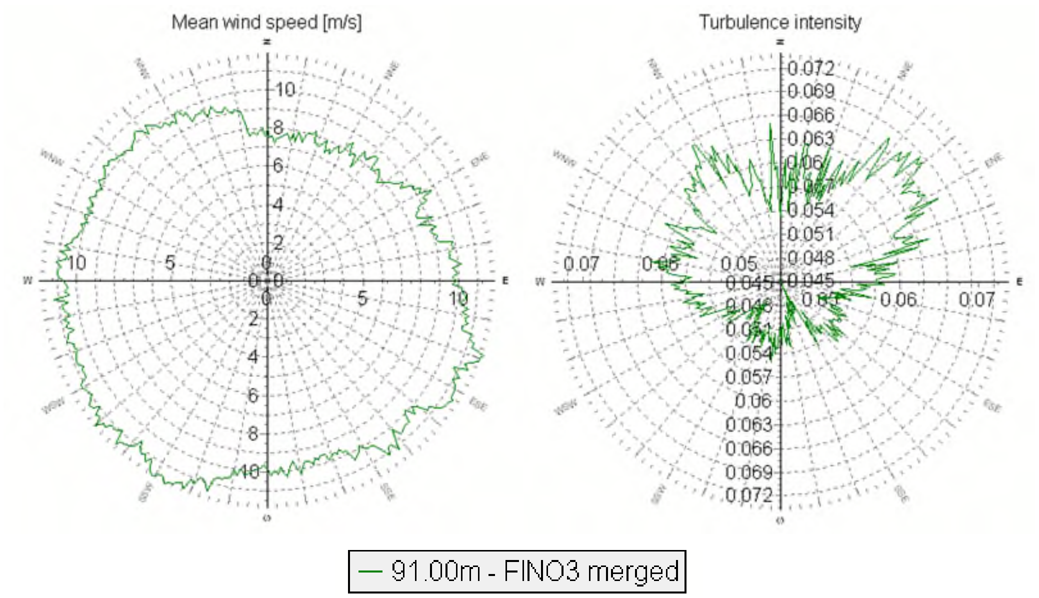

Figure 70. Directional Mean wind speed (left) and Turbulence Intensity (right) at 91 m, after merging.

In general, the data quality is good. The wind directions data at each height correlates well with wind direct at the other heights and wind speed data at each height correlates well with wind speed data at the other heights. The data has been filtered for faulty equipment and failures.

4 full years have been selected from 01/01/2010-31/12/2013. The data from the 91 m anemometer is the primary data from the FINO3 met mast considered in the study. It is deemed more reliable than the 101 and 107 m data, heavily impacted by the mast shadowing. The recovery rate of the merged data for the 4-year period is 92.2%. The following major gaps (consecutive days with missing or erroneous data) in the wind data (wind speed at 91 m-B and wind direction at 101 m) can be noted:

- 50 days from 14/01/2013
- 35 days from 03/07/2013
- 17 days from 08/11/2010, gap concerning all channels.
- 11 days from 01/01/2011, gap concerning all channels.
- 9 days from 11/01/2012, gap concerning all channels.
- 8 days from 27/07/2011, gap concerning all channels.

Due to the unavailability of some information, as mast's maintenance and instrument certification, it was not possible to precisely assess an uncertainty on FINO3's measurements. The uncertainty on FINO3 measurements was estimated to be in the magnitude of 3.5%, taking into account the lack of information, the noncompliance to the standards [59] and compensating for the possibility to correct the mast distortion.

vi. Ground Meteo Stations

ANHOLT

The observations made at Anholt come from a meteorological mast (#06079) from Danish Meteorological Institute (DMI) [8]. Wind speed and direction measurements are recorded at 10 m AGL. Temperature measurements are recorded at 2 m AGL. No turbulence data are available. The observations have been conducted from several locations during the measurement period as shown on Figure 71 and Table 56.

Table 56. Measuring information of Anholt meteorological station

Location	Longitude	Latitude	Measured period	Resolution
An1	11.6511	56.7360	01/01/1961 - 31/10/1965	3 hours
An2	11.5470	56.7034	01/10/1967 - 24/11/1976	4 hours
An3	11.5436	56.7011	25/11/1976 - 06/04/1980	4 hours
An4	11.5098	56.7169	01/05/1993 - 28/09/1999 29/09/1999 - 01/05/2024	1 hour 10 minutes

The coordinates available for the first three positions cannot be validated from the orthophoto map.

The forth position can be confirmed satellite imagery from Google Earth. The mast is located about 17-25 m from the pier, at an altitude of 2.3 m ASL. The mast does not seem obstructed by local obstacles in the main wind direction. However, effects can be expected from a building about 50 m south-east of the mast. The setup of the anemometer on the mast is unknown, which prevents the assessment of possible distortion from the mast.

Figure 71. Four positions of Anholt met mast (DMI #06079) over time. Source: windPRO European Satellite Imagery.

Raw data verification and data treatment

In general, the data quality is good. The data have been filtered for faulty equipment and failures due to weather conditions.

To ensure the consistency of data in terms of location and time resolution, only the data from the last period of measurements and with 10 minute resolution is kept for this analysis (29/09/1999 – 01/05/2024).

The data is trimed to 24 full years (01/05/2000 – 01/05/2024). The recovery rate of the wind data for this period is very good with 98.9%. The following gaps (consecutive days with missing or erroneous data) in the wind data can be noted:

- 5 days in 09/2000
- 7 days in 07/2001
- 7 days in 10/2006
- 14 days in 04/2013
- 1 months between 04/05/2013 and 03/06/2013
- 2 days in 02/2018
- 5 days in 03/2022

The reasons for missing data is unknown.

The recovery rate of the temperature data is also good with 95.7%.

GNIBEN

The observations made at Gniben come from a meteorological mast (#06169) from Danish Meteorological Institute (DMI) [8]. Wind speed and direction measurements are recorded at 10 m AGL. Temperature measurements are recorded at 2 m AGL. No turbulence data are available

The DMI met mast of Gniben is located on Sjællands Odde peninsula. At this outermost point, the peninsula is only 200 m wide, so the location of the met mast is well exposed to the open sea. However, the site is elevated from the sea level by 14 m at the position of the mast. At 23 m south of the met mast, one can notice a large (about 6 m wide) and tall (about 60 m high) lattice tower. Flow distortion from this tower can be expected on the measurements, however with a minimum impact as it does not concern any primary wind directions. Buildings east of the met mast are less than the measurement height and far enough to impact the flow. Steep slopes 80 m upwind in the western direction may affect the flow and hence the quality of the measurements. The setup of the anemometer on the mast is unknown, which prevents the assessment of possible distortion from the mast.

Observations at Gnibben have been conducted in different periods, characterized by different time interval and locations, as provided by DMI [8]. The locations are shown on Figure 72 and listed on Table 57.

Table 57. Measuring information of Gniben meteorological station

Location	Longitude	Latitude	Measured period	Resolution
Gn1	11.2805	56.0067	01/01/1961 - 31/07/1974	3 hours
Gn2	11.2792	56.0064	01/08/1974 - 24/11/1976	3 hours
Gn3	11.2787	56.0083	03/04/1979 - 14/02/1983	3 hours
Gn4	11.2787	56.0083	15/02/1983 - 06/08/2002 28/08/2002 - 01/05/2024	1 hour 10 minutes

Figure 72. Four positions of Gniben met mast (DMI #06069)

Raw data verification and data treatment

In general, the data quality is good. The data have been filtered for faulty equipment and failures due to weather conditions.

To ensure the consistency of data in terms of location and time resolution, only the data from the last period of measurements is kept for this analysis. Out of this period, only 21 full years of 10 minutes values have been selected (01/05/2003 - 01/05/2024). The recovery rate of the wind data for this period is very good with 98.1%.

The following gaps (consecutive days with missing or erroneous data) in the wind data can be noted:

- 6 days in 08/2006
- 2 and 7 days in 04/2011
- 23 days between 05/2011 and 06/2011
- 32 days between 12/2012 and 01/2013
- 1 day in 04/2014
- 3 days in 12/2021

The reasons for missing data is unknown.

The recovery rate of the temperature data is also good with 97.4%.

NAKKEHOVED

The observations made at Nakkehoved comes from a meteorological mast (#06168) from Danish Meteorological Institute (DMI) [8]. Wind speed and direction measurements are recorded at 10 m AGL. Temperature data is measured at 2 m AGL. No turbulence data are available.

The met mast of Nakkehoved is located on the northern coast of Sjælland, about 100 m from the shore. The surroundings are characterized by high roughness terrain with forest and cities (Gilleleje and Munkerup). The vicinity of trees (5-10 m tall) just next to the mast compromises the quality of the measurements due to the turbulences and displacement of the wind flow created by the canopy. The elevation of the mast is 36.4 m ASL.

Observations at Nakkehoved have been conducted with different time intervals. Two very similar and close sets of coordinates are available, see Table 58. The actual position ("Na2" on Figure 73) which is valid for the 10 minutes interval datasets can be verified from the Danish Orthophoto Mosaic (source: Geodatastyrelsen). The setup of the anemometer on the mast is unknown, which prevents the assessment of possible distortion from the mast.

Table 58. Measuring information of Nakkehoved meteorological station.

Location	Longitude	Latitude	Measured period	Resolution
Na1	12.3429	56.1193	07/02/1982 – 28/10/1983 02/09/1986 – 29/09/1999 30/09/1999 – 17/01/2001	3 hours 1 hour 10 minutes
Na2	11.2792	56.0064	18/01/2001 – 01/05/2024	10 minutes

Figure 73. Two positions of Nakkehoved met mast (DMI #06068)

Raw data verification and data treatment

In general, the data quality is good. The data have been filtered for erroneous data usually due to faulty equipment and failures due to weather conditions.

To ensure the consistency of data in terms of location and time resolution, only the data from the last period of measurements is kept for this analysis. Out of this period, only 23 full years of 10 minutes values have been selected (01/05/2001 - 01/05/2024). The recovery rate of the wind data for this period is very good with 98.7%.

The following gaps (consecutive days with missing or erroneous data) in the wind data can be noted:

- 1 day in 07/2005
- 43 days between 01/2007 and 02/2007
- 27 days in 03/2014
- 17 days between 07/2021 and 08/2021

The reasons for missing data is unknown.

The recovery rate of the temperature data is also good with 98.5%.

HALLANDS VÄDERÖ

The observations made at Hallands Väderö come from a meteorological mast (#62260) from Swedish Meteorological and Hydraulic Institute (SMHI) [9]. The met mast is located on the northwest part of the island of Hallands-Väderö in Sweden. Wind speed, wind direction and temperature data are measured at 2 m AGL. No turbulence data are available.

Observations at Väderö have been conducted during two different periods at different locations. The first period consists of about 4.5 years (between 1961 and 1965), 540 m from the west coast of the island. The second period starts in 1995 (still ongoing) in the vicinity of the lighthouse, about 140 m from the west coast and at an elevation of 8.3 m ASL. The lighthouse and its dwelling are located about 25 - 32 m in the western direction. Flow distortion from these obstacles can affect the quality of measurements made at 2 m AGL. The landscape is open, but with low vegetation to the east.

The wind data is available as 10-minute averages delivered every hour. The temperature data are instantaneous values, also available as hourly data.

Table 59. Measuring information of Hallands-Väderö meteorological station.

Location	Longitude	Latitude	Measured period	Resolution
Va1	12.5500	56.4500	01/01/1951 – 30/06/1965	6 hours
Va2	12.5453	56.4496	01/08/1995 – 01/01/2024	1 hour

Figure 74. Two positions of Hallands-Väderö met mast (SMHI #62260).

Raw data verification and data treatment

In general, the data quality is good. No filtering of erroneous data has been necessary. The data seems already filtered.

28 full years of hourly data have been selected from 01/01/1996 - 01/01/2024. The recovery rate of the data for this period is good with 95.3%. The following gaps (consecutive days with missing or erroneous data) in the wind data can be noted:

- 12 days in 02/1996
- 1 day in 10/1996
- 14 days in 08/1997
- 7 days in 05/1998
- 10 days in 05/1999
- 4 days in 07/2000
- 34 days between 04/2002 – 05/2002
- 2 days in 09/2003
- 3, 4, 3 and 10 days in 10/2003
- 2 and 1 days in 11/2003
- 7 and 1 days in 03/2004

- 43 days between 01/2005 – 02/2005
- 8 and 4 days in 03/2005
- 9 days in 07/2005
- 24 days between 03/2011 – 04/2011
- 4 days in 05/2011
- 59 days between 11/2011 – 01/2012
- 8 days between 06/2017 – 07/2017
- 20 days in 03/2018
- 40 days between 02/2020 – 04/2020
- 22 days between 07/2021 – 08/2021
- 57 days between 02/2023 – 04/2023

Possible reasons for missing data:

- the station or transmitter has been out of order.
- the station has only delivered values with quality code Red (R).

The recovery rate of the temperature data is also good at 96.3%.

RØSNÆS FYR

The observations made at Røsnæs Fyr comes from a meteorological mast (#06159) from Danish Meteorological Institute (DMI) [8]. Wind speed and direction measurements are recorded at 10 m AGL. Temperature data is measured at 2 m AGL. No turbulence data are available.

The met mast of Røsnæs Fyr is located on the western coast of Sjælland, about 30 m from the shore. At this outermost point, the peninsula is only 90 m wide, so the location of the met mast is well exposed to the open sea, and the site elevation is only 1 m ASL at the position of the mast. At 10 m west of the met mast, one can notice a water tower (about 4 m wide and about 10 m high). Flow distortion from this tower is expected on the measurements. The vicinity of buildings and trees just next to the mast, also compromises the quality of the measurements due to the turbulences and displacement of the wind flow created by the canopy. The setup of the anemometer on the mast is unknown, which prevents the assessment of possible distortion from the mast.

Observations at Røsnæs Fyr have been conducted with different time intervals and from two different locations, see Table 60 and Figure 75.

Table 60. Measuring information of Røsnæs Fyr meteorological station.

Location	Longitude	Latitude	Measured period	Resolution
Ro1	10.8691	55.7436	01/01/1959 – 14/11/2001	3 hours
Ro2	10.8694	55.7435	15/11/2001 – 01/05/2024	10 minutes

Figure 75. Two positions of Røsnæs Fyr met mast (DMI #06159)

Raw data verification and data treatment

In general, the data quality is good. The data have been filtered for erroneous data usually due to faulty equipment and failures due to weather conditions.

To ensure the consistency of data in terms of location and time resolution, only the data from the last period of measurements is kept for this analysis. Out of this period, only 22 full years of 10 minutes values have been selected (01/05/2002 - 01/05/2024). The recovery rate of the wind data for this period is very good with 98.9%.

The following gaps (consecutive days with missing or erroneous data) in the wind data can be noted:

- 1 day in 04/2006
- 8 days between 12/2007 and 01/2008
- 19 days in 02/2008
- 5 days in 09/2011
- 1 day in 09/2014
- 1 day in 10/2014
- 7 days in 04/2015
- 2 days in 02/2016
- 6 days in 09/2023

The reasons for missing data is unknown.

The recovery rate of the temperature data is also good with 98.9%.

SLETTERHAGE FYR

The observations made at Sletterhage Fyr comes from a meteorological mast (#06073) from Danish Meteorological Institute (DMI) [8]. Wind speed and direction measurements are recorded at 10 m AGL. Temperature data is measured at 2 m AGL. No turbulence data are available.

The met mast of Sletterhage Fyr is located on the southern coast of Sjælland, about 30 m from the shore. At this outermost point, the peninsula is only 90 m wide, so the location of the met mast is well exposed to the open sea, and the site elevation is only 1 m ASL at the position of the mast. The vicinity of buildings and trees just next to the mast, compromises the quality of the measurements due to the turbulences and displacement of the wind flow created by the canopy. The setup of the anemometer on the mast is unknown, which prevents the assessment of possible distortion from the mast.

Observations at Sletterhage Fyr have been conducted with different time intervals and from two different locations, see Table 60 and Figure 75.

Table 61. Measuring information of Sletterhage Fyr meteorological station.

Location	Longitude	Latitude	Measured period	Resolution
Sl1	10.5134	56.0954	01/07/1977 – 30/04/1985	3 hours
Sl2	10.5135	56.0955	21/05/2001 – 01/05/2024	10 minutes

Figure 76. Two positions of Sletterhage Fyr met mast (DMI #06073)

Raw data verification and data treatment

In general, the data quality is good. The data have been filtered for erroneous data usually due to faulty equipment and failures due to weather conditions.

To ensure the consistency of data in terms of location and time resolution, only the data from the last period of measurements is kept for this analysis. Out of this period, only 22 full years of 10 minutes values have been selected (01/05/2002 - 01/05/2024). The recovery rate of the wind data for this period is very good with 99.4%.

The following gaps (consecutive days with missing or erroneous data) in the wind data can be noted:

- 2 days in 07/2004
- 3 days in 09/2005
- 6 days in 06/2017
- 2 and 1 days in 11/2017
- 6 days between 02/2022 and 03/2022

The reasons for missing data is unknown.

The recovery rate of the temperature data is also good with 99.2%.

vii. Measuring Stations Not Used

Several other meteorological stations were considered, but not used in this study for different reasons which are presented below.

The data measured by the LiDAR ("ANH") located on a platform inside the Anholt OWF has not been used. Besides incomplete available information, the data is heavily impacted by the Anholt wind turbines. The use of turbulence data from undisturbed sectors are not relevant because they are deemed unreliable when measured from a LiDAR.

Data (of salinity and temperature) from meteorological stations Anholt E, L:A Middelgrund, N14 Falkenberg, Stora Middelgrund could not been found on the SMHI website [9]. With data otherwise available, this information would have been redundant and the issue was not pursued.

The data measured from the Fladen Lighthouse and Ringhals have not been selected as they have been considered redundant with Anholt Haven station. They are also considered to be too far away from the analyzed wind farm area.

The period of the measured data from the Anholt OWF, Hamlstad Flygplats and P22 are too short and therefore not suitable for the study. The goal of these type of data being to check the long-term consistency and the air temperature.

Appendix A.2. Data Analysis of Supporting Data

WIND SPEED DISTRIBUTION

The following table summarizes the resulting measured wind speeds.

Table 62. Summary of secondary data wind speed

Station	HEIGHT [m]	ARITHMETIC MEAN WIND SPEEDS [m/s]	MAX MEAN WIND SPEED [m/s]	WEIBULL MEAN [m/s]	WEIBULL – A PARAMETER	WEIBULL – K PARAMETER
Kattegat (KG-1-LB)	150	10.00	32.02	9.97	11.26	2.17
Hesselø (H1)	150	9.87	33.42	9.98	11.27	2.17
Læsø (M1)	62	8.8	28.39	8.94	10.09	2.36

WIND DIRECTION DISTRIBUTION

The frequency and energy distributions indicate that there is not only one defined main direction, but scattered distribution, being the third and fourth quadrant, from South-southwest to Northwest, the most dominant wind directions.

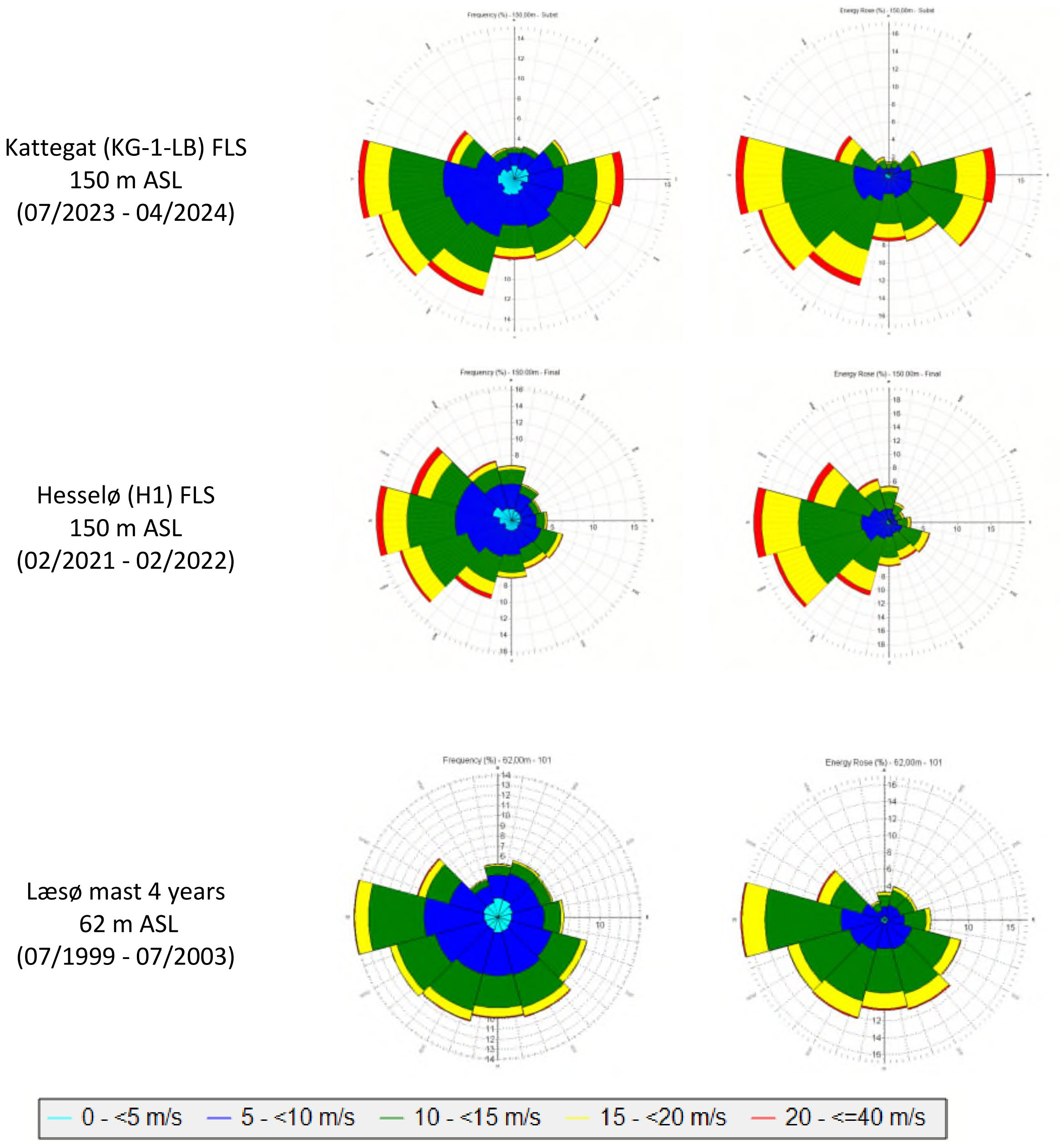

Figure 77. Supporting data wind direction frequency (on the left) and energy (on the right) distribution.

TURBULENCE INTENSITY

The turbulence intensity calculated from the mean wind speed and its standard deviation is presented in Figure 78. For FINO3, the 91 m mean turbulence intensity is presented while FINO2 the 102 m mean turbulence intensity is presented. The observed mean turbulence intensity for Læsø at 62 m is added for comparison. As observed on Figure 79 the turbulence intensity has a uniform distribution across the direction sectors in all three observations.

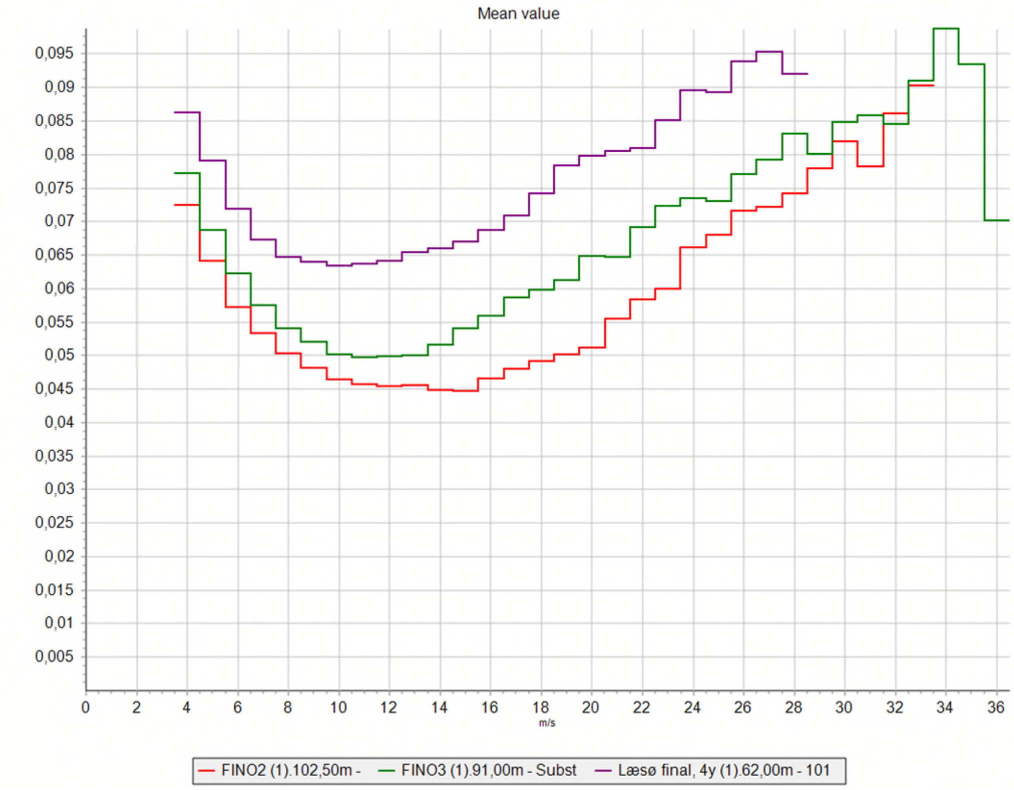

Figure 78. Turbulence intensity measured at FINO3, FINO2 and Læsø

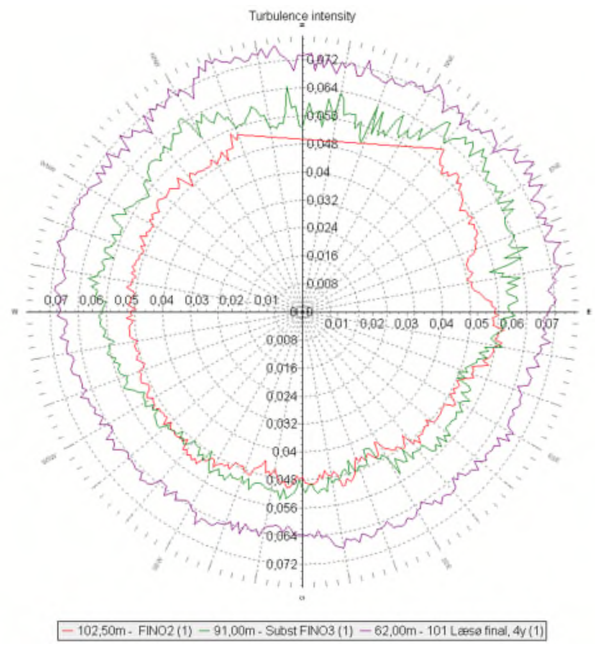

Figure 79. Measured turbulence intensity measured at FINO3, FINO2 and Læsø by wind direction.

The Læsø turbulence measurements are considered not representative of the Hesselø South site, due to very low water depth at Læsø, and they were disqualified in the discussion in section 9.1.3. It is, however, interesting to compare the combined turbulence function based on FINO2 and FINO3 with a turbulence model at 150 m based on Læsø data (Figure 80). The match on mean and standard deviation is poor, but the characteristic turbulence functions are surprisingly close.

EMD has verified the combined model against confidential measurement in the Kattegat that confirms the combined turbulence model with good match on mean, standard deviation and characteristic turbulence from 12 m/s and up.

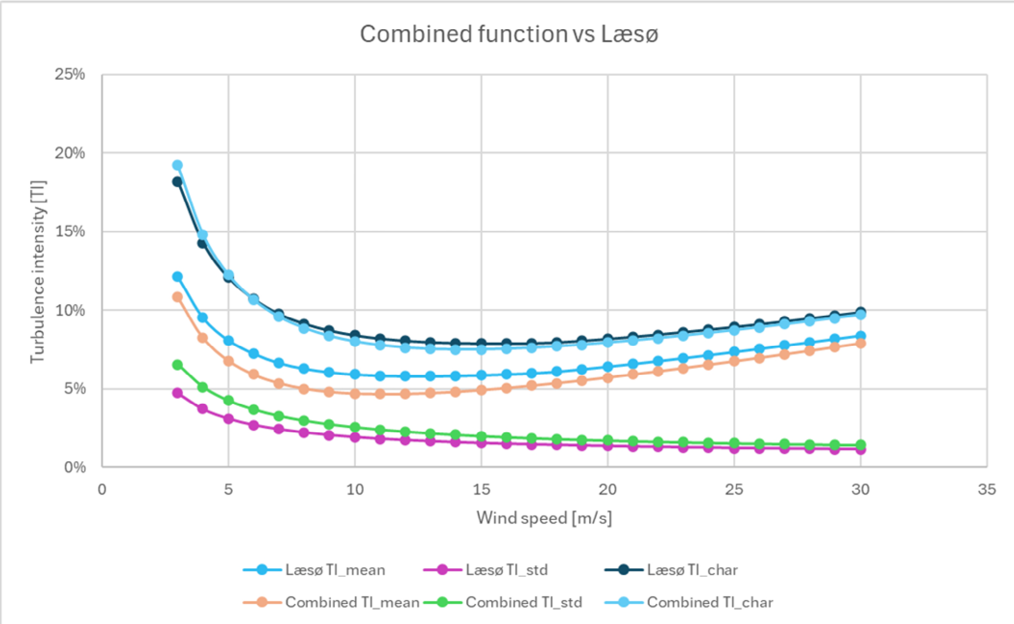

Figure 80. Mean turbulence intensity (TI_mean), Standard deviation of turbulence intensity (TI_std) and Characteristic turbulence intensity for the Combined model and Læsø turbulence extrapolated to 150 m.

DIURNAL VARIATION WIND SPEED

The wind speed is lowest at midday and highest during the night.

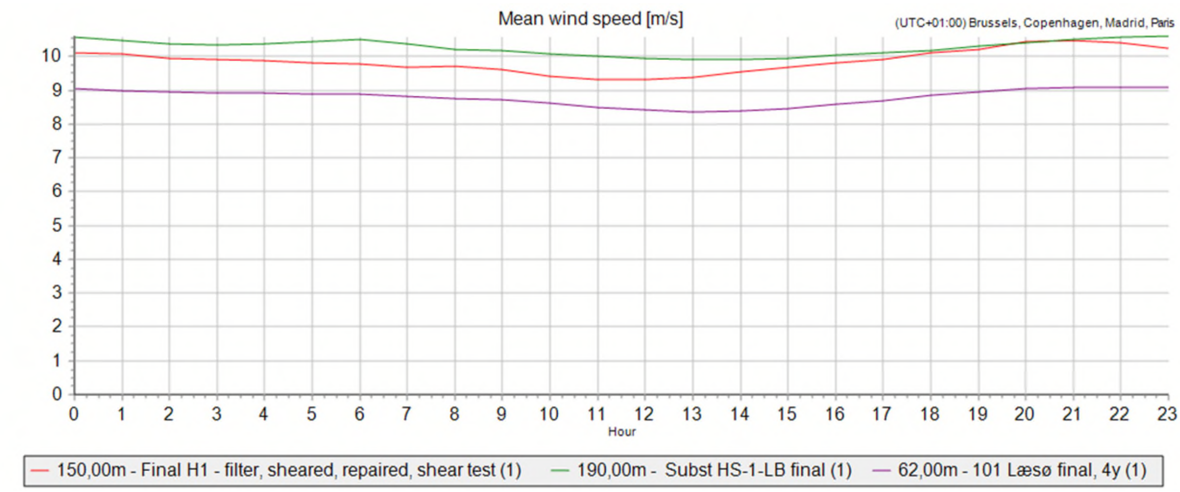

Figure 81. Daily variation of wind speed at H1, 1 year - 150 m (red), HS-1, 1 year 150 m (green) and M1, 4 year, 62 m (purple).

SEASONAL VARIATION WIND SPEED

The monthly wind speed variations point to highest wind speeds during the late autumn and winter.

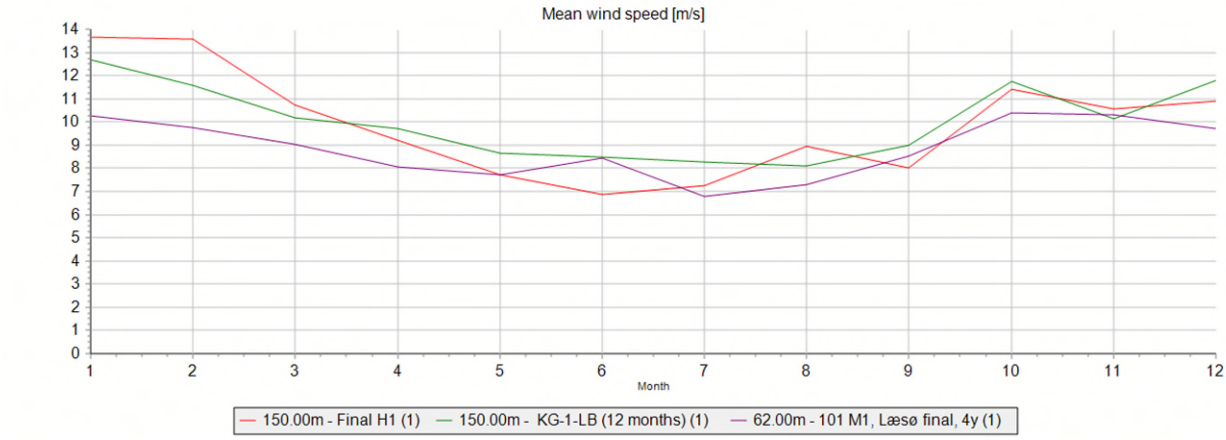

Figure 82. Monthly variation of wind speed measured at H1 - 150 m (1 year) (in red), KG-1-LB - 150 m (1 year) (in green) and M1 - 62 m (4 years) (in purple).

TEMPERATURE

A summary of the mean temperature measured on the 9 secondary data sources is presented in Table 63.

The diurnal distribution of temperature shows a distinct difference between onshore and offshore stations. The amplitude is far smaller on the offshore sites as expected, which will resemble the Hesselø South OWF more than the onshore stations Figure 83.

Table 63. Summary of Secondary Temperature data

Source	Height (ASL) [m]	Position	Period		Mean Temperature [°C]
Læsø (M1)	55	Offshore	07/1999 - 07/2003	4	9.5
Anholt Haven	10	Onshore	05/2000 - 05/2024	24	9.44
Gniben	10	Onshore	05/2003 - 05/2024	21	9.54
Nakkehoved Fyr	10	Onshore	05/2001 - 05/2024	23	9.12
Hallands Väderö	2	Onshore	01/1996 - 01/2024	28	9.02
Røsnæs Fyr	10	Onshore	05/2002 - 05/2024	22	9.72
Sletterhage Fyr	10	Onshore	05/2002 - 05/2024	22	9.48

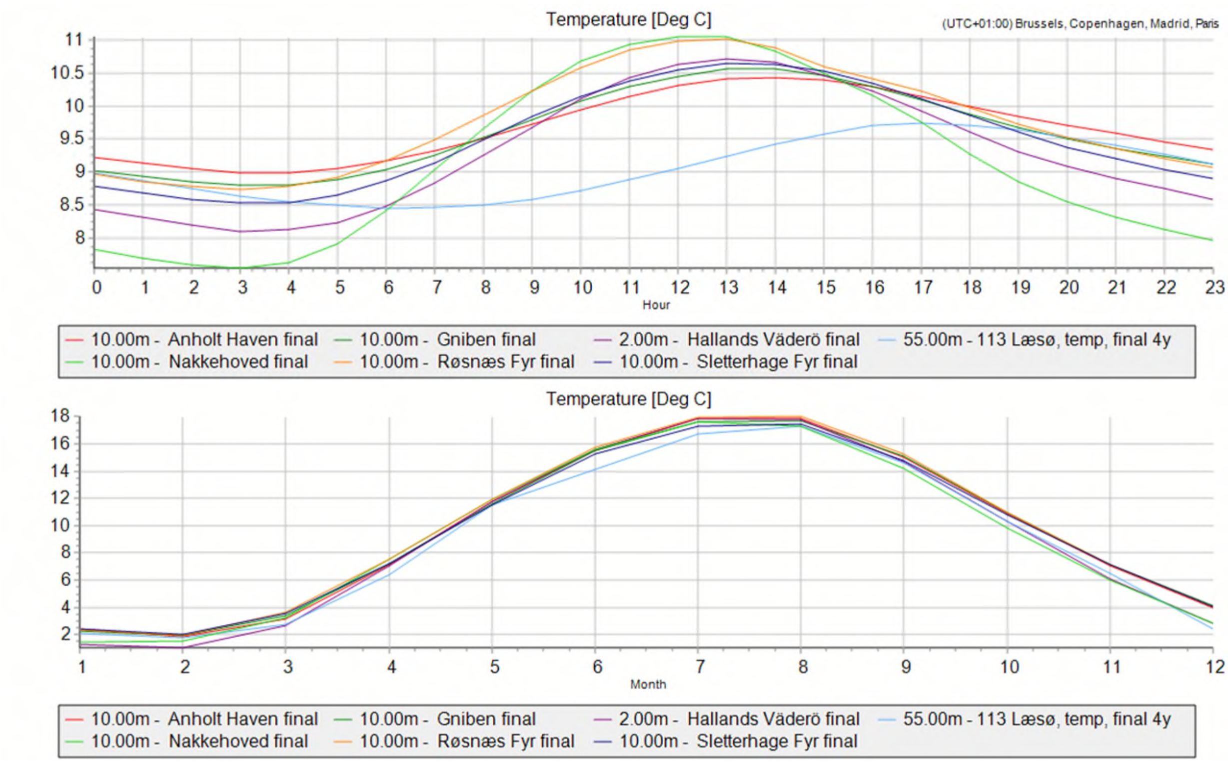

Figure 83. Diurnal and monthly variation of absolute temperature at the 7 secondary data sources.

Appendix A.3. Long-term Correction of Supporting Data

The measurement data from Kattegat (KG-1-LB), Hesselø (H1) and Læsø (M1) have been long-term corrected for wind model validation use. The reference period used is 2002-2023 (22 years). The argumentation for use of this period is presented in section 6.1.2.

REFERENCE DATA AND CORRELATION

For each dataset, three different reference datasets were considered: EMD-WRF, ERA5(T) and NORA3. These reference datasets are discussed in section 5. The closest node to each location was used.

EMD has several long-term correction methodologies at disposal. A full description of these can be found in the WindPRO reference document on Measure-Correlate-Predict (MCP) methods [26].

In each case correlation on wind speed, monthly correlation on energy content (index), self-prediction (concurrent period) and 24-hour slicing test (both converted to production output) as well as the ability to correctly reproduce observed directional distribution and wind speed frequency distribution was considered. The reference data and methodology with the best combined success was selected. This is summarized in Table 64.

Table 64. Best performing reference data and long-term correction methodology (LTC) for each secondary dataset.

REF: EMD-WRF	KG-1-LB	H1	M1
Reference dataset	ERA5(T)	EMD-WRF	EMD-WRF
Correlation, r [%] Wind Speed, hourly	94.4	94.9	93.5
Correlation, r [%] Wind Energy, monthly	99.4	99.8	99.1
LTC methodology	Matrix	Matrix	Matrix
MBE, 24-hour slicing test, % production	1.84	0.75	-0.64
MBE, Concurrent period prediction test, % production	0.37	0.23	-0.03

LONG-TERM WIND SPEED DISTRIBUTION

The long-term corrected wind speeds and wind distributions are presented in Table 65.

Frequency tables for each dataset can be found in appendix E.

Table 65. Long-term corrected wind speed and wind distribution, secondary data.

	ELEVATION ASL [m]	PERIOD [Y]	ARITHMETIC MEAN WIND SPEEDS [m/s]	WEIBULL MEAN [m/s]	WEIBULL - A PARAMETER	WEIBULL - k PARAMETER
KG-1-LB	150	22	9.51	9.60	10.83	2.27
H1	150	22	9.73	9.86	11.13	2.21
M1	62	22	8.98	9.14	10.31	2.40

LONG-TERM WIND DIRECTION DISTRIBUTION

KG-1-LB, 22 years
150 m ASL
(01/2002 - 12/2023)

H1, 22 years
150 m ASL
(01/2002 - 12/2023)

M1, 22 years
62 m ASL
(01/2002 - 12/2023)

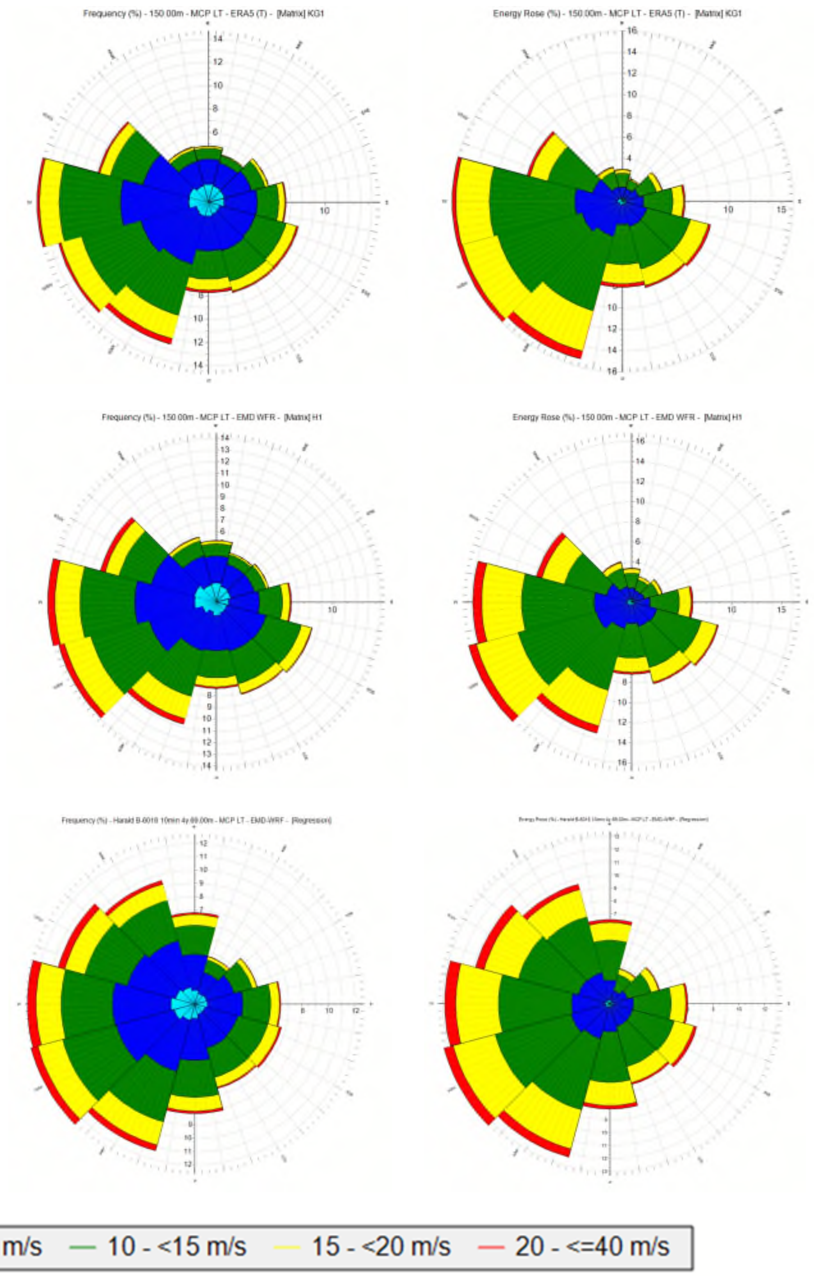

Figure 84. Long-term corrected frequency and energy roses, secondary data.

LONG-TERM DIURNAL VARIATIONS

Daily variation of the three long-term corrected datasets is presented in Figure 85. All datasets are quite parallel, with higher wind speed at night than at daytime. The same pattern is observed in the measured data. Note that the anomaly seen for the long-term corrected data at KG-1-LB at around 10:00 is inherent to the ERA5(T) data.

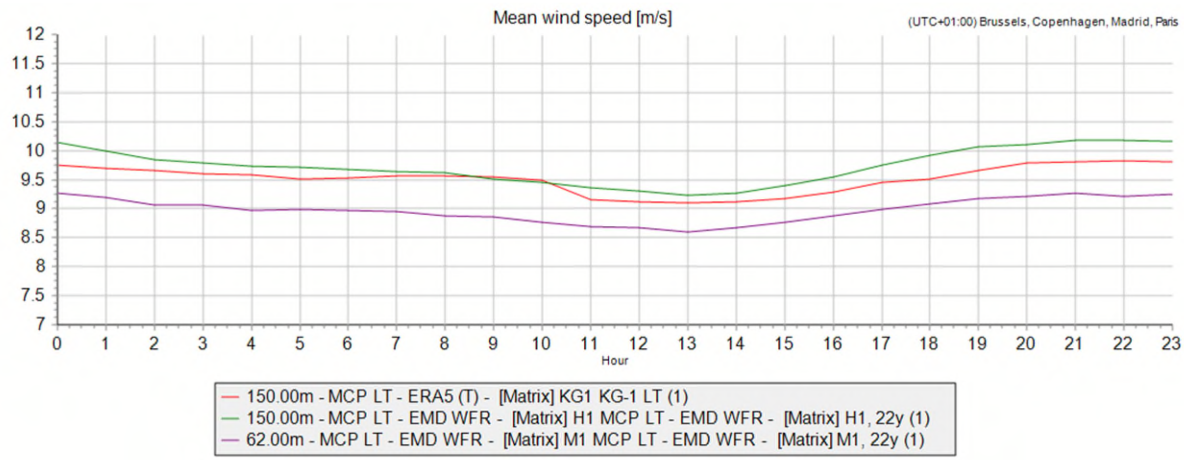

Figure 85. Long-term corrected diurnal variation, secondary data. Red: KG-1-LB, green: H1, purple: M1.

LONG-TERM SEASONAL VARIATIONS

The long-term seasonal variation mirrors that of the observation but is not more regular in shape with high wind speed at winter and lower wind speed in summer.

There is a distinctly different directional energy distribution summer and winter common for all three datasets.

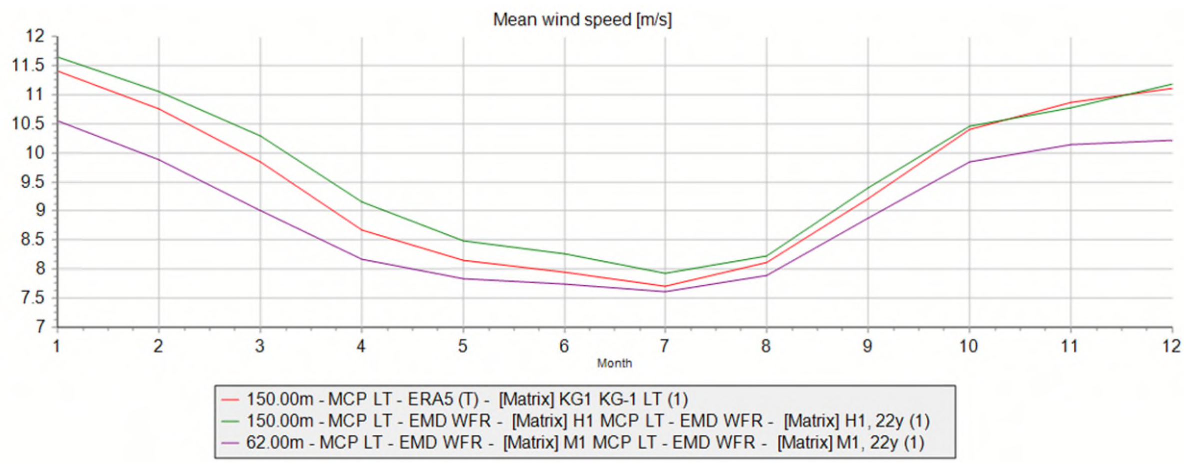

Figure 86. Long-term corrected seasonal variation, secondary data. Red: KG-1-LB, green: H1, purple: M1.

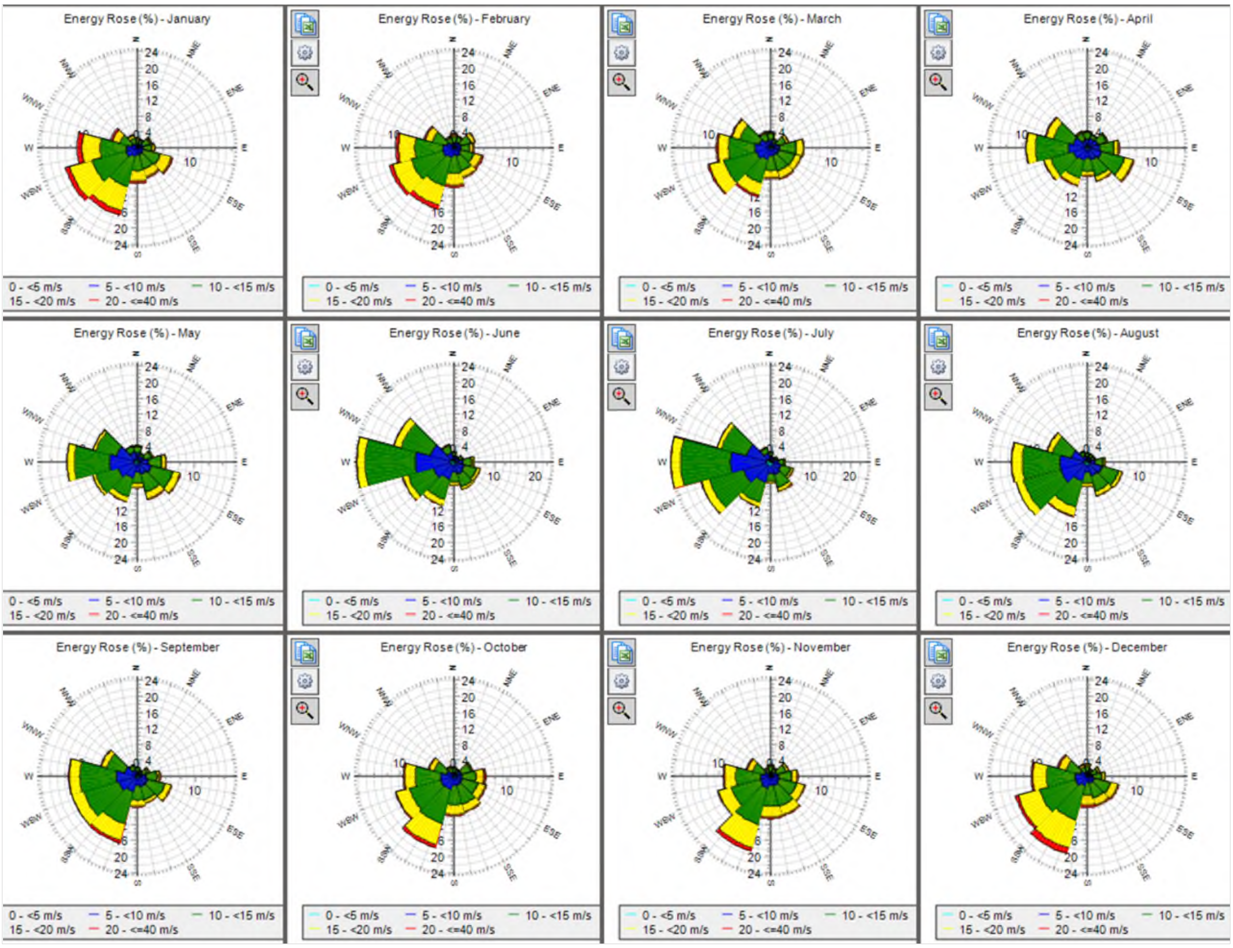

Figure 87. Long-term monthly energy roses, KG-1-LB (first line: January-April; second line: May-August; last line: September-December).

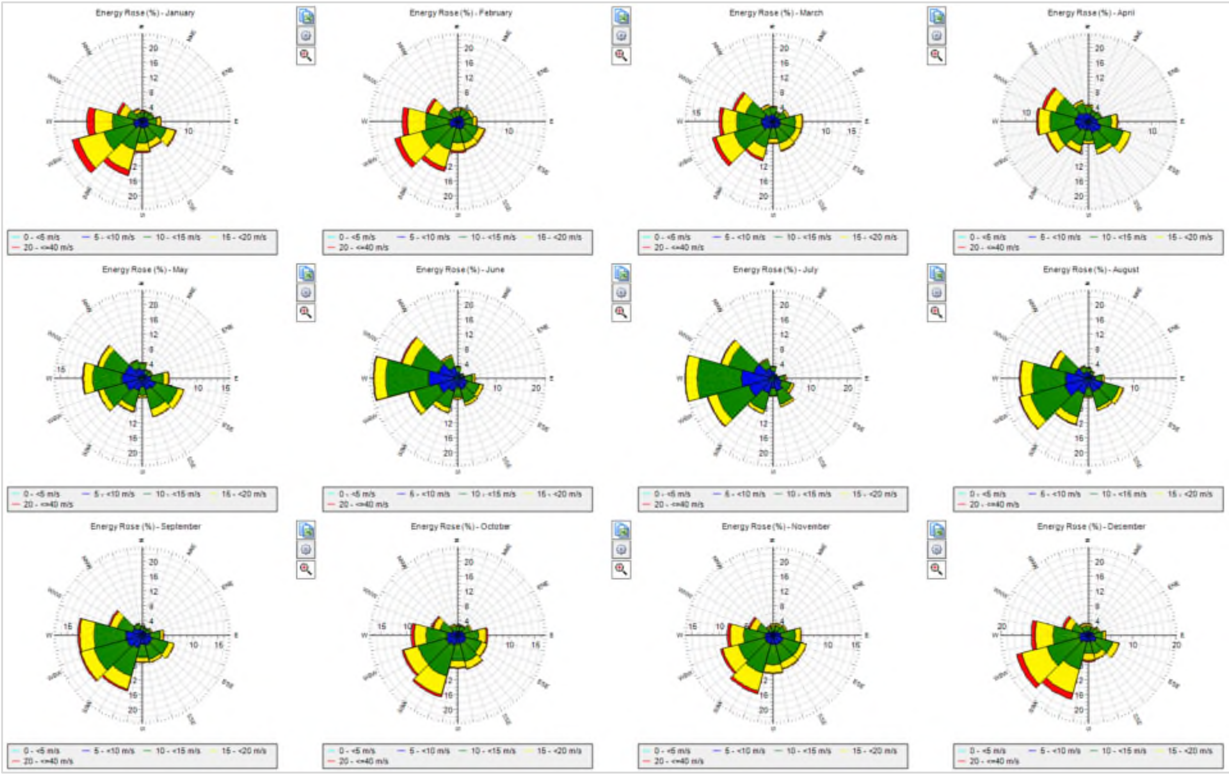

Figure 88. Long-term monthly energy roses, H1 (first line: January-April; second line: May-August; last line: September-December).

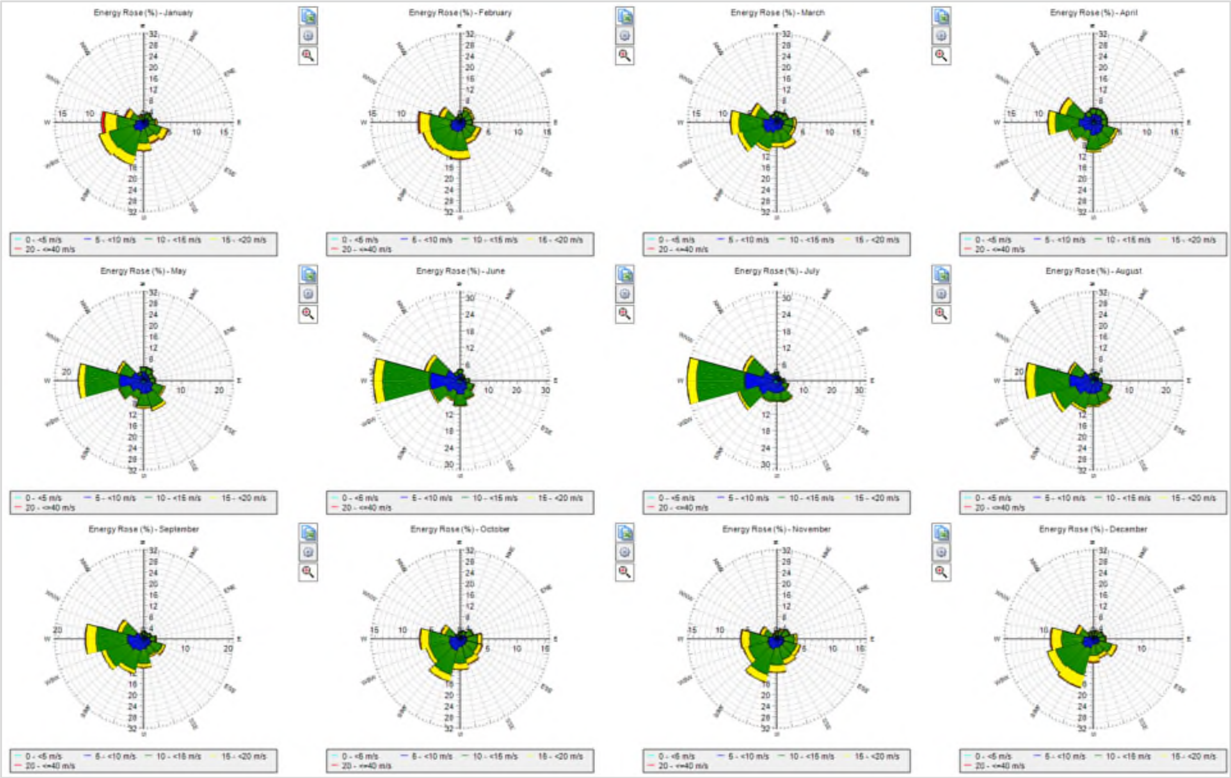

Figure 89. Long-term monthly energy roses, M1 (first line: January-April; second line: May-August; last line: September-December)

Appendix B. Verification and Classification Uncertainty

Verification uncertainty at 160 m height for SWLB059 [15].

Table 6-4 Uncertainty calculation at 160 m

SWLB059 height 160 m													
BIN lower [m/s]	BIN upper [m/s]	# of 10 min data sets	V_{FLS} [m/s]	V_{REF} [m/s]	V_{FLSmax} [m/s]	V_{FLSmin} [m/s]	Std_{VFLS} [m/s]	$Std_{VFLS}/\sqrt{n}$ [m/s]	Mean deviation [%]	Mounting uncertainty [%]	Separation Uncertainty [%]	V_{REF} Uncertainty [%]	**V_{FLS} Uncertainty (k=1) [%]**
3.75	4.25	128	4.06	4.01	4.93	3.45	0.25	0.022	1.29%	0.50%	0.25%	1.94%	**2.46%**
4.25	4.75	142	4.53	4.51	5.36	3.85	0.26	0.022	0.52%	0.50%	0.25%	1.63%	**1.87%**
4.75	5.25	148	5.03	5.00	5.70	4.30	0.23	0.019	0.55%	0.50%	0.25%	1.70%	**1.91%**
5.25	5.75	181	5.51	5.51	6.20	4.38	0.32	0.023	-0.07%	0.50%	0.25%	1.76%	**1.89%**
5.75	6.25	198	6.01	5.99	6.63	4.97	0.27	0.019	0.31%	0.50%	0.25%	1.63%	**1.77%**
6.25	6.75	226	6.52	6.51	7.66	5.58	0.28	0.019	0.12%	0.50%	0.25%	1.63%	**1.75%**
6.75	7.25	173	6.97	6.99	8.70	5.77	0.29	0.022	-0.17%	0.50%	0.25%	1.47%	**1.61%**
7.25	7.75	143	7.45	7.49	8.32	6.07	0.31	0.026	-0.54%	0.50%	0.25%	1.45%	**1.68%**
7.75	8.25	151	7.98	8.00	9.04	6.51	0.29	0.024	-0.28%	0.50%	0.25%	1.46%	**1.62%**
8.25	8.75	156	8.51	8.50	9.78	7.65	0.31	0.025	0.10%	0.50%	0.25%	1.42%	**1.56%**
8.75	9.25	117	8.91	8.98	10.10	7.79	0.30	0.027	-0.77%	0.50%	0.25%	1.39%	**1.71%**
9.25	9.75	73	9.33	9.48	10.07	7.88	0.39	0.046	-1.56%	0.50%	0.25%	1.37%	**2.21%**
9.75	10.25	32	9.99	9.98	10.88	9.34	0.35	0.063	0.17%	0.50%	0.25%	1.37%	**1.62%**
10.25	10.75	46	10.46	10.48	11.45	8.63	0.42	0.062	-0.21%	0.50%	0.25%	1.33%	**1.58%**
10.75	11.25	18	11.05	10.97	12.84	10.58	0.51	0.120	0.76%	0.50%	0.25%	1.34%	**1.97%**
11.25	11.75	20	11.56	11.48	12.14	10.84	0.27	0.060	0.71%	0.50%	0.25%	1.39%	**1.74%**
11.75	12.25	12	12.17	12.07	12.67	11.72	0.26	0.075	0.88%	0.50%	0.25%	1.37%	**1.83%**
12.25	12.75	35	12.69	12.48	13.39	12.22	0.33	0.056	1.65%	0.50%	0.25%	1.42%	**2.29%**
12.75	13.25	33	13.06	12.99	13.70	12.46	0.35	0.061	0.55%	0.50%	0.25%	1.35%	**1.63%**
13.25	13.75	24	13.50	13.49	14.27	12.72	0.37	0.075	0.12%	0.50%	0.25%	1.43%	**1.63%**
13.75	14.25	35	14.25	14.03	15.66	13.59	0.49	0.082	1.59%	0.50%	0.25%	1.45%	**2.30%**
14.25	14.75	22	14.52	14.48	15.74	12.95	0.56	0.119	0.24%	0.50%	0.25%	1.58%	**1.88%**
14.75	15.25	28	15.06	15.01	16.11	14.31	0.53	0.100	0.34%	0.50%	0.25%	1.39%	**1.68%**
15.25	15.75	17	15.64	15.54	16.80	14.47	0.48	0.117	0.61%	0.50%	0.25%	1.33%	**1.74%**
15.75	16.25	13	16.06	15.98	18.04	14.94	0.81	0.226	0.50%	0.50%	0.25%	1.84%	**2.43%**

Verification uncertainty at 140 m height for SWLB059 [15]

Table 6-5 Uncertainty calculation at 140 m

SWLB059 height 140 m													
BIN lower [m/s]	BIN upper [m/s]	# of 10 min data sets	V_{FLS} [m/s]	V_{REF} [m/s]	V_{FLSmax} [m/s]	V_{FLSmin} [m/s]	Std_{VFLS} [m/s]	$Std_{VFLS}/\sqrt{n}$ [m/s]	Mean deviation [%]	Mounting uncertainty [%]	Separation Uncertainty [%]	V_{REF} Uncertainty [%]	**V_{FLS} Uncertainty (k=1) [%]**
3.75	4.25	127	4.04	4.00	4.91	2.72	0.29	0.026	1.05%	0.50%	0.25%	1.94%	**2.37%**
4.25	4.75	140	4.51	4.52	5.34	3.53	0.30	0.025	-0.17%	0.50%	0.25%	1.63%	**1.82%**
4.75	5.25	155	5.03	5.01	6.21	3.56	0.29	0.024	0.29%	0.50%	0.25%	1.70%	**1.87%**
5.25	5.75	177	5.49	5.51	6.15	4.02	0.31	0.023	-0.40%	0.50%	0.25%	1.76%	**1.93%**
5.75	6.25	201	5.97	6.00	7.36	4.66	0.32	0.022	-0.39%	0.50%	0.25%	1.63%	**1.80%**
6.25	6.75	214	6.51	6.50	7.73	5.31	0.26	0.018	0.18%	0.50%	0.25%	1.63%	**1.75%**
6.75	7.25	210	7.01	7.00	8.11	6.21	0.27	0.018	0.16%	0.50%	0.25%	1.47%	**1.60%**
7.25	7.75	165	7.45	7.50	9.13	6.25	0.31	0.024	-0.73%	0.50%	0.25%	1.45%	**1.75%**
7.75	8.25	143	8.01	8.00	9.60	6.79	0.34	0.028	0.07%	0.50%	0.25%	1.46%	**1.60%**
8.25	8.75	152	8.44	8.49	9.23	7.32	0.27	0.022	-0.66%	0.50%	0.25%	1.42%	**1.68%**
8.75	9.25	121	8.89	8.97	9.67	7.73	0.27	0.024	-0.87%	0.50%	0.25%	1.39%	**1.75%**
9.25	9.75	67	9.38	9.45	10.47	7.80	0.45	0.055	-0.79%	0.50%	0.25%	1.37%	**1.78%**
9.75	10.25	49	10.05	10.01	11.26	8.83	0.37	0.053	0.44%	0.50%	0.25%	1.37%	**1.63%**
10.25	10.75	28	10.59	10.48	12.71	10.09	0.47	0.089	1.05%	0.50%	0.25%	1.33%	**1.98%**
10.75	11.25	19	11.03	10.95	11.67	10.26	0.33	0.076	0.75%	0.50%	0.25%	1.34%	**1.78%**
11.25	11.75	14	11.49	11.44	11.96	11.07	0.25	0.066	0.41%	0.50%	0.25%	1.39%	**1.66%**
11.75	12.25	25	12.24	12.04	12.87	11.74	0.26	0.053	1.65%	0.50%	0.25%	1.37%	**2.26%**
12.25	12.75	38	12.65	12.49	13.30	11.89	0.37	0.059	1.22%	0.50%	0.25%	1.42%	**2.01%**
12.75	13.25	29	13.15	13.03	14.45	12.46	0.36	0.067	0.95%	0.50%	0.25%	1.35%	**1.82%**
13.25	13.75	37	13.70	13.56	15.34	12.12	0.59	0.098	1.05%	0.50%	0.25%	1.43%	**1.99%**
13.75	14.25	35	14.04	13.98	15.25	12.80	0.44	0.075	0.45%	0.50%	0.25%	1.45%	**1.70%**
14.25	14.75	18	14.70	14.50	15.96	13.44	0.67	0.158	1.34%	0.50%	0.25%	1.58%	**2.40%**
14.75	15.25	19	15.06	14.95	15.77	14.47	0.41	0.095	0.73%	0.50%	0.25%	1.39%	**1.78%**
15.25	15.75	20	15.77	15.47	17.12	15.20	0.44	0.099	1.99%	0.50%	0.25%	1.33%	**2.54%**
15.75	16.25	16	15.66	15.91	16.53	15.04	0.40	0.100	-1.55%	0.50%	0.25%	1.84%	**2.55%**

Verification uncertainty at 160 m height for WS190 [17].

Table 6-4 Uncertainty calculation at 160 m

WS190 height 160 m													
BIN lower [m/s]	BIN upper [m/s]	# of 10 min data sets	V_{FLS} [m/s]	V_{REF} [m/s]	V_{FLSmax} [m/s]	V_{FLSmin} [m/s]	Std_{VFLS} [m/s]	$Std_{VFLS}/\sqrt{n}$ [m/s]	Mean deviation [%]	Mounting uncertainty [%]	Separation Uncertainty [%]	V_{REF} Uncertainty [%]	**V_{FLS} Uncertainty (k=1) [%]**
3.75	4.25	281	4.06	4.01	6.39	2.98	0.31	0.018	1.26%	0.50%	0.20%	1.94%	**2.42%**
4.25	4.75	358	4.57	4.51	6.07	3.42	0.31	0.016	1.28%	0.50%	0.20%	1.63%	**2.17%**
4.75	5.25	344	5.06	5.01	7.59	3.39	0.36	0.019	0.95%	0.50%	0.20%	1.70%	**2.06%**
5.25	5.75	330	5.53	5.51	6.69	3.56	0.32	0.018	0.40%	0.50%	0.20%	1.76%	**1.91%**
5.75	6.25	390	6.02	5.99	8.14	3.39	0.37	0.019	0.35%	0.50%	0.20%	1.63%	**1.77%**
6.25	6.75	289	6.49	6.50	7.67	5.34	0.32	0.019	-0.07%	0.50%	0.20%	1.63%	**1.74%**
6.75	7.25	222	6.96	6.99	7.97	5.01	0.33	0.022	-0.38%	0.50%	0.20%	1.47%	**1.64%**
7.25	7.75	199	7.43	7.50	8.54	6.19	0.36	0.025	-0.91%	0.50%	0.20%	1.45%	**1.82%**
7.75	8.25	187	7.99	8.00	9.26	5.90	0.41	0.030	-0.11%	0.50%	0.20%	1.46%	**1.61%**
8.25	8.75	231	8.55	8.51	9.98	7.27	0.36	0.024	0.51%	0.50%	0.20%	1.42%	**1.63%**
8.75	9.25	238	9.05	9.00	10.82	7.61	0.38	0.025	0.53%	0.50%	0.20%	1.39%	**1.60%**
9.25	9.75	211	9.51	9.49	11.77	7.84	0.48	0.033	0.27%	0.50%	0.20%	1.37%	**1.53%**
9.75	10.25	142	10.01	9.98	11.83	8.71	0.45	0.038	0.25%	0.50%	0.20%	1.37%	**1.54%**
10.25	10.75	103	10.56	10.50	11.62	9.07	0.44	0.043	0.63%	0.50%	0.20%	1.33%	**1.62%**
10.75	11.25	105	11.07	11.00	17.00	9.42	0.81	0.079	0.73%	0.50%	0.20%	1.34%	**1.77%**
11.25	11.75	64	11.49	11.49	12.29	9.88	0.41	0.051	0.02%	0.50%	0.20%	1.39%	**1.56%**
11.75	12.25	72	12.03	12.01	12.98	10.94	0.35	0.042	0.17%	0.50%	0.20%	1.37%	**1.52%**
12.25	12.75	87	12.46	12.44	15.90	11.72	0.50	0.053	0.19%	0.50%	0.20%	1.42%	**1.59%**
12.75	13.25	50	13.07	12.97	14.16	12.24	0.45	0.064	0.72%	0.50%	0.20%	1.35%	**1.70%**
13.25	13.75	43	13.65	13.53	14.56	12.76	0.40	0.061	0.89%	0.50%	0.20%	1.43%	**1.82%**
13.75	14.25	53	14.24	14.00	15.40	13.29	0.47	0.065	1.69%	0.50%	0.20%	1.45%	**2.33%**
14.25	14.75	36	14.69	14.52	15.35	14.01	0.38	0.064	1.16%	0.50%	0.20%	1.58%	**2.08%**
14.75	15.25	36	15.23	14.98	16.85	13.82	0.59	0.098	1.68%	0.50%	0.20%	1.39%	**2.34%**
15.25	15.75	36	15.74	15.52	17.12	14.71	0.60	0.101	1.44%	0.50%	0.20%	1.33%	**2.13%**
15.75	16.25	30	16.10	16.02	17.23	15.34	0.55	0.101	0.52%	0.50%	0.20%	1.84%	**2.08%**

Verification uncertainty at 140 m height for WS190 [17].

Table 6-5 Uncertainty calculation at 140 m

WS190 height 140 m													
BIN lower [m/s]	BIN upper [m/s]	# of 10 min data sets	V_{FLS} [m/s]	V_{REF} [m/s]	V_{FLSmax} [m/s]	V_{FLSmin} [m/s]	Std_{VFLS} [m/s]	$Std_{VFLS}/\sqrt{n}$ [m/s]	Mean deviation [%]	Mounting uncertainty [%]	Separation Uncertainty [%]	V_{REF} Uncertainty [%]	**V_{FLS} Uncertainty (k=1) [%]**
3.75	4.25	309	4.04	4.00	5.29	3.17	0.28	0.016	1.11%	0.50%	0.20%	1.94%	**2.33%**
4.25	4.75	351	4.56	4.51	6.60	3.36	0.31	0.017	1.14%	0.50%	0.20%	1.63%	**2.10%**
4.75	5.25	398	5.02	5.00	6.26	3.67	0.27	0.014	0.54%	0.50%	0.20%	1.70%	**1.88%**
5.25	5.75	338	5.54	5.51	7.04	4.24	0.30	0.017	0.47%	0.50%	0.20%	1.76%	**1.92%**
5.75	6.25	407	6.00	5.99	7.87	4.09	0.33	0.016	0.22%	0.50%	0.20%	1.63%	**1.75%**
6.25	6.75	289	6.48	6.48	7.65	5.64	0.30	0.018	0.02%	0.50%	0.20%	1.63%	**1.73%**
6.75	7.25	256	7.01	6.99	7.84	6.02	0.28	0.018	0.30%	0.50%	0.20%	1.47%	**1.61%**
7.25	7.75	220	7.43	7.50	8.82	5.68	0.37	0.025	-0.86%	0.50%	0.20%	1.45%	**1.80%**
7.75	8.25	184	8.08	8.02	9.72	6.69	0.41	0.030	0.72%	0.50%	0.20%	1.46%	**1.75%**
8.25	8.75	266	8.52	8.50	9.86	6.80	0.35	0.022	0.18%	0.50%	0.20%	1.42%	**1.55%**
8.75	9.25	254	9.05	8.99	11.49	7.66	0.39	0.025	0.62%	0.50%	0.20%	1.39%	**1.63%**
9.25	9.75	197	9.52	9.49	10.59	7.95	0.41	0.029	0.27%	0.50%	0.20%	1.37%	**1.53%**
9.75	10.25	120	10.03	9.98	11.43	8.37	0.44	0.040	0.52%	0.50%	0.20%	1.37%	**1.61%**
10.25	10.75	113	10.50	10.49	12.34	8.77	0.49	0.046	0.05%	0.50%	0.20%	1.33%	**1.50%**
10.75	11.25	99	11.04	11.00	14.17	9.78	0.56	0.056	0.37%	0.50%	0.20%	1.34%	**1.58%**
11.25	11.75	58	11.57	11.47	12.49	10.89	0.32	0.042	0.87%	0.50%	0.20%	1.39%	**1.77%**
11.75	12.25	98	12.04	12.01	13.26	11.13	0.38	0.038	0.24%	0.50%	0.20%	1.37%	**1.53%**
12.25	12.75	55	12.57	12.48	14.23	11.63	0.44	0.059	0.75%	0.50%	0.20%	1.42%	**1.76%**
12.75	13.25	44	13.10	13.00	14.14	12.35	0.47	0.070	0.78%	0.50%	0.20%	1.35%	**1.73%**
13.25	13.75	49	13.79	13.52	15.66	12.69	0.55	0.078	1.99%	0.50%	0.20%	1.43%	**2.57%**
13.75	14.25	46	14.08	13.99	15.23	13.19	0.45	0.066	0.60%	0.50%	0.20%	1.45%	**1.72%**
14.25	14.75	36	14.68	14.48	16.26	14.12	0.44	0.074	1.37%	0.50%	0.20%	1.58%	**2.22%**
14.75	15.25	34	15.16	14.94	16.38	14.28	0.49	0.085	1.43%	0.50%	0.20%	1.39%	**2.14%**
15.25	15.75	43	15.73	15.49	16.96	14.42	0.60	0.091	1.59%	0.50%	0.20%	1.33%	**2.22%**
15.75	16.25	22	16.19	15.99	17.30	15.31	0.50	0.106	1.23%	0.50%	0.20%	1.84%	**2.37%**

Type specific classification uncertainty from classification report for ZX300 by DNV-GL [18]

ZX300 Type Class Table											
EVs / Heights	Max influence (m x Range)								Preliminary accuracy	Type specific class	Standard uncertainty
	Temperature Gradient	Air Temperature	Turbulence Intensity	Wind Veer	Wind Shear	Air Density	Rain	Flow inclination angle			
[m]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
135	-1.85	-1.81	0.46	0.60	-2.48	*	-0.59	0.71	3.78	2.67	1.54
130	-2.03	-1.34	0.62	0.57	-1.14	*	-0.60	1.17	3.11	2.20	1.27
125	-1.80	-1.37	0.70	0.59	-1.20	*	-0.96	1.07	3.07	2.17	1.25
120	-1.91	-1.13	0.78	0.58	-0.61	*	-0.92	0.96	2.83	2.00	1.16
115	-1.97	-0.90	0.87	0.57	-0.02	*	-0.87	0.86	2.70	1.91	1.10
110	-2.03	-0.66	0.95	0.57	0.57	*	-0.82	0.76	2.71	1.92	1.11
105	-2.09	-0.42	1.04	0.56	1.16	*	-0.77	0.65	2.88	2.04	1.18
100	-1.52	2.50	1.71	0.00	1.02	-0.45	-0.01	0.55	3.61	2.55	1.47
95	-1.18	1.96	1.47	0.12	1.17	-0.33	0.20	0.22	2.99	2.12	1.22
90	-0.82	1.42	1.43	0.23	1.31	-0.20	0.23	-0.11	2.57	1.81	1.05
85	-0.46	0.91	1.40	0.34	1.52	-0.07	0.25	-0.66	2.43	1.72	0.99
80	-0.10	0.57	1.50	0.47	1.68	0.05	0.28	-0.63	2.47	1.75	1.01
75	0.11	0.61	1.61	0.60	2.23	0.18	0.30	-0.59	2.96	2.10	1.21
70	0.14	1.11	1.33	0.72	2.79	0.31	0.28	-0.56	3.43	2.43	1.40
65	0.23	1.35	1.09	0.89	2.36	0.75	0.26	-0.52	3.21	2.27	1.31
60	0.23	1.77	0.86	1.04	2.05	1.13	0.24	-0.49	3.28	2.32	1.34
55	0.25	2.07	0.71	0.45	1.91	1.51	0.23	*	3.32	2.34	1.35
50	0.28	1.03	0.52	0.61	1.60	1.89	0.28	*	2.83	2.00	1.15
45	0.32	0.41	0.39	0.77	1.29	2.27	0.31	*	2.82	2.00	1.15
40	0.16	-0.22	0.27	0.93	0.99	2.66	0.35	*	3.03	2.14	1.24
35	0.10	-0.61	0.41	0.45	0.13	0.48	0.38	*	1.07	0.75	0.44
30	0.03	-0.76	0.53	0.34	-0.44	-0.41	0.41	*	1.23	0.87	0.50
25	0.02	-0.78	0.67	0.29	-1.01	-1.30	0.45	*	2.01	1.42	0.82
20	0.00	-0.71	0.82	0.23	-1.58	-2.18	0.48	*	2.95	2.09	1.21

* EV was not assessed in the height

Appendix C. Filtered & Repaired Dataset: HS-1-LB

Project:
Hesselø South (23406)

Licensed user:
EMD International A/S
Niels Jernes Vej 10
- -
+45 6916 4850
Thomas Sørensen / ts@emd.dk
Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

300,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			10,64	6,88	6,22	7,89	11,46	10,83	9,24	9,70	10,91	11,54	12,54	11,63	8,26
0		0,49	3	0	0	0	0	2	1	0	0	0	0	0	0
1	0,50	1,49	497	38	32	36	45	46	47	79	48	41	37	23	25
2	1,50	2,49	1228	71	132	119	100	116	119	114	110	108	96	65	78
3	2,50	3,49	2105	188	171	206	196	156	180	203	187	182	161	124	151
4	3,50	4,49	2815	188	192	244	238	196	289	226	255	305	236	239	207
5	4,50	5,49	3169	260	148	219	278	278	338	246	242	336	329	245	250
6	5,50	6,49	3571	268	147	256	332	306	327	275	323	414	448	294	181
7	6,50	7,49	3787	170	196	244	380	307	294	256	333	561	548	324	174
8	7,50	8,49	3777	109	222	180	328	342	316	238	375	659	574	268	166
9	8,50	9,49	3416	67	133	156	317	358	354	182	387	550	536	250	126
10	9,50	10,49	3490	70	82	152	252	417	364	244	349	676	535	239	110
11	10,50	11,49	3490	100	63	117	263	419	309	249	296	724	623	230	97
12	11,50	12,49	2795	65	17	82	281	352	317	182	262	432	494	217	94
13	12,50	13,49	2654	55	4	82	301	354	271	186	266	463	381	216	75
14	13,50	14,49	2357	30	0	67	292	301	174	191	236	436	440	161	29
15	14,50	15,49	2427	22	0	70	362	321	198	169	245	360	495	167	18
16	15,50	16,49	2026	14	0	45	338	239	128	143	208	390	378	124	19
17	16,50	17,49	1573	11	0	14	185	255	73	94	158	311	335	108	29
18	17,50	18,49	1414	10	1	16	205	170	59	81	139	295	323	93	22
19	18,50	19,49	1117	5	5	36	166	103	29	82	82	214	288	90	17
20	19,50	20,49	928	9	3	19	127	96	22	46	80	178	263	72	13
21	20,50	21,49	783	3	6	12	70	58	21	26	65	150	275	80	17
22	21,50	22,49	590	2	2	9	64	26	11	19	52	99	219	65	22
23	22,50	23,49	476	0	3	4	70	13	2	9	46	70	170	72	17
24	23,50	24,49	378	0	0	3	42	2	0	14	24	49	155	75	14
25	24,50	25,49	250	0	0	3	46	0	1	5	26	34	79	45	11
26	25,50	26,49	168	0	0	1	23	0	0	4	12	32	53	38	5
27	26,50	27,49	111	0	0	0	5	0	0	0	13	28	24	37	4
28	27,50	28,49	86	0	0	0	2	0	0	0	16	21	8	38	1
29	28,50	29,49	48	0	0	0	1	0	0	0	16	6	3	21	1
30	29,50	30,49	36	0	0	0	0	0	0	0	13	7	1	15	0
31	30,50	31,49	36	0	0	0	0	0	0	0	16	6	0	14	0
32	31,50	32,49	9	0	0	0	0	0	0	0	7	1	0	1	0
33	32,50	33,49	3	0	0	0	0	0	0	0	3	0	0	0	0
34	33,50	34,49	1	0	0	0	0	0	0	0	0	1	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

260,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			10,50	6,91	6,23	8,01	11,22	10,74	9,02	9,62	10,89	11,42	12,31	11,35	8,14
0		0,49	5	0	0	0	1	2	1	1	0	0	0	0	0
1	0,50	1,49	516	35	35	27	49	53	41	85	39	40	60	25	27
2	1,50	2,49	1300	85	142	108	111	94	146	106	120	121	95	82	90
3	2,50	3,49	2148	189	177	196	206	166	192	212	197	194	154	119	146
4	3,50	4,49	2776	178	192	215	238	205	283	221	247	291	263	238	205
5	4,50	5,49	3202	246	136	248	284	292	351	243	240	326	334	264	238
6	5,50	6,49	3594	257	146	263	366	294	307	254	351	409	454	299	194
7	6,50	7,49	3823	173	213	248	416	295	309	268	330	566	545	287	173
8	7,50	8,49	3809	99	223	209	336	338	321	231	398	687	520	276	171
9	8,50	9,49	3442	69	130	180	322	389	334	213	380	542	518	243	122
10	9,50	10,49	3598	74	91	155	272	444	415	234	358	643	568	222	122
11	10,50	11,49	3463	104	50	128	292	426	298	230	312	702	603	228	90
12	11,50	12,49	2852	64	21	73	316	378	304	190	268	472	475	196	95
13	12,50	13,49	2737	60	1	83	347	353	265	212	270	480	407	191	68
14	13,50	14,49	2522	28	0	76	320	359	187	197	254	440	472	165	24
15	14,50	15,49	2363	22	0	61	383	313	145	167	280	385	443	146	18
16	15,50	16,49	1967	22	0	45	305	269	101	129	198	383	380	114	21
17	16,50	17,49	1574	9	0	19	179	239	73	82	177	329	324	117	26
18	17,50	18,49	1369	6	2	21	205	129	51	96	117	293	338	84	27
19	18,50	19,49	1086	5	7	29	149	108	30	66	97	208	279	92	16
20	19,50	20,49	882	8	3	19	94	90	22	37	78	185	255	81	10
21	20,50	21,49	747	5	6	17	71	39	13	32	75	140	275	60	14
22	21,50	22,49	513	1	2	8	57	19	5	10	56	75	188	71	21
23	22,50	23,49	455	0	3	4	65	9	1	11	35	74	167	71	15
24	23,50	24,49	317	0	2	5	48	1	0	11	29	36	109	59	17
25	24,50	25,49	220	0	1	2	42	0	0	6	19	33	71	38	8
26	25,50	26,49	126	0	0	0	16	0	0	1	17	28	30	30	4
27	26,50	27,49	116	0	0	0	3	0	0	0	24	23	16	46	4
28	27,50	28,49	57	0	0	0	1	0	0	0	15	4	3	34	0
29	28,50	29,49	41	0	0	0	0	0	0	0	20	2	0	19	0
30	29,50	30,49	18	0	0	0	0	0	0	0	10	0	1	7	0
31	30,50	31,49	7	0	0	0	0	0	0	0	3	2	0	2	0
32	31,50	32,49	7	0	0	0	0	0	0	0	6	1	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

220,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			10,38	6,80	6,26	8,02	11,14	10,61	8,97	9,55	10,83	11,29	12,14	11,04	8,06
0		0,49	3	0	0	0	0	0	0	2	1	0	0	0	0
1	0,50	1,49	531	41	32	33	45	59	42	84	44	43	47	31	30
2	1,50	2,49	1321	90	135	103	131	99	137	119	94	130	98	95	90
3	2,50	3,49	2170	178	184	207	198	169	194	200	229	189	160	112	150
4	3,50	4,49	2764	175	182	223	240	216	260	222	245	287	267	236	211
5	4,50	5,49	3293	272	136	240	271	305	386	236	255	340	332	277	243
6	5,50	6,49	3599	225	144	282	375	298	322	258	330	431	440	300	194
7	6,50	7,49	3872	174	225	253	430	287	293	290	369	558	548	299	146
8	7,50	8,49	3810	102	235	208	334	387	318	229	369	679	505	253	191
9	8,50	9,49	3542	66	137	223	333	360	363	244	397	547	505	237	130
10	9,50	10,49	3640	75	81	166	287	449	410	269	332	665	551	240	115
11	10,50	11,49	3468	88	52	127	321	416	329	216	319	678	605	227	90
12	11,50	12,49	2908	63	18	92	341	419	308	171	263	495	460	190	88
13	12,50	13,49	2817	43	1	92	347	364	245	256	268	501	441	190	69
14	13,50	14,49	2623	39	0	66	336	403	194	188	298	449	477	147	26
15	14,50	15,49	2325	21	0	71	387	302	131	185	260	374	428	153	13
16	15,50	16,49	1891	19	0	36	280	266	84	116	217	378	371	110	14
17	16,50	17,49	1598	9	0	19	190	203	82	109	173	336	341	105	31
18	17,50	18,49	1382	6	5	30	195	140	64	83	123	277	339	97	23
19	18,50	19,49	1006	5	6	33	130	102	18	49	92	232	252	71	16
20	19,50	20,49	897	9	2	16	93	78	14	40	90	191	267	83	14
21	20,50	21,49	637	3	6	16	61	31	12	19	57	120	238	55	19
22	21,50	22,49	517	0	2	9	72	13	2	12	53	78	176	78	22
23	22,50	23,49	371	0	5	3	57	3	0	10	33	60	134	54	12
24	23,50	24,49	286	0	0	3	56	0	0	9	36	36	90	45	11
25	24,50	25,49	184	0	0	0	37	0	0	3	32	23	47	31	11
26	25,50	26,49	130	0	0	0	4	0	0	0	24	24	24	49	5
27	26,50	27,49	73	0	0	0	3	0	0	0	14	4	4	47	1
28	27,50	28,49	36	0	0	0	1	0	0	1	14	2	1	17	0
29	28,50	29,49	16	0	0	0	0	0	0	0	12	0	0	4	0
30	29,50	30,49	9	0	0	0	0	0	0	0	8	0	0	1	0
31	30,50	31,49	2	0	0	0	0	0	0	0	1	0	0	1	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

190,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			10,26	6,71	6,35	7,99	11,06	10,46	8,88	9,53	10,74	11,18	11,98	10,81	7,97
0		0,49	2	0	0	0	0	1	0	0	1	0	0	0	0
1	0,50	1,49	571	37	33	37	45	70	62	86	53	50	41	26	31
2	1,50	2,49	1343	111	118	110	125	118	138	115	96	139	88	91	94
3	2,50	3,49	2173	177	187	194	201	154	195	197	236	196	162	119	155
4	3,50	4,49	2760	181	187	192	245	234	245	221	245	275	273	234	228
5	4,50	5,49	3270	268	131	251	275	306	367	232	250	336	340	284	230
6	5,50	6,49	3634	229	152	303	354	305	334	263	328	419	434	320	193
7	6,50	7,49	3928	164	227	273	469	296	307	288	380	567	523	293	141
8	7,50	8,49	3849	97	224	238	331	387	325	264	386	677	496	251	173
9	8,50	9,49	3611	67	148	227	335	405	343	244	392	544	512	252	142
10	9,50	10,49	3726	86	89	172	316	454	429	263	356	667	556	233	105
11	10,50	11,49	3503	80	49	132	342	446	337	221	318	689	571	220	98
12	11,50	12,49	3003	53	18	99	347	424	325	218	267	499	477	183	93
13	12,50	13,49	2870	49	1	93	360	396	227	249	276	505	446	207	61
14	13,50	14,49	2688	35	0	61	377	419	181	223	312	455	477	123	25
15	14,50	15,49	2265	22	0	77	352	316	118	176	255	390	424	120	15
16	15,50	16,49	1833	19	0	34	257	244	89	130	218	342	374	111	15
17	16,50	17,49	1603	10	0	17	206	186	83	110	167	334	355	106	29
18	17,50	18,49	1323	7	3	28	185	136	49	69	135	286	311	91	23
19	18,50	19,49	1007	5	7	37	123	97	22	34	91	241	257	81	12
20	19,50	20,49	833	8	5	14	87	63	14	30	85	176	262	71	18
21	20,50	21,49	588	2	2	13	67	19	8	21	66	113	189	69	19
22	21,50	22,49	454	0	6	5	75	12	1	14	46	76	143	56	20
23	22,50	23,49	359	0	6	3	63	1	0	10	45	49	113	55	14
24	23,50	24,49	250	0	0	0	51	0	0	8	32	28	80	40	11
25	24,50	25,49	143	0	0	1	23	0	0	3	23	13	25	48	7
26	25,50	26,49	103	0	0	0	4	0	0	0	20	8	18	49	4
27	26,50	27,49	53	0	0	0	2	0	0	1	16	4	3	27	0
28	27,50	28,49	13	0	0	0	1	0	0	0	9	0	0	3	0
29	28,50	29,49	10	0	0	0	0	0	0	0	9	0	0	1	0
30	29,50	30,49	3	0	0	0	0	0	0	0	2	0	0	1	0
31	30,50	31,49	1	0	0	0	0	0	0	0	1	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

170,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			10,16	6,60	6,33	8,05	10,97	10,32	8,87	9,40	10,71	11,09	11,78	10,66	8,02
0		0,49	1	0	0	0	0	0	1	0	0	0	0	0	0
1	0,50	1,49	588	35	38	41	49	56	70	86	49	68	35	40	21
2	1,50	2,49	1332	112	121	103	120	117	129	122	105	134	87	83	99
3	2,50	3,49	2170	192	177	168	192	176	184	201	241	195	181	116	147
4	3,50	4,49	2829	199	198	207	236	238	249	225	258	281	267	249	222
5	4,50	5,49	3273	251	124	258	268	336	345	232	227	364	345	293	230
6	5,50	6,49	3647	238	161	287	385	312	316	284	319	416	433	304	192
7	6,50	7,49	4022	164	232	294	464	327	306	309	378	576	527	297	148
8	7,50	8,49	3851	98	228	249	365	358	342	273	391	670	482	232	163
9	8,50	9,49	3710	73	133	232	374	402	401	249	400	545	488	257	156
10	9,50	10,49	3736	76	93	193	287	476	391	259	356	660	580	252	113
11	10,50	11,49	3547	77	46	147	393	450	356	220	307	705	559	196	91
12	11,50	12,49	3136	54	22	82	395	436	319	247	284	512	481	203	101
13	12,50	13,49	2917	38	1	98	378	454	219	252	285	479	454	194	65
14	13,50	14,49	2582	38	0	70	365	370	159	222	306	437	469	125	21
15	14,50	15,49	2297	20	0	66	347	328	122	186	273	384	446	114	11
16	15,50	16,49	1761	18	0	39	259	213	91	120	228	324	340	111	18
17	16,50	17,49	1606	11	0	24	178	193	85	95	191	341	351	109	28
18	17,50	18,49	1314	7	4	28	191	123	51	62	132	309	301	86	20
19	18,50	19,49	978	6	5	35	107	89	15	35	114	224	266	62	20
20	19,50	20,49	746	5	7	13	91	50	15	20	75	179	207	73	11
21	20,50	21,49	557	2	6	9	69	20	4	19	52	116	162	71	27
22	21,50	22,49	404	0	3	9	78	4	1	11	32	86	111	51	18
23	22,50	23,49	330	0	4	2	57	0	0	15	42	37	104	53	16
24	23,50	24,49	216	0	0	1	40	0	0	4	35	20	64	44	8
25	24,50	25,49	133	0	0	0	24	0	0	1	25	9	24	45	5
26	25,50	26,49	93	0	0	0	4	0	0	2	19	4	12	49	3
27	26,50	27,49	31	0	0	0	1	0	0	0	12	1	3	13	1
28	27,50	28,49	12	0	0	0	1	0	0	0	8	0	0	3	0
29	28,50	29,49	2	0	0	0	0	0	0	0	2	0	0	0	0
30	29,50	30,49	2	0	0	0	0	0	0	0	1	0	0	1	0
31	30,50	31,49	0	0	0	0	0	0	0	0	0	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
Hesselø South (23406)

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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

150,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			10,05	6,58	6,37	8,16	10,87	10,16	8,78	9,31	10,55	11,00	11,61	10,53	7,85
0		0,49	4	0	0	0	0	0	0	0	2	1	1	0	0
1	0,50	1,49	597	32	44	35	54	59	77	74	65	61	34	30	32
2	1,50	2,49	1351	103	98	104	122	135	123	136	124	139	85	85	97
3	2,50	3,49	2170	213	165	166	168	192	179	178	235	208	175	122	169
4	3,50	4,49	2864	190	218	212	237	240	250	228	271	276	278	236	228
5	4,50	5,49	3221	249	121	255	267	328	329	213	236	358	349	281	235
6	5,50	6,49	3679	216	171	272	375	339	343	321	310	429	404	311	188
7	6,50	7,49	4093	147	238	311	512	321	330	326	402	549	538	286	133
8	7,50	8,49	3999	107	241	252	383	360	349	281	401	686	519	239	181
9	8,50	9,49	3724	84	139	258	383	402	407	271	394	516	455	268	147
10	9,50	10,49	3850	76	86	202	317	494	411	247	389	706	582	229	111
11	10,50	11,49	3620	79	54	160	408	473	351	222	325	680	556	218	94
12	11,50	12,49	3287	51	18	93	445	495	323	284	282	496	493	207	100
13	12,50	13,49	2888	43	0	94	358	447	207	232	311	501	469	166	60
14	13,50	14,49	2549	26	1	64	348	396	138	255	285	445	456	112	23
15	14,50	15,49	2238	19	0	77	349	278	104	168	300	380	433	118	12
16	15,50	16,49	1729	18	0	39	261	198	94	104	223	317	359	101	15
17	16,50	17,49	1575	10	0	14	159	185	80	92	190	354	352	109	30
18	17,50	18,49	1291	5	6	36	177	130	38	55	139	328	278	79	20
19	18,50	19,49	897	8	4	36	107	64	20	26	100	229	225	66	12
20	19,50	20,49	674	3	5	18	86	39	9	22	62	172	164	74	20
21	20,50	21,49	491	3	8	12	69	14	5	12	48	100	142	61	17
22	21,50	22,49	390	0	3	6	76	3	2	12	43	60	114	48	23
23	22,50	23,49	292	0	2	4	55	0	0	10	51	19	83	57	11
24	23,50	24,49	175	0	1	1	38	0	0	4	20	10	42	48	11
25	24,50	25,49	125	0	0	0	16	0	0	0	27	6	28	45	3
26	25,50	26,49	65	0	0	0	4	0	0	0	17	4	12	27	1
27	26,50	27,49	12	0	0	0	2	0	0	0	6	0	0	4	0
28	27,50	28,49	8	0	0	0	0	0	0	0	3	0	0	5	0
29	28,50	29,49	5	0	0	0	0	0	0	0	4	0	0	1	0
30	29,50	30,49	1	0	0	0	0	0	0	0	0	0	0	1	0
31	30,50	31,49	0	0	0	0	0	0	0	0	0	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

130,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,90	6,52	6,33	8,27	10,73	9,93	8,69	9,11	10,50	10,85	11,41	10,35	7,73
0		0,49	1	0	0	0	1	0	0	0	0	0	0	0	0
1	0,50	1,49	584	37	48	31	46	65	62	83	72	52	33	26	29
2	1,50	2,49	1396	98	89	93	135	154	118	142	141	133	103	73	117
3	2,50	3,49	2188	209	176	152	162	200	195	204	214	199	172	147	158
4	3,50	4,49	2909	177	234	206	239	260	260	223	273	294	269	237	237
5	4,50	5,49	3318	249	142	251	291	323	330	217	243	376	378	287	231
6	5,50	6,49	3760	216	174	280	410	358	356	348	320	424	363	307	204
7	6,50	7,49	4067	132	251	301	501	308	345	332	384	551	533	296	133
8	7,50	8,49	4014	105	223	271	396	387	352	294	403	650	502	249	182
9	8,50	9,49	3899	84	166	253	413	419	440	302	412	546	460	261	143
10	9,50	10,49	3991	79	90	239	365	485	398	254	406	738	599	228	110
11	10,50	11,49	3804	79	56	163	433	533	373	266	324	677	581	224	95
12	11,50	12,49	3332	62	15	96	456	499	325	264	302	509	487	218	99
13	12,50	13,49	2789	31	1	99	356	400	201	256	310	515	433	132	55
14	13,50	14,49	2603	19	0	76	349	412	130	241	312	444	487	110	23
15	14,50	15,49	2108	19	0	65	346	236	95	153	310	374	384	115	11
16	15,50	16,49	1778	15	0	35	235	196	94	104	235	335	401	107	21
17	16,50	17,49	1537	8	0	22	167	176	79	77	218	361	317	85	27
18	17,50	18,49	1173	7	3	37	152	107	39	48	125	309	243	82	21
19	18,50	19,49	811	7	6	34	115	52	9	20	88	207	201	60	12
20	19,50	20,49	590	1	8	19	87	22	10	17	62	142	135	69	18
21	20,50	21,49	435	3	4	10	65	8	2	12	49	76	122	62	22
22	21,50	22,49	345	0	4	9	67	1	0	16	41	31	101	58	17
23	22,50	23,49	261	0	2	2	63	0	0	6	39	11	72	56	10
24	23,50	24,49	158	0	0	1	30	0	0	2	16	4	47	51	7
25	24,50	25,49	100	0	0	0	11	0	0	0	25	2	19	40	3
26	25,50	26,49	29	0	0	0	3	0	0	0	13	3	2	7	1
27	26,50	27,49	11	0	0	0	1	0	0	0	4	0	1	5	0
28	27,50	28,49	7	0	0	0	1	0	0	0	3	0	0	3	0
29	28,50	29,49	1	0	0	0	0	0	0	0	1	0	0	0	0
30	29,50	30,49	2	0	0	0	0	0	0	0	1	0	0	1	0
31	30,50	31,49	0	0	0	0	0	0	0	0	0	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

100,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,66	6,44	6,43	8,34	10,47	9,65	8,46	8,94	10,22	10,56	11,08	10,03	7,59
0		0,49	2	0	0	0	0	0	0	0	0	1	0	1	0
1	0,50	1,49	609	37	39	30	47	67	72	79	81	54	38	32	33
2	1,50	2,49	1401	97	81	104	129	150	112	134	155	141	108	87	103
3	2,50	3,49	2250	217	163	160	187	213	215	181	213	201	163	154	183
4	3,50	4,49	2964	166	238	191	235	285	271	245	289	309	272	239	224
5	4,50	5,49	3487	259	165	256	329	315	366	239	272	406	351	310	219
6	5,50	6,49	3889	225	193	291	443	396	355	356	329	404	390	294	213
7	6,50	7,49	4150	132	246	323	501	294	366	352	397	556	532	302	149
8	7,50	8,49	4081	106	214	247	421	412	385	299	439	608	510	261	179
9	8,50	9,49	4164	80	173	291	477	456	477	316	413	600	473	285	123
10	9,50	10,49	4317	95	115	245	448	515	395	281	443	784	661	232	103
11	10,50	11,49	4020	81	51	178	503	577	389	305	388	636	560	238	114
12	11,50	12,49	3286	58	7	106	430	469	309	318	318	549	463	161	98
13	12,50	13,49	2775	17	0	93	348	406	171	293	328	484	464	128	43
14	13,50	14,49	2499	16	0	84	364	328	127	210	343	456	445	107	19
15	14,50	15,49	2107	20	0	76	318	235	82	131	298	386	427	123	11
16	15,50	16,49	1788	14	0	47	195	200	113	78	260	395	356	109	21
17	16,50	17,49	1380	10	0	30	158	153	57	52	177	361	283	75	24
18	17,50	18,49	946	5	10	36	136	70	17	25	114	256	179	81	17
19	18,50	19,49	585	6	6	27	107	26	3	16	53	142	119	64	16
20	19,50	20,49	469	0	10	18	77	11	3	11	67	64	125	67	16
21	20,50	21,49	382	3	6	13	75	0	0	22	48	35	102	55	23
22	21,50	22,49	311	0	2	7	69	1	0	4	39	15	97	62	15
23	22,50	23,49	198	0	0	2	46	0	0	2	20	9	50	60	9
24	23,50	24,49	127	0	0	2	25	0	0	2	21	3	31	37	6
25	24,50	25,49	42	0	0	0	6	0	0	0	12	2	9	13	0
26	25,50	26,49	20	0	0	0	4	0	0	0	7	1	1	7	0
27	26,50	27,49	6	0	0	0	2	0	0	0	1	0	0	3	0
28	27,50	28,49	4	0	0	0	0	0	0	0	4	0	0	0	0
29	28,50	29,49	1	0	0	0	0	0	0	0	0	0	0	1	0
30	29,50	30,49	0	0	0	0	0	0	0	0	0	0	0	0	0
31	30,50	31,49	0	0	0	0	0	0	0	0	0	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

80,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,42	6,41	6,26	8,35	10,26	9,30	8,30	8,76	9,89	10,27	10,84	9,72	7,55
0		0,49	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0,50	1,49	631	40	49	34	48	68	65	81	69	64	41	42	30
2	1,50	2,49	1457	105	104	82	121	161	121	146	167	147	115	85	103
3	2,50	3,49	2380	198	206	164	185	277	200	200	248	205	149	156	192
4	3,50	4,49	3066	180	221	203	261	298	299	231	288	324	280	260	221
5	4,50	5,49	3611	232	185	264	343	361	375	257	282	409	353	312	238
6	5,50	6,49	3959	223	218	312	464	351	367	326	383	395	411	315	194
7	6,50	7,49	4261	135	237	337	469	328	392	378	424	555	512	309	185
8	7,50	8,49	4398	118	226	261	493	461	412	360	486	604	525	276	176
9	8,50	9,49	4361	73	183	282	537	541	510	291	424	667	500	242	111
10	9,50	10,49	4592	103	103	272	509	535	417	309	461	814	675	256	138
11	10,50	11,49	4100	71	48	186	545	552	416	366	400	666	528	214	108
12	11,50	12,49	3293	42	9	123	431	489	249	346	344	563	462	163	72
13	12,50	13,49	2732	20	0	109	308	342	171	301	370	487	462	122	40
14	13,50	14,49	2503	19	0	92	359	331	131	197	348	451	448	110	17
15	14,50	15,49	2065	18	0	93	253	204	89	89	324	444	412	125	14
16	15,50	16,49	1605	13	0	40	164	165	100	64	208	407	334	91	19
17	16,50	17,49	1102	11	2	26	155	128	28	32	124	260	234	77	25
18	17,50	18,49	696	3	10	37	124	42	7	14	62	180	139	63	15
19	18,50	19,49	463	4	8	21	93	21	1	14	68	69	87	58	19
20	19,50	20,49	416	4	9	17	73	5	0	16	60	32	109	66	25
21	20,50	21,49	368	2	6	14	86	0	0	17	32	24	98	65	24
22	21,50	22,49	279	1	2	0	69	0	0	5	28	11	86	65	12
23	22,50	23,49	162	0	0	2	41	0	0	2	20	5	46	39	7
24	23,50	24,49	89	0	0	0	20	0	0	0	17	2	26	20	4
25	24,50	25,49	34	0	0	0	6	0	0	0	7	2	5	14	0
26	25,50	26,49	8	0	0	0	4	0	0	0	1	1	0	2	0
27	26,50	27,49	7	0	0	0	2	0	0	0	4	0	0	1	0
28	27,50	28,49	3	0	0	0	0	0	0	0	3	0	0	0	0
29	28,50	29,49	1	0	0	0	0	0	0	0	0	0	0	1	0
30	29,50	30,49	0	0	0	0	0	0	0	0	0	0	0	0	0
31	30,50	31,49	0	0	0	0	0	0	0	0	0	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 10.49

Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

40,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			8,83	6,15	6,18	8,04	9,80	8,70	7,70	8,12	9,12	9,43	10,25	9,28	7,28
0		0,49	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0,50	1,49	631	37	50	31	61	65	59	81	70	62	39	43	33
2	1,50	2,49	1528	126	114	89	124	145	119	145	189	160	117	91	109
3	2,50	3,49	2583	210	196	177	211	319	220	243	271	210	168	176	182
4	3,50	4,49	3364	184	204	274	265	349	332	243	317	375	273	290	258
5	4,50	5,49	4015	258	217	320	399	401	422	282	369	441	391	303	212
6	5,50	6,49	4128	191	252	308	440	404	414	375	407	415	407	307	208
7	6,50	7,49	4905	135	238	361	531	477	473	507	512	635	534	311	191
8	7,50	8,49	5052	116	233	267	687	572	500	356	564	764	540	271	182
9	8,50	9,49	4819	77	172	303	653	546	501	329	469	855	514	263	137
10	9,50	10,49	4875	75	96	278	518	579	513	445	507	873	650	216	125
11	10,50	11,49	4108	59	34	196	502	513	328	410	478	713	578	208	89
12	11,50	12,49	3085	33	3	135	337	405	216	275	499	518	439	171	54
13	12,50	13,49	2659	23	0	118	333	335	106	188	326	578	498	129	25
14	13,50	14,49	2191	17	0	110	302	245	100	100	253	491	431	124	18
15	14,50	15,49	1508	19	0	65	215	178	40	55	198	304	317	92	25
16	15,50	16,49	861	15	2	20	145	118	13	20	107	133	182	82	24
17	16,50	17,49	624	2	9	33	148	47	1	17	67	79	127	73	21
18	17,50	18,49	478	8	8	26	109	22	0	17	51	54	89	76	18
19	18,50	19,49	382	3	9	19	82	5	0	14	43	21	96	74	16
20	19,50	20,49	369	2	7	9	100	0	0	10	36	16	95	70	24
21	20,50	21,49	251	1	4	6	60	0	0	1	22	9	83	49	16
22	21,50	22,49	171	0	0	1	59	0	0	2	15	8	49	29	8
23	22,50	23,49	74	0	0	0	23	0	0	0	15	3	20	10	3
24	23,50	24,49	29	0	0	0	6	0	0	0	4	2	4	13	0
25	24,50	25,49	7	0	0	0	2	0	0	0	5	0	0	0	0
26	25,50	26,49	4	0	0	0	0	0	0	0	2	0	0	2	0
27	26,50	27,49	0	0	0	0	0	0	0	0	0	0	0	0	0
28	27,50	28,49	0	0	0	0	0	0	0	0	0	0	0	0	0
29	28,50	29,49	0	0	0	0	0	0	0	0	0	0	0	0	0
30	29,50	30,49	0	0	0	0	0	0	0	0	0	0	0	0	0
31	30,50	31,49	0	0	0	0	0	0	0	0	0	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

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Meteo data report - Frequency distribution (TAB file data)

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)

Frequency distribution (TAB file data)

12,00m - Subst

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			8,06	5,89	5,97	7,64	8,98	7,98	6,89	7,19	8,18	8,48	9,41	8,56	6,75
0		0,49	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0,50	1,49	648	31	38	38	59	67	65	73	84	58	54	41	40
2	1,50	2,49	1738	135	122	97	159	167	145	186	203	167	134	95	128
3	2,50	3,49	2972	213	217	200	261	368	270	270	297	274	190	221	191
4	3,50	4,49	4060	208	225	299	321	472	465	312	402	457	334	298	267
5	4,50	5,49	4694	266	247	348	486	497	514	393	474	482	437	336	214
6	5,50	6,49	4904	183	267	356	589	441	470	496	528	583	440	337	214
7	6,50	7,49	5502	129	247	367	716	487	554	583	595	797	540	281	206
8	7,50	8,49	5565	101	230	292	670	631	543	473	615	1009	573	249	179
9	8,50	9,49	5468	72	146	320	602	639	537	376	651	1022	669	286	148
10	9,50	10,49	4564	81	80	260	542	507	354	310	568	876	657	228	101
11	10,50	11,49	3439	58	19	176	418	470	193	219	423	616	597	188	62
12	11,50	12,49	2859	21	0	166	426	388	110	168	328	442	565	211	34
13	12,50	13,49	2090	21	0	124	313	258	71	114	244	336	456	127	26
14	13,50	14,49	1316	20	1	61	248	138	24	41	152	238	275	94	24
15	14,50	15,49	811	12	3	27	151	96	6	29	94	132	160	76	25
16	15,50	16,49	636	4	13	44	138	52	1	17	66	73	111	98	19
17	16,50	17,49	482	5	7	28	110	16	0	16	47	26	116	84	27
18	17,50	18,49	364	4	13	10	107	1	0	5	20	22	100	62	20
19	18,50	19,49	282	1	3	9	75	0	0	3	29	14	86	47	15
20	19,50	20,49	141	0	0	2	48	0	0	0	19	10	35	22	5
21	20,50	21,49	55	0	0	1	19	0	0	0	9	7	8	11	0
22	21,50	22,49	12	0	0	0	6	0	0	0	3	0	0	3	0
23	22,50	23,49	3	0	0	0	0	0	0	0	1	0	0	2	0
24	23,50	24,49	0	0	0	0	0	0	0	0	0	0	0	0	0
25	24,50	25,49	0	0	0	0	0	0	0	0	0	0	0	0	0
26	25,50	26,49	0	0	0	0	0	0	0	0	0	0	0	0	0
27	26,50	27,49	0	0	0	0	0	0	0	0	0	0	0	0	0
28	27,50	28,49	0	0	0	0	0	0	0	0	0	0	0	0	0
29	28,50	29,49	0	0	0	0	0	0	0	0	0	0	0	0	0
30	29,50	30,49	0	0	0	0	0	0	0	0	0	0	0	0	0
31	30,50	31,49	0	0	0	0	0	0	0	0	0	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

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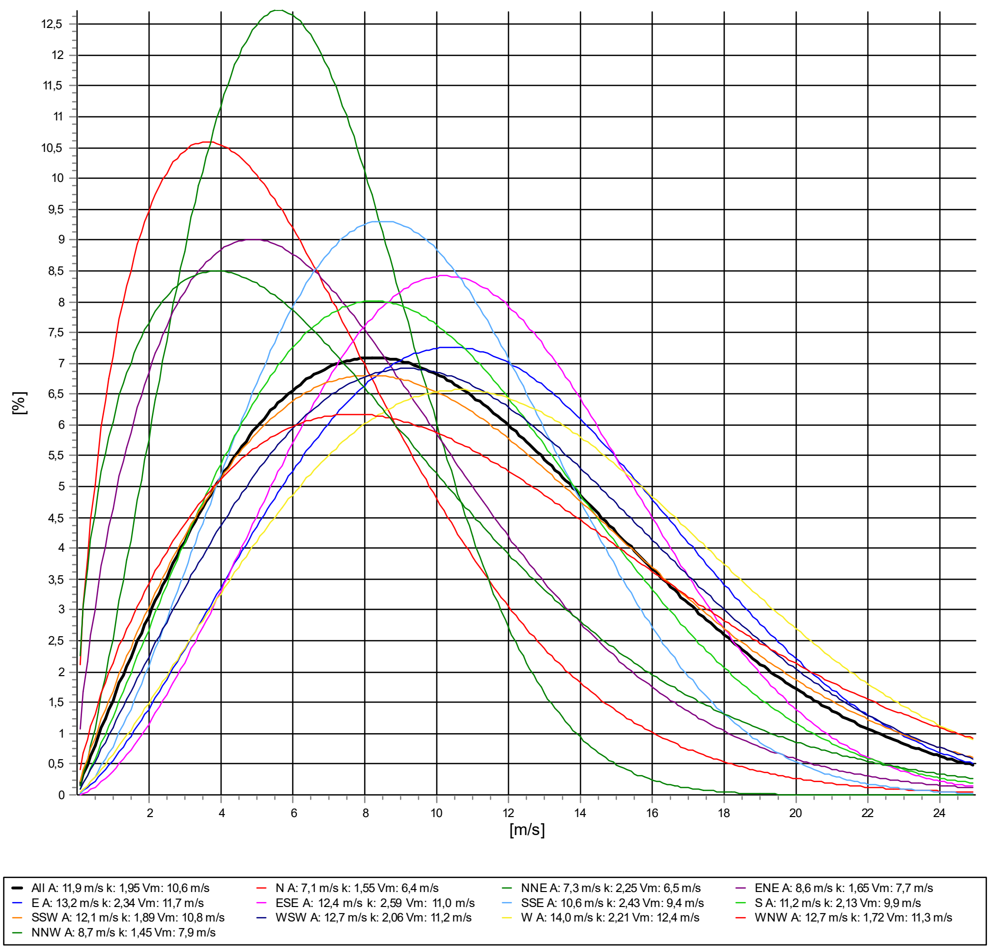
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **300,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	7,10	1,547	3,40	6,39
1-NNE	7,32	2,249	3,02	6,48
2-ENE	8,56	1,651	4,63	7,65
3-E	13,21	2,341	10,29	11,71
4-ESE	12,35	2,593	10,14	10,97
5-SSE	10,60	2,427	8,22	9,40
6-S	11,16	2,126	6,90	9,88
7-SSW	12,14	1,886	9,47	10,78
8-WSW	12,67	2,063	15,77	11,22
9-W	13,98	2,209	16,48	12,38
10-WNW	12,73	1,721	7,85	11,35
11-NNW	8,70	1,448	3,82	7,89
Mean	**11,91**	**1,955**	**100,00**	**10,56**



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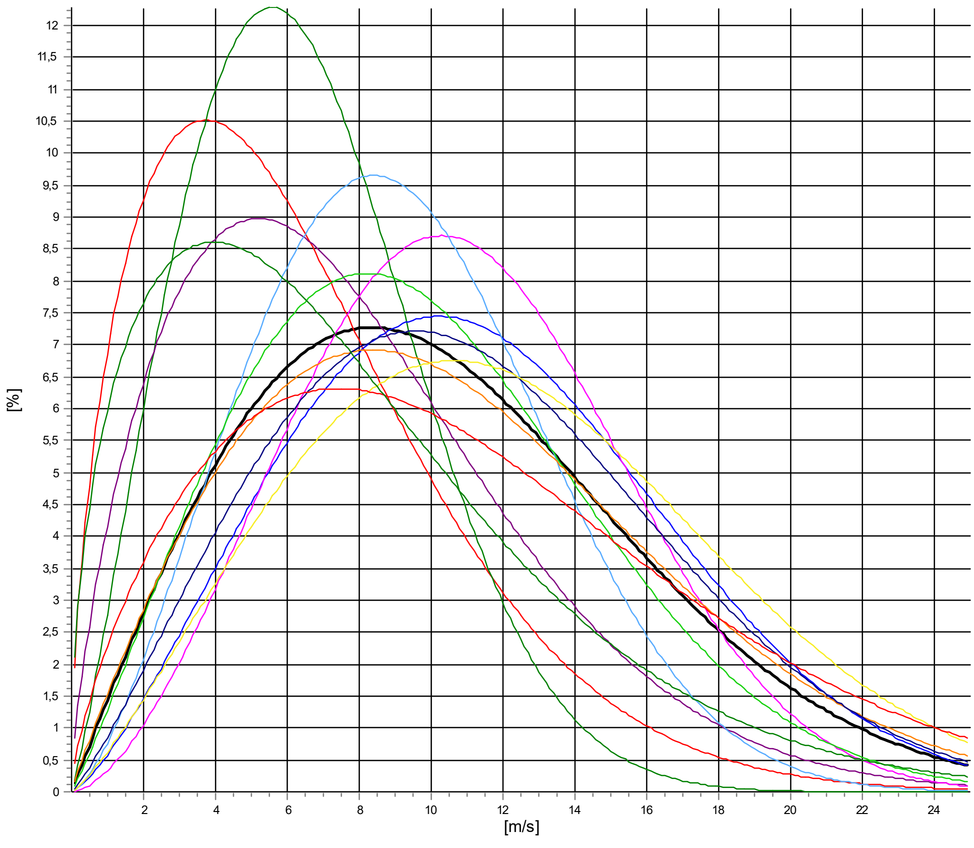
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **260,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	7,18	1,564	3,37	6,45
1-NNE	7,40	2,174	3,06	6,55
2-ENE	8,72	1,705	4,72	7,78
3-E	12,93	2,351	10,64	11,46
4-ESE	12,26	2,678	10,27	10,90
5-SSE	10,38	2,475	8,12	9,21
6-S	11,04	2,135	6,86	9,78
7-SSW	12,16	1,939	9,72	10,78
8-WSW	12,65	2,188	15,71	11,20
9-W	13,79	2,251	16,16	12,22
10-WNW	12,42	1,712	7,56	11,07
11-NNW	8,61	1,469	3,81	7,80
Mean	**11,80**	**2,002**	**100,00**	**10,46**



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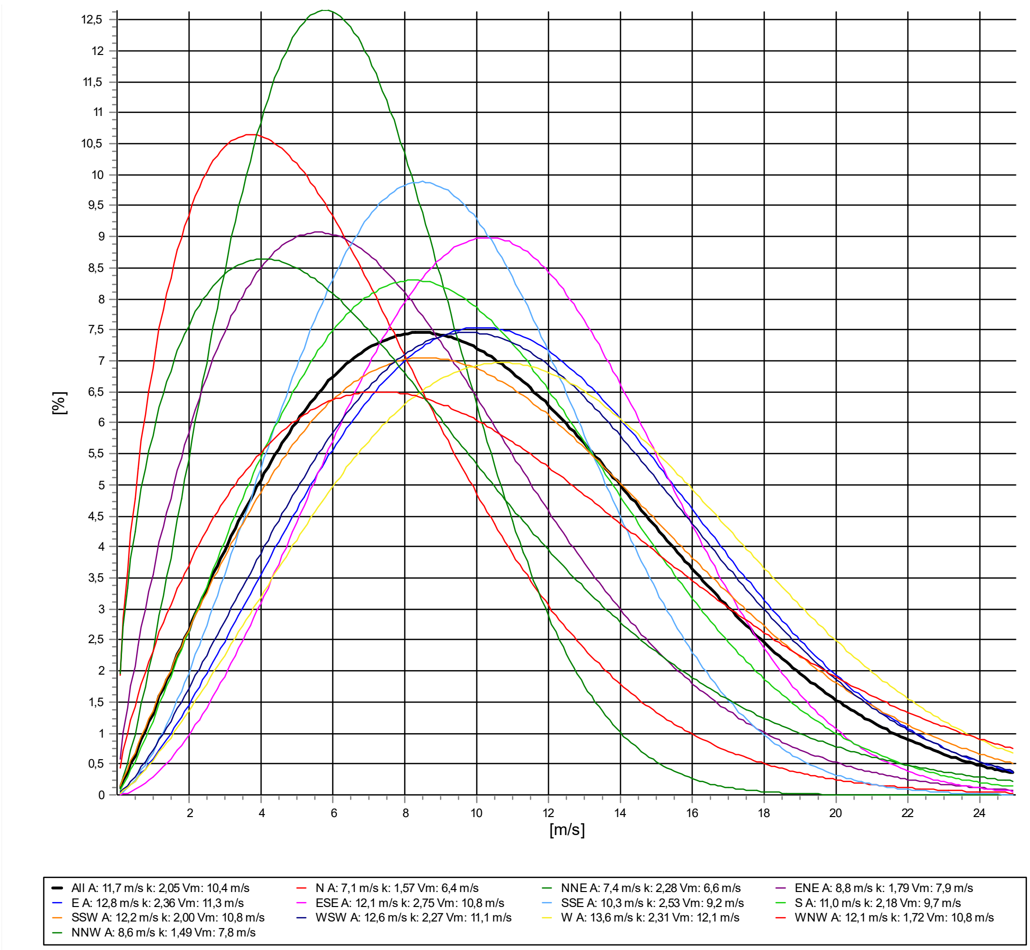
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **220,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	7,10	1,572	3,29	6,38
1-NNE	7,44	2,284	3,07	6,59
2-ENE	8,84	1,789	4,93	7,87
3-E	12,81	2,362	10,74	11,35
4-ESE	12,15	2,752	10,38	10,81
5-SSE	10,32	2,531	8,14	9,16
6-S	10,95	2,175	7,00	9,70
7-SSW	12,15	1,997	9,77	10,77
8-WSW	12,59	2,274	15,71	11,15
9-W	13,64	2,313	15,75	12,09
10-WNW	12,10	1,724	7,41	10,78
11-NNW	8,61	1,489	3,80	7,78
Mean	**11,70**	**2,052**	**100,00**	**10,37**



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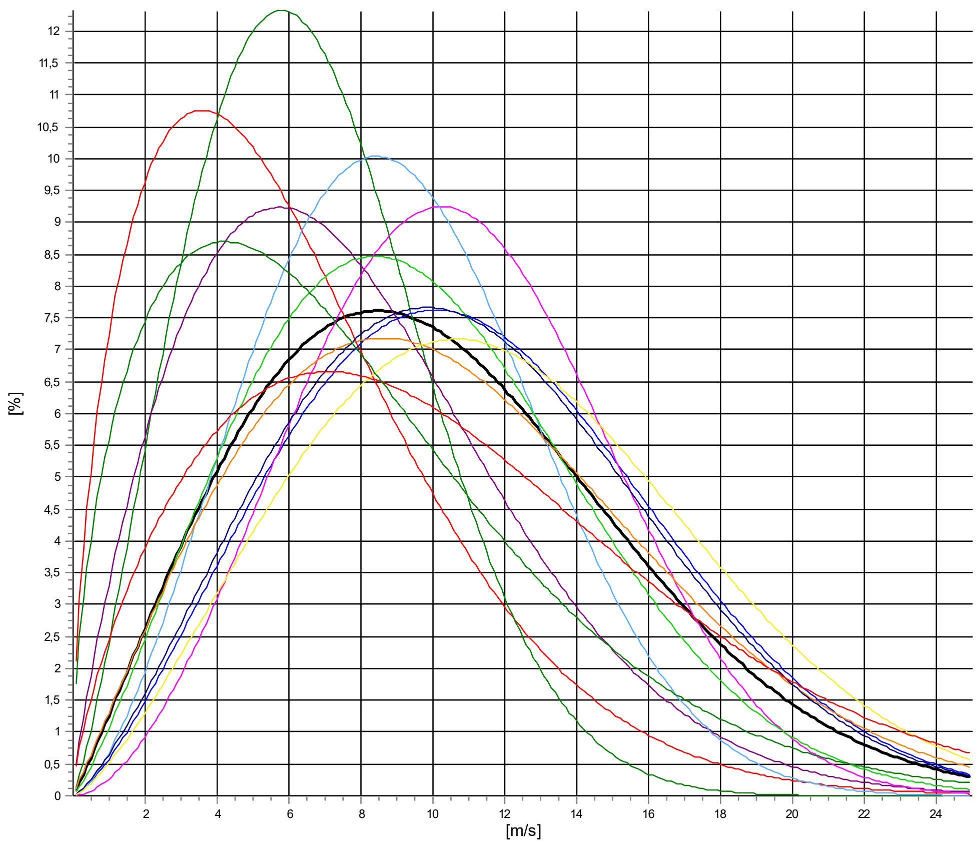
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **190,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	7,00	1,552	3,30	6,29
1-NNE	7,54	2,245	3,08	6,68
2-ENE	8,82	1,838	5,04	7,84
3-E	12,70	2,367	10,85	11,25
4-ESE	12,00	2,803	10,60	10,68
5-SSE	10,24	2,556	8,11	9,09
6-S	10,95	2,237	7,13	9,70
7-SSW	12,05	2,028	9,88	10,67
8-WSW	12,50	2,335	15,60	11,08
9-W	13,47	2,360	15,36	11,94
10-WNW	11,80	1,719	7,27	10,52
11-NNW	8,60	1,518	3,78	7,75
Mean	**11,59**	**2,085**	**100,00**	**10,27**



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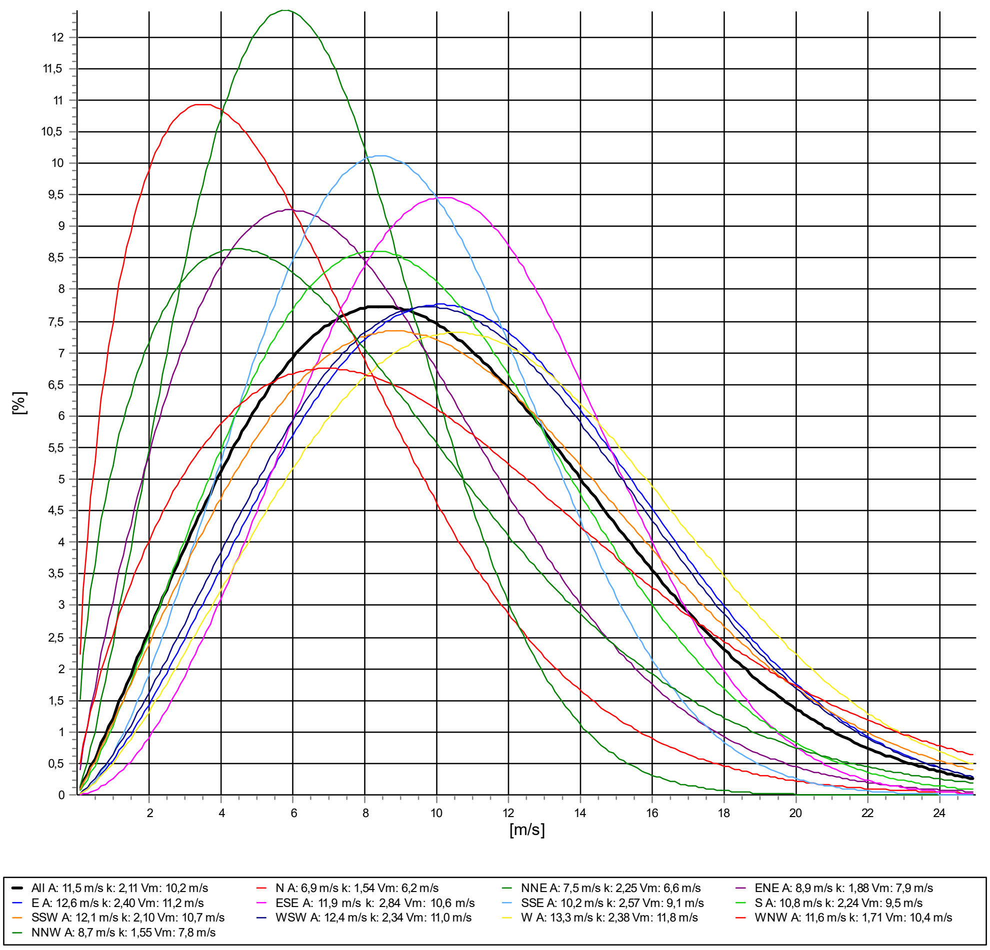
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **170,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	6,88	1,545	3,31	6,19
1-NNE	7,51	2,253	3,09	6,65
2-ENE	8,90	1,876	5,12	7,90
3-E	12,61	2,402	11,03	11,17
4-ESE	11,86	2,840	10,67	10,56
5-SSE	10,21	2,574	8,05	9,07
6-S	10,78	2,239	7,24	9,54
7-SSW	12,06	2,096	9,93	10,68
8-WSW	12,42	2,341	15,58	11,00
9-W	13,27	2,379	15,01	11,76
10-WNW	11,62	1,712	7,19	10,36
11-NNW	8,71	1,550	3,77	7,83
Mean	**11,49**	**2,108**	**100,00**	**10,18**



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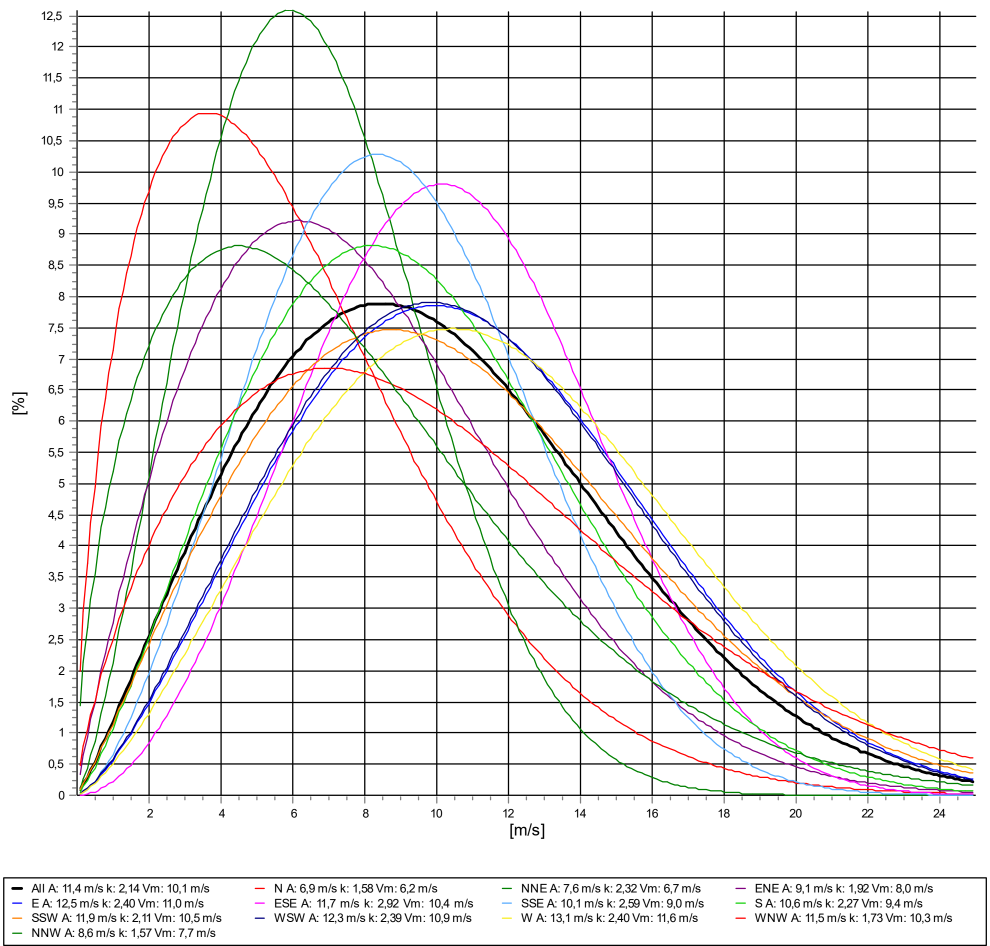
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **150,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	6,92	1,575	3,24	6,21
1-NNE	7,56	2,316	3,13	6,70
2-ENE	9,06	1,915	5,25	8,03
3-E	12,45	2,400	11,14	11,04
4-ESE	11,72	2,919	10,78	10,45
5-SSE	10,09	2,585	8,04	8,96
6-S	10,62	2,268	7,27	9,41
7-SSW	11,89	2,106	10,15	10,53
8-WSW	12,34	2,394	15,48	10,94
9-W	13,07	2,402	14,70	11,59
10-WNW	11,50	1,729	7,01	10,25
11-NNW	8,58	1,571	3,80	7,71
Mean	**11,37**	**2,138**	**100,00**	**10,07**



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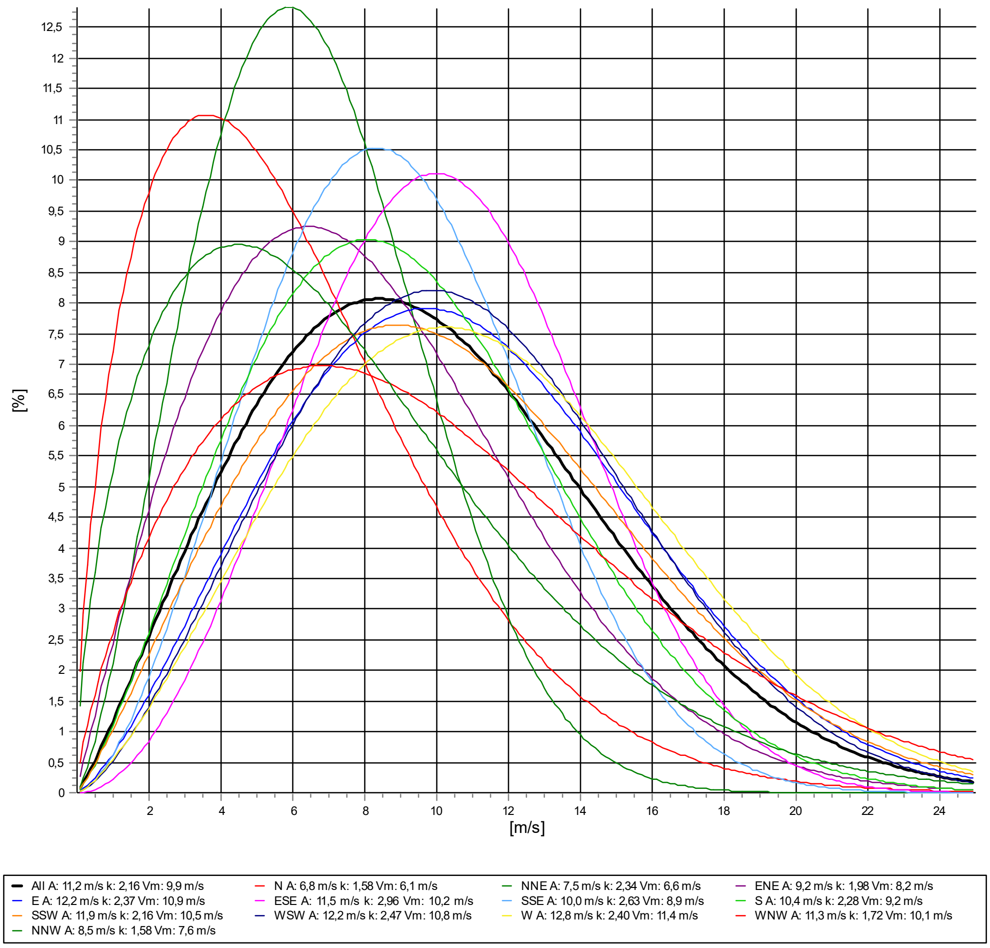
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **130,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	6,85	1,582	3,15	6,14
1-NNE	7,48	2,338	3,25	6,62
2-ENE	9,20	1,975	5,28	8,16
3-E	12,24	2,370	11,34	10,85
4-ESE	11,48	2,957	10,77	10,24
5-SSE	10,00	2,633	8,10	8,89
6-S	10,41	2,279	7,46	9,22
7-SSW	11,86	2,165	10,28	10,50
8-WSW	12,19	2,470	15,31	10,81
9-W	12,84	2,396	14,32	11,38
10-WNW	11,28	1,724	6,92	10,06
11-NNW	8,46	1,579	3,82	7,60
Mean	**11,21**	**2,162**	**100,00**	**9,93**



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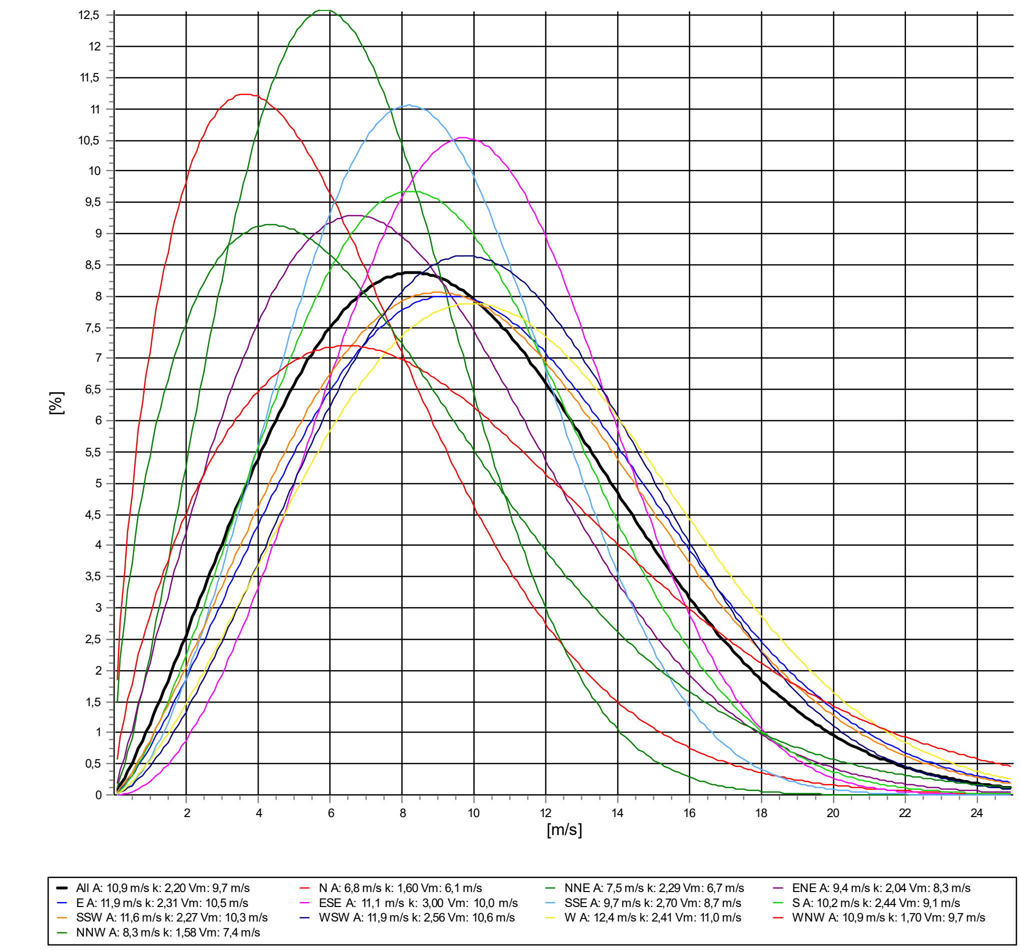
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **100,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	6,78	1,604	3,15	6,08
1-NNE	7,51	2,295	3,29	6,65
2-ENE	9,35	2,040	5,47	8,29
3-E	11,87	2,311	11,63	10,52
4-ESE	11,15	2,996	10,68	9,95
5-SSE	9,73	2,702	8,20	8,65
6-S	10,24	2,442	7,56	9,08
7-SSW	11,63	2,269	10,58	10,30
8-WSW	11,89	2,557	15,04	10,56
9-W	12,45	2,409	13,79	11,03
10-WNW	10,87	1,705	6,87	9,70
11-NNW	8,28	1,577	3,75	7,43
Mean	**10,94**	**2,201**	**100,00**	**9,69**



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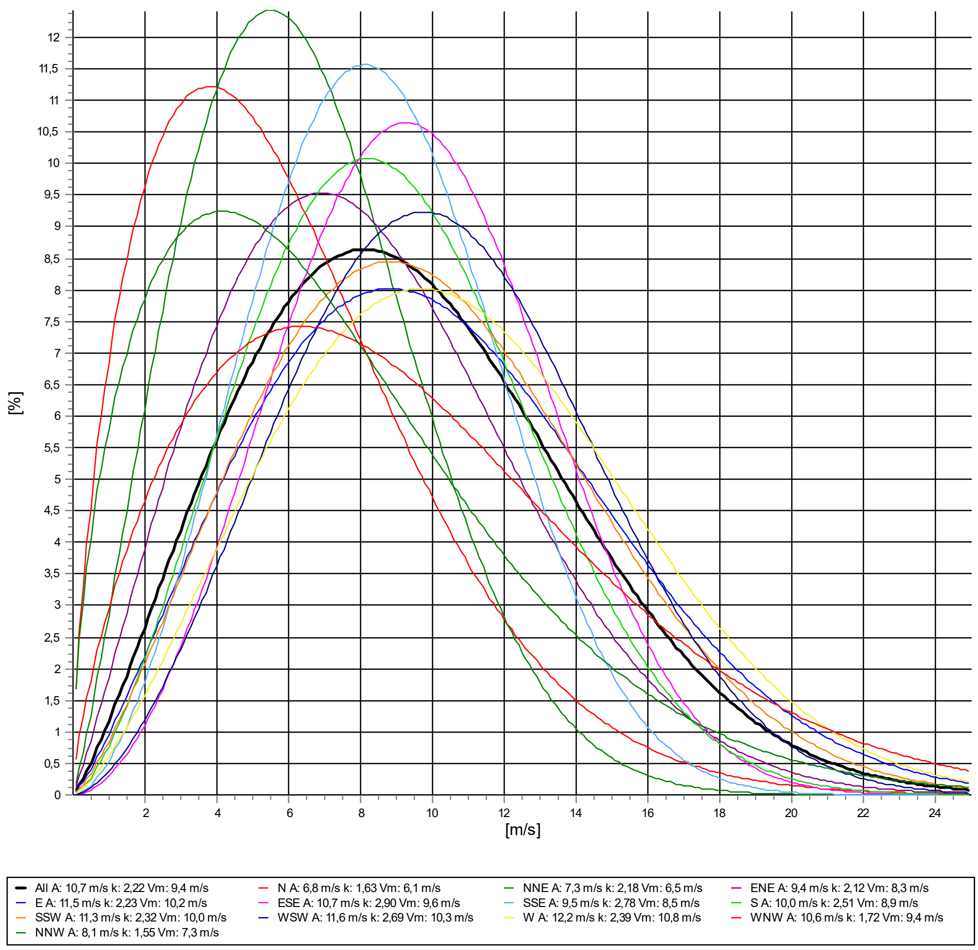
Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **80,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	6,83	1,628	3,07	6,11
1-NNE	7,31	2,176	3,47	6,48
2-ENE	9,35	2,118	5,64	8,28
3-E	11,54	2,231	11,71	10,22
4-ESE	10,73	2,902	10,75	9,56
5-SSE	9,53	2,783	8,26	8,48
6-S	10,05	2,509	7,68	8,92
7-SSW	11,27	2,319	10,74	9,99
8-WSW	11,60	2,690	14,79	10,32
9-W	12,17	2,394	13,37	10,79
10-WNW	10,58	1,716	6,74	9,44
11-NNW	8,14	1,550	3,78	7,32
Mean	**10,66**	**2,218**	**100,00**	**9,44**



Project:
Hesselø South (23406)

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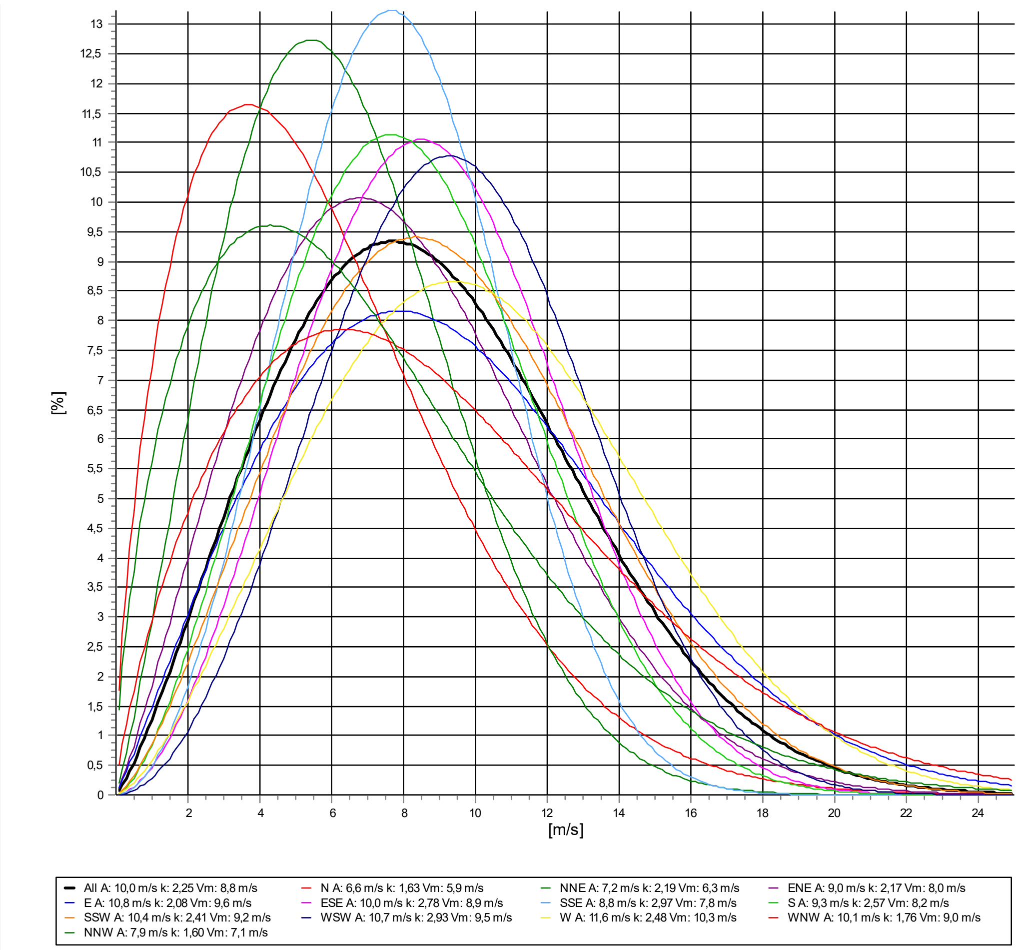
Calculated:
23/09/2024 10.49

Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **40,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	6,59	1,631	3,02	5,90
1-NNE	7,16	2,187	3,51	6,34
2-ENE	9,01	2,172	5,97	7,98
3-E	10,79	2,082	11,98	9,56
4-ESE	9,97	2,781	10,86	8,87
5-SSE	8,79	2,966	8,27	7,85
6-S	9,27	2,571	7,81	8,23
7-SSW	10,42	2,408	11,00	9,24
8-WSW	10,69	2,932	14,65	9,54
9-W	11,58	2,479	12,60	10,27
10-WNW	10,14	1,763	6,59	9,02
11-NNW	7,93	1,603	3,75	7,11
Mean	**9,99**	**2,254**	**100,00**	**8,85**



Project:
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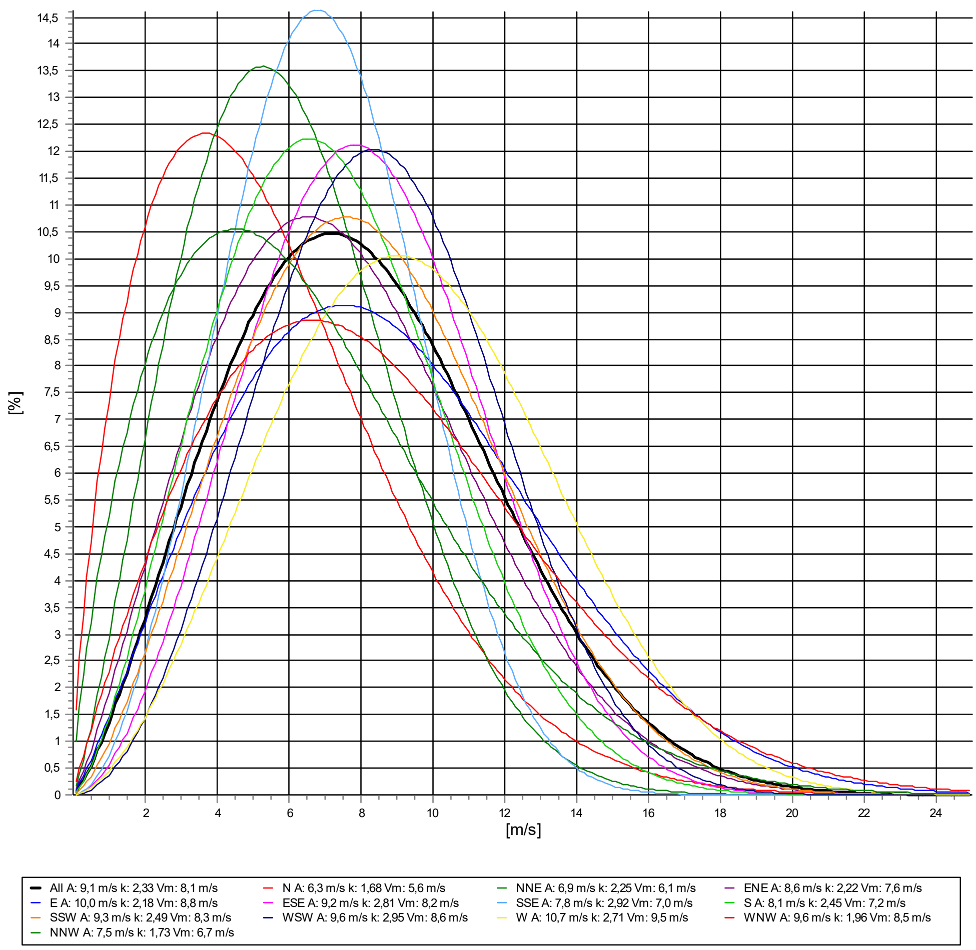
Calculated:
23/09/2024 10.49

Meteo data report - Weibull data overview

Mast: HS-1-LB final **Period:** Full period: 21/07/2023 - 21/07/2024 (12,0 months)
Height: **12,00m - Subst**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	6,30	1,679	2,98	5,62
1-NNE	6,86	2,251	3,57	6,07
2-ENE	8,55	2,217	6,13	7,57
3-E	9,97	2,181	12,29	8,83
4-ESE	9,17	2,808	10,83	8,17
5-SSE	7,84	2,916	8,22	6,99
6-S	8,13	2,454	7,76	7,21
7-SSW	9,34	2,489	11,12	8,28
8-WSW	9,62	2,946	14,53	8,58
9-W	10,70	2,705	12,43	9,52
10-WNW	9,57	1,963	6,46	8,49
11-NNW	7,46	1,728	3,70	6,65
Mean	**9,14**	**2,333**	**100,00**	**8,10**



Appendix D. Long-term Corrected Dataset: HS-1-LB, HS-A, HS-B and HS-C

Project:
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23/09/2024 12.50

Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

300,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			10,09	7,74	6,79	7,70	9,03	9,91	9,70	9,82	11,02	11,60	11,29	10,93	8,27
0		0,49	518	28	25	18	33	33	99	38	37	42	32	66	67
1	0,50	1,49	2915	223	335	234	265	260	303	255	236	243	252	147	162
2	1,50	2,49	6558	460	545	568	572	563	445	446	658	683	600	460	558
3	2,50	3,49	9931	955	765	900	759	731	718	725	841	965	906	838	828
4	3,50	4,49	13047	1129	935	971	1012	875	953	958	1257	1387	1230	1200	1140
5	4,50	5,49	13928	1423	711	948	943	1047	1151	1072	1220	1287	1411	1388	1327
6	5,50	6,49	15862	1129	915	954	939	1335	1410	1052	1244	1860	2005	1754	1265
7	6,50	7,49	15510	785	825	821	935	1219	1419	1065	1328	1993	2020	1755	1345
8	7,50	8,49	15796	648	1044	721	847	1594	1585	1070	1447	2062	1951	1589	1238
9	8,50	9,49	15655	429	639	673	914	1610	1656	1086	1612	2310	2199	1579	948
10	9,50	10,49	15944	763	570	530	822	1500	1495	1354	1423	2485	2377	1661	964
11	10,50	11,49	14910	761	444	411	944	1378	1226	1115	1448	2140	2493	1691	859
12	11,50	12,49	13359	628	238	520	744	1146	1237	850	1474	2069	2035	1582	836
13	12,50	13,49	12221	463	172	461	775	978	936	797	1400	2203	1929	1577	530
14	13,50	14,49	10728	285	153	373	719	1000	1004	813	1041	1948	1808	1252	332
15	14,50	15,49	10275	213	118	370	682	957	964	757	1257	1968	1576	1129	284
16	15,50	16,49	8476	220	63	112	415	814	777	532	1013	1667	1620	1026	217
17	16,50	17,49	6041	171	50	54	245	509	502	396	821	1173	1199	767	154
18	17,50	18,49	5442	112	15	127	199	417	318	375	821	1262	920	657	219
19	18,50	19,49	4092	54	7	61	88	375	330	311	567	886	854	469	90
20	19,50	20,49	2877	39	3	32	94	161	189	195	332	801	632	324	75
21	20,50	21,49	2748	22	3	15	46	165	121	147	578	596	576	419	60
22	21,50	22,49	1564	12	0	6	23	38	39	87	305	394	335	291	34
23	22,50	23,49	1072	4	1	4	20	27	12	49	175	284	241	227	28
24	23,50	24,49	799	2	0	5	17	22	6	31	85	247	176	173	35
25	24,50	25,49	492	4	0	1	5	4	1	20	55	128	154	107	13
26	25,50	26,49	385	0	0	1	3	0	0	11	39	178	72	73	8
27	26,50	27,49	311	0	0	0	2	1	1	9	45	115	42	95	1
28	27,50	28,49	210	0	0	0	0	0	0	6	51	76	39	35	3
29	28,50	29,49	153	0	0	0	0	0	0	2	32	31	25	60	3
30	29,50	30,49	127	0	0	0	0	0	0	0	29	57	24	17	0
31	30,50	31,49	71	0	0	0	0	0	0	0	18	14	19	20	0
32	31,50	32,49	27	0	0	0	0	0	0	0	8	5	9	5	0
33	32,50	33,49	15	0	0	0	0	0	0	0	0	1	6	8	0
34	33,50	34,49	11	0	0	0	0	0	0	0	1	2	4	4	0
35	34,50	35,49	12	0	0	0	0	0	0	0	0	0	5	7	0
36	35,50	36,49	7	0	0	0	0	0	0	0	1	0	3	3	0
37	36,50	37,49	2	0	0	0	0	0	0	0	1	0	0	1	0
38	37,50	38,49	3	0	0	0	0	0	0	0	1	1	0	1	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	1	0	0	0	0	0	0	0	0	1	0	0	0
41	40,50		1	0	0	0	0	0	0	0	0	1	0	0	0

Project:
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Calculated:
23/09/2024 12.50

Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

260,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,95	7,71	6,85	7,73	8,89	9,92	9,51	9,73	10,98	11,43	11,02	10,70	8,21
0		0,49	558	52	71	45	91	30	52	33	51	42	51	12	28
1	0,50	1,49	3053	230	271	223	241	248	237	311	285	300	264	185	258
2	1,50	2,49	7104	599	594	635	562	469	506	435	745	747	643	547	622
3	2,50	3,49	9660	975	784	792	731	655	807	724	754	916	1038	737	747
4	3,50	4,49	12791	984	911	980	987	913	1104	1006	1104	1305	1220	1187	1090
5	4,50	5,49	14287	1376	777	917	1060	1066	1182	1075	1220	1303	1571	1411	1329
6	5,50	6,49	16225	994	961	1016	1038	1381	1413	1110	1407	1835	2016	1766	1288
7	6,50	7,49	15800	833	907	826	931	1303	1374	1060	1420	2166	1976	1681	1323
8	7,50	8,49	15706	656	955	838	916	1503	1405	1048	1540	1950	1990	1722	1183
9	8,50	9,49	15524	514	685	607	889	1783	1622	1157	1488	2221	2125	1487	946
10	9,50	10,49	16143	756	528	561	986	1608	1524	1285	1427	2322	2443	1764	939
11	10,50	11,49	15277	849	462	431	941	1408	1332	1159	1510	2244	2590	1554	797
12	11,50	12,49	13746	494	262	608	863	1189	1296	928	1506	2245	1922	1593	840
13	12,50	13,49	12462	469	228	389	746	1177	1008	978	1334	2139	1944	1487	563
14	13,50	14,49	11058	297	198	421	776	1086	969	850	1221	2034	1740	1135	331
15	14,50	15,49	10025	232	124	343	628	1068	823	690	1313	1994	1508	1089	213
16	15,50	16,49	8027	253	60	127	331	688	714	457	1077	1625	1535	949	211
17	16,50	17,49	6319	163	41	73	211	536	513	422	903	1385	1102	762	208
18	17,50	18,49	5297	96	22	136	167	351	398	358	681	1218	1012	664	194
19	18,50	19,49	3674	56	6	61	106	295	161	255	493	929	773	463	76
20	19,50	20,49	2770	42	2	21	72	224	90	205	486	648	573	327	80
21	20,50	21,49	2100	9	5	15	31	81	111	160	447	455	406	334	46
22	21,50	22,49	1438	12	1	2	29	52	24	65	358	336	295	220	44
23	22,50	23,49	995	2	0	4	19	27	12	29	155	307	250	166	24
24	23,50	24,49	658	5	0	1	10	3	0	38	103	231	139	102	26
25	24,50	25,49	480	3	0	2	8	4	0	21	67	144	121	92	18
26	25,50	26,49	276	0	0	1	5	0	0	8	52	77	62	68	3
27	26,50	27,49	189	0	0	0	0	0	1	11	37	55	34	46	5
28	27,50	28,49	152	1	0	0	0	0	0	1	35	26	26	62	1
29	28,50	29,49	125	0	0	0	0	0	0	1	31	18	26	48	1
30	29,50	30,49	95	0	0	0	0	0	0	0	26	34	13	22	0
31	30,50	31,49	33	0	0	0	0	0	0	0	3	3	17	10	0
32	31,50	32,49	21	0	0	0	0	0	0	0	2	0	11	8	0
33	32,50	33,49	12	0	0	0	0	0	0	0	0	1	7	4	0
34	33,50	34,49	6	0	0	0	0	0	0	0	0	2	1	3	0
35	34,50	35,49	6	0	0	0	0	0	0	0	0	0	2	4	0
36	35,50	36,49	1	0	0	0	0	0	0	0	1	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	2	0	0	0	0	0	0	0	0	2	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		1	0	0	0	0	0	0	0	0	1	0	0	0

Project:
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Calculated:
23/09/2024 12.50

Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

220,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,83	7,72	6,75	7,76	8,91	9,80	9,35	9,61	10,92	11,32	10,85	10,48	8,10
0		0,49	596	59	91	11	58	39	58	49	60	40	60	24	47
1	0,50	1,49	3128	197	286	229	194	267	331	265	263	341	267	224	264
2	1,50	2,49	7108	570	648	708	530	516	511	496	748	710	602	482	587
3	2,50	3,49	9754	976	870	771	651	760	708	700	815	902	1084	753	764
4	3,50	4,49	12782	1039	888	957	992	898	1145	962	1179	1269	1213	1173	1067
5	4,50	5,49	14595	1326	742	934	1074	1150	1236	1058	1130	1362	1676	1532	1375
6	5,50	6,49	16125	1051	974	1007	1061	1368	1405	1139	1444	1682	1967	1773	1254
7	6,50	7,49	16315	820	965	929	1001	1422	1410	1177	1456	2149	1987	1668	1331
8	7,50	8,49	15620	668	932	806	919	1597	1363	1136	1389	1914	1938	1658	1300
9	8,50	9,49	15893	581	730	693	959	1616	1688	1274	1687	2167	2108	1532	858
10	9,50	10,49	16483	772	469	606	1051	1637	1594	1310	1391	2406	2539	1744	964
11	10,50	11,49	15320	672	494	535	954	1513	1265	1131	1538	2304	2558	1604	752
12	11,50	12,49	14045	549	274	586	888	1312	1315	1012	1557	2167	1987	1538	860
13	12,50	13,49	12124	443	226	353	733	1222	923	1020	1307	2193	1919	1319	466
14	13,50	14,49	11817	345	175	396	780	1216	1015	866	1525	2172	1795	1206	326
15	14,50	15,49	9693	224	121	367	561	1034	828	614	1436	1808	1568	935	197
16	15,50	16,49	7956	251	60	130	303	693	674	552	1075	1577	1505	918	218
17	16,50	17,49	6131	171	38	103	208	487	489	376	840	1273	1048	891	207
18	17,50	18,49	5034	80	23	117	164	393	301	284	592	1325	1048	542	165
19	18,50	19,49	3523	55	6	60	96	271	142	276	651	848	650	392	76
20	19,50	20,49	2565	39	4	22	56	187	127	156	546	590	414	342	82
21	20,50	21,49	1814	9	4	12	35	36	55	118	388	488	377	243	49
22	21,50	22,49	1237	12	1	3	30	50	12	61	234	376	237	189	32
23	22,50	23,49	818	8	0	4	19	14	7	40	145	233	203	122	23
24	23,50	24,49	599	7	0	2	3	3	0	21	99	169	154	119	22
25	24,50	25,49	353	3	0	1	10	3	1	15	77	92	80	60	11
26	25,50	26,49	210	0	0	1	3	1	0	13	26	70	29	66	1
27	26,50	27,49	177	0	0	0	0	0	1	2	62	30	39	40	3
28	27,50	28,49	130	0	0	0	0	0	0	1	19	16	24	69	1
29	28,50	29,49	60	1	0	0	0	0	0	1	11	9	17	20	1
30	29,50	30,49	37	0	0	0	0	0	0	0	4	4	15	14	0
31	30,50	31,49	21	0	0	0	0	0	0	0	1	2	10	8	0
32	31,50	32,49	17	0	0	0	0	0	0	0	1	1	9	6	0
33	32,50	33,49	8	0	0	0	0	0	0	0	0	2	1	5	0
34	33,50	34,49	5	0	0	0	0	0	0	0	1	0	3	1	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	3	0	0	0	0	0	0	0	0	3	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 12.50

Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

190,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,72	7,70	6,70	7,89	8,79	9,65	9,30	9,51	10,76	11,24	10,70	10,28	8,01
0		0,49	724	36	84	43	59	84	60	43	63	94	41	80	37
1	0,50	1,49	3144	201	284	243	184	336	391	283	238	275	236	248	225
2	1,50	2,49	7186	564	733	614	577	500	466	502	748	735	623	466	658
3	2,50	3,49	10208	1033	868	790	755	739	714	836	1022	871	1007	766	807
4	3,50	4,49	12406	977	802	894	973	870	1170	894	1210	1073	1234	1273	1036
5	4,50	5,49	14588	1390	782	913	1012	1124	1368	954	1010	1413	1705	1503	1414
6	5,50	6,49	16027	926	879	959	1127	1417	1359	1153	1546	1793	1928	1718	1222
7	6,50	7,49	16543	903	1163	967	1113	1447	1434	1225	1483	2077	1931	1526	1274
8	7,50	8,49	16284	600	972	904	1009	1695	1433	1292	1406	1800	2065	1854	1254
9	8,50	9,49	16051	582	734	661	1041	1754	1592	1254	1698	2154	2127	1532	922
10	9,50	10,49	16832	672	467	689	1115	1810	1569	1359	1521	2435	2513	1751	931
11	10,50	11,49	15213	613	436	588	911	1465	1332	1094	1647	2296	2469	1476	886
12	11,50	12,49	14298	568	245	670	860	1313	1328	1119	1456	2314	2182	1492	751
13	12,50	13,49	13022	437	218	417	816	1358	1085	1105	1603	2209	1818	1434	522
14	13,50	14,49	11403	327	201	392	724	1236	938	931	1600	1949	1853	1018	234
15	14,50	15,49	9381	258	117	363	502	1002	780	630	1223	1809	1635	893	169
16	15,50	16,49	7947	282	63	126	326	714	707	546	1066	1543	1414	977	183
17	16,50	17,49	6003	161	29	112	255	421	382	331	811	1441	1027	835	198
18	17,50	18,49	4651	82	18	112	136	366	304	260	720	1203	738	554	158
19	18,50	19,49	3145	49	6	47	85	204	218	225	569	803	550	287	102
20	19,50	20,49	2480	34	2	31	52	114	92	133	513	641	490	319	59
21	20,50	21,49	1632	17	2	9	34	47	43	76	369	457	297	241	40
22	21,50	22,49	949	9	0	7	25	23	18	70	182	267	171	132	45
23	22,50	23,49	707	2	0	1	9	10	1	30	144	215	146	115	34
24	23,50	24,49	471	3	0	3	3	4	2	19	83	118	125	103	8
25	24,50	25,49	299	4	0	0	7	1	0	12	61	59	66	80	9
26	25,50	26,49	187	0	0	0	1	0	0	10	38	37	48	51	2
27	26,50	27,49	131	0	0	0	0	0	0	2	30	18	27	54	0
28	27,50	28,49	71	0	0	0	0	0	0	1	8	17	23	21	1
29	28,50	29,49	41	0	0	0	0	0	0	0	10	5	15	10	1
30	29,50	30,49	33	0	0	0	0	0	0	0	6	4	6	17	0
31	30,50	31,49	13	0	0	0	0	0	0	0	1	2	7	3	0
32	31,50	32,49	9	0	0	0	0	0	0	0	0	1	6	2	0
33	32,50	33,49	8	0	0	0	0	0	0	0	0	0	6	2	0
34	33,50	34,49	4	0	0	0	0	0	0	0	0	0	2	2	0
35	34,50	35,49	2	0	0	0	0	0	0	0	0	1	0	1	0
36	35,50	36,49	3	0	0	0	0	0	0	0	1	2	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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23/09/2024 12.50

Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

170,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,63	7,72	6,78	7,80	8,74	9,54	9,19	9,46	10,73	11,07	10,66	10,11	7,86
0		0,49	690	17	58	56	65	41	56	95	36	85	65	95	21
1	0,50	1,49	3158	183	231	214	238	264	342	353	228	372	210	215	308
2	1,50	2,49	7194	613	683	596	525	548	547	545	787	685	597	445	623
3	2,50	3,49	10703	1000	908	953	676	743	784	800	991	910	1075	939	924
4	3,50	4,49	12355	1033	865	863	998	1004	1058	830	997	1216	1231	1227	1033
5	4,50	5,49	14169	1375	755	824	998	1289	1302	1043	1175	1311	1393	1435	1269
6	5,50	6,49	16218	991	919	977	1236	1496	1376	1292	1508	1717	1761	1662	1283
7	6,50	7,49	17185	894	1107	1058	1145	1550	1399	1270	1580	2194	2083	1796	1109
8	7,50	8,49	16167	627	1022	882	1070	1573	1598	1347	1407	1759	1855	1645	1382
9	8,50	9,49	16861	685	795	664	1060	1809	1701	1388	1640	2182	2307	1633	997
10	9,50	10,49	17244	609	578	673	1131	1759	1533	1220	1671	2631	2692	1796	951
11	10,50	11,49	15039	611	467	604	1037	1407	1341	1154	1714	2177	2356	1392	779
12	11,50	12,49	14653	586	292	496	964	1512	1375	1228	1534	2196	2126	1532	812
13	12,50	13,49	12827	492	230	538	746	1422	1028	900	1652	2396	1779	1228	416
14	13,50	14,49	11045	325	160	405	633	1055	897	913	1506	1869	1943	1108	231
15	14,50	15,49	9065	218	89	323	496	1016	755	633	1216	1776	1427	970	146
16	15,50	16,49	7740	236	53	119	332	610	587	625	1213	1579	1405	807	174
17	16,50	17,49	5831	213	38	92	214	424	518	420	804	1334	959	649	166
18	17,50	18,49	4615	100	5	142	117	336	245	321	763	1218	720	520	128
19	18,50	19,49	2988	55	3	28	93	154	131	213	535	776	569	371	60
20	19,50	20,49	2436	32	2	23	50	120	83	138	539	548	453	378	70
21	20,50	21,49	1444	14	3	7	41	76	29	68	319	387	244	210	46
22	21,50	22,49	868	8	0	4	13	31	10	64	183	247	172	101	35
23	22,50	23,49	565	1	0	3	9	10	1	36	88	170	139	90	18
24	23,50	24,49	363	7	0	1	7	2	0	16	52	84	96	74	24
25	24,50	25,49	259	2	0	2	3	1	0	15	56	46	71	56	7
26	25,50	26,49	195	1	0	0	3	1	0	9	45	25	33	78	0
27	26,50	27,49	88	0	0	0	0	0	0	6	15	13	22	29	3
28	27,50	28,49	35	0	0	0	0	0	0	2	5	7	8	12	1
29	28,50	29,49	37	0	0	0	0	0	0	1	6	3	18	7	2
30	29,50	30,49	22	0	0	0	0	0	0	0	5	1	9	7	0
31	30,50	31,49	11	0	0	0	0	0	0	0	0	0	7	4	0
32	31,50	32,49	11	0	0	0	0	0	0	0	1	1	4	5	0
33	32,50	33,49	7	0	0	0	0	0	0	0	0	0	6	1	0
34	33,50	34,49	1	0	0	0	0	0	0	0	0	0	1	0	0
35	34,50	35,49	3	0	0	0	0	0	0	0	0	2	1	0	0
36	35,50	36,49	3	0	0	0	0	0	0	0	0	2	0	1	0
37	36,50	37,49	1	0	0	0	0	0	0	0	0	0	0	1	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Calculated:
23/09/2024 12.50

Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

150,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,52	7,61	6,78	7,91	8,69	9,42	9,12	9,39	10,53	10,96	10,50	9,94	7,82
0		0,49	739	23	52	47	85	50	100	83	79	57	44	65	54
1	0,50	1,49	3138	193	220	215	218	291	376	307	291	354	245	193	235
2	1,50	2,49	7154	661	508	547	586	610	490	540	864	691	553	472	632
3	2,50	3,49	11064	1079	956	851	696	746	744	904	1057	970	1176	1031	854
4	3,50	4,49	11986	1026	980	861	901	912	968	774	991	1194	1167	1179	1033
5	4,50	5,49	14730	1378	777	812	1062	1381	1352	1070	1199	1384	1427	1558	1330
6	5,50	6,49	15781	899	1004	951	1125	1505	1368	1367	1397	1710	1795	1534	1126
7	6,50	7,49	17208	821	1061	1096	1354	1565	1444	1323	1513	2011	2096	1691	1233
8	7,50	8,49	17214	742	1164	901	1096	1710	1688	1363	1568	1921	1909	1762	1390
9	8,50	9,49	16703	598	681	839	1099	1808	1757	1486	1742	2167	2029	1602	895
10	9,50	10,49	17806	734	675	823	1086	1849	1584	1168	1807	2615	2832	1648	985
11	10,50	11,49	16218	677	427	603	1164	1562	1454	1307	1743	2324	2337	1762	858
12	11,50	12,49	14601	567	245	548	970	1528	1375	1189	1758	2178	2128	1422	693
13	12,50	13,49	12530	449	222	449	640	1317	953	1019	1546	2310	1992	1215	418
14	13,50	14,49	10830	291	143	426	647	1065	897	940	1373	1931	1875	1037	205
15	14,50	15,49	8739	207	74	275	542	822	725	663	1354	1693	1282	964	138
16	15,50	16,49	7391	197	52	159	268	567	652	534	1160	1634	1331	663	174
17	16,50	17,49	5818	208	44	115	193	528	444	480	733	1247	922	714	190
18	17,50	18,49	4376	95	6	98	135	256	201	312	926	1170	667	420	90
19	18,50	19,49	2744	58	10	49	106	190	101	150	451	651	518	385	75
20	19,50	20,49	2004	29	5	14	47	104	68	103	381	538	336	321	58
21	20,50	21,49	1197	10	1	8	29	52	18	67	337	340	189	114	32
22	21,50	22,49	846	5	0	5	14	28	1	52	167	271	183	96	24
23	22,50	23,49	419	6	1	1	12	5	1	24	53	88	122	72	34
24	23,50	24,49	348	5	0	2	10	4	0	23	47	71	101	80	5
25	24,50	25,49	207	0	0	1	1	0	0	10	43	40	46	53	13
26	25,50	26,49	90	0	0	0	1	0	0	7	18	25	15	24	0
27	26,50	27,49	100	0	0	0	0	0	0	3	10	9	26	52	0
28	27,50	28,49	52	0	0	0	0	0	0	3	9	3	20	15	2
29	28,50	29,49	23	0	0	0	0	0	0	0	2	5	9	7	0
30	29,50	30,49	16	0	0	0	0	0	0	0	1	1	9	5	0
31	30,50	31,49	8	0	0	0	0	0	0	0	1	2	2	3	0
32	31,50	32,49	8	0	0	0	0	0	0	0	0	1	6	1	0
33	32,50	33,49	3	0	0	0	0	0	0	0	0	0	1	2	0
34	33,50	34,49	3	0	0	0	0	0	0	0	0	1	0	2	0
35	34,50	35,49	2	0	0	0	0	0	0	0	1	1	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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23/09/2024 12.50

Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

130,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,39	7,24	6,77	7,90	8,55	9,33	9,04	9,32	10,50	10,76	10,36	9,77	7,65
0		0,49	718	40	57	46	79	70	66	85	76	61	73	23	42
1	0,50	1,49	3582	266	280	236	223	357	385	347	429	372	248	192	247
2	1,50	2,49	7562	819	583	481	535	589	497	603	801	673	690	534	757
3	2,50	3,49	10667	946	1036	791	643	777	752	814	931	1063	966	979	969
4	3,50	4,49	12429	1045	949	853	963	992	1130	886	1024	1262	1202	1067	1056
5	4,50	5,49	14476	1231	815	987	1114	1242	1246	897	1214	1333	1382	1568	1447
6	5,50	6,49	16628	912	1016	1021	1362	1527	1458	1344	1404	1887	1747	1756	1194
7	6,50	7,49	17180	810	1043	1062	1304	1693	1557	1437	1529	1760	2055	1782	1148
8	7,50	8,49	17277	791	1076	874	1156	1707	1595	1390	1554	2014	2210	1715	1195
9	8,50	9,49	17590	639	794	806	1056	1702	1765	1513	1846	2463	2368	1665	973
10	9,50	10,49	18241	785	646	894	1219	1889	1615	1254	2077	2689	2496	1612	1065
11	10,50	11,49	15384	694	418	681	1064	1494	1381	1187	1533	2167	2301	1677	787
12	11,50	12,49	14586	557	268	489	895	1522	1514	1339	1770	2238	1950	1414	630
13	12,50	13,49	12217	348	229	376	634	1333	1103	1022	1595	2300	1943	955	379
14	13,50	14,49	10862	226	166	428	631	1092	712	944	1602	1958	1830	1041	232
15	14,50	15,49	8822	164	100	305	490	788	710	549	1463	1770	1455	827	201
16	15,50	16,49	7466	169	70	160	221	633	659	538	1209	1688	1186	752	181
17	16,50	17,49	5480	108	33	151	188	477	395	483	904	1248	907	490	96
18	17,50	18,49	3763	48	25	91	130	192	164	237	843	889	578	410	156
19	18,50	19,49	2741	25	11	20	91	187	88	170	481	610	516	476	66
20	19,50	20,49	1750	17	6	19	42	111	51	92	338	550	266	217	41
21	20,50	21,49	916	7	4	5	19	39	26	80	193	236	164	121	22
22	21,50	22,49	684	6	0	6	16	12	6	47	152	155	145	96	43
23	22,50	23,49	405	4	0	1	7	6	1	25	45	89	140	69	18
24	23,50	24,49	256	3	1	2	7	4	0	16	45	47	68	56	7
25	24,50	25,49	179	0	0	0	3	1	0	11	30	30	33	63	8
26	25,50	26,49	96	0	0	0	0	0	0	4	17	12	25	38	0
27	26,50	27,49	46	0	0	0	0	0	0	1	2	8	17	17	1
28	27,50	28,49	34	0	0	0	0	0	0	0	11	2	9	12	0
29	28,50	29,49	19	0	0	0	0	0	0	0	4	2	8	4	1
30	29,50	30,49	15	0	0	0	0	0	0	0	0	3	5	7	0
31	30,50	31,49	9	0	0	0	0	0	0	0	0	3	4	2	0
32	31,50	32,49	9	0	0	0	0	0	0	0	0	1	3	5	0
33	32,50	33,49	2	0	0	0	0	0	0	0	0	0	0	2	0
34	33,50	34,49	2	0	0	0	0	0	0	0	1	1	0	0	0
35	34,50	35,49	2	0	0	0	0	0	0	0	0	1	0	1	0
36	35,50	36,49	1	0	0	0	0	0	0	0	0	0	0	1	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

100,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,15	7,13	6,84	7,86	8,54	9,09	8,80	9,01	10,25	10,37	10,07	9,45	7,56
0		0,49	679	58	52	34	49	53	67	92	79	76	61	37	21
1	0,50	1,49	3678	265	315	230	186	334	363	414	440	382	262	248	239
2	1,50	2,49	7537	804	491	536	501	700	519	612	712	765	628	543	726
3	2,50	3,49	10778	905	892	799	549	855	756	870	1027	1113	1011	998	1003
4	3,50	4,49	12726	1022	1029	829	982	1063	1141	887	1051	1274	1267	1229	952
5	4,50	5,49	15376	1259	977	1075	1113	1349	1320	1141	1207	1374	1485	1668	1408
6	5,50	6,49	16804	882	1096	1047	1459	1589	1541	1462	1413	1777	1793	1571	1174
7	6,50	7,49	17395	859	1131	1059	1337	1581	1531	1366	1480	1806	2203	1824	1218
8	7,50	8,49	18130	736	1117	819	1179	1944	2029	1509	1739	2043	2091	1804	1120
9	8,50	9,49	18457	810	894	923	1216	1791	1770	1478	1915	2638	2378	1576	1068
10	9,50	10,49	19000	882	717	898	1271	1974	1559	1326	2214	2681	2809	1689	980
11	10,50	11,49	16587	616	412	671	1092	1816	1626	1502	1919	2168	2278	1651	836
12	11,50	12,49	13826	451	275	499	799	1413	1305	1379	1836	2282	1839	1239	509
13	12,50	13,49	12509	315	201	455	686	1367	1032	1088	1686	2393	1999	969	318
14	13,50	14,49	10494	214	183	478	583	1093	750	759	1581	1762	1817	1102	172
15	14,50	15,49	8776	154	109	247	448	704	661	647	1468	1737	1517	865	219
16	15,50	16,49	6795	167	80	152	191	559	558	475	1264	1685	985	555	124
17	16,50	17,49	4767	86	34	133	196	379	260	372	1008	1011	696	464	128
18	17,50	18,49	2809	29	16	68	155	207	136	156	481	620	438	384	119
19	18,50	19,49	1841	18	12	26	62	113	57	104	340	447	283	311	68
20	19,50	20,49	1112	12	7	18	35	41	32	90	229	259	210	151	28
21	20,50	21,49	767	6	4	6	16	23	6	42	196	168	159	104	37
22	21,50	22,49	516	5	1	2	12	10	1	38	65	116	155	78	33
23	22,50	23,49	312	3	0	1	13	2	1	17	40	57	94	73	11
24	23,50	24,49	162	1	1	3	1	2	0	6	15	45	35	46	7
25	24,50	25,49	111	0	0	0	0	0	0	2	15	17	28	48	1
26	25,50	26,49	53	0	0	0	1	0	0	0	5	9	13	24	1
27	26,50	27,49	31	0	0	0	0	0	0	0	3	3	16	9	0
28	27,50	28,49	27	0	0	0	0	0	0	0	1	5	13	8	0
29	28,50	29,49	21	0	0	0	0	0	0	0	1	3	9	8	0
30	29,50	30,49	8	0	0	0	0	0	0	0	0	1	5	2	0
31	30,50	31,49	8	0	0	0	0	0	0	0	0	1	3	4	0
32	31,50	32,49	1	0	0	0	0	0	0	0	0	1	0	0	0
33	32,50	33,49	1	0	0	0	0	0	0	0	1	0	0	0	0
34	33,50	34,49	1	0	0	0	0	0	0	0	0	1	0	0	0
35	34,50	35,49	1	0	0	0	0	0	0	0	0	1	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

80,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			8,96	7,02	6,73	7,81	8,30	8,89	8,64	8,93	10,05	10,02	9,90	9,27	7,41
0		0,49	818	48	47	52	78	65	81	65	118	108	45	46	65
1	0,50	1,49	3617	284	257	224	239	335	385	407	352	459	276	218	181
2	1,50	2,49	7387	804	578	505	433	667	487	622	725	697	649	540	680
3	2,50	3,49	11346	922	938	864	742	964	811	863	1051	1055	1036	990	1110
4	3,50	4,49	13101	1016	988	855	1108	1077	1179	815	1127	1360	1219	1367	990
5	4,50	5,49	15801	1318	1157	962	1202	1446	1341	1046	1186	1508	1523	1566	1546
6	5,50	6,49	16736	996	1085	1202	1373	1488	1480	1436	1488	1652	1670	1630	1236
7	6,50	7,49	18213	744	1071	1029	1322	1784	1690	1473	1549	1989	2213	2097	1252
8	7,50	8,49	19301	871	1137	890	1474	2097	2020	1492	1997	2261	2117	1642	1303
9	8,50	9,49	18847	796	949	999	1415	1888	1598	1494	1954	2675	2595	1554	930
10	9,50	10,49	19398	892	618	833	1209	1889	1807	1601	2208	2755	2780	1762	1044
11	10,50	11,49	16410	533	430	787	1213	1795	1568	1533	2019	2444	2171	1272	645
12	11,50	12,49	13876	373	226	600	823	1481	1262	1303	1995	2237	1890	1231	455
13	12,50	13,49	12742	245	202	468	607	1438	969	1131	1895	2399	2078	1020	290
14	13,50	14,49	10573	204	131	340	508	962	807	816	1821	2001	1665	1090	228
15	14,50	15,49	8086	156	103	295	368	591	692	521	1475	1621	1340	745	179
16	15,50	16,49	5981	168	75	134	226	465	428	398	1227	1169	1008	539	144
17	16,50	17,49	3435	90	30	89	157	279	155	239	574	770	521	385	146
18	17,50	18,49	2391	45	18	68	84	149	87	160	462	540	350	322	106
19	18,50	19,49	1411	18	10	18	65	126	44	93	279	246	211	252	49
20	19,50	20,49	1074	14	9	14	37	41	20	76	188	215	240	182	38
21	20,50	21,49	589	5	3	7	14	16	3	47	107	102	155	102	28
22	21,50	22,49	367	4	3	4	9	6	2	21	54	71	108	68	17
23	22,50	23,49	243	0	0	4	8	4	0	17	22	31	89	57	11
24	23,50	24,49	160	2	0	1	3	0	0	5	18	36	26	64	5
25	24,50	25,49	78	0	1	0	4	0	0	2	7	12	16	35	1
26	25,50	26,49	43	0	0	0	0	0	0	0	7	1	20	13	2
27	26,50	27,49	28	0	0	0	1	0	0	0	1	5	8	13	0
28	27,50	28,49	16	0	0	0	0	0	0	0	1	1	9	5	0
29	28,50	29,49	14	0	0	0	0	0	0	0	0	2	6	5	1
30	29,50	30,49	6	0	0	0	0	0	0	0	0	0	2	4	0
31	30,50	31,49	6	0	0	0	0	0	0	0	1	1	1	3	0
32	31,50	32,49	1	0	0	0	0	0	0	0	0	1	0	0	0
33	32,50	33,49	1	0	0	0	0	0	0	0	0	1	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

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Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

40,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			8,41	6,54	6,80	7,49	7,95	8,47	8,05	8,27	9,21	9,23	9,38	8,74	7,08
0		0,49	672	57	32	54	69	31	65	100	113	44	31	36	40
1	0,50	1,49	3867	396	262	192	312	276	437	340	403	441	280	237	291
2	1,50	2,49	8032	866	575	556	466	713	575	677	765	783	666	638	752
3	2,50	3,49	12241	956	891	999	818	1013	1065	926	1081	1208	1006	1208	1070
4	3,50	4,49	14570	1103	1005	1035	1186	1248	1213	887	1371	1515	1324	1466	1217
5	4,50	5,49	16770	1262	1095	1036	1436	1565	1477	1251	1363	1669	1620	1644	1352
6	5,50	6,49	18086	936	1114	1225	1407	1747	1769	1642	1756	1690	1687	1765	1348
7	6,50	7,49	21059	903	1288	1108	1752	2033	2085	1833	1867	2237	2408	2063	1482
8	7,50	8,49	21087	769	1134	978	1860	2117	1956	1543	2258	2994	2465	1680	1333
9	8,50	9,49	19883	713	783	1035	1375	1977	1877	1800	2327	2936	2692	1445	923
10	9,50	10,49	20484	706	658	885	1189	2092	2110	1907	2616	3013	2636	1905	767
11	10,50	11,49	16914	440	488	720	883	1557	1656	1452	2729	2788	2154	1415	632
12	11,50	12,49	13854	370	270	689	756	1523	1076	1189	2021	2368	2016	1214	362
13	12,50	13,49	11862	172	268	445	621	1292	931	870	1940	2208	1815	1063	237
14	13,50	14,49	8428	154	149	290	535	764	568	488	1351	1573	1509	830	217
15	14,50	15,49	5565	136	89	147	343	436	372	396	1058	832	1010	592	154
16	15,50	16,49	3051	105	55	78	200	262	159	160	352	479	603	444	154
17	16,50	17,49	1950	41	36	106	143	207	60	107	283	329	255	263	120
18	17,50	18,49	1476	21	11	31	67	116	32	100	273	300	194	288	43
19	18,50	19,49	906	17	12	22	40	41	10	43	159	149	219	156	38
20	19,50	20,49	546	4	4	8	26	13	6	35	44	91	169	100	46
21	20,50	21,49	316	4	3	6	4	2	0	16	37	89	92	37	26
22	21,50	22,49	169	4	0	2	4	3	0	5	20	36	55	33	7
23	22,50	23,49	126	0	1	0	4	1	0	2	15	20	37	34	12
24	23,50	24,49	97	0	0	1	1	0	0	0	2	10	18	61	4
25	24,50	25,49	36	0	0	0	0	0	0	0	3	4	11	17	1
26	25,50	26,49	24	0	0	0	0	0	0	0	0	3	11	8	2
27	26,50	27,49	14	0	0	0	0	0	0	0	0	1	3	10	0
28	27,50	28,49	6	0	0	0	0	0	0	0	0	0	2	4	0
29	28,50	29,49	2	0	0	0	0	0	0	0	1	0	0	1	0
30	29,50	30,49	2	0	0	0	0	0	0	0	0	1	0	1	0
31	30,50	31,49	1	0	0	0	0	0	0	0	0	1	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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23/09/2024 12.50

Meteo data report - Frequency distribution (TAB file data)

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Frequency distribution (TAB file data)

12,00m - EMD WFR - [Matrix]

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			7,78	6,15	6,46	7,03	7,50	8,02	7,49	7,62	8,49	8,34	8,64	8,04	6,47
0		0,49	540	56	43	56	49	32	28	19	62	39	45	67	44
1	0,50	1,49	3607	466	247	217	328	347	319	295	329	314	308	247	190
2	1,50	2,49	9058	949	609	618	590	708	682	718	930	952	852	713	737
3	2,50	3,49	13667	951	920	943	917	1244	1051	938	1202	1454	1253	1347	1447
4	3,50	4,49	17453	1342	1159	1283	1425	1583	1383	1351	1504	1829	1559	1635	1400
5	4,50	5,49	18944	1384	1325	1296	1528	1519	1632	1497	1762	2042	1888	1694	1377
6	5,50	6,49	20587	906	1187	1346	1714	1567	2074	1955	1922	2262	2000	2090	1564
7	6,50	7,49	22576	857	1168	1151	1764	1990	2192	2088	2390	3166	2442	1867	1501
8	7,50	8,49	24092	927	1210	1117	1724	2658	2275	2014	2955	3683	2618	1713	1198
9	8,50	9,49	22601	607	709	961	1447	2424	2168	1925	3172	3720	2801	1882	785
10	9,50	10,49	19080	661	600	669	1275	1968	1782	1461	2668	3131	2577	1557	731
11	10,50	11,49	15551	451	373	614	908	1845	1173	1206	2351	2322	2513	1359	436
12	11,50	12,49	12795	248	294	749	922	1481	959	878	2073	1882	1815	1252	242
13	12,50	13,49	8401	186	245	400	617	692	522	638	1268	1337	1506	806	184
14	13,50	14,49	5415	187	111	149	325	460	247	333	991	971	992	540	109
15	14,50	15,49	3190	75	51	99	180	314	163	212	325	524	584	520	143
16	15,50	16,49	2015	20	19	100	102	209	75	100	303	320	387	315	65
17	16,50	17,49	1254	17	8	19	53	138	29	59	249	183	261	158	80
18	17,50	18,49	565	8	3	7	21	46	9	29	93	90	159	74	26
19	18,50	19,49	335	4	5	3	8	9	2	19	50	48	92	71	24
20	19,50	20,49	199	3	1	3	11	2	0	4	30	43	47	47	8
21	20,50	21,49	100	2	0	1	3	0	0	2	10	7	26	46	3
22	21,50	22,49	34	0	0	0	4	0	1	0	1	4	11	13	0
23	22,50	23,49	17	0	0	0	0	0	0	0	0	4	10	3	0
24	23,50	24,49	8	0	0	0	0	0	0	0	0	0	2	6	0
25	24,50	25,49	6	0	0	0	0	0	0	0	1	1	1	3	0
26	25,50	26,49	1	0	0	0	0	0	0	0	0	1	0	0	0
27	26,50	27,49	5	0	0	0	0	0	0	0	0	1	0	4	0
28	27,50	28,49	0	0	0	0	0	0	0	0	0	0	0	0	0
29	28,50	29,49	0	0	0	0	0	0	0	0	0	0	0	0	0
30	29,50	30,49	0	0	0	0	0	0	0	0	0	0	0	0	0
31	30,50	31,49	0	0	0	0	0	0	0	0	0	0	0	0	0
32	31,50	32,49	0	0	0	0	0	0	0	0	0	0	0	0	0
33	32,50	33,49	0	0	0	0	0	0	0	0	0	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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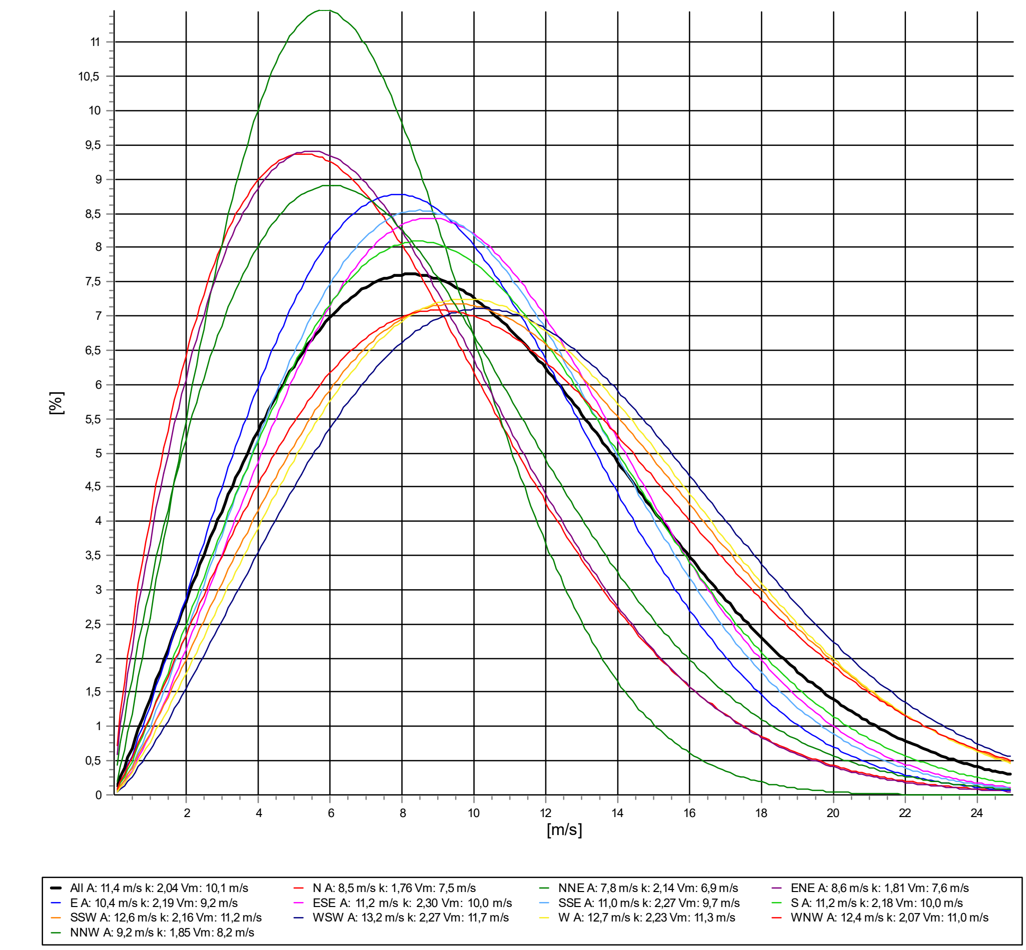
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **300,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,48	1,759	4,94	7,55
1-NNE	7,83	2,141	3,86	6,94
2-ENE	8,57	1,806	4,45	7,62
3-E	10,40	2,191	5,88	9,21
4-ESE	11,24	2,304	8,45	9,96
5-SSE	10,96	2,269	8,51	9,71
6-S	11,24	2,179	7,03	9,96
7-SSW	12,61	2,164	10,31	11,17
8-WSW	13,19	2,271	15,11	11,68
9-W	12,75	2,229	14,31	11,29
10-WNW	12,38	2,069	11,01	10,97
11-NNW	9,18	1,853	6,13	8,15
Mean	**11,43**	**2,044**	**100,00**	**10,13**



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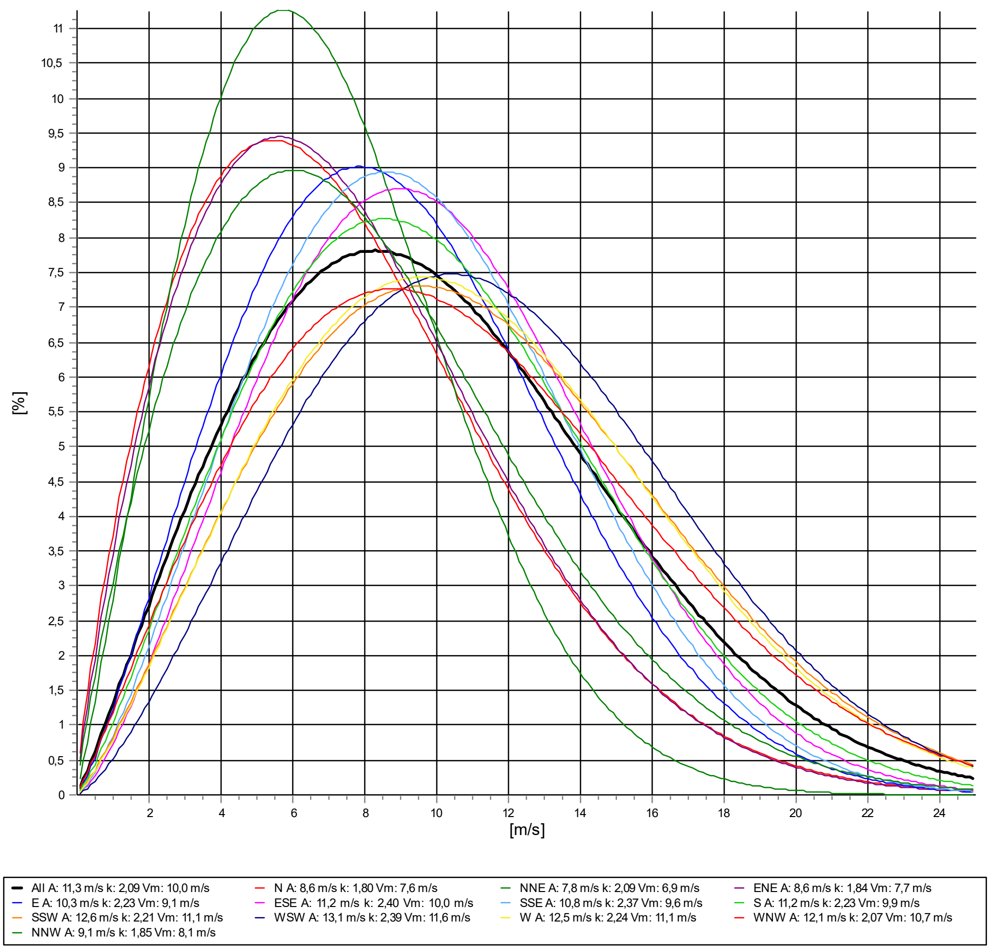
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **260,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,55	1,796	4,93	7,61
1-NNE	7,84	2,090	3,99	6,95
2-ENE	8,63	1,839	4,54	7,66
3-E	10,27	2,232	6,02	9,09
4-ESE	11,24	2,399	8,62	9,96
5-SSE	10,83	2,370	8,41	9,60
6-S	11,18	2,228	7,15	9,90
7-SSW	12,59	2,210	10,48	11,15
8-WSW	13,05	2,393	14,98	11,57
9-W	12,48	2,238	14,16	11,06
10-WNW	12,09	2,072	10,68	10,70
11-NNW	9,13	1,854	6,05	8,11
Mean	**11,31**	**2,091**	**100,00**	**10,02**



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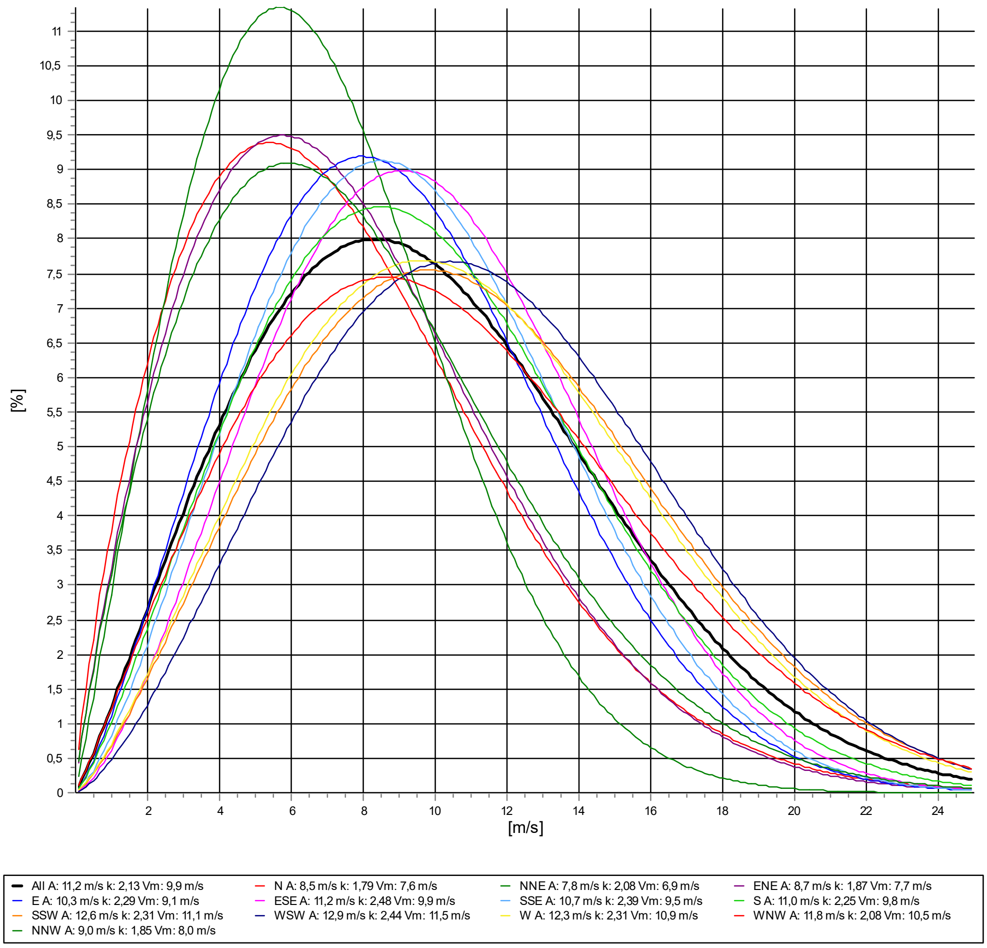
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **220,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,54	1,789	4,92	7,60
1-NNE	7,77	2,084	4,06	6,88
2-ENE	8,67	1,872	4,66	7,70
3-E	10,26	2,288	6,00	9,09
4-ESE	11,18	2,485	8,87	9,92
5-SSE	10,69	2,394	8,38	9,47
6-S	11,01	2,253	7,26	9,75
7-SSW	12,56	2,306	10,67	11,13
8-WSW	12,93	2,444	14,72	11,46
9-W	12,33	2,306	14,02	10,93
10-WNW	11,84	2,082	10,45	10,49
11-NNW	8,99	1,850	5,99	7,98
Mean	**11,20**	**2,132**	**100,00**	**9,92**



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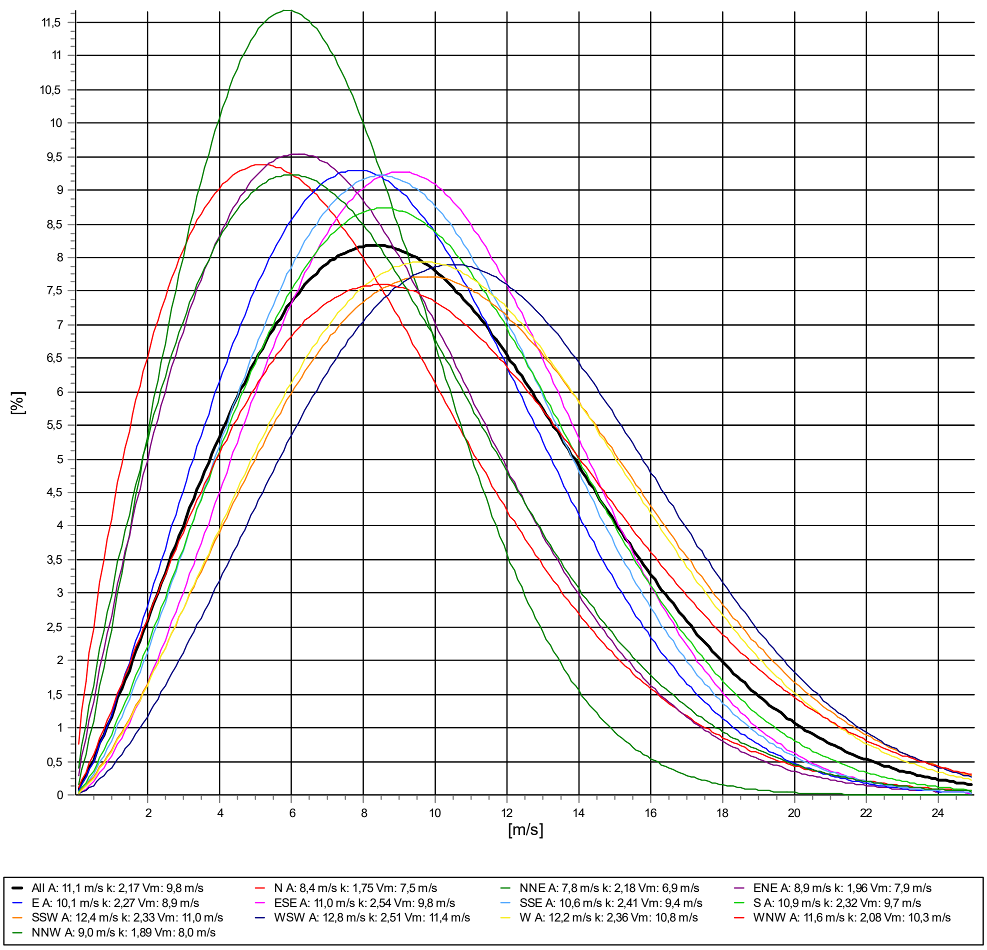
Calculated:
23/09/2024 12.50

Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **190,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,45	1,748	4,83	7,52
1-NNE	7,80	2,181	4,10	6,91
2-ENE	8,88	1,964	4,75	7,88
3-E	10,09	2,273	6,17	8,94
4-ESE	11,02	2,538	9,03	9,78
5-SSE	10,64	2,409	8,46	9,43
6-S	10,92	2,323	7,38	9,68
7-SSW	12,38	2,329	10,84	10,97
8-WSW	12,84	2,511	14,47	11,40
9-W	12,18	2,364	13,75	10,80
10-WNW	11,61	2,083	10,28	10,28
11-NNW	8,96	1,886	5,94	7,95
Mean	**11,09**	**2,170**	**100,00**	**9,82**



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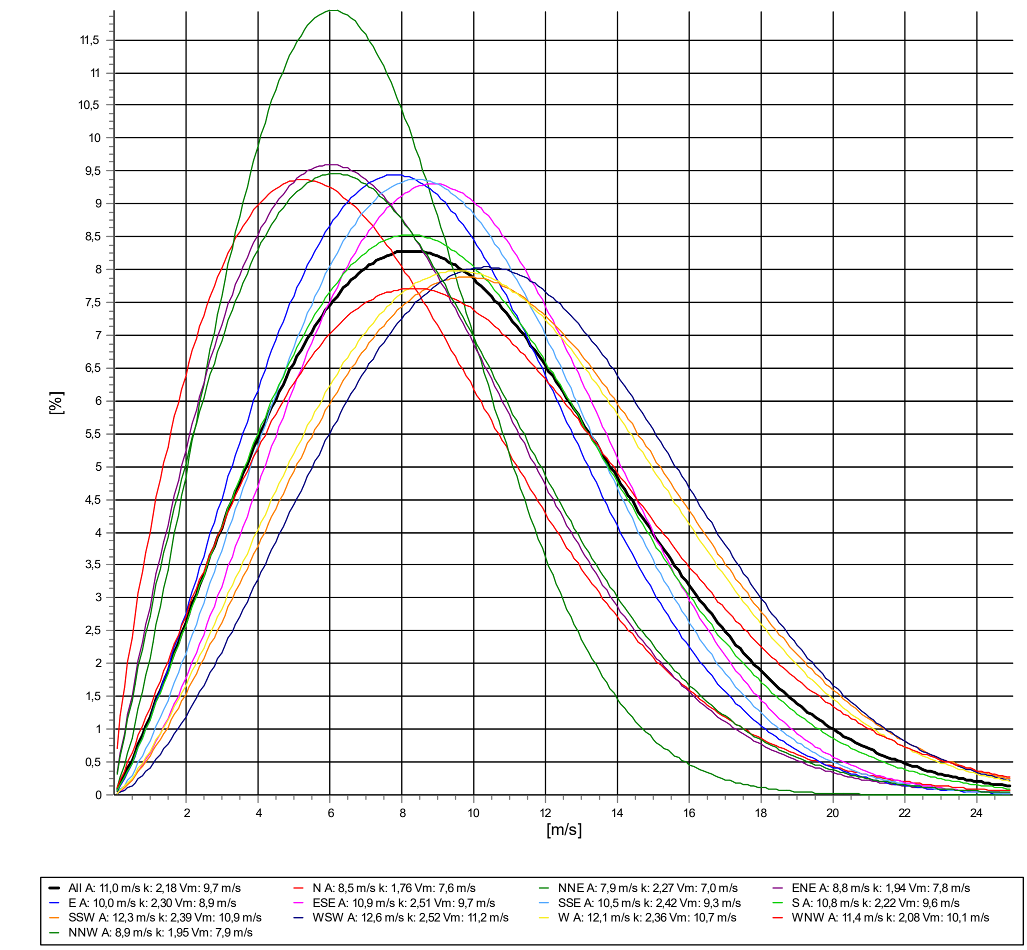
Calculated:
23/09/2024 12.50

Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **170,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,49	1,760	4,92	7,56
1-NNE	7,86	2,275	4,17	6,96
2-ENE	8,76	1,937	4,75	7,77
3-E	10,02	2,298	6,26	8,88
4-ESE	10,88	2,507	9,12	9,65
5-SSE	10,50	2,420	8,42	9,31
6-S	10,80	2,216	7,63	9,56
7-SSW	12,34	2,385	10,93	10,94
8-WSW	12,65	2,521	14,37	11,22
9-W	12,09	2,359	13,43	10,71
10-WNW	11,40	2,077	10,14	10,10
11-NNW	8,91	1,946	5,86	7,90
Mean	**10,97**	**2,176**	**100,00**	**9,72**



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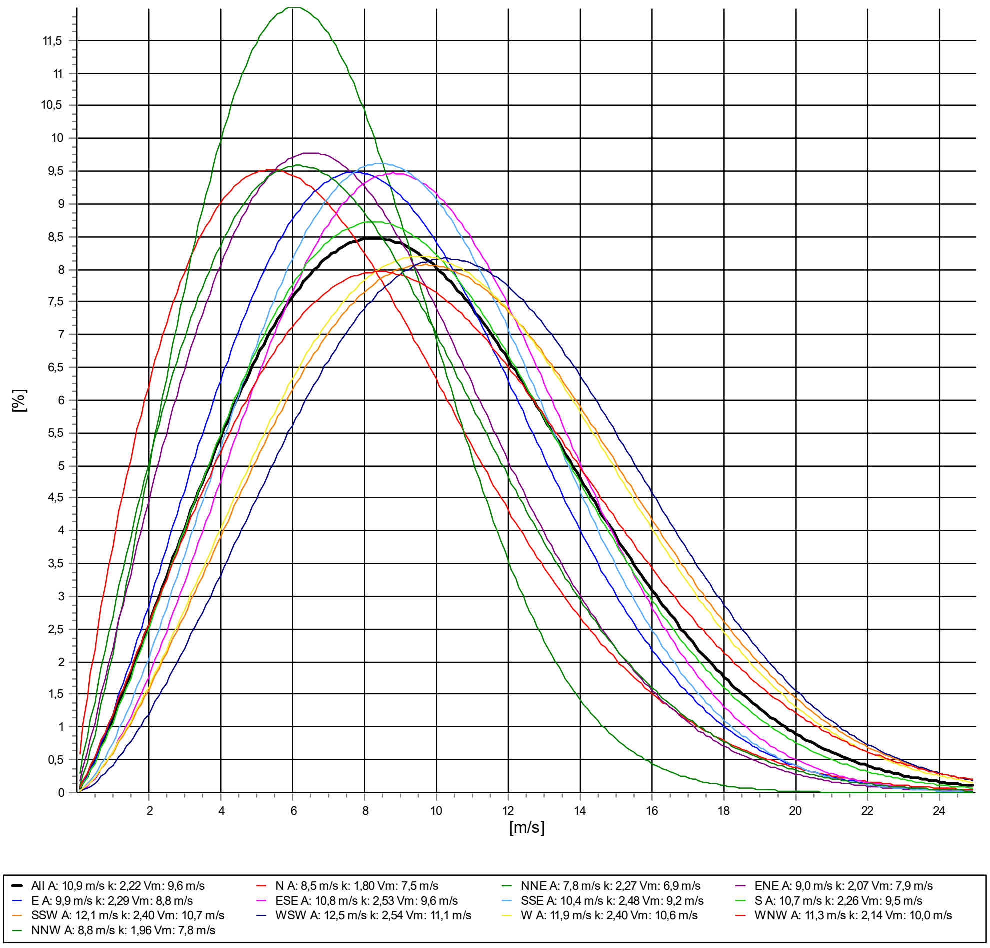
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **150,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,46	1,803	4,93	7,52
1-NNE	7,82	2,272	4,19	6,92
2-ENE	8,97	2,069	4,82	7,95
3-E	9,94	2,287	6,34	8,81
4-ESE	10,77	2,529	9,21	9,55
5-SSE	10,42	2,476	8,45	9,24
6-S	10,71	2,260	7,78	9,49
7-SSW	12,12	2,401	11,09	10,74
8-WSW	12,51	2,536	14,23	11,11
9-W	11,95	2,404	13,23	10,59
10-WNW	11,29	2,142	9,98	10,00
11-NNW	8,85	1,965	5,75	7,84
Mean	**10,87**	**2,216**	**100,00**	**9,62**



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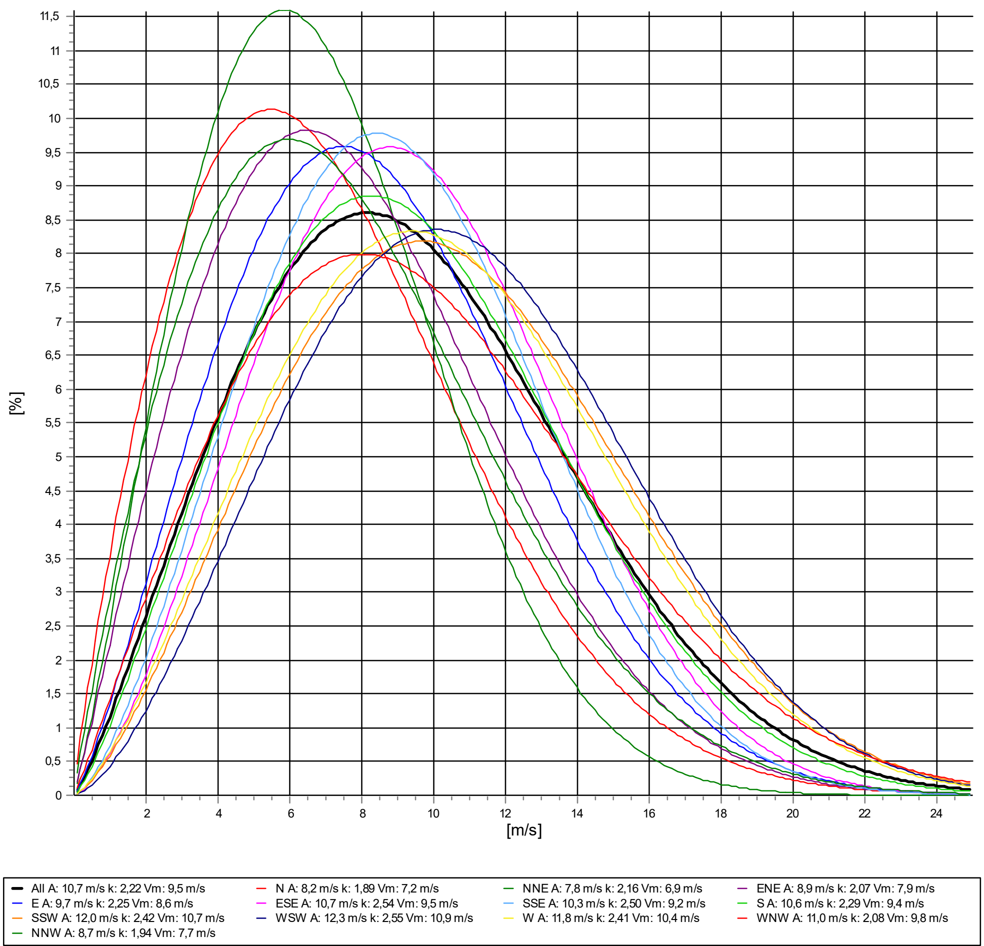
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **130,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,16	1,886	4,80	7,25
1-NNE	7,80	2,160	4,33	6,91
2-ENE	8,93	2,066	4,86	7,91
3-E	9,72	2,250	6,35	8,61
4-ESE	10,69	2,541	9,20	9,49
5-SSE	10,34	2,502	8,50	9,17
6-S	10,64	2,286	7,80	9,43
7-SSW	12,04	2,421	11,31	10,67
8-WSW	12,27	2,548	14,22	10,89
9-W	11,77	2,409	13,05	10,44
10-WNW	11,02	2,079	9,75	9,76
11-NNW	8,68	1,938	5,84	7,70
Mean	**10,71**	**2,215**	**100,00**	**9,48**



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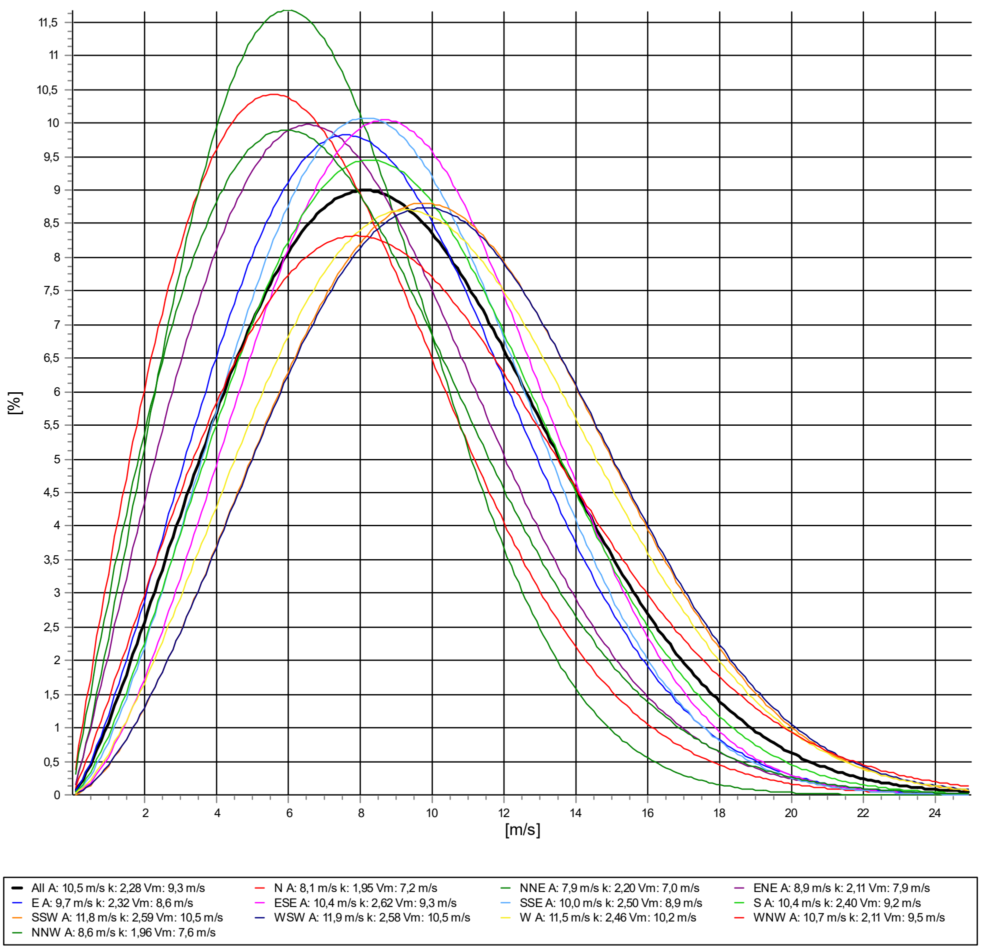
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Height: **100,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,08	1,946	4,75	7,17
1-NNE	7,86	2,204	4,52	6,96
2-ENE	8,91	2,107	4,96	7,89
3-E	9,71	2,323	6,36	8,61
4-ESE	10,43	2,618	9,44	9,27
5-SSE	10,02	2,499	8,56	8,89
6-S	10,36	2,404	8,03	9,19
7-SSW	11,80	2,591	11,45	10,48
8-WSW	11,86	2,581	13,83	10,53
9-W	11,46	2,460	12,87	10,16
10-WNW	10,70	2,114	9,58	9,48
11-NNW	8,56	1,960	5,64	7,59
Mean	**10,46**	**2,283**	**100,00**	**9,27**



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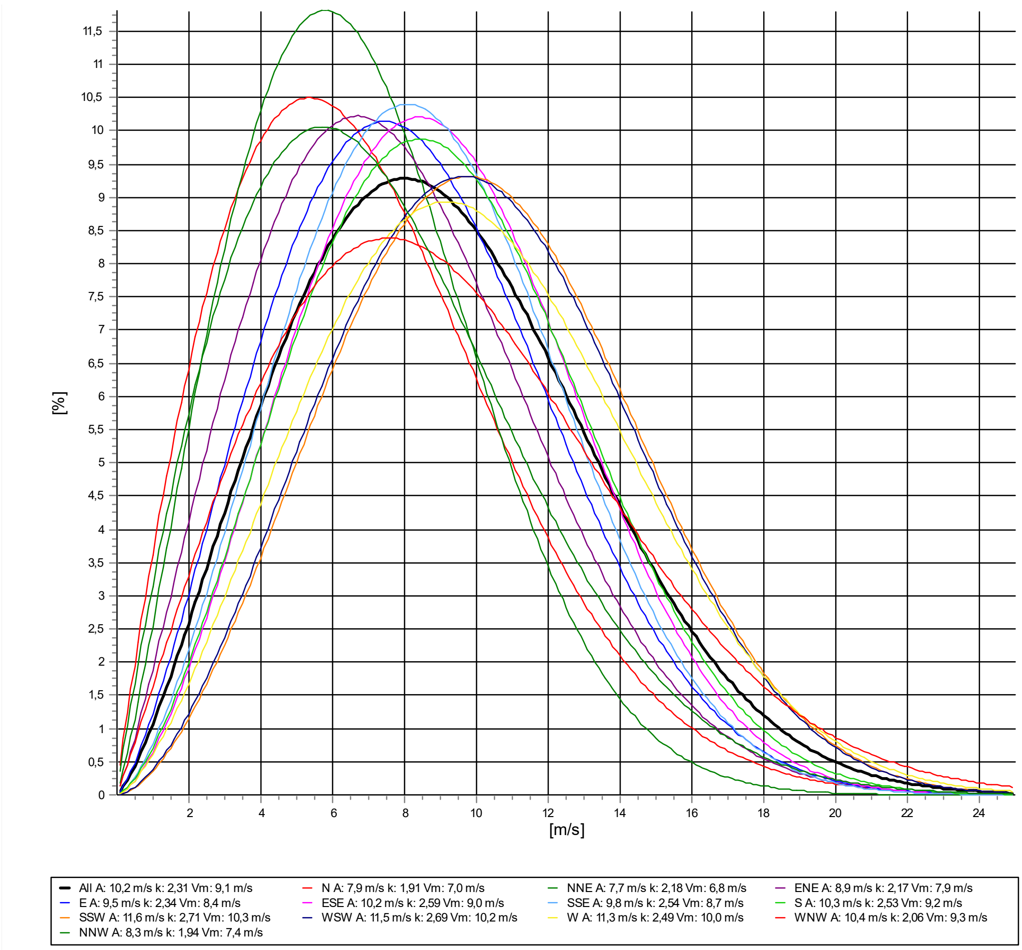
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **80,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	7,93	1,908	4,75	7,04
1-NNE	7,70	2,176	4,53	6,82
2-ENE	8,88	2,172	5,06	7,86
3-E	9,46	2,340	6,63	8,38
4-ESE	10,17	2,588	9,48	9,03
5-SSE	9,84	2,541	8,52	8,73
6-S	10,31	2,526	7,96	9,15
7-SSW	11,60	2,715	11,67	10,31
8-WSW	11,49	2,685	13,70	10,22
9-W	11,27	2,489	12,62	9,99
10-WNW	10,45	2,063	9,37	9,25
11-NNW	8,35	1,935	5,71	7,41
Mean	**10,25**	**2,315**	**100,00**	**9,08**



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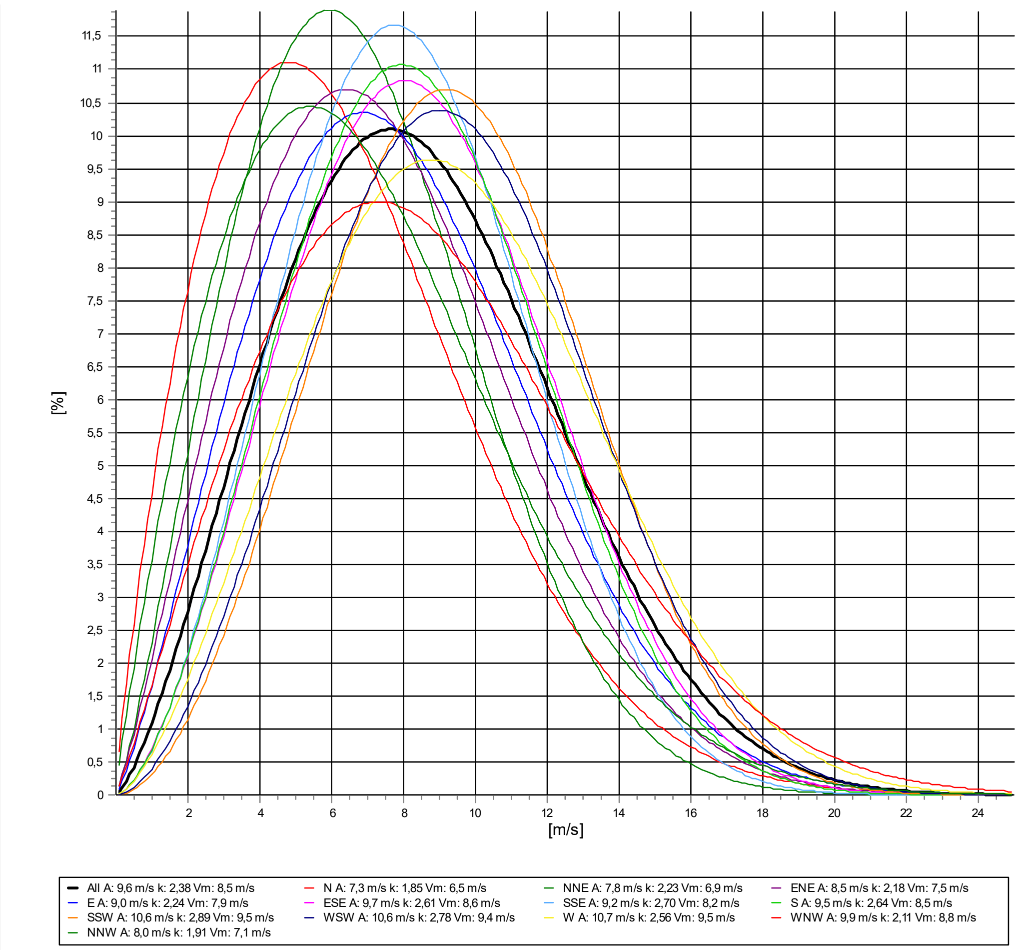
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)
Height: **40,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	7,35	1,845	4,56	6,53
1-NNE	7,77	2,227	4,60	6,88
2-ENE	8,50	2,180	5,24	7,53
3-E	8,96	2,237	6,98	7,94
4-ESE	9,66	2,614	9,47	8,58
5-SSE	9,21	2,702	8,78	8,19
6-S	9,53	2,640	8,00	8,47
7-SSW	10,65	2,893	11,80	9,49
8-WSW	10,60	2,778	13,42	9,44
9-W	10,66	2,555	12,15	9,47
10-WNW	9,90	2,115	9,30	8,77
11-NNW	7,98	1,910	5,69	7,08
Mean	**9,62**	**2,379**	**100,00**	**8,53**



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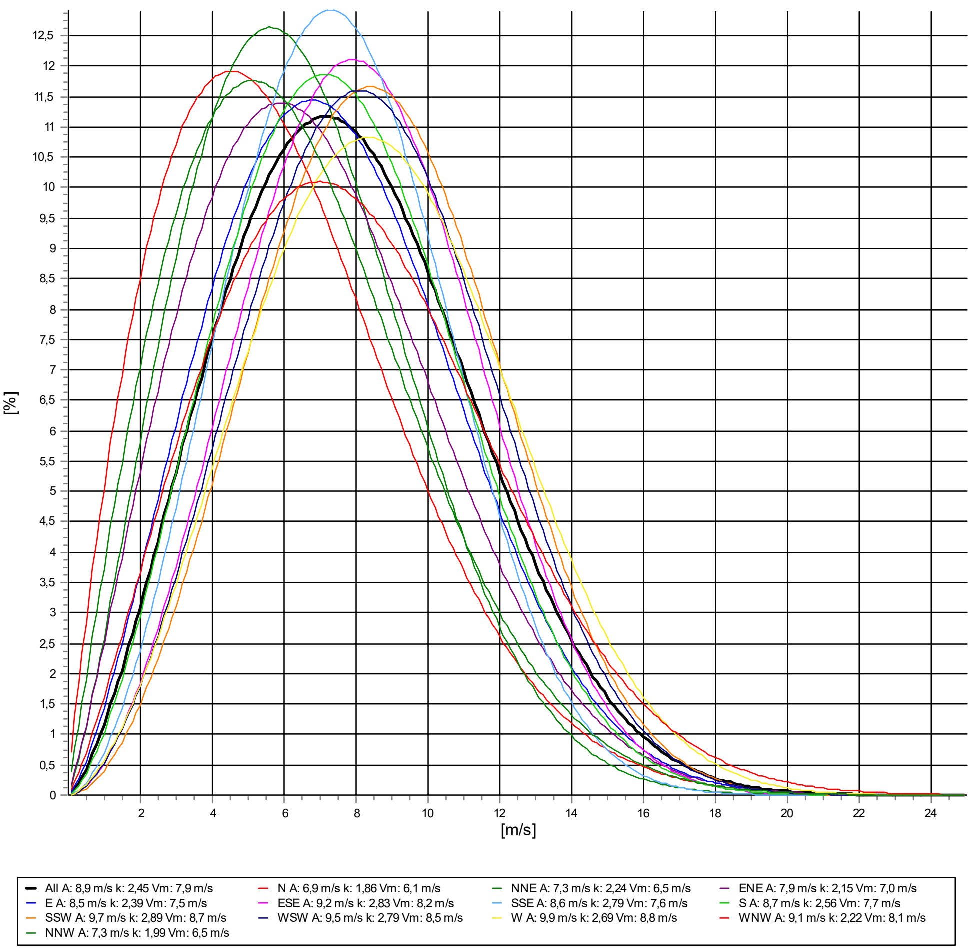
Meteo data report - Weibull data overview

Mast: HS1 LT - all heights; (Phase2) **Period:** Full period: 01/04/1999 - 01/08/2024 (304,0 months)

Height: **12,00m - EMD WFR - [Matrix]**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	6,88	1,857	4,64	6,11
1-NNE	7,33	2,235	4,63	6,50
2-ENE	7,91	2,151	5,31	7,01
3-E	8,51	2,387	7,17	7,55
4-ESE	9,24	2,831	9,56	8,23
5-SSE	8,56	2,794	8,45	7,62
6-S	8,67	2,557	7,99	7,69
7-SSW	9,75	2,885	12,00	8,69
8-WSW	9,52	2,786	13,66	8,47
9-W	9,91	2,692	12,04	8,81
10-WNW	9,14	2,224	9,02	8,10
11-NNW	7,28	1,995	5,54	6,45
Mean	**8,90**	**2,450**	**100,00**	**7,89**



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Meteo data report - Frequency distribution (TAB file data)

Mast: HS-A LT; EMD WFR - [Matrix] HS1; Complete period **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)

Frequency distribution (TAB file data)

150,00m - MCP LT - EMD WFR - [Matrix] HS1 no time shift Scaled Anholt gradient

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,62	7,59	6,81	8,24	8,84	9,55	9,31	9,46	10,43	11,06	10,58	10,05	8,10
0		0,49	607	15	49	34	70	43	77	71	63	45	36	57	47
1	0,50	1,49	2637	164	185	166	180	243	315	262	260	303	205	163	191
2	1,50	2,49	6070	576	451	443	464	516	406	471	766	595	485	396	501
3	2,50	3,49	9386	933	829	685	585	615	629	766	907	834	1013	889	701
4	3,50	4,49	10163	900	841	771	734	770	770	656	859	1035	988	996	843
5	4,50	5,49	12386	1136	657	643	885	1171	1080	901	1092	1209	1220	1316	1076
6	5,50	6,49	13523	778	876	811	975	1247	1170	1176	1203	1433	1584	1291	979
7	6,50	7,49	14614	686	915	934	1143	1338	1169	1125	1260	1753	1786	1495	1010
8	7,50	8,49	14902	630	1035	843	954	1413	1417	1125	1442	1660	1666	1527	1190
9	8,50	9,49	14390	556	607	717	971	1529	1433	1309	1451	1850	1735	1382	850
10	9,50	10,49	15327	638	588	732	895	1590	1391	1012	1607	2205	2468	1426	775
11	10,50	11,49	14403	622	388	632	1072	1376	1148	1074	1548	2065	2038	1538	902
12	11,50	12,49	12560	492	231	440	853	1242	1189	1020	1540	1855	1901	1275	522
13	12,50	13,49	11334	385	196	480	617	1155	866	876	1352	2023	1766	1067	551
14	13,50	14,49	9433	247	110	362	548	875	739	811	1203	1671	1704	969	194
15	14,50	15,49	8033	179	66	334	512	777	664	614	1213	1507	1172	870	125
16	15,50	16,49	6497	147	46	166	271	489	586	488	958	1440	1176	599	131
17	16,50	17,49	5204	158	41	116	162	487	450	423	648	1089	832	632	166
18	17,50	18,49	4111	79	6	99	124	279	241	315	780	1087	604	391	106
19	18,50	19,49	2444	48	8	68	99	160	78	123	312	638	477	359	74
20	19,50	20,49	1913	22	4	28	53	135	75	89	358	492	312	287	58
21	20,50	21,49	1065	7	1	9	22	52	36	59	245	315	161	111	47
22	21,50	22,49	716	4	0	7	12	35	1	45	98	254	164	78	18
23	22,50	23,49	343	4	1	2	6	10	1	20	42	73	95	63	26
24	23,50	24,49	336	7	0	1	2	4	0	16	47	77	96	62	24
25	24,50	25,49	174	0	0	2	2	1	0	10	26	37	42	44	10
26	25,50	26,49	84	0	0	1	1	0	0	7	10	23	14	23	5
27	26,50	27,49	79	0	0	0	0	0	0	2	7	10	17	43	0
28	27,50	28,49	49	0	0	0	0	0	0	2	5	3	18	20	1
29	28,50	29,49	20	0	0	0	0	0	0	0	1	3	6	9	1
30	29,50	30,49	17	0	0	0	0	0	0	0	1	1	10	5	0
31	30,50	31,49	5	0	0	0	0	0	0	0	0	2	2	1	0
32	31,50	32,49	9	0	0	0	0	0	0	0	0	1	7	1	0
33	32,50	33,49	2	0	0	0	0	0	0	0	0	0	1	1	0
34	33,50	34,49	2	0	0	0	0	0	0	0	0	1	0	1	0
35	34,50	35,49	2	0	0	0	0	0	0	0	1	1	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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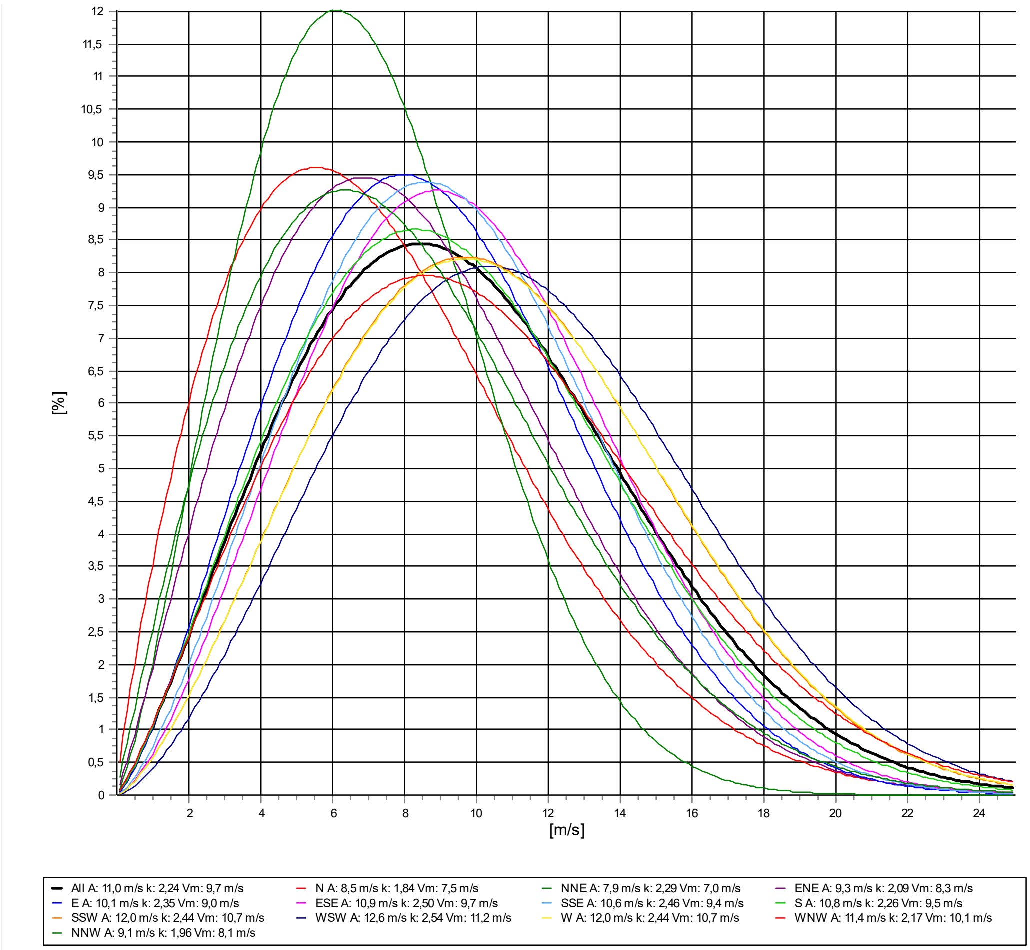
Calculated:
23/09/2024 12.57

Meteo data report - Weibull data overview

Mast: HS-A LT; EMD WFR - [Matrix] HS1; Complete period **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)
Height: **150,00m - MCP LT - EMD WFR - [Matrix] HS1 no time shift Scaled Anholt gradient**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,49	1,842	4,88	7,54
1-NNE	7,86	2,294	4,22	6,96
2-ENE	9,34	2,092	4,94	8,28
3-E	10,12	2,346	6,33	8,97
4-ESE	10,92	2,504	9,10	9,69
5-SSE	10,63	2,461	8,26	9,42
6-S	10,78	2,257	7,71	9,55
7-SSW	12,02	2,441	11,05	10,66
8-WSW	12,63	2,540	14,31	11,21
9-W	12,05	2,437	13,38	10,68
10-WNW	11,42	2,174	10,05	10,11
11-NNW	9,15	1,962	5,77	8,11
Mean	**10,99**	**2,238**	**100,00**	**9,73**



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Meteo data report - Frequency distribution (TAB file data)

Mast: HS-B LT; EMD WFR - [Matrix] HS1; Complete period **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)

Frequency distribution (TAB file data)

150,00m - MCP LT - EMD WFR - [Matrix] HS1 no time shift Scaled Anholt gradient

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,54	7,66	6,82	8,03	8,53	9,31	9,25	9,33	10,60	10,96	10,46	10,11	7,82
0		0,49	615	14	49	36	72	45	77	72	62	45	36	56	51
1	0,50	1,49	2691	164	184	178	198	253	316	266	249	304	215	162	202
2	1,50	2,49	6173	547	448	466	486	542	416	485	741	612	495	390	545
3	2,50	3,49	9555	934	828	732	629	645	632	785	893	843	1033	871	730
4	3,50	4,49	10376	868	842	747	783	836	791	670	854	1052	1026	984	923
5	4,50	5,49	12658	1154	656	707	945	1204	1095	952	1033	1240	1242	1300	1130
6	5,50	6,49	13688	764	870	825	1036	1319	1164	1162	1189	1457	1612	1300	990
7	6,50	7,49	14886	705	923	974	1162	1376	1186	1159	1266	1755	1814	1474	1092
8	7,50	8,49	14906	647	1010	817	993	1489	1435	1160	1320	1675	1669	1525	1166
9	8,50	9,49	14590	511	626	742	940	1611	1453	1312	1500	1910	1822	1369	794
10	9,50	10,49	15557	656	585	744	1052	1558	1371	987	1541	2269	2486	1396	912
11	10,50	11,49	13988	627	391	552	1002	1314	1153	1132	1501	1996	2072	1510	738
12	11,50	12,49	12834	501	227	517	798	1312	1188	984	1567	1932	1868	1326	614
13	12,50	13,49	10856	386	198	426	553	1021	841	868	1370	1983	1830	1045	335
14	13,50	14,49	9481	248	122	373	596	956	752	804	1208	1654	1599	992	177
15	14,50	15,49	7651	180	64	273	391	636	656	584	1187	1513	1175	875	117
16	15,50	16,49	6424	146	43	143	187	490	578	461	1039	1407	1158	610	162
17	16,50	17,49	5066	177	45	103	158	443	422	438	633	1109	763	624	151
18	17,50	18,49	3849	83	5	96	99	186	222	240	798	1023	590	417	90
19	18,50	19,49	2420	47	9	48	74	165	85	128	423	590	438	355	58
20	19,50	20,49	1711	29	4	9	31	80	71	82	317	467	262	307	52
21	20,50	21,49	1097	8	1	9	16	45	26	49	305	304	169	140	25
22	21,50	22,49	713	6	0	5	6	20	0	40	153	238	144	77	24
23	22,50	23,49	346	6	1	1	2	5	1	16	46	75	101	64	28
24	23,50	24,49	272	5	0	1	2	1	0	15	42	61	79	58	8
25	24,50	25,49	168	0	0	2	1	0	0	6	37	36	29	49	8
26	25,50	26,49	87	0	0	0	0	0	0	7	14	20	18	28	0
27	26,50	27,49	68	0	0	0	0	0	0	3	7	8	20	30	0
28	27,50	28,49	59	0	0	0	0	0	0	1	6	4	11	35	2
29	28,50	29,49	19	0	0	0	0	0	0	0	1	3	9	6	0
30	29,50	30,49	16	0	0	0	0	0	0	0	1	0	7	8	0
31	30,50	31,49	10	0	0	0	0	0	0	0	1	3	5	1	0
32	31,50	32,49	4	0	0	0	0	0	0	0	0	0	3	1	0
33	32,50	33,49	2	0	0	0	0	0	0	0	0	0	1	1	0
34	33,50	34,49	2	0	0	0	0	0	0	0	0	2	0	0	0
35	34,50	35,49	2	0	0	0	0	0	0	0	1	0	0	1	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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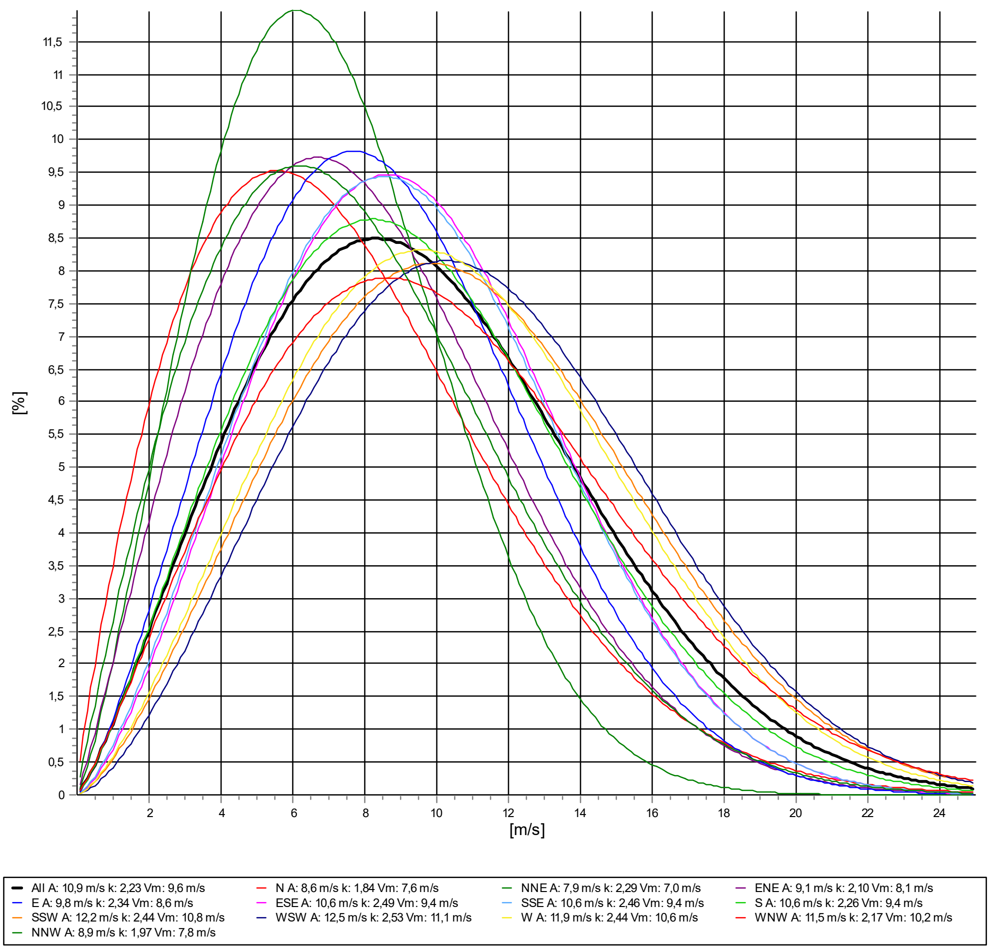
Calculated:
23/09/2024 12.58

Meteo data report - Weibull data overview

Mast: HS-B LT; EMD WFR - [Matrix] HS1; Complete period **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)
Height: **150,00m - MCP LT - EMD WFR - [Matrix] HS1 no time shift Scaled Anholt gradient**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,55	1,839	4,88	7,60
1-NNE	7,87	2,287	4,22	6,98
2-ENE	9,12	2,102	4,94	8,07
3-E	9,76	2,338	6,33	8,64
4-ESE	10,62	2,487	9,10	9,42
5-SSE	10,55	2,456	8,26	9,36
6-S	10,64	2,260	7,71	9,42
7-SSW	12,22	2,441	11,05	10,84
8-WSW	12,52	2,533	14,31	11,11
9-W	11,91	2,439	13,38	10,56
10-WNW	11,50	2,172	10,05	10,19
11-NNW	8,85	1,973	5,77	7,85
Mean	**10,89**	**2,228**	**100,00**	**9,65**



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Calculated:
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Meteo data report - Frequency distribution (TAB file data)

Mast: HS-C LT; EMD WFR - [Matrix] HS1; Complete period **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)

Frequency distribution (TAB file data)

150,00m - MCP LT - EMD WFR - [Matrix] HS1 no time shift Scaled Anholt gradient

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,61	7,48	6,68	8,31	9,00	9,54	9,28	9,52	10,54	11,02	10,62	10,04	7,66
0		0,49	609	15	51	34	69	41	77	71	62	45	36	56	52
1	0,50	1,49	2667	172	193	166	178	246	316	261	252	304	202	167	210
2	1,50	2,49	6128	595	463	430	440	518	410	464	750	602	482	395	579
3	2,50	3,49	9419	936	868	675	559	615	629	757	904	841	1003	892	740
4	3,50	4,49	10321	940	839	770	724	774	782	650	847	1044	980	1003	968
5	4,50	5,49	12388	1126	670	635	838	1166	1096	893	1052	1215	1219	1335	1143
6	5,50	6,49	13550	788	910	791	979	1260	1161	1161	1194	1437	1565	1282	1022
7	6,50	7,49	14793	706	960	943	1070	1341	1183	1120	1272	1758	1772	1502	1166
8	7,50	8,49	14725	597	995	841	995	1418	1413	1122	1363	1664	1679	1526	1112
9	8,50	9,49	14352	594	622	716	968	1515	1451	1293	1485	1876	1694	1353	785
10	9,50	10,49	15465	635	556	729	859	1612	1383	1025	1544	2240	2464	1427	991
11	10,50	11,49	13958	628	353	626	1039	1364	1150	1057	1531	2027	2026	1541	616
12	11,50	12,49	12766	489	222	435	873	1245	1191	1023	1553	1897	1932	1265	641
13	12,50	13,49	11003	349	178	500	666	1147	854	887	1369	1997	1753	1052	251
14	13,50	14,49	9387	226	99	357	534	871	746	811	1201	1681	1722	983	156
15	14,50	15,49	8037	172	53	334	554	776	666	613	1194	1497	1174	870	134
16	15,50	16,49	6656	151	48	186	323	493	573	502	1017	1423	1172	589	179
17	16,50	17,49	5200	149	33	125	172	484	439	422	647	1109	867	642	111
18	17,50	18,49	4073	70	6	95	145	264	224	343	797	1053	598	396	82
19	18,50	19,49	2470	36	6	82	88	163	83	137	379	615	478	344	59
20	19,50	20,49	1943	20	5	31	77	139	73	88	341	482	335	307	45
21	20,50	21,49	1061	6	0	11	33	51	29	62	271	314	153	111	20
22	21,50	22,49	768	3	1	6	17	31	1	44	133	244	178	80	30
23	22,50	23,49	340	9	0	4	6	13	1	25	42	72	94	56	18
24	23,50	24,49	300	1	0	1	2	4	0	14	40	73	98	58	9
25	24,50	25,49	196	0	0	2	3	1	0	12	36	39	49	51	3
26	25,50	26,49	78	0	0	1	0	0	0	5	14	21	13	24	0
27	26,50	27,49	79	0	0	0	1	0	0	3	5	8	17	43	2
28	27,50	28,49	51	0	0	0	0	0	0	3	6	3	20	19	0
29	28,50	29,49	17	0	0	0	0	0	0	0	1	3	6	7	0
30	29,50	30,49	19	0	0	0	0	0	0	0	1	1	10	7	0
31	30,50	31,49	5	0	0	0	0	0	0	0	1	2	1	1	0
32	31,50	32,49	10	0	0	0	0	0	0	0	0	1	8	1	0
33	32,50	33,49	2	0	0	0	0	0	0	0	0	0	1	1	0
34	33,50	34,49	2	0	0	0	0	0	0	0	0	1	0	1	0
35	34,50	35,49	2	0	0	0	0	0	0	0	1	1	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
Hesselø South (23406)

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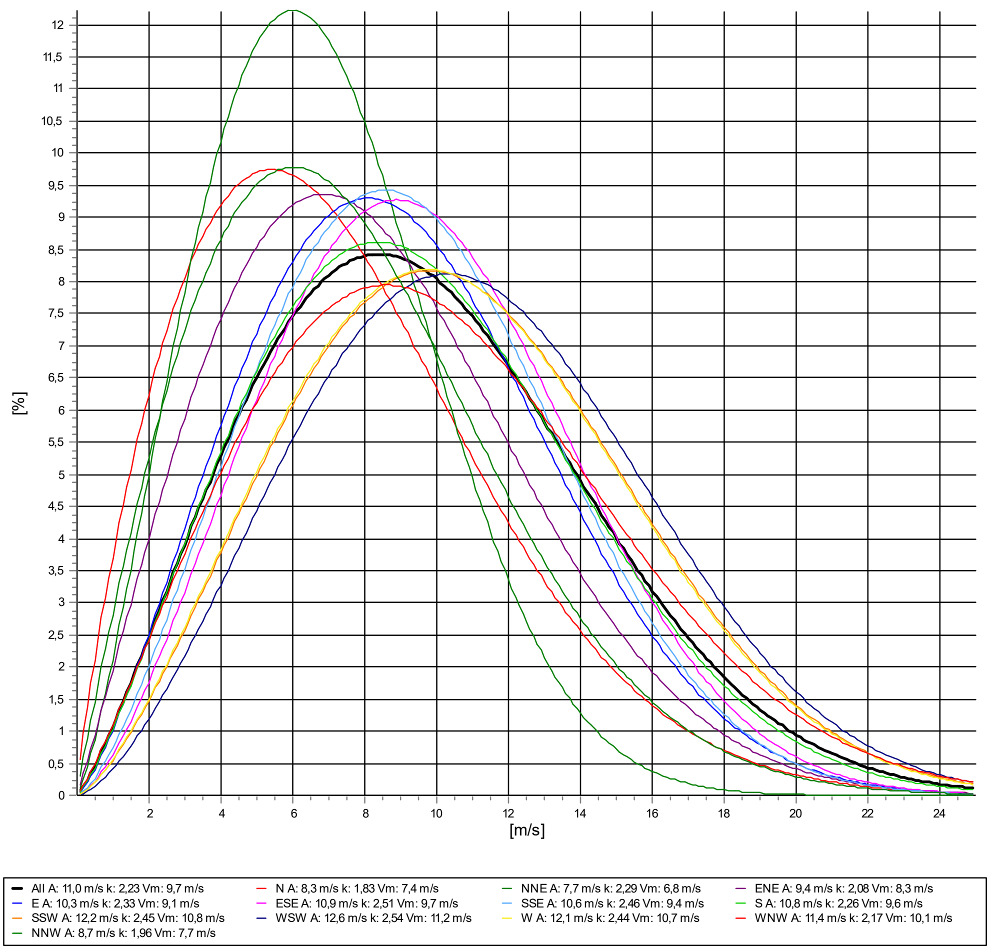
Calculated:
23/09/2024 13.00

Meteo data report - Weibull data overview

Mast: HS-C LT; EMD WFR - [Matrix] HS1; Complete period **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)
Height: **150,00m - MCP LT - EMD WFR - [Matrix] HS1 no time shift Scaled Anholt gradient**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,34	1,831	4,88	7,41
1-NNE	7,72	2,289	4,22	6,84
2-ENE	9,41	2,081	4,94	8,33
3-E	10,29	2,334	6,33	9,12
4-ESE	10,91	2,506	9,10	9,68
5-SSE	10,59	2,462	8,26	9,39
6-S	10,84	2,260	7,71	9,60
7-SSW	12,15	2,447	11,05	10,78
8-WSW	12,58	2,538	14,31	11,17
9-W	12,10	2,440	13,38	10,73
10-WNW	11,42	2,172	10,05	10,12
11-NNW	8,66	1,961	5,77	7,67
Mean	**10,98**	**2,229**	**100,00**	**9,72**



Appendix E. Secondary models KG-1-LB, H1, M1

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Meteo data report - Frequency distribution (TAB file data)

Mast: Secondary model KG-1 transferred to HS-1 **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)

Frequency distribution (TAB file data)

150,00m -

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,48	7,35	6,56	7,76	8,75	9,79	9,04	9,11	10,37	11,21	10,52	9,34	7,61
0		0,49	598	1	11	20	35	23	37	60	155	93	69	84	10
1	0,50	1,49	2644	133	161	186	162	155	294	329	367	198	246	269	144
2	1,50	2,49	6164	464	509	669	533	358	678	764	588	280	369	548	404
3	2,50	3,49	8686	670	588	772	675	601	750	914	872	671	706	830	637
4	3,50	4,49	10779	878	1025	879	727	889	843	786	985	870	1068	906	923
5	4,50	5,49	13083	1137	889	1151	1017	824	1100	981	1124	1101	1496	1320	943
6	5,50	6,49	13581	784	850	1041	1177	1017	932	896	1367	1266	1831	1432	988
7	6,50	7,49	15425	929	980	850	1291	1284	1202	913	1700	1640	1754	1651	1231
8	7,50	8,49	15912	812	943	754	1091	1476	1242	839	1703	2070	2171	1838	973
9	8,50	9,49	14729	584	658	802	1090	1340	1241	889	1528	2180	2316	1411	690
10	9,50	10,49	14231	595	233	855	1011	1257	1232	1048	1371	2204	2378	1297	750
11	10,50	11,49	13995	482	318	739	742	1209	1157	931	1544	2291	2588	1502	492
12	11,50	12,49	12817	480	197	544	766	1207	1082	870	1390	2318	2219	1191	553
13	12,50	13,49	11783	303	145	442	688	1253	1104	898	1456	2269	1922	1060	243
14	13,50	14,49	9546	160	117	462	708	865	711	651	1241	1972	1739	782	138
15	14,50	15,49	7632	120	63	226	397	725	526	542	1437	1593	1353	566	84
16	15,50	16,49	6564	88	31	139	317	586	529	466	1126	1566	1121	464	131
17	16,50	17,49	4792	50	17	111	228	451	287	335	896	1246	723	356	92
18	17,50	18,49	3423	56	16	61	198	342	204	276	591	783	564	290	42
19	18,50	19,49	2156	32	8	36	99	154	113	130	346	458	481	261	38
20	19,50	20,49	1403	12	5	11	29	115	41	109	292	296	295	145	53
21	20,50	21,49	938	7	3	8	12	34	18	63	125	279	225	140	24
22	21,50	22,49	603	2	1	2	12	8	10	46	132	155	149	70	16
23	22,50	23,49	526	6	0	0	13	8	3	37	111	170	125	49	4
24	23,50	24,49	330	0	0	1	4	4	1	14	78	95	89	34	10
25	24,50	25,49	136	0	0	0	2	0	0	6	28	40	31	21	8
26	25,50	26,49	95	0	0	0	1	0	0	3	16	28	23	24	0
27	26,50	27,49	46	0	0	0	0	0	0	1	3	12	14	14	2
28	27,50	28,49	26	0	0	0	0	0	0	1	4	3	10	8	0
29	28,50	29,49	20	0	0	0	0	0	0	1	4	2	7	6	0
30	29,50	30,49	9	0	0	0	0	0	0	0	1	2	5	1	0
31	30,50	31,49	4	0	0	0	0	0	0	0	1	0	2	1	0
32	31,50	32,49	5	0	0	0	0	0	0	0	1	2	2	0	0
33	32,50	33,49	1	0	0	0	0	0	0	0	1	0	0	0	0
34	33,50	34,49	0	0	0	0	0	0	0	0	0	0	0	0	0
35	34,50	35,49	0	0	0	0	0	0	0	0	0	0	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	2	0	0	0	0	0	0	0	1	1	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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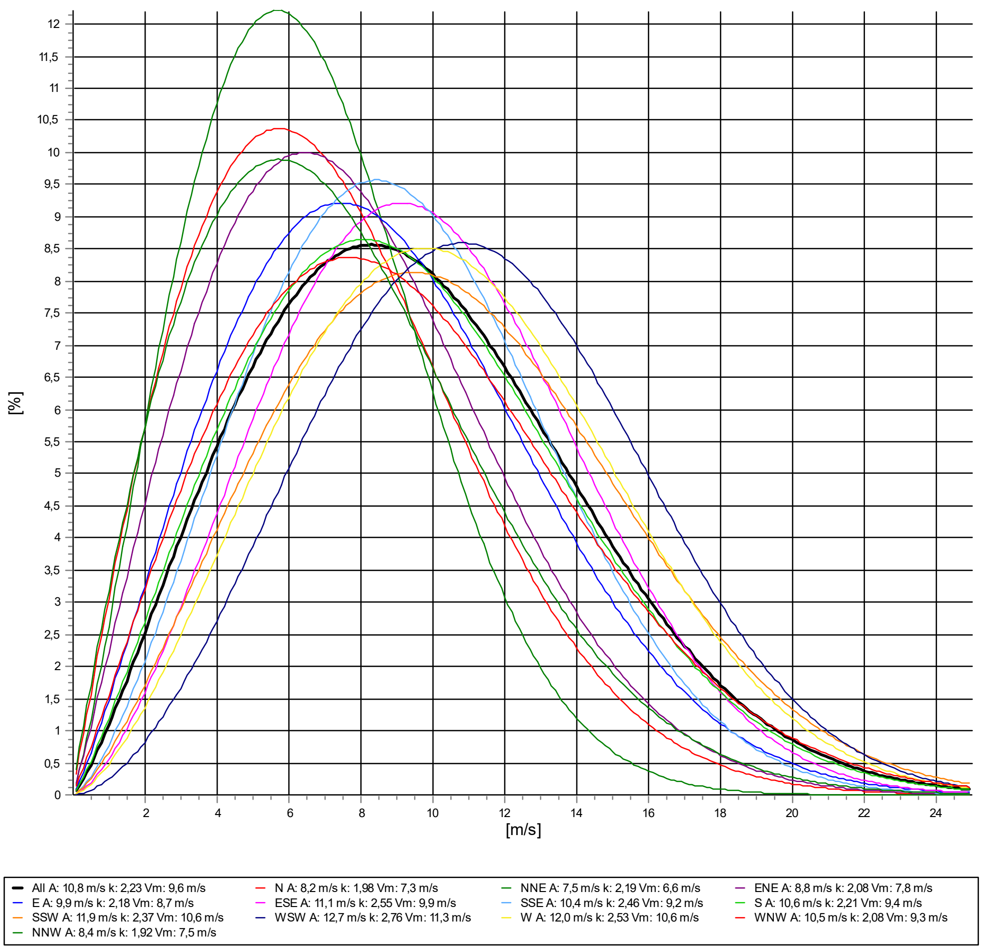
Calculated:
23/09/2024 13.06

Meteo data report - Weibull data overview

Mast: Secondary model KG-1 transferred to HS-1 **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)
Height: **150,00m -**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,20	1,975	4,56	7,27
1-NNE	7,49	2,194	4,03	6,63
2-ENE	8,82	2,085	5,58	7,81
3-E	9,88	2,181	6,76	8,75
4-ESE	11,12	2,546	8,40	9,87
5-SSE	10,43	2,463	7,96	9,25
6-S	10,63	2,211	7,16	9,41
7-SSW	11,92	2,372	11,72	10,56
8-WSW	12,74	2,760	14,61	11,34
9-W	11,96	2,526	14,58	10,62
10-WNW	10,52	2,080	9,64	9,32
11-NNW	8,44	1,916	4,99	7,48
Mean	**10,82**	**2,235**	**100,00**	**9,58**



Project:
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Calculated:
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Meteo data report - Frequency distribution (TAB file data)

Mast: Secondary model H1 transferred to HS-1 **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)

Frequency distribution (TAB file data)

150,00m -

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,70	7,47	7,43	7,85	9,38	9,76	9,42	9,52	11,07	10,95	10,55	9,72	7,99
0		0,49	593	76	66	88	88	9	11	67	63	25	20	40	40
1	0,50	1,49	2754	380	166	364	259	150	206	150	147	233	223	217	259
2	1,50	2,49	5657	525	324	479	451	372	420	327	436	636	531	603	553
3	2,50	3,49	8984	715	825	554	444	592	542	591	841	1251	979	1046	604
4	3,50	4,49	11674	854	1054	630	580	683	822	918	1101	1615	1278	1243	896
5	4,50	5,49	12662	1020	844	837	735	1179	950	1161	955	1279	1468	1172	1062
6	5,50	6,49	12530	946	729	842	1008	1402	758	1055	832	1226	1411	1296	1025
7	6,50	7,49	13436	904	701	813	914	1193	1083	1023	930	1307	1893	1639	1036
8	7,50	8,49	14322	796	661	571	944	1129	1526	1066	1411	1559	2075	1587	997
9	8,50	9,49	15312	734	592	476	1070	1269	1497	1226	1413	1911	2532	1646	946
10	9,50	10,49	13805	667	441	545	900	1405	1271	1013	1224	1802	2314	1337	886
11	10,50	11,49	13258	612	598	677	740	1290	1232	1022	1336	1935	2055	1074	687
12	11,50	12,49	13558	463	485	851	907	1347	1230	1205	1375	2096	1969	1109	521
13	12,50	13,49	11816	325	357	426	723	1140	997	993	1487	2090	1926	945	407
14	13,50	14,49	9539	188	256	260	375	1019	900	709	1203	1700	1755	942	232
15	14,50	15,49	8558	144	164	187	645	904	514	439	1357	1749	1439	825	191
16	15,50	16,49	7120	179	121	112	551	791	397	499	1030	1344	1156	743	197
17	16,50	17,49	4971	92	51	126	374	438	269	312	819	1140	696	513	141
18	17,50	18,49	4373	84	41	61	193	240	290	345	915	976	605	523	100
19	18,50	19,49	2991	56	12	26	120	101	78	190	665	810	539	329	65
20	19,50	20,49	1724	26	9	6	60	47	35	74	289	469	454	208	47
21	20,50	21,49	941	17	3	4	30	18	19	72	172	248	200	111	47
22	21,50	22,49	913	7	6	3	10	11	13	56	252	223	197	106	29
23	22,50	23,49	433	7	0	3	8	3	5	18	60	111	123	80	15
24	23,50	24,49	276	4	0	0	3	2	0	9	38	75	81	54	10
25	24,50	25,49	169	1	0	3	1	0	0	6	19	44	52	35	8
26	25,50	26,49	100	2	0	0	4	0	0	5	11	17	32	29	0
27	26,50	27,49	50	2	0	0	2	0	0	1	2	5	24	11	3
28	27,50	28,49	40	0	0	0	0	0	0	0	5	9	15	11	0
29	28,50	29,49	28	1	0	0	1	0	0	0	0	6	8	12	0
30	29,50	30,49	16	0	0	0	0	0	0	0	1	2	10	3	0
31	30,50	31,49	8	0	0	0	0	0	0	0	0	0	3	5	0
32	31,50	32,49	7	0	0	0	0	0	0	0	0	0	6	1	0
33	32,50	33,49	2	0	0	0	0	0	0	0	0	0	1	1	0
34	33,50	34,49	3	0	0	0	1	0	0	0	0	0	1	1	0
35	34,50	35,49	2	0	0	0	0	0	0	0	1	1	0	0	0
36	35,50	36,49	1	0	0	0	0	0	0	0	0	1	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	0	0	0	0	0	0	0	0	0	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

Project:
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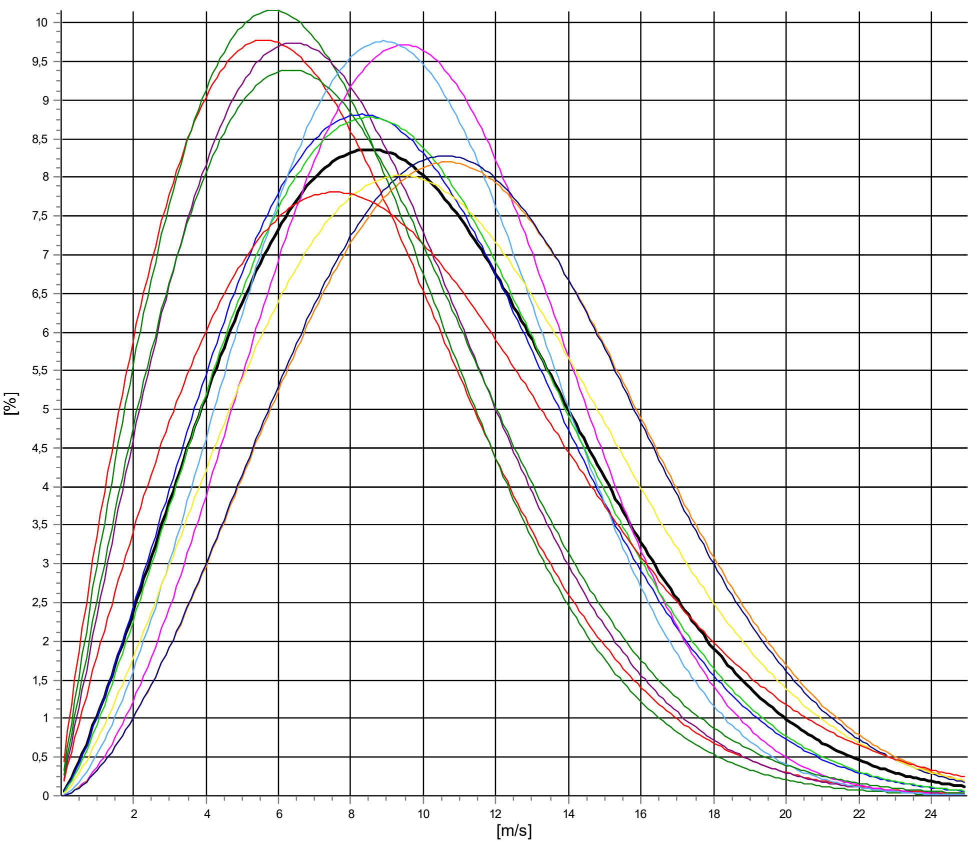
Meteo data report - Weibull data overview

Mast: Secondary model H1 transferred to HS-1 **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)
Height: **150,00m -**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,44	1,878	5,10	7,49
1-NNE	8,36	1,968	4,42	7,41
2-ENE	8,92	2,040	4,64	7,90
3-E	10,68	2,283	6,30	9,46
4-ESE	11,18	2,734	8,69	9,95
5-SSE	10,71	2,611	7,82	9,52
6-S	10,85	2,317	7,55	9,61
7-SSW	12,79	2,619	10,59	11,36
8-WSW	12,71	2,630	14,48	11,29
9-W	11,93	2,333	14,57	10,57
10-WNW	10,85	1,964	10,12	9,62
11-NNW	9,06	1,974	5,71	8,03
Mean	**11,08**	**2,236**	**100,00**	**9,82**



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Meteo data report - Frequency distribution (TAB file data)

Mast: Secondary model M1 to HS-1 **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)

Frequency distribution (TAB file data)

150,00m - B Sheared

Bin	Start	End	Sum	0-N	1-NNE	2-ENE	3-E	4-ESE	5-SSE	6-S	7-SSW	8-WSW	9-W	10-WNW	11-NNW
Mean			9,61	7,88	7,41	7,80	8,89	9,65	8,93	8,98	10,77	10,77	10,26	10,08	8,58
0		0,49	654	0	0	0	0	0	112	237	178	116	11	0	0
1	0,50	1,49	1818	35	32	62	1	27	331	346	317	242	238	144	43
2	1,50	2,49	4061	211	195	264	193	279	491	528	496	416	423	353	212
3	2,50	3,49	7001	410	506	453	454	620	714	733	605	644	774	665	423
4	3,50	4,49	10019	717	748	655	700	879	824	839	899	1009	1141	1034	574
5	4,50	5,49	12282	785	838	810	1053	1043	990	983	1068	1279	1408	1347	678
6	5,50	6,49	14226	1042	807	852	1110	1325	1056	1108	1253	1440	1846	1471	916
7	6,50	7,49	15596	1163	748	760	1214	1599	1267	1239	1310	1454	2210	1630	1002
8	7,50	8,49	16340	1064	737	800	1252	1758	1480	1266	1277	1570	2443	1776	917
9	8,50	9,49	16836	925	783	876	1344	1728	1379	1226	1360	1712	2796	1825	882
10	9,50	10,49	16541	751	572	781	1195	1723	1318	1294	1454	1916	2966	1795	776
11	10,50	11,49	15480	510	516	663	1088	1680	1219	1157	1562	1998	2854	1623	610
12	11,50	12,49	13642	340	331	526	870	1572	983	957	1567	1977	2660	1462	397
13	12,50	13,49	11557	227	169	264	759	1282	796	865	1477	1903	2212	1259	344
14	13,50	14,49	9965	155	119	153	599	998	758	734	1508	1726	1839	1119	257
15	14,50	15,49	7768	152	75	83	341	690	505	569	1349	1482	1406	933	183
16	15,50	16,49	6025	111	29	60	209	542	350	383	1169	1211	1014	794	153
17	16,50	17,49	4336	72	18	13	121	371	256	333	893	882	697	568	112
18	17,50	18,49	3058	47	9	6	53	221	171	178	682	612	522	454	103
19	18,50	19,49	1964	24	5	9	33	121	122	128	421	414	325	311	51
20	19,50	20,49	1201	11	7	5	15	79	59	94	272	222	194	196	47
21	20,50	21,49	800	4	1	3	10	41	37	64	180	132	167	133	28
22	21,50	22,49	539	2	1	2	1	13	24	28	138	112	110	87	21
23	22,50	23,49	351	2	0	2	1	5	15	17	52	125	52	63	17
24	23,50	24,49	242	1	1	1	0	1	5	10	46	81	37	43	16
25	24,50	25,49	134	0	0	0	0	1	1	7	32	39	28	23	3
26	25,50	26,49	88	2	0	0	0	0	0	5	13	29	23	13	3
27	26,50	27,49	52	0	0	0	0	0	0	1	7	19	10	15	0
28	27,50	28,49	40	1	0	0	0	0	0	2	9	15	7	6	0
29	28,50	29,49	25	0	0	0	0	0	0	1	4	11	5	4	0
30	29,50	30,49	19	0	0	0	0	0	0	0	2	3	6	8	0
31	30,50	31,49	9	0	0	0	0	0	0	0	3	2	1	3	0
32	31,50	32,49	2	0	0	0	0	0	0	0	0	0	1	1	0
33	32,50	33,49	4	0	0	0	0	0	0	0	0	2	1	1	0
34	33,50	34,49	2	0	0	0	0	0	0	0	0	1	1	0	0
35	34,50	35,49	1	0	0	0	0	0	0	0	0	1	0	0	0
36	35,50	36,49	0	0	0	0	0	0	0	0	0	0	0	0	0
37	36,50	37,49	0	0	0	0	0	0	0	0	0	0	0	0	0
38	37,50	38,49	1	0	0	0	0	0	0	0	1	0	0	0	0
39	38,50	39,49	0	0	0	0	0	0	0	0	0	0	0	0	0
40	39,50	40,49	0	0	0	0	0	0	0	0	0	0	0	0	0
41	40,50		0	0	0	0	0	0	0	0	0	0	0	0	0

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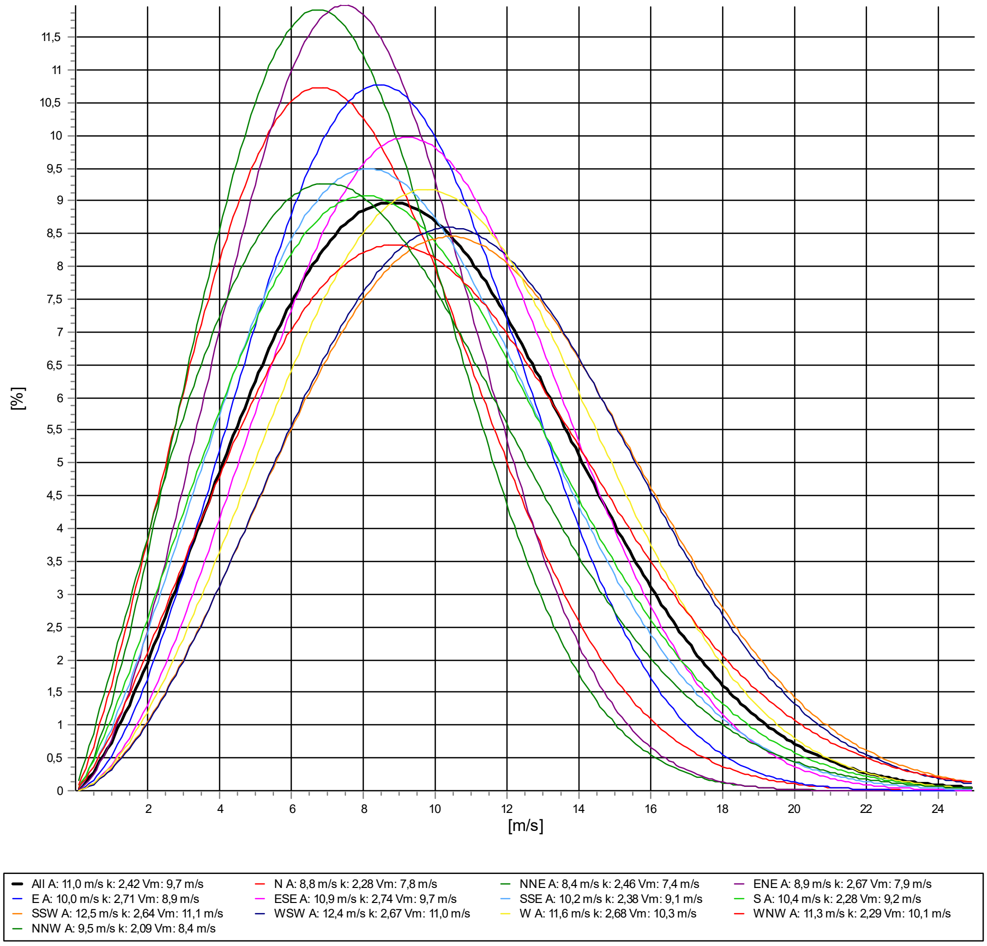
Meteo data report - Weibull data overview

Mast: Secondary model M1 to HS-1 **Period:** Full period: 01/01/2002 - 31/12/2023 (264,0 months)
Height: **150,00m - B Sheared**

Weibull data

Sector	A [m/s]	k	f	Mean wind speed [m/s]
0-N	8,76	2,279	4,55	7,76
1-NNE	8,35	2,455	3,76	7,41
2-ENE	8,90	2,673	4,21	7,91
3-E	10,01	2,711	6,55	8,91
4-ESE	10,90	2,736	9,65	9,70
5-SSE	10,23	2,378	7,92	9,07
6-S	10,37	2,284	7,96	9,19
7-SSW	12,48	2,640	11,21	11,09
8-WSW	12,39	2,669	12,87	11,01
9-W	11,63	2,675	15,79	10,34
10-WNW	11,35	2,293	10,98	10,05
11-NNW	9,53	2,091	4,55	8,44
Mean	**10,96**	**2,417**	**100,00**	**9,71**



Appendix F. Normal Turbulence Model (150 m)

Wind speed [m/s]	Turbulence intensity mean value (TI_{μ}) [%]	Turbulence intensity standard deviation (TI_{σ}) [%]	Turbulence intensity 90% quantile [%]
3	10.8	6.6	19.2
4	8.2	5.1	14.8
5	6.8	4.3	12.3
6	5.9	3.7	10.7
7	5.4	3.3	9.6
8	5.0	3.0	8.9
9	4.8	2.8	8.3
10	4.7	2.6	8.0
11	4.7	2.4	7.8
12	4.7	2.3	7.6
13	4.7	2.2	7.5
14	4.8	2.1	7.5
15	4.9	2.0	7.5
16	5.1	1.9	7.5
17	5.2	1.9	7.6
18	5.4	1.8	7.7
19	5.5	1.8	7.8
20	5.7	1.7	7.9
21	5.9	1.7	8.1
22	6.1	1.6	8.2
23	6.3	1.6	8.4
24	6.5	1.6	8.5
25	6.8	1.5	8.7

Wind speed [m/s]	TURBULENCE MEAN VALUE (σ_μ) [M/S]	TURBULENCE STANDARD DEVIATION (σ_σ) [M/S]	Turbulence 90% QUANTILE [m/s]
3	0.32	0.20	0.58
4	0.33	0.21	0.59
5	0.34	0.21	0.61
6	0.35	0.22	0.64
7	0.38	0.23	0.67
8	0.40	0.24	0.71
9	0.43	0.25	0.75
10	0.47	0.26	0.80
11	0.51	0.27	0.85
12	0.56	0.27	0.91
13	0.62	0.28	0.98
14	0.67	0.29	1.05
15	0.74	0.30	1.12
16	0.81	0.31	1.20
17	0.89	0.32	1.29
18	0.97	0.33	1.38
19	1.05	0.33	1.48
20	1.15	0.34	1.58
21	1.24	0.35	1.69
22	1.35	0.36	1.81
23	1.45	0.37	1.93
24	1.57	0.38	2.05
25	1.69	0.39	2.18