HESSELØ

FINAL DATA REPORT

(28/02/2021 00:00 UTC - 27/02/2022 23:50 UTC)

PREPARED		REVISED		APPPROVED	
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Date	30/05/2022	Date	30/05/2022	Date	27/06/2022

REVISIONS		
Revision	**Modification causes**	**Date**
01	Document creation	29/03/2022
02	Comments Energinet v1	05/04/2022
03	Comments Energinet v2	13/04/2022
04	Comments Energinet v3	30/05/2022
05	Comments Energinet v4	22/06/2022

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1. INTRODUCTION

1.1. OBJECTIVE

The main objective of this document is to present the measurement campaign availability based on the statistics for the observation period 28/02/2021 00:00 UTC -27/02/2022 23:50 UTC, as well as basic statistics and graphs of the main metocean measurements collected by the FLS200 system during the full campaign period.

1.2. EOLOS FLS200 UNIT LOCATION

The unit is installed at the HESSELØ Project site (see Figure 1), specifically on locations:

Date Range	Latitude	Longitude
28/02/2021- 14/07/2021	56º 27' 51.12'' N	11º 50' 06.24'' E
17/07/2021- 27/02/2022	56º 27' 50.34'' N	11º 50' 14.40'' E

The unit has not been adrift during the period and been located within the allowable drift radius of 97 meters as defined by the unit mooring system.

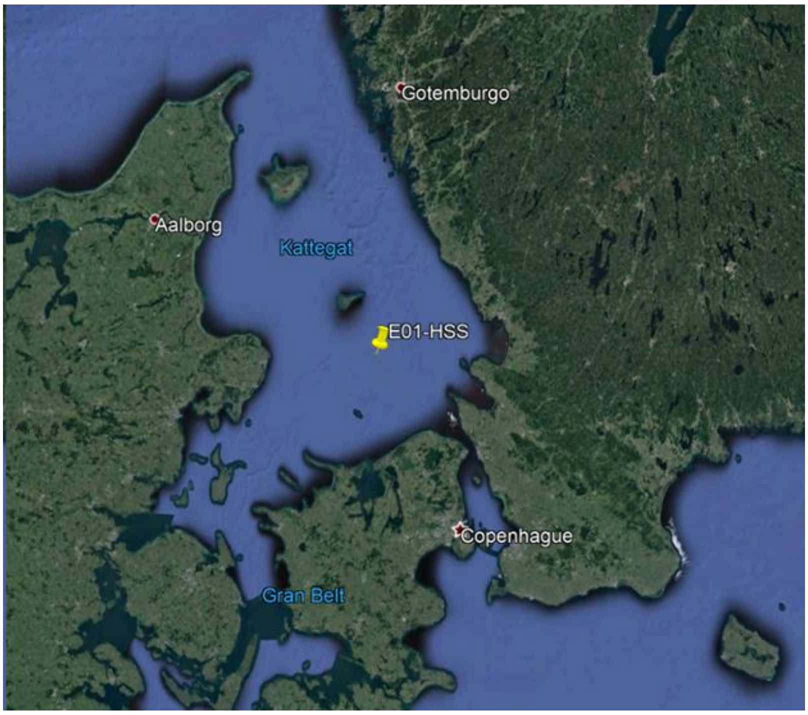

Figure 1. Location of EOLOS FLS200 unit.

1.3. REFERENCES TO MONTHLY DATA REPORTS

The monthly data reports delivered to the CLIENT are referenced in the following table.

Month #	Period included	Document name
1	28/02/2021 – 27/03/2021	EOL-HSS21-V04-OPS-Monthly Data Report - Month 1.pdf
2	28/03/2021 – 27/04/2021	EOL-HSS26-V03-OPS-Monthly Data Report - Month 2.pdf
3	28/04/2021 – 27/05/2021	EOL-HSS30-V03-OPS-Monthly Data Report - Month 3.pdf
4	28/05/2021 – 27/06/2021	EOL-HSS32-V03-OPS-Monthly Data Report - Month 4.pdf
5	28/06/2021 – 27/07/2021	EOL-HSS34-V03-OPS-Monthly Data Report - Month 5.pdf
6	28/07/2021 – 27/08/2021	EOL-HSS37-V03-OPS-Monthly Data Report - Month 6.pdf
7	28/08/2021 – 27/09/2021	EOL-HSS39-V01-OPS-Monthly Data Report - Month 7.pdf
8	28/09/2021 – 27/10/2021	EOL-HSS41-V01-OPS-Monthly Data Report - Month 8.pdf
9	28/10/2021 – 27/11/2021	EOL-HSS44-V01-OPS-Monthly Data Report - Month 9.pdf
10	28/11/2021 – 27/12/2021	EOL-HSS47-V01-OPS-Monthly Data Report - Month 10.pdf
11	28/12/2021 – 27/01/2021	EOL-HSS51-V01-OPS-Monthly Data Report - Month 11.pdf
12	28/01/2021 – 27/02/2021	EOL-HSS54-V01-OPS-Monthly Data Report - Month 12.pdf

Table 1. Monthly data reports references.

1.4. REFERENCES TO VALIDATION REPORTS

1. LEG Validation report:
   - **Title**: Assessment of EOLOS FLS-200 E01 Floating Lidar PRE-Deployment Verification at the TNO Lichteiland Goeree Offshore Test Site, NL
   - **Document name**: MV-3005-PV1-113-R-001-D.pdf
2. LIDAR onshore Validation report:
   - **Title**: Independent analysis and reporting of ZX Lidars performance verification executed by Zephir Ltd. at Pershore test site, including IEC compliant validation analysis
   - **Document name**: E01_ZEPHIR_300M_ZX839_GLGH-Lidar unit validation report_20190129_EOL_E01.pdf

1.5. HSE ISSUES

In what follows, we present an accident/incident HSE (Health Safety and Environment) form for each operation. Each table corresponds to the operation described in its title. An explanation of the table entries is included at the end of the section.

Installation of the FLS200 E01 at the Hesselø site (EOL-HSS16-V01-Installation Report).				
27/02/2021	EOLOS	WSP		TOTAL
Onshore Manhours	8	0		8
Offshore Manhours	37.5	0		37.5
Average No. of Persons on Site	3	0		3
Medical Treatment Incident (MTI)	0	0		0
First Aid Incident (FAI)	0	0		0
Minor Incident	0	0		0
Near Miss Incident (NMI)	0	0		0
Hazard Report	0	0		0
Authorities Interventions	0	0		0
Environmental Near Miss Incident	0	0		0
Environmental Incident	0	0		0
Notice from Regulatory Authority	0	0		0
Confirmed complaint (environmental) from statutory consultee	0	0		0

Table 2. HSE form installation 27/02/2021

Corrective Maintenance (EOL-HSS28-Maintenance Report E01-20210319)				
19/03/2022	EOLOS	WSP		TOTAL
Onshore Manhours	0	0		0
Offshore Manhours	36	0		36
Average No. of Persons on Site	3	0		3
Medical Treatment Incident (MTI)	0	0		0
First Aid Incident (FAI)	0	0		0
Minor Incident	0	0		0
Near Miss Incident (NMI)	0	0		0
Hazard Report	0	0		0
Authorities Interventions	0	0		0
Environmental Near Miss Incident	0	0		0
Environmental Incident	0	0		0
Notice from Regulatory Authority	0	0		0
Confirmed complaint (environmental) from statutory consultee	0	0		0

Table 3. HSE form corrective maintenance 19/03/2022

Data Download (EOL-HSS11-Daily Progress Report 27-04-2021)				
27/04/2021	EOLOS	WSP		TOTAL
Onshore Manhours	0	0		0
Offshore Manhours	26	13		39
Average No. of Persons on Site	2	1		3
Medical Treatment Incident (MTI)	0	0		0
First Aid Incident (FAI)	0	0		0
Minor Incident	0	0		0
Near Miss Incident (NMI)	0	0		0
Hazard Report	0	0		0
Authorities Interventions	0	0		0
Environmental Near Miss Incident	0	0		0
Environmental Incident	0	0		0
Notice from Regulatory Authority	0	0		0
Confirmed complaint (environmental) from statutory consultee	0	0		0

Table 4. HSE form data download 27/04/2021

Data Download (EOL-HSS11-Daily Progress Report 01-06-2021)				
01/06/2021	EOLOS	WSP		TOTAL
Onshore Manhours	0	0		0
Offshore Manhours	10	10		20
Average No. of Persons on Site	1	1		2
Medical Treatment Incident (MTI)	0	0		0
First Aid Incident (FAI)	0	0		0
Minor Incident	0	0		0
Near Miss Incident (NMI)	0	0		0
Hazard Report	0	0		0
Authorities Interventions	0	0		0
Environmental Near Miss Incident	0	0		0
Environmental Incident	0	0		0
Notice from Regulatory Authority	0	0		0
Confirmed complaint (environmental) from statutory consultee	0	0		0

Table 5. HSE form data download 01/06/2021

Control Box Replacement Operation (EOL-HSS36-OPS-Maintenance Report E01-20210714)				
14/07/2021-17/07/2021	EOLOS	WSP		TOTAL
Onshore Manhours	32	0		**32**
Offshore Manhours	42	0		**42**
Average No. of Persons on Site	2	0		**2**
Medical Treatment Incident (MTI)	0	0		**0**
First Aid Incident (FAI)	0	0		**0**
Minor Incident	0	0		**0**
Near Miss Incident (NMI)	0	0		**0**
Hazard Report	0	0		**0**
Authorities Interventions	0	0		**0**
Environmental Near Miss Incident	**0**	**0**		**0**
Environmental Incident	**0**	**0**		**0**
Notice from Regulatory Authority	**0**	**0**		**0**
Confirmed complaint (environmental) from statutory consultee	**0**	**0**		**0**

Table 6. HSE form control box replacement 14/07/2021

ADCP Replacement Operation (EOL-HSS49-Maintenance Report E01-20211223)				
23/12/2021	EOLOS	WSP		TOTAL
Onshore Manhours	0	0		**0**
Offshore Manhours	49.5	0		**49.5**
Average No. of Persons on Site	3	0		**3**
Medical Treatment Incident (MTI)	0	0		**0**
First Aid Incident (FAI)	0	0		**0**
Minor Incident	0	0		**0**
Near Miss Incident (NMI)	0	0		**0**
Hazard Report	0	0		**0**
Authorities Interventions	0	0		**0**
Environmental Near Miss Incident	**0**	**0**		**0**
Environmental Incident	**0**	**0**		**0**
Notice from Regulatory Authority	**0**	**0**		**0**
Confirmed complaint (environmental) from statutory consultee	**0**	**0**		**0**

Table 7. HSE form ADCP replacement 23/12/2021

Recovery Operation from the Hesselø site (EOL-HSS58-Recovery Report E01-20220319)				
19/03/2022	**EOLOS**	**WSP**		**TOTAL**
Onshore Manhours	2	0		**2**
Offshore Manhours	18	0		**18**
Average No. of Persons on Site	2	0		**2**
Medical Treatment Incident (MTI)	0	0		**0**
First Aid Incident (FAI)	0	0		**0**
Minor Incident	0	0		**0**
Near Miss Incident (NMI)	0	0		**0**
Hazard Report	0	0		**0**
Authorities Interventions	0	0		**0**
Environmental Near Miss Incident	**0**	**0**		**0**
Environmental Incident	**0**	**0**		**0**
Notice from Regulatory Authority	**0**	**0**		**0**
Confirmed complaint (environmental) from statutory consultee	**0**	**0**		**0**

Table 8. HSE form recovery 19/03/2022

The following table presents the definition of the terms used in the previous HSE forms.

Definitions	
Medical Treatment Incident (MTI)	An incident that requires treatment beyond the normal competence of a first aider, e.g. from a doctor, nurse, dentist or surgeon.
First Aid Incident (FAI)	An injury that requires treatment by a first aider and this is sufficient to treat the injury.
Minor Incident	A minor injury that does not require first aid, e.g. a minor cut.
Near Miss Incident (NMI)	An incident that had the potential to result in injury but did not.
Hazard Report	A report of unsafe acts or conditions with the potential to cause injury, e.g. persons working at height without the means to arrest or capture falling items. An item falling but not injuring anyone would be classified as a near-miss.
Environmental Near Miss Incident	Activity which had the potential to result in a environmental incident had it not been amended before the incident occurred or activity that had the potential to result in an environmental incident but did not.
Environmental Incident	Activity that resulted in pollution to land, controlled waters and air; management of waste outwith duty of care requirements and an activity undertaken in breach of legal requirements, without appropriate permission, licence or consent, or in breach of consent conditions.
Notice from Regulatory Authority	Notice in regard to an environmental incident which gives rise to a prosecution, regulatory notice, caution, warning letter, or other form of enforcement action/notification from a regulatory body or authority.
Confirmed complaint (environmental) from statutory consultee	Confirmed complaint received from Regulatory bodies (such as Government Agencies, Local Authority, Marine Management Organisation, Maritime and Coastguard Agency and complaints received from consultees such as Non Government Organisations. in regard to environmental issues associated with EOLOS activities undertaken at development and operational sites (excludes complaints or representations in regard to the Development Consent Process)

Table 9. HSE definitions

COMMENTARY - Enter full details for any incident recorded above	
-	-

COMMENTARY - Enter full details for any incident recorded above	
-	-

Table 10. HSE comments

1.6. ABBREVIATIONS

List of abbreviations used throughout the text:

- HSE: Health Safety and Environment
- Camp.: campaign
- S/N: Serial Number
- HSS: HesselØ
- MSL: mean sea level
- LSN: Lidar serial number
- yyyy / YYYY: year start / end
- mm / MM: month start / end
- dd / DD: day start / end
- HH: Hour
- mm: minute
- SS: second
- ###: reference numbers (001, 002, …)
- Min, max: minimum, maximum
- Std: standard deviation
- Avg: average
- Hs: significant wave height
- Tp: Peak wave period
- DriAvg: Average wave direction

2. CONFIGURATION OF BUOY AND INSTRUMENTATION

2.1. LIST OF SENSORS

Below is a detailed list of the devices on board of the FLS200 E01 for the HesselØ project. The table includes the period in which the instrument was boarded, brand, model, and S/N.

SENSOR SPECIFICATIONS				
SENSOR	**Period**	**Brand**	**Model**	**Serial Number**
LIDAR	whole camp.	ZX	ZX 300M	ZX839M
LIDAR WEATHER STATION	whole camp.	AIRMAR	200WX	4174105
WEATHER STATION	whole camp.	VAISALA	WXT536	S4720763
CURRENT PROFILER (ADCP)	28/02/2021 – 23/12/2021	Nortek	Signature 500	102459
CURRENT PROFILER (ADCP)	23/12/2021 – 28/02/2022	Nortek	Signature 500	102851
WAVE SENSOR	whole camp.	Automasjon & Data AS	AIM 3.5.16	2009
COMPASS METMAST	whole camp.	KVH	C100	121000639
GPS	whole camp.	GARMIN	19X HVS	2J5051321
PYRANOMETER	whole camp.	LI-COR	LI-200/R	103837
COMPASS ROOF	whole camp.	KVH	C100	2009W082

Table 11. List of sensors and specifications.

2.2. SAMPLING INTERVALS AND AVERAGING PERIODS

The table below presents the main instruments' sampling configuration.

SENSOR SAMPLING CONFIGURATION			
SENSOR	**Sampling frequency**	**Sampling duration**	**Sampling interval**
LIDAR	*	10 min	10 min
WEATHER STATION	1 HZ	10 min	10 min
CURRENT PROFILER	1 HZ	3 min	30 min
WAVE SENSOR (motion variables)	4 HZ	10 min	10 min
WAVE SENSOR (wave variables)	4 HZ	20 min	30 min
GPS	1 HZ	1 sec	10 min
PYRANOMETER	1 HZ	10 min	10 min
NOTE			
* For each specific height, line-of-sight measurements are taken at 50 Hz during 1 second. The data sampling procedure of the Lidar is explained in detail in section 2.4.1 below.			

Table 12. Sampling configuration of sensors.

2.3. SAMPLE HEIGHTS

2.3.1. LIDAR measurement height levels

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

Table 13. Floating LIDAR measurement heights.

All heights are measured above sea level.

Lidar measurement heights configured apply a window height above sea level of 2m as ZX-Lidars allows only integer values, i.e: if a measurement is due to be performed at 40m, the Lidar measurement configuration is set to 38m. Distance between the LIDAR measuring lens and the sea surface level is 1.6m, and measurement is performed at 39.6m instead of originally targeted to 40m. Hence, in postprocessing when tidal correction is applied, an extra offset of 0.4m is added as a constant, with the following formula:

$$Final\_Height = Lidar\_height + window\_height + constant,$$

where $window\_height = 2m$, $constant = -0.4m$.

2.3.2. CURRENT depth measurement levels

The ADCP depths measurement levels correspond to the vertical distance from the transducer to the center of the measurement cell, which is computed with the formula:

$$Center\ of\ the\ n^{th}\ cell = Blanking\ distance + n * cell\ size.$$

For the whole campaign period, the number of cells and cell size value have been:

- Number of cells (n): 22
- Cell size: 1.6 m

As described in the incidence report "E01-HSS-INC012_v01.pdf", the blanking distance was changed on the 14/07/2021. The values of the blanking distance have been:

- Blanking distance (28/02/2021 to 14/07/2021): 3.6 m

- Blanking distance (14/07/2021 to 28/02/2022): 1.2 m

This change in the blanking distance results in different measurement depths of the ADCP for those two periods.

Since start of campaign to 14/07/2021, the EOLOS FLS200 unit was configured to measure the current at the following depths.

Current Sensor Measurement depths	
Level	**Configured ADCP depths + offset (m)**
1	5.2+ 0.8 = 6.0
2	6.8+ 0.8 = 7.6
3	8.4+ 0.8 = 9.2
4	10 + 0.8 = 10.8
5	11.6 + 0.8 = 12.4
6	13.2 + 0.8 = 14.0
7	14.8 + 0.8 = 15.6
8	16.4 + 0.8 = 17.2
9	18.0 + 0.8 = 18.8
10	19.6 + 0.8 = 20.4
11	21.2 + 0.8 = 22.0
12	22.8 + 0.8 = 23.6
13	24.4 + 0.8 = 25.2
14	26.0 + 0.8 = 26.8
15	27.6 + 0.8 = 28.4
16	29.2 + 0.8 = 30.0
17	30.8 + 0.8 = 31.6
18	32.4 + 0.8 = 33.2
19	34.0 + 0.8 = 34.8
20	35.6 + 0.8 = 36.4
21	37.2 + 0.8 = 38.0
22	38.8 + 0.8 = 39.6

Table 14. ADCP Cells Depth (period: 28/02/2021-14/07/2021)

Since 17/07/2021 to end of campaign, the EOLOS FLS200 unit was configured to measure the current at the following depths:

Current Sensor Measurement depths	
Level	**Configured ADCP depths + offset (m)**
1	2.8+ 0.8 = 3.6
2	4.4+ 0.8 = 5.2
3	6.0+ 0.8 = 6.8
4	7.6 + 0.8 = 8.4
5	9.2 + 0.8 = 10.0
6	10.8+ 0.8 = 11.6
7	12.4 + 0.8 = 13.2
8	14.0 + 0.8 = 14.8
9	15.6 + 0.8 = 16.4
10	17.2 + 0.8 = 18.0
11	18.8 + 0.8 = 19.6
12	20.4 + 0.8 = 21.2
13	22.0 + 0.8 = 22.8
14	23.6 + 0.8 = 24.4
15	25.2 + 0.8 = 26.0
16	26.8 + 0.8 = 27.6
17	28.4 + 0.8 = 29.2
18	30.0 + 0.8 = 30.8
19	31.6 + 0.8 = 32.4
20	33.2 + 0.8 = 34.0
21	34.8 + 0.8 = 35.6
22	36.4 + 0.8 = 37.2

Table 15. ADCP Cells Depth (period: since 17/07/2021)

NOTE: All depths are referenced to sea level. The offset of 0.8 meters is the distance between the current sensor measuring transducer and the sea surface level.

2.4. SENSORS GENERAL DESCRIPTION AND MEASUREMENT PRINCIPLES

2.4.1. LiDAR

The EOLOS FLS200 mounts a ZX300M, the fully marinized version of the ZX300, a vertical Continuous Wave (CW) LiDAR manufactured by ZXLidars Ltd, see figure 1.

Figure 2: ZXLidars - ZX300M, Source: www.zxlidars.com

This device measures the wind speed vector at user-defined heights. To measure the wind speed, the LiDAR emits a high-power infrared laser and focuses it at the configured height. The laser beam is deflected about 30º degrees from the vertical and is continuously rotated such that it covers the surface of a cone, completing one revolution per second. In that time, 50 line-of-sight wind speed measurements are performed [1]. There is subsequently a sub second delay to focus between the different heights.
The laser's emitted light is backscattered by the natural-atmospheric aerosols present in the air (such as dust, pollen, or rain droplets) and detected by a photodetector. The difference of frequency between the original and the received signal, known as Doppler shift, is directly related to the wind speed (speed of the back-scattering particles).
Homodyne coherent detection is used to measure the frequency change. It consists of mixing the backscattered signal with the original laser source (local oscillator) [2]. A limitation of homodyne detection is that it only detects the magnitude of the frequency change but cannot determine its sign. This leads to a 180º ambiguity in the wind direction. This ambiguity is resolved by incorporating an extra wind sensor at the instrument's base, such as a sonic anemometer. Of the two candidate directions detected by the LiDAR, the closest to the direction measured by the anemometer will be identified as the correct one. This procedure allows to obtain the three wind speed vector components.
The one second wind-speed vector is computed with the Velocity Azimuth Display (VAD) analysis technique from the 50 measurements taken during the 1 second rotation scan at each height. The one second data is saved, as well as its 10-min average in separate files. The Lidar offers a maximum of 10 configurable heights plus 2 default ones at 38 and 100 m. There is a trade-off between the number of heights and the accuracy of the 10-min average measurements, since adding heights reduces the number of measurements per height.
The device Measurement specifications are:

- **Range:** 10-200+ metres (Validated measurements only up to 200m, by DNV GL.)
- **Probe Length:**
  - ±0.07 metres @ 10 metres
  - ±7.70 metres @ 100 metres
- **Heights:** 10 User Configurable

- **Sampling rate:** 50 Hz (up to 50 measurement points every second)
- **Averaging rate:**
    - True 1-second averaging
    - 10 minute averaging
- **Accuracy wind speed:** 0.1 m/s
- **Direction variation:** <0.5º
- **Range:** 1 m/s to 80 m/s

All Lidar units are validated at the ZXLidars test facility near Pershore, UK. Validations are carried out by DNV-GL in the role of independent third party. The unit's performance verification and uncertainty calculations are carried out in accordance with the current edition of the IEC 61400-12-1 standard.

2.4.2. ADCP

The EOLOS FLS200 mounts Signature500, a five-beam current profiling system manufactured by Nortek Group.

Figure 3. Signature500. Source: www.nortekgroup.com

An acoustic Doppler current profiler (ADCP) measures current speed and direction by transmitting high-frequency sound waves into the water column. The instrument measures velocities along its individual beams by calculating the Doppler shift (D) of the returned signal. The distance to the measurement volume is defined by the two-way travel time of the transmit pulse. The speed of sound (C) is used to convert the Doppler shift to velocity, and a transformation matrix (T) defined by the orientation of the individual beams transforms the beam estimates to Cartesian 3D velocities in a XYZ coordinate system, V = T x C × D. The built-in compass and attitude sensor can further transform the XYZ coordinates to Earth referenced coordinates, ENU. [3]

The Signature500 also offers an altimeter functionality allocated on the 5th vertically oriented beam. The altimeter measures the distance between the instrument's transducer and a physical boundary (such as the sea bottom). That is done by transmitting a short pulse and analyzing the received signal with the Leading Edge Algorithm. This algorithm finds the distance to the seabed where the rate of change in the amplitude of the received signal is at its highest.

The measurement specifications of the Signature500 are:

- Current Profiler
    - Maximum profiling range: 70 metres
    - Cell size: 0.5 – 4 m
    - Maximum number of cells: 200
    - Maximum sampling rate: 8 Hz
    - Velocity range (along beam): User-selectable 2.5 or 5.0 m/s
    - Velocity resolution: 0.1 m/s
    - Minimum accuracy: 0.3% of measured value ± 0.3 cm/s

- Altimeter
  - Altimeter range: 0.5-70 m
  - Altimeter cell size: 0.024 m

2.4.3. WAVE

The EOLOS FLS200 mounts an AIM motion sensor + WAVE designed for application within wave buoys, from the manufacturer Automasjon og Data AS (A+D).

Figure 4: AIM WAVE Source: www.wisegroupsystems.com

The AIM sensor includes several Inertial Measurement Units (IMU). It incorporates a 3-axis accelerometer and gyroscope in two different locations of the unit plus a magnetometer. The data from the sensors in different locations is consolidated in real time using algorithms within the overall AIM firmware to yield full accelerations, velocity, and displacements in 3 axes, plus magnetic heading.
With these basic real time measurements, time history and spectral analysis is performed in order to yield a wide range of wave statistical values. Note that the wave analysis operates in parallel with the data collection, with all results updated approximately every 5 seconds. [4]
The accuracy of processed wave data is:

- Heave
  - Range: +/- 30 metres
  - Resolution: 0.01 m
  - Accuracy: Typically or better 2%
- Period
  - Range: 1.5 to 30 s
  - Resolution: 0.0391 Hz
  - Accuracy: Typically or better 2%
- Direction
  - Range: 0 to 360 degrees
  - Resolution: 0.1 degrees
  - Accuracy: +/- 1 degree

2.4.4. Meteo stations

The EOLOS FLS200 mounts two different weather stations to maximize weather data availability. The primary station is the VAISALA WXT536 and the secondary one is the Airmar 200WX. Both instruments include sonic anemometers and are mounted at the same quota with respect to SWL, so consistency in measurements is preserved regardless of the instrumentation used.

VAISALA WXT536

The Vaisala Weather Transmitter WXT536 is a flexible, integrated building block for weather applications. Besides wind, it offers four of the most important weather parameters, which are air pressure, temperature, humidity, and rainfall. The WXT536 exceeds the IEC60945 maritime standard and accounts with DNV-GL Type Examination.

Figure 5: VAISALA WXT536. Source: www.vaisala.com

The different quantities are measured according to the following measuring principles

- **Wind**: The transmitter incorporates 3 equally spaced ultrasonic transducers on the top horizontal plane. The speed and direction of the wind are computed by comparing the time it takes the emitted soundwave to travel from one transducer to another.
- **Precipitation**: The precipitation sensor consists of a steel cover and a piezoelectrical sensor which detects the impact of individual raindrops. The signals from the impact are proportional to the volume of the drops and they can be converted directly to accumulated rainfall.
- **Pressure, Temperature, Humidity (PTU module)**: It includes an advanced RC oscillator and to reference capacitors against which the capacitors from the pressure, temperature, and humidity sensors are compared. [5]

Its measurement specifications are:

- Wind Speed:
  - Range: 0 - 60 m/s
  - Response time: 0.25s
  - Acuracy: ±3% at 10 m/s
  - Output resolution: 0.1 m/s
- Wind Direction:
  - Azimuth: 0 – 360 º
  - Response time: 0.25s
  - Acuracy: ±3.0º at 10 m/s
  - Output resolution: 1º
- PTU

	Range	Accuracy	Resolution
Pressure	600-1100 hPa	±0.5 hPa at 0 … +30 °C ±1 hPa at -52 … +60 °C	0.1 hPa
Temperature	-52 ... +60 °C	±0.3 °C	0.1 °C
Humidity	0 ... 100 %RH	±3 %RH at 0 ... 90 %RH ±5 %RH at 90 ... 100 %RH	0.1 %RH

- Rainfall (cumulative)

- Collecting area: 60 cm^2
- Output resolution: 0.01 mm
- Field accuracy for daily accumulation: better than 5 %, weather-dependent

Airmar 200WX

The Airmar 200WX is the original weather station chosen by the Lidar manufacturer ZXLidars. This is the reason it has been kept in the FLS200 despite not having any maritime certification. Like the Vaisala, it offers the most common weather parameters besides wind.

Figure 6: Airmar 200WX. Source: www.airmar.com

For this station wind measurement specifications are:

- Wind Speed:
  - Range: 0 - 40 m/s
  - Accuracy: ±5% at 10 m/s
  - Resolution: 0.1 m/s
- Wind Direction:
  - Range: 0 – 359.9 º
  - Accuracy: ±3% at 10 m/s
  - Resolution: 0.1 º

2.4.5. Compass

The FLS200 mounts the C100 Compass Engine manufactured by KVH Industries.

Figure 7: C100 Compass Engine. Source: www.kvh.com

The C100 microprocessor-controlled fluxgate compass consists of a toroidal fluxgate sensor element and a small electronics board. Each C100 has a saturable ring core in a Lexan cylinder, free floating in an inert fluid to keep it horizontal with respect to the earth. Windings surround the Lexan housing, electrically driving the ring core into saturation and measuring the amplitude of induced pulses which are proportional to the earth's magnetic field. This data is then sent to the microprocessor, which compensates for the hard and soft iron magnetic interference of the host platform. The resulting output is translated into extremely accurate heading data. [6]
The measurement specifications of the C100 Compass Engine are:

- Accuracy: ±0.5°
- Resolution: 0.1°
- Range: 0 – 359.9 º

2.4.6. Pyranometer

The LI200R pyranometer manufactured by LI-COR Biosciences, monitors sun plus sky radiation.

Figure 8: LI-200R. Source: www.licor.com

The LI-200R measures global solar radiation (solar irradiance received on a horizontal surface) with a silicon photodiode mounted under a cosine-corrected acrylic diffuser. The acrylic diffuser compensates for the factor cosine of the angle between the sun beams and the surface normal vector, up until an angle of 82°. Errors are typically less than ± 5% for angles less than 82° from the normal axis. The sensor output is a current (µA) signal that is directly proportional to hemispherical solar radiation. A multiplier is used to convert the current signal into units of radiation (W m-2). [7]

The measurement specifications of the LI200R pyranometer are:

- Accuracy: ± 3% typical; ± 5% maximum
- Sensitivity: Typically 75 µA per 1000 W m-2
- Linearity: Maximum deviation of 1% up to 3000 W m-2
- Cosine Correction: Cosine corrected up to 82° angle of incidence

3. DATA PROCESSING AND DATA QUALITY

3.1. DATA EXTRACTION PROCEDURE

The data from the instruments on the buoy is stored in different devices and the retrieval from this data can be done through different communication channels.

i. Internal storage of the devices (data loggers and instruments).
   a. The data from the instruments is stored in two data loggers: the slave, and the master.
   b. There are instruments that apart from sending data to the data loggers, also store it internally. These instruments are the LIDAR, Wave and ADCP.

ii. Communication channels.
   a. Telemetry.
      i. Mobile network communication (3G).
      ii. Satellite communication (Iridium).
   b. In situ internal memory recovery.
      Data is downloaded from the internal memory of the device via:
      i. Wi-Fi.
      ii. Cable.
      iii. Memory card extraction.

Each device has different communication channels available. The following table gives an overview of which communication channels are accessible for each device.

		Master	Slave	Lidar	Wave	ADCP
Telemetry	3G					
	Iridium					
In situ internal memory recovery	Wi-Fi					
	Cable					
	Memory card extraction					

Table 16 – Data accessibility per device and communication channel.
Green: accessible, red: not accessible.

To extract the data, all the different channels are used when available, in order to obtain the highest data availability. The priority with which each data recovery channel is used, is depicted in the following flowchart, where numbers indicate the priority of the channel. The tag F2M in the flowchart stands for "format to master" and means that the format of the data is changed to match the format of the master data logger. The F2M formatting is applied to all the data except to the data from the master data logger, which already has this format. This step is necessary so that all data has the same format prior to the post-processing. At the end of the process the data obtained through all channels is merged, indicated in the flowchart by the symbol $\oplus$. A detailed explanation of the flowchart follows.

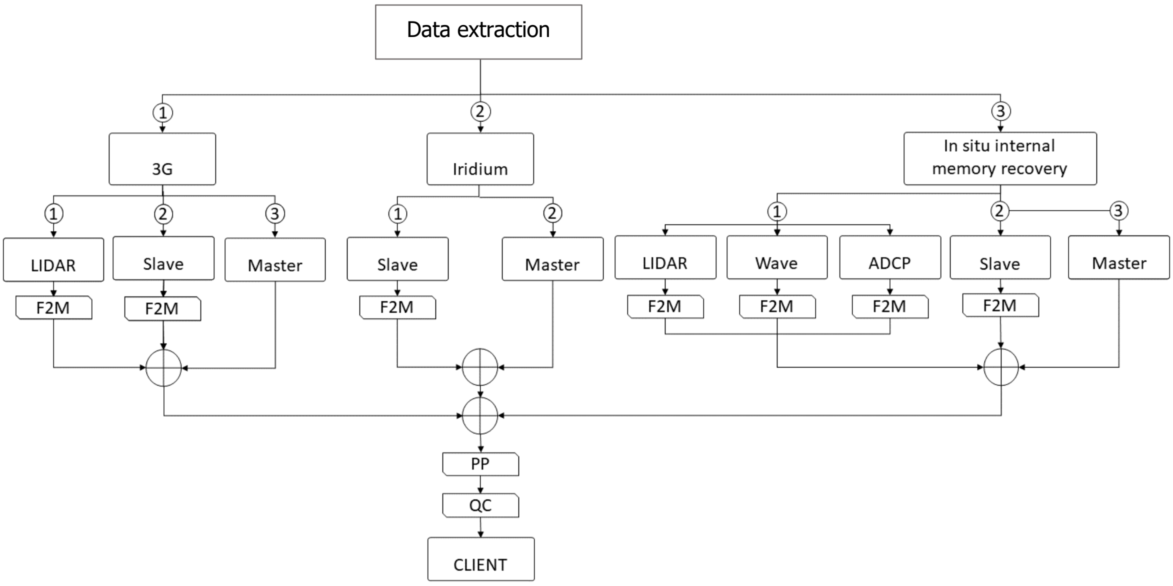

Figure 9. Data extraction flowchart.

The process starts by selecting a communication channel. The preferred one is mobile network communication (3G), if it is not available, satellite communication (iridium) is used. If the data from the devices has been recovered in situ through an expedition to the buoy, this data is also used.

The next step consists of merging the data available from different devices (data loggers and instruments). The devices that are available and the order in which the data is taken depends on which instrument's data is being retrieved.

i. LIDAR

In the first place, if the telemetry communication channel is 3G, the data from the internal memory storage of the LIDAR is taken, because it normally contains the highest amount of data. This data is then formatted to match the master's data format (F2M). Then, the Slave's data is taken, and it is formatted and merged with the previous data. Afterwards the master's data is taken and merged (no formatting is needed). Additionally, if the internal memory storage of the LIDAR has been recovered in situ through an expedition to the buoy, this data might also be taken, formatted, and merged with the rest.

ii. Wave and ADCP

The data is first taken from the Slave and formatted to match the master format (F2M). Then the data is taken from the master and merged with the previous one. Additionally, the data might be taken directly from the Wave and ADCP's internal memory storage if it has been retrieved through an expedition to the buoy, and also formatted and merged with the rest.

iii. Other instruments

For all other instruments, the data is first taken from the Slave and formatted (F2M). Then the data is taken from the master and merged with the rest.

Note that the order in which the merge operations are performed does not affect the result. Once all the data from the different communication channels and devices has been analyzed, a union of all datasets is performed, the post-processing (PP) process is executed, and the data undergoes a manual quality control (QC). Finally, this data is sent to the client.

3.2. VARIABLE UNITS AND FILTER RANGES

3.2.1. Periodical variables

The following table shows a list of all the variables sent to the CLIENT periodically every month. It shows from which sensor they come, their units, variable definition and the filter ranges applied to it in the quality control if applicable.

Sensor	Variable Name	Units	Variable Definition	Data quality control checks Max and Min values
CURRENT SENSOR	ADCPtemp	Celsius	Surface water temperature	(-4) – 40 ºC
	ADCP_vcXX	m/s	Current velocity (**)	0 – 2.5 m/s
	ADCP_vcXX	Deg	Current direction (**)	0 – 360 Deg
	alti_ADCPlevelA_Avg	m	Distance between seabed and surface	30 – 37 m♦♦
METEO	meteo_Sn_min	m/s	Meteo wind speed minimum	-
	meteo_Sm_avg	m/s	Meteo wind speed mean	0 – 60 m/s
	meteo_Sx_max	m/s	Meteo wind Speed maximum	-
	meteo_Dir_bear	Deg	Meteo wind direction mean	0 – 360 Deg
	meteo_Ta_avg	Celsius	Meteo air temperature	(-52) – 60 ºC
	meteo_Ua_avg	%	Meteo relative air humidity	0 – 100 %
	meteo_Pa_avg	hPa	Meteo air pressure	600 – 1100 hPa
	meteo_Rc	mm	Meteo rain	0 – 1000 mm
WAVE	wave_Havg	m	Average wave height, zero crossing	0 – 25 m
	wave_Tz	s	Mean spectral period (TM02), spectral	1.6 – 30 s
	wave_Hmax	m	Maximum wave height, zero crossing	0 – 25 m
	wave_Hs	m	Significant wave height, zero crossing	0 – 25 m
	wave_Ts	s	Significant wave period, zero crossing	1.6 – 30 s
	wave_H_10	m	Average height highest 1/10 waves, zero crossing	0 – 25 m

Sensor	Variable Name	Units	Variable Definition	Data quality control checks Max and Min values
	wave_T_10	s	Average period highest 1/10 waves, zero crossing	1.6 – 30 s
	wave_Tavg	s	Average wave period, zero crossing	1.6 – 30 s
	wave_Tp	s	Peak period, spectral	1.6 – 30 s
	wave_HM0	m	Significant wave height, spectral	0 – 25 m
	wave_DirAvg	Deg	Average wave direction,spectral	0 – 360 Deg
	wave_DirAvgSpr	Deg	Average directional spread, spectral	0 – 90 Deg
	wave_DirP	Deg	Peak wave direction,spectral	0 – 360 Deg
	AHRS_AHRSroll_Max	Deg	Maximum roll	-
	AHRS_AHRSroll_Min	Deg	Minimum roll	-
	AHRS_AHRSpitch_Max	Deg	Maximum pitch	-
	AHRS_AHRSpitch_Min	Deg	Minimum pitch	-
	AHRS_AHRSyaw_Max	Deg	Maximum yaw	-
	AHRS_AHRSyaw_Min	Deg	Minimum yaw	-
LIDAR	LidarXXm_Z10_HorizWS	m/s	Lidar mean horizontal wind speed at XXm (*)	0 – 50 m/s
	LidarXXm_Z10_StdDevWS	m/s	Lidar STD horizontal wind speed at XXm (*)	-
	LidarXXm_Z10_MaxWS	m/s	Lidar max horizontal wind speed at XXm (*)	-
	LidarXXm_Z10_MinWS	m/s	Lidar min horizontal wind speed at XXm (*)	-
	LidarXXm_Z10_WD	Deg	Lidar mean wind direction at XXm (*)	0 – 360 Deg
	LidarXXm_Z10_VertWS	m/s	Lidar vertical wind speed at XXm (*)	-
	LidarXXm_Z10_InfoFlag	-	Lidar Info Flag at XXm (*)	-
	LidarXXm_Z10_StatFlag	-	Lidar Status Flag at XXm (*)	-
	LidarXXm_Z10_Packets	-	Lidar Packets at XXm (*)	-
	LidarXXm_Z10_TurbInt	-	Lidar turbulence intensity at XXm (*)	-
	LidarXXm_code	-	Data quality code (*)	-
OTHER SECONDARY SENSORS	meteo_SlrW_Avg	W/m^2	Solar light	0 – 3000 W/m^2
	buoy_status_CR6S_batt_Avg	Volts	Voltage level power/control	-
	buoy_status_GPSlat	Deg	Position of buoy (Latitude)	♦

Sensor	Variable Name	Units	Variable Definition	Data quality control checks Max and Min values
	buoy_status_GPSlong	Deg	Position of buoy (Longitude)	♦
NOTES				
(*) For each height. (**) For each of the water depths (between seabed and sea surface) measured with the current sensor. ♦ Must be within the drift radius of 97 meters. ♦♦ Further quality control filtering is applied to variable *alti_ADCPlevelA_Avg*, as described in detail in the document "EOL-HSS50-V02-OPS-Report ADCP E01 HESSELØ.pdf". All the results shown in this document are created from the dataset that has undergone this filtering. Note that this filtering was not applied to the monthly reports documents and therefore results may differ.				

Table 17. Periodical FLS200 data variables.

3.2.2. End of campaign variables

The following table shows a list of all the extra variables sent to the CLIENT at the end of the campaign. This includes the high frequency LIDAR variables (sampling: duration 1s, interval 1s and frequency 1Hz) and the wave spectral data (sampling: duration 20 min, interval 20 min and frequency 4Hz) . It shows from which sensor they come, their units, variable definition.

Sensor	Variable Name	Units	Variable Definition
LIDAR 1Hz data	Reference	-	Reference
	Time and Date	dd/mm/yyyy hh:MM	Time and Date
	Timestamp	dd/mm/yyyy hh:MM	Timestamp
	Info. Flags	-	Info. Flags
	Status Flags	-	Status Flags
	Battery	Volts	Battery
	Generator	Volts	Generator
	Upper Temp	Celsius	Upper Temp.
	Lower Temp	Celsius	Lower Temp.
	Pod Humidity	%	Pod Humidity
	GPS	degree	GPS
	Met Compass Bearing	Deg	Met Compass Bearing
	Met Tilt	Deg	Met Tilt
	Met Air Temp	Celsius	Met Air Temp
	Met Pressure	mbar	Met Pressure
	Met Humidity	%	Met Humidity
	Met Wind Speed	m/s	Met Wind Speed
	Met Wind Direction	Deg	Met Wind Direction
	Rainning	-	Raining
	Fog	-	Fog

Sensor	Variable Name	Units	Variable Definition
	Wind direction at XXm	Deg	Wind direction at XXm
	Horizontal Wind Speed at XXm	m/s	Horizontal Wind Speed at XXm
	Vertical Wind Speed at XXm	m/s	Vertical Wind Speed at XXm
	Checksum	-	Checksum
WAVE spectral data*	column 1	-	Index number from within the FFT operation
	column 2	Hz	Frequency component: f
	column 3	m^2 s / rad	Spectral Energy Component: E(ω)
	column 4	Deg	Mean Direction: $W_D(f)$
	column 5	Deg	Direction Spread: $W_S(f)$
WAVE surface elevation	Eta	m	Surface elevation
WAVE raw AHRS	column 1	-	Timestamp
	column 2	-	Starting characters
	column 3	m	Displacement X direction
	column 4	m	Displacement Y direction
	column 5	m	Displacement Z direction
	column 6	m/s^2	Acceleration X direction
	column 7	m/s^2	Acceleration Y direction
	column 8	m/s^2	Acceleration Z direction
	column 9	Deg	Roll
	column 10	Deg	Pitch
	column 11	Deg	Yaw
	column 12	Deg	(- column 11)
	column 13	-	Ending characters

Table 18. End of campaign FLS200 data variables.

*These are variables measured by the WAVE sensor. From them the traditional 2D wave spectrum S(f, θ) can be computed. The S(f, θ) is an industry standard which is defined as follows:

- S(f,θ)=E(f)*D(f, θ)
- D(f,θ) is a Gaussian distribution with:
    - Mean=$W_D(f)$
    - Standard Deviation=$W_S(f)$

The frequency range spans from 0.667 Hz to 0.033 Hz, frequencies outside this range will not be included in the wave spectral parameter calculations.

Note that the Spectral Energy Component, E(ω), is given as a function of the angular frequency ω, which is related to the linear frequency f by: ω = 2πf. For all calculations the units of the frequency dependency of E must coincide with the units of the frequency. This is achieved through the transformation: $E(f)\left[\frac{m^2}{Hz}\right] = 2\pi\, E(\omega)\left[\frac{m^2 s}{rad}\right]$. For example, to compute H_{m0} first transform $E(\omega) \rightarrow E(f)$ and then evaluate the formula $H_{m0} = 4\sqrt{\sum_f E(f)\Delta f}$.

See example of a 2D wave spectrum as result of the application of the method described above.

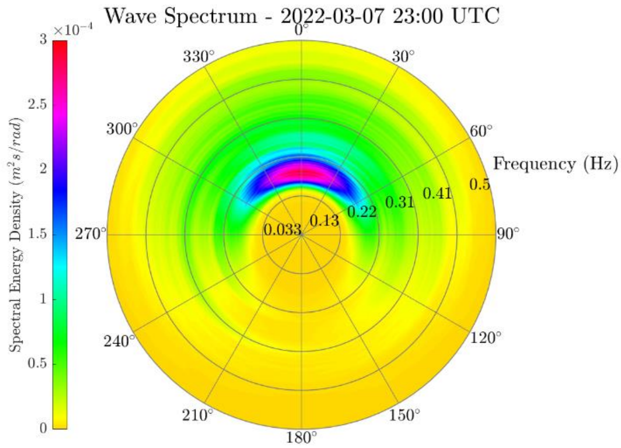

Figure 10: 2D Spectrum in polar coordinates. Radius is the frequency and angle is the direction.

3.3. MISSING AND INVALID DATA HANDLING

3.3.1. All sensors

For all sensors except for the LiDAR and pyranometer, faulty data entries are tagged with:

- NAN: if the data entry is missing.
- 999: if the data entry was flagged by the Eolos QC.

Faulty data entries are delivered to the client appropriately tagged.

3.3.2. Pyranometer

The values of the solar irradiance measured by the pyranometer are valid if they fall within a range of 0 - 3000 W/m^2. Therefore 999 is not an appropriate flagging value since it falls within the acceptance range.

The monthly data received by the client was flagged with 999 values for missing or invalid data, which leads to a subsequent miscalculation of the data availability. This issue is reported in the incidence document "E01-HSS-INC014_v01.pdf".

In the complete dataset received by the client at the end of the campaign, all invalid and missing values of the pyranometer are tagged with a NAN, and the data availability is appropriately computed.

3.3.3. LiDAR

In the LiDAR's case, faulty data entries are tagged with:

- NAN: if the data entry is missing.
- 9999: if the data entry was flagged due to impossibility of high-quality wind speed measurement. Typically caused by very low wind speed, partial obscuration of the Lidar's window, or significant interference with the laser beam at the specified height.
- 9998: if the data entry was flagged due to environmental causes (e.g., thick fog or precipitation) [8].

Faulty data entries are delivered to the client appropriately tagged.

Furthermore, the EOLOS Data Postprocessing algorithm creates a quality control parameter for each measurement height. Such parameters are named "code" and take the following values:

- 0 - System not available
- 1 - System available & Postprocessed Data passing quality checks
- 2 - System available but data filtered for not passing quality checks
- 3 - System available & Postprocessed Data passing quality checks for Wind Speed but not passing quality checks for Wind Direction

3.4. END OF CAMPAIGN FILES

For each type of files, the file name, content definition and number of files is indicated.

3.4.1. Post-processed files

EOLOS_yyyymmdd_0000_YYYYMMDD_2350_10minCompassM_Code.dat

- Data from sensors that output at 10-min frequency. Lidar data corrected with Mast compass. Includes Lidar quality code variables.
- 1 file

EOLOS_yyyymmdd_0000_YYYYMMDD_2350_10minCompassZX_Code.dat

- Data from sensors that output at 10-min frequency. Lidar data corrected with Airmar compass. Includes Lidar quality code variables.
- 1 file

EOLOS_yyyymmdd_0000_YYYYMMDD_2350_30min.dat

- Data from sensors that output at 30-min frequency.
- 1 file

SYYYYMMDD_HHmmSS_New_record_Original_record.csv

- Multiple csv files containing wave spectral data, structured as explained in section 3.2.2. These files are named as above, where:
  - S: stands for Spectral
  - New_record: record number given in posterior reprocessing
  - Original_record: record number given by instrument
- Mapping to EOLOS timestamp: round to nearest 30-minute timestamp
- 16,266 files
  - Of which 16107 correspond to wave data in the 30-min file with no NaNs.
  - Of which 159 correspond to wave data in the 30-min file with at least one NaN.

Eta_timeseries_YYYYMMDDHHmm.dat

- Multiple .dat files each containing 20 minutes of surface elevation data at 5 Hz.
- 16,266 files
  - Of which 16107 correspond to wave data in the 30-min file with no NaNs.
  - Of which 159 correspond to wave data in the 30-min file with at least one NaN.

3.4.2. Original files

LIDAR original files

Wind_LSN@Yyyyy_Mmm_Ddd.ZPH.csv

- High frequency Lidar data for all heights.
- 7 files

Wind10_LSN@Yyyyy_Mmm_Ddd.ZPH.csv

- 10-min averaged Lidar data for all heights.
- 1 file

ADCP original files

E01_HSS_yyyymmdd_YYYYMMDD.ad2cp

Converter program	Signature Deployment
Converted file extension	.mat and .csv

- High frequency measurement data from all configured sensors, averaged raw altimeter measurements, instrument configuration, variable description, and variable units.
- 3 files

E01_HSS_yyyymmdd_YYYYMMDD_avgd.ad2cp

Converter program	Signature Deployment
Converted file extension	.mat and .csv

- Averaged measurement data from all configured sensors, instrument configuration, variable description, and variable units.
- 3 files

E01_HSS_yyyymmdd_YYYYMMDD.cfg

- Set of commands that describe the configuration of the ADCP, automatically and internally generated by the ADCP. It might differ from the .deploy file if there was an error in the deployment steps or if the configuration has been later changed through the ADCP terminal. This is the real configuration with which the ADCP has measured. The meaning of each of those commands can be found in the Nortek Manual "Signature Integration" [9] . Most of the configuration parameters are also saved in the data files with extension .ad2cp described above.
- 3 files

E01_HSS_yyyymmdd_YYYYMMDD.hdr

- Contains information about the file format of the other files, in addition to the setup and configuration of the instrument. Internally generated by the ADCP.
- 3 files

telemetryfile.bin

- File created during measurement, containing the data which will be read by the datalogger. It is configured using the appropriate SETTMxxx commands. The meaning of those commands can be found in the Nortek Manual "Signature Integration". The data format is DF104, which is the format expected by the datalogger.
- 2 files

AD2CP_500kHz_900000_ yyyymmdd_YYYYMMDD.deploy

- Files created a posteriori. They do not contain all the actual ADCP configuration.
- Set of commands used to configure the measurement plan of the ADCP. The configuration is done through the Signature Deployment software, which outputs the .deploy file. The meaning of each of those commands can be found in the Nortek Manual "Signature Integration". [9]

- 3 files

E01_ADCP_getall_20211223.log

- File generated when interacting with the ADCP through the command line. Contains the outputs of such interaction.
- 1 file

WAVE original files

Raw AHRS

Provides motion 6 degrees of freedom data at the unit location (displacement and rotation along three axes). Data format is defined in the manual from the manufacturer (Automasjon og Data) called "AIM ADAPTIVE INERTIAL MATRIX TECHNICAL MANUAL" in section "Message 23" and in section 3.2.2 of this document. There are two types of files:

E01_ch1_10HZ_###.txt

- Data sampling at 10 Hz from WAVE internal SD card. From campaign start until 29/01/2022.
- 161 files

E01_ch1_5HZ_162.txt

- Data sampling at 5 Hz from Slave datalogger. From 28/01/2022 until campaign end.
- 1 file

4. DATA AVAILABILITY

4.1. DEFINITIONS

The availabilities are computed in accordance with section 2.3 of the Measurement Plan. [10]

4.2. DATA AVAILABILITY TABLES AND GRAPHS

For each sensor, availability table and bar charts are presented for the corresponding variables.

The tables show the availability per variable for the whole campaign period. They contain the name of the sensor, the variable name, the number of total possible data entries for the campaign period, the number of valid system data, system availability, the number of post-processed valid data, and post-processed availability. The rows for which the post-processed columns are empty correspond to variables that are not post-processed.

Each bar chart shows the monthly availability for a specific variable. The month tags in the x-axis correspond to day 28 of the first month to day 28 of the second month. The graphs show system and post-processed availability, both monthly (bars) as well as averaged for the whole campaign period (horizontal lines).

4.2.1. LIDAR

LIDAR AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
LIDAR	lidar_lidar10m_Z10_HorizWS	52560	52063	**99.05**	51038	**97.10**
	lidar_lidar10m_WD_alg_03	52560	52063	**99.05**	51038	**97.10**
	lidar_lidar10m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar10m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar38m_Z10_HorizWS	52560	52063	**99.05**	51402	**97.80**
	lidar_lidar38m_WD_alg_03	52560	52063	**99.05**	51402	**97.80**

LIDAR AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
	lidar_lidar38m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar38m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar68m_Z10_HorizWS	52560	52063	**99.05**	50986	**97.01**
	lidar_lidar68m_WD_alg_03	52560	52063	**99.05**	50986	**97.01**
	lidar_lidar68m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar68m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar98m_Z10_HorizWS	52560	52063	**99.05**	50440	**95.97**
	lidar_lidar98m_WD_alg_03	52560	52063	**99.05**	50440	**95.97**
	lidar_lidar98m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar98m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar118m_Z10_HorizWS	52560	52063	**99.05**	49639	**94.44**
	lidar_lidar118m_WD_alg_03	52560	52063	**99.05**	49639	**94.44**
	lidar_lidar118m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar118m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar138m_Z10_HorizWS	52560	52063	**99.05**	49267	**93.73**
	lidar_lidar138m_WD_alg_03	52560	52063	**99.05**	49267	**93.73**
	lidar_lidar138m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar138m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar158m_Z10_HorizWS	52560	52063	**99.05**	49029	**93.28**

LIDAR AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
	lidar_lidar158m_WD_alg_03	52560	52063	**99.05**	49029	**93.28**
	lidar_lidar158m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar158m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar178m_Z10_HorizWS	52560	52063	**99.05**	48372	**92.03**
	lidar_lidar178m_WD_alg_03	52560	52063	**99.05**	48372	**92.03**
	lidar_lidar178m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar178m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar198m_Z10_HorizWS	52560	52063	**99.05**	47624	**90.61**
	lidar_lidar198m_WD_alg_03	52560	52063	**99.05**	47624	**90.61**
	lidar_lidar198m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar198m_Z10_TurbInt	52560	52063	**99.05**		
	lidar_lidar238m_Z10_HorizWS	52560	52063	**99.05**	47629	**90.62**
	lidar_lidar238m_WD_alg_03	52560	52063	**99.05**	47629	**90.62**
	lidar_lidar238m_Z10_VertWs	52560	52063	**99.05**		
	lidar_lidar238m_Z10_TurbInt	52560	52063	**99.05**		

Table 19. LIDAR availability.

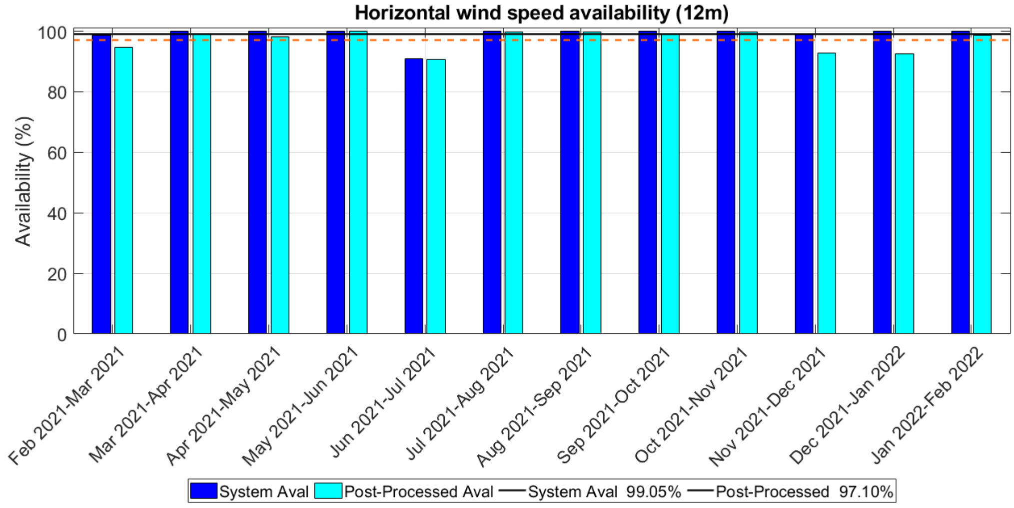

Figure 11. Bar chart for availability of horizontal wind speed at 12 m.

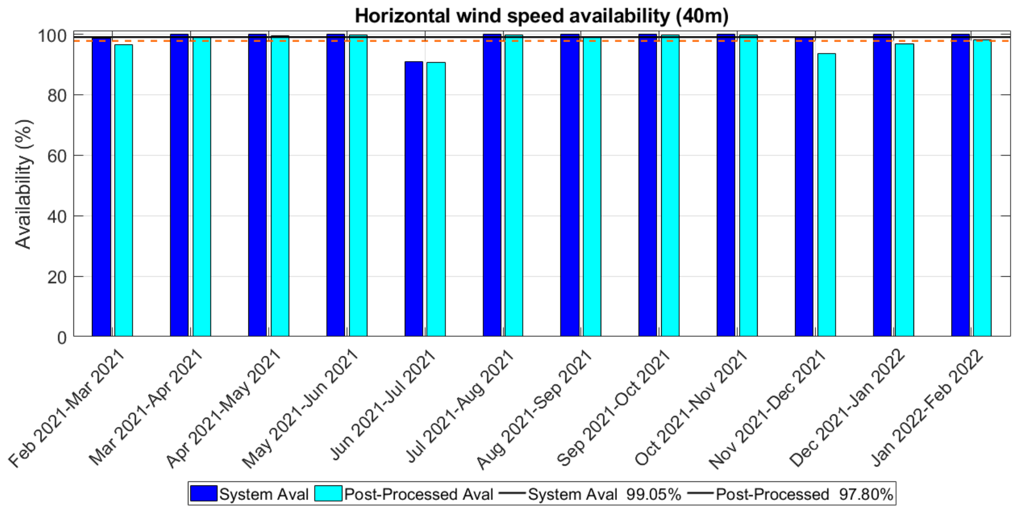

Figure 12. Bar chart for availability of horizontal wind speed at 40 m.

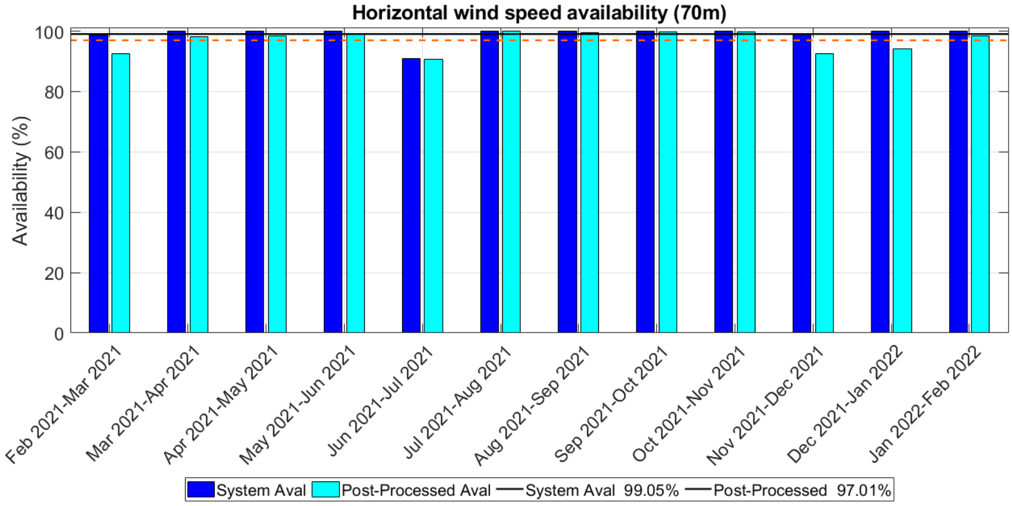

Figure 13. Bar chart for availability of horizontal wind speed at 70 m.

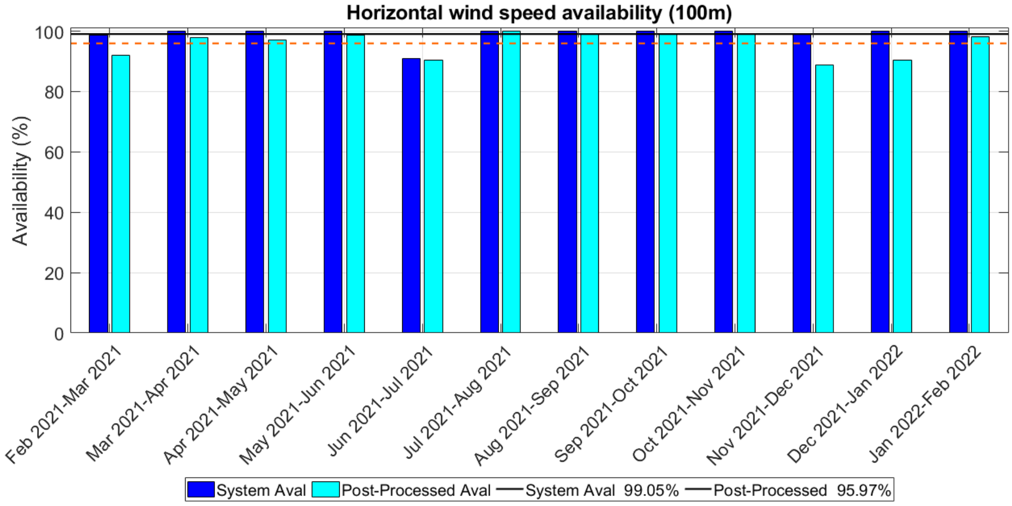

Figure 14. Bar chart for availability of horizontal wind speed at 100 m.

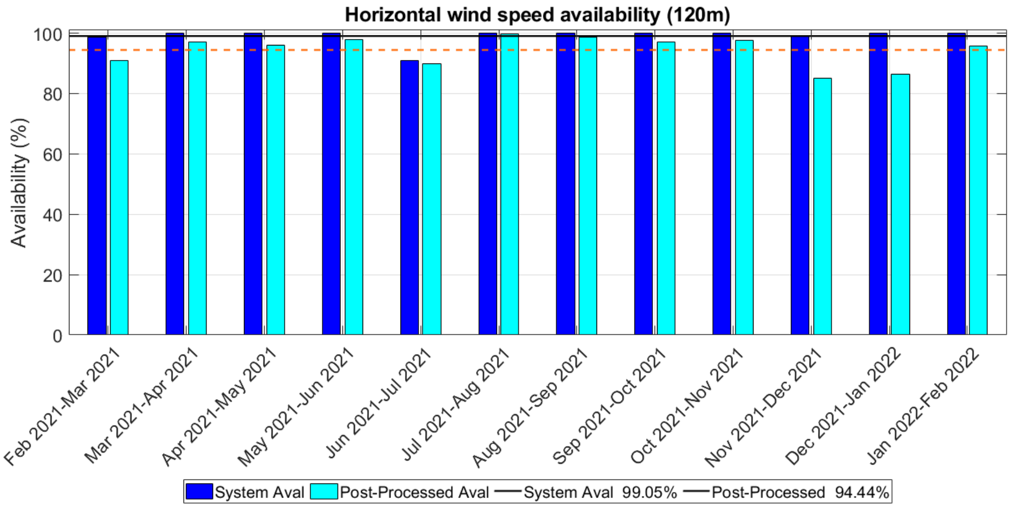

Figure 15. Bar chart for availability of horizontal wind speed at 120 m.

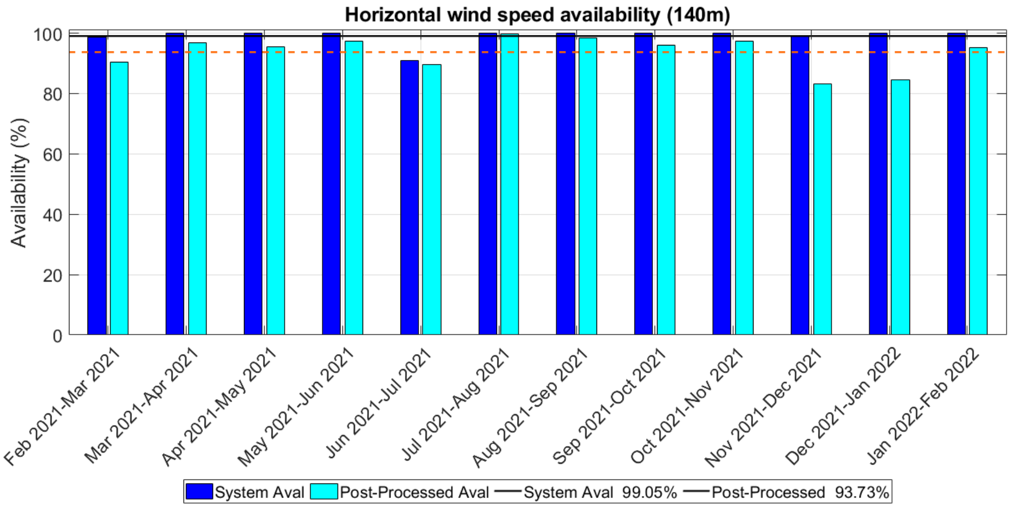

Figure 16. Bar chart for availability of horizontal wind speed at 140 m.

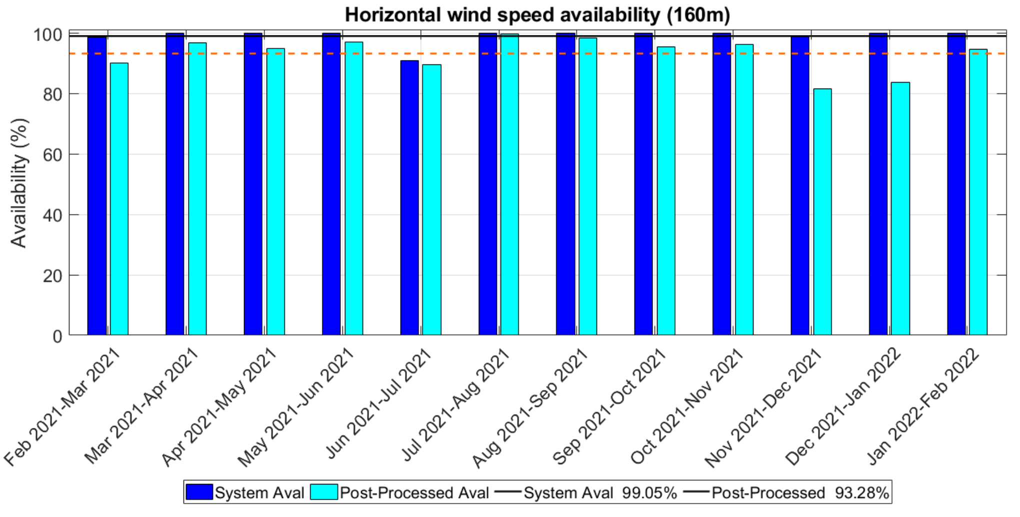

Figure 17. Bar chart for availability of horizontal wind speed at 160 m.

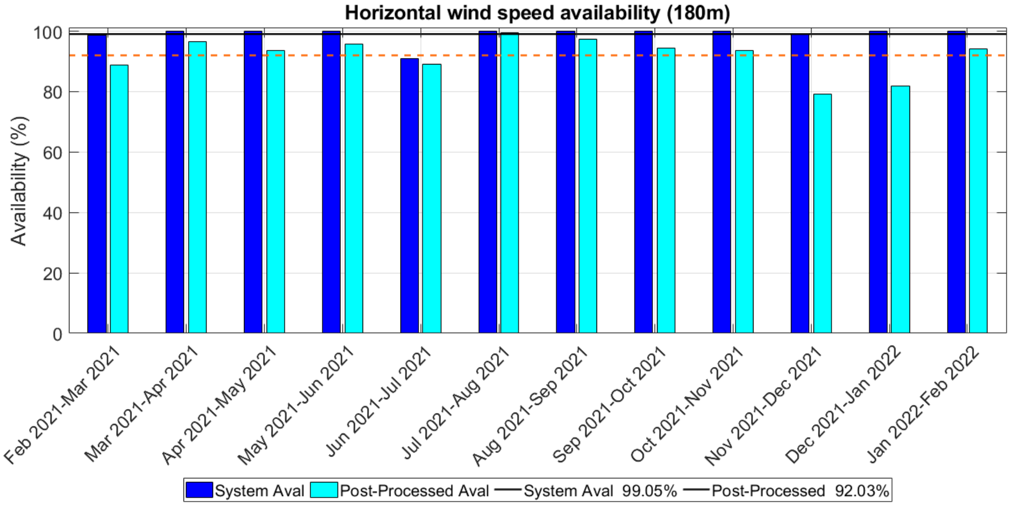

Figure 18. Bar chart for availability of horizontal wind speed at 180 m.

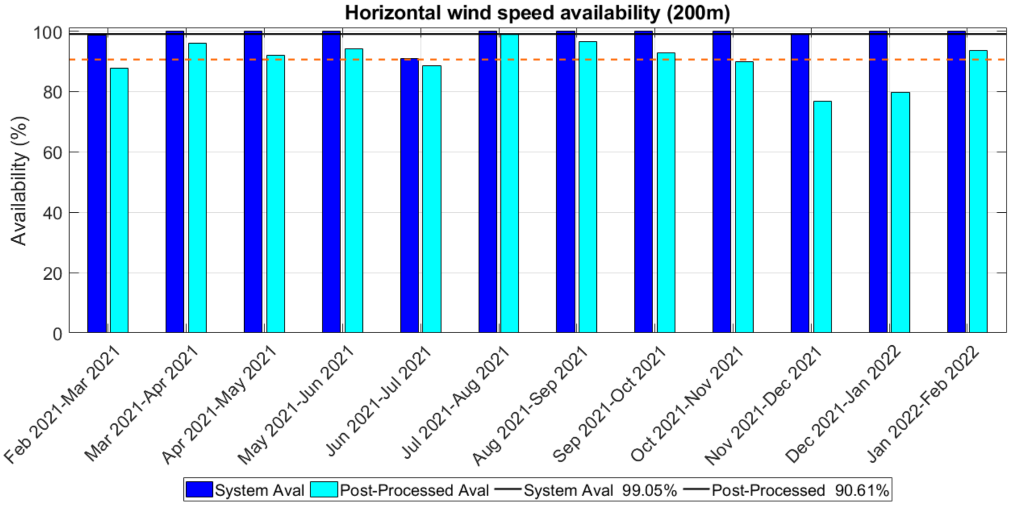

Figure 19. Bar chart for availability of horizontal wind speed at 200 m.

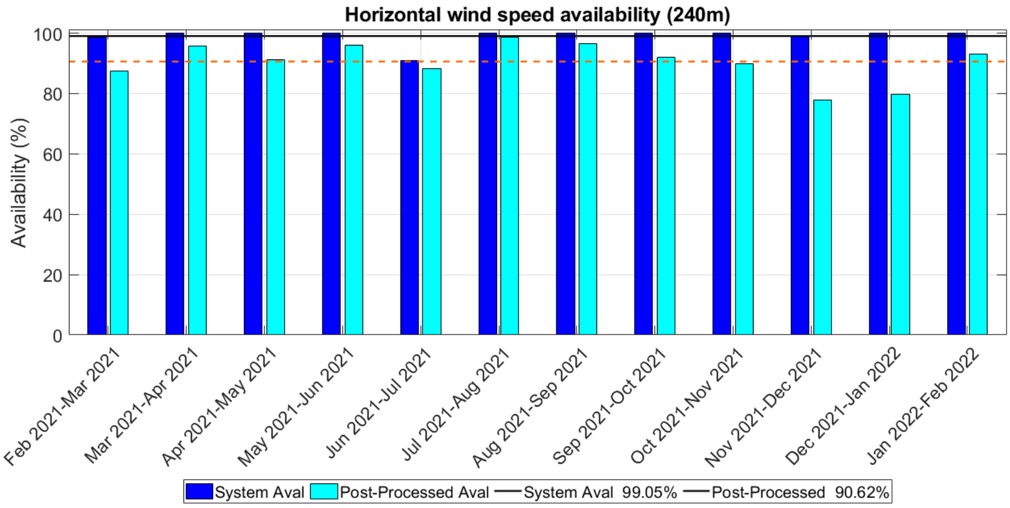

Figure 20. Bar chart for availability of horizontal wind speed at 240 m.

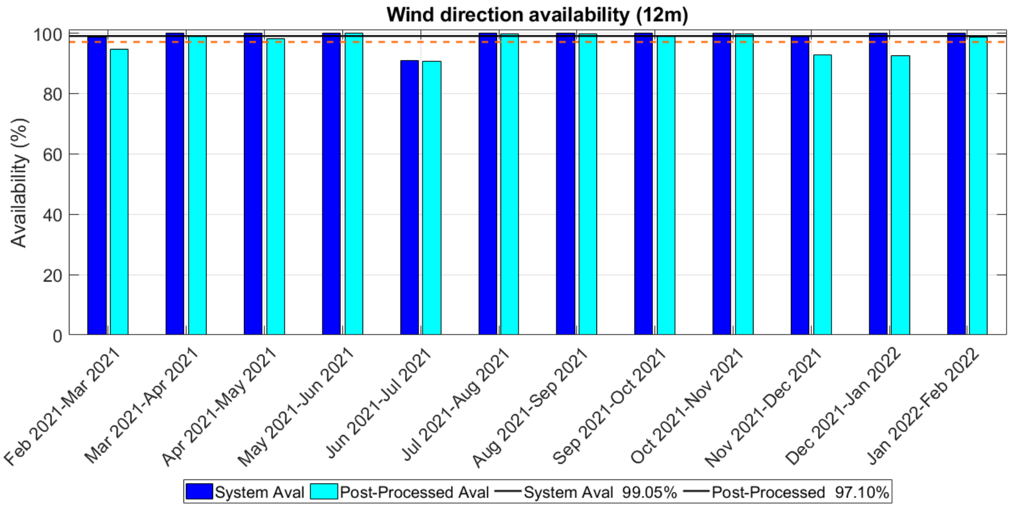

Figure 21. Bar chart for availability of wind direction at 12 m.

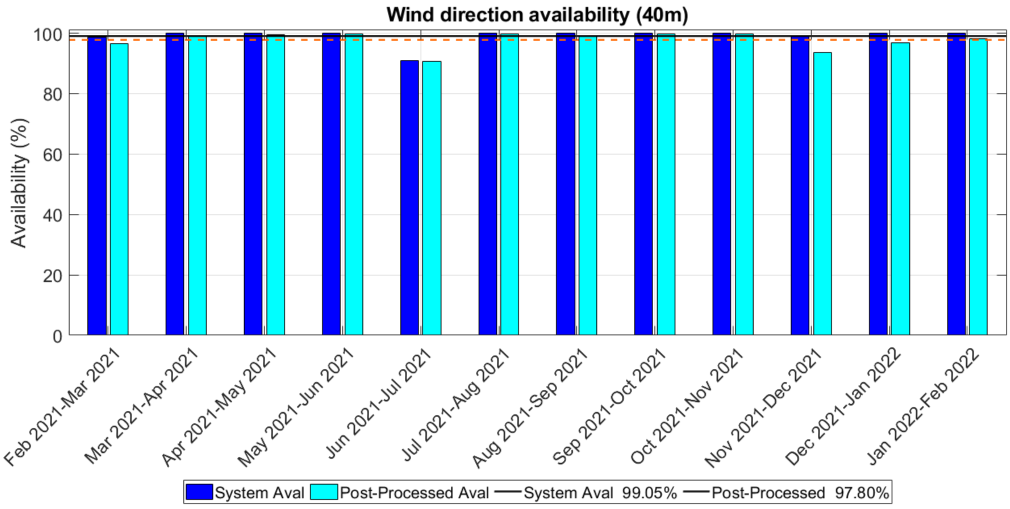

Figure 22. Bar chart for availability of wind direction at 40 m.

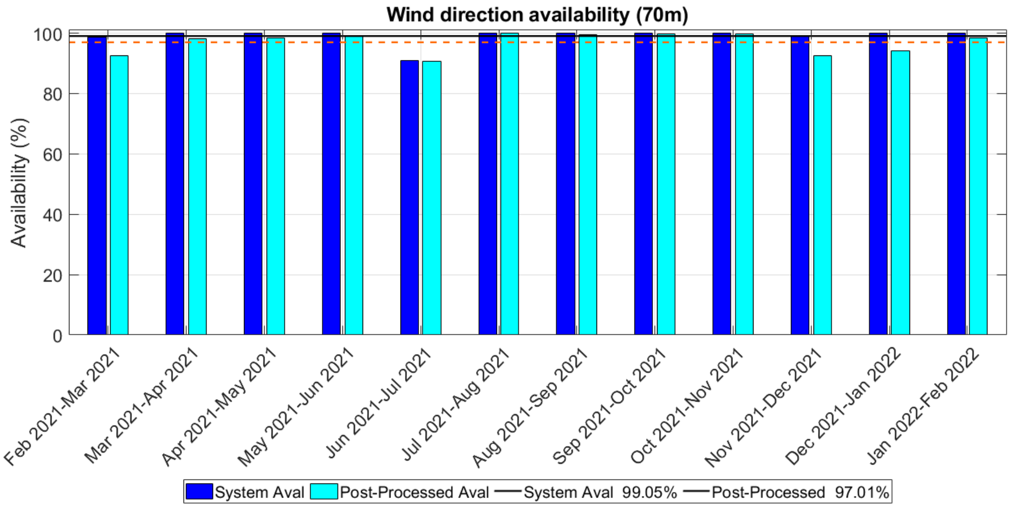

Figure 23. Bar chart for availability of wind direction at 70 m.

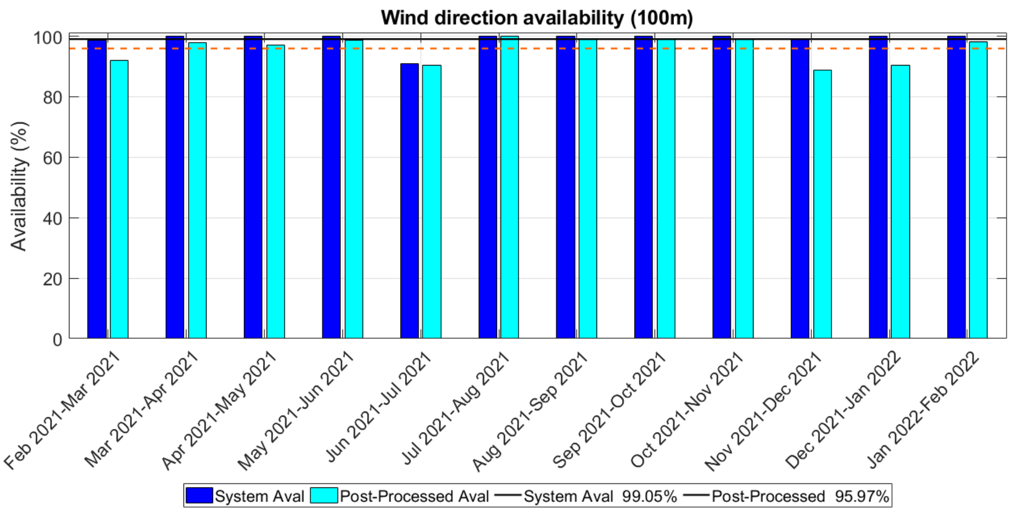

Figure 24. Bar chart for availability of wind direction at 100 m.

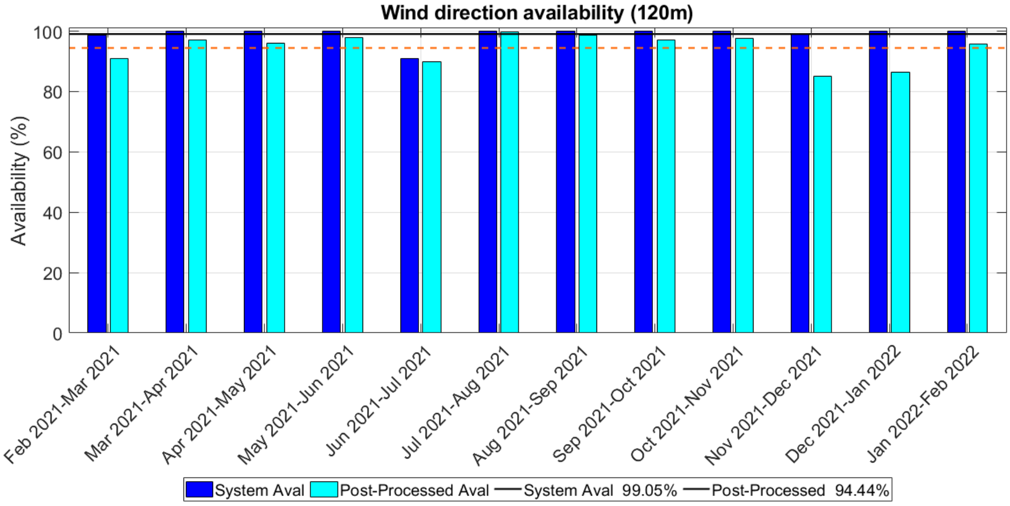

Figure 25. Bar chart for availability of wind direction at 120 m.

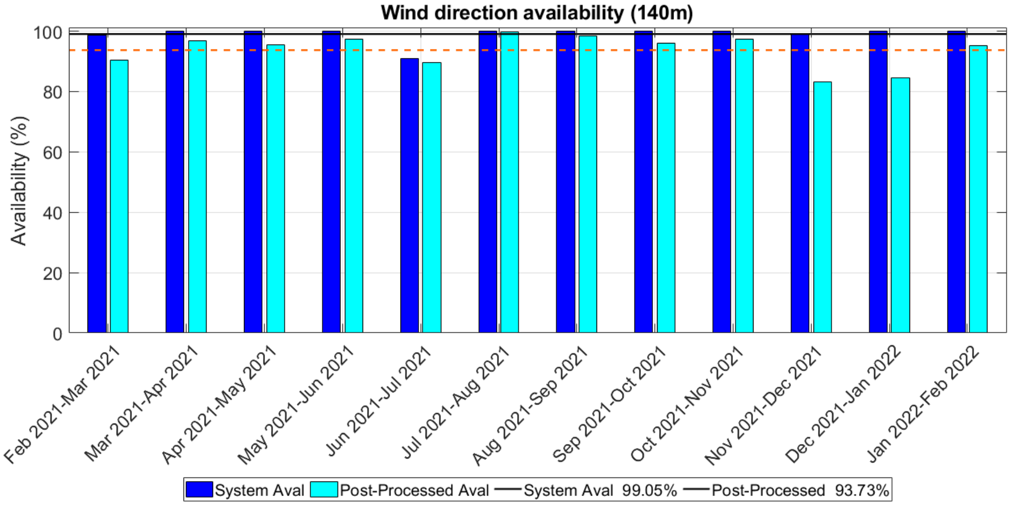

Figure 26. Bar chart for availability of wind direction at 140 m.

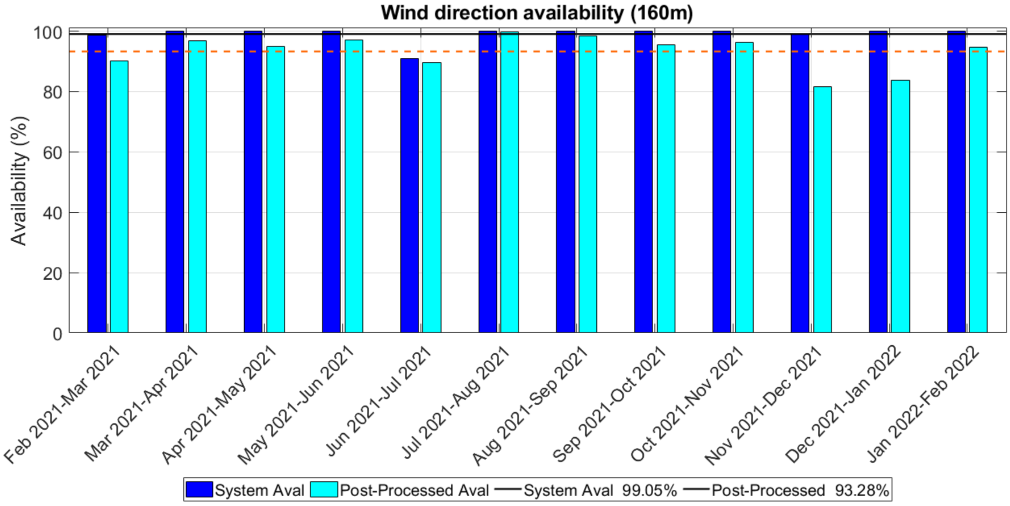

Figure 27. Bar chart for availability of wind direction at 160 m.

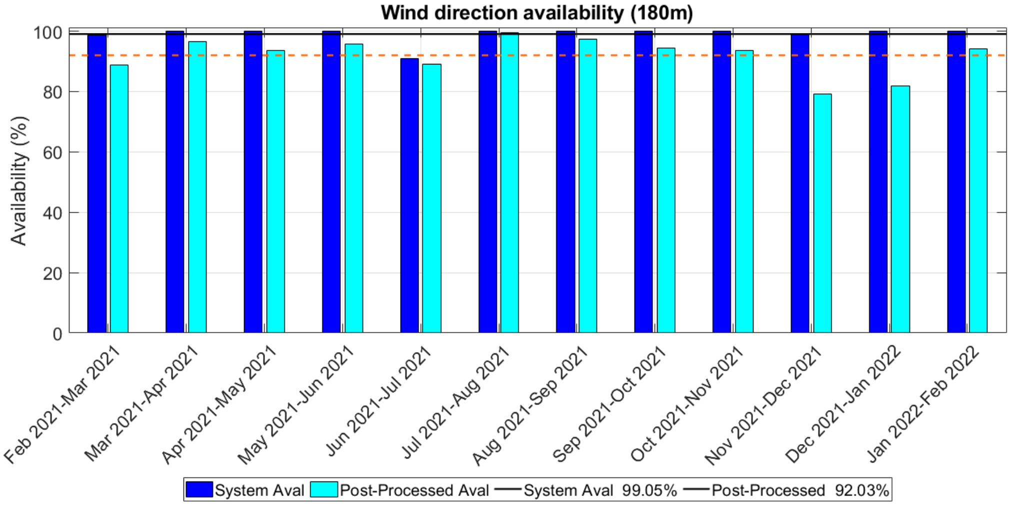

Figure 28. Bar chart for availability of wind direction at 180 m.

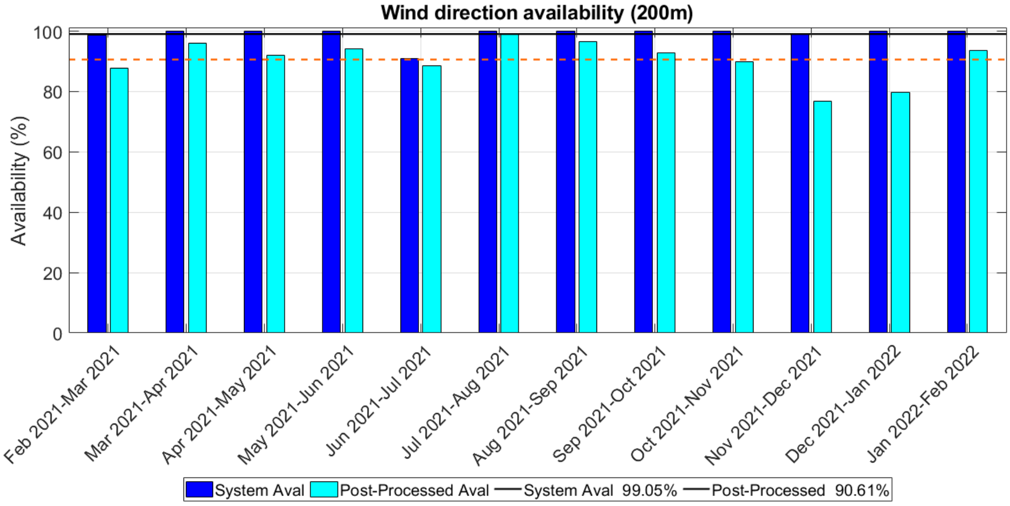

Figure 15. Bar chart for availability of wind direction at 200 m.

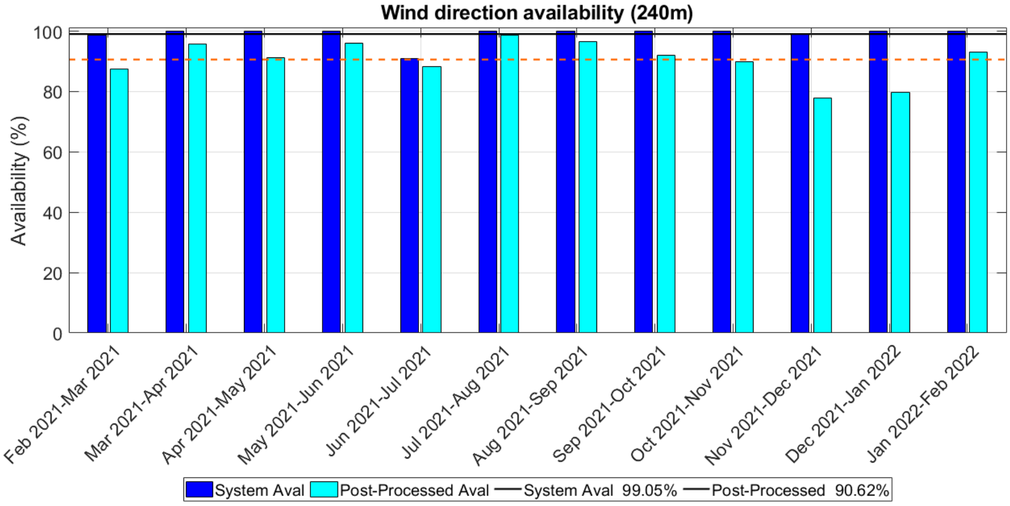

Figure 16. Bar chart for availability of wind direction at 240 m.

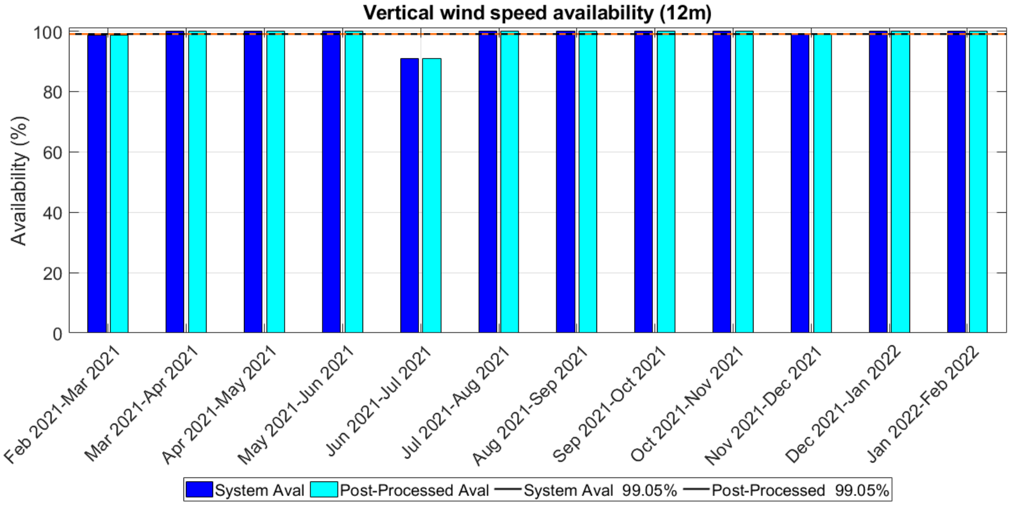

Figure 29. Bar chart for availability of vertical wind speed at 12 m.

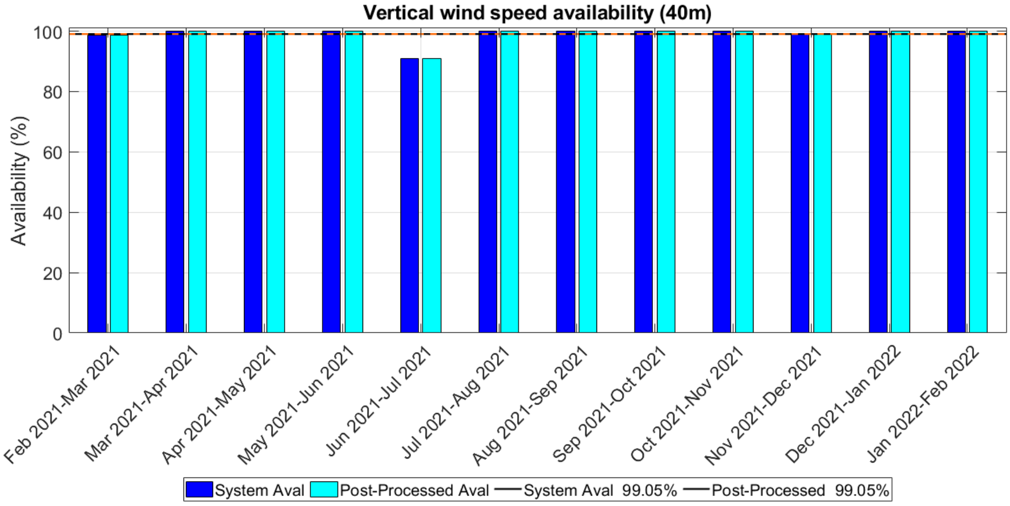

Figure 30. Bar chart for availability of vertical wind speed at 40 m.

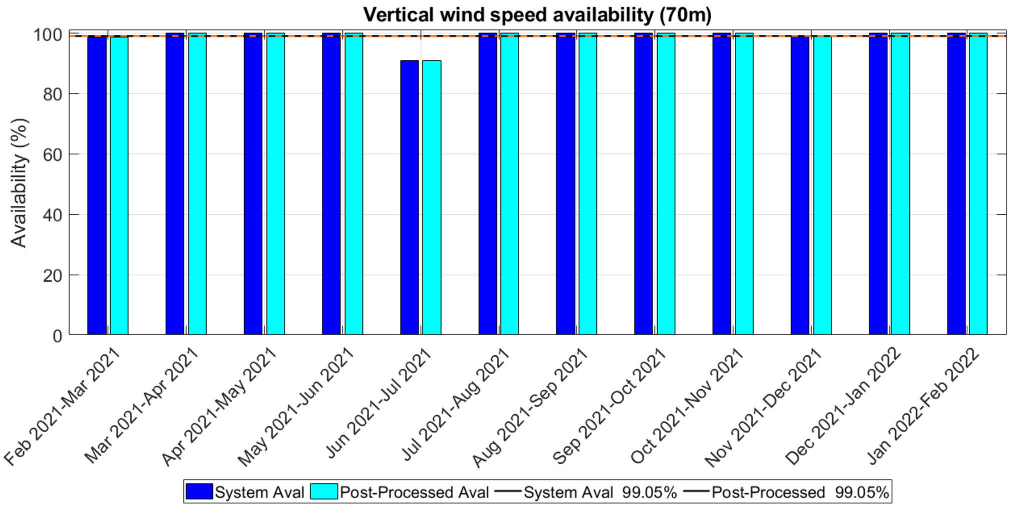

Figure 31. Bar chart for availability of vertical wind speed at 70 m.

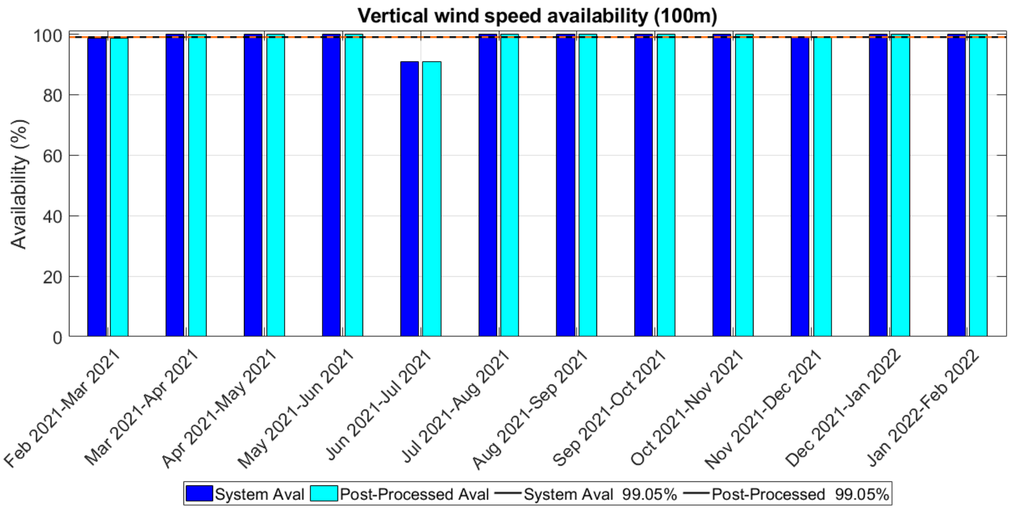

Figure 32. Bar chart for availability of vertical wind speed at 100 m.

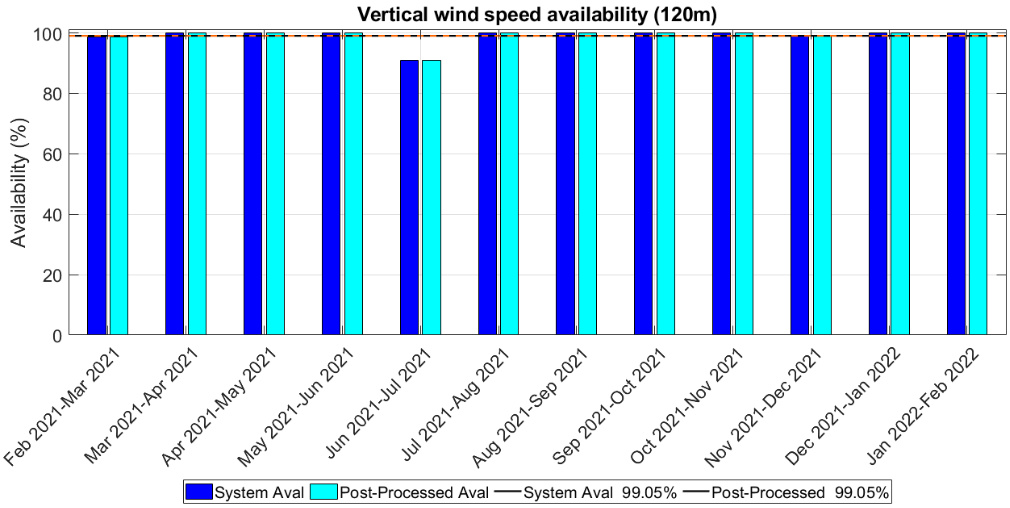

Figure 33. Bar chart for availability of vertical wind speed at 120 m.

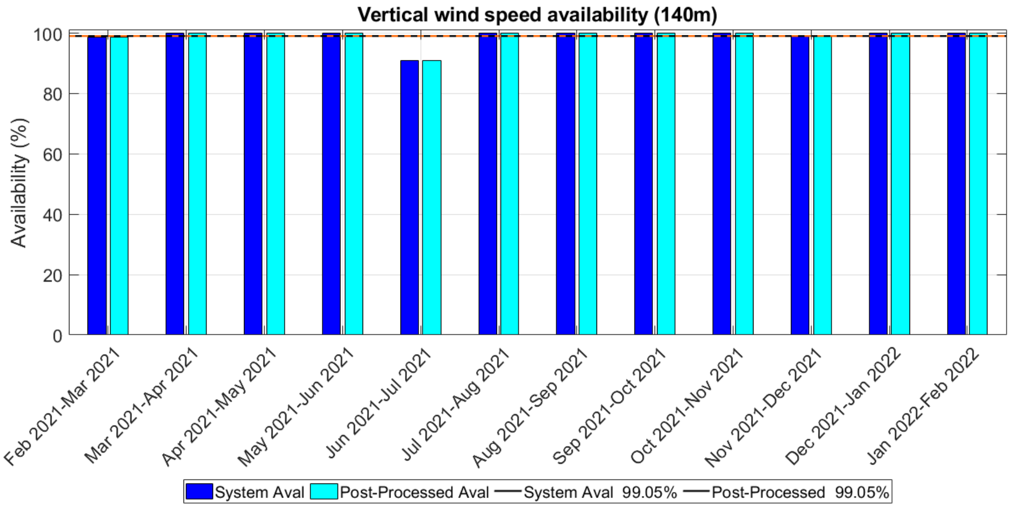

Figure 34. Bar chart for availability of vertical wind speed at 140 m.

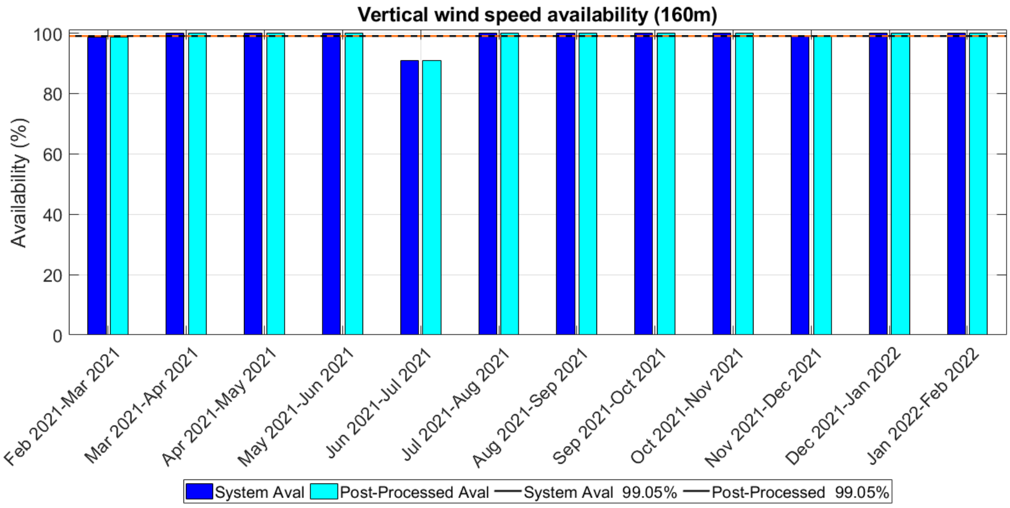

Figure 35. Bar chart for availability of vertical wind speed at 160 m.

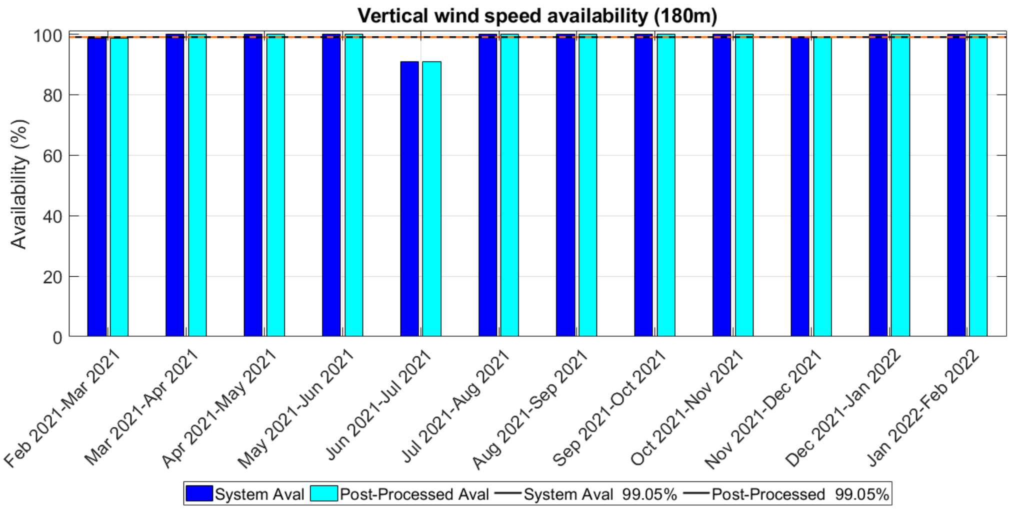

Figure 36. Bar chart for availability of vertical wind speed at 180 m.

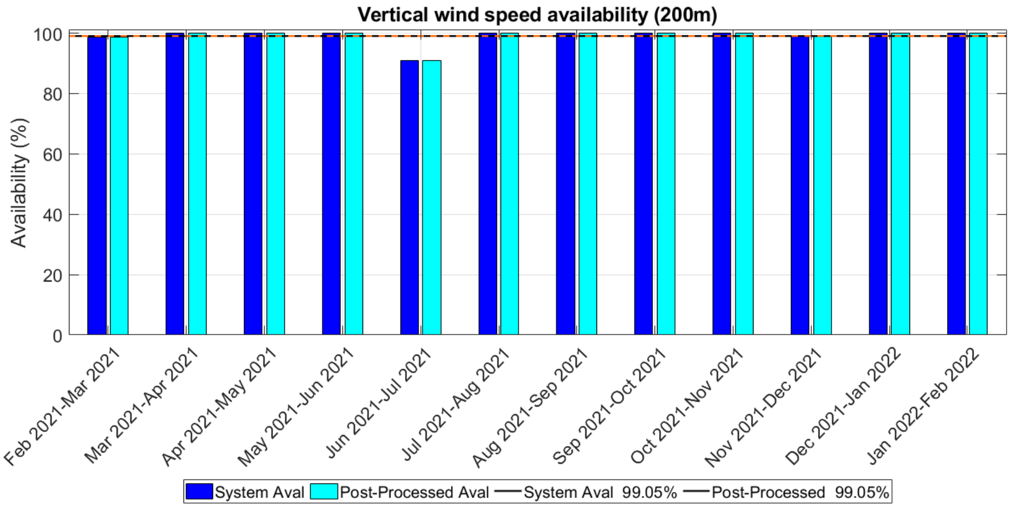

Figure 37. Bar chart for availability of vertical wind speed at 200 m.

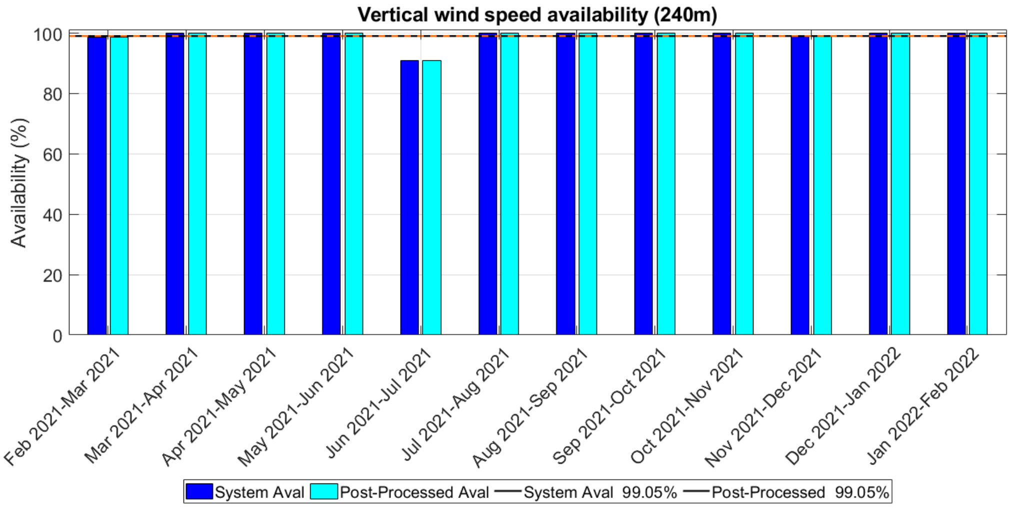

Figure 38. Bar chart for availability of vertical wind speed at 240 m.

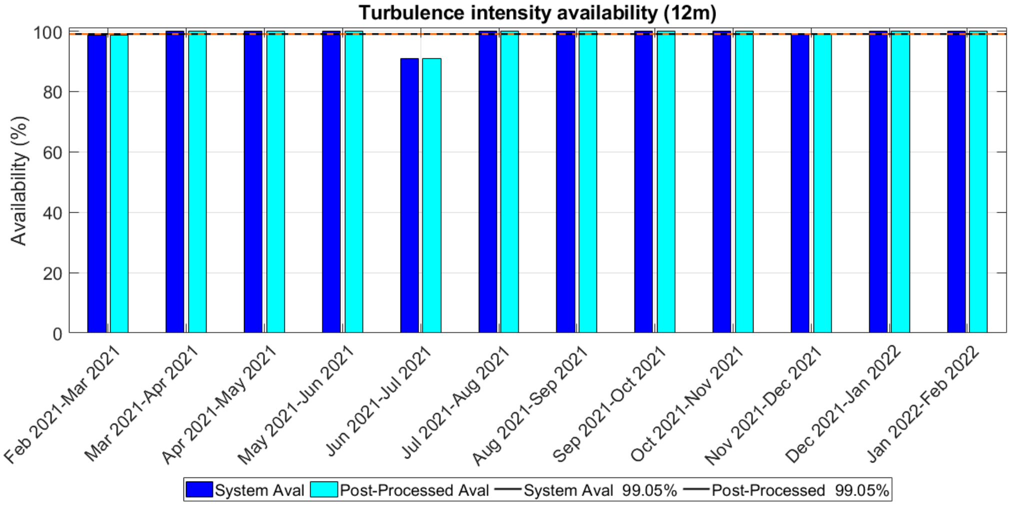

Figure 39. Bar chart for availability of turbulent intensity at 12 m.

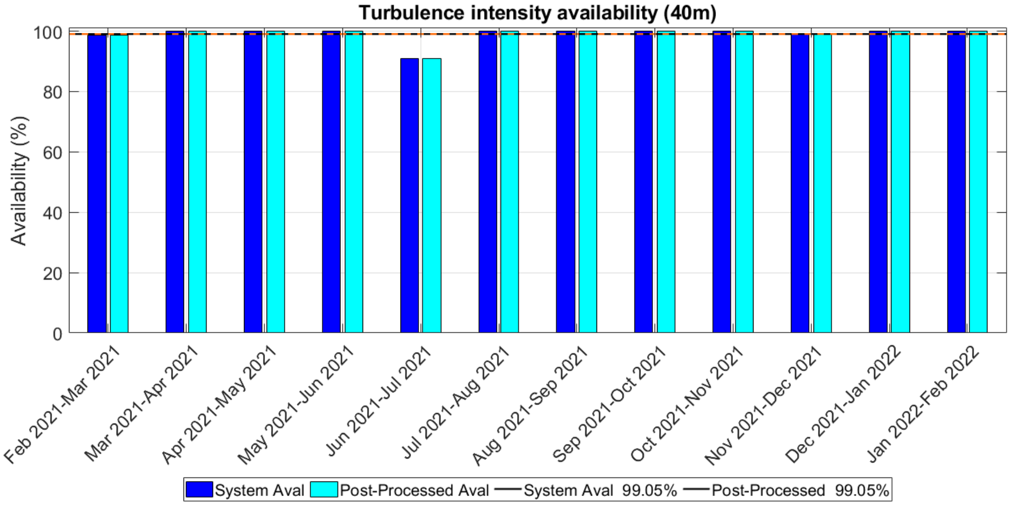

Figure 40. Bar chart for availability of turbulent intensity at 40 m.

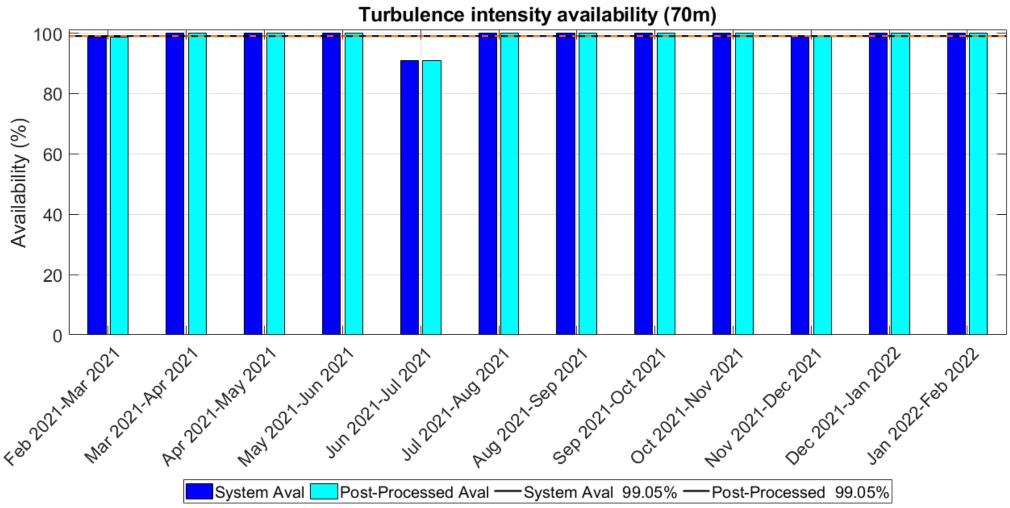

Figure 41. Bar chart for availability of turbulent intensity at 70 m.

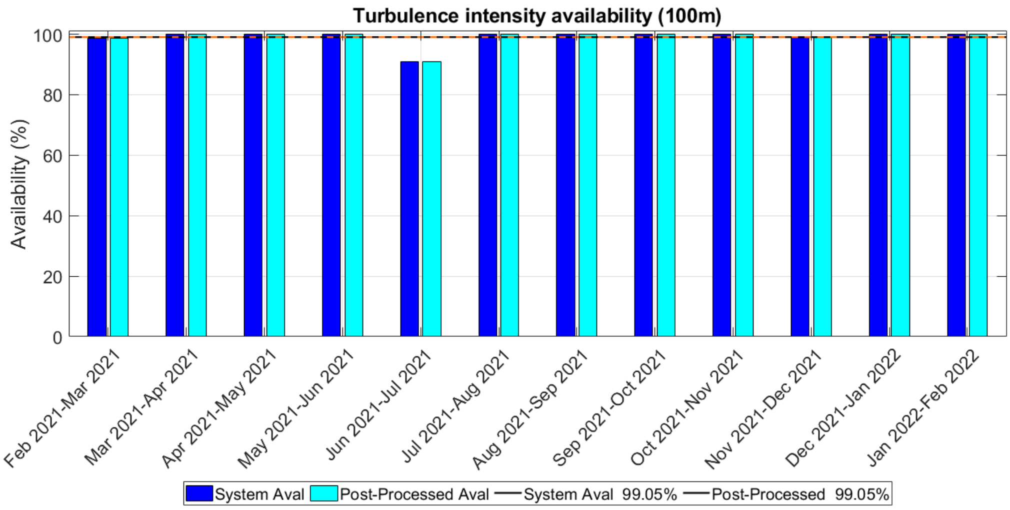

Figure 42. Bar chart for availability of turbulent intensity at 100 m.

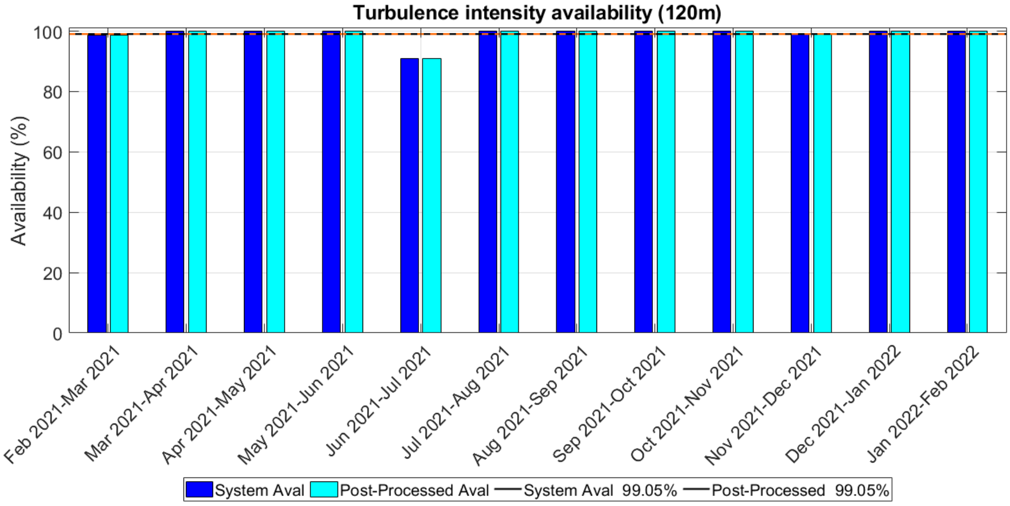

Figure 43. Bar chart for availability of turbulent intensity at 120 m.

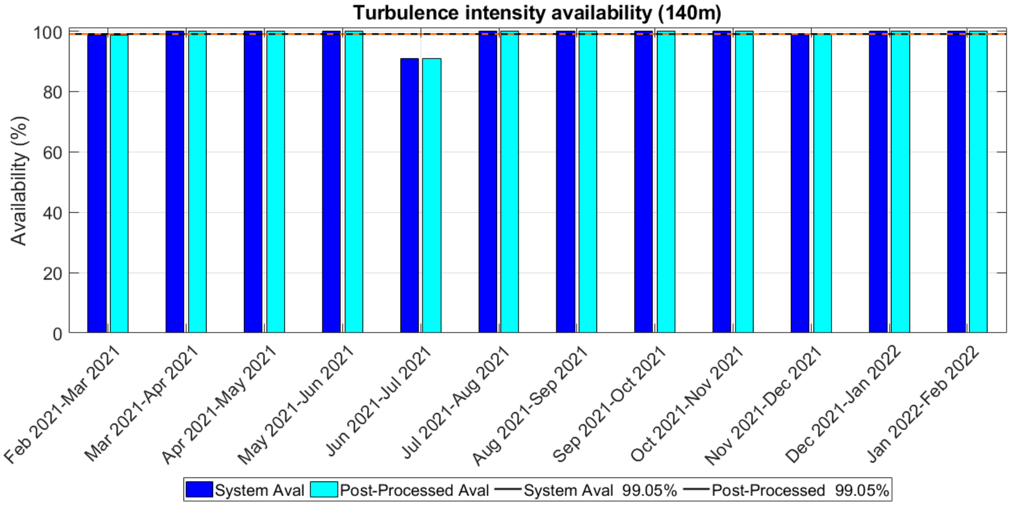

Figure 44. Bar chart for availability of turbulent intensity at 140 m.

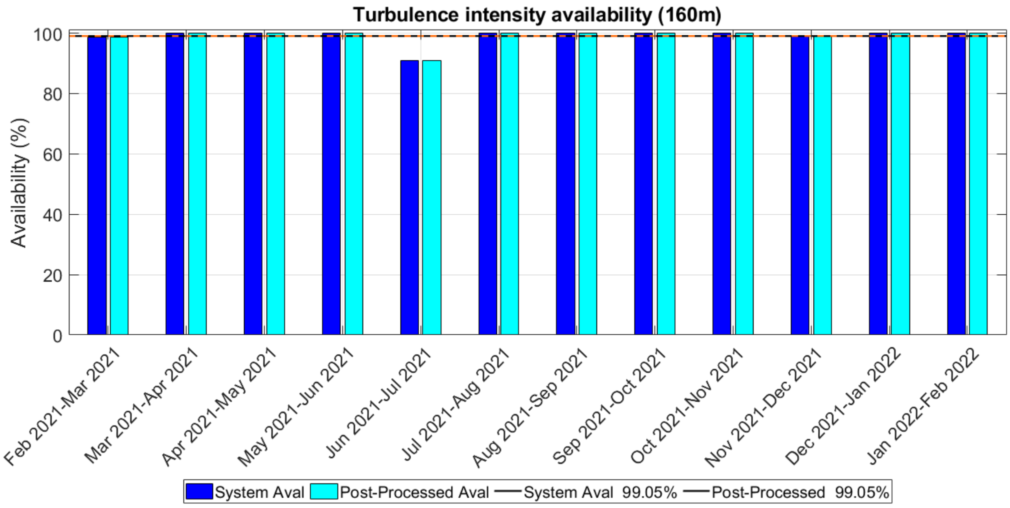

Figure 45. Bar chart for availability of turbulent intensity at 160 m.

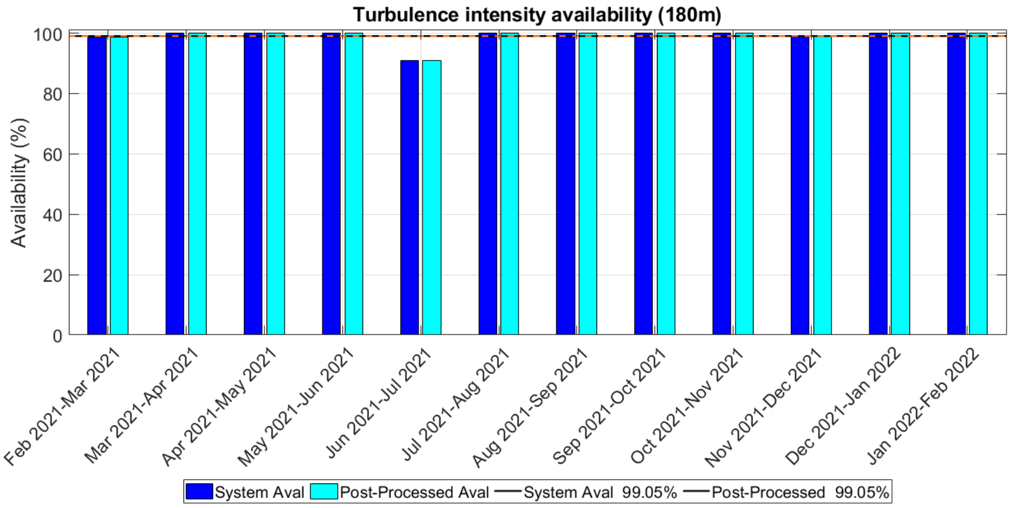

Figure 46. Bar chart for availability of turbulent intensity at 180 m.

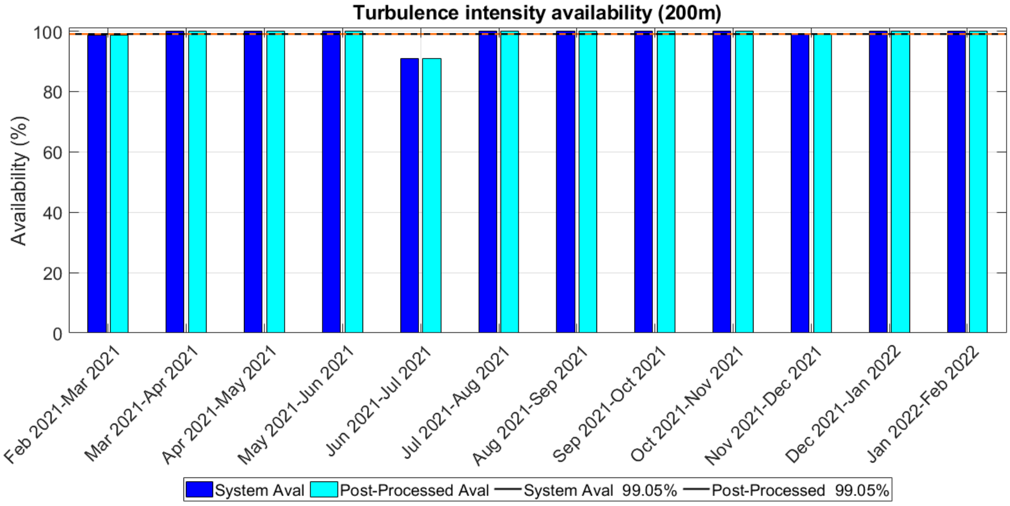

Figure 47. Bar chart for availability of turbulent intensity at 200 m.

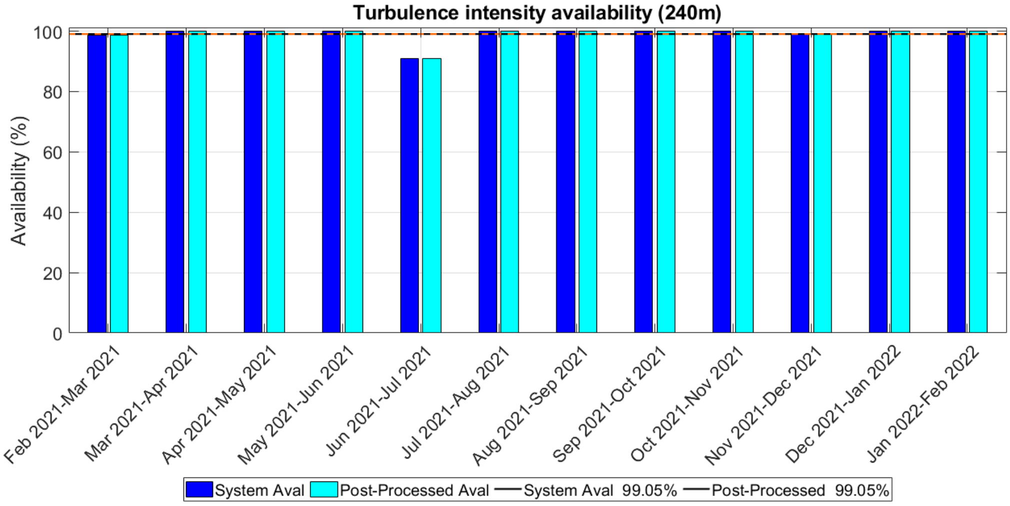

Figure 48. Bar chart for availability of turbulent intensity at 240 m.

4.2.2. METEO

METEO AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
METEO	meteo_Sm_avg	52560	47047	**89.51**	47047	**89.51**
	meteo_Dir_bear	52560	47047	**89.51**	47042	**89.50**
	meteo_Pa_avg	52560	47047	**89.51**	47047	**89.51**
	meteo_Ta_avg	52560	47047	**89.51**	47047	**89.51**
	meteo_Ua_avg	52560	47047	**89.51**	47047	**89.51**
	meteo_Rc	52560	47047	**89.51**	47047	**89.51**

Table 20. METEO availability

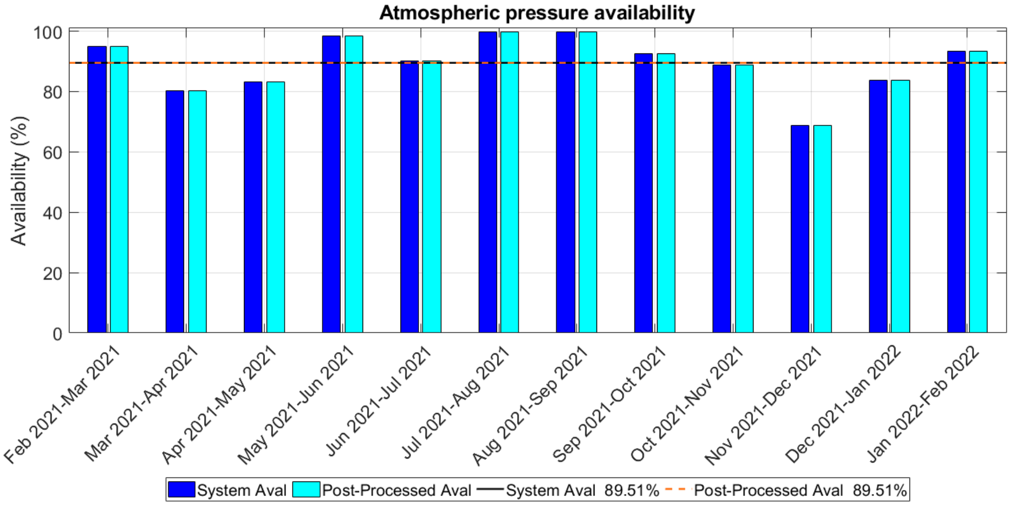

Figure 49. Bar chart for availability of atmospheric pressure.

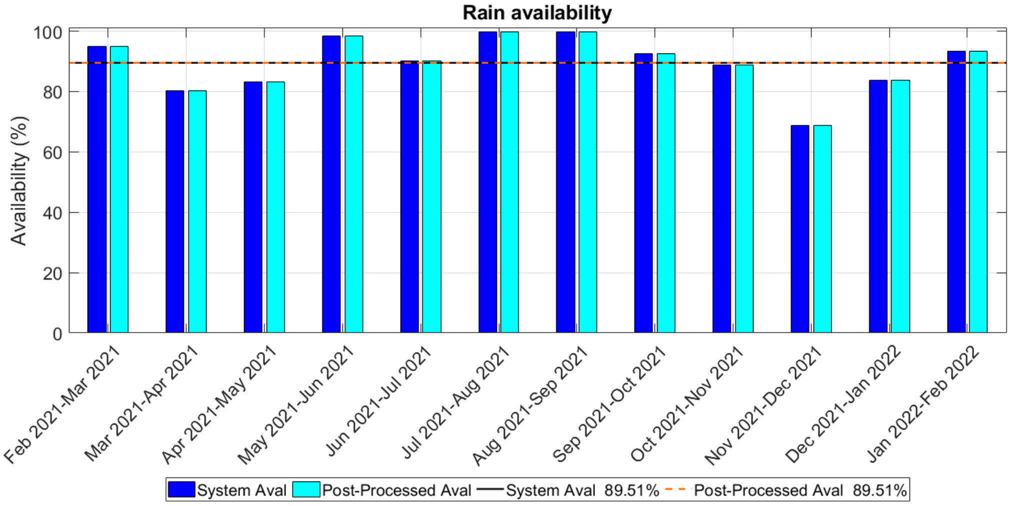

Figure 50. Bar chart for availability of rain.

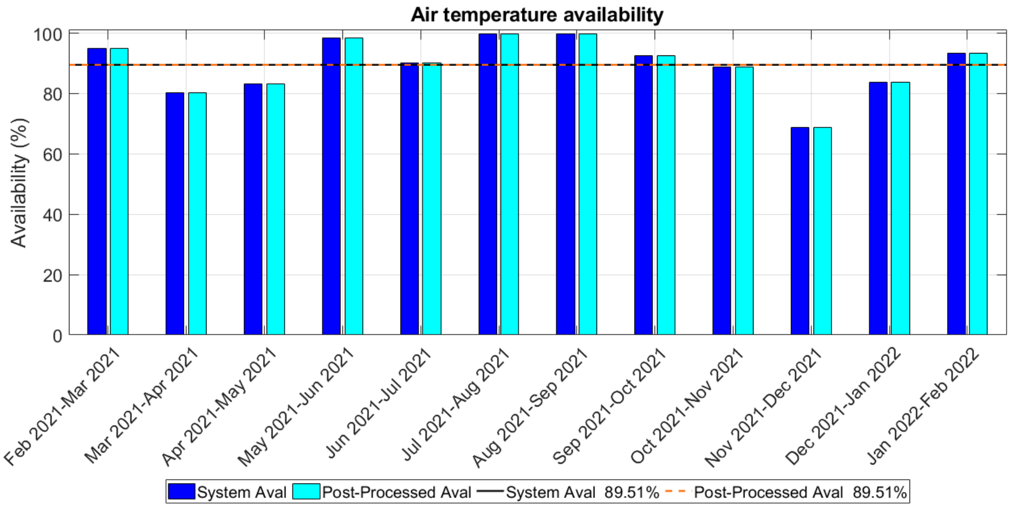

Figure 51. Bar chart for availability of air temperature.

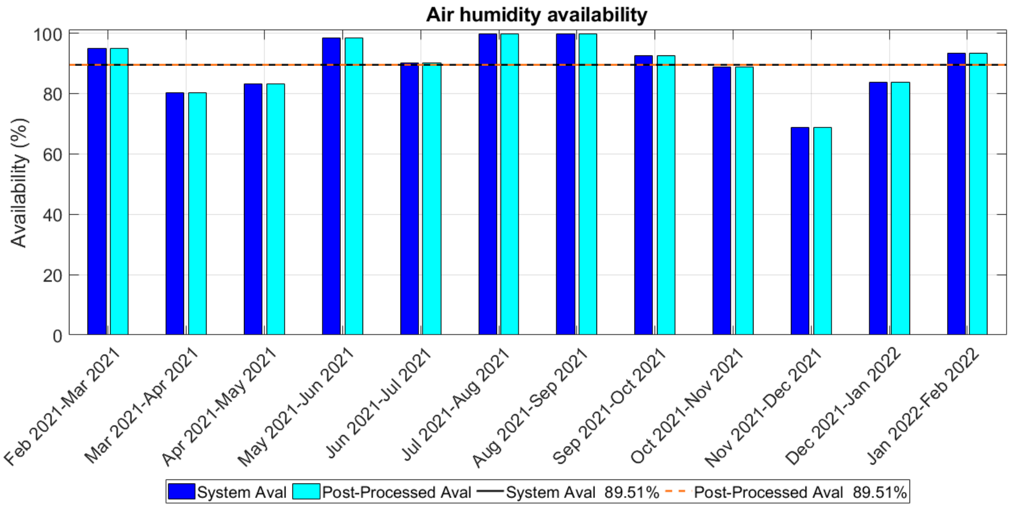

Figure 52. Bar chart for availability of air humidity.

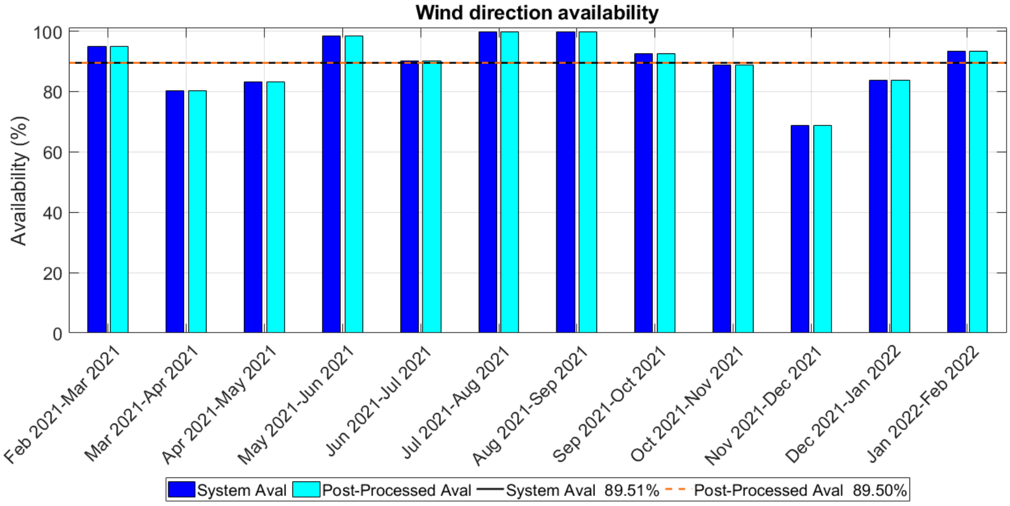

Figure 53. Bar chart for availability of wind direction.

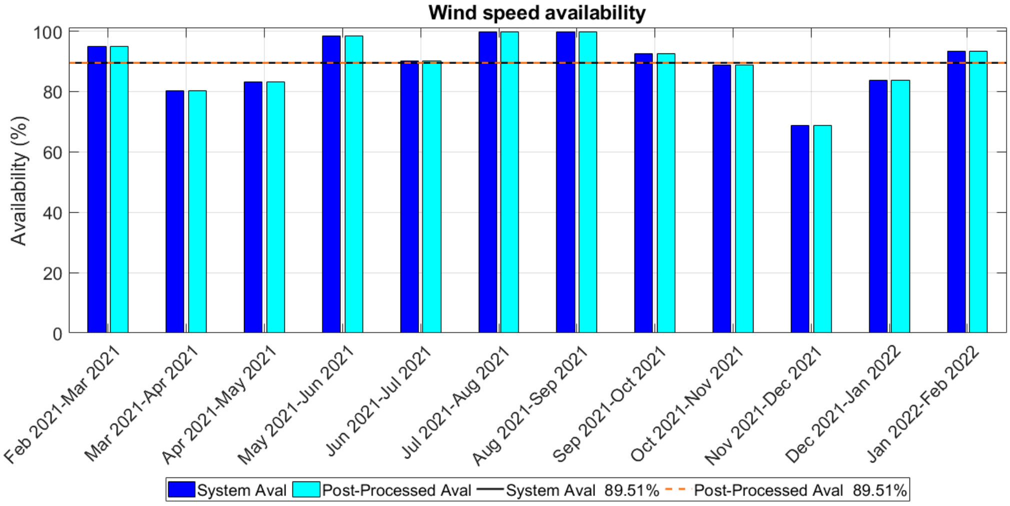

Figure 54. Bar chart for availability of wind speed.

4.2.3. ADCP

ADCP AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
ADCP	ADCP_vc1	17520	17344	**99.00**	17307	**98.78**
	ADCP_dc1	17520	17344	**99.00**	17307	**98.78**
	ADCP_vc2	17520	17344	**99.00**	17340	**98.97**
	ADCP_dc2	17520	17344	**99.00**	17340	**98.97**
	ADCP_vc3	17520	17344	**99.00**	17336	**98.95**
	ADCP_dc3	17520	17344	**99.00**	17336	**98.95**
	ADCP_vc4	17520	17344	**99.00**	17335	**98.94**
	ADCP_dc4	17520	17344	**99.00**	17335	**98.94**
	ADCP_vc5	17520	17344	**99.00**	17291	**98.69**
	ADCP_dc5	17520	17344	**99.00**	17291	**98.69**
	ADCP_vc6	17520	17344	**99.00**	17258	**98.50**
	ADCP_dc6	17520	17344	**99.00**	17258	**98.50**
	ADCP_vc7	17520	17344	**99.00**	17239	**98.40**
	ADCP_dc7	17520	17344	**99.00**	17239	**98.40**
	ADCP_vc8	17520	17344	**99.00**	17155	**97.92**
	ADCP_dc8	17520	17344	**99.00**	17155	**97.92**
	ADCP_vc9	17520	17344	**99.00**	16477	**94.05**

ADCP AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
	ADCP_dc9	17520	17344	**99.00**	16477	**94.05**
	ADCP_vc10	17520	17344	**99.00**	16088	**91.83**
	ADCP_dc10	17520	17344	**99.00**	16088	**91.83**
	ADCP_vc11	17520	17344	**99.00**	15729	**89.78**
	ADCP_dc11	17520	17344	**99.00**	15729	**89.78**
	ADCP_vc12	17520	17344	**99.00**	15168	**86.58**
	ADCP_dc12	17520	17344	**99.00**	15168	**86.58**
	ADCP_vc13	17520	17344	**99.00**	14406	**82.23**
	ADCP_dc13	17520	17344	**99.00**	14406	**82.23**
	ADCP_vc14	17520	17344	**99.00**	13696	**78.17**
	ADCP_dc14	17520	17344	**99.00**	13696	**78.17**
	ADCP_vc15	17520	17344	**99.00**	13222	**75.47**
	ADCP_dc15	17520	17344	**99.00**	13222	**75.47**
	ADCP_vc16	17520	17344	**99.00**	8962	**51.15**
	ADCP_dc16	17520	17344	**99.00**	8962	**51.15**
	ADCP_vc17	17520	17344	**99.00**	14747	**84.17**
	ADCP_dc17	17520	17344	**99.00**	14747	**84.17**
	ADCP_vc18	17520	17344	**99.00**	15203	**86.78**
	ADCP_dc18	17520	17344	**99.00**	15203	**86.78**
	ADCP_vc19	17520	17344	**99.00**	17199	**98.17**

ADCP AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
	ADCP_dc19	17520	17344	**99.00**	17199	**98.17**
	ADCP_vc20	17520	17344	**99.00**	10821	**61.76**
	ADCP_dc20	17520	17344	**99.00**	10821	**61.76**
	ADCP_vc21	17520	17344	**99.00**	17252	**98.47**
	ADCP_dc21	17520	17344	**99.00**	17252	**98.47**
	ADCP_vc22	17520	17344	**99.00**	17080	**97.49**
	ADCP_dc22	17520	17344	**99.00**	17080	**97.49**
	ADCP_ADCPtemp	17520	17344	**99.00**	17344	**99.00**
	alti_ADCPlevelA_Avg	17520	15412	**87.97**	15412	**87.97**

Table 21. ADCP availability

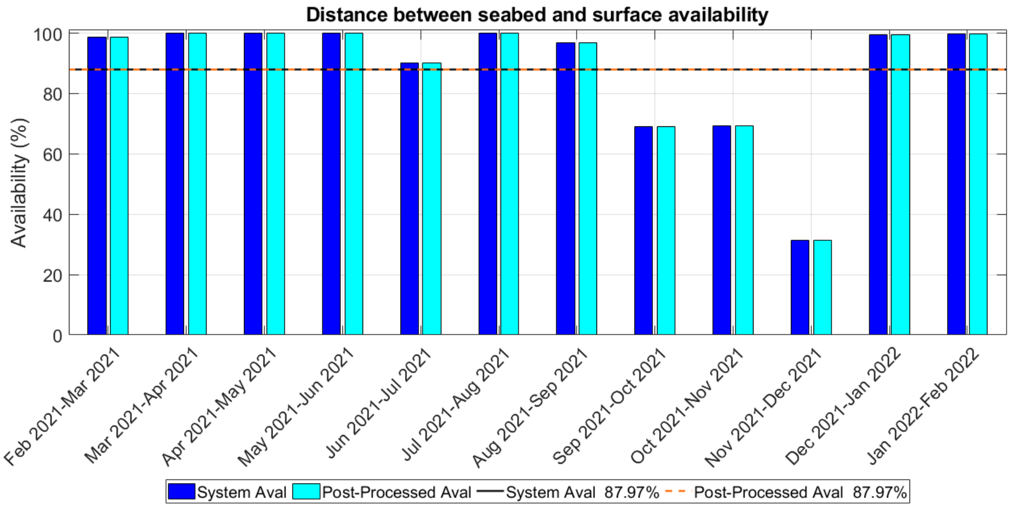

Figure 55. Bar chart for availability of altimeter distance.

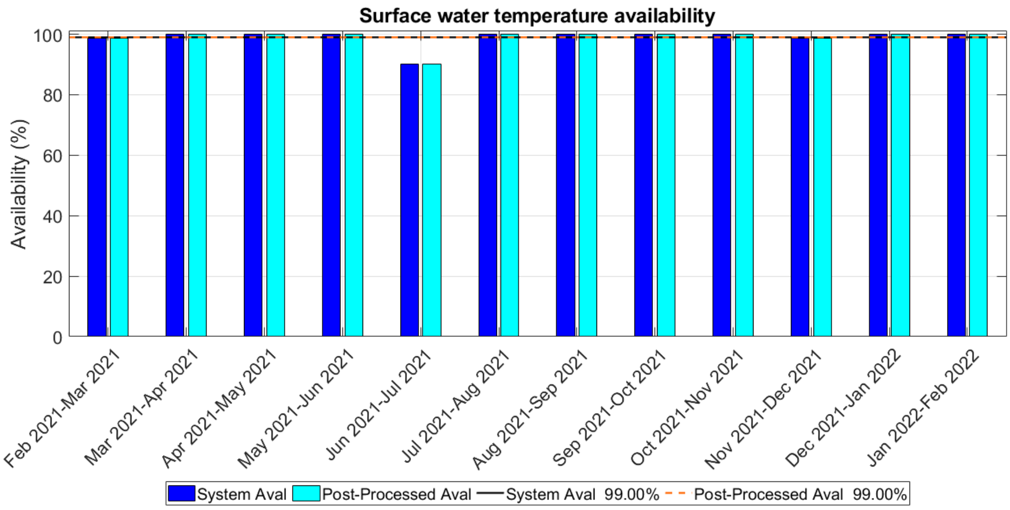

Figure 56. Bar chart for availability of surface water temperature.

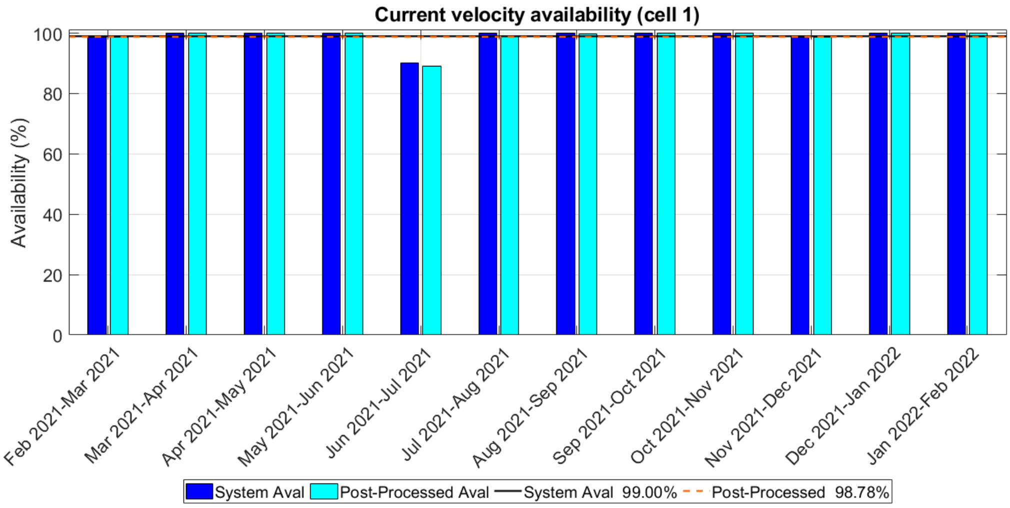

Figure 57. Bar chart for availability of current speed at cell 1.

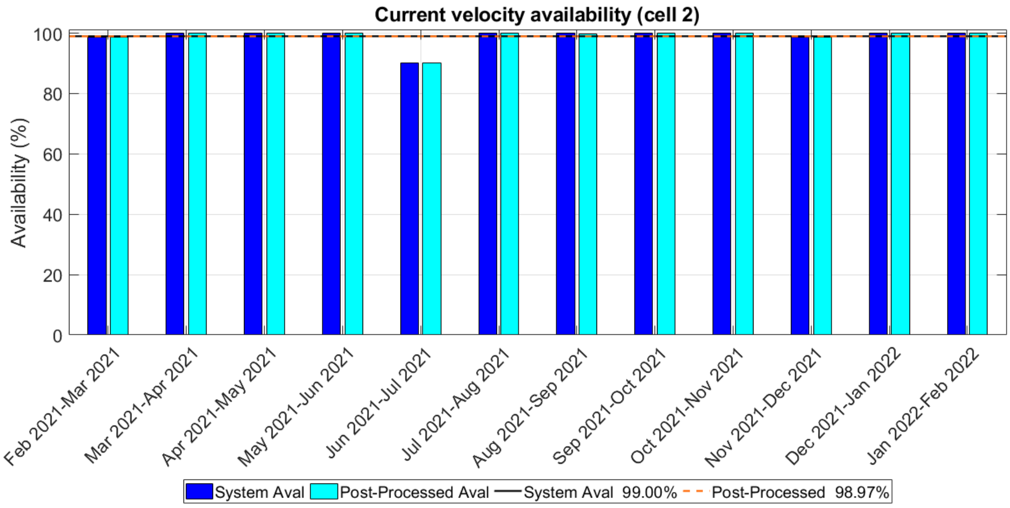

Figure 58. Bar chart for availability of current speed at cell 2.

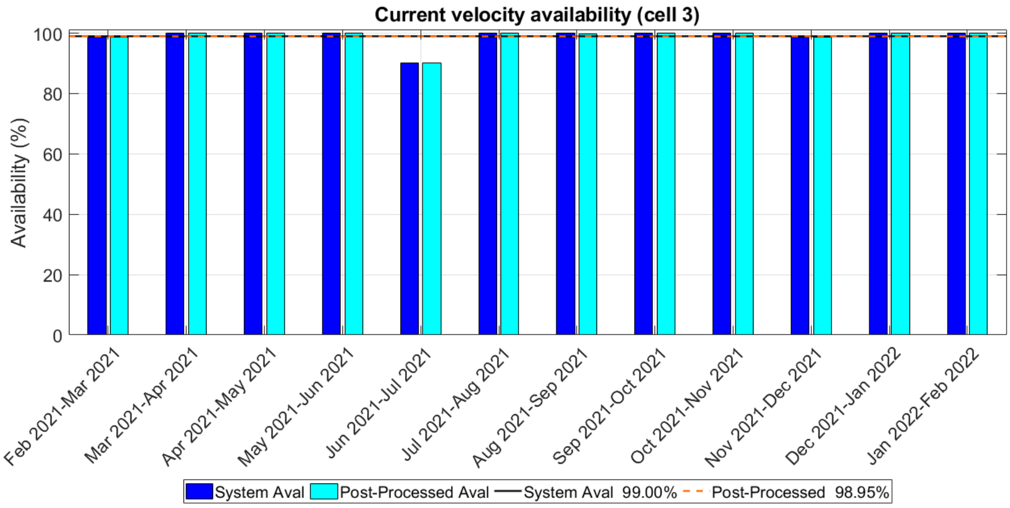

Figure 59. Bar chart for availability of current speed at cell 3.

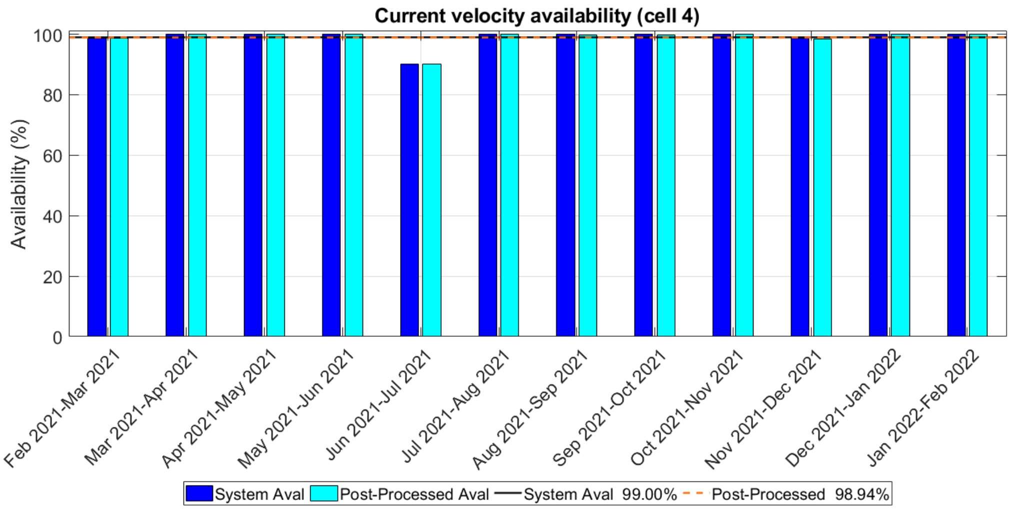

Figure 60. Bar chart for availability of current speed at cell 4.

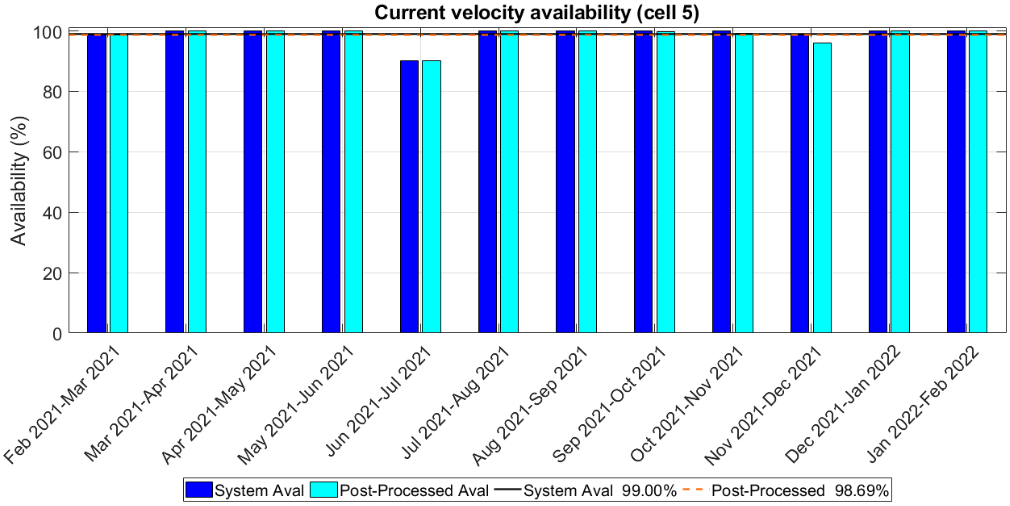

Figure 61. Bar chart for availability of current speed at cell 5.

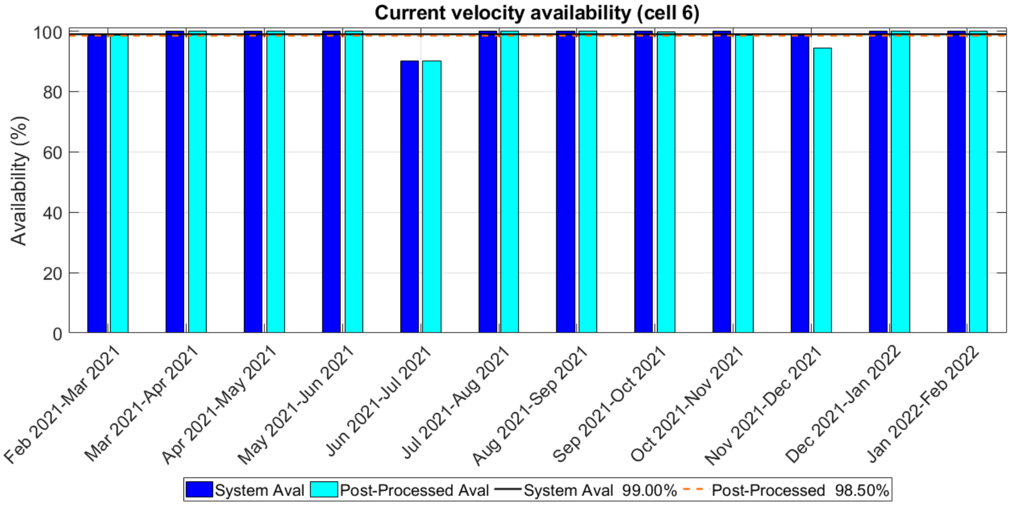

Figure 62. Bar chart for availability of current speed at cell 6.

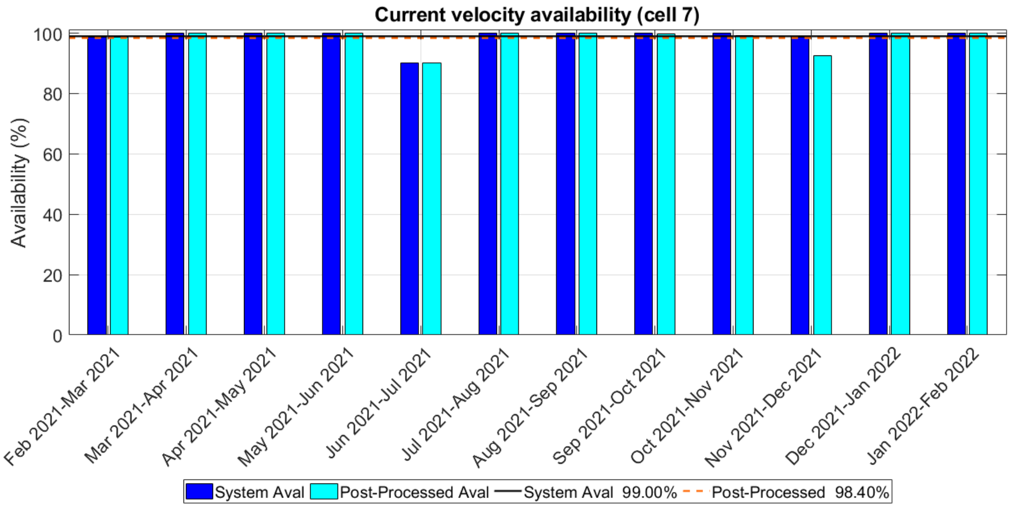

Figure 63. Bar chart for availability of current speed at cell 7.

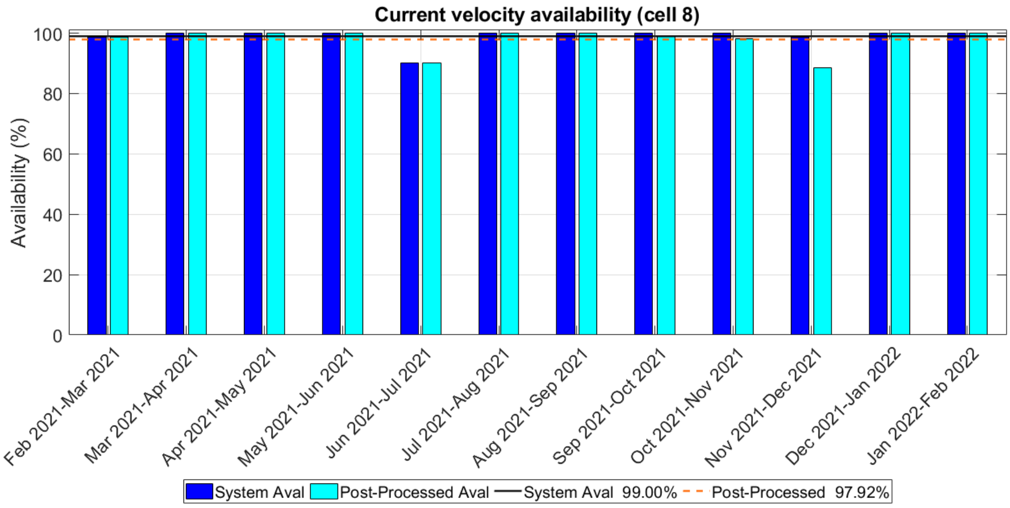

Figure 64. Bar chart for availability of current speed at cell 8.

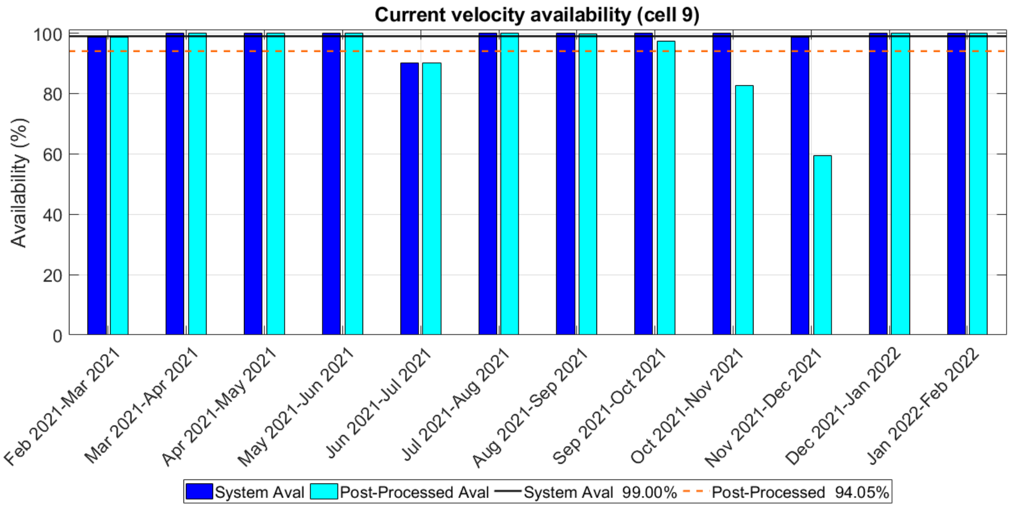

Figure 65. Bar chart for availability of current speed at cell 9.

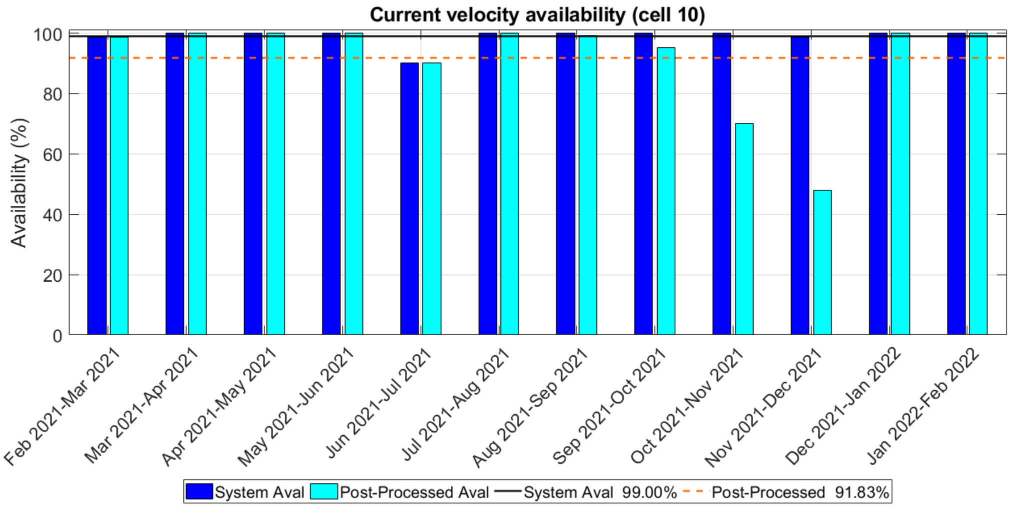

Figure 66. Bar chart for availability of current speed at cell 10.

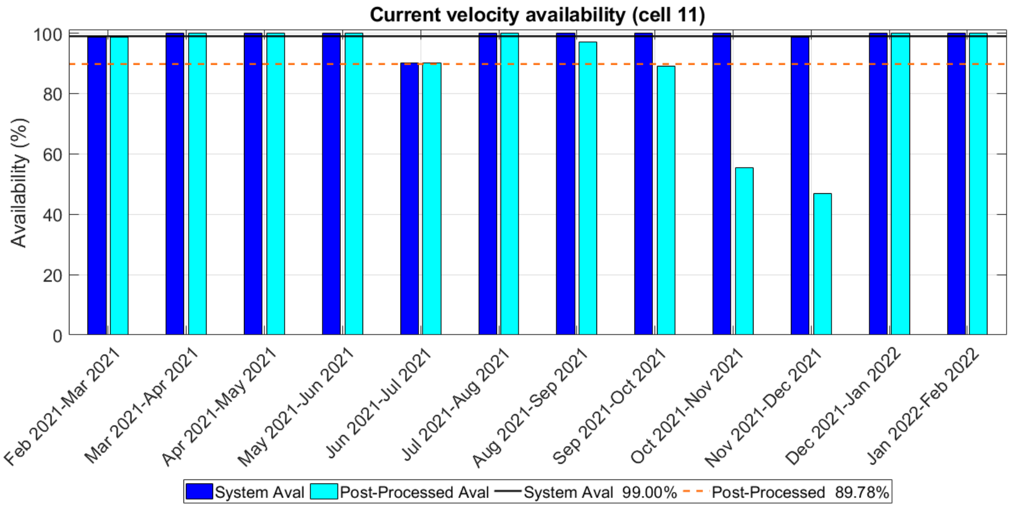

Figure 67. Bar chart for availability of current speed at cell 11.

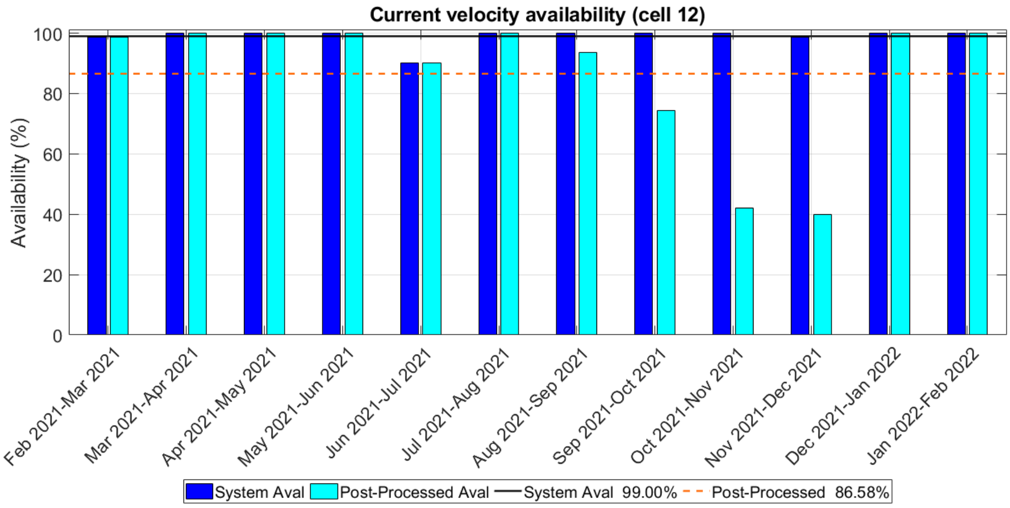

Figure 68. Bar chart for availability of current speed at cell 12.

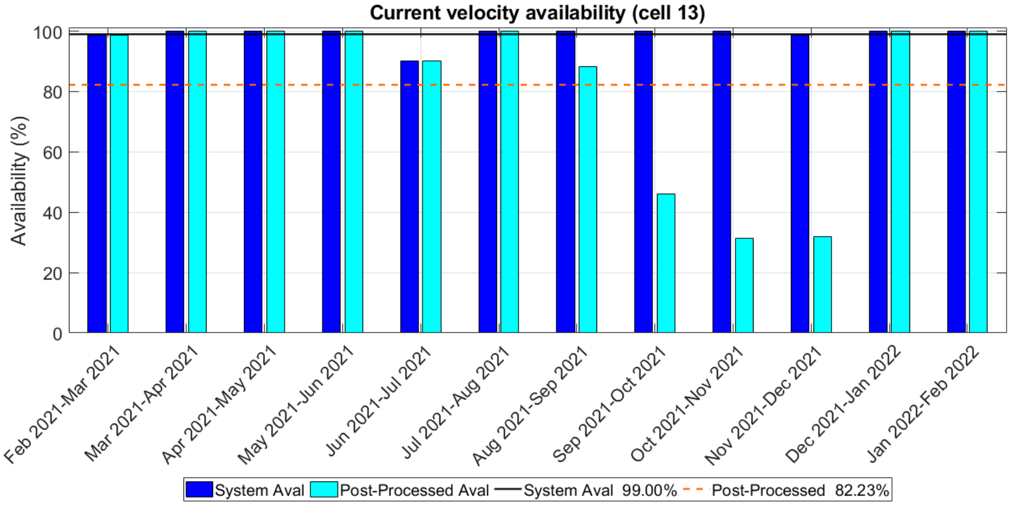

Figure 69. Bar chart for availability of current speed at cell 13.

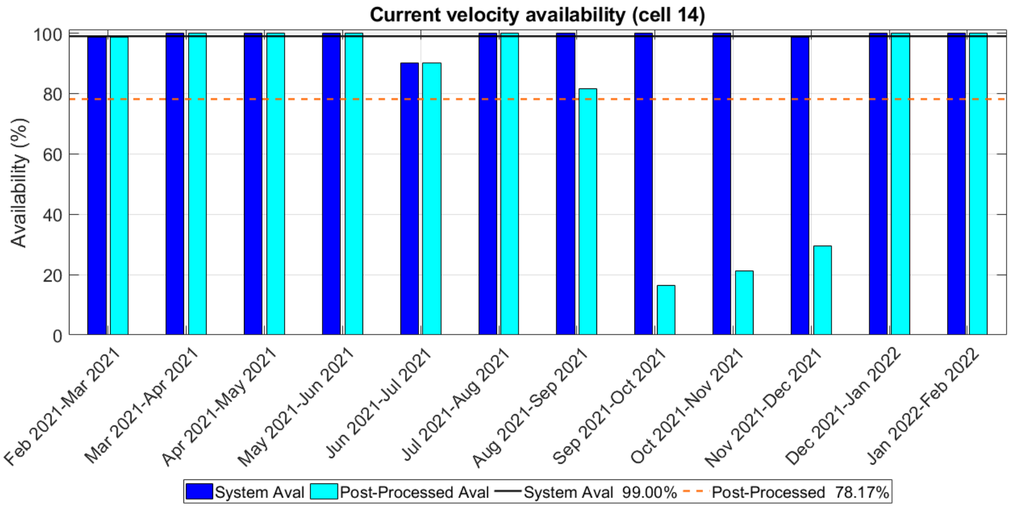

Figure 70. Bar chart for availability of current speed at cell 14.

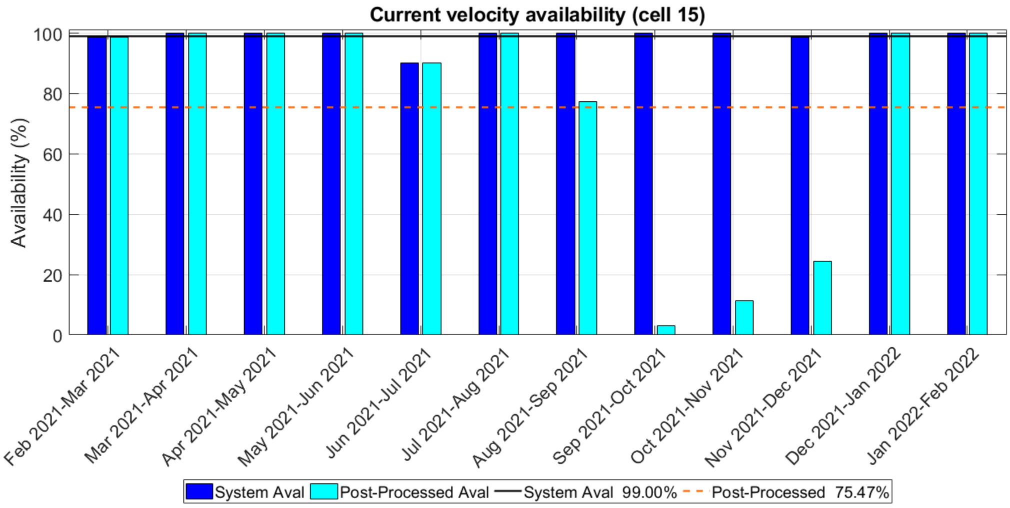

Figure 71. Bar chart for availability of current speed at cell 15.

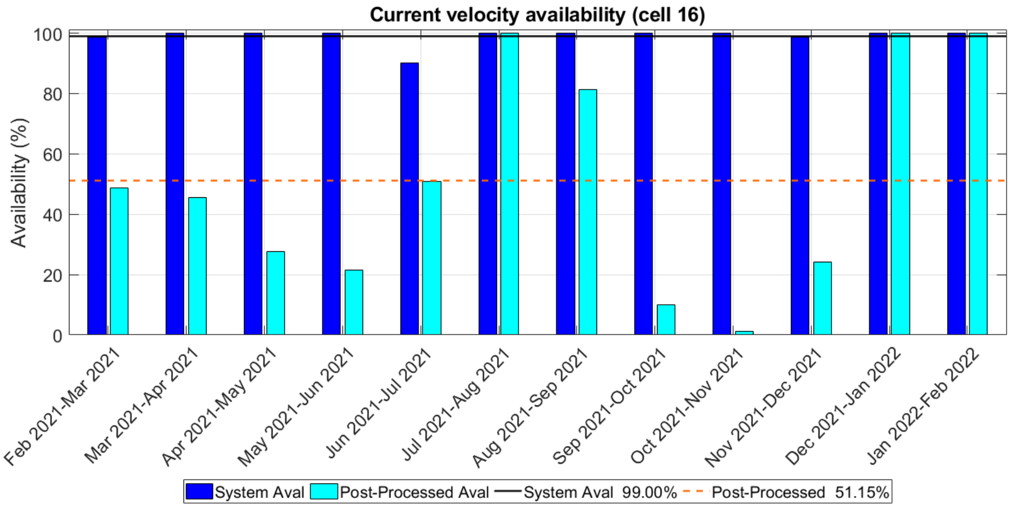

Figure 72. Bar chart for availability of current speed at cell 16.

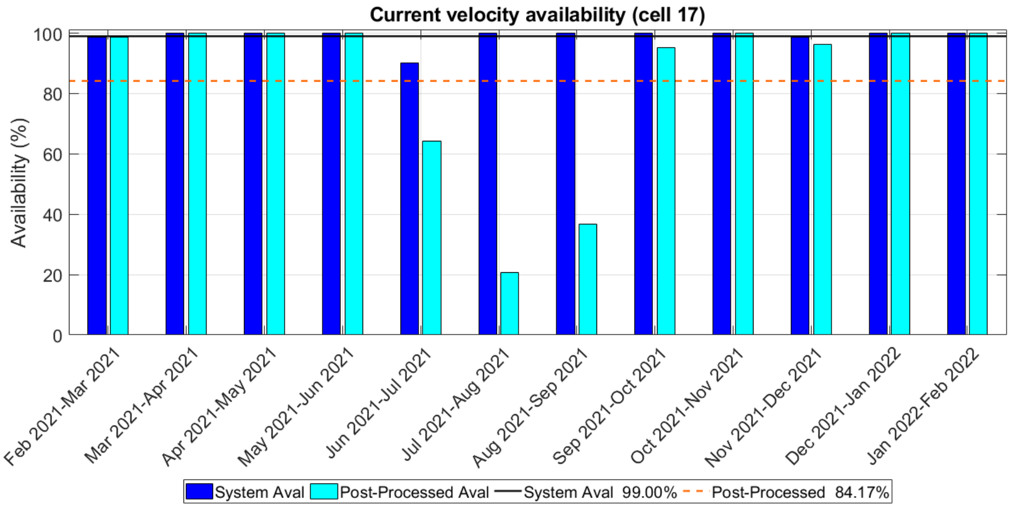

Figure 73. Bar chart for availability of current speed at cell 17.

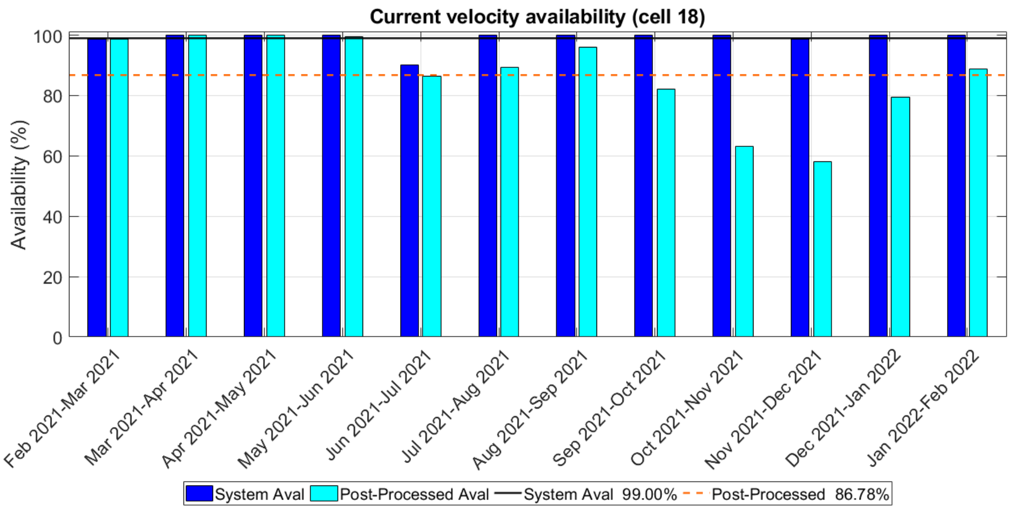

Figure 74. Bar chart for availability of current speed at cell 18.

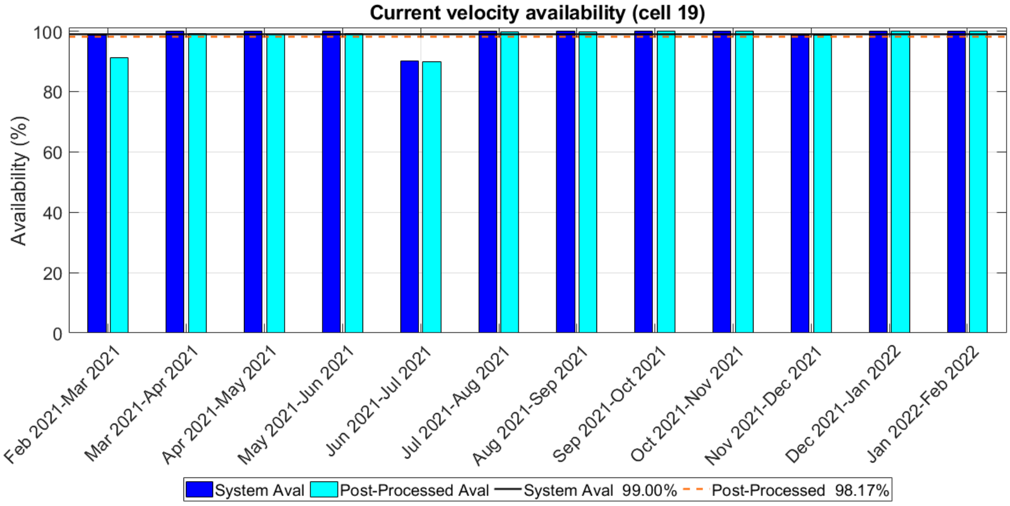

Figure 75. Bar chart for availability of current speed at cell 19.

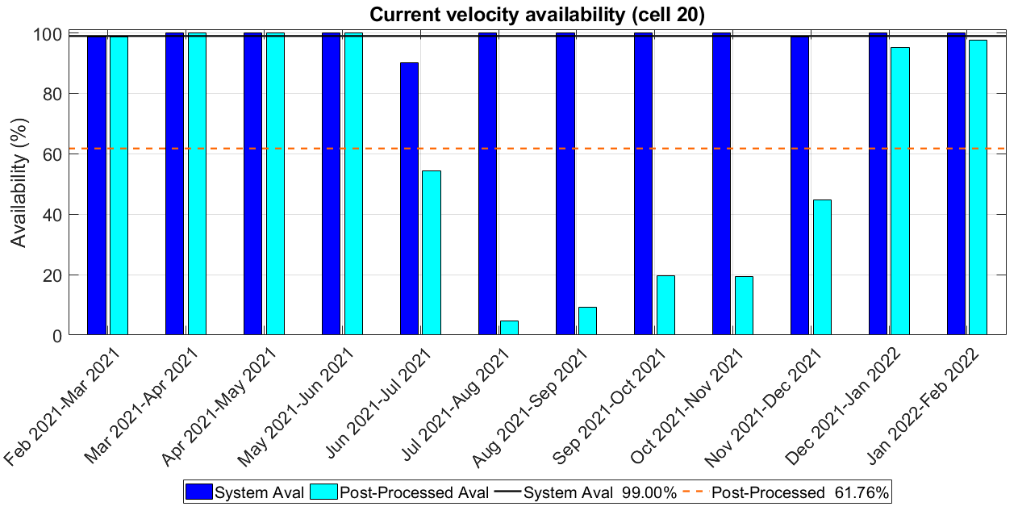

Figure 76. Bar chart for availability of current speed at cell 20.

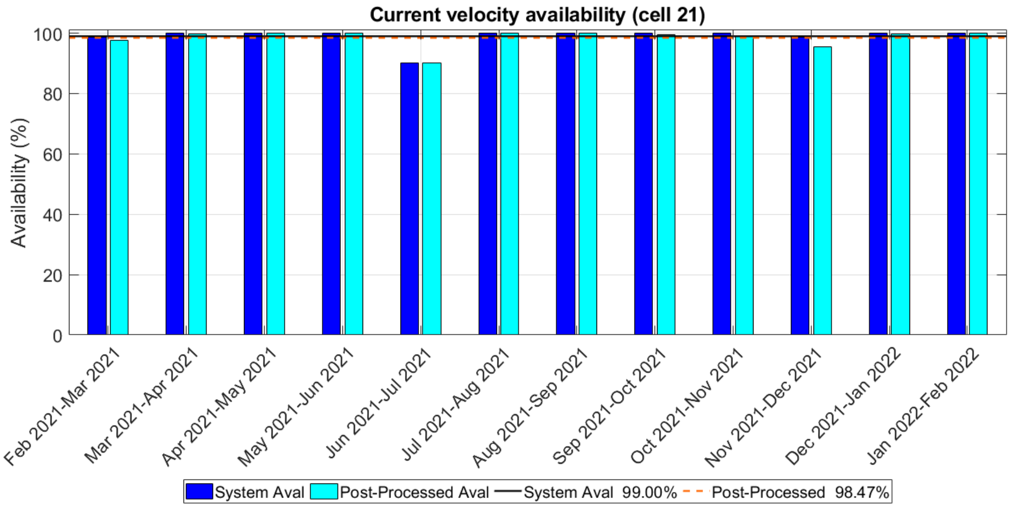

Figure 77. Bar chart for availability of current speed at cell 21.

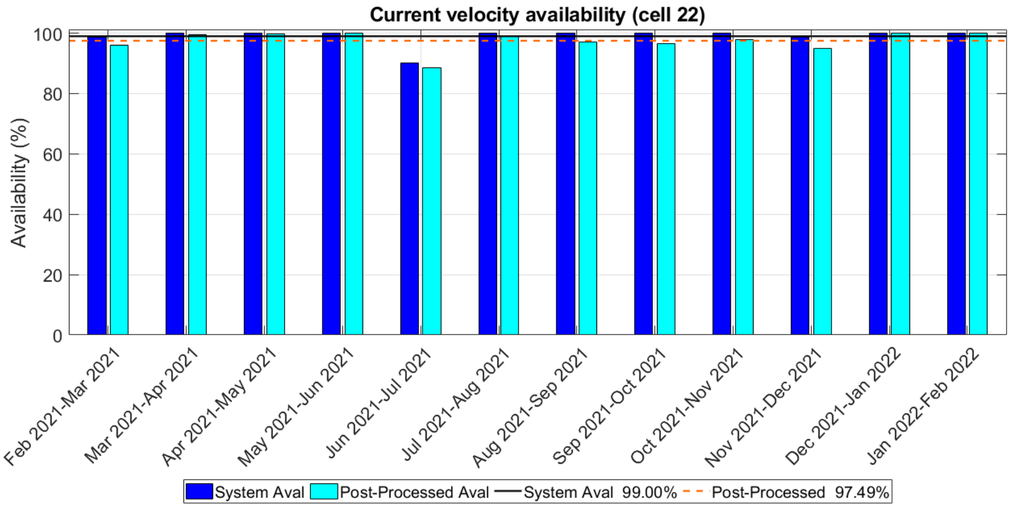

Figure 78. Bar chart for availability of current speed at cell 22.

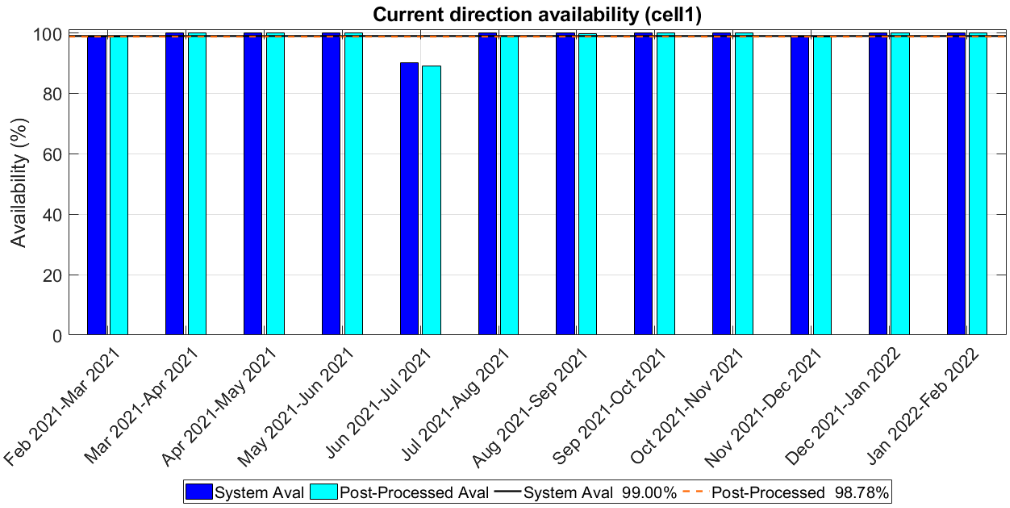

Figure 79. Bar chart for availability of current direction at cell 1.

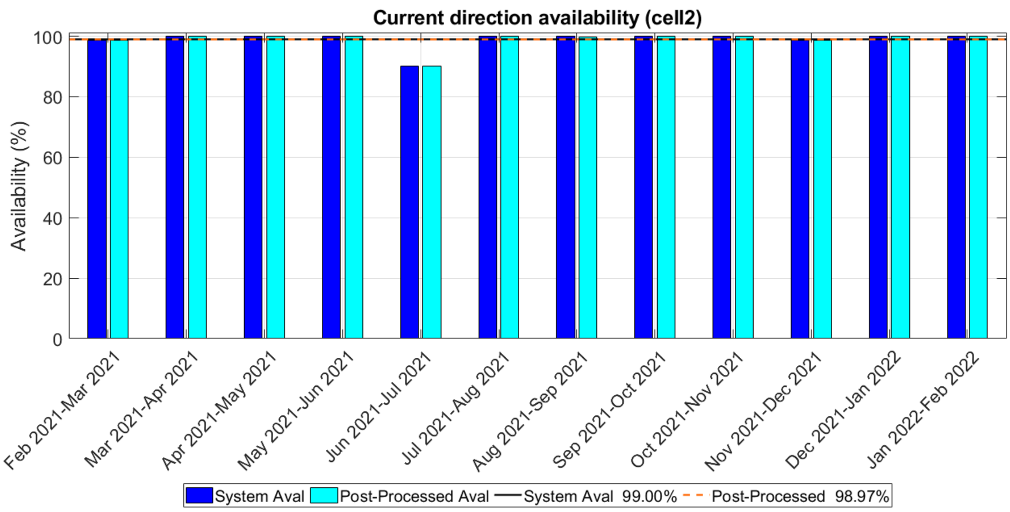

Figure 80. Bar chart for availability of current direction at cell 2.

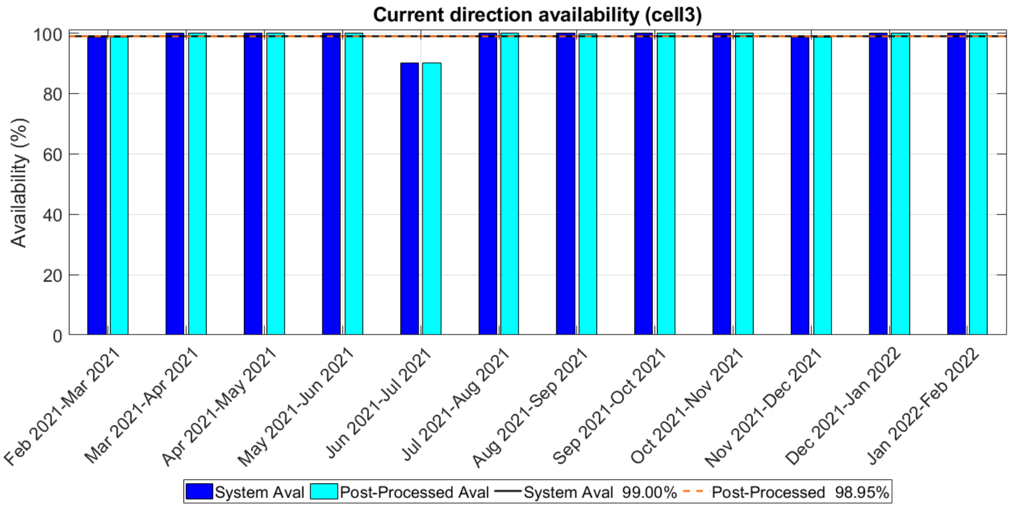

Figure 81. Bar chart for availability of current direction at cell 3.

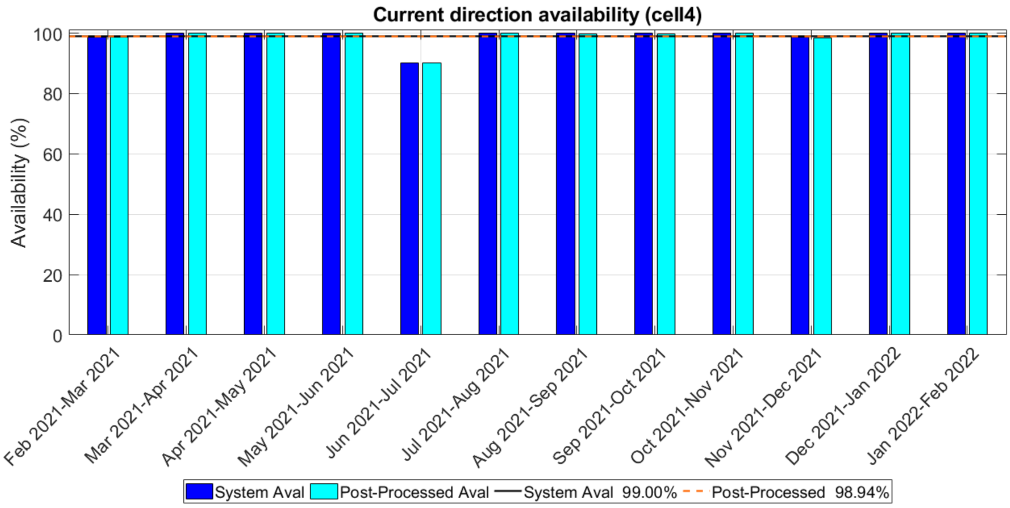

Figure 82. Bar chart for availability of current direction at cell 4.

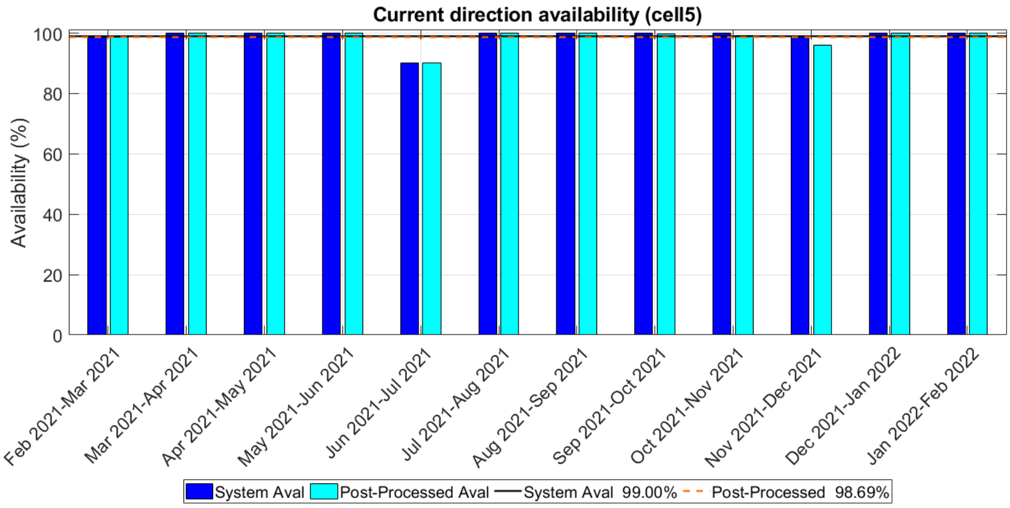

Figure 83. Bar chart for availability of current direction at cell 5.

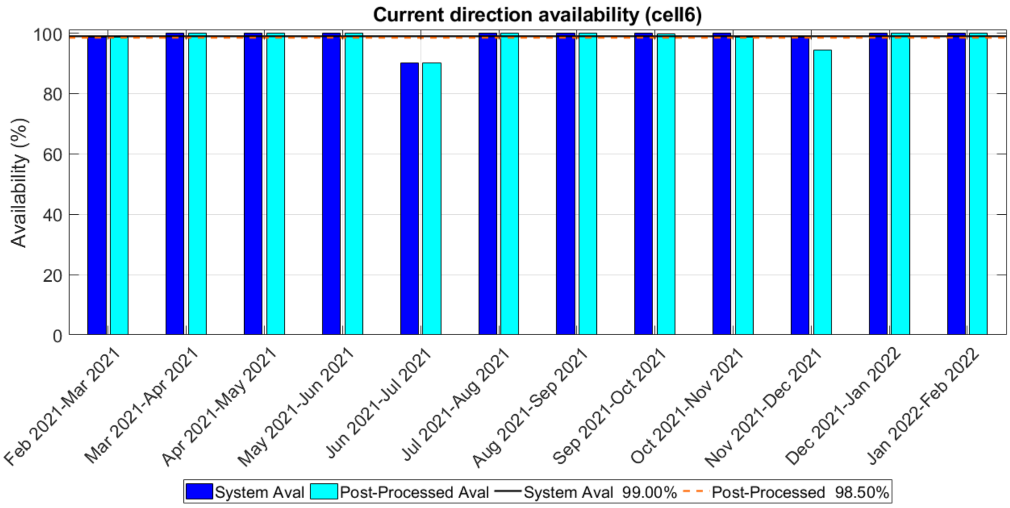

Figure 84. Bar chart for availability of current direction at cell 6.

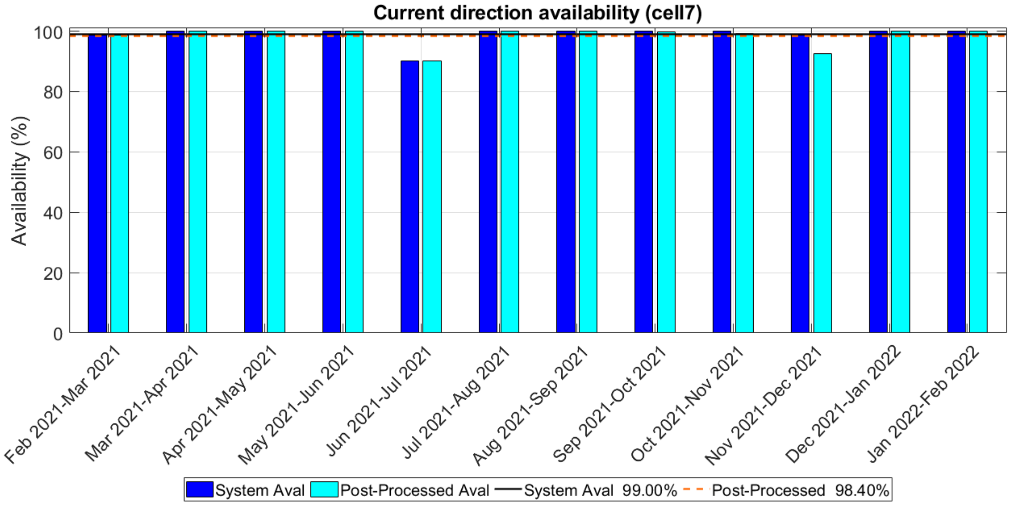

Figure 85. Bar chart for availability of current direction at cell 7.

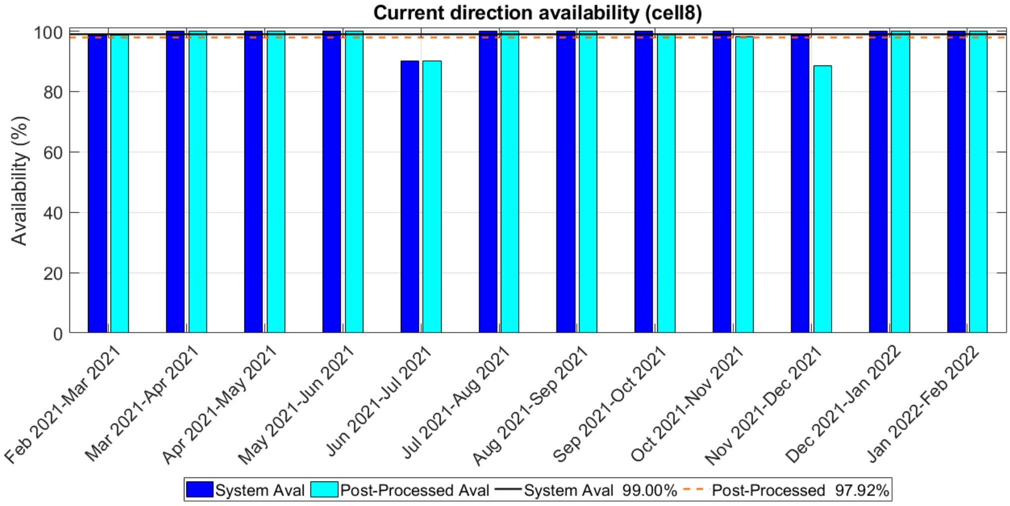

Figure 86. Bar chart for availability of current direction at cell 8.

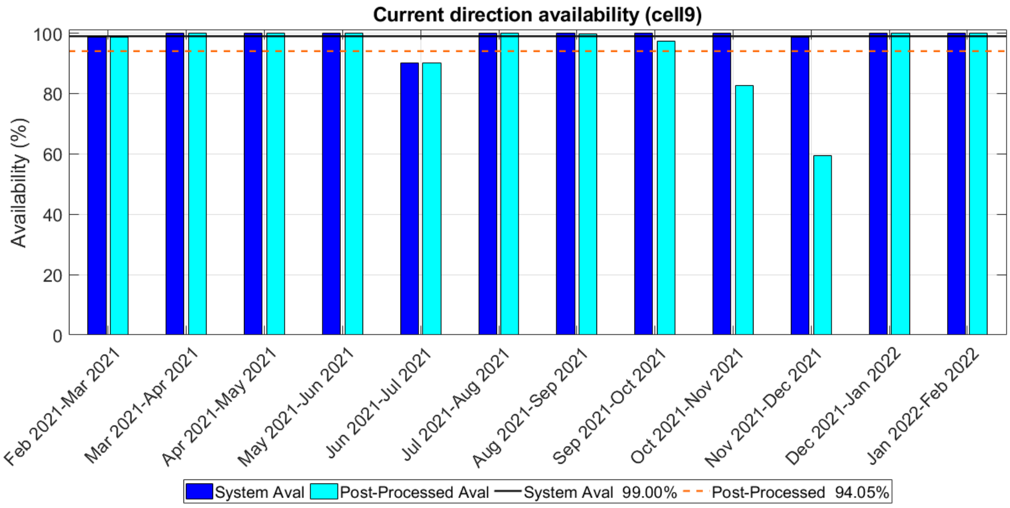

Figure 87. Bar chart for availability of current direction at cell 9.

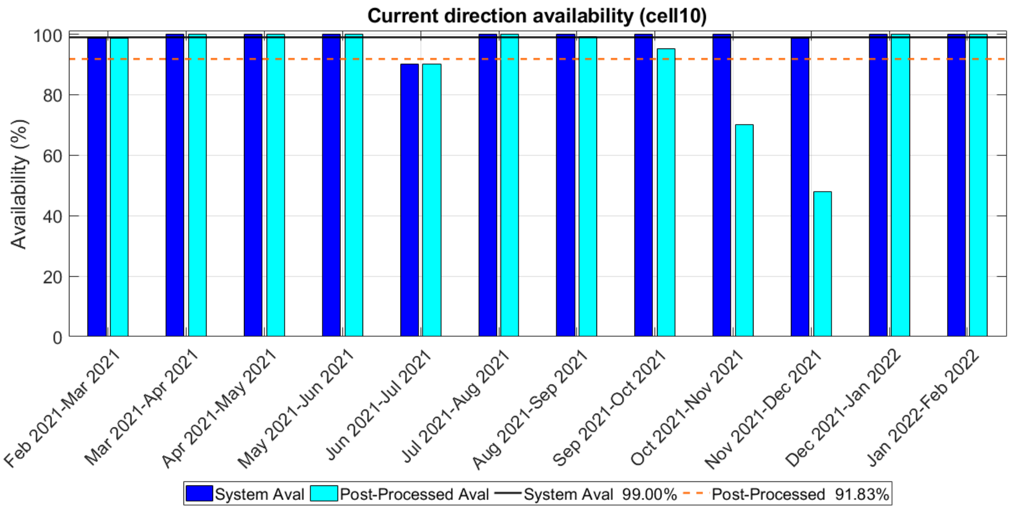

Figure 88. Bar chart for availability of current direction at cell 10.

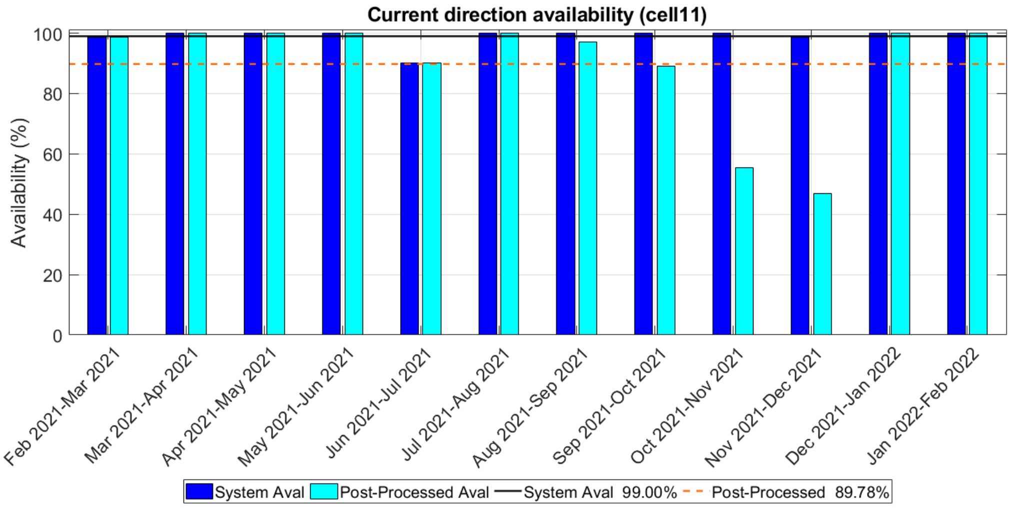

Figure 89. Bar chart for availability of current direction at cell 11.

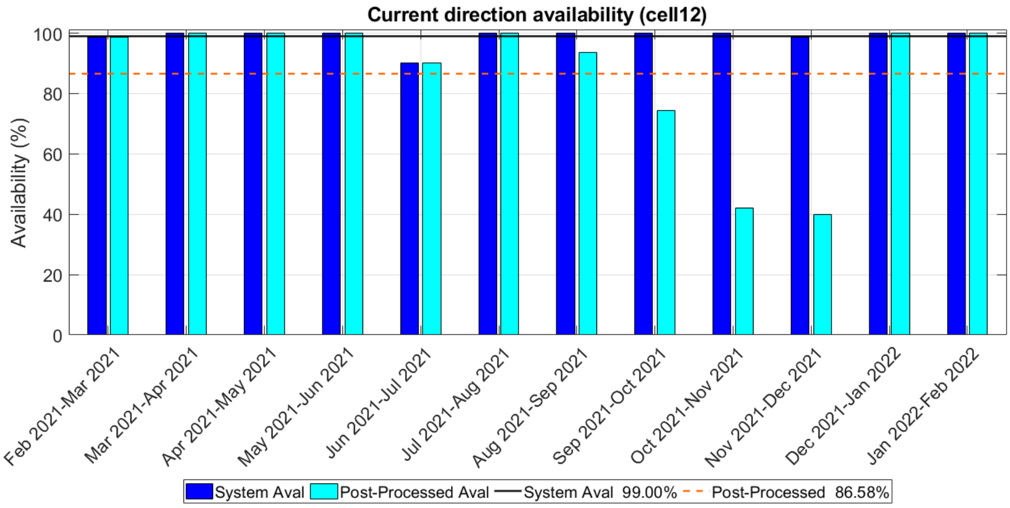

Figure 90. Bar chart for availability of current direction at cell 12.

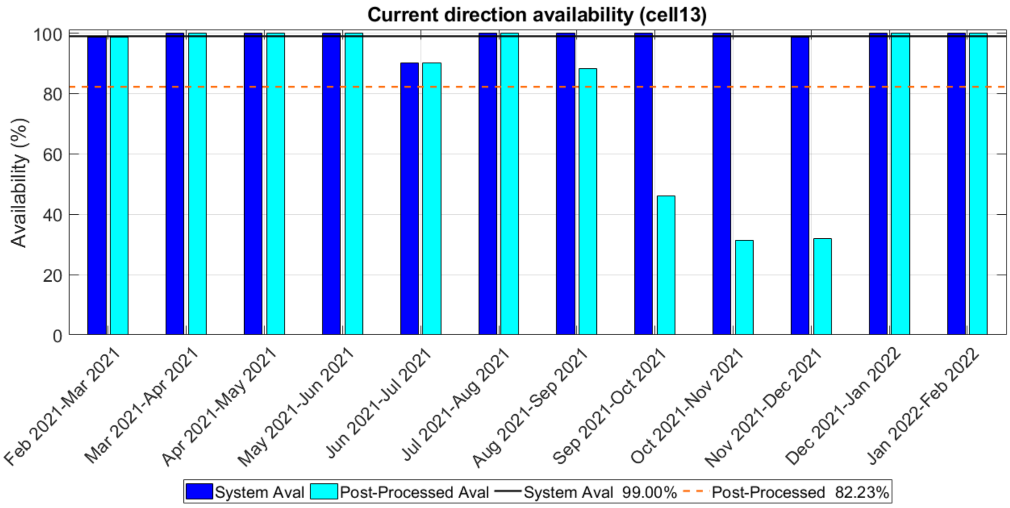

Figure 91. Bar chart for availability of current direction at cell 13.

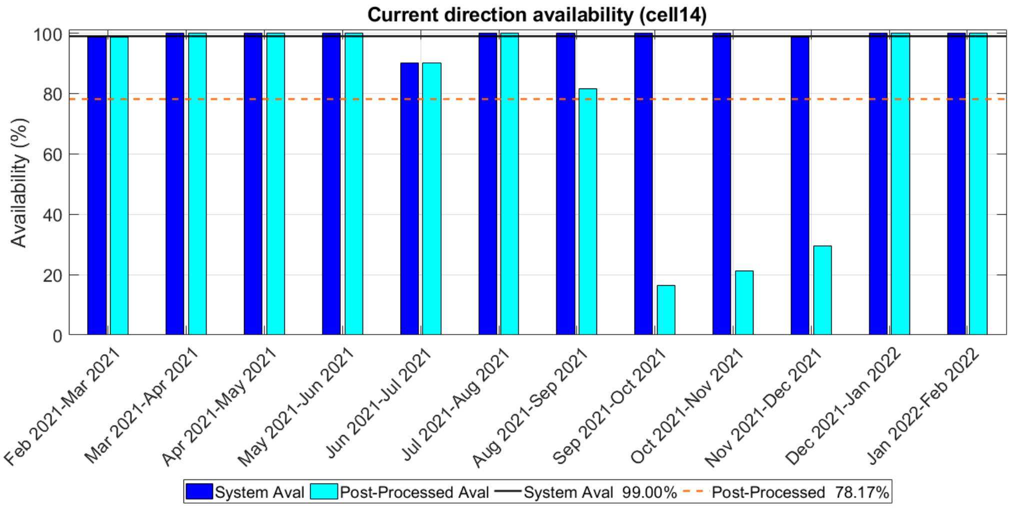

Figure 92. Bar chart for availability of current direction at cell 14.

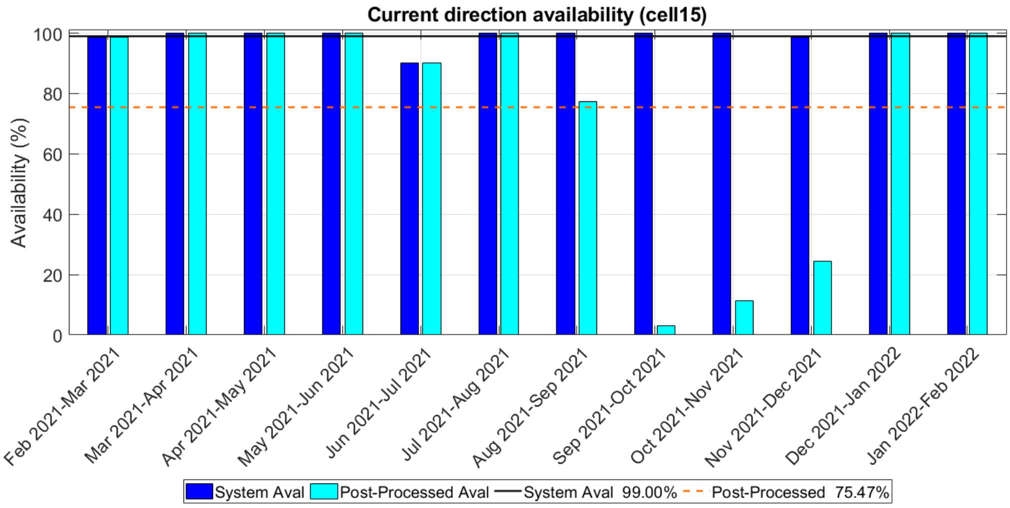

Figure 93. Bar chart for availability of current direction at cell 15.

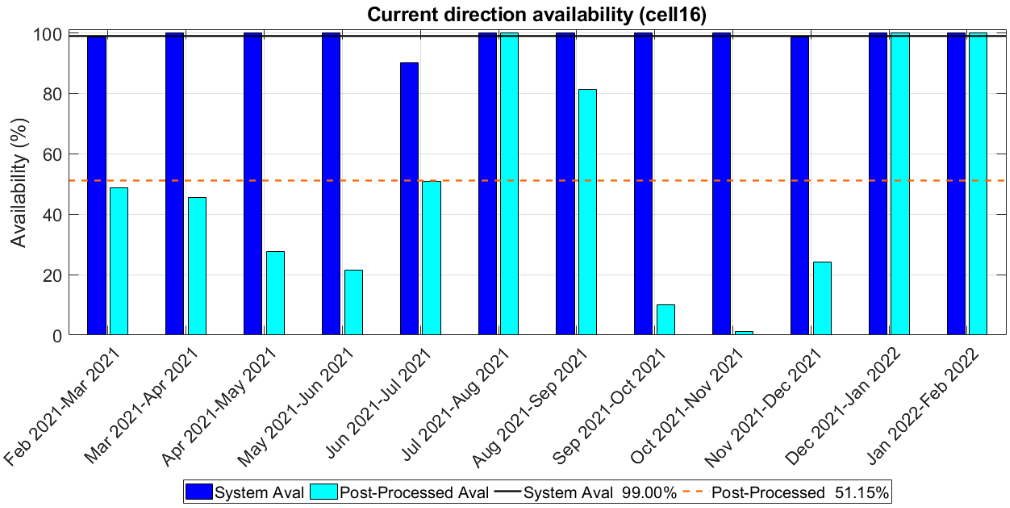

Figure 94. Bar chart for availability of current direction at cell 16.

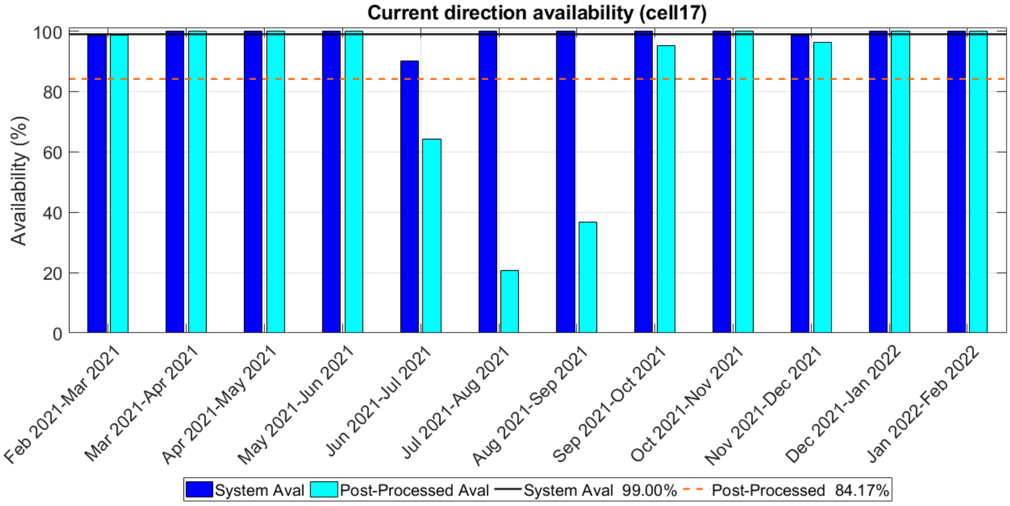

Figure 95. Bar chart for availability of current direction at cell 17.

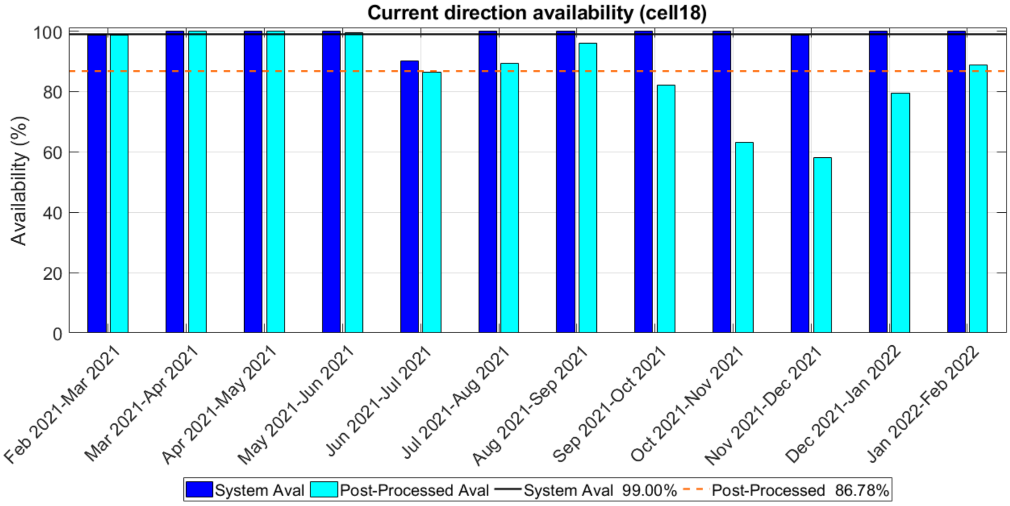

Figure 96. Bar chart for availability of current direction at cell 18.

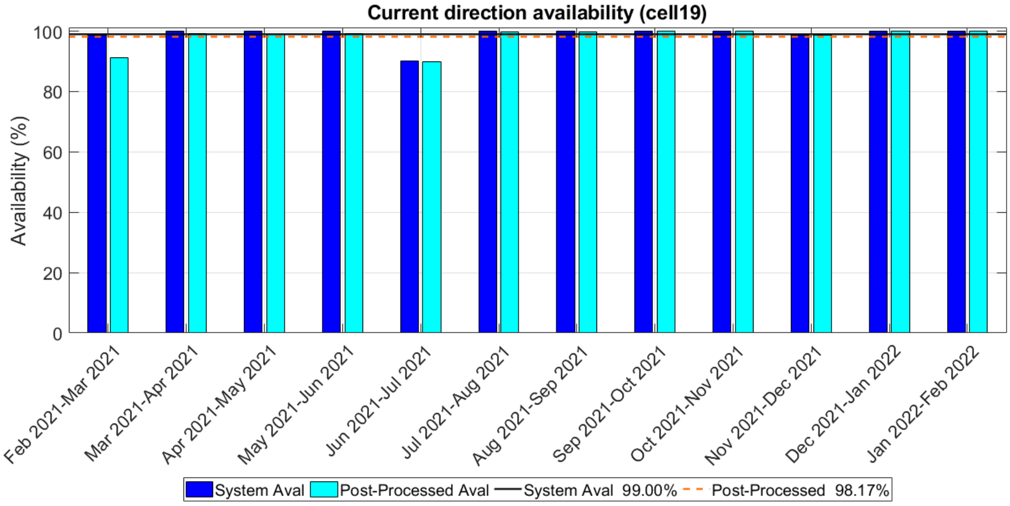

Figure 97. Bar chart for availability of current direction at cell 19.

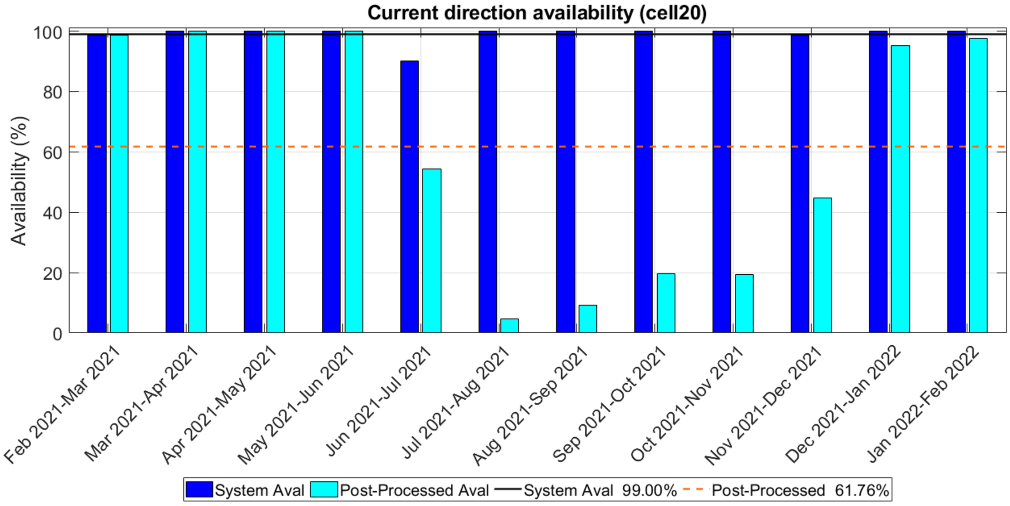

Figure 98. Bar chart for availability of current direction at cell 20.

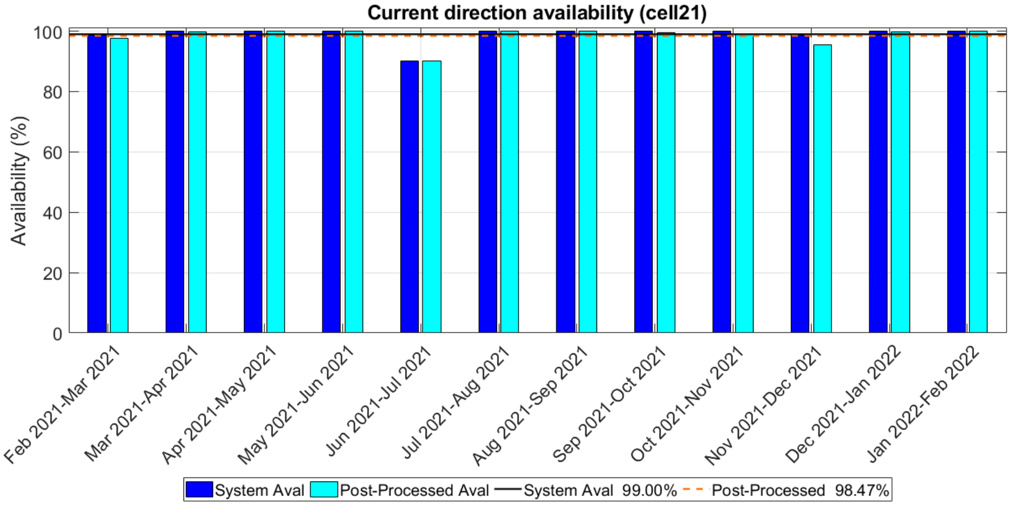

Figure 99. Bar chart for availability of current direction at cell 21.

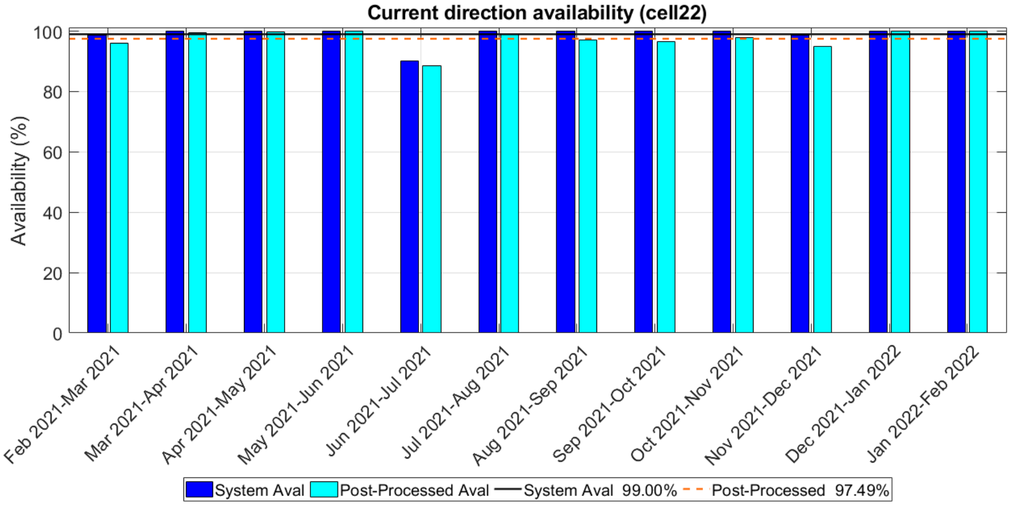

Figure 100. Bar chart for availability of current direction at cell 22.

4.2.4. WAVE

WAVE AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
WAVE	wave_HM0	17520	16330	**93.21**	16264	**92.83**
	wave_Hs	17520	16330	**93.21**	16258	**92.80**
	wave_Hmax	17520	16330	**93.21**	16258	**92.80**
	wave_H10	17520	16330	**93.21**	16258	**92.80**
	wave_Havg	17520	16330	**93.21**	16260	**92.81**
	wave_Tp	17520	16330	**93.21**	16116	**91.99**
	wave_Tz	17520	16330	**93.21**	16240	**92.69**
	wave_Ts	17520	16330	**93.21**	16240	**92.69**
	wave_T10	17520	16330	**93.21**	16240	**92.69**
	wave_Tavg	17520	16330	**93.21**	16240	**92.69**
	wave_DirP	17520	16330	**93.21**	16325	**93.18**
	wave_DirAvg	17520	16330	**93.21**	16330	**93.21**
	wave_DirAvgSpr	17520	16330	**93.21**	16330	**93.21**

Table 22. WAVE availability.

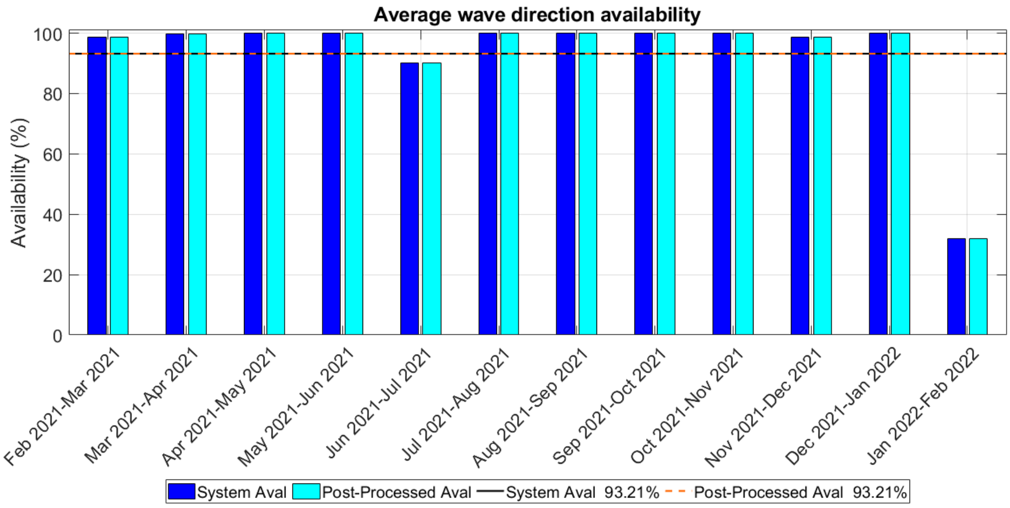

Figure 101. Bar chart for availability of average wave direction.

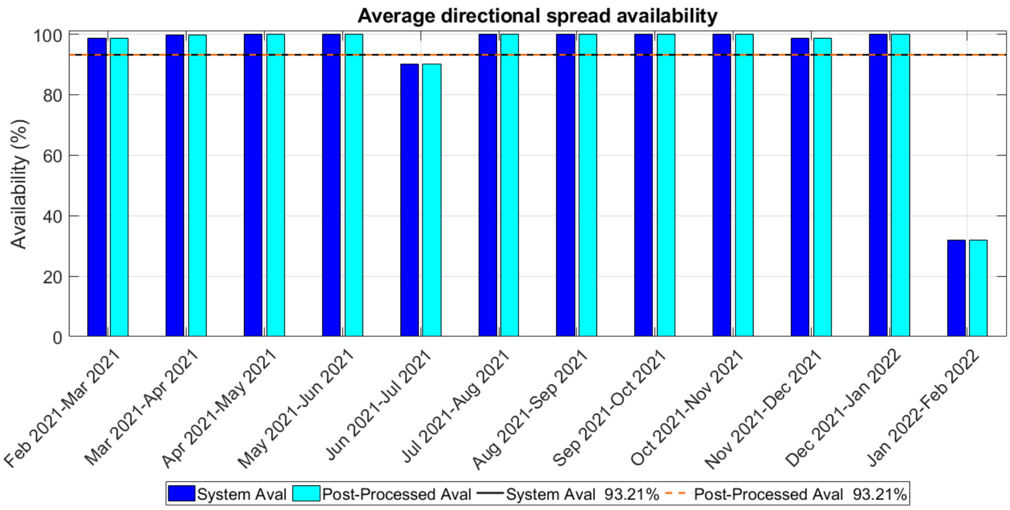

Figure 102. Bar chart for availability of average directional spread.

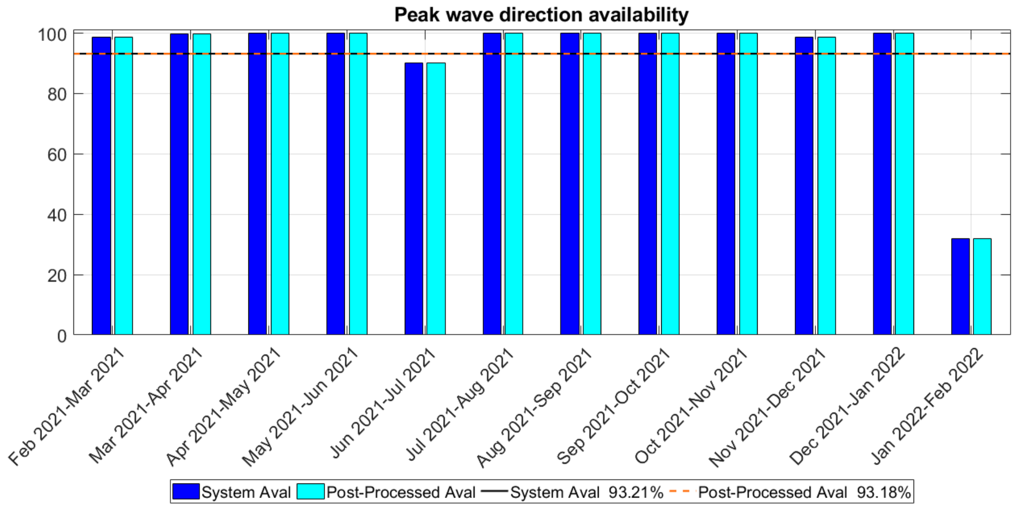

Figure 103. Bar chart for availability of peak wave direction.

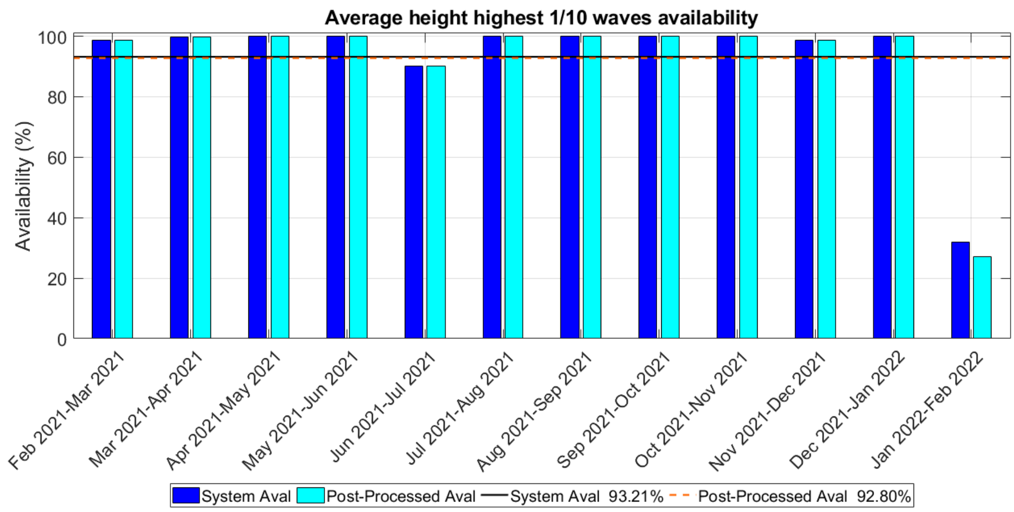

Figure 104. Bar chart for availability of average height highest 1/10 waves.

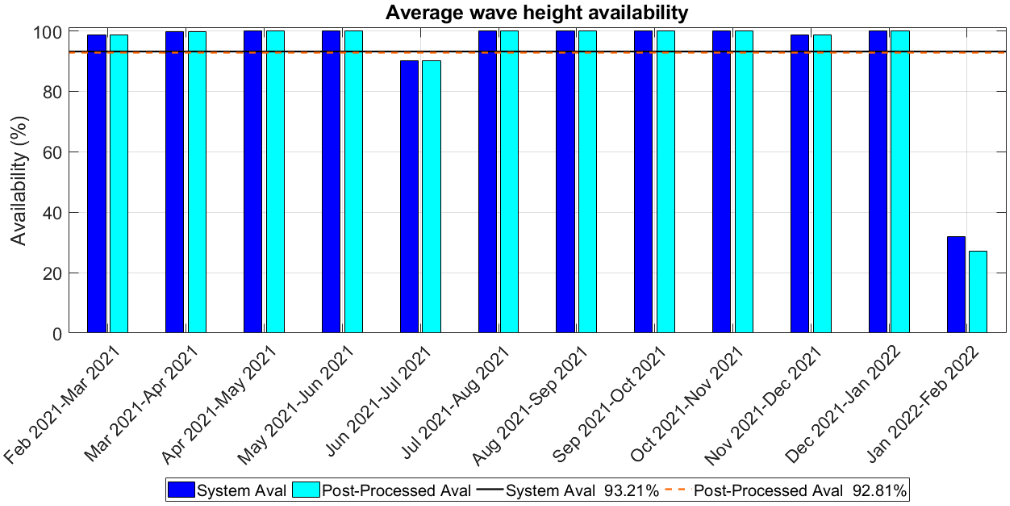

Figure 105. Bar chart for availability of average wave height.

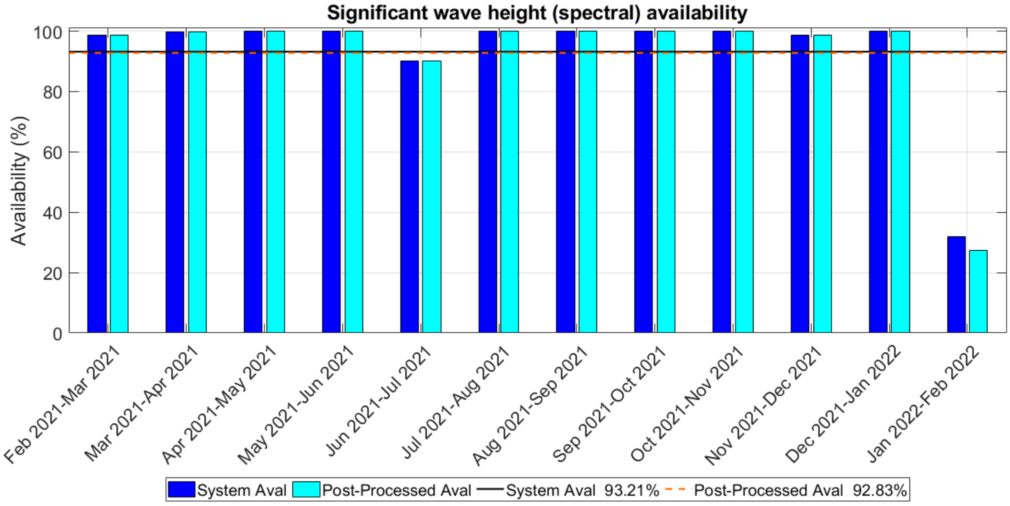

Figure 106. Bar chart for availability of significant wave height (spectral).

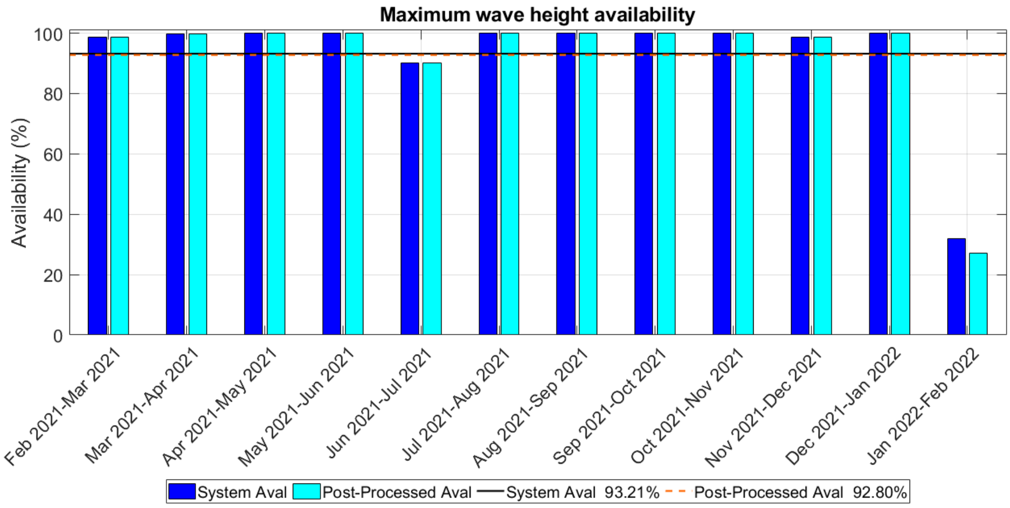

Figure 107. Bar chart for availability of maximum wave height.

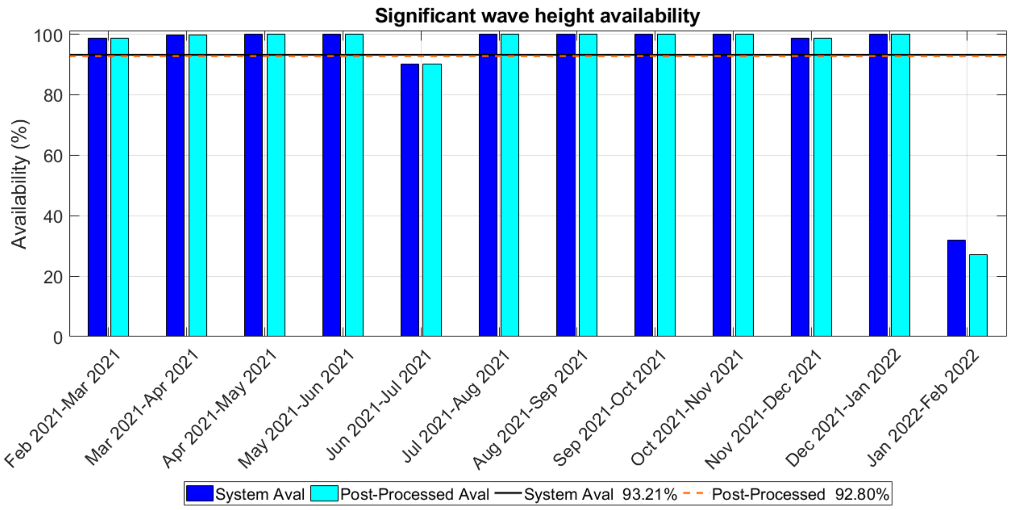

Figure 108. Bar chart for availability of significant wave height.

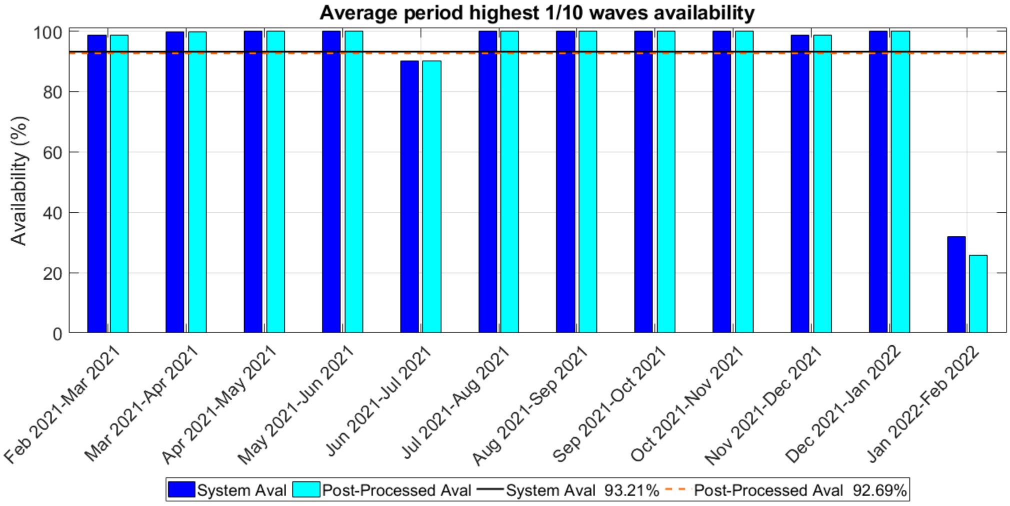

Figure 109. Bar chart for availability of average period highest 1/10 waves.

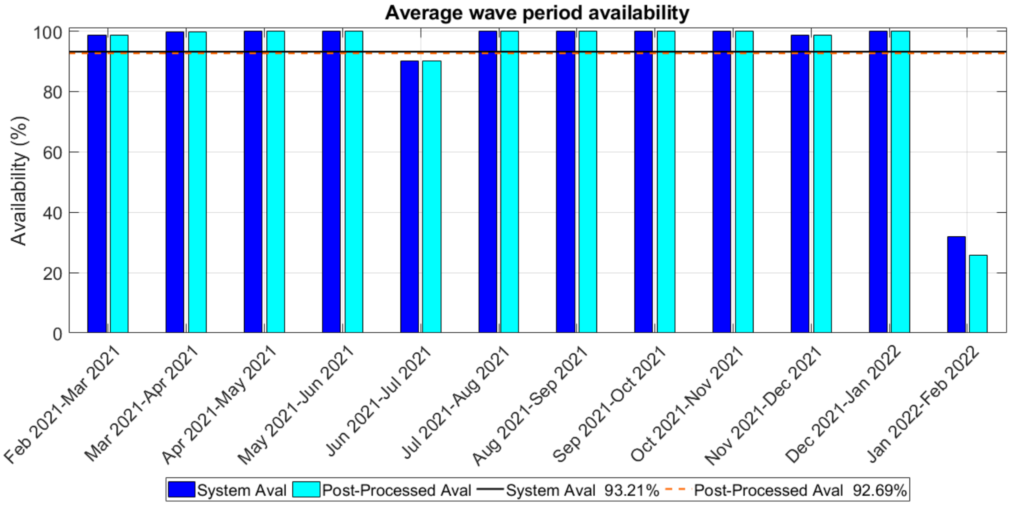

Figure 110. Bar chart for availability of average wave period.

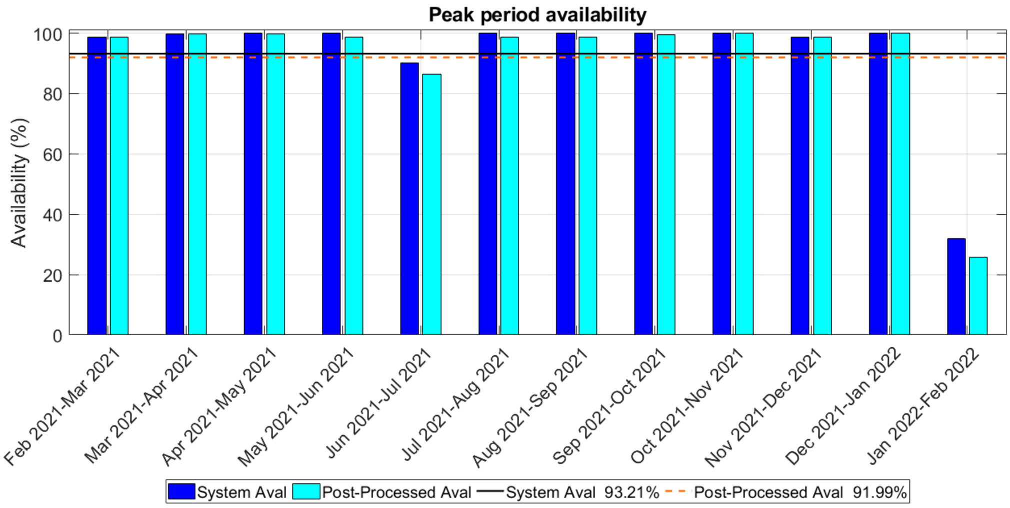

Figure 111. Bar chart for availability of peak wave period.

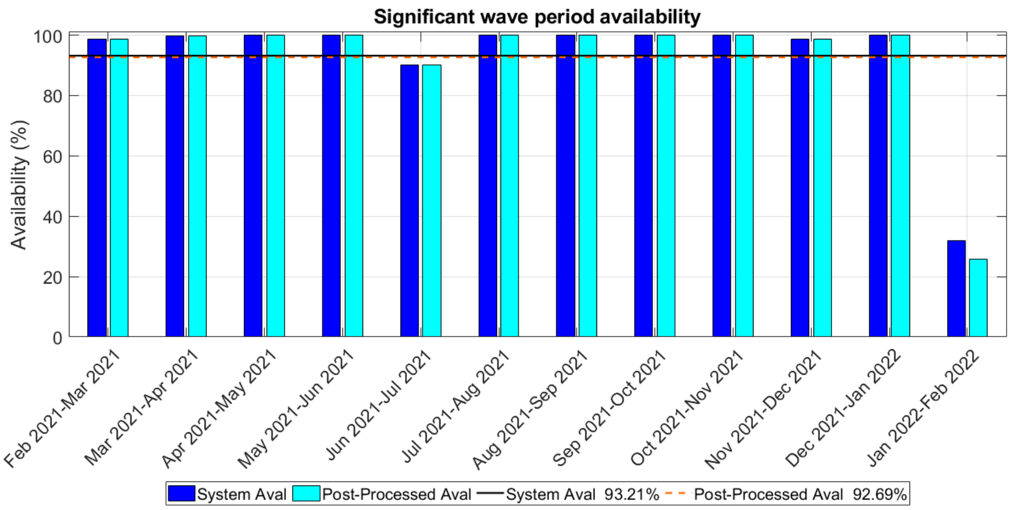

Figure 112. Bar chart for availability of significant wave period.

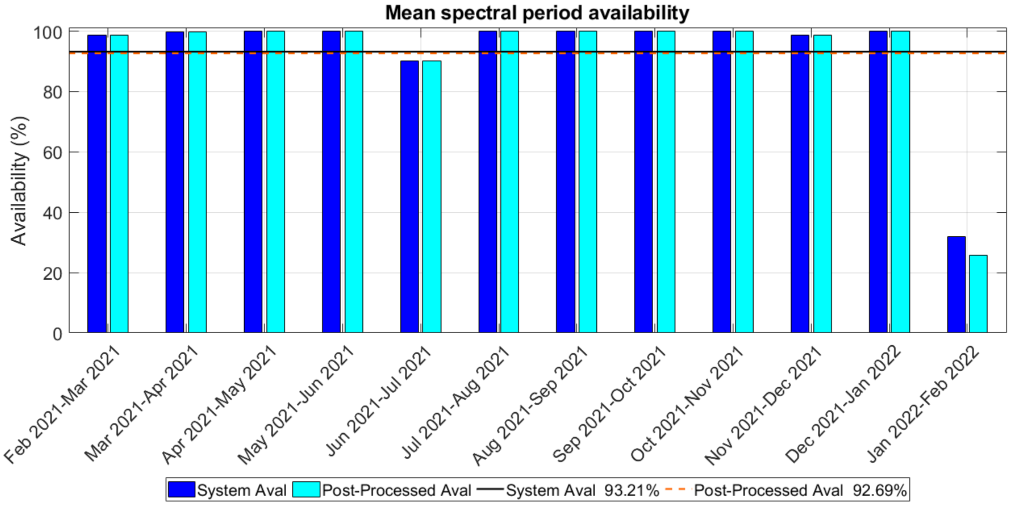

Figure 113. Bar chart for availability of mean spectral period.

4.2.5. OTHER SENSORS

OTHER SENSORS AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
AHRS	AHRSpitch_Max	52560	41890	**79.70**		
	AHRSpitch_Min	52560	41890	**79.70**		
	AHRSroll_Max	52560	41890	**79.70**		
	AHRSroll_Min	52560	41890	**79.70**		
	AHRSyawl_Max	52560	41890	**79.70**		
	AHRSyaw_Min	52560	41890	**79.70**		
Pyranometer	meteo_SlrW_Avg	52560	31131	**59.23**	31128	**59.22**
GPS	buoy_status_GPSlat	52560	41398	**78.76**	41398	**78.76**
	buoy_status_GPSlong	52560	41398	**78.76**	41398	**78.76**

Table 23. Other sensors availability

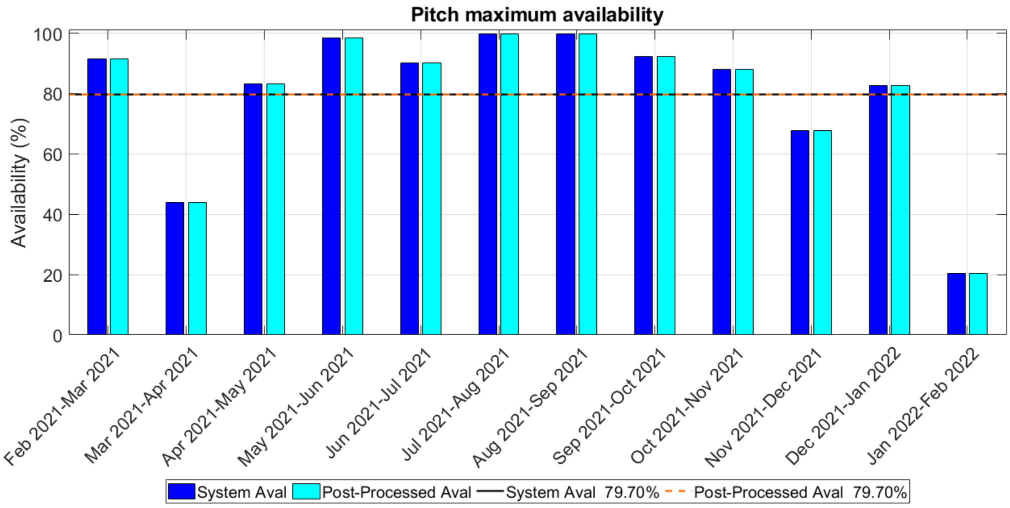

Figure 114. AHRS. Bar chart for availability of maximum pitch.

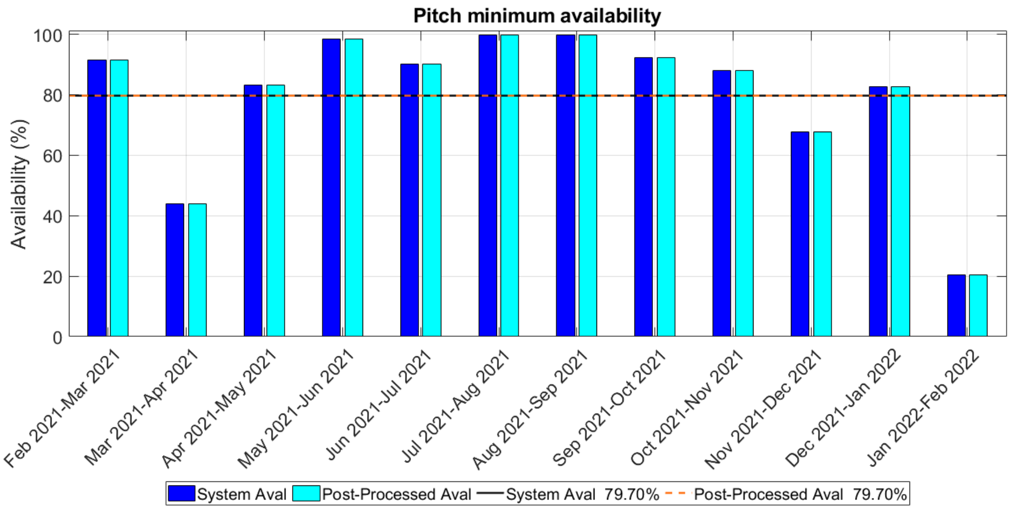

Figure 115. AHRS. Bar chart for availability of minimum pitch.

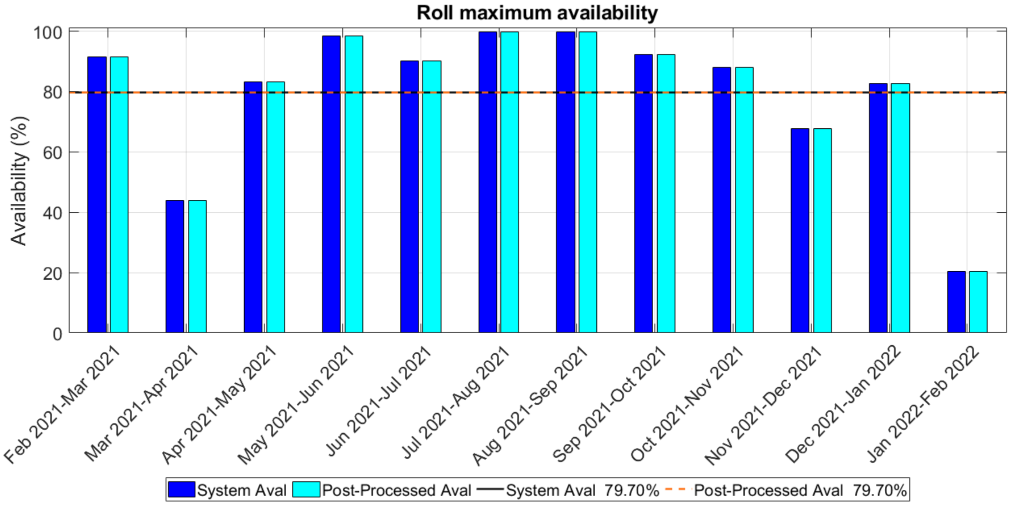

Figure 116. AHRS. Bar chart for availability of maximum roll.

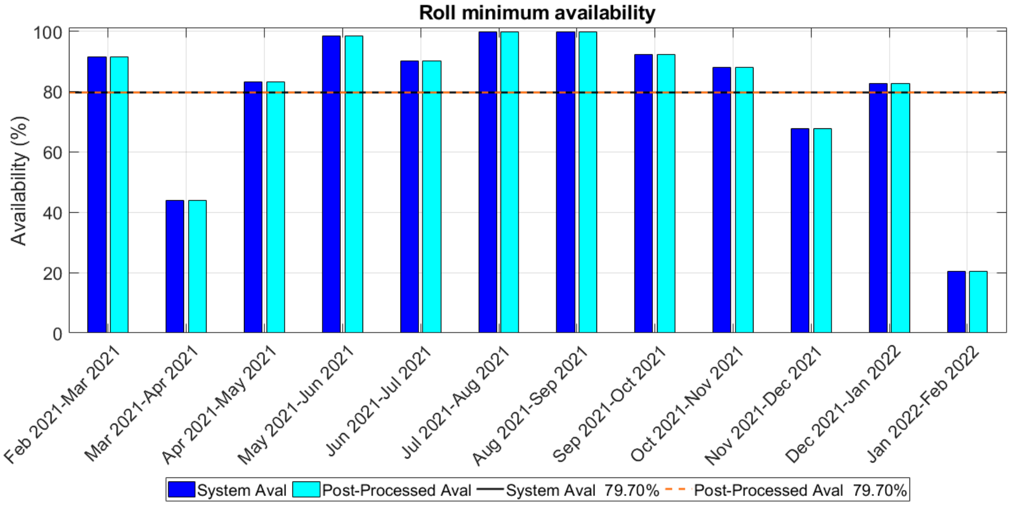

Figure 117. AHRS. Bar chart for availability of minimum roll.

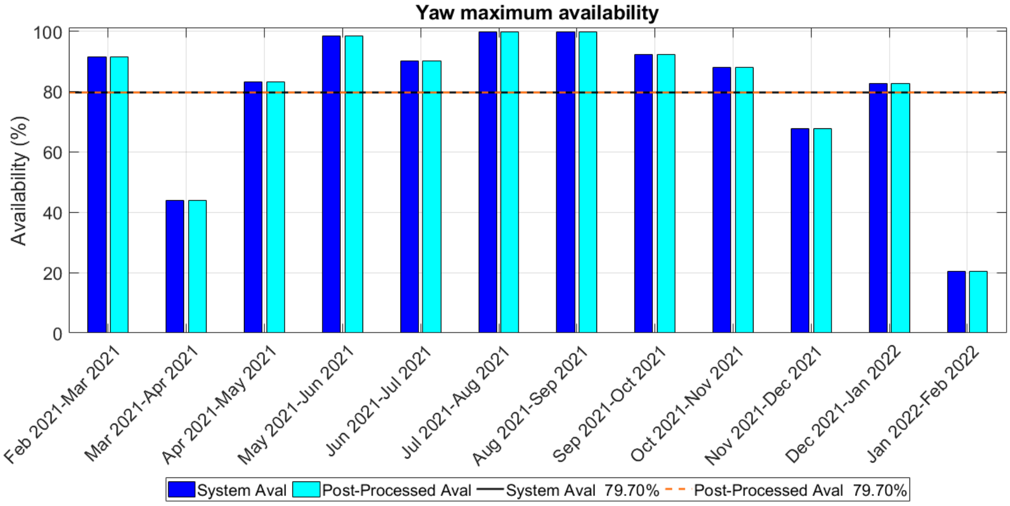

Figure 118. AHRS. Bar chart for availability of maximum yaw.

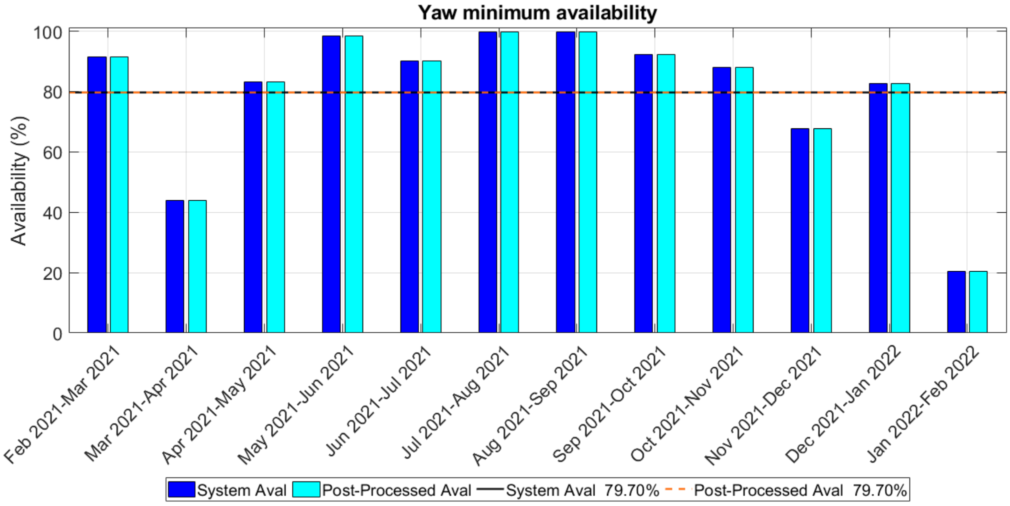

Figure 119. Bar chart for availability of minimum yaw.

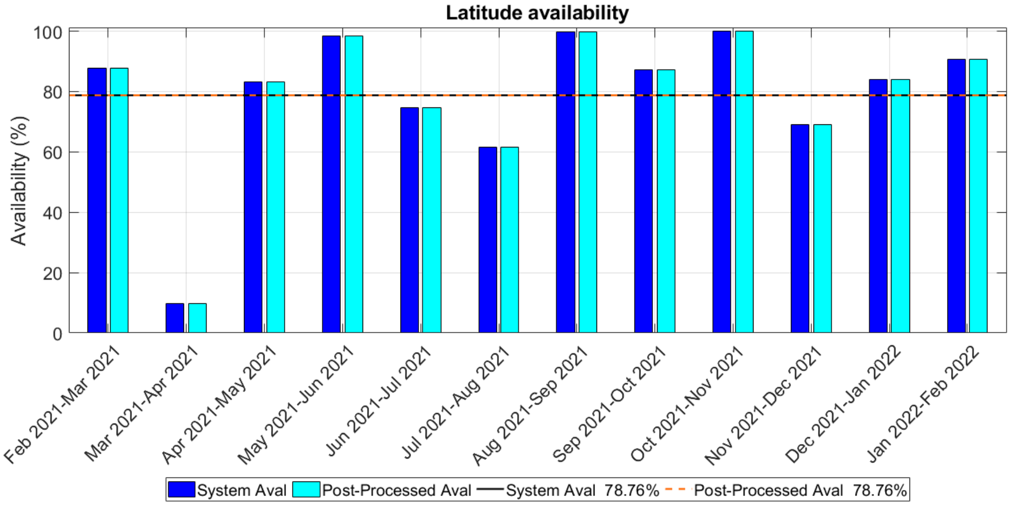

Figure 120. GPS. Bar chart for availability of latitude.

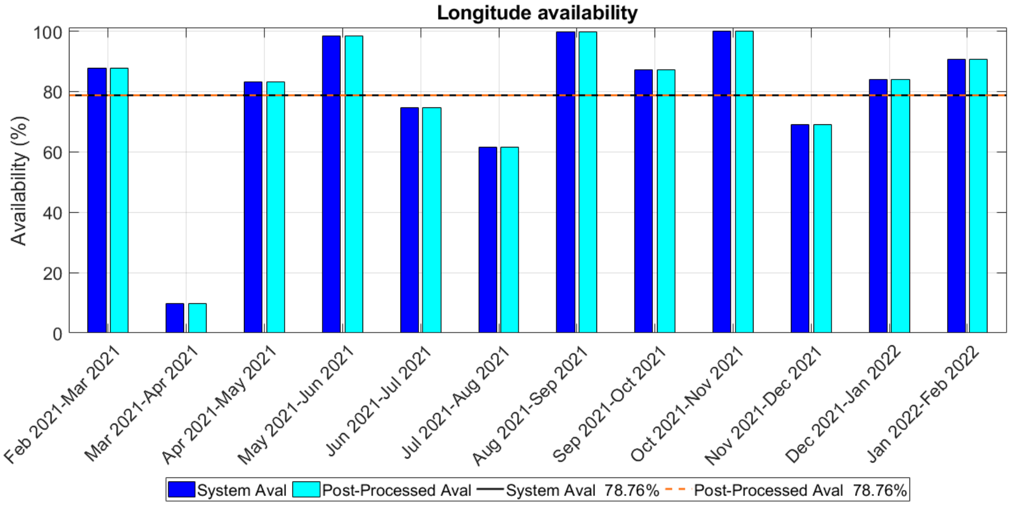

Figure 121. GPS. Bar chart for availability of longitude.

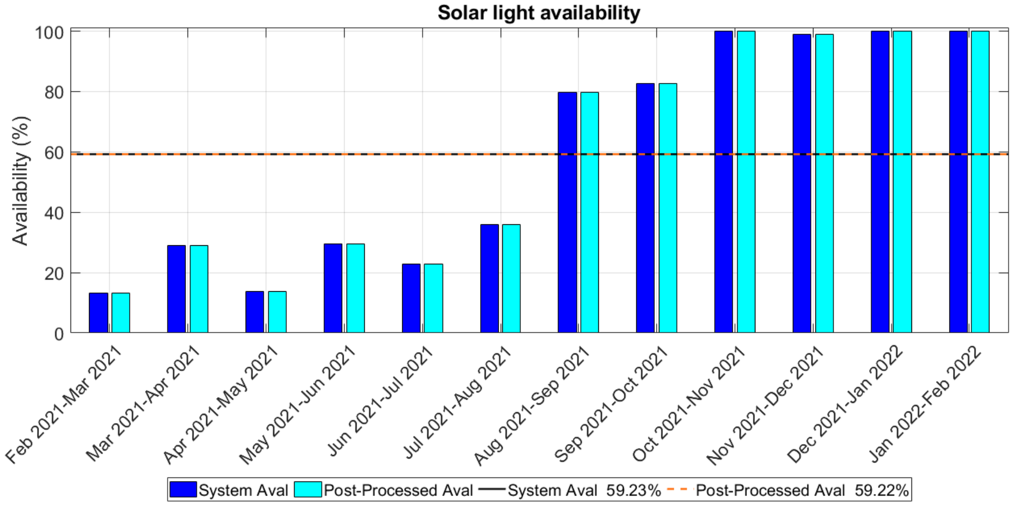

Figure 122. Pyranometer. Bar chart for availability of solar irradiance.

4.3. LOG OF INCIDENTS AND MAINTENANCES

The data operation log covers the performance of the EOLOS FLS200 unit in reference to the data delivered to the client. In the case of EOLOS buoy face any issues related to the data provided to the client, it will be shortly described here.

4.3.1. Data-sensor: operation LOG

#	Sensor	Issue Description	Start Date	Resolution Date	Reference documentation
01	All sensors	Data gaps events	19/03/2021	17/07/2021	E01-HSS-INC003.pdf
02	All sensors	Maintenance	19/03/2021	19/03/2021	EOL-HSS28-V01-OPS-Maintenance Report E01-20210319.pdf
03	Compass	Data availability	19/03/2021	28/06/2021	EOL-HSS24-V02-OPS-FLS200 E01 Compass Comparison.pdf
04	All sensors	Maintenance	14/07/2021	17/07/2021	EOL-HSS36-V01-OPS-Maintenance Report E01-20210714.pdf
05	ADCP (variable: distance between seabed and surface)	Data gaps due to values out of quality check ranges	25/08/2021	28/02/2022 (end of campaign)	E01-HSS-INC004_v01.pdf "EOL-HSS50-V03-OPS-Report ADCP E01 HESSELO.pdf"
06	Master datalogger	Code upgrade	05/10/2021	5/10/2021	NOT00031_v.01_Firmware Update.pdf
07	All sensors	Data gap events	17/07/2021	28/02/2022 (end of campaign)	E01-HSS-INC005_v02.pdf
08	ADCP	NaN events (mid-column)	28/10/2021	28/02/2022 (end of campaign)	E01-HSS-INC007_v01.pdf "EOL-HSS61-OPS-ACDP Nortek Signature 500 SN-102459 Test Report.pdf" Innova report: "CN22649Eng_v3_DigSign"
09	Slave datalogger	Code upgrade	30/11/2021	30/11/2021	NOT00032_v.01_Firmware Update.pdf
10	All sensors	Data gap event	03/12/2021	09/12/2021	E01-HSS-INC008_v01.pdf
11	Compass mast	Inconsistent behavior	03/12/2021	23/12/2021	E01-HSS-INC009_v01.pdf
12	All sensors	Maintenance	23/12/2021	23/12/2021	EOL-HSS49-V01-OPS-Maintenance Report E01-20211223.pdf

#	Sensor	Issue Description	Start Date	Resolution Date	Reference documentation
13	Lidar	Flags (9999)	28/12/2021	28/02/2022 (end of campaign)	E01-HSS-INC010_v01.pdf
14	ADCP	ADCP configuration change	28/02/2021	14/07/2021	E01-HSS-INC012_v01.pdf
15	WAVE	Frozen data	04/02/2022	28/02/2022 (end of campaign)	E01-HSS-INC011_v01.pdf
16	AHRS	Frozen data	04/02/2022	28/02/2022 (end of campaign)	E01-HSS-INC011_v01.pdf
17	Wave	Inconsistent behavior	23/12/2021	28/02/2022 (end of campaign)	E01-HSS-INC013_v02.pdf
18	Pyranometer	Data availability	28/02/2021 (start of campaign)	28/02/2022 (end of campaign)	E01-HSS-INC014_v02.pdf
19	All sensors	Partial mooring break	23/12/2021	28/02/2022 (end of campaign)	E01-HSS-INC015_v01.pdf EOL-HSS60-V01-OPS-Mooring Partial Break Analysis.pdf

Table 24. Incidence LOG.

4.3.2. Incidence summary description

#	Reference documentation	Description
01	E01-HSS-INC003.pdf	Dataloggers do not communicate properly and consequently data is not received by Master Datalogger.
05	E01-HSS-INC004_v01.pdf	Inconsistent altimeter behavior. Values out of quality check ranges. Since 25 to 28 August data is affected. After closing the INC, the event starts again in mid-September. Refer to the ADCP report "EOL-HSS50-V03-OPS-Report ADCP E01 HESSELO.pdf" for more details.
07	E01-HSS-INC005_v02.pdf	There are some gaps in the files due to dataloggers' reboot.
08	E01-HSS-INC007_v01.pdf	ADCP is filtering almost all the cells between cell #5 and cell #19. Detected biofouling during maintenance on 23/12/2021. • Refer to report "EOL-HSS61-OPS-ACDP Nortek Signature 500 SN-102459 Test Report.pdf". • Refer to Innova report Innova report: "CN22649Eng_v3_DigSign"
10	E01-HSS-INC008_v01.pdf	No data received from 3/12/2021 at 19:01 until 9/12/2021 at 11:00. Solved with a Datalogger reboot.

#	Reference documentation	Description
11	E01-HSS-INC009_v01.pdf	Inconsistent compass behavior. Values frozen and not matching with roof compass (compass2) nor Airmar. Solved with a device reset.
13	E01-HSS-INC010_v02.pdf	Some flags "9999" in Lidar data. Flag 9999 – High quality wind speed measurement is not possible. This is often caused by very low wind speed, or due to partial obscuration of the ZephIR window, or significant interference with the laser beam at the specified height.
14	E01-HSS-INC012_v02.pdf	Since the beginning of the campaign until 14/07/2021 the ADCP device has wrong configuration of the blanking distance (3.6 mts).
15	E01-HSS-INC011_v02.pdf	Variables AHRS with NaNs, Wave variables 0 and WaveVoltage 0V. Final diagnosis: Wave device flooded.
17	E01-HSS-INC013_v01.pdf	Variable DirAvgSprd behavior changed after maintenance on 24/12/2021. Under investigation with raw data analysis.
18	E01-HSS-INC014_v01.pdf	Variable "SlrW" in the monthly report was wrongly accepted, because it was collected from Slave datalogger, and the flagged data has a numeric value (999) instead of NaN.
19	E01-HSS-INC015_v01.pdf	Break of the east chain of the upper mooring. Refer to "EOL-HSS60-V01-OPS-Mooring Partial Break Analysis.pdf" for an in-depth analysis.

Table 25. Incidence summary description.

5. DATA PRESENTATION

5.1. LIDAR

5.1.1. Distributions

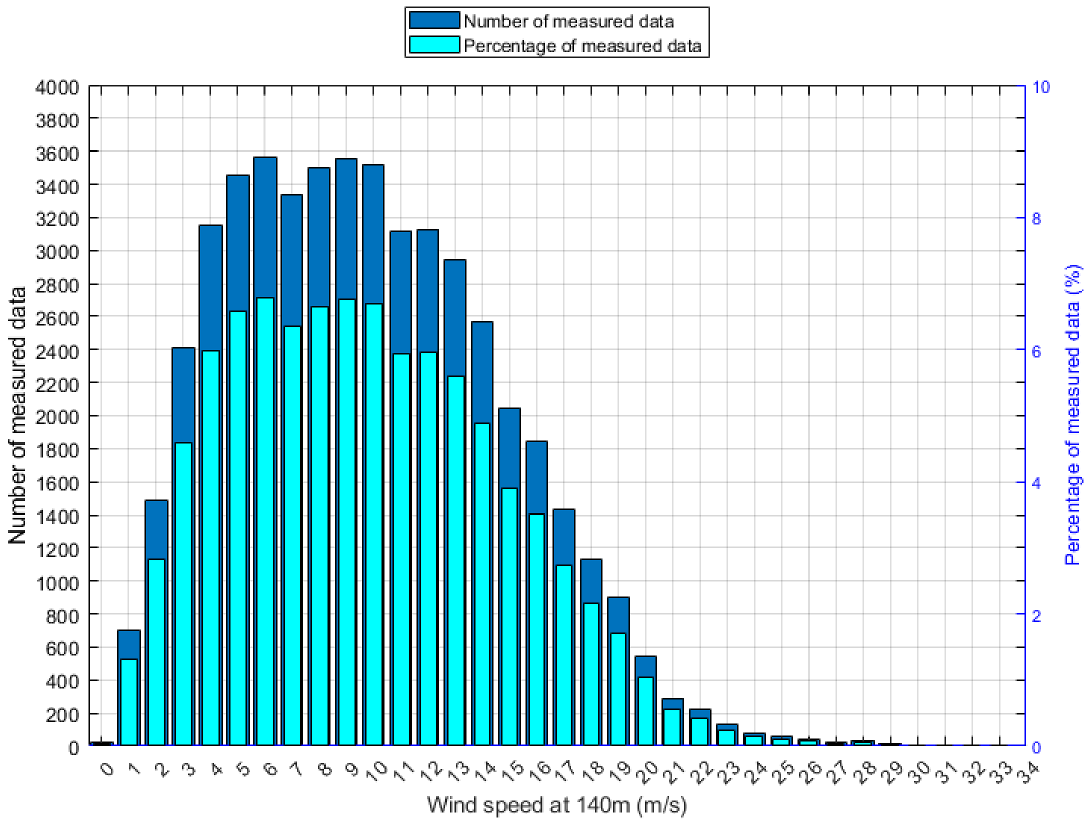

Figure 123. Horizontal wind speed distribution at 140 m.

5.1.2. Time series

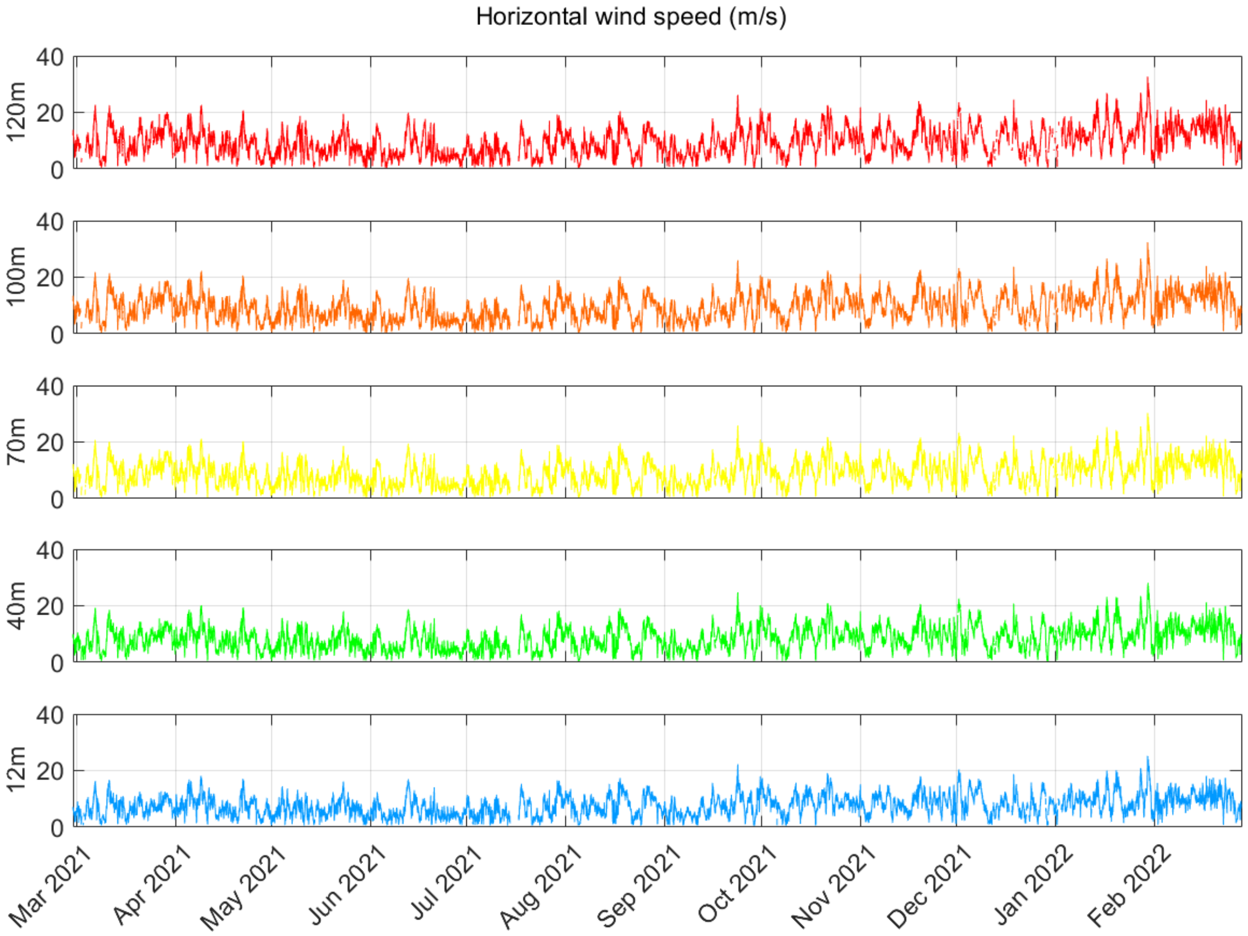

Figure 124. Horizontal wind speed time series for heights from 12 to 120 m.

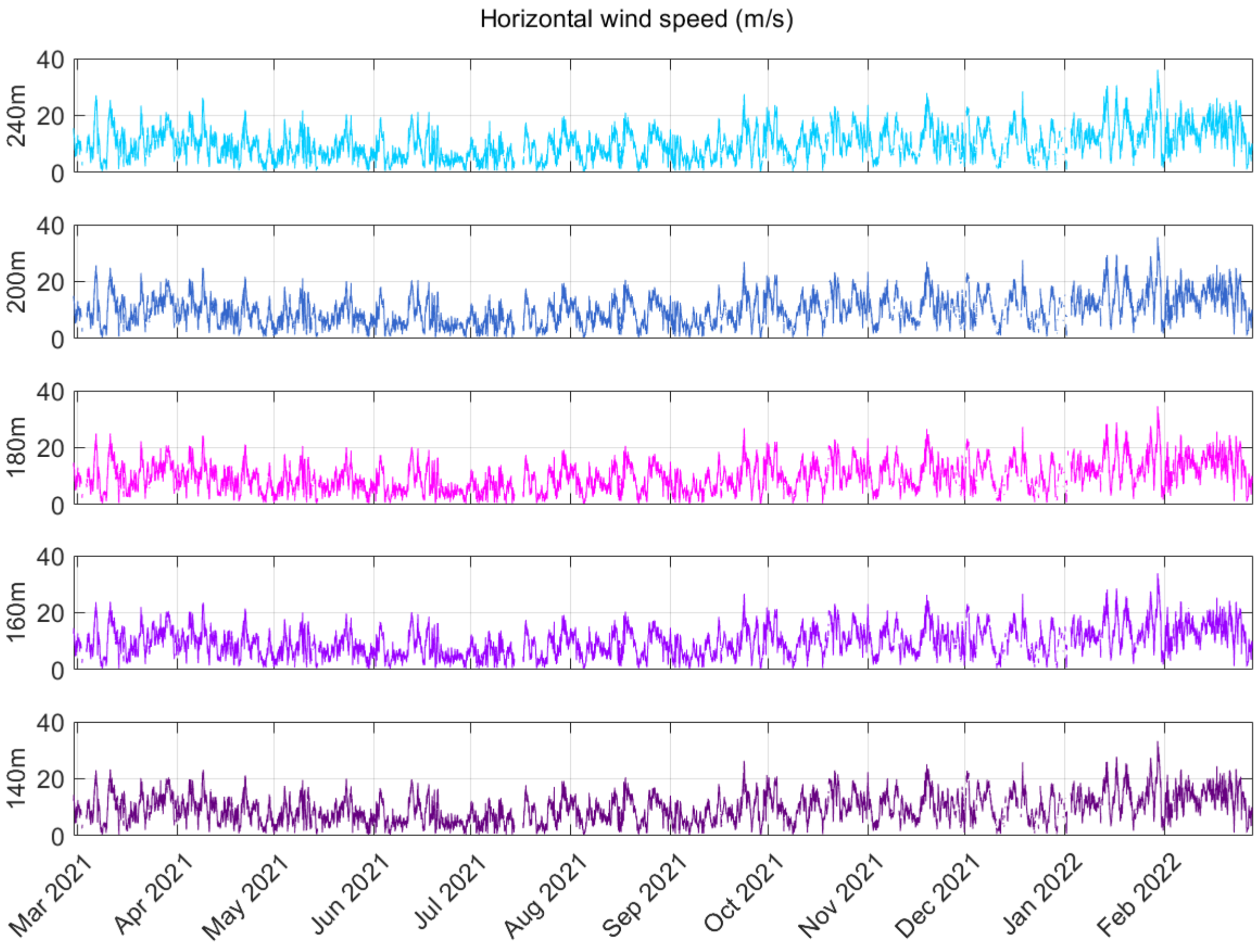

Figure 125. Horizontal wind speed time series for heights from 140 to 240 m.

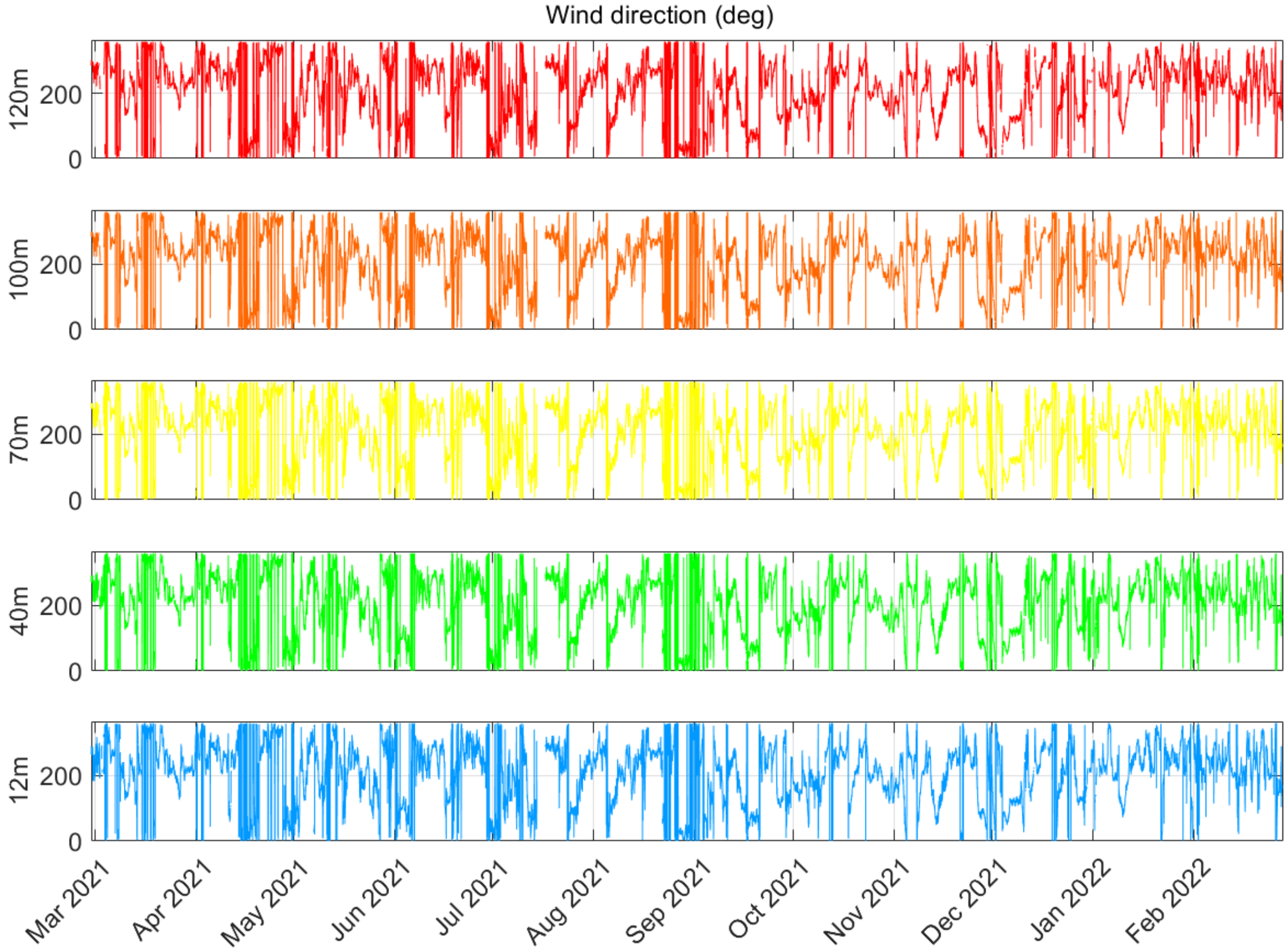

Figure 126. Wind direction time series for heights from 12 to 120 m.

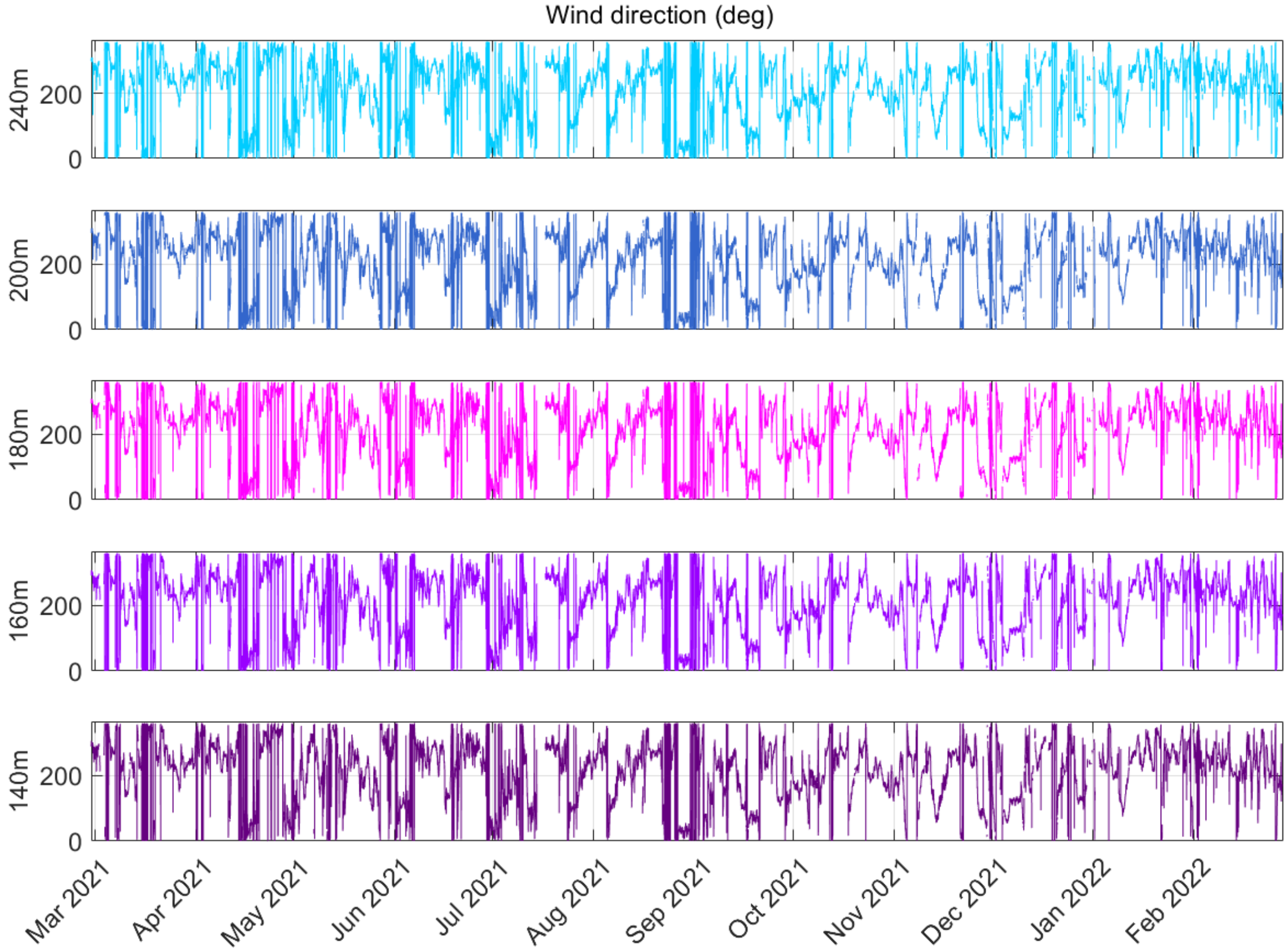

Figure 127. Wind direction time series for heights from 140 to 240 m.

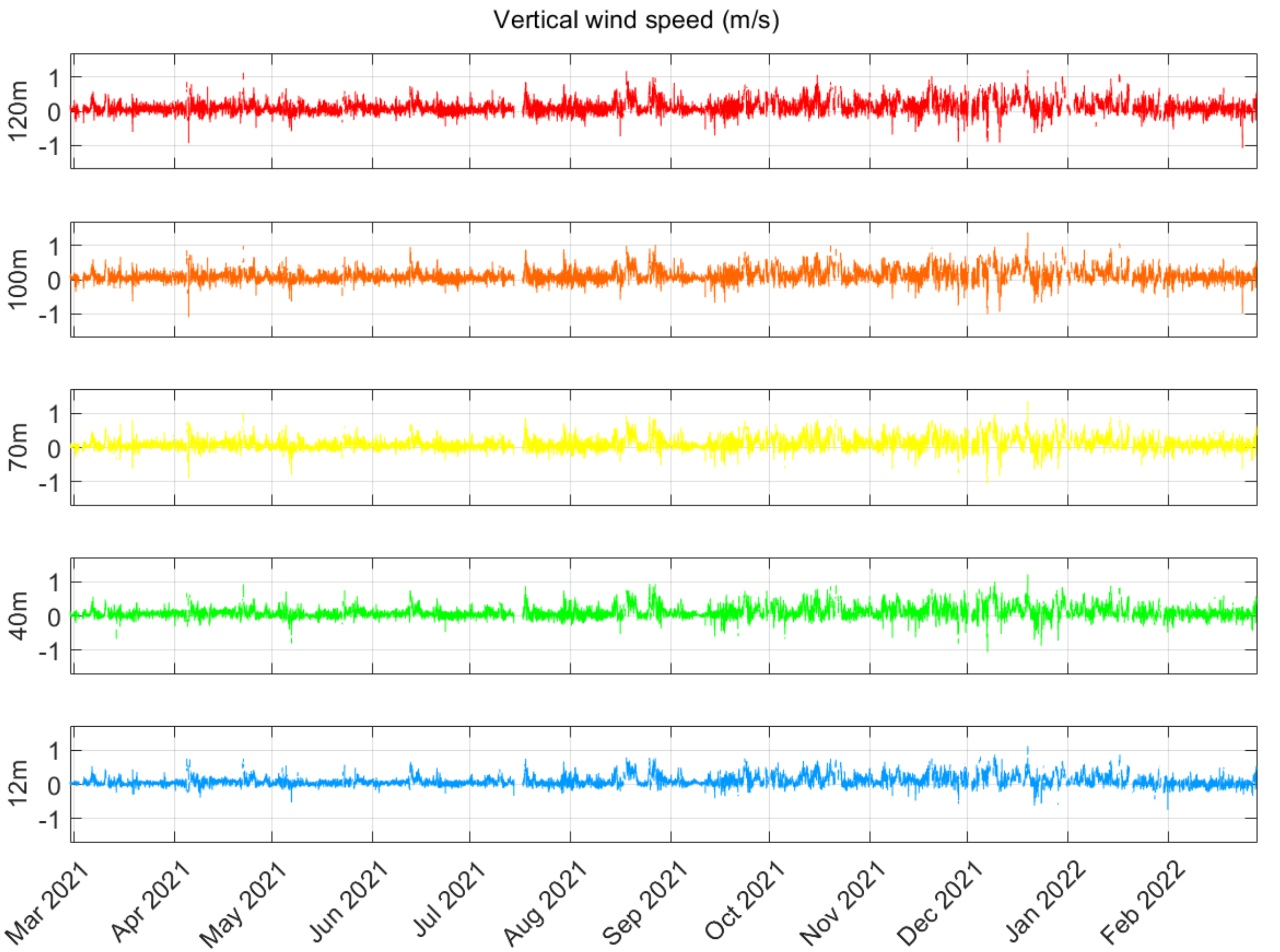

Figure 128. Vertical wind speed time series for heights from 12 to 120 m.

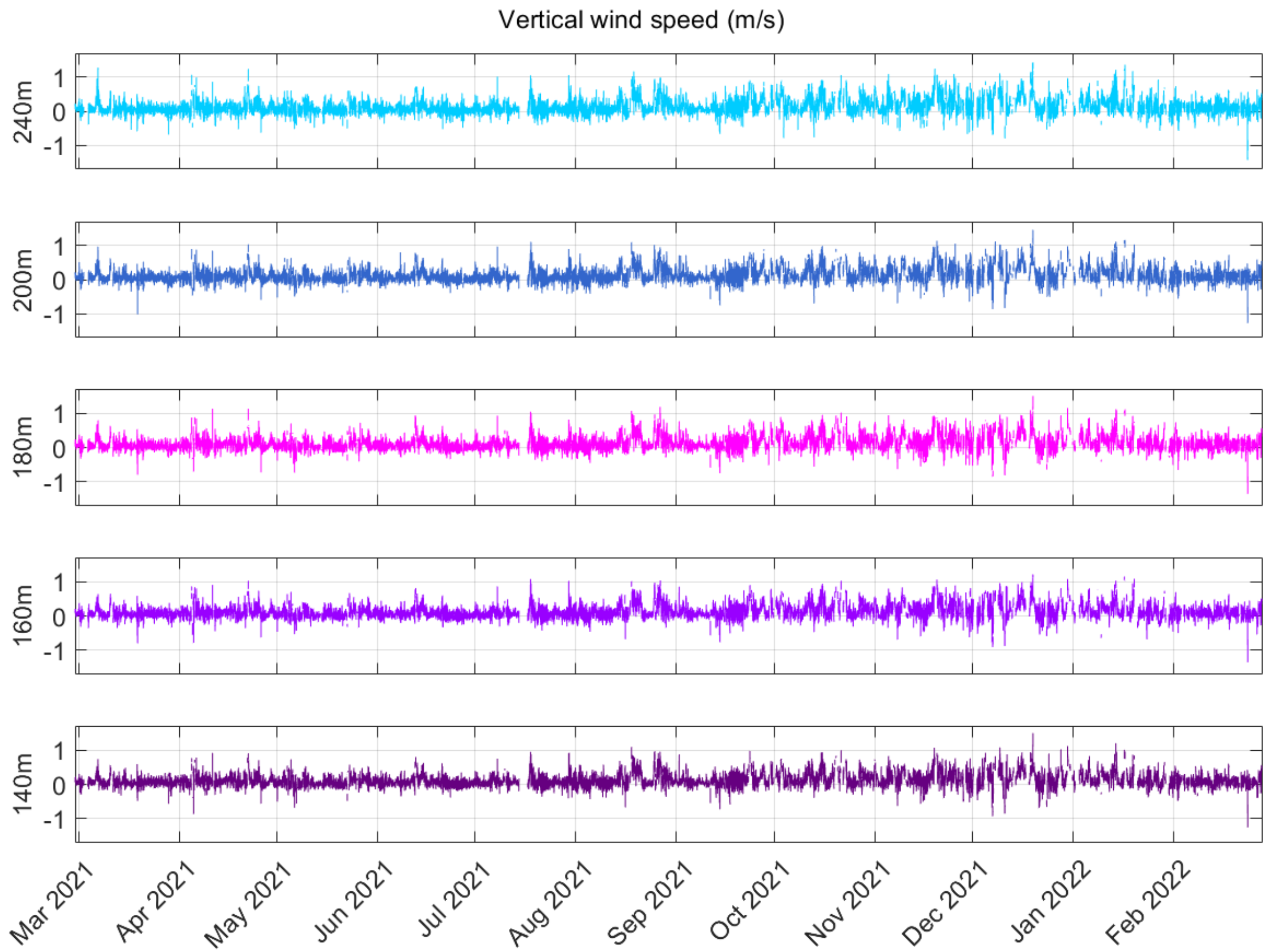

Figure 129. Vertical wind speed time series for heights from 140 to 240 m.

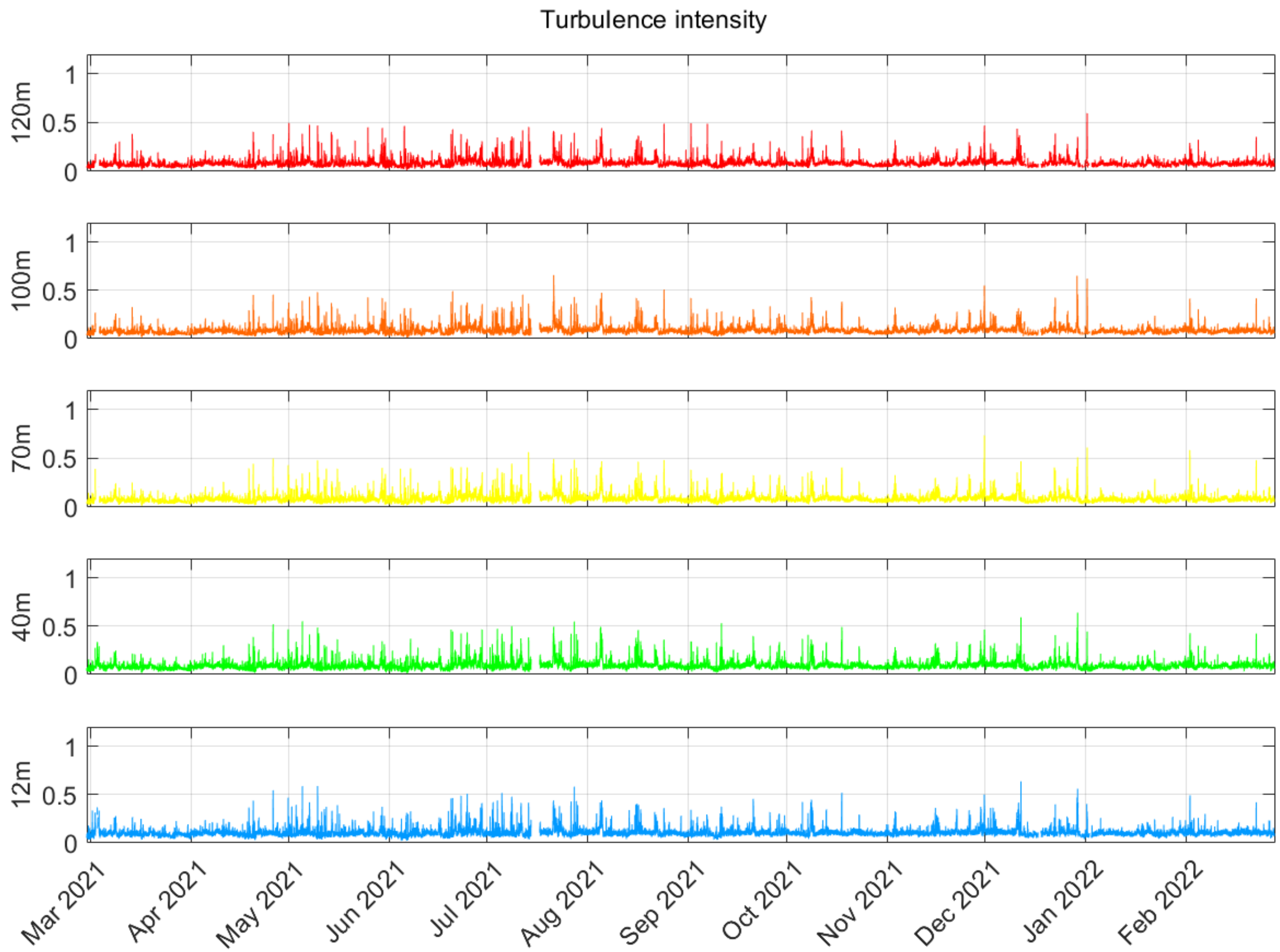

Figure 130. Turbulence intensity time series for heights from 12 to 120 m.

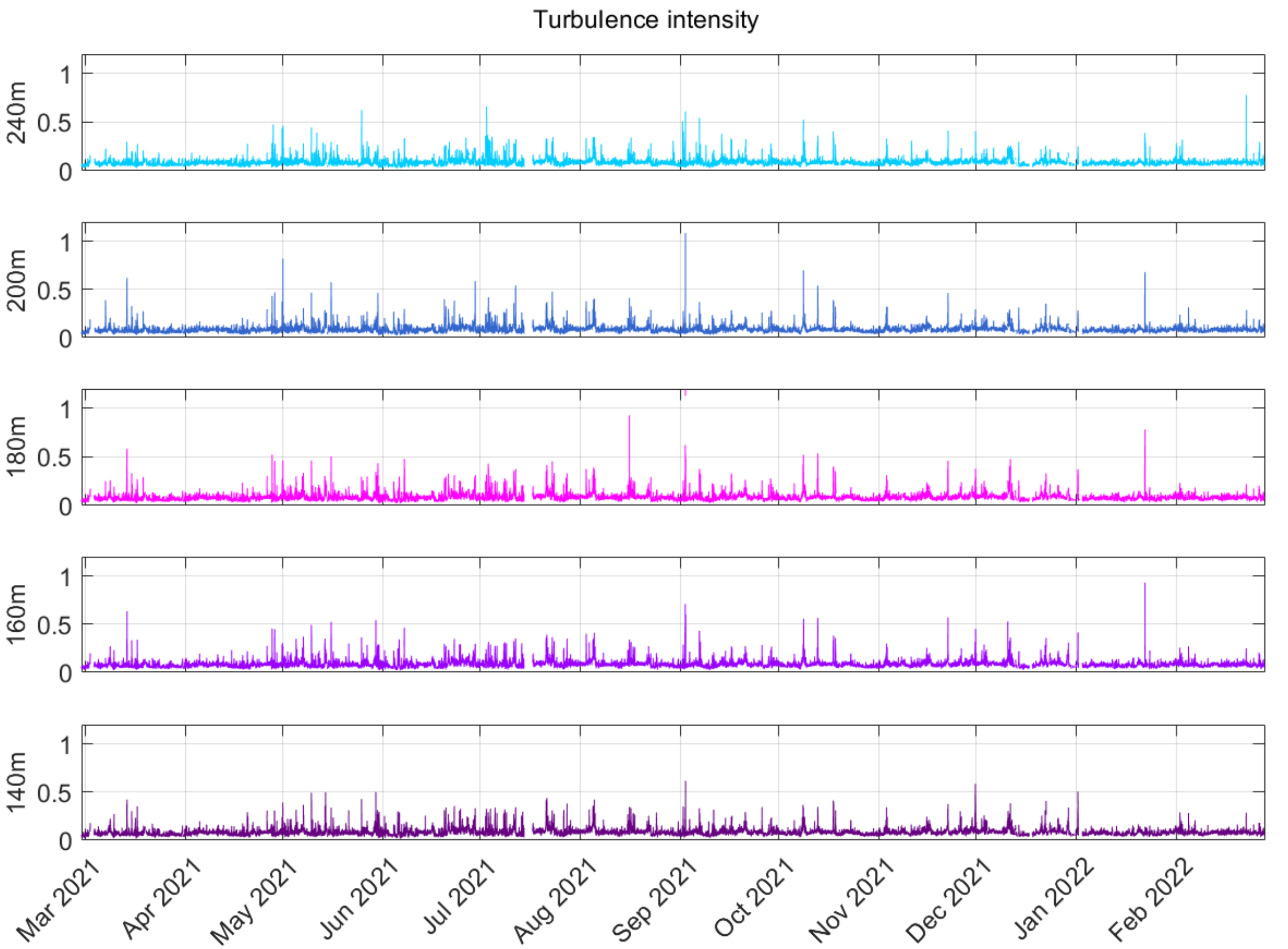

Figure 131. Turbulence intensity time series for heights from 140 to 240 m.

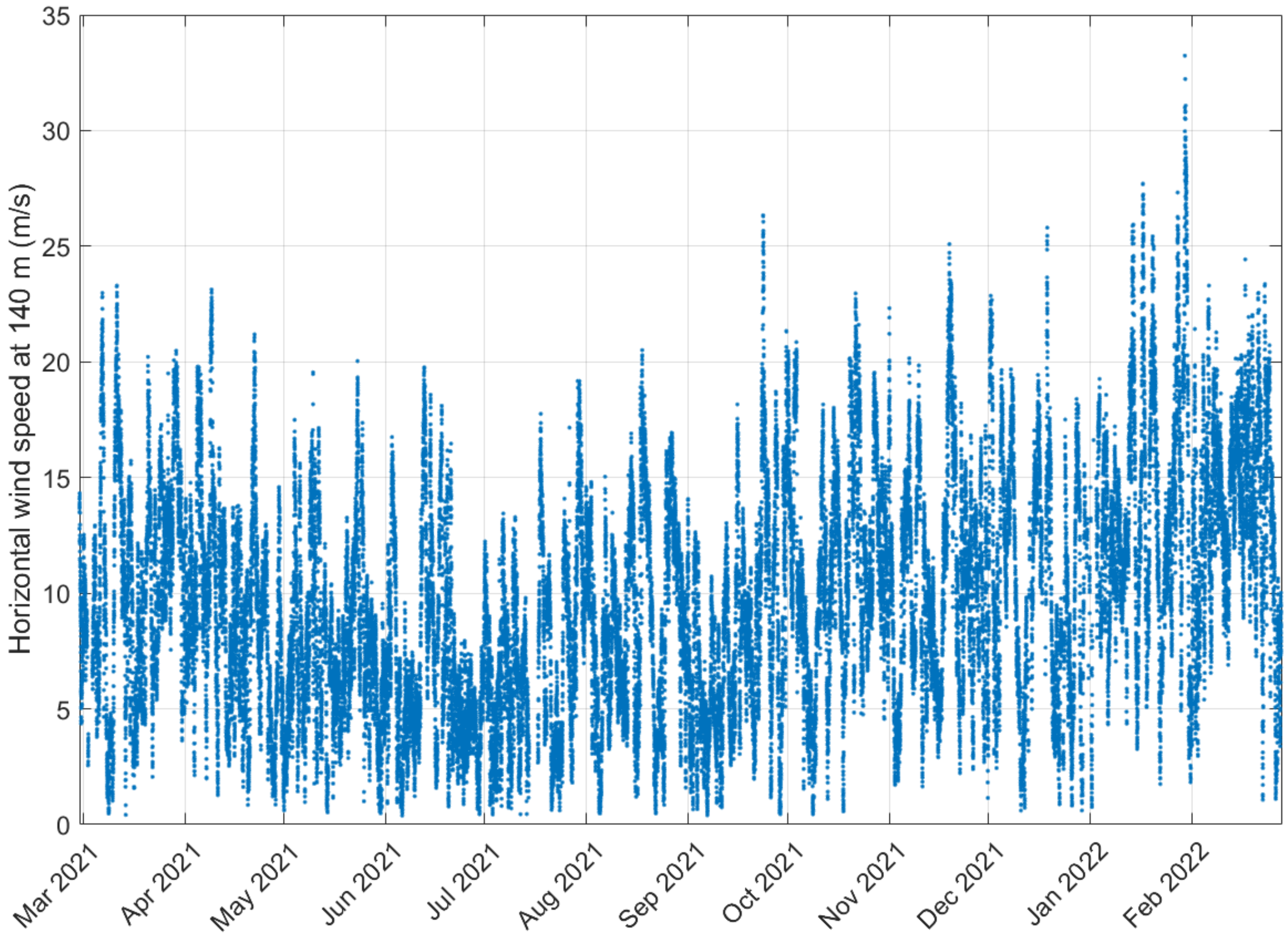

Figure 132. Wind speed time series at 140 m.

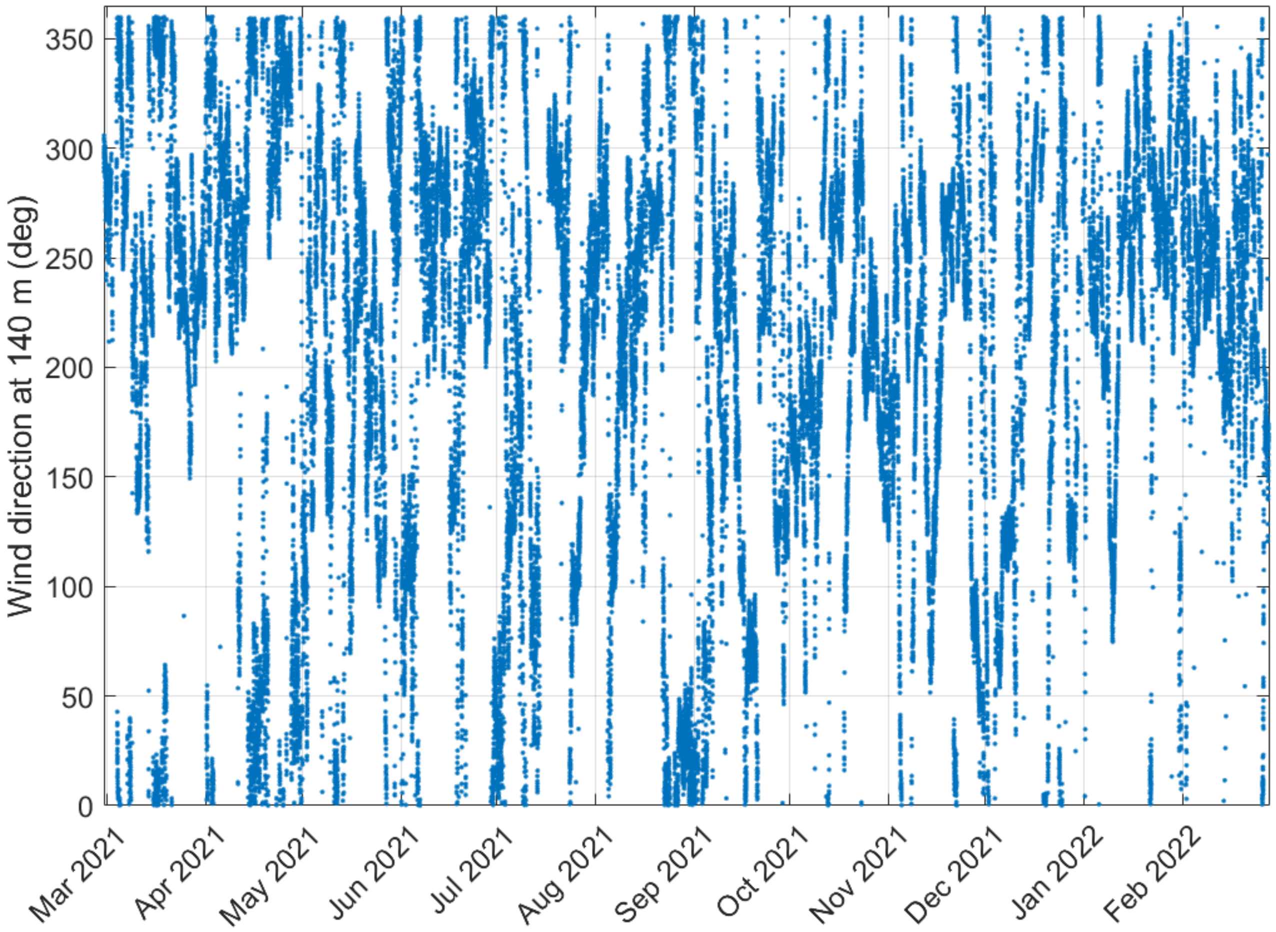

Figure 133. Wind direction time series at 140 m.

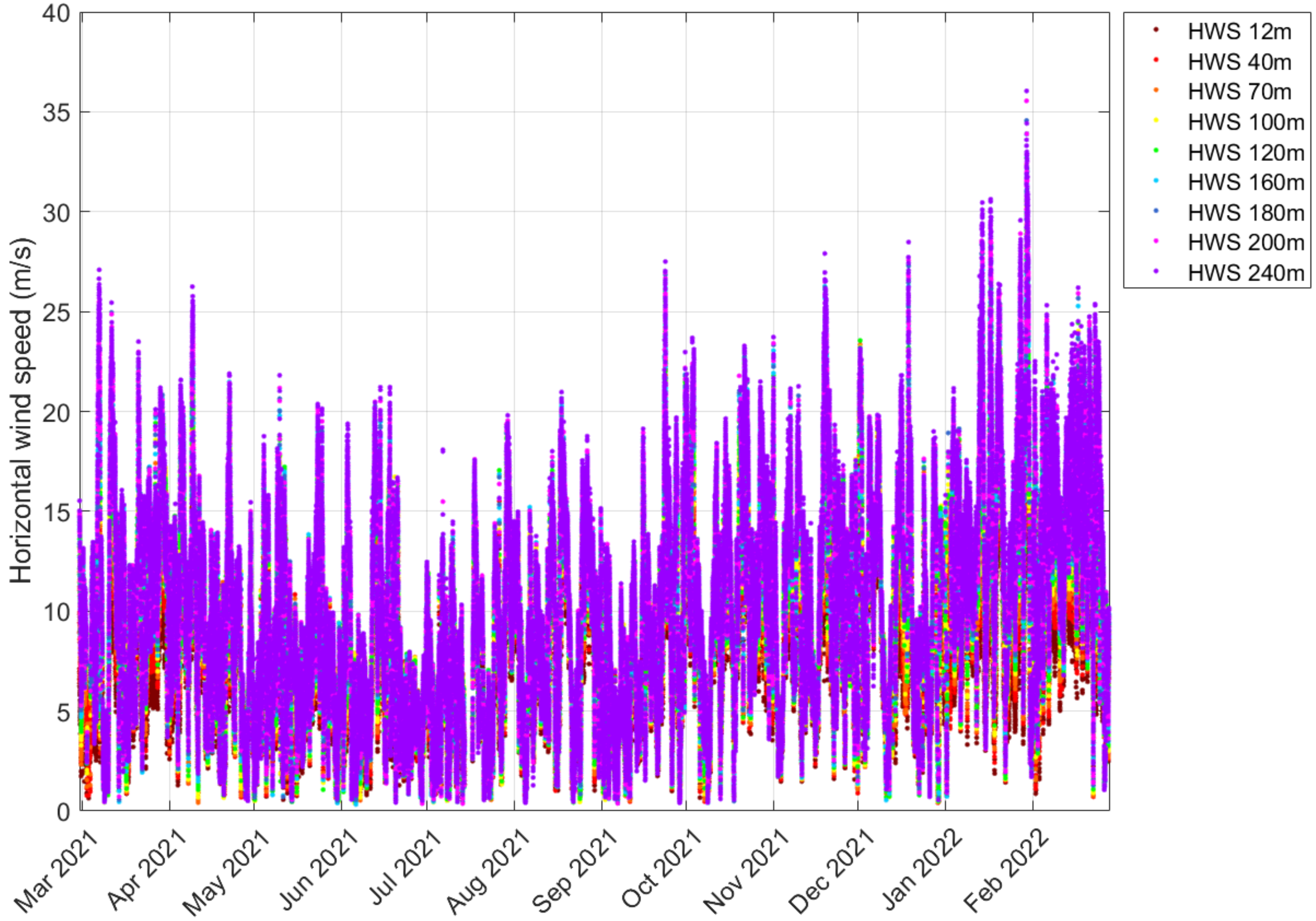

Figure 134. Wind speed time series for all heights except 140 m.

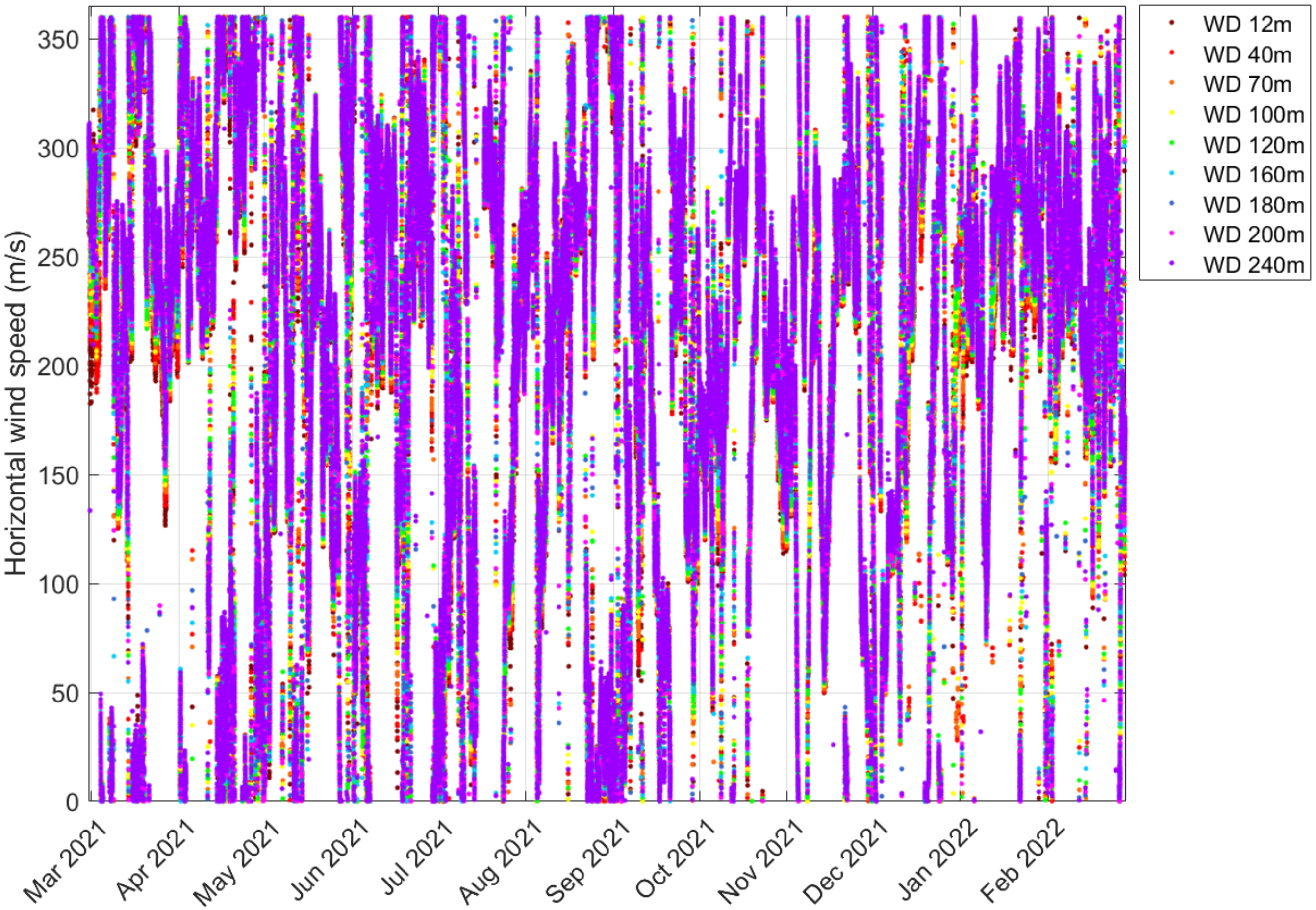

Figure 135. Wind direction time series for all heights except 140 m.

5.1.1. Profiles

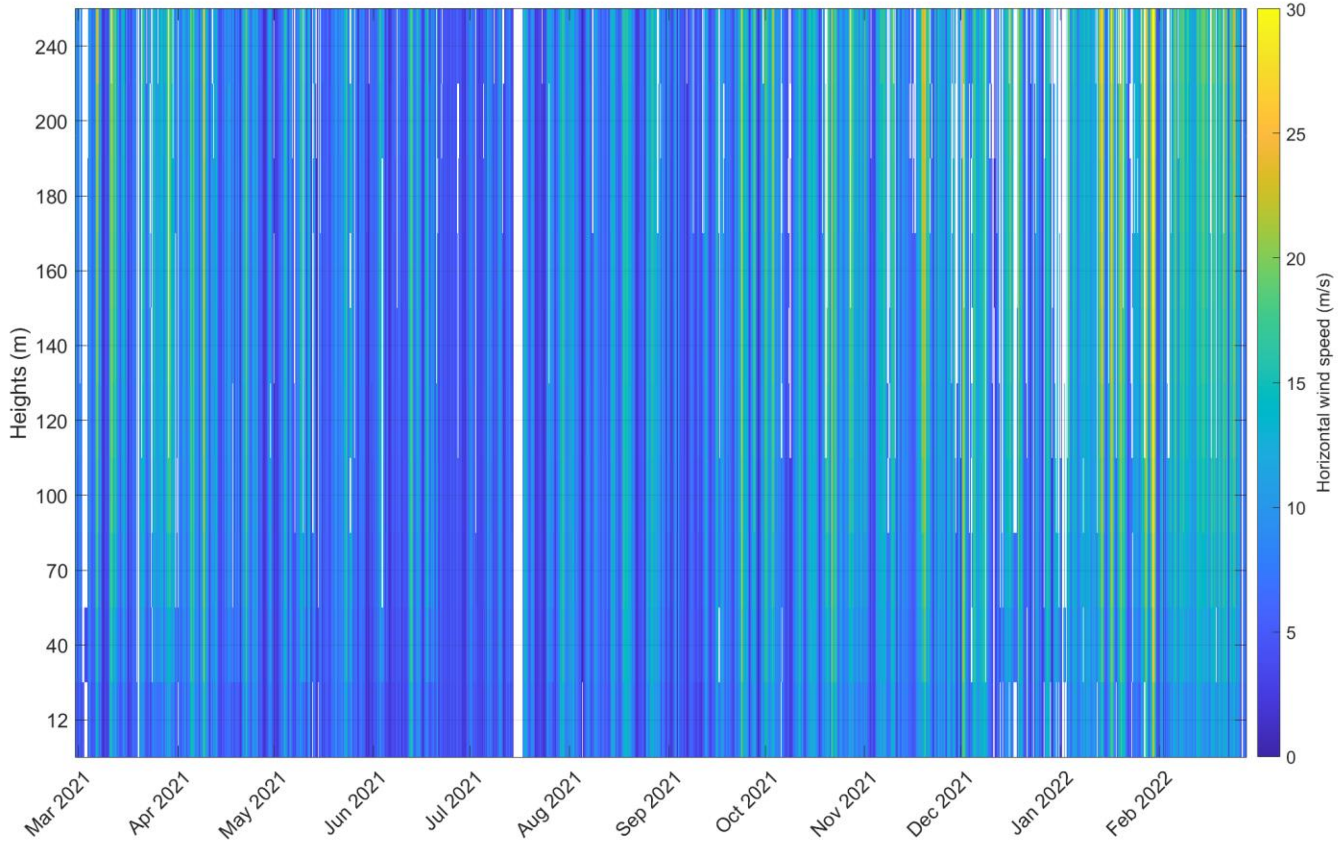

Figure 136. Horizontal wind speed heat map.

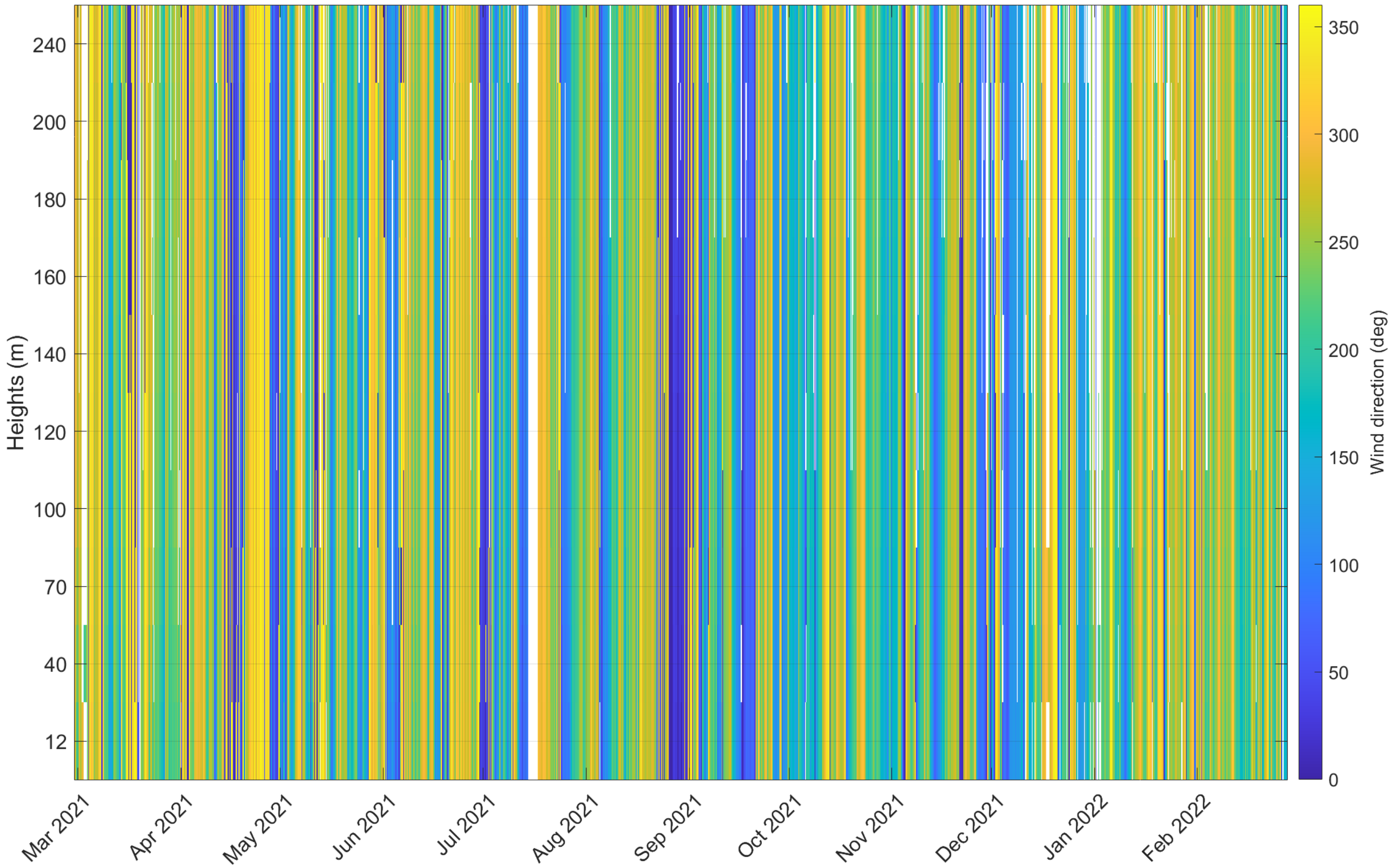

Figure 137. Wind direction heat map.

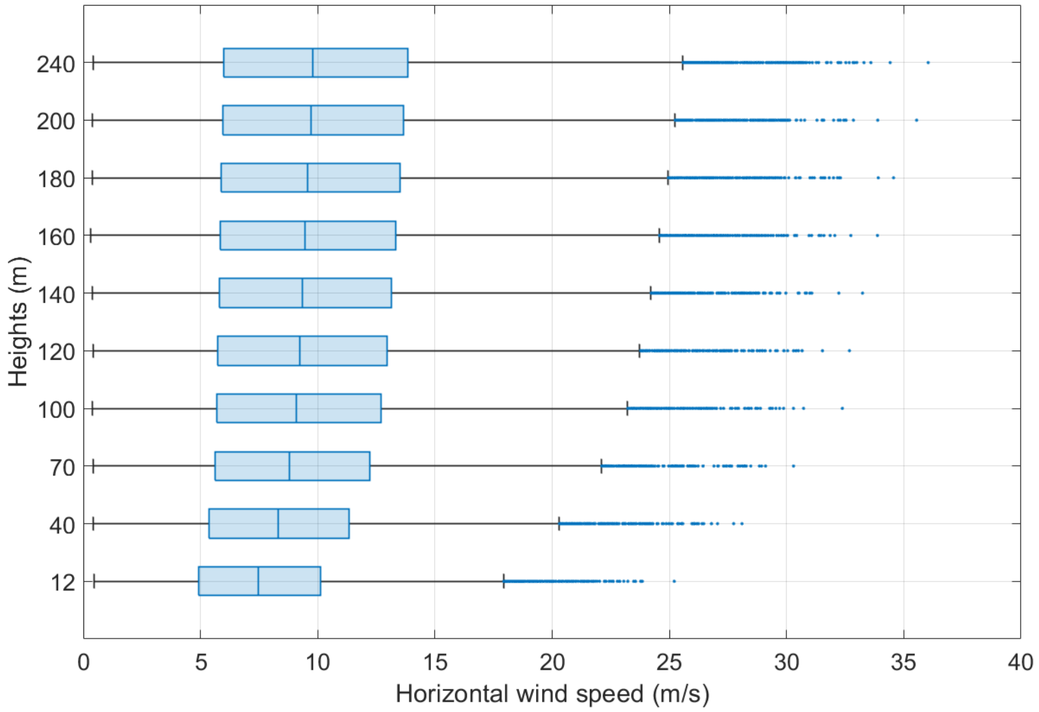

Figure 138. Horizontal wind speed box chart.

Each box shows the values of the median (middle line) and the 25th and 75th quartiles (left and right delimiters respectively). The whiskers extend to the minimum and maximum values that are not outliers. Outliers are values that are more than 1.5 · interquartile range (IQR) away from the left or right of the box. Any outliers are plotted as individual points.

5.1.2. Wind roses

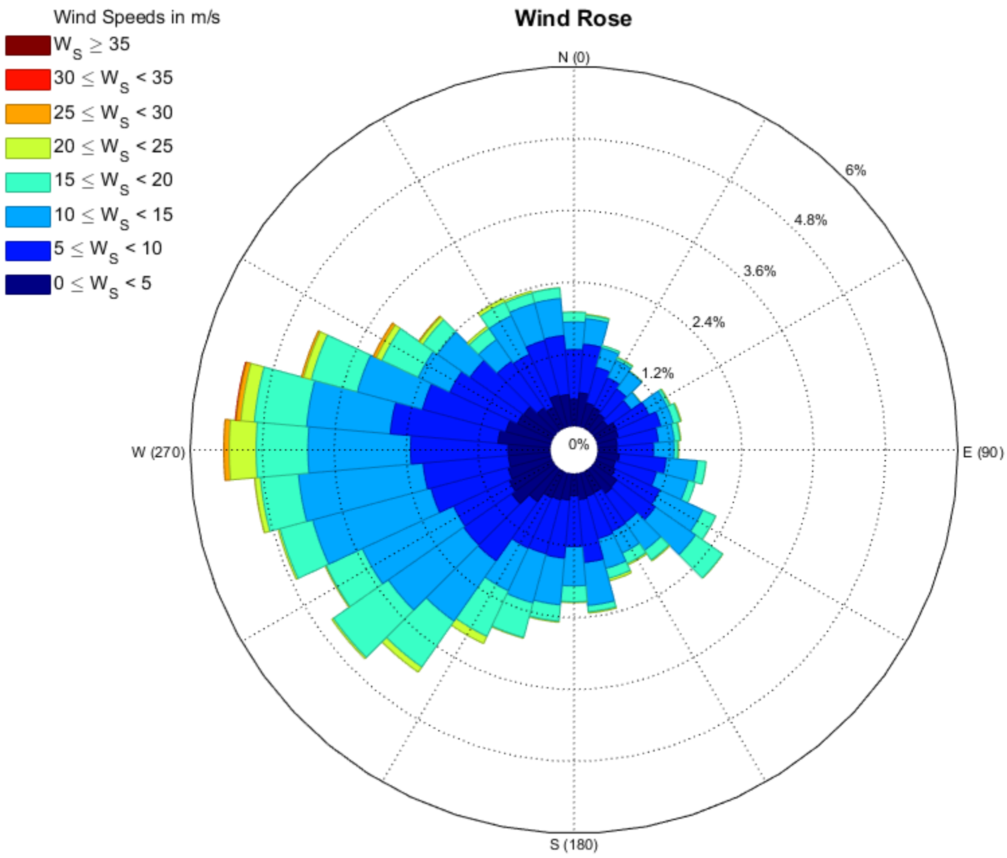

Figure 139. Wind rose at 140 m.

5.1.3. Statistics

LIDAR Horizontal Wind Speed (m/s)										
Period	Heights (m)									
Feb 2021 - Feb 2022	12	40	70	100	120	140	160	180	200	240
Mean	7.71	8.57	9.11	9.44	9.61	9.75	9.89	10.02	10.15	10.31
Max	25.21	28.10	30.30	32.38	32.68	33.24	33.88	34.56	35.55	36.04
Min	0.46	0.41	0.42	0.38	0.43	0.39	0.33	0.39	0.37	0.41
Std	3.62	4.07	4.41	4.66	4.81	4.93	5.05	5.15	5.24	5.39

Table 26. LIDAR statistics.

5.2. METEO

5.2.1. Time series

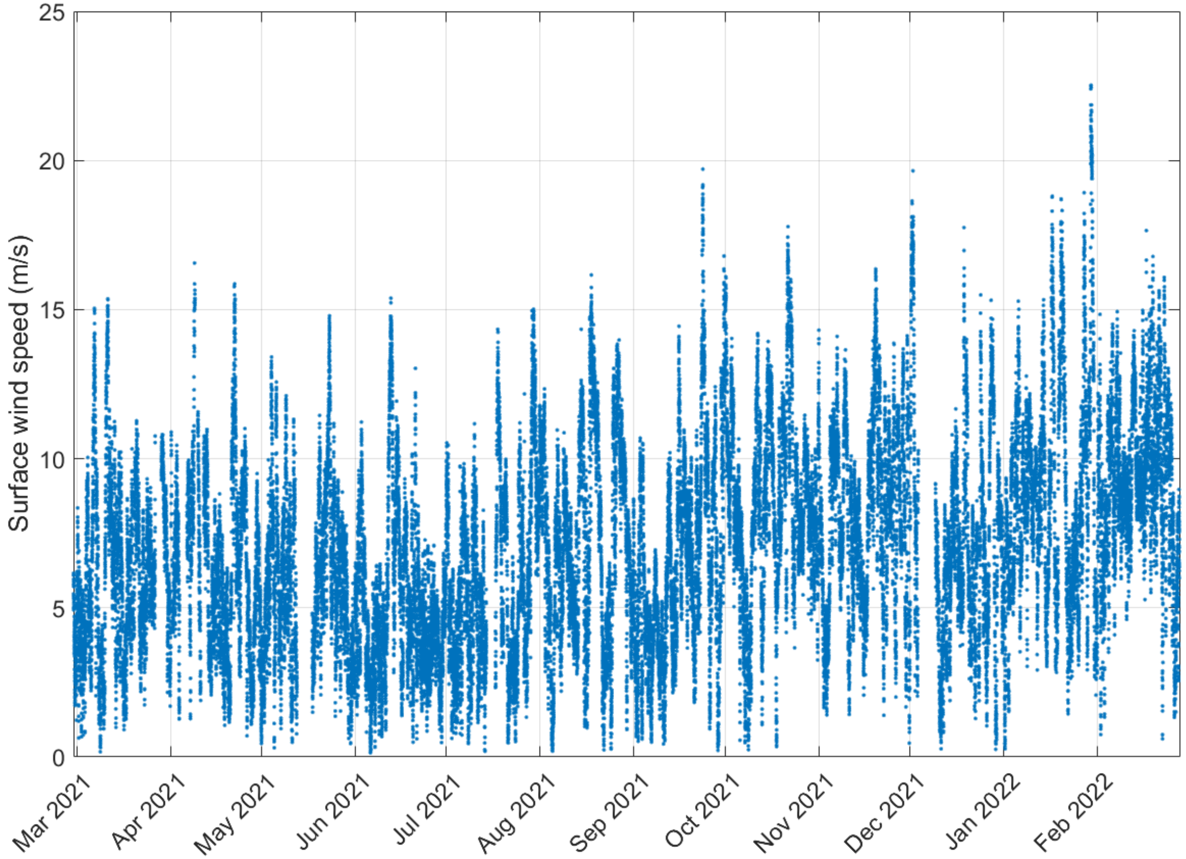

Figure 140. Wind speed at surface time series.

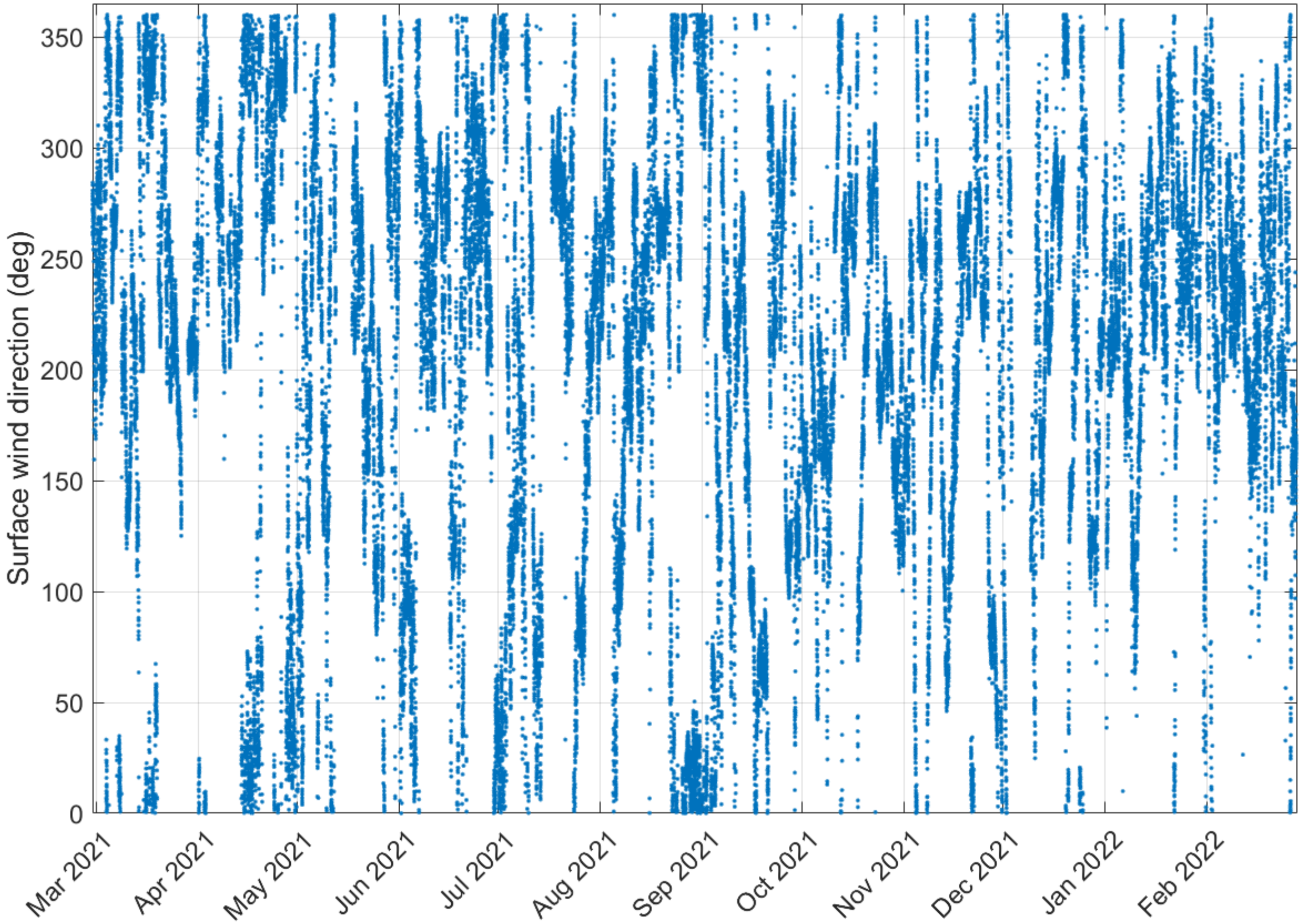

Figure 141. Wind direction at surface time series.

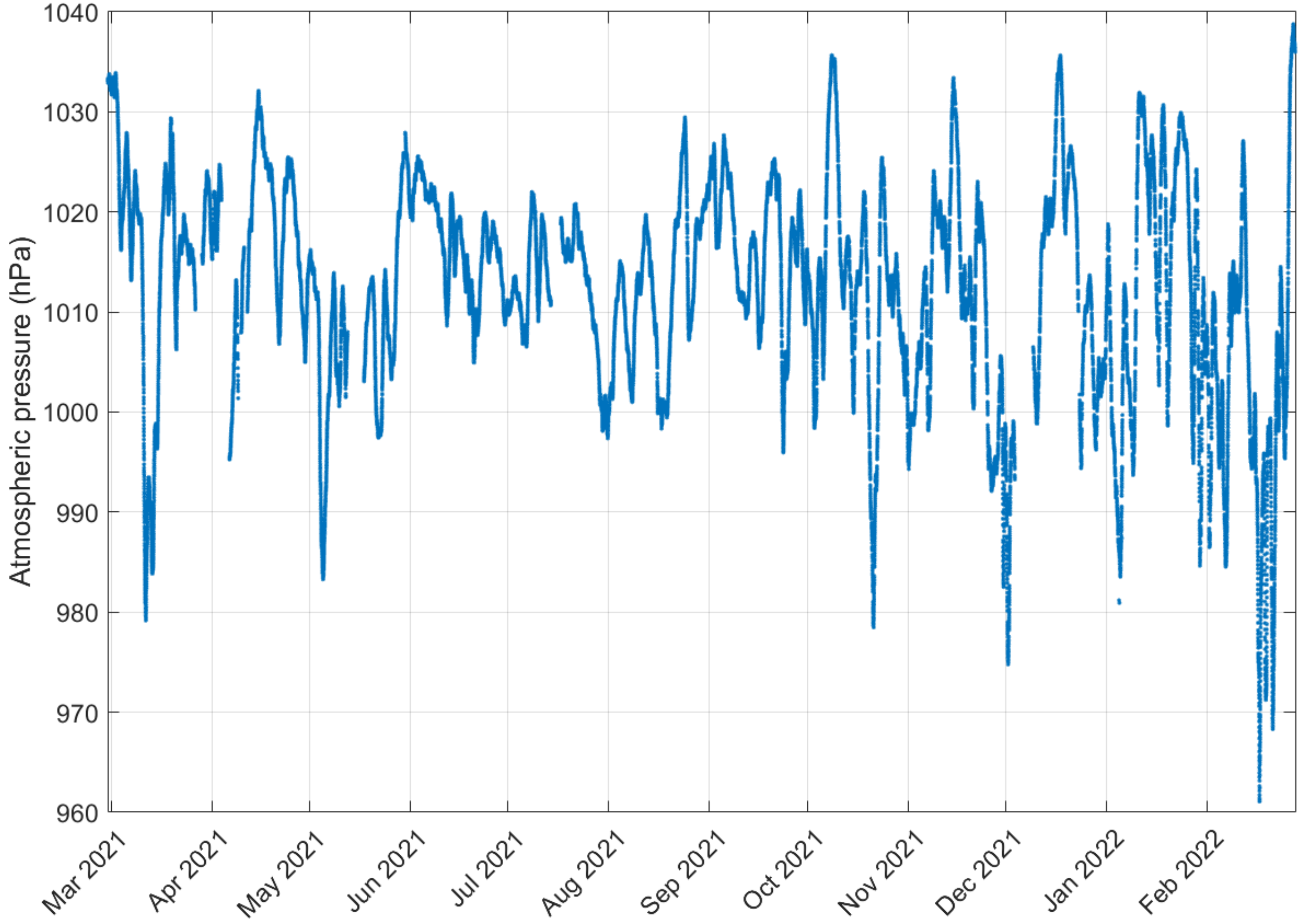

Figure 142. Atmospheric pressure time series.

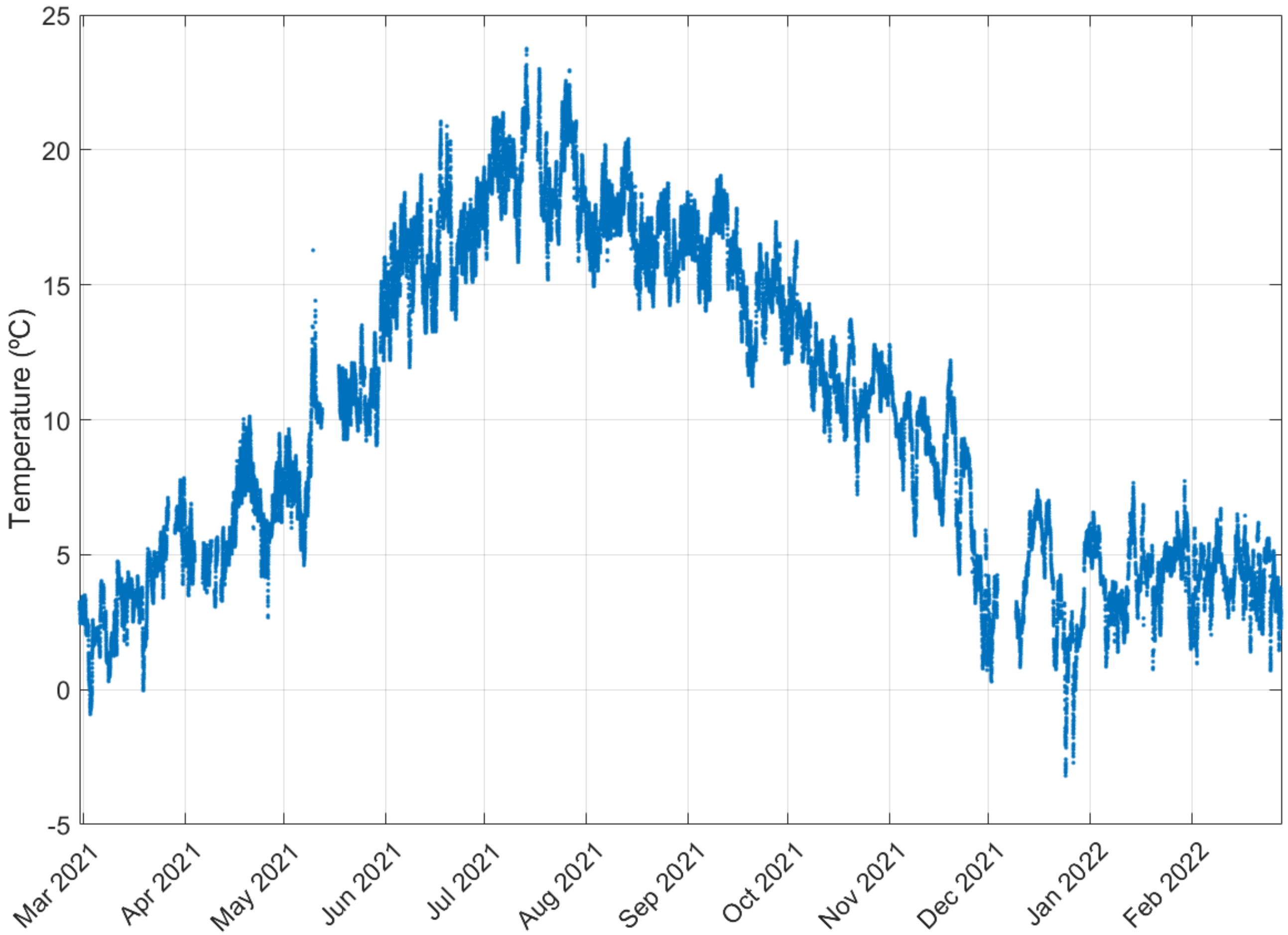

Figure 143. Air temperature time series.

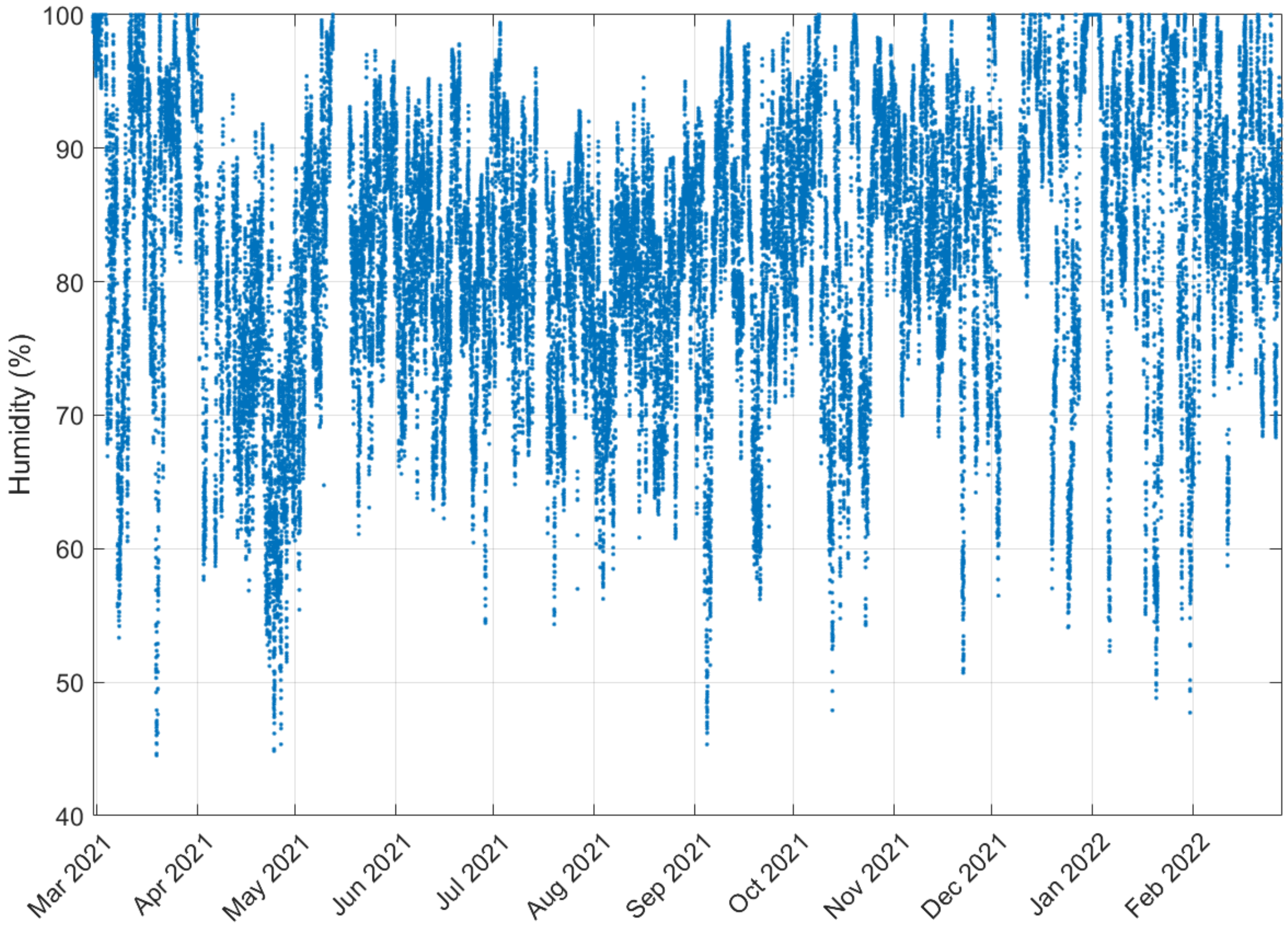

Figure 144. Humidity time series.

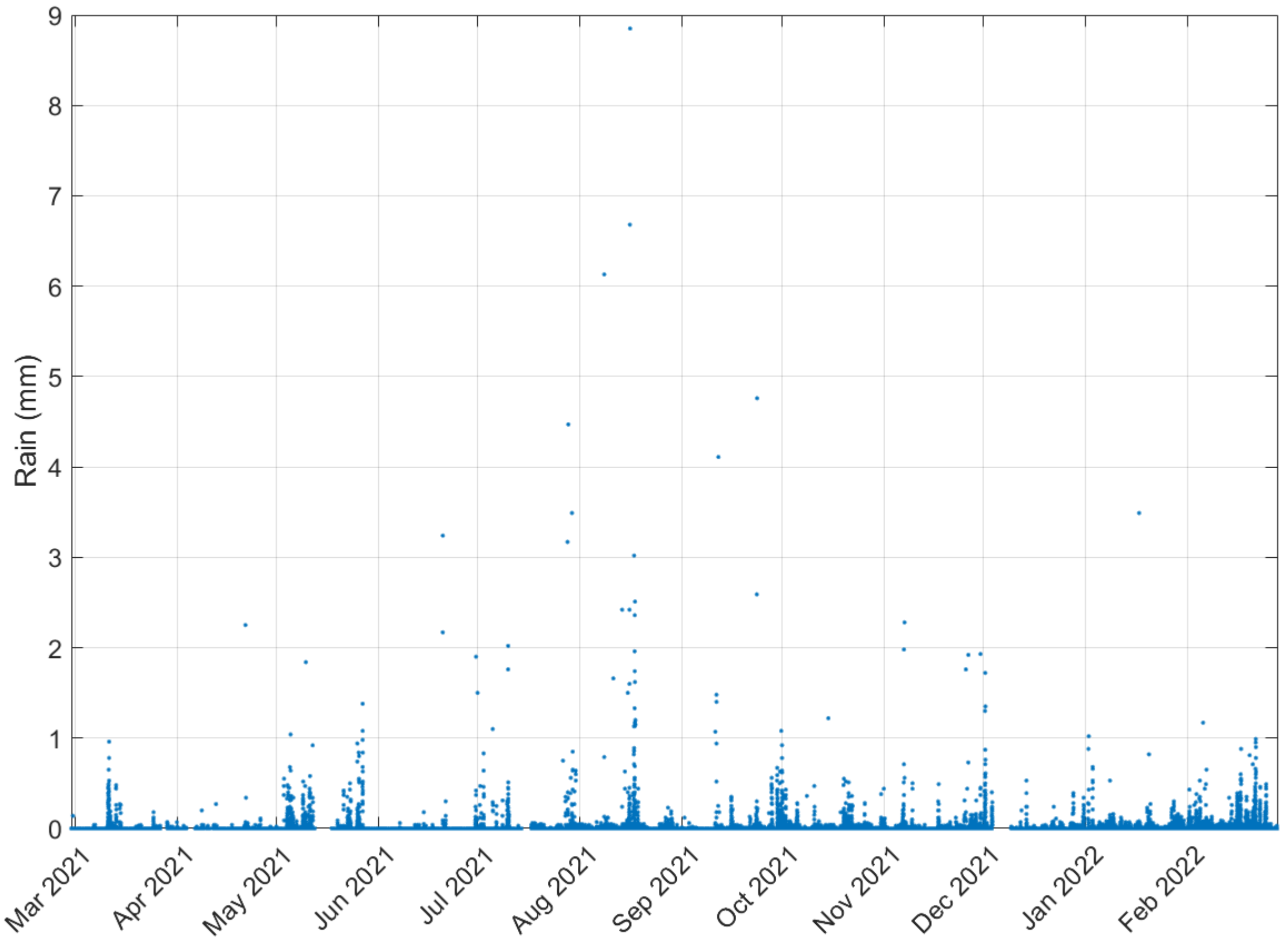

Figure 145. Rain time series.

5.2.2. Wind roses

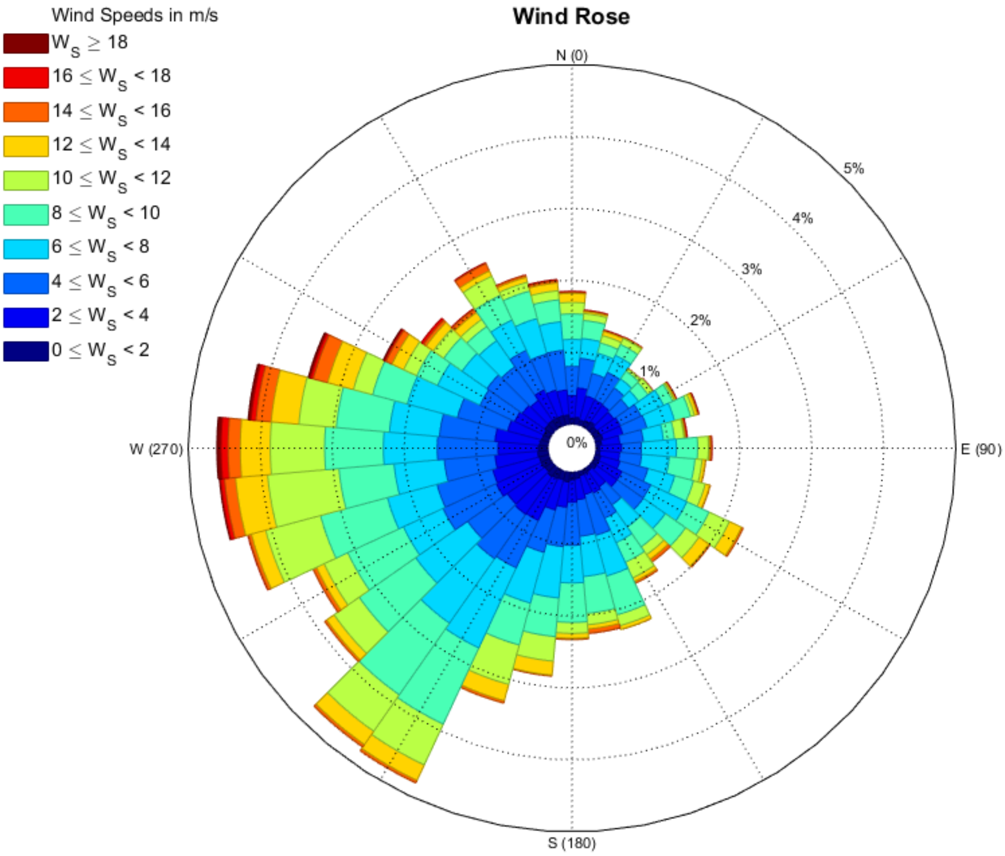

Figure 146. Wind rose at surface.

5.2.3. Statistics

METEO					
Month Feb 2021 - Feb 2022	Variables				
	Wind speed (m/s)	Air temperature (ºC)	Atm pressure (hPa)	Rain (mm)	Air humidity (%)
Mean	7.05	10.31	1012.67	0.01	82.84
Max	22.52	23.75	1038.76	8.85	100.00
Min	0.14	-3.20	961.08	0.00	44.52
Std	3.34	5.87	10.89	0.10	10.38

Table 27. Meteo statistics.

5.3. ADCP

As described in section 2.3.2, the ADCP measurement depths are different in the following time periods:

- Period 1: 28/02/2021 – 14/07/2021
- Period 2: 14/07/2021 – 28/02/2022.

Therefore, some of the following plots will be split in two periods.

5.3.1. Distributions

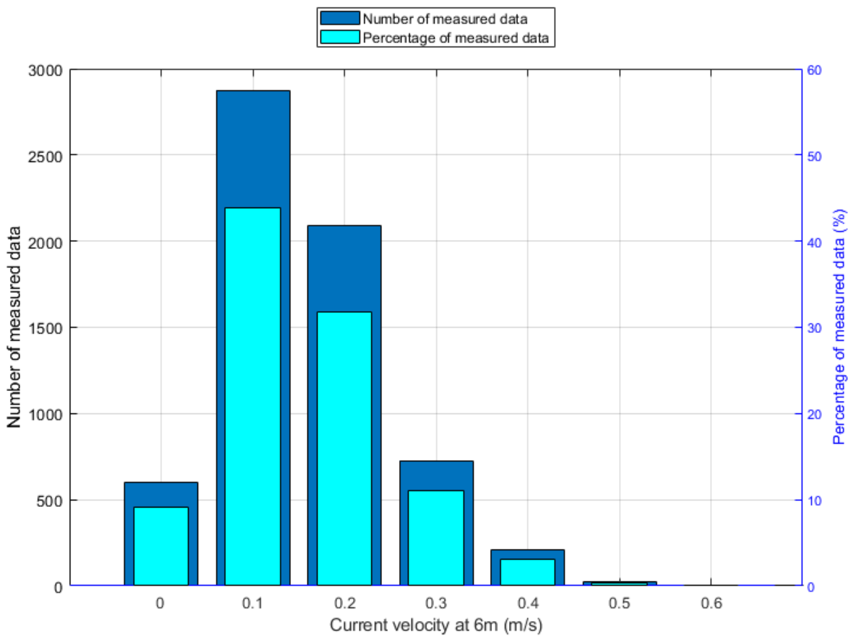

Figure 147. Current speed distribution at surface (28/02/2021 – 14/07/2021).

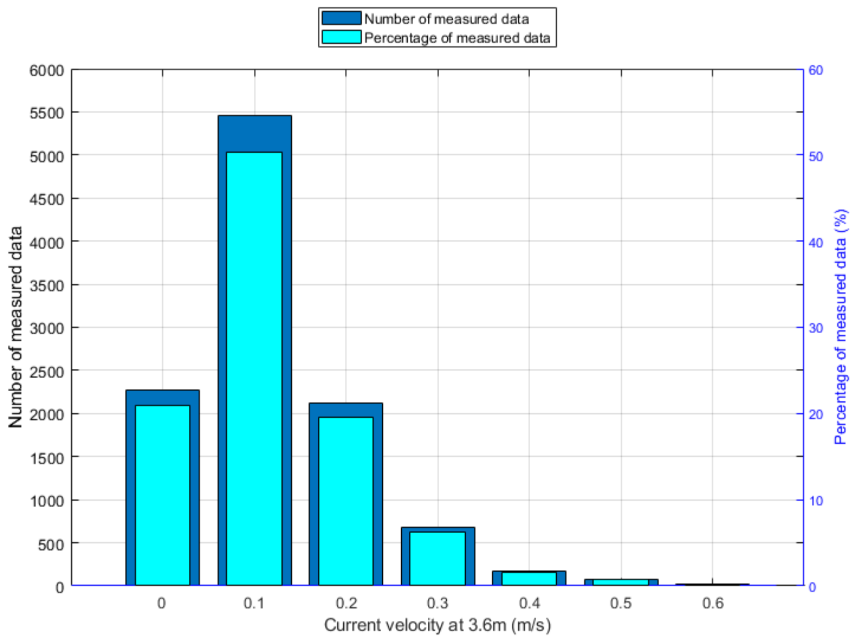

Figure 148. Current speed distribution at surface (14/07/2021 – 28/02/2022).

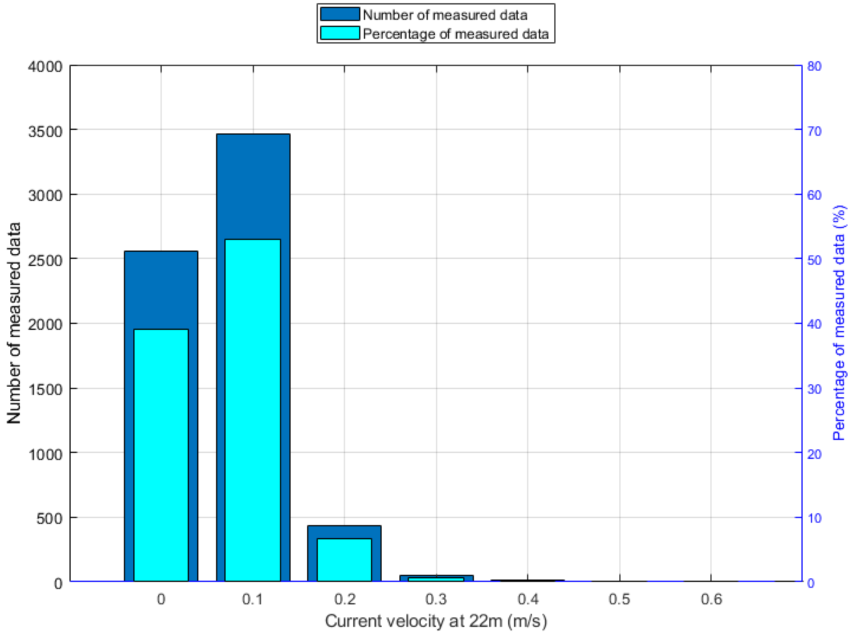

Figure 149. Current speed distribution at mid-column (28/02/2021 – 14/07/2021).

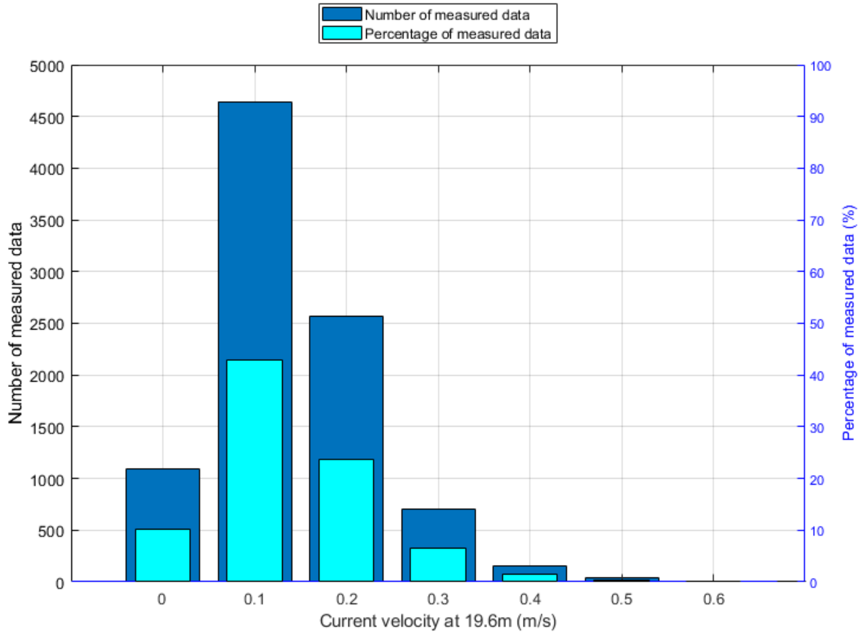

Figure 150. Current speed distribution at mid-column (14/07/2021 – 28/02/2022).

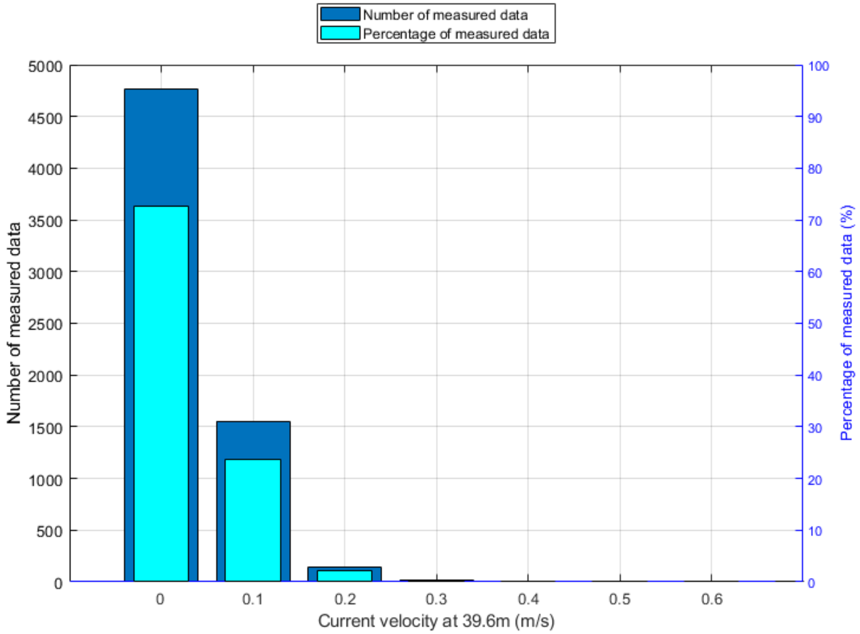

Figure 151. Current speed distribution near seabed (28/02/2021 – 14/07/2021).

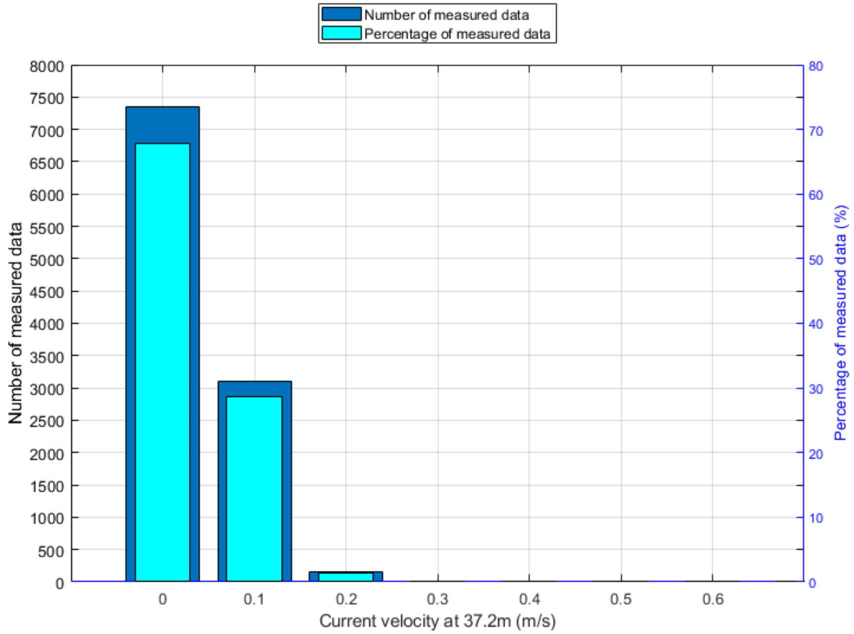

Figure 152. Current speed distribution near seabed (14/07/2021 – 28/02/2022).

5.3.2. Time series

Figure 153. Surface water temperature time series.

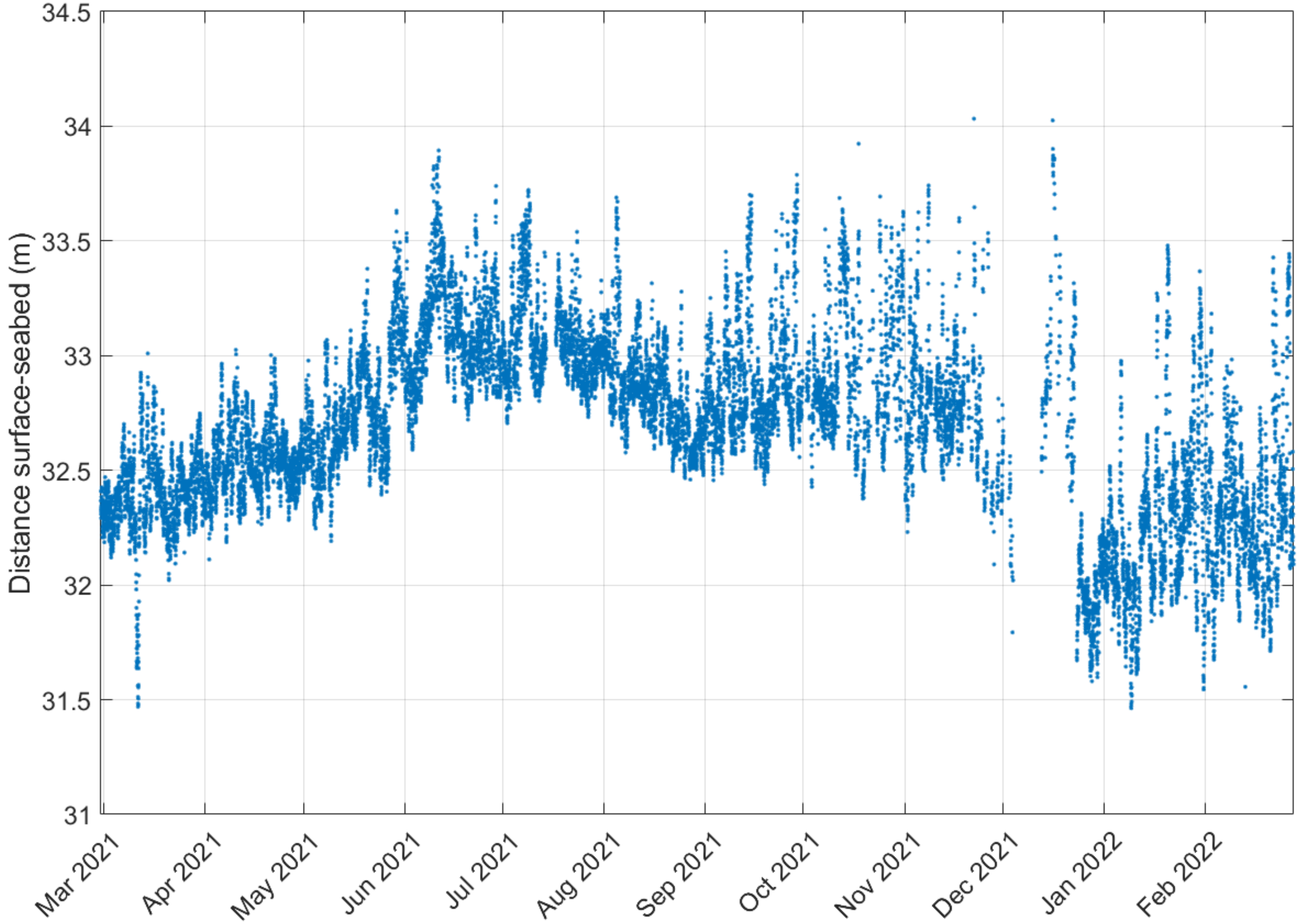

Figure 154. Distance surface - seabed time series.

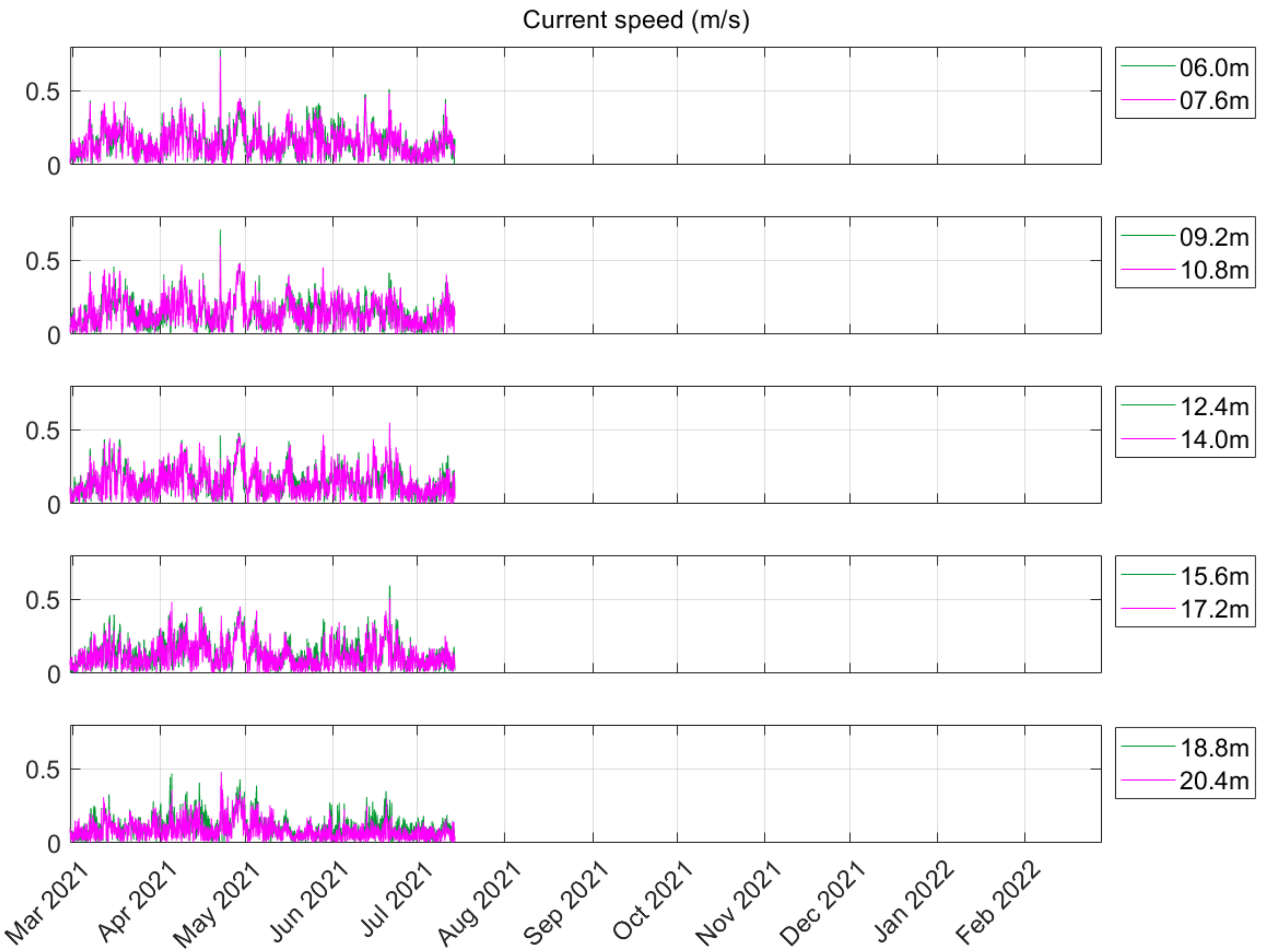

Figure 155. Current speed for depths from 6 to 20.4 m (28/02/2021 – 14/07/2021).

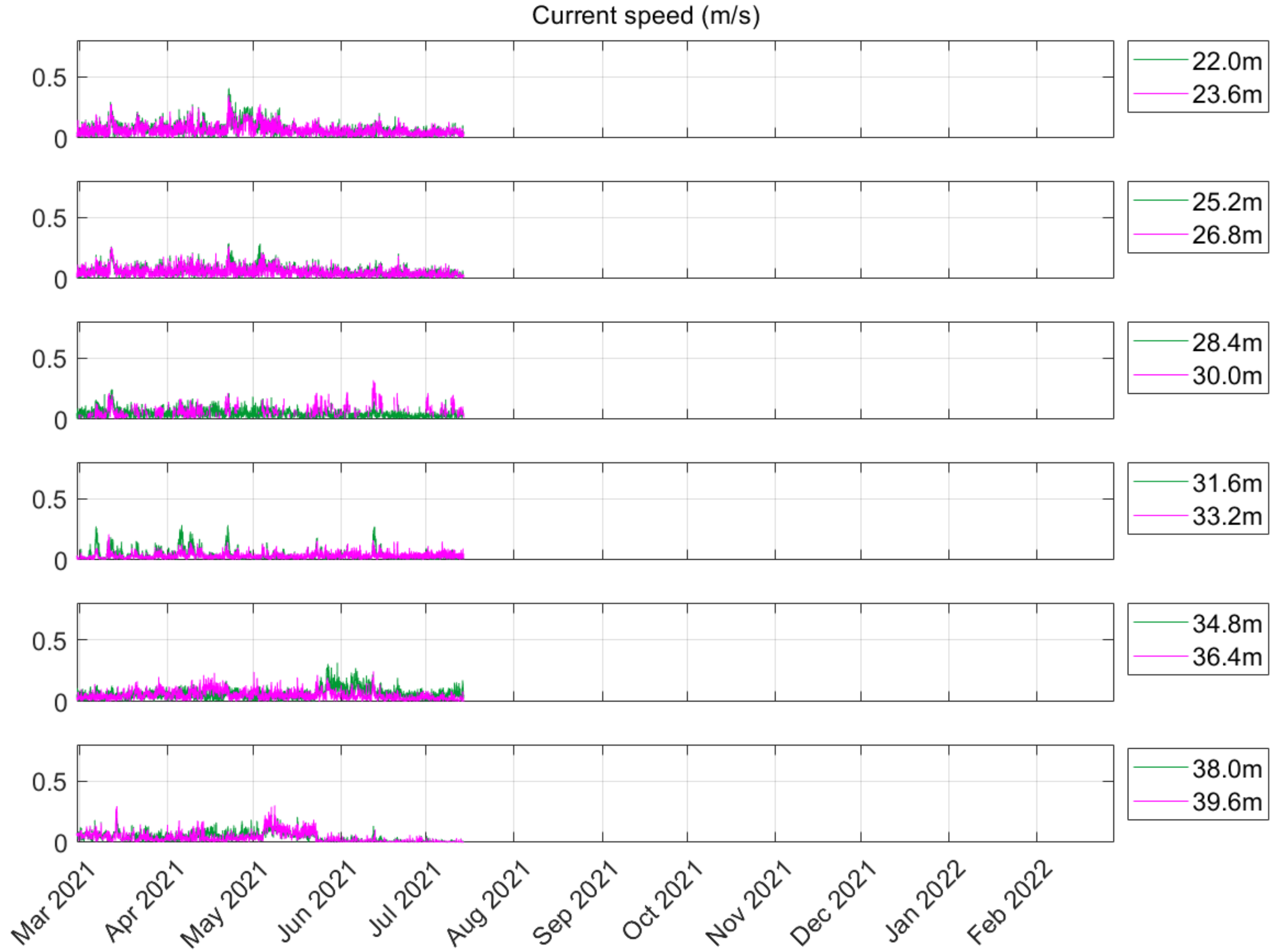

Figure 156. Current speed for depths from 22 to 39.6 m (28/02/2021 – 14/07/2021).

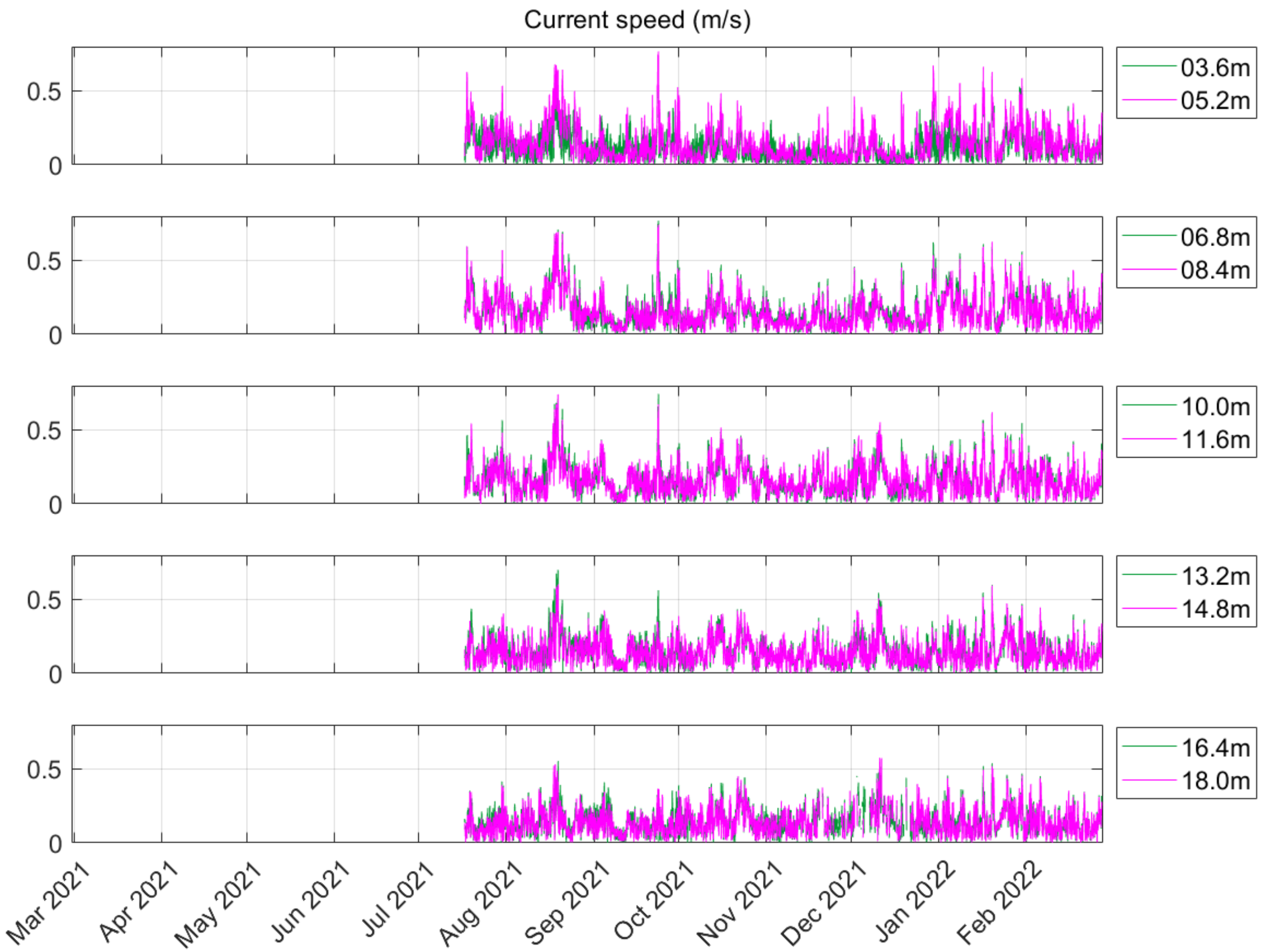

Figure 157. Current speed for depths from 3.6 to 18 m (14/07/2021 – 28/02/2022).

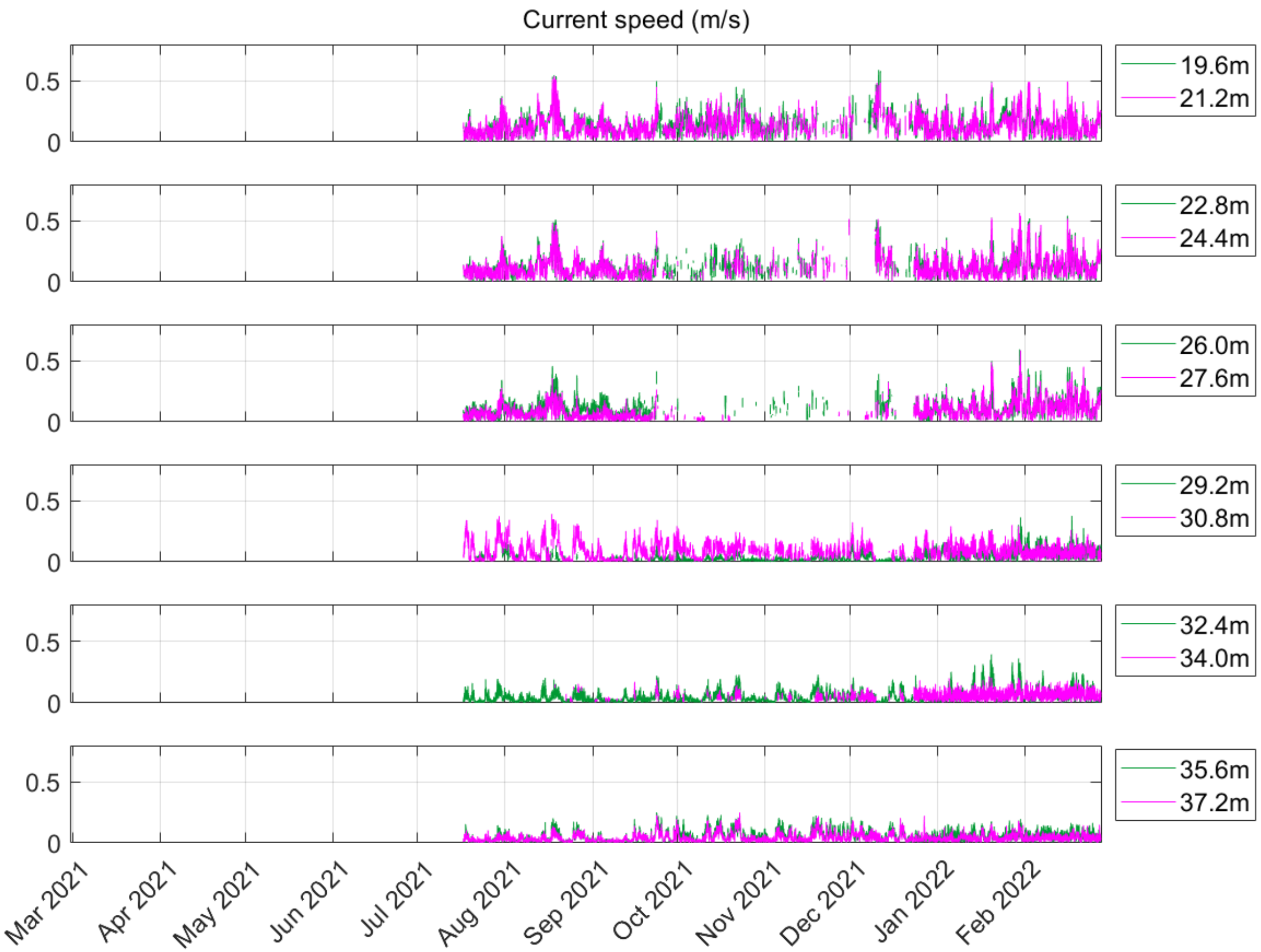

Figure 158. Current speed for depths from 19.6 to 37.2 m (14/07/2021 – 28/02/2022).

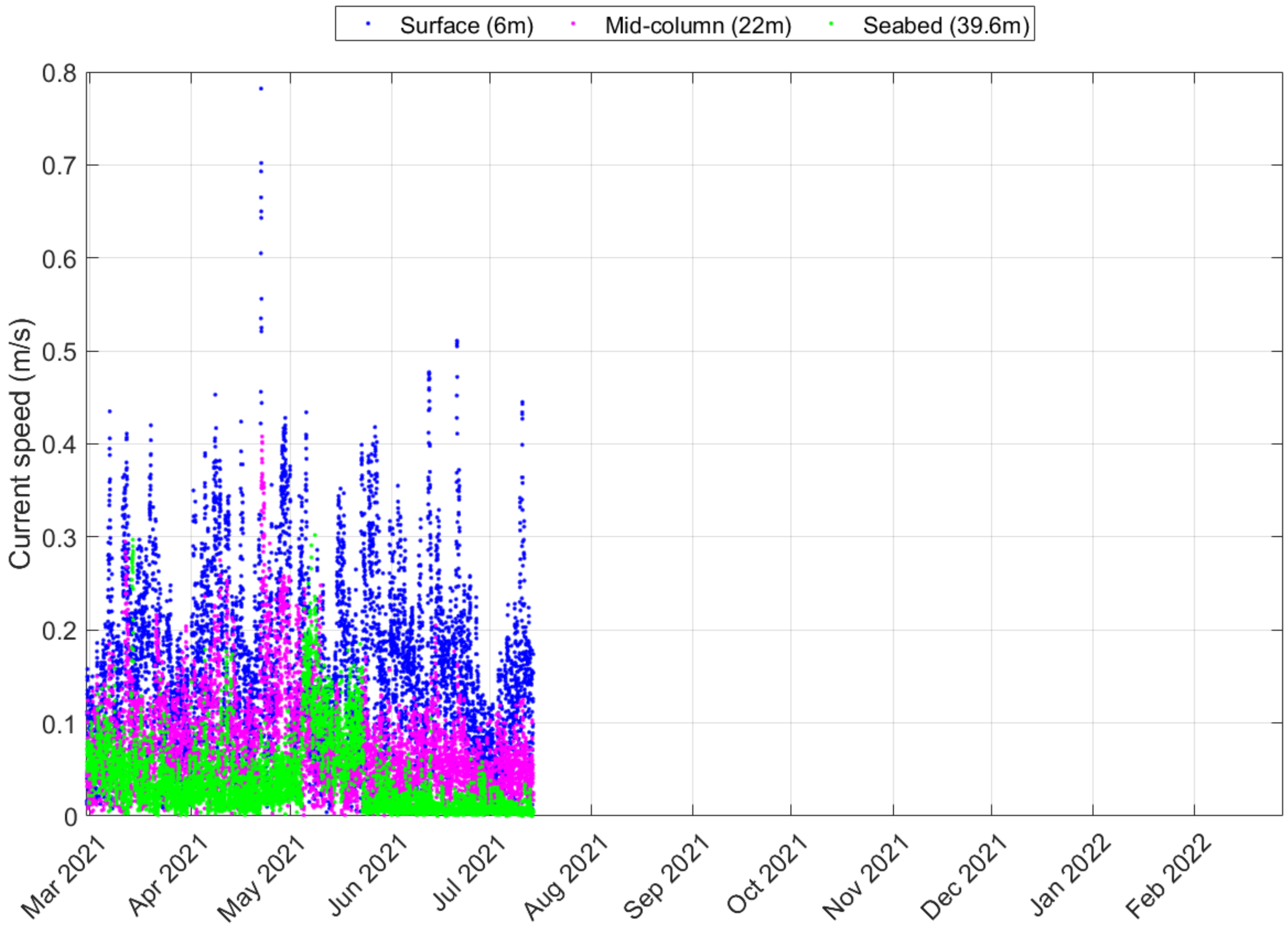

Figure 159. Time series of current speed at surface, mid-column, and near seabed (28/02/2021 – 14/07/2021).

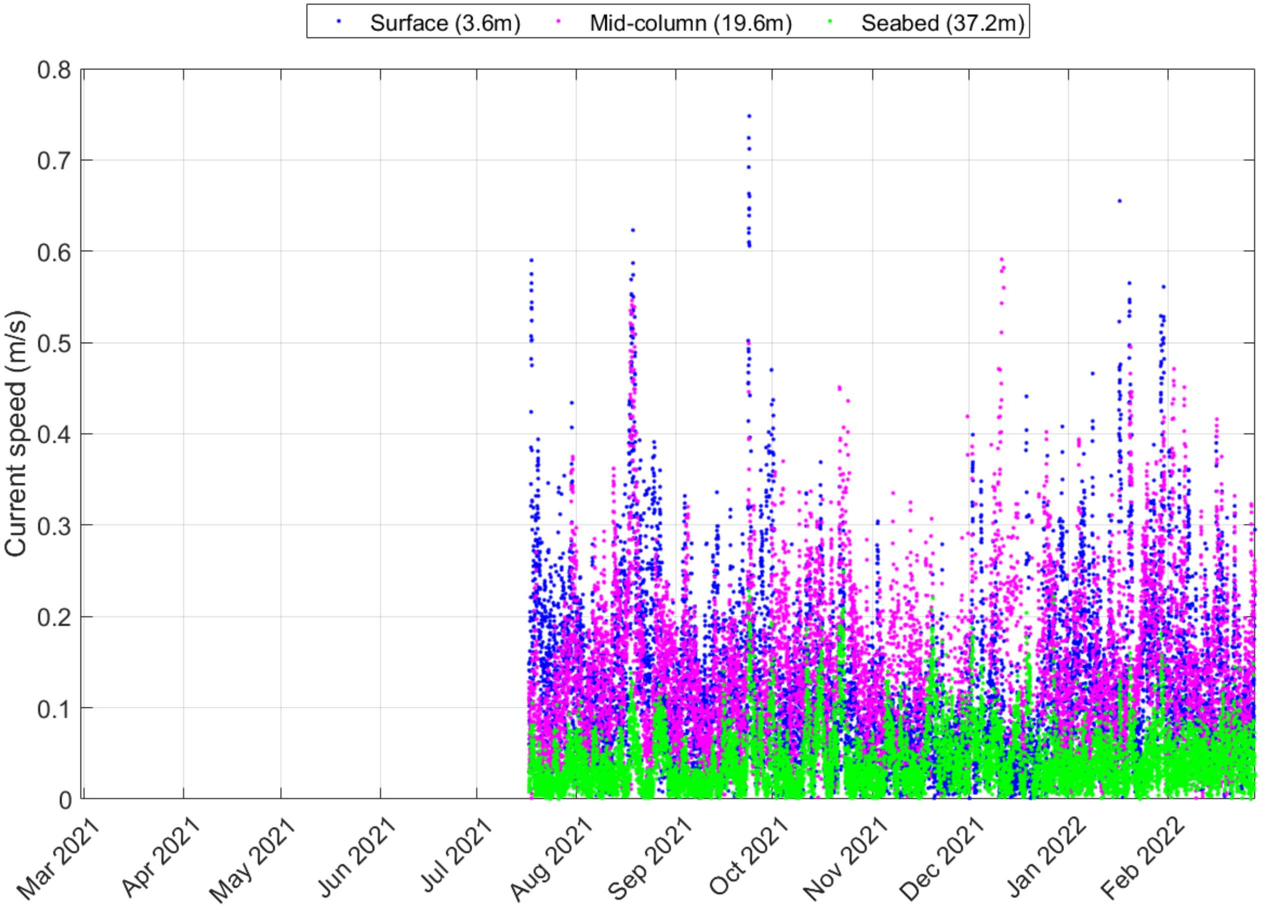

Figure 160. Time series of current speed at surface, mid-column, and near seabed (14/07/2021 – 28/02/2022).

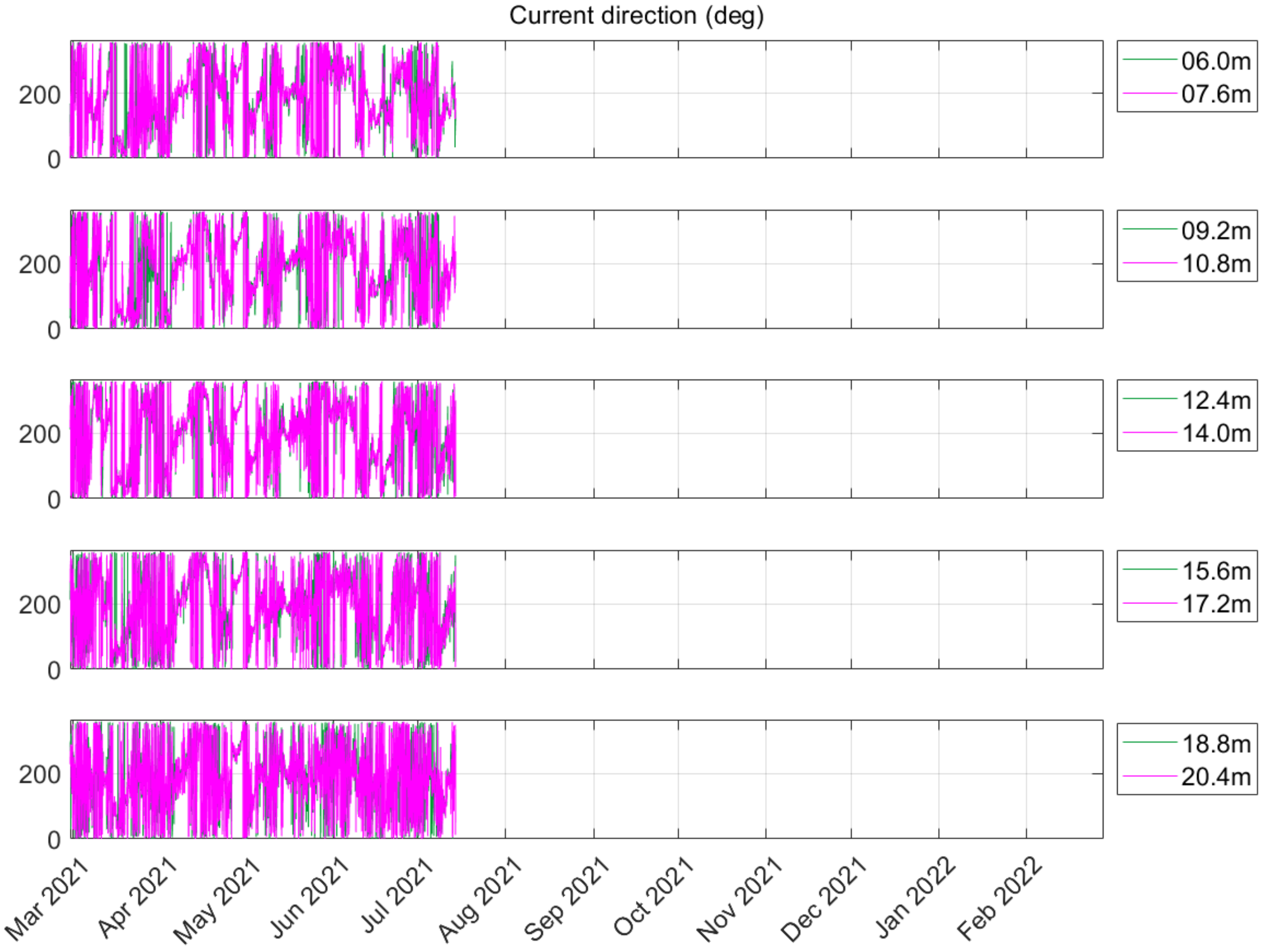

Figure 161. Current direction for depths from 6 to 20.4 m (28/02/2021 – 14/07/2021).

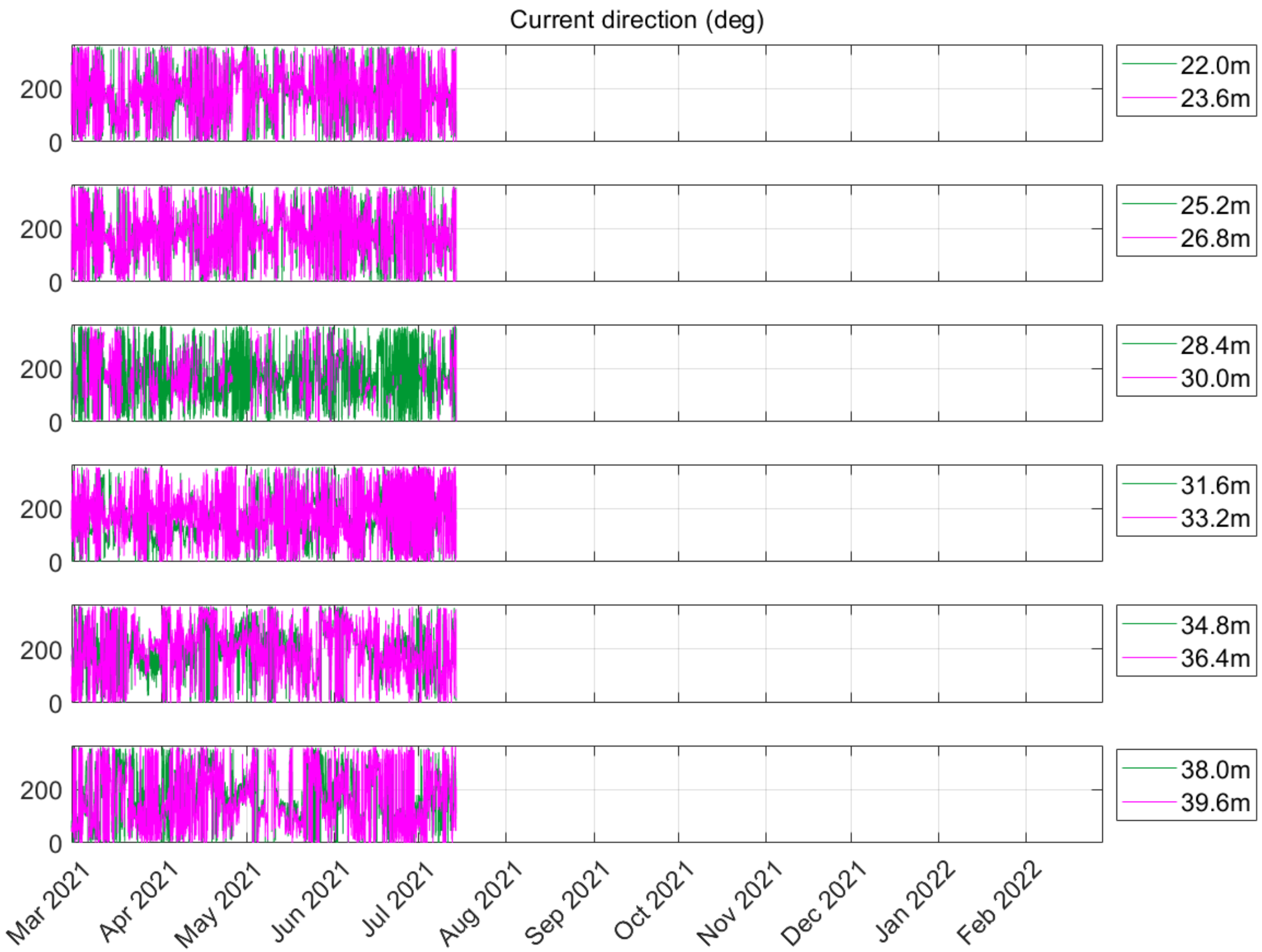

Figure 162. Current direction for depths from 22 to 39.6 m (28/02/2021 – 14/07/2021).

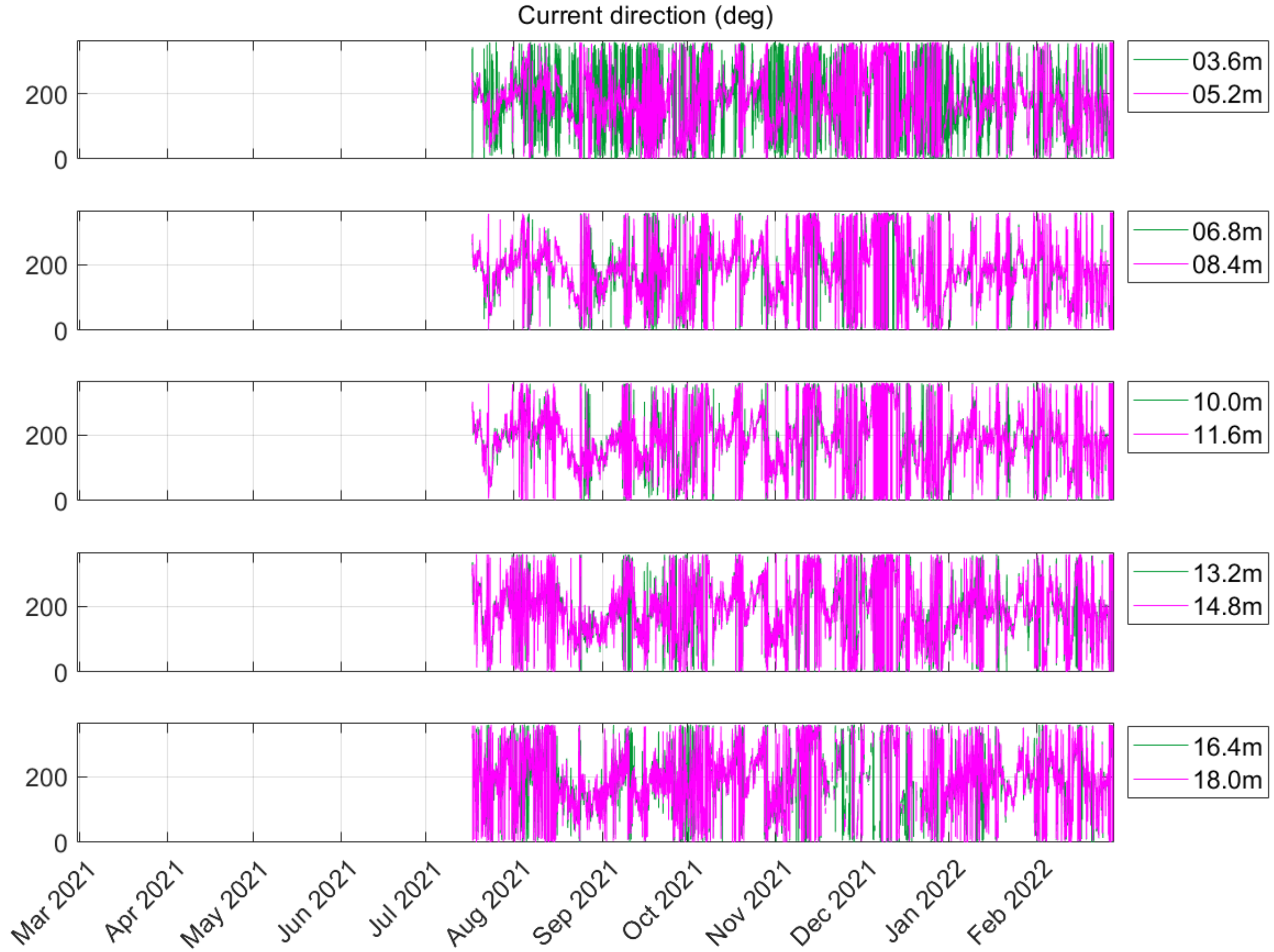

Figure 163. Current directions for depths from 3.6 to 18 m (14/07/2021 – 28/02/2022).

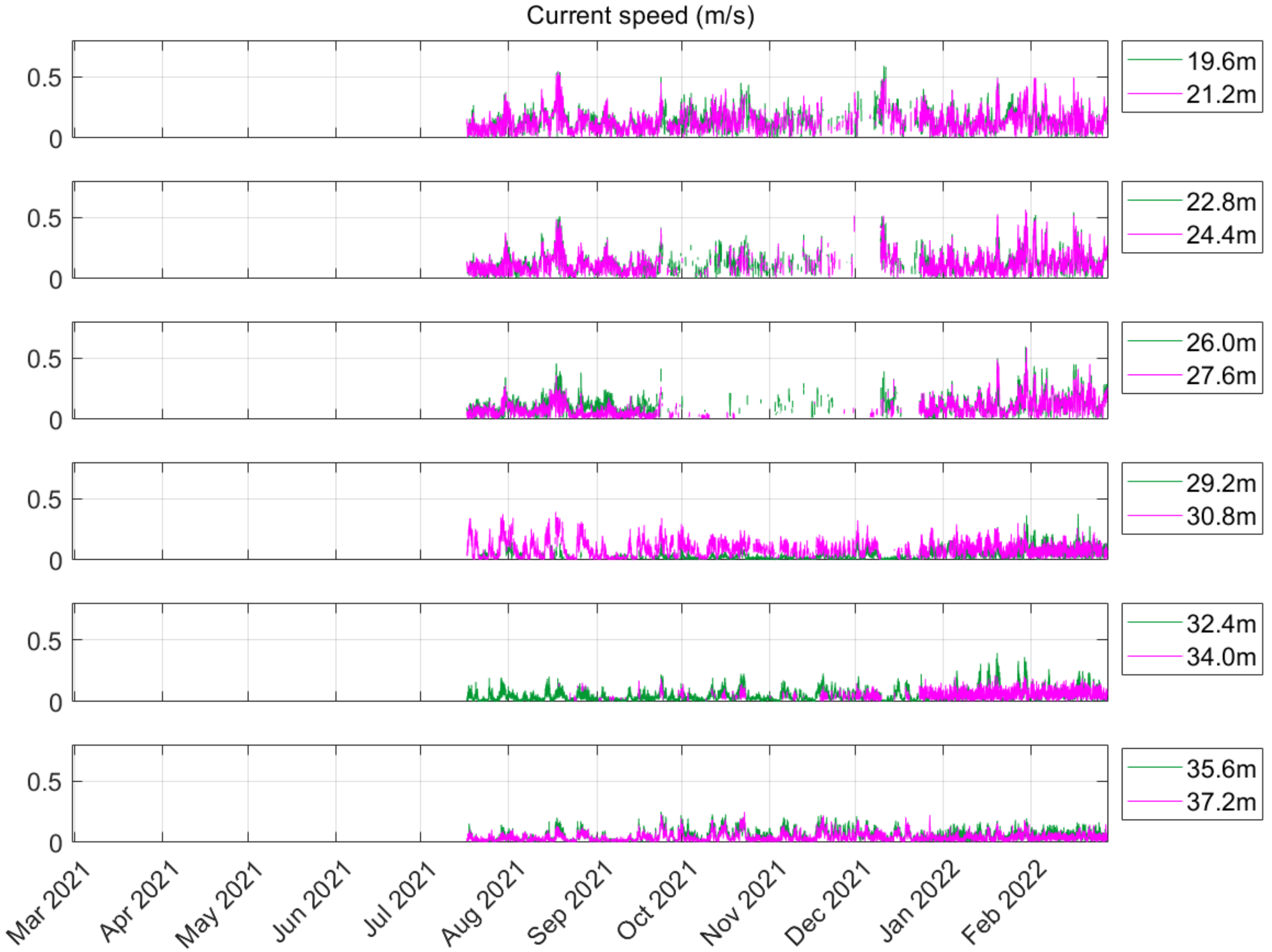

Figure 164. Current directions for depths from 19.6 to 37.2 m (14/07/2021 – 28/02/2022).

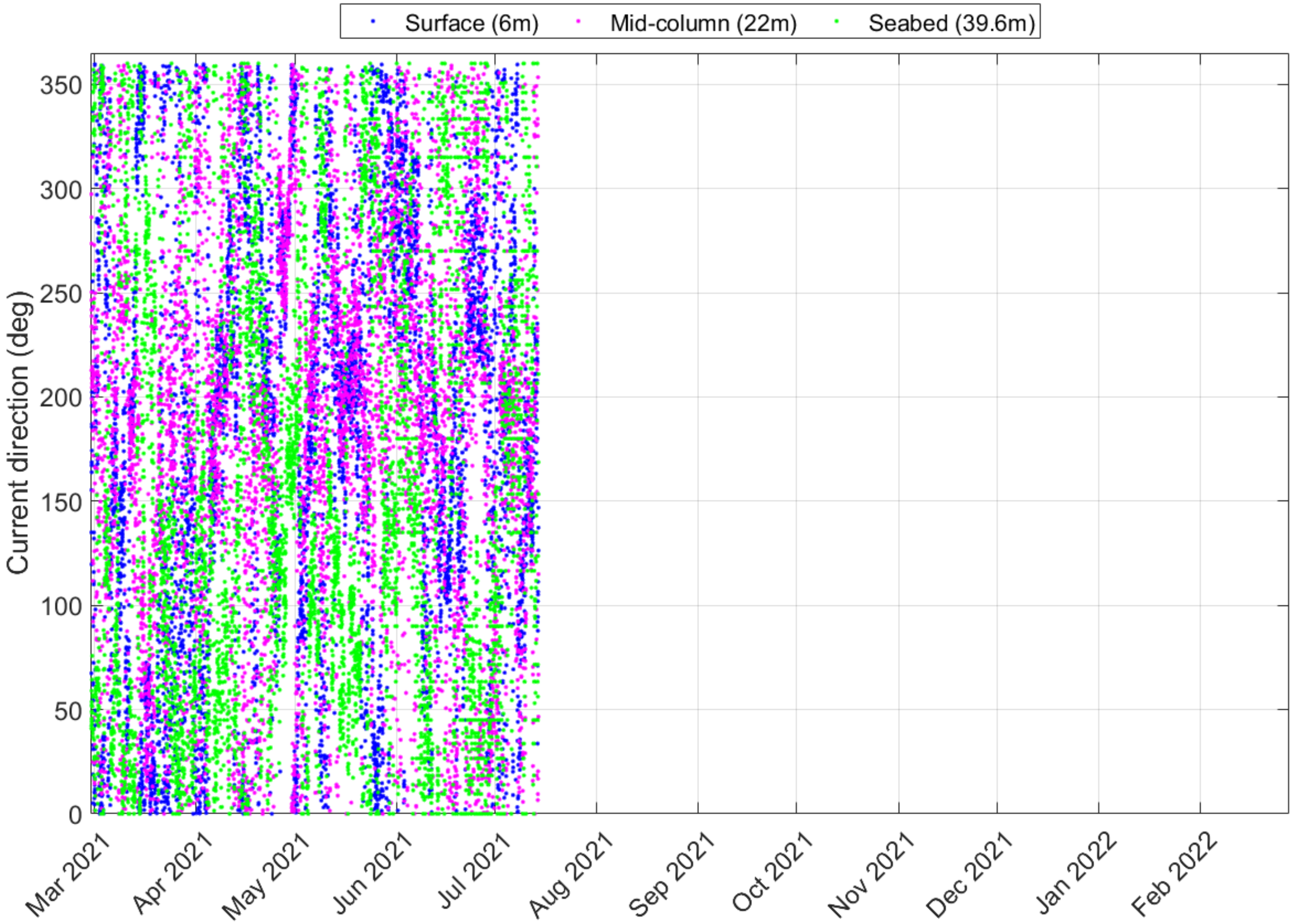

Figure 165. Time series of current direction at surface, mid-column, and near seabed (28/02/2021 – 14/07/2021).

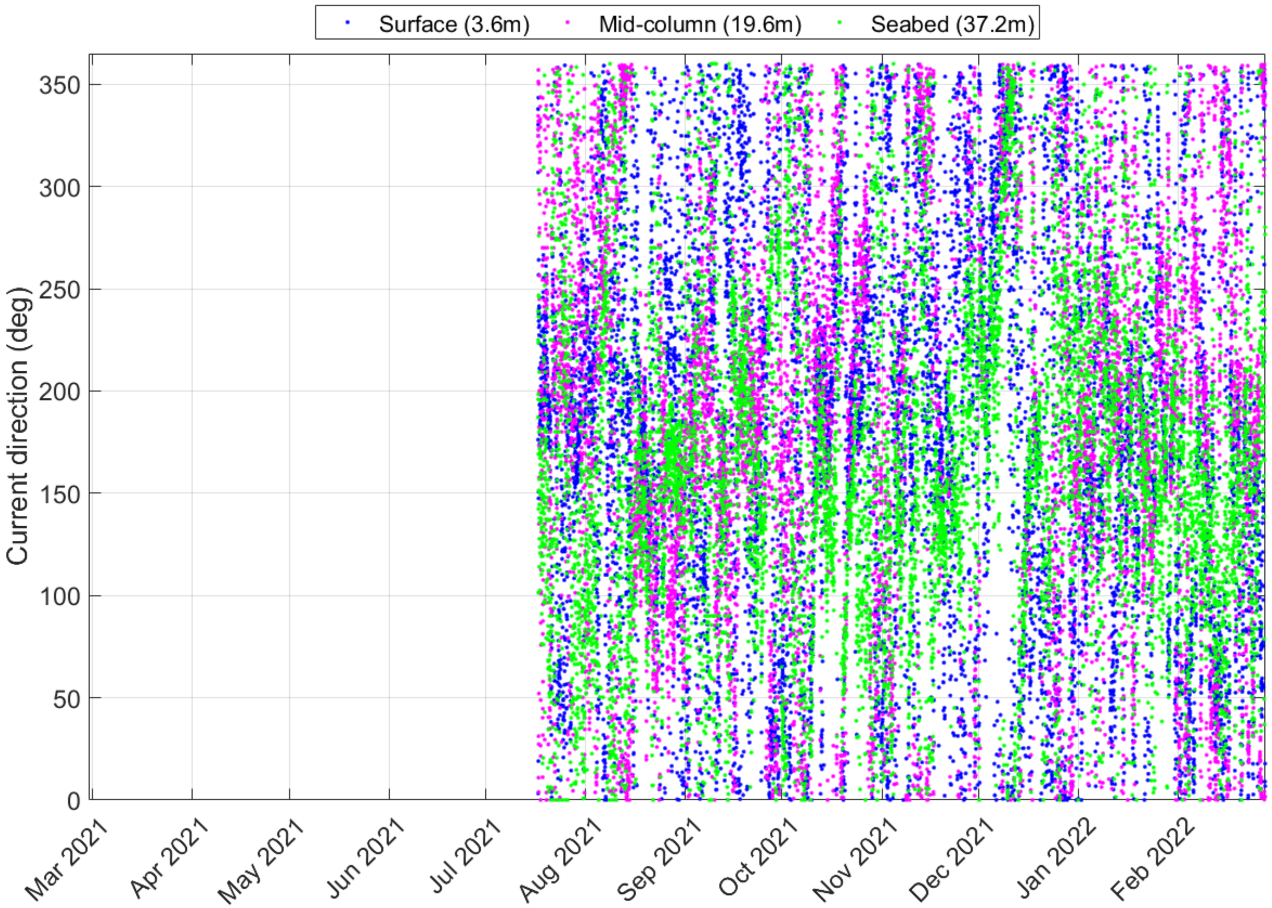

Figure 166. Time series of current direction at surface, mid-column, and near seabed (14/07/2021 – 28/02/2022).

5.3.3. Profiles

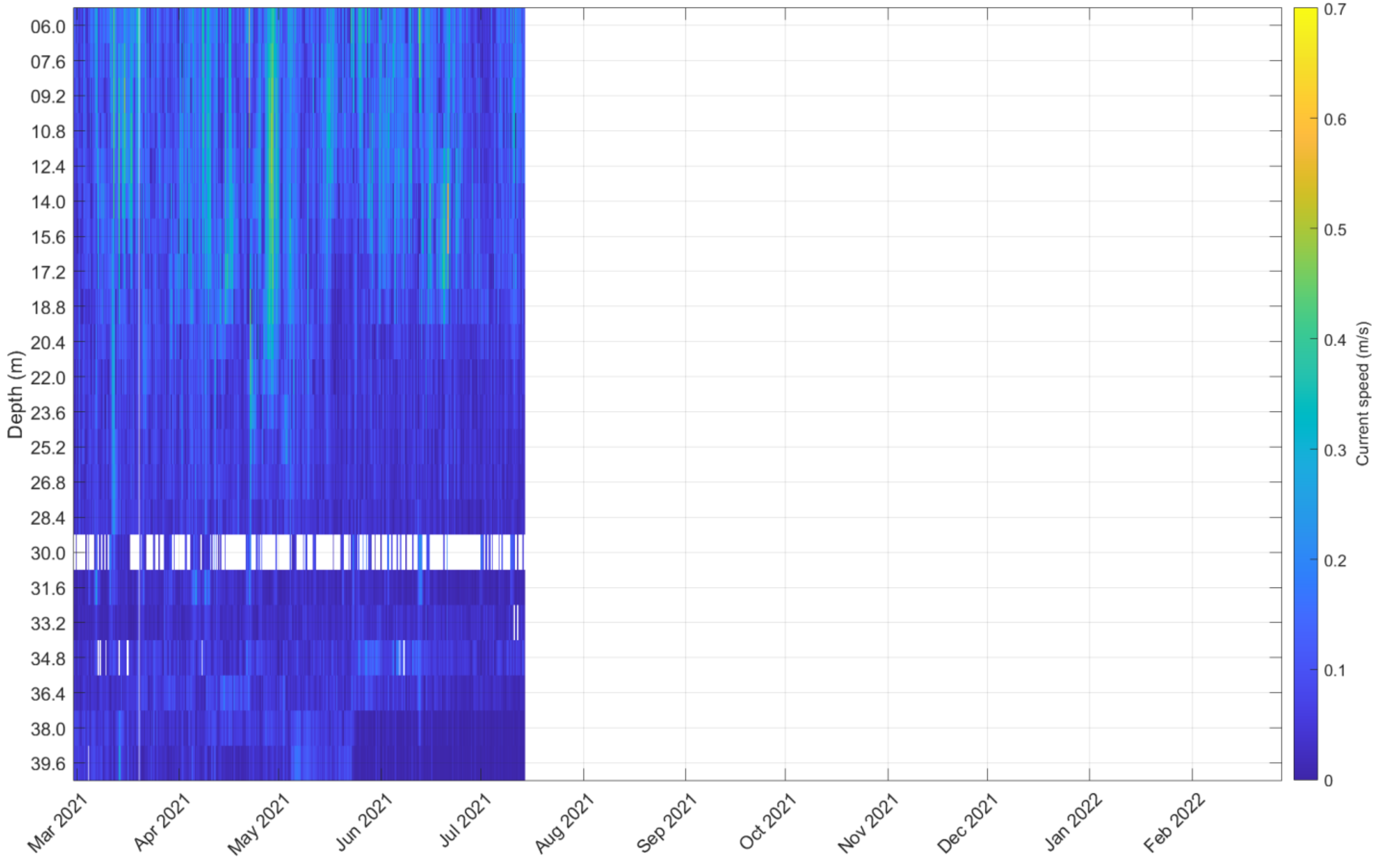

Figure 167. Current speed heat map (28/02/2021 – 14/07/2021).

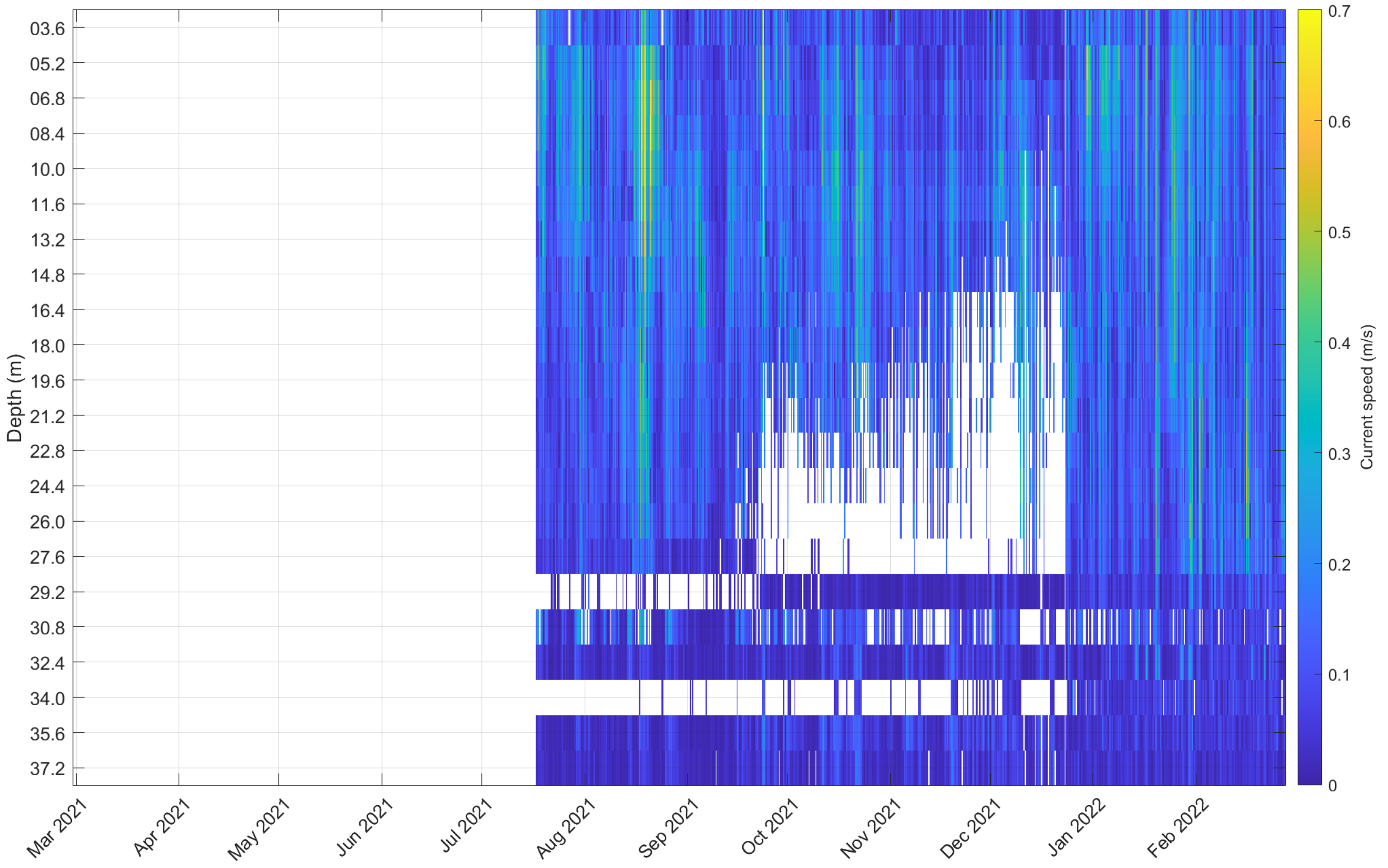

Figure 168. Current speed heat map (14/07/2021 – 28/02/2022).

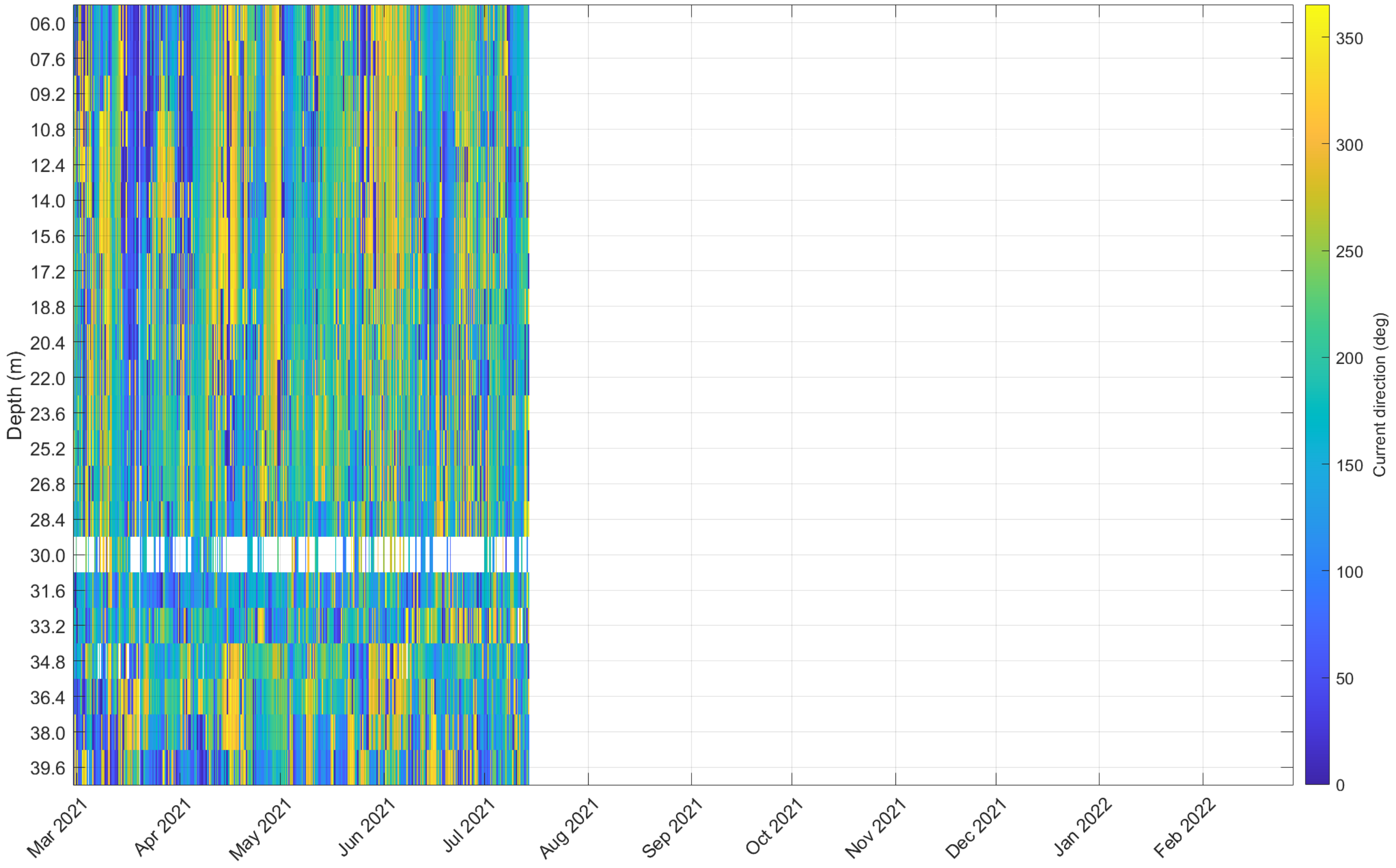

Figure 169. Current direction heat map (28/02/2021 – 14/07/2021).

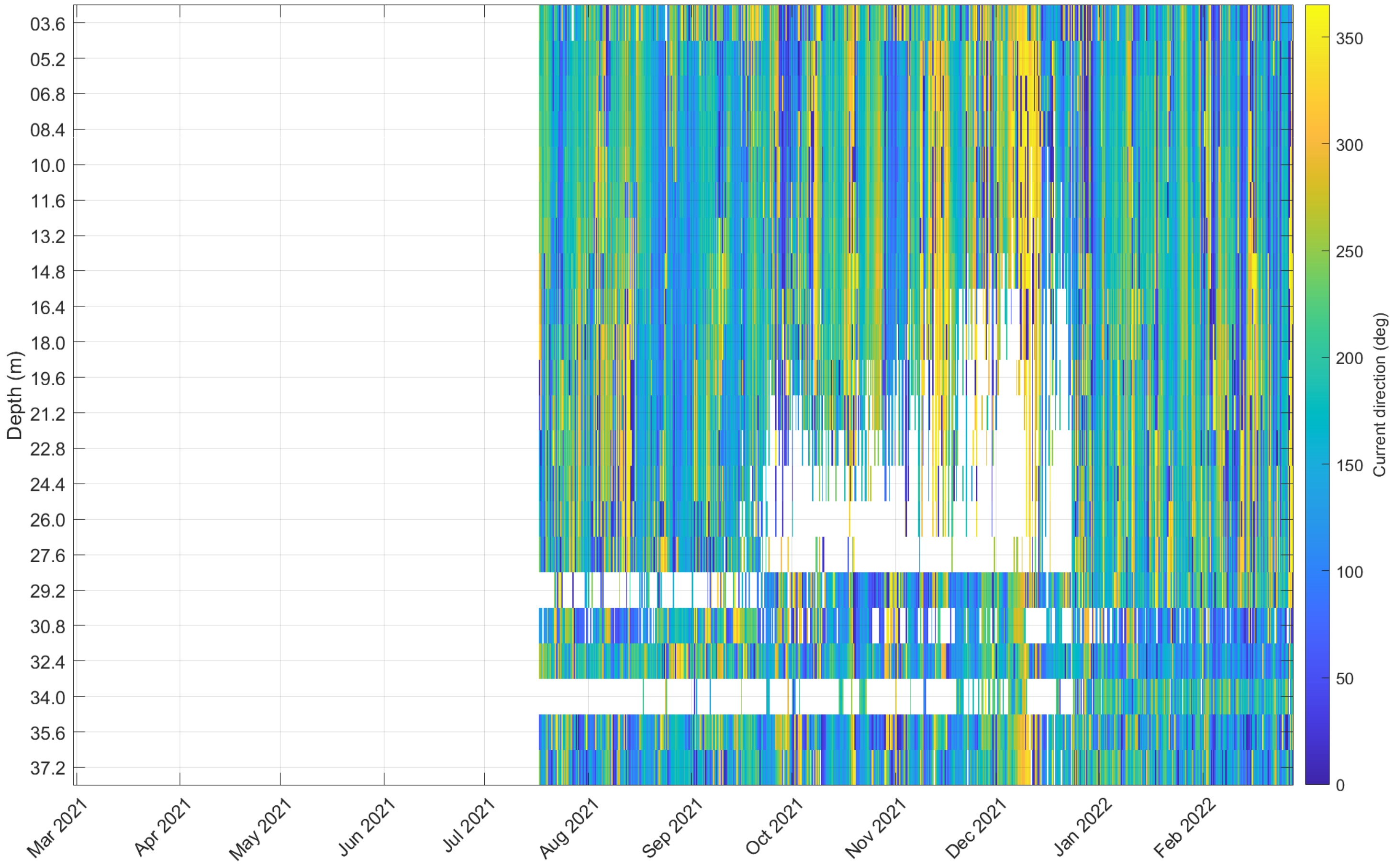

Figure 170. Current direction heat map (14/07/2021 – 28/02/2022).

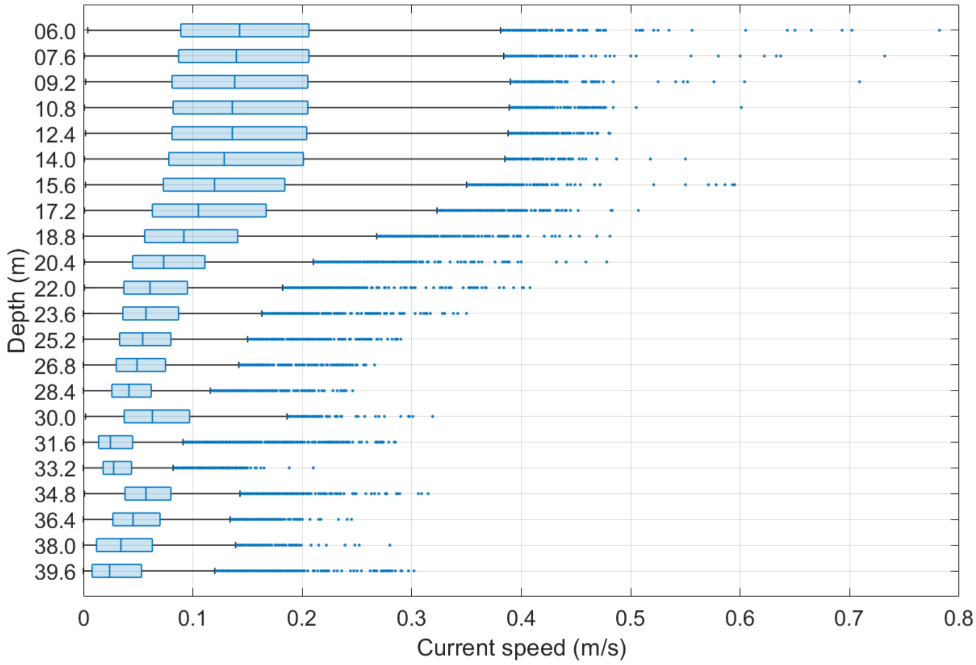

Figure 171. Current speed box chart (28/02/2021 – 14/07/2021).

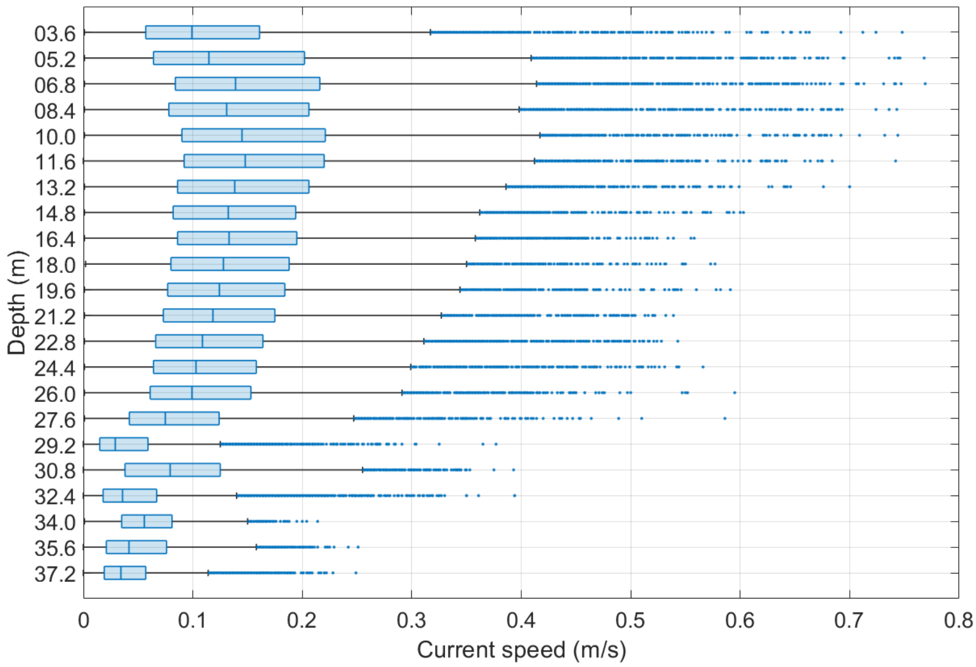

Figure 172. Current speed box chart (14/07/2021 – 28/02/2022).

Each box shows the values of the median (middle line) and the 25th and 75th quartiles (left and right delimiters respectively). The whiskers extend to the minimum and maximum values that are not outliers. Outliers are values that are more than 1.5 · interquartile range (IQR) away from the left or right of the box. Any outliers are plotted as individual points.

5.3.4. Wind roses

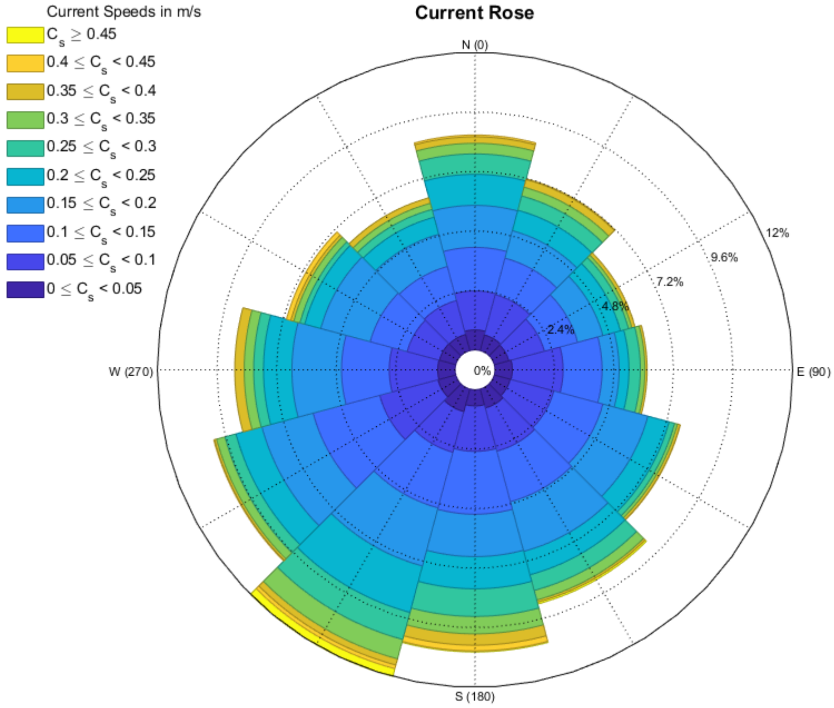

Figure 173. Current rose at surface (28/02/2021 – 14/07/2021).

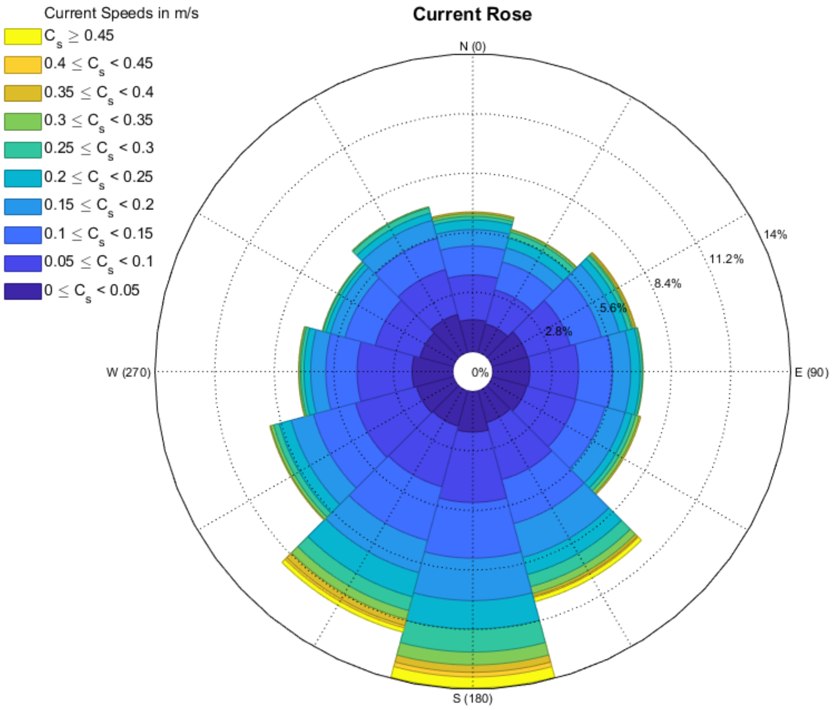

Figure 174. Current rose at surface (14/07/2021 – 28/02/2022).

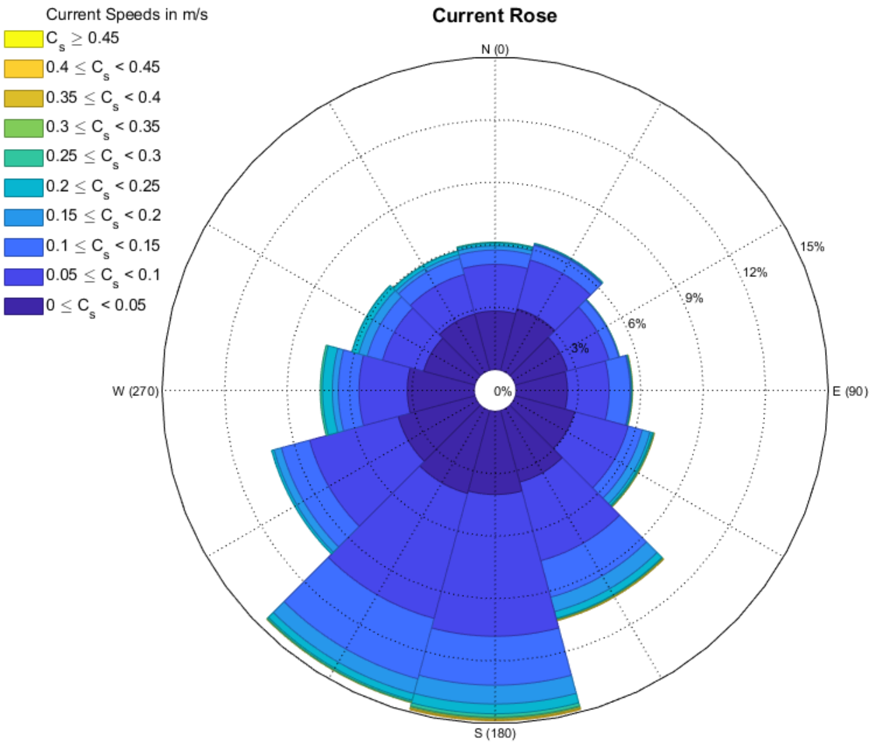

Figure 175. Current rose at mid-column (28/02/2021 – 14/07/2021).

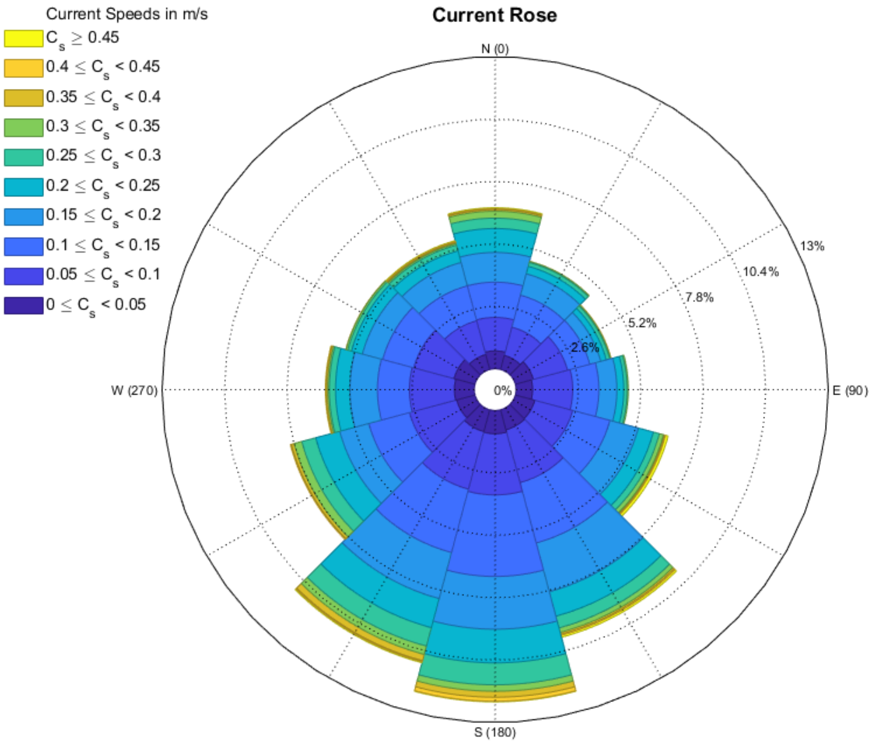

Figure 176. Current rose at mid-column (14/07/2021 – 28/02/2022).

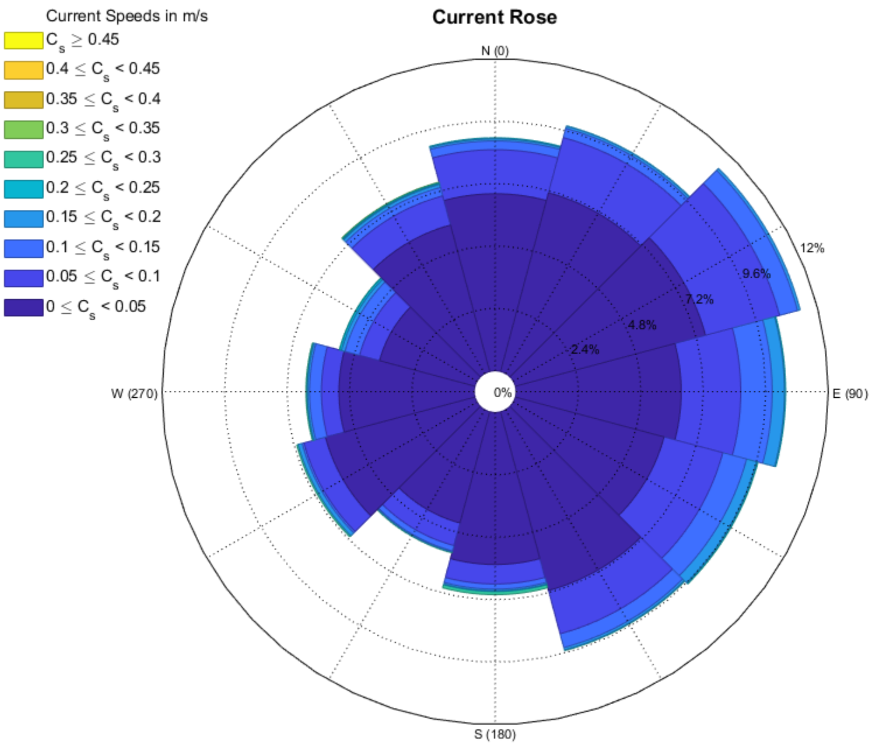

Figure 177. Current rose near seabed (28/02/2021 – 14/07/2021).

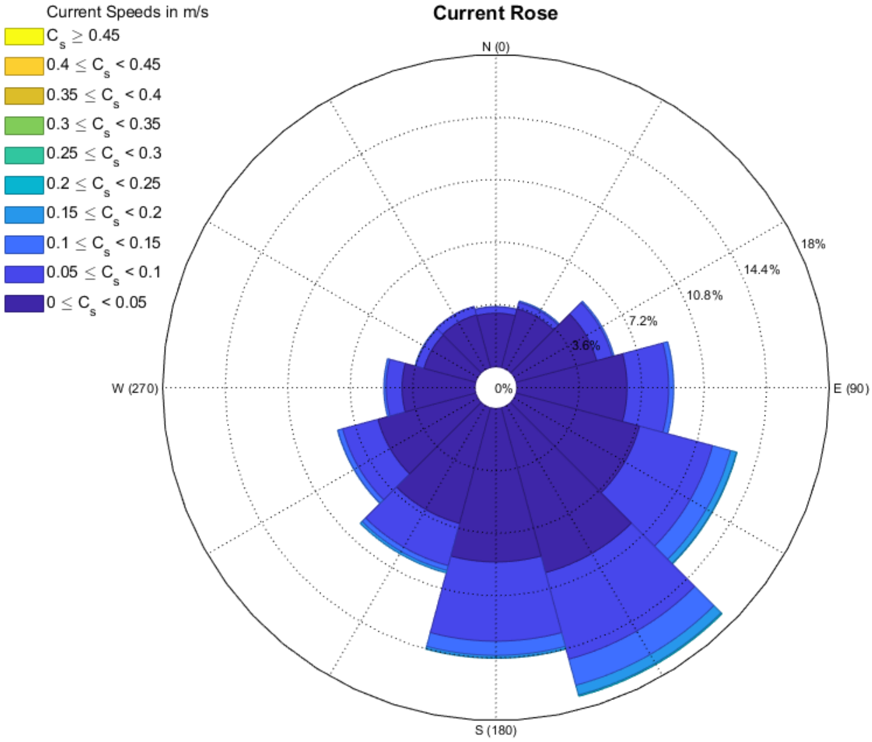

Figure 178. Current rose near seabed (14/07/2021 – 28/02/2022).

5.3.5. Statistics

ADCP		
Month Feb 2021 - Feb 2022	Variables	
	Sea surface temperature (ºC)	Distance seabed-surface (m)
Mean	10.80	32.69
Max	23.04	34.03
Min	1.92	31.46
Std	5.99	0.40

Table 28. ADCP temperature and altimeter statistics.

ADCP			
Month Feb 2021 - Jul 2021	Variables		
	Current speed at 6m (m/s)	Current speed at 22m (m/s)	Current speed at 39.6m (m/s)
Mean	0.16	0.07	0.04
Max	0.78	0.41	0.30
Min	0.00	0.00	0.00
Std	0.09	0.05	0.04

Table 29. ADCP current speed statistics (Feb 2021 - Jul 2021).

ADCP			
Month Jul 2021 - Feb 2022	Variables		
	Current speed at 3.6m (m/s)	Current speed at 19.6m (m/s)	Current speed at 37.2m (m/s)
Mean	0.12	0.14	0.04
Max	0.75	0.59	0.25
Min	0.00	0.00	0.00
Std	0.09	0.08	0.03

Table 30. ADCP current speed statistics (Jul 2021 - Feb 2022).

5.4. WAVE

5.4.1. Distributions

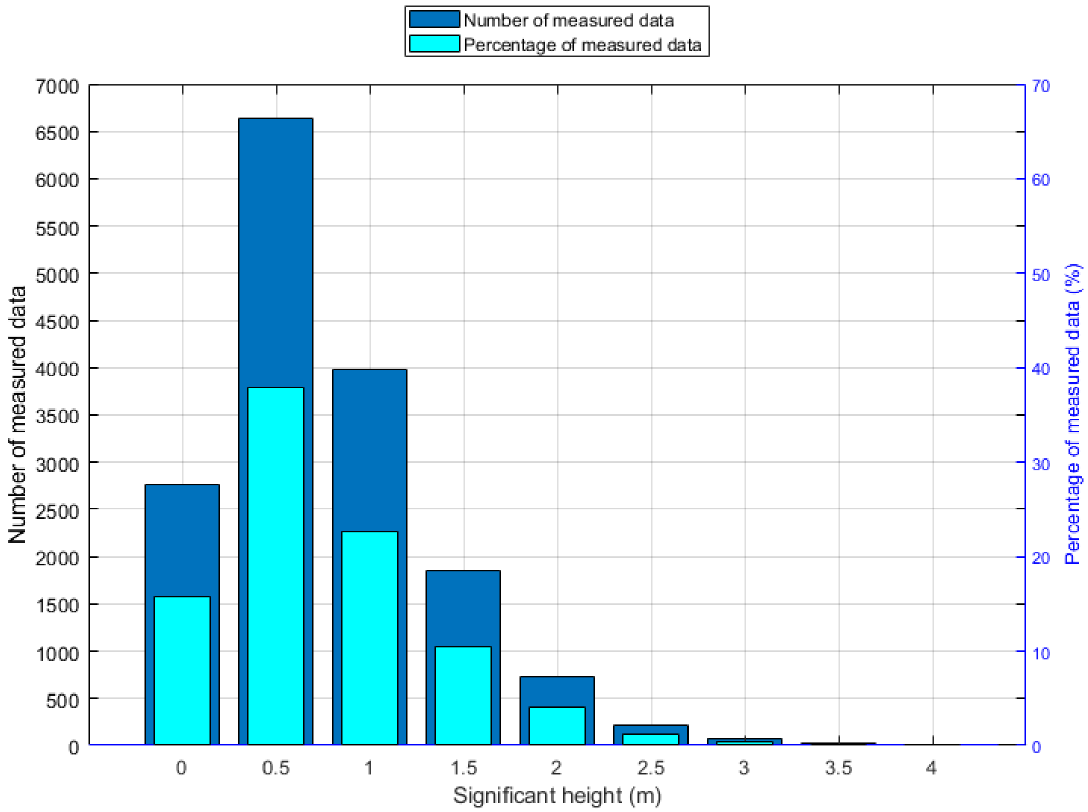

Figure 179. Significant wave height distribution.

5.4.2. Time series

Figure 180. Time series of wave heights. The panels from top to bottom present: average wave height, spectral significant wave height, significant wave height, average height of the highest 1/10th of all waves, and maximum wave height.

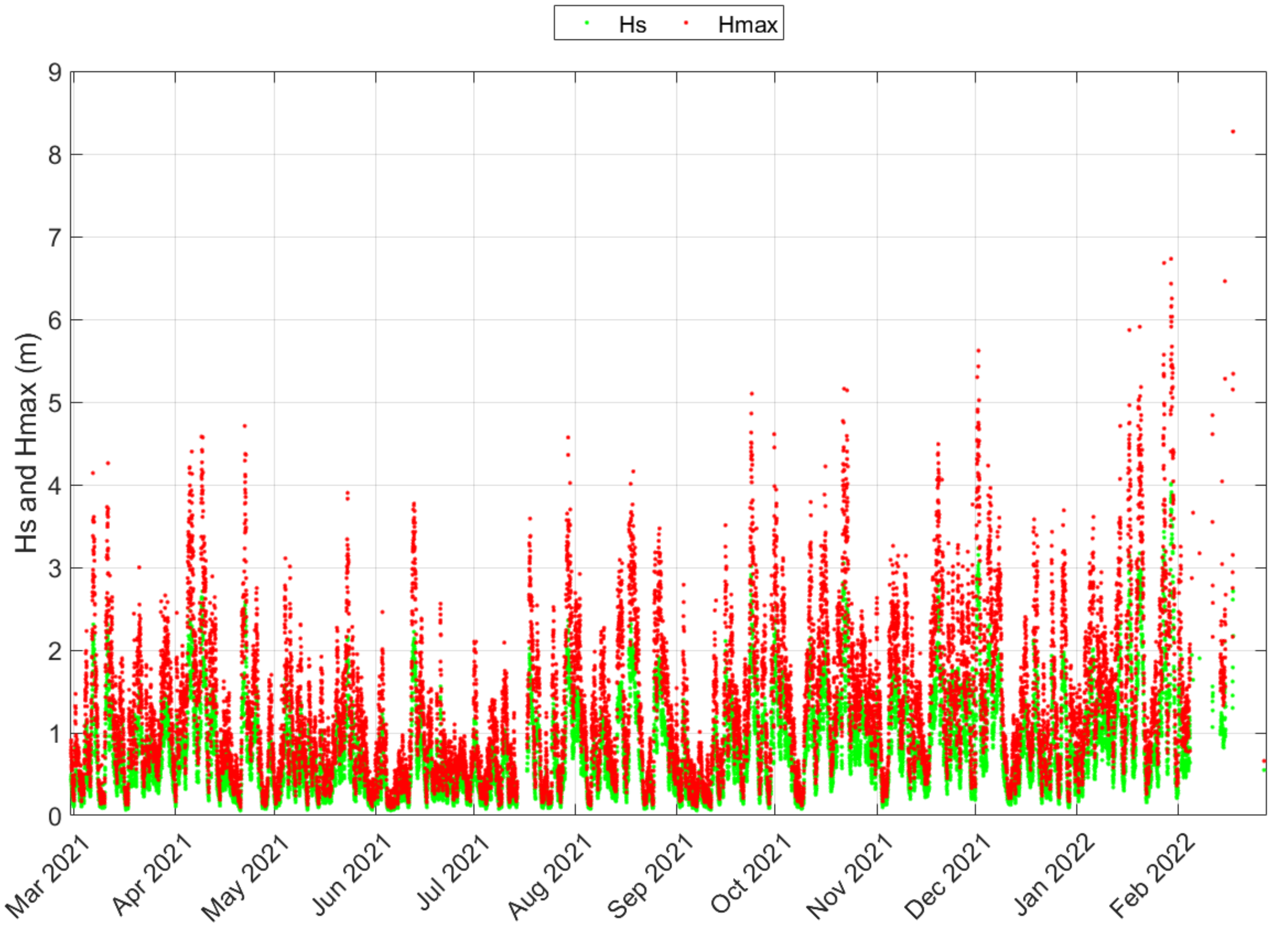

Figure 181. Time series of significant wave height (Hs) and maximum wave height (Hmax).

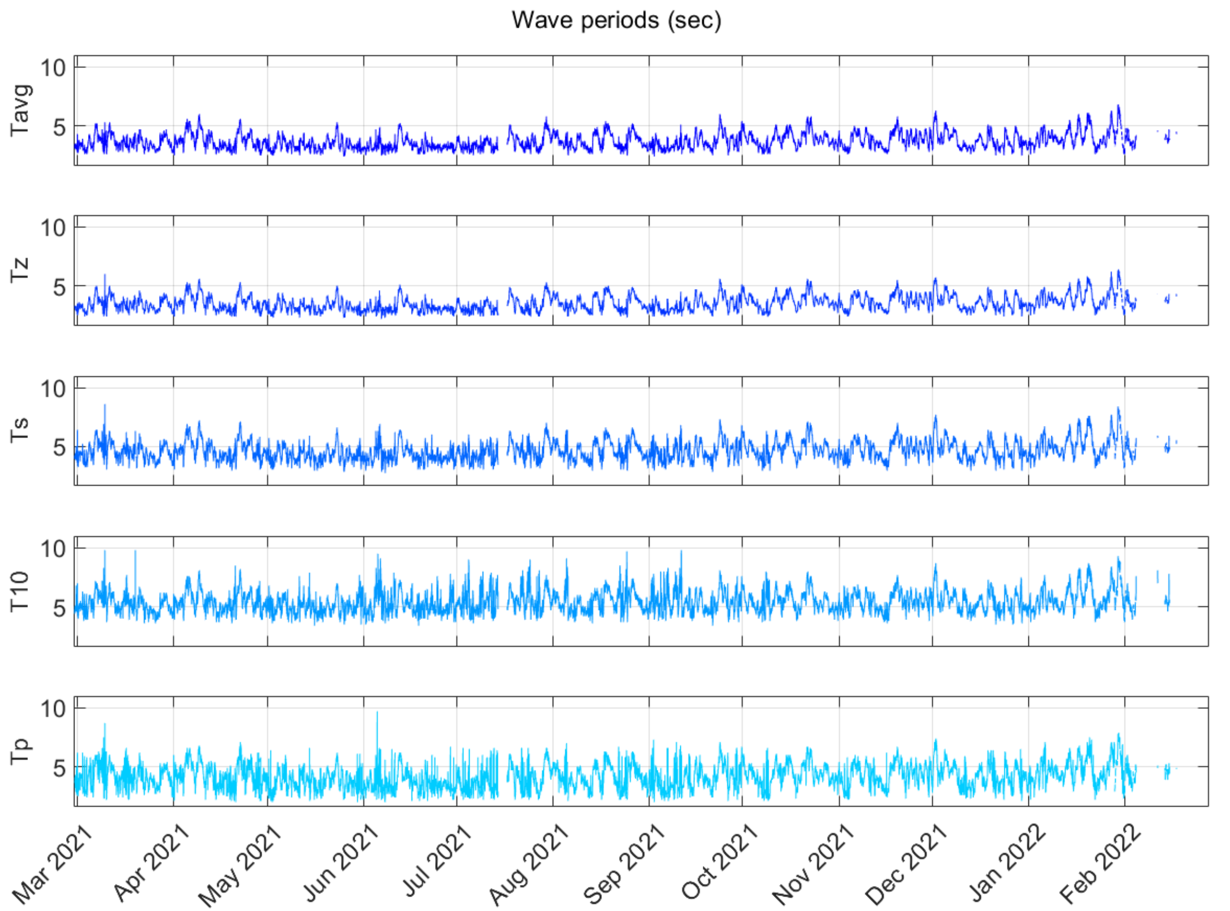

Figure 182. Time series of wave periods. The panels from top to bottom present: average wave period, mean spectral period, significant wave period, average period of the highest 1/10th of all waves, and peak wave period.

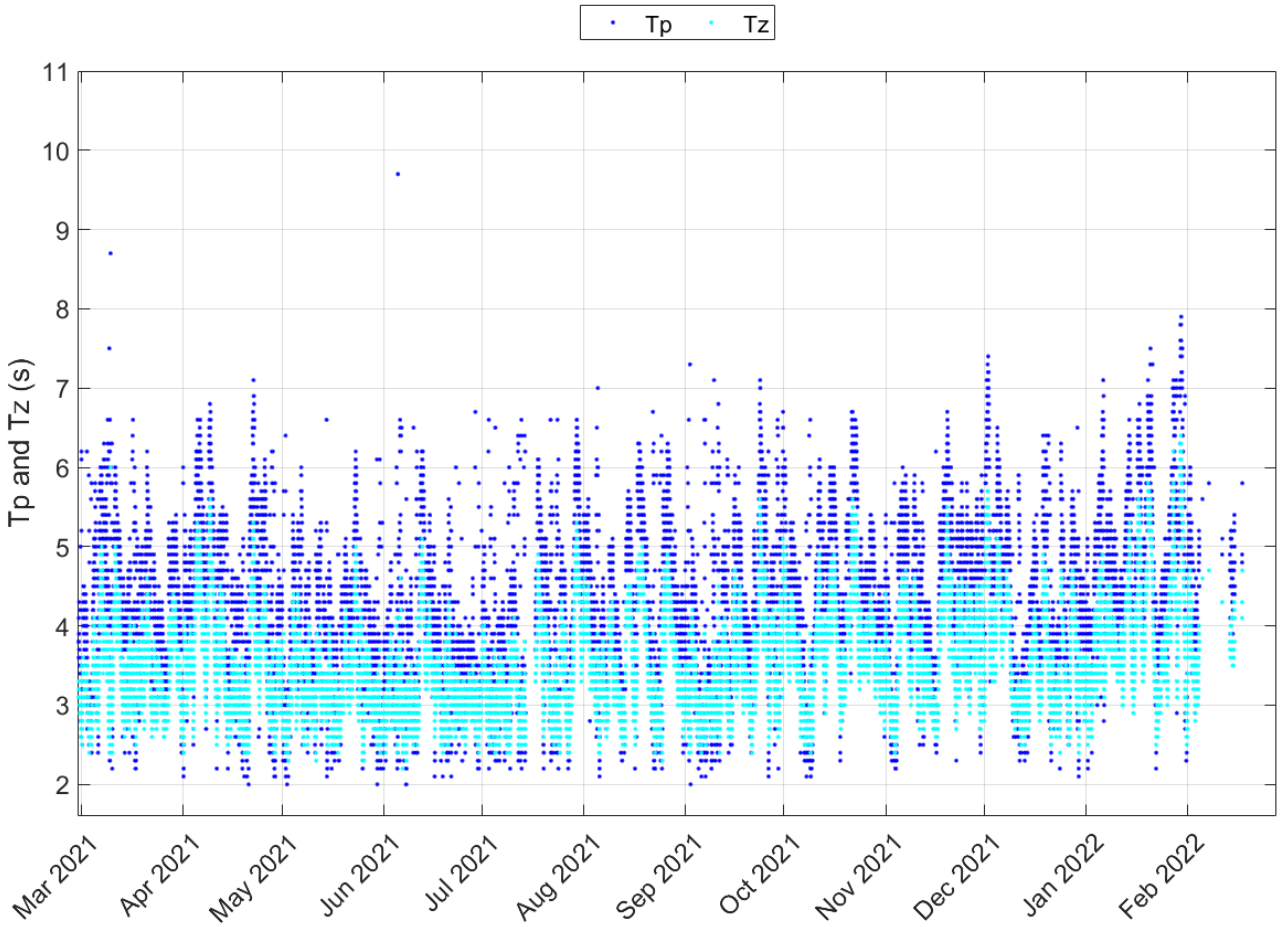

Figure 183. Time series of peak period (Tp) and mean spectral period (Tz).

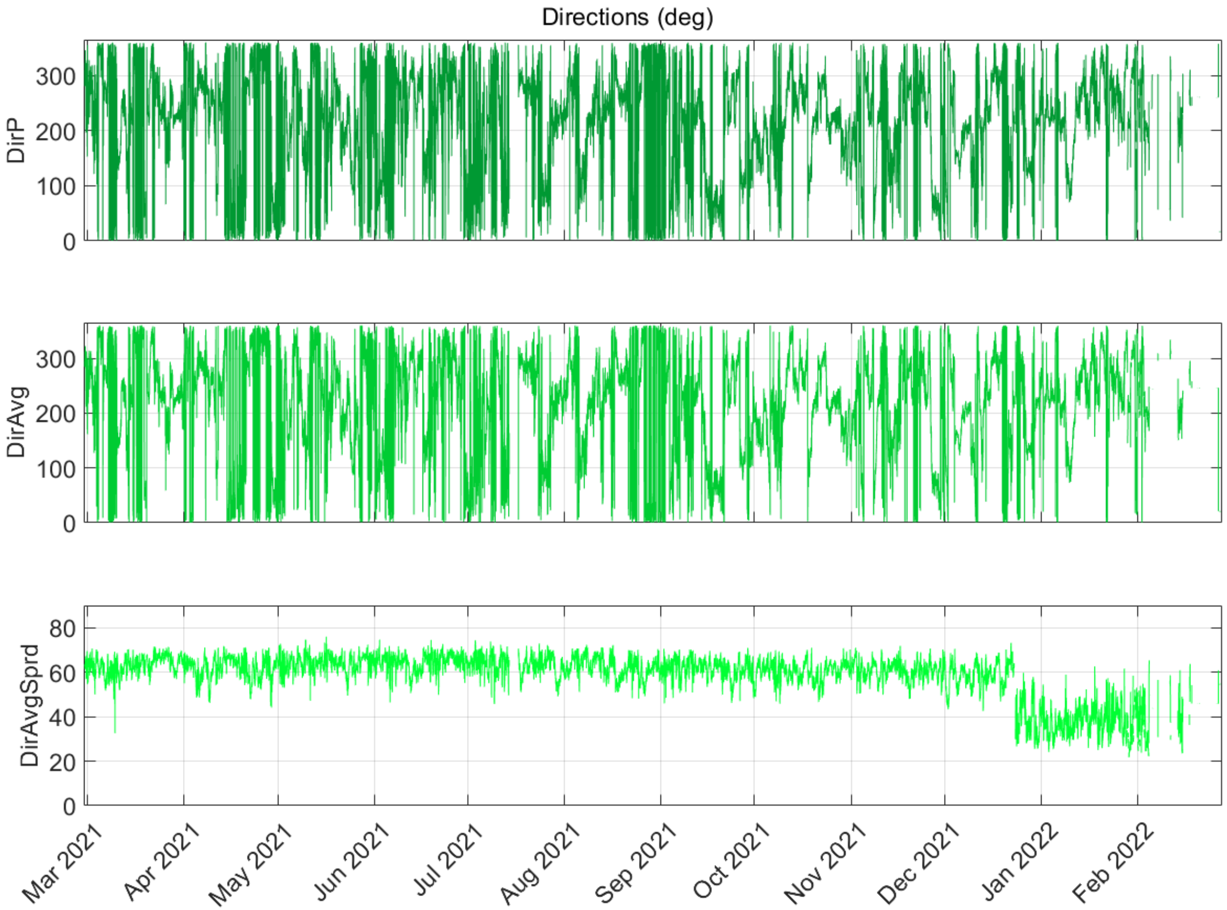

Figure 184. Time series of wave directions. The panels from top to bottom present: peak wave direction, average wave direction, and average direction spread.

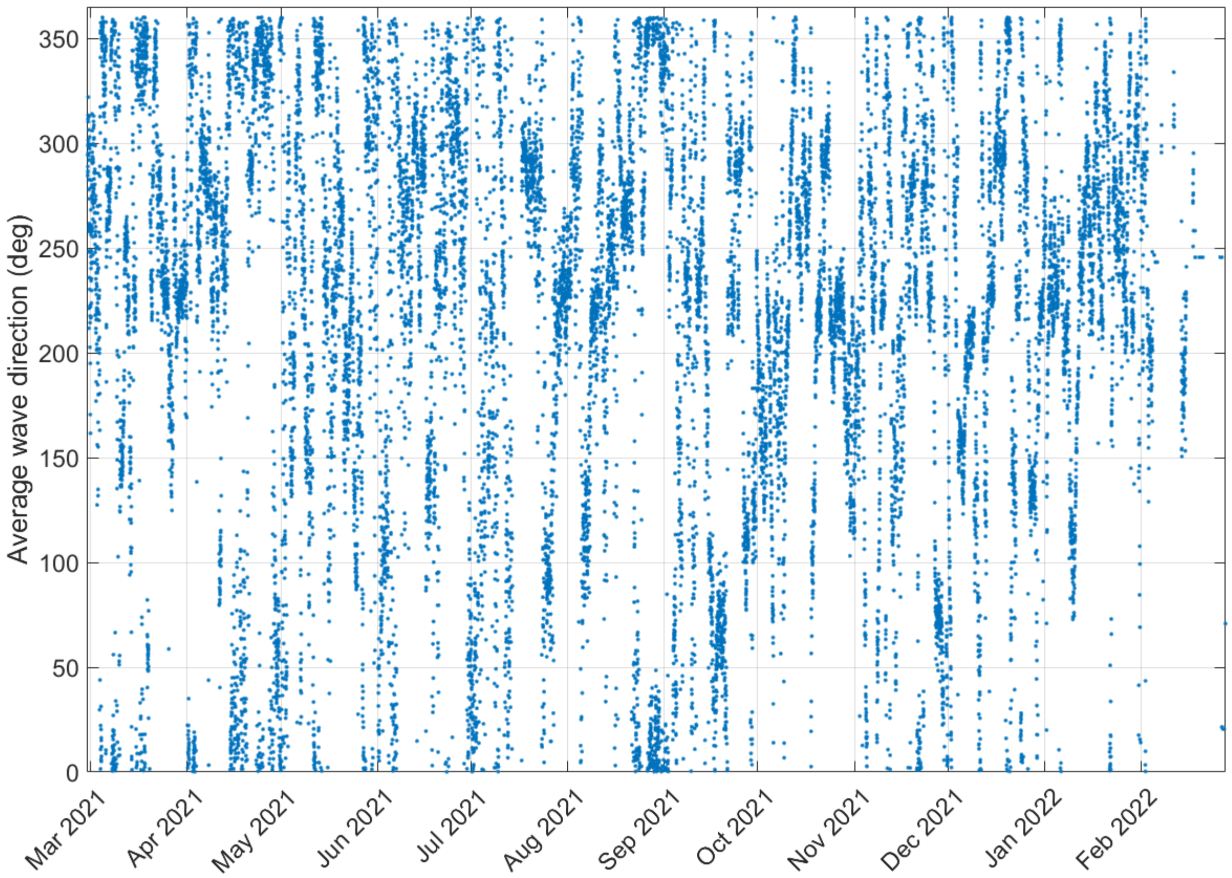

Figure 185. Time series of average wave direction.

5.4.3. Wave roses

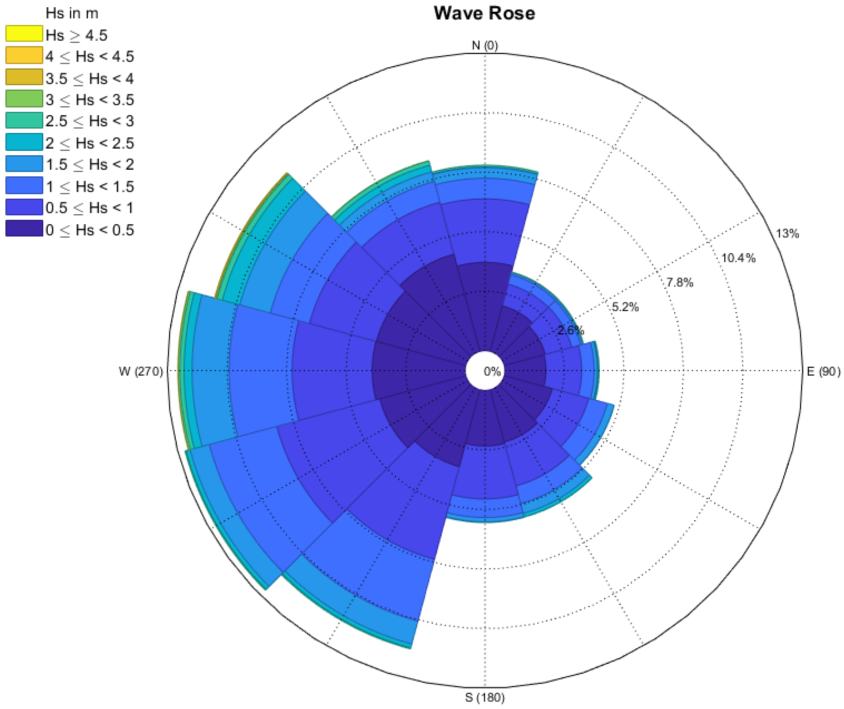

Figure 186. Wave rose of significant height (Hs).

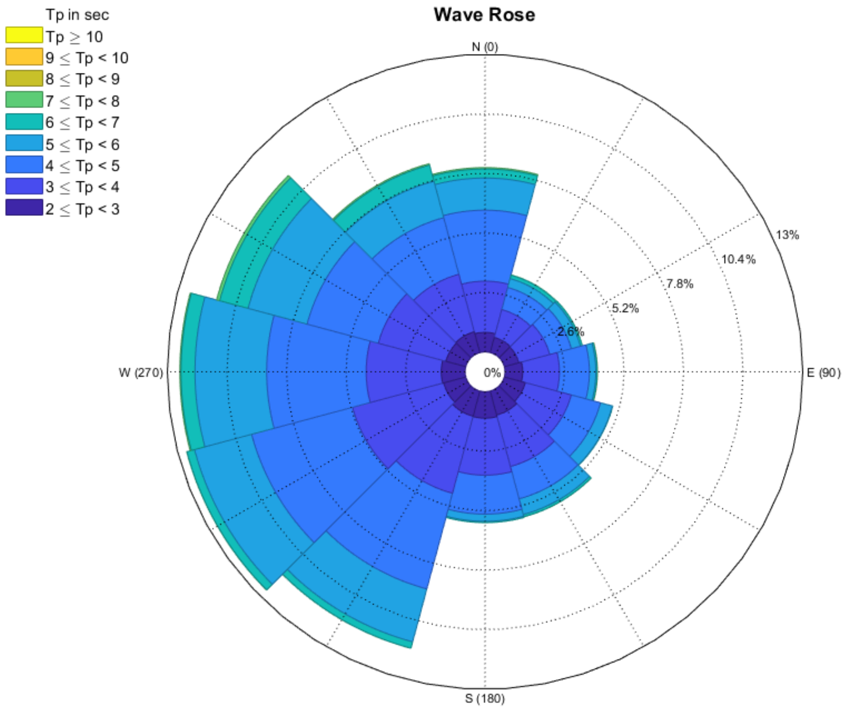

Figure 187. Wave rose of peak period (Tp).

5.4.4. Statistics

WAVE				
Month Feb 2021 - Feb 2022	Variables			
	Hs (m)	Hmax (m)	Tp (sec)	Tz (sec)
Mean	0.77	1.30	4.16	3.52
Max	4.01	8.27	9.70	6.40
Min	0.06	0.09	2.00	2.20
Std	0.56	0.93	1.02	0.64

5.4.5. Spectra

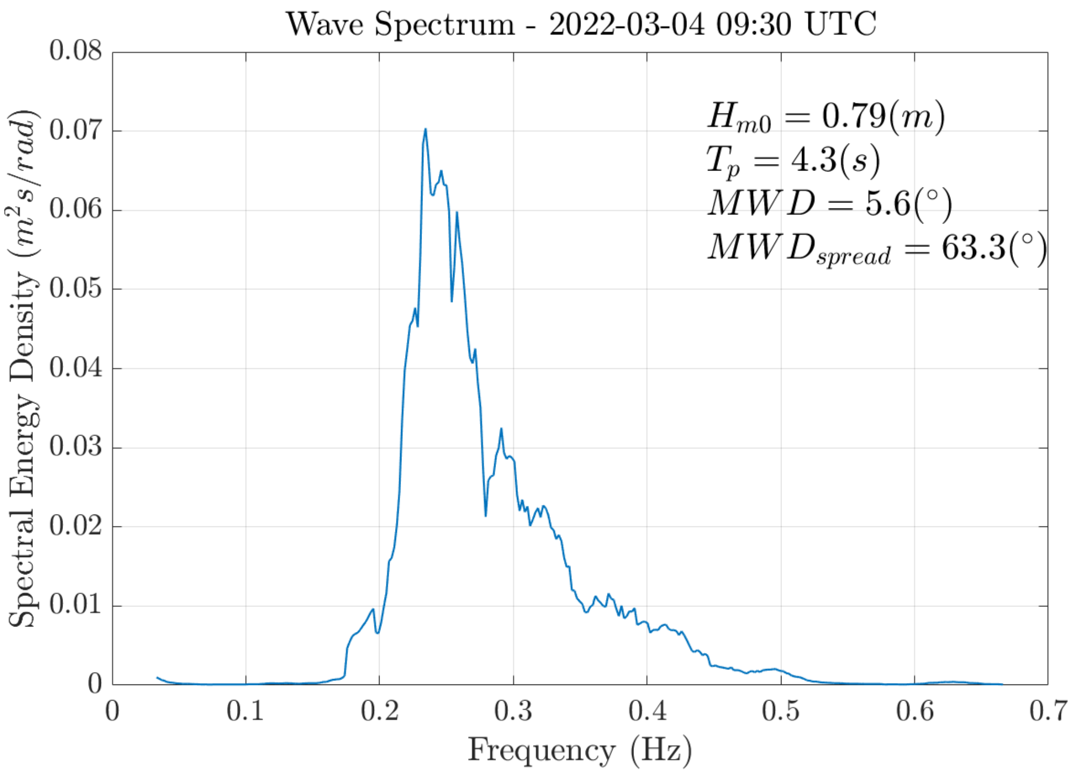

Figure 188. 1D Wave spectrum of a sea state with Hs equal to the average Hs of the whole campaign.

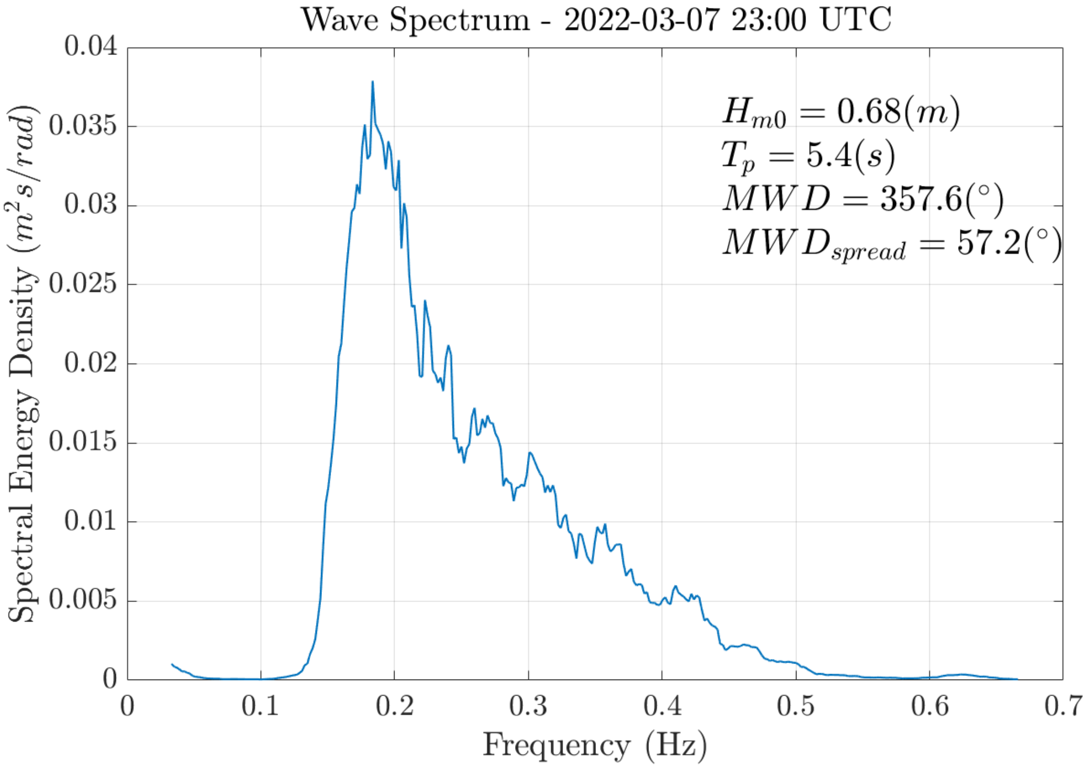

Figure 189. 1D Wave spectrum of a sea state with Hs equal to the 50th percentile of Hs of the whole campaign.

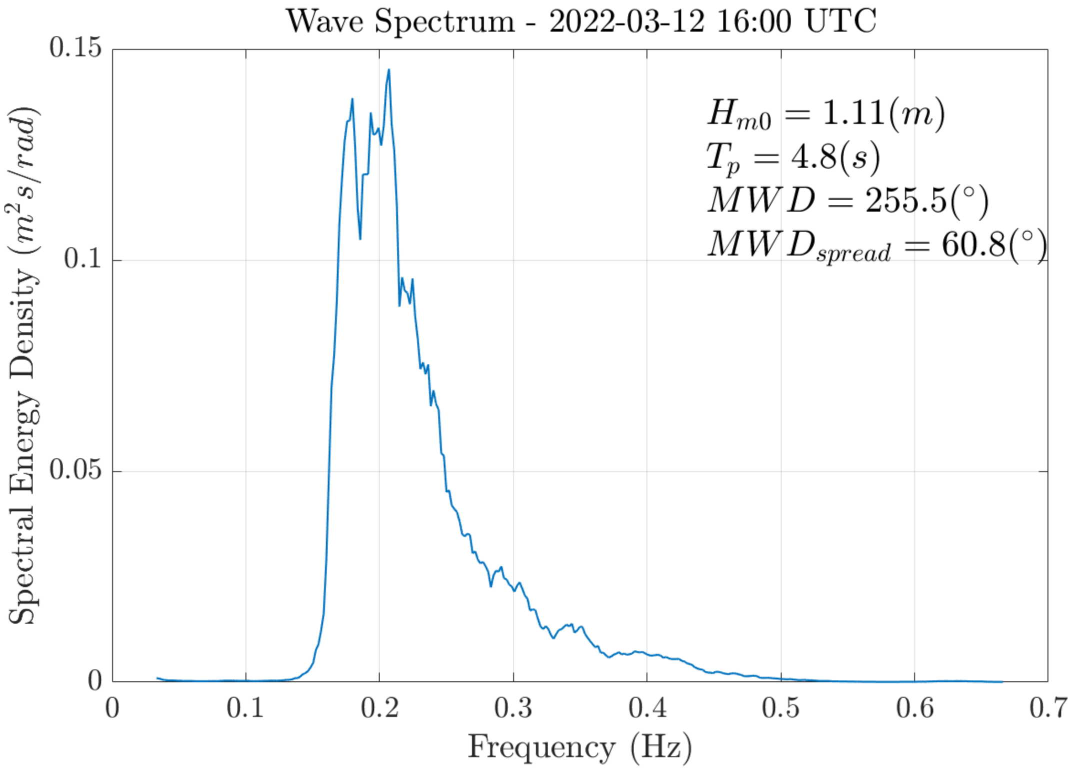

Figure 190. 1D Wave spectrum of a sea state with Hs equal to the 75th percentile of Hs of the whole campaign.

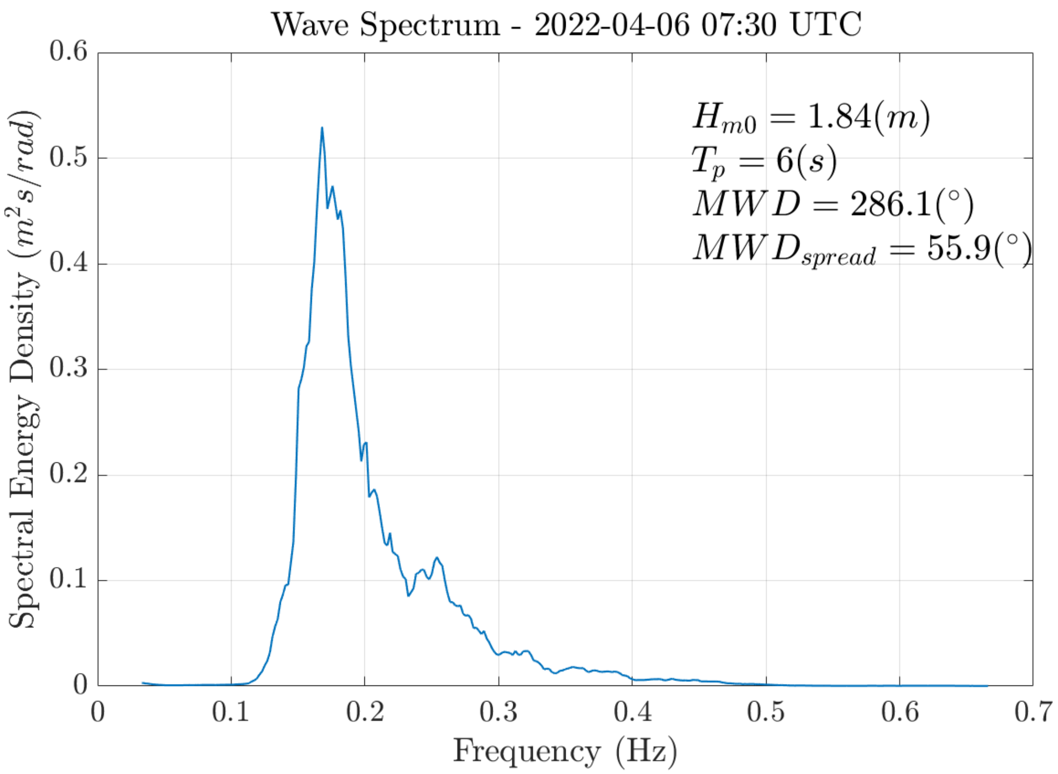

Figure 191. 1D Wave spectrum of a sea state with Hs equal to the 95th percentile of Hs of the whole campaign.

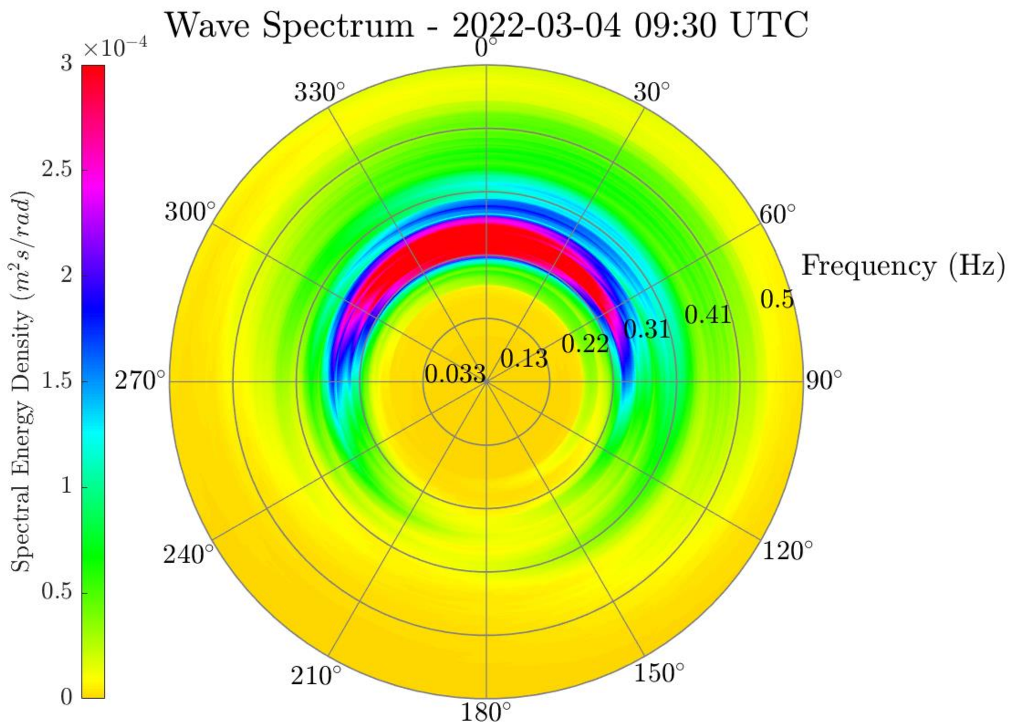

Figure 192. 2D Wave spectrum of a sea state with Hs equal to the average Hs of the whole campaign.

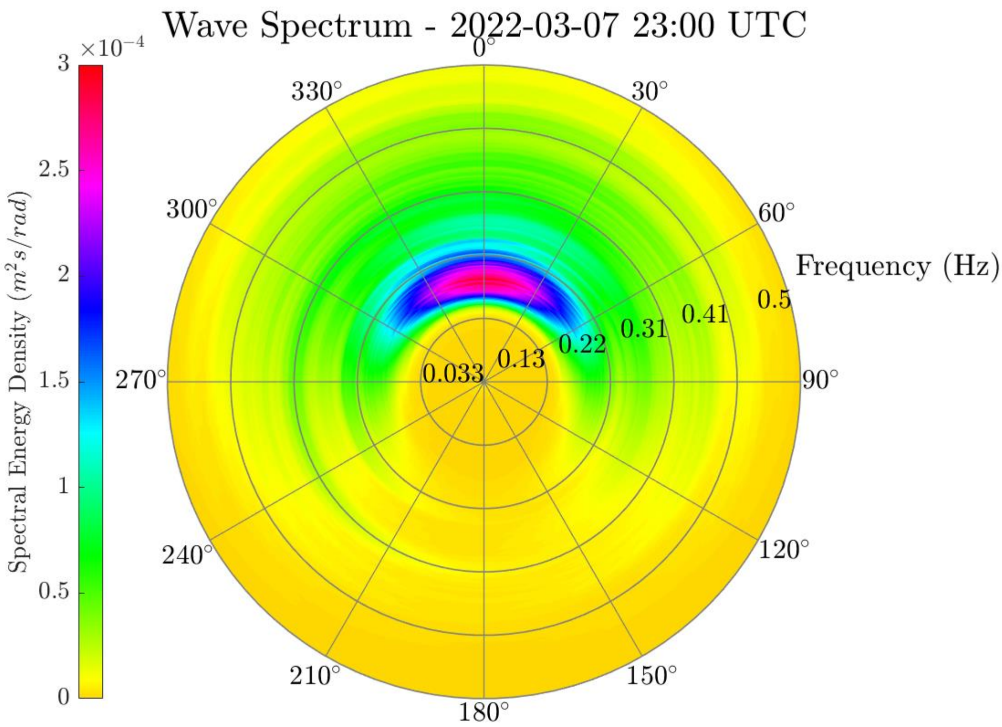

Figure 193. 2D Wave spectrum of a sea state with Hs equal to the 50th percentile of Hs of the whole campaign.

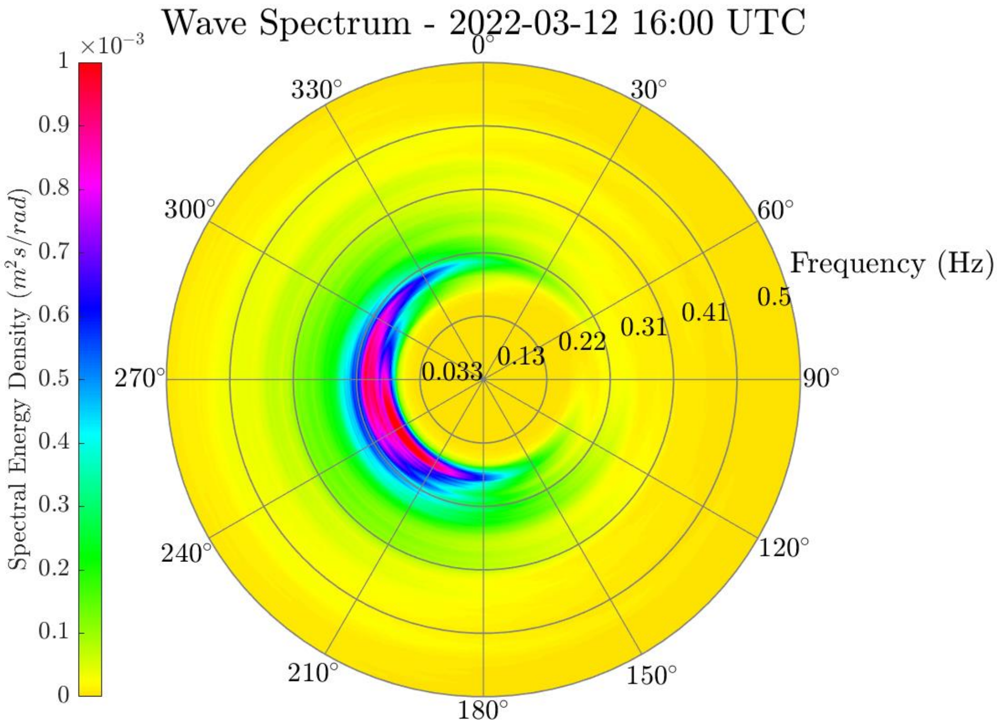

Figure 194. 2D Wave spectrum of a sea state with Hs equal to the 75th percentile of Hs of the whole campaign.

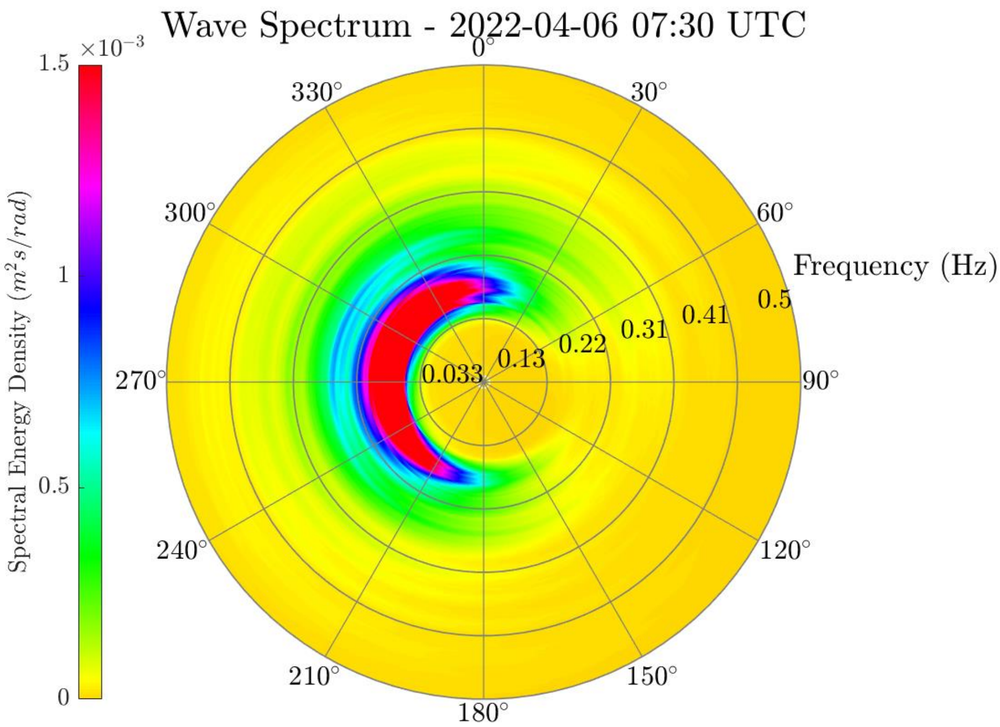

Figure 195. 2D Wave spectrum of a sea state with Hs equal to the 95th percentile of Hs of the whole campaign.

5.5. OTHER SENSORS

5.5.1. Time series

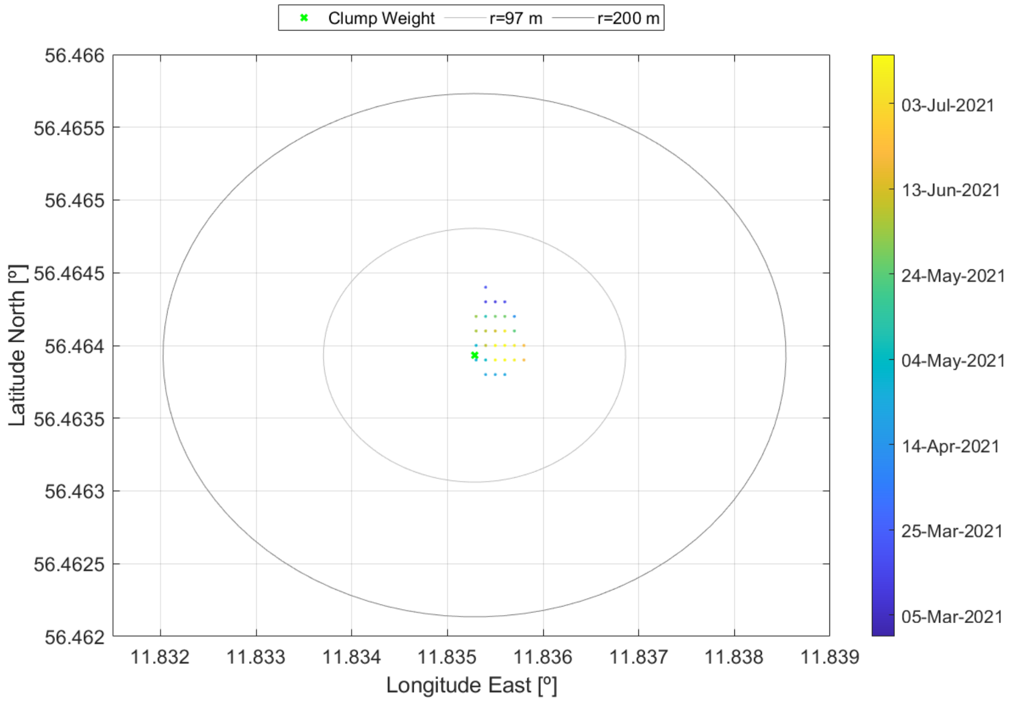

Figure 196. GPS. Buoy location (28/02/2021 - 14/07/2021).

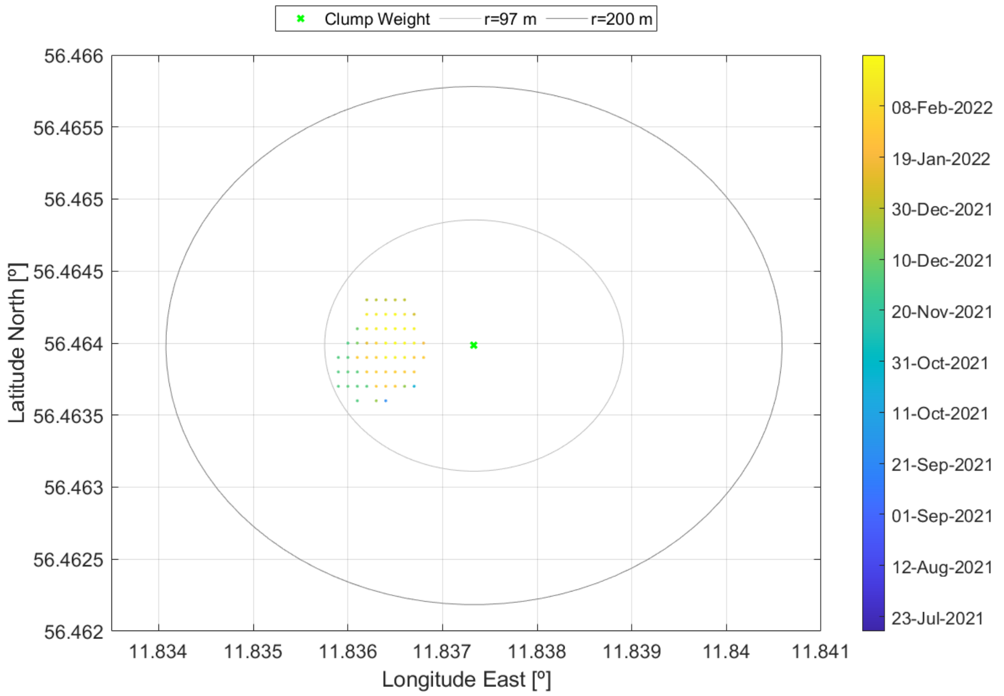

Figure 197. GPS. Buoy location (14/07/2021 - 28/02/2022).

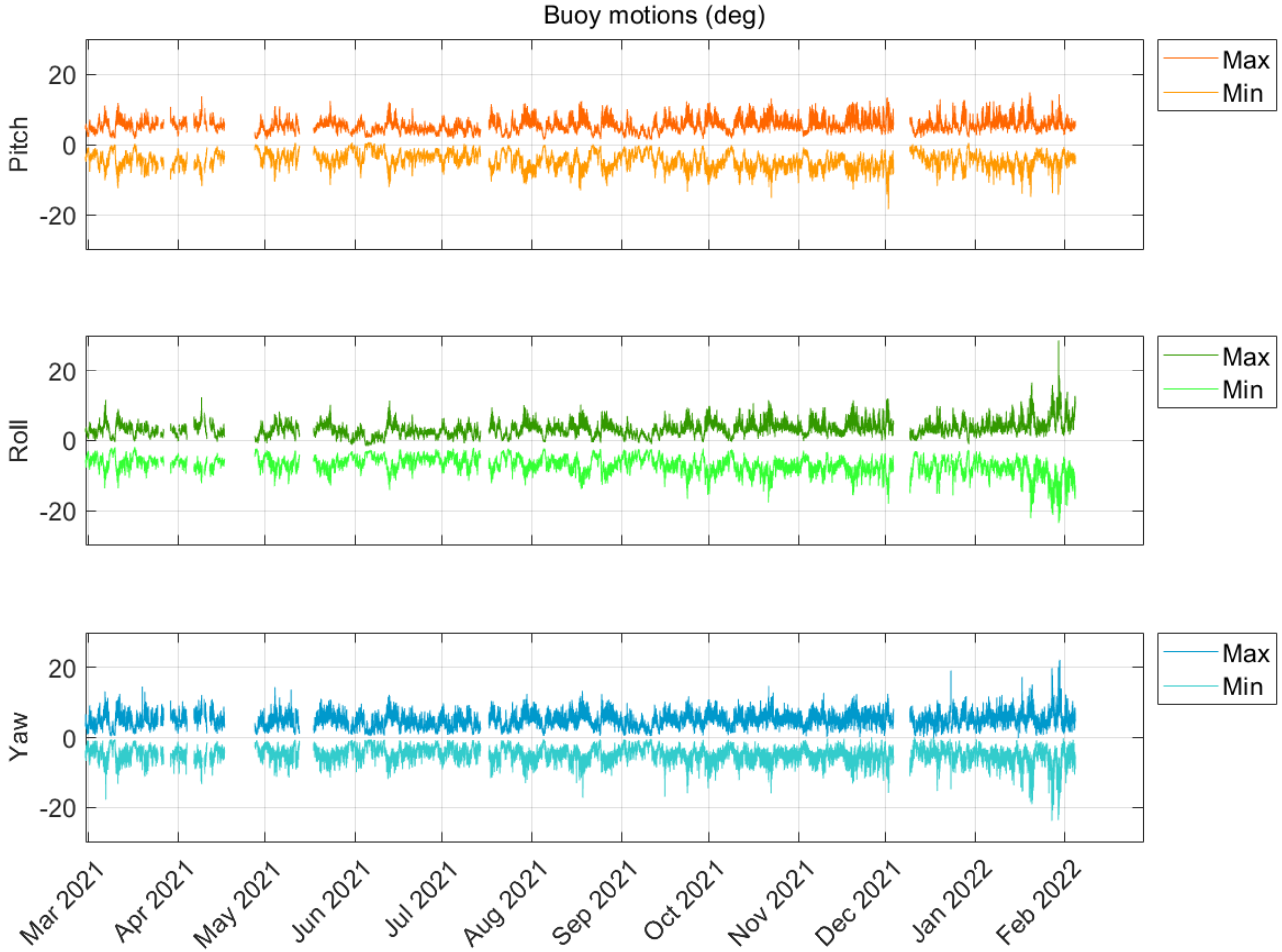

Figure 198. AHRS. Minimum and maximum pitch, roll and yaw time series.

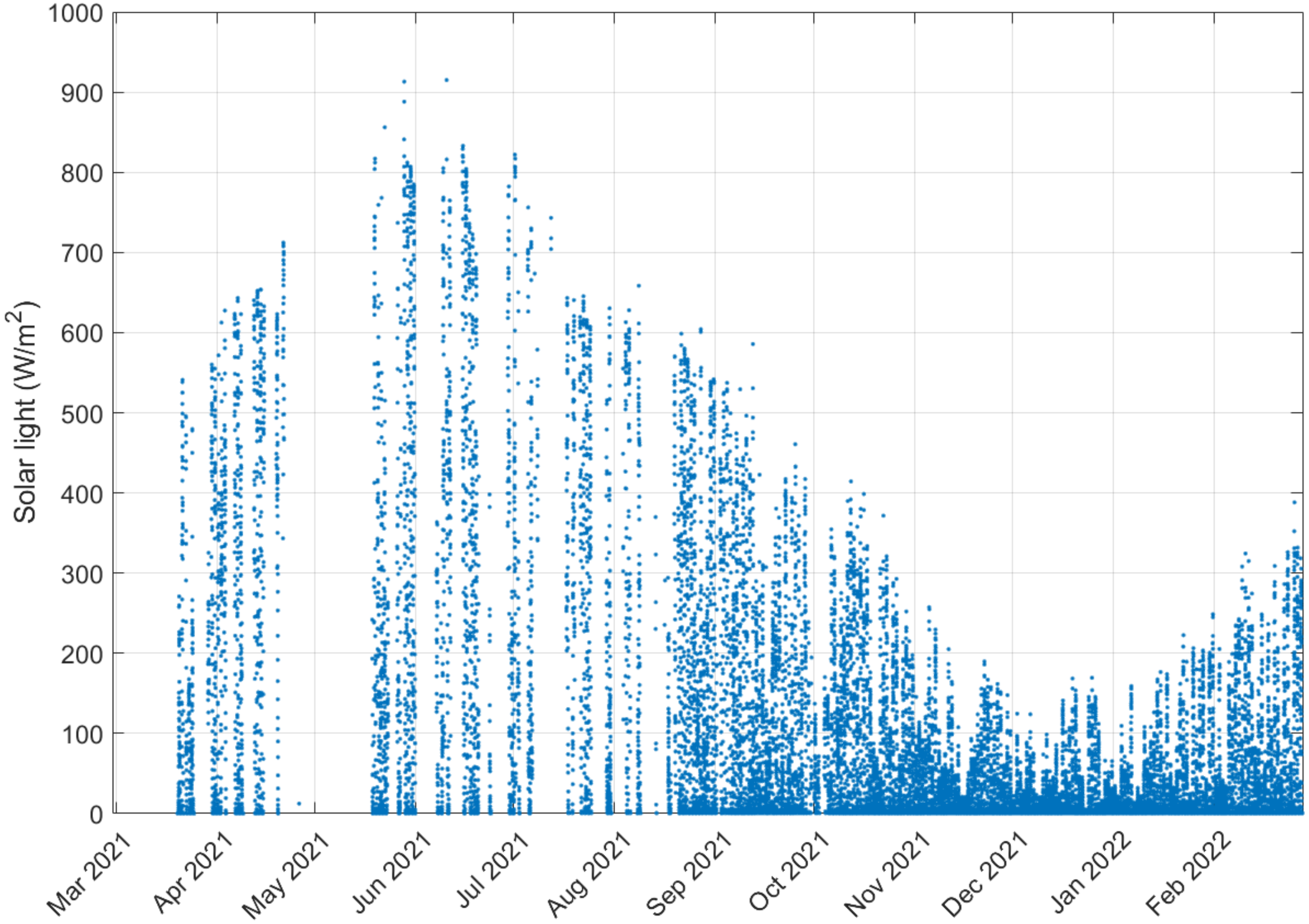

Figure 199. Pyranometer. Solar irradiance time series.

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7. APPENDIX

7.1. WIND DIRECTION DATA CORRECTED WITH COMPASS M

All the results of wind direction presented above are corrected with compass ZX (ZX Lidar's own compass). This appendix shows the results of wind direction corrected with Mast compass, hereinafter compass M, (installed close to the top of the buoy's mast).

7.1.1. Availability

WIND DIRECTION AVAILABILITY						
Sensor	**Variable**	**Possible Data**	**Valid Data (System)**	**System Availability (%)**	**Valid Data (Post-processed)**	**Post-processed Availability (%)**
LIDAR	lidar_lidar10m_WD_alg_03	52560	52063	**99.05**	44332	**84.35**
	lidar_lidar38m_WD_alg_03	52560	52063	**99.05**	44501	**84.67**
	lidar_lidar68m_WD_alg_03	52560	52063	**99.05**	44220	**84.13**
	lidar_lidar98m_WD_alg_03	52560	52063	**99.05**	43858	**83.44**
	lidar_lidar118m_WD_alg_03	52560	52063	**99.05**	43281	**82.35**
	lidar_lidar138m_WD_alg_03	52560	52063	**99.05**	43015	**81.84**
	lidar_lidar158m_WD_alg_03	52560	52063	**99.05**	42847	**81.52**
	lidar_lidar178m_WD_alg_03	52560	52063	**99.05**	42350	**80.57**
	lidar_lidar198m_WD_alg_03	52560	52063	**99.05**	41767	**79.47**
	lidar_lidar238m_WD_alg_03	52560	52063	**99.05**	41807	**79.54**
Meteo	meteo_Dir_bear	52560	47047	**89.51**	44733	**85.11**

Table 31. Availability of wind direction variables corrected with compass M.

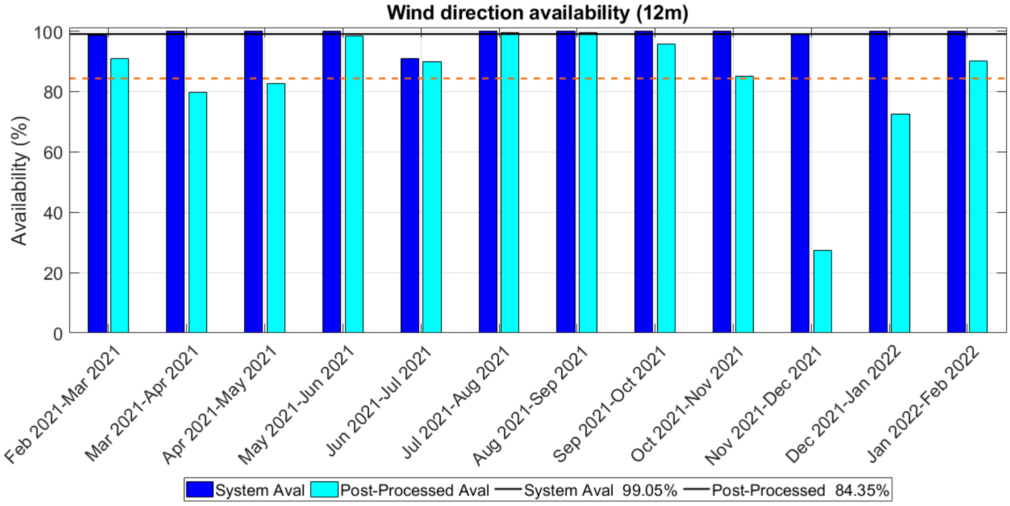

Figure 200. Bar chart for availability of wind direction at 12 m, corrected with compass M.

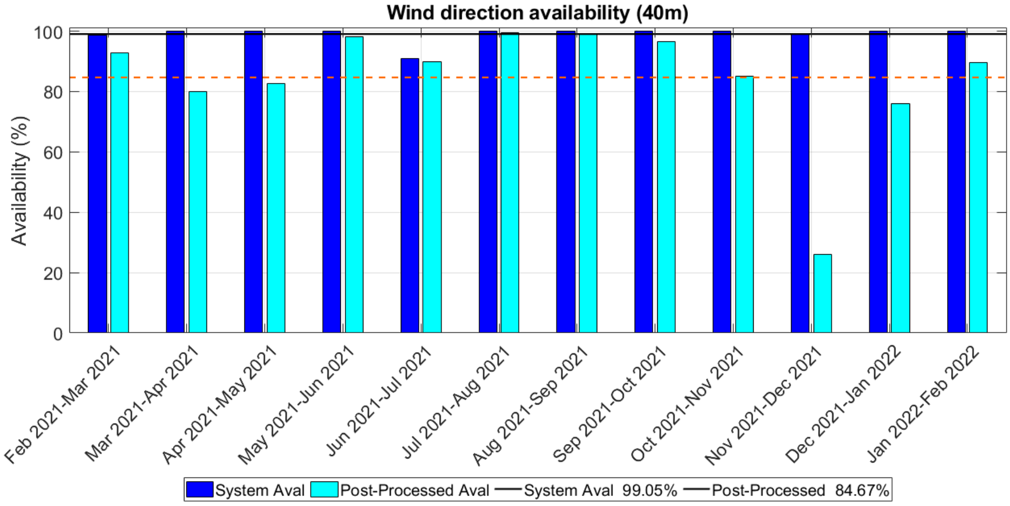

Figure 201. Bar chart for availability of wind direction at 40 m, corrected with compass M.

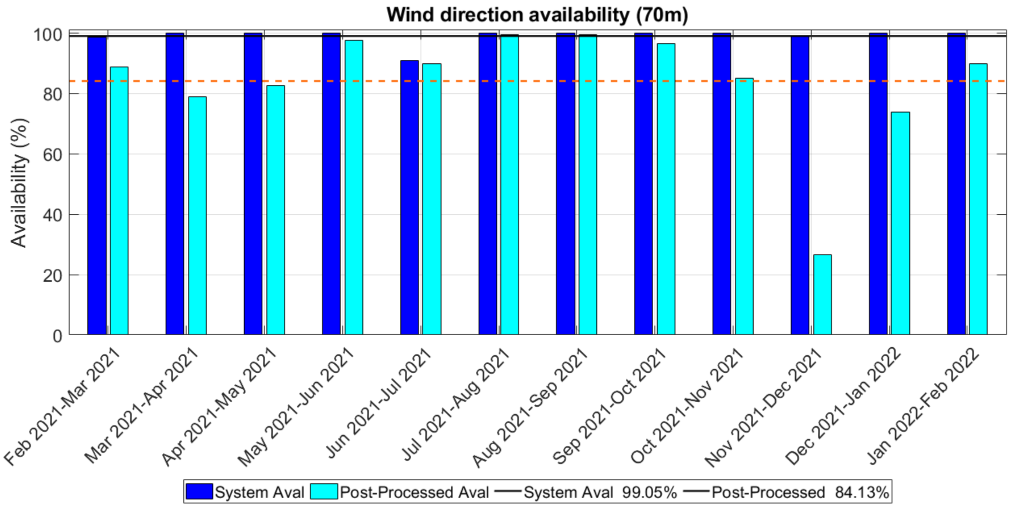

Figure 202. Bar chart for availability of wind direction at 70 m, corrected with compass M.

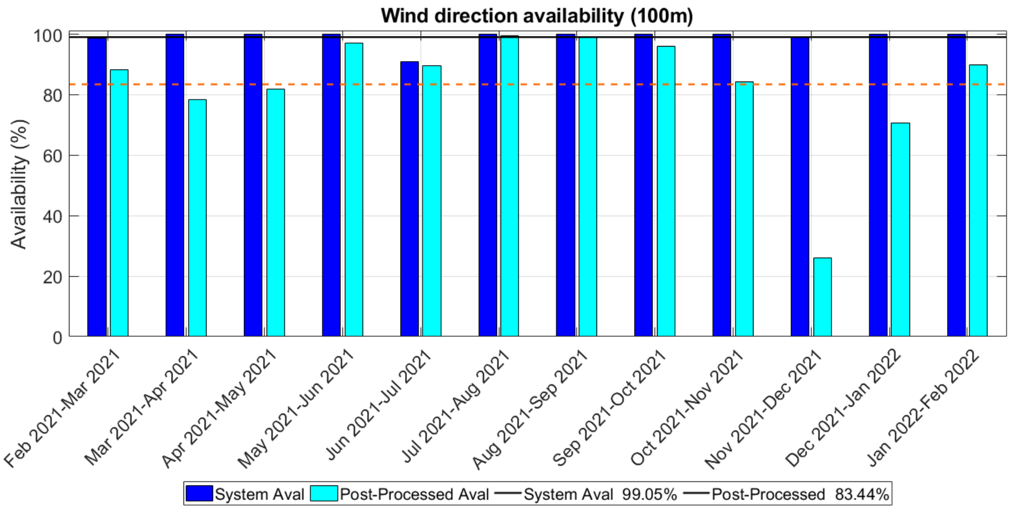

Figure 203. Bar chart for availability of wind direction at 100 m, corrected with compass M.

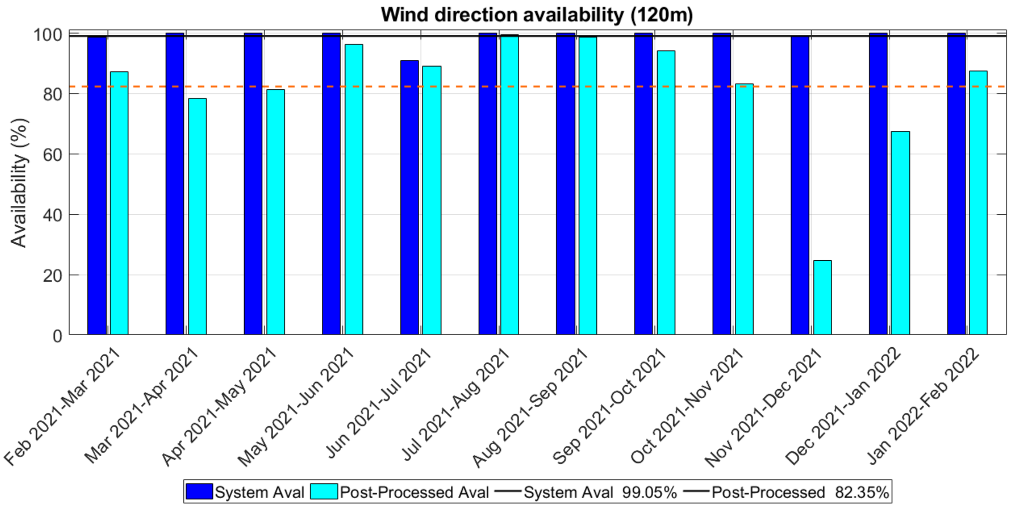

Figure 204. Bar chart for availability of wind direction at 120 m, corrected with compass M.

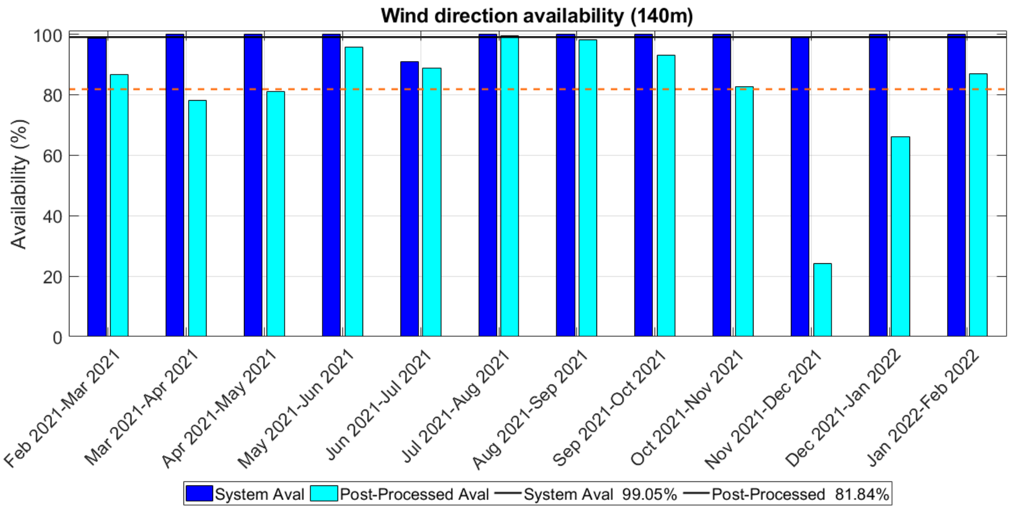

Figure 205. Bar chart for availability of wind direction at 140 m, corrected with compass M.

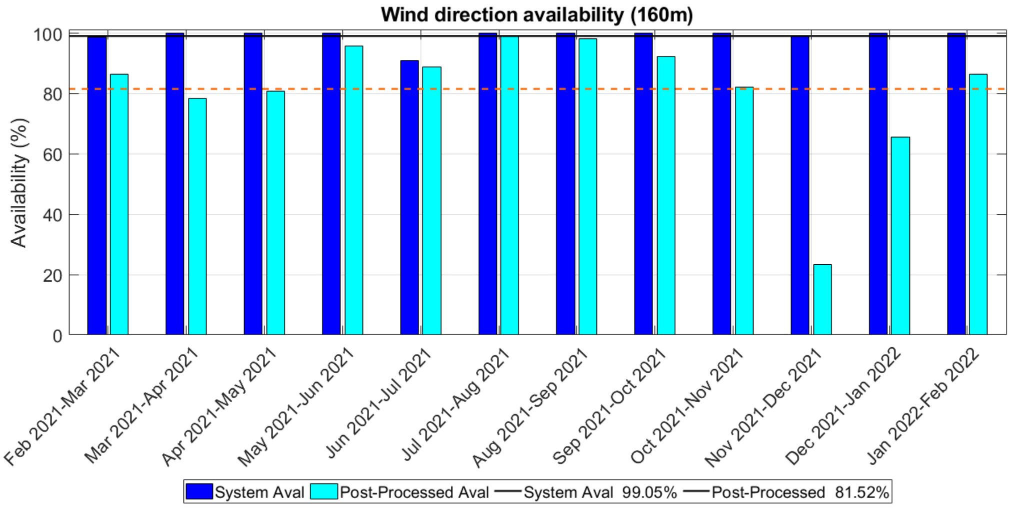

Figure 206. Bar chart for availability of wind direction at 160 m, corrected with compass M.

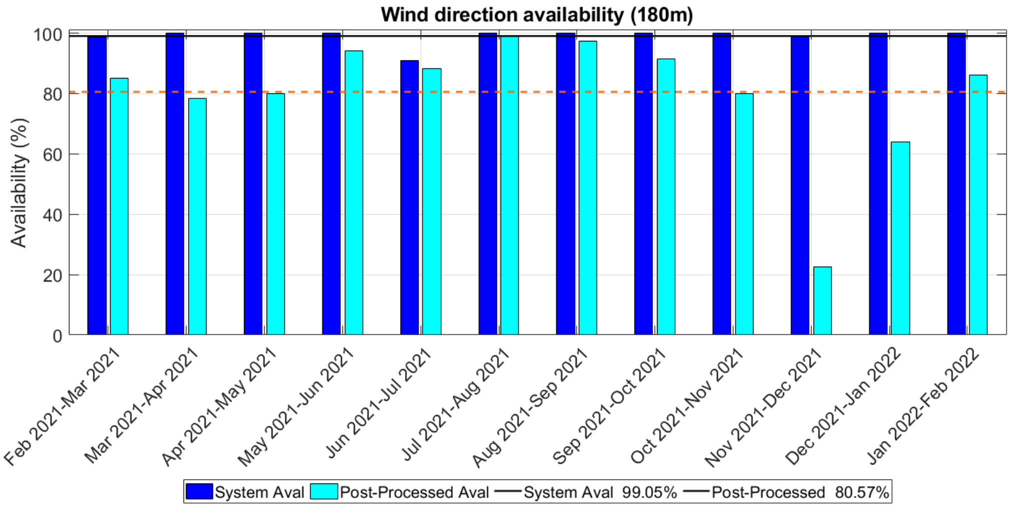

Figure 207. Bar chart for availability of wind direction at 180 m, corrected with compass M.

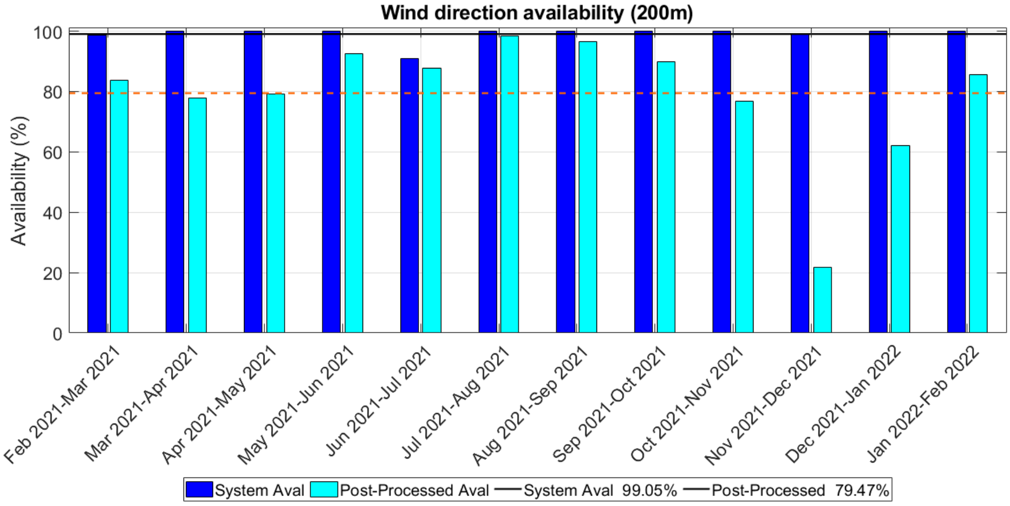

Figure 208. Bar chart for availability of wind direction at 200 m, corrected with compass M.

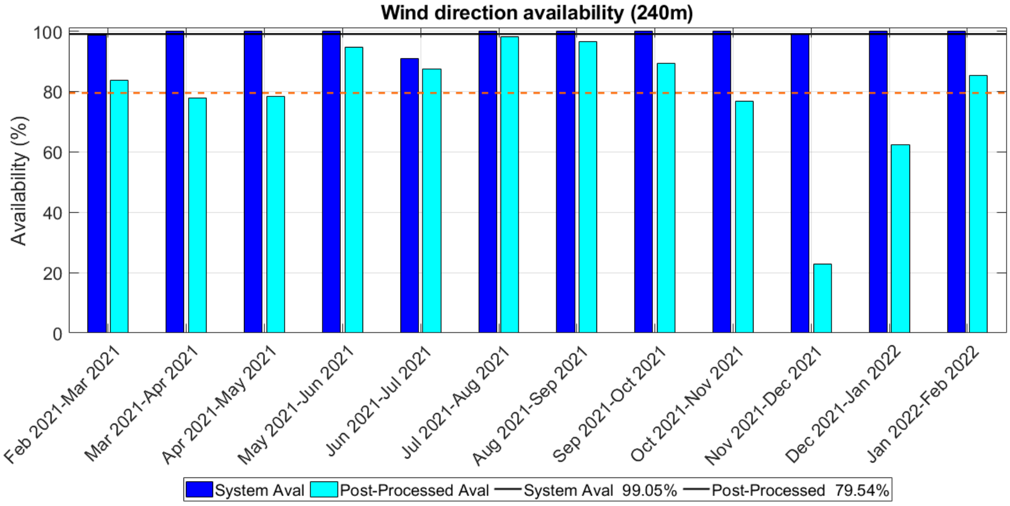

Figure 209. Bar chart for availability of wind direction at 240 m, corrected with compass M.

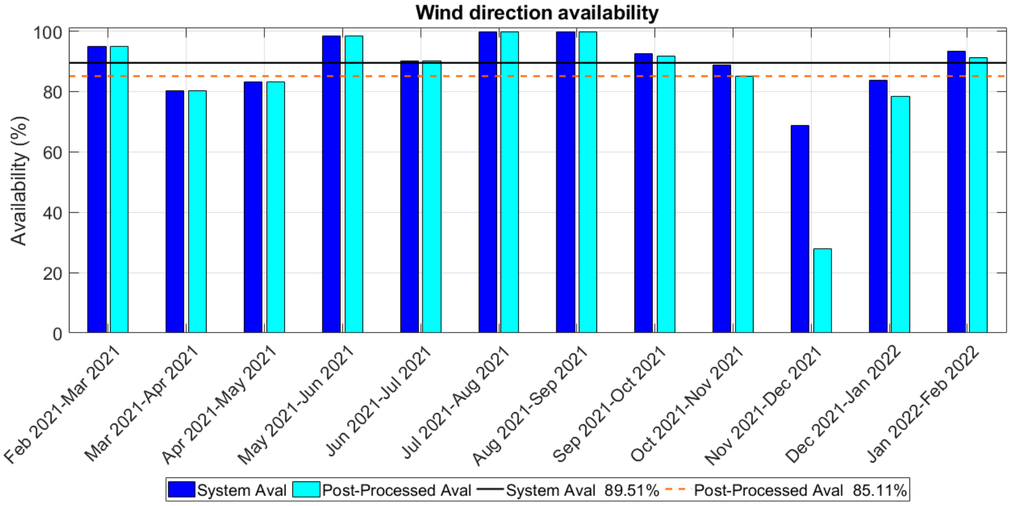

Figure 210. Bar chart for availability of METEO wind direction, corrected with compass M.

7.1.1. Time series

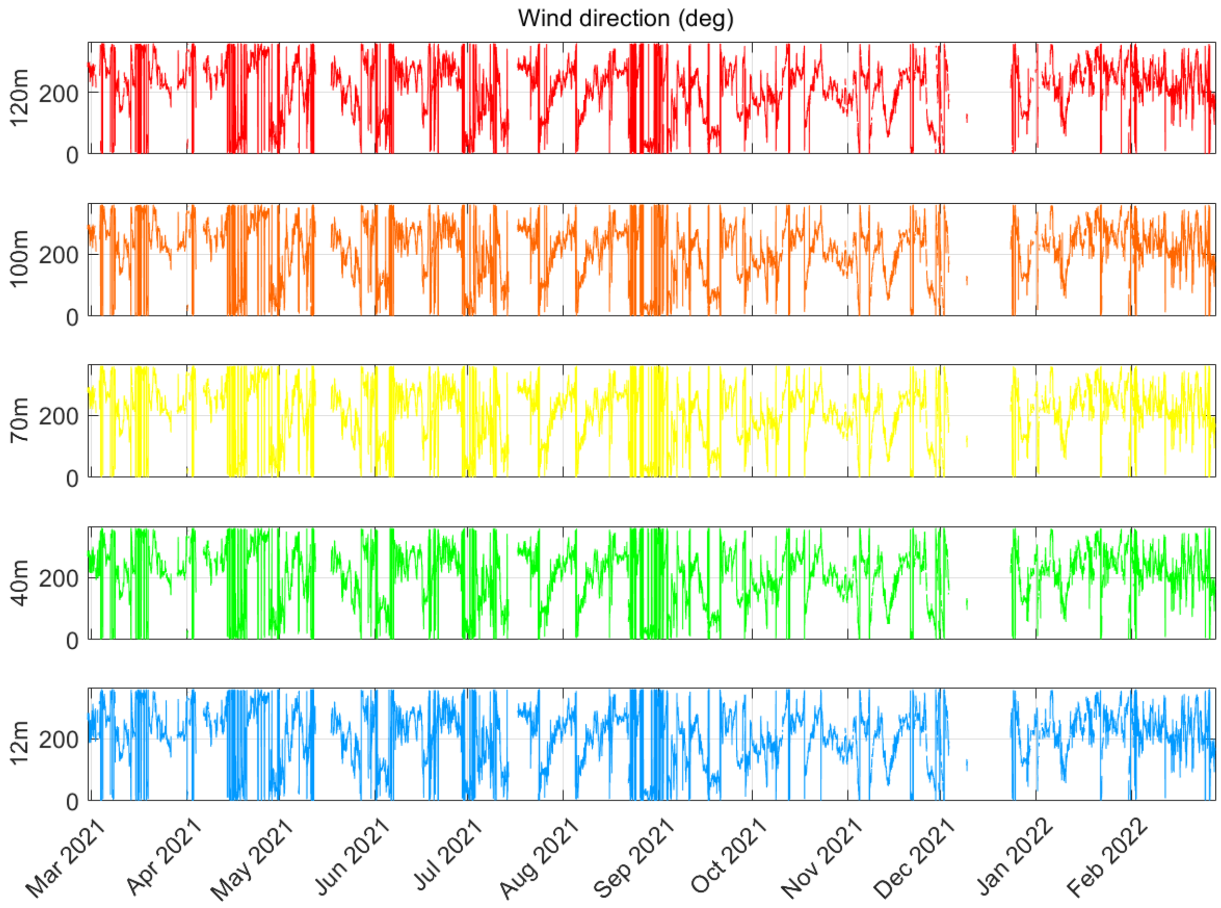

Figure 211. LIDAR. Horizontal wind speed time series for heights from 12 to 120 m, corrected with compass M.

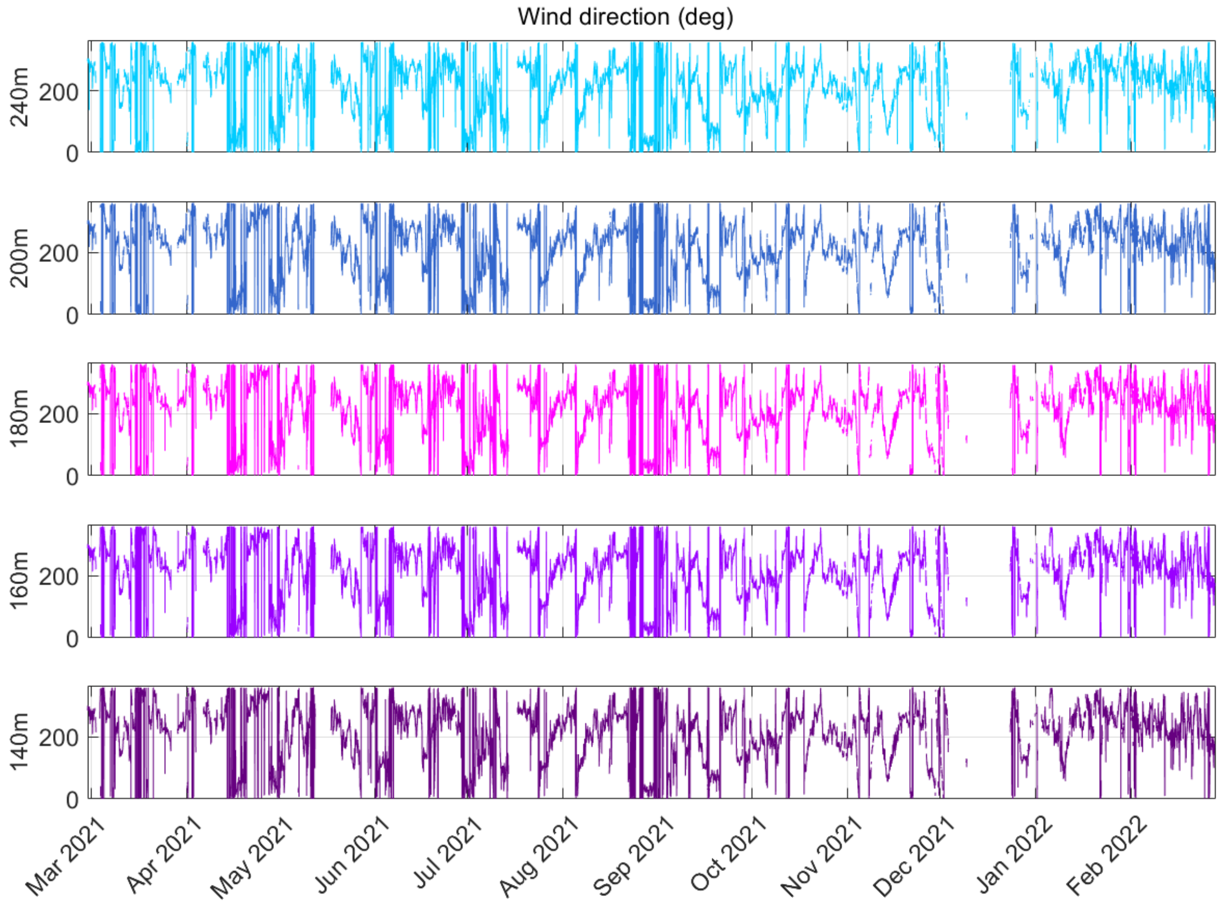

Figure 212. LIDAR. Horizontal wind speed time series for heights from 140 to 240 m, corrected with compass M.

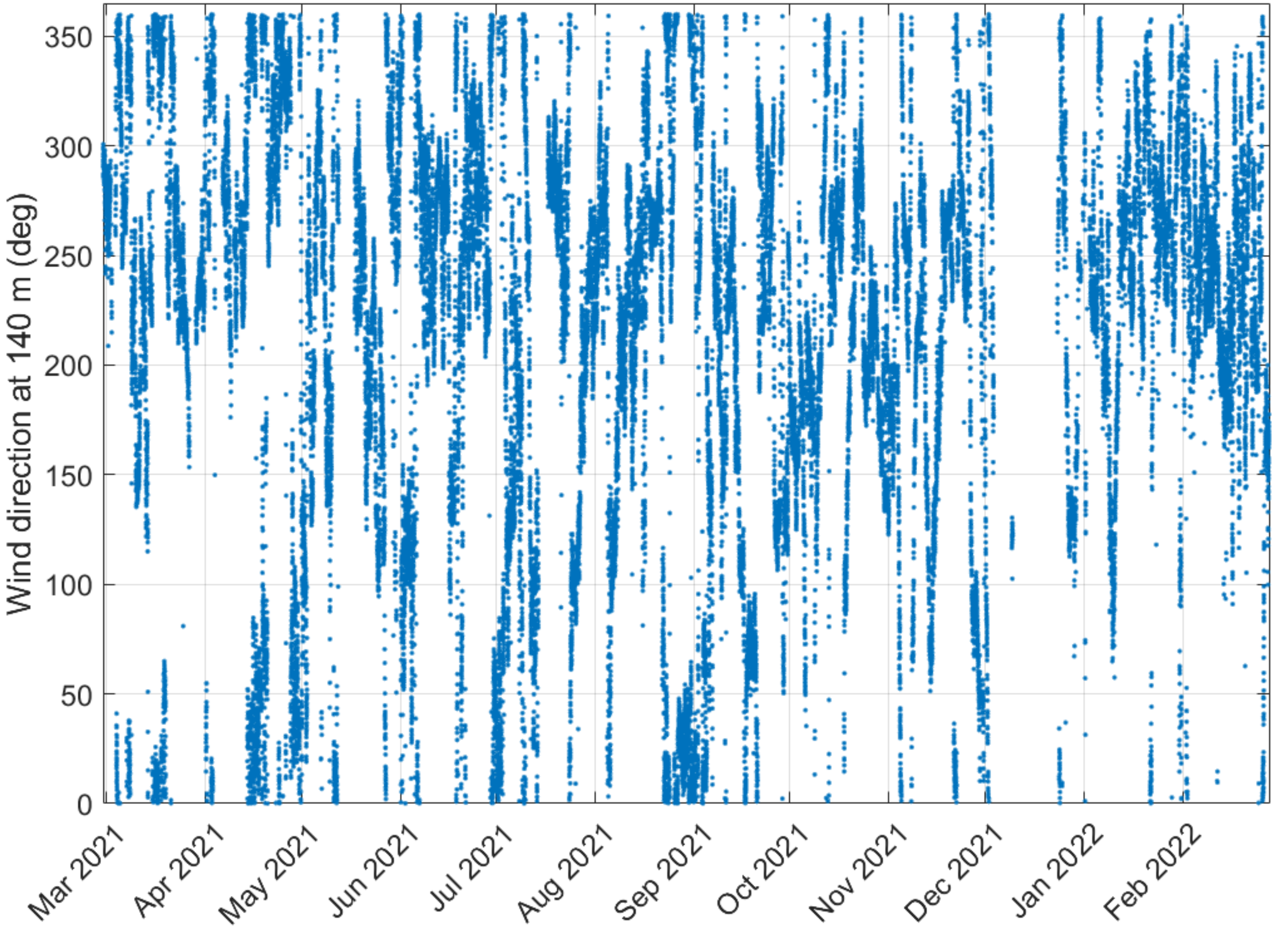

Figure 213. LIDAR. Wind direction time series at 140 m, corrected with compass M.

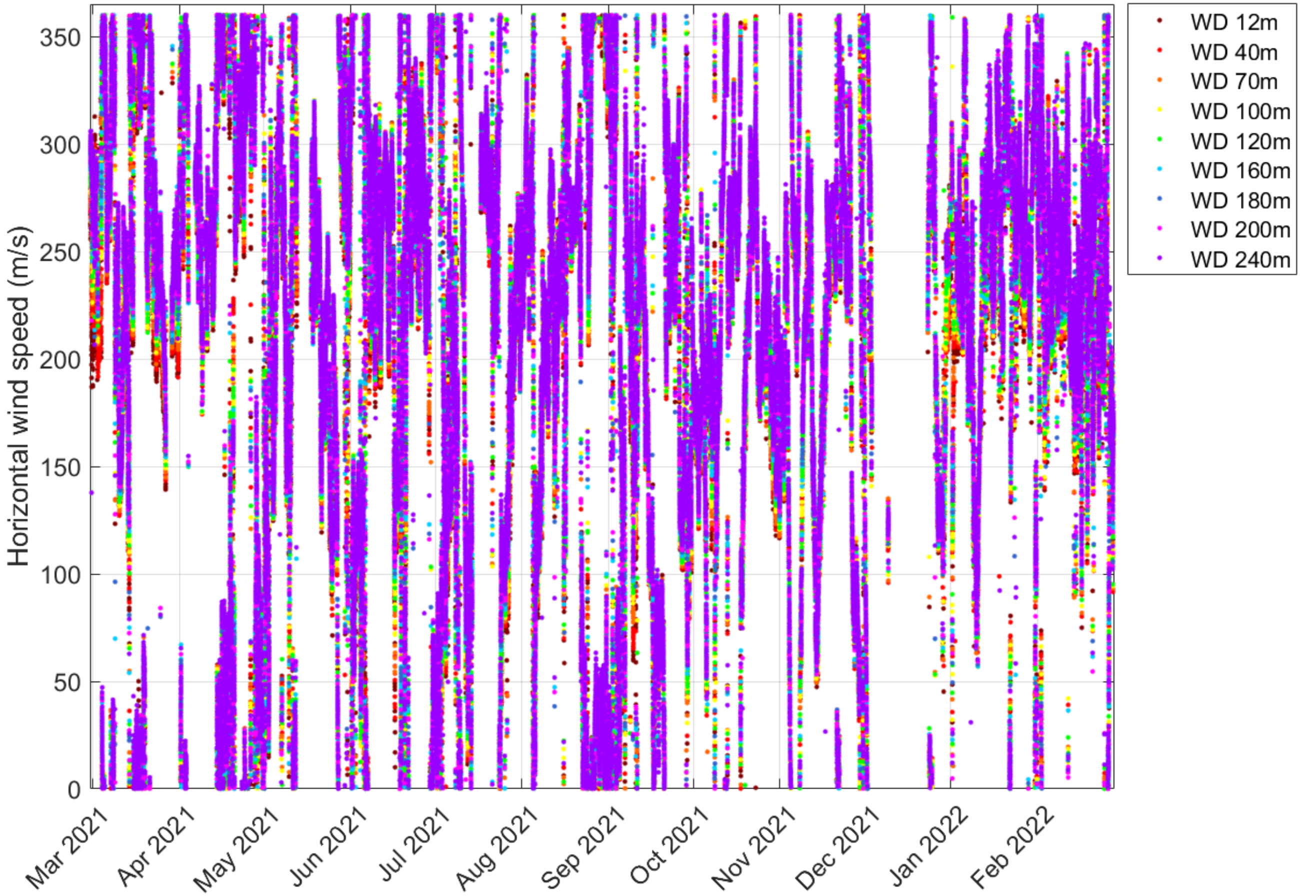

Figure 214. LIDAR. Wind direction time series for all heights except 140 m, corrected with compass M.

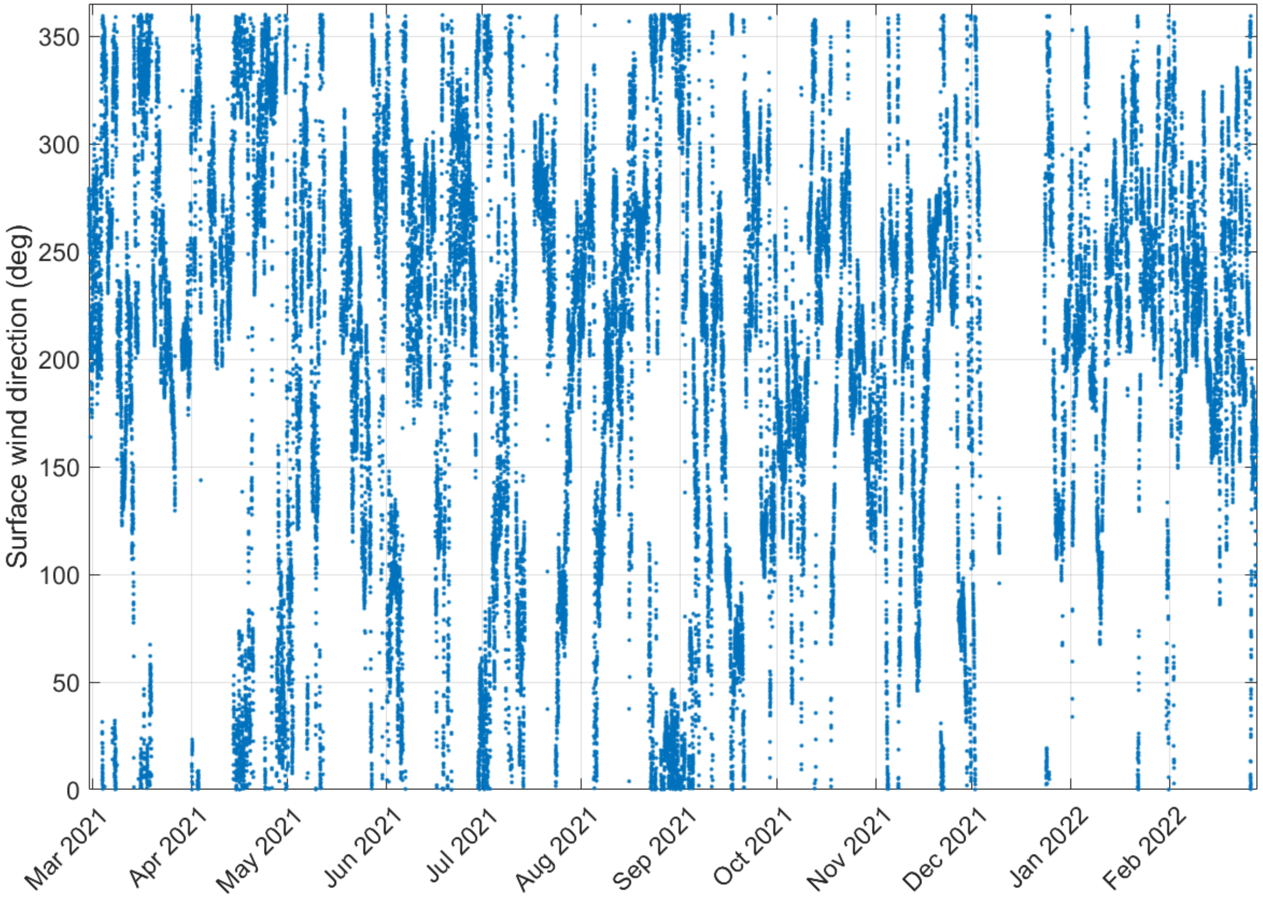

Figure 215. METEO. Wind direction at surface time series, corrected with compass M.

7.1.2. Wind roses

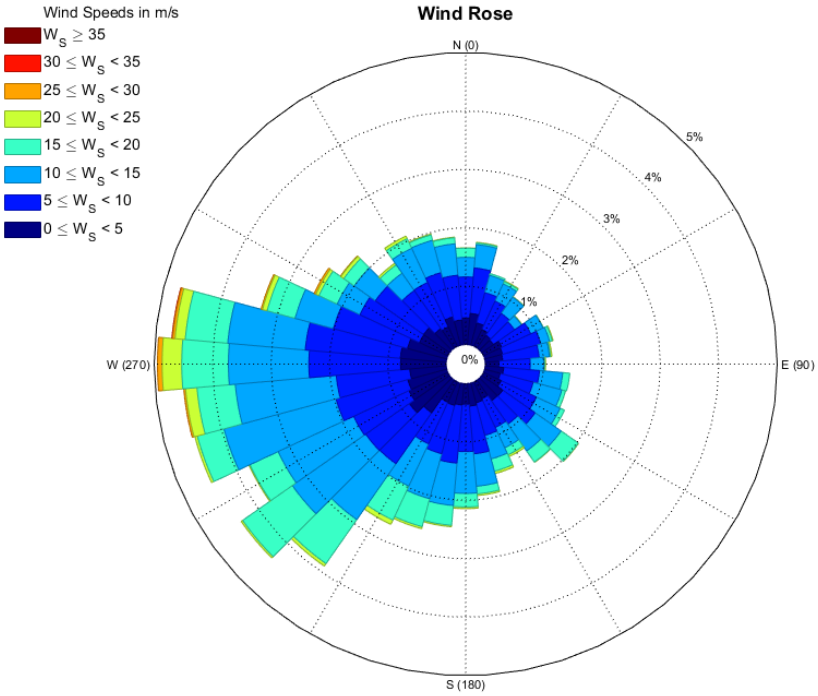

Figure 216. LIDAR. Wind rose at 140 m, corrected with compass M.

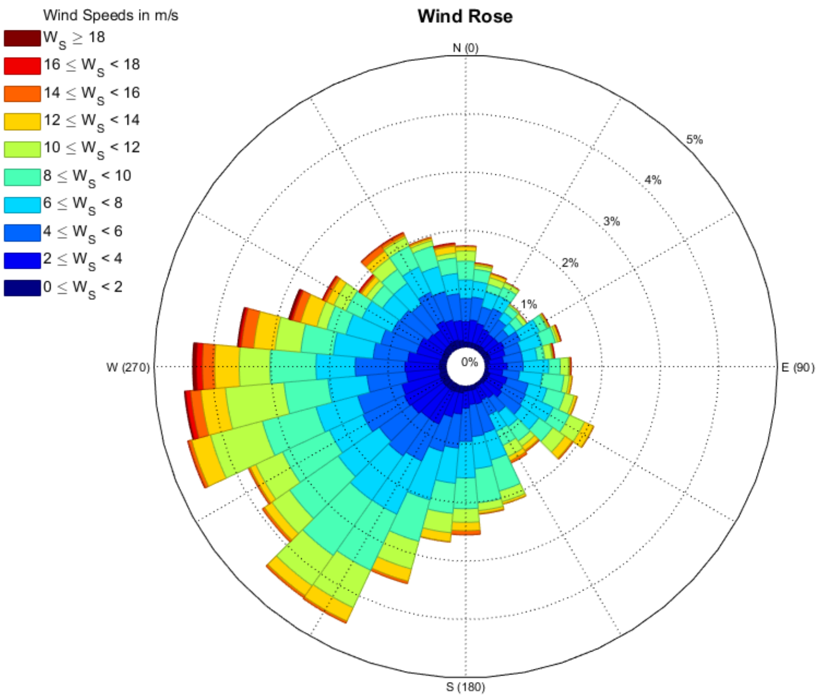

Figure 217. METEO. Wind rose at surface, corrected with compass M.