Offshore wind energy deployment in the North Sea by 2030: long-term measurement campaign. LEG, 2014-2022

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- NTF/NPC measurements according to IEC61400-12-2
- Mechanical loads measurements according to IEC61400-13
- Meteorological parameters (windspeed, wind direction, temperature, air pressure, relative humidity) conform to IEC 61400-12-1
- Verificaiton of ground-based or nacelle -mounted Remote Sensing Devices conform to IEC 61400-12-1, Appendix L
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Summary

The Netherlands has set clear ambitions to accelerate the energy transition. By 2050 all energy used in the country shall come from sustainable sources and offshore wind energy plays a vital role in the transition to a carbon-free energy supply. The government has defined a roadmap for the Dutch offshore wind portfolio aiming to add 4.5 GW by 2023 in a first phase, to further expand to 21.5 GW by 2030 . The Netherlands is moving ahead with yearly tendering rounds for upcoming development areas. Recently, the winners of the Hollandse Kust West development zones were announced at the end of 2022, and the most recent IJmuiden Ver tender has commenced in April 2023.

TNO has been performing offshore wind measurement campaigns at strategic locations in the North Sea since 2011 with the installation and data management of both a 100-meter met-mast and a co-located LiDAR situated 75 km west of IJmuiden. From 2014 onwards, TNO has further organized wind measurement campaigns with LiDARs on offshore platforms for the Dutch Ministry of Economic Affairs and Climate Policy. These campaigns are part of the “Wind op Zee” project to support the Dutch wind offshore roadmap. They consist of three longstanding locations: Lichteiland Goeree (LEG), Europlatform (EPL) and Wintershall platform K13a. Since March 15th 2023 a LiDAR has been deployed for wind measurements at a fourth platform, L2-FA-1, located north of the Wadden Islands. TNO is accredited for performing these measurements in accordance with IEC 61400-50-2.

This report refers to the measurement campaign at the LEG platform where a LEOSPHERE WINDCUBE V2 LiDAR has been deployed, providing high quality data since 2014. The data are publicly available to be used for further purposes (www.windopzee.net).

At the LEG platform, the wind analysis for the 2014-2022 period shows that the wind profiles are dominated by the regional climate, mainly by the positive phase effect of North Atlantic Oscillation (NAO). The prevailing wind direction is from the southwest with a mean direction ranging from 234° to 244° across the different sensor heights (62 m to 240 m). The average calculated wind speed ranges from 8.92 m/s at the lowest measured height of 62 m up to 10.21 m/s at 240 m, increasing gradually.

The Weibull distribution, which describes the shape of measured wind frequency distribution and inter-annual variability, shows typical offshore wind shape and scale parameters for the North Sea (k = 2.103 and c = 10.880 m/s at 140 m height). The wind speed frequency distribution is flatter and moderately skewed to the right at higher sensor heights, with more frequent wind speeds greater than 26 m/s.

The resulting assessment of the shear profile shows an annualized range of 0.086 to 0.093 considering the entire data period between matched sequential sensor height pairs of the LiDAR. For the year 2022, the calculated day and night time shear was found to be approximately 0.08.

From February 16th to February 20th 2022, a triplet of storms hit the Netherlands, with the most severe and powerful one being Storm Eunice on February 18th. This storm was registered as the third most severe in the past 50 years. Wind speeds ranged between 25 and 35 m/s. The sustained duration of extreme winds as a result of Storm Eunice dominates the entire top 10 list of recorded extreme timestamps, barring one occurrence in 2018, and two in 2016.

Contents

1 Introduction

The Netherlands has set clear ambitions to accelerate the energy transition. By 2050 all energy used in the country shall come from sustainable sources and offshore wind energy plays a vital role in the transition to a carbon-free energy supply [1].The government has defined a roadmap for the Dutch offshore wind portfolio aiming to add 4.5 GW by 2023 in a first phase, followed by deploying a further 21 GW by 2030 [2].The Netherlands is moving ahead with yearly tendering rounds for upcoming development areas. Recently, the winners of the Hollandse Kust West development zones were announced at the end of 2022, and the most recent IJmuiden Ver tender has commenced in April 2023 [3] [4].

To reach such ambitious realization of operational offshore wind farms in the Dutch part of the North Sea, importance must be given to both spatial planning, and characterization of this precious, valuable and variable resource in order to ensure profitability and an overall sound business case.

One crucial requirement to evaluate the financing of a project is the wind resource assessment (WRAs) of a given site. Therefore, accurate long-term offshore wind measurements allow for improved estimations of WRAs by reducing uncertainties and increasing the financial success of a project. This increases the trust between the interested stakeholders including developers, consultants, the financial community, the government and policymakers. At the same time it allows the selection and identification of strategic locations.

TNO has been performing offshore wind measurement campaigns at strategic locations in the North Sea since 2011 with the installation and data management of both a 100-meter met-mast and a co-located LiDAR situated 75 km west of IJmuiden. From 2014 onwards, TNO has further organized wind measurement campaigns with LiDARs on offshore platforms for the Dutch Ministry of Economic Affairs and Climate Policy. These campaigns are part of the "Wind op Zee" project to support the Dutch wind offshore roadmap. They consist of three longstanding locations: Lichteiland Goeree (LEG), Europlatform (EPL) and Wintershall platform K13a. Since March 15th 2023 a LiDAR has been deployed for wind measurements at a fourth platform, L2-FA-1, located north of the Wadden Islands (**Figure 1**). TNO is accredited for performing these measurements in accordance with IEC 61400-50-2.

This report will focus on the wind conditions characterization of the Lichteiland Goeree (LEG) platform, located about 30 km south-west from the coast of Hoek van Holland.

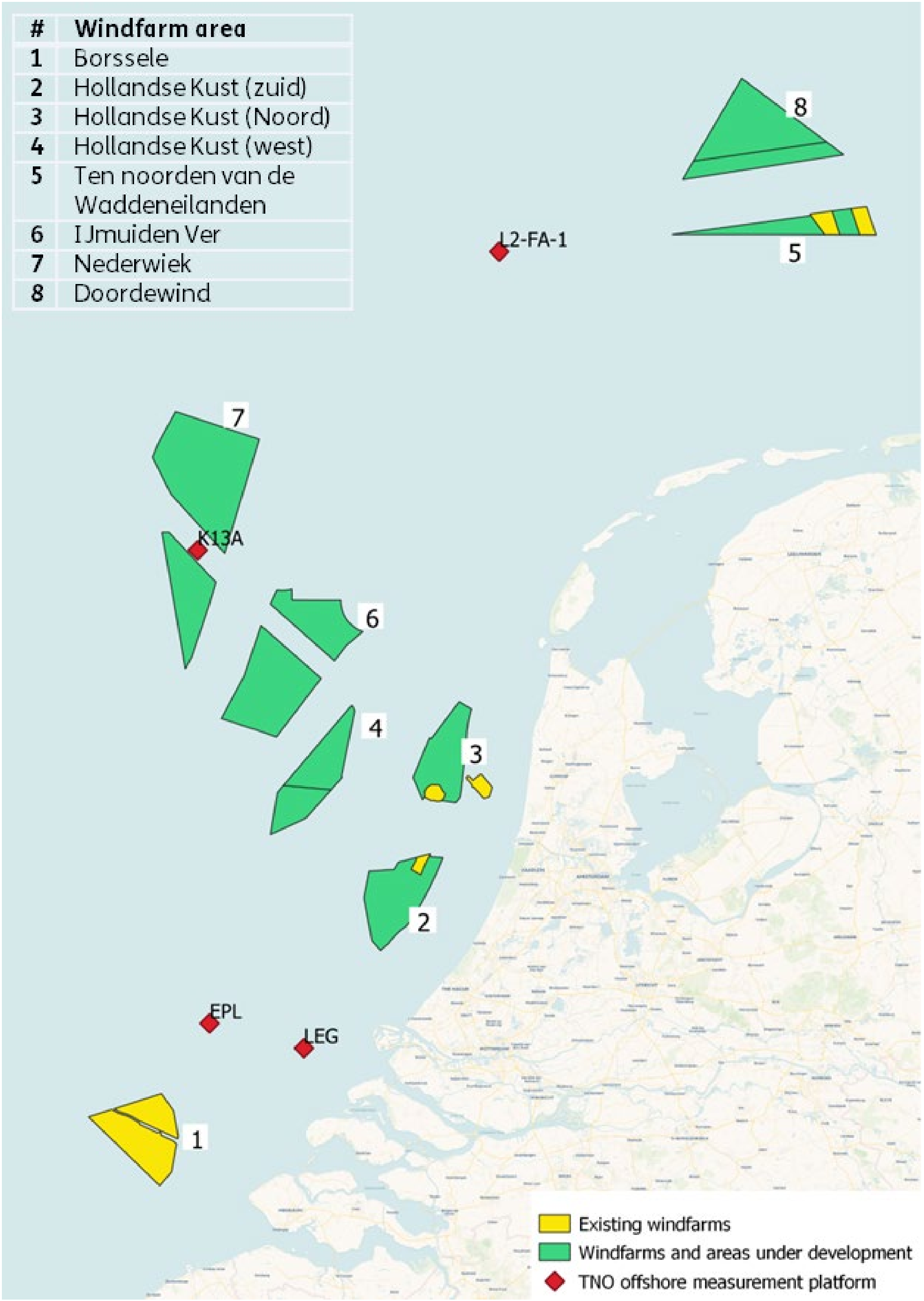

Figure 1:Illustration of TNO long-term offshore wind measurement campaign locations at Lichteiland Goeree (LEG), Europlatform (EPL) and Wintershall platform (K13a), and L2-FA-1, along with wind farm development zones in the Dutch North Sea

2 Wind Measurement Campaigns in the North Sea

2.1 TNO's leading role on offshore measuring campaigns

Before the introduction of LiDARs in offshore wind resource assessments, meteorological masts (met mast) have been widely used at TNO with examples such as the met mast at IJmuiden (MMIJ), and the met mast at the Egmond aan Zee Offshore Wind farm (OWEZ).

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

2.2 Open-access and public datasets

Since 2020 TNO has published annual reports on the wind conditions for the Lichteiland Goeree location (LEG). They are referred to in the Table 1. These reports are available at https://www.windopzee.net/en/. This report includes the specific wind conditions for the period 2014-2022 at the LEG platform. This report has been updated with improved practices for deducing the wind direction, wind veer and wind shear.

Table 1 Publication History of Wind Conditions for LEG

Reference	LEG Wind Conditions Period
[5]	LEG platform for the periods 2014-2019
[6]	LEG platform for the periods 2014-2020
[7]	LEG platform for the periods 2014-2021

The data measured in the “Wind op Zee” project are retrieved and post-processed before making the information publicly accessible through the web-service https://nimbus.windopzee.net/. Post-processed data are reported each month for verification purposes. Users can download the data after free registration.

To use "Wind op Zee" measured data in publications, further research or commercial purposes, users must acknowledge the use of the data as:

1. Citation to the instrumentation report *with the type of data used, location and date*:
   Bergman, G., Verhoef, J.P., Werkhoven E., P.A. van de Werff (2022) Lichteiland Goeree LiDAR measurement campaign; Instrumentation Report 2022, TNO 2022 R10766
2. Citation of this report:
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The publication date at which the data have last been accessed must be indicated along the citations(e.g. *Last accessed April 2023*).

The data is shared in .csv format. In the case of the LEG measurement campaign please adhere to the following information:
- https://www.windopzee.net/en/locations/lichteiland-goeree/
- For monthly files: **LEG-yyyy-mm.CSV**
- After a quarter of a year is completed the monthly files will be replaced by: **LEG-yyyy-Qx.CSV**
- After the year is completed the quarterly files will be replaced by a yearly file as: **LEG-yyyy.CSV.**

3 Measurement campaign at LEG

3.1 Location and instrumentation

The Lichteiland Goeree (LEG) is located about 30 km south-west from the coast of Hoek van Holland (**Figure 1**). Serving as a beacon for ships on the North Sea, it includes a helicopter pad, accommodation deck and a lighthouse (**Figure 2**). The platform is part of the North Sea Monitoring Network consisting of several permanent monitoring locations over the North Sea.

Since its installation in October 2014, the aim is to collect up-to-date meteorological information (including the air pressure, wind speed and direction, air temperature, relative humidity and visibility) as well as oceanographic data (water level, temperature and height). These activities are coordinated by the weather meteorological agency (KNMI) and Rijkswaterstaat, the Dutch Ministry of Infrastructure and the Environment.

Figure 2: Lichteiland Goeree (LEG) platform in March 2022 (left), close up photograph of the lighthouse beacon (right)

TNO has been conducting an ongoing measurement campaign at LEG since 2014, and has accumulated not only important meteorological data, but has also gathered a collection of imagery regarding installation practices, maintenance, replacement, and observations of weather conditions that have occurred at the site. **Figure 3** shows the LiDAR at its location on the platform, after being inspected on February 27th, 2023.

Figure 3: View of LiDAR unit following most recent inspection in February 2023

3.2 Installation plan of instrumentation

The initial phase of a measurement campaign is formed by the evaluation of the platform to place the LiDAR on. This evaluation is described in the installation plan of the instrumentation, which provides a description of how the measurement equipment will be mounted and the agreement with Rijkswaterstaat about the installation and safety measures required [8] [9]. The second phase includes onsite installation, electrical infrastructure and the operational activities (control, maintenance and replacements of the instrumentation, quality control of the measured data). Health and safety aspects are also part of the measurement campaign activities.

To ensure good quality measurements it is crucial to select the right location for the LiDAR on the platform. The description and information regarding the installation at the LEG platform has been recently updated and described in the installation report [10] . At LEG, the suitable place was found beside the cage-ladder on the north-west side of the platform (**Figure 4** a, b). The LiDAR had to be installed in a built mounting frame, oriented with the 'North' marker on the left side, pointing away from the lighthouse, which is aligned to true North (**Figure 4** c, d).

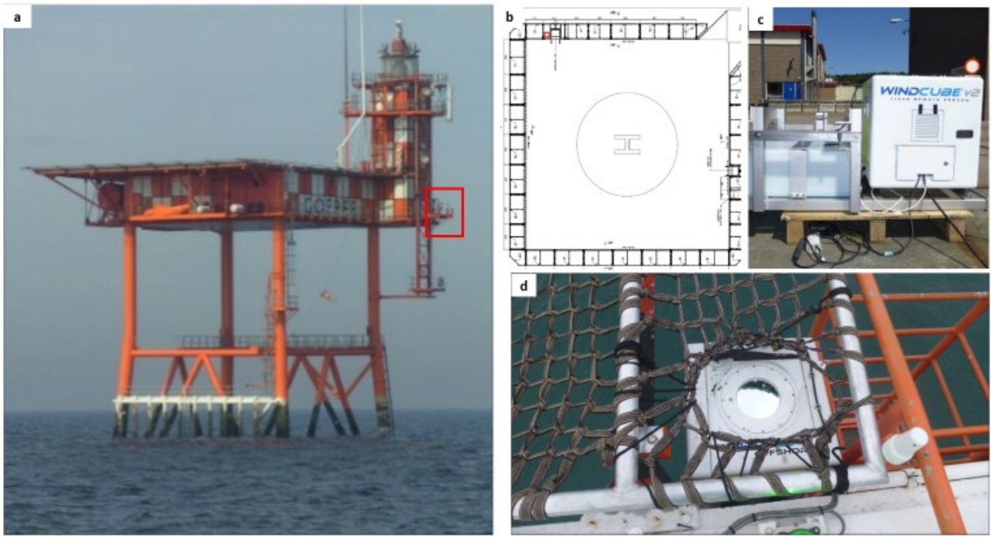


Figure 4: a) Front and b) top view of Lichteiland Goeree platform [LAT LON coordinates: 51.92503°N, 3.66844°E], helicopter deck at a height of 24.58m and the accommodation deck at 20.04m above mean sea level; c) mounting frame to place the LiDAR at the selected location in the platform; d) original installation of the LiDAR

3.3 Onsite installation and operational status

The LiDAR chosen at LEG was the LEOSPHERE WINDCUBE V2. The instrument measures wind profiles up to 10 different heights by sending infrared pulses into the atmosphere (see Annex A for additional LiDAR specifications). Before the LiDAR was installed at the LEG platform it was first calibrated [11] [12] [9]. Manufacturers guarantee data quality up to 200 m although some V2 LiDAR's can measure beyond that height.

The LiDAR was mounted 22 m above Mean Sea Level (MSL) and provides both wind speed and direction measurements at 10 different heights between 62 m and 290 m above MSL. While previous reports based the reference height on the Lowest Low Water Spring level (LLWS), which is 1.03 meter lower than the MLS, the reference heights for the measurements in this report refer to the MSL [10] [13].

The data is timestamped at the start of the 10-minute time frame. This is the same configuration as for the LiDARs at other measurement locations like EPL and K13a platforms. Manufacturers guarantee data quality up to 200 m above the LiDAR although the WINDCUBE can measure beyond that height too. The analysis of the data at highest measurement levels shows the same quality patterns as at the guaranteed heights (see section 3 and 4).

Two different electrical connections are required in order to have the LiDAR fully operational:

- 230V AC power supply connection, provided at the computer room of the platform where the AC-DC power converter of the LiDAR is placed.
- A network connection, as the LiDAR is connected by ethernet cable to a TNO laptop located in the computer room.

As defined by TNO's ISO17025 quality system, the LiDAR should be serviced after one year of operation and replaced every two years (**Table 2**). All operational aspects with respect to installing and maintaining the LiDAR are recorded in a logbook of the team responsible for the measurement campaign.

During 2022, one maintenance activity was performed upon the observation of a low CNR signal following a routine data quality check. The observance and action(s) taken is presented in **Table 3**.

Table 2: Replacements of LiDAR at the LEG platform.

Id LiDAR	LiDAR in operation	Reason of replacement
127	06-10-2014 to 10-04-2015	1st installation, 3g communication switch
258	10-04-2015 to 28-09-2015	Switched from satellite to GSM to improve communications
127	28-09-2015 to 05-10-2017	Periodic replacement
577	05-10-2017 to 24-10-2019	Periodic replacement
258	24-10-2019 to 06-09-2021	Periodic replacement
127	06-09-2021 to present	Present Lidar onsite

Table 3: Down-time periods and actions taken at LEG platform during the year 2022.

Date	Reason
07-09-2022 to 09-09-2022	The LiDAR reported low CNR signals and was inspected on September 9 2022. The lens was cleaned and the CNR signal was restored. The wiper was not working well and was replaced

3.4 Health and safety measures

Health, safety and environment are main priorities at TNO. TNO follows a strict program to train the employees for the measurement campaigns, more detailed information in the Annex A. Additional agreed safety measures with Rijkswaterstaat for the safe installation of the frame and the LiDAR were:

- A job-risk-assessment (AD-130, project RI&E) is made and signed by both parties involved.
- Toolbox meetings among the teams to agree on the alignment of the preparation at the platform.
- TNO employees have valid GWO certificates, proving that they know how to work safely. TNO employees working on the platform will wear fall-arrest systems, helmets and safety shoes.
- TNO employees have valid HUET certificates (Helicopter Underwater Escape Training). Only in case a visit was planned using a helicopter.

4 LiDAR performance assessment at LEG

Remote sensing devices bring many advantages such as ease of transportation, measurement capabilities beyond meteorological mast configurations, etc. However, these devices are exposed to harsh environmental conditions offshore and therefore measurements can be impacted. The performance and quality of the data recorded by LiDARs during a measurement campaign can be impacted by defective or damaged sensors and cables, other system malfunctions, and also by severe meteorological events. All of these events can lower the data availability of the LiDAR. For this reason, the need for continuous quality assurance and control techniques is paramount during the measurement campaign. The measured data is classified into two categories of availability:

- **System availability**, not influenced by meteorological events, independent to the height: internal temperature of the LiDAR, availability and wiper activation count.
- **Signal availability** at different heights; wind speed and direction, horizontal and vertical and the standard deviation of wind and carrier to noise ratio. The heights considered are 62, 90,115,140,165,190,215,240,265 and 290 m, above MSL (Mean Sea Level).

The data is measured on a 10-minute basis. The data collection period started from 17th of November 2014 at 13:00 UTC (Universal Time Coordinates). This report considers the measurement period until the 31st of December 2022 at 23:50 (UTC). The campaign is still ongoing, with future yearly assessments envisioned.

Table 4: List of variables measured in the LiDAR during the experimental campaign. Where LEG is the platform; HXXX are the different heights measured above mean sea level(MSL): 62, 90,115,140,165,190,215,240,265 and 290 m

Acronym	Signal name	Units
LEG_Int_Temp	Internal temperature of the WINDCUBE	°C
LEG_Wiper_count	Wiper activation count	-
LEG_HXXX_CNR	Carrier to noise ratio	dB
LEG_HXXX_CNR_min	Minimum carrier To noise ratio	dB
LEG_HXXX_Data_Avail	Availability	%
LEG_HXXX_DSB	Doppler spectral broadening	Hz
LEG_HXXX_Wd	wind direction (average wind direction)	°
LEG_HXXX_Ws	average wind speed	m/s
LEG_HXXX_Ws_max	maximum wind speed	m/s
LEG_HXXX_Ws_min	minimum wind speed	m/s
LEG_HXXX_WsDisp	Wind speed dispersion (standard deviation wind speed)	m/s
LEG_HXXX_Z-Ws	Z-Wind	m/s

Data over the whole period of the measurement campaign has been analysed in previous reports. The data availability depends on the height of the measurements, and manufacturers will typically suggest usage of the LiDAR up to a certain height. As indicated in **Table 5** and **Figure 5**, the data available for heights up to 215 m is on average above 84%, while further up to 265 m the availability decreases to 67%, and to 58% at the 290 m height. The decrease in data availability and coverage with increasing measurement height is mainly due to the lower concentration of aerosols in the air, which implies that there are less moving particles that the device can detect at those heights.

During the years 2017 and 2018, the two highest sensor levels showed invalid data. The analysis of the data availability are based on the available measurements periods. Therefore, the percentage of data availability in **Table 5** are biased by incomplete years along with LiDAR system replacements or downtime periods. Please note that the measurements started in November 2014, and data was not available from May to August in 2015.

In conclusion for this report, heights above 240 m are not considered for further analysis due to low data availability. Additionally to the data availability, there is degradation present as function of height. From **Figure 5** it is noticeable that the signals have a tendency to reduce their data availability along the time of operation.

Higher monthly data availability is shown by the system when it has been newly installed, as seen in the periods of October-March 2015, September 2017 and October 2019. Similar behaviour seems to be present over the period of October to December 2021, and following the wiper replacement in September 2022. This leads to a conclusion that the signals suffer degradation over time, providing lower data availability in the end of its operational period. This effect is more prevalent at higher heights. This performance could be improved by a more regular maintenance, cleaning and by regularly replacing the wiper system.

Table 5: Data measured availability (in %) by height and by year. Data >90% available in green, <90% in yellow and in red if data is not available.

Year	H 62 (%)	H 90 (%)	H 115 (%)	H 140 (%)	H 165 (%)	H190 (%)	H 215 (%)	H 240 (%)	H 265 (%)	H290 (%)
2014	99.9	99.9	99.9	99.4	97.9	95.9	92.4	85.9	76.3	64.6
2015	99.2	99.2	98.7	97.9	96.7	94.1	89.1	80.7	69.9	59.0
2016	96.4	97.1	97.3	96.0	93.2	88.2	80.7	71.0	59.2	47.5
2017	91.9	92.3	92.4	90.6	86.9	80.9	73.0	64.0	35.7	26.4
2018	97.4	96.4	96.1	94.7	91.8	86.7	79.6	70.7	NA	NA
2019	96.8	95.7	95.4	94.1	91.3	86.1	76.9	64.4	74.3	62.3
2020	99.9	99.9	99.9	99.7	96.8	93.6	87.0	76.6	63.8	71.7
2021	97.1	97.0	96.7	96.0	94.3	91.1	85.7	77.8	68.0	58.5
2022	99.2	98.8	98.4	97.9	97.2	96.5	95.1	92.7	89.0	85.7

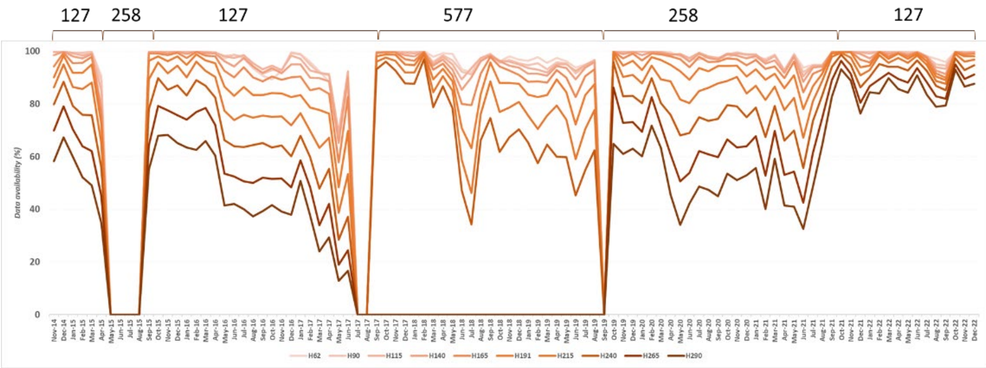


Figure 5: Monthly averages of the data available (fraction based) measured by the LEOSPHERE WINDCUBE V2 LiDAR by height at the LEG platform for the period 2014-2022 and Id of the LiDAR during the operational period.

During the measurement campaign, data verification is performed at different levels with quality checks carried out on a daily basis, using *daily plots* (see example in Annex A). Lead engineers check the signals for deviations of or failures to be able to react on a short notice. During these checks, no data filtering is applied on the data availability. As mentioned before, data availability refers to the number of valid data readings within an interval of 10 minutes.

There are complementary reports with data verification comparing with other measurements. In particular, [14] examines the wind speed and direction measurements campaigns at eight offshore measurement locations distributed throughout the North Sea, including the LEG platform. The study focuses on comparing the wind shear and veer from 2012 to the first quarter of 2018 with the aim of better understanding the wind conditions over the North Sea. The analysis is also a part of the data verification.

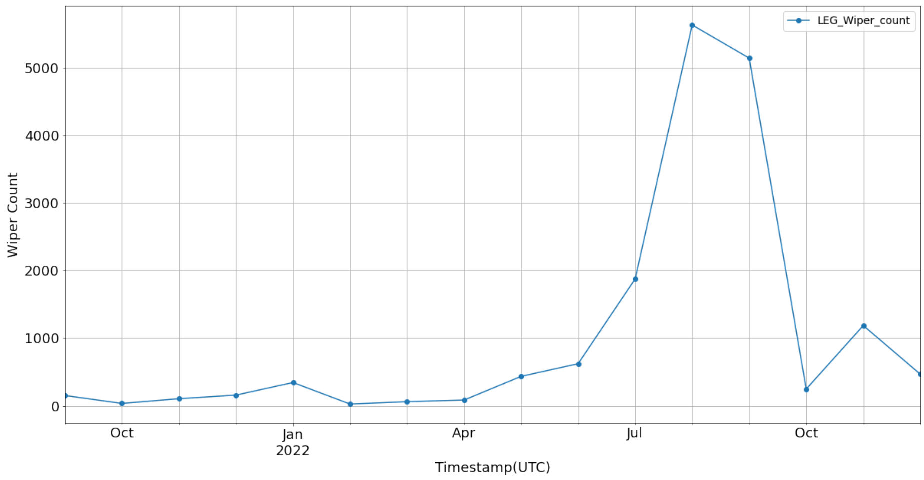


Figure 6 presents the monthly sum of the wiper count signal, an indicator of reduced data availability and **Figure 7** shows the monthly average Carrier to Noise Ratio (CNR), an indicator of the signal to noise ratio. When the CNR measures < -23, the signal to noise ratio is considered too low and the data point is flagged with a “NaN”.

A sharp increase in the wiper count is observed, along with a decrease in the CNR ratio, leading to reduced availability starting from July 2022 to September 2022. The LiDAR lens was then cleaned and the wiper replaced in shortly after upon an inspection visit to the platform, leading to a recovery of availability for the end of the year, as shown in **Figure 7** and in Table 5. Over the period, the CNR improves after inspection and maintenance.

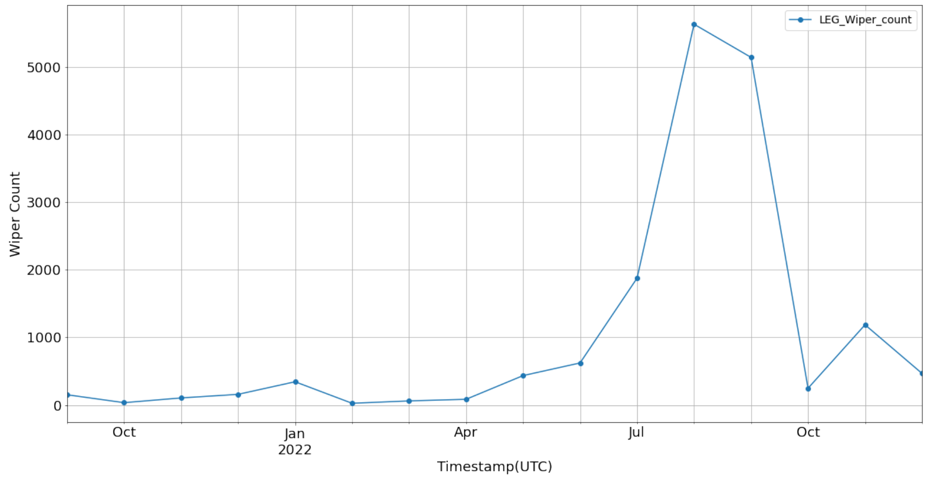


Figure 6: Monthly Wiper Count over one LIDAR system measurement period

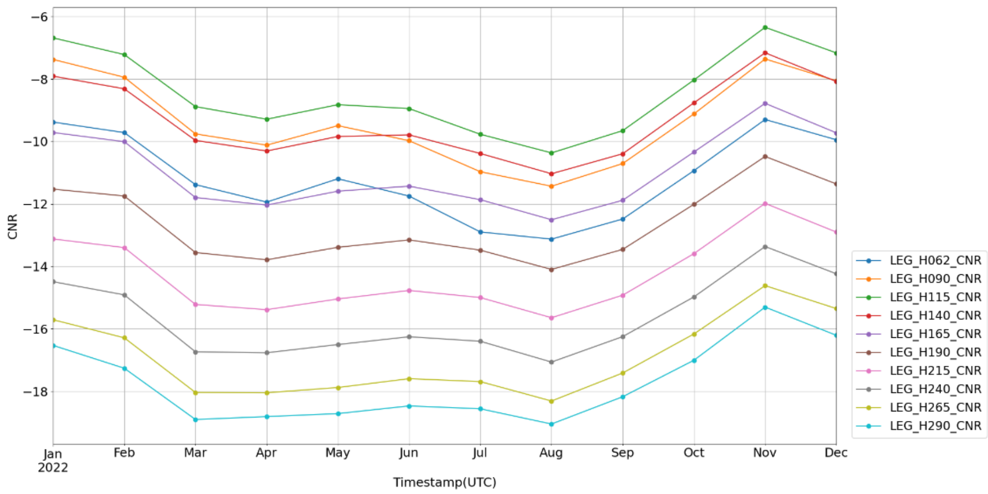


Figure 7: Monthly CNR over one LiDAR system measurement period

5 Wind conditions at LEG

This section presents the results following an assessment of the weather conditions during the measurement campaign at the LEG platform for the entire period of 2014-2022. The main meteorological characteristics are presented in the form of dominant wind directions and wind speed distributions for different heights; temporal variation and the descriptive statistics. Shear and veer were also assessed for different sensor heights. A complementary analysis on the annual and monthly weather conditions at LEG is included in Annex B.

5.1 Weather conditions during the period 2014-2022

Numerous oceanic effects influence the wind conditions on the North Sea including the large-scale atmospheric circulation North Atlantic Oscillation (NAO), the North Atlantic low pressure systems, and the tides. Continental effects in the form of freshwater discharge, heat flow, and input of pollutants can also effect ocean conditions, and further highlight how delicate and interconnected the climate system really is.

The atmosphere mainly controls the general circulation of the North Sea via heat fluxes and their variability. The dominant effect is the positive phase of NAO, which is characterized with higher air temperatures and stronger westerly winds over the North Sea. This induces both higher water temperatures and sea levels. A thermal stratification is generated in the northern and central parts during early summer and remains until early autumn, when stronger winds mix the water again [15] [16].

At the LEG platform, the weather analysis for 2014-2022 shows that the wind profiles are dominated by the effects of the positive NAO.

The calculated mean of monthly mean (MoMM) wind speed ranges from 8.92 m/s at the lowest measured height of 62 m up to 10.21 m/s at 240 m, increasing gradually. The wind direction was calculated considering the average unit wind direction vector. The dominant direction is from the southwest, measuring between 234° at 62 m to 244° degrees at 240 m (**Table 6**). The wind roses presented in **Figure 8** clearly show the dominant wind direction sector for all the heights from the southwest and also that wind speeds with higher intensities (mean wind speeds above 22 m/s) are observed a higher sensor heights.

Table 6: Average wind speed (Ws) and direction (Wd) at different heights for the 2014-2022 period at the LEG platform.

H (m)	62	90	115	140	165	190	215	240
Ws – Min	0.06	0.06	0.05	0.01	0.04	0.04	0.04	0.04
Ws – Mean (MoMM)	8.92	9.24	9.45	9.63	9.79	9.94	10.08	10.21
Ws - Max	33.02	34.38	35.23	36.08	82.61	37.5	37.91	38.27
Wd - Mean	234.5	235.6	236.3	237.3	238.5	239.8	241.4	243.9

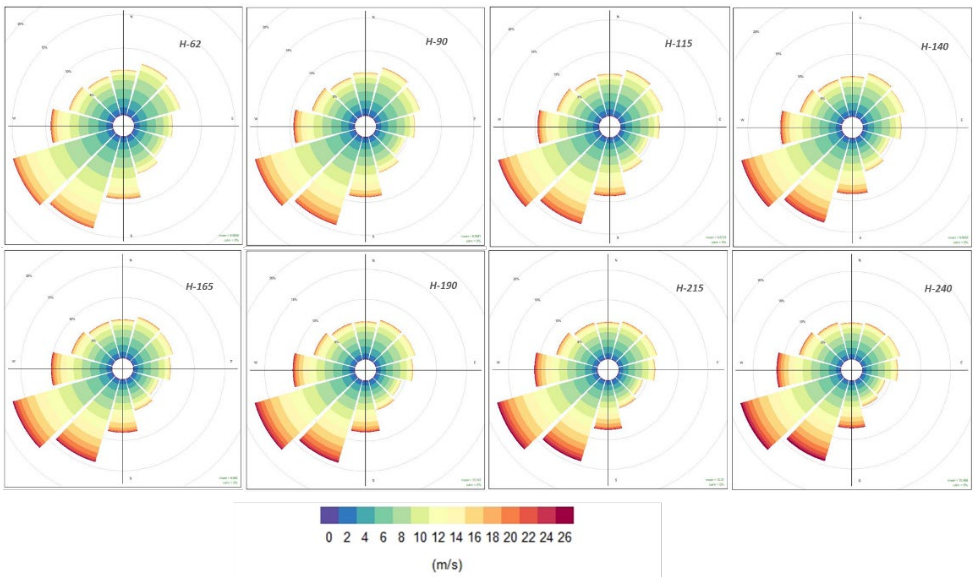


Figure 8: Wind roses at different heights showing the wind prevailing direction for the 2014 - 2022 period.

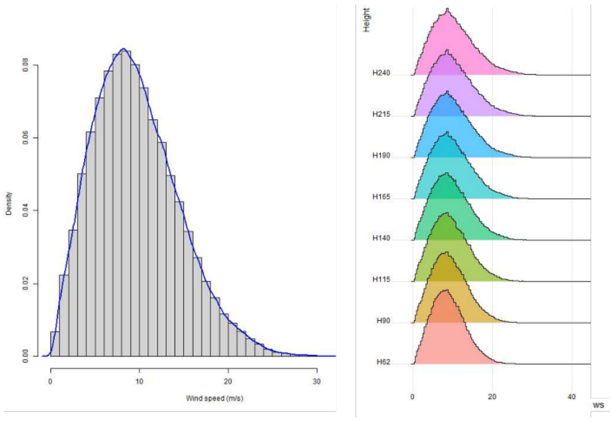
Wind regime frequency distributions and the intra-annual variability typically represented by the Weibull probability density function. This two-parameter relationship between probability of occurrence for a given wind speed v (in m/s), shape dimensionless parameter, k, and scale parameter, c (in m/s) is expressed by the following formula:

$$f(v;k,c) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1}\exp\left[-\left(\frac{v}{c}\right)^{k}\right] \text{ for v >0 and k, c >0} \qquad (1)$$

The shape parameter (as implied from its name) provides information on the overall shape of the Weibull distribution and is inversely proportional to wind variability. This implies that a large k value indicates less wind variability. The scale parameter is proportional to the average of the wind speed of the distribution and therefore also increases with height.

Over the period 2014-2022 at LEG, the best approximation of the Weibull function at 140 m height yields a shape parameter of 2.103 and a scale parameter of 10.880 m/s (see the table of **Figure 9**). Due to the impact of seasonality on the results, the years 2014 and 2015 were excluded due to incomplete years caused by the start of the campaign or to poor overall availability over months. **Figure 9** (left) shows the wind speed frequency distribution, and the Weibull probability density function fitted over the distribution.

The **Figure 9** (centre) indicates the distribution of the wind speed for each measurement height and it shows how the distribution is flatter and skewed right when increasing in sensor height, as reflected by the height specific shape and scale parameters presented in **Figure 9** (table). A reduction in the shape parameter implies less variability, while the increase in scale parameter indicates higher wind speeds, as expected. Typical shape parameters of approximately 2 are representative of the wind conditions of the Dutch North Sea.



Height (m)	Shape (k)	Scale (c)
62	2.220	10.078
90	2.174	10.438
115	2.134	10.673
140	2.103	10.880
165	2.078	11.071
190	2.060	11.249
215	2.046	11.425
240	2.040	11.598

Figure 9: Frequency distribution and Weibull curve fitting at 140 m height (left), frequency distributions at different heights for the measurement campaign (centre) with k and c parameters (table) at LEG for 2014-2022. **Note:** The years 2014, and 2015 were excluded due to incomplete years caused by the start of the campaign or to poor overall availability.

The **Figure 10** presents the seasonal variation on both annual and diurnal cycle at different sensor heights. The data was filtered by removing timestamps that had a CNR larger than 0, indicating foggy conditions for both wind speed and wind direction. Furthermore timestamps with a wind speed of less that 3m/s were also excluded from the wind direction data considered. Then, the wind speed and wind direction timeseries of each height were matched together to established a common data period across all heights due to the reduction in availability observed at this location with height. The data were then grouped and averaged to the required period (hourly, monthly). The wind direction was calculated considering the average unit wind direction vector.

On an annual cycle, there is a decrease in the mean monthly wind speed of approximately 6 m/s from winter to summer months, due to the change in temperatures over the sea surfaces along the year. The seasonal changes of the wind resource are mainly dominated by the heat flux and by vertical mixing caused by the lower-atmosphere and land energy balance. The wind direction is quite consistent at approximately 225 - 300 degrees year round, except for the month of April and May, where the winds predominantly come from the north, and May where the wind arrive from the north.

Considering the diurnal cycle at the LEG platform, the offshore wind speeds vary within margins of about 1.0 m/s on and of approximately 20 degrees in wind direction depending on height. The average wind direction is noticeably higher in the afternoon hours of the diurnal cycle, and more consistent among heights that in the evening and morning hours.

The wind conditions analysed in this report are in line with the assessment presented in [17], [14]. Such studies present additional description over the temporal variability of horizontal and vertical wind profiles at different offshore locations over the Dutch North Sea.

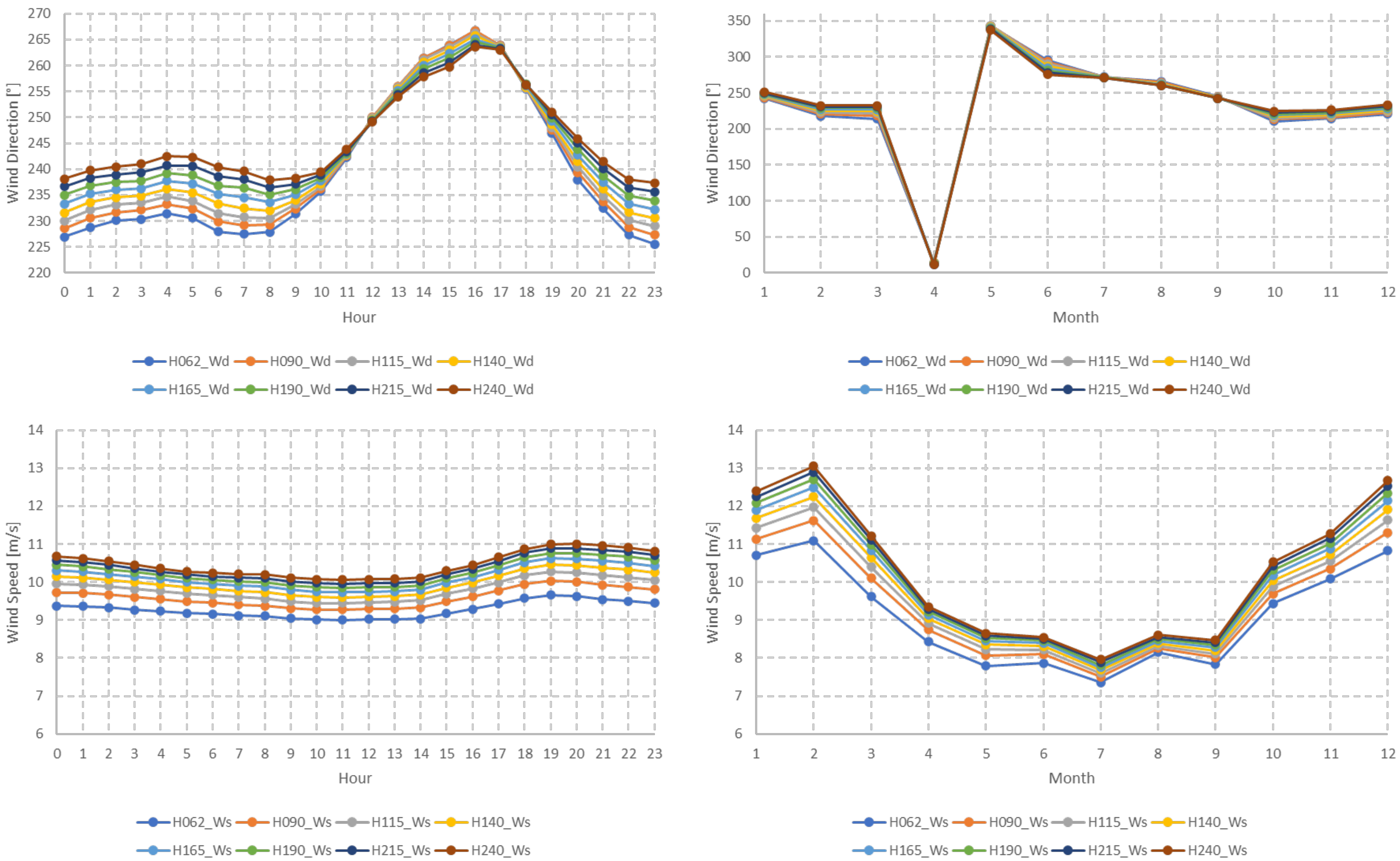


Figure 10: Matched and filtered wind speed and direction monthly averages (right) and average daily cycles (left) at different heights for the 2014-2022 period.

5.2 Annual wind statistics

In regards to the wind regimes and intra-annual variability; **Figure 11** presents the annual Weibull distribution shape and scale parameters at all heights for each successive year to present The c parameter was very similar each year, with observed outliers being 2014 and 2015 where only few months of measurements were available. Data from the year 2022 show a lower mean wind speeds compared to others, with lower values compared to the windiest years of 2020 and 2017. The latter was limited in data availability in particular during the summer months where the wind speed tends to be lower. For the shape parameter, which is inversely proportional to wind variability, the year 2022 shows lower values, meaning higher wind availability compared to the year 2020. Again, the years 2014, 2015 and 2017 show very high values due to lower data availability.

The annual measured frequency distributions at different heights are shown for 2022 **Figure 12**, with previous years presented in Annex B. Annual statistics are further provided in **Table 7**. These statistics are influenced by the available months of data, and do not account for seasonality.

Assessing temporal evolution, **Figure 13** shows the monthly averaged wind speeds for each individual year. Months with no data represents the period of LiDAR replacements. Monthly trends are in line with expectations - the months with highest wind speeds occurred in winter periods. The year 2022 is characterized as mentioned above by lower wind speed in the winter months of December and January, compared to the previous years, and with exceptionally higher wind speeds in November and February. The lowest wind speeds in 2022 were registered in summer in July, and were below most summer months compared to other years. Annex B includes additional annual wind analysis and statistics for the LEG platform.

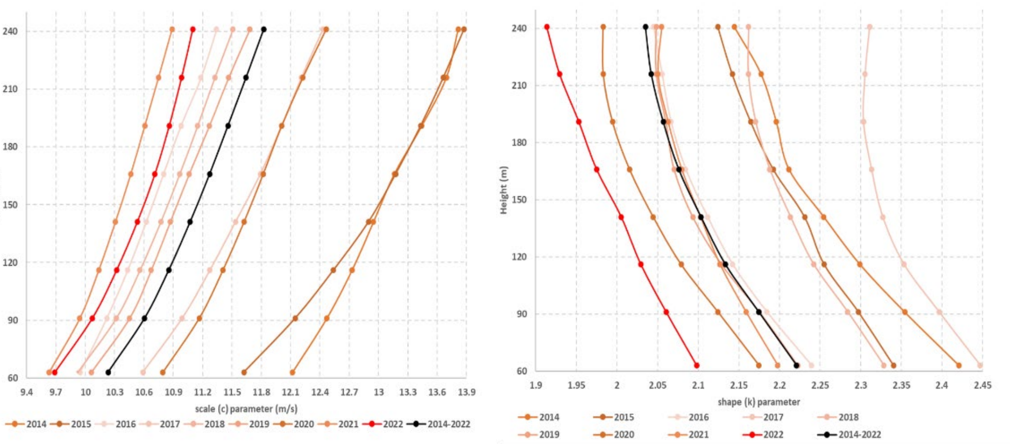


Figure 11: Annual Weibull (left) scale and (right) shape parameters at different heights at the LEG platform from 2014 to 2022.

Table 7: Descriptive annual statistics of the wind speed (Ws) and wind direction (Wd) at 140 m height at the LEG platform.

H140 (m)	2015	2016	2017	2018	2019	2020	2021	2022
Ws (m/s)- Min	0.26	0.30	0.14	0.18	0.20	020	0.09	0.01
Ws (m/s)– 1st q	7.23	5.93	6.75	6.22	6.19	6.21	5.73	5.66
Ws (m/s)-Median	10.87	8.88	9.88	9.16	9.01	9.79	8.65	8.65
Ws (m/s)- Mean	11.42	9.404	10.23	9.547	9.62	10.30	9.13	9.327
Ws (m/s)- 3rd q	15.28	12.35	13.36	12.52	12.51	13.74	11.95	12.32
Ws (m/s)– Max	29.48	34.74	30.9	36.08	28.89	30.37	29.74	34.99
Wd (°)- Mean	216.6	236.5	253.4	222.7	237.4	230.5	270.6	236.3

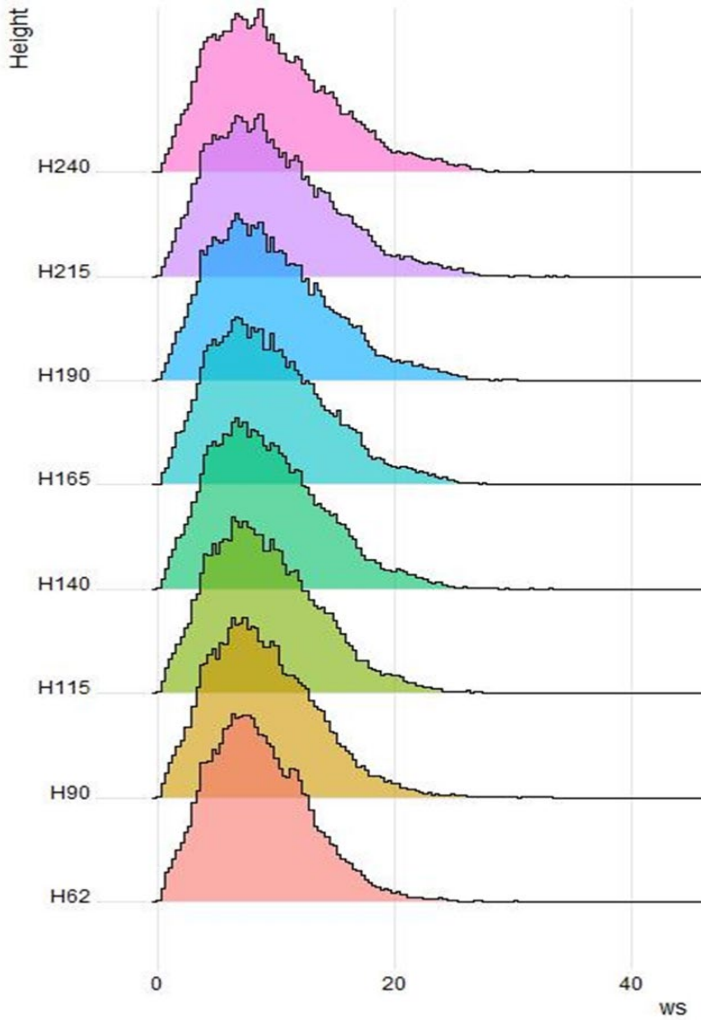


Figure 12: Annual frequency distribution derived for different sensor heights for the year 2022.

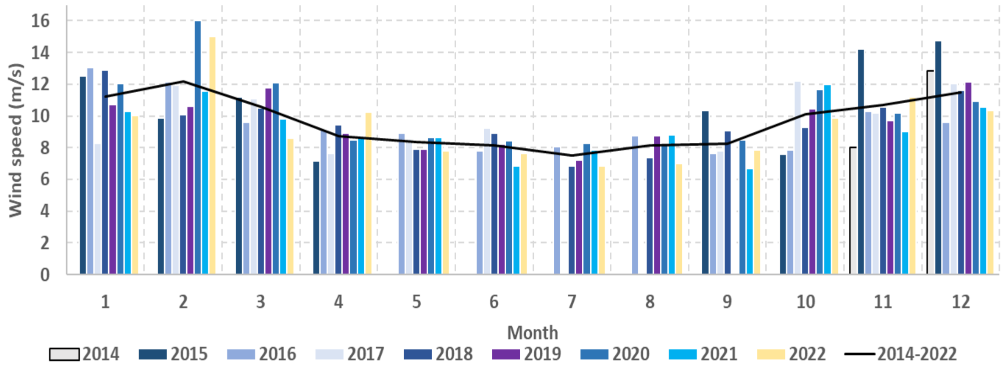


Figure 13: Annual wind speed (m/s) monthly averages bars at 140 m height and 2014-2022 monthly average (black line). **Note:** Measurements started in November 2014; in 2015 data was not available from May to August.

5.3 Analysis of wind shear and veer

Wind shear is described as the variations of wind speed with respect to height, and it is an important characteristic of the wind resource since it impacts the assessment of wind speeds from measurement heights to the proposed hub heights wind turbine technologies. Furthermore, as wind turbines are designed to operate at taller hub heights and with larger rotor blades, the impact of shear on both energy production and loading needs to be accounted for in the design process.

Wind shear can be described by the power law. This function relates the ratio of wind speeds, V_o and V_h, between their respective heights, H_o and H_h, by the shear exponent, α, as expressed below:

$$\left(\frac{V_h}{V_o}\right) = \left(\frac{H_h}{H_o}\right)^{\alpha} \qquad (2)$$

LiDAR measurement data is programable to collect wind speed data at many more heights compared to standard meteorological measurement towers, and thus important insights into the shear profile between different levels can be acquired. The data was first filtered by removing timestamps that had a CNR larger than 0. Then, data between consecutive pairs were matched to established a common data period, adjusting for availability of both timeseries. The wind speeds were then grouped and aggregated over different periods (hourly, monthly, yearly), and finally the shear exponent was calculated using Equation 2 on the average values of the chosen period.

Table 8 shows the sensor pairs and the resulting matched annualized shear value over the entire data period (based on the wind speed mean of monthly means). Here the matched annualized shear exponent regardless of direction are quite consistent, ranging from 0.086 to 0.093.

Figure 14 shows the directional shear profile for different sensor height pairings for the entire data period of 2014 to 2022. The variation of shear exponent by direction is noticeable, ranging from 0.15 from southwest direction to negative shear in the north eastern and south eastern directions. Shear exponents are tightly bound and consistent from the south to north western directions, which are in line with the prevailing wind regime for the site. Larger variations in shear are seen from the north east to the south east, with higher sensor pairs demonstrating negative shear, hence a reduction of wind speed with height.

Shear can be observed on a monthly and hourly basis. **Figure 15** presents these variations for each sensor level pairing. It can be seen that shear is highest in the evening and night-time hours of the day, and during the morning and afternoon hours. Shear exponents were higher over the winter months, while lower in the summer months.

Figure 16 presents the extrapolated shear exponent considering only the data for the year 2022, distinguishing between daytime and night-time hours. During the night we can observe slightly higher shear exponents and wind speeds.

Table 8: Annualized shear exponent for different sensor height pairings at LEG

Shear Pairing	Shear exponent
62 m to 90 m	0.093
90 m to 115 m	0.089
115 m to 140 m	0.090
140 m to 165 m	0.092
165 m to 190 m	0.089
190 m to 215 m	0.087
215 m to 240 m	0.086

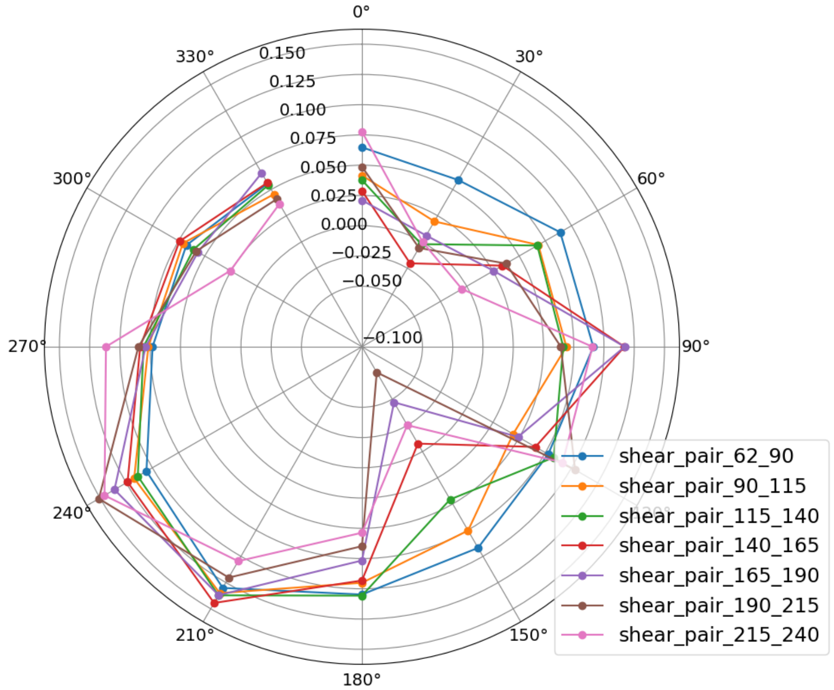


Figure 14: Directional shear profile trends for LiDAR sensor pairings for the entire data period 2014-2022

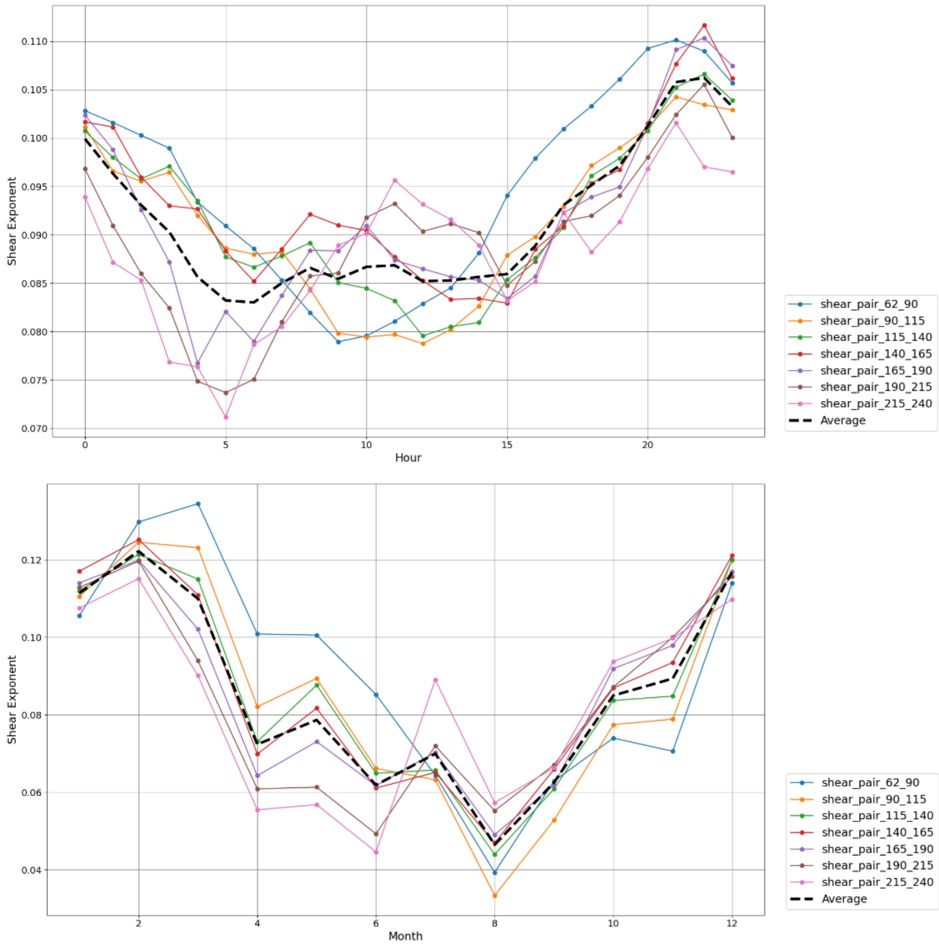


Figure 15: Shear profiles for LiDAR sensor pairs showing diurnal (top) and annual (bottom) trends for the data period of 2014 to 2022

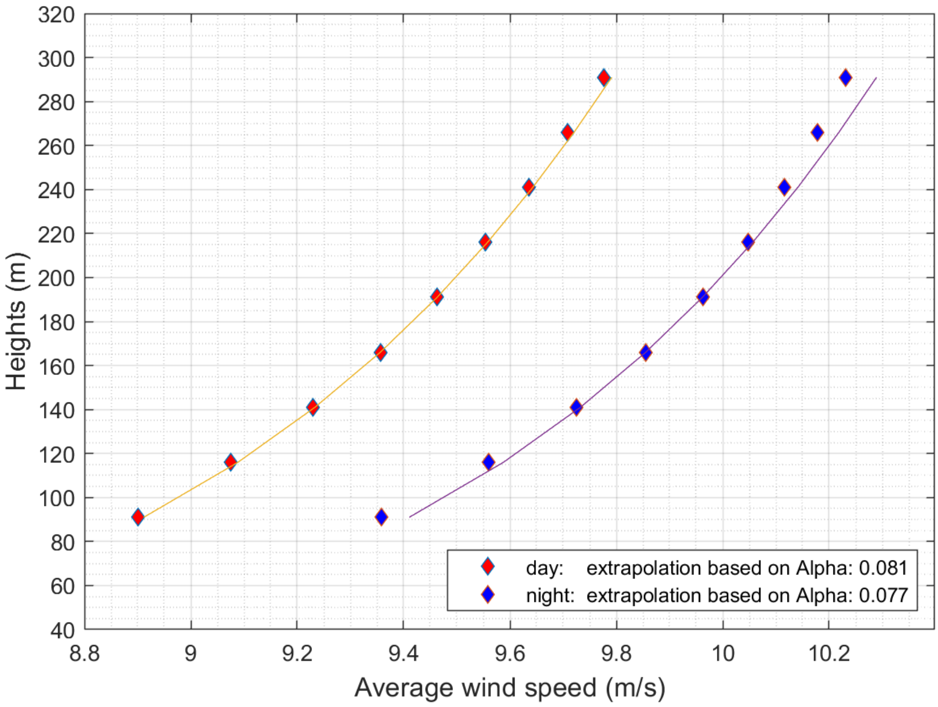


Figure 16: Day and night shear profiles for the year 2022

Wind Veer is the variation in wind direction with height, which is also an important atmospheric input and phenomenon that can impact the overall performance and loading of wind farms. Wind turbines have yaw based controls that allow them to align into the oncoming wind direction. Wind veer can lead to misalignments in the flow along the blades, and could lead to underperformance if the blade rotation is opposing the wind direction at higher heights. Positive values indicate a clockwise direction difference, also known as “veering”, as opposed to negative values that would indicate counter-clockwise direction known as “backing”. An analysis on the wind veer pattern has been conducted, and is summarized in the following figures.

The data was filtered by removing timestamps that had a CNR larger than 0, indicating foggy conditions. Timestamps with a wind speed of less than 3 m/s were also excluded. Then the timeseries of each height were matched together to established a common data period across all heights due to the reduction in availability observed at this location with height up to 240 m. The unit vector wind direction data were then grouped and averaged to the required period (hourly, and monthly), and finally the veer between consecutive heights was calculated.

Figure 17 shows the matched and filtered average wind direction for all sensor heights at LEG considered only over year 2022. At the lowest measured height of 62 m, the matched and filtered average wind direction was calculated to be approximately 240 degrees, while at the highest sensor height of 240 m the average wind direction was found to be approximately 245 degrees. That results in a difference of approximately 5 degrees between these levels. The figure demonstrates an average clockwise increase in wind direction (hence veering) with height.

Figure 18 presents the annual and diurnal variations in veer of the average wind direction over the entire matched and filtered data period considered. Here, it can be seen that the average wind direction changes throughout the hours of the day by approximately 2 degrees, and even backing over the afternoon hours. Trends among the height pairs are consistent to each other. Over the months, veer varies mostly between +3 to – 3 degrees, the largest veer coming in the month of March to June.

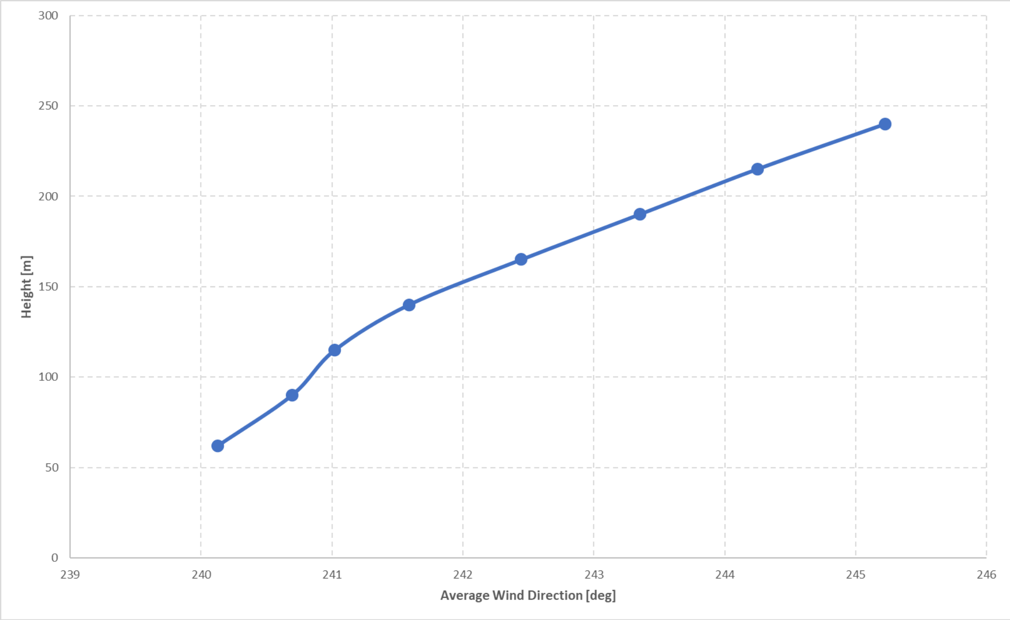


Figure 17: Variations in the matched and filtered average wind direction for different sensor heights over the year 2022

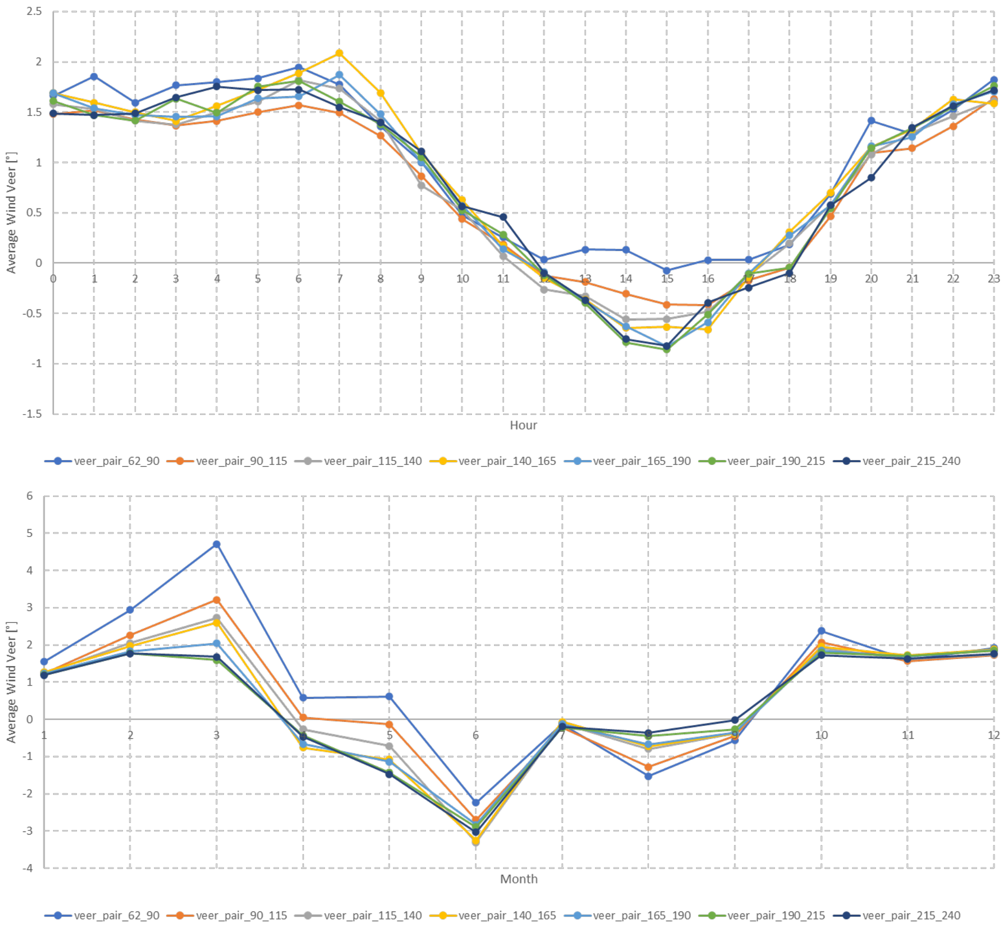


Figure 18: Matched and filtered veer profiles for LiDAR sensor pairs showing diurnal (top) and annual (bottom), trends for the data period of 2014 to 2022

5.4 Past extreme weather events

Building on the analysis of the wind measurements from 2022 presented in this report, it is noticeable that 2022 was characterized by similar wind speed trends as 2021 along most of the year.

However one noticeable exception is February 2022, over which higher wind speeds were observed and are similar to the year 2020. From February 16th to February 20th 2022, a triplet of storms hit the Netherlands, with the most severe and powerful one being Storm Eunice on February 18th. This storm, for which a code orange was issued for most of the Netherlands, was registered as the third most severe in the past 50 years [18]. **Figure 19** shows the time series for the wind speed at the 140 m sensor height, where wind speeds ranged between 25 and 35 m/s. This is also more visually represented in the wind rose and frequency distribution for that particular time period. The sustained duration of extreme winds as a result of Storm Eunice are further highlighted in the **Table 9**, as it dominates the entire top 10 list of recorded extreme timestamps at 140 m height, barring one occurrence in 2018, and two in 2016.

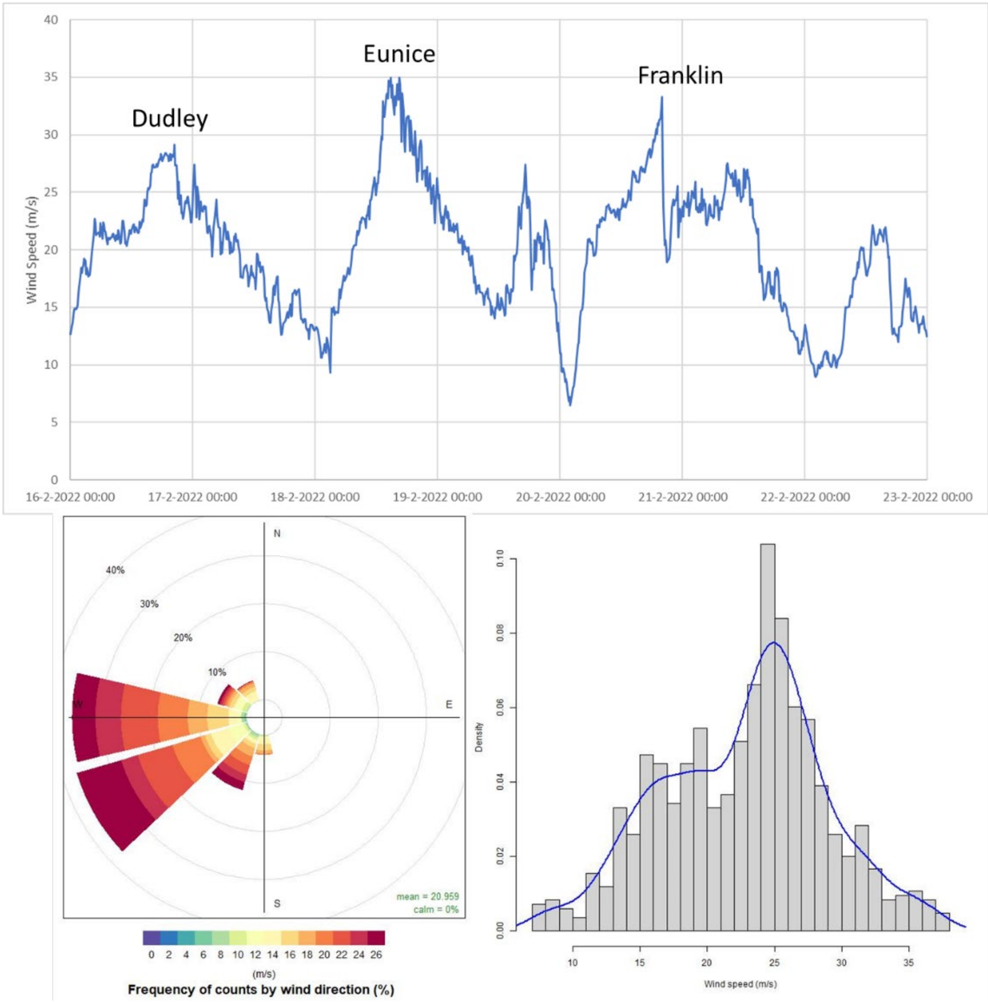


Figure 19: 10-minute wind speed timeseries (top), wind rose (bottom-left), and frequency distribution (bottom-right) measured by the LiDAR at 140 m at the LEG platform during the triplet of storms Dudley, Eunice and Franklin in February 2022

Table 9: Top 10 windiest 10-minute averaged recorded timestamps at 140 m height at LEG from 2014-2022

Rank	Timestamp	Wind Speed Recorded [m/s]
1	18-1-2018 08:00	36.08
2	18-2-2022 14:50	34.99
3	18-2-2022 16:30	34.95
4	20-11-2016 10:20	34.74
5	18-2-2022 14:30	34.74
6	18-2-2022 16:10	34.41
7	18-2-2022 16:40	34.41
8	18-2-2022 15:10	34.35
9	18-2-2022 14:40	34.21
10	20-11-2016 10:30	34.03

6 Conclusions and recommendations

This report refers to the measurement campaign at the LEG platform where a LEOSPHERE WINDCUBE V2 LiDAR has been deployed since 2014, providing high quality data. The data are publicly available to be used for further purposes (www.windopzee.net).

At the LEG platform, the wind analysis for the 2014-2022 period shows that the wind profiles are dominated by the regional climate, mainly by the positive phase effect of North Atlantic Oscillation (NAO). The prevailing wind direction is from the southwest with a mean direction ranging from 234° to 244° across the different sensor heights (62 m to 240 m). The average calculated wind speed ranges from 8.92 m/s at the lowest measured height of 62 m up to 10.21 m/s at 240 m, increasing gradually.

The Weibull distribution, indicating wind regimes and inter-annual variability, shows wind speed distributions with typical offshore wind k, and c parameters ($k = 2.103$ and $c = 10.880$ m/s at 140 m height). The wind speed frequency distribution is flatter and moderately skewed to the right at higher sensor heights, with more frequent wind speeds greater than 26 m/s.

The resulting assessment of the shear profile shows an annualized range of 0.086 to 0.093 considering the entire data period between matched sequential sensor height pairs of the LiDAR. For the year 2022, the calculated day and night time shear was found to be approximately 0.08.

Veer was found to be increasing clockwise (hence veering) with height on average. An overall difference of approximately 5 degrees between the 62 m and 240 m sensor height specifically for 2022.

From February 16th to February 20th 2022 a triplet of storms hit the Netherlands, with the most severe and powerful one being Storm Eunice on February 18th. This storm was registered as the third most severe in the past 50 years. Wind speeds ranged between 25 and 35 m/s. The sustained duration of extreme winds as a result of Storm Eunice dominates the entire top 10 list of recorded extreme timestamps, barring one occurrence in 2018, and two in 2016.

Measurement campaigns play a crucial role for the feasibility studies of offshore wind sites as well as the plant valuation. They are the basis for the financial decision to ensure the profitability. In addition, the measured data can be used for other applications in the energy sector including:

- Long-term and accurate data sets can act as reference points for offshore wind atlases, and models.
- Serve as a basis for the development and validation of high fidelity models. It is necessary to improve the accuracy over a wide range of site conditions, with sufficient resolution in both time and space.

- Improving and reducing uncertainties of the variability due to renewable resources and their increase penetration in the power sector. The adequate modelling of high RES-E penetration systems crucially depends on the accurate representation of the spatial and temporal characterization of the weather conditions. Variability and uncertainty of the wind resource is translated into datasets that inherently bear the risk of being imperfect, inappropriate or incomplete. This might lead to errors in power system studies which in turn could result in either overstating or downplaying the possible role of wind energy in the future energy mix.
- Capturing extreme weather events for developers and wind turbine manufactures to help develop, certify and validate new models under site specific conditions.
- Filtering the data can influence the interpretation or period trends, and averaged results.

7 Acknowledgements

The measurement campaign at the offshore measurement platform LEG is carried out on the authority of the Ministry of Economic Affairs and Climate Policy of The Netherlands.

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Appendix A
LiDAR specifications for WINDCUBE V2

Description and Setup

Four beams are sent successively in four defined directions along a 28° scanning cone. The laser pulses are backscattered by aerosol particles in the air (such as dust, water droplets, aerosol etc.) that move with the wind speed. The collected backscattered light contains information on wind speed and wind direction which can be calculated by using a Doppler induced laser wave length shift [19]. The LIDAR take measurements at 10 different heights.

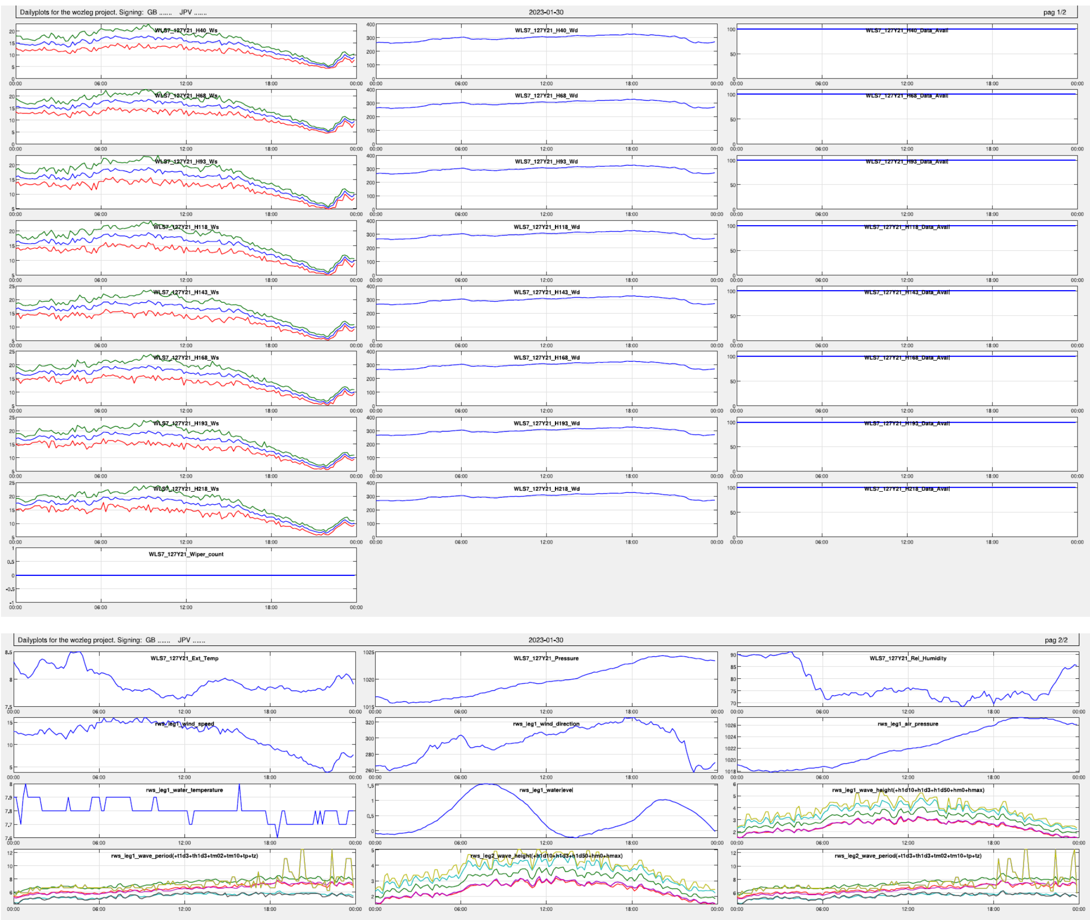
The safety measures for the specific activities of how to handle the LiDAR are defined in the specifications and in the Annex. "*the WINDCUBEv2 is a class 1M laser product and the system should be handled with caution. It is important not to stare directly into the beam with optical instruments like telescopes or binoculars. The laser beam is eye-safe according IEC EN 60825-1, January 2008*" (see Annex A for additional details).

Table 10: Adjustments of the heights above Mean Seal Level from the default configuration

Id	LiDAR height	Adjustments (MSL)
1	40	62
2	68	90
3	93	115
4	118	140
5	143	165
6	168	190
7	193	215
8	218	240
9	243	265
10	268	290

Figure 20: Example of screenshot WINDCUBE V2.

Example of Daily Plot



Technical Specifications

Specifications

MEASUREMENTS

Range	40m to 200m
Data sampling rate	1s
Number of programmable heights	12
Speed accuracy	0.1m/s
Speed range	0 to +60m/s
Direction accuracy	2°

ELECTRICAL

Power supply	18-32V DC / 93 to 264 VAC 50-60 Hz
Power consumption	45W

ENVIRONMENTAL

Temperature range	-30°C to +45°C / -22 °F to 108°F
Operating humidity	0 ... 100 %RH
Housing classification	IP67
Shocks & vibration	ISTA / FEDEX 6A
Safety	Class 1M IEC/EN 60825-1
Compliance	CE

TRANSPORTATION

Size	System : 543 x 552 x 540 mm Transport case : 685 x 745 x 685 mm
Weight	System : 45 kg Transport case : 21 kg

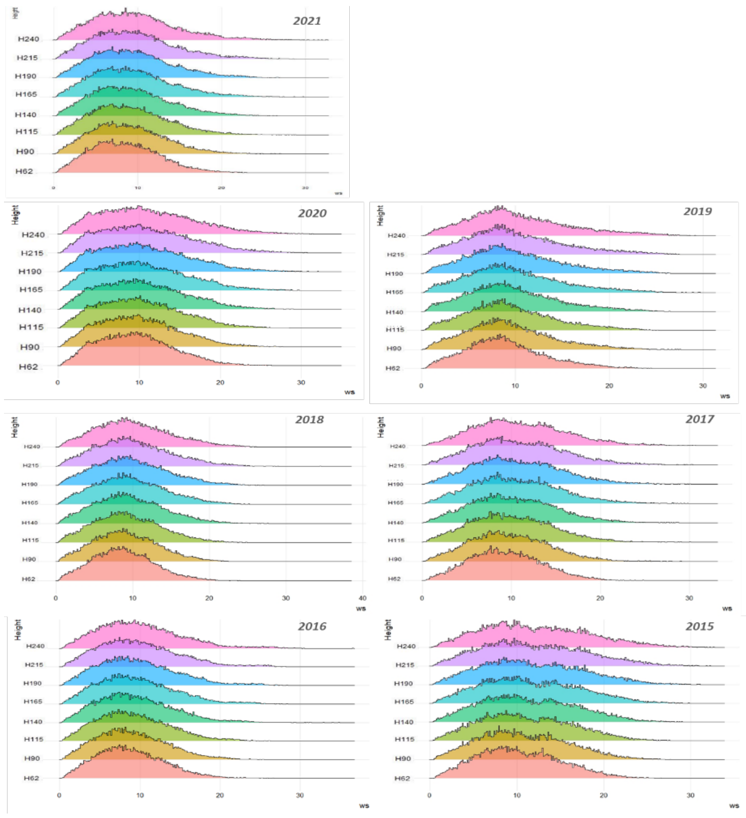
SOFTWARE/DATA

Data format	ASCII
Data storage	SSD and compact flash (backup storage)
Data transfer	LAN/USB
Standard WINDSOFT™ Software	Configuration & control Real time display Diagnostic
Output data	1s/10min horizontal & vertical wind speed Min & max, direction, SNR Quality factor (data availability) GPS coordinates

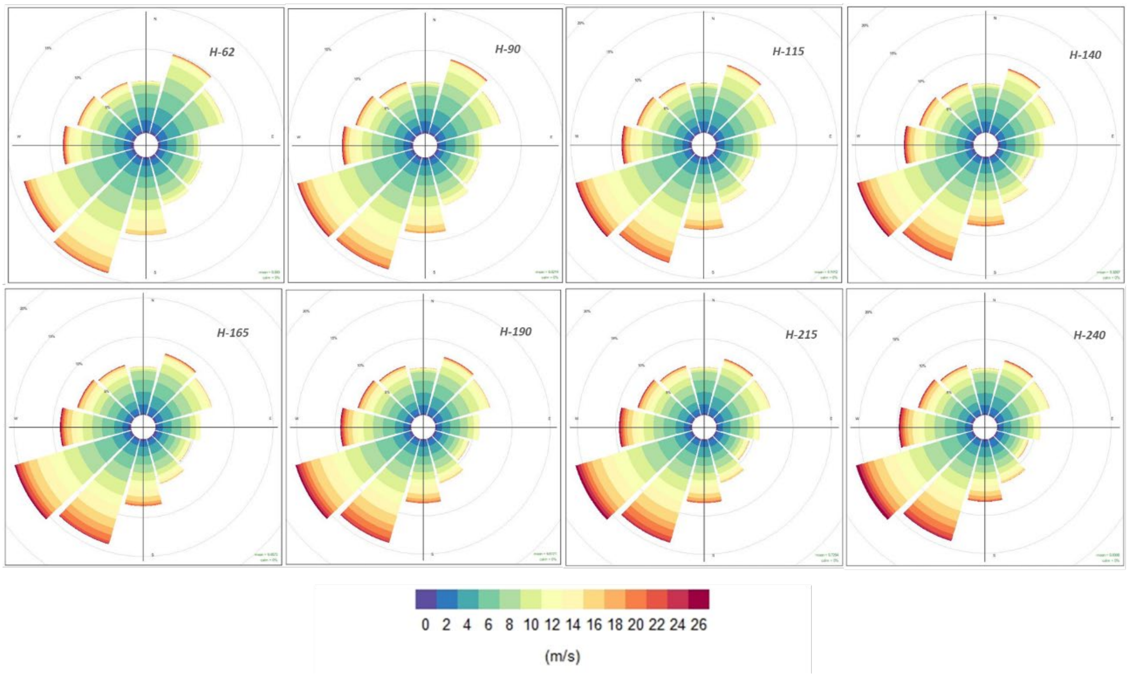
Appendix B
Annual weather conditions during the campaign at LEG

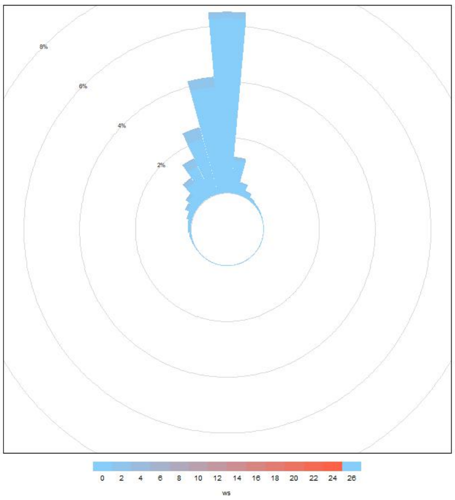
This section contains visual and statistical descriptive summary about the annual weather conditions per year at the LEG from 2022 backwards in time to 2014. These statistics are influenced by the available months of data, and do not account for seasonality (such as 2014, 2015, and 2017). The annual prevailing wind direction recorded was from the southwest, at different heights, as indicated by the wind roses (top). The wind direction was calculated considering the average unit wind direction vector. The wind rose chart (bottom left) shows the difference on wind speed and direction between heights of 240 m and 62 m above MSL level indicating the mean difference of wind direction between lowest and highest height measured._The main wind speed distribution (m/s vs. frequency) at 140 m height (bottom right) and the descriptive statistics for that year are also included. The data considers the available measured data, therefore the statistics are biased by the LiDAR availability.

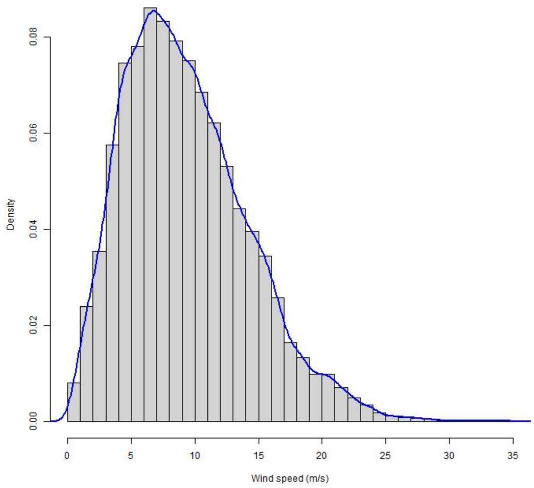
B.1 Yearly Frequency Distributions By Height (Previous Years)



B.2 2022

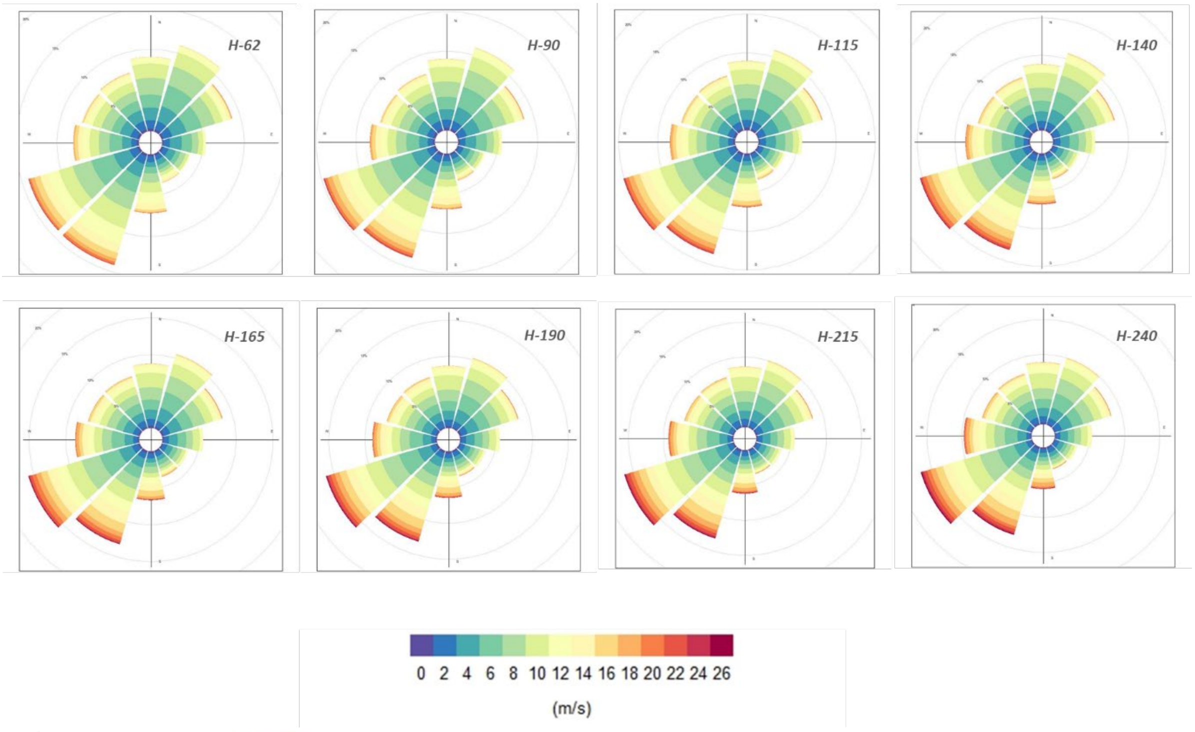


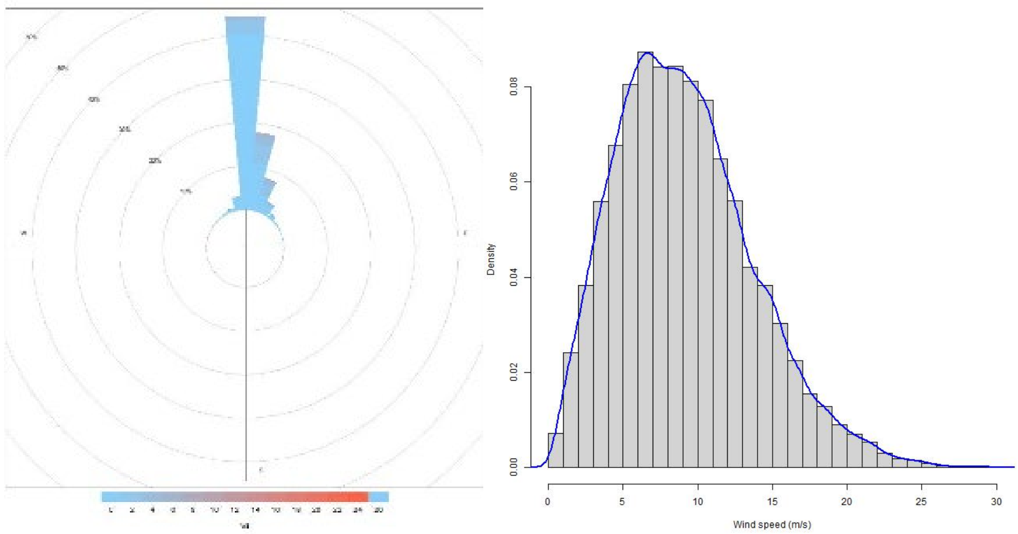




H (m)	62	90	115	140	165	190	215	240
Ws - Min	0.06	0.06	0.05	0.01	0.08	0.04	0.05	0.04
Ws – 1st q	5.44	5.56	5.61	5.66	5.71	5.74	5.74	5.77
Ws - Median	8.08	8.35	8.52	8.65	8.75	8.83	8.87	8.94
Ws - Mean	8.583	8.921	9.141	9.327	9.487	9.617	9.729	9.831
Ws - 3rd q	11.31	11.8	12.07	12.32	12.56	12.74	12.9	13.04
Ws – Max	31.97	33.33	34.21	34.99	82.61	36.35	37.11	37.78
Wd - Mean	233.9	235.2	235.5	236.3	237.5	238.8	240.1	241.6

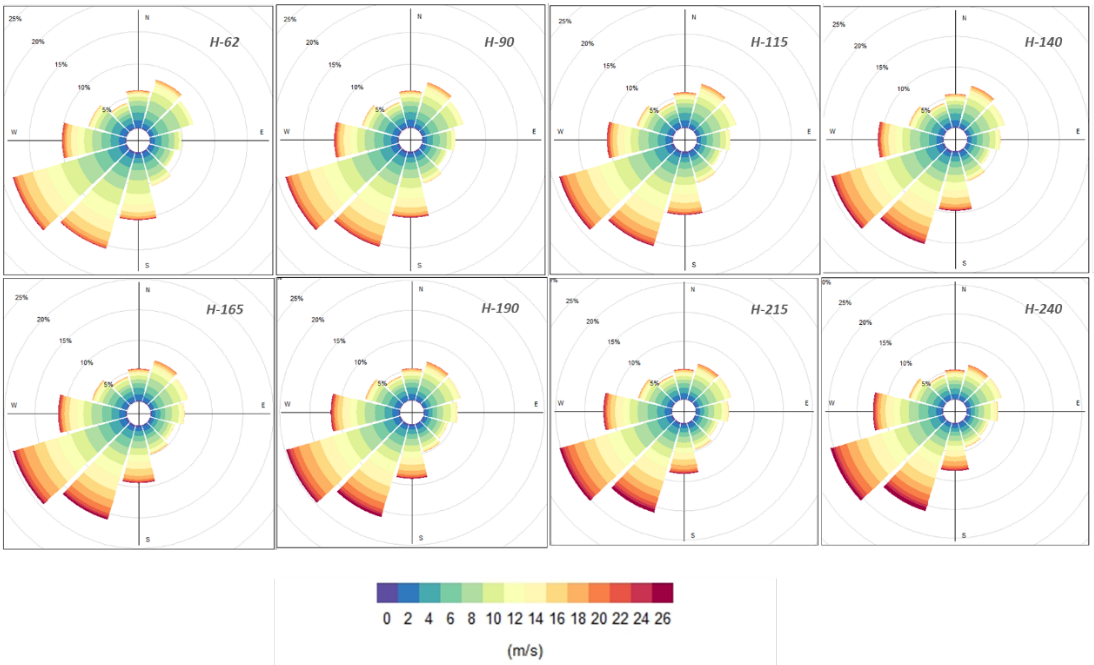
B.3 2021

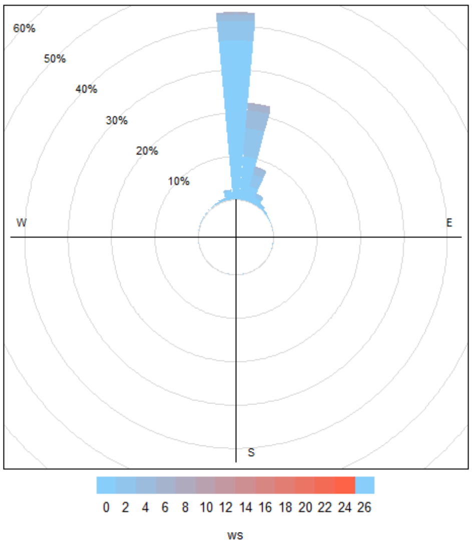


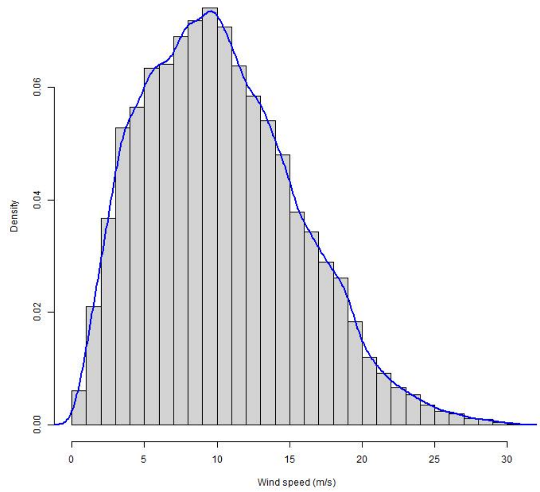


H (m)	62	90	115	140	165	190	215	240
Ws - Min	0.06	0.13	0.07	0.09	0.04	0.13	0.04	0.06
Ws – 1st q	5.46	5.6	5.67	5.73	5.77	5.83	5.88	5.97
Ws - Median	8.19	8.41	8.54	8.65	8.75	8.86	8.98	9.11
Ws - Mean	8.53	8.807	8.978	9.128	9.267	9.394	9.518	9.64
Ws - 3rd q	11.22	11.58	11.78	11.95	12.09	12.225	12.36	12.48
Ws – Max	26.41	27.84	28.8	29.74	30.53	31.25	31.93	32.62
Wd - Mean	272.2	271.8	271.2	270.6	269.7	268.7	268.9	272.2

B.4 2020

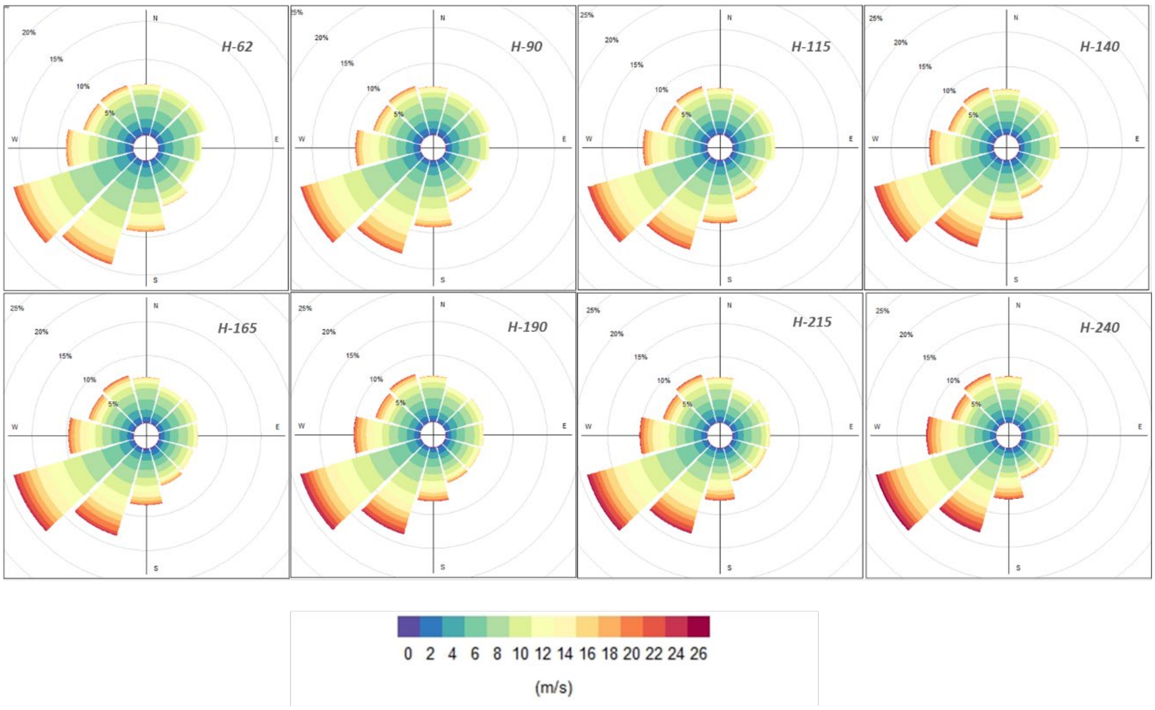


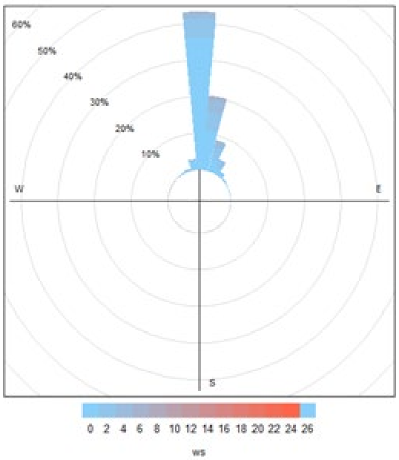


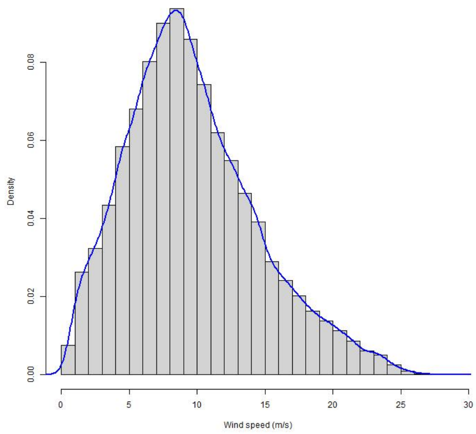


H (m)	62	90	115	140	165	190	215	240
Ws - Min	0.27	0.21	0.13	0.20	0.18	0.21	0.19	0.28
Ws – 1^{st} q	6.01	6.14	6.18	6.21	6.26	6.31	6.41	6.53
Ws - Median	9.25	9.51	9.67	9.79	9.91	10.02	10.17	10.35
Ws - Mean	9.56	9.89	10.11	10.30	10.47	10.64	10.83	11.04
Ws - 3^{rd} q	12.57	13.07	13.42	13.74	14.02	14.26	14.52	14.81
Ws – Max	27.18	28.25	29.48	30.37	31.40	32.46	33.58	34.66
Wd - Mean	233.3	235.1	236.0	237.4	238.6	240.2	242.1	245.7

B.5 2019

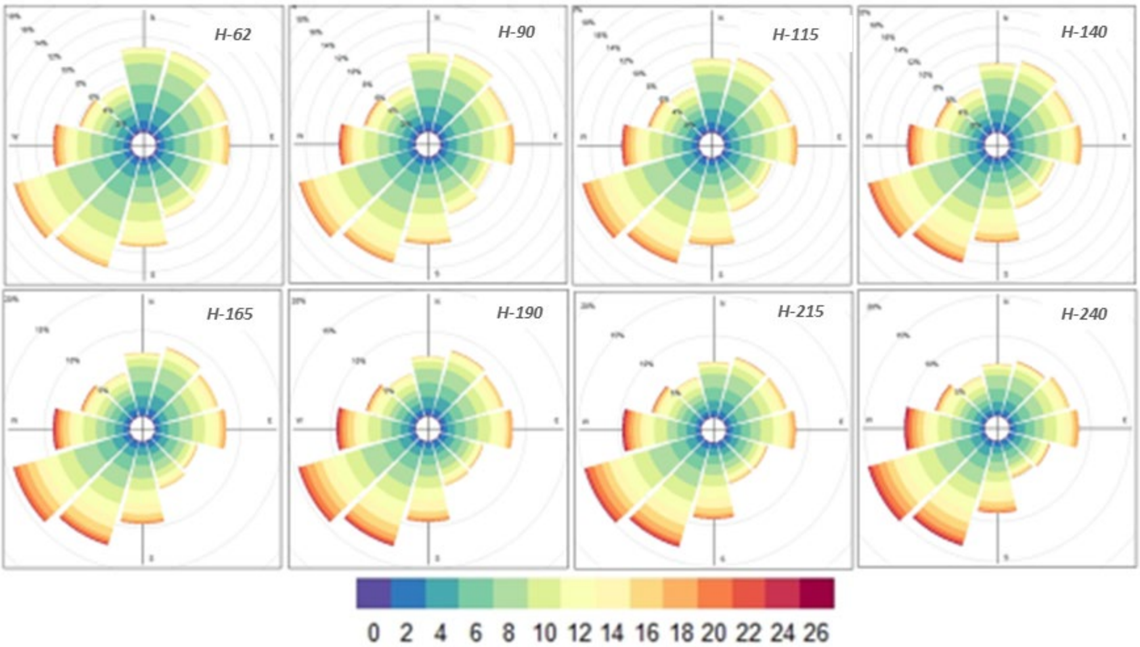


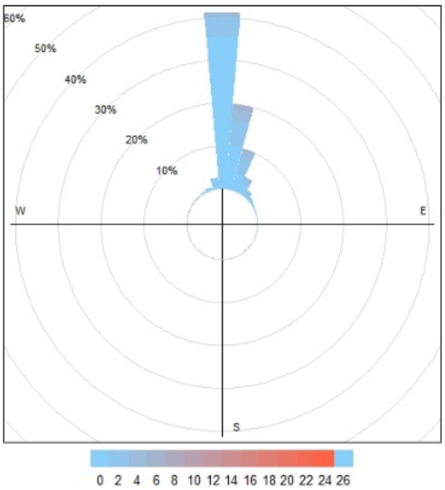


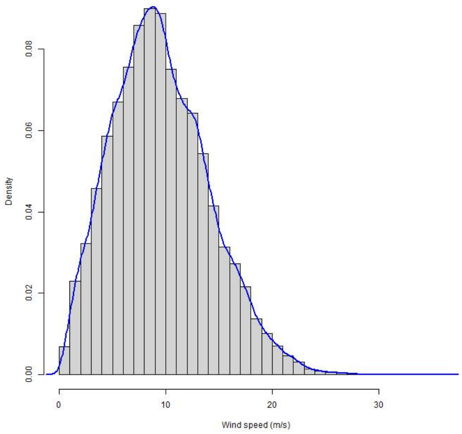


H (m)	62	90	115	140	165	190	215	240
Ws - Min	0.25	0.10	0.23	0.20	0.27	0.19	0.14	0.24
Ws – 1st q	5.94	6.09	6.15	6.19	6.26	6.34	6.42	6.54
Ws - Median	8.47	8.75	8.87	9.01	9.11	9.20	9.28	9.40
Ws - Mean	**8.91**	**9.25**	**9.45**	**9.62**	**9.79**	**9.97**	**10.15**	**10.34**
Ws - 3rd q	11.36	11.92	12.24	12.51	12.73	12.96	13.20	13.42
Ws – Max	26.65	27.53	28.15	28.89	29.61	30.24	30.74	31.13
Wd - Mean	**233.3**	**235.1**	**236.0**	**237.4**	**238.6**	**240.2**	**242.1**	**245.7**

B.6 2018

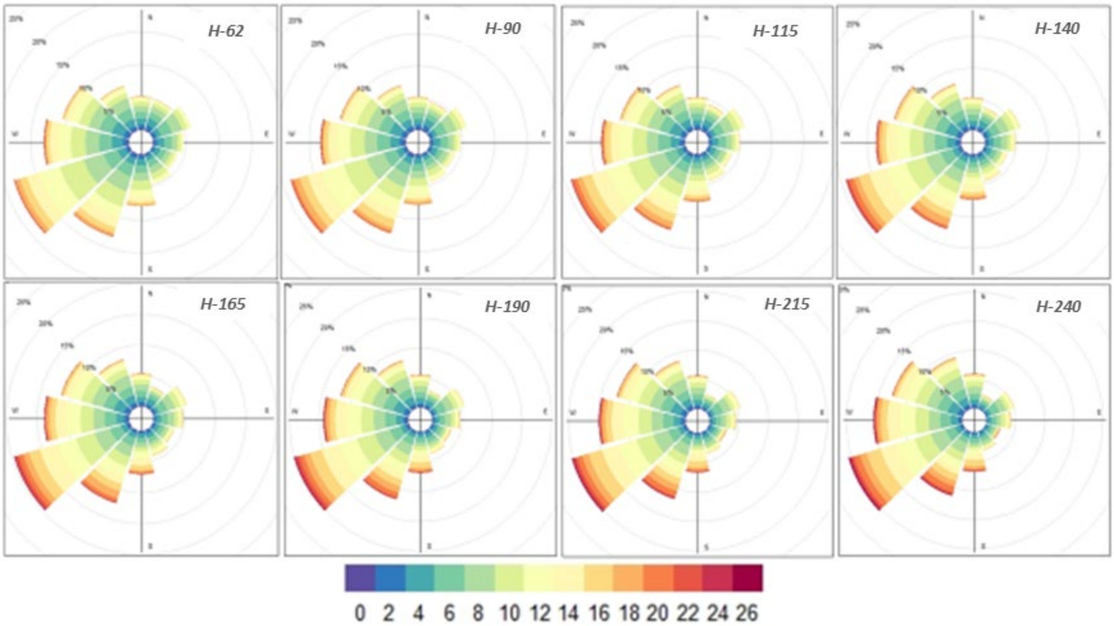


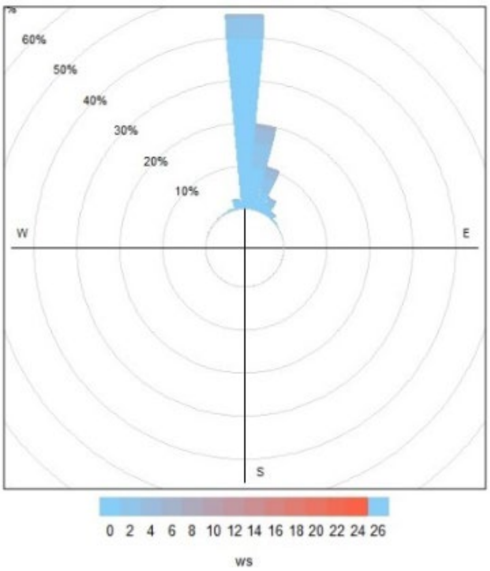


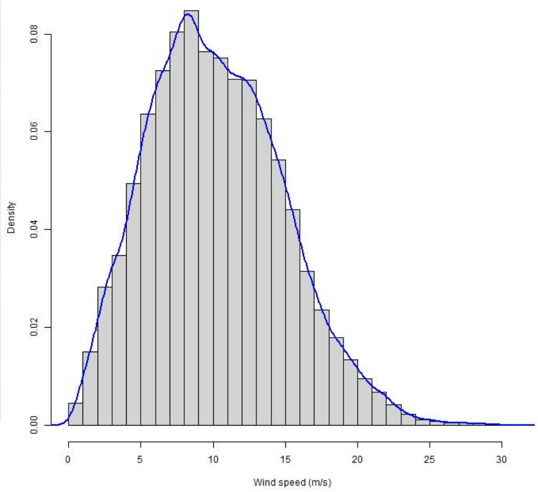


H (m)	62	90	115	140	165	190	215	240
Ws - Min	0.22	0.19	0.23	0.18	0.15	0.15	0.17	0.22
Ws – 1st q	5.89	6.05	6.13	6.22	6.31	6.39	6.47	6.57
Ws - Median	8.56	8.84	9.02	9.16	9.31	9.44	9.54	9.64
Ws - Mean	**8.80**	**9.15**	**9.36**	**9.55**	**9.72**	**9.88**	**10.03**	**10.19**
Ws - 3rd q	11.41	11.93	12.25	12.52	12.75	12.93	13.08	13.28
Ws – Max	33.02	34.38	35.23	36.08	36.97	37.50	37.91	38.27
Wd - Mean	**217.6**	**219.8**	**221.2**	**222.7**	**224.1**	**224.8**	**226.2**	**228.3**

B.7 2017

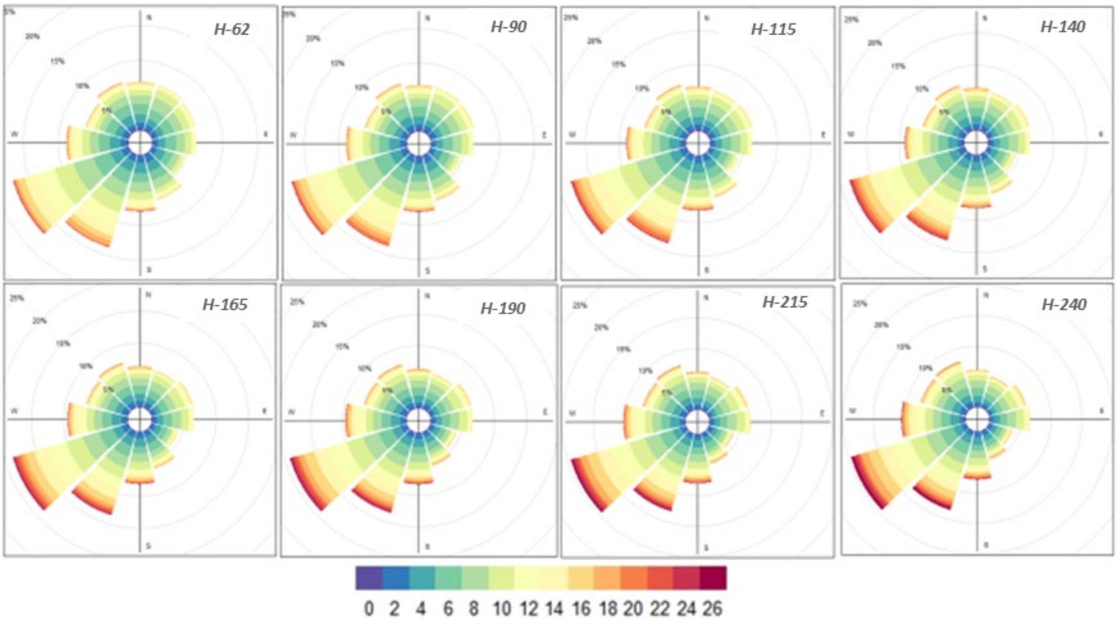


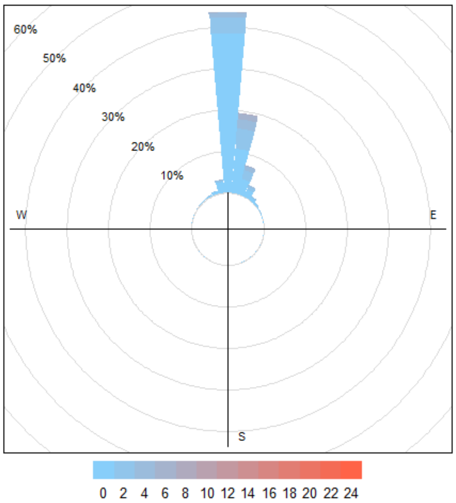


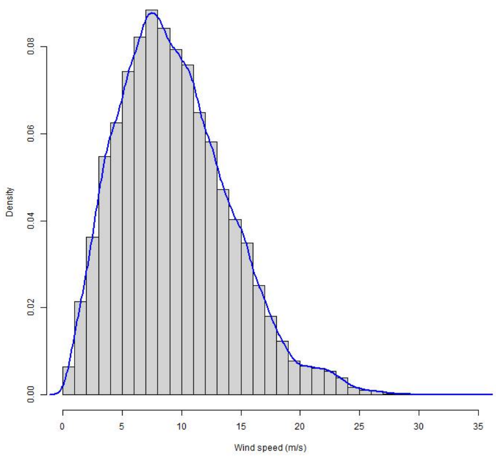


H (m)	62	90	115	140	165	190	215	240
Ws - Min	0.27	0.12	0.19	0.14	0.19	0.22	0.26	0.38
Ws – 1st q	6.40	6.57	6.65	6.75	6.91	7.02	7.16	7.29
Ws - Median	9.13	9.46	9.69	9.88	10.05	10.17	10.34	10.51
Ws - Mean	9.40	9.75	10.00	10.23	10.45	10.64	10.82	11.01
Ws - 3rd q	12.12	12.69	13.05	13.36	13.67	13.91	14.09	14.29
Ws – Max	27.52	29.06	30.06	30.90	31.51	32.14	32.57	32.98
Wd - Mean	249.7	250.9	251.9	253.4	255.0	257.0	258.8	261.2

B.8 2016

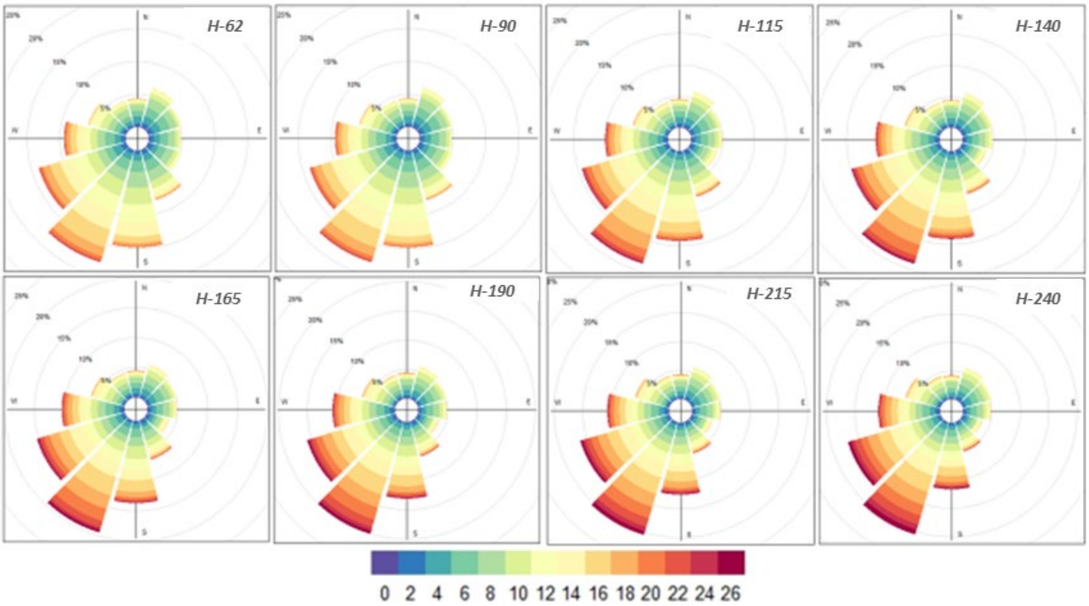


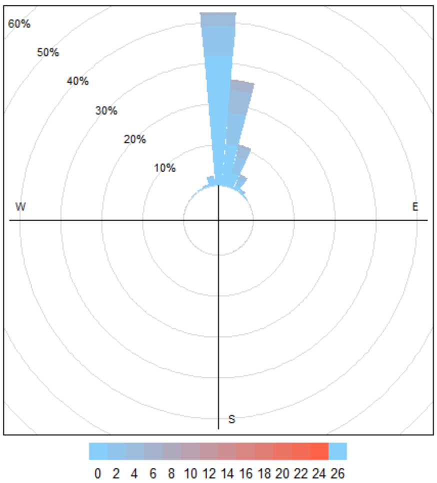


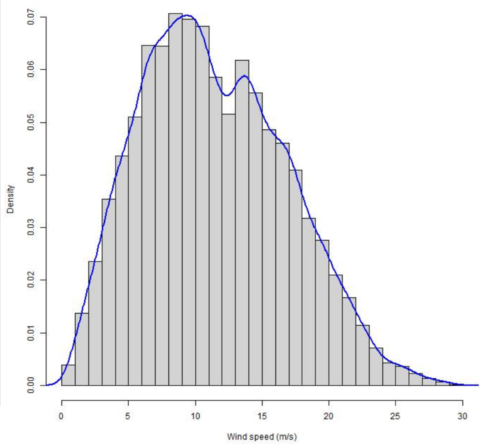


H (m)	62	90	115	140	165	190	215	240
Ws - Min	0.30	0.29	0.25	0.30	0.19	0.28	0.30	0.25
Ws – 1st q	5.71	5.79	5.86	5.93	5.99	6.07	6.16	6.24
Ws - Median	8.40	8.60	8.76	8.88	9.02	9.14	9.29	9.40
Ws - Mean	**8.81**	**9.05**	**9.24**	**9.40**	**9.56**	**9.72**	**9.90**	**10.04**
Ws - 3rd q	11.52	11.88	12.15	12.35	12.52	12.71	12.91	13.06
Ws – Max	32.07	33.46	34.07	34.74	35.46	35.81	36.25	36.60
Wd - Mean	234.9	235.0	235.6	236.5	237.7	239.4	242.6	245.0

B.9 2015







H (m)	62	90	115	140	165	190	215	240
Ws - Min	0.50	0.50	0.23	0.26	0.28	0.20	0.24	0.25
Ws – 1st q	6.72	6.93	7.08	7.23	7.32	7.43	7.52	7.57
Ws - Median	9.87	10.30	10.60	10.87	11.07	11.27	11.44	11.59
Ws - Mean	10.30	10.76	11.11	11.42	11.67	11.89	12.10	12.28
Ws - 3rd q	13.54	14.27	14.81	15.28	15.68	16.02	16.30	16.59
Ws – Max	26.56	27.58	28.31	29.48	30.79	31.91	32.78	33.77
Wd - Mean	210.9	212.7	214.6	216.6	218.8	220.9	222.8	224.9

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