Welcome

- Introduction of the webinar
- Presentation of Metocean Campaign by Richard Davies (Fugro)
- Chat for questions by expert panel: Edwin Beringen (Fugro), Arve Berg (Fugro), Irene Pathirana (Fugro), Sofia Caires (Deltares) Miriam van Endt (Blix Consultancy) and Erik Holtslag (Pondera)

Netherlands Enterprise Agency

Webinar Metocean Campaign

Hollandse Kust (west) Wind Farm Zone

15 October 2020

Matté Brijder

Metocean Campaign for the Hollandse Kust West Wind Farm Zone

Performed by: Fugro
Client: RVO

Webinar 15. October 2020: Richard Davies, Edwin Beringen, Irene Pathirana, Arve Berg (Fugro), Sofia Caires (Deltares)

Contents

Introduction to the Metocean Campaign

Purpose, project overview, observations and comparison

Purpose of the measurements

Fugro carried out a metocean measurement campaign at the Hollandse Kust (west) Offshore wind farm (OWF) to support future wind farm developers.

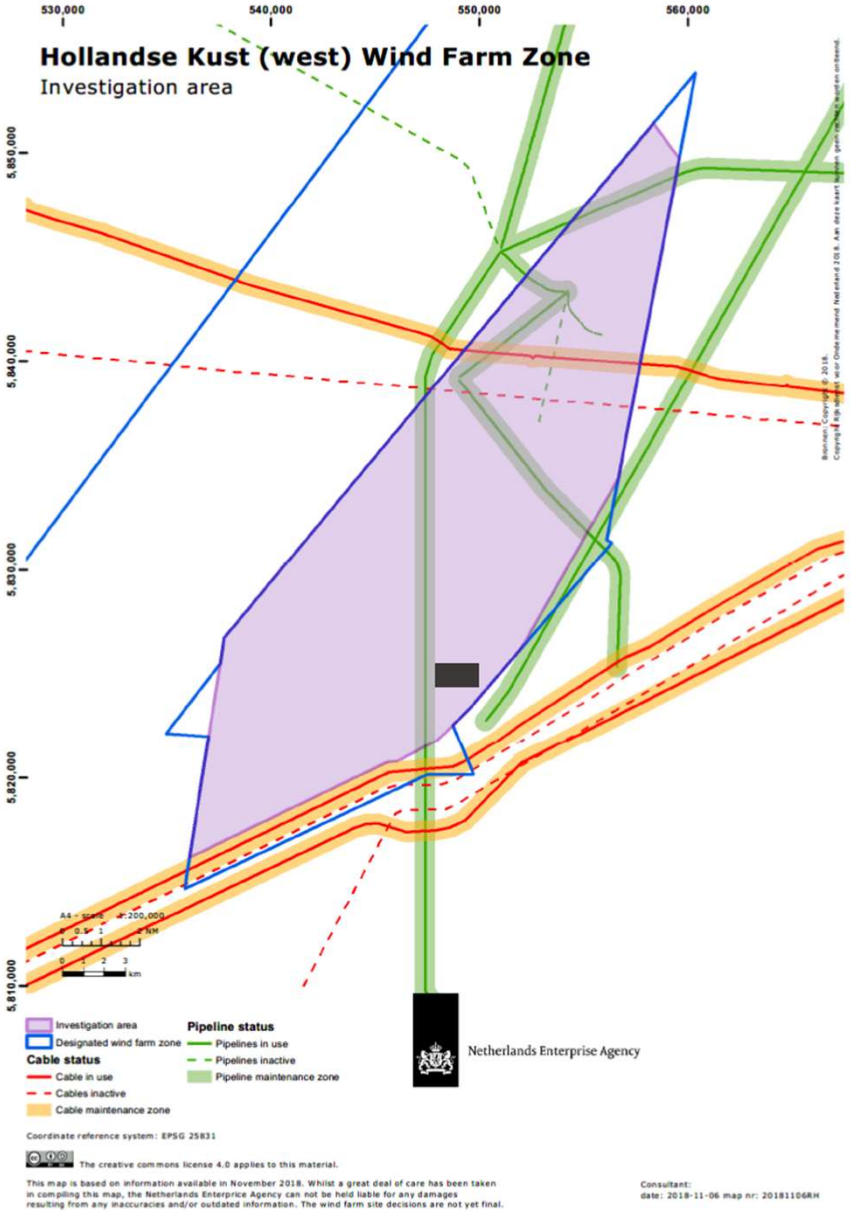
The resulting dataset should allow developers to **reduce the uncertainties in the metocean conditions** and;

Carry out more accurate calculations of the annual energy yield;

Calibrate and/or validate metocean models available for the wind farm design.

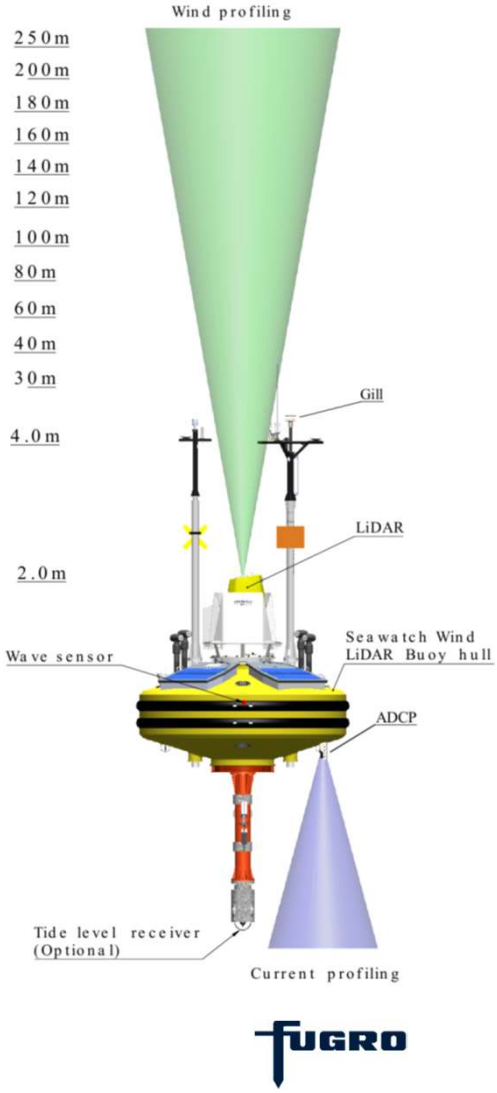
Project Location

- 2 Seawatch Wind LiDAR Buoys deployed in parallel
- 3 stations: HKWA, HKWB, HKWC
- Data collected from February 2019 onwards
- Buoys were deployed approximately 15 NM offshore
- Water depths of 22 m and 30 m



Parameters observed

- Wind at 11 elevations up to 250 m
  - Speed
  - Direction
  - Turbulence intensity
  - Inflow angle
  - Wind shear/veer
- Wave
  - Height
  - Period
  - Direction
- Current profile down to 22 m / 30 m
- Water temperature
- Atmosphere
  - Pressure
  - Humidity
  - Temperature
  - Wind speed (mast top, 4m)
- Water level or relative tide

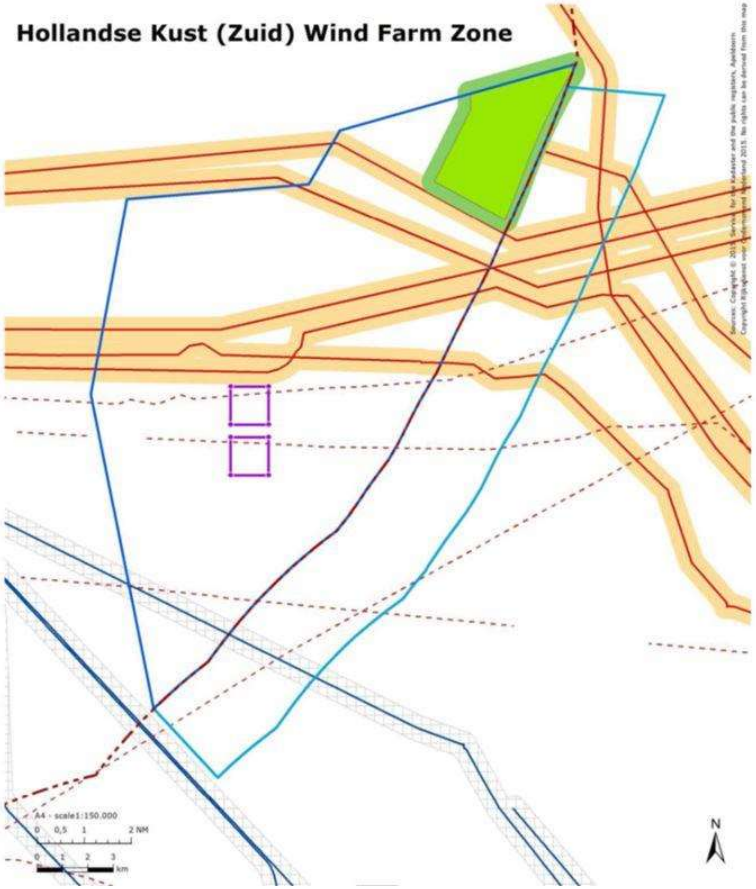


HKZ – RVO - June 2016 – June 2018

2 SeaWatch Wind LiDAR buoys deployed

Parameters:

- Mooring at 23 m water depth
- Wave height, period and direction
- Current profile (22 m) and water temperature
- Wind speed and direction at 11 elevations
- Air pressure
- Air humidity and temperature
- Water level (tide)



Wind observations

Wind speed and direction, turbulence intensity, inflow angle and wind shear/veer

HKN – RVO - April 2017 – April 2019

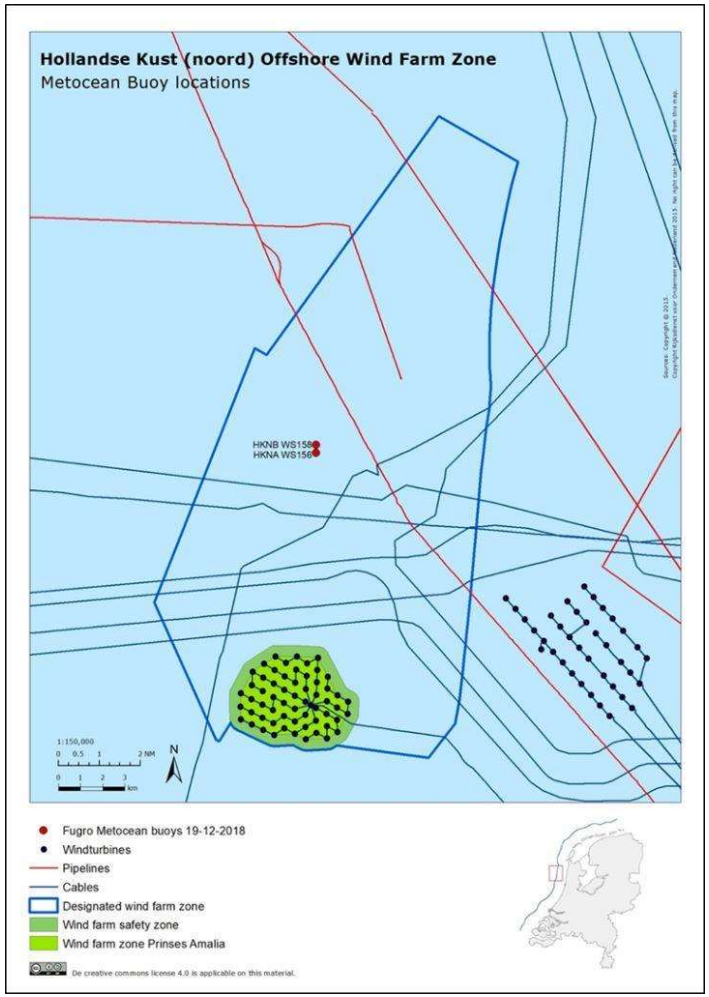
2 SeaWatch Wind LiDAR buoys deployed

Parameters:

- Mooring at 23 m water depth
- Wave height, period and direction
- Current profile (22 m) and water temperature
- Wind speed and direction at 11 elevations
- Air pressure
- Air humidity and temperature
- Water level (tide)

Wind observations

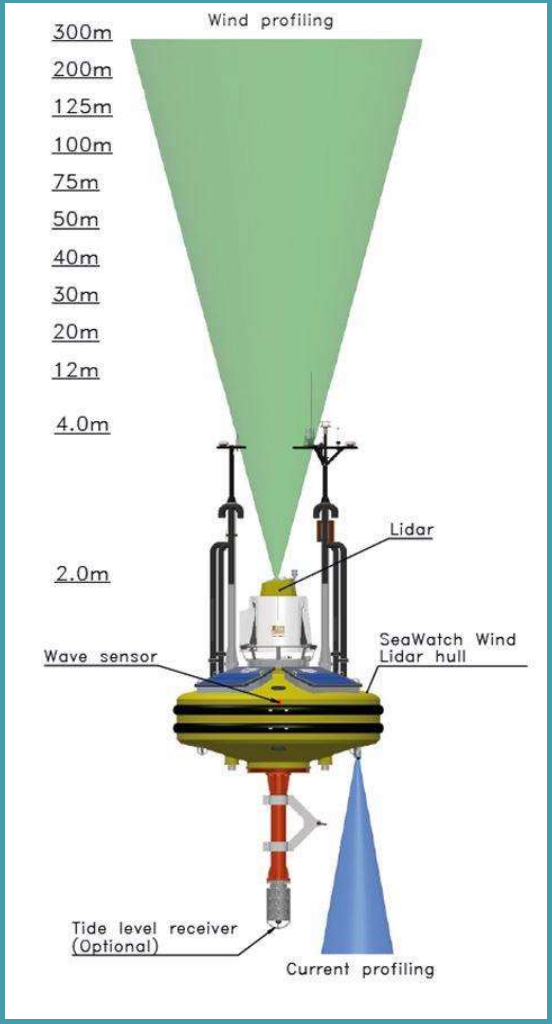
Wind speed and direction, turbulence intensity, inflow angle and wind shear/veer



Fugro SEAWATCH Wind LiDAR Buoy

Building upon proven technology:

A compact, proven measurement buoy that includes wind profile, waves, current profile, and meteorology



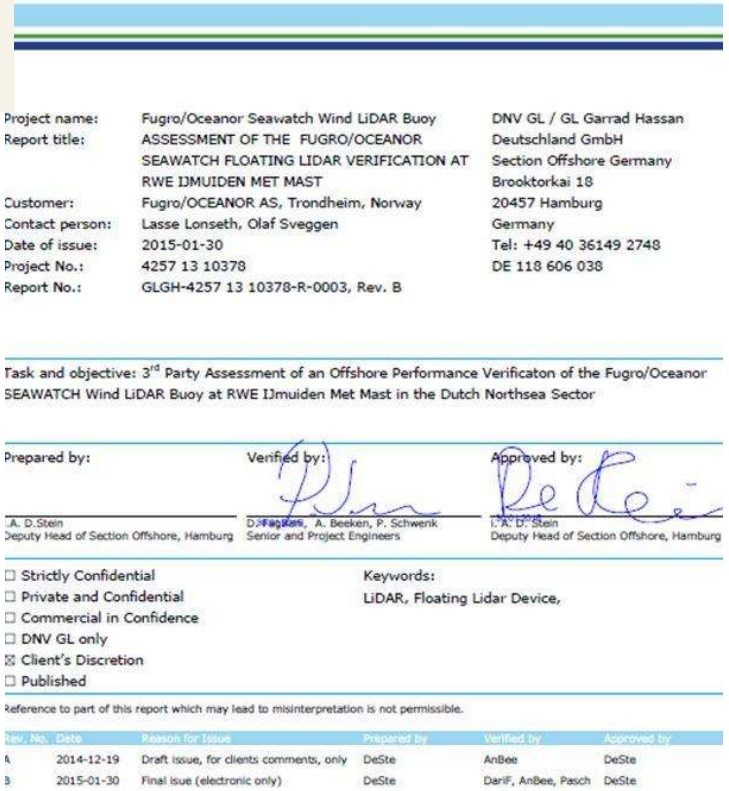
Replaces Conventional Met Masts

High reduction in:

- Construction time before first data
- Foundations complexities
- Difficulties to access and crew transfer (safety)
- High cost of design, installation and maintenance

SEAWATCH Wind LiDAR Buoy - Approval Pre-commercial

DNV GL Pre-commercial approval certificate for 2014-2015 validations



Project name:	Fugro/Oceanor Seawatch Wind LiDAR Buoy	DNV GL / GL Garrad Hassan
Report title:	ASSESSMENT OF THE FUGRO/OCEANOR SEAWATCH FLOATING LIDAR VERIFICATION AT RWE IJMUIDEN MET MAST	Deutschland GmbH Section Offshore Germany Brooktorkai 18
Customer:	Fugro/OCEANOR AS, Trondheim, Norway	20457 Hamburg
Contact person:	Lasse Lonseth, Olaf Sveggen	Germany
Date of issue:	2015-01-30	Tel: +49 40 36149 2748
Project No.:	4257 13 10378	DE 118 606 038
Report No.:	GLGH-4257 13 10378-R-0003, Rev. B	

Task and objective: 3rd Party Assessment of an Offshore Performance Verificaton of the Fugro/Oceanor SEAWATCH Wind LiDAR Buoy at RWE IJmuiden Met Mast in the Dutch Northsea Sector

Prepared by:	Verified by:	Approved by:
A. D.Stein Deputy Head of Section Offshore, Hamburg	D. Fagerli, A. Beeken, P. Schwenk Senior and Project Engineers	I. A. D. Stein Deputy Head of Section Offshore, Hamburg

- ☐ Strictly Confidential
- ☐ Private and Confidential
- ☐ Commercial in Confidence
- ☐ DNV GL only
- ☒ Client's Discretion
- ☐ Published

Keywords:
LiDAR, Floating Lidar Device,

Reference to part of this report which may lead to misinterpretation is not permissible.

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	2014-12-19	Draft issue, for clients comments, only	DeSte	AnBee	DeSte
B	2015-01-30	Final isue (electronic only)	DeSte	DariF, AnBee, Pasch	DeSte

"An evaluation of the Fugro/Oceanor SWL Buoy floating LiDAR system was completed by comparing its measurements against data from the IEC-compliant IJmuiden met mast. Sufficient data were collected to allow an assessment in line with the Roadmap. In the IJmuiden offshore trial very encouraging results were indeed obtained. DNV GL concludes that the FO SWL Buoy system has demonstrated its capability to produce accurate wind speed and direction data across the range of sea states and meteorological conditions experienced in this trial (i.e. up to about 5.8 m significant wave height and 9.8 m maximum wave height and 10 min averaged wind speeds up to 26 m/s). Furthermore, it has recorded excellent availability throughout the 6 month period and demonstrated structural survivability in the met-ocean conditions present from early spring."

Seawatch Wind LiDAR buoy – Sensors

Parameter	Manufacturer and Model
Wave height, period and direction:	Fugro WaveSense 3
Current profile and water temperature:	Nortek Aquadopp Profiler 600 kHz
Wind speed and direction:	Gill Windsonic
Wind speed and direction profile:	ZephIR 300 LiDAR
Air pressure:	Vaisala PTB330
Air humidity and temperature:	Vaisala HMP155
Water level (Tide):	Thelma Water Level Sensor

Seawatch Wind LiDAR buoy – Redundancy & backup

Power

- 4 independent fuel cells and compartments
- 3 different sources (fuel cells, solar panels, lithium batteries)
- 9 months autonomy

Equipment/Sensors

- 3 different compasses + DGPS
- 2 Met stations (1 on the LiDAR + 1 in the mast)

Data Collection

- Raw wind data (10 min average + scanning frequency/pattern of Zephir LiDAR (1 Hz)) stored internally in the LiDAR + in onboard datalogger
- Raw current data stored internally in the current meter + in onboard datalogger
- Raw wave data stored internally in the wave sensor (= onboard datalogger)
- Raw and processed wind data (10 min average + 1 Hz) stored in the datalogger
- All other data stored in the datalogger
- All 10 min data transmitted to shore in real time

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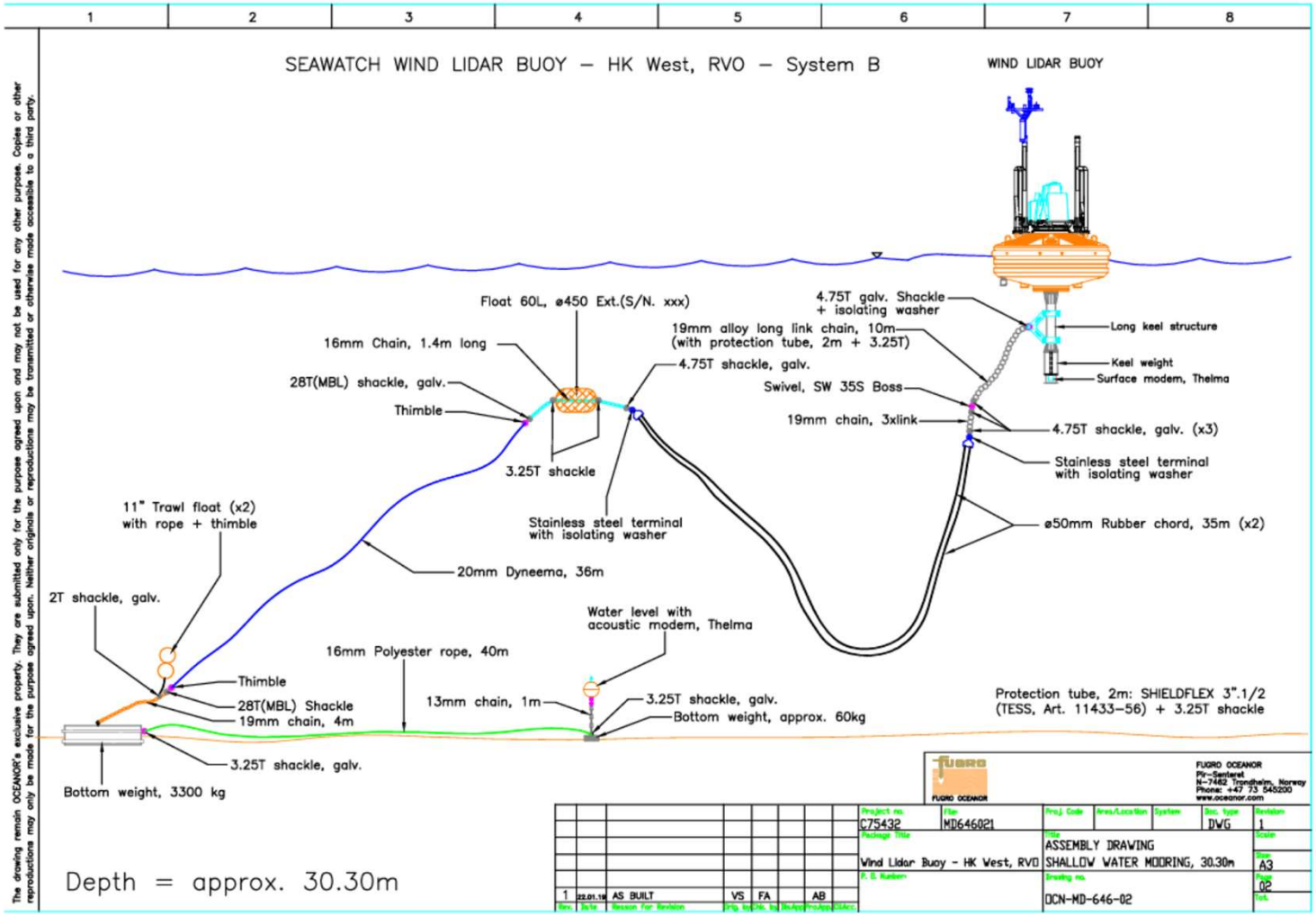
Seawatch Wind LiDAR buoy – Mooring



Quality Assurance

Of the system and collected metocean data

Quality Assurance

Measurement System Quality

- Offshore Wind Accelerator (Carbon Trust - OWA) Type Validated Pre-commercial stage system according to OWA roadmap
- Manufacturing according to ISO standard ISO9001 compliance since 1985, ISO9001:2008
- Factory calibrated sensors - LiDAR onshore validated against UK met mast
- Factory Acceptance Test
- OWA Unit Validated Pre-deployment system validation – min 40 measurements in each wind class

Data Validation

- Comparison with nearby similar measurements (wind and waves) performed by Deltares

Double Measurements

- Comparison between two SWLB as one redundant system

SeaWatch Wind LiDAR Buoy - Validation process

Pre-Commercialisation validation	LIDAR Supplier validation	Project validation	Project validation
OWA Type Validation Approval by DNV GL: (RWE) IJmuiden IEC-compliant met mast comparison 2014 (5.8m Hs 9.8m Hmax)	Pre-supply Approved by DNV GL: Pershore IEC met mast comparison, UK Each unit Completed	OWA Pre-Deployment Approved by DNV GL: Titran, Frøya 2019 Completed	Met, wave and current validations Deltares independent validation reports 2019 - ongoing

Deltares
Enabling Delta Life

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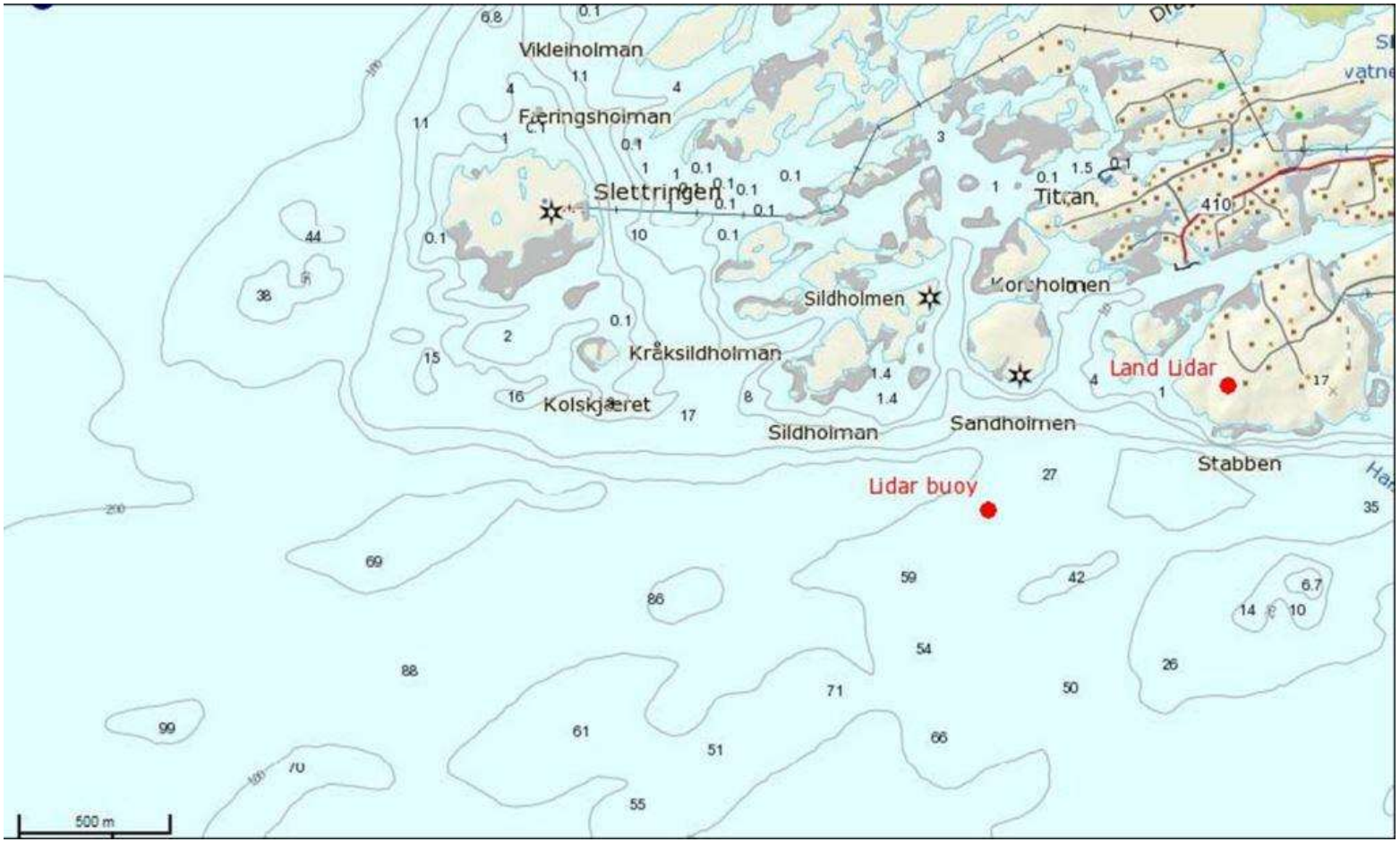
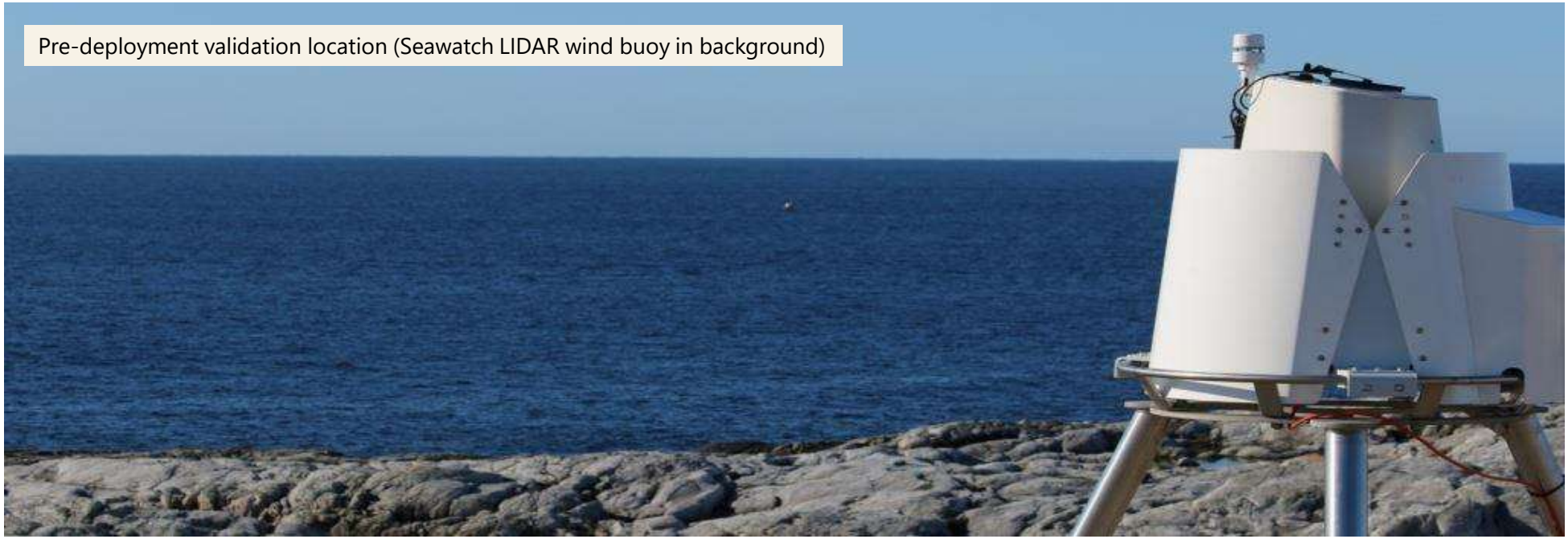
Pre/Post - deployment validation site: Titran, Frøya



Positions of SEAWATCH Wind LiDAR Buoy and Land LIDAR at the Island Frøya

Pre/Post - deployment validation – Titran, Frøya

- Pre- and post validation site approved by DNVGL
- Onshore LiDAR reference at Stabben Fort is established; standard anemometry reference masts (NTNU [Norwegian University of Science & Technology]) available
- More than ten SWLB successfully validated at site since March 2015



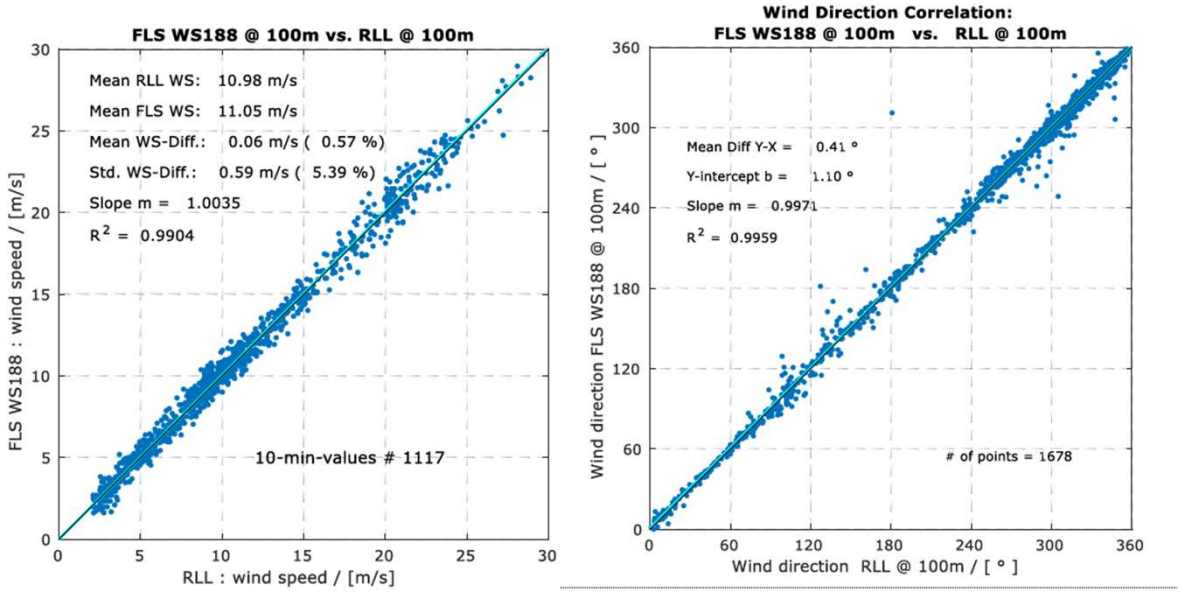
Pre-deployment validation location (Seawatch LIDAR wind buoy in background)

Wind LiDAR buoys – pre-deployment validation results

Mean Offset (OFF_{mwd}) accuracy for wind direction (WD) has been a significantly improved from Borssele, HKZ & HKN campaigns. Achieved by using a differential GPS as heading.

Buoy no	Validation period	Max WS
WS188	03/01 - 20/01/2019	25 – 33.3 m/s
WS187	04/01 - 21/01/2019	25 – 30.1 m/s
WS170 *	16/06 - 11/08/2019	23 – 28.6 m/s

* In situ validation at HKW



Correlation of LIDAR buoy and Land LIDAR for 100 m height (buoy WS188): Wind Speed (left) and Wind Direction (right)

Data reports

https://offshorewind.rvo.nl/windwaterw

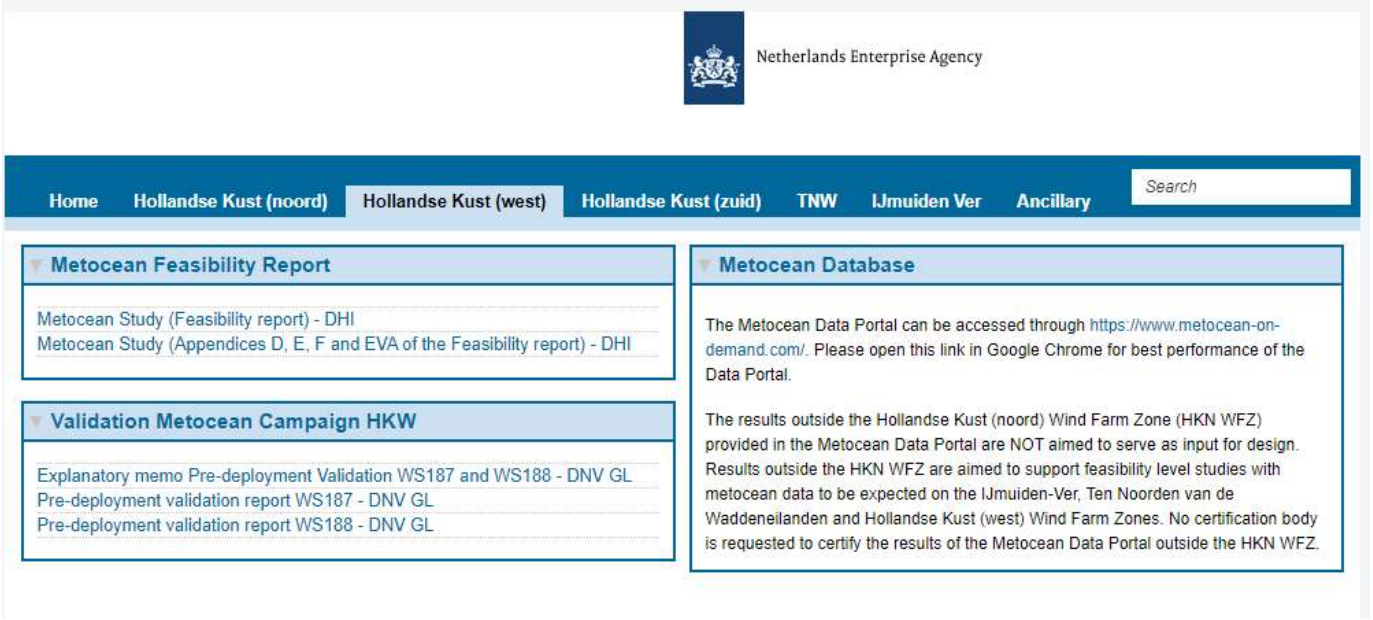
Data Set types

1st year Feb 2019 – Jan 2020:

- To be published soon
- Data & descriptive report (PDF)
- Deltares validation report (PDF)
- Raw data files (Excel)

2nd year Feb 2020 – Jan 2021:

- Monthly data and descriptive reports (PDF)
- Monthly validation reports (PDF)



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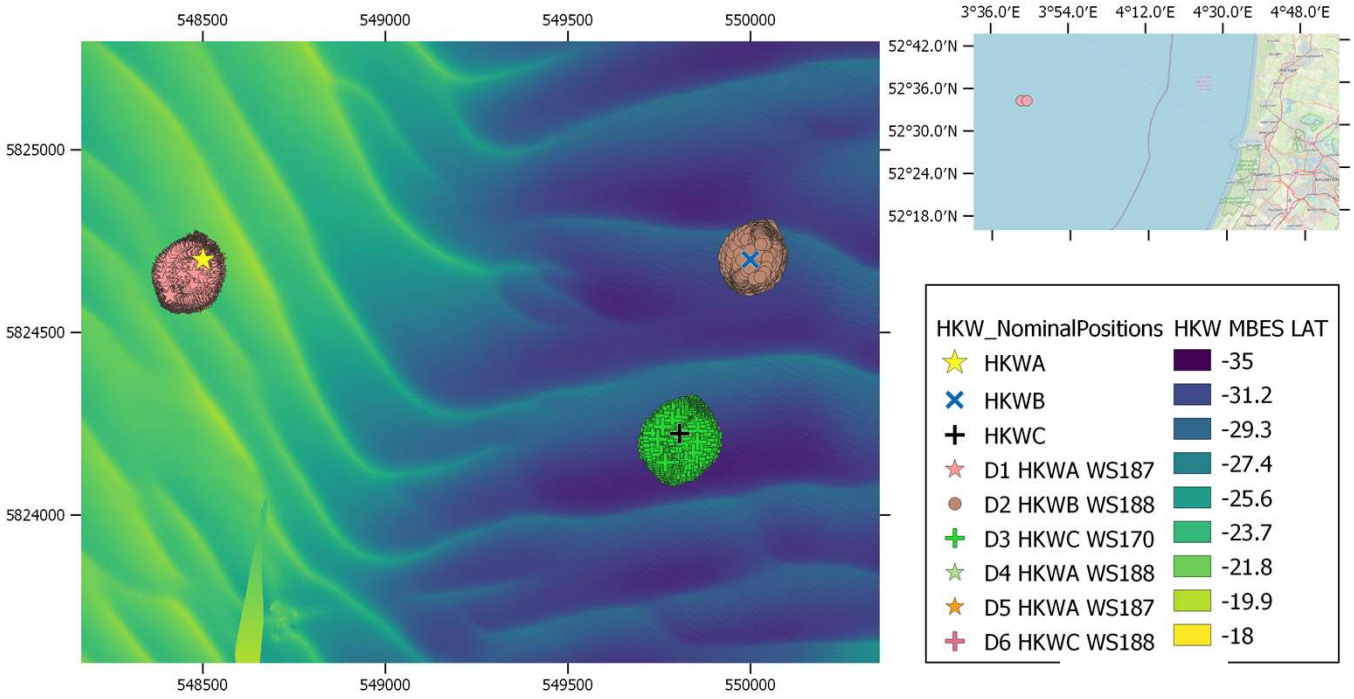
HKW Measurement Summary

Note: Year 1 report and data submission outstanding:

Preliminary discussion only

HKW Wind Farm Zone

- Two stations HKWA and HKWB established and maintained throughout the project since 2019
- 3rd station HKWC established in June 2019
- An operational backup system kept ready on shore
- High availability ensured by swapping the operational backup system with an active offshore station
- The active buoy then serviced on-shore and prepared as operational backup (‘leap frogging’)

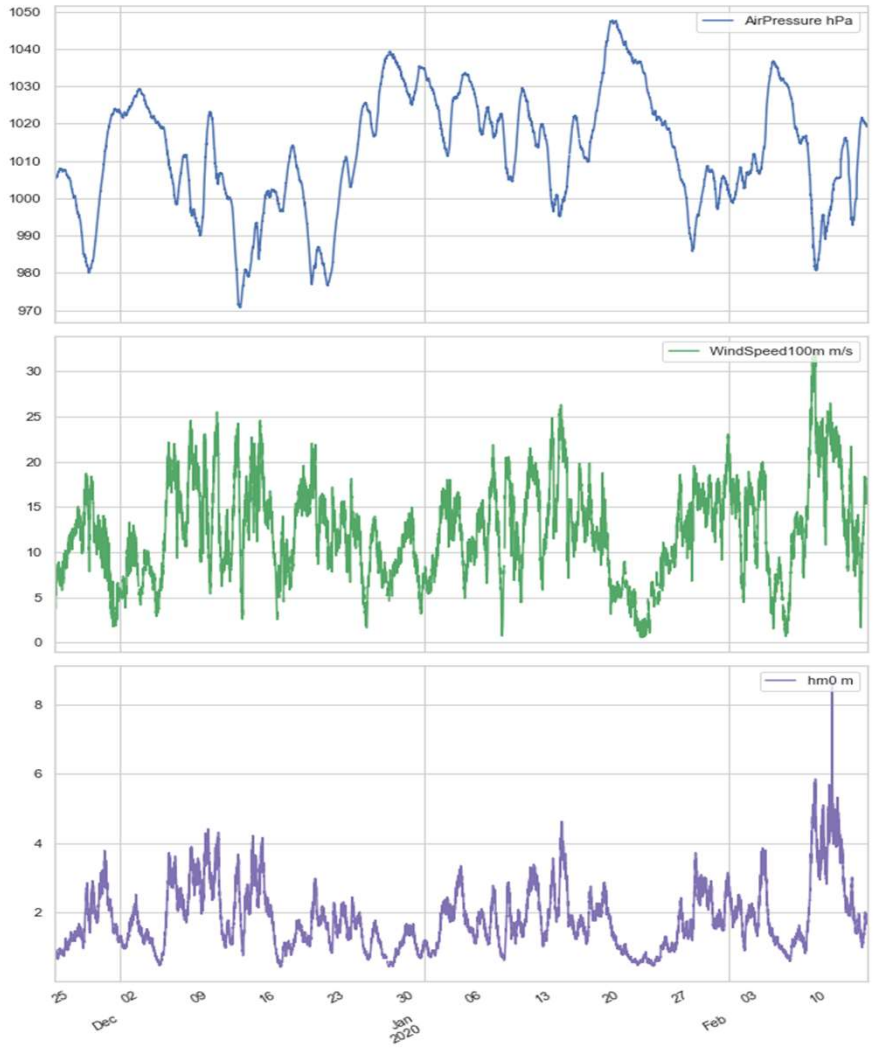


HKW Wind Farm Zone – Preliminary Results

Very good data return in spite of harsh conditions at site and winter-time challenges

6 deployments during year 1

Example data from deployment 5



HKW Wind Farm Zone – RVO 2019-2021 Preliminary Results Year 1

Environmental conditions experienced at HKW Wind farm

Parameter		Value	Date
Highest Significant Wave height	m	8.7	Feb 2020
Max wave height	m	10.0	Feb 2020
Highest 10 min Average Wind speed (30 m)	m/s	28.6	Feb 2020
Highest 10 min Average Wind speed (250 m)	m/s	39.7	Feb 2020

HKW Wind Farm Zone – Preliminary Results

% Data Return (system availability wind speed & direction, waves, currents, other)

	Wind	Waves	Water Level	Currents	Air Pressure	Temperature
D1	86.0	99.8	92.5	98.1	100.0	97.6
D2	81.1	99.0	94.6	80.4	100.0	89.4
D3	98.0	100.0	55.0	83.5	100.0	97.4
D4	64.1	99.9	90.6	100.0	100.0	99.4
D5	98.4	99.6	94.0	99.5	99.6	98.2
D6	32.6	98.8	94.9	98.2	99.0	96.9

Good data return in spite of harsh conditions at site and winter-time challenges

Operational Experience

Reasons for operations

All deployed buoys had their scheduled service visits for refueling but there were a number of occasions we had to perform some emergency response operations.

Friday the 7th of February 2020 we received a **drift alert that on of our buoys was gone adrift.** The buoy was recovered in Scheveningen and brought for service. After service, the buoy was made ready for redeployment.

Operational Challenges

Vessels and their challenges

- 8 third party vessel hired
- On average vessels were on hire for 2 days
- Spot market vessel availability is not always guaranteed
- Suitability of vessel equipment was not always guaranteed
- Crew was sometimes unfamiliar with equipment and intended operations
- COVID-19 challenges

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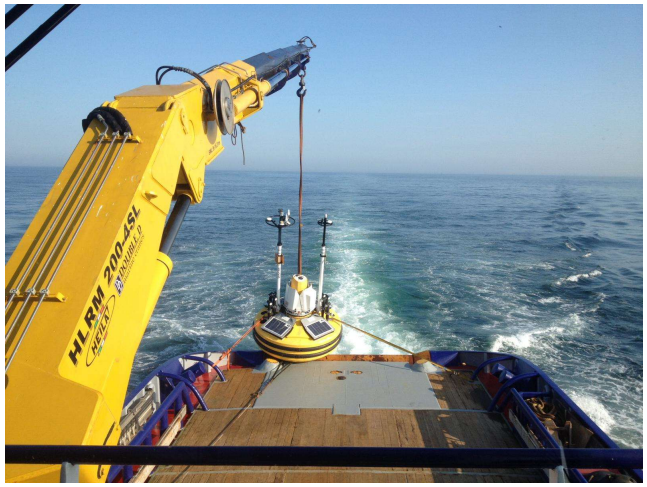
Operational Challenges

Maintenance & emergency response operations

- Weather windows were usually narrow (max. 1m wave and 20 knt windspeed)
- Fast-track mobilisation
- Fast-track familiarisation with Fugro HSSE principles
- Fast-track introduction to project specifics
- Lifting operations and guidelines
- Availability of safety equipment on the vessels
- Remote support due to COVID-19



Operational challenges overcome

Results

- 7 successful operational site visits
  - Suitable vessels available
  - Goals achieved
  - Safe operations: No injuries
  - No or only minor damage to equipment
- 1 unsuccessful operational site visit
  - During mobilisation LiDAR failure
- Numerous improvements on;
  - Crew safety
  - Equipment and Procedures
  - Fast-track of third party hire
  - Communication with stakeholders
  - Trained service engineers based in the Netherlands

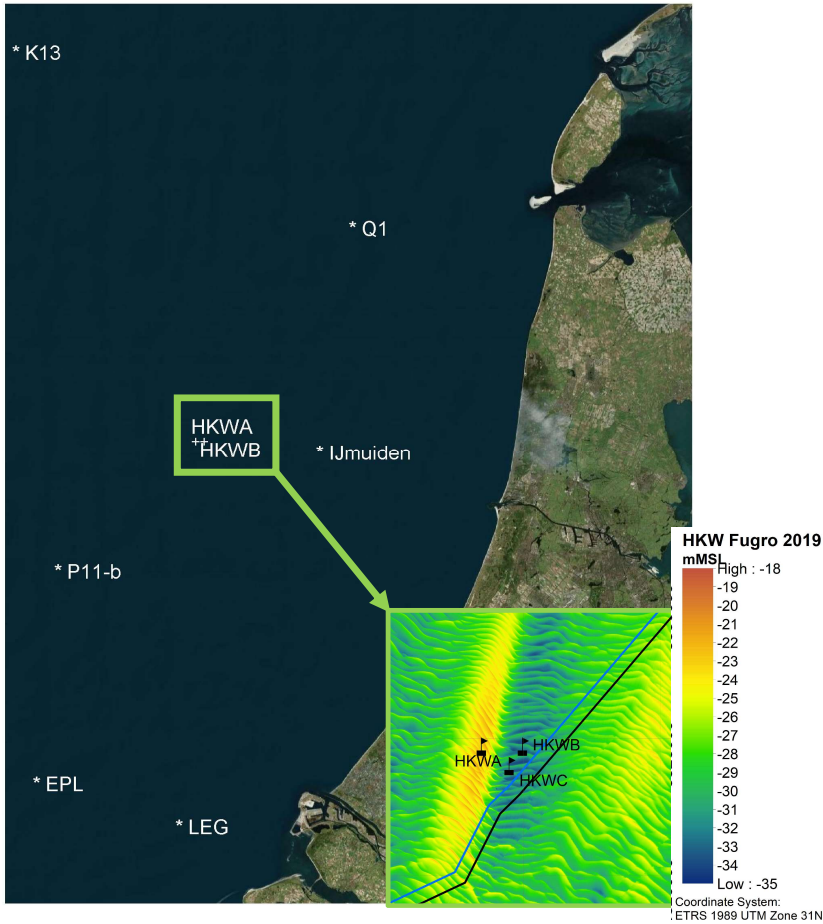
Data evaluation - Deltares

HKW – Field Data Validation: Approach

HKWA, HKWB and HKWC observations validated

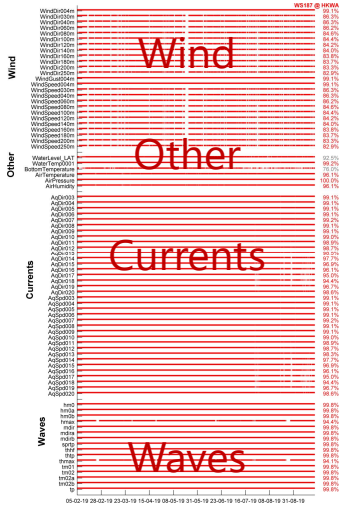
Wind, waves, air and water temperature, air pressure, water levels and currents validated by intercomparing (HKWA vs HKWB or HKWC) in overlapping periods and against reliable observations from fixed North Sea stations (see map), 3D hydrodynamic model results and reanalysis (ERA5) wind and wave data.

The quantitative assessments are enhanced with qualitative assessments of general data characteristics, such as vertical profiles of the wind and current speeds.

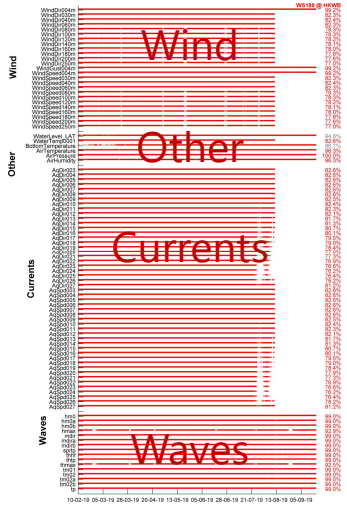


HKW – Field Data Validation: Availability

D1&D2
Redundant arrangement leads to almost 100% availability

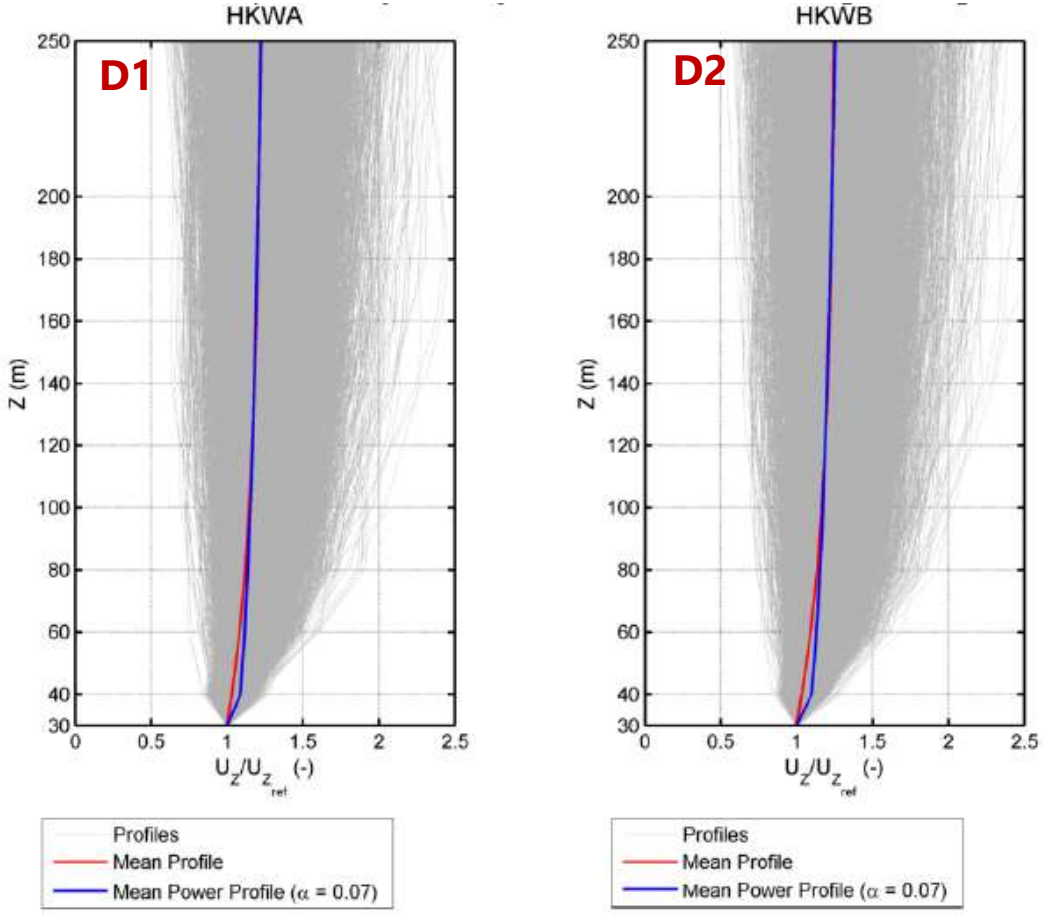


D1: HKWA (WS187) 5/2/2019 – 21/9/2019



D2: HKWB (WS188) 10/2/2019 – 19/9/2019

HKW – Field Data Validation - Wind



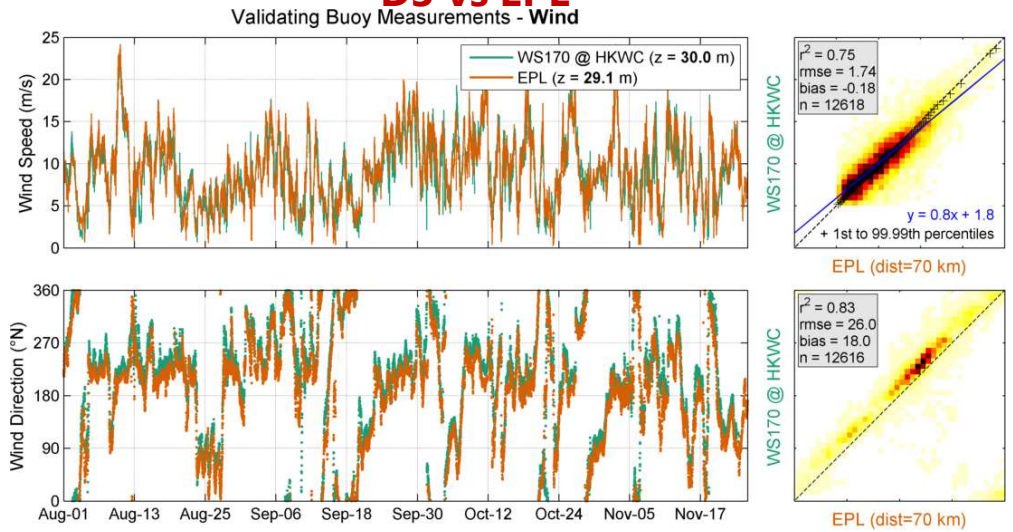
D5 vs D6

Table 3.3: Statistical comparison between the winds from the buoys HKWA (D5) and HKWC (D6) with elevation (from 18-Dec-2019 09:20:00 until 07-Feb-2020 18:40:00).

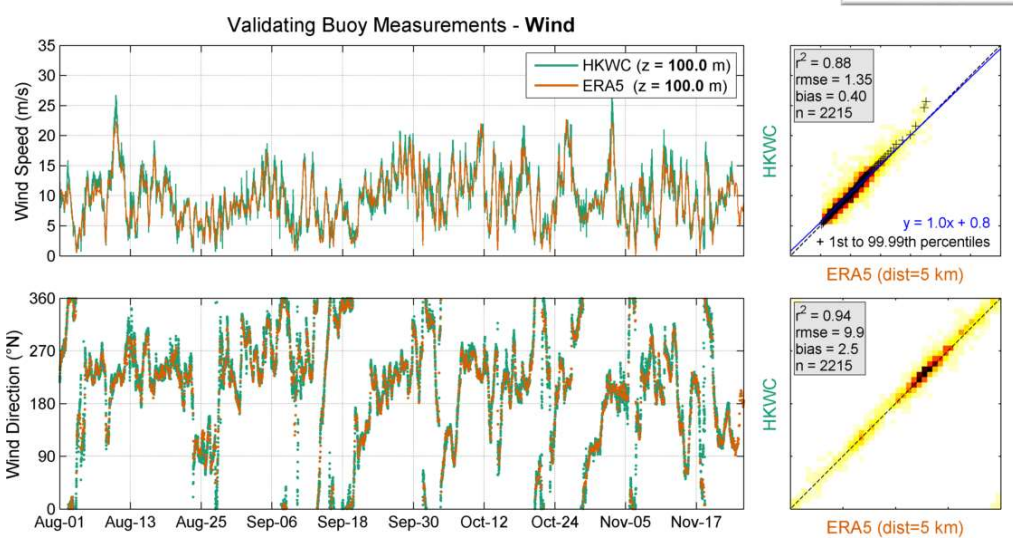
	Wind Speed				Wind Direction		
Elev. (m)	r^2 (-)	Bias (m/s)	Sym. Slope (-)	n (-)	r^2 (-)	Bias (°N)	n (-)
4	0.98	-0.04	1.00	7017	0.98	-0.5	7017
30	0.97	0.00	1.00	1909	0.99	1.4	1909
40	0.98	-0.00	1.00	1913	0.99	1.4	1913
60	0.98	-0.00	1.00	1911	0.99	1.5	1911
80	0.98	-0.01	1.00	1838	0.99	1.4	1838
100	0.99	0.02	1.00	1839	0.99	1.4	1839
120	0.99	0.02	1.00	1838	0.99	1.3	1838
140	0.99	0.03	1.00	1845	0.99	1.3	1845
160	0.99	0.02	1.00	1847	0.99	1.3	1847
180	0.99	0.03	1.00	1839	0.99	1.2	1839
200	0.99	0.02	1.00	1841	0.99	0.9	1841
250	0.99	0.00	1.00	1830	0.97	0.6	1830

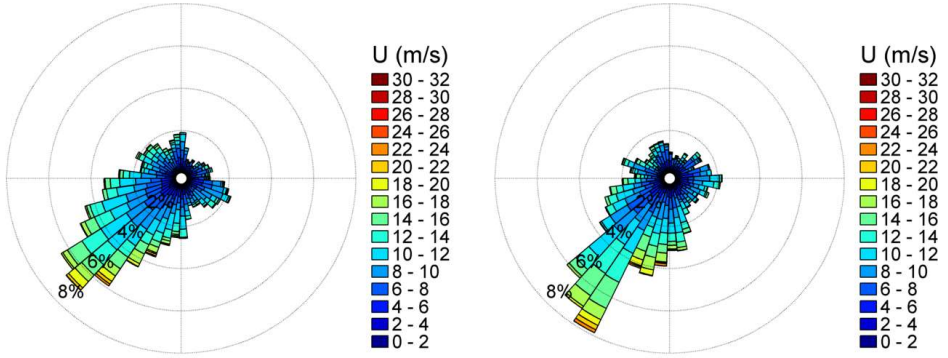
HKW – Field Data Validation - Wind

D3 vs EPL



D3 vs ERA5





WS170 @ HKWC (z = **30.0** m)

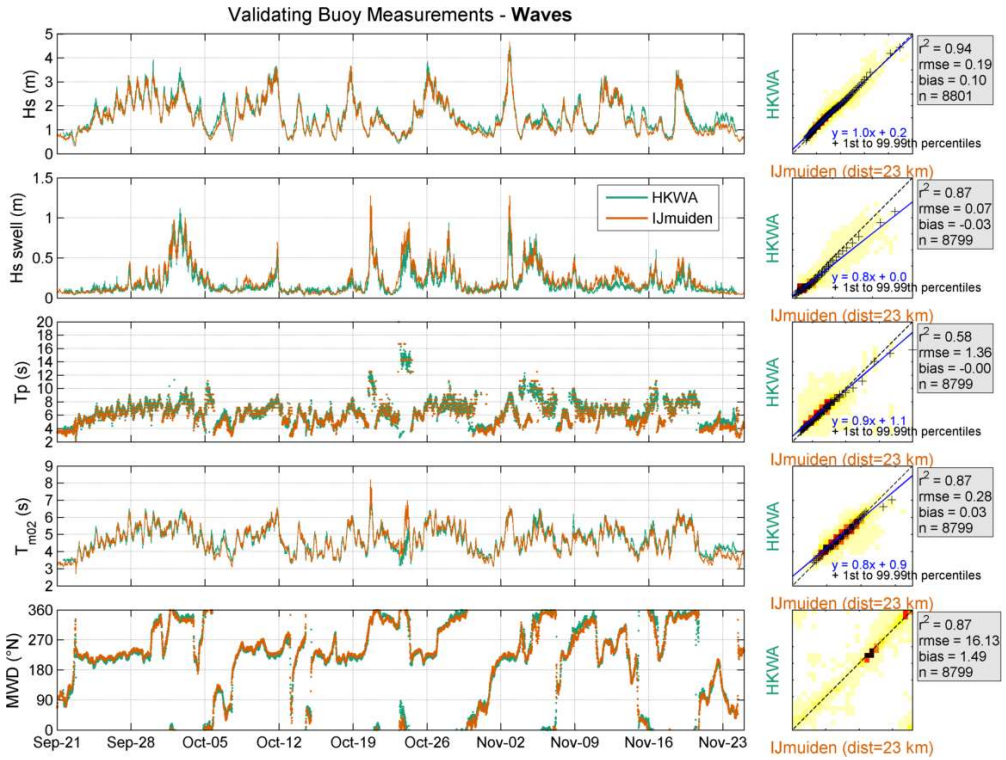
EPL (z = **29.1** m)

HKWA, HKWB & HKWC Wind Speed & Direction show very strong correlations

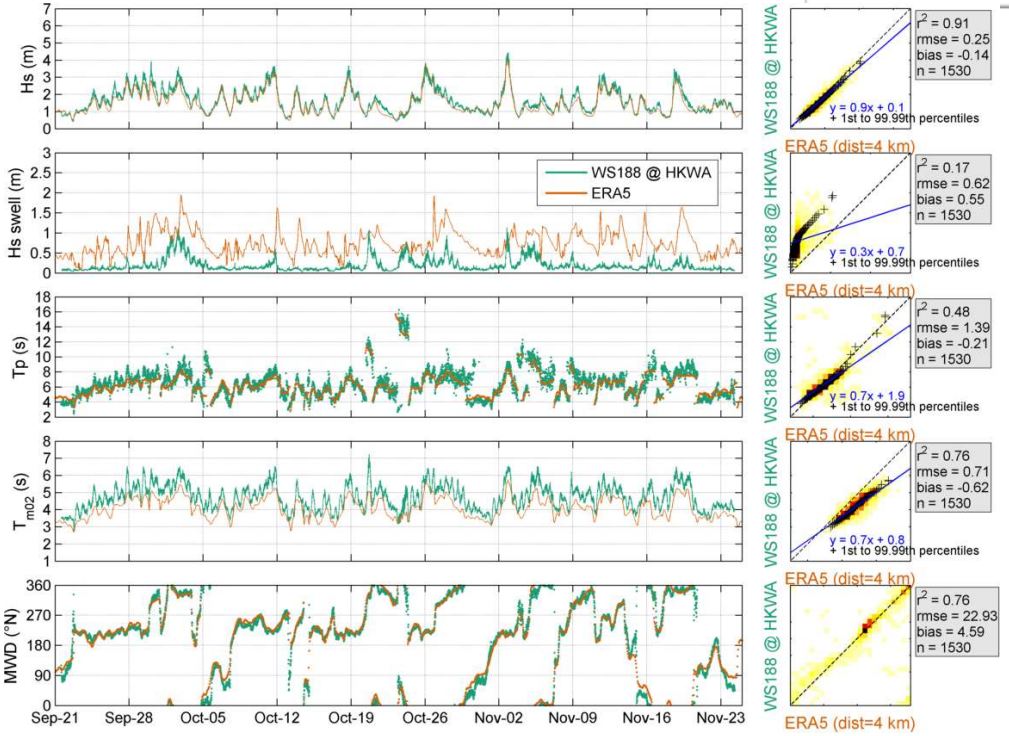
- **vs reference stations: Q1, EPL, LEG, K13 (anemometer & LiDAR) and**
- **vs ERA5**

HKW – Field Data Validation - Waves

D4 vs IJmuiden

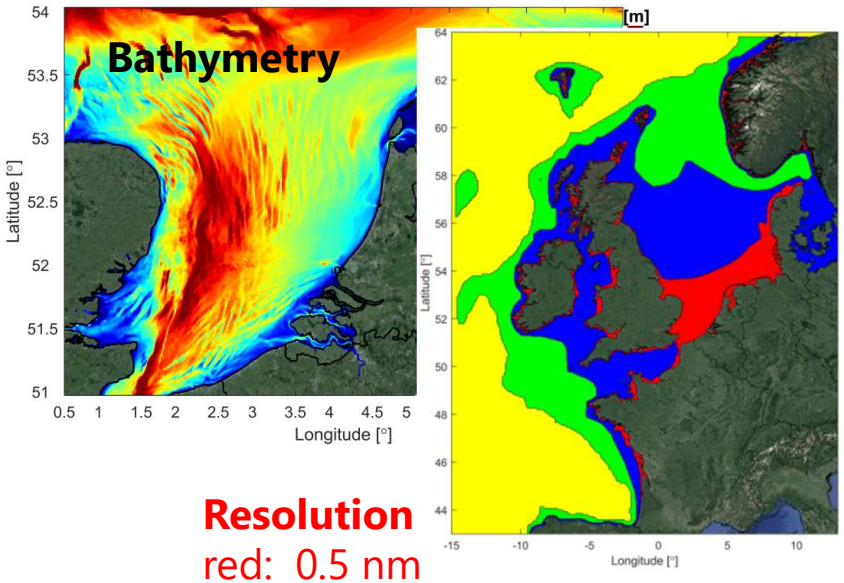


D4 vs ERA5



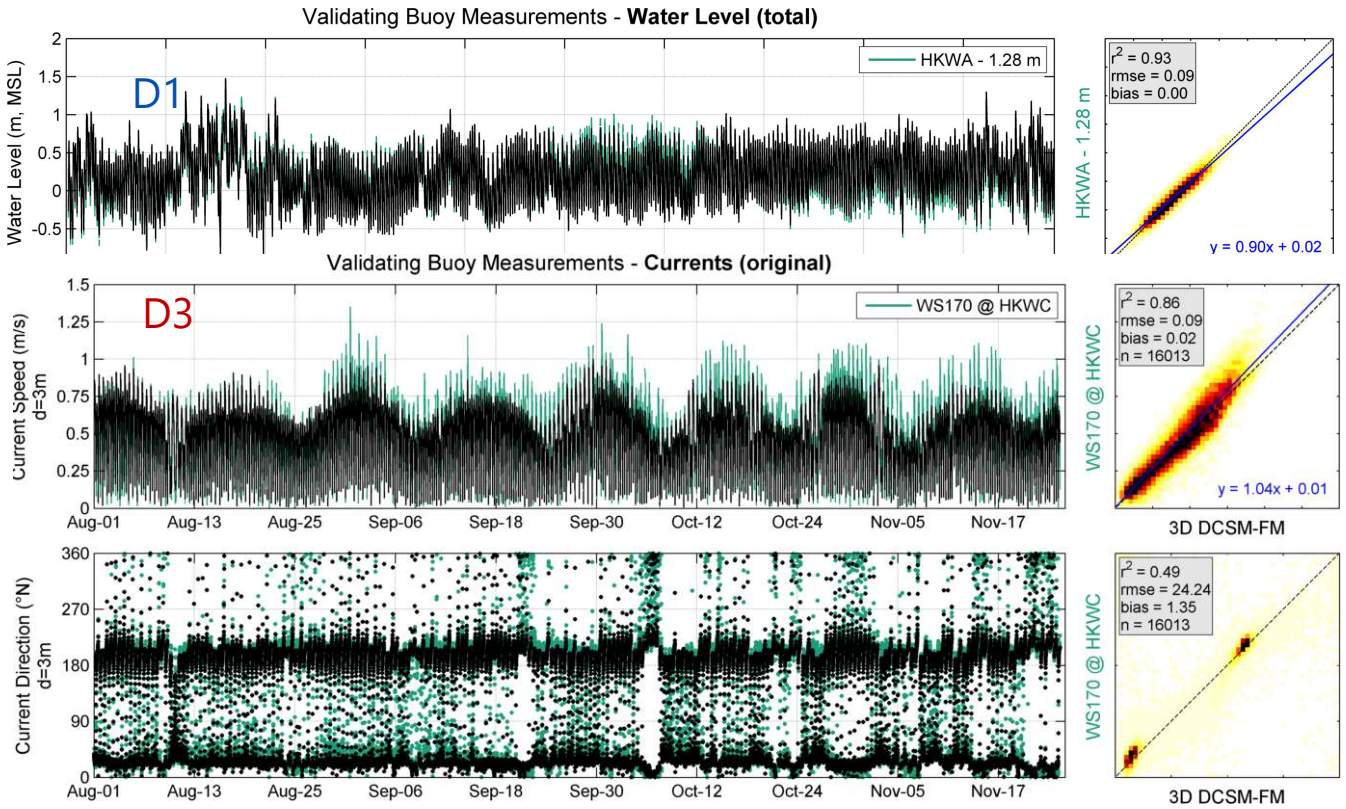
HKWA, HKWB & HKWC waves
show very strong correlations
vs reference stations: Q1, EPL, K13, and IJmuiden
And vs ERA5

HKW – Field Data Validation - Currents and water levels



Resolution
red: 0.5 nm
20 vertical layers

Deltares Delft3D Flexible Mesh – Dutch Continental Shelf model (DCSM-FM) run purposely for these validations



Closing Remarks

HKW Deltares Validation Assessment - preliminary

The overall conclusion of the validation is that the quality of the HKW data is high and the dataset trustworthy.

This makes the dataset, which is rather comprehensive, including vertical wind and current profiles and directional wave spectra, relatively useful and of interest for site study analyses.

Together we create a safe and liveable world

Thank you for your time

Fugro Team

Webinar RVO October 2020

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Netherlands Enterprise Agency

Closing the webinar

Please fill in the questionnaire

You can watch this webinar again and download the powerpoint presentation and the list with questions and answers from: https://offshorewind.rvo.nl

Thank you for participating in this webinar

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