CRC 1463
Offshore-
Megastructures

DFG

Offshore Megastructures Design Basis

CRC 1463 - Integrated design and operation methodology for offshore megastructures

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This document is based on the Project "UpWind" design basis (Fischer et al. 2010). Quotations from the UpWind Design Basis are not marked explicitly.

(Hersbach et al. 2018) was downloaded from the Copernicus Climate Change Service (C3S) Climate Data Store. The results contain modified Copernicus Climate Change Service information 2020. Neither the European Commission nor ECMWF is responsible for any use that may be made of the Copernicus information or data it contains.

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Status				Confidentiality		
S0	Approved/Released	**X**		**R0**	General public	**X**
S1	Reviewed			**R1**	Restricted to project members	
S2	Pending for review					
S3	Draft for comments					
S4	Under preparation					

Table of Contents

1. General remarks and definitions

The following design basis should document the design envelope and environmental conditions in the project “offshore megastructures”. In this project, methodologies for an integrated design and operation of very large offshore wind turbines are investigated, accompanied with the development and use of a digital twin. Thus, this project does not aim on developing a turbine ready for certification but rather emphasises on challenges and specific demands in the multidisciplinary design of future offshore wind turbines. This document will summarize major key assumptions for the megastructure itself as well as for its environmental conditions.

The relevant design parameters and methods within this design basis are taken from the DNVGL-ST-0437 standard (edition November 2016) “Loads and site conditions for wind turbines” (DNVGL-ST-0437). Further standards are quoted when used.

The physical form of the wind turbine is documented in the windIO documentation scheme (Bortolotti 2020). This wind turbine ontology scheme was developed by the IEA wind task 37 with the objective of generalizing the way of documentation and simplifying data transfer within researcher groups.

1.1. Coordinate Systems

Figure 1 shows a wind turbine including all coordinate systems (COS) that are necessary to describe its current position. In the following, they are explained in more detail. The global COS is used to describe the positions of the bodies. Note that the local COS move with the structures to which they belong. They intend to describe the body geometry and deformations. The following description of the local COS are initial systems in the non-deformed state. All used COS are right-handed, orthonormal systems.

- **Global coordinate system** (see Figure 1)
  Origin: The global COS is located at the mean water level (MWL). The water levels are depicted in Figure 6.
    - The x_{global}-axis points in nominal 0° downwind direction
    - The y_{global}-axis points perpendicular to the nominal 0° downwind direction
    - The z_{global}-axis points in vertical direction

- **Local COS foundation** (see Figure 1)
  Origin: The local COS of the wind turbine foundation (here jacket) is located in the centre of the substructures cross-section at the level of the mudline. It translates and rotates with the structure. Without deflection, this local COS is aligned with the global COS:
    - the x_f-axis points in nominal 0° downwind direction
    - the y_f-axis points perpendicular to the nominal 0° downwind direction
    - the z_f-axis points in length direction of the foundation structure

- **Local COS tower** (see Figure 1)
  Origin: The local COS of the wind turbine tower is located in the centre of its cross-section. It is further located in the intersection between platform and tower at tower bottom. The local COS translates and rotates with the tower. Without deflection, this local COS is aligned with the global COS:
    - the x_t-axis points in nominal 0° downwind direction
    - the y_t-axis points perpendicular to the nominal 0° downwind direction
    - the z_t-axis points in length direction of the tower

- **Local COS nacelle** (see Figure 1)
  Origin: The local COS of the nacelle is located at its centre of gravity. It rotates with the yaw and tilt angle of the nacelle and translates with the nacelle. The yaw-angle is a rotation around the local z-axis, the tilt-angle is a rotation around the local y-axis. For a zero tilt and yaw angle and without deflection, this local COS is aligned with the global COS. The local COS nacelle is defined as:
  - the x_n-axis points in tilted shaft direction toward the downwind end of the nacelle
  - the y_n-axis points horizontally and perpendicular to the x_n-axis
  - the z_n-axis points perpendicular to the x_n-axis and y_n-axis

- **Local COS hub** (see Figure 1)
  Origin: The local COS of the hub is located at its centre of gravity. It rotates and translates with the hub. In operation, the hub and its local COS rotates around the x_h-axis. For zero azimuth angle the local COS hub is aligned with the local COS nacelle:
  - the x_h-axis points in x_n-axis direction
  - the y_h-axis points perpendicular x_h-axis and z_h-axis
  - the z_h-axis points parallel to z_n-axis for zero azimuth angle

- **COS blades** (see Figure 2)
  Origin: All blades feature a separate local coordinate system. These are located in the connection point to the hub. The origin lies in the centre of the blade cross-section. The local COS rotates and translates with the blade. Therefore, the coordinate system rotates when the blade pitches.
  - the x_b-axis points in thickness-direction towards the upper lifting surface
  - the y_b-axis points in chord-direction
  - the z_b-axis is perpendicular to the surface spanned by the x_b and y_b-axes. For a straight blade the axis points in span direction

- **Director triad (finite element nodal coordinate systems) for blades** (see Figure 2)
  Origin: For the finite element model, the cross-sections of a blade are described at discrete points. For this purpose, further COS, i.e. director triads are used. The origin of each director triad is located at the reference axis (see Figure 2, top). The reference axis might be defined in different ways (e.g., centre of mass, elastic centre, shear centre). The director triad at finite element nodes is twisted with the blade's geometry. The directors rotate and translate with the blade.
  - the d_1-axis points in thickness-direction towards the upper lifting surface
  - the d_2-axis points in chord-direction towards the trailing edge
  - the d_3-axis is perpendicular to the surface spanned by the d_1 and d_2-axis.

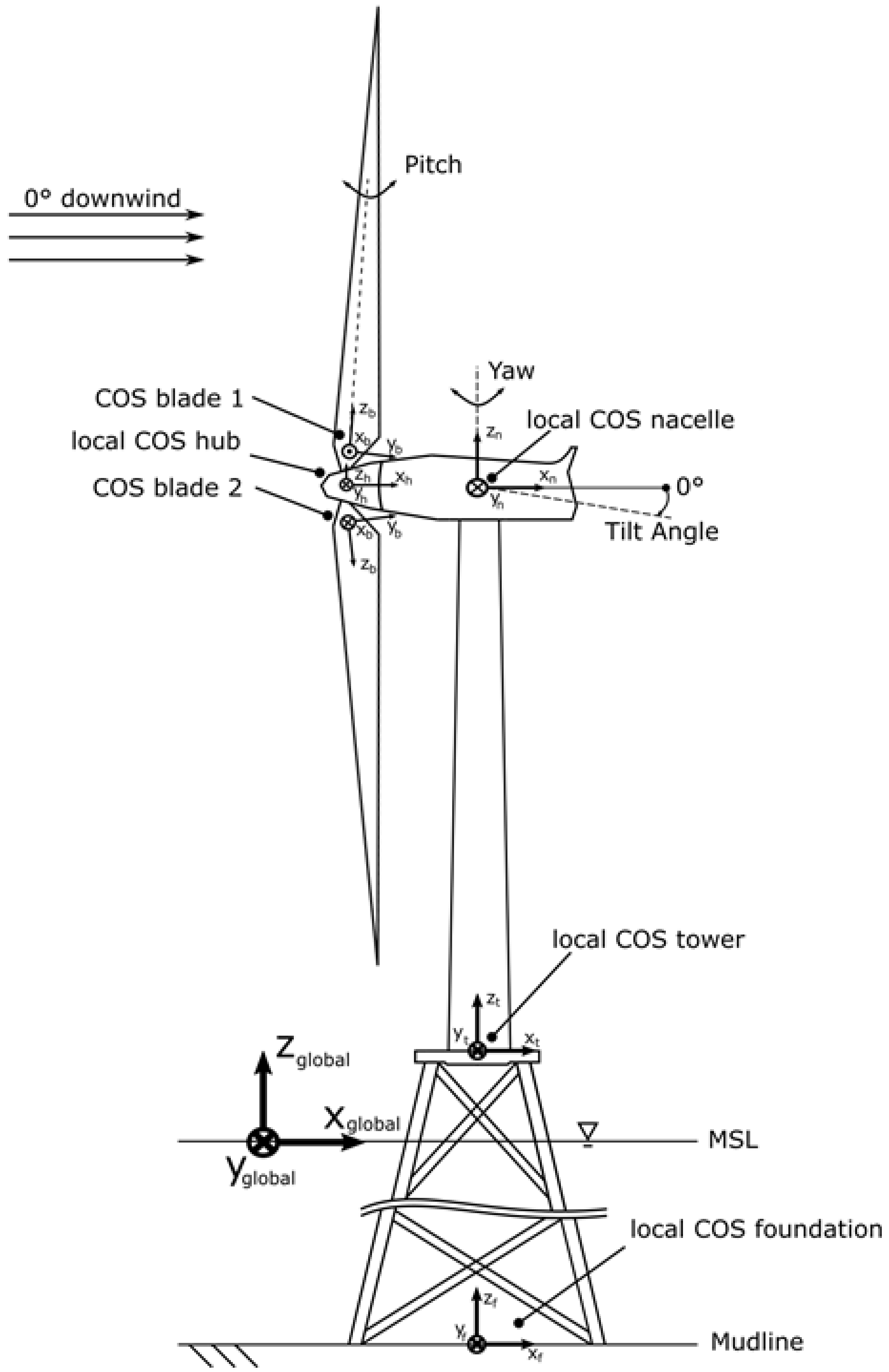


Figure 1: Wind turbine with global and local COS for zero yaw-, tilt- and pitch-angle

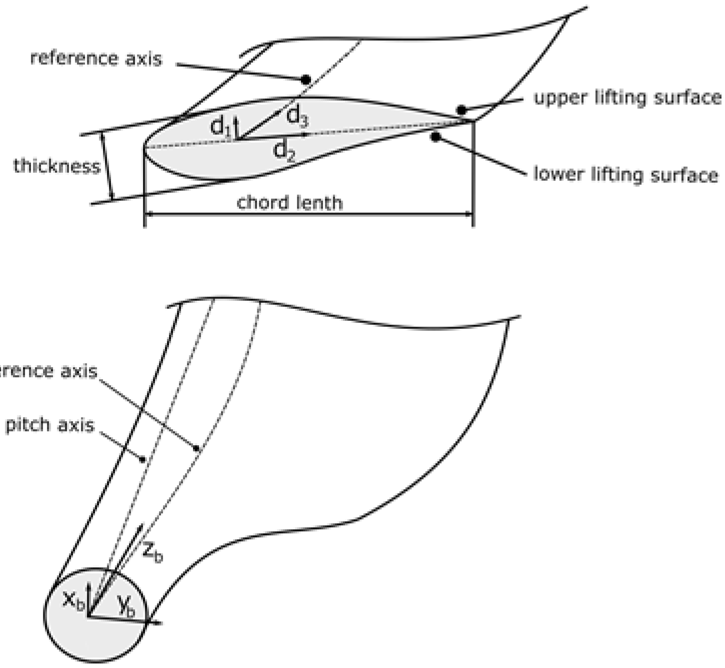


Figure 2: Bottom: COS of the blade, Top: local COS of the blade at a discrete node of the finite element model

2. Reference site

The following design is based on a location in the German North Sea, where currently no wind farm is located. The site will be denoted as “reference site” in the following. The coordinates of the reference site are 55°15’00’’ N, 4°45’00’’ E (as shown in Figure 3) and the water depth is approximately 48.2 m MSL. The site is located within the German Exclusive Economic Zone (EEZ) and categorized as a reservation area for wind energy in the Maritime Spatial Plan (Bundesamt für Seeschifffahrt und Hydrographie 2021).

Environmental conditions are mainly based on reanalysis data from the data sets ERA-5 (Hersbach et al. 2018), Coast-Dat 2 (Gaslikova and Weisse 2013), and the New European Wind Atlas (NEWA Consortium 2019), supported by field measurements from the field measurement station FINO-1, which is located in approximately 175 km southeast of the chosen location. Temporal coverages differ for the individual data sets and their respective sub-modules (atmospheric, waves, currents). A comprehensive overview of temporal and spatial resolutions with indications, which environmental parameters have been chosen from which dataset, has been added in Appendix A.

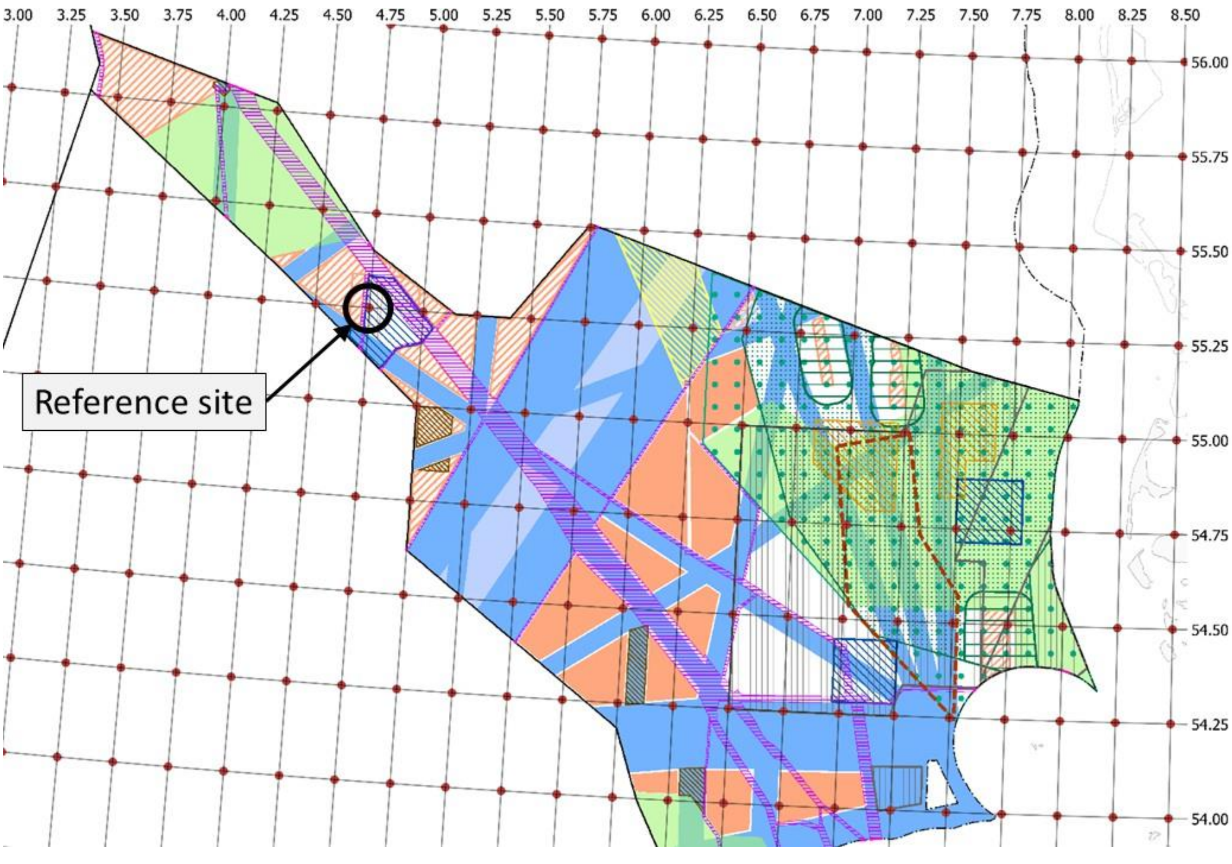


Figure 3: Location of the chosen reference site within the Maritime Spatial Plan of the German North Sea (Bundesamt für Seeschifffahrt und Hydrographie 2021)

3. Turbine design considerations

In the scope of the offshore megastructures project, a digital twin of a 25 MW wind turbine will be set up. This turbine model will be documented in the windIO ontology scheme in a separated YAML-file.

3.1 Tower and sub-structure design considerations

To design a jacket structure for the initial digital twin, certain design considerations should be followed:

- The jacket will be designed as a 3-legged jacket with pile foundation
- A standard scour protection will be foreseen
- The transition piece should not be affected by any wave loads. Therefore, the following information should be considered when defining the lower end of the transition piece:
    - Maximum wave height (see Section 4.5)
    - Maximum sea levels (see Section 4.3)
    - Sea level rise, settlement, air gap and installation tolerance (appropriate assumptions should be made)
- The height of the transition piece is defined by the designer. The tower base is expected to be at the height of the lower blade tip position. The height of the transition piece is expected to be large enough to provide sufficient clearance from the blade tip to the operating platform of the transition piece.

3.2 System masses

Initial system masses (masses of the rotor nacelle assembly, generator, bearings, drive train, hub etc.) were derived by scaling the masses from the IEA 15 MW reference turbine with the cubic scaling law. As this approach is rather conservative and further advances in technology will be expected by the time that 25 MW turbines will be installed. Therefore, all system masses are reduced by the fraction given in the so-called technology factor. The blades are optimized on a high-fidelity level. In this case, mass savings are achieved by a coupled aero-elastic optimization as described in (Werthen et al. 2023) and the technology factor is not applied to the blade materials.

Technology factor: 15 %

4. Environmental conditions

4.1. Sea water

For the sea water, the following values are assumed:

Table 1: Sea water parameter

Description	Value	Unit
Water density	1025	kg/m^3
Water salinity	35	‰
Water temperature (min/max)	0 / 21.8	°C

The water density is assumed to 1025 kg/m^3 as recommended by (DNVGL-ST-0437). The salinity is taken to 3.5 %, as this value was found by (Maar et al. 2011) and the (Bundesamt für Seeschifffahrt und Hydrographie 2020) and can be found in Figure 4 and Figure 5. The minimum water temperature is assumed to 0 °C according to (DNVGL-ST-0437). The maximum water temperature is calculated to 21.8 °C. Hourly values of the water temperature for the reference site, were taken from the ERA-5 dataset (Hersbach et al. 2018). As stated in DNVGL-ST_0437 these are used to determine the yearly extremes. A normal distribution with a 50-year return period is used for calculating the maximum water temperature.

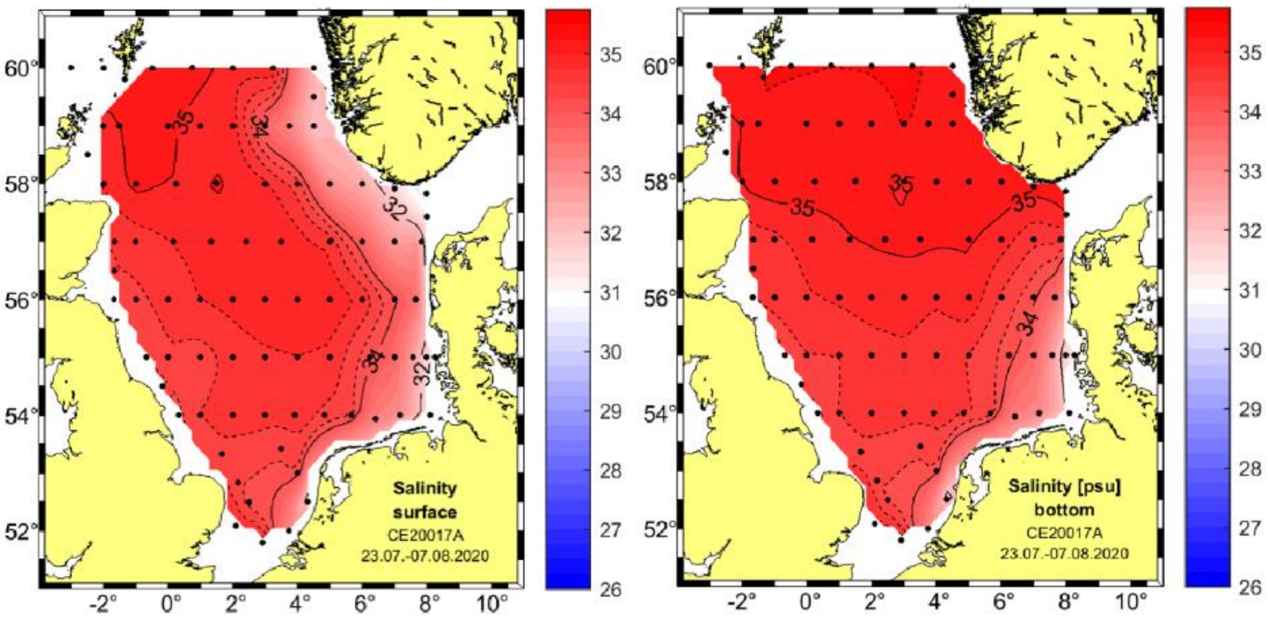


Figure 4: Salinity in the North Sea in ‰ (Bundesamt für Seeschifffahrt und Hydrographie (BSH) 2020)

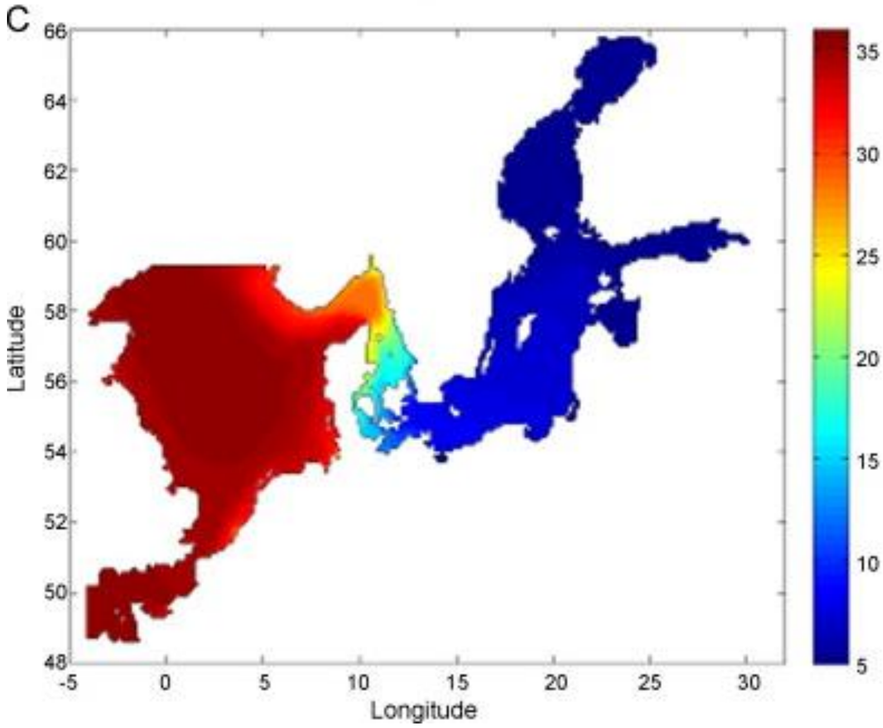


Figure 5: Salinity in North and Baltic Sea in ‰ (Maar et al. 2011)

4.2. Water depths

The water depth at the reference site (55.25°N, 4.75°E) is assumed to be 48.2 m (Sievers et al. 2020). The value does not include any scour effect.

4.3. Water levels

Due to the proximity of the reference site to an amphidromic point, the corresponding tidal range from the CoastDat-2 TRIM hincast model is uncharacteristically low for the German North Sea. Since this design basis aims to represent exemplary environmental conditions and design considerations, the authors have chosen to replace this particular case of low tidal range with surrogate data. In order to provide a more generally applicable design basis, the water levels are adopted from the final report of the "Hydrographic conditions Borkum West" (DOTI GmbH 2007) for the approval of the Alpha Ventus wind farm (approximately at 54°N 6° E). This report provides tidal range data that is typical for a larger range of North Sea locations. The measurement location is close to the measurement platform FINO-1, which is used to provide surrogate data for the reference site in further cases (see section 4.8). The highest and lowest astronomical tide can be found in Table 2, as well as the highest and lowest still water levels. Abbreviations are visualized in Figure 6. The high water level and the low water level for different return periods can be found in Table 3.

Table 2: Water levels (50-yr return period)

HSWL	2.7 m
HAT	1.38 m
MSL	0
LAT	-1.37 m
LSWL	-2.1 m

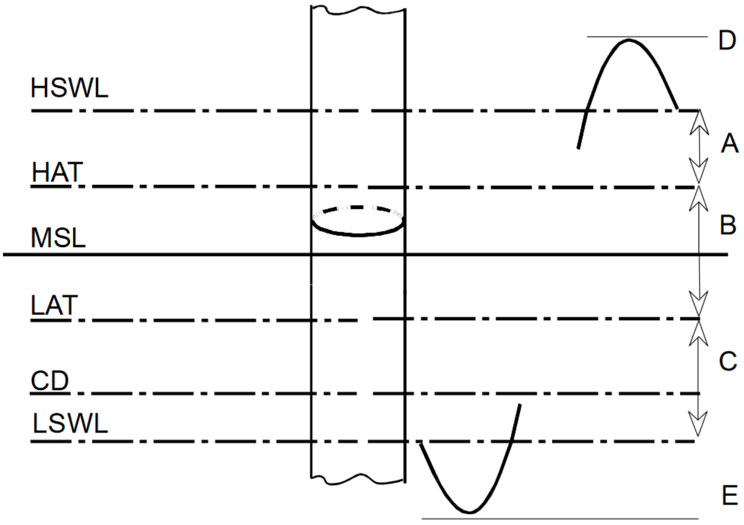


Figure 6: Water levels according to (DNVGL-ST-0437)

Table 3: Water levels for different return periods according to (DOTI GmbH, 2007)

Return period [years]	**LSWL [m MSL]**	**HSWL [m MSL]**
1	-1.6	1.9
5	-1.8	2.2
10	-1.9	2.3
25	-2.0	2.5
50	-2.1	2.7
100	-2.2	2.8

4.4. Currents

Information on currents is retrieved from the CoastDat-2 TRIM dataset. Currents are considered to consist of sub surface currents, mainly driven by the tide, as well as of wind generated near surface currents. Both develop depth-dependent current profiles. Since no depth-resolved current information is present for the chosen location, profiles can be assumed following (IEC 61400-3-1, 2019), Chapters 6.3.3.3.2 (subsurface currents) and 6.3.3.3.3 (wind generated currents).

The 1-year and 50-year return period values of the sea surface current velocities have been derived from the CoastDat-2 Data Set and are given in Table 4. The current velocity for the normal current model has been derived as a mean value calculation of the respective dataset.

Table 4: Current velocities according to load situation.

Load Situation	**T_{return}**	**Current at MSL [m/s]**
Normal current model	(-)	0.266
Extreme current model	1 year	1.05
Extreme current model	50 years	1.35

4.5. Wave parameters

4.5.1. Scatter diagram

For the planning of offshore wind turbines, 3-D scatter diagrams are used, which output the relative frequency of each combination. A Matlab script of the Ludwig-Franzius-Institute of the Leibniz University Hannover is used for this purpose. The wind speed V_w (New European Wind Atlas), the significant wave height H_s and the wave period T_P (CoastDat-2 WAM) are included. First of all, a classification into bins is made. The V_w bins cover 2.0 m/s, the H_s bins cover 0.5 m and the T_P bins span 1.0 s. Here, for example, the bin H_s-=3.0 m covers all significant wave heights in the range between ≥2.75 m and <3.25 m and the bin T_P = 5.0 s lists all wave periods in the range between ≥4.5 s and <5.5 s. After the data is filtered and the absolute frequencies in each bin are known, they are divided by the number of all data, for the relative frequencies. The wind speeds used are 10 min mean values at hub height (200 m). These were determined with a constant factor of 0.95 according to IEC for the transformation from 1 h-values. The wave parameters used are 3 h mean values.

A scatter plot is created for each V_w bin. These are given in the Appendix C. Scatter diagrams ($V_\mathrm{w} - H_s - T_z$).

Table 5: 3-D scatter diagram with the relative frequency x 1000

all Windspeeds		Tp [s]																								
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,0
	13,0																									0,0
	12,5																0,0									0,0
	12,0															0,0										0,0
	11,5															0,0	0,0		0,0							0,0
	11,0															0,0	0,1	0,0								0,1
	10,5															0,1	0,0	0,0	0,0							0,1
	10,0													0,0	0,1	0,0	0,1	0,0								0,2
	9,5													0,0	0,1	0,1	0,1	0,0								0,3
	9,0												0,0	0,1	0,1	0,1	0,1	0,0								0,4
	8,5												0,1	0,2	0,1	0,2	0,1	0,0								0,7
	8,0											0,0	0,2	0,4	0,1	0,3	0,1	0,1								1,1
	7,5											0,1	0,5	0,5	0,1	0,3	0,1	0,0	0,0	0,0						1,6
Hs [m]	7,0											0,6	0,9	0,7	0,1	0,3	0,1	0,0		0,0						2,7
	6,5										0,0	1,6	1,4	0,8	0,1	0,4	0,1	0,0								4,4
	6,0										0,3	2,9	1,6	1,1	0,2	0,4	0,1	0,1	0,0							6,7
	5,5									0,0	1,8	4,6	2,0	1,3	0,1	0,3	0,1	0,1	0,0	0,0						10,4
	5,0									0,4	5,8	5,2	2,1	1,1	0,1	0,4	0,1	0,0		0,1						15,5
	4,5									4,2	9,8	6,4	1,5	0,9	0,2	0,6	0,2	0,3	0,0	0,1	0,0					24,1
	4,0								0,3	12,7	12,2	5,4	2,1	1,3	0,4	0,4	0,4	0,2	0,1	0,1	0,0	0,0				35,5
	3,5								2,4	25,6	11,8	4,9	2,2	1,7	0,4	0,9	0,6	0,5	0,1	0,1		0,0				51,3
	3,0							0,4	10,3	36,9	10,8	5,2	3,1	1,7	0,4	1,6	0,7	0,6	0,0	0,2	0,0	0,0				71,9
	2,5							5,0	33,0	39,4	9,4	5,8	3,7	3,3	0,4	2,8	1,1	0,5	0,1	0,3	0,1	0,1		0,1		105,0
	2,0						1,4	31,6	42,6	33,0	10,9	7,3	5,7	6,0	0,8	2,8	1,1	0,8	0,1	0,4	0,1	0,2		0,0		144,7
	1,5					0,6	19,7	54,2	34,9	31,3	11,6	9,9	8,1	4,9	1,1	2,8	1,8	1,6	0,3	0,9	0,1	0,2	0,0	0,0		183,9
	1,0				0,2	15,4	36,1	50,5	27,8	28,1	11,7	11,6	7,0	4,4	0,8	4,0	2,9	2,7	0,3	0,9	0,1	0,2	0,0	0,1		204,7
	0,5			0,4	6,7	22,9	25,9	19,7	10,2	12,8	7,0	6,2	4,5	4,6	0,7	4,1	2,1	1,6	0,2	0,6	0,0	0,1		0,0		130,2
	<0,25			0,2	0,7	0,9	0,4	0,5	0,3	0,3	0,2	0,6	0,3	0,1	0,0	0,0		0,1								4,5
		0,0	0,0	0,5	7,6	39,8	83,6	161,9	161,8	224,6	103,3	78,3	47,0	35,2	6,1	22,9	12,0	9,2	1,2	3,6	0,4	0,8	0,0	0,2	0,0	1000

4.5.2. Extreme Values

An overview of the calculated extreme values for the wave parameters and the according return periods can be found in Table 6. The extreme wave data has been taken from the CoastDat-2 hindcast dataset (Groll and Weisse 2016). The data is valid for the reference site location.

Table 6: Overview of the wave parameters

T_{return} [years]	H_s [m]	H_{max} [m]	$T(H_s)$ [s]
1	9.20	17.12	10.75
5	10.52	19.57	11.50
10	11.25	20.93	11.89
50	12.53	23.31	12.54
100	12.96	24.10	12.76

The stated wave parameter extreme values are calculated as followed. A 3-Parameter Weibull distribution,

$$F(x) = \exp\left[-\left(\frac{\omega - x}{\omega - w}\right)^k\right] \tag{1}$$

is used as it has shown the best fit to the actual data. The distribution Parameters *w, k* and ω are shown in Table 7.

Table 7: Weibull-Parameter

w	8.7086
k	5.1775
ω	15.9269

$$p = 1 - \frac{1}{R} \tag{2}$$

The quantile p to the according return periods are given in Table 8. Equation (1) is only valid if yearly extreme values are used. R represents the return period. For the calculation of the wave design parameters, return periods of 1, 5, 10, 50 and 100 years and the according quantiles are calculated. The estimated value of the significant wave height with the required return periods can then be determined by inserting the required quantile into the inverse cumulative distribution function (icdf).

Table 8: Quantiles and return periods

T_{return} [years]	Quantile p [-]
1	0,5
5	0,8
10	0,9
50	0,98
100	0,99

The according wave periods to the significant wave heights are calculated using the lower bound of the following equation (cf. (DNVGL-ST-0437)):

$$11.1\sqrt{\frac{H_s}{g}} \leq T \leq 14.3\sqrt{\frac{H_s}{g}} \tag{3}$$

The maximum wave height is assumed to follow a proportional relation to the significant wave height:

$$H_{max} = 1.86 \cdot H_s \tag{4}$$

as given in (IEC 61400-3-1:2019).

The extreme significant wave height H_S of the severe sea state (SSS) can be defined as $H_{S,50-yr}$ according to the standard DNVGL-ST-0437 Section 2.4.4.2. The significant wave height H_S corresponds to a constant stationary condition over a 3-hour period with a 50-year return period. For the extreme sea state (ESS), the significant wave height H_S are denoted as $H_{S,50-yr}$ and $H_{S,1-yr}$ for the return periods of 50-years and 1-year (DNVGL-ST-0437 Section 2.4.4.3).

4.5.3. Wave directions

The scatter diagram neglects the directionality. Therefore, another diagram is generated which represents the direction dependence. The wave direction is defined as the “wave-from” direction. For this purpose, the significant wave heights are classified into 0.5 m bins and the wave directions are classified into 10° bins. The individual relative occurrence frequencies of each direction bin are presented as shown in Figure 7 for all significant wave heights. 0° corresponds to north. The dominant wave direction corresponds to north-north-west (NNW).

The full series of wave roses sorted for each wave height is given in the Appendix B.

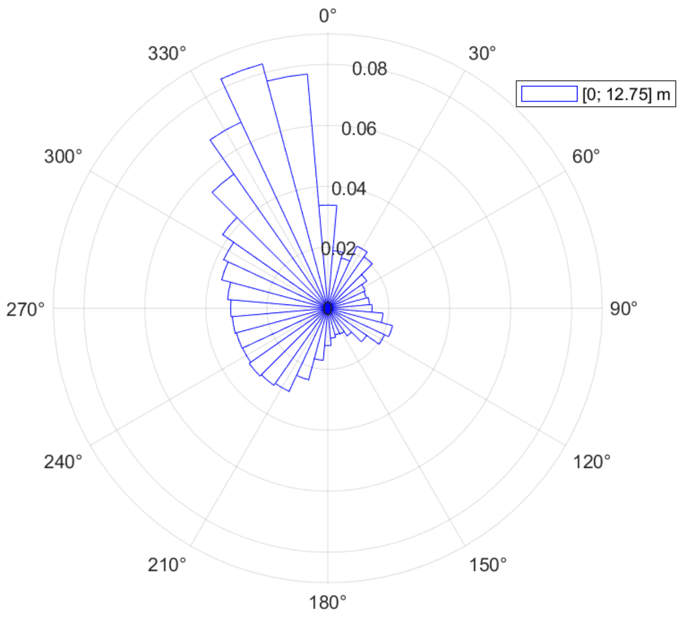


Figure 7: Wave rose as 3-hour average for all significant wave heights. Indicated are the relative occurrence frequencies [-] classified in direction bins

4.5.4. Breaking waves

The breaking limit can be calculated using:

$$\frac{H_b}{\lambda} = 0.142 \tanh\left(\frac{2\pi d}{\lambda}\right) \tag{5}$$

Therefore, the breaking limit is dependent on the wave length λ and the water depth d. The wave length can be calculated iteratively for a given wave period and water depth. Using the 50-year return wave period of $T(H_s) = 12.54\,s$ and the water depth of 48.2 m, the wave length is approximately 217.10 m. Inserting this value into Equation (4) the breaking limit is calculated to 27.26 m. Thus, the breaking limit is significantly higher than the calculated 50- and 100-year maximum wave heights with $H_{max,50} = 24.01\text{ m}$ and $H_{max,100} = 25.06\text{ m}$. Hence, the effect of breaking waves will be neglected.

4.5.5. Wave shape

The approximation of H_{max} (Equation (4)) following the IEC-61400-3 recommendations for cases, where it is not possible to extract H_{max} directly, is based on the linear Rayleigh distribution. To give account to the high influence of nonlinearity in extreme wave heights, the wave shape will be assessed in terms of crest and trough height with regard to a nonlinear approach.

Based on the water depth (MSL) of 48.2 m, the surface elevation maximum (wave crest) and minimum (wave trough) have been derived following a linear (Airy/Laplace) and a nonlinear (stream function theory 10^{th} order after Fenton) wave theory for a single wave. Results are given in Table 9.

Table 9: Surface elevation maxima and minima following different wave theories

Wave Theory	Surface elevation maximum	Surface elevation minimum
Airy/ Laplace	59.86 m	36.54 m
Stream Function Theory 10^{th} order	63.65 m	40.34 m

4.6. Wind parameters

Wind data is analysed from NEWA (NEWA Consortium 2019) for the given reference site. At this stage of the project, no cluster wake effects are considered.

4.6.1. Wind shear and veer

Wind shear will be taken into consideration in the generation process of the synthetic wind fields. The value of the wind shear exponent will be calculated from the data extracted from NEWA. The wind shear follows the formula (IEC 61400-1: 2019):

$$\frac{v}{v_{ref}} = (\frac{z}{z_{ref}})^{\alpha} \quad (6)$$

From the analysis of NEWA wind data (shown in Figure 8), shear exponent (α) value was found to be 0.142857. This value lays within the common range of wind shear for smooth surfaces since it represents an offshore site.

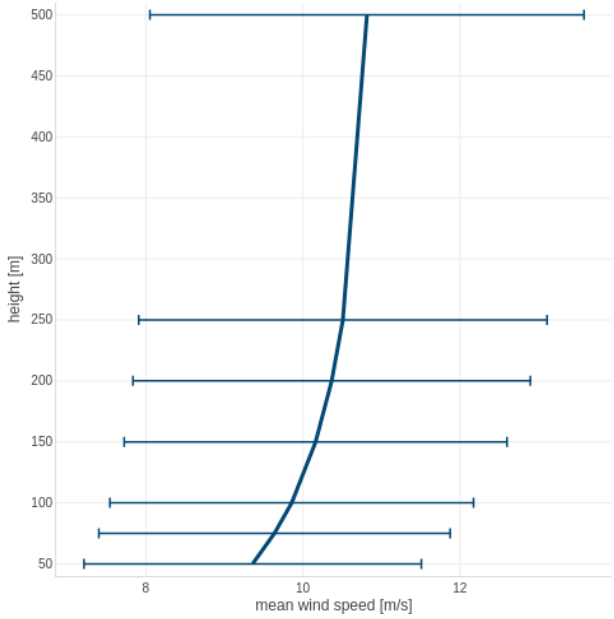


Figure 8: Wind velocity change with altitude extracted from NEWA.

4.6.2. Wind distributions

Wind velocity distributions of the reference site at 150 m and 200 m height are determined. The istribution for 200 m height is shown in Figure 9. The distributions were generated by fitting Weibull distributions to the wind velocity data generated from NEWA. The Weibull distributions in this case take the form:

$$p(v) = \frac{k}{A}(\frac{v}{A})^{k-1}e^{-(v/A)^k} \quad (7)$$

From this fitting at 150m height, it is found that k = 2.22 and A = 11.48 m/s. While at 200m height k = 2.17 and A = 11.72 m/s.

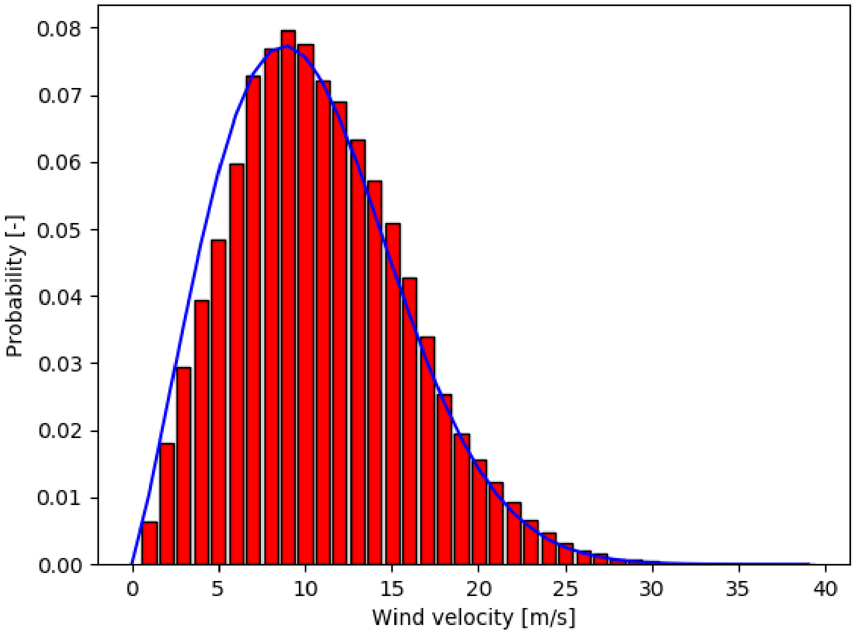


Figure 9: Wind probability density distribution at 200m height and the fitted Weibull probability density function of wind speeds from NEWA data

4.6.3. Turbulence intensity

In this project, turbulence intensity (Ti) at this site was calculated using turbulent kinetic energy (TKE). By knowing this value, Ti can be calculated from the following equation:

$$Ti = \frac{\sqrt{\frac{2}{3}TKE}}{U_{mean}} \tag{8}$$

This resulted in mean Ti = 6.264% and a corresponding mean wind speed of 10.39 m/s. The relationship between the wind velocity and turbulence intensity is shown in Figure 10.

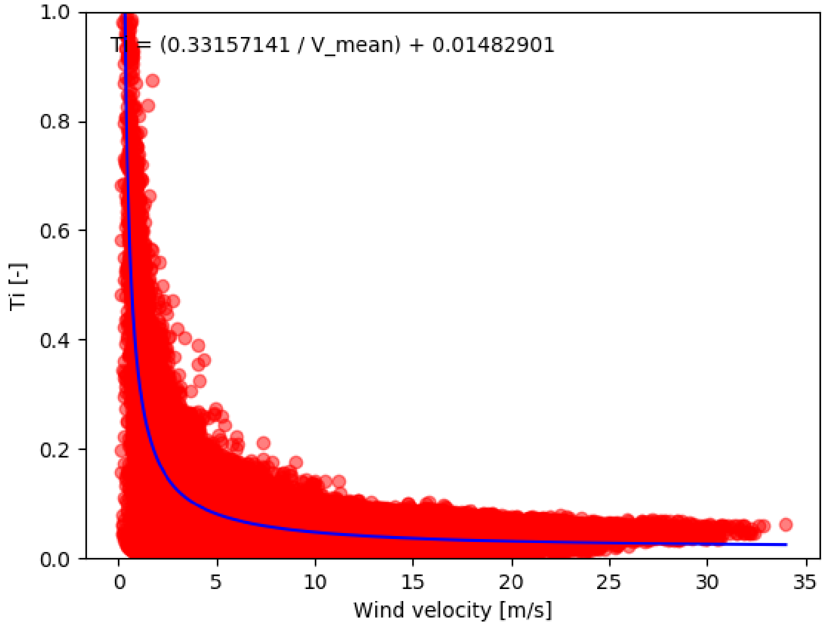


Figure 10: Turbulence intensity versus wind speed from NEWA data at 200m height

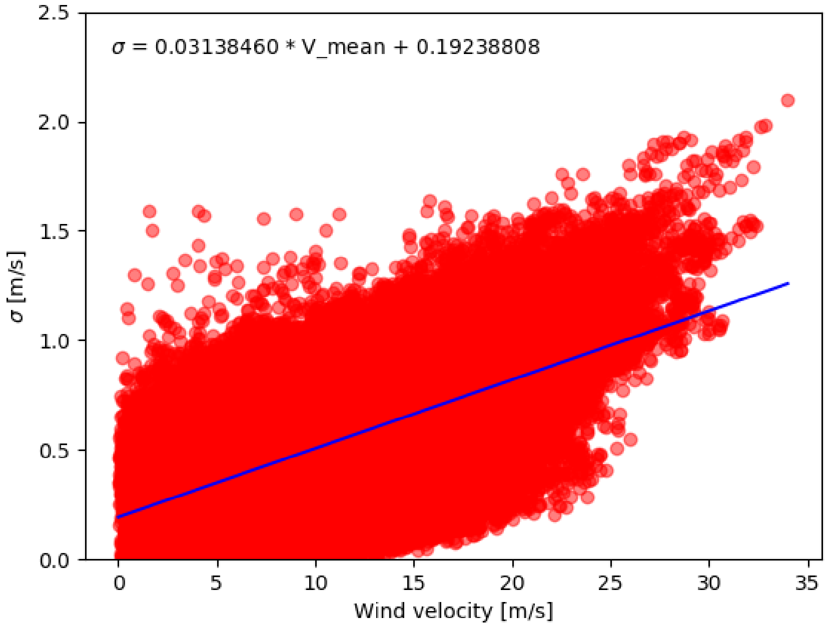


Figure 11: Standard deviation versus wind speed from NEWA data at 200m height

Table 10: Mean wind speed and respective standard deviation from NEWA data at 200m height

Mean wind speed [m/s]	Standard deviation [m/s]
5	0.3493
10	0.5062
15	0.6632
20	0.8201
25	0.9770
30	1.1339
35	1.2908

4.6.4. Wind directions

The scatter diagram neglects the directionality. Therefore, another diagram is generated which represents the direction dependence. For this purpose, the data is classified into 2.0 m/s wind speed bins and the wind directions are classified into 10° bins. The individual relative occurrence frequencies of each direction bin are presented as shown in Figure 12 for all wind speeds. 0° corresponds to north. The dominant wind direction corresponds to west-west-south (WWS).

The full series of wind roses sorted for each wind speed bin is given in the Appendix B.

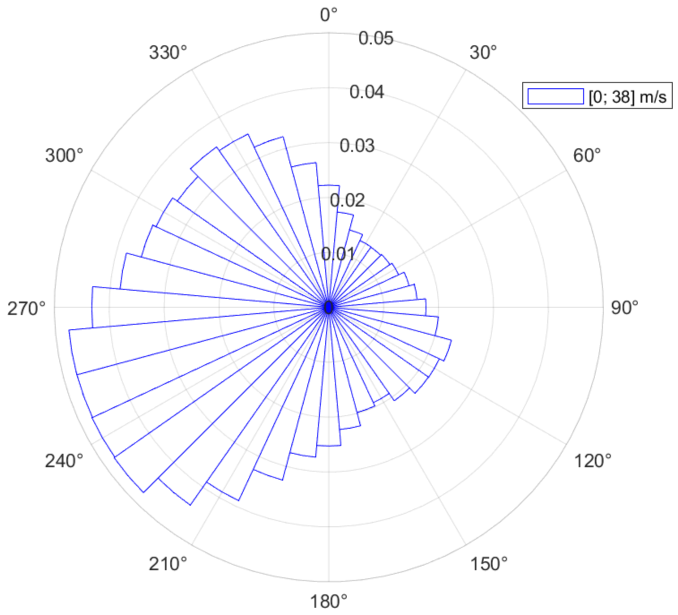


Figure 12: Wind rose at hub height (200m) as 10 min average value for all wind speeds. Indicated are the relative occurrence frequencies [-] classified in direction bins

4.6.5. Extreme values

Extreme wind speeds can be calculated by extrapolating maximum wind speeds over different time periods of extracted data (see Figure 13). A Gringorten method was used to calculate the maximum wind speed. In this method, the cumulative distribution function F(v) is calculated by:

$$F(v) = \frac{m - 0.44}{N - 0.12} \quad (9)$$

where m is the rank of the maximum wind speed and N is the total number of years of the studied sample (Palutikof et al. 1999). After that, the F(v) is fitted to a straight line to take the form:

$$v_{max} = m\,(-\ln(-\ln(F(v)))) + c \quad (10)$$

Then, the extrapolated value can be found from the following equation

$$v_{max} = m\left(\left(-ln\left(-ln(1 - \frac{1}{R}\right)\right)\right) + c \quad (11)$$

where R is the number of years.

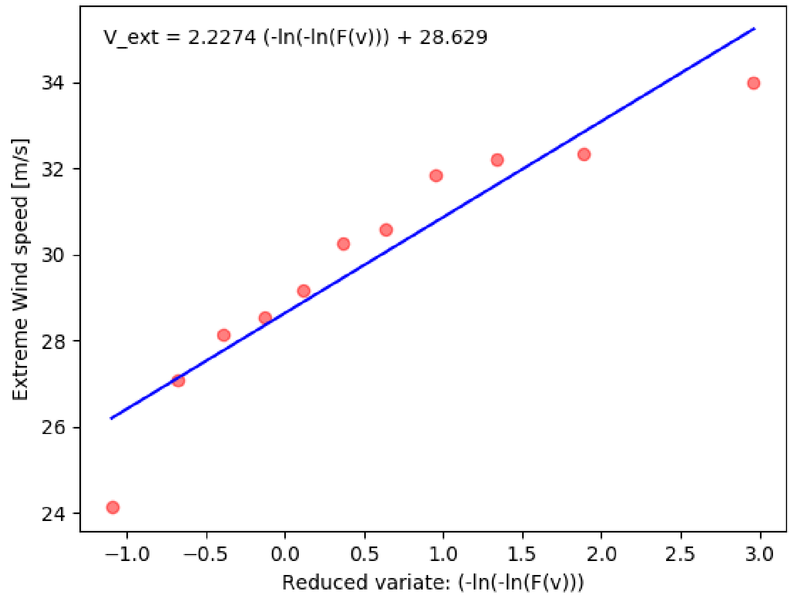


Figure 13: Extreme wind speed extrapolation at 200m height

As the estimation is based on the 30-minute mesoscale data from the new European wind atlas a correction of the 50-year wind speed is needed to compensate smoothing effects of the simulation. To do so, the approach by (Bastine et al. 2018) is followed using the Spectral Correction Method (SCM). The method extracts a correction factor from a correction of the power spectra for small scales and an extrapolation of the spectra down to 10-minutes. The corresponding correction factor for the herein defined reference site is in the order of 1.2, which is in good agreement with other offshore sites (FINO1 and FINO3) investigated and compared to measurement data in (Bastine et al. 2018). This leads to extreme wind velocities for 150m and 200m height of 44.15 m/s and 45.36 m/s over 50 years respectively.

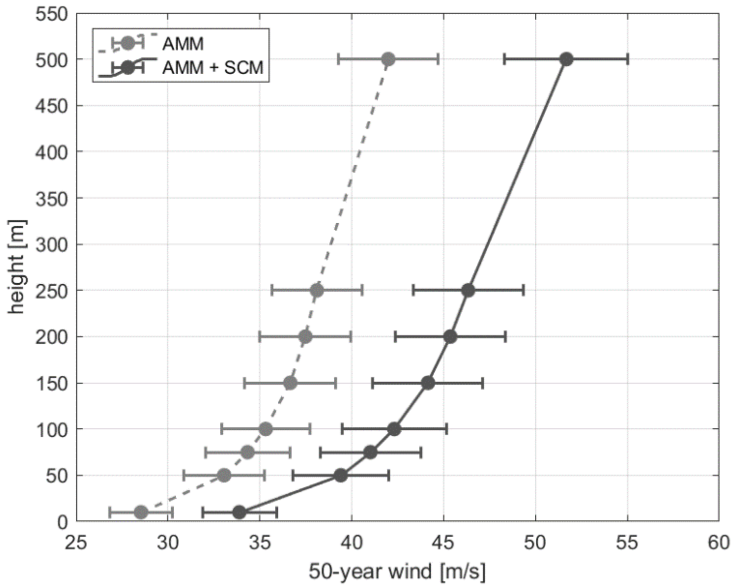


Figure 14: 50-year wind speed estimated based on the annual maximum method (AMM) with and without the spectral correction method (SCM) for different heights

4.7. Further meteorological - oceanographical parameters

4.7.1. Temperature

Temperature parameters are stated in Table 11. Further information about sea water temperature can be found in Section 4.1.

Table 11: Water and air temperature parameters

Water temperature at the surface [°C]		**Air temperature [°C]**	
Mean	11.3	Mean	+ 15° C
Maximum	21.8	Extremes	-20° C to +50° C
Minimum	0		According to (DNVGL-ST-0437)

4.7.2. Marine growth

Unless data indicate otherwise, (DNVGL-ST-0437) suggests that the following marine growth profile may be used for design in Norwegian and UK waters:

Table 12: Assumptions for marine growth

Depth below MSL (m)	**Marine growth thickness (mm)**	
	Central and Northern North Sea (56° to 59° N)	**Norwegian Sea (59° to 72° N)**
-2 to 40	100	60
> 40	50	30

Values given for the Central and Northern North Sea are assumed for the chosen location. Unless more accurate data are available, which is not the case, the density of the marine growth may be set equal to 1325 kg/m³.

4.8. Soil conditions

4.8.1. Soil investigation and soil classification

The soil condition was used from the FINO1 research platform (Platform Fino-1: Soil conditions) near Borkum, because no soil investigations were available for the reference site. It is generally known that the soil conditions in the German North Sea are relatively homogenous within the occurring inherent soil variations. Therefore, the data from FINO1 was transferred to the reference site.

For the investigation of the soil conditions in the North Sea a cased dry borehole according to DIN 4021 with a final depth of 32 m below seabed was drilled in 2001. In addition, a cone-penetration-test (CPT) according to DIN 4094 with a final depth of 28.5 m was carried out.

Figure 15 shows the cone resistance and the related friction ratio. The soils are fine and medium sands with different additions of large grained, medium and fine sand. The same results are present in the CPT, as the friction ratio R_f is mostly about 1 % indicating a non-cohesive soil. In some areas, different additions of silt and locally pieces of coal were also encountered (friction ratio is between 1-2 %). On the basis of the achieved cone resistance of the CPT, the sand is very loosely bedded in the near-surface area up to about 2.2 m. From about 2.2 m up to the final depth, a dense to very dense bedding, locally also medium dense bedding, is to be expected.

4.8.2. Geotechnical procedure

The geotechnical soil model was generally developed using CPT correlation approaches with the program ACPPile. The correlation approaches were applied to the soil type (Ramsey 2002), relative density I_d (Jamiolkowski, M., Lo Presti, D. C. F., Manssero, M. 2001), buoyant unit weight γ’ (Mayne 2007), friction angle φ’ (Kulhawy, F.H. et Mayne, P.W. 1990) , oedometric stiffness Es (Mayne 2007), dynamic shear modulus G0 (Deutsche Gesellschaft für Geotechnik 2002) and permeability kf. The angle of dilatancy only depends on the angle of internal friction. A more detailed description can be found in (Lunne, T., Robertson, P. K., Powell, J. J. M. 1997).

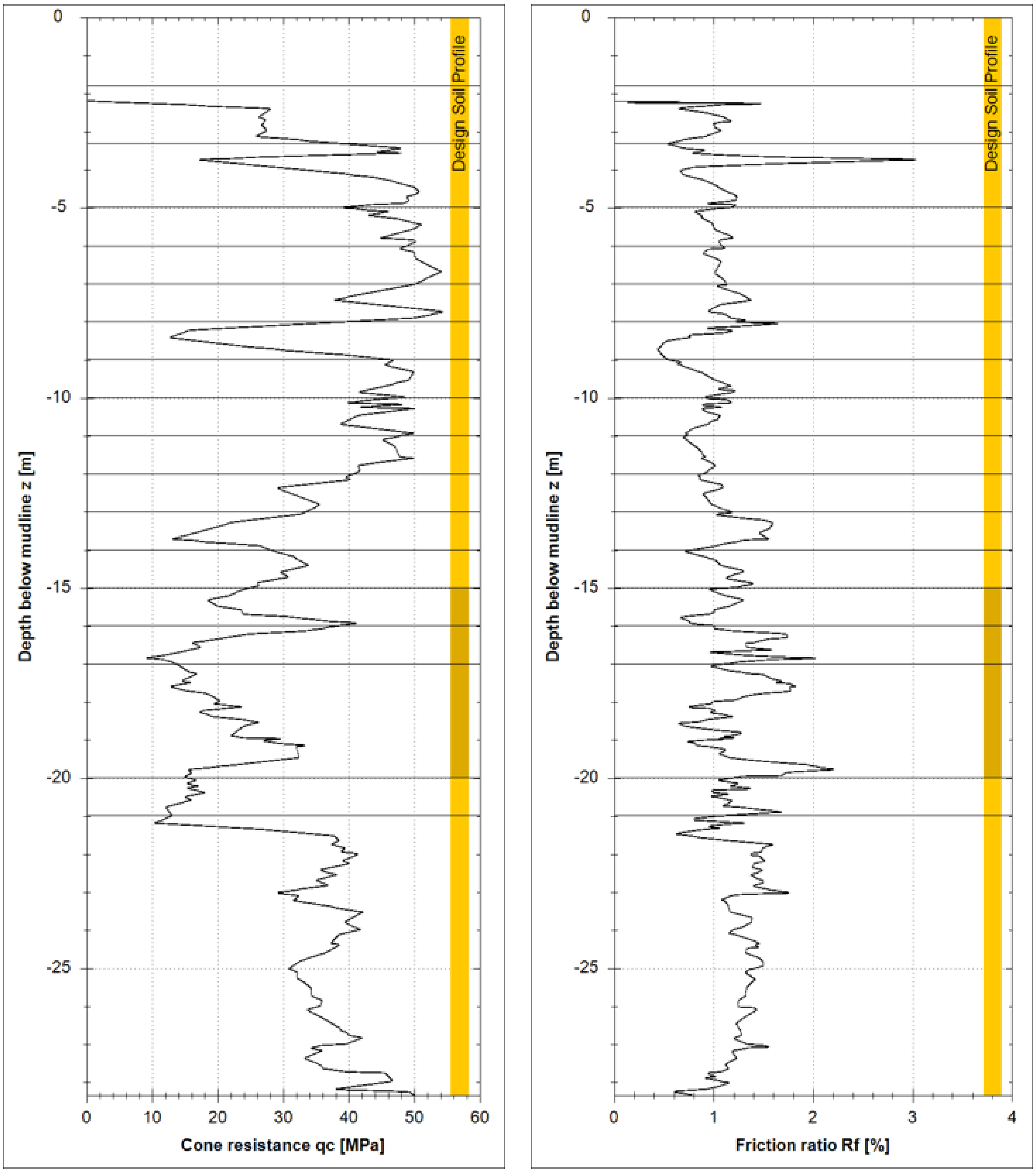


Figure 15: Results of the CPT

4.8.3 Soil Profiles

The following two tables show a summary of the evaluated geotechnical soil parameters.

Table 13: Derived soil properties

No.	Depth below seabed z	Soil type	Cone resistance q_c	Relative density Id	Buoyant unit weight γ‘	Friction angle φ‘	Cohesion c‘
	m	-	MPa	%	kN/m³	°	kN/m²
1	0.0 – 2.2	Sand, very loose	0	0	7.5	15	0
2	2.2 – 3.3	Sand, very dense	26	110	10.5	45	0
3	3.3 – 5.0	Sand, very dense	44	120	11	45	0
4	5.0 – 6.0	Sand, very dense	47	117	11	45	0
5	6.0 – 7.0	Sand, very dense	51	116	11	45	0
6	7.0 – 8.0	Sand, very dense	45	110	11	45	0
7	8.0 – 9.0	Sand, dense	23	85	9.5	44	0
8	9.0 – 10.0	Sand, very dense	47	107	10.5	45	0
9	10.0 – 11.0	Sand, very dense	43	102	10.5	45	0
10	11.0 – 12.0	Sand, very dense	46	103	10.5	45	0
11	12.0 – 13.0	Sand, very dense	34	91	10	45	0
12	13.0 – 14.0	Sand, dense	21	74	10	42	0
13	14.0 – 15.0	Sand, dense	30	85	10	44	0
14	15.0 – 16.0	Sand/Silt, dense	23	76	10	43	0
15	16.0 – 17.0	Sand/Silt, medium dense	16	64	10	41	0
16	17.0 – 20.0	Sand/Silt, dense	19	68	10	41	0
17	20.0 – 21.0	Sand, medium dense	15	58	9.5	40	0
18	21.0 – 32.0	Sand, very dense	36	82	10	43	0

No.	**Undrained shear strength c_u**	**Oedometric stiffness Es**	**Dynamic shear modulus G0**	**Permeability k_f**	**R_{Inter}**	**Dilatance angle ψ**
	kN/m²	MPa	MPa	m/s	-	°
1	0	6	13	$0.00 \cdot 10^{-4}$	0.667	0
2	0	131	166	$3.40 \cdot 10^{-4}$	0.667	15
3	0	218	242	$5.18 \cdot 10^{-4}$	0.667	15
4	0	236	257	$4.81 \cdot 10^{-4}$	0.667	15
5	0	253	271	$4.65 \cdot 10^{-4}$	0.667	15
6	0	225	248	$2.78 \cdot 10^{-4}$	0.667	15
7	0	112	148	$1.25 \cdot 10^{-4}$	0.667	10
8	0	231	253	$3.84 \cdot 10^{-4}$	0.667	15
9	0	215	240	$2.78 \cdot 10^{-4}$	0.667	15
10	0	228	251	$3.96 \cdot 10^{-4}$	0.667	15
11	0	167	198	$1.61 \cdot 10^{-4}$	0.667	15
12	0	101	137	$1.75 \cdot 10^{-5}$	0.667	12
13	0	148	181	$6.90 \cdot 10^{-5}$	0.667	14
14	0	112	148	$4.53 \cdot 10^{-5}$	0.667	13
15	0	79	116	$1.04 \cdot 10^{-5}$	0.667	11
16	0	97	130	$1.66 \cdot 10^{-5}$	0.667	11
17	0	73	110	$7.15 \cdot 10^{-6}$	0.667	10
18	0	176	206	$3.42 \cdot 10^{-5}$	0.667	13

5. Structural load assumptions

5.1. Partial safety factors

Safety factors have to be added for load calculations. According to (DNVGL-ST-0437) different load types are distinguished. Further information can be found in the GL guideline (DNVGL-ST-0437). The number of design load cases (DLC) refer to the numbering in the GL Guideline 2016.

Table 14: Partial safety factors according to (DNVGL-ST-0437)

Ultimate limit state		Fatigue limit state	Accidental limit state	Serviceability limit states
Normal	Abnormal			
N 1.35	A 1.1	F 1.0	F 1.0	F 1.0

5.2. Load assumptions

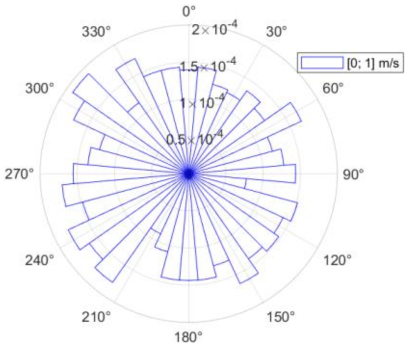
The scope of this project is not to design a turbine ready for certification, but to investigate the challenges in the multidisciplinary design process of an offshore megastructure. Still, the most relevant Design Load Cases (DLCs) have to be checked and critical DLCs are identified. From preliminary investigations, the following DLCs are identified as most critical. The set of load cases might be adapted in the further course of the project when more simulation data is analysed. DLC numbers refer to the numbering in the GL guideline 2016 (DNVGL-ST-0437).

Table 15: Set of design load cases

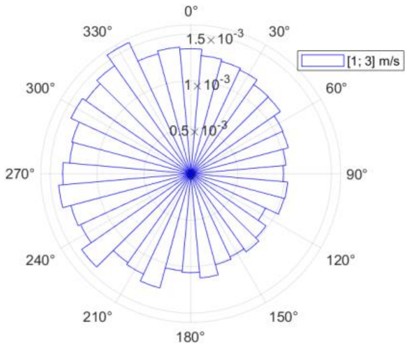
DLC number	Description	Ultimate strength (U) / Fatigue (F)
DLC 1.5	Extreme wind shear (vertical and horizontal wind shear)	U
DLC 1.6	Power Production, NTM, severe sea state (SSS)	U
DLC 6.1	Extreme wind speed model, 50-years storm, yaw misalignment of +/- 8°	U
DLC 6.3	Extreme wind speed model, 1-year storm, yaw misalignment of +/- 20°	U
DLC 7.2	Parked conditions $(v < v_{out})$	F

6. Appendix

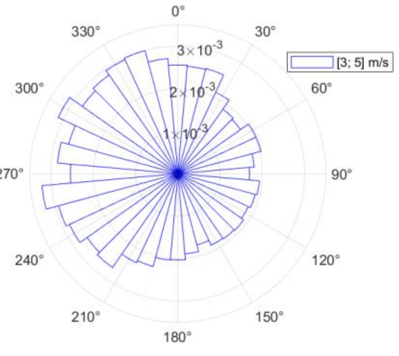
A. Wind roses



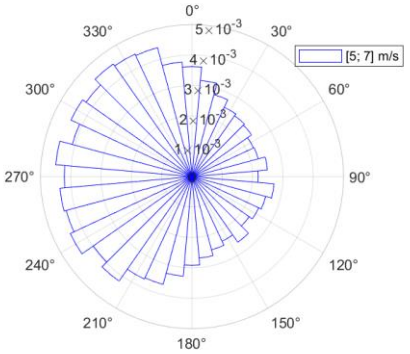
Σ bin [0 ; 1] = 0.0051122



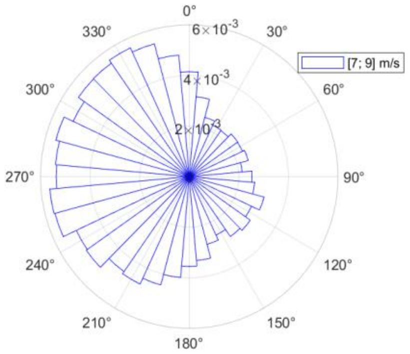
Σ bin [1 ; 3] = 0.0433176



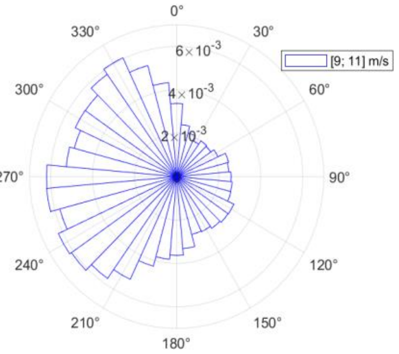
Σ bin [3 ; 5] = 0.0843239



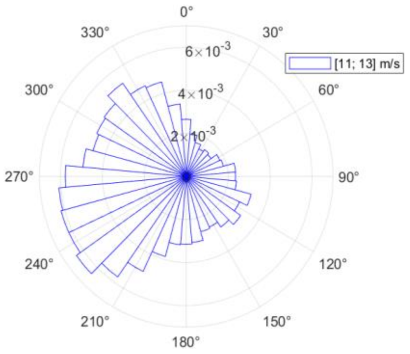
Σ bin [5 ; 7] = 0.1197285



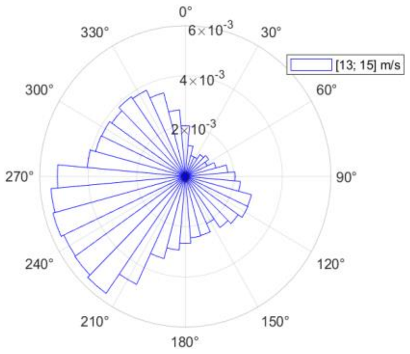
Σ bin [7 ; 9] = 0.1400841



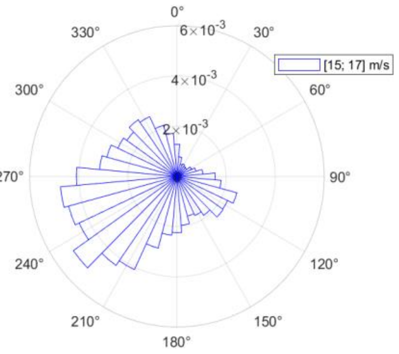
Σ bin [9 ; 11] = 0.1421934



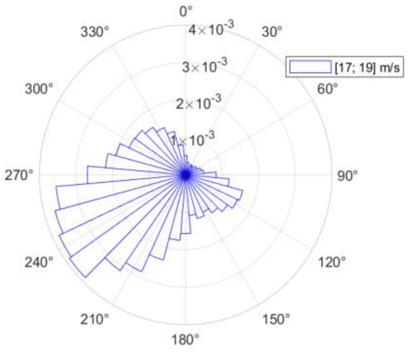
Σ bin [11 ; 13] = 0.1299451



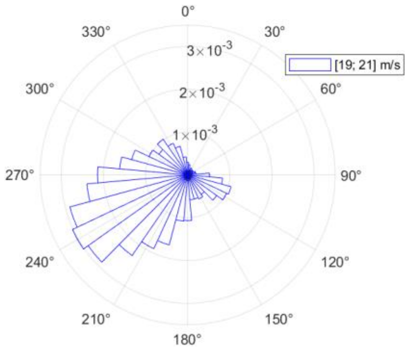
Σ bin [13 ; 15] = 0.1094847



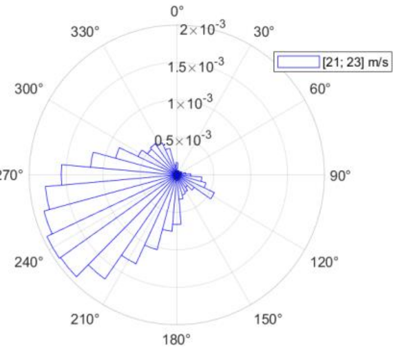
Σ bin [15 ; 17] = 0.0836519



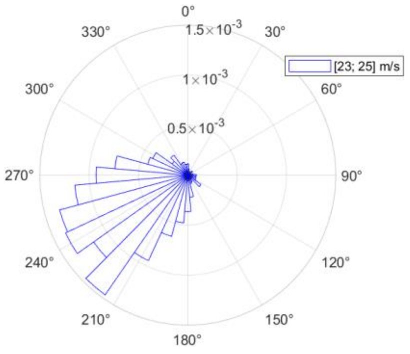
Σ bin [17 ; 19] = 0.0562535



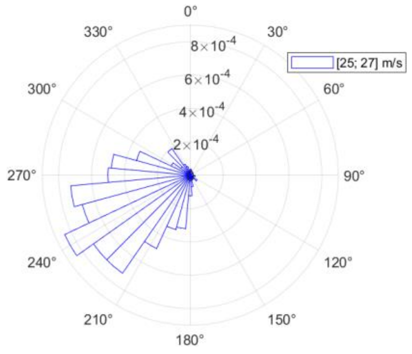
Σ bin [19 ; 21] = 0.0374013



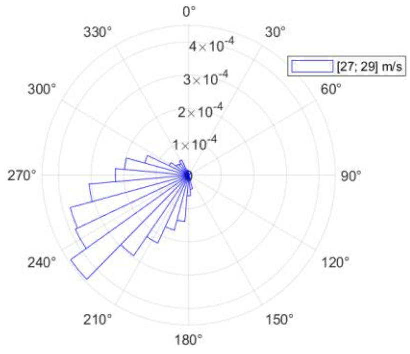
Σ bin [21 ; 23] = 0.0226280



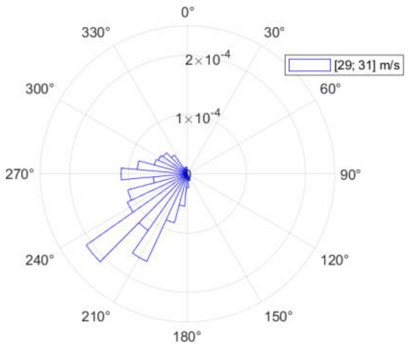
Σ bin [23 ; 25] = 0.0135186



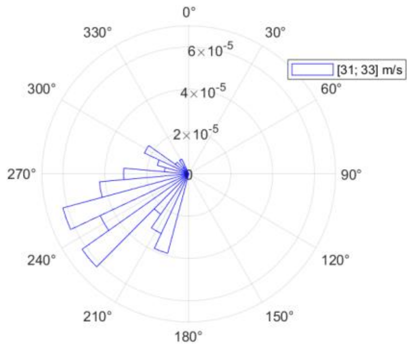
Σ bin [25 ; 27] = 0.0071749



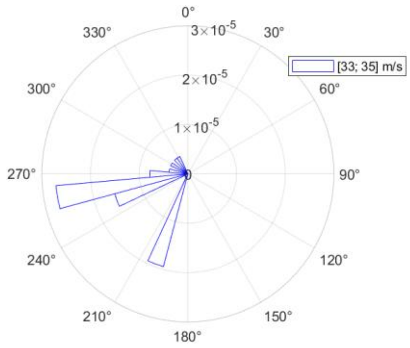
Σ bin [27 ; 29] = 0.0032670



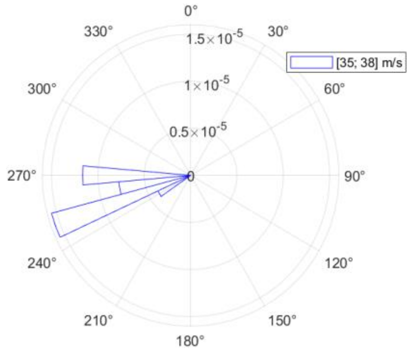
Σ bin [29 ; 31] = 0.0013829



Σ bin [31 ; 33] = 0.0004079

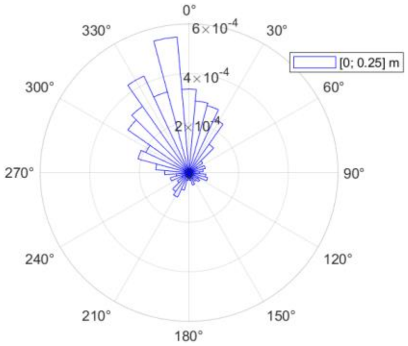


Σ bin [33 ; 35] = 0.0000855

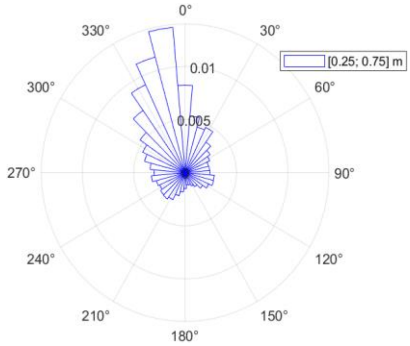


Σ bin [35 ; 38] = 0.0000388

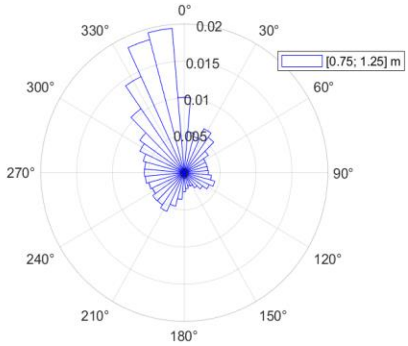
B. Wave roses



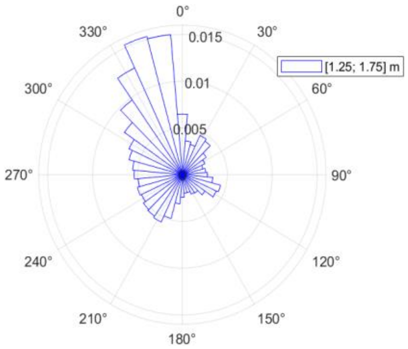
Σ bin [0 ; 0.25] = 0.0050714



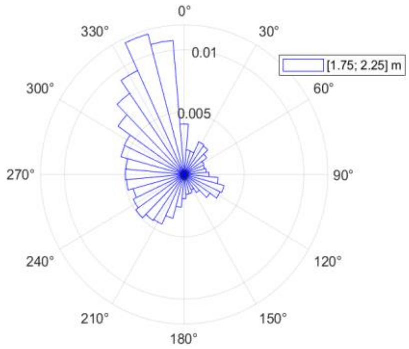
Σ bin [0.25 ; 0.75] = 0.1396177



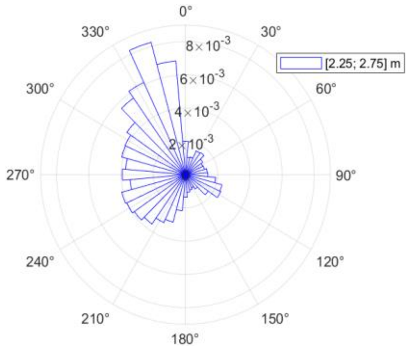
Σ bin [0.75 ; 1.25] = 0.2106685



Σ bin [1.25 ; 1.75] = 0.1859755



Σ bin [1.75 ; 2.25] = 0.1451298



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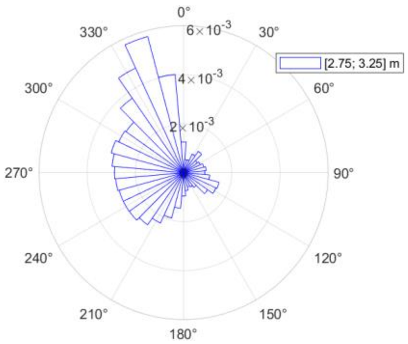
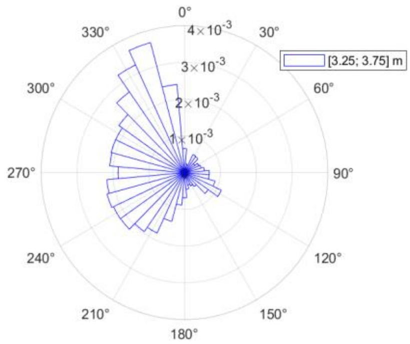
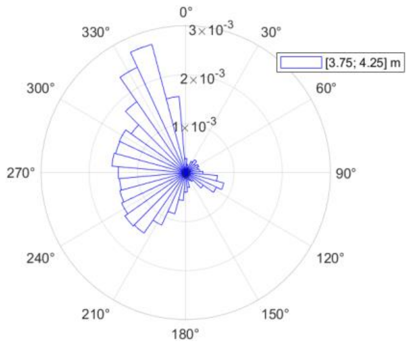


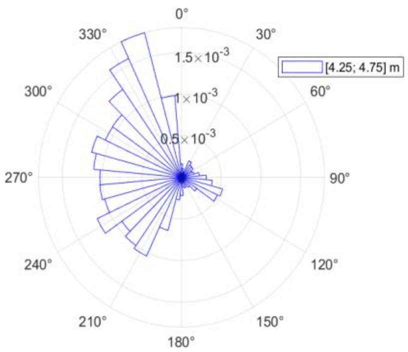
Σ bin [2.75 ; 3.25] = 0.0697544



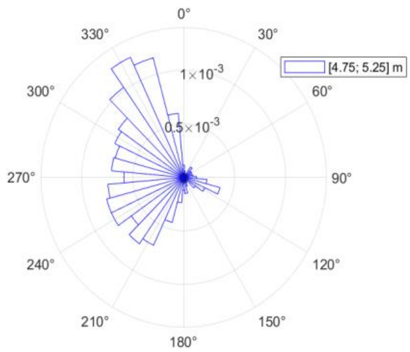
Σ bin [3.25 ; 3.75] = 0.0477786



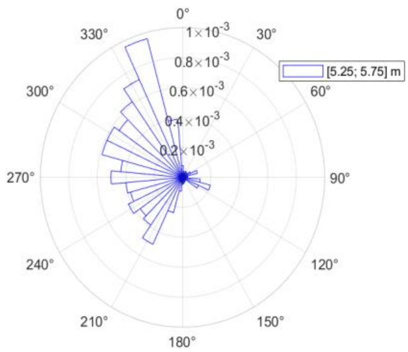
Σ bin [3.75 ; 4.25] = 0.0321549



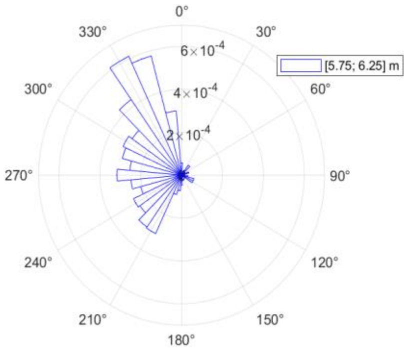
Σ bin [4.25 ; 4.75] = 0.0222299



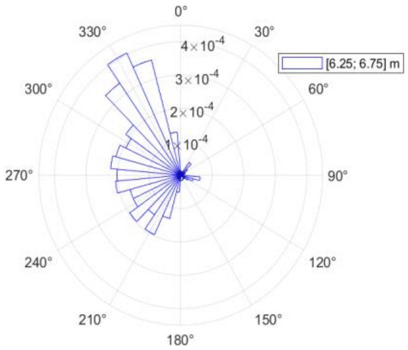
Σ bin [4.75 ; 5.25] = 0.0148355



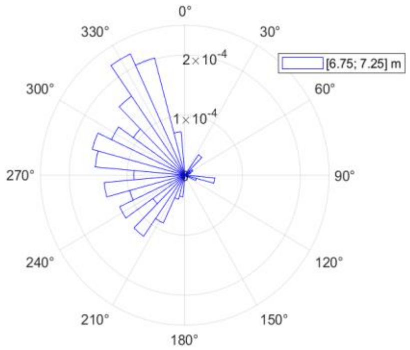
Σ bin [5.25 ; 5.75] = 0.0092664



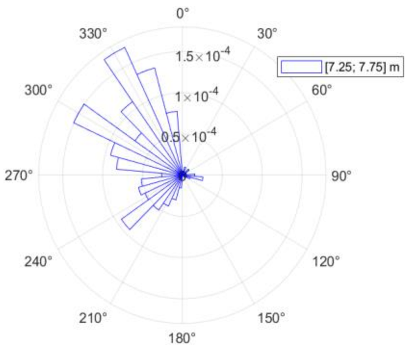
Σ bin [5.75 ; 6.25] = 0.0056314



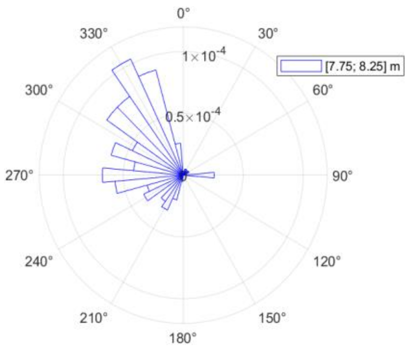
Σ bin [6.25 ; 6.75] = 0.0038424



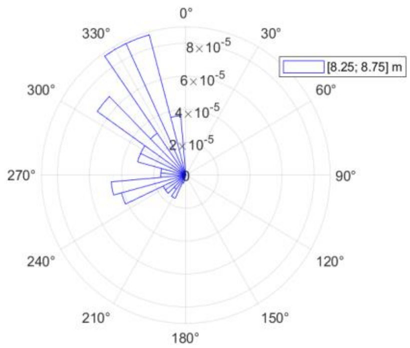
Σ bin [6.75 ; 7.25] = 0.0022142



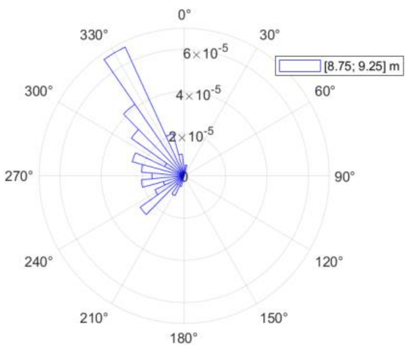
Σ bin [7.25 ; 7.75] = 0.0014053



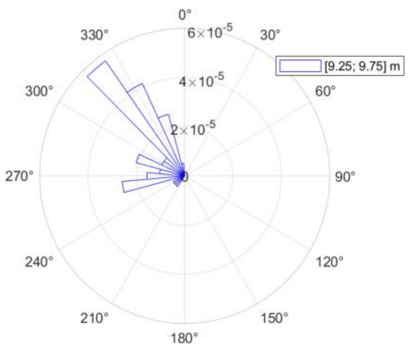
Σ bin [7.75 ; 8.25] = 0.0008504



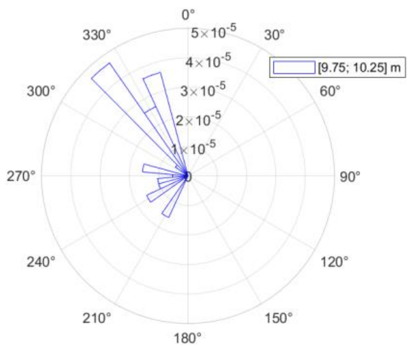
Σ bin [8.25 ; 8.75] = 0.0005548



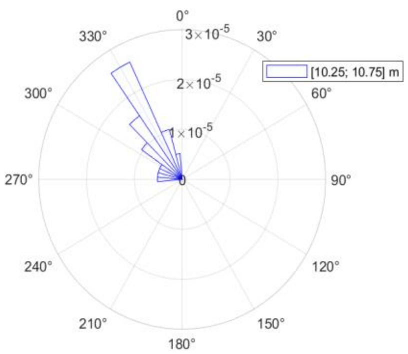
Σ bin [8.75 ; 9.25] = 0.0003422



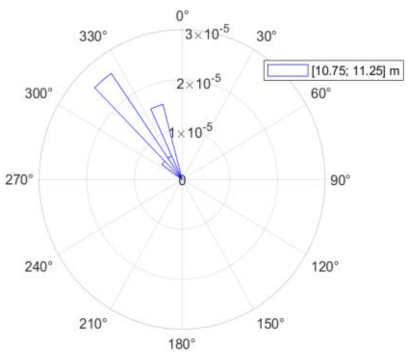
Σ bin [9.25 ; 9.75] = 0.0002385



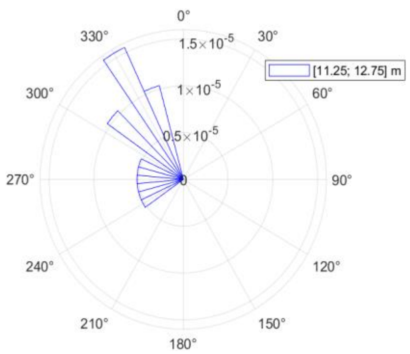
Σ bin [9.75 ; 10.25] = 0.0001867



Σ bin [10.25 ; 10.75] = 0.0000882



Σ bin [10.75 ; 11.25] = 0.0000519



Σ bin [11.25 ; 12.75] = 0.0000674

C. Scatter diagrams (V_W-H_S-T_P)

All Windspeeds		Tp [s]																							
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																0,00001									0,00001
	12,0															0,00003										0,00003
	11,5															0,00001	0,00001		0,00001							0,00004
	11,0															0,00001	0,00005	0,00001								0,00008
	10,5															0,00005	0,00001	0,00001	0,00001							0,00009
	10,0													0,00003	0,00007	0,00003	0,00007	0,00001								0,00020
	9,5													0,00001	0,00007	0,00012	0,00005	0,00003								0,00028
	9,0												0,00001	0,00015	0,00008	0,00007	0,00008	0,00003								0,00042
	8,5												0,00005	0,00024	0,00008	0,00020	0,00012	0,00001								0,00071
	8,0											0,00003	0,00022	0,00039	0,00007	0,00027	0,00007	0,00007								0,00111
	7,5											0,00011	0,00047	0,00049	0,00008	0,00030	0,00012	0,00003	0,00001	0,00001						0,00162
Hs [m]	7,0											0,00055	0,00089	0,00070	0,00011	0,00030	0,00008	0,00001		0,00001						0,00266
	6,5										0,00001	0,00159	0,00142	0,00082	0,00005	0,00040	0,00009	0,00003								0,00442
	6,0										0,00028	0,00293	0,00163	0,00109	0,00019	0,00036	0,00008	0,00009	0,00004							0,00670
	5,5									0,00004	0,00182	0,00457	0,00200	0,00128	0,00015	0,00028	0,00011	0,00008	0,00001	0,00001						0,01036
	5,0									0,00045	0,00581	0,00521	0,00205	0,00112	0,00015	0,00042	0,00013	0,00001		0,00011						0,01546
	4,5									0,00415	0,00983	0,00637	0,00150	0,00093	0,00016	0,00062	0,00019	0,00026	0,00001	0,00005	0,00001					0,02409
	4,0								0,00028	0,01265	0,01219	0,00537	0,00205	0,00129	0,00039	0,00045	0,00042	0,00020	0,00005	0,00011	0,00001	0,00001				0,03549
	3,5								0,00244	0,02564	0,01182	0,00490	0,00221	0,00170	0,00036	0,00090	0,00061	0,00049	0,00007	0,00011		0,00004				0,05128
	3,0							0,00036	0,01033	0,03686	0,01080	0,00515	0,00312	0,00174	0,00035	0,00156	0,00067	0,00061	0,00004	0,00022	0,00003	0,00001				0,07187
	2,5							0,00504	0,03303	0,03937	0,00942	0,00581	0,00375	0,00329	0,00042	0,00277	0,00115	0,00050	0,00007	0,00026	0,00005	0,00005		0,00005		0,10504
	2,0						0,00139	0,03162	0,04256	0,03298	0,01090	0,00731	0,00572	0,00598	0,00080	0,00282	0,00108	0,00082	0,00012	0,00038	0,00007	0,00019		0,00003		0,14475
	1,5					0,00062	0,01967	0,05421	0,03485	0,03132	0,01156	0,00991	0,00813	0,00487	0,00111	0,00277	0,00175	0,00162	0,00026	0,00088	0,00012	0,00018	0,00001	0,00001		0,18385
	1,0				0,00022	0,01538	0,03615	0,05049	0,02781	0,02806	0,01168	0,01164	0,00696	0,00441	0,00076	0,00403	0,00287	0,00270	0,00027	0,00086	0,00011	0,00022	0,00003	0,00011		0,20475
	0,5			0,00035	0,00669	0,02293	0,02594	0,01965	0,01020	0,01276	0,00697	0,00623	0,00445	0,00459	0,00069	0,00413	0,00212	0,00155	0,00020	0,00061	0,00004	0,00009		0,00003		0,13022
	<0,25			0,00016	0,00066	0,00088	0,00042	0,00049	0,00027	0,00031	0,00020	0,00059	0,00032	0,00008	0,00001	0,00001		0,00005								0,00446
		0,00000	0,00000	0,00051	0,00757	0,03981	0,08356	0,16186	0,16178	0,22460	0,10331	0,07828	0,04695	0,03521	0,00614	0,02292	0,01196	0,00923	0,00119	0,00361	0,00045	0,00080	0,00004	0,00023	0,00000	1,00000

Vw = 0 - 1 [m/s]	Tp [s]																								
Hs [m]	<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
>13,25																									0,00000
13,0																									0,00000
12,5																									0,00000
12,0																									0,00000
11,5																									0,00000
11,0																									0,00000
10,5																									0,00000
10,0																									0,00000
9,5																									0,00000
9,0																									0,00000
8,5																									0,00000
8,0																									0,00000
7,5																									0,00000
7,0																									0,00000
6,5																									0,00000
6,0																									0,00000
5,5																									0,00000
5,0																									0,00000
4,5																									0,00000
4,0																0,00001			0,00001						0,00002
3,5																									0,00001
3,0										0,00001					0,00002		0,00001								0,00004
2,5									0,00001	0,00002	0,00002	0,00003			0,00001										0,00010
2,0								0,00001	0,00003	0,00001	0,00007	0,00008	0,00003		0,00001										0,00025
1,5						0,00005	0,00012	0,00008	0,00022	0,00012	0,00013	0,00012	0,00004		0,00005	0,00002									0,00096
1,0					0,00001	0,00009	0,00032	0,00026	0,00027	0,00016	0,00019	0,00009	0,00004	0,00001	0,00001	0,00002	0,00002	0,00001							0,00152
0,5				0,00003	0,00017	0,00023	0,00044	0,00022	0,00027	0,00009	0,00017	0,00015	0,00008	0,00002	0,00007	0,00002	0,00002		0,00002						0,00201
<0,25					0,00001	0,00000			0,00002		0,00002	0,00000													0,00006
	0,00000	0,00000	0,00000	0,00003	0,00018	0,00038	0,00089	0,00058	0,00083	0,00042	0,00061	0,00047	0,00020	0,00004	0,00018	0,00008	0,00006	0,00001	0,00003	0,00000	0,00000	0,00000	0,00000	0,00000	0,00499

Vw = 1 - 3 [m/s]	Tp [s]																								
Hs [m]	<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
>13,25																									0,00000
13,0																									0,00000
12,5																									0,00000
12,0																									0,00000
11,5																									0,00000
11,0																									0,00000
10,5																									0,00000
10,0																									0,00000
9,5																									0,00000
9,0																									0,00000
8,5																									0,00000
8,0																									0,00000
7,5																									0,00000
7,0																									0,00000
6,5																									0,00000
6,0																									0,00000
5,5																0,00001									0,00001
5,0																0,00002									0,00002
4,5										0,00001						0,00001	0,00002								0,00004
4,0										0,00002	0,00003					0,00002			0,00003						0,00009
3,5									0,00002	0,00005	0,00003				0,00002	0,00002	0,00001								0,00015
3,0								0,00002	0,00007	0,00003	0,00004	0,00001	0,00003		0,00004	0,00005	0,00005								0,00036
2,5							0,00002	0,00004	0,00014	0,00018	0,00012	0,00008	0,00012		0,00010	0,00002	0,00005								0,00087
2,0						0,00001	0,00021	0,00024	0,00045	0,00046	0,00051	0,00038	0,00038	0,00006	0,00022	0,00003	0,00002	0,00002			0,00004				0,00304
1,5						0,00007	0,00066	0,00082	0,00182	0,00092	0,00088	0,00096	0,00035	0,00008	0,00018	0,00011	0,00004		0,00005	0,00004					0,00697
1,0					0,00025	0,00084	0,00295	0,00295	0,00289	0,00116	0,00107	0,00071	0,00034	0,00009	0,00028	0,00028	0,00011	0,00001	0,00005	0,00002	0,00005				0,01404
0,5			0,00004	0,00024	0,00149	0,00277	0,00344	0,00169	0,00176	0,00131	0,00088	0,00081	0,00090	0,00013	0,00063	0,00029	0,00031	0,00001	0,00016		0,00001				0,01686
<0,25				0,00012	0,00023	0,00004	0,00009	0,00003	0,00013	0,00003	0,00013	0,00012													0,00092
	0,00000	0,00000	0,00004	0,00036	0,00197	0,00373	0,00737	0,00579	0,00729	0,00417	0,00369	0,00308	0,00213	0,00037	0,00147	0,00086	0,00059	0,00005	0,00029	0,00005	0,00010	0,00000	0,00000	0,00000	0,04338

Vw = 3 - 5 [m/s]		Tp [s]																								
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00000
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5																									0,00000
	9,0																									0,00000
	8,5																									0,00000
	8,0																									0,00000
	7,5																									0,00000
Hs [m]	7,0												0,00001													0,00001
	6,5																									0,00001
	6,0																									0,00000
	5,5																									0,00000
	5,0																									0,00001
	4,5										0,00001							0,00001								0,00003
	4,0										0,00003	0,00001	0,00001				0,00004									0,00010
	3,5									0,00007	0,00009	0,00003	0,00001	0,00004	0,00001	0,00007	0,00004	0,00007								0,00043
	3,0								0,00007	0,00023	0,00008	0,00009	0,00006	0,00007	0,00001	0,00008	0,00003	0,00004								0,00076
	2,5							0,00003	0,00027	0,00052	0,00019	0,00026	0,00022	0,00020	0,00004	0,00017	0,00007	0,00005								0,00202
	2,0						0,00002	0,00035	0,00053	0,00123	0,00112	0,00089	0,00072	0,00077	0,00005	0,00033	0,00013	0,00011	0,00001	0,00001		0,00003				0,00629
	1,5						0,00027	0,00161	0,00236	0,00432	0,00202	0,00182	0,00133	0,00081	0,00015	0,00039	0,00024	0,00019	0,00004	0,00017	0,00002	0,00004				0,01579
	1,0				0,00003	0,00049	0,00229	0,00673	0,00499	0,00609	0,00253	0,00280	0,00119	0,00093	0,00011	0,00049	0,00061	0,00043	0,00004	0,00015	0,00004	0,00010				0,03002
	0,5			0,00004	0,00075	0,00337	0,00587	0,00478	0,00245	0,00300	0,00175	0,00167	0,00111	0,00109	0,00014	0,00116	0,00050	0,00041	0,00004	0,00014		0,00001		0,00001		0,02831
	<0,25			0,00006	0,00026	0,00033	0,00016	0,00013	0,00012	0,00009	0,00006	0,00023	0,00010	0,00003		0,00001										0,00159
		0,00000	0,00000	0,00010	0,00104	0,00420	0,00861	0,01363	0,01078	0,01554	0,00788	0,00780	0,00478	0,00395	0,00051	0,00272	0,00167	0,00130	0,00013	0,00047	0,00006	0,00018	0,00000	0,00001	0,00000	0,08537

Vw = 5 - 7 [m/s]		Tp [s]																								
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00000
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5																									0,00000
	9,0																									0,00000
	8,5																									0,00000
	8,0																									0,00000
	7,5															0,00001										0,00001
Hs [m]	7,0																									0,00000
	6,5																0,00001									0,00002
	6,0																									0,00000
	5,5																									0,00000
	5,0											0,00001	0,00002													0,00004
	4,5										0,00002	0,00002														0,00004
	4,0									0,00001	0,00007	0,00004	0,00004	0,00002			0,00004									0,00022
	3,5								0,00002	0,00022	0,00018	0,00012	0,00002	0,00010	0,00002	0,00006	0,00004	0,00006	0,00001							0,00085
	3,0								0,00013	0,00050	0,00024	0,00028	0,00019	0,00016	0,00003	0,00017	0,00003	0,00008								0,00183
	2,5							0,00004	0,00067	0,00105	0,00066	0,00070	0,00058	0,00051	0,00006	0,00043	0,00012	0,00008		0,00002						0,00492
	2,0						0,00005	0,00081	0,00188	0,00290	0,00161	0,00127	0,00107	0,00094	0,00014	0,00049	0,00013	0,00011	0,00002	0,00006		0,00001				0,01151
	1,5					0,00004	0,00073	0,00410	0,00536	0,00642	0,00242	0,00220	0,00154	0,00107	0,00014	0,00066	0,00033	0,00037	0,00008	0,00026		0,00003				0,02574
	1,0					0,00165	0,00539	0,01093	0,00726	0,00667	0,00271	0,00286	0,00174	0,00105	0,00021	0,00117	0,00079	0,00075	0,00005	0,00031	0,00004	0,00005	0,00002	0,00004		0,04369
	0,5			0,00006	0,00124	0,00518	0,00582	0,00422	0,00238	0,00339	0,00171	0,00151	0,00095	0,00102	0,00013	0,00104	0,00058	0,00041	0,00009	0,00020	0,00004	0,00005		0,00002		0,03004
	<0,25			0,00006	0,00008	0,00016	0,00019	0,00022	0,00004	0,00004	0,00005	0,00011	0,00007	0,00005	0,00001			0,00000								0,00109
		0,00000	0,00000	0,00012	0,00132	0,00702	0,01218	0,02032	0,01775	0,02120	0,00966	0,00912	0,00623	0,00494	0,00076	0,00405	0,00207	0,00187	0,00026	0,00085	0,00008	0,00014	0,00002	0,00006	0,00000	0,12002

Vw = 7 - 9 [m/s]		Tp [s]																								
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00000
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5																									0,00000
	9,0																									0,00000
	8,5															0,00001										0,00001
	8,0															0,00001										0,00001
	7,5																									0,00000
Hs [m]	7,0																									0,00000
	6,5															0,00001	0,00003									0,00005
	6,0																									0,00001
	5,5												0,00001	0,00001												0,00004
	5,0										0,00001	0,00001	0,00005	0,00002			0,00002			0,00001						0,00013
	4,5										0,00002	0,00007	0,00004	0,00002	0,00001	0,00001	0,00002	0,00000								0,00019
	4,0									0,00005	0,00008	0,00012	0,00005	0,00005	0,00004	0,00003	0,00004	0,00001		0,00001						0,00049
	3,5								0,00001	0,00030	0,00025	0,00022	0,00012	0,00011	0,00004	0,00012	0,00005	0,00006	0,00001							0,00130
	3,0							0,00001	0,00020	0,00089	0,00062	0,00062	0,00042	0,00027	0,00004	0,00027	0,00010	0,00011	0,00001							0,00357
	2,5							0,00004	0,00108	0,00266	0,00150	0,00112	0,00062	0,00071	0,00009	0,00062	0,00036	0,00008	0,00001	0,00003				0,00001		0,00892
	2,0						0,00006	0,00192	0,00472	0,00596	0,00248	0,00161	0,00126	0,00126	0,00020	0,00057	0,00029	0,00016	0,00002	0,00006	0,00001					0,02061
	1,5					0,00007	0,00246	0,00982	0,00739	0,00762	0,00240	0,00184	0,00149	0,00082	0,00018	0,00052	0,00043	0,00039	0,00004	0,00015	0,00002	0,00005				0,03567
	1,0				0,00001	0,00280	0,00842	0,01081	0,00576	0,00585	0,00229	0,00206	0,00141	0,00097	0,00017	0,00099	0,00054	0,00067	0,00012	0,00024			0,00001	0,00006		0,04318
	0,5			0,00007	0,00160	0,00462	0,00532	0,00329	0,00185	0,00251	0,00109	0,00105	0,00082	0,00082	0,00014	0,00081	0,00039	0,00023	0,00004	0,00006		0,00002				0,02473
	<0,25			0,00003	0,00010	0,00009	0,00002	0,00004	0,00005	0,00002	0,00002	0,00005	0,00001					0,00000								0,00044
		0,00000	0,00000	0,00010	0,00171	0,00758	0,01628	0,02593	0,02106	0,02586	0,01075	0,00878	0,00632	0,00508	0,00091	0,00399	0,00228	0,00172	0,00025	0,00057	0,00004	0,00008	0,00001	0,00007	0,00000	0,13936

Vw = 9 - 11 [m/s]		Tp [s]																								
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00000
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5																									0,00000
	9,0																									0,00000
	8,5																									0,00000
	8,0															0,00001										0,00001
	7,5												0,00001													0,00001
Hs [m]	7,0																									0,00000
	6,5											0,00001														0,00002
	6,0											0,00002					0,00001									0,00004
	5,5										0,00001	0,00002	0,00003													0,00006
	5,0										0,00002	0,00004	0,00006	0,00004			0,00002			0,00001						0,00020
	4,5									0,00004	0,00009	0,00011	0,00004	0,00007	0,00001	0,00004	0,00003	0,00002		0,00001						0,00045
	4,0									0,00022	0,00034	0,00032	0,00022	0,00017	0,00001	0,00007	0,00008	0,00003		0,00001	0,00001					0,00149
	3,5								0,00003	0,00086	0,00060	0,00066	0,00036	0,00021	0,00008	0,00018	0,00010	0,00008		0,00001						0,00317
	3,0							0,00003	0,00034	0,00275	0,00155	0,00098	0,00079	0,00041	0,00007	0,00036	0,00011	0,00009		0,00004						0,00750
	2,5							0,00029	0,00274	0,00671	0,00247	0,00118	0,00081	0,00056	0,00009	0,00061	0,00027	0,00012	0,00002	0,00006	0,00001	0,00001		0,00001		0,01598
	2,0						0,00012	0,00481	0,00874	0,00839	0,00230	0,00129	0,00083	0,00112	0,00015	0,00051	0,00024	0,00014		0,00008	0,00001	0,00003				0,02877
	1,5					0,00007	0,00419	0,01256	0,00772	0,00575	0,00182	0,00130	0,00123	0,00060	0,00027	0,00033	0,00019	0,00036	0,00007	0,00013	0,00001	0,00004				0,03664
	1,0				0,00006	0,00332	0,00755	0,00879	0,00344	0,00320	0,00142	0,00132	0,00095	0,00057	0,00006	0,00052	0,00034	0,00038	0,00003	0,00008		0,00001				0,03206
	0,5			0,00008	0,00120	0,00357	0,00308	0,00211	0,00089	0,00110	0,00057	0,00058	0,00040	0,00042	0,00010	0,00027	0,00013	0,00009	0,00001							0,01459
	<0,25			0,00001	0,00009	0,00003			0,00002	0,00001	0,00002	0,00001	0,00002					0,00002								0,00022
		0,00000	0,00000	0,00009	0,00135	0,00698	0,01495	0,02858	0,02392	0,02902	0,01121	0,00783	0,00577	0,00419	0,00084	0,00290	0,00153	0,00132	0,00013	0,00043	0,00004	0,00009	0,00000	0,00002	0,00000	0,14120

Vw = 11 - 13 [m/s]		Tp [s]																							
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00000
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5																									0,00000
	9,0																									0,00000
	8,5																									0,00000
	8,0																0,00001									0,00001
	7,5												0,00002													0,00003
Hs [m]	7,0											0,00001														0,00001
	6,5											0,00001	0,00001	0,00001												0,00004
	6,0											0,00002	0,00002	0,00004		0,00002		0,00002								0,00012
	5,5										0,00002	0,00005	0,00009	0,00004		0,00002	0,00001	0,00002								0,00026
	5,0										0,00011	0,00015	0,00011	0,00007	0,00003	0,00004	0,00001	0,00001								0,00054
	4,5									0,00007	0,00023	0,00026	0,00007	0,00017	0,00002	0,00008	0,00006	0,00007		0,00001						0,00105
	4,0									0,00038	0,00045	0,00066	0,00038	0,00025	0,00009	0,00007	0,00009	0,00005	0,00002	0,00002		0,00001				0,00247
	3,5								0,00009	0,00158	0,00158	0,00104	0,00053	0,00046	0,00009	0,00018	0,00008	0,00011								0,00574
	3,0							0,00006	0,00071	0,00572	0,00268	0,00133	0,00081	0,00030	0,00007	0,00027	0,00013	0,00008	0,00001	0,00005	0,00003	0,00001				0,01226
	2,5							0,00054	0,00645	0,00959	0,00202	0,00130	0,00070	0,00049	0,00007	0,00038	0,00012	0,00006		0,00004	0,00001			0,00001		0,02177
	2,0						0,00024	0,00770	0,01053	0,00667	0,00154	0,00082	0,00067	0,00077	0,00007	0,00030	0,00006	0,00016	0,00000	0,00004	0,00002	0,00003		0,00002		0,02968
	1,5					0,00014	0,00415	0,01056	0,00567	0,00269	0,00101	0,00089	0,00080	0,00042	0,00013	0,00037	0,00015	0,00017	0,00002	0,00004	0,00002	0,00001				0,02726
	1,0				0,00004	0,00299	0,00556	0,00516	0,00184	0,00188	0,00081	0,00069	0,00045	0,00030	0,00007	0,00040	0,00017	0,00019	0,00001	0,00002	0,00001					0,02059
	0,5			0,00003	0,00089	0,00241	0,00169	0,00085	0,00039	0,00049	0,00029	0,00018	0,00017	0,00014	0,00003	0,00010	0,00013	0,00002		0,00002						0,00785
	<0,25				0,00001	0,00001					0,00002	0,00003						0,00002								0,00009
		0,00000	0,00000	0,00003	0,00094	0,00554	0,01163	0,02487	0,02569	0,02908	0,01077	0,00744	0,00483	0,00346	0,00066	0,00225	0,00105	0,00098	0,00007	0,00026	0,00010	0,00006	0,00000	0,00003	0,00000	0,12975

Vw = 13 - 15 [m/s]		Tp [s]																							
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00000
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5																									0,00000
	9,0																									0,00000
	8,5																									0,00000
	8,0															0,00001										0,00001
	7,5											0,00001	0,00001													0,00002
Hs [m]	7,0												0,00002	0,00001												0,00003
	6,5											0,00001	0,00002	0,00002	0,00001	0,00001	0,00001									0,00009
	6,0											0,00003	0,00007	0,00012	0,00002	0,00001		0,00004								0,00030
	5,5										0,00004	0,00008	0,00013	0,00022	0,00003	0,00002		0,00002	0,00001	0,00001						0,00056
	5,0										0,00013	0,00030	0,00015	0,00023	0,00004	0,00005	0,00002			0,00002						0,00095
	4,5									0,00013	0,00048	0,00080	0,00035	0,00026	0,00004	0,00018	0,00003	0,00004	0,00001							0,00233
	4,0									0,00083	0,00135	0,00114	0,00058	0,00038	0,00009	0,00013	0,00002	0,00004	0,00001	0,00002						0,00460
	3,5								0,00019	0,00404	0,00311	0,00128	0,00058	0,00036	0,00007	0,00014	0,00010	0,00007	0,00001	0,00004						0,01001
	3,0							0,00002	0,00178	0,00865	0,00239	0,00105	0,00045	0,00027	0,00007	0,00016	0,00007	0,00005		0,00007						0,01502
	2,5							0,00114	0,00801	0,00877	0,00134	0,00058	0,00030	0,00036	0,00004	0,00026	0,00010	0,00004	0,00001		0,00001	0,00001				0,02099
	2,0						0,00032	0,00686	0,00801	0,00408	0,00077	0,00049	0,00041	0,00031	0,00005	0,00023	0,00008	0,00003	0,00002	0,00005	0,00001	0,00003				0,02176
	1,5					0,00013	0,00329	0,00768	0,00287	0,00141	0,00058	0,00044	0,00036	0,00048	0,00004	0,00014	0,00014	0,00007		0,00004	0,00001	0,00001	0,00001			0,01770
	1,0				0,00003	0,00196	0,00329	0,00292	0,00074	0,00076	0,00040	0,00043	0,00026	0,00016	0,00002	0,00010	0,00010	0,00012		0,00001						0,01131
	0,5			0,00002	0,00048	0,00134	0,00072	0,00040	0,00023	0,00016	0,00013	0,00016	0,00004	0,00009		0,00003	0,00006	0,00004								0,00387
	<0,25					0,00002					0,00000	0,00001						0,00001								0,00005
		0,00000	0,00000	0,00002	0,00051	0,00344	0,00762	0,01901	0,02184	0,02883	0,01073	0,00681	0,00375	0,00326	0,00053	0,00148	0,00074	0,00058	0,00009	0,00028	0,00003	0,00006	0,00001	0,00000	0,00000	0,10960

Vw = 15 - 17 [m/s]	Tp [s]																							
Hs [m]	<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
>13,25																									0,00000
13,0																									0,00000
12,5																									0,00000
12,0																									0,00000
11,5																									0,00000
11,0																									0,00000
10,5																									0,00000
10,0																									0,00000
9,5																									0,00000
9,0																									0,00000
8,5													0,00001												0,00001
8,0															0,00002										0,00003
7,5												0,00001			0,00006										0,00008
7,0													0,00003		0,00004										0,00007
6,5											0,00004	0,00003	0,00006	0,00001	0,00004	0,00001									0,00019
6,0										0,00001	0,00013	0,00011	0,00011	0,00002	0,00004	0,00001	0,00002	0,00001							0,00048
5,5										0,00012	0,00024	0,00022	0,00022	0,00003	0,00006	0,00003	0,00004								0,00095
5,0										0,00029	0,00054	0,00045	0,00036	0,00005	0,00014	0,00001			0,00002						0,00187
4,5									0,00036	0,00117	0,00139	0,00043	0,00022	0,00004	0,00020	0,00001	0,00004			0,00001					0,00388
4,0								0,00002	0,00193	0,00280	0,00131	0,00040	0,00024	0,00009	0,00005	0,00004	0,00005	0,00001							0,00696
3,5								0,00032	0,00607	0,00270	0,00082	0,00031	0,00026	0,00004	0,00007	0,00009	0,00001	0,00001	0,00001		0,00003				0,01073
3,0							0,00005	0,00241	0,00833	0,00176	0,00041	0,00018	0,00012	0,00003	0,00011	0,00004	0,00003		0,00004						0,01352
2,5							0,00118	0,00641	0,00525	0,00063	0,00030	0,00022	0,00018	0,00004	0,00009	0,00004	0,00001			0,00001	0,00002		0,00001		0,01440
2,0						0,00029	0,00476	0,00455	0,00183	0,00037	0,00022	0,00019	0,00025	0,00003	0,00010	0,00009	0,00006	0,00001	0,00004	0,00001	0,00003				0,01283
1,5					0,00011	0,00245	0,00406	0,00163	0,00066	0,00018	0,00026	0,00020	0,00019	0,00008	0,00005	0,00006	0,00003	0,00001	0,00004				0,00001		0,01002
1,0				0,00004	0,00119	0,00176	0,00138	0,00036	0,00036	0,00014	0,00013	0,00009	0,00005		0,00002	0,00002	0,00003								0,00557
0,5			0,00001	0,00018	0,00048	0,00036	0,00010	0,00009	0,00007	0,00003	0,00001		0,00003				0,00002								0,00138
<0,25																									0,00000
	0,00000	0,00000	0,00001	0,00021	0,00178	0,00486	0,01152	0,01580	0,02487	0,01020	0,00581	0,00284	0,00233	0,00046	0,00111	0,00045	0,00034	0,00007	0,00016	0,00004	0,00008	0,00000	0,00003	0,00000	0,08296

Vw = 17 - 19 [m/s]	Tp [s]																							
Hs [m]	<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
>13,25																									0,00000
13,0																									0,00000
12,5																									0,00000
12,0																									0,00000
11,5																									0,00000
11,0																									0,00000
10,5																									0,00000
10,0																									0,00000
9,5																									0,00000
9,0																									0,00000
8,5															0,00001										0,00001
8,0													0,00001		0,00003		0,00003								0,00008
7,5												0,00001	0,00001		0,00004	0,00004									0,00010
7,0												0,00004	0,00004	0,00002	0,00002										0,00013
6,5											0,00006	0,00007	0,00013		0,00006	0,00001									0,00034
6,0										0,00003	0,00016	0,00017	0,00022	0,00005	0,00013	0,00002	0,00001	0,00001							0,00082
5,5										0,00016	0,00054	0,00043	0,00041	0,00004	0,00012	0,00004									0,00174
5,0									0,00006	0,00073	0,00111	0,00054	0,00018	0,00002	0,00010	0,00001									0,00275
4,5									0,00081	0,00181	0,00152	0,00033	0,00012	0,00001	0,00006	0,00003	0,00002								0,00471
4,0								0,00005	0,00314	0,00266	0,00095	0,00018	0,00010	0,00005	0,00002	0,00003	0,00002								0,00722
3,5								0,00048	0,00586	0,00160	0,00043	0,00015	0,00013	0,00001	0,00002	0,00006		0,00002	0,00003						0,00880
3,0							0,00009	0,00229	0,00522	0,00081	0,00022	0,00008	0,00009	0,00001	0,00005	0,00009	0,00004		0,00001						0,00899
2,5							0,00090	0,00384	0,00252	0,00022	0,00015	0,00012	0,00010	0,00000	0,00007	0,00002		0,00001	0,00007	0,00001					0,00803
2,0						0,00014	0,00232	0,00210	0,00086	0,00015	0,00008	0,00005	0,00008	0,00003	0,00003	0,00001	0,00003	0,00001	0,00002						0,00592
1,5					0,00003	0,00121	0,00204	0,00061	0,00020	0,00006	0,00012	0,00007	0,00005	0,00001	0,00004	0,00006	0,00001								0,00450
1,0					0,00051	0,00067	0,00038	0,00016	0,00009	0,00002	0,00006	0,00006	0,00001		0,00003										0,00200
0,5			0,00001	0,00006	0,00025	0,00004	0,00003	0,00001			0,00002						0,00001								0,00044
<0,25																									0,00000
	0,00000	0,00000	0,00001	0,00006	0,00078	0,00206	0,00575	0,00955	0,01877	0,00826	0,00542	0,00230	0,00170	0,00028	0,00083	0,00042	0,00017	0,00005	0,00014	0,00001	0,00000	0,00000	0,00000	0,00000	0,05659

Vw = 19 - 21 [m/s]		Tp [s]																							
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5															0,00001										0,00001
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5																									0,00000
	9,0																	0,00003								0,00004
	8,5													0,00002		0,00001	0,00001									0,00004
	8,0												0,00001	0,00001		0,00004		0,00002								0,00009
	7,5												0,00001	0,00003	0,00002	0,00007		0,00001								0,00014
Hs [m]	7,0											0,00005	0,00007	0,00006	0,00002	0,00010	0,00001			0,00001						0,00032
	6,5											0,00008	0,00025	0,00023	0,00001	0,00016	0,00001									0,00075
	6,0										0,00005	0,00037	0,00045	0,00031	0,00005	0,00009	0,00001									0,00132
	5,5										0,00028	0,00094	0,00051	0,00022	0,00002	0,00005	0,00001									0,00203
	5,0									0,00010	0,00144	0,00123	0,00046	0,00012	0,00001	0,00004				0,00001						0,00341
	4,5									0,00112	0,00217	0,00112	0,00017	0,00004	0,00002	0,00003	0,00000	0,00004								0,00470
	4,0								0,00004	0,00284	0,00198	0,00042	0,00013	0,00005	0,00001	0,00003										0,00550
	3,5								0,00052	0,00377	0,00091	0,00014	0,00007	0,00002		0,00002	0,00002					0,00001				0,00549
	3,0							0,00007	0,00125	0,00275	0,00037	0,00009	0,00005	0,00002	0,00002	0,00001	0,00001	0,00002	0,00001							0,00467
	2,5							0,00050	0,00219	0,00131	0,00007	0,00004	0,00003	0,00005		0,00002	0,00001			0,00004						0,00427
	2,0						0,00005	0,00125	0,00081	0,00039	0,00006	0,00004	0,00004	0,00003												0,00268
	1,5					0,00002	0,00055	0,00078	0,00025	0,00013	0,00002	0,00003	0,00002	0,00002	0,00001	0,00001	0,00002									0,00187
	1,0					0,00015	0,00022	0,00009	0,00004		0,00001	0,00003														0,00055
	0,5				0,00003	0,00006	0,00004	0,00001																		0,00014
	<0,25																									0,00000
		0,00000	0,00000	0,00000	0,00003	0,00023	0,00086	0,00271	0,00510	0,01241	0,00737	0,00457	0,00226	0,00123	0,00020	0,00071	0,00014	0,00012	0,00001	0,00006	0,00000	0,00001	0,00000	0,00000	0,00000	0,03802

Vw = 21 - 23 [m/s]		Tp [s]																							
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00000
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5															0,00002										0,00002
	9,0															0,00001	0,00002									0,00004
	8,5													0,00002	0,00001	0,00004	0,00005									0,00012
	8,0												0,00001	0,00002	0,00001	0,00006	0,00003									0,00013
	7,5												0,00005	0,00005	0,00003	0,00005	0,00004		0,00001	0,00001						0,00025
Hs [m]	7,0											0,00005	0,00011	0,00022	0,00003	0,00010	0,00003	0,00001								0,00055
	6,5											0,00020	0,00031	0,00015		0,00009		0,00001								0,00077
	6,0										0,00001	0,00052	0,00038	0,00019	0,00002	0,00004	0,00001									0,00116
	5,5									0,00002	0,00039	0,00092	0,00036	0,00010	0,00003											0,00182
	5,0									0,00010	0,00126	0,00092	0,00015	0,00007		0,00003				0,00001						0,00254
	4,5									0,00073	0,00192	0,00074	0,00005	0,00002	0,00001	0,00001										0,00348
	4,0								0,00005	0,00171	0,00143	0,00023	0,00004	0,00001		0,00003										0,00351
	3,5								0,00042	0,00173	0,00048	0,00007	0,00002													0,00272
	3,0								0,00062	0,00108	0,00014	0,00003	0,00001			0,00002										0,00193
	2,5							0,00023	0,00077	0,00051	0,00004	0,00003	0,00002	0,00001												0,00162
	2,0						0,00007	0,00045	0,00031	0,00013	0,00003			0,00002												0,00102
	1,5					0,00001	0,00019	0,00018	0,00007	0,00004	0,00001	0,00002				0,00002										0,00054
	1,0					0,00005	0,00007	0,00003	0,00001		0,00001		0,00001													0,00019
	0,5																									0,00001
	<0,25																									0,00000
		0,00000	0,00000	0,00000	0,00000	0,00007	0,00034	0,00089	0,00226	0,00606	0,00572	0,00374	0,00152	0,00091	0,00013	0,00052	0,00020	0,00003	0,00002	0,00003	0,00000	0,00000	0,00000	0,00000	0,00000	0,02244

Vw = 23 - 25 [m/s]	Tp [s]																								
Hs [m]	<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
>13,25																									0,00000
13,0																									0,00000
12,5																									0,00000
12,0																									0,00000
11,5																									0,00000
11,0																0,00001									0,00001
10,5															0,00002										0,00002
10,0																0,00001									0,00001
9,5														0,00001	0,00002	0,00002									0,00004
9,0													0,00002	0,00001	0,00001	0,00003									0,00008
8,5													0,00002	0,00001	0,00005	0,00004									0,00012
8,0												0,00007	0,00006	0,00002	0,00005	0,00002	0,00001								0,00023
7,5											0,00002	0,00010	0,00009	0,00002	0,00004	0,00003									0,00031
7,0											0,00009	0,00016	0,00019	0,00001	0,00004	0,00004									0,00053
6,5										0,00000	0,00036	0,00040	0,00008	0,00001	0,00002		0,00002								0,00090
6,0										0,00004	0,00070	0,00024	0,00007	0,00001	0,00003										0,00110
5,5									0,00001	0,00030	0,00087	0,00014	0,00003												0,00136
5,0									0,00009	0,00104	0,00054	0,00004	0,00002						0,00001						0,00175
4,5									0,00050	0,00134	0,00018	0,00001							0,00001						0,00205
4,0								0,00007	0,00099	0,00067	0,00012	0,00000							0,00001						0,00187
3,5								0,00022	0,00085	0,00022	0,00002	0,00001				0,00002	0,00001								0,00135
3,0							0,00000	0,00032	0,00047	0,00007	0,00001	0,00001			0,00001	0,00001									0,00093
2,5							0,00009	0,00040	0,00021	0,00003	0,00001		0,00001												0,00074
2,0						0,00001	0,00010	0,00005	0,00004		0,00001	0,00001			0,00001										0,00025
1,5					0,00001	0,00003	0,00004	0,00001	0,00004																0,00014
1,0					0,00002																				0,00003
0,5																									0,00000
<0,25																									0,00000
	0,00000	0,00000	0,00000	0,00000	0,00003	0,00004	0,00024	0,00107	0,00321	0,00371	0,00294	0,00120	0,00060	0,00012	0,00032	0,00023	0,00005	0,00000	0,00004	0,00000	0,00000	0,00000	0,00000	0,00000	0,01382

Vw = 25 - 27 [m/s]	Tp [s]																								
Hs [m]	<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
>13,25																									0,00000
13,0																									0,00000
12,5																0,00001									0,00001
12,0																									0,00000
11,5																		0,00001							0,00001
11,0																									0,00000
10,5																									0,00000
10,0													0,00001	0,00001		0,00001									0,00004
9,5															0,00003	0,00001	0,00001								0,00005
9,0													0,00003	0,00001	0,00001	0,00001									0,00007
8,5												0,00002	0,00004	0,00002	0,00007	0,00001	0,00001								0,00017
8,0											0,00002	0,00002	0,00013	0,00002	0,00003										0,00023
7,5											0,00004	0,00009	0,00016	0,00001	0,00003		0,00001								0,00035
7,0											0,00018	0,00022	0,00009	0,00001											0,00050
6,5											0,00042	0,00022	0,00009												0,00073
6,0										0,00007	0,00050	0,00017	0,00002	0,00001				0,00001							0,00079
5,5										0,00027	0,00051	0,00004	0,00001												0,00084
5,0									0,00004	0,00056	0,00024	0,00003													0,00089
4,5									0,00024	0,00042	0,00011														0,00078
4,0								0,00002	0,00036	0,00023	0,00001														0,00062
3,5								0,00012	0,00020	0,00004	0,00001	0,00003													0,00040
3,0							0,00002	0,00012	0,00014	0,00002		0,00001													0,00032
2,5							0,00005	0,00012	0,00007	0,00001		0,00001													0,00027
2,0						0,00001	0,00005	0,00004	0,00001																0,00013
1,5						0,00002	0,00001	0,00003				0,00001													0,00007
1,0																									0,00000
0,5																									0,00000
<0,25																									0,00000
	0,00000	0,00000	0,00000	0,00000	0,00000	0,00003	0,00013	0,00045	0,00107	0,00164	0,00205	0,00088	0,00059	0,00009	0,00018	0,00007	0,00004	0,00002	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00727

Vw = 27 - 29 [m/s]		Tp [s]																							
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00001
	11,0																									0,00000
	10,5															0,00002		0,00001	0,00001							0,00004
	10,0														0,00004	0,00000	0,00003	0,00001								0,00008
	9,5														0,00002	0,00004		0,00001								0,00007
	9,0													0,00002	0,00002	0,00001	0,00001									0,00006
	8,5												0,00001	0,00003	0,00003	0,00001										0,00008
	8,0												0,00005	0,00006												0,00012
	7,5											0,00001	0,00009	0,00007												0,00017
Hs [m]	7,0											0,00009	0,00018	0,00005												0,00033
	6,5											0,00028	0,00008	0,00001												0,00038
	6,0										0,00004	0,00033	0,00003	0,00001												0,00042
	5,5										0,00013	0,00027	0,00002	0,00002												0,00045
	5,0									0,00004	0,00016	0,00006														0,00027
	4,5									0,00009	0,00009	0,00004	0,00001													0,00023
	4,0								0,00002	0,00013	0,00008		0,00001													0,00024
	3,5								0,00002	0,00004	0,00001	0,00001				0,00001										0,00009
	3,0							0,00001	0,00003	0,00004	0,00003															0,00011
	2,5								0,00004	0,00003	0,00002															0,00009
	2,0								0,00001								0,00001									0,00002
	1,5																									0,00000
	1,0																									0,00000
	0,5																									0,00000
	<0,25																									0,00000
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00001	0,00012	0,00038	0,00056	0,00112	0,00048	0,00028	0,00011	0,00009	0,00007	0,00004	0,00002	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00326

Vw = 29 - 31 [m/s]		Tp [s]																							
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0															0,00001										0,00001
	11,5																0,00001									0,00001
	11,0															0,00001	0,00003									0,00005
	10,5																									0,00001
	10,0														0,00002	0,00001	0,00001									0,00004
	9,5														0,00002	0,00001										0,00004
	9,0													0,00006	0,00002	0,00001										0,00009
	8,5													0,00005	0,00001											0,00007
	8,0												0,00001	0,00004		0,00001										0,00007
	7,5												0,00005	0,00004												0,00010
Hs [m]	7,0											0,00006	0,00006													0,00013
	6,5											0,00009	0,00001	0,00002												0,00012
	6,0										0,00001	0,00011														0,00013
	5,5										0,00009	0,00011														0,00019
	5,0										0,00004	0,00004														0,00008
	4,5									0,00006	0,00004	0,00001														0,00011
	4,0								0,00001	0,00004	0,00001															0,00006
	3,5									0,00003																0,00004
	3,0								0,00002	0,00001			0,00001													0,00005
	2,5									0,00001																0,00002
	2,0																									0,00000
	1,5																									0,00000
	1,0																									0,00000
	0,5																									0,00000
	<0,25																									0,00000
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00003	0,00016	0,00021	0,00044	0,00015	0,00022	0,00007	0,00008	0,00006	0,00001	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00141

Vw = 31 - 33 [m/s]	Tp [s]																								
Hs [m]	<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
>13,25																									0,00000
13,0																									0,00000
12,5																									0,00000
12,0															0,00001										0,00001
11,5																									0,00000
11,0																									0,00000
10,5																0,00001									0,00001
10,0													0,00001			0,00001									0,00002
9,5															0,00001	0,00001									0,00003
9,0												0,00001		0,00001	0,00001										0,00003
8,5												0,00001	0,00003												0,00004
8,0												0,00003	0,00003												0,00006
7,5											0,00001	0,00002													0,00003
7,0											0,00002			0,00001											0,00003
6,5											0,00001														0,00001
6,0											0,00002														0,00002
5,5											0,00002														0,00003
5,0										0,00002															0,00002
4,5									0,00001																0,00002
4,0																									0,00000
3,5																									0,00000
3,0																									0,00000
2,5										0,00001															0,00002
2,0																									0,00000
1,5																									0,00000
1,0																									0,00000
0,5																									0,00000
<0,25																									0,00000
	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00004	0,00009	0,00009	0,00008	0,00003	0,00004	0,00003	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00041

Vw = 33 - 35 [m/s]	Tp [s]																								
Hs [m]	<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
>13,25																									0,00000
13,0																									0,00000
12,5																									0,00000
12,0																									0,00000
11,5																									0,00000
11,0																	0,00001								0,00001
10,5																									0,00000
10,0																									0,00000
9,5													0,00001												0,00001
9,0													0,00001												0,00001
8,5													0,00001												0,00002
8,0													0,00001												0,00001
7,5																									0,00000
7,0																									0,00000
6,5																									0,00000
6,0											0,00001														0,00001
5,5																									0,00000
5,0																									0,00000
4,5																									0,00000
4,0																									0,00000
3,5																									0,00000
3,0																									0,00000
2,5																									0,00000
2,0																									0,00000
1,5																									0,00000
1,0																									0,00000
0,5																									0,00000
<0,25																									0,00000
	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00002	0,00000	0,00005	0,00000	0,00001	0,00000	0,00001	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00010

Vw = > 35 [m/s]		Tp [s]																							
		<0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22,5	
	>13,25																									0,00000
	13,0																									0,00000
	12,5																									0,00000
	12,0																									0,00000
	11,5																									0,00000
	11,0																									0,00000
	10,5																									0,00000
	10,0																									0,00000
	9,5														0,00001											0,00001
	9,0																									0,00000
	8,5																									0,00000
	8,0																									0,00000
	7,5												0,00001													0,00001
Hs [m]	7,0																									0,00000
	6,5																									0,00000
	6,0																									0,00000
	5,5																									0,00000
	5,0																									0,00000
	4,5																									0,00000
	4,0									0,00001																0,00001
	3,5																									0,00000
	3,0																									0,00000
	2,5																									0,00000
	2,0																									0,00000
	1,5																									0,00000
	1,0																									0,00000
	0,5																									0,00000
	<0,25																									0,00000
		0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00001	0,00000	0,00000	0,00001	0,00000	0,00001	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00004

D. Data sets overview

Table 16: General overview of the used data sets; spatial and temporal resolutions

General overview datasets						
	ERA-5 ECMWF (atmospheric)	ERA-5 ECMWF (waves)	CoastDat-2 WAM (waves)	CoastDat-2 Cosmo (atmosphere)	CoastDat-2 TRIM (currents)	New European Wind Atlas
spatial resolution	0.25° x 0.25°	0.5° x 0.5°	0.05° x 0.05°	0.22° x 0.22°	0.12° x 0.12°	Approx. 0.03° x 0.03°
	approx. 28 km x 28 km	approx. 55 km x 55 km	approx. 5.5 km x 5.5 km	approx. 24.2 km x 24.2 km	approx. 12.8 km x 12.8 km German Bight: 1.6 km x 1.6km (0.014° x 0.014°)	3 km x 3 km (Coverage EU countries + 100 km Offshore)
Grid point available at reference site?	yes	Points in 0.25° lon & 0.25° lat distance	yes	Tilted grid, no point exactly at reference site but in very close proximity	yes	yes
Temporal resolution	Hourly/Monthly	Hourly/Monthly	Hourly	Hourly	Hourly	30 min
Temporal coverage	1979-to present	1979-to present	1949-2014	1948-2012	1948-2015	1989-2018

Table 17: Data availability for atmospheric parameters

Atmospheric Parameter

Used dataset for design basis

Available Data/No Data

	ERA-5 ECMWF (atmospheric)	ERA-5 ECMWF (waves)	CoastDat-2 WAM (waves)	CoastDat-2 Cosmo (atmosphere)	CoastDat-2 TRIM (currents)	New European Wind Atlas
V_w (wind speed at hub height)	Wind data available at 10 m and 100 m height	Wind data available at 10 m height	Wind data available at 10 m height	Wind data available at 10 m height in u/x and v/y direction	Wind data available in 10 m height	Data available height resolved
Turbulence Intensity I	No data	No data	No data	No data	No data	Can be calculated from the available parameters
Wind direction	u and v components of the wind available	u and v components of the wind available	Data available	u and v components of the wind available	u/x and v/y components of the wind available	Data available (height resolved)
Air temperature	Data available at 2 m	No data	No data	Data available at 2 m	No data	Data available (height resolved)

Table 18: Data availability for oceanic parameters

Ocean / Hydrodynamic Parameter						Used dataset for design basis Available data/No data
	ERA-5 ECMWF (atmospheric)	ERA-5 ECMWF (waves)	CoastDat-2 WAM (waves)	CoastDat-2 Cosmo (atmosphere)	CoastDat-2 TRIM (currents)	New European Wind Atlas
Currents	No data	No data	No data	No data	Data available	No data
Waves (H_s)	No data	Data available	Data available	No data	No data	No data
Water density	No data	No data	Data available	No data	No data	No data
Water salinity	No data	No data	No data	No data	No data	No data
Temperature (T_p)	No data	Data available	Data available	No data	No data	No data
Waves (H_{max})	No data	Data available	Data available	No data	No data	No data
Wave spreading/ direction	No data	Data available	Data available	No data	No data	No data
Water temperature	No data	Data available	No data	No data	No data	No data
Water depth	No data	No data	No data	No data	No data	No data
Water levels	No data	No data	No data	No data	Data available	No data
Waves ($H_{s,\,max}$)	No data	Data available	Data available	No data	No data	No data

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