Netherlands Enterprise Agency

Webinar Metocean Desk Study and database

Hollandse Kust (west) Wind Farm Zone

15 October 2020

Matté Brijder

Welcome

- Introduction of the webinar
- Presentation of Metocean Desk Study and database by Natacha Fery (DHI A/S)
- Chat for questions by expert panel: Maziar Golestani (DHI A/S), Miriam van Endt (Blix Consultancy) and Marco Westra (Metocean Consult)

This presentation is prepared for RVO and intended to be used in the webinar on
THURSDAY, 15 OCTOBER 2020 | 9:30 – 10:30 CEST

Metocean Desk Study and database for Hollandse Kust (west)

Natacha Fery

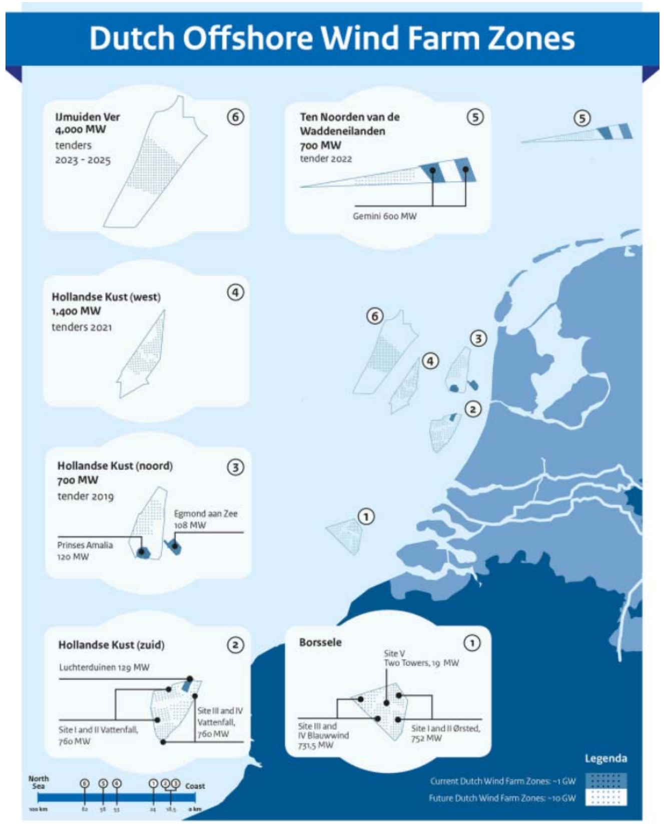
Metocean Engineer
Ports and Offshore Technologies
DHI A/S

DHI

Before we start ...

- Previous metocean desk studies for **Borssele**, **Hollandse Kust (zuid)** and **Hollandse Kust (noord)** Offshore Wind Farm Zones
- Feasability study for Hollandse Kust (west) in 2019 => **NOW replaced** by detailed design study in 2020
- **What is new now?**
  - high-resolution modelling in HKW
  - new bathymetry at site and in the Dutch waters
  - longer time series => **01.01.1979 to 01.01.2020**

https://offshorewind.rvo.nl/windwaterw



Source: www.government.nl/topics/renewable-energy/offshore-wind-energy

Some important information...

- The results of this metocean desk study are meant to be used as input for **design**, **installation** and **maintenance** of offshore wind farms at Hollandse Kust (west)
- Please refer to the Wind Resource Assessment results for **yield analysis**
- **State-of-the-art** methods in accordance with offshore standards
- World's first **certified** web-based metocean database

https://offshorewind.rvo.nl/windwaterw

Webinar Agenda

01

Introduction to DHI A/S & the team

02
MetOcean data

- Wind
- Waves
- Currents
- Water Levels

03
Modelling activities

- Hydrodynamic
- Waves

04
Analyses

- Operational
- Extremes

05
Web-based Database

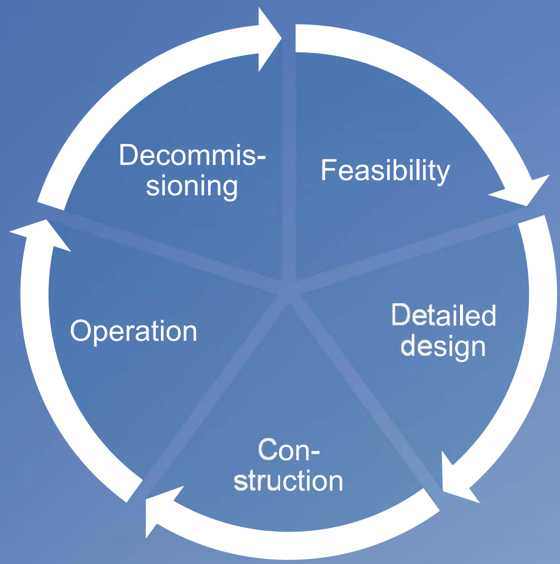
- Website
- API

01.

Introduction to DHI A/S

Who are we?

- We're an independent, private and not-for-profit organisation
- DHI A/S has been **pioneer** in offshore wind since 1991 when the world's first offshore wind farm was constructed in Denmark
- DHI A/S has **supported a significant number of offshore wind projects** in Europe and elsewhere
- DHI A/S is heavily involved in R&D related to offshore wind (reduction of risks and optimization)



"More than 85% of all offshore wind farms in the world have had a DHI input"

The team leads involved in Hollandse Kust (west) Metocean Desk Study

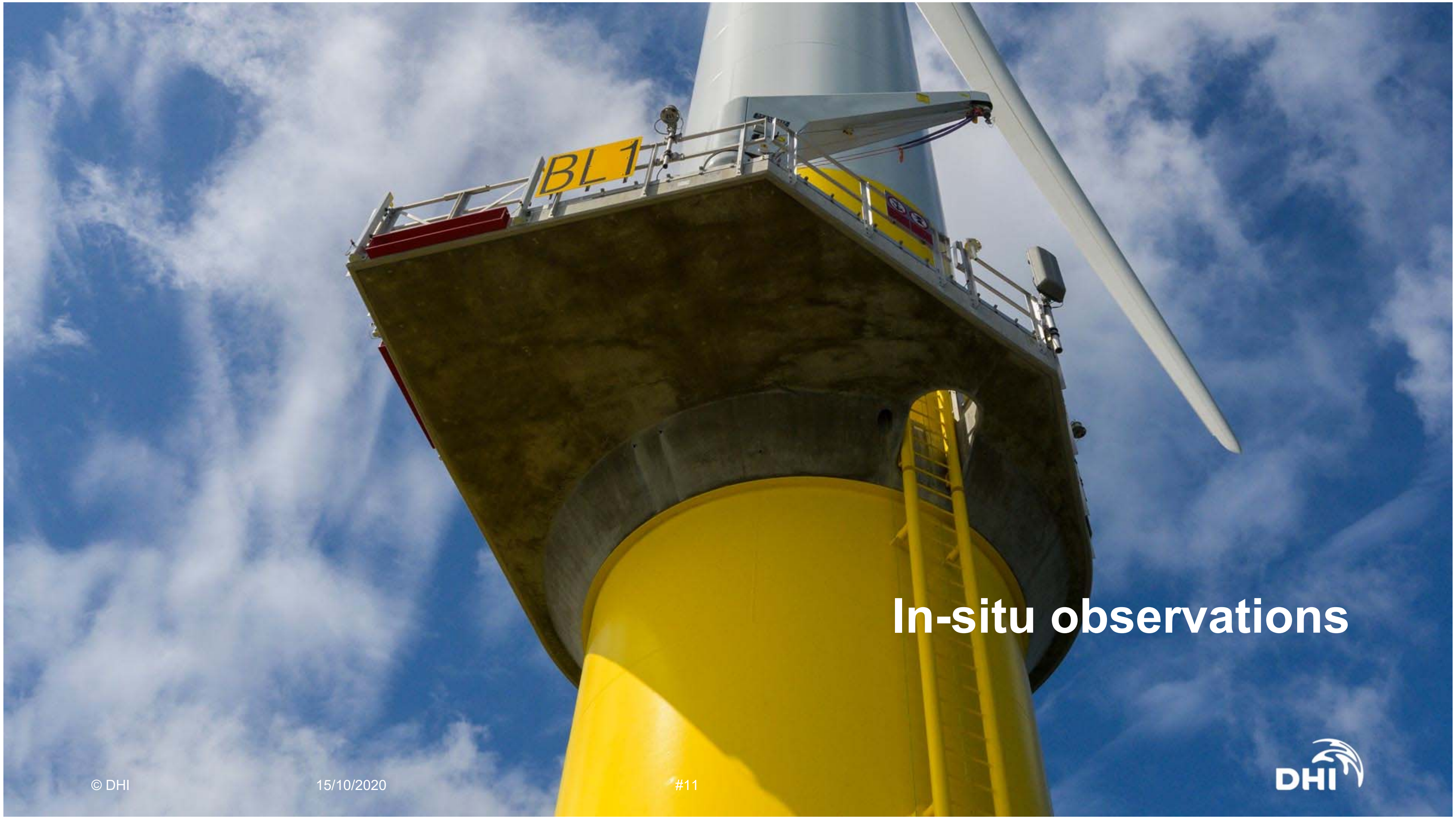
Natacha Fery
Metocean Engineer
Ports and Offshore Technologies

Maziar Golestani
Head of Department
Ports and Offshore Technologies

02.

Metocean data

In-situ observations

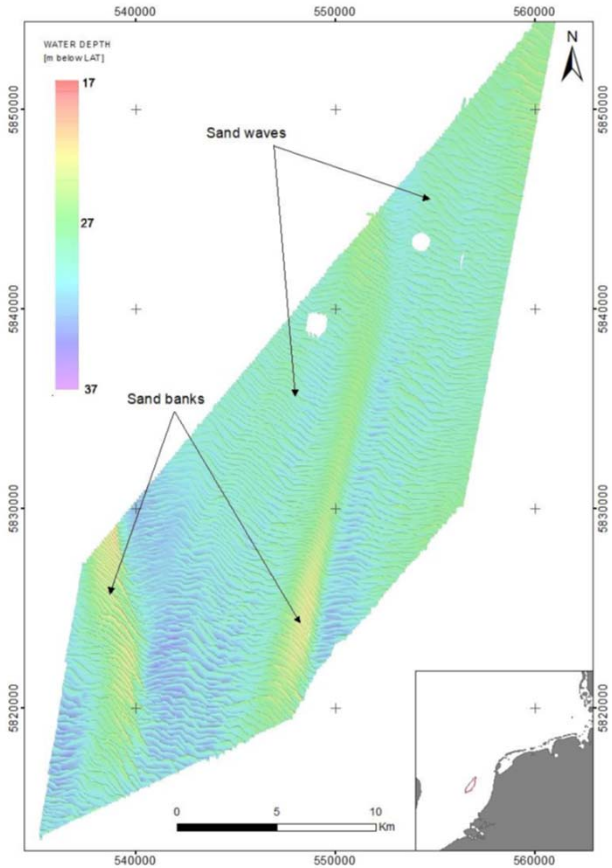


In-situ data 1/2 - **Bathymetry**

- **Various sources**

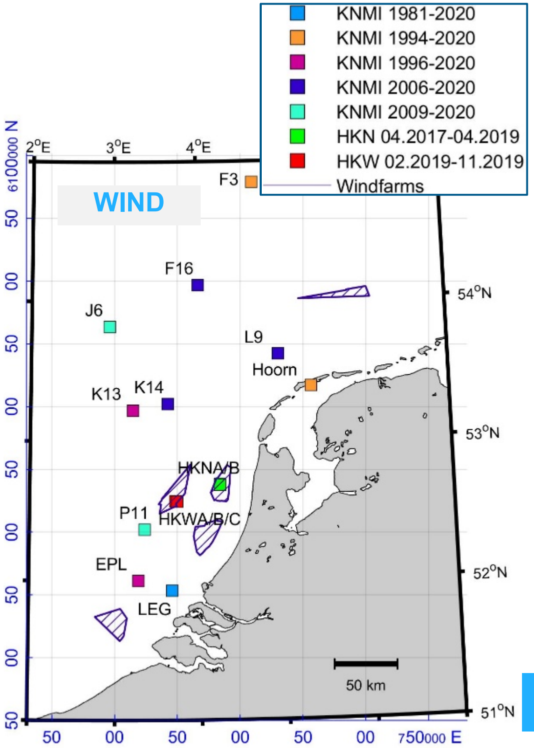
1. Geophysical survey by Fugro at Hollandse Kust (west)
2. Geophysical survey by Fugro at Hollandse Kust (noord)
3. Geophysical survey by Fugro at Hollandse Kust (zuid)
4. Vaklodingen by Rijkswaterstaat
5. EMODnet v2018 **(now replacing EMODnet v2016)**

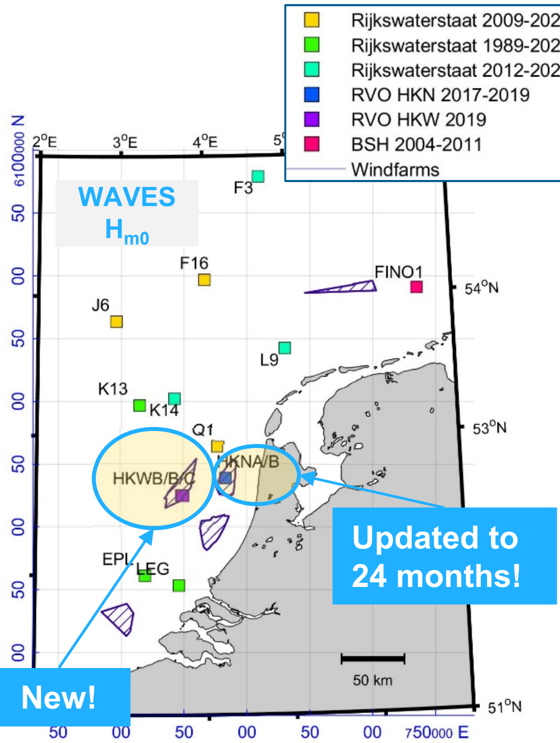
- Site characterized by **two sand banks**, **sand waves** and **mega ripples**

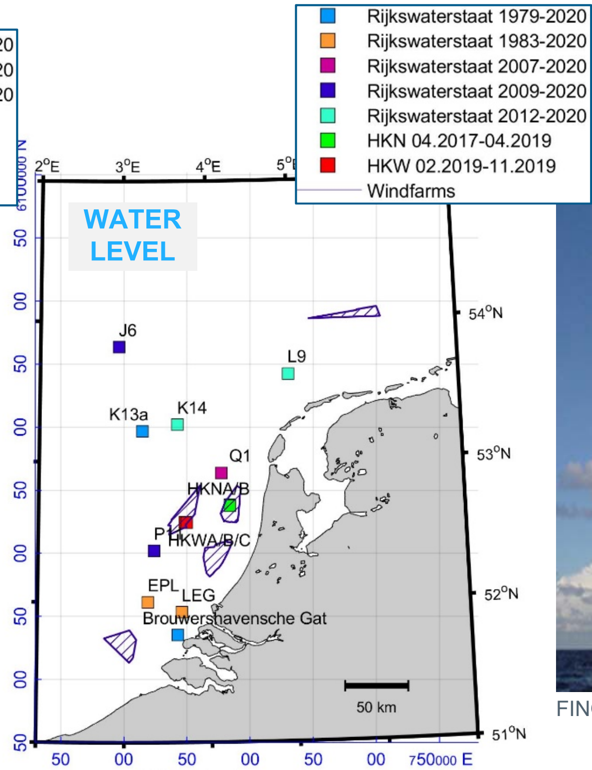


Bathymetry at HKW source: Fugro

In-situ data 2/2 - **Metocean observations**







FINO1 source: BSH

Wind Forcing for modelling activities

Climate **F**orecast **S**ystem **R**eanalysis (**CFSR**)

- **Hourly** atmospheric data available since 1979 (**10m wind**)
- Spatial resolution

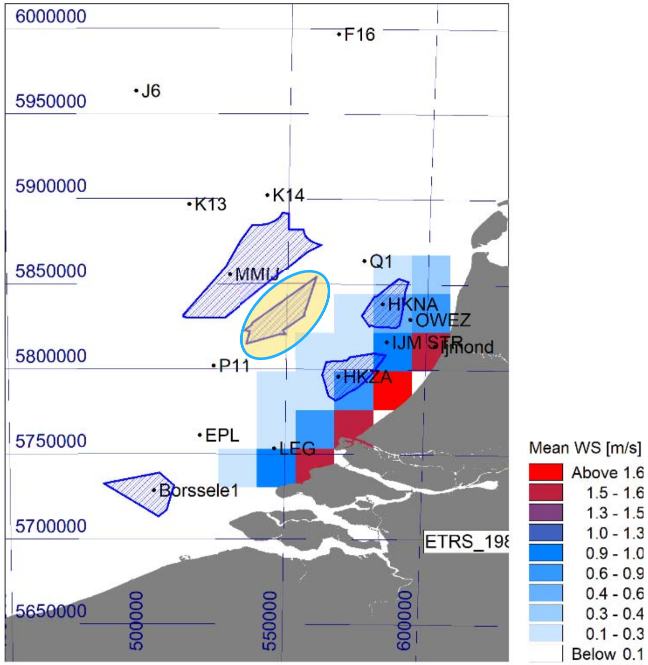
Before 2011	0.3°
After 2011	0.2°

Updated until 01.2020 !

- Corrections carried out to **correct coastal effects from land**

Step 1	Directional bias correction based on wind observations at OWEZ
Step 2	Shifting cells from offshore to onshore
Step 3	Stability correction for wave modelling

- **Validation** of the final product (met masts and scatterometer)



Example for the year 2017 : Difference of wind speed between corrected and original wind fields

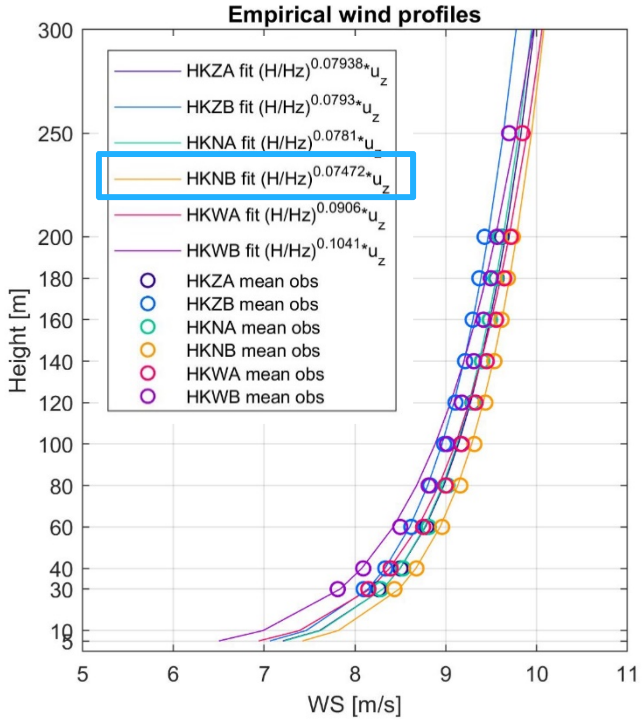
How to obtain wind up until 300m?

- Empirical shear from the HKN study (2019) – based on **LiDAR** measurements

Normal conditions	0.0742
Extreme conditions	0.1

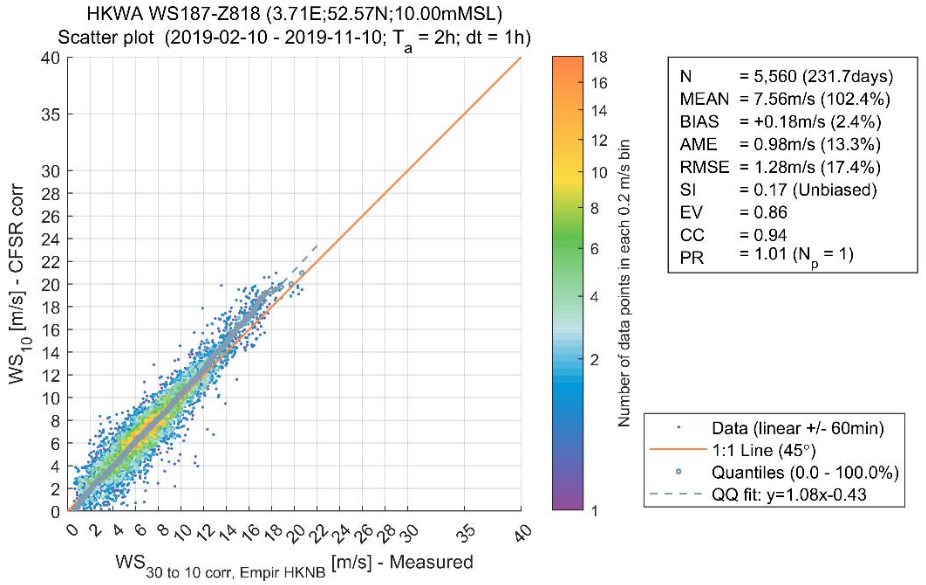
$$U_{z2} = {H_2/_{H_1}}^{\alpha} U_{z1}$$

- Proven to be better less conservative than the Frøya profile for high wind speeds
- **Why not using the HKW data?**
  9-months data is too short to produce an accurate empirical profile

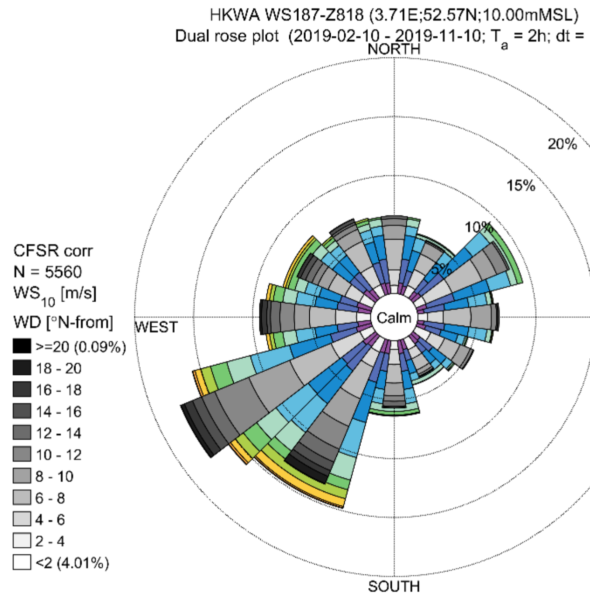


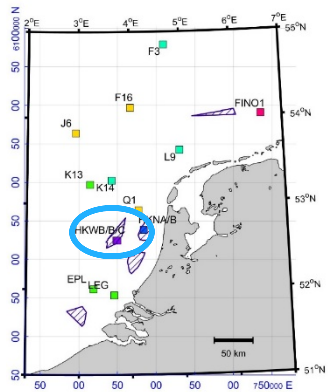
Empirical wind profiles at the stations HKZA, HKZB, HKNA, HKNB, HKWA, HKWB and HKWC – based on mean wind speeds

Validation of CFSR – Example at **HKWA**



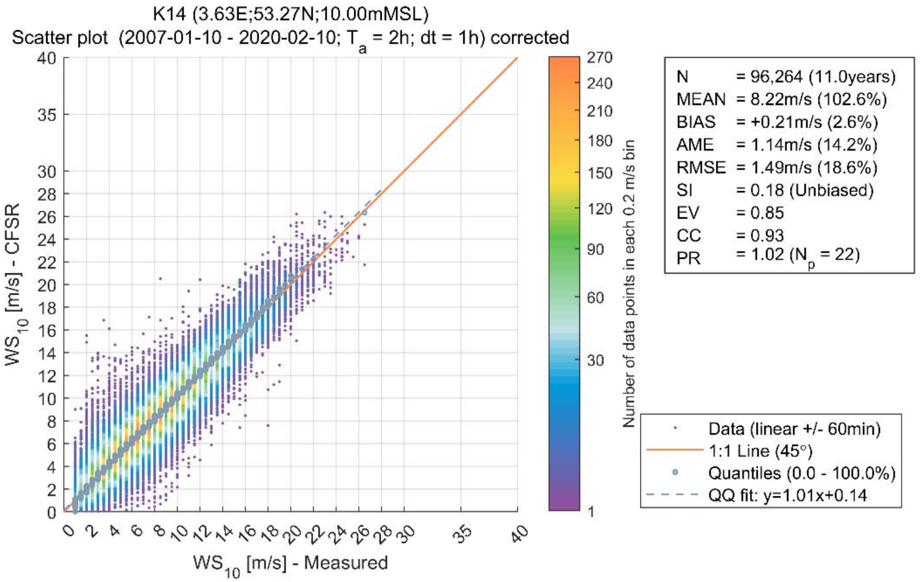
Scatter plot comparison at HKWA – 10m wind



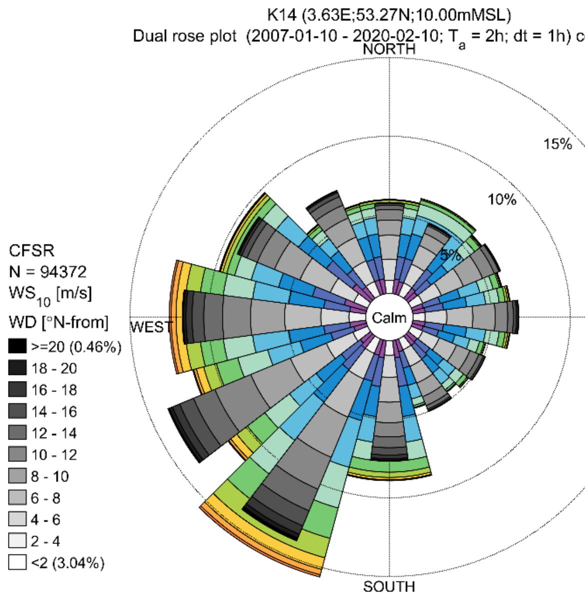


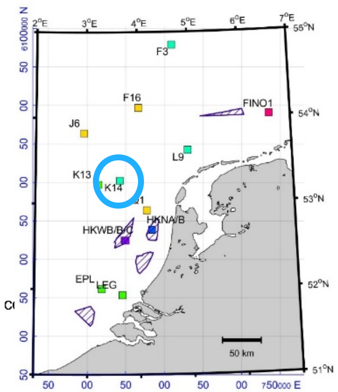
Wind rose at HKWA – 10m wind

Validation of CFSR – Example at **K14**



Scatter plot comparison at K14 – 10m wind





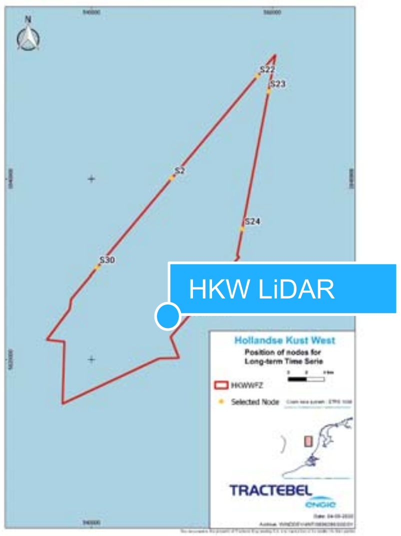
Wind rose at K14 – 10m wind

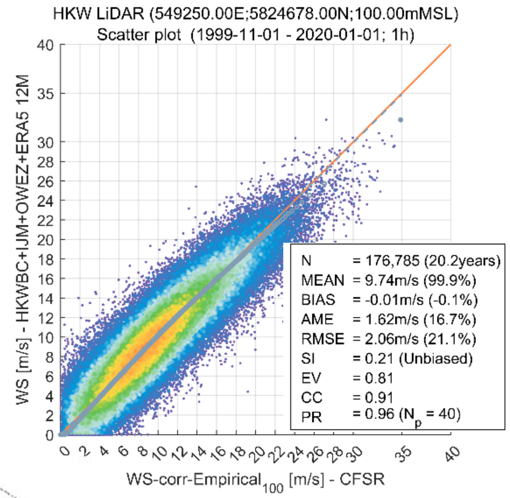
Alignment **100m wind** with the Wind Resource Assessment

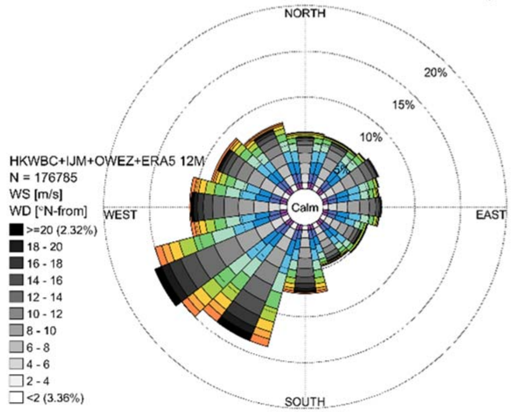
- Alignment with time series generated by **Tractebel** at 6 nodes

Source	HKW buoys +ERA5+ IJM & OWEZ met masts 1999-2019 [20 years]

Alignment within 0.1m/s







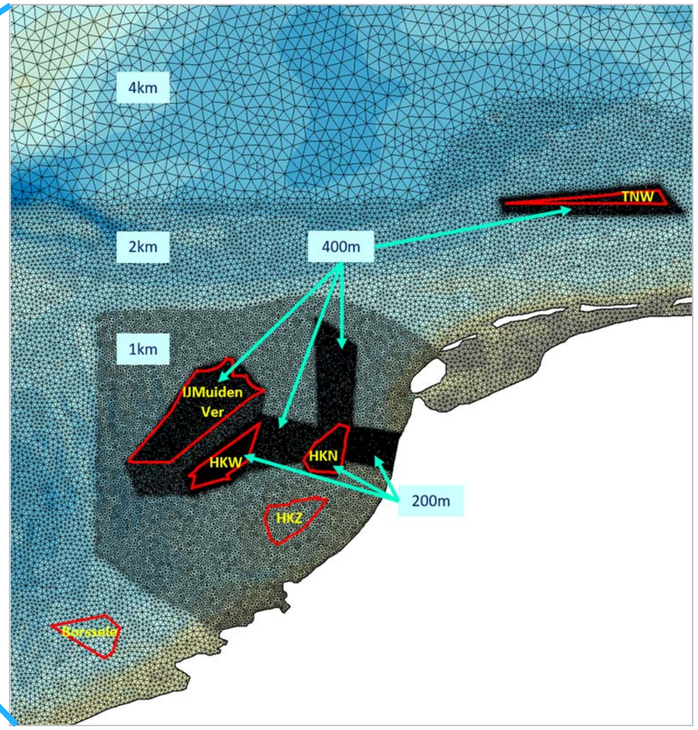
03.

Modelling activities

Numerical Hydrodynamic (HD) Model
Water levels and currents

Hydrodynamic modelling 1/5 – Downscaling and nesting

Regional North Atlantic Hydrodynamic model HD_{NA_DA}



Local Hydrodynamic model for the Dutch Wind Farm Zones area $HD_{DWF2020}$

Hydrodynamic modelling 2/5 – Model specifications

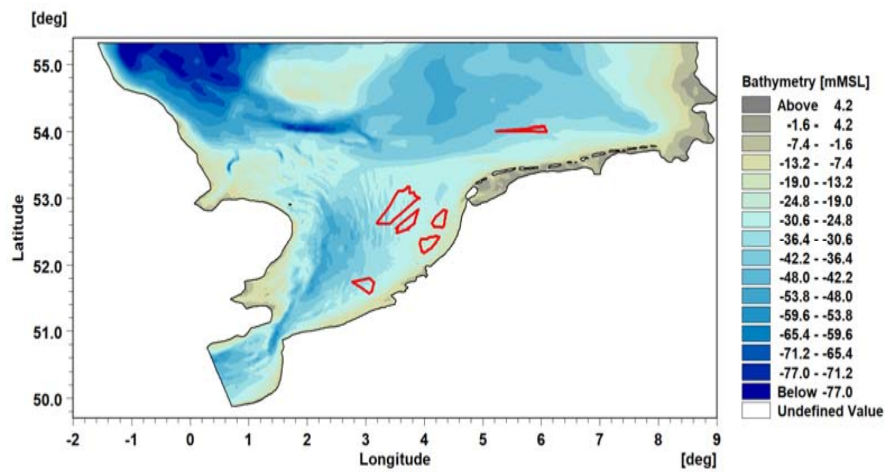
Modelling period : 01.01.1979 - 31.12.2019

- 1. **Regional** North Atlantic Hydrodynamic model

Data Assimilation	1994-2018
Validated against various stations	
Used as boundary conditions for the local hydrodynamic model	

- 2. **Local** Hydrodynamic model for the Dutch Wind Farm Zones

No Data Assimilation	
Spatial resolution	5km to 200m
Time resolution	15min output time step

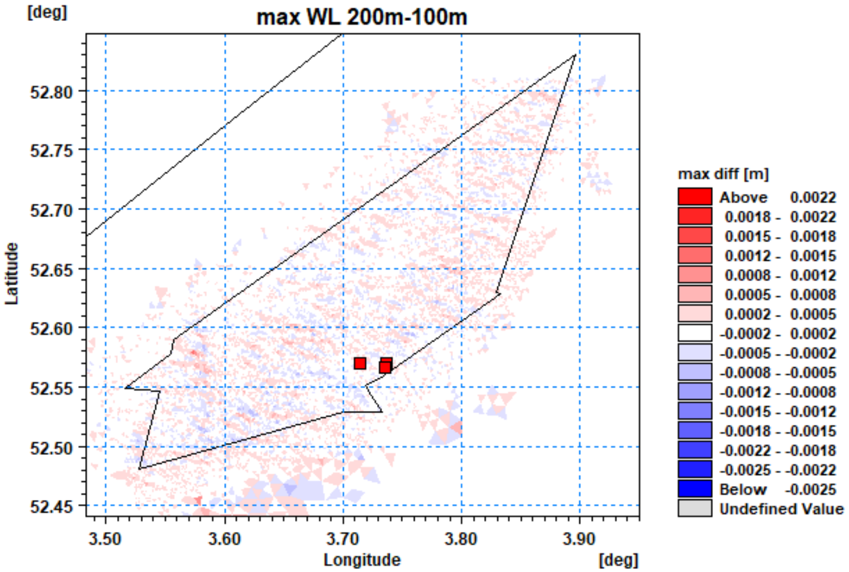


Domain of the local Hydrodynamic model

Hydrodynamic modelling 3/5 – Mesh convergence & Calibration

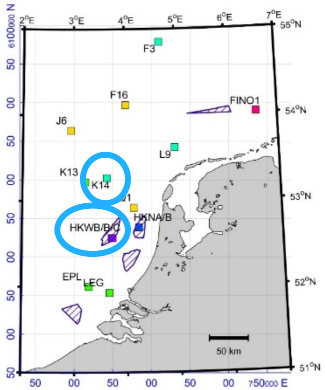
- Mesh convergence study for **100m** and **200m** resolutions for a 15-days period
- Calibration conducted to assess the validity of the model after modification of the bathymetry for one year (2019)
- **Results**:

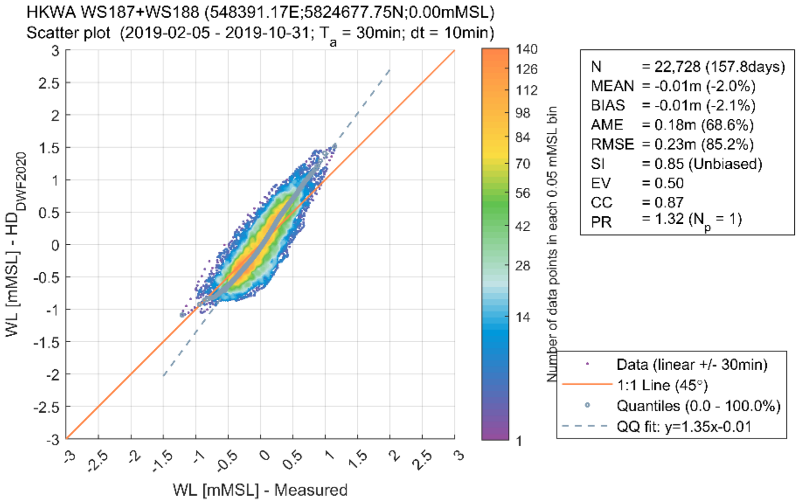
Differences of water level and currents negligible between 100m and 200m resolution
Recalibration not necessary (same accuracy achieved as in the HKN study)



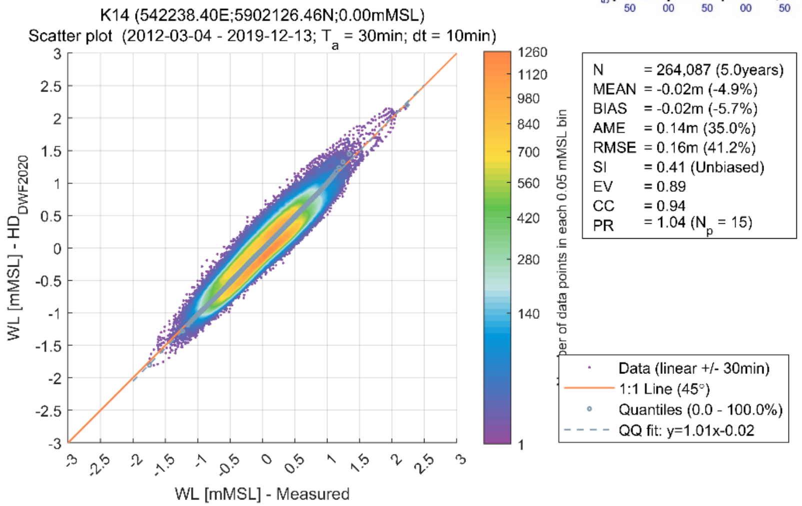
Difference map of maximum water level based on 15-days analysis period. Negative values (blue contours) indicate higher water level in the 100m grid. The red squares correspond to the HKW stations

Hydrodynamic modelling 4/5 – Some results



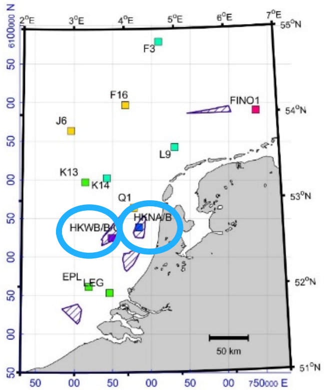


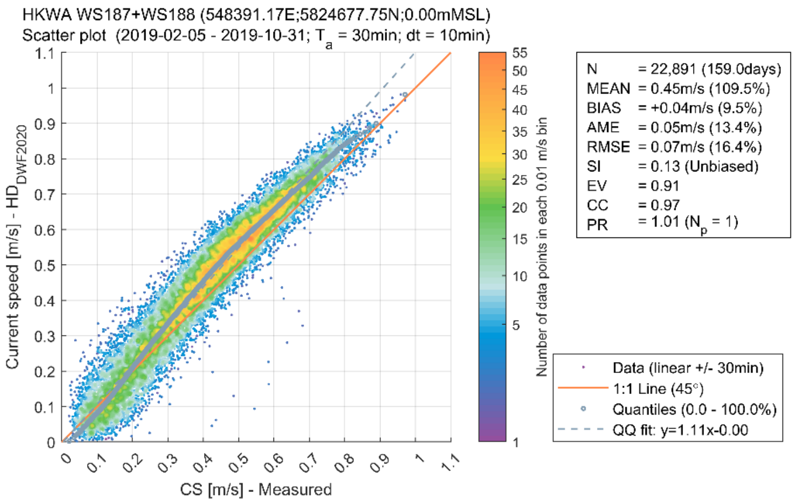
Validation of water level [m] at HKWA



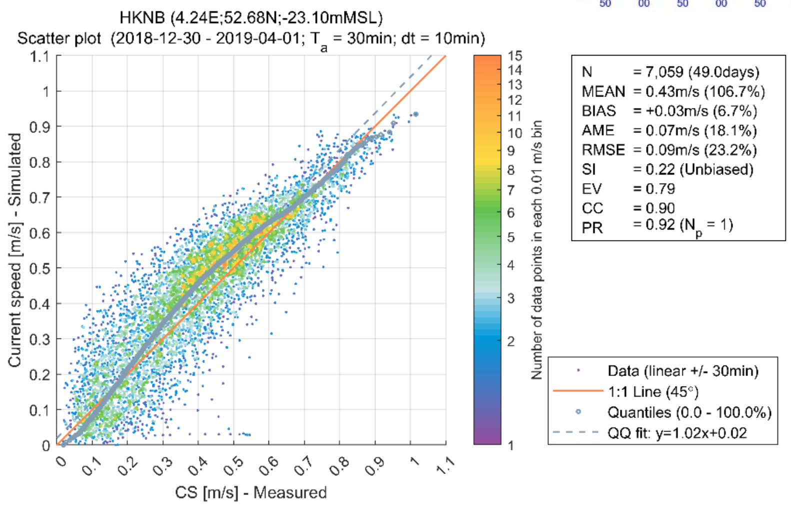
Validation of water level [m] at K14

Hydrodynamic modelling 5/5 – Some results

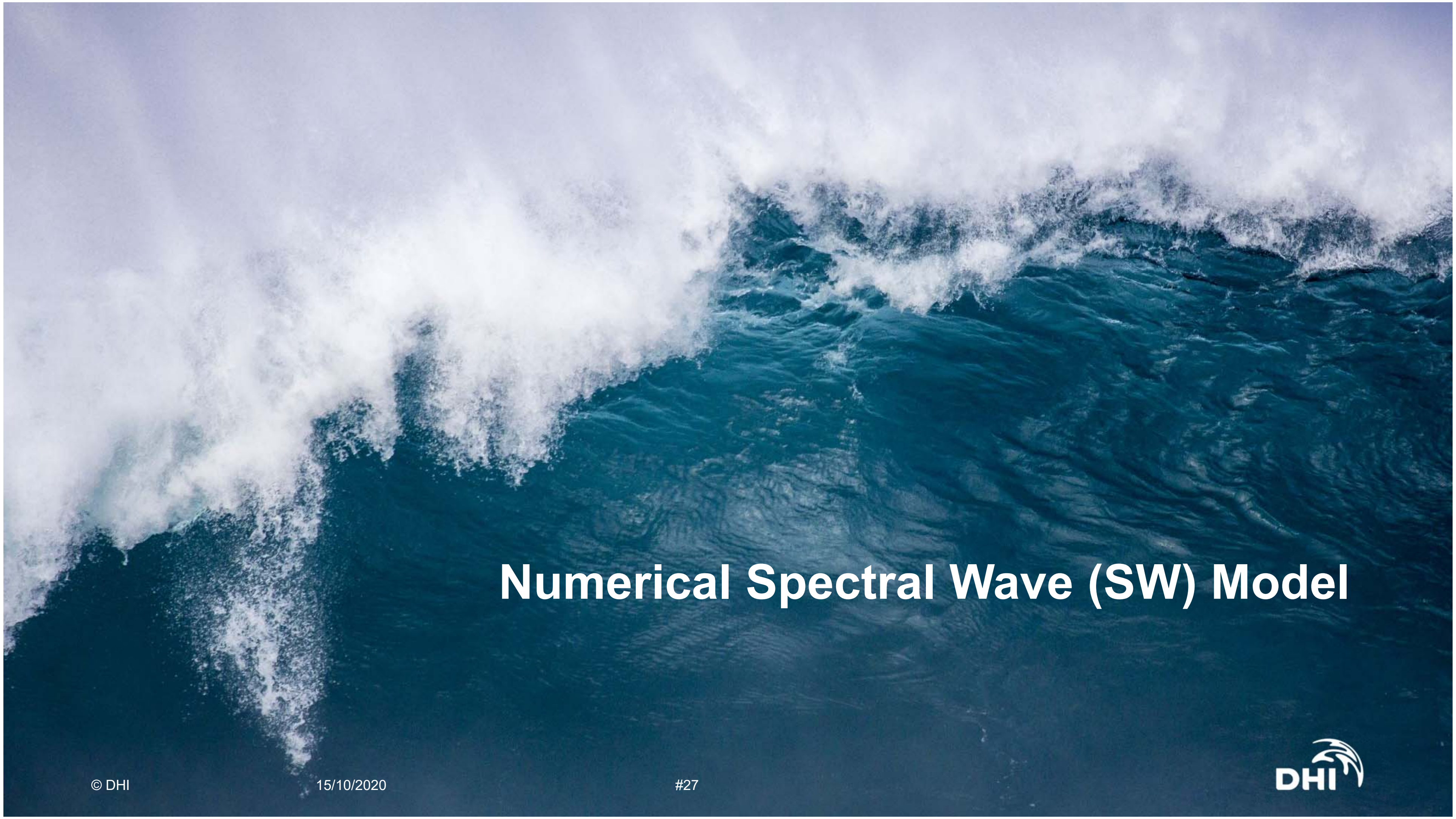




Validation of current speed [m/s] at HKWA

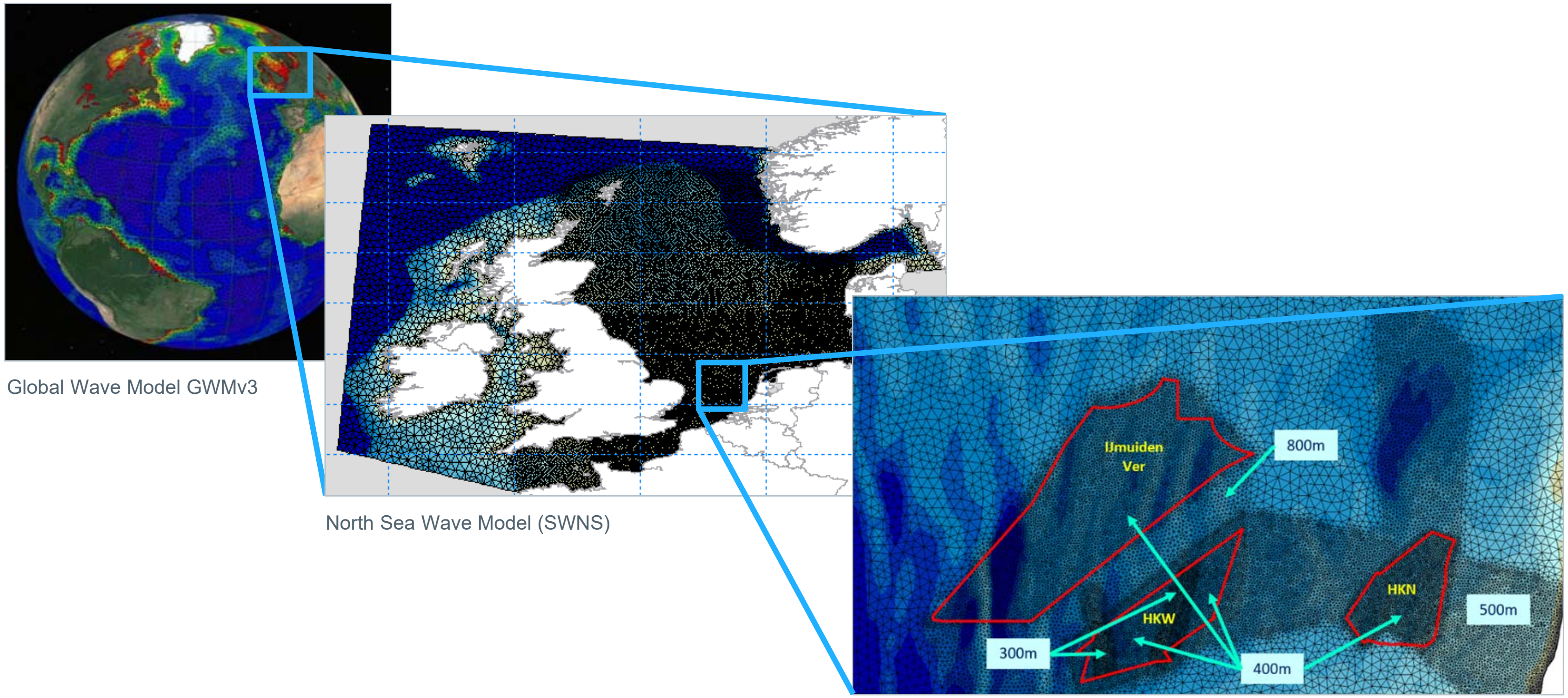


Validation of current speed [m/s] at HKNB



Numerical Spectral Wave (SW) Model

Wave modelling 1/6 - Downscaling and nesting



Global Wave Model GWMv3

North Sea Wave Model (SWNS)

Local Dutch Wind Farms Wave Model ($SW_{DWF2020}$)

Wave modelling 2/6 – Model specifications

Special features:	**Stability corrected wind fields, air-sea density ratio and cap on friction velocity**
Modelling period:	**01.01.1979 - 31.12.2019**

- 1. **Global** Wave Model

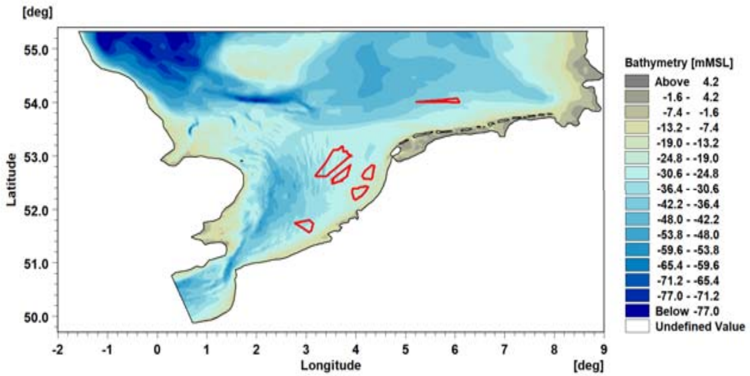
Spatial resolution	~50km to ~100km
Used as boundary conditions for the regional spectral wave model	

- 2. **Regional** North Sea Wave Model

Spatial resolution	~16km to ~5km
Validated against various stations and altimetry	
Used as boundary conditions for the local spectral wave model	

- 3. **Local** Dutch Wind Farm Wave Model

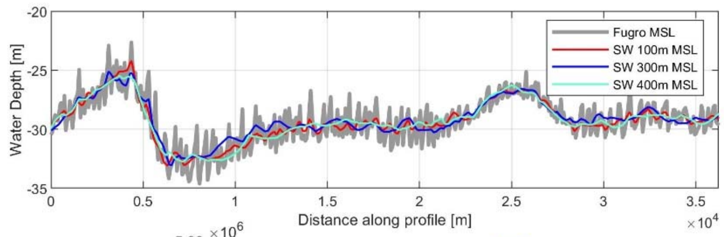
Spatial resolution	~5km to ~300m
Fully spectral in-stationary 40 frequencies/ 41 directions	
Uses varying water level and currents from the local hydrodynamic model	

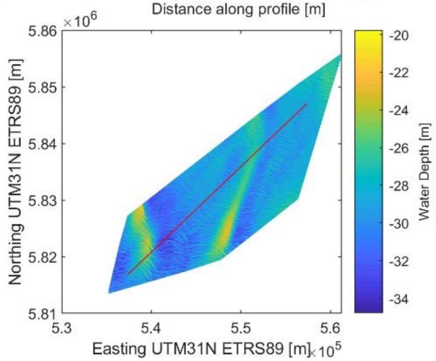


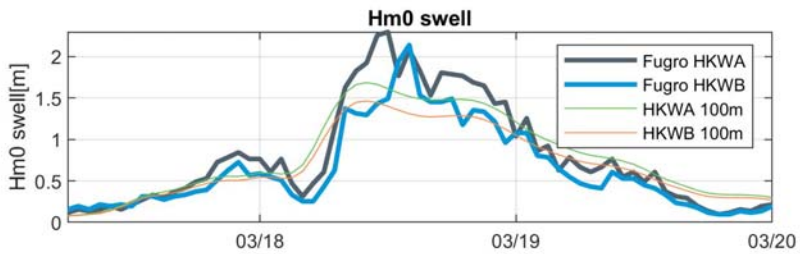
Wave modelling 3/6 – Mesh convergence

- Mesh convergence study for **100m, 300m** and **400m** resolutions
- **Hybrid** meshes have been generated for the wave model for better representation of the sand banks
- Selection of **8 storms** from dominant storm sectors
- **Results**:

Similar results between the 100m and the 400m hybrid mesh
Limitation of the wave model to capture observed differences of swell height between HKWA and HKWB (top and trough of sand wave) though energy is well distributed in the model
Limitation of the wave model to capture the effect of sand waves and mega ripples (mesh resolution>200m)



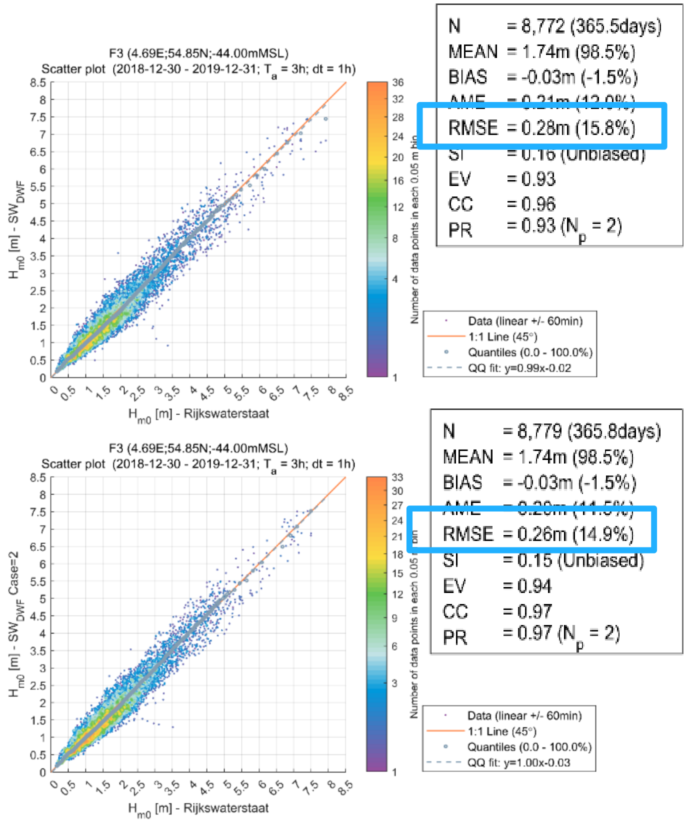




Wave modelling 4/6 – Calibration

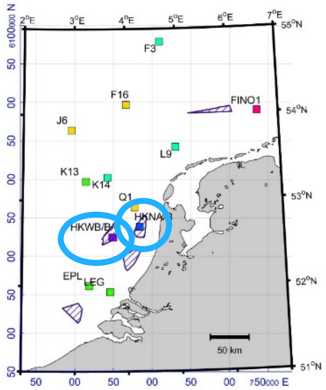
- Calibration conducted to assess the validity of the model after **modification** of the bathymetry (EMODnet v2018)
- Based on **56 storms**
- **Results:**

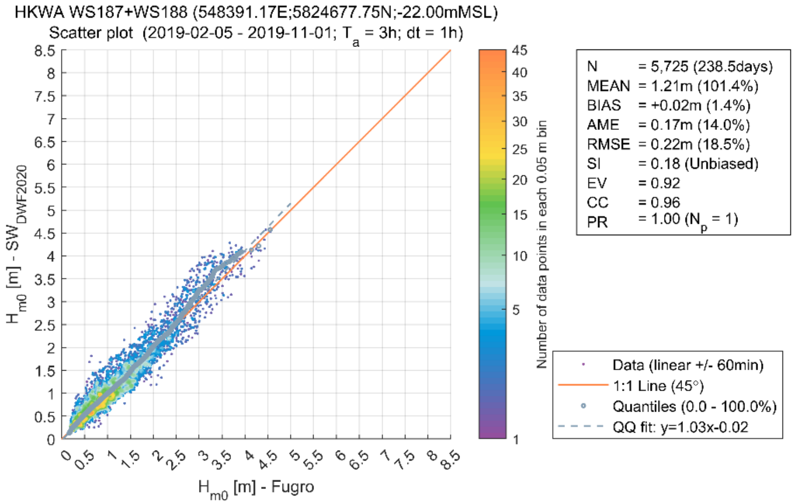
Recalibration of the wave model not necessary (same accuracy achieved as in the HKN study)
Some improvements of RMSE and Scatter Index for some stations



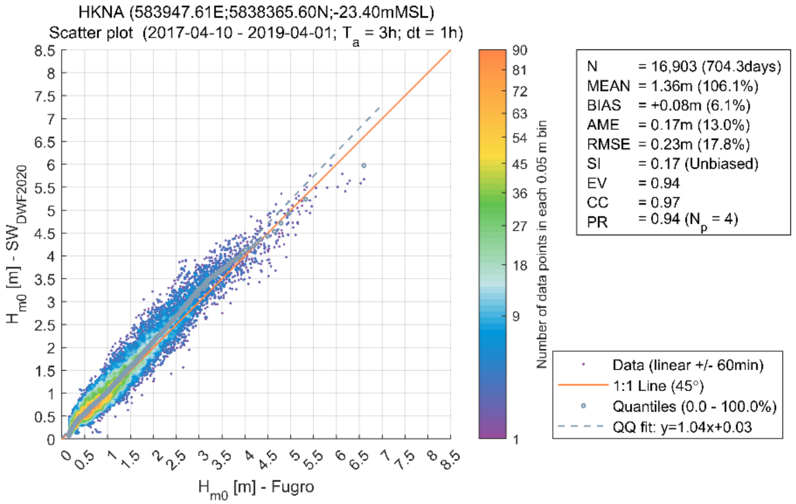
Before (top) and after (bottom) update of the EMODnet bathymetry at F3

Wave modelling 5/6 – Some results



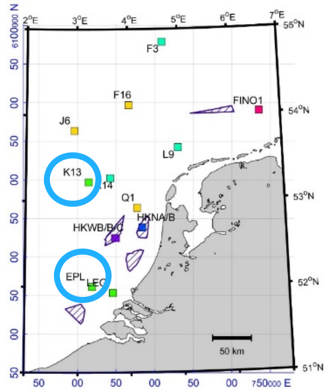


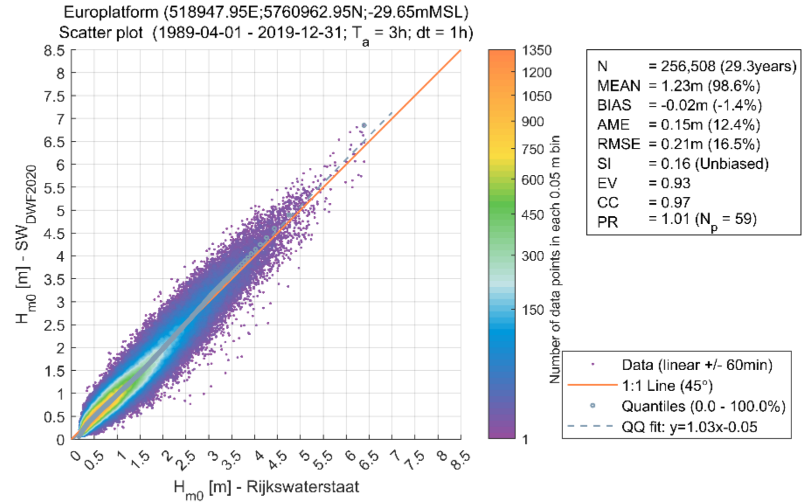
Validation of significant wave height H_{m0} [m] at HKWA



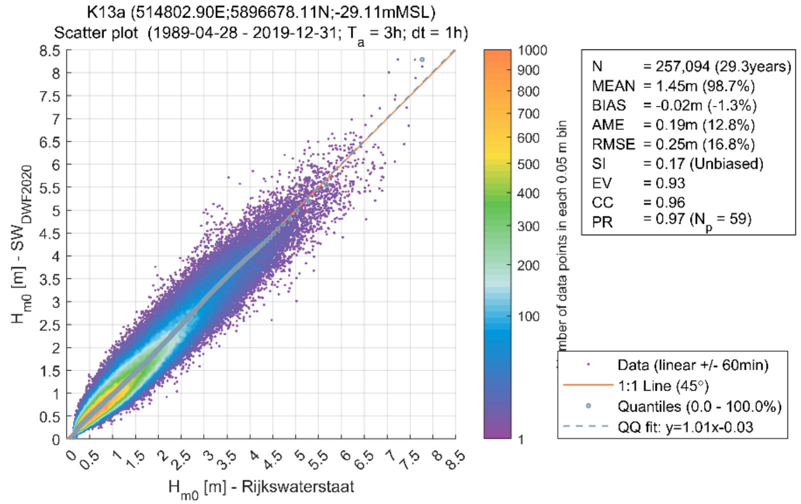
Validation of significant wave height H_{m0} [m] at HKNA

Wave modelling 6/6 – Some results





Validation of significant wave height H_{m0} [m] at Europlatform



Validation of significant wave height H_{m0} [m] at K13a

04.

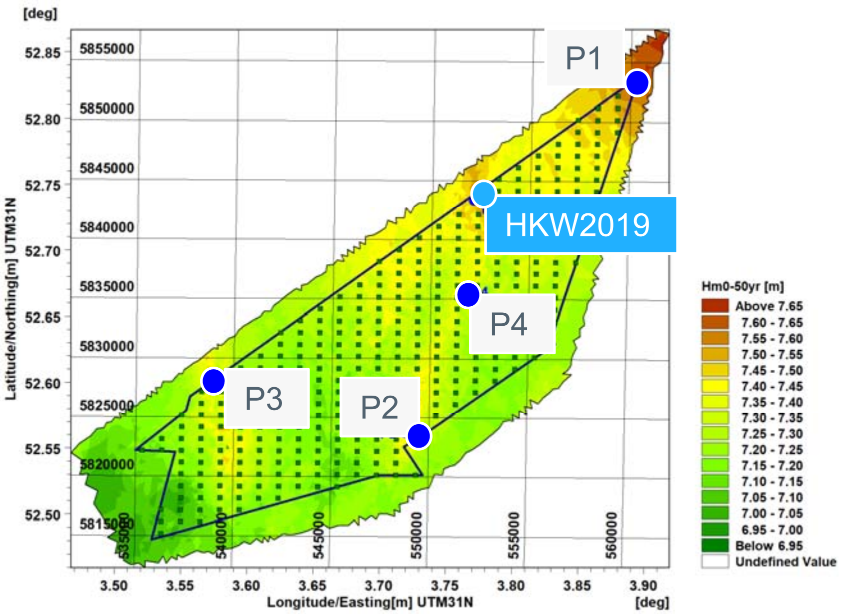
Analyses

Analysis Points and Deliverables 1/2

- Normal conditions provided at **HKW2019**
- Extreme conditions provided at **5 points**
- Detailed analyses are provided in the report and its appendices

- Other deliverables include:

Methodology	Report
Specifications/Calibration-Validation of numerical models	Report
Analytics	Report & web-based database
41 years time series of metocean data (all elements)	Web-based database
Wave spectra (every 1km)	Web-based database



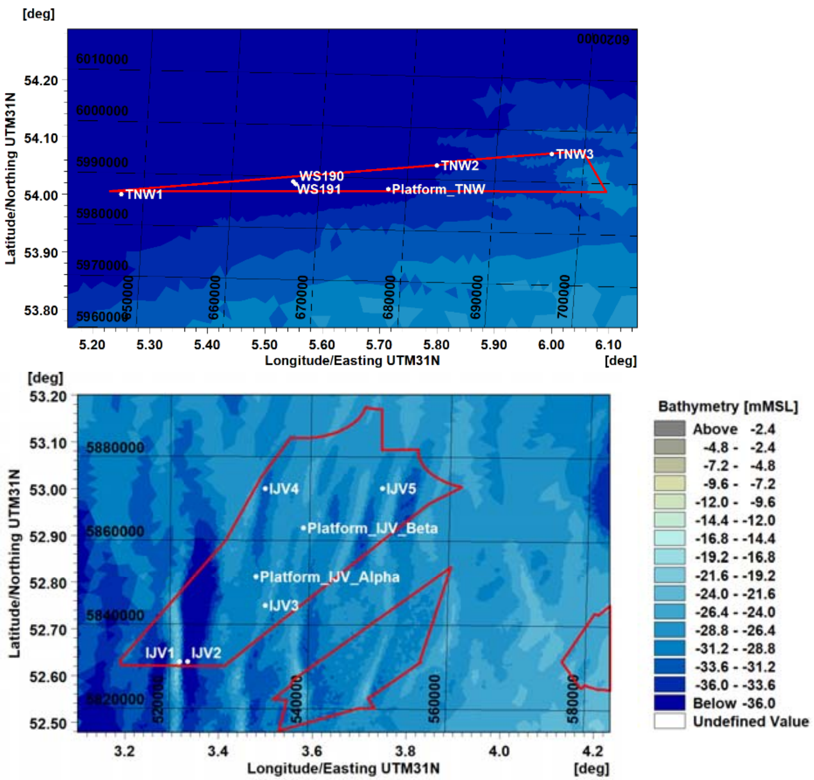
Locations of the points selected for the analyses of normal and extreme metocean conditions and output locations for wave spectra –map of annual median maximum 50-years H_{m0}

Analysis Points and Deliverables 2/2

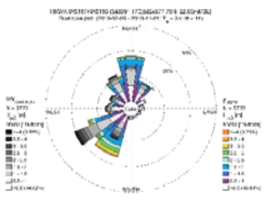
- Extra points have been saved:

41 years time series of metocean data	Web-based database
Wave spectra	Web-based database

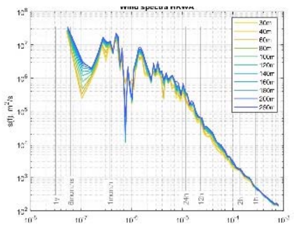
Not available in the web-based database
Please contact DHI for more information



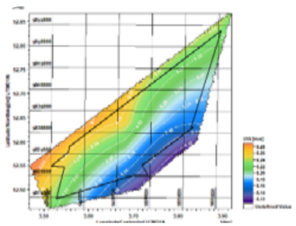
Normal Conditions



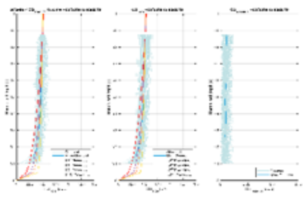
Time series, Rose plots, Scatter diagrams



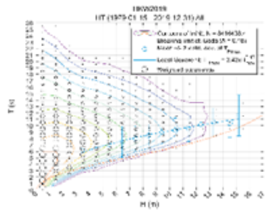
Wind spectra & Turbulence Intensity



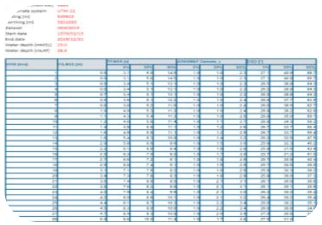
Spatial variations & maps



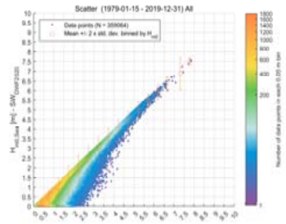
Velocity profiles



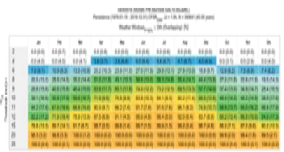
Fatigue



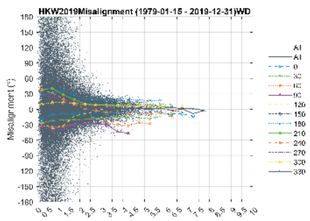
Normal **S**ea-**S**tate (**NSS**) & Weibull parameters



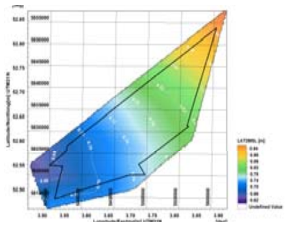
Sea/Swell contribution & spectra



Weather-windows



Wind-wave misalignment



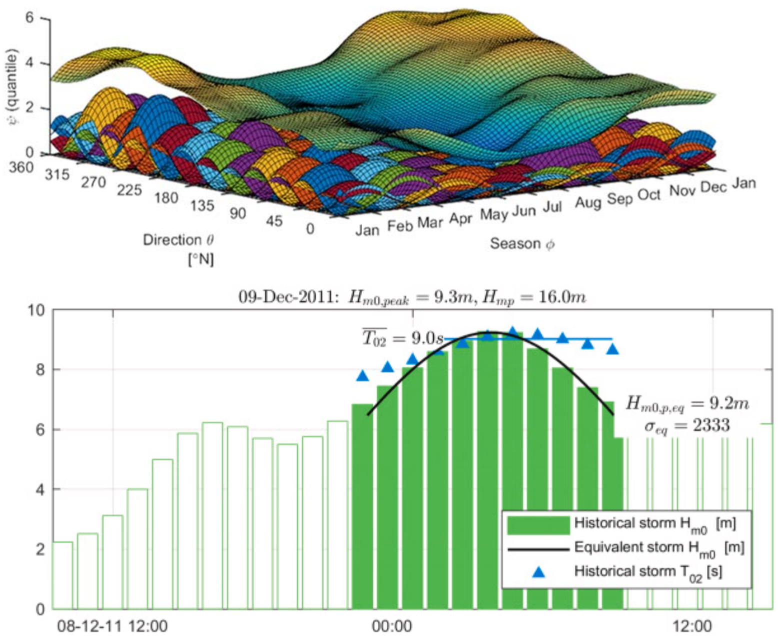
Astronomical tides

Extreme Conditions – **J**oint **E**xtreme **V**alue **A**nalysis (**J-EVA**)

Since the HKN study, J-EVA has been used in the offshore wind industry in Taiwan, U.S. and Baltic Sea

- Less conservatism & better representation of directional and seasonal variability
  1. Storm model
  2. Statistical model

- **J-EVA** simulations
  - 10,000 to 50,000 years extremes
  - As an example, simulations are 1 to 4 million years long for 10,000 years extremes



from H. Hansen *et al.*, Directional-seasonal extreme value analysis of North Sea storm conditions, *Ocean Engineering*, vol 195, 2020

Top: Bayesian p-splines for 2-dimensional description of model parameters

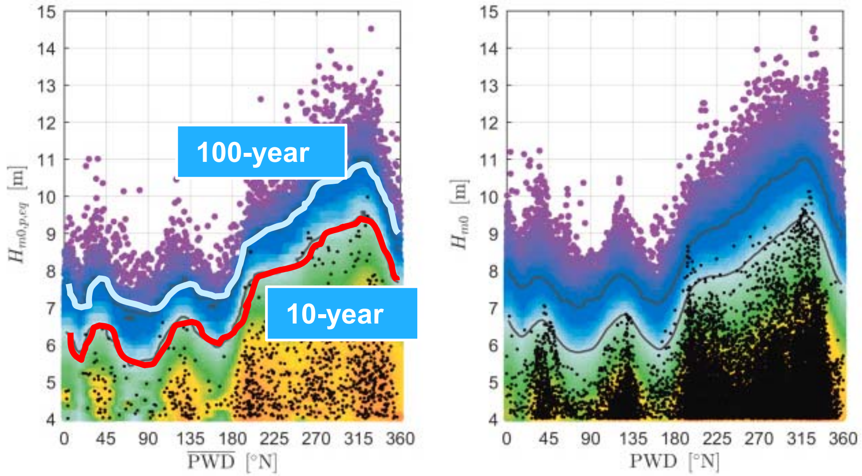
Bottom: Examples of hindcast storms and storm model parametrization

Extreme Conditions – **J**oint **E**xtreme **V**alue **A**nalysis (**J-EVA**)

- The tool in itself ...

Applies a Bayesian non-stationary extreme value analysis method
Based on extreme value analysis methods developed at the University of Lancaster **https://www.maths.lancs.ac.uk/~tawn/**
Matured in Oil&Gas industry over the last decade **http://www.lancs.ac.uk/~jonathan/**
Implemented and further developed by DHI fro major Oil&Gas operators
Applied and 3rd party verified in re-assessment of structural integrity

Example for 50,000 years simulated data

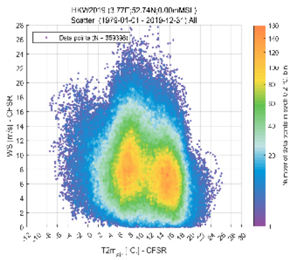


from H. Hansen *et al.*, Directional-seasonal extreme value analysis of North Sea storm conditions, *Ocean Engineering*, vol 195, 2020

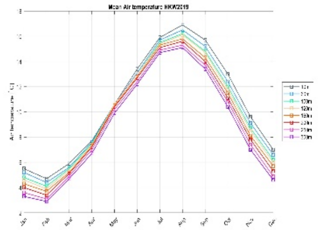
Left: Characteristics storm $H_{m0,p,eq}$ vs mean PWD

Right: Hourly values of H_{m0} vs PWD

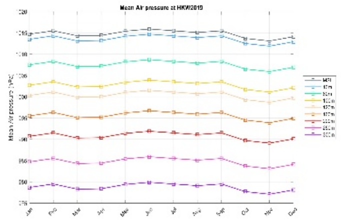
Additional Analyses



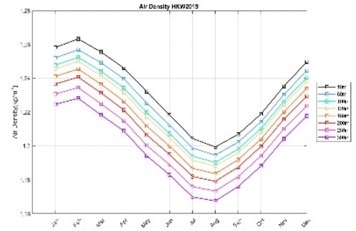
Icing



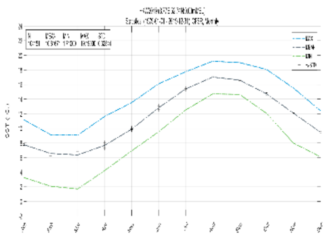
Air temperature
Specific humidity



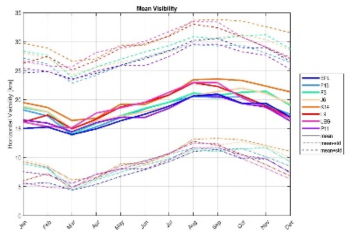
Air pressure



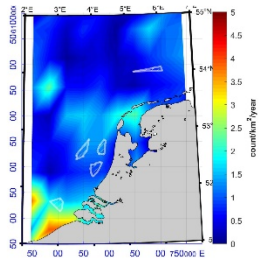
Air density



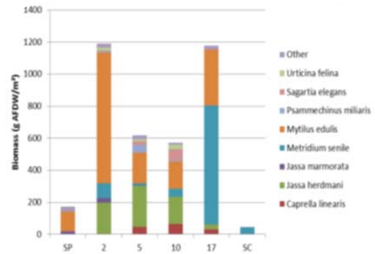
Sea water
temperature
Salinity



Visibility



Lightning



Marine growth

05.

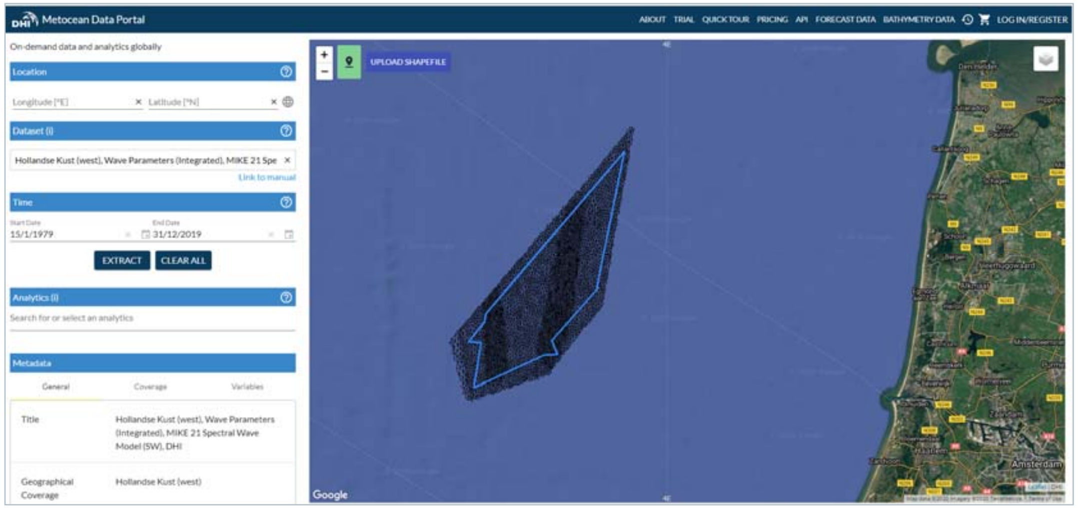
Web-based Database

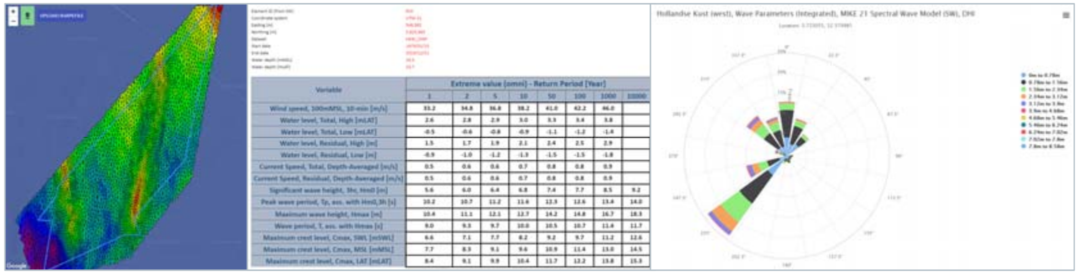
Website

https://www.metocean-on-demand.com

- Access to 41 years time series of **metocean data** and **spectral data** at HKW
- **Normal Sea States** and **extreme** conditions tables at all elements
- **Analytics**
  - time series plot
  - weather windows
  - rose plots
  - scatter plot & tables
  - altimeter comparisons
  - histogram
- **Maps** for normal and extreme conditions

Follows GDPR regulations





API

https://api.metocean-on-demand.com/APIHelp/#about-mood-downloader-api

- Retrieve metocean data from **cURL**, **Matlab** or **Python**
- Based on a key system
- Documentation is provided
- Support from DHI for any question from the user

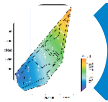
Follows GDPR regulations

DHI

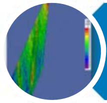
06.

To conclude

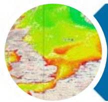
What did we achieve? What did we learn?



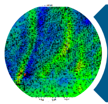
Detailed design metocean parameters (normal and extreme conditions) for Hollandse Kust (west) now available



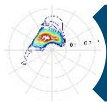
New dataset containing 41 years of metocean data at the Hollandse Kust (west) Wind Farm Zone available on the database



Slight improvements were achieved with the update of the bathymetry from EMODnet v2016 to EMODnet v2018



The bathymetry plays an important role locally for accurate wave modelling (implementation of higher mesh resolution in the future in areas of complex bathymetry)



Mesh convergence studies should be based on wave spectra comparison if such data is made available

Upcoming improvements of the database (multiple extraction, analytics through API...)

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

All webinars about the Hollandse Kust (west) Wind Farm Zone can be found on https://offshorewind.rvo.nl