NAUTICAL AND RISK STUDIES FOR THE DELIMARA LNG TERMINAL IN MARSAXLOKK PORT, MALTA

Item 2: Wave penetration study

Final report

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Item 2: Wave penetration study

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NAUTICAL AND RISK STUDIES FOR THE DELIMARA LNG TERMINAL IN MARSAXLOKK PORT, MALTA

ITEM 2: WAVE PENETRATION STUDY

MARIN

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1 Introduction

1.1 PROJECT BACKGROUND

Enemalta is developing a new gas-fired power station near the existing Delimara Power Station on the north-eastern shore of Marsaxlokk Bay. The gas for the power plant will be imported through a new to build LNG terminal in Marsaxlokk Bay. Figure 1-1 shows the approximate position of the new terminal.

Figure 1-1: Marsaxlokk Port and approximate position of LNG terminal (source: Google Earth)

Enemalta has awarded the contract for design, construction and operation of the new power plant and LNG terminal to Electrogas Malta. The LNG terminal proposed by Electrogas consists of a jetty from the shore south of the power plant to a berth that is positioned where the bay is deeper, so that no or only limited dredging is required. On the jetty a converted LNG carrier will be permanently moored as Floating Storage Unit (FSU), delivering LNG through a cryogenic line over the jetty to the regasification unit onshore. The FSU berth has a conventional layout consisting of a platform, breasting dolphins and mooring dolphins (Figure 1-2). LNG will be imported by LNG carriers (further shortened to LNGCs) that will moor alongside the FSU.

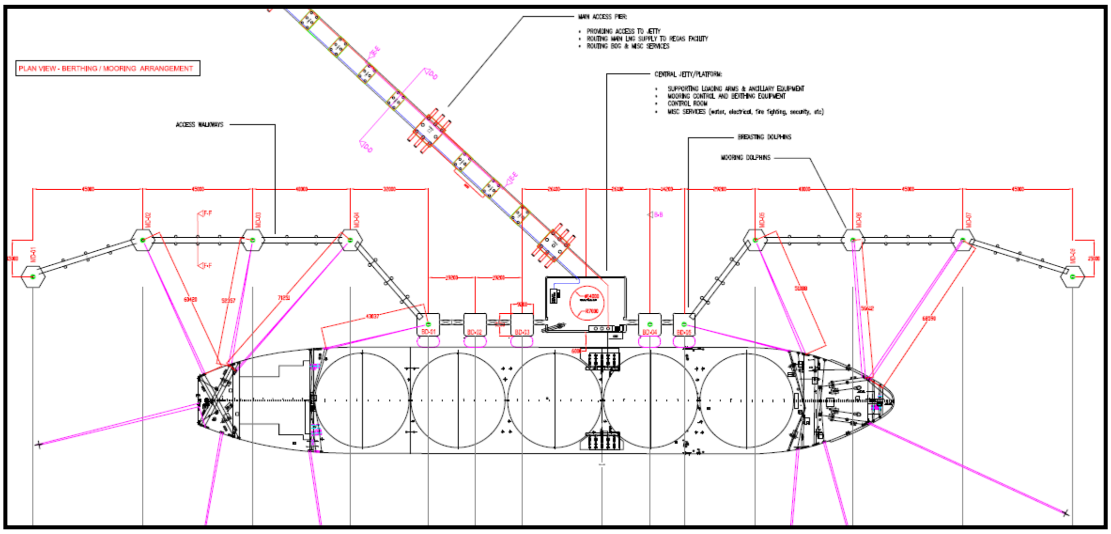

Figure 1-2: Proposed jetty configuration

To verify the design and evaluate safety aspects related to the permanent presence of the FSU in the port and to the regular call of LNGCs to the new LNG terminal, Enemalta has commissioned MARIN to carry out nautical and safety studies for the new LNG terminal. The study addresses a number of items raised by Transport Malta, the authority responsible for the port, who required:

1. Validation of proposed jetty/berth layout
2. Nautical and safety study
    a. Determine the required minimum navigation channel/fairway
    b. Determine the risk involved in the handling of an FSU and LNG carriers when navigating to the terminal
    c. Determine the nautical procedures for the handling of the FSU and LNGC during routine procedures and emergency situations
3. Site specific risk (safety) assessment including
    a. Cargo release
    b. Collision
    c. Fire and explosion
    d. Grounding

The contract for the study (Ref: DPS-GEN-1190) was signed on 25 August 2014 and is based on MARIN's proposal of 24 March 2014.

1.2 OBJECTIVE, APPROACH AND SCOPE OF WORK

Objective

The objectives of the present nautical and risk study for the Delimara LNG terminal are:

- To evaluate the dimensions of the manoeuvring area and port approach
- To determine the operational envelope for ship manoeuvres (input for nautical procedures);
- To evaluate the proposed jetty layout and to determine the limiting operational conditions for safe offloading and for staying safely at the berth (input for nautical procedures);
- To determine the risk involved in the LNG operations in the port regarding grounding of LNGCs and collisions involving FSU or LNGC,
- To determine the consequences (cargo release, fire and explosion) of incidents involving the FSU or an LNGC.

Approach

The above mentioned items are evaluated in this dedicated nautical and safety study for the Delimara LNG terminal. The study consists of the following items:

1. Wave climate study to determine the normal and extreme wave climate outside Marsaxlokk port (frequency of occurrence of directions and wave heights)
2. Wave penetration calculations to determine the wave conditions at the terminal
3. Numerical moored ship response simulations to validate the jetty/berth layout and determine operational limits for the moored FSU;
4. Real-time manoeuvring simulations to verify dimensions of the fairway and determine operational limits for sailing with LNG carriers;
5. Nautical risk study to determine the risks of grounding and collisions involving the FSU or LNG carrier
6. Quantitative Risk Assessment to determine the consequences of collisions in terms of cargo release and risk of fire and explosion

The wave studies (items 1 and 2), which serve as input for the nautical studies (items 3 and 4) were carried out by ARCADIS. Items 3 and 5 were carried out by MARIN. Item 4 was carried out by MARIN in cooperation with MMP (Malta Maritime Pilots) and MMRTC (Malta Maritime Research and Training Centre). SGS Tecnos SA carried out the QRA in item 6.

1.3 REPORTS

The total study is presented in a series of reports, each one treating one of the above mentioned study items. Table 1-1 gives an overview of the reports presenting the results of the study.

Volume	Title	Main author
27689-1-MSCN	Item 1: Wave climate study	ARCADIS
27689-2-MSCN	**Item 2: Wave penetration study**	**ARCADIS**
27689-3-MSCN	Item 3: Moored ship response study	MARIN
27689-4-MSCN	Item 4: Real-time manoeuvring simulations	MARIN
27689-5-MSCN	Item 5: Nautical risk study	MARIN
27689-6-MSCN	Item 6: Nautical Quantitative Risk Assessment	SGS Tecnos

Table 1-1: Overview of reports

To support the design of the modifications to the FSU and the storm mooring for the FSU, some additional analysis was carried out for ElectroGas Malta on the data from the wave climate and wave penetration studies. This has been reported directly to EGM.

1.4 THIS REPORT

This report (marked in bold in Table 1-1) describes the approach and the results of the wave penetration study. It presents the evaluation of the yearly average wave climate and extreme wave conditions at the jetty. The applied methodology is described in Chapter 2, the schematisation and set-up of the models is described in Chapter 3. The resulting wave conditions at the project site are presented in Chapter 4. In Chapter 5 conclusions are given.

Detailed results in the form of tables of the yearly average wave climate are presented in Appendix 4 and of the extreme wave climate in Appendix 5.Figures of the spatial distribution of the significant wave height from various simulations are presented in Appendix 6.

This report is an updated final report to include references to the additional metocean analysis carried out for ElectroGas Malta. The contents of the report is further unchanged.

1.4.1 CONVENTIONS AND DEFINITIONS

Units
All parameters and variables have units according to the international SI conventions except where explicitly stated.

Directions
Unless otherwise stated, wind and wave directions are given according to the nautical convention. For winds and waves, they refer to the direction from which they are coming in degrees, measured clockwise with respect to the North. For example, a wave direction of 90 degrees means the waves are coming from the East.

Coordinate Systems
All the coordinates given in this report are provided in Universal Transverse Mercator zone 33N (WGS 84) unless otherwise stated. The vertical datum used for the bathymetry and different levels is Chart Datum unless otherwise stated.

Notations
The following notations are used in this report:

.	decimal point. Thus 1.5 means one and half.
,	digit grouping symbol. Thus 12,000,000 means 12 million.
E	for the scientific notation with the exponent of 10. Thus 1.2E-3 means $1.2 \times 10^{-3} = 0.0012$

1.4.2 INTERPRETATION OF WIND AND WAVE ROSES

Roses provide a compact graphical summary directional wind and wave condition statistics. The number in the centre of the rose represents the percentage of the time that calm conditions occur (height, period or speed in the lowest class). Calm conditions are those with significant wave height lower than 0.25 m, i.e. lower value of the lowest class of wave heights. The direction that the arm points to (from the centre) represents the direction that winds or waves come from. The length of an arm represents the percentage of the time that winds or waves (other than those in the lowest class) occur in the corresponding direction sector. The colour of a section indicates the corresponding height or speed class. The length of each section represents the percentage of the time that conditions in the given direction sector occur in a given speed, period or height class.

1.4.3 DEFINITION OF WAVE PARAMETERS

The definition of wave parameters is according to the description in SWAN manual [3].

Significant wave height

$$H_{m0} = m_0 = \sqrt{\iint E(\omega,\theta)d\omega d\theta}$$

Peak wave period

$$T_p = \frac{1}{f_p}$$

Mean wave period

$$T_{m-1,0} = 2\pi\frac{m_{-1}}{m_0} = 2\pi\frac{\iint \omega^{-1}E(\omega,\theta)d\omega d\theta}{\iint E(\omega,\theta)d\omega d\theta}$$

Mean wave direction

$$dir = \arctan\left[\frac{\int \sin\theta\, E(\omega,\theta)d\omega d\theta}{\int \cos\theta\, E(\omega,\theta)d\omega d\theta}\right]$$

Peak wave direction

The direction corresponding to the maximum energy in the two dimensional spectrum.

$$\theta_p = \theta(E_{max})$$

Directional spreading

The directional spreading is the one-sided width, or standard deviation, of the spectrum, as defined by Kuik et al [6].

$$dspr = \frac{\pi}{180}\sqrt{2\left(1-\sqrt{\left[\left(\int \sin\theta\frac{\int E(\omega,\theta)d\omega}{\int E(\omega)d\omega}d\theta\right)^2+\left(\int \cos\theta\frac{\int E(\omega,\theta)d\omega}{\int E(\omega)d\omega}d\theta\right)^2\right]}\right)}$$

Directional distribution

The following directional distribution was applied in this study:

$$D(\theta) = \cos^m(\theta-\theta_p)$$

The parameter m is referred to a directional distribution power. A fixed relationship exists between the value of m and the directional spreading.

Deep water wave steepness

The wave steepness is defined as wave height divided by wave length. In deep water, the wave length is equal to:

$$L_{deep} = \frac{gT^2}{2\pi}$$

The deep water steepness then expressed as:

$$s_{deep} = \frac{H_s}{L_{deep}} = \frac{2\pi H_s}{gT_p^2} \approx \frac{H_s}{1.56T_p^2}$$

With:

E	variance density spectrum [m^2]
θ	wave direction [°N]
ω	radian frequency [Hz]
f_p	peak frequency, the frequency of the maximum variance density [Hz]
m_n	n-th order moment of the spectrum, defined as $\iint \omega^n E(\omega,\theta)d\omega d\theta$

2 Methodology

2.1 INTRODUCTION

In the wave climate study carried out by ARCADIS [1], the nearshore yearly average and the extreme wave climate in front of Marsaxlokk Bay were determined. The yearly average wave climate is available in the form of two time series; one representing wind sea conditions and one representing swell conditions. The corresponding wind climate is available at an offshore location (see [1]).

This chapter discusses the methodology applied for propagating the nearshore wave climate in front of Marsaxlokk port to locations inside the port.

2.2 MODEL SELECTION

The wave model MIKE21BW (see Appendix 2) is used to propagate wave conditions from outside the bay towards the new LNG terminal. MIKE21BW is based on the numerical solution of the extended two-dimensional Boussinesq equations including non-linearity and frequency dispersion. The model is capable of reproducing the combined effects of most wave phenomena of interest in coastal and harbour engineering. These include shoaling, refraction, diffraction and partial reflection of irregular short-crested and long-crested finite-amplitude waves propagating over complex bathymetries.

Due to the formulations of the extended Boussinesq equations, the maximum water depth determines the minimum wave period that can be represented accurately by the model. Since, for the project site the water depths are relatively large, this implies that for short waves the bathymetry must be adapted (water depth must be reduced). Another restriction of the MIKE21BW model is that the effect of wind is not included in the simulations. For relatively long waves, wind is not expected to influence the amount of wave penetration, whereas for shorter waves wind effects affect should be included. Therefore, in the present study for short waves ($T_p \leq 6$s) and wind sea conditions, the spectral wave model SWAN was applied.

Although SWAN does not explicitly solve the effect of diffraction, its effects are smoothed out in case of wave fields with relatively large directional spreading. It is expected that the accuracy of the SWAN model results is sufficient for the above cases for the following reasons:

- The proposed FRSU is very large in size (LOA around 180m) and its motion response to waves with periods smaller than 6 seconds is expected to be negligible.

- Wind sea waves have a large directional spreading (in the order of 25° one-sided). For wave conditions with a large directional spreading, the effect of diffraction is not very important [4]. Wind waves are generally steep waves which will dissipate quite strongly over short distances. By including wind in the SWAN simulations, the dissipation will be balanced by wind growth. This leads to more representative and conservative results.

Very close to a diffraction point (e.g. a breakwater tip), the effect of diffraction on the significant wave height is large, but several wave lengths further this effect diminishes. As the new LNG terminal is situated in an open area and at a relative large distance from the diffraction points, the SWAN results will be sufficiently accurate. From a comparison of SWAN and MIKE21BW simulations with two identical representative boundary conditions, it was confirmed that outside the direct vicinity of diffracting obstacles, the results are comparable (compare Figure 2-1 and Figure 2-2). Therefore, using SWAN to model short swell and wind sea waves, which does not solve diffraction, is justified for this project.

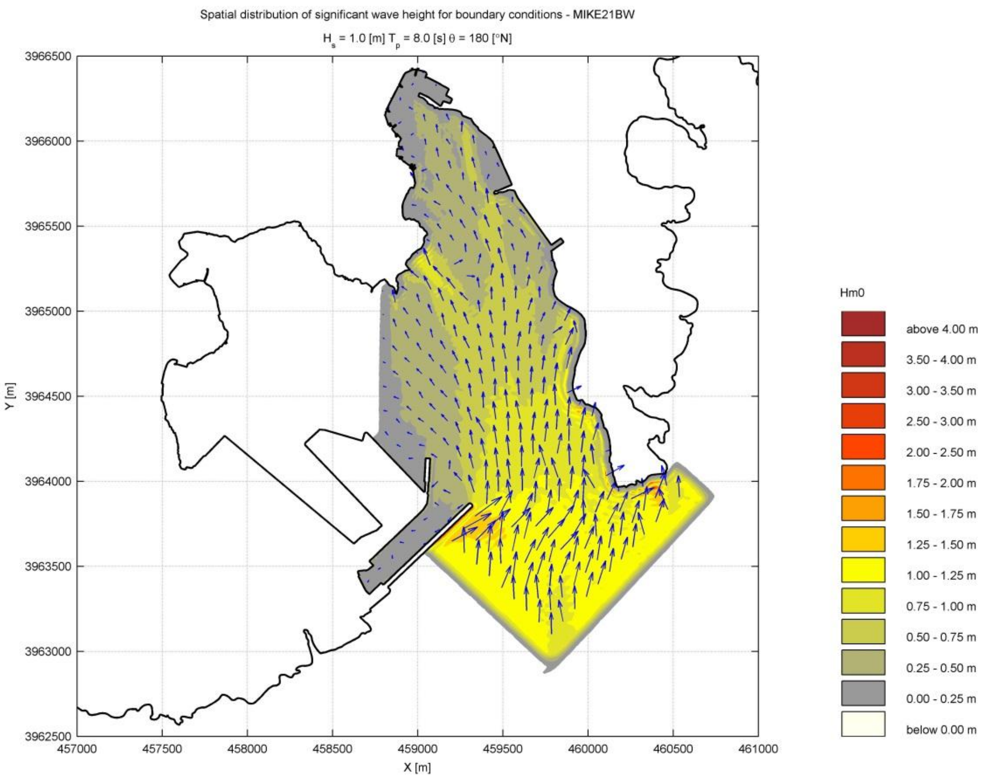

Figure 2-1: Spatial distribution of Hm0 [m] of MIKE21BW swell simulations for boundary conditions Hm0 = 1.0m, Tp = 8.0s, Dir = 180°N

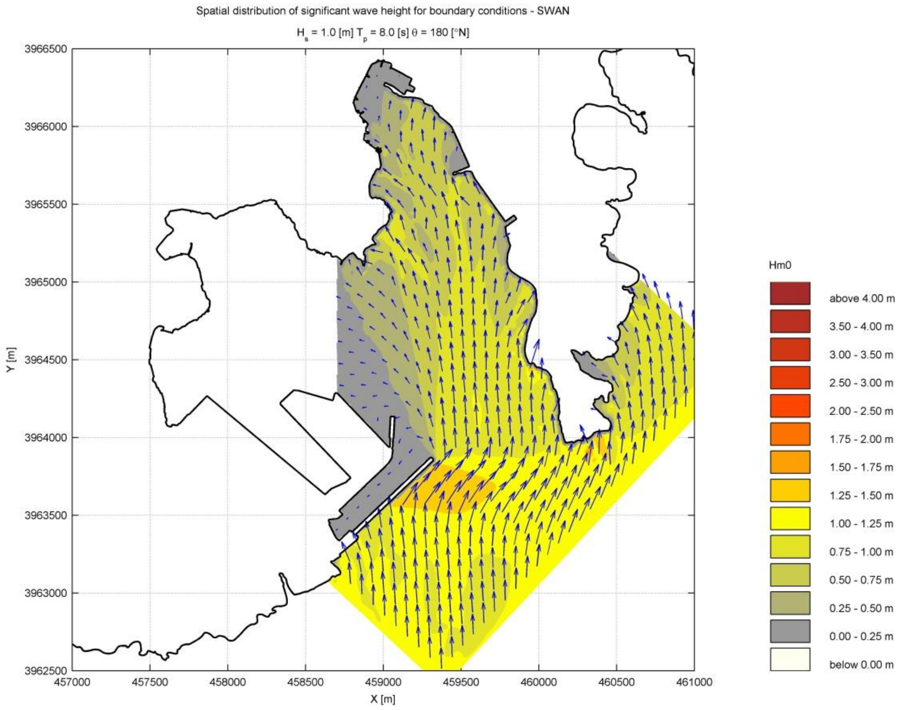

Figure 2-2: Spatial distribution of Hm0 [m] of SWAN swell simulations for boundary conditions Hm0 = 1.0m, Tp = 8.0s, Dir = 180°N

2.3 DETERMINATION OF YEARLY AVERAGE WAVE CLIMATE

The wave conditions in front of the bay were propagated to the new jetty using the wave models MIKE21BW (swell conditions with Tp > 6.0 s) and SWAN (swell conditions with Tp = 6.0 s and wind sea conditions).

The method to transform the wave climate is based on a transformation matrix. A transformation matrix is a set of look-up tables giving the wave conditions near the jetty (such as significant wave height, wave period and wave direction) for combinations of values of wave conditions at the bay entrance (such as significant wave height, wave period, wave direction). Each element (or node) in the matrix thus represents one wave condition at the bay entrance for a set of carefully chosen set of wave parameters. The range of the sets of wave parameters should be such that they envelope the occurring wave parameters at the bay entrance. Transformation matrices were generated for each output location. These transformation matrices were then used to transform the time series at the bay entrance to time series at locations of the future jetty.

This method was selected since it is capable of efficiently transforming all occurring sea states accurately, without loss of available data. At the same time, the computational effort is limited since identical sea states are not modelled repeatedly.

Simulations for conditions representing either wind sea or swell were performed, resulting in two transformation matrices for each output location, one for wind sea and one for swell. Using these transformation matrices two time series were created at each output location.

The conditions at the bay entrance (wind sea or swell), consisting of combinations of wave height, wave steepness and wave direction, were transformed as follows:

- The nearest surrounding nodes (wave height, wave period, wave direction) are found in the look-up tables and the corresponding values for the wave conditions at the output location established;
- Multi-dimensional linear interpolation is carried out to establish the corresponding wave conditions at the output location;
- Where interpolation is not possible, extrapolation is performed based on the ratio of the conditions near the jetty and at the bay entrance of the nearest wave conditions in the transformation matrix. By selecting the nodes in the matrix such that they envelope most of the occurring conditions that need to be transformed, the need for extrapolation is minimal;
- The results of the transformation are stored in a time series of wave parameters at the evaluated location.

The time series of wind sea and swell conditions were combined afterwards. For the combination of time series, it is assumed that a linear superposition (in terms of wave variance) of wind sea and swell conditions is allowed. This assumption is valid for relatively short distances where limited depth induced wave breaking occurs (the rate of dissipation depends on the total energy. The combination of wind sea and swell conditions was done according to the following relations:

$$H_{m0}^{tot} = 4\sqrt{m_0^{tot}} = 4\sqrt{m_0^{sea} + m_0^{swell}}$$

$$T_{m-1,0}^{tot} = \frac{m_{-1}^{tot}}{m_0^{tot}} = \frac{m_{-1}^{sea} + m_{-1}^{swell}}{m_0^{sea} + m_0^{swell}}$$

$$\theta^{tot} = \text{atan}\left(\frac{b}{a}\right)$$
$$a = m_0^{sea} cos(\theta^{sea}) + m_0^{swell} cos(\theta^{swell})$$
$$b = m_0^{sea} sin(\theta^{sea}) + m_0^{swell} sin(\theta^{swell})$$

The superscripts *tot*, *sea* and *swell* refer to total, wind sea and swell conditions. The spectral moments m_n are defined as:

$$m_n = \int f^n E(f) df$$

The mean wave period $T_{m-1,0}$ was used instead of the peak wave period T_p because the SWAN and MIKE21BW results for the mean wave period are generally more accurate and robust than the peak wave period results. Moreover, the mean wave period $T_{m-1,0}$ is preferred above other period measures because it is a robust representation of the characteristic wave period (see Goda [5], p. 53), it yields smoother results than the peak wave period in case of double peaked spectra and is less affected by nonlinear transformation of the waves. As such, it is generally more suitable for extreme (design) conditions, mooring and ship manoeuvring studies. The peak wave period were calculated from the known ratio between $T_{m-1,0}$ and T_p for JONSWAP spectra with a peak enhancement factor of 3.3 (which is approximately 1.11, see Goda [5]).

The models have not been calibrated because no nearshore or inshore calibration data was available.

3 Model schematisation

3.1 INTRODUCTION

In this chapter the setup of the MIKE21BW and SWAN wave models is described. MIKE21BW was used to propagate the swell waves with Tp > 6.0s and the extreme wave conditions and SWAN was used for the swell waves with Tp = 6.0s and yearly average wind sea conditions. After setting up the models, production runs were performed to generate the transformation matrices for the yearly average conditions. Separately, simulations were done for the transformation of the extreme conditions.

Setting-up of the MIKE21BW model is discussed in Section 3.2. The SWAN model setup is discussed in Section 3.3. Descriptions of both models are enclosed as Appendix 2 and 3, respectively.

3.2 MIKE21BW

3.2.1 BATHYMETRY

In the Boussinesq equations, a relation exists between the water depths in the domain, the spatial resolution and the required computational time. Effort was put in optimizing the domain in order to reduce computational time and ensure numerically stable simulations. The effect of dissipation and (partial) reflection at the shorelines and quays is included by adding porosity layers along the land perimeter of the computational domain.

A grid was created covering the entire bay with a spatial resolution of 2m by 2m. The characteristics of the grid are presented in Table 3-1 and its orientation is presented by thick black lines in Figure 3-1.

Grid name	x0 [m]	y0 [m]	Alpha [^{0}]	lx [m]	ly [m]	dx [m]	dy [m]
G03	456900	3964700	-43	3400	2800	2	2

Table 3-1: Characteristics of the MIKE21BW computational grid

The following survey data inside the bay was provided by the Client and used for schematizing the bathymetry for MIKE21BW:

- 1839DEL8_00 MSL - survey of shore in harbour.dwg;
- 1839DEL7_02 MSL - bathymetric survey.dwg;
- Bathymetric Survey TM - 2013.dwg.

The bathymetric data was exported from the AutoCAD drawings and the coordinates were transformed from .geographical to UTM33. The reference height of the data (which was provided w.r.t. LAT) was set to MSL by adding 0.63m to the data. The data set was extended with sample points at MSL along the shoreline at sloping parts of the bathymetry where no vertical quays are present. The resulting data set was then interpolated onto the computational grid using a triangulation interpolation technique.

Due to the combination of a large modelling domain and a small spatial resolution, the computational time was too large given the limited available time for the project. In order to restrict the required computational time, the north-western part of the bay was excluded from the simulations. Exclusion of this part of the bay was deemed allowable as it does not affect the wave conditions at the new LNG facility.

Because the effect of wave breaking is not very important for the wave conditions at the jetty (which is located at an approximate depth of 15m), this is not included in the modelling, thus saving time and avoiding instabilities.

In order to avoid modelling instabilities at shallow locations, the minimum water depth was set to 3m. The resulting bathymetry for grid G03 is called B06 and is presented in Figure 3-1.

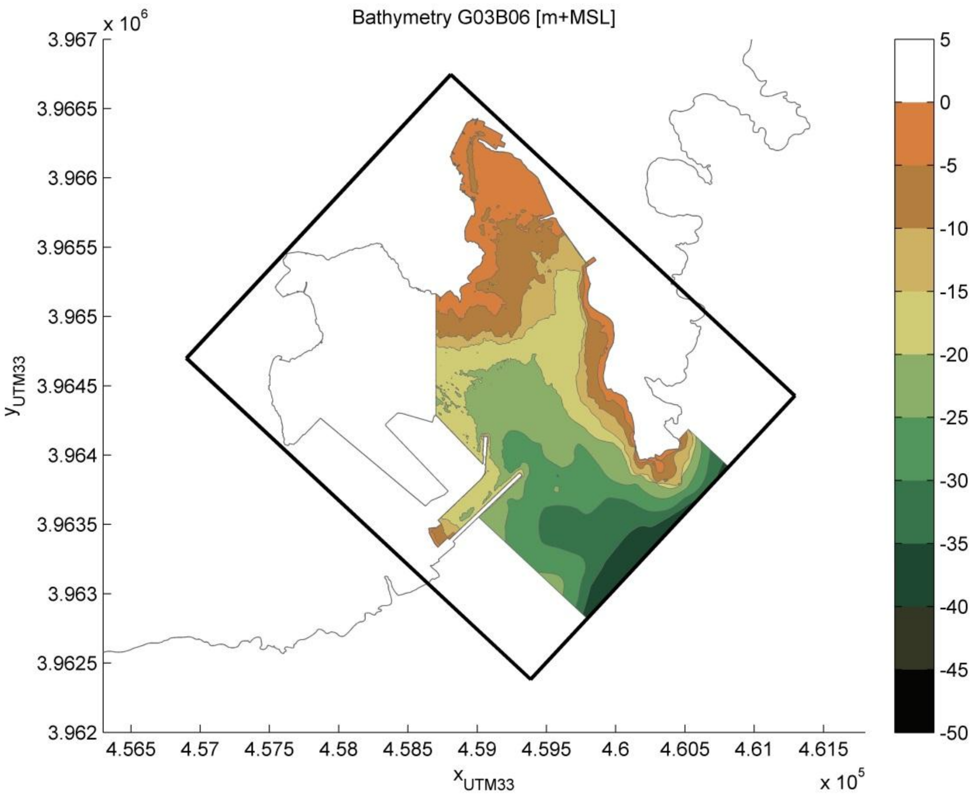

Figure 3-1: Bathymetry for MIKE21BW grid G03 [m+MSL]. Thin black lines: land contour, thick black lines: grid perimeter

Modifications for minimum wave period

The minimum wave period that can be modelled using the actual bathymetry (bathymetry B06, see Table 3-2) is 7.6s. For this wave period, the wavelength to depth ratio is 0.5, which is the maximum for the extended Boussinesq equations. Shorter periods cannot be modelled accurately with MIKE21BW.

A sea state is a combination of many waves with different periods. The energy of waves with various period (or equivalent frequencies) is commonly represented as a wave spectrum. Due to the minimum wave period restriction of MIKE21BW, part of the spectrum cannot be solved. By assuming that at least 75% of the energy in the spectrum must be well resolved and a JONSWAP spectral shape (with gamma = 3.3) a minimum peak wave period can be calculated for a given minimum wave period. A minimum peak wave period of 10.0s corresponds to a minimum wave period of 7.6s.

To evaluate the propagation of waves with shorter periods, the maximum depth has to be reduced. For minimum wave periods shorter than 7.6s (and corresponding peak wave periods less than 10.0s), an additional bathymetry (B07, see Table 3-2) has been created with a smaller maximum depth.

Bathymetry	Description	Maximum depth [m]	Minimum period [s]	Minimum peak period [s]
B06	Actual bathymetry	45	7.6	≥ 10.0
B07	Bathymetry with reduced maximum depth	31	6.3	8.0

Table 3-2: Characteristics of the MIKE21BW bathymetries

Modifications for numerical stability

In order to increase the numerical stability, for some simulations it was necessary to smoothen the bathymetry locally. Modifications were made in such a manner, that they were not affecting the conditions at the jetty. Especially, a shallow area just south of the headland east of the bay entrance and shoals in the bay were causing unwanted instability issues. Figure 3-2 shows the difference between the original (B06) and the modified bathymetry B07.

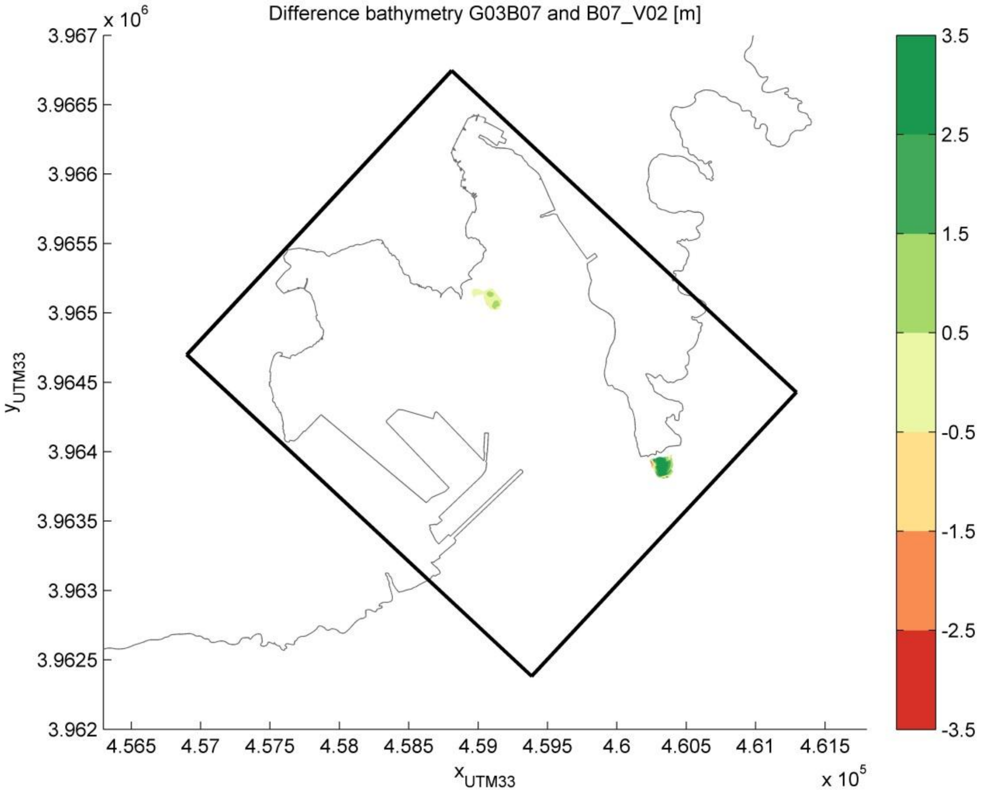

Figure 3-2: Differences between bathymetry B07 [m] and a modified version. Thin black lines: land contour, thick black lines: grid perimeter

3.2.2 BOUNDARY CONDITIONS

Three wave generating boundaries have been included in the model: northeast, southeast, and southwest (see the red lines in Figure 3-3). The wave conditions are applied uniformly along the (wet parts of the) boundaries. As a note, the assumption of uniformity is not valid close to the shoreline, but as this effect is very local we do not expect this to affect our results at the output locations. A maximum deviation of angle from the mean wave direction of 40° was selected for prescribing the boundary conditions. Depending on the direction of the incoming wave, one or two of these boundaries have been included.

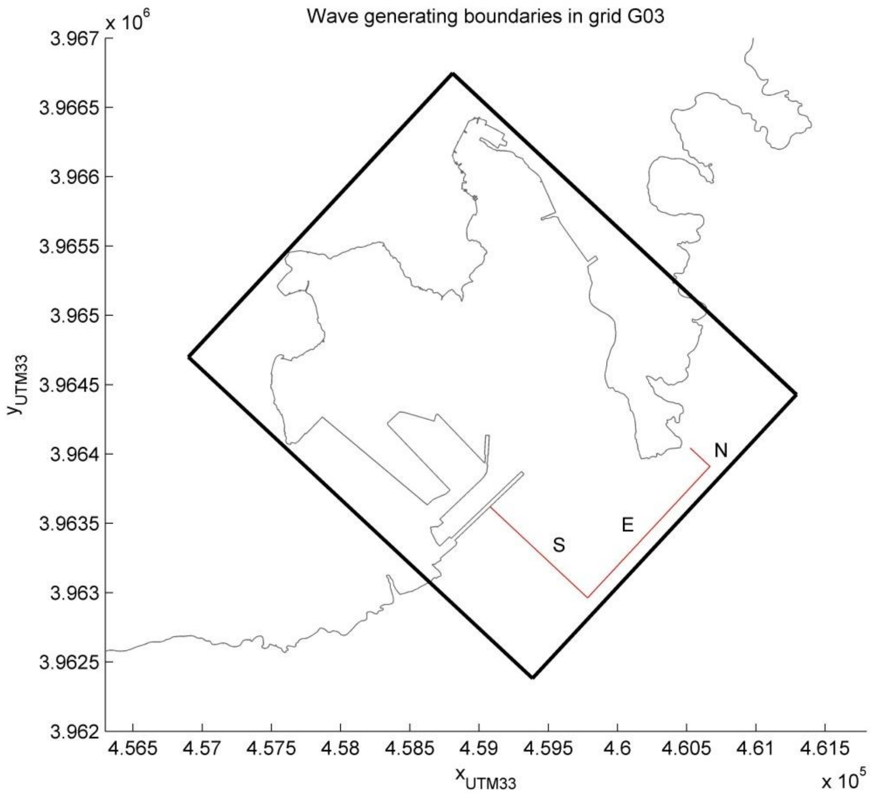

Figure 3-3: MIKE21BW wave generating boundaries S, E and N (red lines).Thin black lines: land contour, thick black lines: grid perimeter

Time series of surface elevation and curvature have been generated for each of the wave generating boundaries, representing the 2-dimensional wave spectra at the boundary. The part of the spectrum with periods shorter than the minimum wave period (as explained in Section 3.2.1) cannot be modelled by the model. The contribution that is otherwise omitted by excluding the short waves, is added to the simulations by spreading its variance over the part of the spectrum with larger periods in such a way that the significant wave height of the rescaled spectrum is the same.

Swell

Based on the nearshore (at Marsaxlokk Bay entrance) swell wave climate (see [1], Figure 3-4, Figure 3-5), a series of boundary conditions were selected. The conditions were selected to envelope the range of occurring conditions at the at the bay entrance and represent its variation accurately. The following conditions were selected for the propagation of swell wave conditions:

- Significant wave height: 1.0, 2.0, 3.0, 4.0*m
- Peak wave period: 8.0, 10.0, 12.0s;
- Mean wave direction: 60°N, 90°N, 120°N, 150°N, 180°N, 210°N;
- Spectral shape: JONSWAP
- Spectral peakedness parameter (γ): 3.3
- Directional distribution function $\cos^m$
- Directional distribution power (m): 8 (corresponding to a directional spr. of 18.8°)
- Water level: MSL

*For peak wave period 8.0s, a significant wave height of 4.0m was not simulated because there were no records of such events in the time series (see Figure 3-5).

Swell wave conditions with peak wave periods of 6.0s were propagated with SWAN (see Section 2.2). Nearshore wave conditions which were outside the range of the modelled conditions are extrapolated based on the ratio of the boundary conditions and the corresponding wave conditions at the jetty of the nearest wave conditions in the transformation matrix. As explained in Section 2.3, this method is both accurate and computationally efficient.

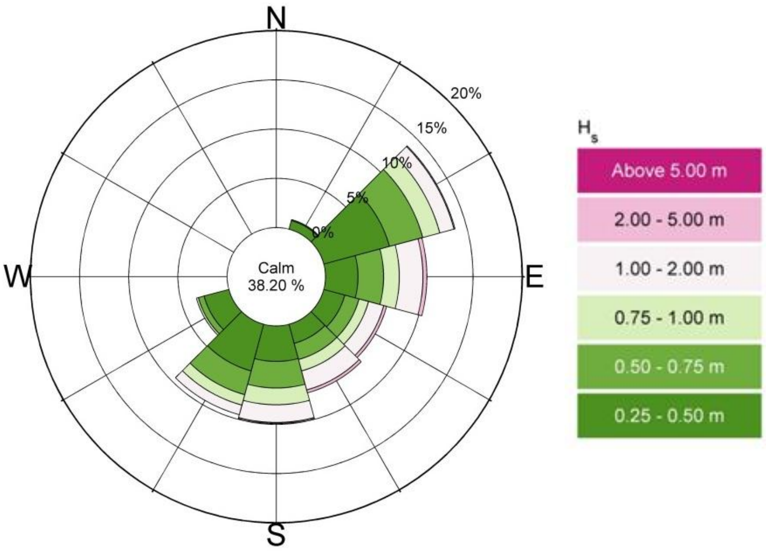

Figure 3-4: Nearshore significant wave height roses for swell

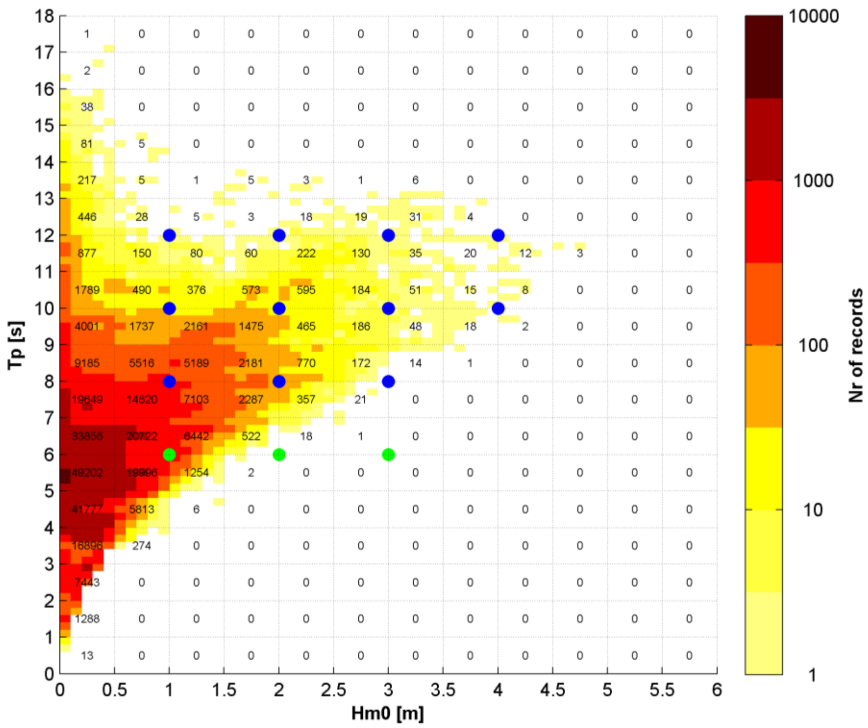

Figure 3-5: Peak wave period [s] against significant wave height [m] for swell conditions at the bay entrance. The blue dots represent the swell wave conditions that were simulated with MIKE21BW, the green dots those with SWAN

Extreme wave conditions

Extreme wave conditions in front of the bay were transformed to the jetty location for offshore directions between 60°N and 240°N with 30° intervals. Other direction were not deemed relevant for the present study as the corresponding wave conditions at the jetty are much lower and as such not expected to yield limiting design loads. In Table 3-4, the nearshore extreme wave conditions that were applied in MIKE21BW are listed.

The boundary conditions for MIKE21BW were obtained from the SWAN results (see [1] for the description of the propagation of extreme wave conditions from offshore to the bay entrance) The results obtained from SWAN did not include the reflected wave from the vertical breakwater sheltering the bay.

SWAN results were obtained at 14 locations near the bay entrance. The boundary conditions for the MIKE21BW simulations were obtained from three different SWAN output locations. Depending on the offshore direction, one of these three locations as listed in Table 3-3 is used.. The location of these and other points (that were not used as boundary conditions) is presented in Figure 3-6.

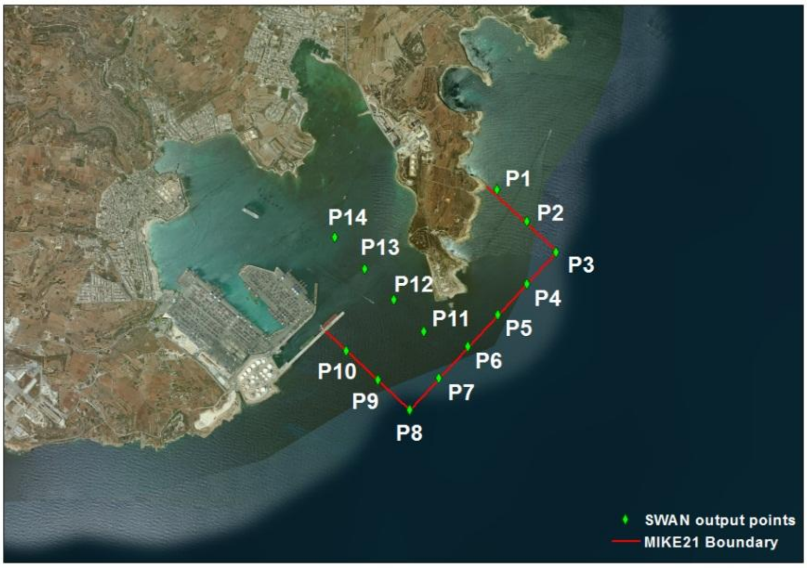

Figure 3-6: Nearshore output locations

Offshore direction [°N]	Wave climate study output location
60	P3
90	P3
120	P7
150	P7
180	P7
210	P8
240	P8

Table 3-3: Wave climate study output locations that were selected for MIKE21BW boundary conditions

To apply the MIKE21BW model, additional information is needed about the spectral shape of the boundary conditions. For the frequency spectrum a JONSWAP spectrum with a spectral peakedness parameter (γ) of 3.3 was selected and a $\cos^m$ shape was selected for the directional distribution.

As described in Section 2.4 of the report on the wave climate study [1], detailed information about the extreme water levels was unavailable. A water level of MSL+0.47m was applied as an estimate for occurring barometric and tidal water level variations (consistent with the methodology of the wave climate study; see [1] Section 2.4 for a motivation of this choice).

Return period [yr]	Offshore direction [°N]	Offshore U10 [m/s]	Offshore Hm0 [m]	Offshore Tp [s]	Nearshore Hm0 [m]	Nearshore Tm-1,0 [s]	Nearshore Dir [°N]
1	60	15.0	3.9	10.3	3.8	8.8	66
5	60	18.3	5.3	11.1	5.1	9.7	68
10	60	19.5	5.9	11.6	5.7	10.2	69
25	60	21.0	6.6	12.3	6.4	10.8	70
50	60	22.1	7.1	12.7	6.9	11.2	70
100	60	23.1	7.6	13.1	7.4	11.6	70
1	90	14.8	3.5	10.0	3.6	8.3	91
5	90	17.5	4.8	10.7	4.8	9.2	91
10	90	18.4	5.4	10.9	5.3	9.4	92
25	90	19.6	6.2	11.6	6.0	10.1	92
50	90	20.4	6.8	12.1	6.5	10.5	93
100	90	21.1	7.4	12.6	7.0	11.0	93
1	120	15.1	3.5	9.3	3.7	8.0	121
5	120	17.3	4.7	10.4	4.9	9.1	121
10	120	18.1	5.1	10.7	5.3	9.4	121
25	120	19.1	5.8	11.2	5.9	9.9	121
50	120	19.8	6.2	11.6	6.4	10.3	121
100	120	20.4	6.7	12.0	6.8	10.6	121
1	150	15.4	3.6	9.2	3.8	8.0	151
5	150	18.0	4.7	10.1	4.8	8.8	151
10	150	19.0	5.1	10.5	5.2	9.2	151
25	150	20.2	5.6	11.0	5.7	9.6	151
50	150	21.1	5.9	11.3	6.0	9.9	150
100	150	21.9	6.3	11.7	6.4	10.2	150
1	180	14.1	3.1	8.5	3.2	7.4	181
5	180	16.4	4.0	9.4	4.1	8.2	181
10	180	17.3	4.3	9.7	4.4	8.5	180
25	180	18.4	4.8	10.3	4.8	8.9	179
50	180	19.2	5.1	10.6	5.1	9.2	179
100	180	20.0	5.4	10.9	5.3	9.5	178
1	210	13.3	2.9	8.3	3.0	7.3	202
5	210	16.0	4.0	9.5	4.1	8.4	199
10	210	17.1	4.5	9.9	4.5	8.7	198
25	210	18.5	5.2	10.7	5.0	9.4	196
50	210	19.6	5.7	11.2	5.4	9.8	195
100	210	20.7	6.2	11.7	5.7	10.2	195
1	240	15.3	3.5	9.0	2.8	7.5	219
5	240	17.8	4.6	10.1	3.6	8.5	214
10	240	18.8	5.1	10.7	3.9	9.0	212
25	240	19.9	5.7	11.3	4.3	9.6	209
50	240	20.7	6.2	11.8	4.5	10.0	208
100	240	21.4	6.6	12.2	4.7	10.4	207

Table 3-4: Offshore and nearshore extreme wave conditions as applied in MIKE21BW

3.2.3 SPONGE LAYERS

Behind the wave generating boundary, sponge layers were applied that dissipate all wave energy to prevent unwanted wave reflection against the model boundary. . The position and sponge layer coefficients [-] are shown in Figure 3-7. In order to increase the numerical stability and reduce the computational time of the simulations, a sponge layer was also implemented in front of the western part of the bay that was excluded from the model domain.

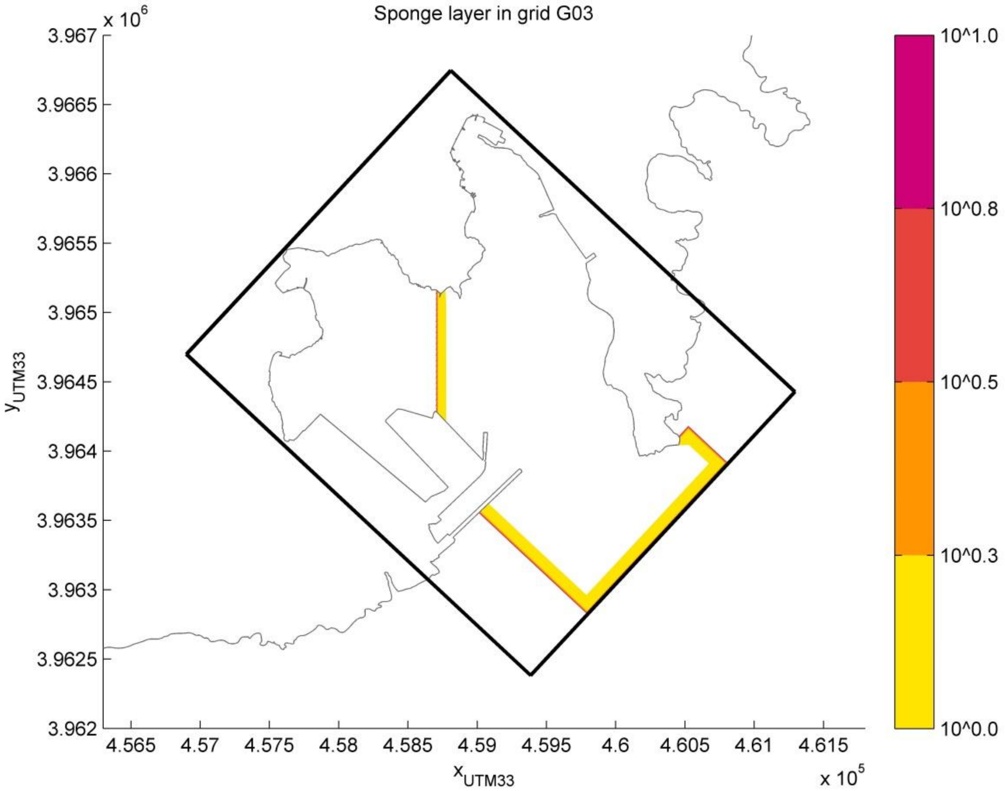

Figure 3-7: Sponge coefficient values as applied in the MIKE21BW schematisation

3.2.4 POROSITY LAYERS

To include the effect of (partial) reflection, porosity maps were applied along the perimeters of the coastline. The porosity value that should be applied in the layers, depends on the intended reflectivity as well as the incoming wave conditions. To find the right porosity value, two steps have to be taken. First, the intended reflectivity should be determined, then the incoming wave conditions should be established and finally the corresponding porosity value needs to be derived.

The applied reflectivity for various coastal structures inside the bay are presented in Table 3-5. The sections of the applied reflectivity are presented in Figure 3-8. The chosen reflectivity is based on a detailed analysis of the perimeter of the bay.

Structure type / coastal feature	Reflectivity

	[%]
Vertical wall	90
Irregular rocky coast	70
Rubble mound breakwater	50
Gently sloping (rocky) beach	30

Table 3-5: Applied reflectivity for various coastal types

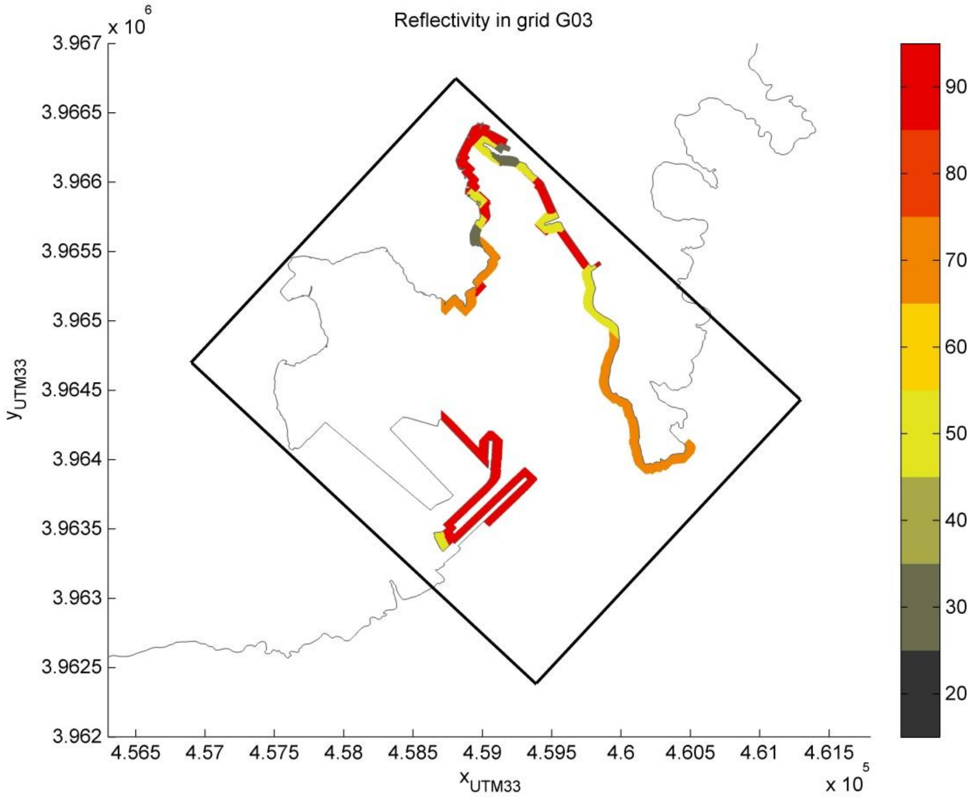

Figure 3-8: Applied reflectivity in MIKE21BW and SWAN

The porosity value for a given reflectivity depends on the incoming significant wave height, peak wave period and the local water depth. As a consequence, the porosity values to be applied will vary for each boundary condition and for each location along the perimeter of the grid. To estimate the incoming wave conditions for various/each boundary conditions, a series of test simulations were performed with a sponge layer applied in front of the land boundary to suppress wave reflection such that only the incoming wave conditions are considered. To first order this is a practical way to estimate the incoming wave conditions, as in reality incoming wave conditions may partly of consist of waves reflected elsewhere. The significant wave height and peak wave period were kept constant at 1.0m resp. 10.0s, and the mean wave directions were varied. As an example, the spatial distribution of the significant wave height for a simulations with a mean wave direction of 180°N is presented in Figure 3-9. From these test simulations, an estimate of the wave conditions inside the bay can be made and the required porosity values can be calculated. As an example, the porosity map that was applied for a swell simulation (Hm0 = 1.0m, Tp = 10.0s, Dir = 180°N) is presented in Figure 3-10.

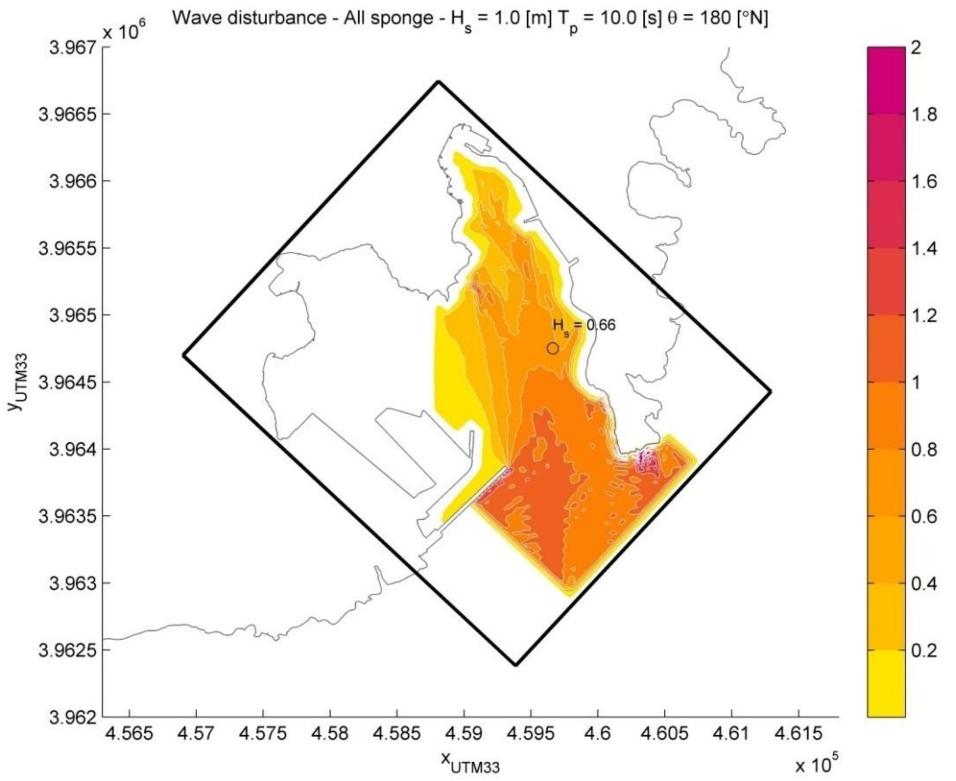

Figure 3-9: Spatial distribution of the significant wave height [m] computed using MIKE21BW with sponge layers along the land contour and a boundary conditions with Hm0 = 1.0m, Tp = 10.0s, Dir = 180°N

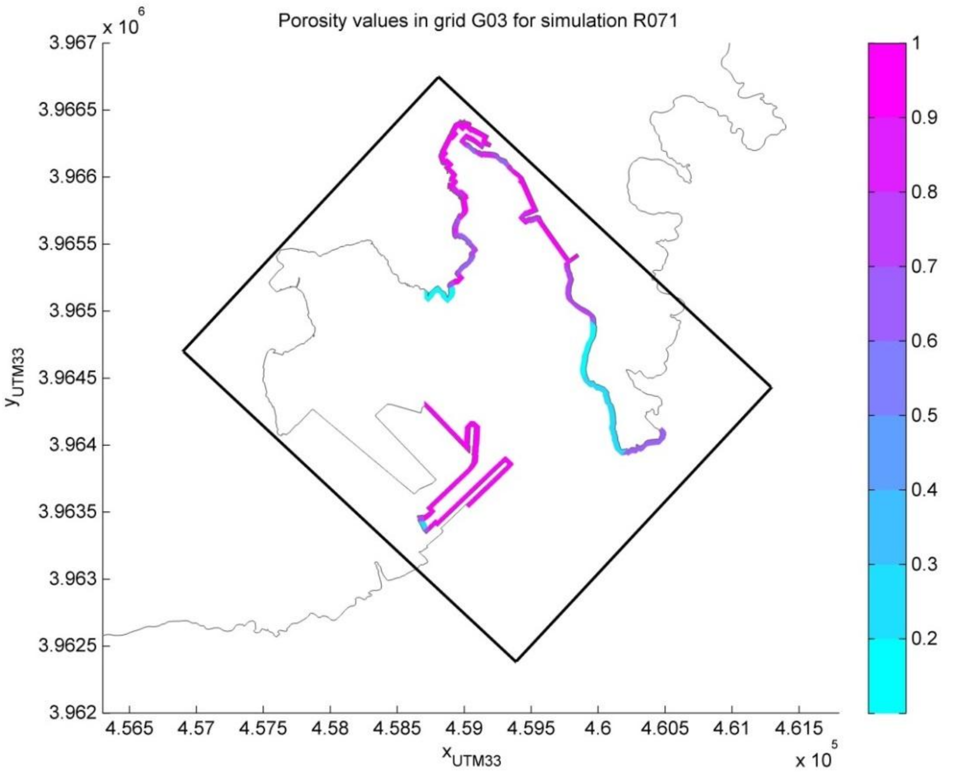

Figure 3-10: Applied porosity values [-] for a simulation of swell waves with boundary conditions Hm0 = 1.0m, Tp = 10.0s, Dir = 180°N

3.2.5 NUMERICAL SETTINGS

The numerical settings are presented in Table 3-6. The simulation time was the same for all conditions and is considered long enough (excluding spin-up time) to obtain time series of surface elevations for the determination of wave parameters. The time step followed from the stability criteria imposed by the MIKE21BW model.

Setting	Value
Typo of equations	Two-dimensional extended Boussinesq
Simulation time	40min
Time step	0.05s
Spatial resolution	2m

Table 3-6: Applied numerical settings in MIKE21BW

3.2.6 OUTPUT LOCATIONS

Two-dimensional spectra were obtained from the simulations, by Fourier transforming the surface elevation and fluxes (depth average velocities) in x- and y-direction, thus mimicking a directional buoy. From these spectra, integral parameters such as the significant wave height, mean wave period, mean wave direction, etc. were calculated. These parameters were then used for building the transformation matrix.

The Fourier transformation and calculation of wave parameters was performed with the Wave Analysis Toolbox from DHI. The locations for which these results were created are presented in Table 3-7 and Figure 3-11. Additionally, the spatial distribution of the significant wave height, mean wave period and mean wave direction in the modelling domain were obtained.

Output location	X [m UTM33]	Y [m UTM33]	depth [m +MSL]
1	459714	3965127	16.9
2	459714	3965087	17.0
3	459714	3965047	17.3
4	459714	3965007	17.3
5 (stern)	459713	3964967	17.6
6	459713	3964927	17.7
7	459713	3964887	17.9
8 (midship)	459713	3964847	17.6
9	459713	3964807	17.3
10	459712	3964767	17.6
11	459712	3964727	17.3
12 (bow)	459712	3964687	17.0
13	459712	3964647	16.8
14	459712	3964607	15.9
15	459712	3964567	15.3

Table 3-7: Output locations and associated depth. The locations of special interest for the nautical studies are marked

Figure 3-11: Output locations

3.3 SWAN

3.3.1 COMPUTATIONAL GRID AND BATHYMETRY

The characteristics of the detailed SWAN grid (C00) are presented in Table 3-8. The boundaries of the grid and applied bathymetry are presented in Figure 3-12. This C00 grid was nested in the existing SWAN model that was used for propagating the offshore wave climate to the port entrance (see [1]).

Grid name	x0 [m]	y0 [m]	Alpha [^{0}]	lx [m]	ly [m]	dx [m]	dy [m]
C00	456900	3964700	-43	3400	2800	10	10

Table 3-8: Characteristics of the SWAN grid

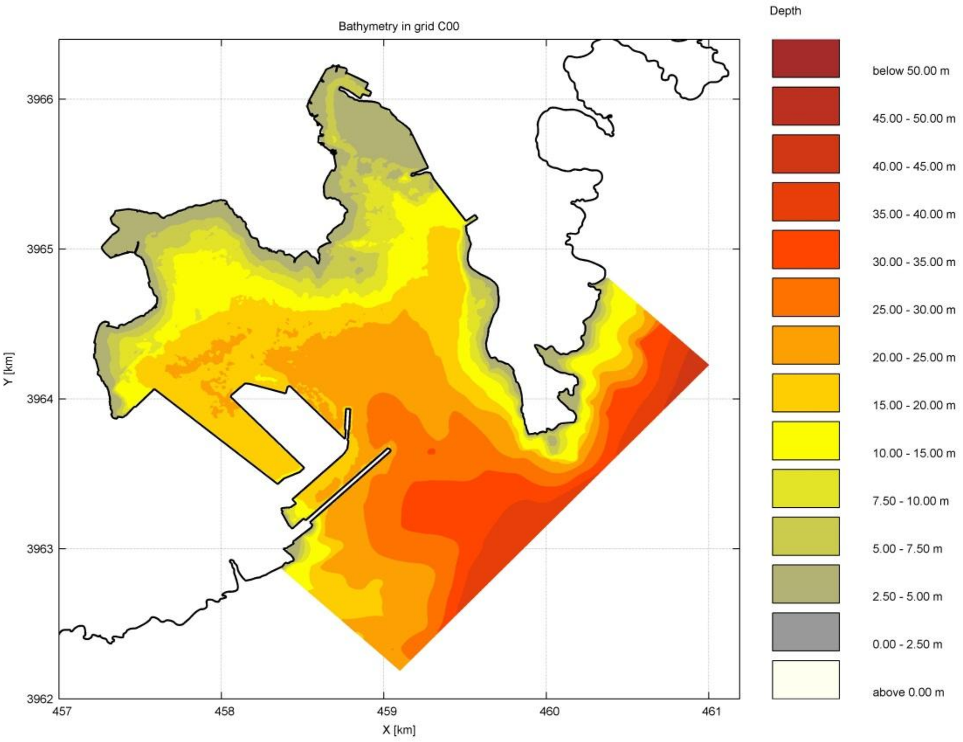

Figure 3-12: Applied bathymetry [m +MSL] in the SWAN C00 grid

3.3.2 BOUNDARY CONDITIONS

Wind Sea

Two nested grids (B00 and C00) were used to provide sufficient level of detail in the port area. The boundary conditions for these finer grids were obtained from the coarser grid. Consequently, uniform boundary conditions were only applied at the offshore boundary and not at any nested grid boundary.

Based on statistical analysis of the offshore conditions supported with numerical experiments, the following conditions were applied at the offshore boundary of grid A00 for wind sea conditions ([1]):

- Significant wave height: 0.5, 1.0, 1.5, 2.5, 4.0, 5.0 and 8.0m;
- Deep water wave steepness: 0.005, 0.015, 0.030, 0.060;
- Mean wave direction: 0°N, 30°N, 60°N, 90°N, 120°N, 150°N, 180°N, 210°N, 240°N, 270°N, 300°N and 330°N.
- Spectral shape: JONSWAP
- Spectral peakedness parameter (γ): 3.3
- Directional distribution function $\cos^m$
- Directional distribution power (m): 3 (corresponding to a directional spr. of 27.6°)
- Water level: MSL

The conditions cover more than 99% of the events occurring in the time series (33 years of data), see Figure 3-13. Because the uniform boundary conditions were only applied at the offshore grid boundary, the offshore wind sea conditions are presented here.

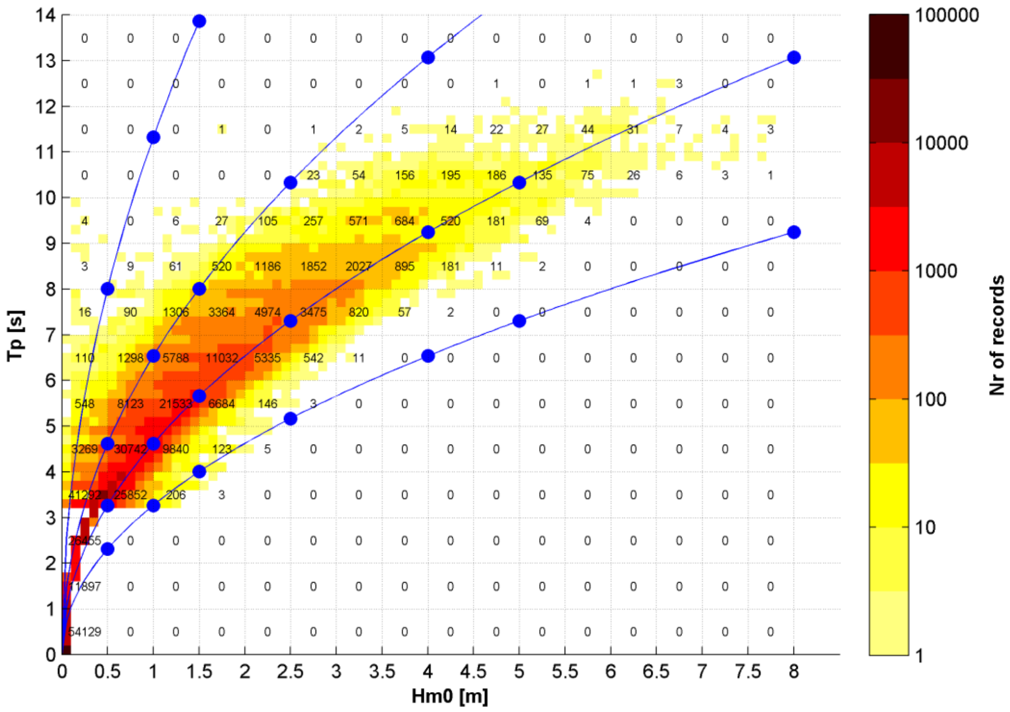

Figure 3-13: Offshore peak wave period [s] against significant wave height [m] for wind sea conditions, and applied SWAN boundary conditions (A00 grid) represented by the blue dots

Swell

Additionally, swell wave conditions with Tp = 6.0s were propagated using SWAN (see Section 2.2, Section 3.2.2 and Figure 3-5). The following conditions were applied at the boundary of the C00 grid.

▪ Significant wave height:	1.0, 2.0, 3.0m
▪ Peak wave period:	6.0s;
▪ Mean wave direction:	60°N, 90°N, 120°N, 150°N, 180°N, 210°N;
▪ Spectral shape:	JONSWAP
▪ Spectral peakedness parameter (γ):	3.3
▪ Directional distribution function	$\cos^m$
▪ Directional distribution power (m):	8 (corresponding to a directional spr. of 18.8°)
▪ Water level:	MSL

3.3.3 REFLECTIVITY

In SWAN the same reflectivity as applied in MIKE21BW was used by adding a series of obstacles with a prescribed reflectivity (in terms of significant wave height) along the coastline (Table 3-5 and Figure 3-8). As SWAN does not use porosity layers, you can directly specify the desired reflection, which is independent of the incoming wave conditions.

3.3.4 NUMERICAL SETTINGS

The spectral directions cover the full circle and are subdivided into 72 bins, yielding a directional resolution of 5°. The lowest discrete frequency applied is 0.03 Hz and the highest 1.5 Hz. The number of frequency bins is 37 and the frequencies of each bin increase in a geometric progression (fixed ratio between subsequent frequencies of approximately 1.1).

The following numerical settings were applied in SWAN:

```
MODE STATIONARY
CGRID REGULAR   456900.  3964700.  -43.00    3400.    2800.    340   280  &
             CIRCLE     72   0.030   1.500    37
NUM ACCUR     0.010    0.010    0.010   99.500  STAT  mxitst= 50  alfa=0.01  limiter=0.1
LIM URSELL=10.0  qb=1.0
```

The following physical settings were applied in SWAN as recommended by the SWAN team (2014) [3].

```
GEN3 KOMEN AGROW
WCAP KOMEN delta=1.0
FRIC  JONSWAP 0.038
BREAK CON     1.00    0.73
```

3.3.5 OUTPUT LOCATIONS

The same output locations as used in MIKE21BW were specified in SWAN and the same output parameters were obtained.

4 Results

4.1 INTRODUCTION

In this chapter the results of the wave penetration computations are presented. The results of the wave study were provided to MARIN and served as input for their ship manoeuvring simulations and mooring analysis. Spatial fields of the significant wave height for wind sea and swell separately were also provided for the ship manoeuvring study. Wind sea wave fields were provided for wind speeds of 10, 12 and 14 m/s and directions 150, 180, 210, 240, 270, 300 and 330°N. Examples of provided spatial fields are presented in Appendix 6.

For the mooring study both the extreme and yearly average climate at the output locations in front of the jetty were provided to MARIN.

In this chapter first the derived yearly average wave climate at the jetty is presented. Then, in Section 4.3 the results of the extreme conditions computations are discussed.

4.2 YEARLY AVERAGE WAVE CLIMATE

Following the methodology described in Chapter 2, time series have been created for 3 different output locations:

- P5: stern;
- P8: mid ship; and
- P12: bow.

These time series have been statistically analysed using ARCADIS in-house tool HYDROBASE to obtain tables presenting the joint probability of significant wave height and peak wave periods for all directional sectors. Furthermore, wave spectra were analysed to obtain information on the peak wave direction and the reflected wave component. It was concluded that the reflected waves are minor compared to the main incoming waves. In Figure 4-1 the 2D wave spectrum is presented for an extreme wave event with a return period of 1:100 year coming from 150^{0}N offshore. It can be seen that a relative small amount of wave energy is coming from the northwest. This is caused by waves reflecting against the cliffs inside the port basin. For the other directions the reflected waves were even less pronounced.

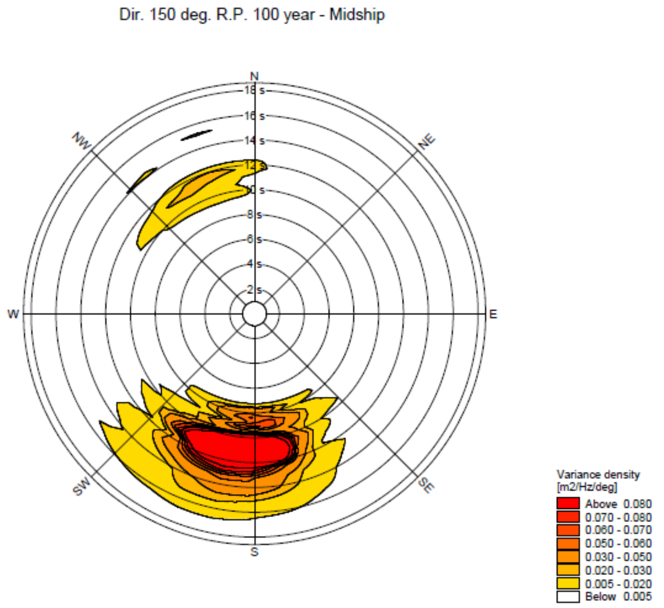

Figure 4-1: Wave spectrum at location P8 (mid ship) obtained from MIKE21BW simulation for return period 1:100 year and offshore direction of 150⁰N

Wave roses presenting the yearly average wave climate for wind sea, swell and total at the 3 different locations are presented in Figure 4-4, Figure 4-5 and Figure 4-6 . From these figures it can be seen that:

- The significant wave heights at the output locations are reduced in comparison with the conditions at the bay entrance;
- The wave conditions vary quite from output locations at the bow of the proposed vessel location to the stern;
- The wave climate at the bow is the most severe;
- The direction of incoming swell waves varies from S-SSW at the bow to SSW-SW at the stern (most northern output location).

To gain more insight and confidence in the processes causing these differences, a spatial field of the variation in significant wave height, as computed by MIKE21BW, is presented in Figure 4-2. A detailed plot of the bathymetry at the location of the jetty is presented in Figure 4-3. The bow is the southernmost end of the vessel and the stern the northernmost.

From the figures it can be concluded that this change of direction and the reduction in wave height are caused by the effect of refraction. Due to the bathymetry at the location of the jetty part of the wave energy is refracted towards the shore and a part is propagated to the north. As a result the wave conditions at the stern of the vessel are less severe than those at the bow. Based on this example and similar analyses (not shown in this report) we concluded that the differences in wave conditions along the ship can be explained by differences in the local bathymetry and associated wave processes.

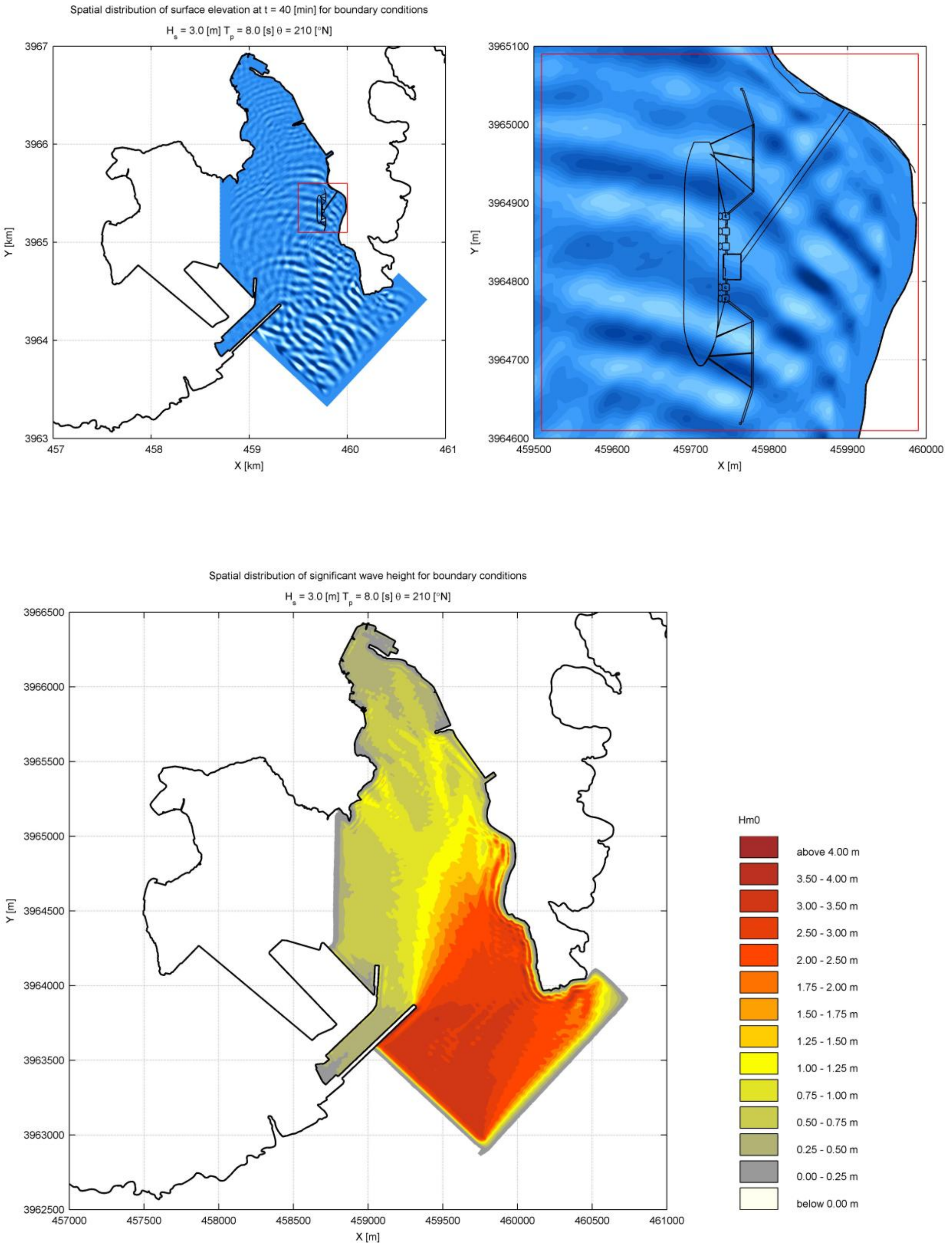

Figure 4-2: Spatial distribution of surface elevation and significant wave height [m], as computed by MIKE21BW, for boundary condition Hm0 = 3.0m, Tp = 8.0s, Dir = 210^{0}N

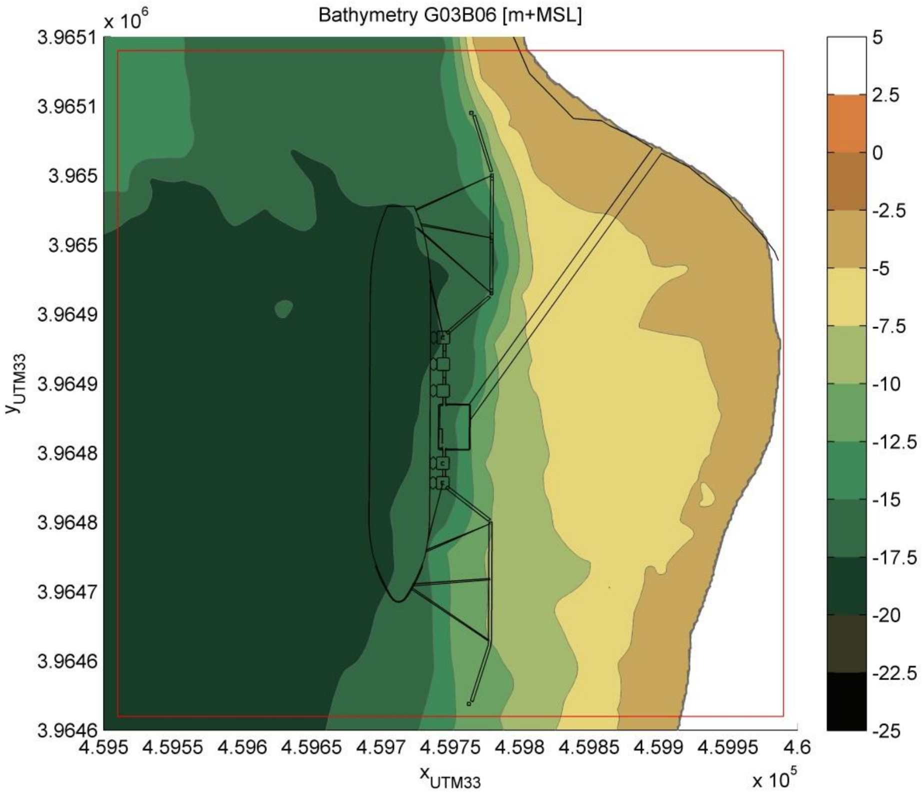

Figure 4-3: Bathymetry [m +MSL] at the location of the jetty

Considering the fact that the conditions at the bow are most severe, only the results for location 12 are presented. Tables for the yearly average wave climate at all 3 locations can be found in Appendix 4.

The joint probability of occurrence tables for significant wave height versus mean wave period for location P12 (bow) are presented in Table 4-1 - Table 4-3 for wind sea, swell and total, respectively. The probability of exceedance of significant wave height for various directional sectors is presented for wind sea, swell and total, respectively in Table 4-4 to Table 4-6. A noteworthy result is that, a total significant wave height of 1.0m is exceeded 5.3% of the time. The exceedance of only swell waves with a significant wave height of 1.0 is less than 0.2%.

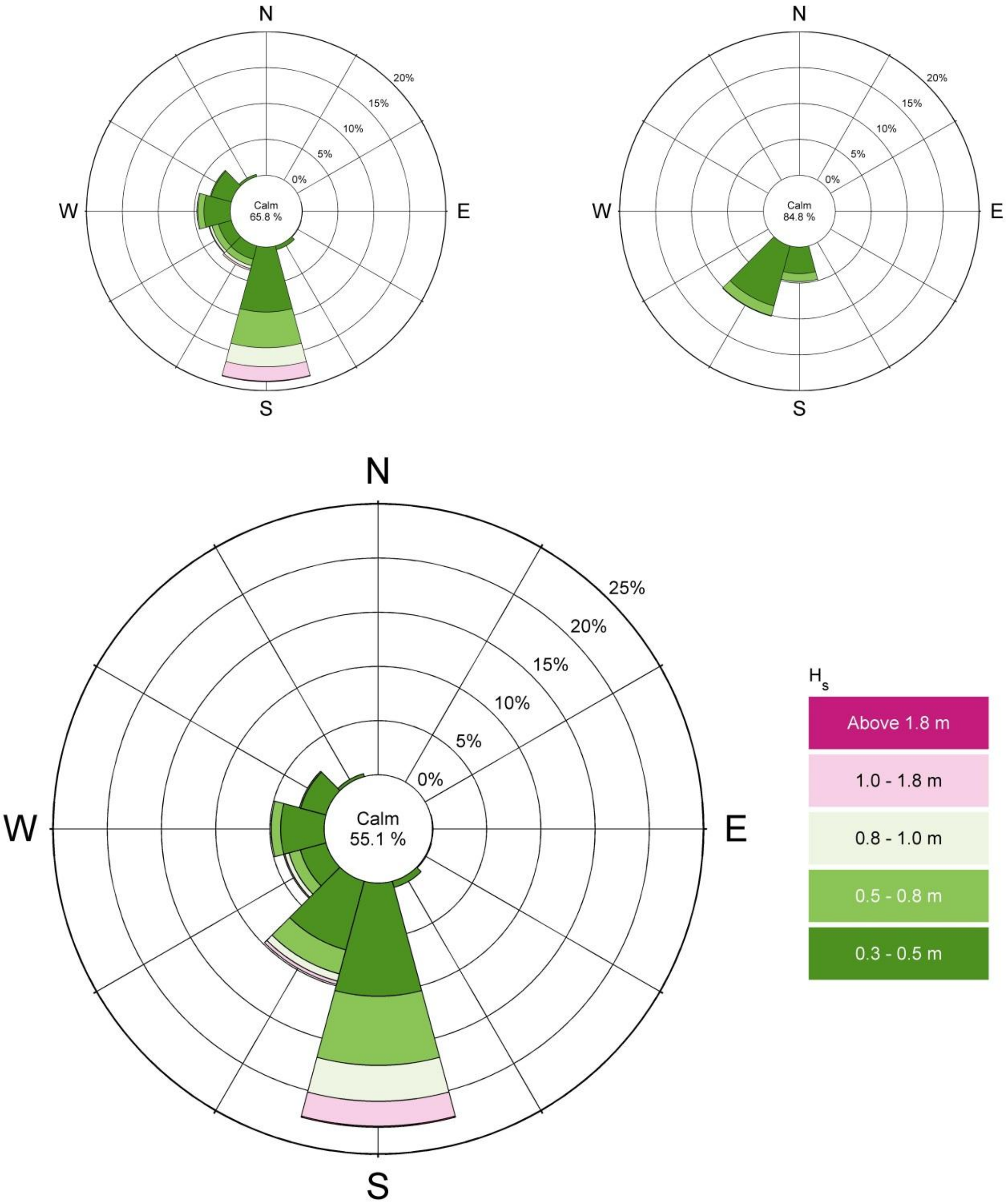

Figure 4-4: Significant wave height roses at output location P5 (stern) for wind sea (top left), swell (top right) and total sea states (below)

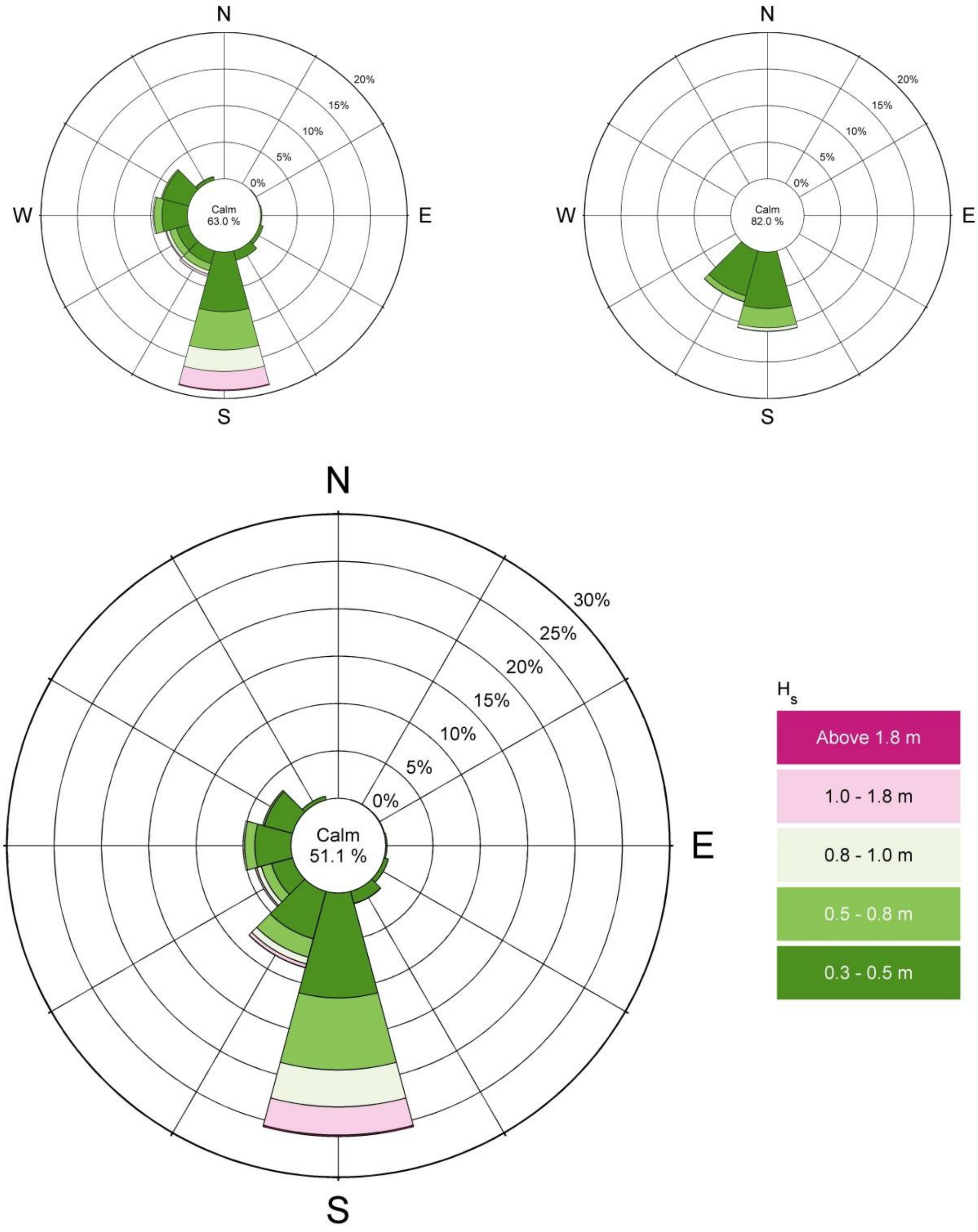

Figure 4-5: Significant wave height roses at output location P8 (mid ship) for wind sea (top left), swell (top right) and total sea states (below)

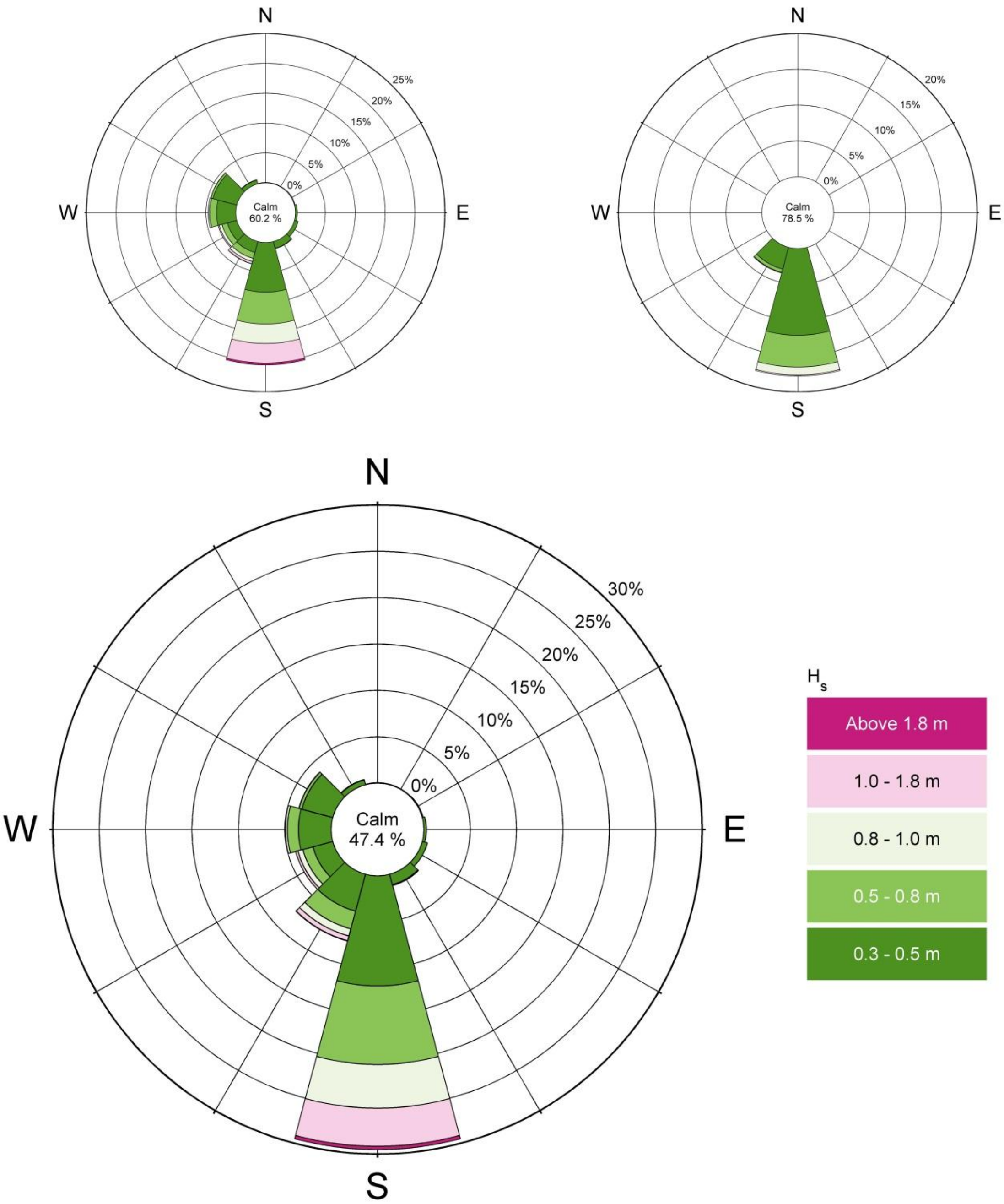

Figure 4-6: Significant wave height roses at output location P12 (bow) for wind sea (top left), swell (top right) and total sea states (below)

Hs		spectral mean wave period seconds														
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	54.85	5.35	.03	.	.	.	.	.	.	.	.	.	.	.	60.22
.25	.50	4.07	12.29	5.55	.19	.01	.00	.	.	.	.	.	.	.	.	22.10
.50	.75	.	1.10	5.32	2.34	.16	.01	.	.	.	.	.	.	.	.	8.93
.75	1.00	.	.00	.51	3.52	.42	.08	.00	.00	.	.	.	.	.	.	4.52
1.00	1.25	.	.	.	.74	1.39	.12	.04	.00	.00	.	.	.	.	.	2.30
1.25	1.50	.	.	.	.00	.82	.24	.03	.01	.00	.	.	.	.	.	1.10
1.50	1.75	.	.	.	.	.05	.39	.03	.01	.00	.	.	.	.	.	.48
1.75	2.00	.	.	.	.	.	.13	.07	.01	.00	.00	.	.	.	.	.21
2.00	2.25	.	.	.	.	.	.01	.07	.00	.00	.00	.	.	.	.	.08
2.25	2.50	.	.	.	.	.	.	.02	.01	.00	.	.	.	.	.	.03
2.50	2.75	.	.	.	.	.	.	.00	.01	.00	.	.	.	.	.	.01
2.75	3.00	.	.	.	.	.	.	.	.00	.00	.	.	.	.	.	.01
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		58.92	18.73	11.40	6.78	2.85	.98	.26	.05	.02	.00	.	.	.	.	100.00

Table 4-1: Joint probability of occurrence of wind sea significant wave height [m] for given mean wave period [s] classes at location P12

Hs		spectral mean wave period seconds														
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	26.89	4.10	8.45	10.12	9.55	8.88	6.21	3.31	.80	.14	.04	.01	.00	.00	78.51
.25	.50	.	.08	1.87	4.89	2.84	2.13	1.49	1.00	.86	.07	.00	.00	.	.00	15.22
.50	.75	.	.	.02	1.07	1.57	.94	.73	.30	.21	.07	.00	.	.	.	4.91
.75	1.00	.	.	.	.06	.38	.34	.21	.14	.04	.01	.00	.	.	.	1.18
1.00	1.25	.	.	.	.00	.01	.03	.03	.04	.02	.00	.	.	.	.	.14
1.25	1.50	.	.	.	.	.	.00	.00	.01	.01	.00	.	.	.	.	.03
1.50	1.75	.	.	.	.	.	.	.	.00	.00	.00	.	.	.	.	.00
1.75	2.00	.	.	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.00	2.25	.	.	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.25	2.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.50	2.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		26.89	4.18	10.33	16.14	14.35	12.33	8.67	4.81	1.94	.30	.04	.02	.00	.00	100.00

Table 4-2: Joint probability of occurrence of swell significant wave height [m] for given mean wave period [s] classes at location P12

Hs		spectral mean wave period seconds														
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	27.11	7.35	4.44	3.01	2.37	1.86	.91	.27	.04	.00	.00	.	.	.	47.36
.25	.50	2.23	9.86	8.95	3.81	1.44	.79	.38	.23	.15	.00	.	.	.	.	27.84
.50	.75	.	.76	5.30	4.49	1.58	.62	.28	.08	.05	.00	.	.	.	.	13.18
.75	1.00	.	.	.44	4.05	1.23	.44	.12	.03	.01	.00	.	.	.	.	6.32
1.00	1.25	.	.	.00	.80	1.78	.28	.09	.02	.01	.	.	.	.	.	2.98
1.25	1.50	.	.	.	.00	.92	.32	.06	.02	.00	.	.	.	.	.	1.33
1.50	1.75	.	.	.	.	.07	.46	.05	.01	.00	.	.	.	.	.	.59
1.75	2.00	.	.	.	.	.	.15	.07	.01	.01	.00	.	.	.	.	.24
2.00	2.25	.	.	.	.	.	.01	.07	.01	.00	.00	.	.	.	.	.10
2.25	2.50	.	.	.	.	.	.	.03	.01	.00	.	.	.	.	.	.04
2.50	2.75	.	.	.	.	.	.	.00	.01	.00	.	.	.	.	.	.02
2.75	3.00	.	.	.	.	.	.	.	.00	.00	.	.	.	.	.	.01
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		29.34	17.98	19.12	16.18	9.39	4.94	2.07	.71	.27	.01	.00	.	.	.	100.00

Table 4-3: Joint probability of occurrence of total significant wave height [m] for given mean wave period [s] classes at location P12

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	5.19	3.03	1.79	1.73	1.88	3.59	36.00	7.77	6.91	9.85	14.18	8.08	100.00
.25	.06	.06	.11	.31	.64	1.21	20.47	3.86	3.23	4.60	4.51	.71	39.78
.50	.	.	.	.	.	.05	12.19	1.99	1.62	1.39	.39	.06	17.68
.75	.	.	.	.	.	.	6.85	.94	.68	.25	.02	.00	8.75
1.00	.	.	.	.	.	.	3.60	.40	.19	.03	.00	.	4.23
1.25	.	.	.	.	.	.	1.74	.16	.03	.00	.	.	1.93
1.50	.	.	.	.	.	.	.76	.07	.00	.	.	.	.83
1.75	.	.	.	.	.	.	.31	.03	.	.	.	.	.34
2.00	.	.	.	.	.	.	.13	.01	.	.	.	.	.14
2.25	.	.	.	.	.	.	.05	.00	.	.	.	.	.05
2.50	.	.	.	.	.	.	.02	.00	.	.	.	.	.02
2.75	.	.	.	.	.	.	.01	.	.	.	.	.	.01
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 4-4: Probability of exceedance of wind sea significant wave height [m] for all directional sectors at location P12 (bow)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	3.00	1.76	.65	.77	1.70	3.19	41.89	27.02	11.41	3.39	2.39	2.84	100.00
.25	.	.	.	.	.	.	17.78	3.72	.	.	.	.	21.49
.50	.	.	.	.	.	.	5.70	.57	.	.	.	.	6.27
.75	.	.	.	.	.	.	1.26	.09	.	.	.	.	1.35
1.00	.	.	.	.	.	.	.16	.01	.	.	.	.	.17
1.25	.	.	.	.	.	.	.04	.	.	.	.	.	.04
1.50	.	.	.	.	.	.	.01	.	.	.	.	.	.01
1.75	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.00	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.25	.	.	.	.	.	.	.	.	.	.	.	.	.
2.50	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 4-5: Probability of exceedance of swell significant wave height [m] for all directional sectors at location P12 (bow)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	1.65	1.25	1.08	1.18	1.72	3.25	37.43	15.38	7.52	8.99	16.65	3.91	100.00
.25	.04	.04	.08	.26	.57	1.24	29.50	7.44	4.13	4.98	3.78	.58	52.64
.50	.	.	.	.	.	.08	17.64	3.33	1.92	1.45	.33	.05	24.80
.75	.	.	.	.	.	.	9.18	1.36	.80	.26	.02	.00	11.62
1.00	.	.	.	.	.	.	4.47	.56	.24	.03	.00	.	5.30
1.25	.	.	.	.	.	.	2.07	.20	.04	.00	.	.	2.32
1.50	.	.	.	.	.	.	.89	.09	.01	.	.	.	.99
1.75	.	.	.	.	.	.	.36	.04	.	.	.	.	.39
2.00	.	.	.	.	.	.	.14	.01	.	.	.	.	.16
2.25	.	.	.	.	.	.	.05	.01	.	.	.	.	.06
2.50	.	.	.	.	.	.	.02	.00	.	.	.	.	.02
2.75	.	.	.	.	.	.	.01	.	.	.	.	.	.01
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 4-6: Probability of exceedance of total significant wave height [m] for all directional sectors at location P12 (bow)

4.3 EXTREME WAVE CLIMATE

Two methods were applied to derive the extreme conditions at the project site:

1. Propagating the offshore extremes to the project site;
2. Extrapolating the time series obtained ta the project site using the POT method.

Nearshore extremes are presented for output location P12 (bow). The output locations at the stern and mid ship are presented in Appendix 5. Table 4-7 presents the results of the propagated offshore extremes for various directions and return periods. Note that the presented values are the best estimates for the independent extreme values. Confidence intervals and the joint occurrence of extreme values are presented in [7].

The extreme wave conditions for various return periods at location P12 (bow) were also derived based on extrapolation of the obtained time series using the POT method. The maximum significant wave height peaks within a time window of 96hr (48hr before and after the peak) and above a threshold value of 1.5 m was selected. The time window and threshold are included to avoid including multiple peaks from one storm and to ensure independence of storm peaks. The threshold value was chosen such that the only the most severe storm conditions were included in the data selection, while sufficient data is included to establish a reliable fitting of the probability of exceedance (in the order of 5 events per year). By fitting the Weibull probability distribution function to the obtained data set the extreme significant wave heights were obtained for return periods of 1, 5, 10, 25, 50 and 100 years. The Weibull fit for omnidirectional wave heights is presented in Figure 4-7. The resulting omnidirectional extreme significant wave heights are presented in Table 4-8.

It is concluded that both methods yield very similar results. The largest differences were found for the 1:1 year return period, the resulting extreme significant wave height at the bow from the first method (the maximum of all offshore directions was taken, i.e.1.8m for offshore directions 150°N and 180°N) is 0.4m lower than that from the second method (2.2m). For the 1:100 year return period, the first method yields a maximum significant wave height of 3.4m for offshore direction180°N, while the second method is 0.2m lower (3.2m).

Spatial distribution of significant wave height for all extreme wave computations are enclosed in Appendix 6.3.

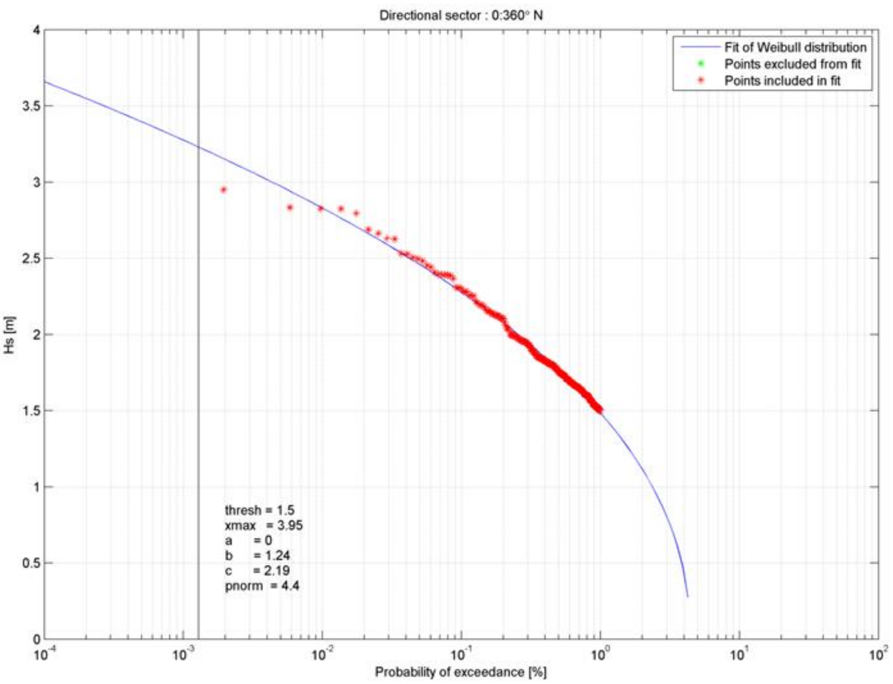

Figure 4-7: Weibull fit extrapolation of significant wave height (location P12, bow) for all peaks above a threshold of 1.5m

Return period [yr]	Offshore direction [°N]	U10 [m/s]	Hm0 [m]	Tp [s]		Bow (location 12)		
						Hm0 [m]	Tm-1,0 [s]	Dir [°N]
1	60	15.0	3.9	10.3		0.7	9.6	187
1	90	14.8	3.5	10.0		0.9	9.1	182
1	120	15.1	3.5	9.3		1.3	8.9	189
1	150	15.4	3.6	9.2		1.8	8.7	189
1	180	14.1	3.1	8.5		1.8	8.1	194
1	210	13.3	2.9	8.3		1.6	7.9	194
1	240	15.3	3.5	9.0		1.2	8.5	196
5	60	18.3	5.3	11.1		1.0	10.1	188
5	90	17.5	4.8	10.7		1.2	9.7	184
5	120	17.3	4.7	10.4		2.0	9.7	186
5	150	18.0	4.7	10.1		2.3	9.2	191
5	180	16.4	4.0	9.4		2.5	9.0	193
5	210	16.0	4.0	9.5		2.0	9.1	199
5	240	17.8	4.6	10.1		1.8	9.2	194
10	60	19.5	5.9	11.6		1.1	10.2	188
10	90	18.4	5.4	10.9		1.4	9.8	184
10	120	18.1	5.1	10.7		2.2	9.9	185
10	150	19.0	5.1	10.5		2.5	9.9	191
10	180	17.3	4.3	9.7		2.7	9.2	193
10	210	17.1	4.5	9.9		2.2	9.4	198
10	240	18.8	5.1	10.7		2.1	9.5	194
25	60	21.0	6.6	12.3		1.2	10.3	189
25	90	19.6	6.2	11.6		1.6	9.9	186
25	120	19.1	5.8	11.2		2.6	10.1	185
25	150	20.2	5.6	11.0		2.8	9.7	190
25	180	18.4	4.8	10.3		3.0	9.5	193
25	210	18.5	5.2	10.7		2.6	9.7	198
25	240	19.9	5.7	11.3		2.5	9.8	194
50	60	22.1	7.1	12.7		1.2	10.5	191
50	90	20.4	6.8	12.1		1.7	10.0	187
50	120	19.8	6.2	11.6		2.8	10.2	186
50	150	21.1	5.9	11.3		3.0	9.9	190
50	180	19.2	5.1	10.6		3.2	9.6	194
50	210	19.6	5.7	11.2		2.9	9.9	197
50	240	20.7	6.2	11.8		2.6	10.0	194
100	60	23.1	7.6	13.1		1.3	10.6	191
100	90	21.1	7.4	12.6		1.9	10.5	192
100	120	20.4	6.7	12.0		2.9	10.3	188
100	150	21.9	6.3	11.7		3.2	10.1	190
100	180	20.0	5.4	10.9		3.4	9.8	194
100	210	20.7	6.2	11.7		3.1	10.0	197
100	240	21.4	6.6	12.2		2.8	10.2	195

Table 4-7: Extreme wave climate at output location P12 (bow)

Return period [year]	Omnidirectional Hm0 [m]
1	2.2
5	2.6
10	2.8
25	3.0
50	3.1
100	3.2

Table 4-8: Extreme significant wave height at output location P12 (bow) from fitting a Weibull on the time series

5 Conclusions

5.1 INTRODUCTION

The yearly average wave climate at the location of the new jetty have been determined by transforming the offshore wave climate (see [1]) to the project site. This transformation was done using transformation matrices. Separate matrices were made for the transformation of swell and wind sea waves. The transformation matrices were created with the wave models MIKE21BW and SWAN. Swell conditions with Tp > 6.0s were simulated using the MIKE21BW model, whereas swell conditions with Tp = 6.0s and the wind sea conditions were simulated using the SWAN model. The yearly average wave climate has been determined at three locations near the jetty, viz. at the bow, mid-ship and stern.

The extreme wave conditions have been evaluated by applying two different methods. First, the extreme wave conditions that were derived at the bay entrance in the wave climate study [1], were propagated into the bay using MIKE21BW. Additionally, the extreme wave conditions at location P12 (bow) were derived based on extrapolation of the obtained time series using the POT method.

The models have not been calibrated because no nearshore or inshore calibration data was available.

5.2 CONCLUSIONS

Below the main conclusions of the study are summarized:

- The Boussinesq wave model MIKE21BW was deemed suitable for the propagation of swell waves and extreme wave conditions towards the project site.
- Due to some inherent limitations of MIKE21BW, the spectral wave model SWAN was applied for the propagation of short and wind sea waves towards the jetty.
- The contribution of reflections to the wave conditions at the jetty site is limited. It was found that he mean wave directions at the project site are quite constant, independent of the mean wave direction outside the bay.
- The contribution of swell waves to the total yearly averaged wave conditions at the project site is much smaller than that of wind sea waves.
- The (swell) wave conditions at the bow are more severe than those at mid-ship and at the stern. The direction of incoming dominant swell waves varies from S-SSW at the bow to SSW-SW at the stern.
- Two methodologies were applied to obtain extreme wave conditions at the jetty. Both extreme methods give similar results for various return periods. Note that the presented values are the best estimates for the independent extreme values. Confidence intervals and the joint occurrence of extreme values are presented in [7].

- Some anecdotal information (pilot observations and storm videos) was received indicating that the wave height inside the bay of Marsaxlokk might be higher than predicted in the present study. The lack of available site measurements makes it impossible to properly deal with the anecdotal information and increase the reliability of the study results. Noting the above, the results of the study should be treated with caution during the design.

References

[1] Nautical and risk studies for the Delimara LNG Terminal in Marsaxlokk Port, Malta. Item 1: Wave climate study. Final report, 17 December 2015
[2] MIKE21BW user guide
[3] SWAN development team (2013), "SWAN User Manual" http://swanmodel.sourceforge.net/
[4] Enet, F.; Nahon, A.; van Vledder, G.Ph.; Hurdle, D.; 2007. Evaluation of diffraction behind a semi-infinite breakwater in the swan wave model. Proc. XX Workshop on Wave Hindcasting and Forecasting, Victoria, Canada
[5] Goda, Y. (2000). "Random Seas and Design of Maritime Structures". Advanced Series on Ocean Engineering **15** (2 ed.).
[6] Kuik, A.J., G. van Vledder, L.H. Holthuijsen, 1988: A method for the routine analysis of pitchand-roll buoy wave data. J. Phys. Oceanogr. 18, 1020-1034.
[7] MARIN/ARCADIS, 2015: Nautical and risk studies for the Delimara LNG terminal in Marsaxlokk Port, Malta; Additional metocean analysis. Report 27689-7-MSCN.rev.1, 17 December 2015 (Arcadis report C03051_000014_0200R3_(078630641-D), 21 September 2015). Prepared for Electrogas Malta.

Appendix 1 HYDROBASE

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HYDROBASE — PRESENT

Analysis and presentation of hydraulic design conditions

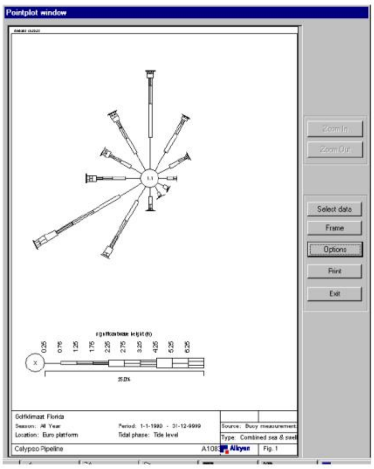
Background

The HYDROBASE program carries out the following activities:

- consistency checks on the data;
- classification of wave observations or measurements according to height, period and direction;
- classification of wind data according to wind speed and direction;
- classification of current data according to water level, current speeds and direction;
- analysis of combinations of up to three of the above variables;
- presentation of classified data in the form of joint occurrence tables, wind, current and wave roses and exceedance curves;
- transformation of series of data or classified data according to a user defined matrix;
- Selection of individual events from a series on the basis of date, record number or height, speed or direction criterion and a facility to code the reliability of an individual record.

HYDROBASE can read data in standard format from the following sources:

- wave hindcast results from the global hindcast model of the Met Office (UK);
- Series of individual ships observations of sea and swell wave height, period and direction and wind speed and direction stored in databases at The Met Office (UK) and at the KNMI (Royal Dutch Meteorological Institute);
- Classified ships observations from The Met Office and condensed format ship observations from the KNMI (this data is cheaper but more restricted);
- User input tables giving the joint probability of occurrence of various conditions;
- Series of values in a number of other standard formats;
- Data can be selected according to month or season, location, year and time of day. Further, classes are included for undetermined or variable values.



For the purposes of the presentation of the exceedance curves, a Weibull fit is made to the wave height or wind speeds data in each direction sector. This can be used to obtain the extreme wave conditions (e.g. those conditions occurring for 6 hours in 50 years) for design purposes (e.g. breakwater design).

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Imagine the result

Applications

- wave, wind and water level conditions
- coastal evolution
- harbour design

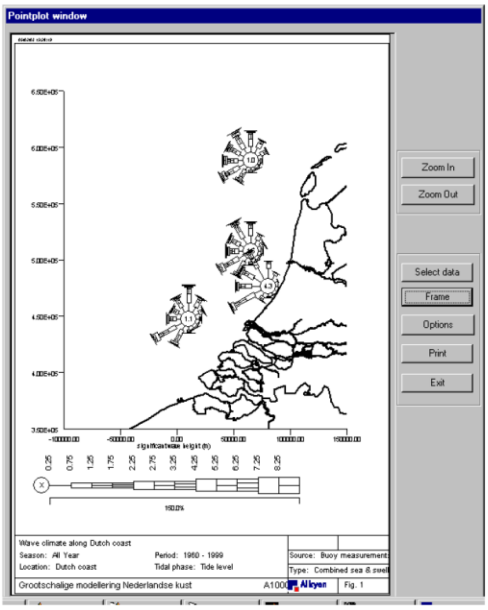
Processes

- classification of data
- transformation of statistics
- quality control

References

CERC, 1984. “Shore protection Manual”. Dept. Of the Army, Waterways Experiment Station, Corps of Engineers, Coastal Engineering Research Station, USA

Hurdle, D.P. and Stive, R.J.H., 1989. “Revision of SPM 1984 wave hindcast model to avoid inconsistencies in engineering applications”, Coastal Engineering, 12 (1989), pp 339-351.



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Appendix 2 MIKE21BW

Application Areas

MIKE 21 BW - Boussinesq Wave Module

MIKE 21 BW is the state-of-the-art numerical modelling tool for studies and analysis of wave disturbance in ports, harbours and coastal areas. The combination of an advanced GUI and efficient computational engines has made it an irreplaceable tool for professional coastal and harbour engineers around the world.

MIKE 21 BW has been used successfully for the analysis of operational and design conditions within ports and harbours. By the inclusion of surf and swash zone dynamics, the application range is extended further into the coastal engineering.

MIKE 21 BW is a state-of-the-art numerical tool for studies and analysis of short and long period wave disturbance in ports and harbours

MIKE 21 BW is capable of reproducing the combined effects of all important wave phenomena of interest in port, harbour and coastal engineering. These include:

- shoaling
- refraction
- diffraction
- wave breaking
- bottom dissipation
- moving shoreline
- partial reflection
- wave transmission
- non-linear wave-wave interactions
- frequency spreading
- directional spreading

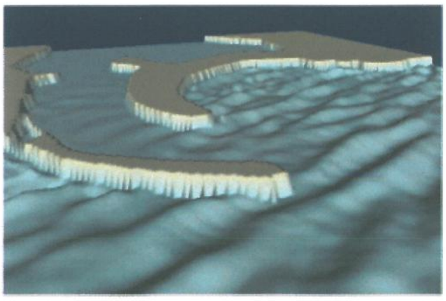
MIKE 21 BW includes the two models:

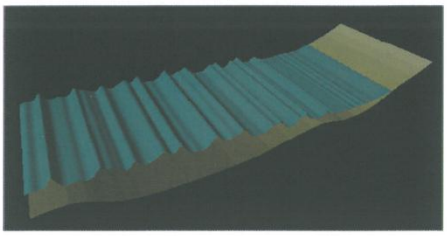
- 2DH Boussinesq wave model
- 1DH Boussinesq wave model

The 2DH model covers two horizontal space-co-ordinates) and the 1DH model one horizontal space-co-ordinate (coastal profiles).

MIKE 21 BW is based on the numerical solution of the time domain formulations of Boussinesq type equations, Madsen et al (1991, 1992, 1997a,b), Sørensen and Sørensen (2001) and Sørensen et al (2004).

Both models solve the Boussinesq type equations using a flux-formulation with improved frequency dispersion characteristics. The enhanced Boussinesq type equations make the models suitable for simulation of propagation of non-linear directional waves from deep to shallow water.





MIKE 21 BW includes two models. The 2DH model (upper panel) is traditionally applied for calculation of wave disturbance in ports, harbours and coastal areas. The 1DH model (lower panel) is selected for calculation of wave transformation from offshore to the beach for the study of surf zone and swash zone dynamics

Software for WATER ENVIRONMENTS 1

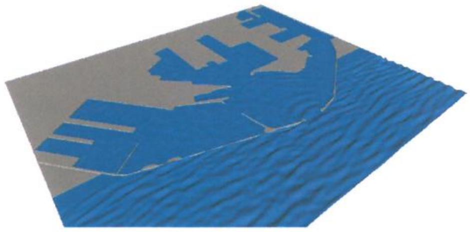
Application Areas

A major application area of MIKE 21 BW is determination and assessment of wave dynamics in ports and harbours and in coastal areas. The disturbance inside harbour basins is one of the most important factors when engineers are to select construction sites and determine the optimum harbour layout in relation to predefined criteria for acceptable wave disturbance, ship movements, mooring arrangements and handling down-time.

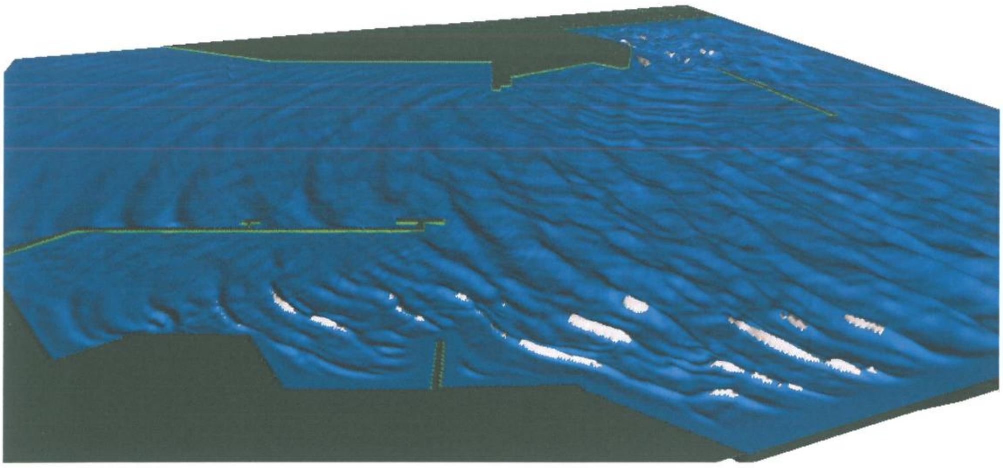
2DH Boussinesq Wave Model

Applications of the 2DH model include:

- determination of wave disturbance caused by wind-waves and swell
- analysis of low-frequency oscillations (seiching and harbour resonance) caused by forcing of e.g. short-wave induced long waves



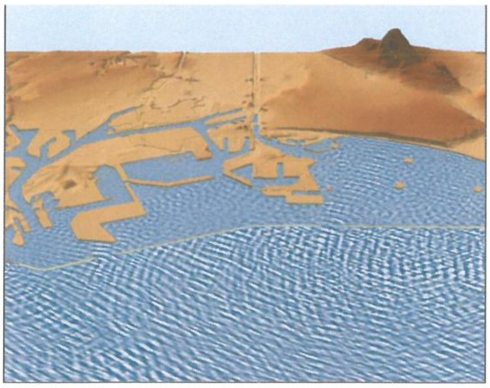
Simulation of wave penetration, Frederikshavn harbour, Denmark



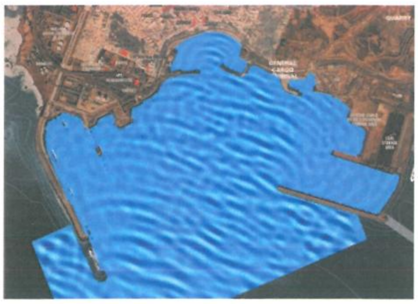
Simulation of wave propagation and agitation in a harbour area for an extreme wave event. The breaking waves (surface rollers) are shown in white

- wave transformation in coastal areas where reflection and/or diffraction are important phenomena
- surf zone calculations including wave-induced circulation and run-up/run-down
- simulation of propagation and transformation of transients such as ship-generated waves and tsunamis

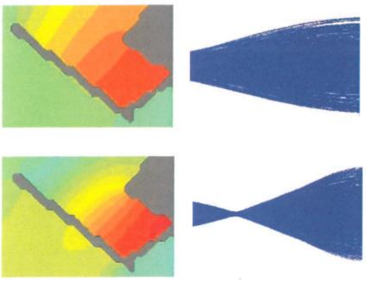
The assessment of low-frequency motions in existing as well as new harbours is often performed by a combination of simulations with synthetic white-noise spectra and simulations with natural wave spectra. The purpose of the former type of simulation is to investigate the potential for seiching/resonance and identify the natural frequencies. This is particularly useful for comparisons of alternative layouts.



Wave transformation in Port of Long Beach, CA, USA

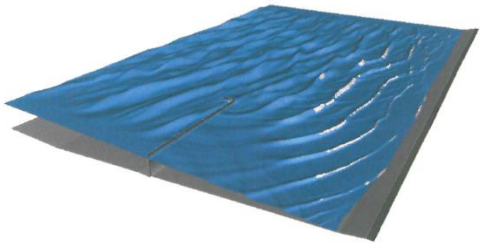


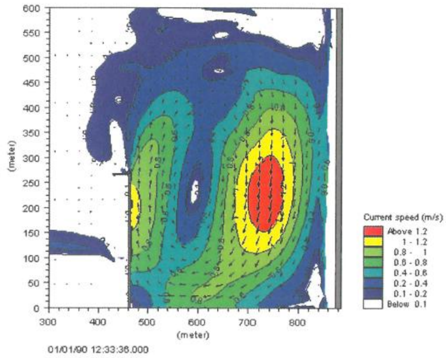
MIKE 21 BW application in Port of Sines, Portugal



Natural fundamental modes of low-frequency oscillation. Long wave energy intensity and surface elevation envelopes along the longitudinal line of the basin. The digital filtering is performed the WSWAT analysis tool included in MIKE Zero

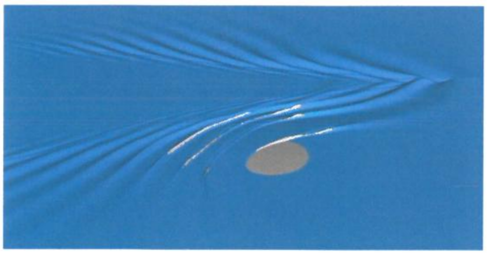
With inclusion of wave breaking and moving shoreline MIKE 21 BW is also an efficient tool for the study of many complicated coastal phenomena, e.g. wave induced-current patterns in areas with complex structures.





Wave transformation, wave breaking and run-up in the vicinity of a detached breakwater parallel to the shoreline. The lower image shows the associated circulation cell behind the breakwater

MIKE 21 BW is also applied for prediction and analysis of the impact of ship-generated waves (also denoted as wake wash) in ports and harbours and coastal areas. Essential boundary conditions (at open or internal boundaries) for the models can be obtained from 3D computational fluid dynamic (CFD) models, experimental data, full-scale data and/or empirical relationships.



Wave breaking and run-up of ship waves on an offshore island

Appendix 3 SWAN

Imagine the result

SWAN

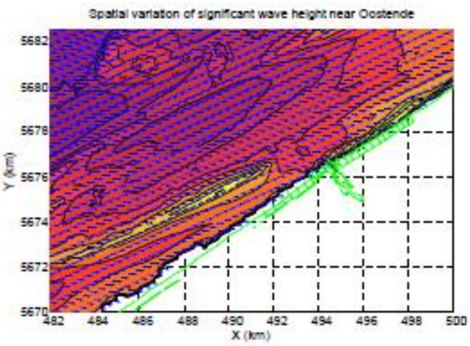
Simulation of wave generation, propagation and dissipation in coastal areas

General
Swan is a third-generation wave model for application in coastal regions. The SWAN model is being developed by Delft University of Technology and has been verified using laboratory and field data.

Applications
Knowledge of the wave conditions is required for the design of offshore installations, breakwaters or harbours and the study of morphological and coastal development.

In many seas, little information is available on the operational and extreme wave climate in shallow water or at locations where the fetch length is restricted. However, data on wind and wave conditions is often available offshore. In such situations, the swan model can be applied to transform the offshore wave climate to nearshore. swan is a wave generation and propagation model suitable for use in water of intermediate and shallow depth. Typical areas for the application of swan range between 10 X 5 km2 and 30 X 100 km2 (e.g. along a coastal strip).

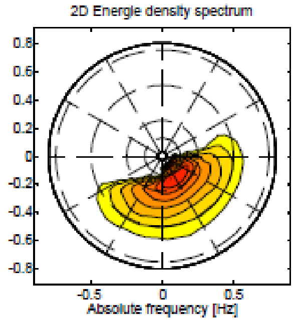
The swan model can be run in stationary and non-stationary mode and can be nested in the wam and wavewatch model to enable an easy transition from ocean scale models to coastal scale applications.

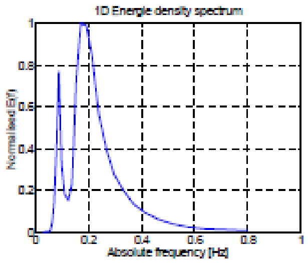


Typical applications:

- determination of wave boundary conditions for coastal protection measures
- transformation of wave climate from deep to shallow water
- wave penetration studies for harbour development
- coastal management
- wave forecasting and hindcasting
- design of offshore and nearshore structures

Imagine the result





Processes

The following processes are modelled by Swan:

- wave generation by the action of the wind
- refraction over a bottom of variable depth
- refraction over a spatially varying ambient current
- wave blocking by currents
- dissipation by whitecapping
- dissipation by wave breaking
- dissipation by bottom friction
- non-linear wave interactions
- partial wave transmission
- partial wave reflection
- diffraction behind breakwaters

Representation

Swan represents the wave field on a two-dimensional horizontal rectangular grid covering the computational area. At each grid point, the wave field is represented by a discrete two-dimensional energy density spectrum using a number of frequencies and directions. The evolution of the wave field in space and time is described by the wave action balance equation. The action balance equation is solved by means of an iterative procedure. This equation includes propagation of wave energy and source terms describing the growth, decay and redistribution of wave energy for all spectral components. The swan model has source terms for wave growth by wind action, dissipation by white-capping, bottom friction or wave breaking, and non-linear triad and quadruplet wave-wave interactions. A nested grid may be used as well as a curvi-linear grid to enable easy interactive coupling with other models, which use the same grid.

References

Booij, N., L.H. Holthuijsen and R.C. Ris and: 1999, A third-generation wave model for coastal regions. 1. Model description and validation. J. Geophys. Res., Vol 10, No. C, 7649-7666

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Appendix 4 Yearly average wave climate at the jetty

In this appendix the resulting wave climate at the jetty is presented for locations P5 (stern), P8 (mid) and P12 (bow).

Appendix 4.1 Location P5: stern

Hs		spectral mean wave period seconds													
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	59.02	6.62	.15	.00	.	.	.	.	.	.	.	.	.	.	65.80
.25	.50	4.17	9.81	5.85	.52	.02	.00	.	.	.	.	.	.	.	.	20.37
.50	.75	.	.88	3.89	2.75	.29	.02	.00	.	.	.	.	.	.	.	7.84
.75	1.00	.	.	.36	2.24	.82	.13	.03	.00	.00	.	.	.	.	.	3.58
1.00	1.25	.	.	.	.22	1.08	.17	.03	.01	.00	.	.	.	.	.	1.51
1.25	1.50	.	.	.	.	.19	.37	.03	.01	.00	.00	.	.	.	.	.61
1.50	1.75	.	.	.	.	.	.14	.05	.00	.01	.	.	.	.	.	.20
1.75	2.00	.	.	.	.	.	.01	.06	.00	.00	.	.	.	.	.	.07
2.00	2.25	.	.	.	.	.	.	.01	.01	.00	.	.	.	.	.	.02
2.25	2.50	.	.	.	.	.	.	.00	.01	.	.	.	.	.	.	.01
2.50	2.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		63.19	17.32	10.25	5.74	2.40	.84	.21	.04	.01	.00	.	.	.	.	100.00

Table A4-1: Joint probability of occurrence of wind sea significant wave height [m] for given mean wave period [s] classes at location P5 (stern)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	1.17	1.05	1.06	1.07	1.30	3.09	35.49	7.74	8.09	11.96	15.80	12.19	100.00
.25	.	.00	.01	.04	.08	.55	18.73	3.53	3.24	4.65	3.06	.32	34.20
.50	.	.	.	.	.	.	9.70	1.62	1.37	1.00	.14	.01	13.83
.75	.	.	.	.	.	.	4.72	.69	.45	.13	.01	.	6.00
1.00	.	.	.	.	.	.	2.07	.25	.09	.01	.	.	2.42
1.25	.	.	.	.	.	.	.80	.09	.01	.	.	.	.90
1.50	.	.	.	.	.	.	.26	.03	.	.	.	.	.29
1.75	.	.	.	.	.	.	.09	.01	.	.	.	.	.10
2.00	.	.	.	.	.	.	.02	.00	.	.	.	.	.02
2.25	.	.	.	.	.	.	.01	.00	.	.	.	.	.01
2.50	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-2: Probability of exceedance of wind sea significant wave height [m] for all directional sectors at location P5 (stern)

Tm-1,0.	wave direction degrees												
seconds	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	1.17	1.05	1.06	1.07	1.30	3.09	35.49	7.74	8.09	11.96	15.80	12.19	100.00
2.0	.	.01	.12	.41	.70	1.43	23.18	3.81	2.83	3.16	1.10	.06	36.81
3.0	.	.	.	.	.01	.50	15.36	1.81	1.18	.58	.05	.00	19.49
4.0	.	.	.	.	.	.00	8.05	.74	.39	.06	.00	.	9.24
5.0	.	.	.	.	.	.	3.19	.23	.07	.00	.	.	3.50
6.0	.	.	.	.	.	.	1.02	.07	.01	.00	.	.	1.10
7.0	.	.	.	.	.	.	.25	.01	.	.	.	.	.26
8.0	.	.	.	.	.	.	.05	.00	.	.	.	.	.05
9.0	.	.	.	.	.	.	.01	.	.	.	.	.	.01
10.0	.	.	.	.	.	.	.00	.	.	.	.	.	.00
11.0	.	.	.	.	.	.	.	.	.	.	.	.	.
12.0	.	.	.	.	.	.	.	.	.	.	.	.	.
13.0	.	.	.	.	.	.	.	.	.	.	.	.	.
14.0	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-3: Probability of exceedance of wind sea mean wave period [s] for all directional sectors at location P5 (stern)

Hs		spectral mean wave period seconds														
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	26.86	4.16	9.35	11.72	10.43	9.35	7.05	4.90	.86	.10	.03	.01	.00	.00	84.84
.25	.50	.	.01	1.01	3.97	2.86	1.94	1.39	.80	.35	.01	.00	.00	.	.	12.34
.50	.75	.	.	.00	.47	.98	.56	.29	.19	.03	.00	.	.	.	.	2.52
.75	1.00	.	.	.	.01	.09	.08	.04	.04	.01	.00	.	.	.	.	.27
1.00	1.25	.	.	.	.	.00	.00	.00	.01	.01	.	.	.	.	.	.02
1.25	1.50	.	.	.	.	.	.	.	.	.00	.	.	.	.	.	.00
1.50	1.75	.	.	.	.	.	.	.	.	.00	.	.	.	.	.	.00
1.75	2.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.00	2.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.25	2.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.50	2.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		26.86	4.17	10.36	16.16	14.36	11.93	8.79	5.94	1.25	.12	.03	.01	.00	.00	100.00

Table A4-4: Joint probability of occurrence of swell significant wave height [m] for given mean wave period [s] classes at location P5 (stern)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	3.00	1.75	.61	.73	1.46	2.82	16.34	53.42	11.25	3.39	2.39	2.84	100.00
.25	.	.	.	.	.	.	5.02	10.14	.	.	.	.	15.16
.50	.	.	.	.	.	.	1.33	1.49	.	.	.	.	2.81
.75	.	.	.	.	.	.	.22	.07	.	.	.	.	.29
1.00	.	.	.	.	.	.	.02	.00	.	.	.	.	.02
1.25	.	.	.	.	.	.	.00	.	.	.	.	.	.00
1.50	.	.	.	.	.	.	.00	.	.	.	.	.	.00
1.75	.	.	.	.	.	.	.	.	.	.	.	.	.
2.00	.	.	.	.	.	.	.	.	.	.	.	.	.
2.25	.	.	.	.	.	.	.	.	.	.	.	.	.
2.50	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-5: Probability of exceedance of swell significant wave height [m] for all directional sectors at location P5 (stern)

Tmm10	wave direction degrees												
seconds	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	3.00	1.75	.61	.73	1.46	2.82	16.34	53.42	11.25	3.39	2.39	2.84	100.00
2.0	.	.	.01	.32	1.35	2.78	16.14	52.36	.17	.	.	.	73.14
3.0	.	.	.	.04	.58	2.50	15.50	50.34	.00	.	.	.	68.97
4.0	.	.	.	.00	.08	1.37	12.38	44.77	.	.	.	.	58.60
5.0	.	.	.	.	.01	.40	7.57	34.45	.	.	.	.	42.44
6.0	.	.	.	.	.00	.03	3.84	24.21	.	.	.	.	28.08
7.0	.	.	.	.	.00	.01	1.51	14.62	.	.	.	.	16.14
8.0	.	.	.	.	.	.00	.51	6.85	.	.	.	.	7.36
9.0	.	.	.	.	.	.00	.11	1.31	.	.	.	.	1.42
10.0	.	.	.	.	.	.	.03	.14	.	.	.	.	.17
11.0	.	.	.	.	.	.	.01	.04	.	.	.	.	.05
12.0	.	.	.	.	.	.	.00	.01	.	.	.	.	.02
13.0	.	.	.	.	.	.	.00	.00	.	.	.	.	.00
14.0	.	.	.	.	.	.	.	.00	.	.	.	.	.00

Table A4-6: Probability of exceedance of swell mean wave period [s] for all directional sectors at location P5 (stern)

Hs		spectral mean wave period seconds														
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	30.49	8.80	5.86	3.87	2.61	1.90	1.03	.45	.04	.00	.	.	.	.	55.06
.25	.50	2.45	8.73	8.62	4.12	1.63	.74	.37	.15	.02	.	.	.	.	.	26.83
.50	.75	.	.60	3.96	4.36	1.35	.34	.09	.02	.00	.	.	.	.	.	10.74
.75	1.00	.	.	.30	2.59	1.32	.26	.06	.01	.00	.	.	.	.	.	4.54
1.00	1.25	.	.	.	.23	1.29	.22	.05	.01	.00	.	.	.	.	.	1.81
1.25	1.50	.	.	.	.	.21	.42	.04	.01	.00	.00	.	.	.	.	.69
1.50	1.75	.	.	.	.	.	.15	.05	.00	.01	.	.	.	.	.	.21
1.75	2.00	.	.	.	.	.	.02	.06	.01	.00	.	.	.	.	.	.09
2.00	2.25	.	.	.	.	.	.	.01	.01	.00	.	.	.	.	.	.02
2.25	2.50	.	.	.	.	.	.	.00	.01	.	.	.	.	.	.	.01
2.50	2.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		32.94	18.14	18.73	15.18	8.42	4.05	1.77	.68	.09	.00	.	.	.	.	100.00

Table A4-7: Joint probability of occurrence of total significant wave height [m] for given mean wave period [s] classes at location P5 (stern)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	.59	.55	.77	.87	1.34	2.77	29.24	21.91	8.61	11.14	17.40	4.80	100.00
.25	.00	.00	.02	.04	.08	.58	22.52	9.85	4.03	5.00	2.53	.28	44.94
.50	.	.	.	.	.	.	12.09	3.30	1.60	1.00	.12	.01	18.10
.75	.	.	.	.	.	.	5.71	1.00	.52	.13	.00	.	7.37
1.00	.	.	.	.	.	.	2.40	.32	.11	.01	.	.	2.83
1.25	.	.	.	.	.	.	.89	.12	.01	.	.	.	1.02
1.50	.	.	.	.	.	.	.29	.04	.	.	.	.	.33
1.75	.	.	.	.	.	.	.10	.01	.	.	.	.	.12
2.00	.	.	.	.	.	.	.02	.00	.	.	.	.	.03
2.25	.	.	.	.	.	.	.01	.00	.	.	.	.	.01
2.50	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-8: Probability of exceedance of total significant wave height [m] for all directional sectors at location P5 (stern)

Tmm10	wave direction degrees												
seconds	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	.59	.55	.77	.87	1.34	2.77	29.24	21.91	8.61	11.14	17.40	4.80	100.00
2.0	.16	.17	.25	.51	1.11	2.33	28.32	20.46	5.45	5.53	2.19	.58	67.06
3.0	.05	.06	.07	.11	.39	1.62	23.44	17.77	3.35	1.60	.38	.09	48.92
4.0	.01	.01	.01	.02	.09	.58	14.08	13.51	1.49	.31	.08	.01	30.19
5.0	.00	.	.	.00	.01	.14	6.01	8.36	.46	.03	.00	.00	15.01
6.0	.	.	.	.	.	.01	1.87	4.66	.06	.00	.	.	6.59
7.0	.	.	.	.	.	.00	.40	2.14	.00	.	.	.	2.54
8.0	.	.	.	.	.	.	.08	.70	.	.	.	.	.78
9.0	.	.	.	.	.	.	.01	.08	.	.	.	.	.09
10.0	.	.	.	.	.	.	.00	.00	.	.	.	.	.00
11.0	.	.	.	.	.	.	.	.	.	.	.	.	.
12.0	.	.	.	.	.	.	.	.	.	.	.	.	.
13.0	.	.	.	.	.	.	.	.	.	.	.	.	.
14.0	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-9: Probability of exceedance of total mean wave period [s] for all directional sectors at location P5 (stern)

Appendix 4.2 Location P8: mid ship

Hs		spectral mean wave period seconds													
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	57.12	5.80	.04	.	.	.	.	.	.	.	.	.	.	.	62.96
.25	.50	4.26	11.13	5.80	.22	.01	.00	.	.	.	.	.	.	.	.	21.41
.50	.75	.	1.06	4.54	2.71	.16	.01	.	.	.	.	.	.	.	.	8.47
.75	1.00	.	.00	.47	2.86	.60	.09	.01	.00	.	.	.	.	.	.	4.03
1.00	1.25	.	.	.	.41	1.33	.14	.04	.00	.00	.	.	.	.	.	1.92
1.25	1.50	.	.	.	.00	.40	.33	.03	.01	.00	.	.	.	.	.	.77
1.50	1.75	.	.	.	.	.00	.22	.05	.01	.01	.00	.	.	.	.	.28
1.75	2.00	.	.	.	.	.	.03	.07	.01	.00	.	.	.	.	.	.11
2.00	2.25	.	.	.	.	.	.	.02	.01	.00	.	.	.	.	.	.03
2.25	2.50	.	.	.	.	.	.	.00	.01	.00	.	.	.	.	.	.01
2.50	2.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		61.38	17.99	10.85	6.20	2.50	.83	.21	.04	.01	.00	.	.	.	.	100.00

Table A4-10: Joint probability of occurrence of wind sea significant wave height [m] for given mean wave period [s] classes at location P8 (mid-ship)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	2.46	2.08	2.14	2.06	2.24	4.27	33.96	7.43	7.52	10.72	14.99	10.13	100.00
.25	.	.02	.05	.18	.53	1.34	18.93	3.61	3.26	4.71	3.91	.50	37.04
.50	.	.	.	.	.	.02	10.79	1.81	1.54	1.23	.21	.02	15.63
.75	.	.	.	.	.	.	5.57	.82	.58	.18	.01	.	7.15
1.00	.	.	.	.	.	.	2.64	.33	.14	.02	.	.	3.12
1.25	.	.	.	.	.	.	1.06	.13	.02	.	.	.	1.20
1.50	.	.	.	.	.	.	.38	.05	.00	.	.	.	.43
1.75	.	.	.	.	.	.	.13	.02	.	.	.	.	.15
2.00	.	.	.	.	.	.	.03	.00	.	.	.	.	.04
2.25	.	.	.	.	.	.	.01	.00	.	.	.	.	.01
2.50	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-11: Probability of exceedance of wind sea significant wave height [m] for all directional sectors at location P8 (mid-ship)

Tm-1,0	wave direction degrees												
seconds	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	2.46	2.08	2.14	2.06	2.24	4.27	33.96	7.43	7.52	10.72	14.99	10.13	100.00
2.0	.	.02	.20	.59	.98	2.27	22.52	3.83	3.00	3.59	1.53	.09	38.62
3.0	.	.	.	.00	.20	.83	15.61	1.93	1.35	.65	.05	.01	20.63
4.0	.	.	.	.	.	.07	8.44	.80	.41	.06	.00	.	9.78
5.0	.	.	.	.	.	.	3.28	.25	.06	.00	.	.	3.59
6.0	.	.	.	.	.	.	1.01	.07	.01	.00	.	.	1.09
7.0	.	.	.	.	.	.	.25	.01	.	.	.	.	.26
8.0	.	.	.	.	.	.	.05	.00	.	.	.	.	.05
9.0	.	.	.	.	.	.	.01	.	.	.	.	.	.01
10.0	.	.	.	.	.	.	.00	.	.	.	.	.	.00
11.0	.	.	.	.	.	.	.	.	.	.	.	.	.
12.0	.	.	.	.	.	.	.	.	.	.	.	.	.
13.0	.	.	.	.	.	.	.	.	.	.	.	.	.
14.0	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-12: Probability of exceedance of wind sea mean wave period [s] for all directional sectors at location P8 (mid-ship)

Hs		spectral mean wave period seconds														
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	26.86	4.10	8.85	10.86	10.00	8.93	6.85	4.52	.88	.07	.02	.01	.00	.00	81.96
.25	.50	.	.03	1.37	4.54	2.92	2.07	1.59	.98	.54	.00	.00	.	.	.	14.04
.50	.75	.	.	.01	.70	1.27	.69	.45	.29	.03	.00	.	.	.	.	3.45
.75	1.00	.	.	.	.03	.16	.15	.07	.09	.01	.00	.	.	.	.	.50
1.00	1.25	.	.	.	.00	.00	.01	.01	.02	.01	.	.	.	.	.	.04
1.25	1.50	.	.	.	.	.	.00	.	.00	.00	.	.	.	.	.	.00
1.50	1.75	.	.	.	.	.	.	.	.00	.	.	.	.	.	.	.00
1.75	2.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.00	2.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.25	2.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.50	2.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		26.86	4.13	10.23	16.14	14.35	11.85	8.97	5.90	1.47	.08	.02	.01	.00	.00	100.00

Table A4-13: Joint probability of occurrence of swell significant wave height [m] for given mean wave period [s] classes at location P8 (mid-ship)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	3.00	1.76	.65	.77	1.66	3.16	44.33	24.92	11.15	3.39	2.39	2.84	100.00
.25	.	.	.	.	.	.	10.83	7.21	.	.	.	.	18.04
.50	.	.	.	.	.	.	3.13	.87	.	.	.	.	4.00
.75	.	.	.	.	.	.	.51	.05	.	.	.	.	.55
1.00	.	.	.	.	.	.	.04	.00	.	.	.	.	.05
1.25	.	.	.	.	.	.	.01	.	.	.	.	.	.01
1.50	.	.	.	.	.	.	.00	.	.	.	.	.	.00
1.75	.	.	.	.	.	.	.	.	.	.	.	.	.
2.00	.	.	.	.	.	.	.	.	.	.	.	.	.
2.25	.	.	.	.	.	.	.	.	.	.	.	.	.
2.50	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-14: Probability of exceedance of swell significant wave height [m] for all directional sectors at location P8 (mid-ship)

Tmm10	wave direction degrees												
seconds	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	3.00	1.76	.65	.77	1.66	3.16	44.33	24.92	11.15	3.39	2.39	2.84	100.00
2.0	.	.	.01	.38	1.58	3.12	43.96	23.94	.15	.	.	.	73.14
3.0	.	.	.	.05	.81	2.92	42.92	22.30	.00	.	.	.	69.02
4.0	.	.	.	.00	.14	1.87	37.42	19.34	.	.	.	.	58.78
5.0	.	.	.	.	.02	.71	27.23	14.69	.	.	.	.	42.65
6.0	.	.	.	.	.00	.08	17.65	10.57	.	.	.	.	28.30
7.0	.	.	.	.	.	.01	9.49	6.95	.	.	.	.	16.45
8.0	.	.	.	.	.	.00	3.04	4.44	.	.	.	.	7.48
9.0	.	.	.	.	.	.	.20	1.38	.	.	.	.	1.58
10.0	.	.	.	.	.	.	.04	.07	.	.	.	.	.11
11.0	.	.	.	.	.	.	.02	.01	.	.	.	.	.03
12.0	.	.	.	.	.	.	.01	.01	.	.	.	.	.01
13.0	.	.	.	.	.	.	.00	.00	.	.	.	.	.00
14.0	.	.	.	.	.	.	.00	.	.	.	.	.	.00

Table A4-15: Probability of exceedance of swell mean wave period [s] for all directional sectors at location P8 (mid-ship)

Hs meters		spectral mean wave period seconds														
		< to 2.0	2.0 to 3.0	3.0 to 4.0	4.0 to 5.0	5.0 to 6.0	6.0 to 7.0	7.0 to 8.0	8.0 to 9.0	9.0 to 10.0	10.0 to 11.0	11.0 to 12.0	12.0 to 13.0	13.0 to 14.0	14.0 to >	Total
Lower	Upper															
<	.25	29.29	7.95	4.87	3.29	2.43	1.81	1.02	.41	.05	.00	.	.	.	.	51.12
.25	.50	2.41	9.43	9.00	3.94	1.57	.82	.41	.20	.05	.	.	.	.	.	27.82
.50	.75	.	.76	4.56	4.65	1.42	.44	.17	.04	.00	.	.	.	.	.	12.03
.75	1.00	.	.	.41	3.28	1.25	.29	.05	.02	.	.	.	.	.	.	5.31
1.00	1.25	.	.	.	.44	1.61	.20	.05	.01	.00	.	.	.	.	.	2.33
1.25	1.50	.	.	.	.00	.45	.41	.04	.01	.00	.	.	.	.	.	.91
1.50	1.75	.	.	.	.	.01	.25	.05	.01	.01	.00	.	.	.	.	.32
1.75	2.00	.	.	.	.	.	.04	.08	.00	.00	.	.	.	.	.	.12
2.00	2.25	.	.	.	.	.	.	.03	.01	.00	.	.	.	.	.	.04
2.25	2.50	.	.	.	.	.	.	.00	.01	.00	.	.	.	.	.	.01
2.50	2.75	.	.	.	.	.	.	.	.00	.	.	.	.	.	.	.00
2.75	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		31.70	18.13	18.83	15.60	8.74	4.26	1.90	.72	.11	.00	.	.	.	.	100.00

Table A4-16: Joint probability of occurrence of total significant wave height [m] for given mean wave period [s] classes at location P8 (mid-ship)

Hs	wave direction degrees												
meters	-15 to 15	15 to 45	45 to 75	75 to 105	105 to 135	135 to 165	165 to 195	195 to 225	225 to 255	255 to 285	285 to 315	315 to 345	Total
<	.82	.81	1.27	1.42	1.97	3.69	36.15	14.48	7.84	9.86	17.28	4.41	100.00
.25	.01	.02	.05	.14	.46	1.34	25.69	8.35	4.08	5.07	3.27	.41	48.88
.50	.	.	.	.	.	.02	14.62	3.18	1.79	1.26	.18	.02	21.06
.75	.	.	.	.	.	.	7.02	1.16	.67	.18	.01	.	9.03
1.00	.	.	.	.	.	.	3.12	.42	.17	.02	.	.	3.73
1.25	.	.	.	.	.	.	1.22	.15	.02	.00	.	.	1.40
1.50	.	.	.	.	.	.	.43	.06	.00	.	.	.	.49
1.75	.	.	.	.	.	.	.14	.02	.	.	.	.	.17
2.00	.	.	.	.	.	.	.04	.01	.	.	.	.	.05
2.25	.	.	.	.	.	.	.01	.00	.	.	.	.	.01
2.50	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.75	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-17: Probability of exceedance of total significant wave height [m] for all directional sectors at location P8 (mid-ship)

Tmm10	wave direction degrees												
seconds	-15 to 15	15 to 45	45 to 75	75 to 105	105 to 135	135 to 165	165 to 195	195 to 225	225 to 255	255 to 285	285 to 315	315 to 345	Total
<	.82	.81	1.27	1.42	1.97	3.69	36.15	14.48	7.84	9.86	17.28	4.41	100.00
2.0	.13	.17	.38	.78	1.58	3.32	35.31	13.09	5.01	5.43	2.54	.57	68.30
3.0	.03	.05	.10	.19	.77	2.25	30.85	10.81	3.11	1.54	.36	.11	50.17
4.0	.01	.01	.01	.04	.16	1.05	20.75	7.73	1.27	.24	.07	.01	31.34
5.0	.	.	.	.00	.02	.32	10.57	4.48	.32	.02	.00	.	15.74
6.0	.	.	.	.	.	.04	4.59	2.33	.04	.00	.	.	7.00
7.0	.	.	.	.	.	.	1.64	1.10	.00	.	.	.	2.74
8.0	.	.	.	.	.	.	.35	.48	.	.	.	.	.84
9.0	.	.	.	.	.	.	.02	.10	.	.	.	.	.12
10.0	.	.	.	.	.	.	.00	.00	.	.	.	.	.00
11.0	.	.	.	.	.	.	.	.	.	.	.	.	.
12.0	.	.	.	.	.	.	.	.	.	.	.	.	.
13.0	.	.	.	.	.	.	.	.	.	.	.	.	.
14.0	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-18: Probability of exceedance of total mean wave period [s] for all directional sectors at location P8 (mid-ship)

Appendix 4.3 Location P12: bow

Hs		spectral mean wave period seconds														
meters		< to 2.0	2.0 to 3.0	3.0 to 4.0	4.0 to 5.0	5.0 to 6.0	6.0 to 7.0	7.0 to 8.0	8.0 to 9.0	9.0 to 10.0	10.0 to 11.0	11.0 to 12.0	12.0 to 13.0	13.0 to 14.0	14.0 to >	Total
Lower	Upper															
<	.25	54.85	5.35	.03	.	.	.	.	.	.	.	.	.	.	.	60.22
.25	.50	4.07	12.29	5.55	.19	.01	.00	.	.	.	.	.	.	.	.	22.10
.50	.75	.	1.10	5.32	2.34	.16	.01	.	.	.	.	.	.	.	.	8.93
.75	1.00	.	.00	.51	3.52	.42	.08	.00	.00	.	.	.	.	.	.	4.52
1.00	1.25	.	.	.	.74	1.39	.12	.04	.00	.00	.	.	.	.	.	2.30
1.25	1.50	.	.	.	.00	.82	.24	.03	.01	.00	.	.	.	.	.	1.10
1.50	1.75	.	.	.	.	.05	.39	.03	.01	.00	.	.	.	.	.	.48
1.75	2.00	.	.	.	.	.	.13	.07	.01	.00	.00	.	.	.	.	.21
2.00	2.25	.	.	.	.	.	.01	.07	.00	.00	.00	.	.	.	.	.08
2.25	2.50	.	.	.	.	.	.	.02	.01	.00	.	.	.	.	.	.03
2.50	2.75	.	.	.	.	.	.	.00	.01	.00	.	.	.	.	.	.01
2.75	3.00	.	.	.	.	.	.	.	.00	.00	.	.	.	.	.	.01
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		58.92	18.73	11.40	6.78	2.85	.98	.26	.05	.02	.00	.	.	.	.	100.00

Table A4-19: Joint probability of occurrence of wind sea significant wave height [m] for given mean wave period [s] classes at location P12 (bow)

Hs	wave direction degrees												
meters	-15 to 15	15 to 45	45 to 75	75 to 105	105 to 135	135 to 165	165 to 195	195 to 225	225 to 255	255 to 285	285 to 315	315 to 345	Total
<	5.19	3.03	1.79	1.73	1.88	3.59	36.00	7.77	6.91	9.85	14.18	8.08	100.00
.25	.06	.06	.11	.31	.64	1.21	20.47	3.86	3.23	4.60	4.51	.71	39.78
.50	.	.	.	.	.	.05	12.19	1.99	1.62	1.39	.39	.06	17.68
.75	.	.	.	.	.	.	6.85	.94	.68	.25	.02	.00	8.75
1.00	.	.	.	.	.	.	3.60	.40	.19	.03	.00	.	4.23
1.25	.	.	.	.	.	.	1.74	.16	.03	.00	.	.	1.93
1.50	.	.	.	.	.	.	.76	.07	.00	.	.	.	.83
1.75	.	.	.	.	.	.	.31	.03	.	.	.	.	.34
2.00	.	.	.	.	.	.	.13	.01	.	.	.	.	.14
2.25	.	.	.	.	.	.	.05	.00	.	.	.	.	.05
2.50	.	.	.	.	.	.	.02	.00	.	.	.	.	.02
2.75	.	.	.	.	.	.	.01	.	.	.	.	.	.01
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-20: Probability of exceedance of wind sea significant wave height [m] for all directional sectors at location P12 (bow)

Tm-1,0	wave direction degrees												
seconds	-15 to 15	15 to 45	45 to 75	75 to 105	105 to 135	135 to 165	165 to 195	195 to 225	225 to 255	255 to 285	285 to 315	315 to 345	Total
<	5.19	3.03	1.79	1.73	1.88	3.59	36.00	7.77	6.91	9.85	14.18	8.08	100.00
2.0	.00	.06	.40	.63	.92	1.96	23.83	4.15	3.08	3.76	2.12	.17	41.08
3.0	.	.	.00	.00	.30	.63	16.81	2.19	1.48	.82	.10	.02	22.35
4.0	.	.	.	.	.	.09	9.26	.96	.53	.10	.01	.	10.94
5.0	.	.	.	.	.	.	3.70	.35	.11	.00	.	.	4.16
6.0	.	.	.	.	.	.	1.18	.12	.01	.	.	.	1.31
7.0	.	.	.	.	.	.	.31	.03	.00	.	.	.	.34
8.0	.	.	.	.	.	.	.07	.00	.	.	.	.	.07
9.0	.	.	.	.	.	.	.02	.	.	.	.	.	.02
10.0	.	.	.	.	.	.	.00	.	.	.	.	.	.00
11.0	.	.	.	.	.	.	.	.	.	.	.	.	.
12.0	.	.	.	.	.	.	.	.	.	.	.	.	.
13.0	.	.	.	.	.	.	.	.	.	.	.	.	.
14.0	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-21: Probability of exceedance of wind sea mean wave period [s] for all directional sectors at location P12 (bow)

Hs		spectral mean wave period seconds														
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	26.89	4.10	8.45	10.12	9.55	8.88	6.21	3.31	.80	.14	.04	.01	.00	.00	78.51
.25	.50	.	.08	1.87	4.89	2.84	2.13	1.49	1.00	.86	.07	.00	.00	.	.00	15.22
.50	.75	.	.	.02	1.07	1.57	.94	.73	.30	.21	.07	.00	.	.	.	4.91
.75	1.00	.	.	.	.06	.38	.34	.21	.14	.04	.01	.00	.	.	.	1.18
1.00	1.25	.	.	.	.00	.01	.03	.03	.04	.02	.00	.	.	.	.	.14
1.25	1.50	.	.	.	.	.	.00	.00	.01	.01	.00	.	.	.	.	.03
1.50	1.75	.	.	.	.	.	.	.	.00	.00	.00	.	.	.	.	.00
1.75	2.00	.	.	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.00	2.25	.	.	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.25	2.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.50	2.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	3.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		26.89	4.18	10.33	16.14	14.35	12.33	8.67	4.81	1.94	.30	.04	.02	.00	.00	100.00

Table A4-22: Joint probability of occurrence of swell significant wave height [m] for given mean wave period [s] classes at location P12 (bow)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	3.00	1.76	.65	.77	1.70	3.19	41.89	27.02	11.41	3.39	2.39	2.84	100.00
.25	.	.	.	.	.	.	17.78	3.72	.	.	.	.	21.49
.50	.	.	.	.	.	.	5.70	.57	.	.	.	.	6.27
.75	.	.	.	.	.	.	1.26	.09	.	.	.	.	1.35
1.00	.	.	.	.	.	.	.16	.01	.	.	.	.	.17
1.25	.	.	.	.	.	.	.04	.	.	.	.	.	.04
1.50	.	.	.	.	.	.	.01	.	.	.	.	.	.01
1.75	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.00	.	.	.	.	.	.	.00	.	.	.	.	.	.00
2.25	.	.	.	.	.	.	.	.	.	.	.	.	.
2.50	.	.	.	.	.	.	.	.	.	.	.	.	.
2.75	.	.	.	.	.	.	.	.	.	.	.	.	.
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-23: Probability of exceedance of swell significant wave height [m] for all directional sectors at location P12 (bow)

Tmm10	wave direction degrees												
seconds	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	3.00	1.76	.65	.77	1.70	3.19	41.89	27.02	11.41	3.39	2.39	2.84	100.00
2.0	.	.	.01	.37	1.61	3.16	41.58	26.12	.25	.	.	.	73.11
3.0	.	.	.	.05	.81	2.95	40.48	24.65	.00	.	.	.	68.93
4.0	.	.	.	.00	.13	1.87	34.49	22.10	.	.	.	.	58.60
5.0	.	.	.	.00	.02	.67	23.30	18.47	.	.	.	.	42.46
6.0	.	.	.	.	.00	.06	14.27	13.77	.	.	.	.	28.10
7.0	.	.	.	.	.00	.01	7.06	8.71	.	.	.	.	15.78
8.0	.	.	.	.	.	.00	2.45	4.66	.	.	.	.	7.11
9.0	.	.	.	.	.	.00	.57	1.73	.	.	.	.	2.30
10.0	.	.	.	.	.	.	.12	.24	.	.	.	.	.36
11.0	.	.	.	.	.	.	.02	.05	.	.	.	.	.06
12.0	.	.	.	.	.	.	.01	.02	.	.	.	.	.02
13.0	.	.	.	.	.	.	.00	.00	.	.	.	.	.01
14.0	.	.	.	.	.	.	.	.00	.	.	.	.	.00

Table A4-24: Probability of exceedance of swell mean wave period [s] for all directional sectors at location P12 (bow)

Hs		spectral mean wave period seconds														
meters		<	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
Lower	Upper	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	>	
<	.25	27.11	7.35	4.44	3.01	2.37	1.86	.91	.27	.04	.00	.00	.	.	.	47.36
.25	.50	2.23	9.86	8.95	3.81	1.44	.79	.38	.23	.15	.00	.	.	.	.	27.84
.50	.75	.	.76	5.30	4.49	1.58	.62	.28	.08	.05	.00	.	.	.	.	13.18
.75	1.00	.	.	.44	4.05	1.23	.44	.12	.03	.01	.00	.	.	.	.	6.32
1.00	1.25	.	.	.00	.80	1.78	.28	.09	.02	.01	.	.	.	.	.	2.98
1.25	1.50	.	.	.	.00	.92	.32	.06	.02	.00	.	.	.	.	.	1.33
1.50	1.75	.	.	.	.	.07	.46	.05	.01	.00	.	.	.	.	.	.59
1.75	2.00	.	.	.	.	.	.15	.07	.01	.01	.00	.	.	.	.	.24
2.00	2.25	.	.	.	.	.	.01	.07	.01	.00	.00	.	.	.	.	.10
2.25	2.50	.	.	.	.	.	.	.03	.01	.00	.	.	.	.	.	.04
2.50	2.75	.	.	.	.	.	.	.00	.01	.00	.	.	.	.	.	.02
2.75	3.00	.	.	.	.	.	.	.	.00	.00	.	.	.	.	.	.01
3.00	3.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	3.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total		29.34	17.98	19.12	16.18	9.39	4.94	2.07	.71	.27	.01	.00	.	.	.	100.00

Table A4-25: Joint probability of occurrence of total significant wave height [m] for given mean wave period [s] classes at location P12 (bow)

Hs	wave direction degrees												
meters	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	1.65	1.25	1.08	1.18	1.72	3.25	37.43	15.38	7.52	8.99	16.65	3.91	100.00
.25	.04	.04	.08	.26	.57	1.24	29.50	7.44	4.13	4.98	3.78	.58	52.64
.50	.	.	.	.	.	.08	17.64	3.33	1.92	1.45	.33	.05	24.80
.75	.	.	.	.	.	.	9.18	1.36	.80	.26	.02	.00	11.62
1.00	.	.	.	.	.	.	4.47	.56	.24	.03	.00	.	5.30
1.25	.	.	.	.	.	.	2.07	.20	.04	.00	.	.	2.32
1.50	.	.	.	.	.	.	.89	.09	.01	.	.	.	.99
1.75	.	.	.	.	.	.	.36	.04	.	.	.	.	.39
2.00	.	.	.	.	.	.	.14	.01	.	.	.	.	.16
2.25	.	.	.	.	.	.	.05	.01	.	.	.	.	.06
2.50	.	.	.	.	.	.	.02	.00	.	.	.	.	.02
2.75	.	.	.	.	.	.	.01	.	.	.	.	.	.01
3.00	.	.	.	.	.	.	.	.	.	.	.	.	.
3.25	.	.	.	.	.	.	.	.	.	.	.	.	.
3.50	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-26: Probability of exceedance of total significant wave height [m] for all directional sectors at location P12 (bow)

Tmm10	wave direction degrees												
seconds	-15	15	45	75	105	135	165	195	225	255	285	315	
	to	to	to	to	to	to	to	to	to	to	to	to	Total
	15	45	75	105	135	165	195	225	255	285	315	345	
<	1.65	1.25	1.08	1.18	1.72	3.25	37.43	15.38	7.52	8.99	16.65	3.91	100.00
2.0	.22	.30	.47	.75	1.46	2.94	36.62	13.85	5.02	5.38	3.03	.61	70.66
3.0	.05	.08	.13	.23	.78	2.02	32.18	11.62	3.23	1.80	.40	.16	52.69
4.0	.01	.01	.02	.05	.15	1.03	21.59	8.82	1.44	.34	.08	.02	33.56
5.0	.	.	.00	.00	.02	.30	10.65	5.96	.40	.04	.01	.00	17.39
6.0	.	.	.	.	.	.03	4.37	3.52	.07	.00	.00	.	8.00
7.0	.	.	.	.	.	.00	1.37	1.68	.01	.	.	.	3.06
8.0	.	.	.	.	.	.	.29	.71	.	.	.	.	.99
9.0	.	.	.	.	.	.	.06	.23	.	.	.	.	.29
10.0	.	.	.	.	.	.	.00	.01	.	.	.	.	.01
11.0	.	.	.	.	.	.	.	.00	.	.	.	.	.00
12.0	.	.	.	.	.	.	.	.	.	.	.	.	.
13.0	.	.	.	.	.	.	.	.	.	.	.	.	.
14.0	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A4-27: Probability of exceedance of total mean wave period [s] for all directional sectors at location P12 (bow)

Appendix 5 Extreme wave climate

Appendix 5.1 Location P5: stern

Return period [yr]	Offshore direction [°N]	U10 [m/s]	Hm0 [m]	Tp [s]	Stern (location 5) Hm0 [m]	Tm-1,0 [s]	Dir [°N]
1	60	15.0	3.9	10.3	0.5	9.5	196
1	90	14.8	3.5	10.0	0.6	9.0	192
1	120	15.1	3.5	9.3	0.9	8.9	208
1	150	15.4	3.6	9.2	1.3	8.6	197
1	180	14.1	3.1	8.5	1.4	8.1	194
1	210	13.3	2.9	8.3	1.3	8.0	189
1	240	15.3	3.5	9.0	1.0	8.5	189
5	60	18.3	5.3	11.1	0.6	10.0	200
5	90	17.5	4.8	10.7	0.7	9.7	198
5	120	17.3	4.7	10.4	1.2	9.4	202
5	150	18.0	4.7	10.1	1.5	9.1	198
5	180	16.4	4.0	9.4	1.8	9.0	195
5	210	16.0	4.0	9.5	1.7	9.0	190
5	240	17.8	4.6	10.1	1.3	9.1	190
10	60	19.5	5.9	11.6	0.7	10.2	200
10	90	18.4	5.4	10.9	0.8	9.9	200
10	120	18.1	5.1	10.7	1.4	9.6	202
10	150	19.0	5.1	10.5	1.7	9.8	199
10	180	17.3	4.3	9.7	2.0	9.2	195
10	210	17.1	4.5	9.9	1.8	9.3	190
10	240	18.8	5.1	10.7	1.6	9.5	190
25	60	21.0	6.6	12.3	0.8	10.5	199
25	90	19.6	6.2	11.6	1.0	10.2	201
25	120	19.1	5.8	11.2	1.6	9.7	200
25	150	20.2	5.6	11.0	1.8	9.6	199
25	180	18.4	4.8	10.3	2.2	9.5	194
25	210	18.5	5.2	10.7	2.1	9.7	192
25	240	19.9	5.7	11.3	1.9	9.9	190
50	60	22.1	7.1	12.7	0.9	10.8	202
50	90	20.4	6.8	12.1	1.1	10.4	201
50	120	19.8	6.2	11.6	1.8	9.8	198
50	150	21.1	5.9	11.3	2.0	9.9	198
50	180	19.2	5.1	10.6	2.4	9.6	194
50	210	19.6	5.7	11.2	2.2	9.9	192
50	240	20.7	6.2	11.8	2.0	10.2	190
100	60	23.1	7.6	13.1	0.9	11.0	205
100	90	21.1	7.4	12.6	1.2	10.5	187
100	120	20.4	6.7	12.0	1.9	9.9	199
100	150	21.9	6.3	11.7	2.2	10.1	195
100	180	20.0	5.4	10.9	2.5	9.7	195
100	210	20.7	6.2	11.7	2.5	10.1	192
100	240	21.4	6.6	12.2	2.2	10.5	189

Appendix 5.2 Location P8: mid ship

Return period [yr]	Offshore direction [°N]	U10 [m/s]	Hm0 [m]	Tp [s]	Mid-ship (location 8) Hm0 [m]	Mid-ship (location 8) Tm-1,0 [s]	Mid-ship (location 8) Dir [°N]
1	60	15.0	3.9	10.3	0.5	9.5	192
1	90	14.8	3.5	10.0	0.7	9.1	191
1	120	15.1	3.5	9.3	1.1	8.7	197
1	150	15.4	3.6	9.2	1.5	8.7	188
1	180	14.1	3.1	8.5	1.5	8.1	193
1	210	13.3	2.9	8.3	1.4	8.0	193
1	240	15.3	3.5	9.0	1.0	8.5	193
5	60	18.3	5.3	11.1	0.7	9.8	193
5	90	17.5	4.8	10.7	0.9	9.5	193
5	120	17.3	4.7	10.4	1.4	9.3	200
5	150	18.0	4.7	10.1	1.8	9.1	192
5	180	16.4	4.0	9.4	1.9	8.9	194
5	210	16.0	4.0	9.5	1.7	9.0	195
5	240	17.8	4.6	10.1	1.4	9.1	194
10	60	19.5	5.9	11.6	0.8	9.9	192
10	90	18.4	5.4	10.9	1.0	9.7	192
10	120	18.1	5.1	10.7	1.6	9.4	200
10	150	19.0	5.1	10.5	1.9	9.7	194
10	180	17.3	4.3	9.7	2.1	9.0	194
10	210	17.1	4.5	9.9	1.9	9.2	196
10	240	18.8	5.1	10.7	1.7	9.4	194
25	60	21.0	6.6	12.3	0.8	10.3	192
25	90	19.6	6.2	11.6	1.1	9.8	190
25	120	19.1	5.8	11.2	1.9	9.6	199
25	150	20.2	5.6	11.0	2.1	9.6	192
25	180	18.4	4.8	10.3	2.4	9.3	194
25	210	18.5	5.2	10.7	2.2	9.7	196
25	240	19.9	5.7	11.3	2.1	9.7	194
50	60	22.1	7.1	12.7	0.9	10.4	193
50	90	20.4	6.8	12.1	1.2	9.7	191
50	120	19.8	6.2	11.6	2.0	9.6	198
50	150	21.1	5.9	11.3	2.2	9.8	191
50	180	19.2	5.1	10.6	2.6	9.5	194
50	210	19.6	5.7	11.2	2.5	9.8	195
50	240	20.7	6.2	11.8	2.2	9.9	194
100	60	23.1	7.6	13.1	1.0	10.6	194
100	90	21.1	7.4	12.6	1.4	10.1	181
100	120	20.4	6.7	12.0	2.1	9.7	197
100	150	21.9	6.3	11.7	2.5	10.0	190
100	180	20.0	5.4	10.9	2.8	9.6	194
100	210	20.7	6.2	11.7	2.6	10.0	196
100	240	21.4	6.6	12.2	2.3	10.1	194

Appendix 5.3 Location P12: bow

Return period [yr]	Offshore direction [°N]	U10 [m/s]	Hm0 [m]	Tp [s]	Bow (location 12) Hm0 [m]	Tm-1,0 [s]	Dir [°N]
1	60	15.0	3.9	10.3	0.7	9.6	187
1	90	14.8	3.5	10.0	0.9	9.1	182
1	120	15.1	3.5	9.3	1.3	8.9	189
1	150	15.4	3.6	9.2	1.8	8.7	189
1	180	14.1	3.1	8.5	1.8	8.1	194
1	210	13.3	2.9	8.3	1.6	7.9	194
1	240	15.3	3.5	9.0	1.2	8.5	196
5	60	18.3	5.3	11.1	1.0	10.1	188
5	90	17.5	4.8	10.7	1.2	9.7	184
5	120	17.3	4.7	10.4	2.0	9.7	186
5	150	18.0	4.7	10.1	2.3	9.2	191
5	180	16.4	4.0	9.4	2.5	9.0	193
5	210	16.0	4.0	9.5	2.0	9.1	199
5	240	17.8	4.6	10.1	1.8	9.2	194
10	60	19.5	5.9	11.6	1.1	10.2	188
10	90	18.4	5.4	10.9	1.4	9.8	184
10	120	18.1	5.1	10.7	2.2	9.9	185
10	150	19.0	5.1	10.5	2.5	9.9	191
10	180	17.3	4.3	9.7	2.7	9.2	193
10	210	17.1	4.5	9.9	2.2	9.4	198
10	240	18.8	5.1	10.7	2.1	9.5	194
25	60	21.0	6.6	12.3	1.2	10.3	189
25	90	19.6	6.2	11.6	1.6	9.9	186
25	120	19.1	5.8	11.2	2.6	10.1	185
25	150	20.2	5.6	11.0	2.8	9.7	190
25	180	18.4	4.8	10.3	3.0	9.5	193
25	210	18.5	5.2	10.7	2.6	9.7	198
25	240	19.9	5.7	11.3	2.5	9.8	194
50	60	22.1	7.1	12.7	1.2	10.5	191
50	90	20.4	6.8	12.1	1.7	10.0	187
50	120	19.8	6.2	11.6	2.8	10.2	186
50	150	21.1	5.9	11.3	3.0	9.9	190
50	180	19.2	5.1	10.6	3.2	9.6	194
50	210	19.6	5.7	11.2	2.9	9.9	197
50	240	20.7	6.2	11.8	2.6	10.0	194
100	60	23.1	7.6	13.1	1.3	10.6	191
100	90	21.1	7.4	12.6	1.9	10.5	192
100	120	20.4	6.7	12.0	2.9	10.3	188
100	150	21.9	6.3	11.7	3.2	10.1	190
100	180	20.0	5.4	10.9	3.4	9.8	194
100	210	20.7	6.2	11.7	3.1	10.0	197
100	240	21.4	6.6	12.2	2.8	10.2	195

Appendix 6 Spatial distribution of significant wave height

Appendix 6.1 Wind Sea (SWAN)

The wind sea wave fields were derived via nesting. In this appendix figures are provided for the wave fields corresponding with a wind speed U10 of 12m/s for 7 directions (150, 180, 210, 240, 270, 300 and 330°N).

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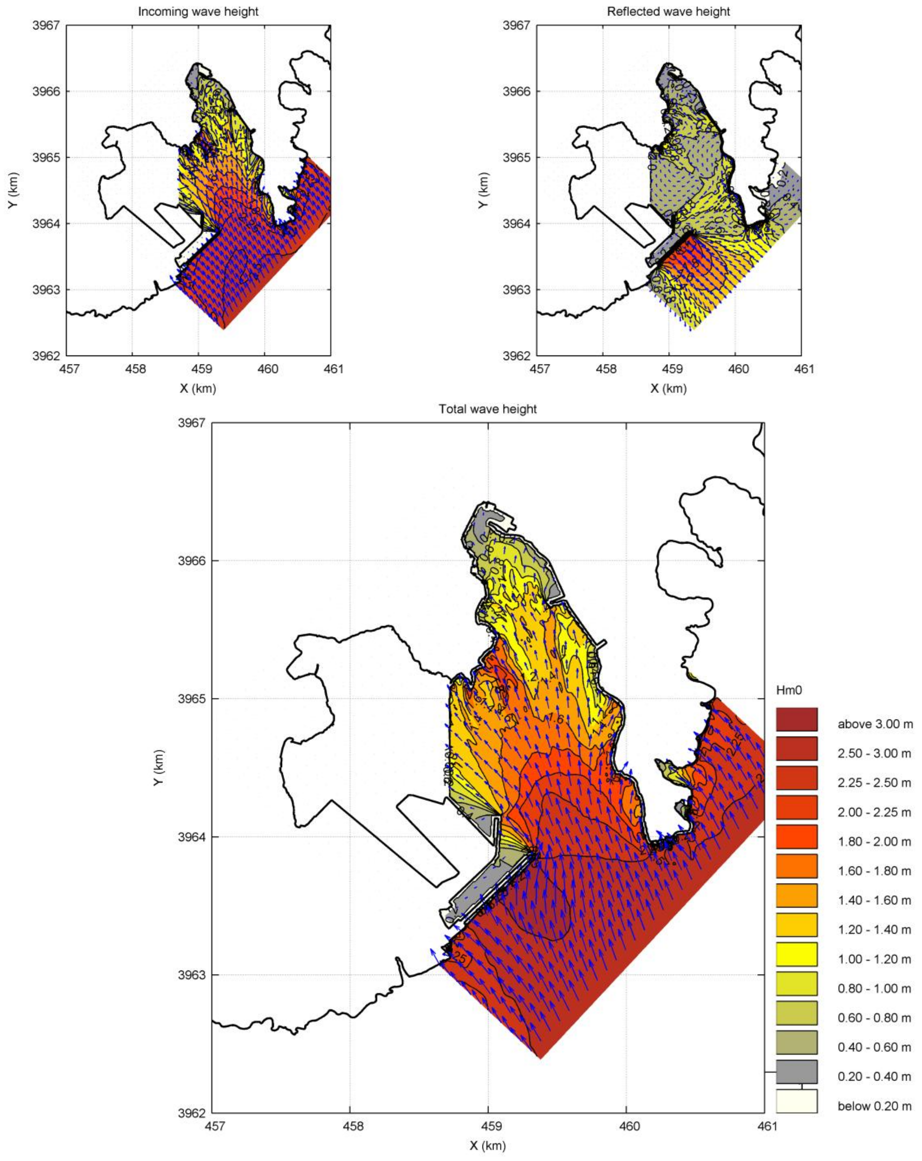

MALTA	Case:	
Offshore conditions: direction: 150°N, H_{m0}=2.27m, T_p=7.47s U10= 12 m/s	C00P2L1H2D150	

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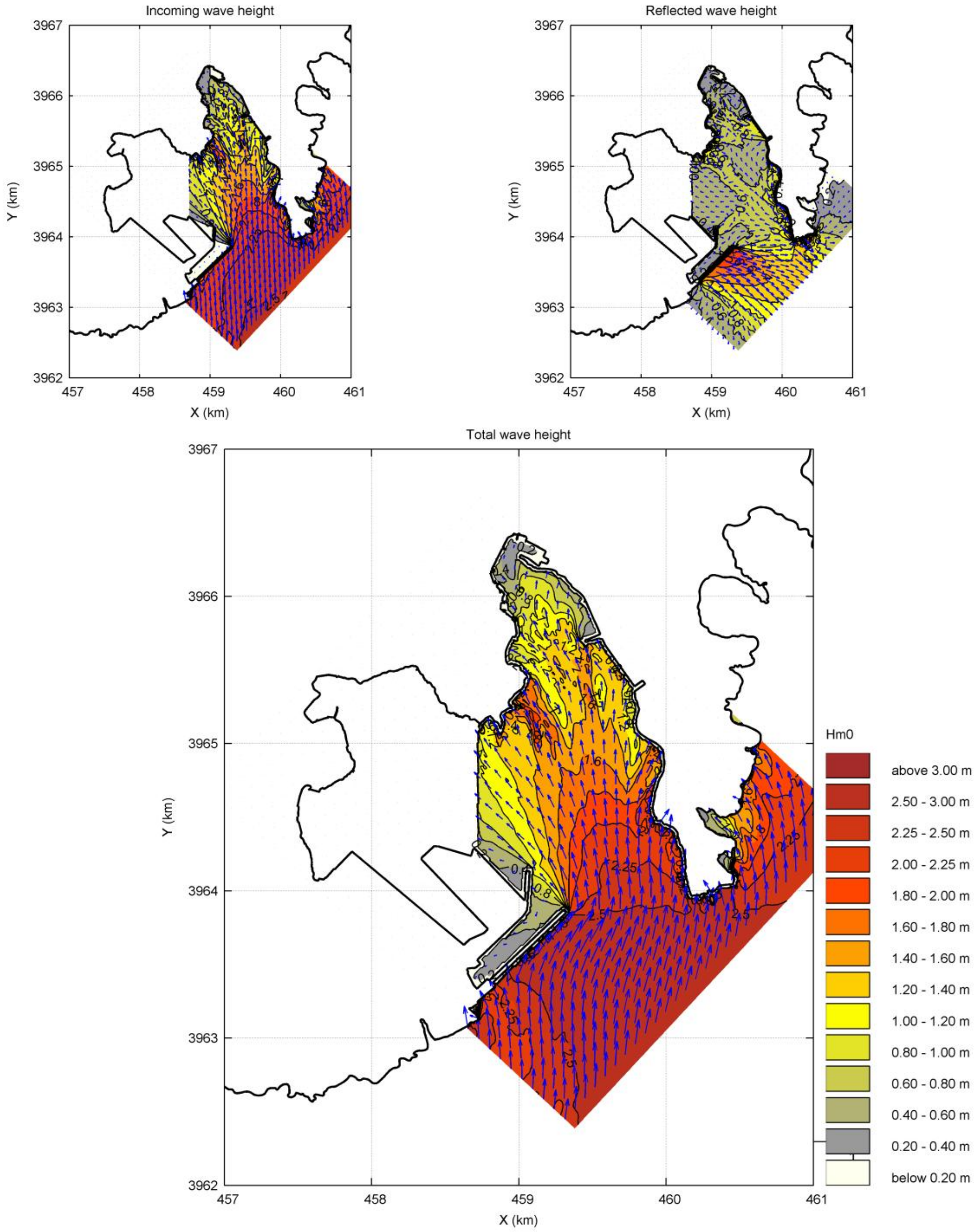

MALTA	Case:
Offshore conditions: direction: 180°N, H_{m0}=2.27m, T_p=7.47s U10= 12 m/s	C00P2L1H2D180

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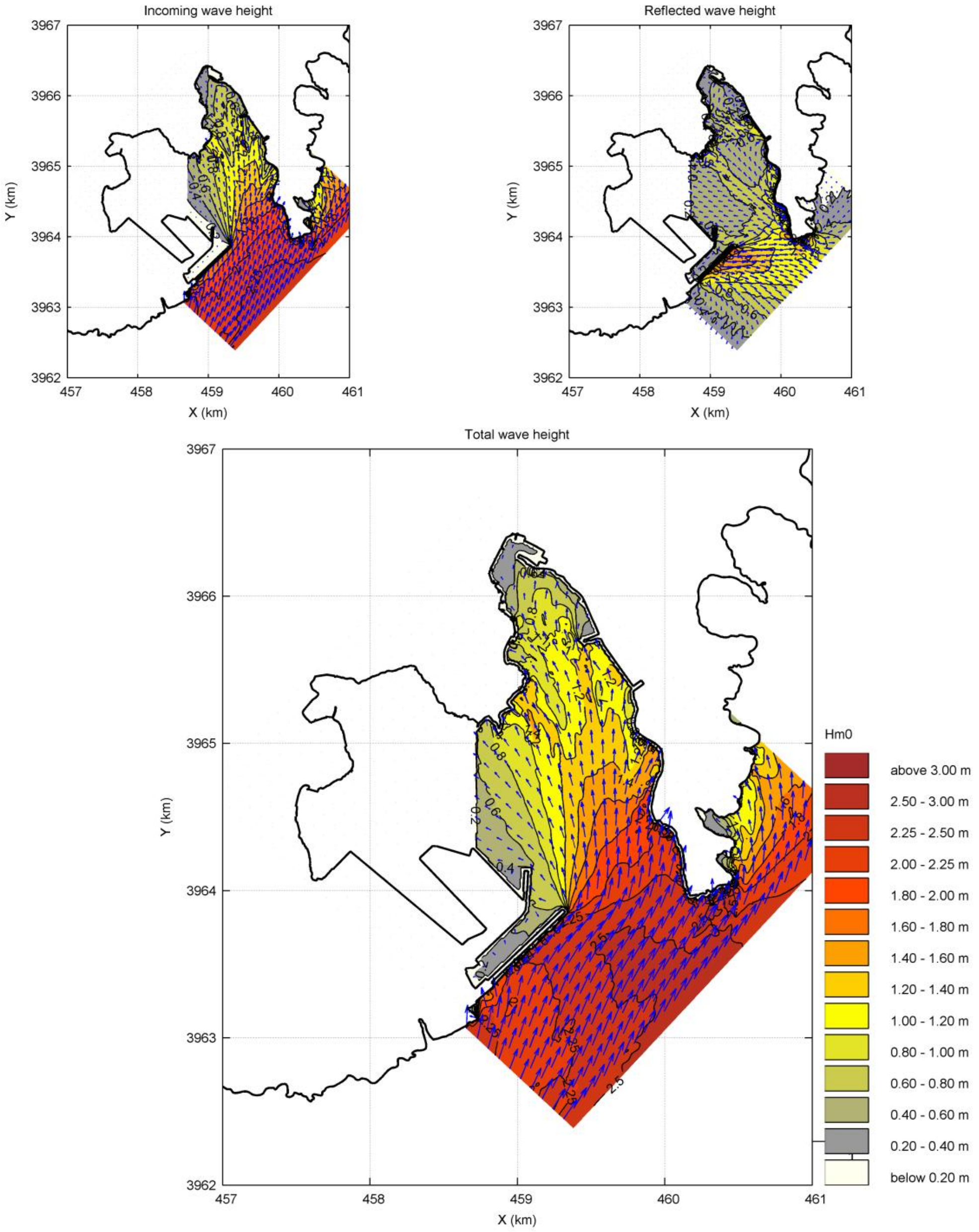

MALTA	Case:
	C00P2L1H2D210
Offshore conditions: direction: 210°N, H_{m0}=2.27m, T_p=7.47s U10= 12 m/s	

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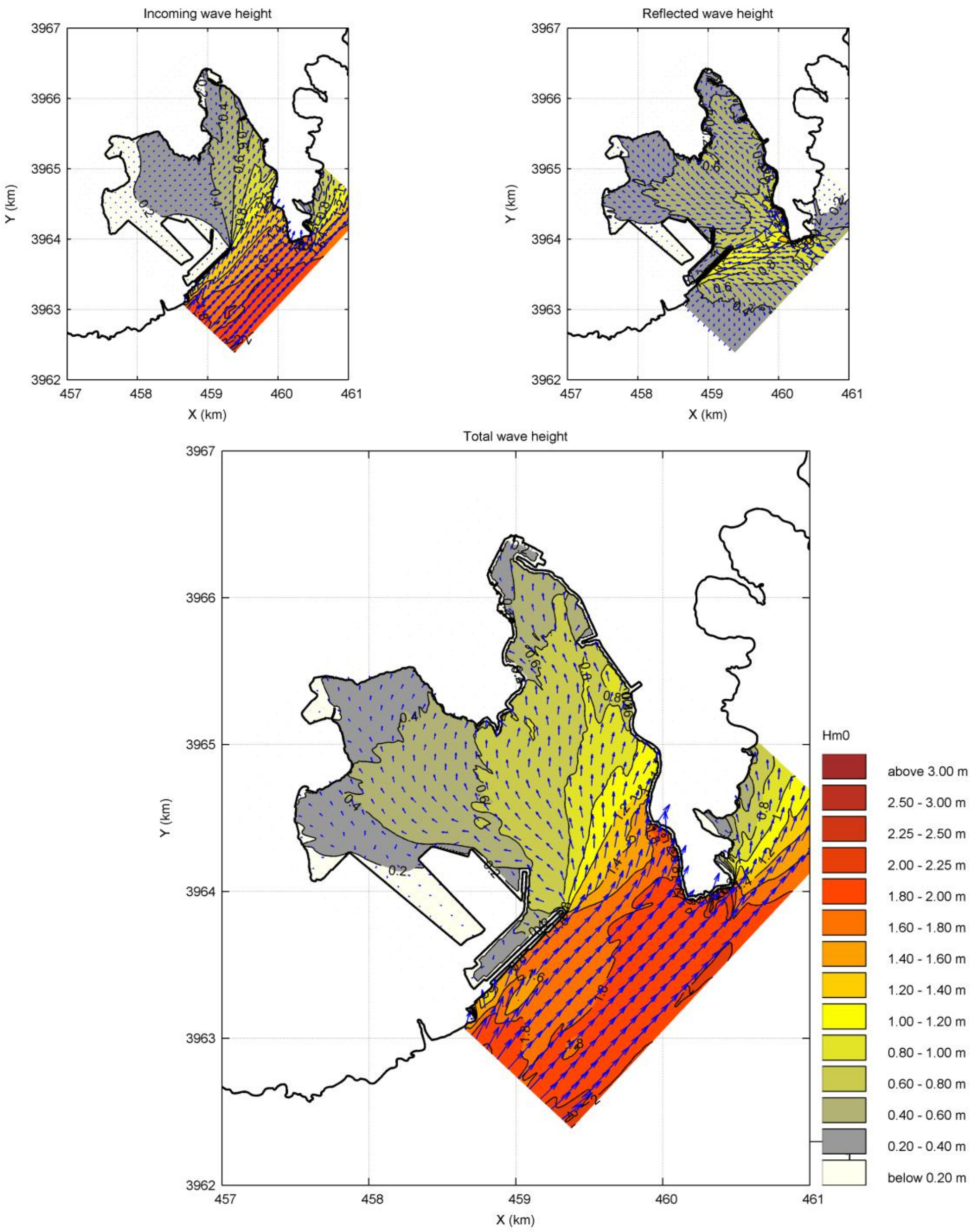

MALTA	Case:
Offshore conditions: direction: 240°N, H_{m0}=2.27m, T_p=7.47s U10= 12 m/s	C00P2L1H2D240

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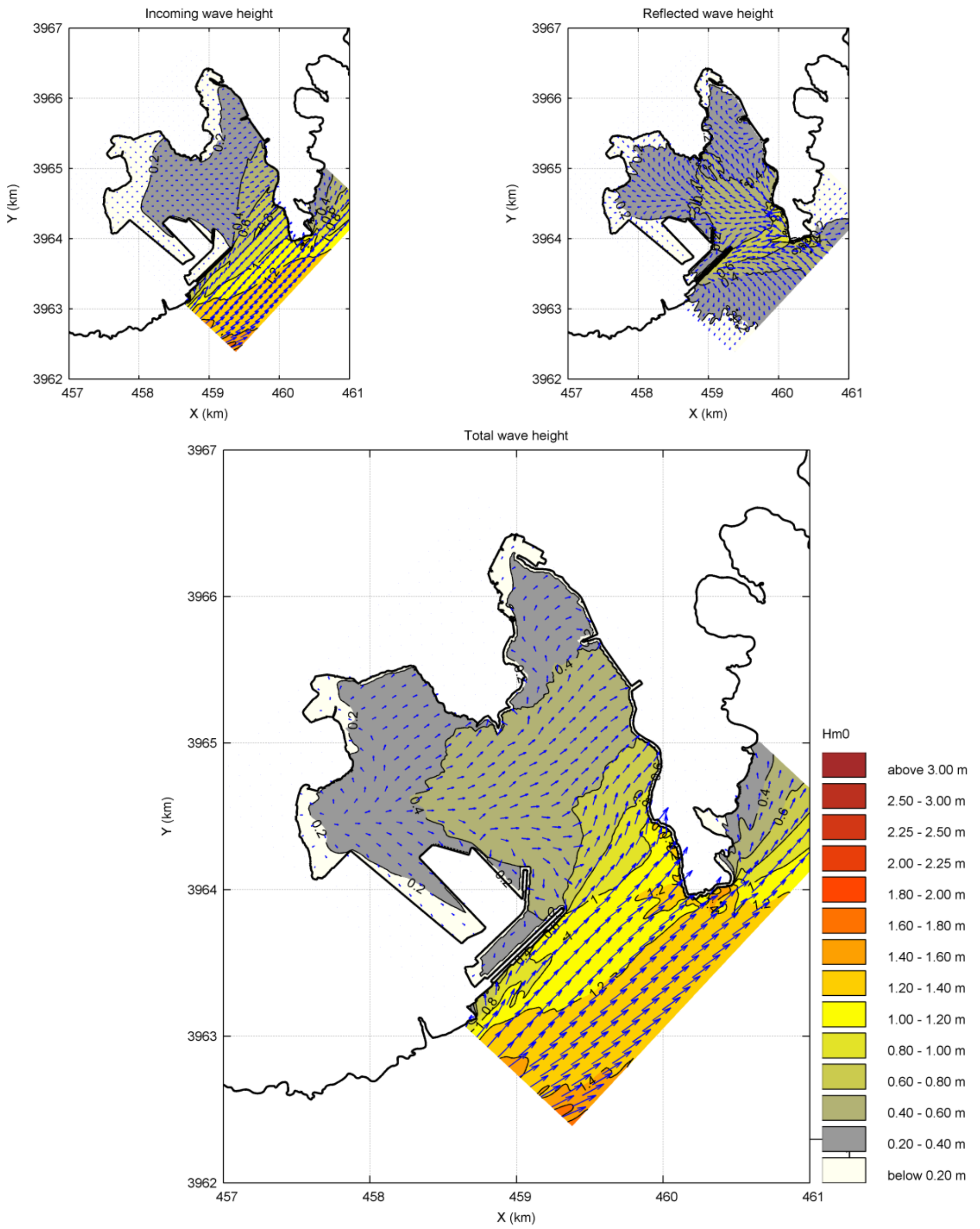

MALTA	Case:	
	C00P2L1H2D270	
Offshore conditions: direction: 270°N, H_{m0}=2.27m, T_p=7.47s U10= 12 m/s		

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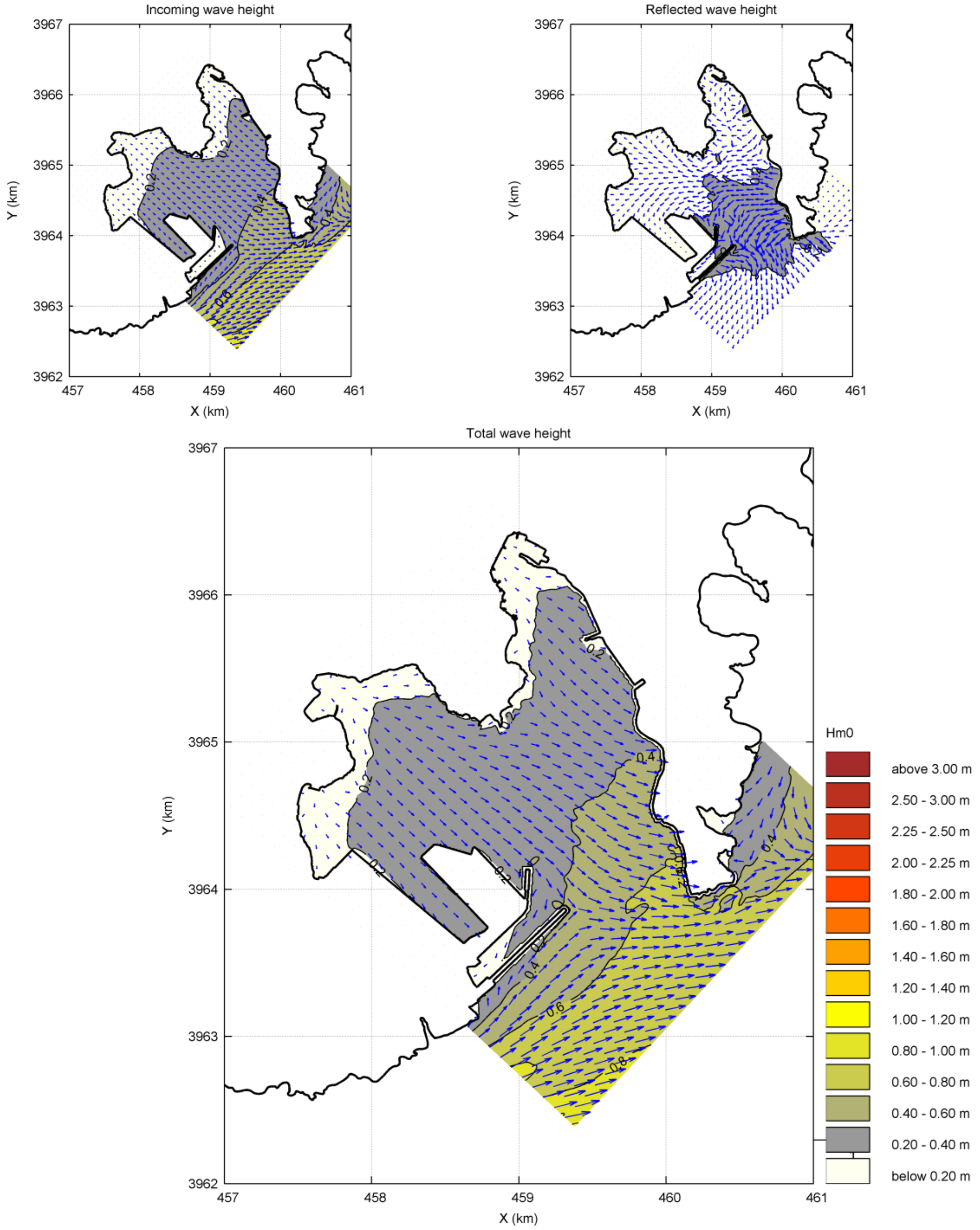

MALTA	Case:
	C00P2L1H2D300
Offshore conditions: direction: 300°N, H_{m0}=2.27m, T_p=7.47s U10= 12 m/s	

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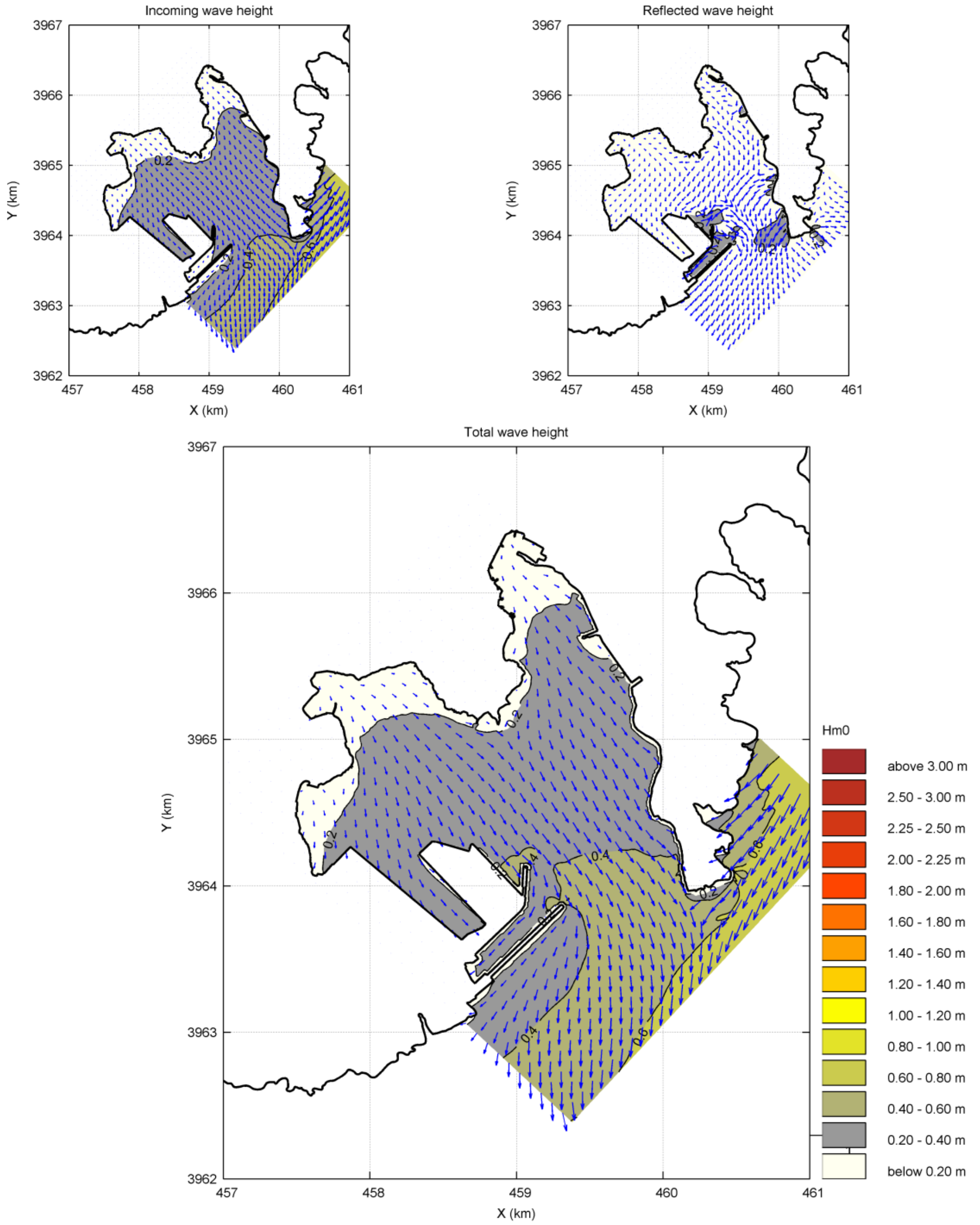
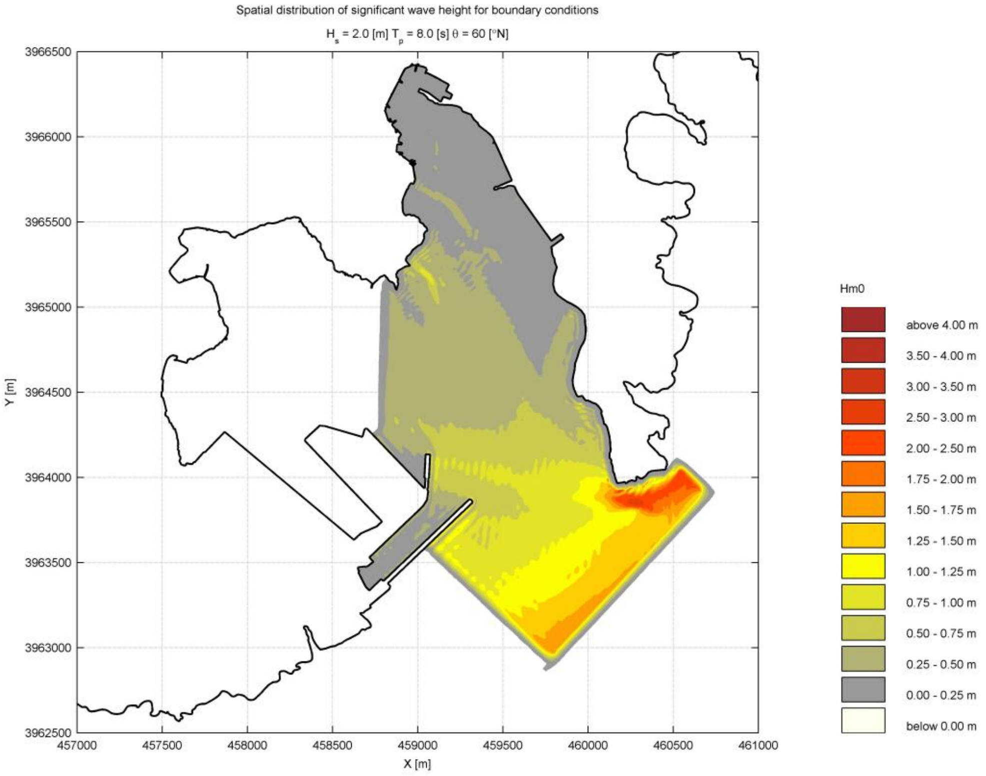
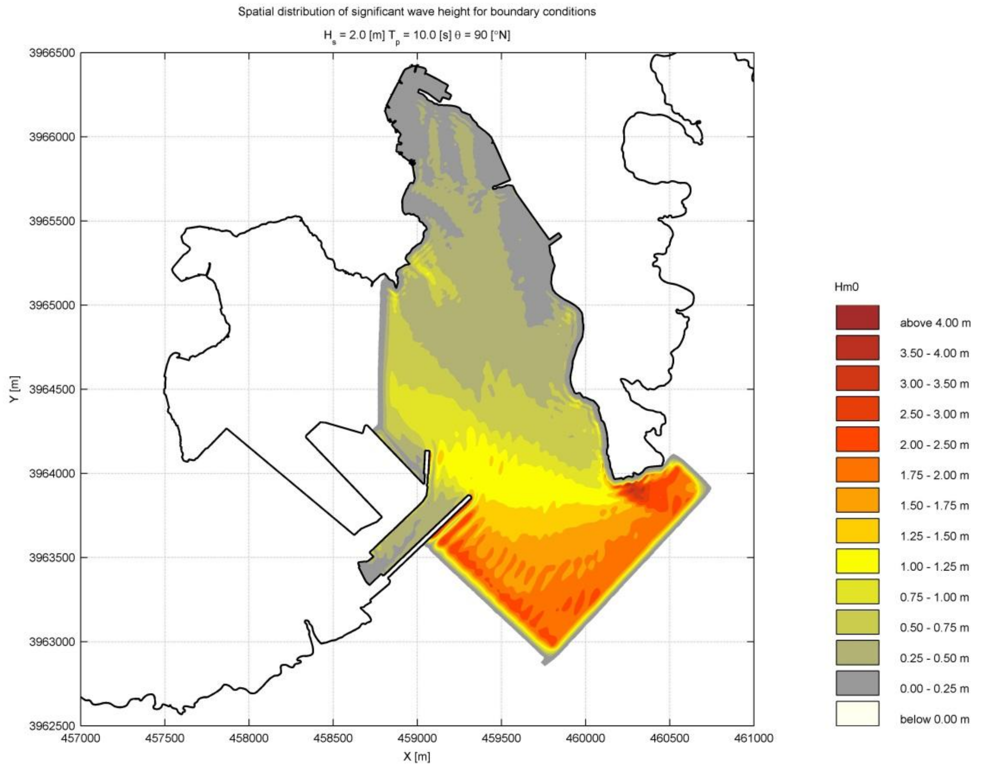


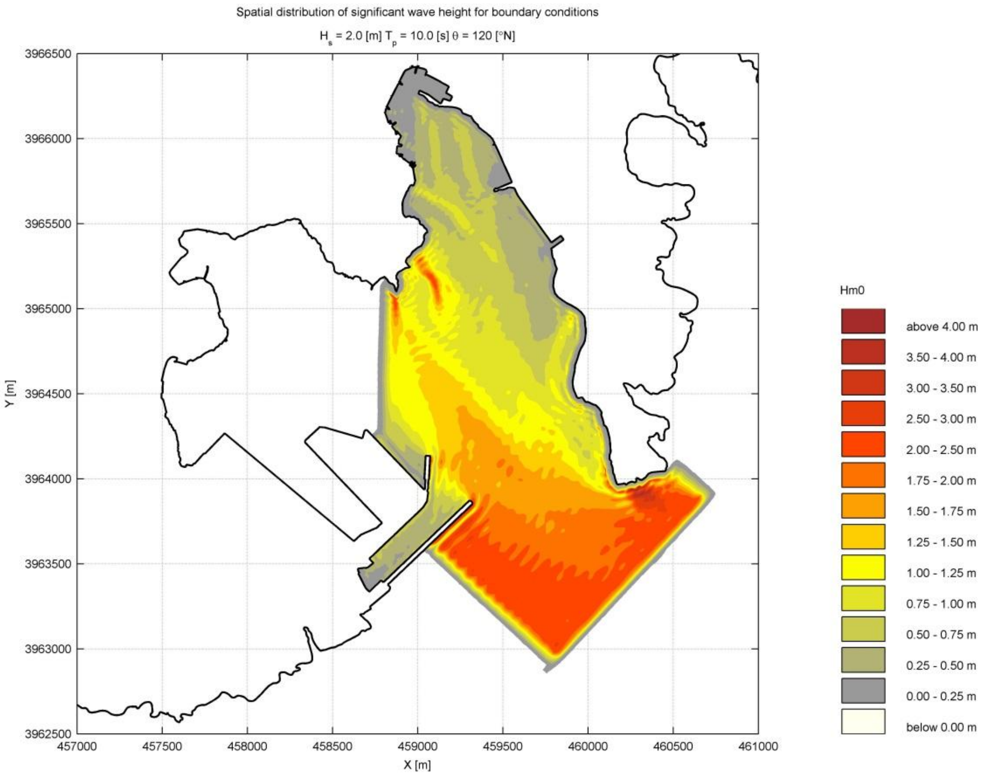
MALTA	Case:
	C00P2L1H2D330
Offshore conditions: direction: 330°N, H_{m0}=2.27m, T_p=7.47s U10= 12 m/s	

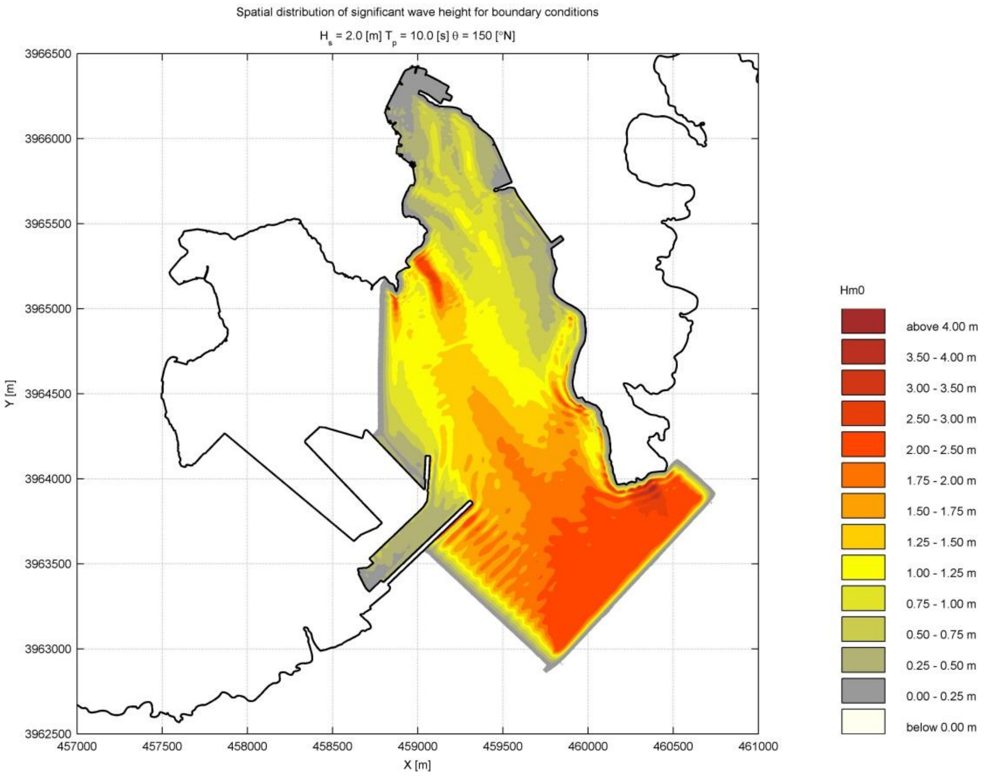
Appendix 6.2 Swell (MIKE21BW)

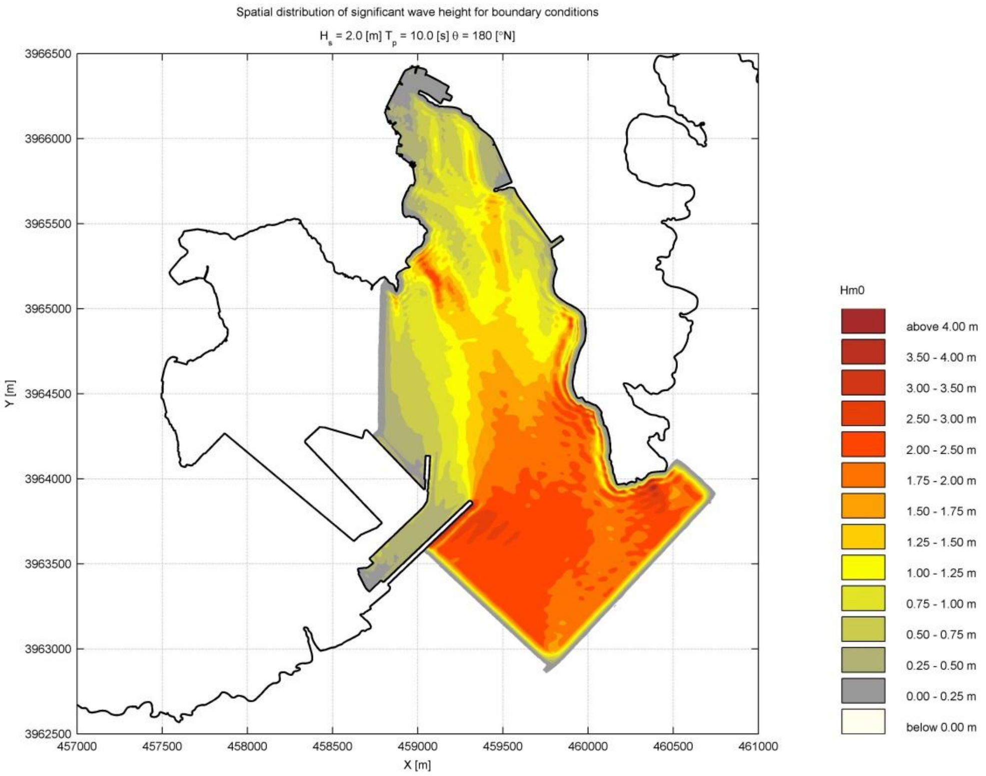
Figures are presented for boundary condition: Hs=2m, Tp=10s, Dir = 60, 90, 120, 150, 180 and 210°N

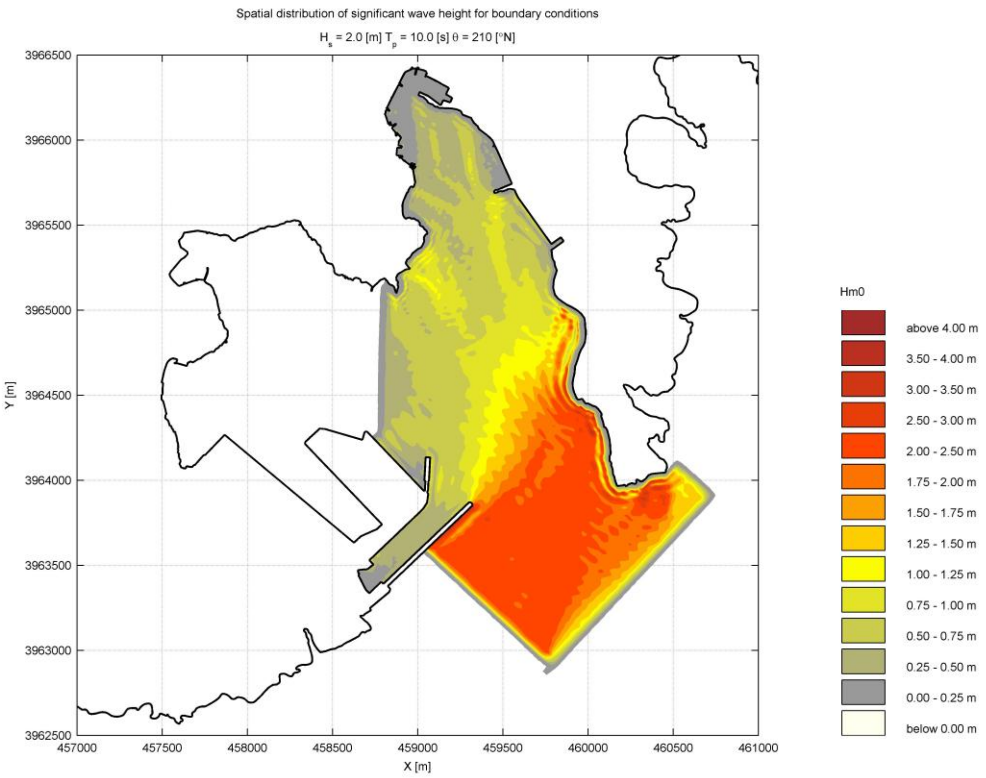

Spatial distribution of significant wave height for boundary conditions
H_s = 2.0 [m] T_p = 8.0 [s] θ = 60 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 4.00 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.75 - 2.00 m
1.50 - 1.75 m
1.25 - 1.50 m
1.00 - 1.25 m
0.75 - 1.00 m
0.50 - 0.75 m
0.25 - 0.50 m
0.00 - 0.25 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
H_s = 2.0 [m] T_p = 10.0 [s] θ = 90 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 4.00 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.75 - 2.00 m
1.50 - 1.75 m
1.25 - 1.50 m
1.00 - 1.25 m
0.75 - 1.00 m
0.50 - 0.75 m
0.25 - 0.50 m
0.00 - 0.25 m
below 0.00 m

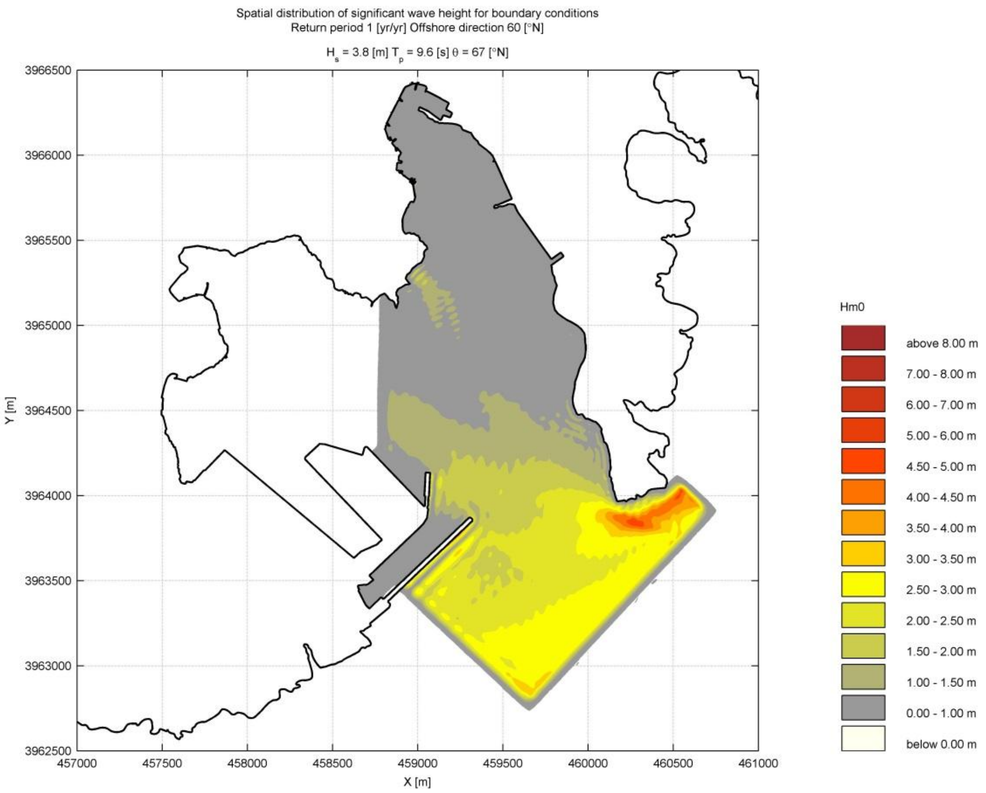

Spatial distribution of significant wave height for boundary conditions
H_s = 2.0 [m] T_p = 10.0 [s] θ = 120 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 4.00 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.75 - 2.00 m
1.50 - 1.75 m
1.25 - 1.50 m
1.00 - 1.25 m
0.75 - 1.00 m
0.50 - 0.75 m
0.25 - 0.50 m
0.00 - 0.25 m
below 0.00 m

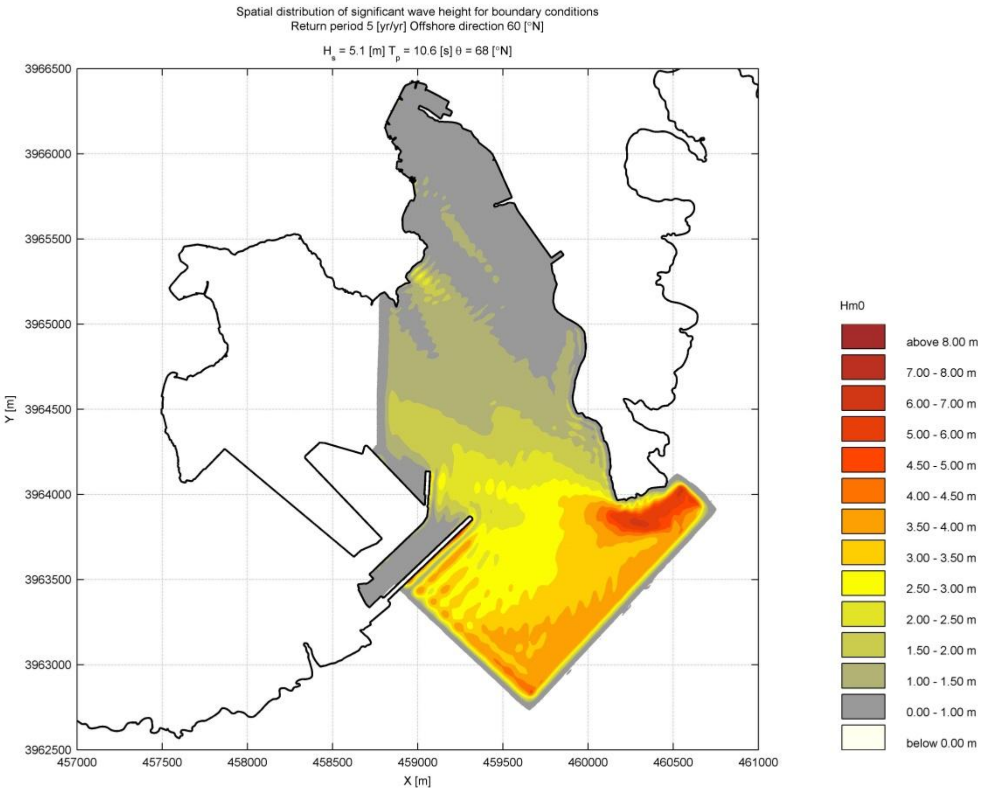

Spatial distribution of significant wave height for boundary conditions
H_s = 2.0 [m] T_p = 10.0 [s] θ = 150 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 4.00 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.75 - 2.00 m
1.50 - 1.75 m
1.25 - 1.50 m
1.00 - 1.25 m
0.75 - 1.00 m
0.50 - 0.75 m
0.25 - 0.50 m
0.00 - 0.25 m
below 0.00 m

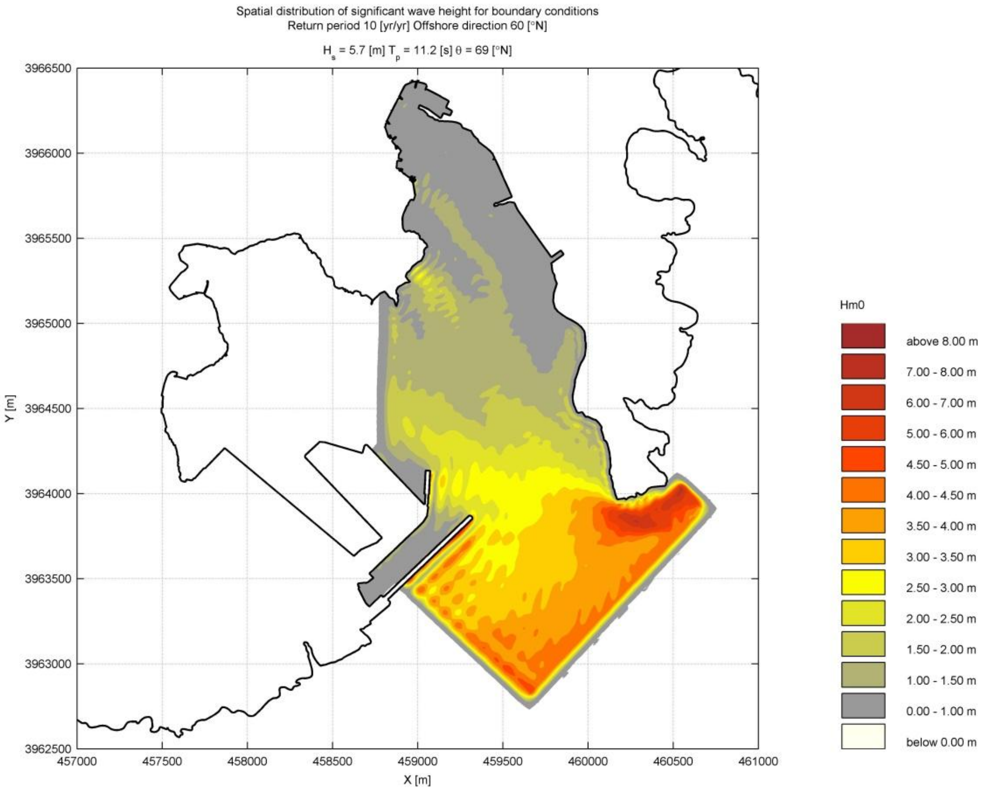

Spatial distribution of significant wave height for boundary conditions
H_s = 2.0 [m] T_p = 10.0 [s] θ = 180 [°N]
Y [m]
X [m]
Hm0
above 4.00 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.75 - 2.00 m
1.50 - 1.75 m
1.25 - 1.50 m
1.00 - 1.25 m
0.75 - 1.00 m
0.50 - 0.75 m
0.25 - 0.50 m
0.00 - 0.25 m
below 0.00 m

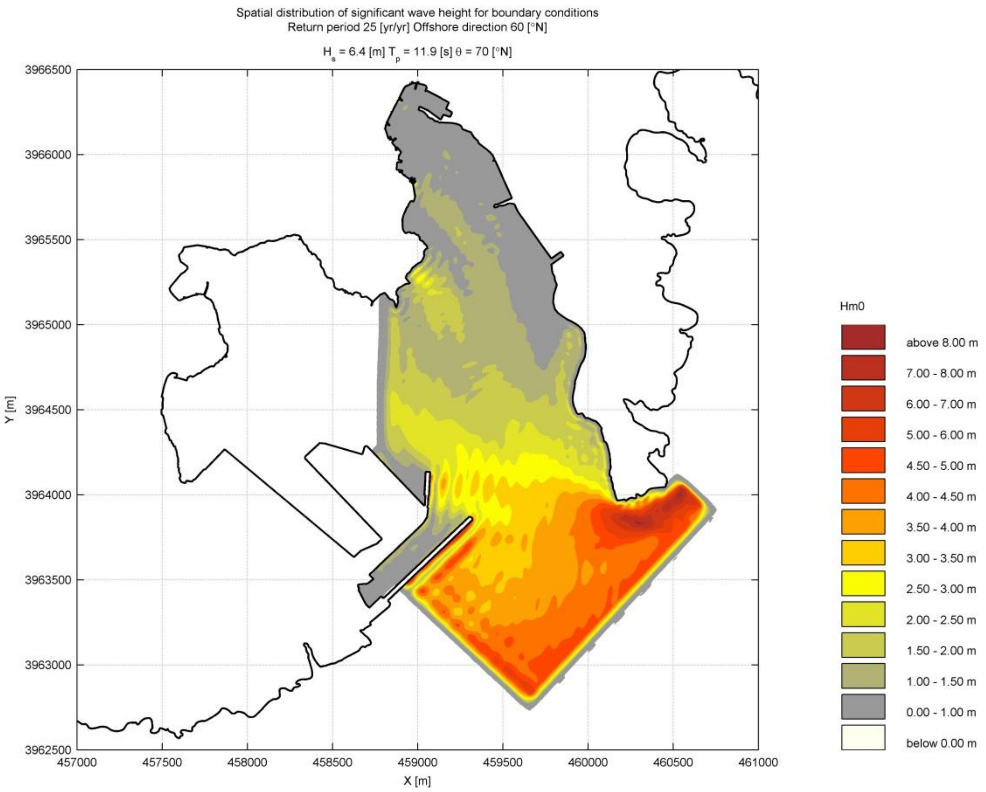

Spatial distribution of significant wave height for boundary conditions
H_s = 2.0 [m] T_p = 10.0 [s] θ = 210 [°N]
Y [m]
X [m]
Hm0
above 4.00 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.75 - 2.00 m
1.50 - 1.75 m
1.25 - 1.50 m
1.00 - 1.25 m
0.75 - 1.00 m
0.50 - 0.75 m
0.25 - 0.50 m
0.00 - 0.25 m
below 0.00 m

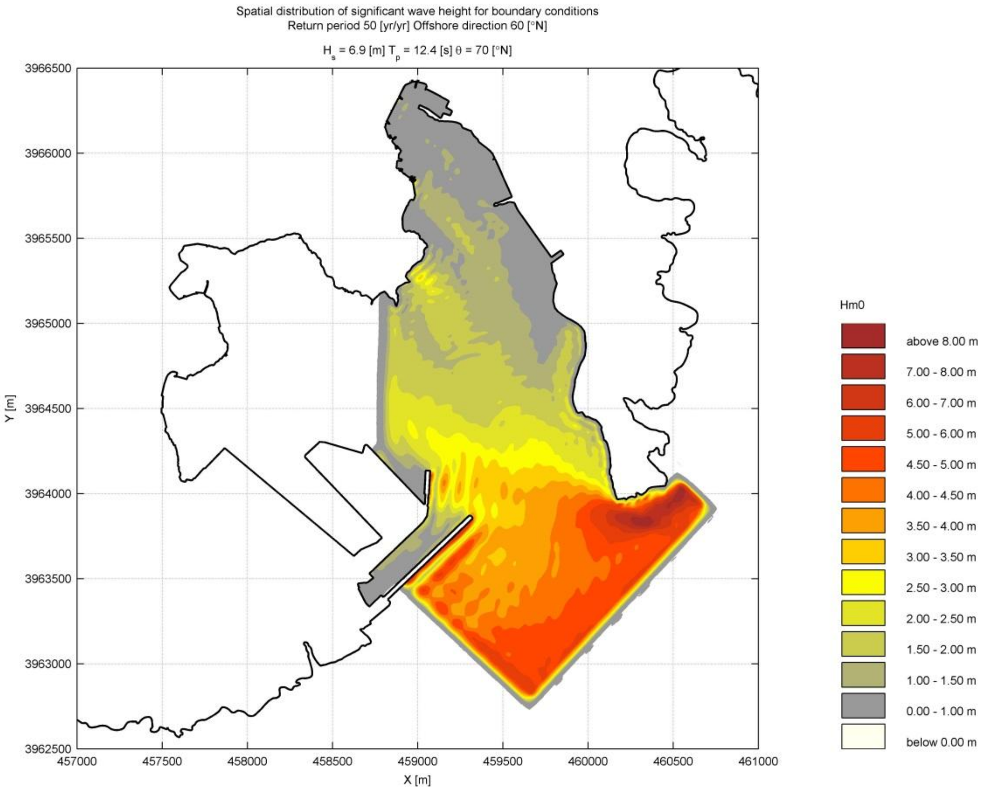
Appendix 6.3 Extremes

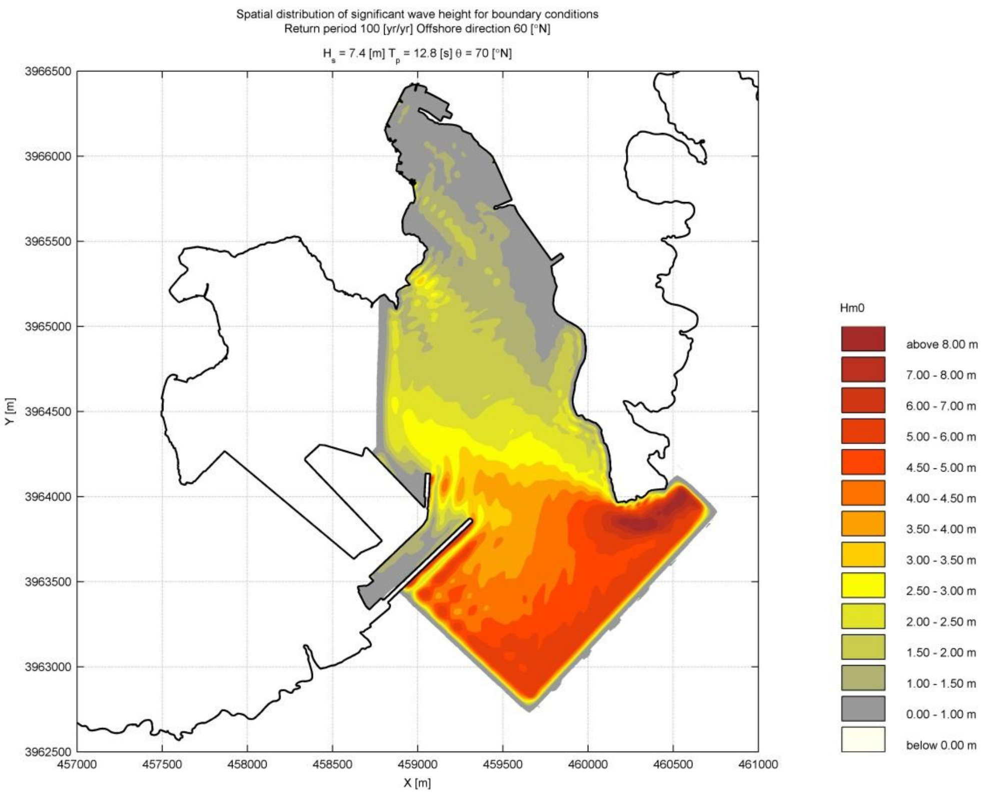


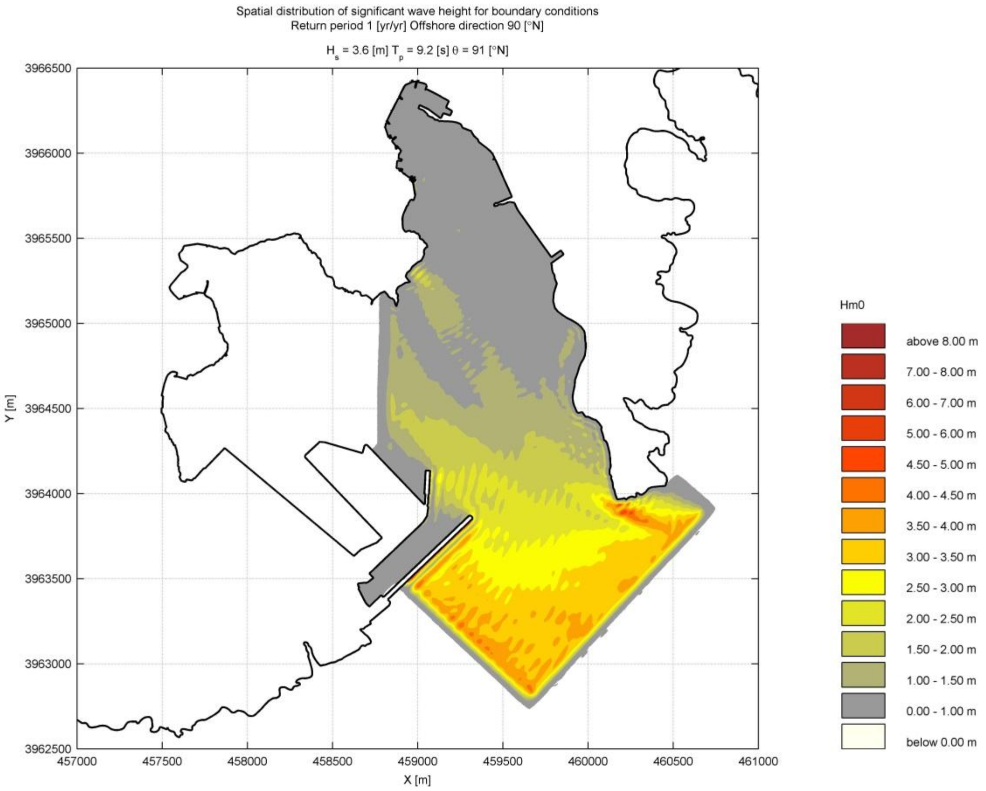


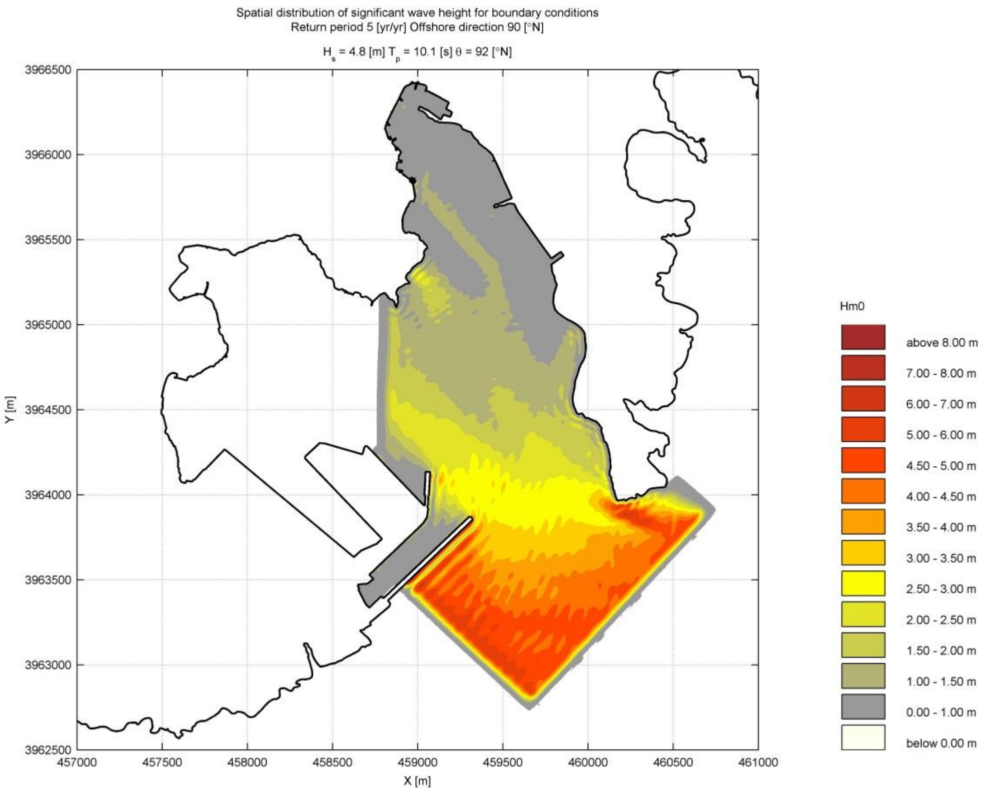

Spatial distribution of significant wave height for boundary conditions
Return period 10 [yr/yr] Offshore direction 60 [°N]
H_s = 5.7 [m] T_p = 11.2 [s] θ = 69 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
Return period 25 [yr/yr] Offshore direction 60 [°N]
H_s = 6.4 [m] T_p = 11.9 [s] θ = 70 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
Return period 50 [yr/yr] Offshore direction 60 [°N]
H_s = 6.9 [m] T_p = 12.4 [s] θ = 70 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
Return period 100 [yr/yr] Offshore direction 60 [°N]
H_s = 7.4 [m] T_p = 12.8 [s] θ = 70 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
Return period 1 [yr/yr] Offshore direction 90 [°N]
H_s = 3.6 [m] T_p = 9.2 [s] θ = 91 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
Return period 5 [yr/yr] Offshore direction 90 [°N]
H_s = 4.8 [m] T_p = 10.1 [s] θ = 92 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
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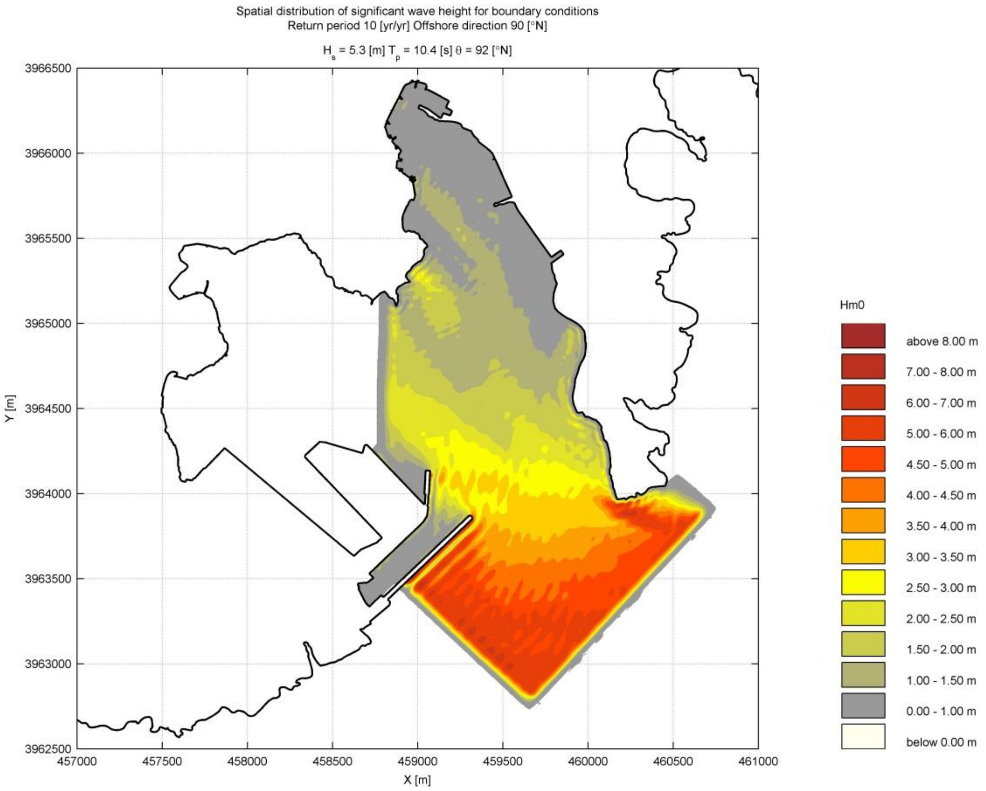
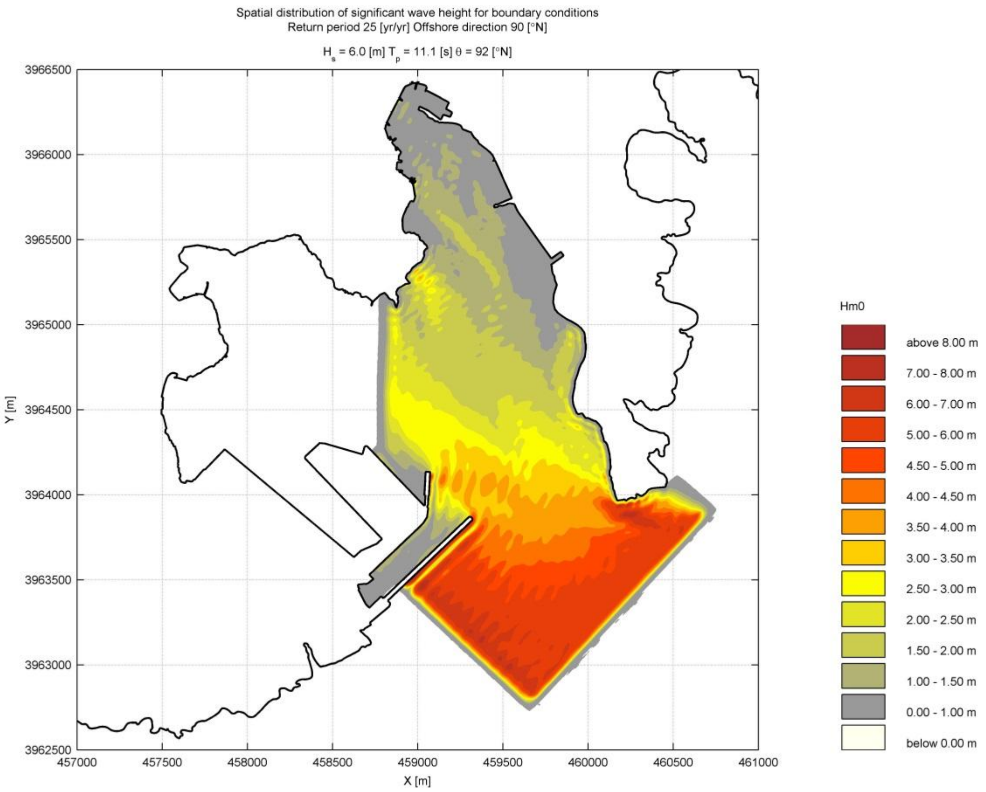
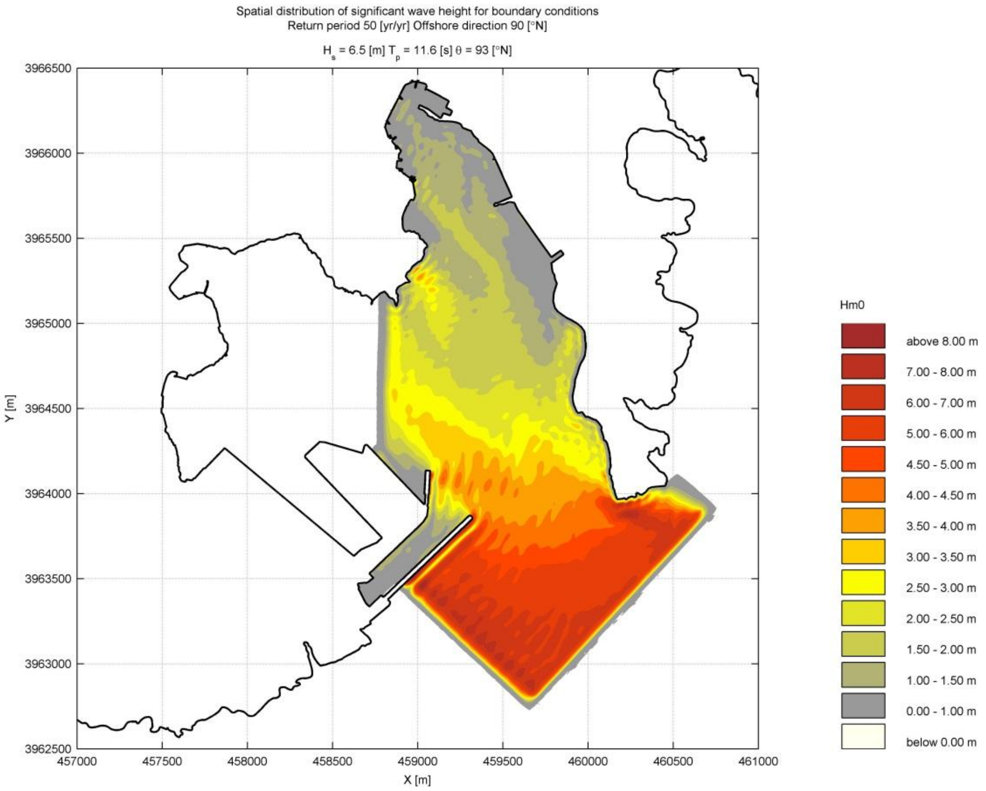
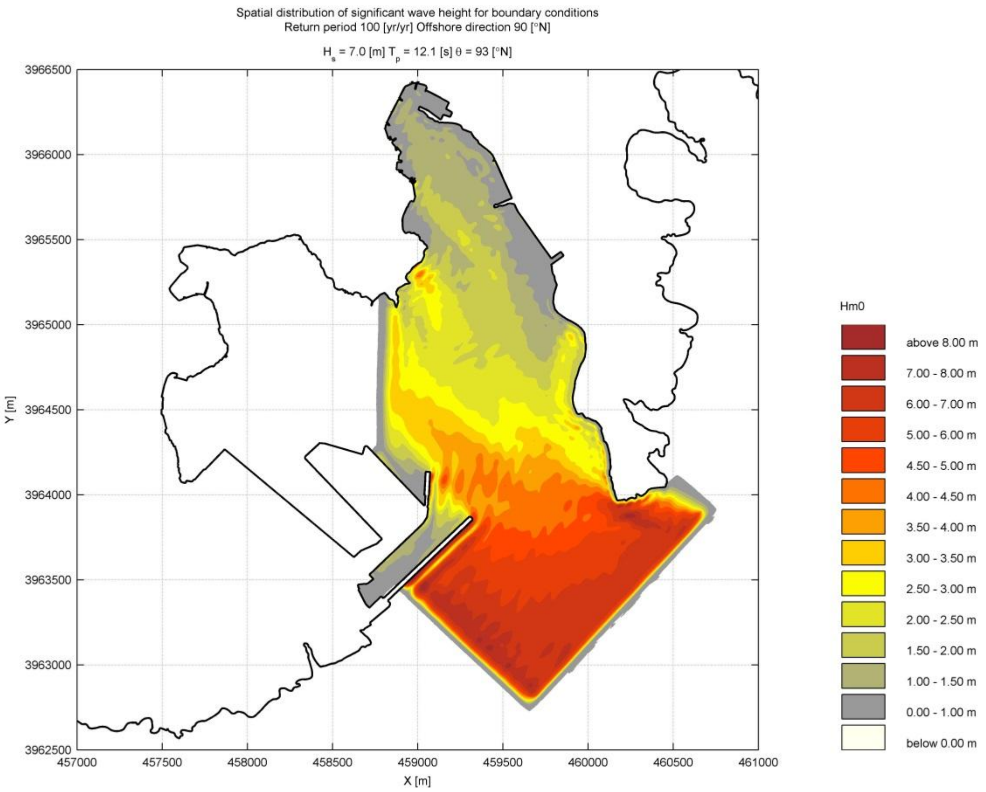
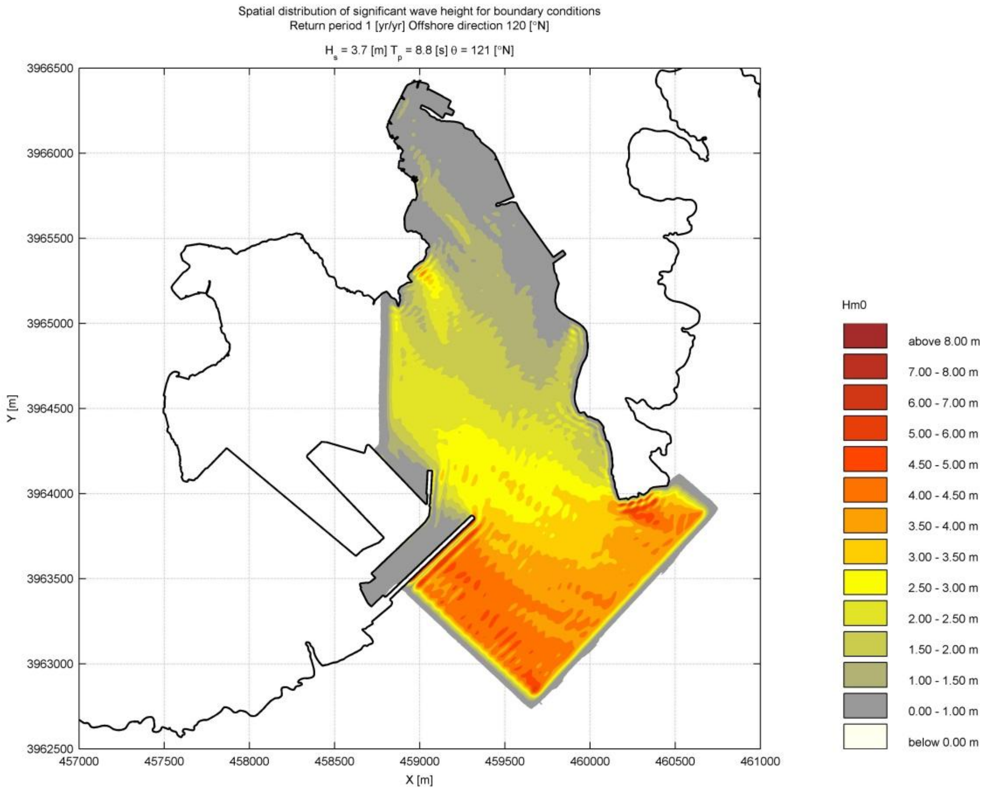
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

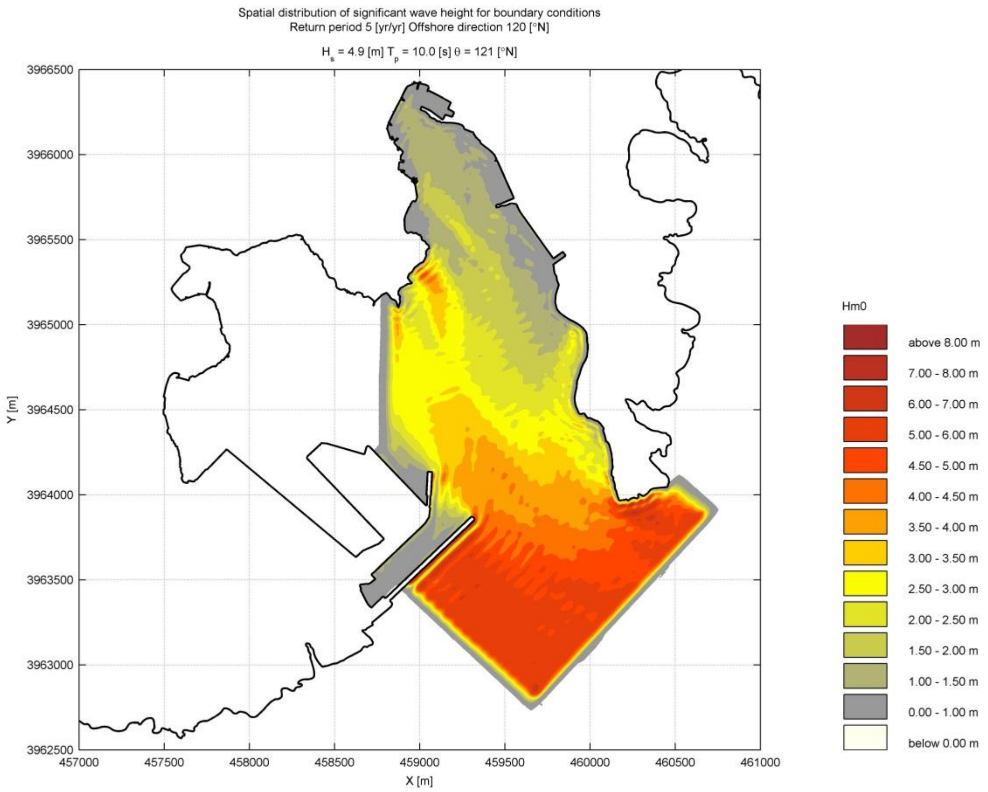

Spatial distribution of significant wave height for boundary conditions
Return period 10 [yr/yr] Offshore direction 90 [°N]
H_s = 5.3 [m] T_p = 10.4 [s] θ = 92 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

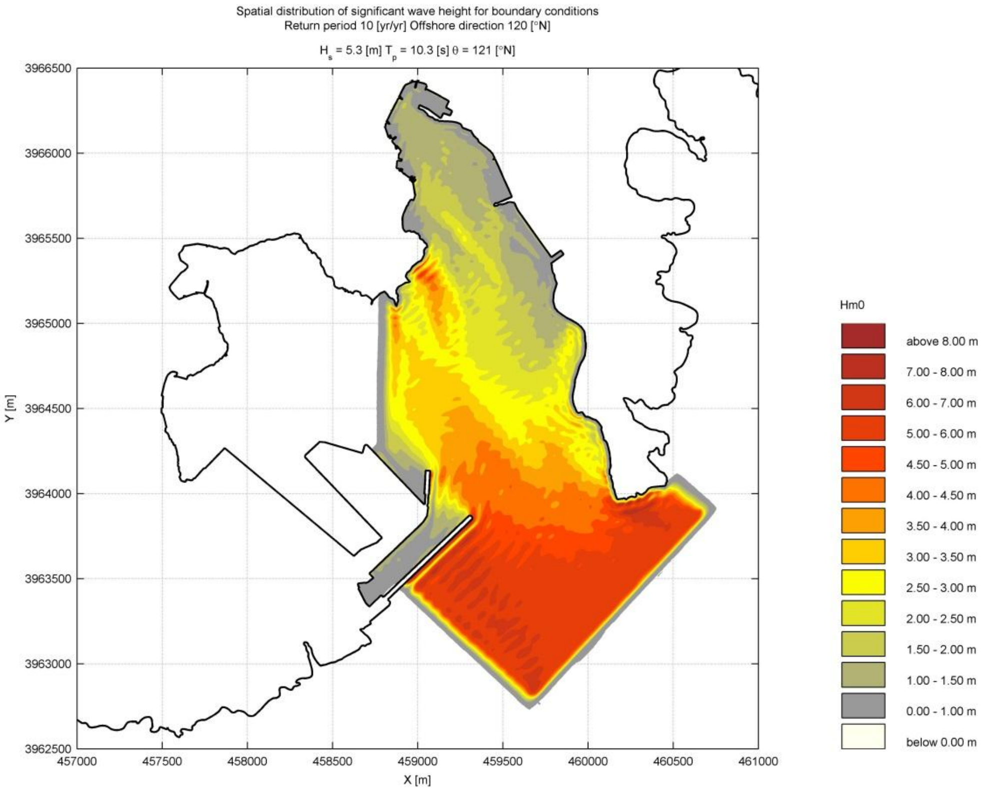

Spatial distribution of significant wave height for boundary conditions
Return period 25 [yr/yr] Offshore direction 90 [°N]
H_s = 6.0 [m] T_p = 11.1 [s] θ = 92 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

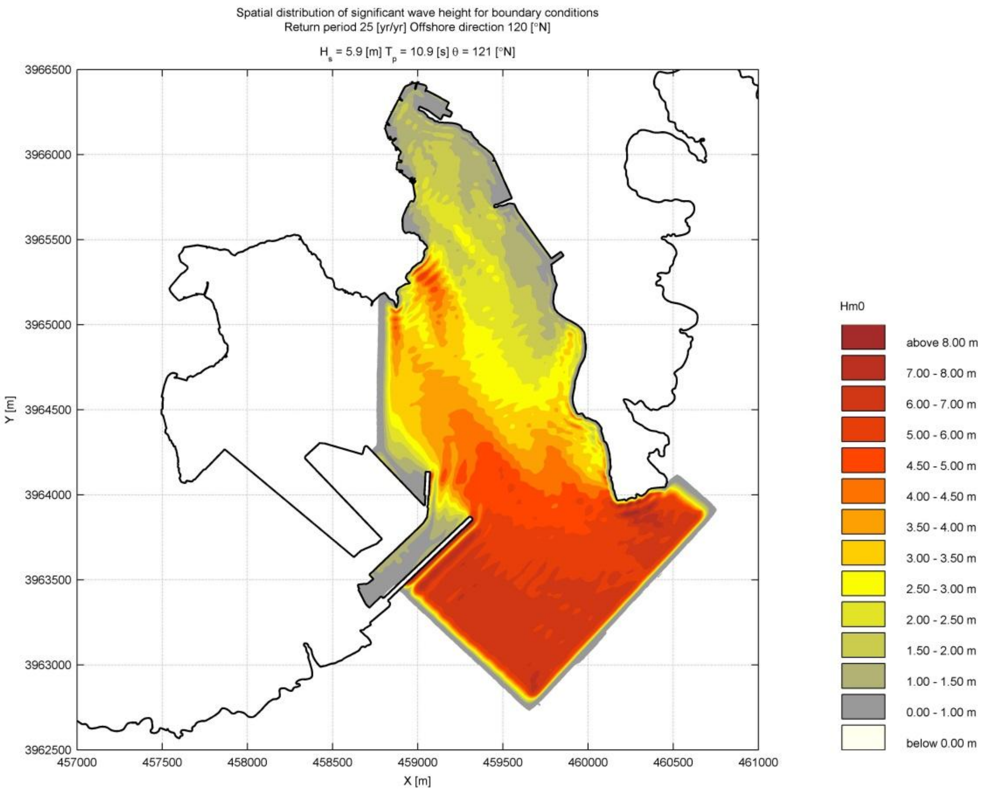

Spatial distribution of significant wave height for boundary conditions
Return period 50 [yr/yr] Offshore direction 90 [°N]
Hs = 6.5 [m] Tp = 11.6 [s] θ = 93 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

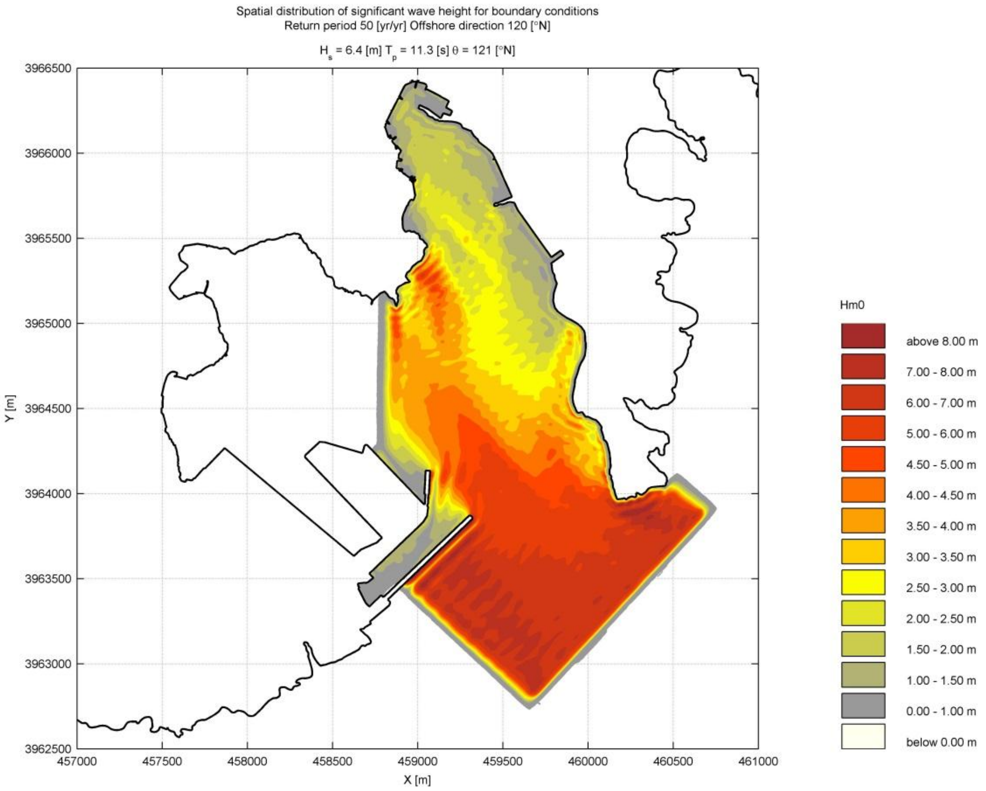

Spatial distribution of significant wave height for boundary conditions
Return period 100 [yr/yr] Offshore direction 90 [°N]
Hs = 7.0 [m] Tp = 12.1 [s] θ = 93 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

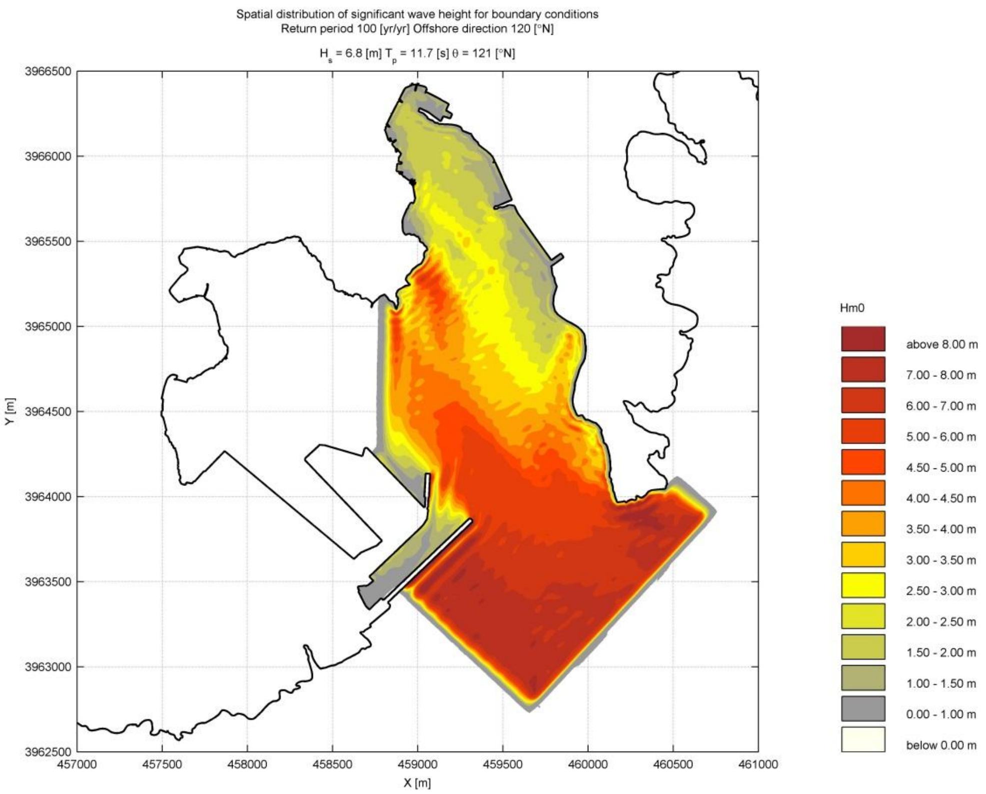

Spatial distribution of significant wave height for boundary conditions
Return period 1 [yr/yr] Offshore direction 120 [°N]
H_s = 3.7 [m] T_p = 8.8 [s] θ = 121 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

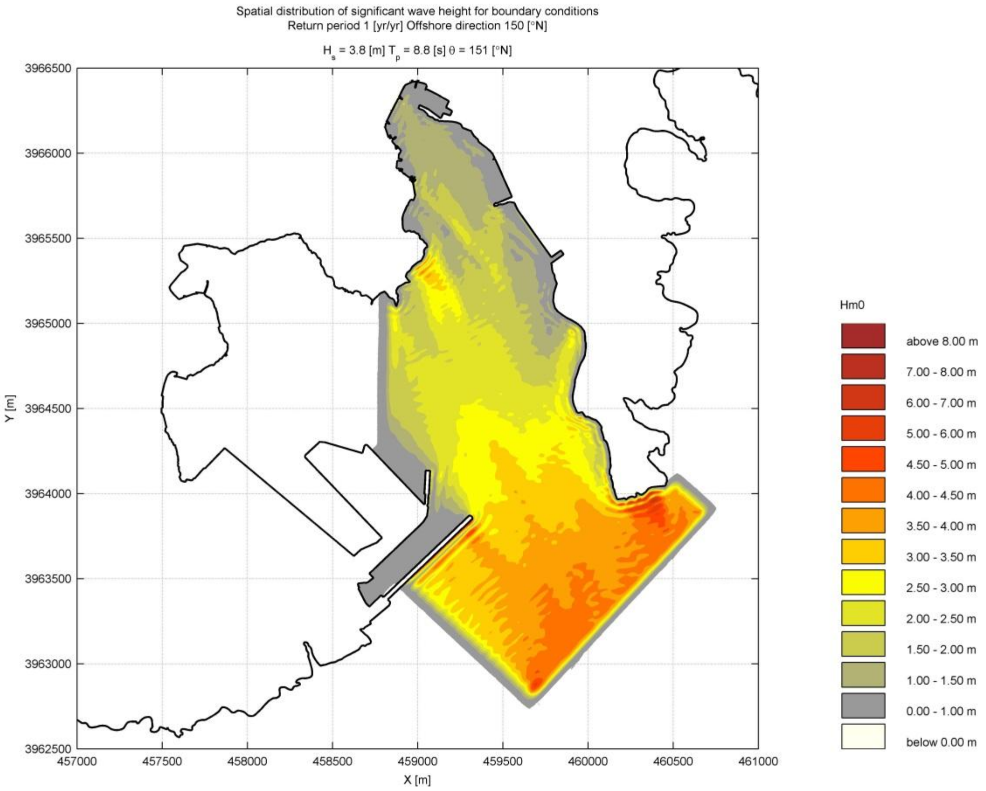

Spatial distribution of significant wave height for boundary conditions
Return period 5 [yr/yr] Offshore direction 120 [°N]
H_s = 4.9 [m] T_p = 10.0 [s] θ = 121 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

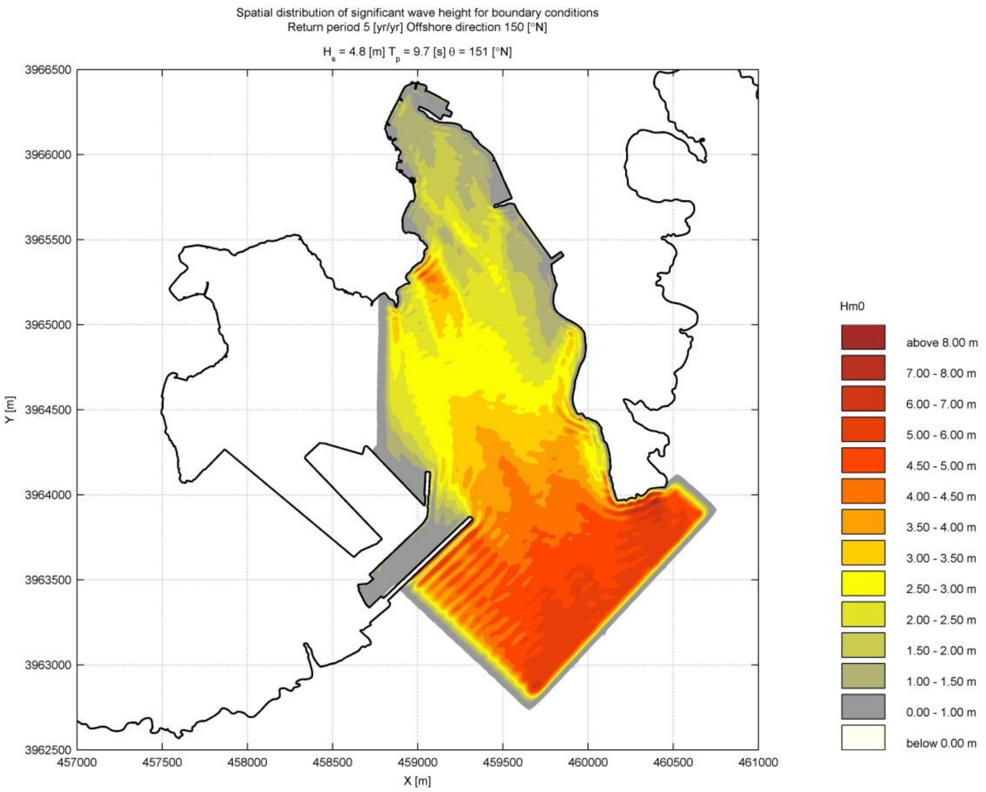

Spatial distribution of significant wave height for boundary conditions
Return period 10 [yr/yr] Offshore direction 120 [°N]
Hs = 5.3 [m] Tp = 10.3 [s] θ = 121 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

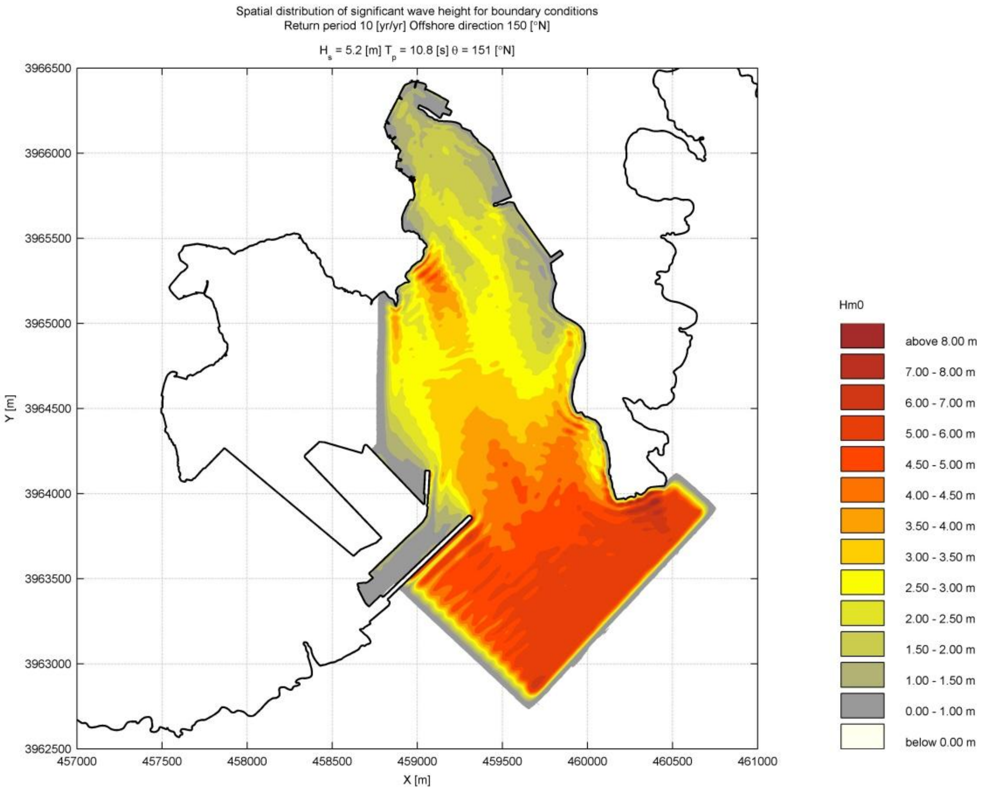

Spatial distribution of significant wave height for boundary conditions
Return period 25 [yr/yr] Offshore direction 120 [°N]
Hs = 5.9 [m] Tp = 10.9 [s] θ = 121 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

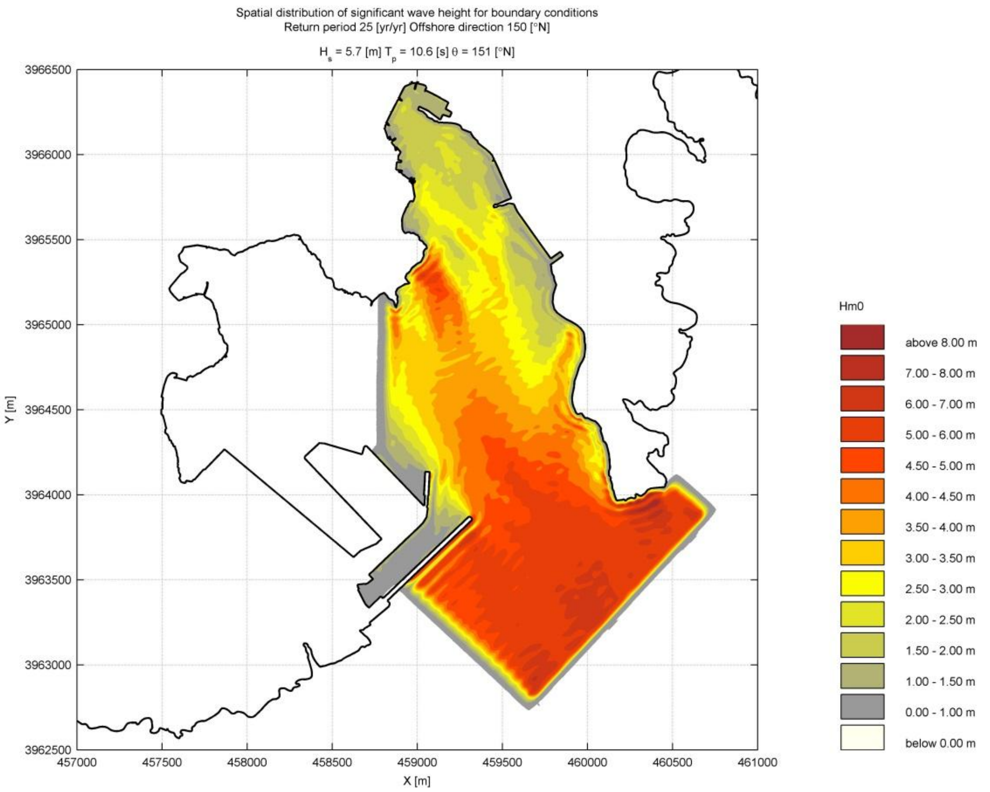

Spatial distribution of significant wave height for boundary conditions
Return period 50 [yr/yr] Offshore direction 120 [°N]
H_s = 6.4 [m] T_p = 11.3 [s] θ = 121 [°N]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
Y [m]
457000
457500
458000
458500
459000
459500
460000
460500
461000
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

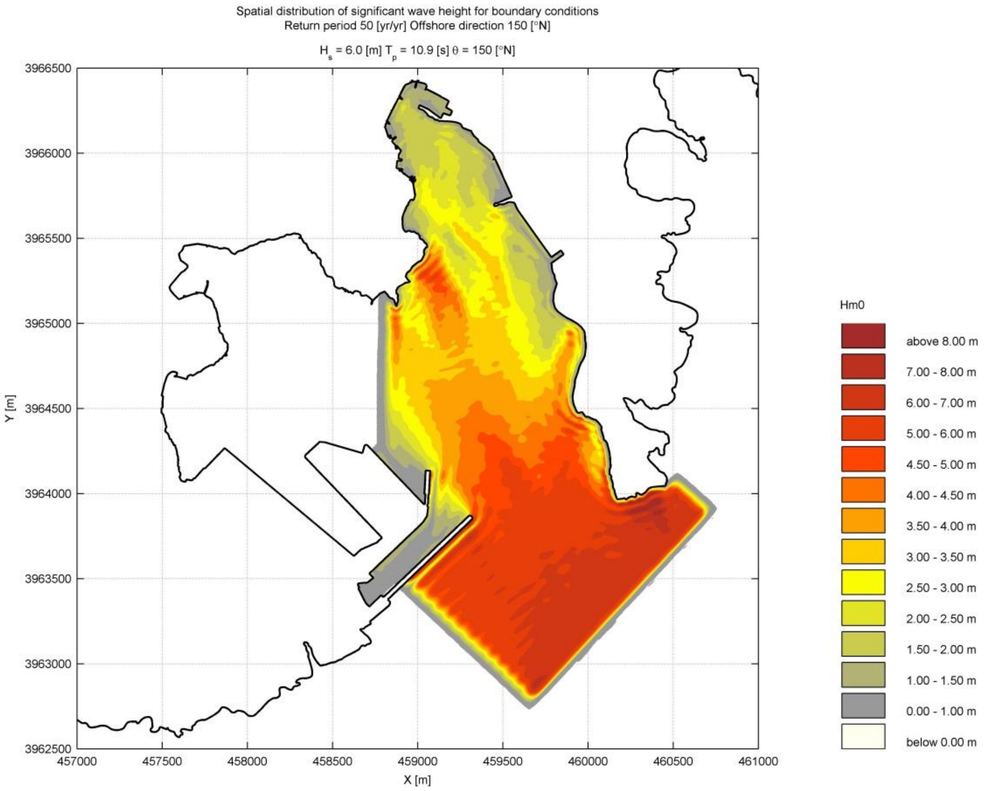

Spatial distribution of significant wave height for boundary conditions
Return period 100 [yr/yr] Offshore direction 120 [°N]
H_s = 6.8 [m] T_p = 11.7 [s] θ = 121 [°N]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
Y [m]
457000
457500
458000
458500
459000
459500
460000
460500
461000
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

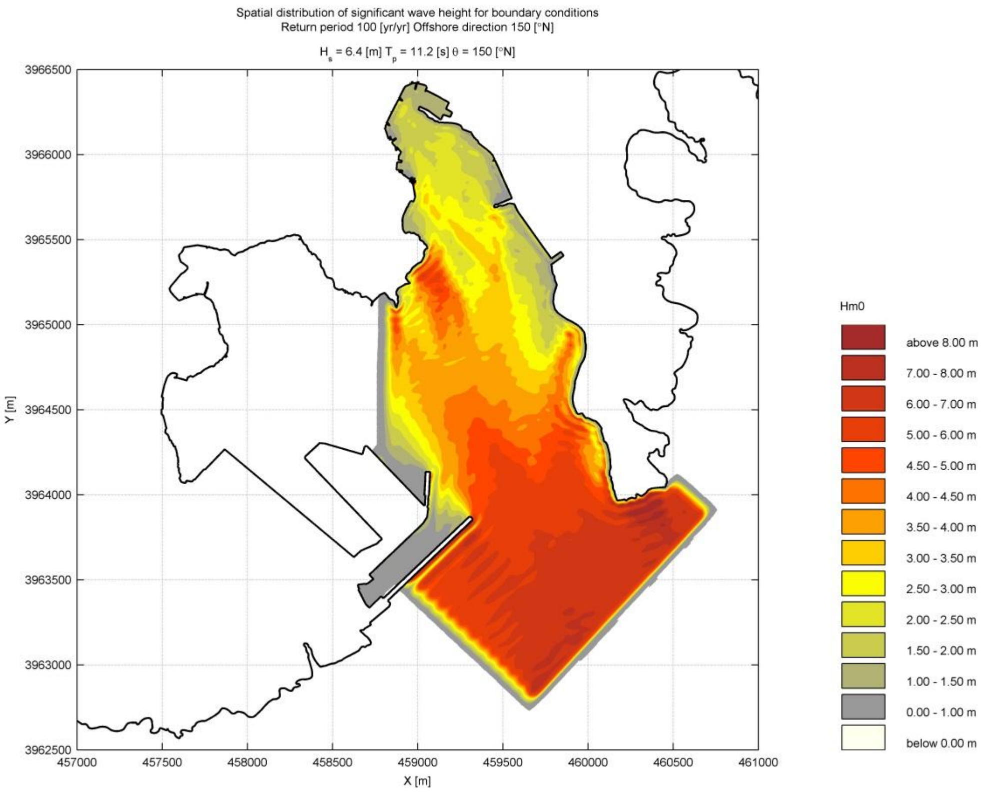

Spatial distribution of significant wave height for boundary conditions
Return period 1 [yr/yr] Offshore direction 150 [°N]
H_s = 3.8 [m] T_p = 8.8 [s] θ = 151 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

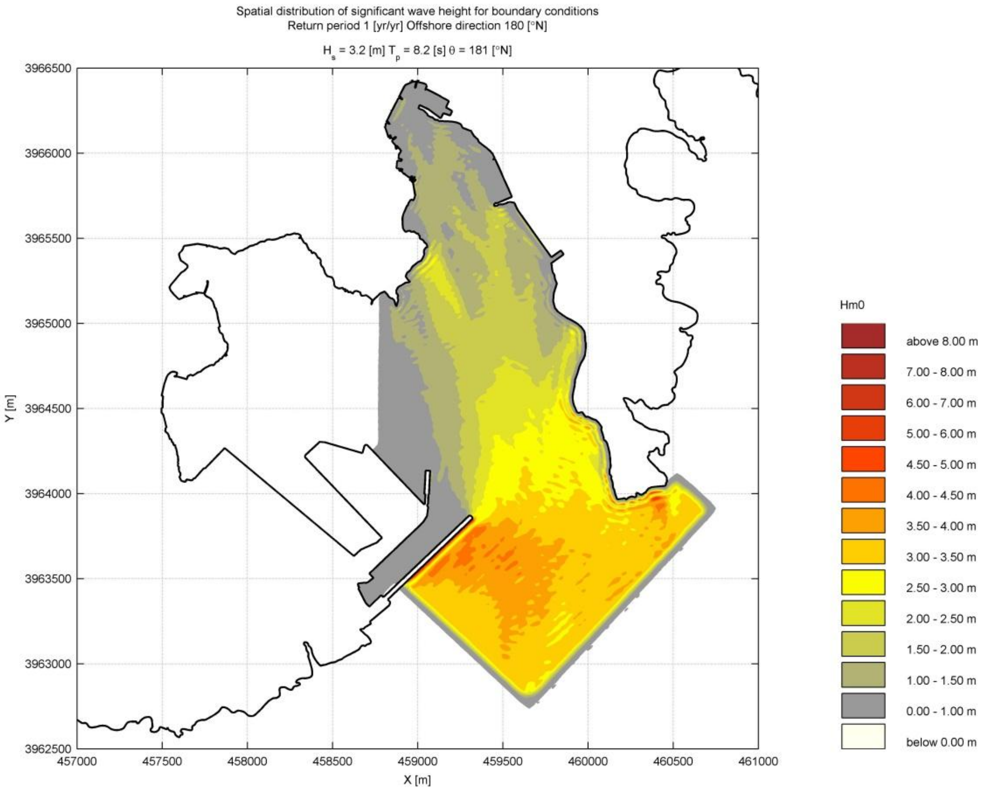

Spatial distribution of significant wave height for boundary conditions
Return period 5 [yr/yr] Offshore direction 150 [°N]
H_s = 4.8 [m] T_p = 9.7 [s] θ = 151 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

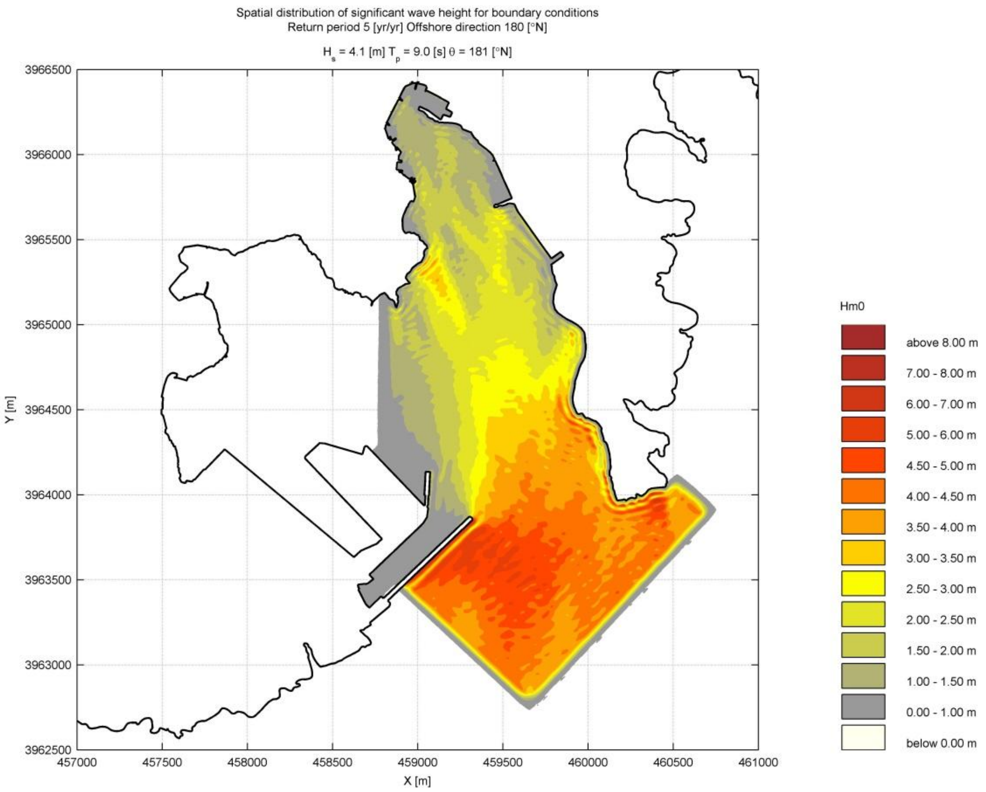

Spatial distribution of significant wave height for boundary conditions
Return period 10 [yr/yr] Offshore direction 150 [°N]
H_s = 5.2 [m] T_p = 10.8 [s] θ = 151 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

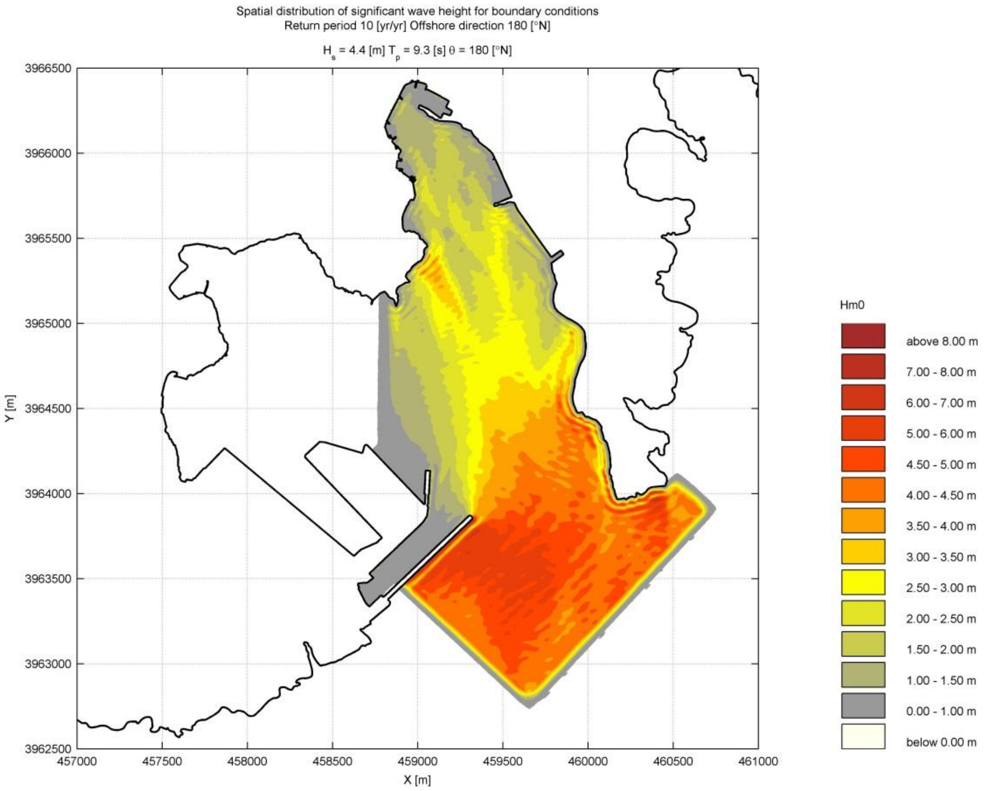

Spatial distribution of significant wave height for boundary conditions
Return period 25 [yr/yr] Offshore direction 150 [°N]
H_s = 5.7 [m] T_p = 10.6 [s] θ = 151 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

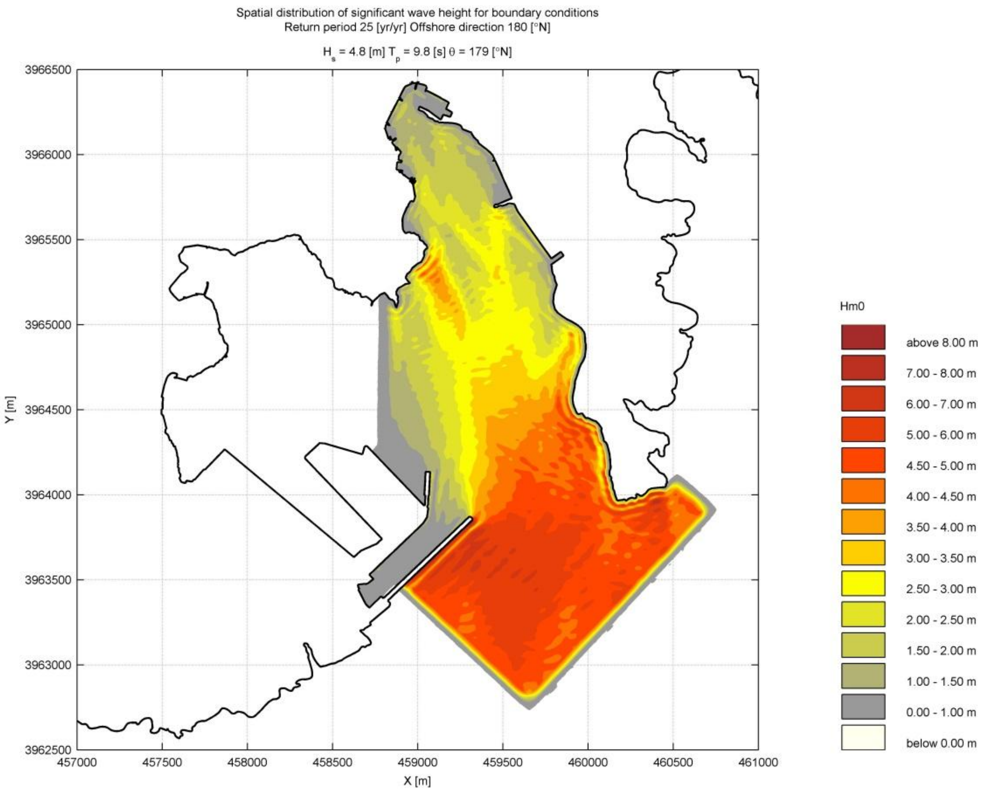

Spatial distribution of significant wave height for boundary conditions
Return period 50 [yr/yr] Offshore direction 150 [°N]
H_s = 6.0 [m] T_p = 10.9 [s] θ = 150 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

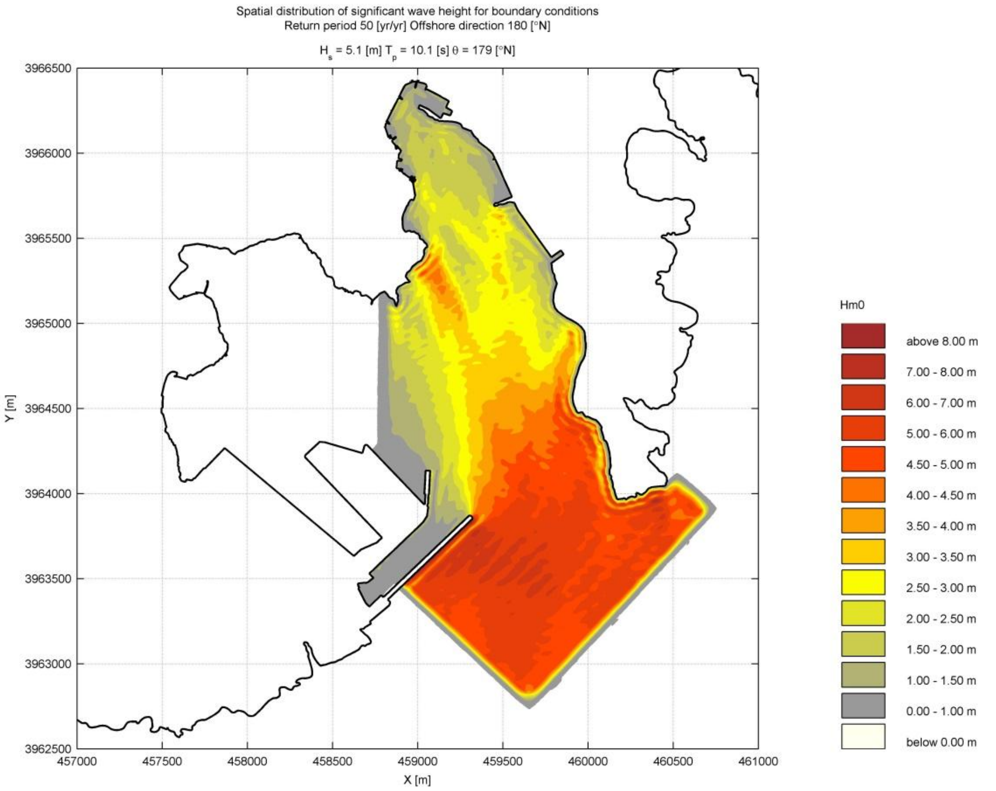

Spatial distribution of significant wave height for boundary conditions
Return period 100 [yr/yr] Offshore direction 150 [°N]
H_s = 6.4 [m] T_p = 11.2 [s] θ = 150 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

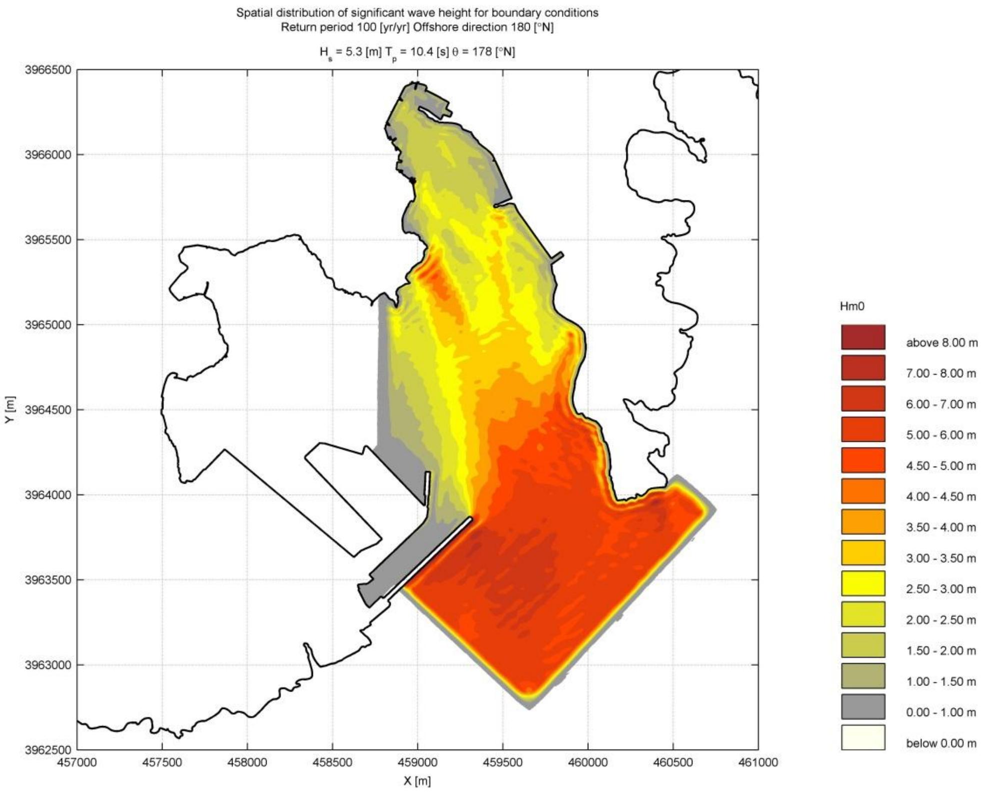

Spatial distribution of significant wave height for boundary conditions
Return period 1 [yr/yr] Offshore direction 180 [°N]
H_s = 3.2 [m] T_p = 8.2 [s] θ = 181 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

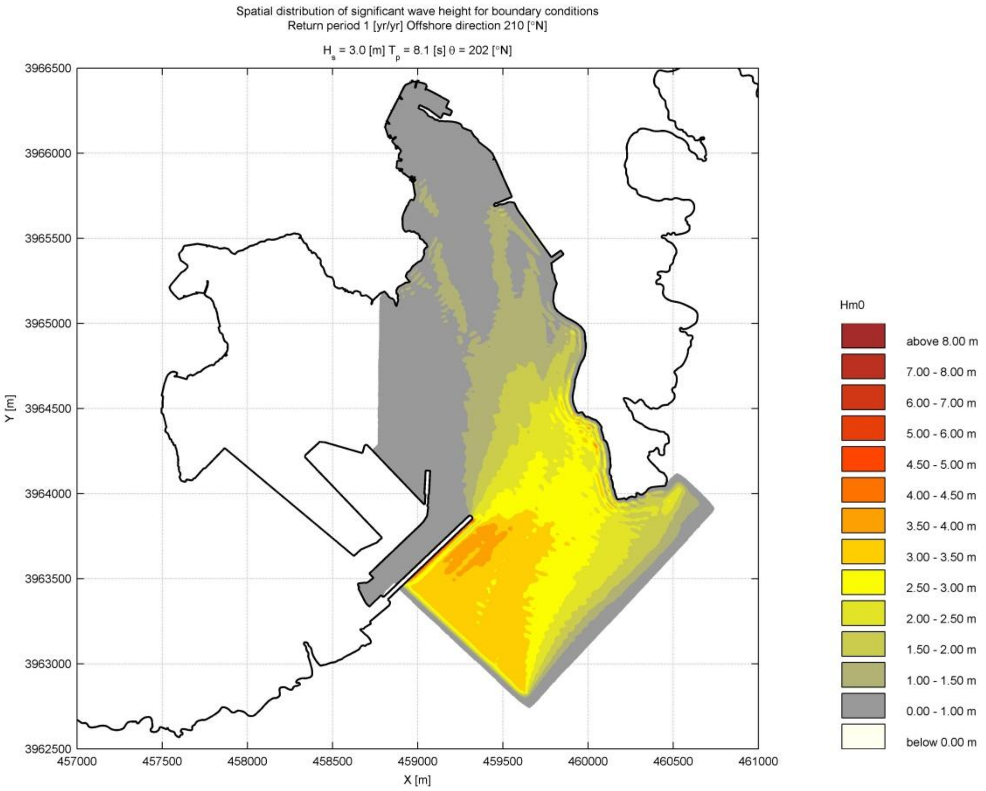

Spatial distribution of significant wave height for boundary conditions
Return period 5 [yr/yr] Offshore direction 180 [°N]
H_s = 4.1 [m] T_p = 9.0 [s] θ = 181 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

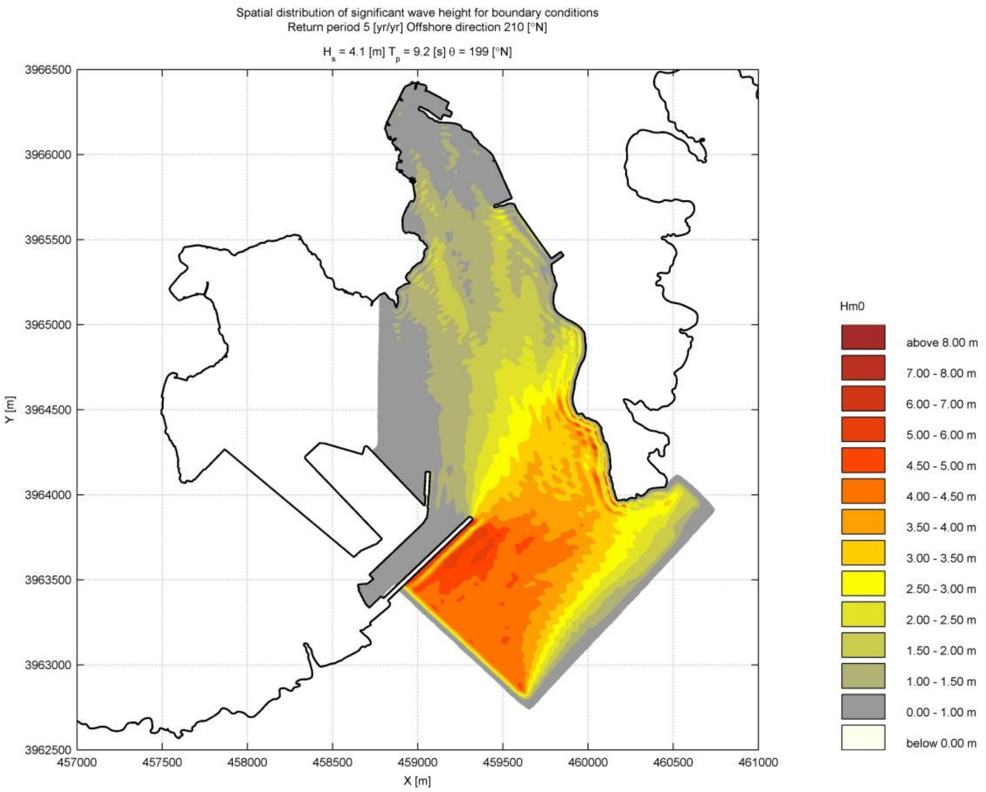

Spatial distribution of significant wave height for boundary conditions
Return period 10 [yr/yr] Offshore direction 180 [°N]
H_s = 4.4 [m] T_p = 9.3 [s] θ = 180 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

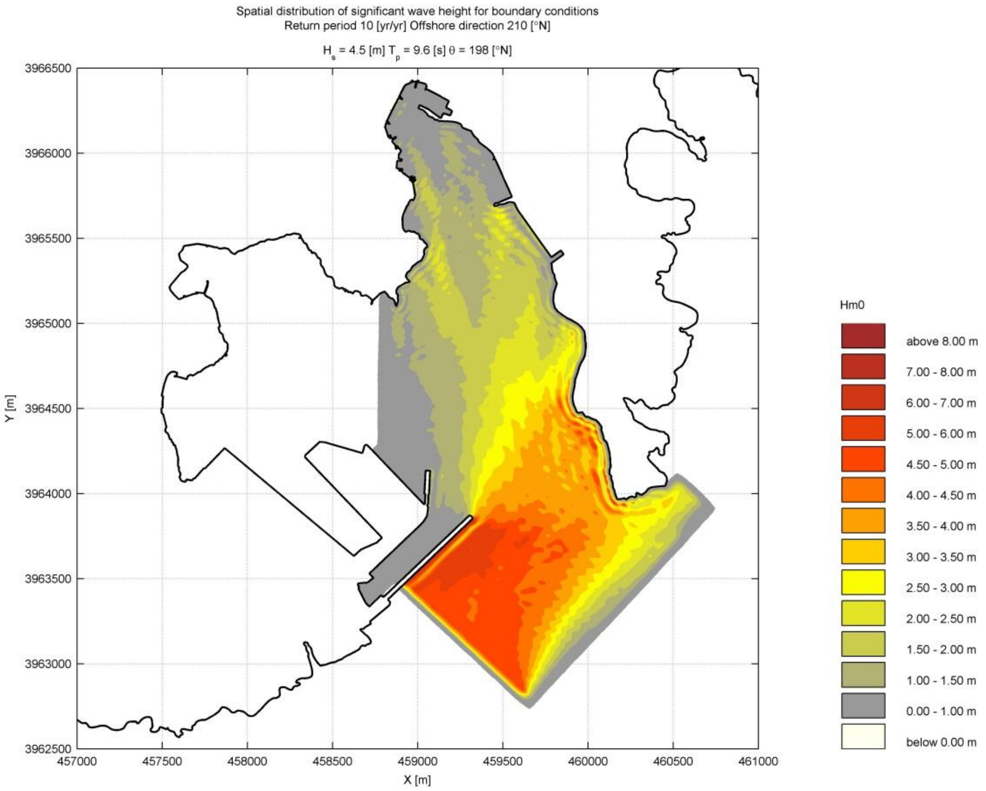

Spatial distribution of significant wave height for boundary conditions
Return period 25 [yr/yr] Offshore direction 180 [°N]
H_s = 4.8 [m] T_p = 9.8 [s] θ = 179 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

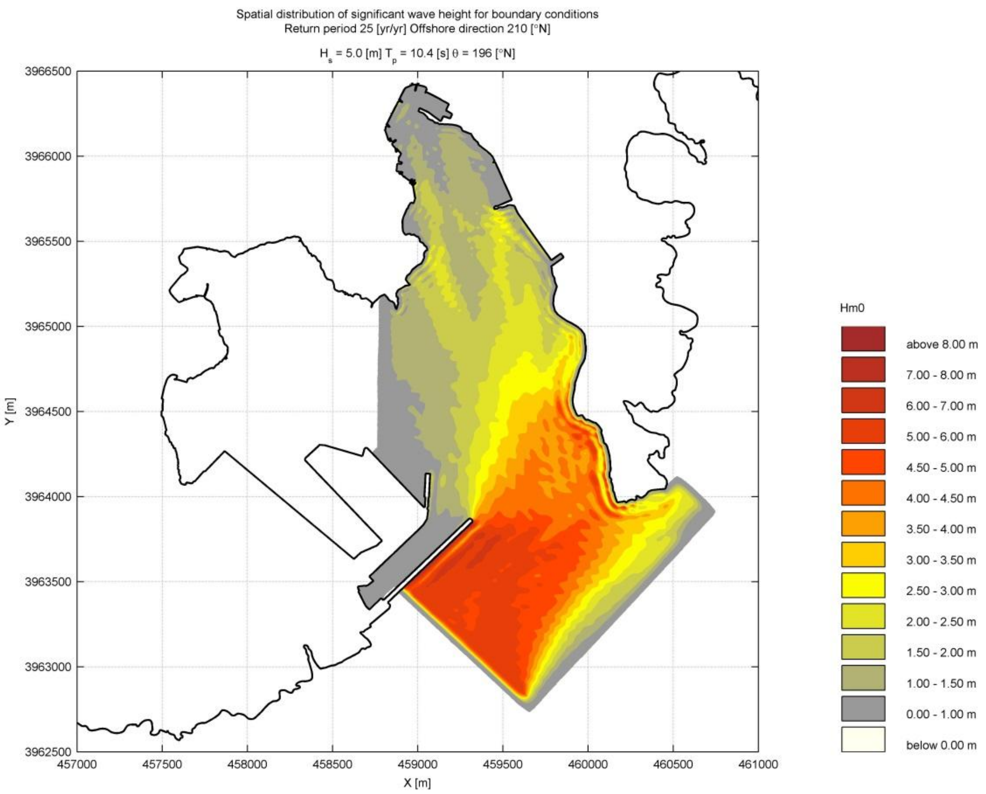

Spatial distribution of significant wave height for boundary conditions
Return period 50 [yr/yr] Offshore direction 180 [°N]
Hs = 5.1 [m] Tp = 10.1 [s] θ = 179 [°N]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
Y [m]
457000
457500
458000
458500
459000
459500
460000
460500
461000
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

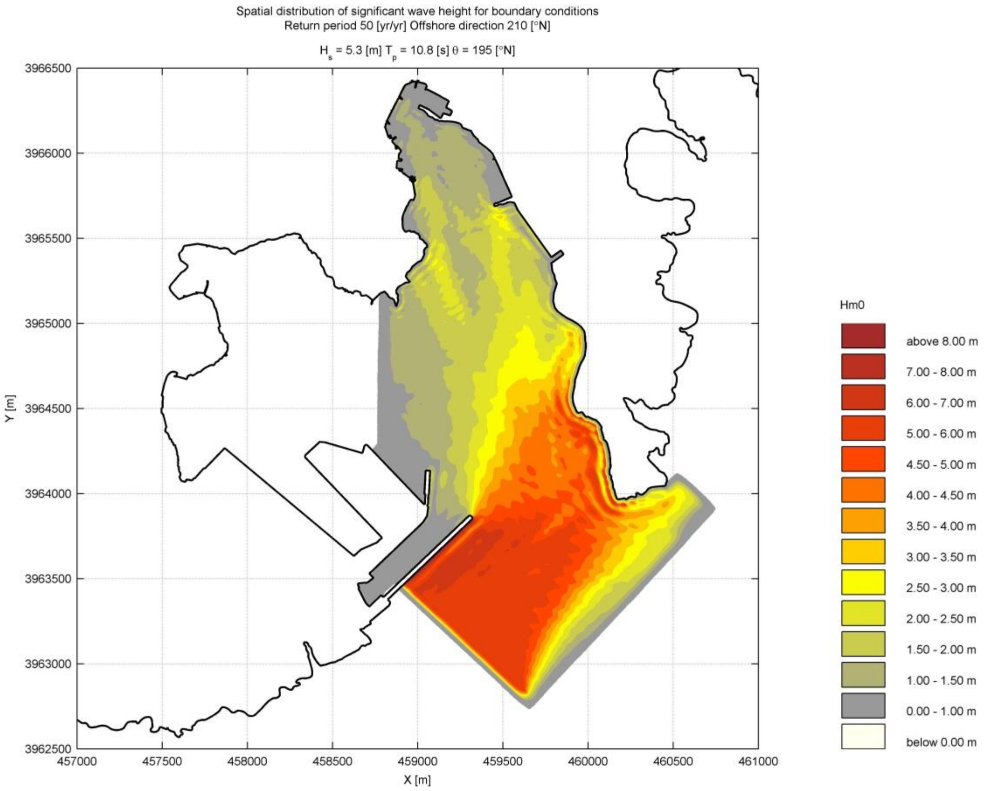

Spatial distribution of significant wave height for boundary conditions
Return period 100 [yr/yr] Offshore direction 180 [°N]
Hs = 5.3 [m] Tp = 10.4 [s] θ = 178 [°N]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
Y [m]
457000
457500
458000
458500
459000
459500
460000
460500
461000
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

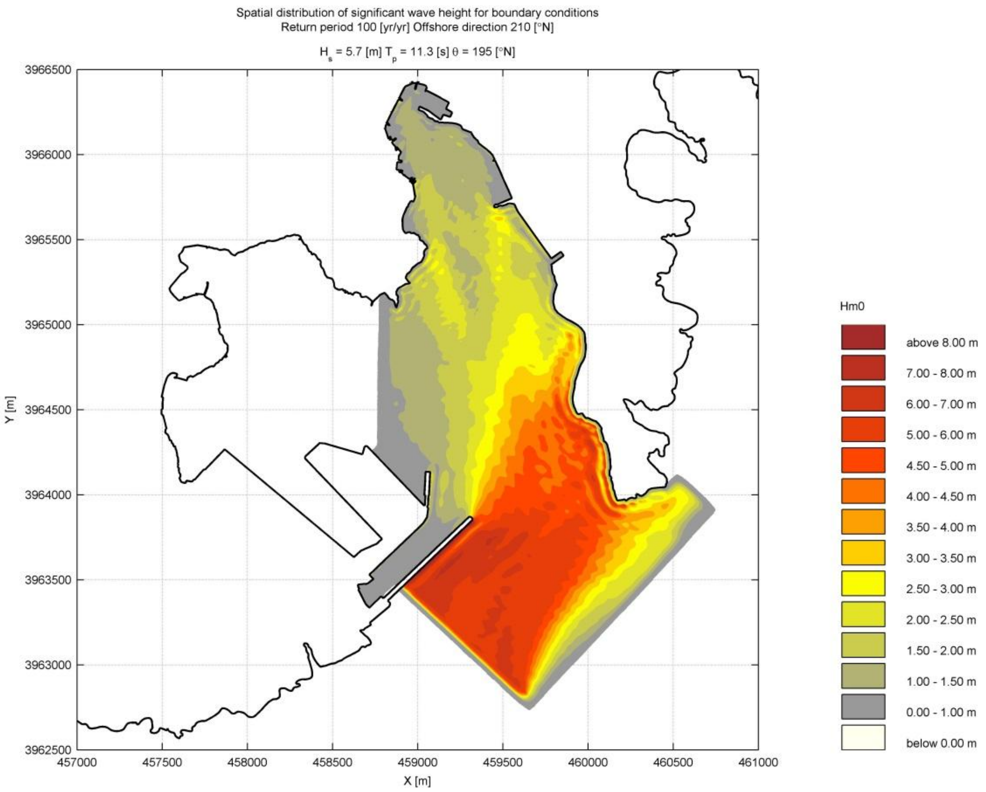

Spatial distribution of significant wave height for boundary conditions
Return period 1 [yr/yr] Offshore direction 210 [°N]
H_s = 3.0 [m] T_p = 8.1 [s] θ = 202 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

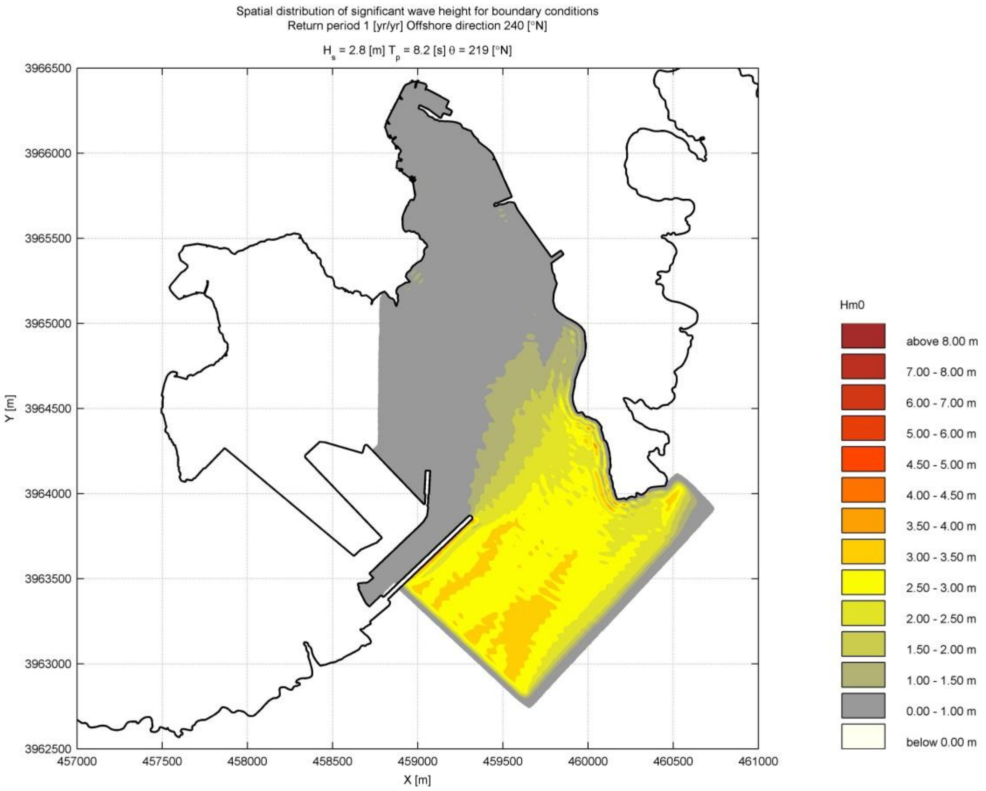

Spatial distribution of significant wave height for boundary conditions
Return period 5 [yr/yr] Offshore direction 210 [°N]
H_s = 4.1 [m] T_p = 9.2 [s] θ = 199 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

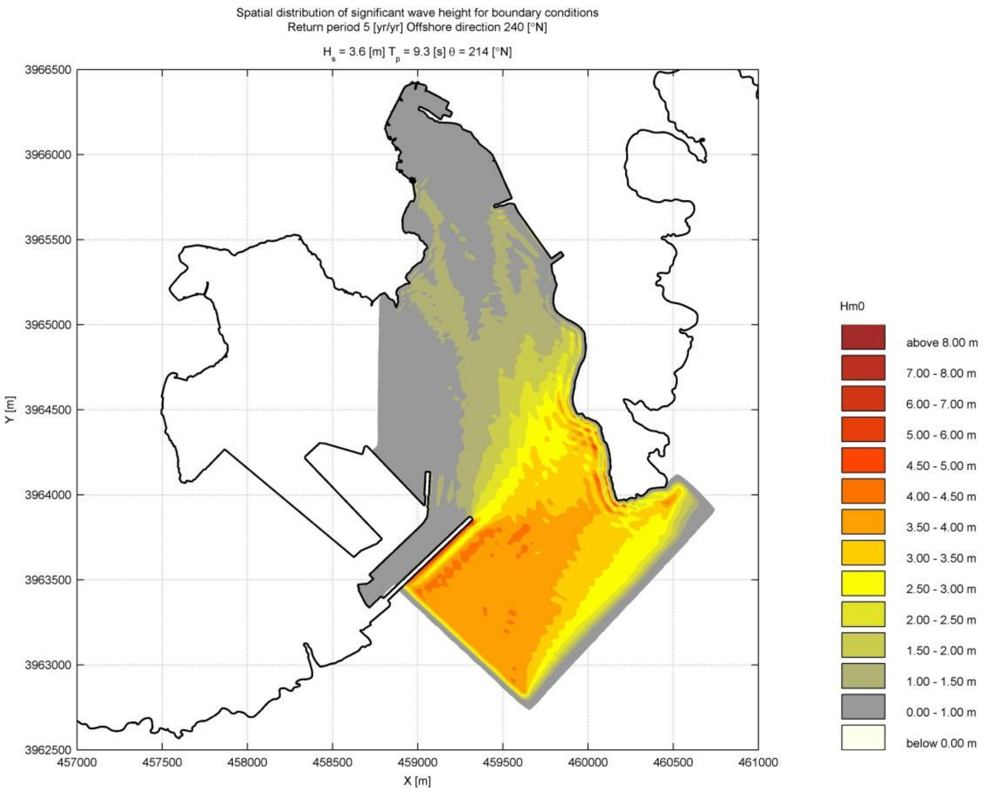

Spatial distribution of significant wave height for boundary conditions
Return period 10 [yr/yr] Offshore direction 210 [°N]
Hs = 4.5 [m] Tp = 9.6 [s] θ = 198 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
Return period 25 [yr/yr] Offshore direction 210 [°N]
Hs = 5.0 [m] Tp = 10.4 [s] θ = 196 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

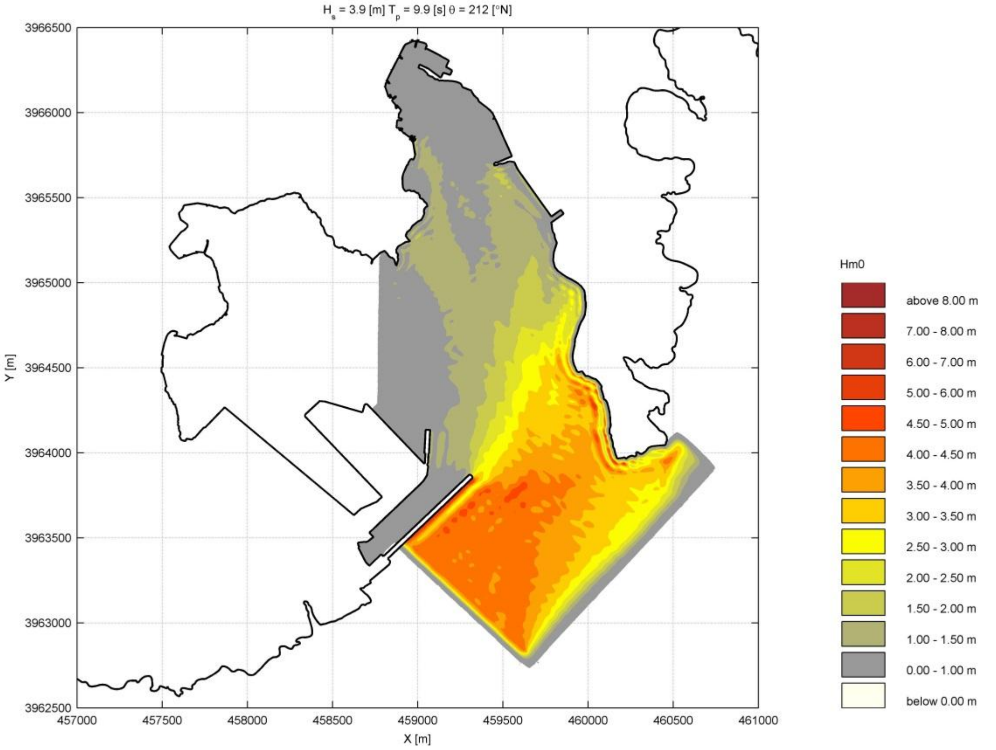

Spatial distribution of significant wave height for boundary conditions
Return period 50 [yr/yr] Offshore direction 210 [°N]
Hs = 5.3 [m] Tp = 10.8 [s] θ = 195 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
Return period 100 [yr/yr] Offshore direction 210 [°N]
Hs = 5.7 [m] Tp = 11.3 [s] θ = 195 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

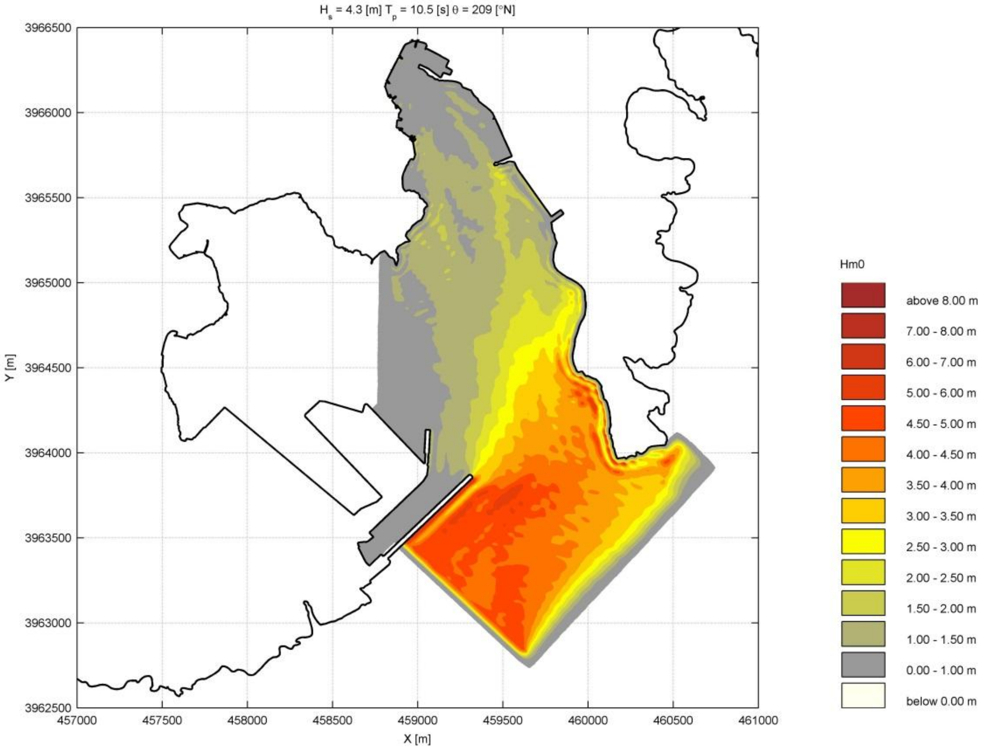

Spatial distribution of significant wave height for boundary conditions
Return period 1 [yr/yr] Offshore direction 240 [°N]
H_s = 2.8 [m] T_p = 8.2 [s] θ = 219 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

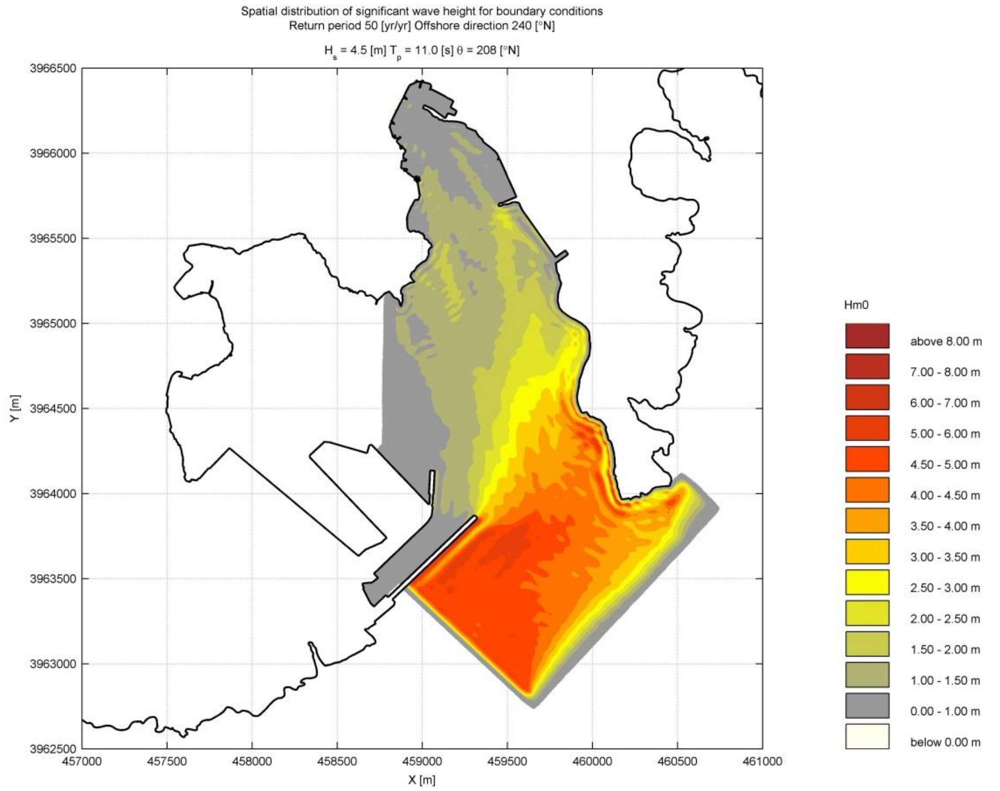

Spatial distribution of significant wave height for boundary conditions
Return period 5 [yr/yr] Offshore direction 240 [°N]
H_s = 3.6 [m] T_p = 9.3 [s] θ = 214 [°N]
Y [m]
X [m]
3966500
3966000
3965500
3965000
3964500
3964000
3963500
3963000
3962500
457000
457500
458000
458500
459000
459500
460000
460500
461000
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m

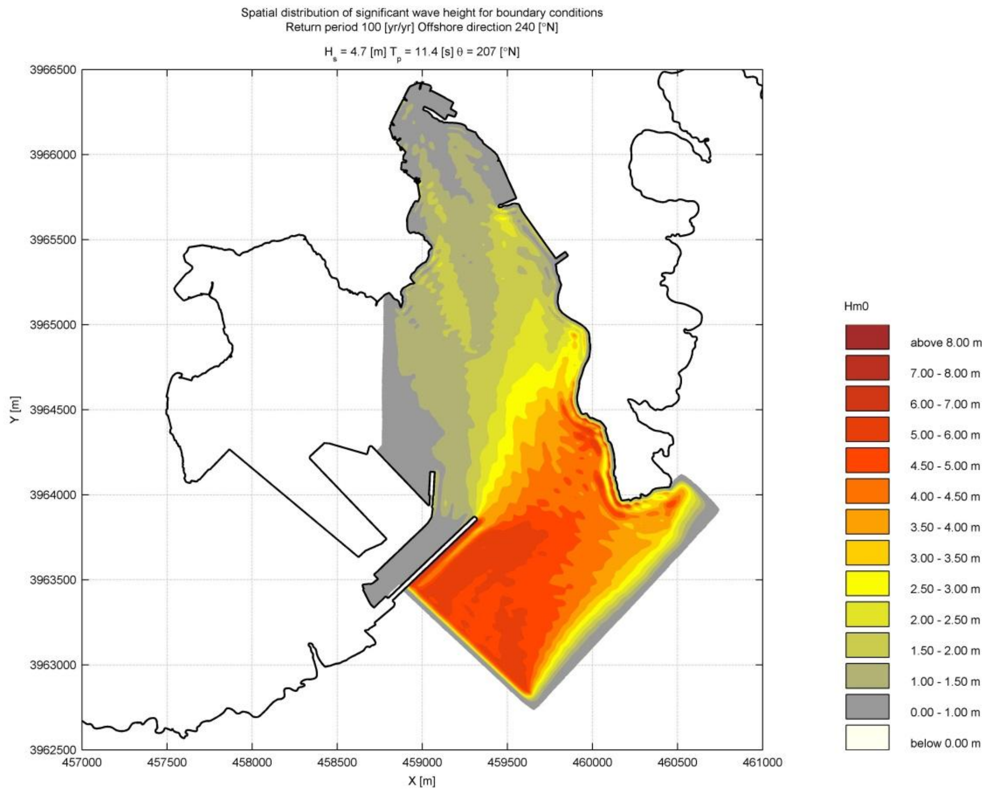
Spatial distribution of significant wave height for boundary conditions
Return period 10 [yr/yr] Offshore direction 240 [°N]
H_s = 3.9 [m] T_p = 9.9 [s] θ = 212 [°N]



Spatial distribution of significant wave height for boundary conditions
Return period 25 [yr/yr] Offshore direction 240 [°N]
H_s = 4.3 [m] T_p = 10.5 [s] θ = 209 [°N]




Spatial distribution of significant wave height for boundary conditions
Return period 50 [yr/yr] Offshore direction 240 [°N]
H_s = 4.5 [m] T_p = 11.0 [s] θ = 208 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m


Spatial distribution of significant wave height for boundary conditions
Return period 100 [yr/yr] Offshore direction 240 [°N]
H_s = 4.7 [m] T_p = 11.4 [s] θ = 207 [°N]
Y [m]
X [m]
Hm0
above 8.00 m
7.00 - 8.00 m
6.00 - 7.00 m
5.00 - 6.00 m
4.50 - 5.00 m
4.00 - 4.50 m
3.50 - 4.00 m
3.00 - 3.50 m
2.50 - 3.00 m
2.00 - 2.50 m
1.50 - 2.00 m
1.00 - 1.50 m
0.00 - 1.00 m
below 0.00 m