FIVE ESTUARIES OFFSHORE WIND FARM

PRELIMINARY ENVIRONMENTAL INFORMATION REPORT

VOLUME 4, ANNEX 2.2: PHYSICAL PROCESSES MODEL DESIGN AND VALIDATION

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Volume 4, Annex 2.2: Physical Processes Model Design and Validation

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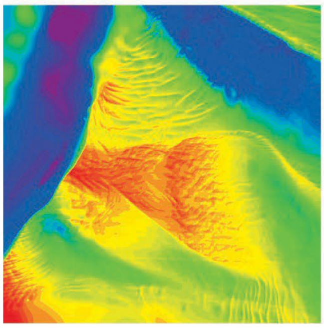
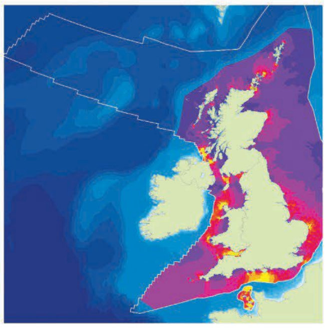
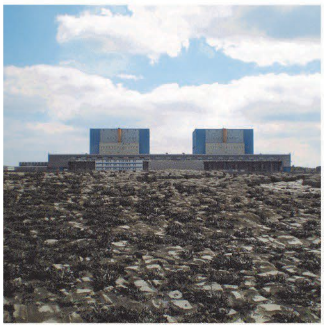
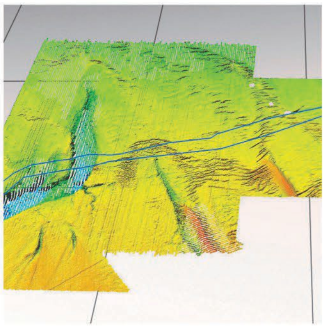

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Notice

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Acronyms and abbreviations

BODC	British Oceanographic Data Centre
CD	Chart Datum
DHI	Danish Hydraulic Institute
DirM	Mean wave direction (coming from)
DirStd	Directional standard deviation of wave energy
DTU	Danish Technical University
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
ES	Environmental Statement
EVA	Extreme Value Analysis
FM	Flexible Mesh (mesh or model type)
GoBe	GoBe Consultants Ltd
HD	Hydrodynamic (MIKE21FM_HD model)
Hs	Significant wave height
LAT	Lowest Astronomical Tide
MDS	Maximum Design Scenario
MSL	Mean Sea Level
OWF	Offshore Wind Farm
RP	Return Period
SW	Spectral Wave (MIKE21FM_SW model)
ST	Sand Transport (MIKE21FM_ST model)
Tp	Peak wave period
UCL	University College London
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
UTM	Universal Transverse Mercator
VORF	Vertical Offshore Reference Frames
VE	Five Estuaries Offshore Wind Farm

Cardinal points/directions are used unless otherwise stated.
SI units are used unless otherwise stated.

1 Introduction

1.1 Overview

ABPmer has been commissioned by GoBe to undertake numerical modelling to inform the Environmental Impact Assessment (EIA) for the proposed Five Estuaries Offshore Wind Farm (referred to here as VE). A range of numerical models have been developed to address the following aims:

- **Hydrodynamics (HD):** simulating the hydrodynamic regime (tidal currents and water levels).
- **Sand Transport (ST):** simulating the sediment transport regime (rate and direction), which is governed by the flow fields from hydrodynamic module.
- **Spectral Waves (SW):** simulating the wave regime (representative scenarios of wave height, period and direction).

In each case, the models will be used to provide both:

- A detailed baseline description of relevant parameters; and
- A direct quantitative assessment of the potential impact of the wind farm infrastructure on the baseline environment (relative and absolute changes to patterns, rates and magnitudes of the relevant parameters).

This report presents supporting information about the design and validation of the above models. This report does not directly report the results of the modelling or consider the potential impacts or implications of any reported changes.

The maximum design scenarios modelled, and presentations and discussion of the results from the modelling are not contained in this report but may be found in Volume 4, Annex 2.3: Physical Processes Technical Assessment.

1.2 General approach to modelling

The numerical modelling for this study has been undertaken using the MIKE21FM (flexible mesh) software package from the Danish Hydraulic Institute (DHI), which has been developed specifically for application in oceanographic, coastal and estuarine environments.

When used by an experienced modeller, and in conjunction with suitable data inputs, these models provide reliable and realistic representations of both baseline environmental conditions and the potential effects of offshore wind farm infrastructure and other construction related activities.

The hydrodynamic modelling described in this report is undertaken using a 2D (depth averaged) tidal model, utilising a flexible mesh with high resolution applied in the study area. The model is run in a tide only mode (no effect of winds or air pressure – astronomical influences only) to simulate a continuous timeseries of water levels and currents over a representative spring-neap period.

The sediment transport modelling described in this report is undertaken in association with the flow fields described by the hydrodynamic module. The flow fields enable the resultant rate and direction of sand transport to be calculated, for characteristic or representative sediment properties.

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The wave modelling described in this report is undertaken using a spectral wave model, utilising a flexible mesh with high resolution in the study area. The model is run in a quasi-stationary mode to simulate a range of discrete representative sea states. The wave model is not required to simulate historical timeseries of actual wave conditions.

2 Tidal Currents and Water Levels

2.1 Overview

This section describes the design and inputs to the hydrodynamic model simulating tidal currents and water levels in the VE EIA study area. The model is used to simulate baseline conditions, and the potential impact of wind farm foundations on baseline conditions. This hydrodynamic model also provides the flow field inputs for the sand transport model as described in Section 3.

Scenario specific information, model inputs and results are described in a separate report (Volume 4, Annex 2.3: Physical Processes Technical Assessment), including:

- Time period of simulation (typically one representative spring-neap cycle)
- Foundation type, dimensions, number and layout for:
  - VE (maximum design scenario)
  - Other nearby wind farms (as built).
- Resulting patterns of:
  - Baseline water levels, current speed and direction;
  - Baseline residual current speed and direction;
- Patterns of change to all of the above as a result of the presence of wind farm foundations.

2.2 Tidal model design

2.2.1 General design

The tidal model is built using the MIKE21FM Hydrodynamic (HD) module, which simulates the propagation of the tidal wave and associated movements of water volume in offshore and coastal settings.

The tidal model creates a timeseries simulation of tidal water levels and depth averaged current speed and direction throughout the model domain.

The tidal model is based on the ABPmer SEASTATES validated regional-scale European Shelf Tide and Surge model, used in a tide-only mode, with locally enhanced resolution in the study area. The design and performance of the regional model are described in a separate report (ABPmer, 2017).

2.2.2 Tidal model mesh extent and resolution

The tidal model grid is based on that used by the ABPmer SEASTATES European Shelf Tide and Surge model (ABPmer, 2017). The extent of the model mesh and the distribution of mesh resolution is shown in Figure 1. A flexible mesh design is used (interlocking triangular 'elements' of varying shape and orientation), providing tailored spatially variable resolution within a single model mesh.

Resolution is uniformly high (approximately 200 m) throughout the main study area between Lowestoft and Margate, also including the VE and the surrounding windfarms. The relatively high resolution provides a sufficiently detailed description of the key bathymetric and coastal features affecting flow patterns in these areas, including the various bedforms (sand waves and mega-ripples) anchored around the Outer Thames region. The higher resolution is also relevant to the resolution of outputs from the sediment transport model described in Section 3.

The (variable) lower resolution of the mesh outside of the study area is sufficient and suitable to simulate the general progression of the tidal wave and associated movement of water volume around the European continental shelf, up to the edges of the local study area.

2.2.3 Tidal model bathymetry

Within the VE array area and cable corridor, high resolution multibeam bathymetric survey data have been collected (Fugro, 2022) and are used to inform the model mesh in these areas.

Outside of the surveyed VE array area and cable corridor, the tidal model bathymetry is the same as used by the validated ABPmer SEASTATES European Shelf Tide and Surge model. The regional bathymetric data was largely sourced from EMODnet (https://www.emodnet-bathymetry.eu/), which is a freely available and generally reliable data source. Numerous other UKHO survey data sets were also incorporated into the ABPmer SEASTATES model mesh bathymetry. The good level of validation achieved by the ABPmer SEASTATES model with respect to water levels and currents (ABPmer, 2017) provides indirect validation of the bathymetry data source.

Spatially varying adjustments are made to convert the bathymetry data from the standard Lowest Astronomic Tide (LAT) and Chart Datum (CD) datums at source, to Mean Sea Level (MSL), as is required for use in the model. Adjustments are made using a combination of VORF (Vertical Offshore Reference Frames, UCL and UKHO, 2005) in UK territorial waters, and mapped statistics of the offset between LAT and MSL from the validated ABPmer SEASTATES European Shelf Tide and Surge model results.

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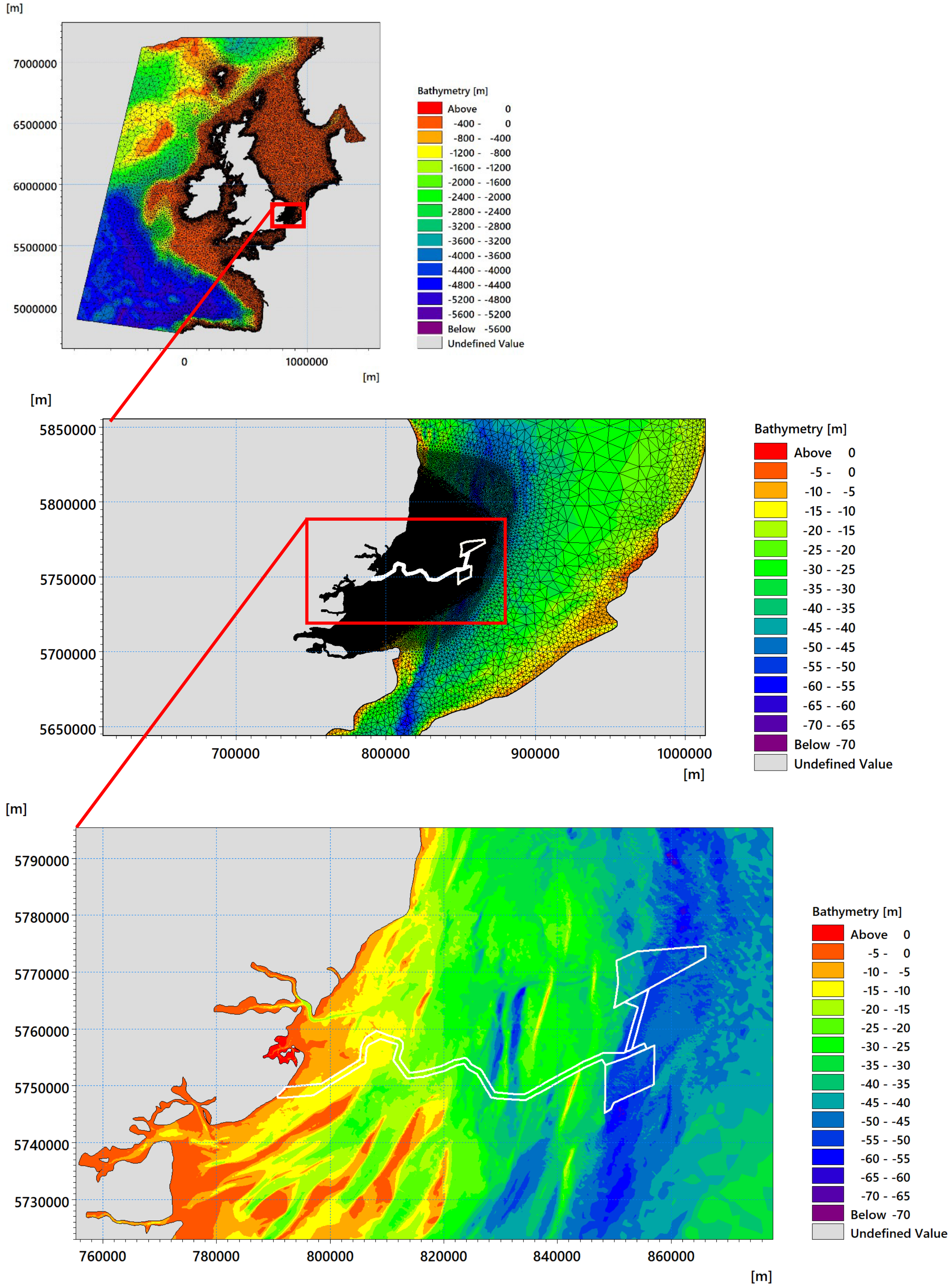

Figure 1. Extent of the tidal model mesh, showing regional and locally enhanced resolution. Lower plot also shows the extent of VE and other nearby windfarms

2.2.4 Tidal model boundary conditions

Offshore tidal boundaries

The tidal model has four open water level boundaries, shown in Figure 2.

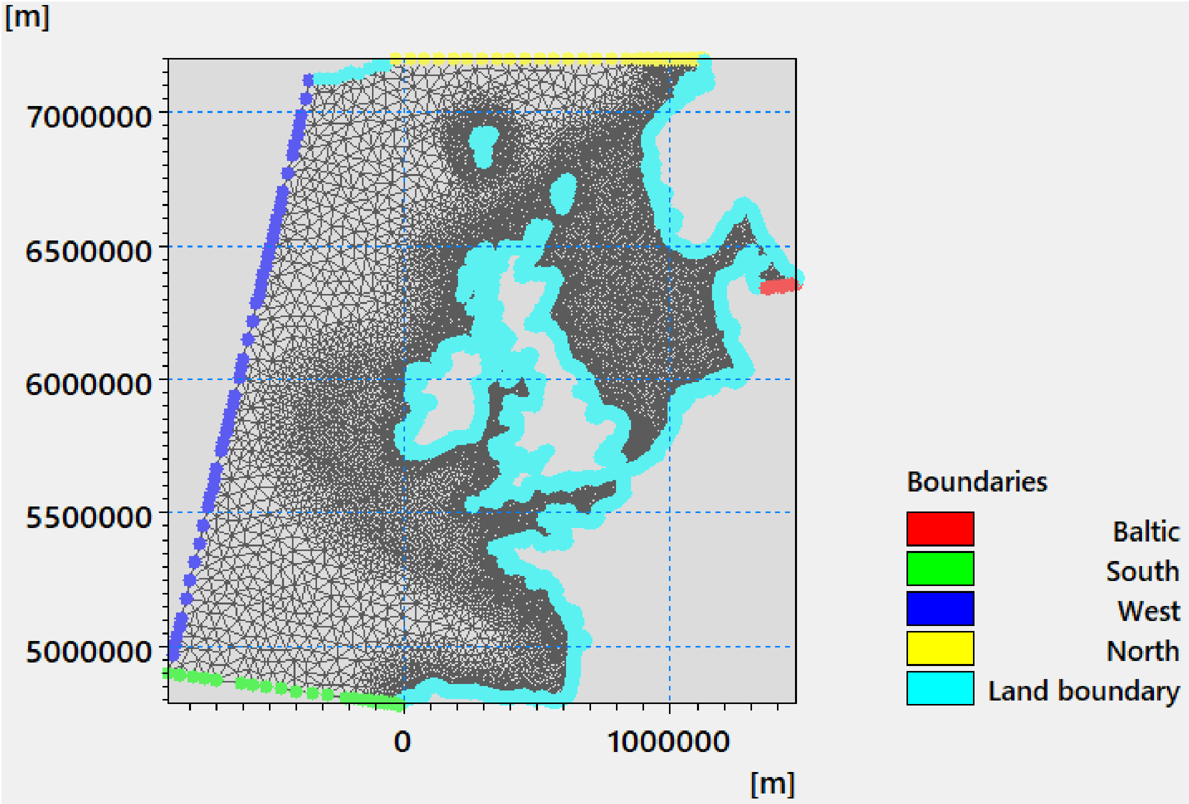

Figure 2. Tidal model boundaries

Temporally and spatially varying tidal water levels are applied at these boundaries, representing the passage of the deep ocean tidal wave from the North Atlantic onto the European shelf (and smaller exchanges with the Baltic Sea). Tidal boundary data are obtained using the DTU10 (DTU, 2010) database of harmonic constituents. The good level of validation achieved by the model with respect to water levels and currents (ABPmer, 2017) provides indirect validation of the tidal boundary data source.

Meteorological boundaries

The effects of winds and air pressure (for non-tidal surge related influences) are only included in the validation model setup to provide a like-for-like comparison against measured data.

In the scenario testing, a representative spring-neap cycle of tide-only (astronomical influence only) conditions are simulated and the more variable effect of weather is excluded.

2.2.5 Tidal model bed roughness

Bed roughness in the model describes the friction from the seabed 'felt' by moving water. Changing the magnitude of bed roughness locally effects the rate at which water moves in that area and so can affect both tidal range and phasing, and (mainly the speed of) tidal currents. As such bed roughness is a key variable in the model that can be varied to optimise the model performance in comparison to coincident measured data.

The ABPmer SEASTATES European Shelf Tide and Surge model utilises a bespoke spatially varying map of bed roughness, created by combining information about the distribution of seabed and sediment type, and water depth. The good level of validation achieved by the model with respect to regional scale patterns of water levels and currents (ABPmer, 2017), which provides indirect validation of the bed roughness values.

The same validated spatially variable bed roughness distribution is applied in the present study, with no adjustments made.

2.3 Tidal model validation

The regional SEASTATES tide model largely controls the timing, magnitude and direction of water levels and currents entering and propagating through the local study area. The regional model has been separately validated against the tide gauge and current meter data in numerous locations around the European continental shelf, including tide gauges at Harwich, Sheerness and Dover (ABPmer, 2017).

The tidal model has also been validated against multiple sets/periods of measured current and water level data from spatially suitable dataset relative to the VE study area. The locations of the used instrumentation are shown in Figure 3.

Comparisons of the total measured and modelled water levels are provided in Figure 4 to Figure 6. The plots generally show that the tidal model provides a good representation of the overall magnitude, timing, and variance of water levels at the three chosen locations.

The time varying water level is important for the correct simulation of time varying total local water depth, which is a relevant factor in the calculation of suspended sediment. The model is shown to provide an accurate description of the absolute water level and the timing of variation in water level (especially relative to currents).

The main axis and direction of rotation of tidal currents, and the relative variation in peak current speed between adjacent flood/ebb tides are all important for the realistic simulation of local tidal asymmetry and net drift, which will contribute towards the rate of the transportation of sediment.

The direction of currents throughout the tide and the rate and direction of flow rotation are generally well represented by the model at each of the four identified current datasets (1 BODC dataset (b7625) and three Total Tide diamonds (SN013H, SN012T & SN012S), (see Figure 3). In addition, the model's capability is further reassured by the variation in current signature between sites SN013H and SN012T, compared to SN012S which provides a very contrasted signature. This is well replicated by the model in a bathymetrically complex location. The plots of both current speed and direction are presented in Figure 8 to Figure 10.

The modelled conditions (peak current speed and high and low water levels) are typically close in magnitude to either the corresponding or adjacent observed tide within a 12 or at most 24-hour period. The differences are small in absolute and relative terms and are within the range of natural variability in the same values from tide to tide.

Some minor differences are observed between the sites where the model simply cannot be calibrated further to simultaneously reproduce all details of all tides at all locations. Some differences may also be the result of local effects of complex bathymetry that are either not represented in the available bathymetry data, or not fully resolved by the resolution of the model.

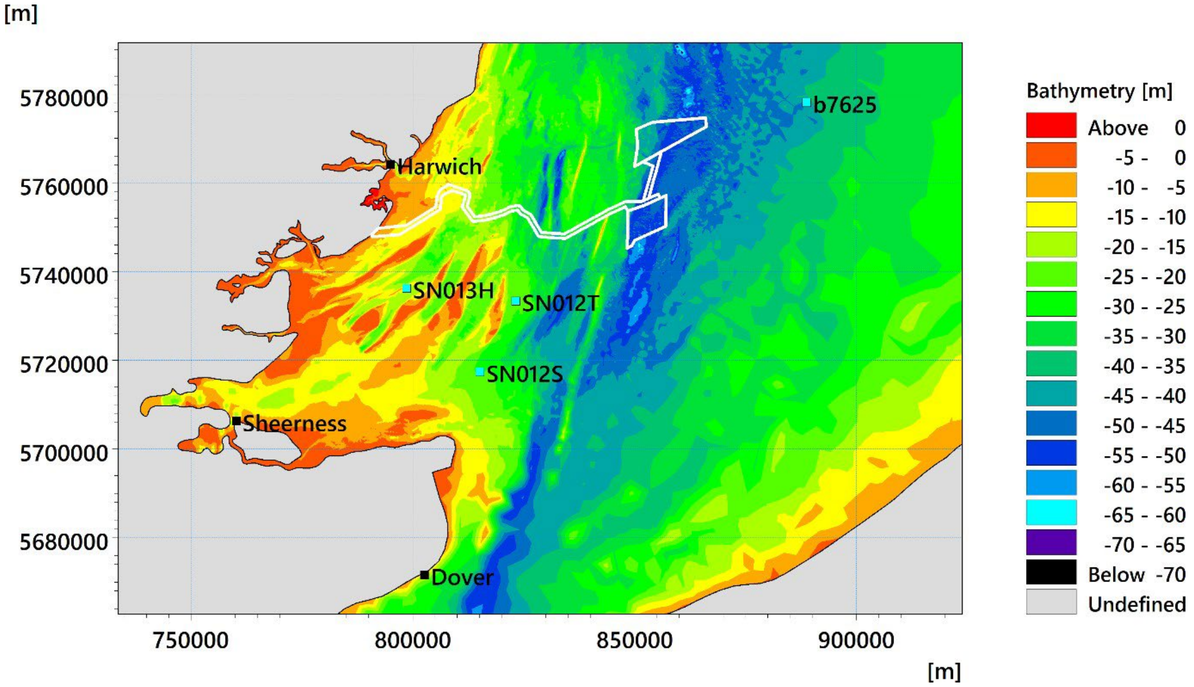

Figure 3. Locations of the measured data used for tidal model validation

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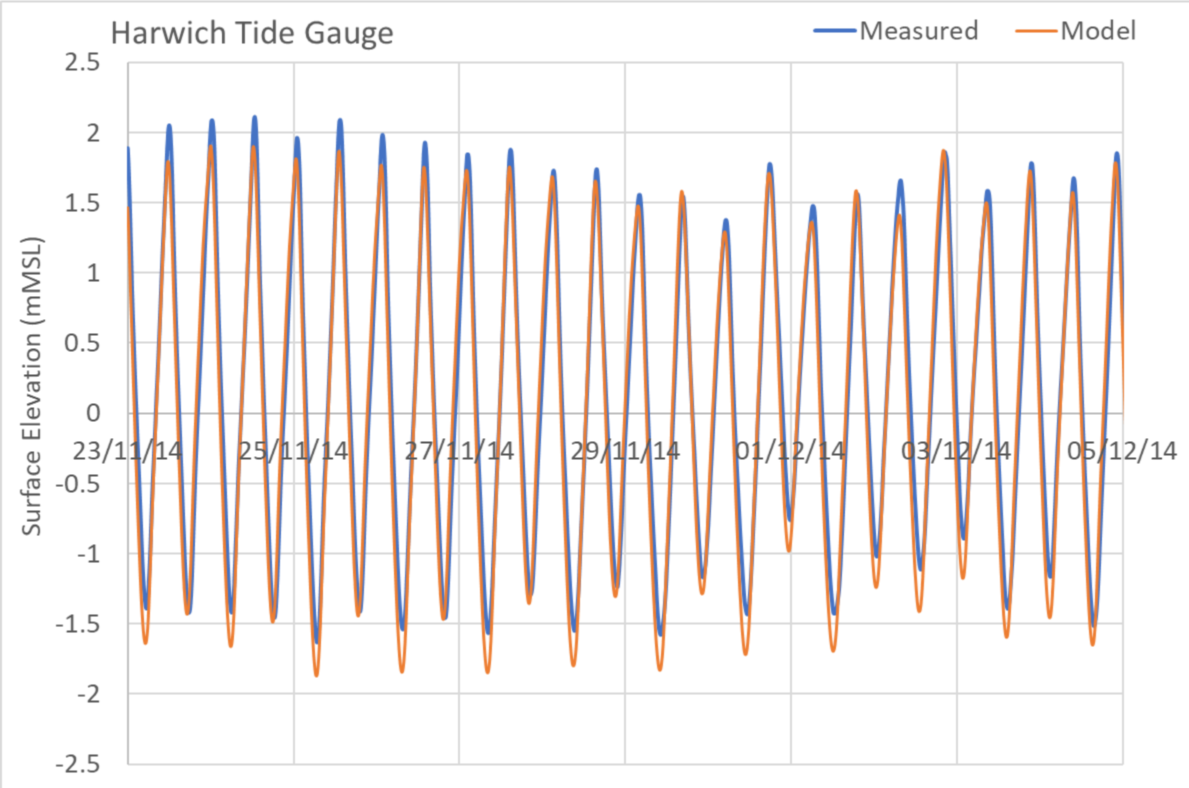

Figure 4. Comparison of total measured and modelled water-levels at Harwich NTSLF tide gauge

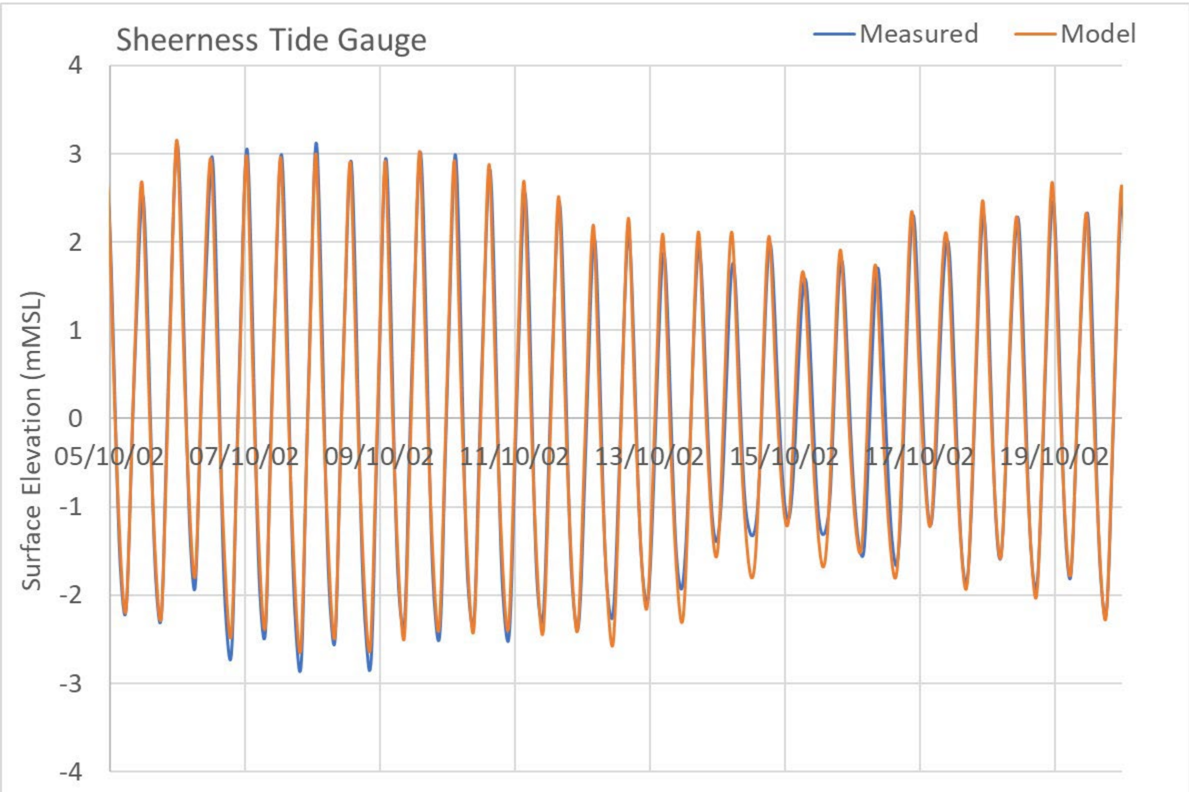

Figure 5. Comparison of total measured and modelled water-levels at Sheerness NTSLF tide gauge.

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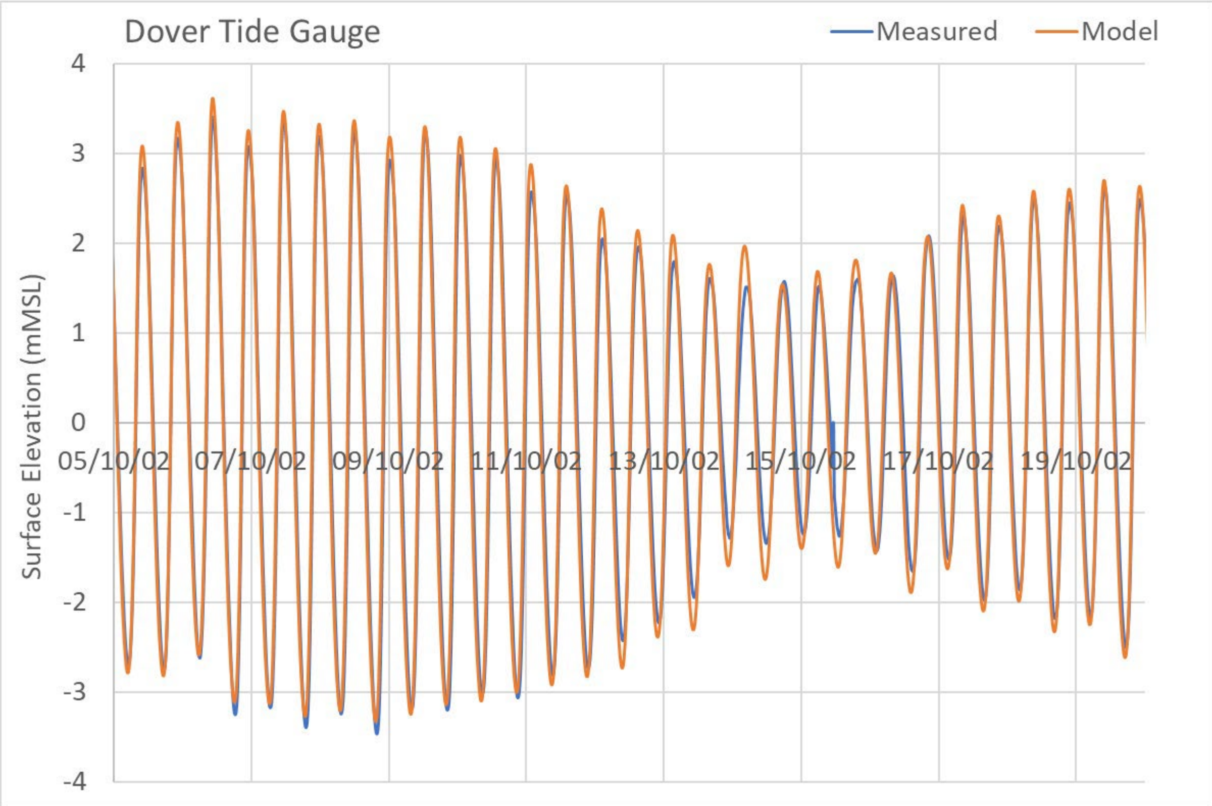

Figure 6. **Comparison of total measured and modelled water-levels at Dover NTSLF tide gauge.**

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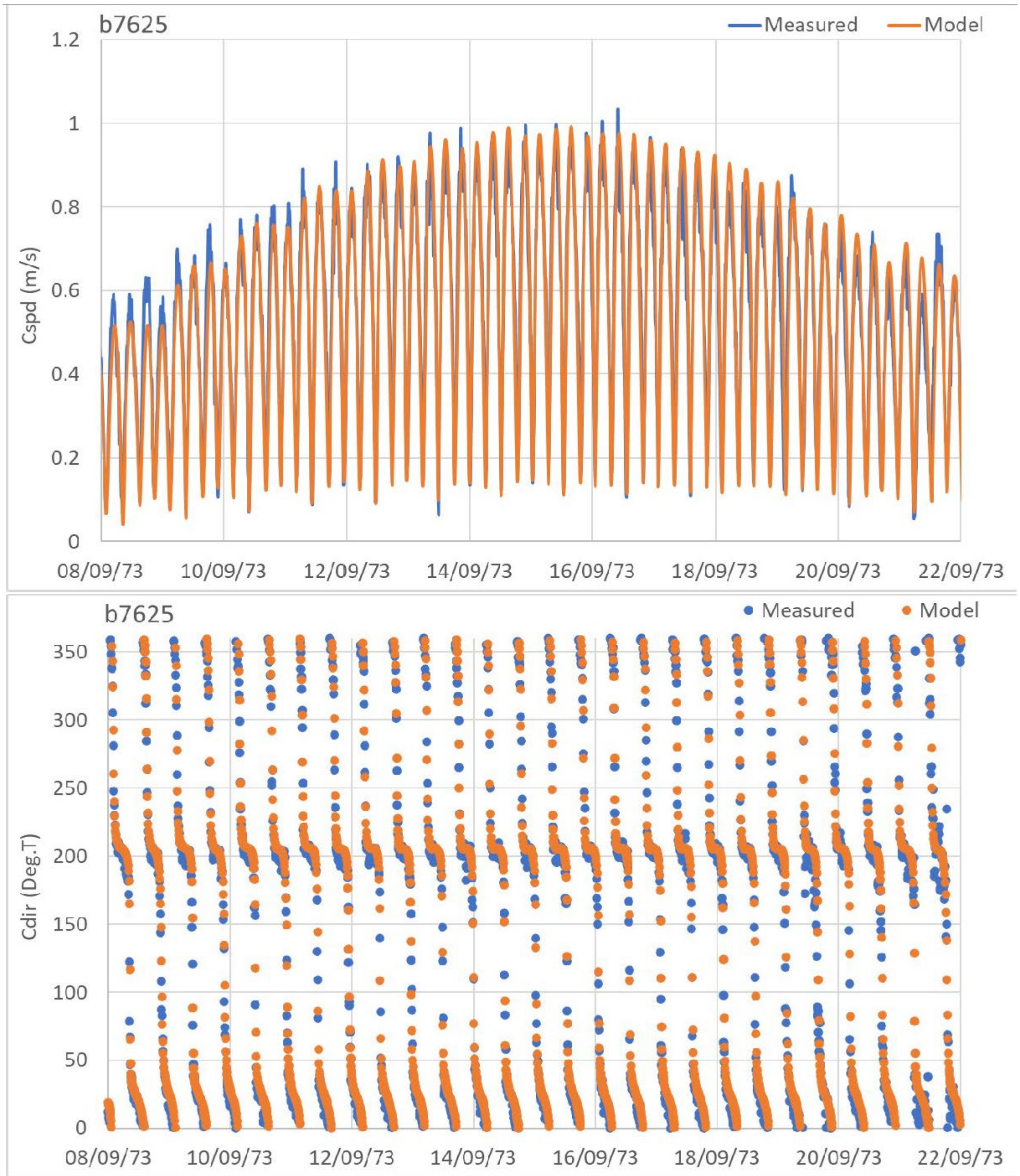

Figure 7. **Comparison of measured (total) and modelled (tide-only) hydrodynamic parameters at b7625, southern North Sea**

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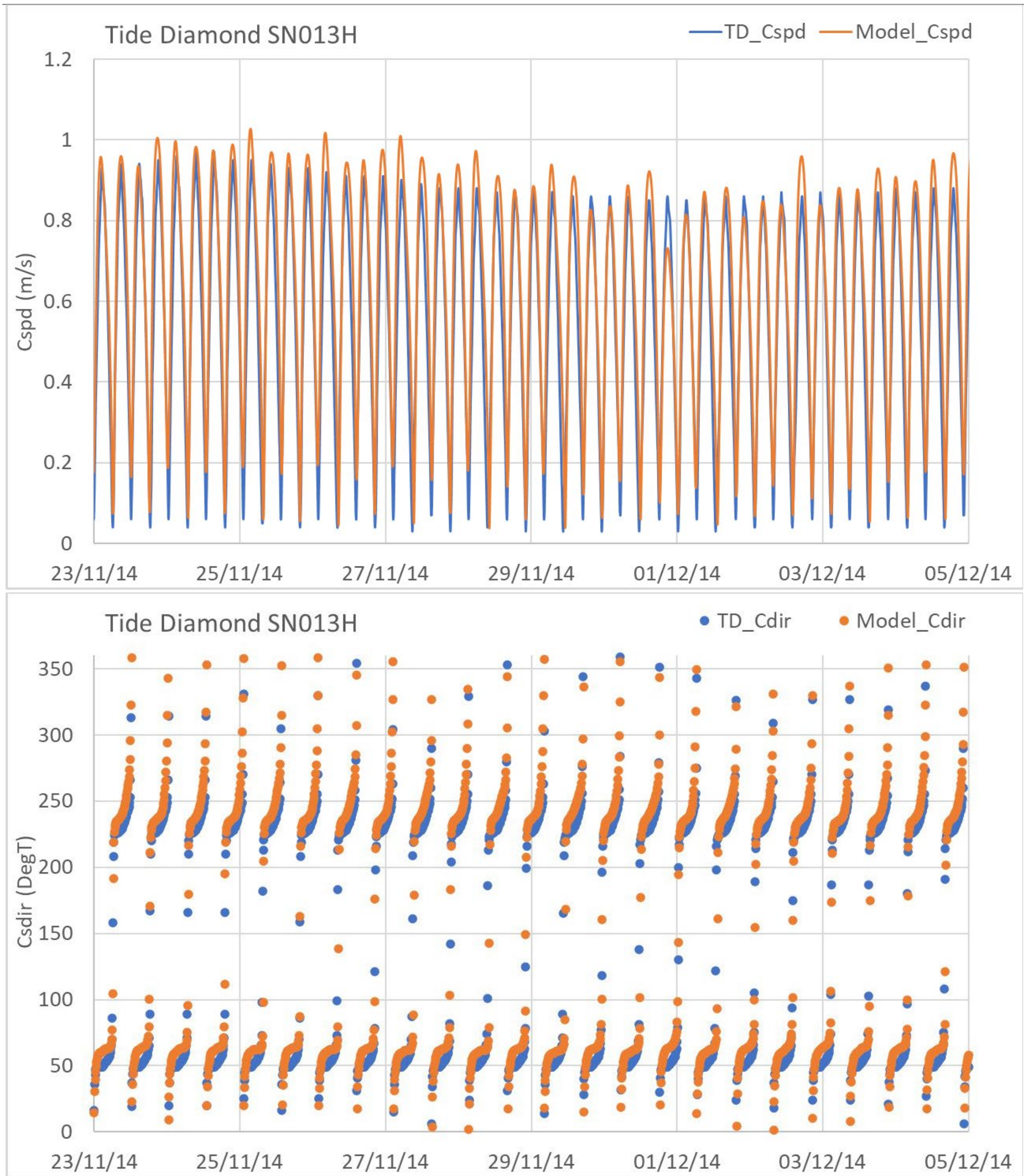

Figure 8. Comparison of tide diamond and modelled hydrodynamic parameters at SN013H, Outer Thames

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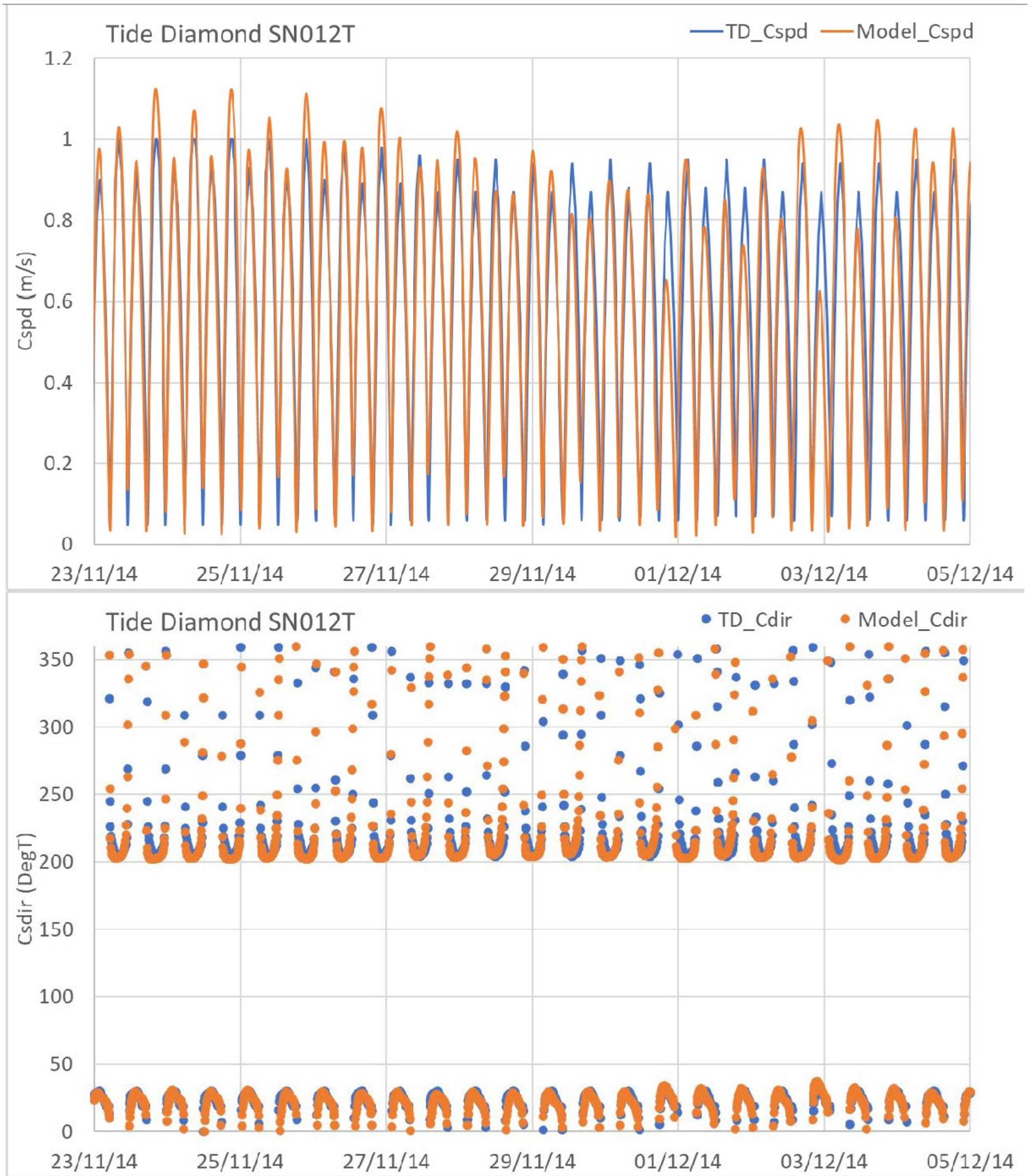

Figure 9. **Comparison of tide diamond and modelled hydrodynamic parameters at SN012T, Outer Thames**

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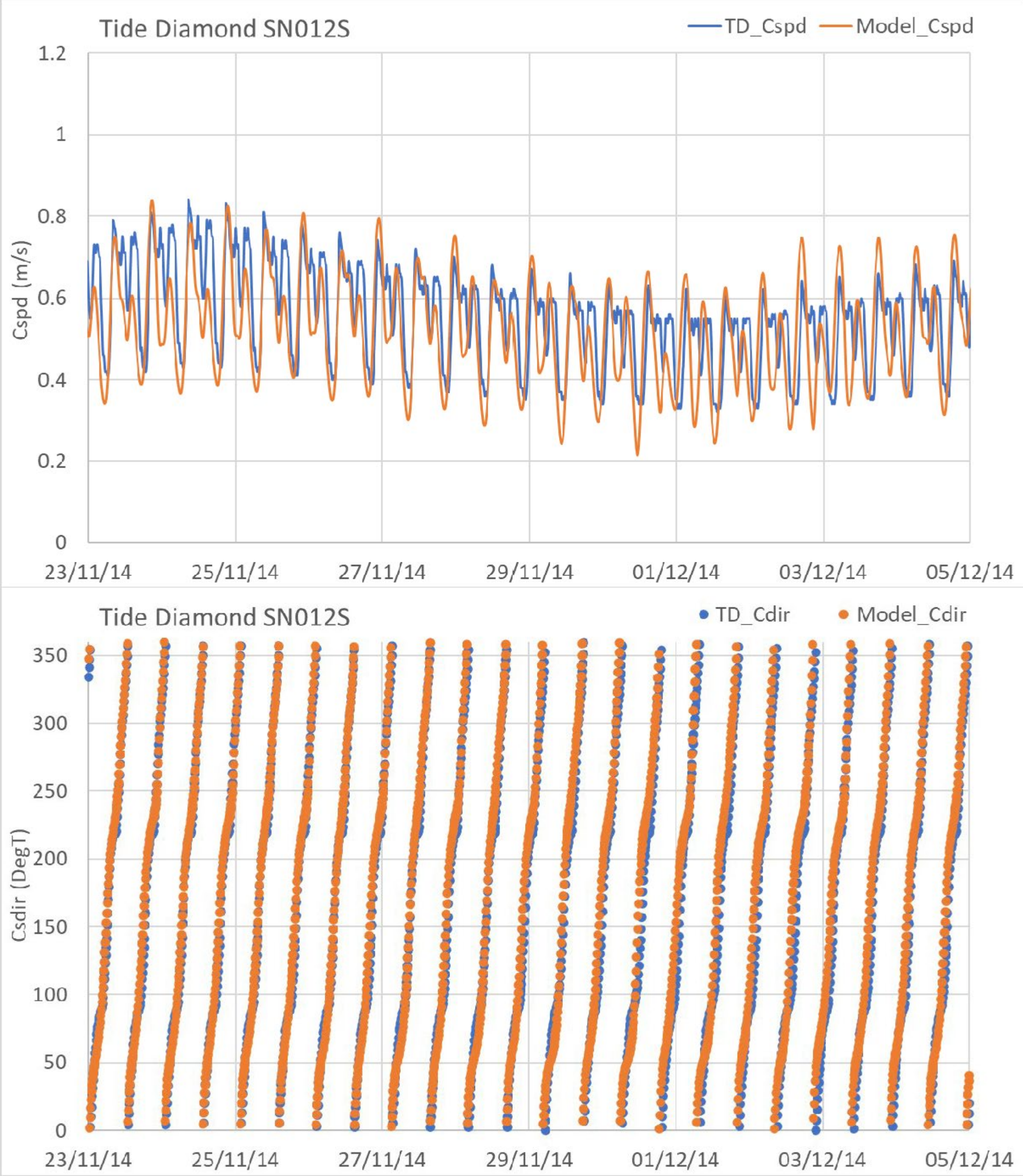

Figure 10. **Comparison of tide diamond and modelled hydrodynamic parameters at SN012S, Outer Thames**

3 Sand Transport

3.1 Overview

This section describes the design and inputs to a sediment transport model, used to simulate patterns of tidally driven sand transport rate and direction in the VE EIA study area. The model will be used to simulate baseline conditions, and the impact of the wind farm foundations on baseline conditions.

Sand is the dominant mobile sediment type within the study area. The study area includes areas of notable present day sedimentary bedforms, including medium to large sand-waves (6-10+m height) and major sandbanks (1-20km length). Such bedforms are likely indicative of, or are the equilibrium result of, regional scale patterns of sediment transport.

Scenario specific information, model inputs and results are described in a separate report (Volume 4, Annex 2.3: Physical Processes Technical Assessment), including:

- Time period of simulation (typically one representative spring-neap cycle)
- Foundation type, dimensions, number, and layout for:
  - VE (maximum design scenario)
  - Other nearby wind farms (as built).
- Resulting patterns of:
  - Baseline (current related) sediment transport rate and direction;
  - Baseline (current related) residual sediment transport rate and direction;
- Patterns of change to all of the above as a result of the presence of wind farm foundations.

3.2 Sand transport model design

3.2.1 General design

The sand transport model is built using the MIKE21FM Sand Transport (ST) module, which simulates the rate and direction of sand transport, as a result of the input flow conditions, for representative sedimentary parameters.

The ST model provides a timeseries simulation of spatially varying sand transport rate and direction within the model domain.

3.2.2 Sand transport model extent, resolution, bathymetry and hydrodynamic inputs

The sand transport model utilises the same model grid and the flow field timeseries generated by the validated hydrodynamic model described in Section 2. The model is therefore able to consider a range of tidal conditions during a representative spring-neap tidal cycle. A relatively high spatial resolution (~200 m) is used throughout the VE study area.

3.2.3 Sand transport model sediment type

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The sand transport model utilises representative sediment properties of a medium sand (250 µm, 0.25 mm) grain size, with a quartz mineral density (2650 kg/m^3). The threshold current speed for initiation of motion for a wider range of sand grainsizes (63 µm to 2000 µm) is broadly similar, and therefore, so is the rate of sand transport resulting from a given current speed in excess of the threshold value. Therefore, the representative medium sand grain size used is also broadly representative of a wider range of sand-sized sediment.

3.3 Sediment plume model validation

Sediment transport models are not normally quantitatively validated, as location specific observations of the processes being simulated are rarely available. However, this type of modelling approach, in conjunction with validated hydrodynamic inputs, is generally accepted to provide a realistic description of sediment transport in the marine environment.

There are a range of alternative but equally valid relationships available for the estimation of sediment transport rates under different circumstances. As such, it is widely accepted that there will be some uncertainty in the absolute magnitude of instantaneous transport. However, it is also widely accepted that the relative patterns of magnitude, asymmetry and direction of net transport are likely to be coherent and meaningful when integrated over longer time periods.

The following points also provide confidence in the modelling process and results:

- Section 2.3 validates the accuracy and representativeness of the water level, current speed and direction data that control the rate and direction of sediment plume advection in the particle tracking model.
- The inputs and settings used in the model and the definitions of the representative sediment type are conservatively realistic. The modelling process and analysis of the results are undertaken by an experienced coastal processes modeller.
- The outputs of the model are consistent with proxy evidence of sediment mobility and transport in the available survey data, including: regional scale patterns/areas of sediment accumulation and erosion; the location of sandbanks and the processes maintaining them; the orientation and direction of migration of sandwave features; the presence or absence of other signs of sediment mobility in certain areas.

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4 Waves

4.1 Overview

This section describes the design and inputs to a wave model simulating patterns of wave height, period and direction in the VE EIA study area. The model will be used to simulate selected baseline conditions, and the impact of the wind farm foundations on baseline conditions.

Scenario specific information, model inputs and results are described in a separate report (Volume 4, Annex 2.3: Physical Processes Technical Assessment), including:

- Foundation type, dimensions, number and layout for:
  - VE (maximum design scenario)
  - Other nearby wind farms (as built).
- Resulting patterns of baseline wave height and wave direction;
- Resulting patterns of change to wave height, wave period and wave direction as a result of the presence of wind farm foundations.

4.2 Wave model design

4.2.1 General design

The wave model is built using the MIKE21FM Spectral Wave (SW) module, which simulates the propagation of the incident waves and their associated movements of water volume in offshore and coastal settings.

The wave model creates discrete simulations of wave height, period and direction throughout the domain, for a representative range of selected every-day and extreme wave conditions (return periods and directions).

4.2.2 Wave model extent and mesh resolution

The extent and resolution of the wave model mesh is shown in Figure 11. A flexible mesh design (interlocking triangular 'elements' of varying shape and orientation) is used, providing tailored resolution within a single model mesh.

The overall extent of the model is smaller than that of the tidal model. The mesh resolution is approximately: 100 m on and around significant sandbank features close to VE and the surrounding windfarms; 200 m within and around VE and the surrounding windfarms; approximately 500m the throughout the main study area between VE and the surrounding windfarms and Lowestoft and Margate; approximately 1000m in the Greater Thames area. The relatively high resolution, especially in areas close to the source of any potential changes, provides a more detailed description of the key bathymetric and coastal features affecting wave patterns in these areas.

4.2.3 Wave model bathymetry

The bathymetry data used for the SW model is the same as that used within the same extent of the hydrodynamic and sediment plume models. See Section 2.2.3 for more details.

The wave model is run with a representative constant depth (mean sea level, with no tidal water level variation). This provides a central description of the range of total water depths that might be experienced within the study area. The timing of larger extreme wave events is independent of the timing of tidal processes (high water/low water/spring/neap). A relatively higher water level might allow larger waves to extend further onto or beyond otherwise shallower areas of the domain or *visa-versa*. However, the effect of the wind turbine foundations occurs in a relatively deep offshore area (approximately 38 to 55 m below mean sea level).

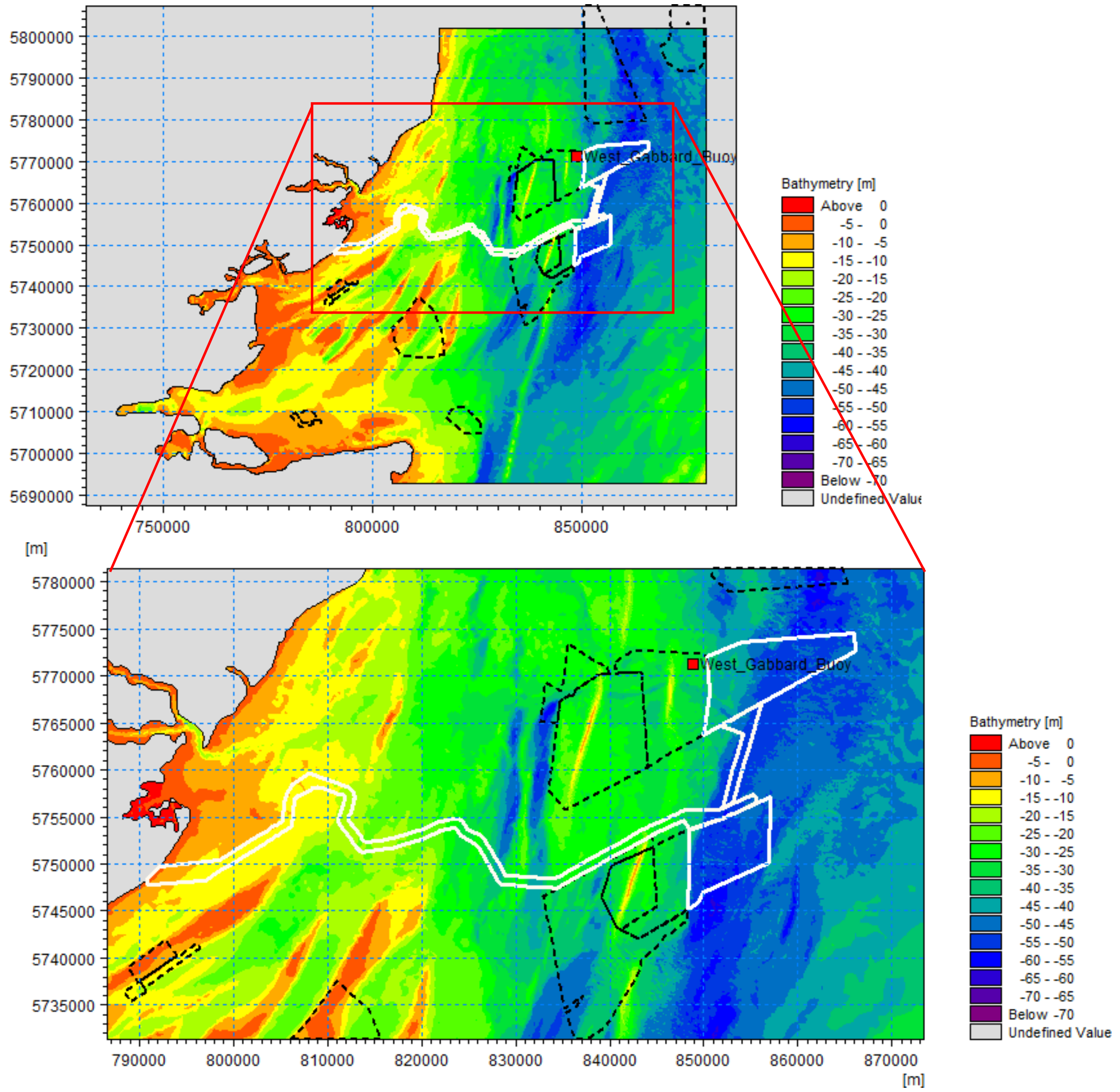

Figure 11. Extent of the wave model mesh with the VE windfarm extent (white) and surrounding windfarms (dashed black) along with the location of the West Gabbard buoy

4.2.4 Spectral and time formulations

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A fully spectral formulation is used. The fully spectral formulation is based on a wave action conservation relationship where the directional-frequency wave action spectrum is the dependent variable. Of the available choices, this formulation is considered to be the most accurate for the nature of the processes being simulated with respect to both general wave propagation and the effect of the wind farm foundations.

A quasi-stationary time formulation is used. Time is removed as an independent variable and a steady state solution is calculated for each seastate being simulated. This choice is appropriate for the limited size of the model domain, within which waves are likely to achieve an equilibrium state dependant on the input wave and wind boundary conditions.

A logarithmic distribution of 36 spectral frequencies is resolved, equivalent to wave periods in the approximate range from 1 to 30 s, with smaller intervals at smaller wave periods. This exceeds the default number and range (25 spectral frequencies, from 1.8 to 18 s) in order to better resolve a wider range of wave periods.

Directional calculations are made using 32 directional sectors (each sector covering a range of 11.25°). This exceeds the default number (16 directional sectors, 22.5°) in order to reduce the occurrence of small magnitude 'radial artefacts' in the scheme effect results when obstacles representing the offshore wind farm infrastructure are included in the model. The baseline wave maps are largely unaffected by the difference.

4.2.5 Wave model boundary conditions

The wave model is forced by wave conditions (height, period, direction and directional spreading) at the three offshore wave boundaries (along the northern, eastern and southern extents of the model domain), and by a constant wind speed and direction applied over the whole domain. The wave model is run with a constant mean water depth (no tidal water level variation) and no currents.

The wave condition scenarios considered by the model for the assessment are:

- Wave coming directions (ENE, E, ESE, SE, and SSE);
- Return periods (50% non-exceedance, 0.1 yr; 1 yr; 10 yr; 50 yr; 100 yr).

An understanding of the potential impacts of OWF infrastructure within this range of conditions will inform the assessments regarding potential impacts on sedimentary/coastal processes and flood risk. These conditions were initially determined using Extreme Value Analysis (EVA) for a location situated North-East of the array area, using hindcast timeseries data from the separately validated ABPmer SEASTATES NW European Shelf Wave Hindcast Model (see Section 4.3). It is important to note that the extreme values associated with the directions being simulated are not necessarily the largest waves that might come from any direction. Other directions might be associated with potentially larger extreme waves, however, waves from other directions are not likely to pass through the VE array areas and then intersect any sensitive physical processes receptors.

The wave boundary condition is applied uniformly along the offshore wave boundaries. The condition is defined by the significant wave height (Hs), peak wave period (Tp), mean wave direction (DirM) and directional standard deviation (DirStd). The directional return period wave boundary conditions tested are listed in Table 1. The shortest return period is the wave condition not exceeded 50% of the time, representing a relatively frequent, everyday wave condition; more severe but infrequent conditions are described by the associated return period (RP), or likelihood of occurrence expressed in years.

The wind boundary condition is applied uniformly across the whole model domain area, representing the wind speed at 10 m above sea level normally associated with the target seastate. The associated wind direction is the same as the wave direction at the boundary. The wind boundary condition is required for natural patterns of wave propagation and development through the model domain from the offshore boundaries. Wind is also a realistic mechanism contributing to wave recovery in the lee of the wind farm. The associated directional return period values of wind speed and direction used are also shown in Table 1.

Table 1. Wave and wind boundary conditions for each of the directional return period seastate conditions tested

Directional Sector	Case (Return Period)	Significant Wave Height (m)	Peak Wave Period (Tp, s)	Mean Wave Direction (°N)	Wind Speed @10 m (m/s)	Wind Direction (°N)
ENE	50% no exc	0.9	3.9	67.5	7.0	67.5
	0.1 yr RP	1.3	4.6	67.5	9.3	67.5
	1 yr RP	2.2	6.0	67.5	13.3	67.5
	10 yr RP	3.7	7.6	67.5	18.1	67.5
	50 yr RP	4.1	8.1	67.5	19.4	67.5
	100 yr RP	4.2	8.2	67.5	19.6	67.5
E	50% no exc	0.9	3.7	90	7.0	90
	0.1 yr RP	1.1	4.2	90	7.9	90
	1 yr RP	1.9	5.4	90	11.9	90
	10 yr RP	3.3	7.2	90	17.0	90
	50 yr RP	3.8	7.6	90	18.5	90
	100 yr RP	3.9	7.8	90	19.0	90
ESE	50% no exc	0.8	3.4	112.5	6.5	112.5
	0.1 yr RP	1.1	4.0	112.5	7.9	112.5
	1 yr RP	1.7	5.0	112.5	11.5	112.5
	10 yr RP	3.1	6.6	112.5	16.4	112.5
	50 yr RP	3.5	7.1	112.5	17.6	112.5
	100 yr RP	3.7	7.3	112.5	18.2	112.5
SE	50% no exc	0.8	3.3	135	6.5	135
	0.1 yr RP	1.1	3.9	135	7.9	135
	1 yr RP	1.8	5.0	135	11.9	135
	10 yr RP	3.5	7.0	135	17.6	135
	50 yr RP	4.4	7.7	135	20.4	135
	100 yr RP	4.7	8.0	135	21.3	135
SSE	50% no exc	0.8	3.4	157.5	6.5	157.5
	0.1 yr RP	1.3	4.2	157.5	9.3	157.5
	1 yr RP	2.2	5.5	157.5	13.3	157.5
	10 yr RP	4.0	7.4	157.5	19.0	157.5
	50 yr RP	4.5	7.8	157.5	20.7	157.5
	100 yr RP	4.6	7.9	157.5	21.2	157.5

4.2.6 Wave breaking, bottom friction and other wave transformation parameters

The settings and values below are either default settings or within the range of normally recommended values and are consistent with numerous similar recent offshore wind farm modelling studies undertaken by ABPmer.

Depth-induced wave breaking is the process by which waves dissipate energy when the waves are too high to be supported by the water depth, i.e., reach a limiting wave height/depth-ratio. Wave breaking is described in MIKE21SW by standard equations that are scaled by a coefficient 'Gamma'. A constant Gamma value of 0.8 was used.

Bottom friction is relevant where, as waves propagate into shallow water, the orbital wave velocities penetrate throughout the full water depth and the source function due to wave-bottom interaction becomes important. A large part of the model domain (towards the adjacent coastlines) is shallow enough, relative to the waves being simulated, to be affected by choices relating to the implementation of bottom friction. The dissipation source function used in the SW module is based on the quadratic friction law and linear wave kinematic theory. The dissipation coefficient depends on the hydrodynamic and sediment conditions. Sediment roughness is characterised by a Nikuradse Roughness length value of 0.04 m.

The wave model also takes account of the following wave transformation processes (using default settings):

- White capping (Dissipation coefficients, constant Cdis = 4.5, constant DELTAdis = 0.5); and
- Quadruplet-wave interaction.

4.3 Wave model validation

The wave model is not required to provide historical (hindcast) predictions of wave conditions in a timeseries mode, therefore, no direct validation of the new wave model against measured timeseries data is required.

Hindcast data from the ABPmer SEASTATES NW European Shelf Wave Hindcast Model are used to inform the specific seastate boundary conditions described in Section 4.2.4. The SEASTATES wave hindcast model has already been regionally validated against numerous wave buoys (ABPmer, 2013). The SEASTATES wave hindcast model is also further locally validated in Figure 12, against measured data from one offshore location (West Gabbard buoy), which is situated near the VE EIA site and is a representation of the local wave climate (Figure 11).

Without adjustment, the SEASTATES wave hindcast model is in general agreement with the buoy measurements. The SEASTATES hindcast slightly (conservatively) over-predicts some of the peaks in significant wave height (Hs, Figure 12), however, peak period (Tp) and mean wave direction (DirM) are a consistently good match with the buoy measurements. Although there are periods of slight variable difference, there is no obvious consistent bias or inconsistency in the pattern simulated. Any differences in the two datasets may be due to the SEASTATES hindcast model having a relatively coarse resolution (approximately 5 km) in a region of particularly complex and variable bathymetry around the location of the measurement buoy.

It is concluded that the above information sufficiently validates the SEASTATES hindcast model data (taken from an offshore location) to provide a realistic representation of example every day and extreme wave conditions within the VE array and surrounding study area. The local wave model performance is not validated explicitly. However, the important components of the model design and inputs (extent, high resolution, bathymetry, coastlines and boundary conditions) have been individually selected and validated to be realistic, accurate and detailed. The resulting model is therefore expected to perform to a similar level.

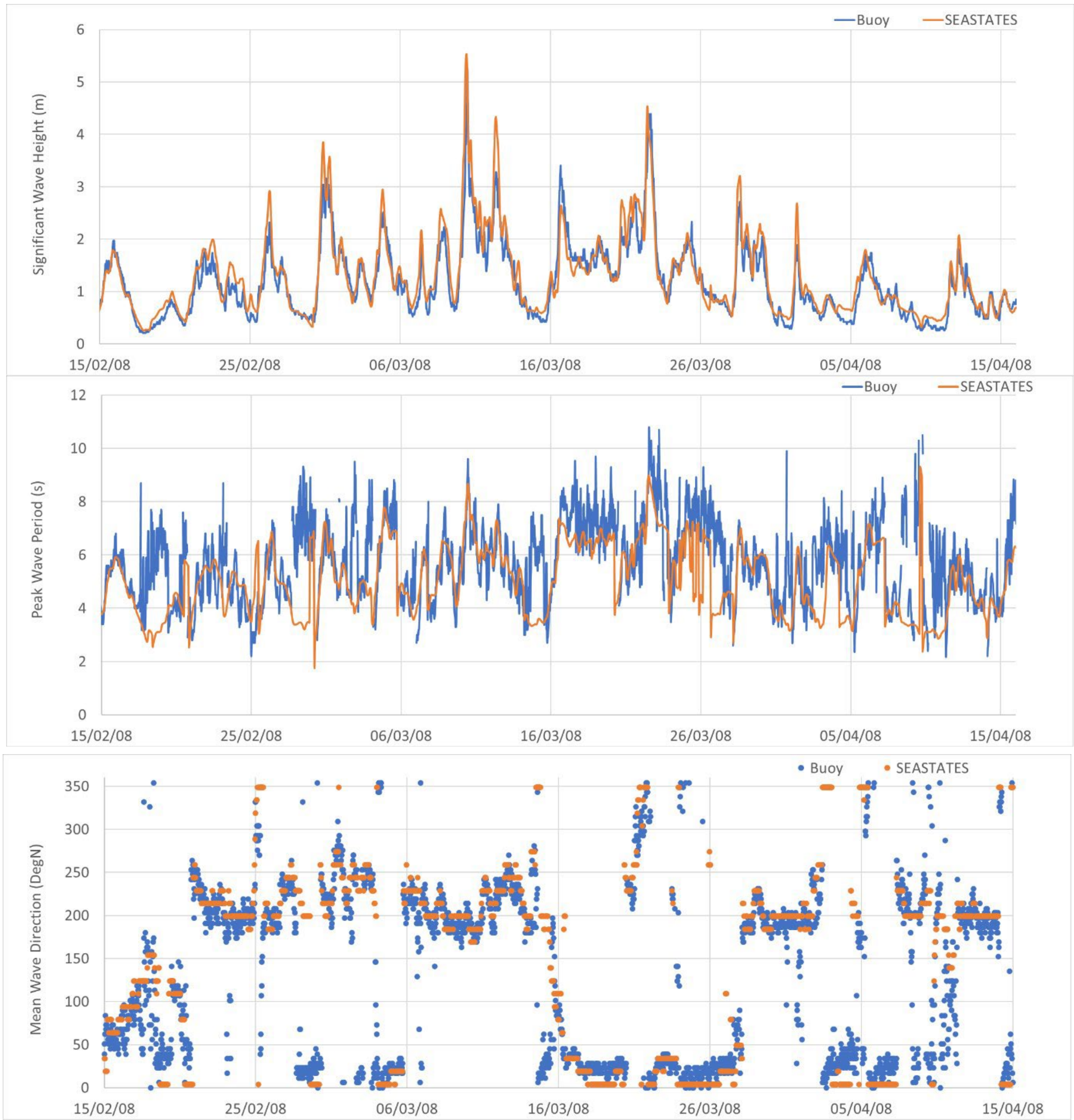

Figure 12. Comparison of measured and modelled (SEASTATES hindcast) wave parameters at location West Gabbard wave buoy

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