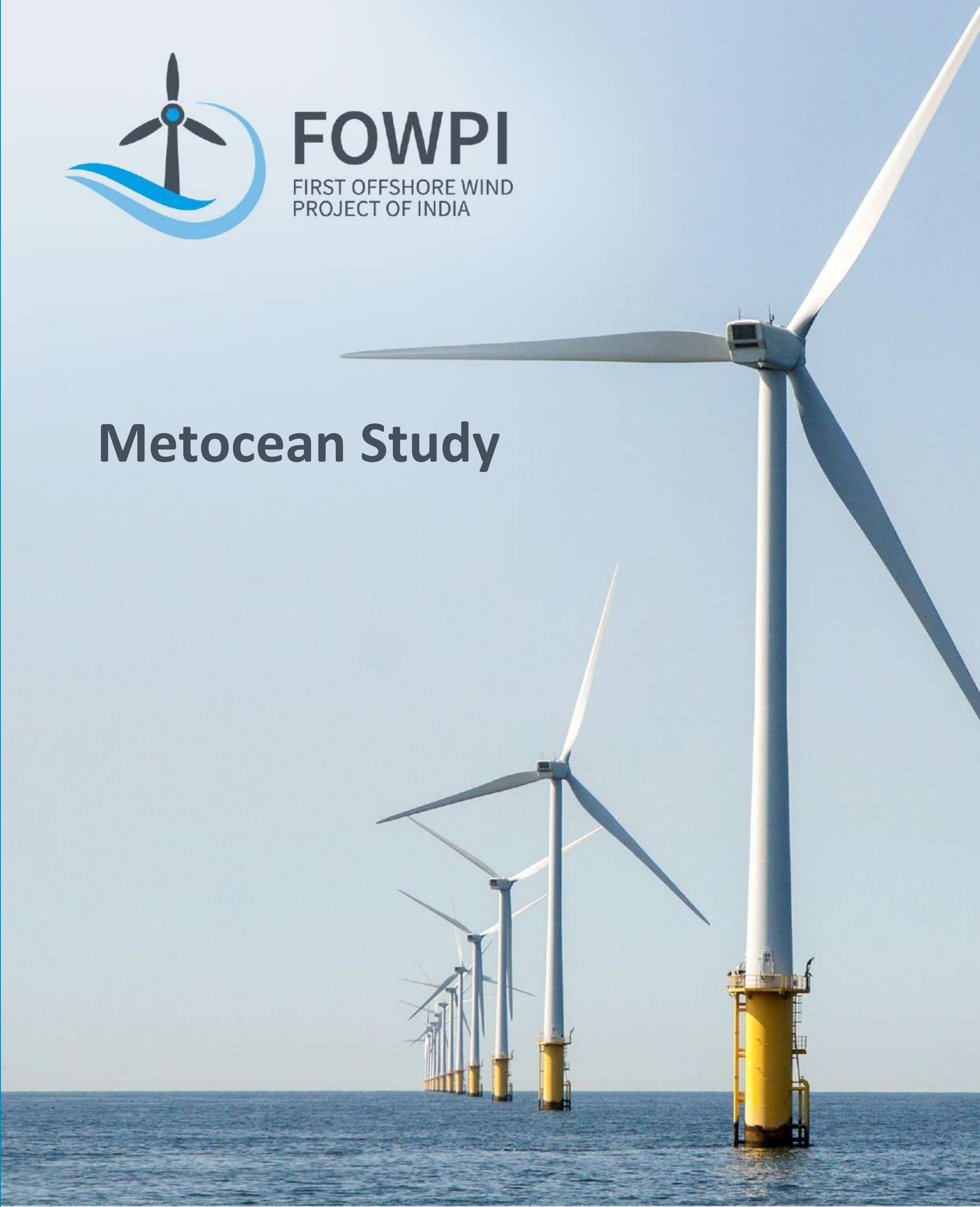
FOWPI
FIRST OFFSHORE WIND
PROJECT OF INDIA

Metocean Study



This Project is funded by The European Union

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1 About FOWPI

The First Offshore Wind Project of India (FOWPI) is part of the “Clean Energy Cooperation with India (CECI) “, which aims at enhancing India's capacity to deploy low carbon energy production and improve energy efficiency, thereby contributing to the mitigation of global climate change. Project activities will support India's efforts to secure the energy supply security, within a well-established framework for strategic energy cooperation between the EU and India.

FOWPI is planned to achieve the first 200MW sized offshore wind farm near the coast of Gujarat, 25km off Jafarabad. Project will emphasis on bringing the vast experience of offshore wind rich European countries to India which aims to provide technical assistance for setting up the wind-farm and creation of a knowledge centre in the country.

FOWPI will be led by COWI A/S (Denmark) with key support from WindDForce Management Ltd. (India). The project is supported by European Union (EU), Ministry of New and Renewable Energy- India (MNRE) and National Institute of Wind Energy- India (NIWE).

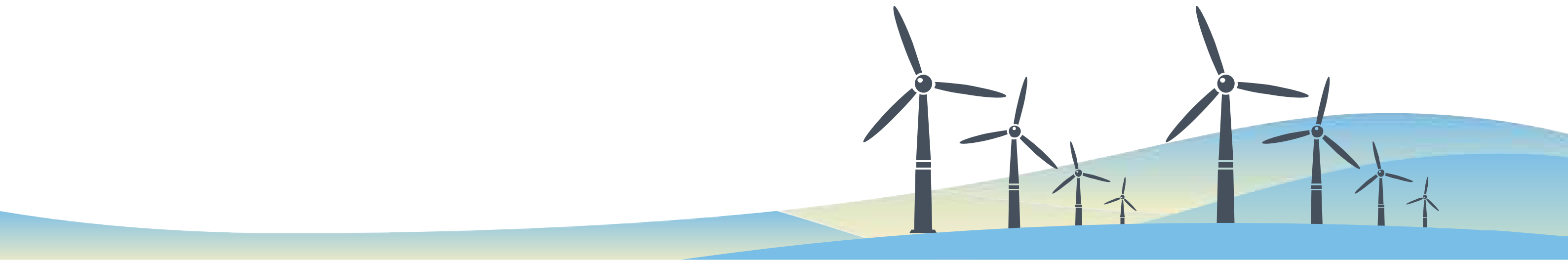
Project is awarded under the Indo-European co-operation on Renewable Energy Program and funded through European Union.

FOWPI will focus on finalisation of design and technical specification of the windfarm including foundation, electrical network, turbines etc.. This will also include undertaking specific technical studies for the selected site (based on the outcome of FOWIND project), including coastal surveys, environmental assessments, cost-benefit analysis, transmission layouts, monitoring systems, safety measures, and other relevant technical studies as identified.

Contract: No 2015/368469 Start 01-2016 Duration: 42 months

2 Disclaimer

3 Copyright statements



4 Acknowledgements

FOWPI is grateful for the suypport provided by European Union (EU), Ministry of New and Renewable Energy-India (MNRE), National Institute of Wind Energy- India (NIWE), and the Wind Industry.

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Metocean Study

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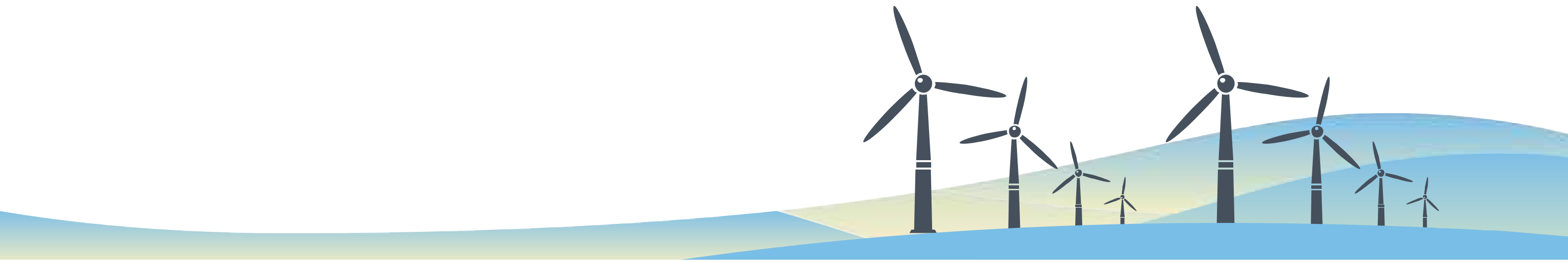

SEPTEMBER 2017
NIWE

FOWPI – METOCEAN STUDY

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FOWPI – METOCEAN STUDY

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CONTENTS

APPENDICES

1 Introduction

This document has been prepared with the purpose of providing preliminary metocean data to be used as basis for preliminary foundation design at the FOWPI Offshore Wind Farm area in Gujarat, India. This document has been prepared by COWI on behalf of NIWE with the purpose to be used by NIWE for call for tenders for supply of a 200 MW offshore windfarm on a Build-Own-Operate basis.

India has one of the fastest growing economies in the world and has an increasing energy demand, which is expected to double in 2020 compared to the present demand. The Clean Energy Corporation Initiative has the purpose to assist India to meet the future energy demand by utilising sustainable energy generation technologies and to introduce energy efficiency measures.

India has already introduced renewable energy in the energy supply system and has installed various renewable energy technologies during recent years. Wind energy plays an important role with approximately 23 GW onshore wind power capacity installed.

Offshore wind energy has become an important factor in the countries in Europe with an installed total offshore wind farm capacity of 11GW at present. The offshore wind farm technology face a number of technical challenges due to the harsh installation and operation conditions. The construction cost for offshore wind farms were high for the first offshore wind farms but are for the new offshore projects in Europe decreasing. This has been achieved through lessons learned related to design issues and development of effective construction methodologies and cost effective O&M strategies.

The Indian engineering expert group of COWI in Chennai has developed a metocean model for the relevant marine area around the pilot plant site. This group has earlier developed similar models for 8 Danish offshore wind farm sites in cooperation with Danish staff.

The present preliminary metocean study is based on the requirements set up in IEC 61400-3 code of practise (Ref. /3/) as also required in Europe. This includes correlation between wind speed and wave height, currents and correlation or lack of correlation between various sets of data – as well as many other details requested by IEC 61400-3 (Ref. /3/).

Site-specific measurements of metocean data (wind, waves, current and water level) have not been made prior to the present study. Hence, measurements from a future campaign need to be considered for future validation and possible update of the data presented in this report.

The present metocean study will need to be updated for use in the detailed design of foundations and WTG once site specific measurements and surveys have been carried out. A 6-12 month continuous on-site measurement campaign with one or two wave and current recorders should be performed. Furthermore, detailed bathymetric and geophysical surveys should be carried out to support the detailed design and to resolve the wave transformation and flow pattern along the cable corridor and at the wind farm. The updated met-ocean study should also be based on a detailed wind study, as also required for WTG design or wind resource assessment.

2 Summary and recommendations

The results of a preliminary metocean study for the proposed Offshore Wind Farm (OWF) site, FOWPI, in the Gulf of Khambhat, India are presented in this report.

The operational data presented in the met-ocean study is based on a hindcast of hydrodynamic and wave conditions during a 5-year long period (2010-2014).

The extreme hydrodynamic and wave conditions in the area are governed by cyclones, which rarely hit directly on the considered site. A preliminary (and conservative) assessment of the hydrodynamic and wave conditions is given in this report based on historical cyclone tracks combined with extreme wind conditions.

The hydrodynamic modelling is accomplished by use of the MIKE 21 FMHD flow model while the wave conditions are made by use of the MIKE 21 SW model – both model developed by the Danish Hydraulic Institute.

Comprehensive validations of the established hydrodynamic and wave models are presented in the report.

Analyses of the hindcast time series and cyclone modelling data from a central position in the proposed OWF area are made in agreement with the requirements set up in IEC 61400-3 code of practise (Ref. /3/) as also required in Europe.

The data analyses comprise seasonal as well as directional statistics of governing parameters like significant wave height, wind, water level and current. Scatter tables and plots are given for a detailed description of operational metocean conditions and extreme value analyses are made for assessment of ultimate limit state design conditions.

Data for planning of marine operations like installation and maintenance are given in the form of weather windows and downtime. The latter data are presented in a separate report (Ref. /18/).

In order to update this preliminary metocean study report to a technical level usable for Detailed Design of foundations and WTG a series of on-site measurements of environmental data are needed. The measured data shall be used for validating the site-specific metocean conditions predicted by the numerical models at the actual wind farm site.

On-site measurements of wind, wave and hydrodynamic data (i.e. water level and current data) during a period covering the monsoon season as well as outside the monsoon season are needed.

The wave and hydrodynamic measurements can be carried out by means of a wave buoy with current-sensor or an ADCP placed at sea-bed while wind speed measurements e.g. can be made with a MEASNET calibrated first class cup anemometer. A 6-12 month continuous on-site measurement campaign (in agreement with governing standards) with one or two recorders should be performed.

As a minimum, the measurements shall provide the following data with a temporal resolution of no longer than one hour:

- Wind speed (10-minute average and gust) and direction
- Integral wave parameters (H_{m0}, T_p, T_{01}, T_{02})
- Mean wave direction (*MWD*)
- Water level
- Current speed and direction at a number of vertical bins over the water depth (preferably with a resolution of 1 m)

The following data may optionally also be measured:

- Directional spreading of waves
- Separation of wind sea and swell
- Wave spectrum
- Water temperature and salinity

Furthermore, detailed bathymetric and geophysical surveys should be carried out to support the detailed design and to resolve the wave transformation and flow pattern along the cable corridor and at the wind farm. The updated met-ocean study should also be based on a detailed wind study, as also required for WTG design or wind resource assessment.

Based on detailed bathymetric surveys the metocean study shall be updated to be used for detailed design using the actual and confirmed bathymetric conditions in and around the site.

3 References, abbreviations and definitions

3.1 References

3.1.1 Standards

Ref. /1/ Det Norske Veritas (DNV): Offshore Standard DNV-OS-J101: Design of Offshore Wind Turbine Structures. May 2014

Ref. /2/ Det Norske Veritas (DNV): Recommended Practice DNV-RP-C205: Environmental Conditions and Environmental Loads. April 2014

Ref. /3/ IEC 61400-3:2009: Wind turbines - Part 3: Design requirements for offshore wind turbines

3.1.2 References – Public

Ref. /4/ http://www.dhigroup.com/mikebydhi

Ref. /5/ https://www.mikepoweredbydhi.com/products/mike-c-map

Ref. /6/ MIKE 21 & MIKE 3 Flow Model FM. Hydrodynamic Module. Short Description. MIKE by DHI

Ref. /7/ MIKE CMAP digitized bathymetry data, DHI, Denmark

Ref. /8/ M21 Tools, Tidal; User Guide by DHI 2016

Ref. /9/ http://polar.ncep.noaa.gov/waves/index2.shtml

Ref. /10/ http://www.ga.gov.au/scientific-topics/hazards/cyclone/capabilities/modelling/tcrm

Ref. /11/ UK Hydrographic Office (2010). Admiralty Tide Tables, Indian Ocean and South China Sea, Vol. 3, 2010 (NP 203-10)

Ref. /12/ UK Hydrographic Office (2016). Admiralty Sailing Directions. West Coast of India Pilot. N38, 18th Edition

Ref. /13/ Dee et al (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Quarterly Journal of the Royal Meteorological Society, 137: 553–597

Ref. /14/ ETOPO1 Global Relief Model, NOAA, https://www.ngdc.noaa.gov/mgg/global/global.html

Ref. /15/ Indian National Centre for Ocean Information Services (INCOIS), MoEF, Govt. of India (www.incois.gov.in)

Ref. /16/ MMAB Operational wave models, NOAA, http://polar.ncep.noaa.gov/waves/index2.shtml

Ref. /17/ COWI Project No. A073635-014: Gujarat. Cyclone Hindcasting Study. COWI. 31-10-2016

Ref. /18/ Gujarat – Weather Windows for Installation. Document No. A073635-014-002. COWI January 2017

Ref. /19/ Critical Habitat Information System for Gulf of Khambhat – Gujarat. Government of India. Department of Coastal Development. May 2002

Ref. /20/ IPCC (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

3.2 Abbreviations

The main abbreviations and symbols used in the present report are listed below.

a	Scale parameter of the Weibull Distribution [-]
b	Shape parameter of the Weibull Distribution [-]
CD	Chart Datum
DHI	Danish Hydraulic Institute
DNV	Det Norske Veritas
ECMWF	European Centre for Medium-Range Weather Forecasts
ERA	ECMWF Re-analysis
ESS	Extreme Sea State
EVA	Extreme value analysis

FOWPI	First Offshore Wind Project in India
HAT	Highest Astronomical Tide [m]
H_{m0}	Significant wave height [m]
H_{max}	Maximum wave height [m]
HSWH	Severe wave height [m]
Hub	Vertical level of RNA of MP [m]
IPCC	Intergovernmental Panel on Climate Change
LAT	Lowest Astronomical Tide [m]
MHHW	Mean Higher High Water [m]
MHLW	Mean Higher Low Water [m]
MHWN	Mean High Water Neap [m]
MHWS	Mean High Water Spring [m]
MLHW	Mean Lower High Water [m]
MLLW	Mean Lower Low Water [m]
MIKE Zero	Software package by DHI
MLLWS	Mean Lowest Low Water Springs [m]
MLWN	Mean Low Water Neap [m]
MLWS	Mean Low Water Spring [m]
MP	Monopile
MSL	Mean Sea Level [m]
MW	MegaWatt
MWD	Mean Wave Direction [deg]
NCEP	National Centres for Environmental Prediction
NSS	Normal Sea State
OWF	Offshore Wind Farm
POT	Peaks-over-Threshold
RNA	Rotor-Nacelle Assembly
SI	ISO International System of units
SLR	Sea Level Rise
SSS	Severe Sea State
SWL	Still water level
T	Wave period [s]
T_{01}	Mean wave period [s]
T_{02}	Zero-crossing wave period [s]
T_{Hmax}	Wave period associated with H_{max} [s]
T_p	Peak period of the sea state [s]
TP	Transition Piece
UTM	Universal Transverse Mercator, grid-based coordinate system
U(T,Z)	Wind Speed with average period T (in minutes) at a height Z (in m above MSL) [m/s]
U_{10}	Reference Wind Speed at 10 m above MSL [m/s]
WD	Wind Direction [deg]
WGS84	World Geodetic System, reference coordinate system
WL	Water Level [m]
WS	Wind Speed [m/s]
WTG	Wind Turbine Generator
γ	Location parameter of Weibull distribution
λ	Number of evets per year
θ	Wave direction [°]
η_{max}	Wave crest height associated with H_{max}

3.3 Definitions

The results from the present metocean report will mainly be used for the design of the substructure of an offshore Wind Turbine Generator (WTG), and for extraction of Weather Window data (Ref. /18/). In order to give an overview, the primary components of the entire structure (including foundation) is described briefly in this section. A definition sketch is shown in Figure 3.1.

In this report, Wind Turbine Generator (WTG) is understood as the Rotor-Nacelle Assembly (RNA) and WTG Tower, while the foundation is formed by the support structure below the WTG tower. For example, a monopile foundation is referred to as a foundation, WTG foundation or substructure.

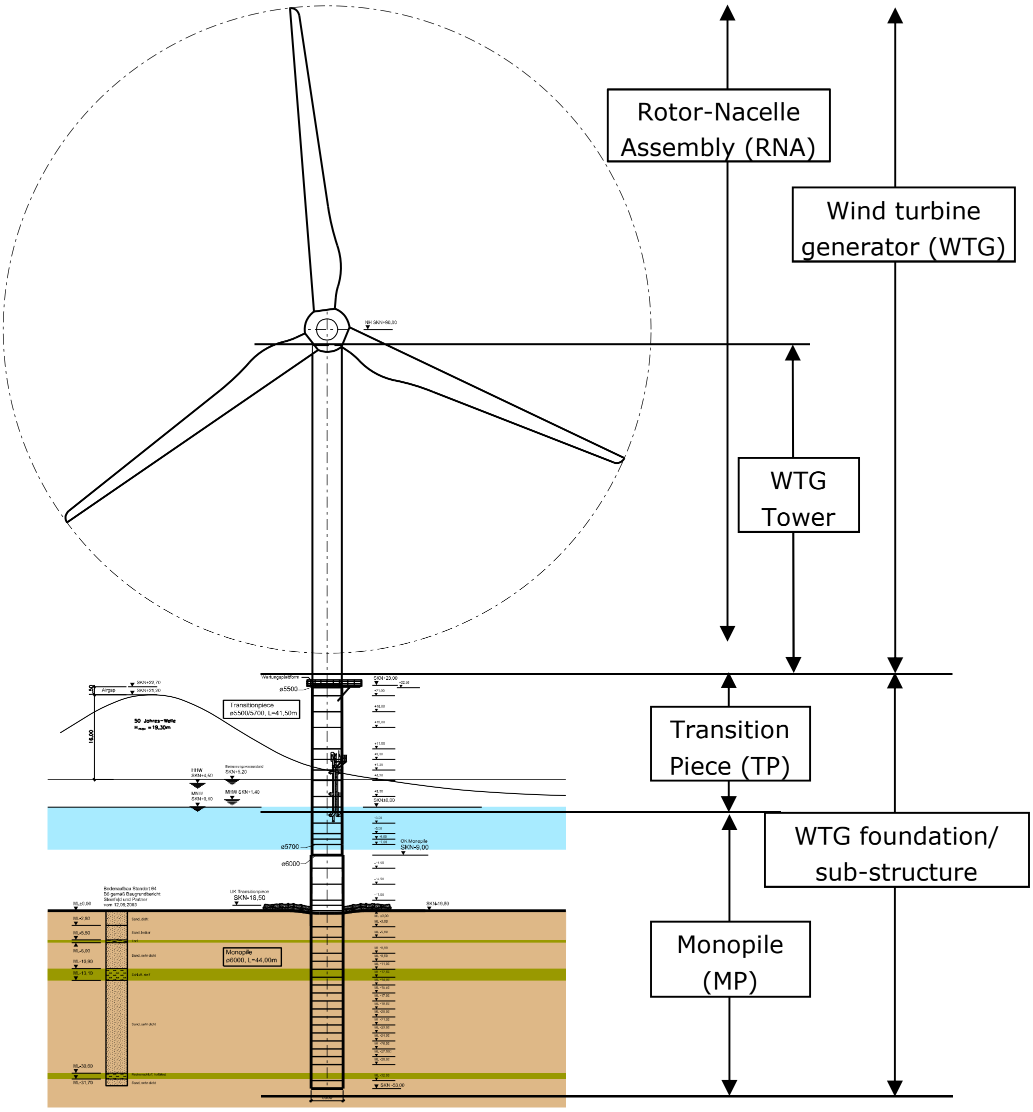


Figure 3.1 *Definition of offshore wind turbine primary components, e.g. monopile foundation.*

4 Data

4.1 Location

The location of the FOWPI site is in the Gulf of Khambhat in Gujarat region, which is located on the North West coast of India, as shown in Figure 4.1. The set-up of the FOWPI site is shown on the map in Figure 4.2 while the bathymetry in the local area (as extracted from MIKE C-Map, Ref. /5/) is shown in Figure 4.3.

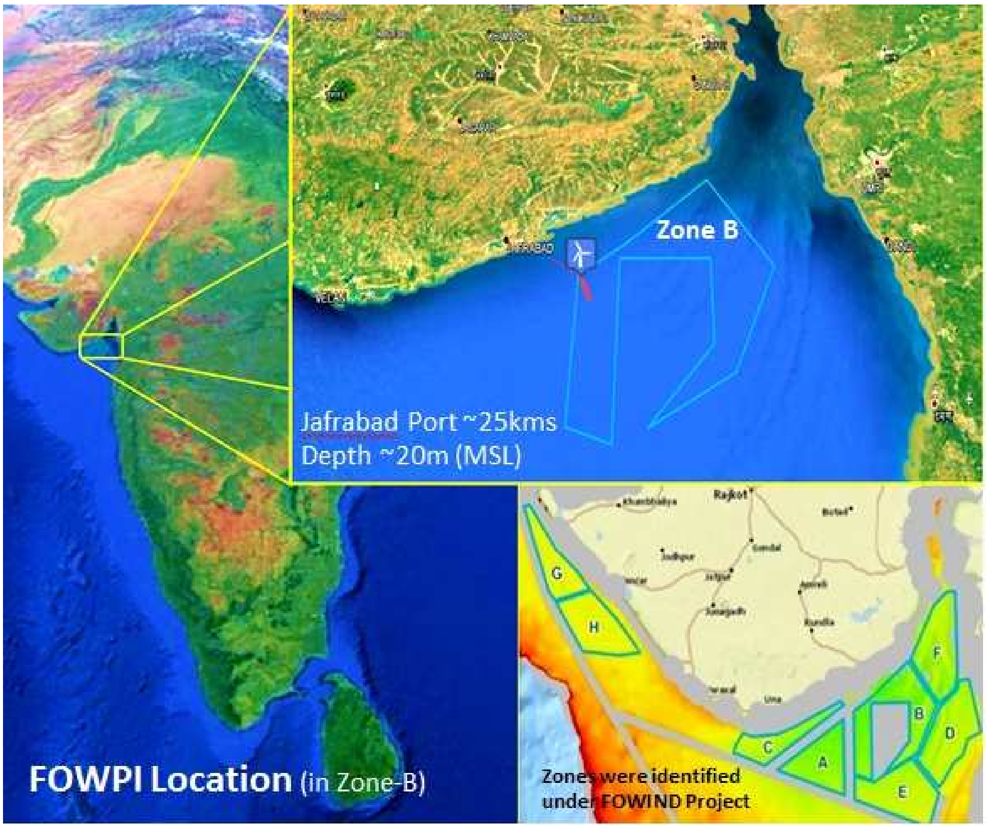


Figure 4.1 Location of FOWPI project in the Gujarat region of India

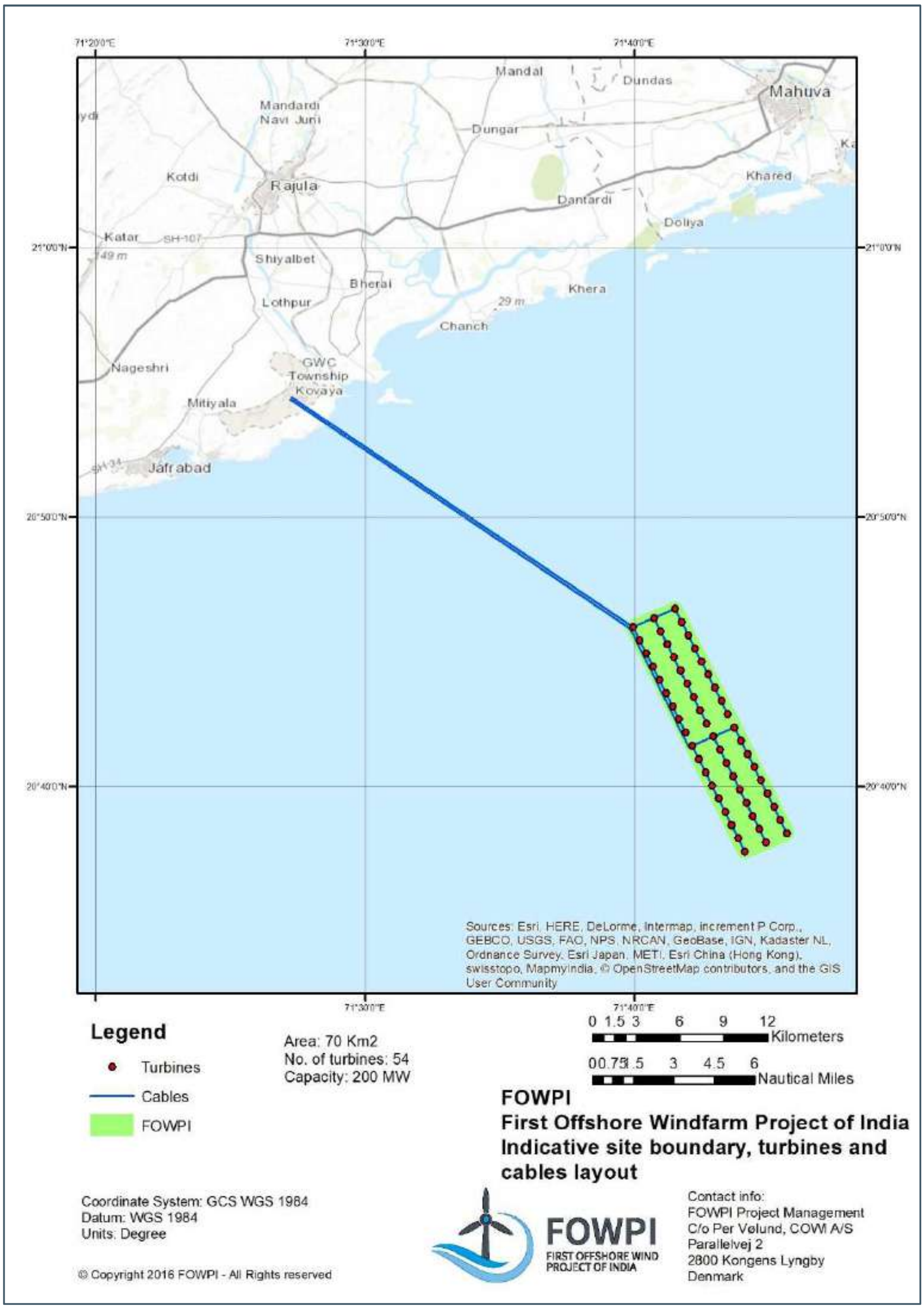


Figure 4.2 FOWPI. Indicative site boundary, turbines and cable layout.

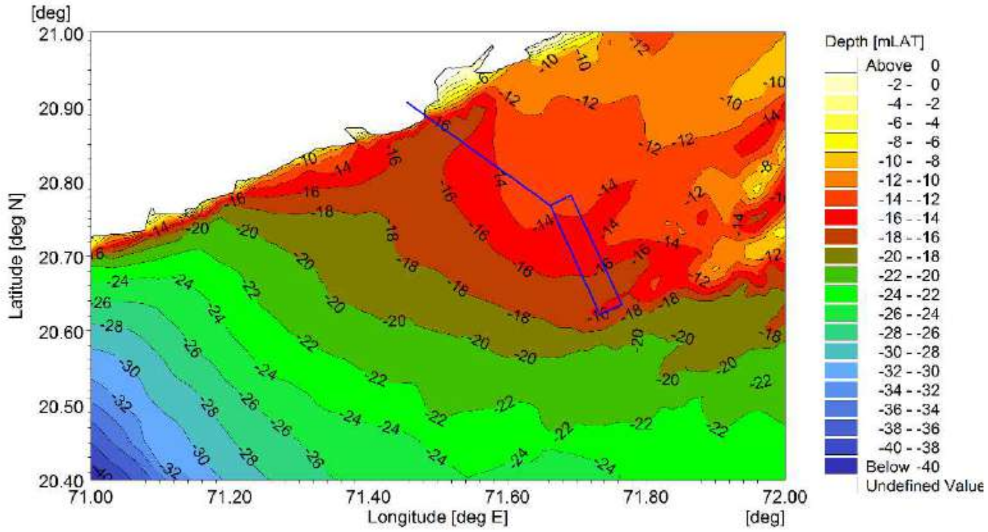


Figure 4.3 Bathymetry at FOWPI site. Indicative site boundary and cable corridor. Water depths are extracted from MIKE C-Map and are given with respect to CD

4.2 General Site Description

The following text is mainly an extract from Ref. /19/ and supplemented by information from Ref. /12/.

The Gulf of Khambhat is a south to north penetration of the Arabian Sea on the western shelf of India between the Saurashtra peninsula and mainland Gujarat. It is located approximately between latitude 20°30′ and 22°20′ N and longitude 71°45′ and 72°53′ E. At its northern end between the Sabarmati and Mahi mouths, the Gulf is barely 5 km wide and it opens out southwards like a funnel, reaching its maximum width south of Gopnath point. Along the north-south axis the Gulf has a length of approximately 115 km. It covers an extent of about 3,120 km^2 mainly of mudflats with some rocky (sandstone) intertidal area and a water volume of 62,400 million m^3. The rocky beaches are common from Mahuva to Gopnath, reducing towards Ghogha and Bhavnagar. A few sandy patches are also observed intermittently. The Gulf is intercepted by several inlets of sea and creeks formed by confluence of major rivers such as Narmada, Tapi, Mahi, Sabarmati, Shetrunji and many minor rivers. All the major rivers form estuaries and their inflow carries heavy loads of suspended sediments into the Gulf. A medium sized delta is present near Shetrunji between Gopnath and Ghogha. The ecosystems of the Gulf comprising mangroves, estuaries, creeks and vast intertidal mud flats are known to have rich biodiversity and a number of endemic flora and fauna.

In the interior of the Gulf, off Ghogha there is a small island viz. Piram Bet and further north there are large intertidal shoals which get exposed during low tide. A linear series of shallow banks at the Gulf mouth make navigation hazardous even for country crafts. The shoreline of the coast between Bhavnagar and Gopnath provides an assemblage of erosional and depositional features related to tectonic and eustatic factors resulting in gaining of land in between

Bhavnagar and Mahuva. Rapid development and heavy industrialisation on the coastline of the Gulf has resulted in the degradation of the environment and decline in biodiversity.

The Gulf receives rains during the southwest monsoon (from June to September), the average annual rainfall varies from 600 mm on the western side to 800 mm on the eastern side. The Gulf has a positive water balance, mainly due to the high volume of river runoff. The relative humidity ranges between 65 and 86% thus offering semi-arid to sub-humid climatic conditions. Temperature in the Gulf is extreme, the lowest being 8.4°C during January and highest of 43.7°C during May.

The depth of the Gulf ranges from 18 to 27 m and is less than 20 m over most of its length. However, the depth at the head is as low as 5 m and in the channel on the eastern side of the Piram Bet it is about 50 m. The tides are of mixed semi-diurnal type, with large diurnal inequality and varying amplitude, which decrease from north to south. Because of its unique position (nearness to the Tropic of Cancer), Gujarat coast experiences very high tides; the highest anywhere along the Indian coast. Because of the funnel shape and the semi-enclosed nature at the head, the tidal height is amplified in the upper part of the Gulf. The mean tidal range during spring is 4.7 m at Mahuva Bandar, which rises to 6.5 m at Gopnath Point and 10.2 m at Bhavnagar. The maximum spring tide recorded at Bhavnagar is 12.5 m, which is second only to that of the highest tide recorded anywhere in the world (around 17 m at the Bay of Fundy on Newfoundland coast of Canada).

Long-shore currents dominate the open coasts at Gujarat facing the Arabian Sea. However, due to exceptionally strong flood and ebb tides, powerful tidal currents with a speed of 3 to 4 knots dominate the flow. Maximum velocities of 6 knots associated with high wave energy occur during mid-tide. Currents in the Gulf, though tidal, are monsoonal in origin and dominated by barotropic tides. The flow adjusts its directional orientation with the changing direction of wind effected by changing seasons of the year. The turnover residence times are quite short because of its shallow depth, large tidal amplitude and strong tidal current.

4.3 Bathymetry and tidal data

The bathymetry used for the simulation models is based on MIKE C-Map which is a digital sea chart including all depth and land boundary data as given in nautical sea charts (see Ref. /5/).

The tidal data used for validation of the hydrodynamic simulation model are extracted from MIKE C-Map while the tidal boundary data along the model boundaries are extracted from the global tidal model by DHI (see Ref. /8/).

4.4 Wind data

Wind and barometric pressure from the ECMWF ERA-Interim reanalysis hindcast model are used to analyse the wind climate at the site. The ERA-Interim model is the latest global atmospheric reanalysis from the European Centre for Medium Range Weather Forecasts (ECMWF), Ref. /13/. The wind data is provided as 3-hourly spatially distributed wind velocity components (U and V) and barometric pressure. The spatial resolution of the data is 0.75 x 0.75 degree latitude/longitude (approximately 83km x 83km). A detailed description of the data can be found in Ref. /13/. The data are not of a quality acceptable for wind energy calculations.

4.5 Wave data

NOAA WAVEWATCH III wave hindcast (see Ref. /9/) data is used as boundary conditions for the wave simulation model. The NOAA wave data are partitioned into Wind Sea and Swell components, and both components are used as boundary conditions.

Buoy measurement data provided by the Indian National Centre for Ocean Information Services (INCOIS) is used for model calibration. Data is available from the buoys CB03 and SW02.

A map showing location of NOAA points, measurements and project site is given in Figure 6.6

4.6 Datum Information

The horizontal datum is chosen as WGS84/Universal Transverse Mercator (UTM) Zone 42N, whereas vertical datum is Mean Sea Level (MSL), which is +1.8m to Admiralty chart Datum (ACD) at Pipavav Bandar, Ref. /11/.

4.7 Software

For hindcast simulations, the MIKE software package by DHI has been used. The data analysis is accomplished by the MIKE Zero software package by DHI and COWI in-house time series analysis software. Further information regarding the DHI MIKE Zero software can be found in Ref. /4/.

5 Hydrodynamic modelling

Modelling of the hydrodynamic conditions in the area is performed with the hydrodynamic module of the MIKE 21 software package (MIKE 21 HDFM) (see Ref. /6/).

The modelling has been carried out to study the flow condition in the FOWPI OWF area located offshore of Pipavav Bandar, Gujarat. A detailed description of the bathymetry, input parameters, model setup and calibration of the model is given in the following sections.

5.1 Tidal levels at nearby ports

Accurate representation of the water level variation is of major importance when assessing the hydrodynamics of the study area. The proposed OWF site being at the entrance to Gulf of Khambhat is primarily influenced by astronomical tidal variations.

The proposed OWF area is situated approximately 25km and 31km to the southeast of Pipavav Bandar and Jafarabad port as shown in Figure 5.1 and geographic locations are given in Table 5.1. The tidal elevation at three ports (Pipavav Bandar, Jafarabad and Veraval) with respect to chart datum as provided in the Admiralty Tide Tables, Ref. /11/, is shown in Table 5.2.

Pipavav Bandar is relatively close to the proposed OWF site and has a higher tidal range than at Jafarabad. At Pipavav Bandar, the mean sea level (MSL) is +1.8 m above Admiralty Chart Datum (CD), and the mean higher high water (MHHW) is +3.2m above ACD.

The predicted tide (based on the Admiralty Tide Table constituents) with respect to mean sea level at Pipavav Bandar for a period of one month during July 2016 is presented in Figure 5.2. This shows that the spring and neap tide ranges during this period are 3.8m and 2m respectively.

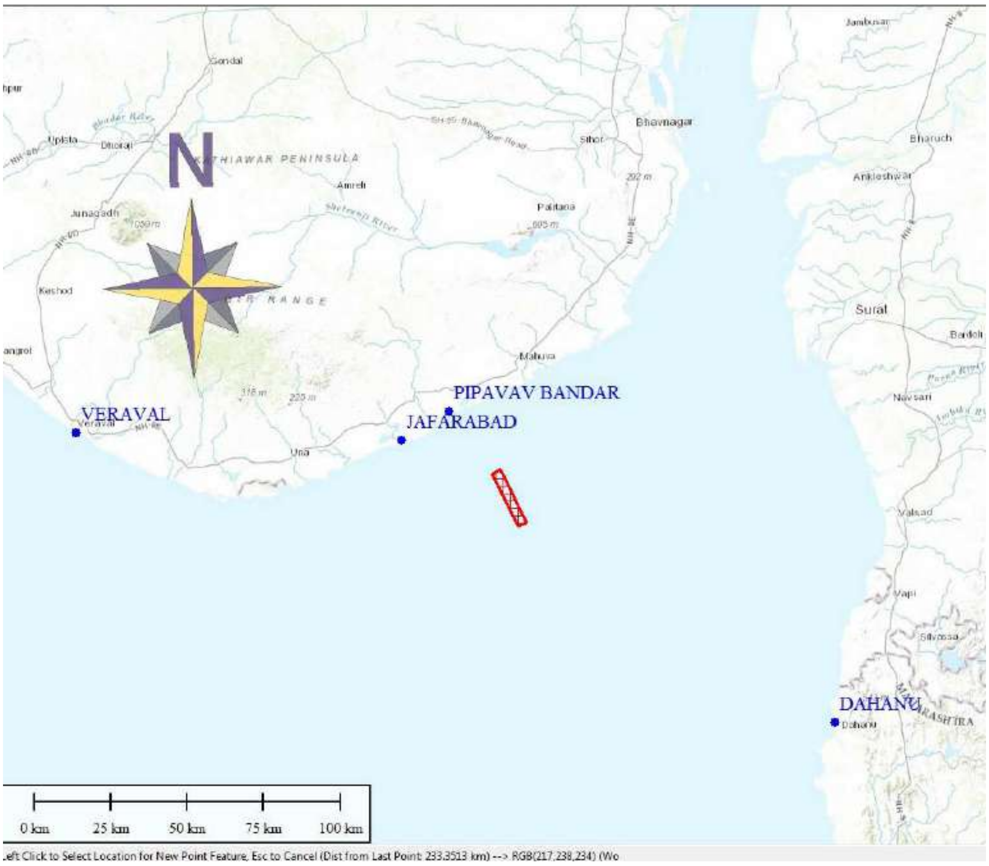


Figure 5.1 *Location of ports around the proposed OWF (Red rectangle) area in Gulf of Khambhat.*

Table 5.1 *Locations of ports surrounding the OWF area*

Ports	Longitude [°E]	Latitude [°N]
Pipavav Bandar	71.5	20.9
Jafarabad	71.3	20.9
Veraval	70.3	20.9
Dahanu	72.7	20.0

Table 5.2 Tidal levels [mCD] at ports surrounding the OWF area (Ref. /11/)

	Abbreviation	Pipavav Bandar	Jafarabad	Veraval
Highest Astronomical Tide	HAT	+4.1	+3.9	+2.6
Mean Higher High Water	MHHW	+3.2	+2.8	+2.0
Mean Lower High Water	MLHW	+2.4	+2.2	+1.8
Mean Sea Level	MSL	+1.8	+1.9	+1.3
Mean Higher Low Water	MHLW	+1.2	+1.5	+1.1
Mean Lower Low Water	MLLW	+0.5	+0.9	+0.4

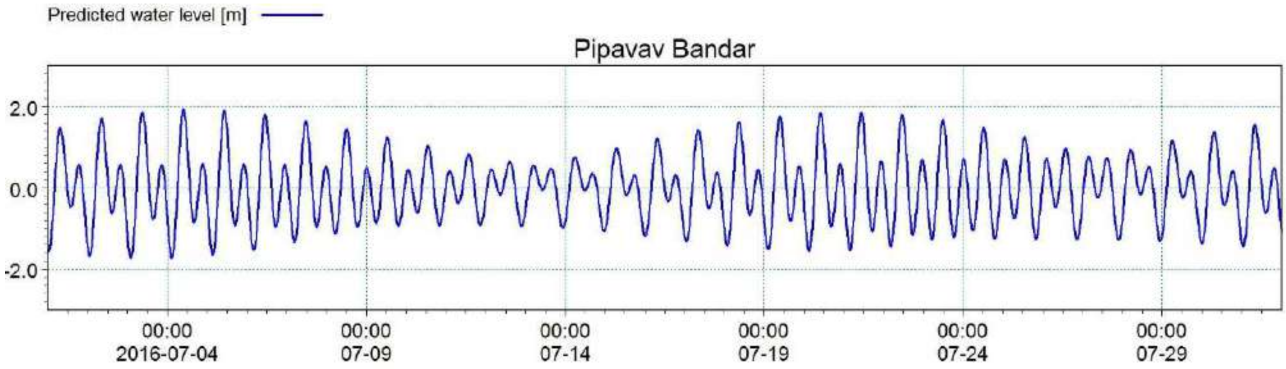


Figure 5.2 Predicted tidal elevation at Pipavav Bandar during July 2016.

5.2 Wind condition

Wind and pressure from the ECMWF ERA-Interim reanalysis hindcast model are used to analyse the wind climate at the site. The ERA-Interim model is the latest global atmospheric reanalysis from the European Centre for Medium Range Weather Forecasts (ECMWF), Ref. /13/. The wind data is provided as 3-hourly spatially distributed wind velocity components (U and V) and barometric pressure. The spatial resolution of the data is 0.75 x 0.75 degree latitude/longitude (approximately 83km x 83km). A detailed description of the data can be found in Ref. /13/. The data are not of a quality acceptable for wind energy calculations.

Figure 5.3 shows a typical scenario of spatially varying wind speed in the Arabian Sea during a southwest monsoon period.

The wind rose at a location in the proposed OWF during 5 year (2010-2014) period is shown in Figure 5.4. It is noticed that the predominant wind directions is from SW-WSW directions with frequent wind speeds of 3m/s to 8m/s which reach 12m/s during the southwest monsoon (May-August).

A secondary peak can be seen from N-NNE direction, which is due to prevailing northeast monsoon (November-February) but not as strong as the southwest monsoon.

In order to check the quality of ECMWF wind hindcast data, a comparison of wind speed was carried out between ECMWF and buoy at SW02 location (refer Table 6.1). The wind speed at SW02 buoy location was digitized manually from the available plots in the INCOIS website, Ref. /15/, as shown in Figure 5.5. Figure 5.6 shows the comparison of wind speed between ECMWF and buoy measurement, which is in good agreement.

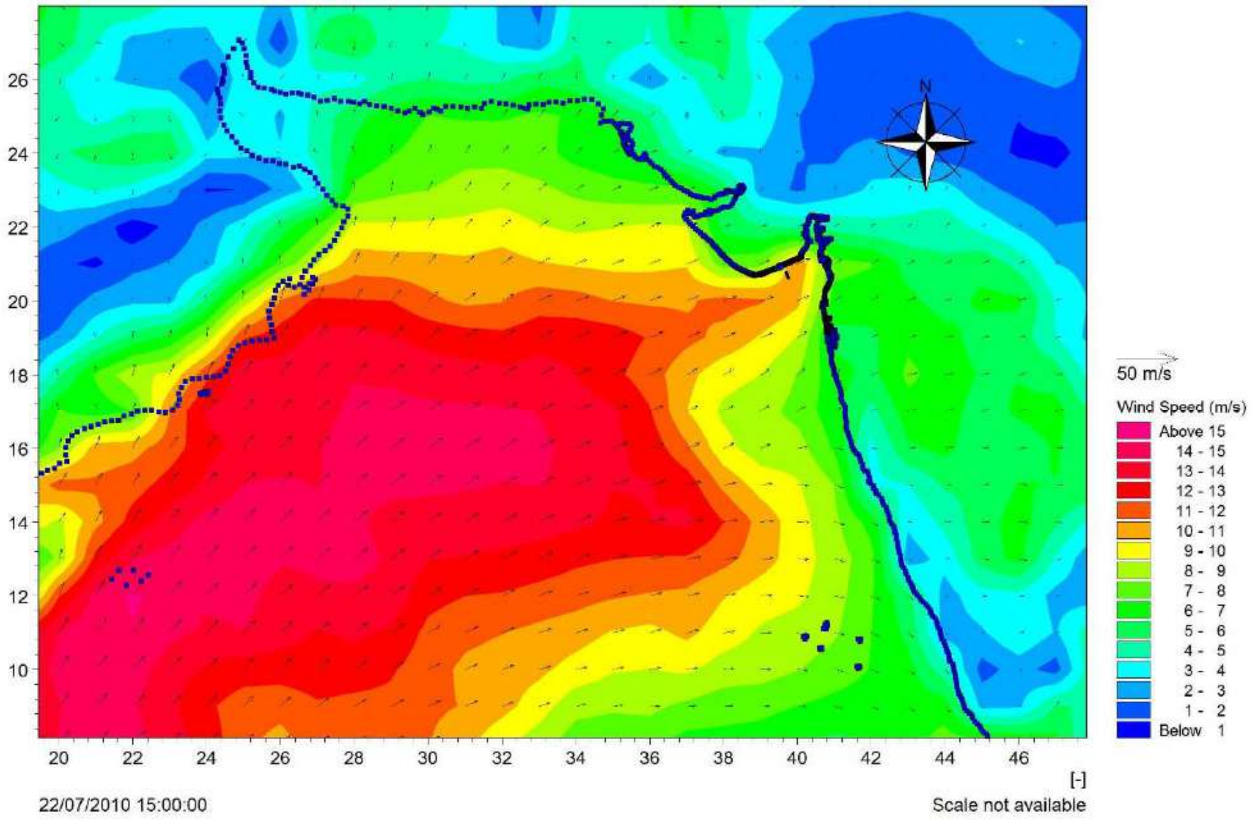


Figure 5.3 Spatially varying wind in Arabian Sea from ECMWF database during the month of July 2010 during south-west monsoon period; Blue dots are representing coastline.

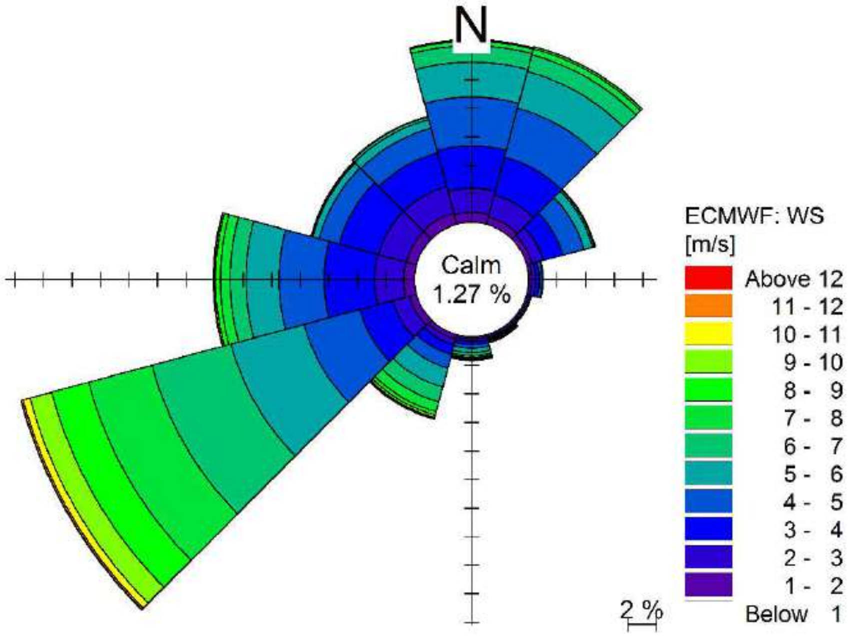


Figure 5.4 *Wind characteristics at the proposed OWF during 5 years period (2010-2014) obtained from ECMWF database. Wind speed is 3-hourly average at a height of 10m above MSL.*

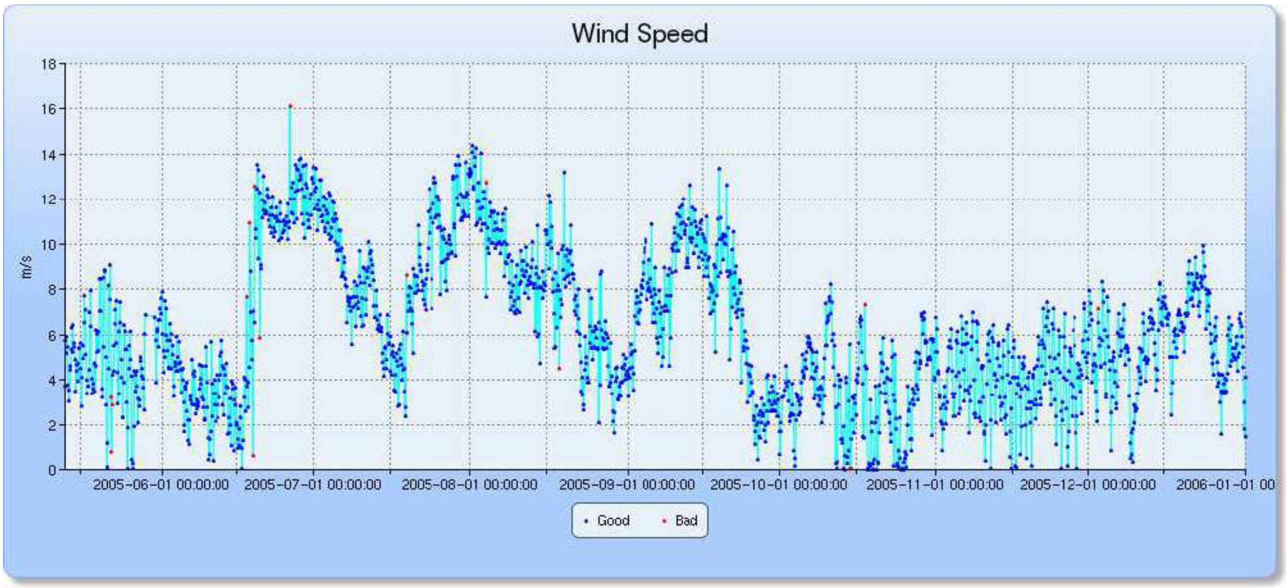


Figure 5.5 *Plot showing wind speed characteristics at SW02 buoy location obtained from INCOIS website, Ref. /15/*

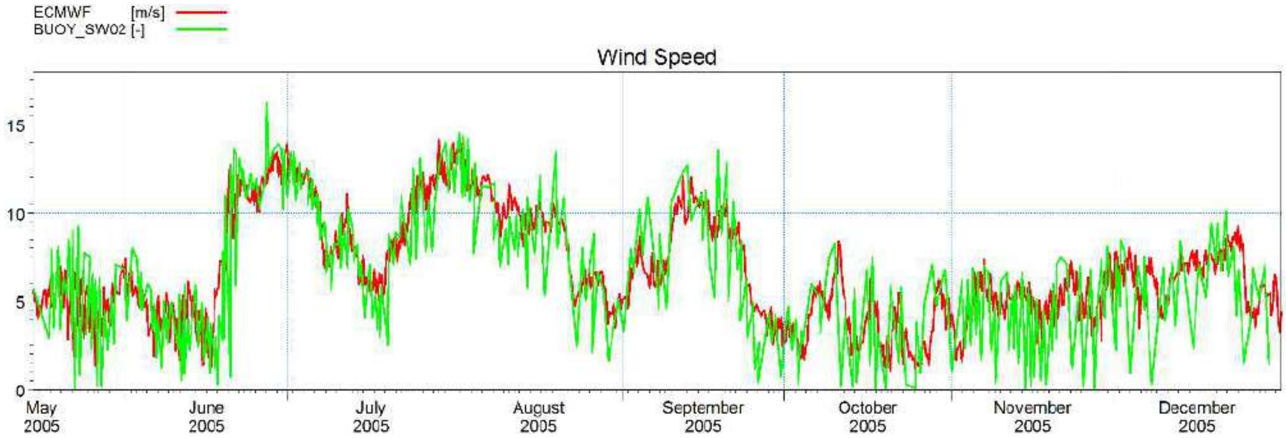


Figure 5.6 Comparison of wind speed between SW02 buoy (manually digitized from Figure 5.5) and ECMWF database during May-December 2005

5.3 Numerical Model (MIKE 21 HDFM)

The numerical flow model applied in the present study is the MIKE 21 HDFM (Hydrodynamic Flexible Mesh) module of the comprehensive 2-dimensional MIKE 21 modelling system from DHI, Denmark (see Ref. /4/). MIKE 21 HDFM is a modelling system for 2D free-surface flows. It can be applied to a wide range of hydraulic and related phenomena. This includes modelling of tidal hydraulics, wind and wave generated currents, storm surges and flood waves. The HDFM module is the basic module of the system and is used in the simulation of hydraulics and related phenomena in lakes, estuaries, bays, coastal areas and seas where the flexibility inherited in the unstructured meshes can be utilized.

The applied MIKE 21 HDFM model requires the following main input for flow simulations:

- Bathymetry of the area
- Hydrographic boundary conditions (water levels or fluxes)
- Wind and/or barometric pressure of the area
- Eddy Viscosity and Bed Resistance (Manning number)

5.4 Bathymetry

The hydrodynamic model domain is created using an unstructured flexible mesh approach, whereby the domain is divided into several zones, in which the resolution becomes progressively higher near the proposed OWF location. The flexibility associated with the triangular elements in the mesh also allows for a smoother representation of land/water boundaries.

MIKE CMAP, Ref. /7/ and ETOPO-2, Ref. /14/ datasets have been used in this study to create the mesh bathymetry in the absence of bathymetry survey datasets. Figure 5.7 shows the bathymetry datasets used for generating the mesh bathymetry.

The spatial resolution of the computational mesh varies from an average element size of ~20 km in the offshore regions to a minimum of ~300 m inside the wind farm areas (see Figure 5.8 and Figure 5.9).

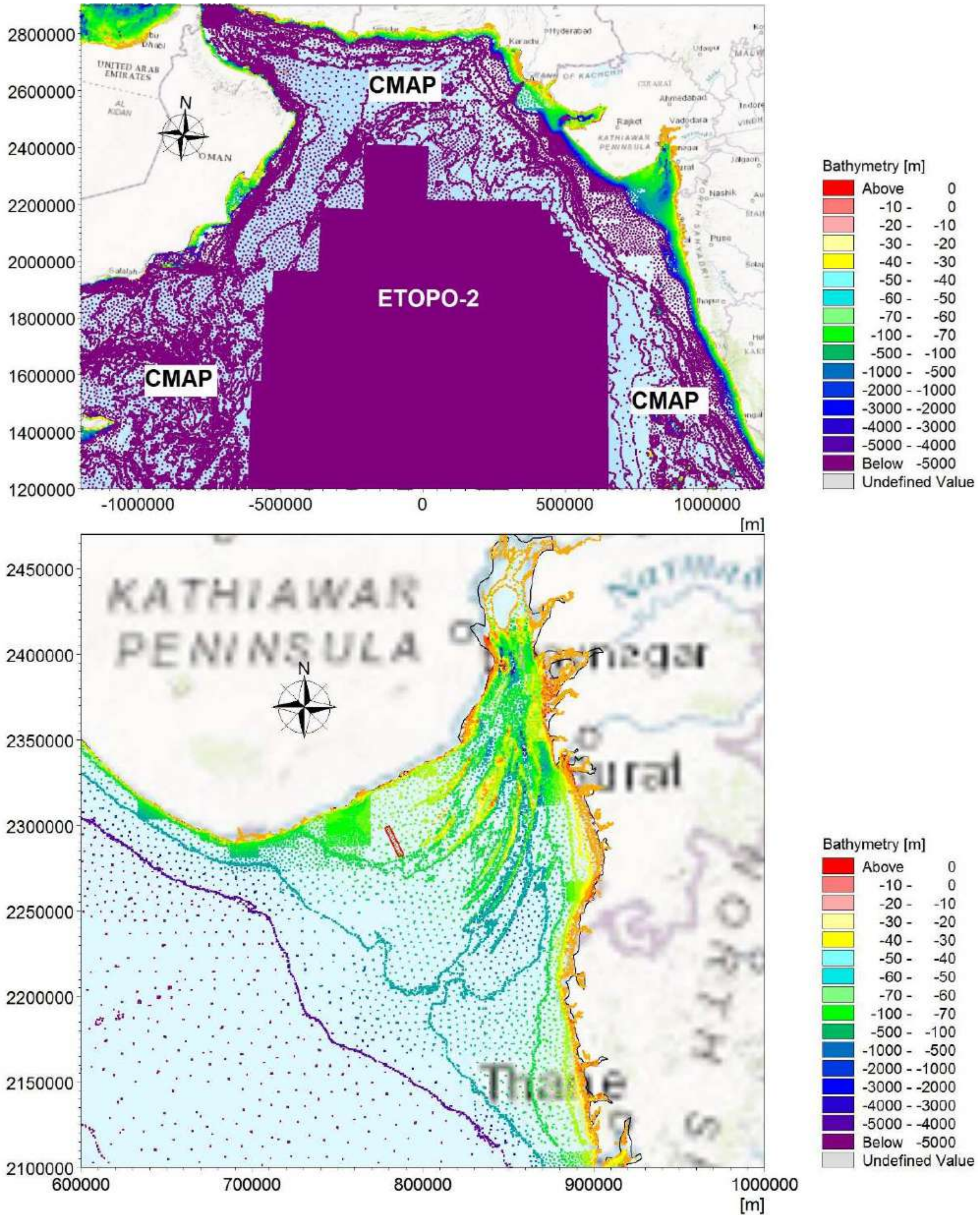


Figure 5.7 *CMAP and ETOPO-2 datasets used to derive the bathymetry; Overall (Top) and zoomed to site (Bottom).Red rectangle shows the proposed OWF location. Levels relative to MSL*

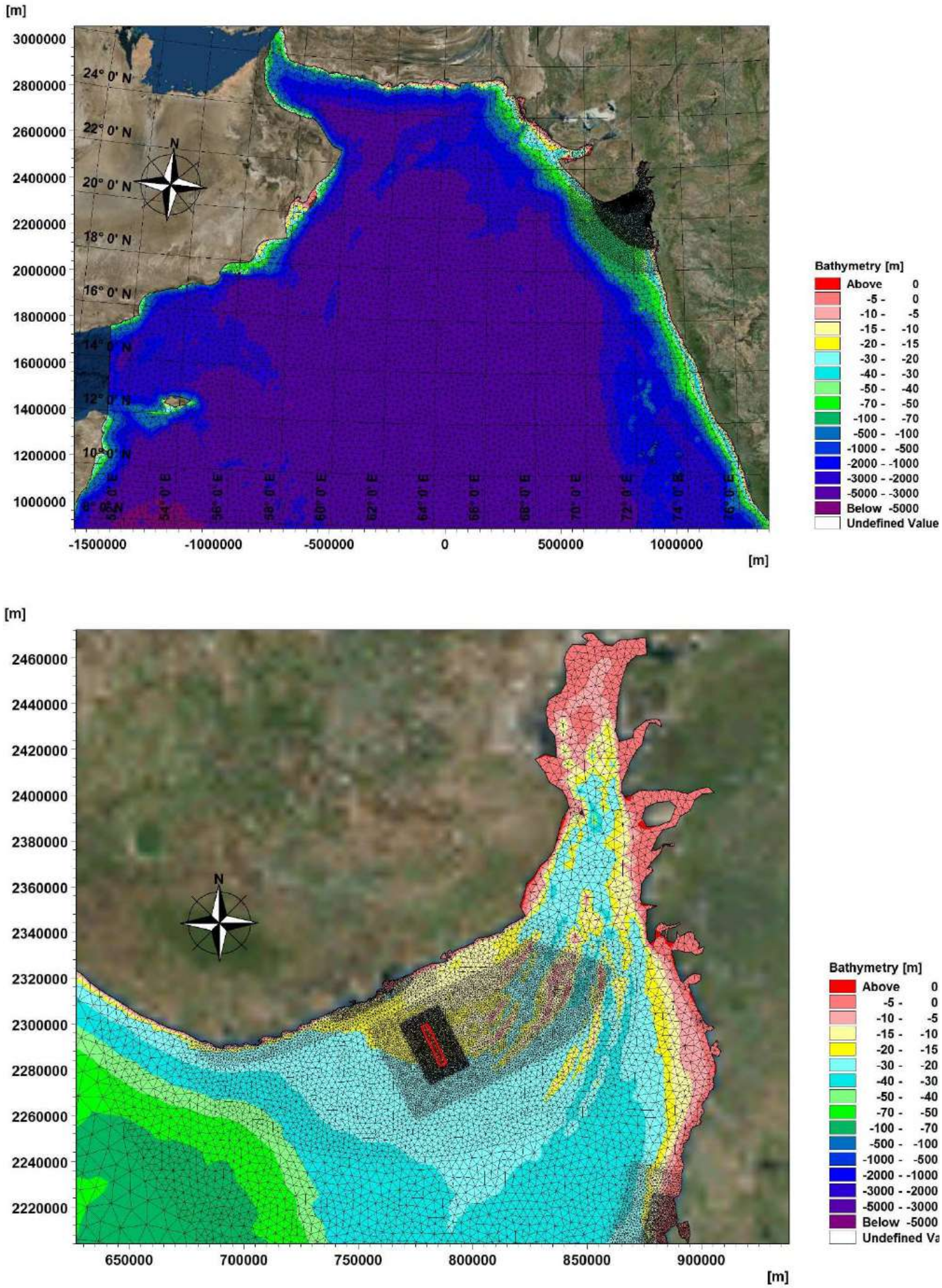


Figure 5.8 *Flexible mesh element bathymetry used for the Hydrodynamic modelling study; Overall (Top) and zoomed to site (Bottom). Red rectangle shows the proposed OWF location. Levels relative to MSL*

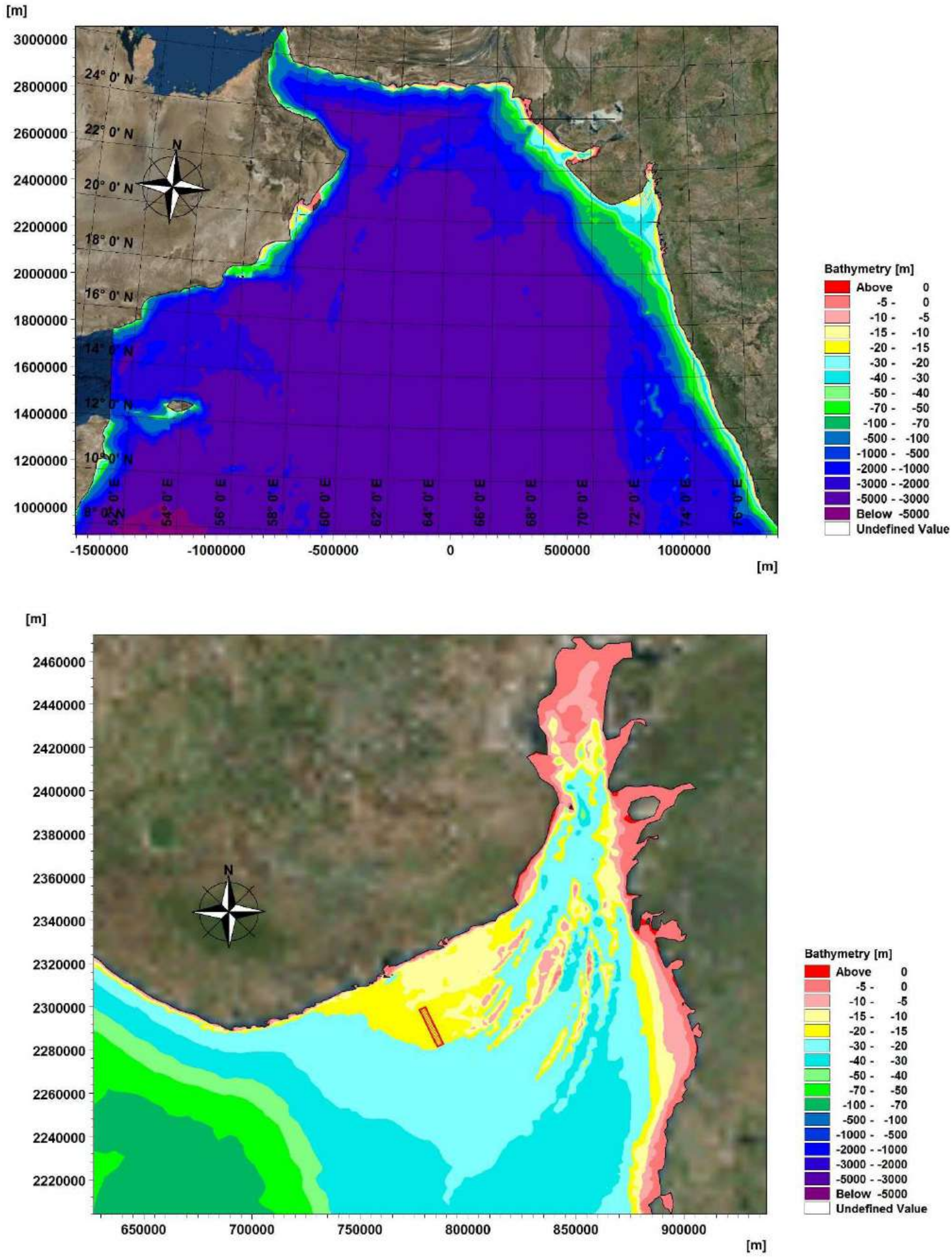


Figure 5.9 *Bathymetry (mMSL) used for the Hydrodynamic modelling study; Overall (Top) and zoomed to site (Bottom). Red rectangle shows the proposed OWF location. Levels relative to MSL*

5.4.1 Model input parameters

The main input parameters to the model consist of boundary conditions, eddy viscosity and bed resistance. Each of these parameters used for the HD simulations are described below.

5.4.2 Boundary conditions

The main input parameter for hydrodynamic model is the tidal elevations at five open boundaries (see Figure 5.10 and Figure 5.11), which is extracted from the global tidal prediction model provided by DHI, Denmark, Ref. /8/. It consists of eight tidal constituents (i.e. Principal lunar semidiurnal M2, Principal solar semidiurnal S2, Lunar diurnal K1, Lunar diurnal O1, Larger lunar elliptic semidiurnal N2, Solar diurnal P1, Lunisolar semidiurnal K2 and Larger lunar elliptic diurnal Q1) for the entire globe in 0.25 x 0.25 degree resolution. The output is time-varying surface elevation using these constituents.

Table 5.3 presents some of the major tidal constituents along the model boundaries.

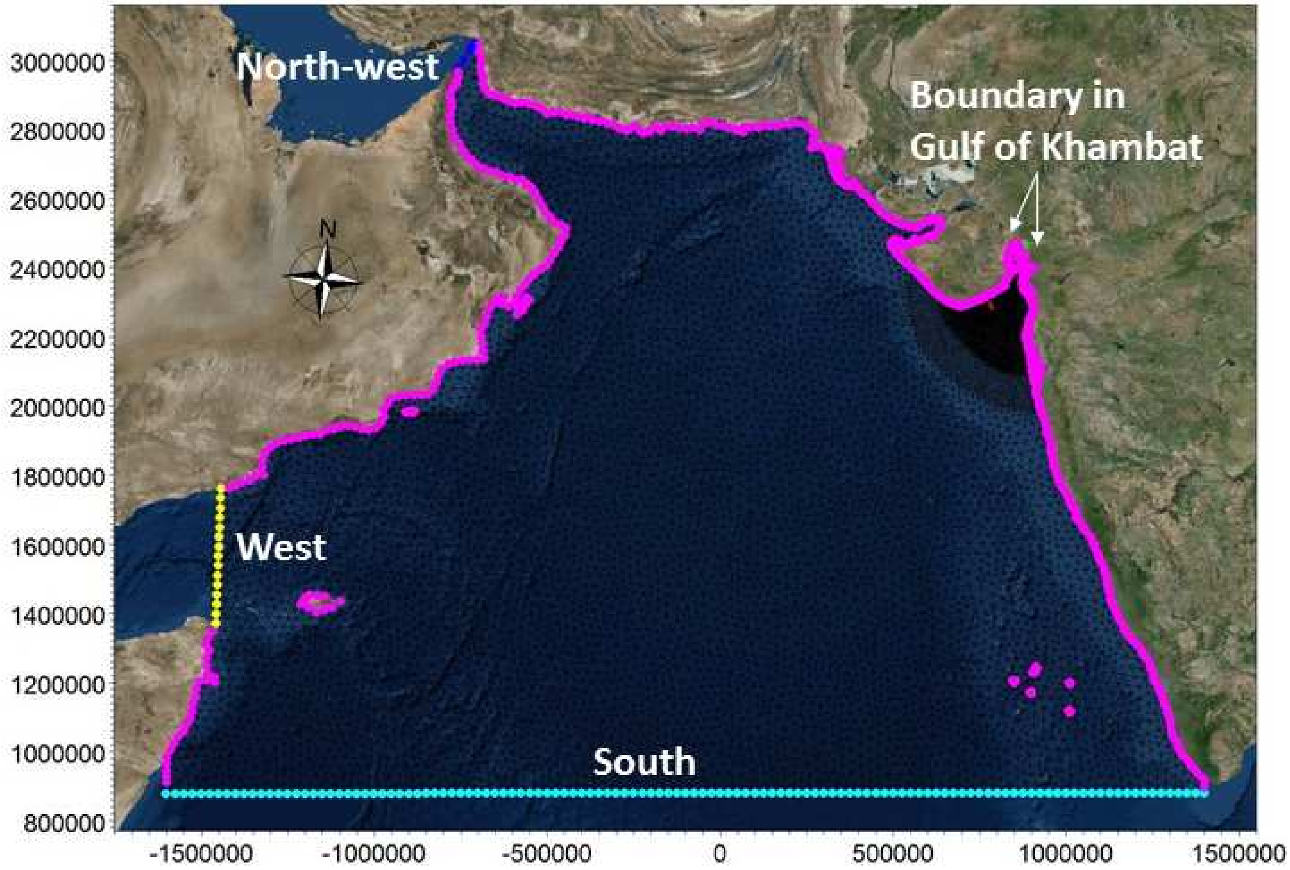


Figure 5.10 Five open boundaries used in the model

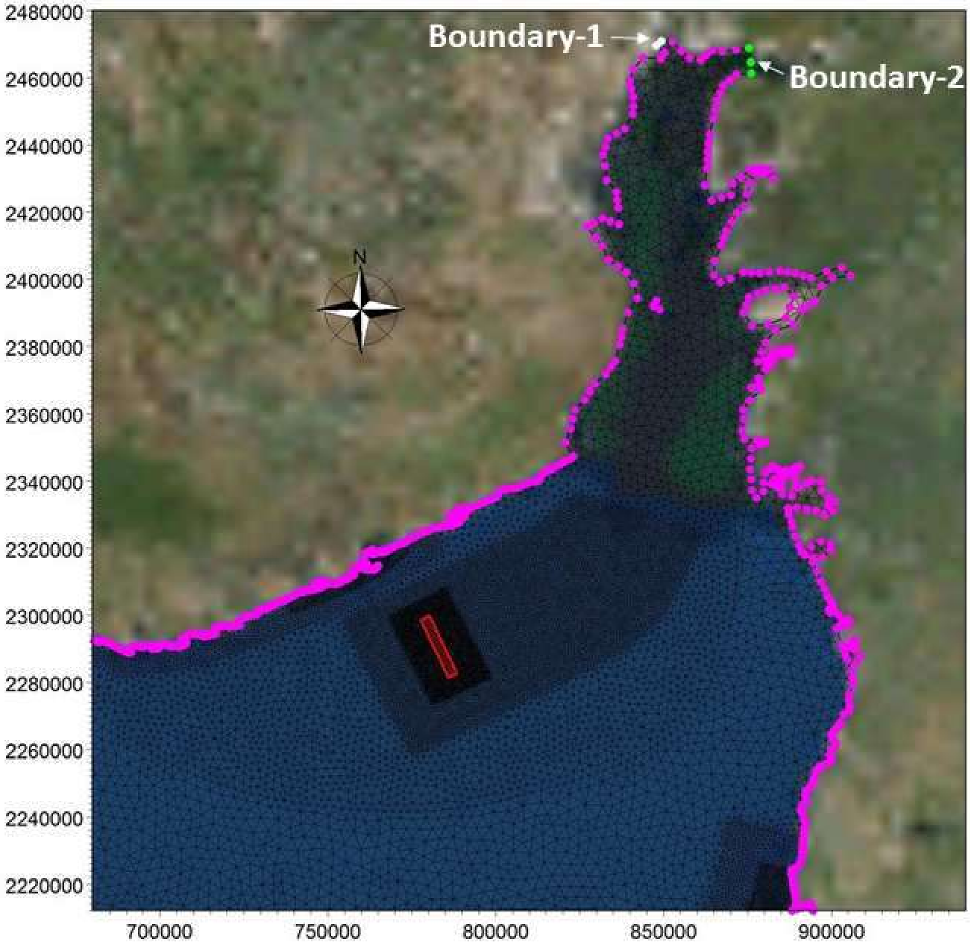


Figure 5.11 *Two open boundaries located northern most part of the Gulf of Khambhat used in the model. Red rectangle shows the proposed OWF location*

Table 5.3 *Tidal constituents along the model boundaries derived from Global tidal model, Ref. /8/*

Boundaries	Amplitude M2 [m]	Amplitude S2 [m]	Amplitude K1 [m]	Amplitude O1 [m]
South Boundary	0.15-0.27	0.07-0.12	0.13-0.31	0.06-0.15
West	0.30-0.33	0.15-0.16	0.37	0.17-0.19
North-West	0.81-0.88	0.31-0.33	0.29-0.34	0.21
Northern Gulf of Khambhat	2.27-2.38	0.82-0.88	0.49-0.51	0.18-0.19

5.4.3 Eddy viscosity and bed resistance

Eddy viscosity and bed resistance are important calibration parameters used in the hydrodynamic model. The bed resistance in the form of a Manning number map with values ranging from 55-70 m1/3/s was found during the calibration processs. Figure 5.12 shows the Manning map used in the simulations. A constant eddy viscosity based on the Smagorinsky formulation with a proportionality constant of 0.28 is used in the simulations. These are obtained based on the results from a series of simulations.

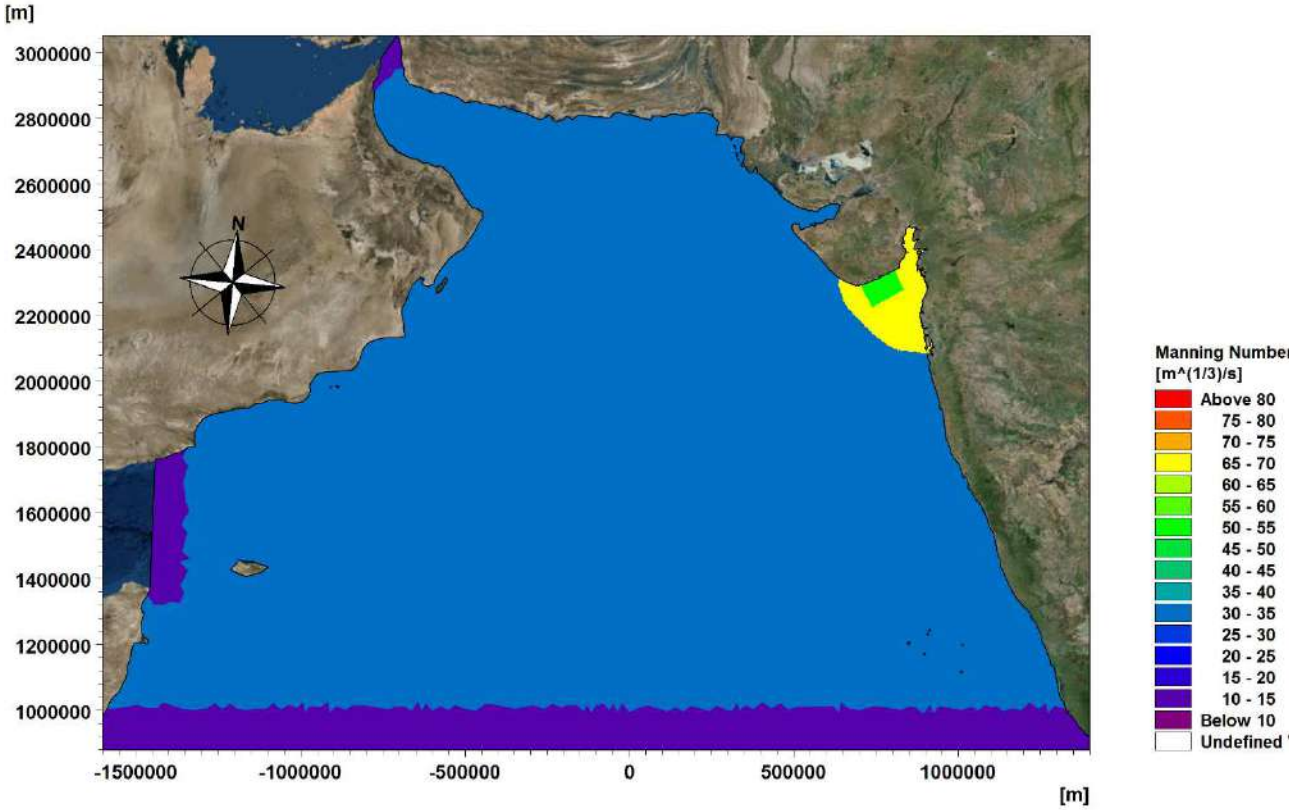


Figure 5.12 Manning Map used in the simulations.

5.5 Validation

The model simulations are carried out with the tidal elevations at five open boundaries and no wind forcing applied over the domain.

The hydrodynamic model has been validated at four port locations along the west coast of India close to the proposed OWF location. Figure 5.1 shows the location of four ports i.e. Veraval, Jafarabad, Pipavav Port and Dahanu (see Table 5.1). Hence, the simulated water levels have been compared with the predicted tidal elevations at these four locations using the harmonic constituents furnished in the Admiralty Tide Tables (Ref. /11/).

A number of simulations were carried out with varying values of bed resistance, so that the root mean square (RMS) differences between the predicted and simulated tidal elevations at these four locations are minimized.

It must be noted that the validation/calibration was done with focus on obtaining a good calibration along the shoreline close to the proposed OWF location. Therefore, the present calibrated model may not be accurate for other areas along the west coast of India.

In Figure 5.13 is shown time-series comparison between predicted and simulated surface elevations at four ports i.e. Veraval, Jafarabad, Pipavav Bandar and Dahanu (cf. Figure 5.1). It can be seen that the tidal levels simulated by model and predicted tide using harmonic constituents are compared well with each other.

Figure 5.14 and Figure 5.15 show a comparison of quantiles of the predicted and simulated water levels (i.e. Q-Q fit).

The Q-Q fit slope and intercept are found from a linear fit to the data quantiles in a least squares sense. The lower and uppermost quantiles are not included in the fit. A regression line slope different from one (1.0) may indicate a trend in the difference.

The following Quality Indices are determined for the hindcast and measured time series datasets:

- N: Number of synchronized data
- MEAN: Mean of each of the two datasets
- BIAS: Mean difference between two datasets
- AME: Mean of the absolute difference between two datasets
- RMSE: Root-mean-square of difference between two datasets
- SI: Scatter index (unbiased)
- CC: Correlation coefficient

The MEAN, BIAS, AME and RMSE are given as absolute values and relative (in percent) to the average of the measured data in the scatter plot.

The scatter index (SI) is a non-dimensional measure of the difference calculated as the unbiased root-mean-square difference relative to the mean absolute value of the observations. In open water, a SI below 0.2 is usually considered as a small difference (excellent agreement) for significant wave heights. In confined areas or during calm conditions, where mean significant wave heights are generally lower, a slightly higher SI may be acceptable.

The correlation coefficient (CC) is a non-dimensional measure reflecting the degree to which the variation of the first variable is reflected linearly in the variation of the second variable. A value close to 0 indicates very limited or no linear correlation between the two data sets, while a value close to 1 indicates a very high or perfect correlation. Typically, a CC above 0.9 is considered as a high correlation (good agreement) for wave heights.

The statistical parameters have been calculated at the four ports where the simulated and predicted water levels and are presented in Figure 5.14 and

Figure 5.15 and the values are presented in Table 5.4. Table 5.5 presents RMS error at four locations, i.e. Veraval is estimated to be 0.08m, which is 4% of the tidal range. Similarly, the RMS error at Jafarabad is 6%, Pipavav Bandar is 5% and Dahanu is 4% of the tidal range respectively. The correlation coefficient for Veraval is found to be 0.99, followed by 0.97 for Jafarabad and Pipavava Bandar and 0.98 for Dahanu.

It must be noted that the ports like Pipavav Bandar, Jafarabad and Dahanu are protected bays with shallower regions. Hence, RMS errors could have reduced if bathymetry survey at these areas were implemented while preparing the model bathymetry. However, this is not considered to be of any significance for the model simulation results.

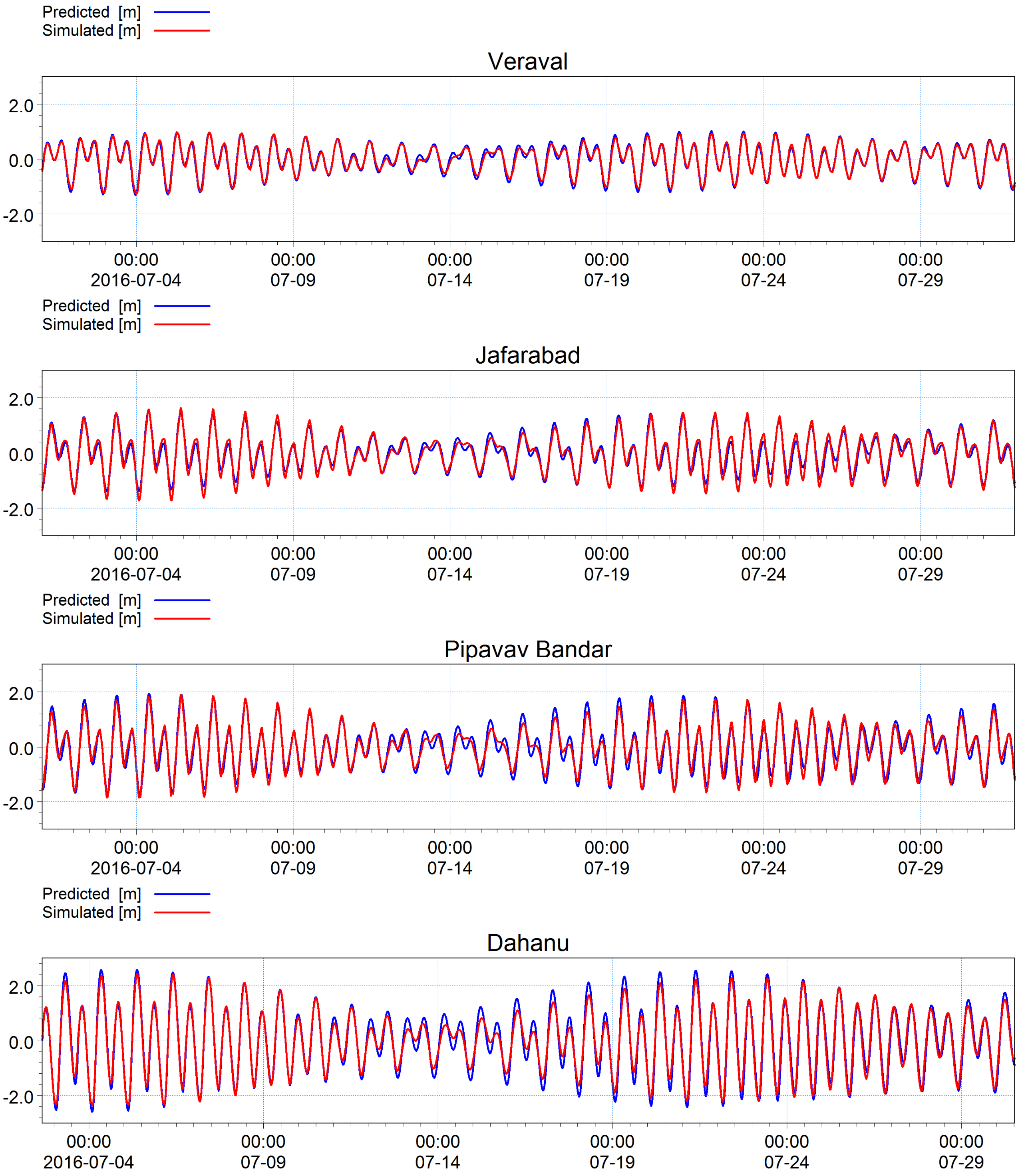


Figure 5.13 Comparison between predicted and simulated tidal elevations at four port locations during July 2016.

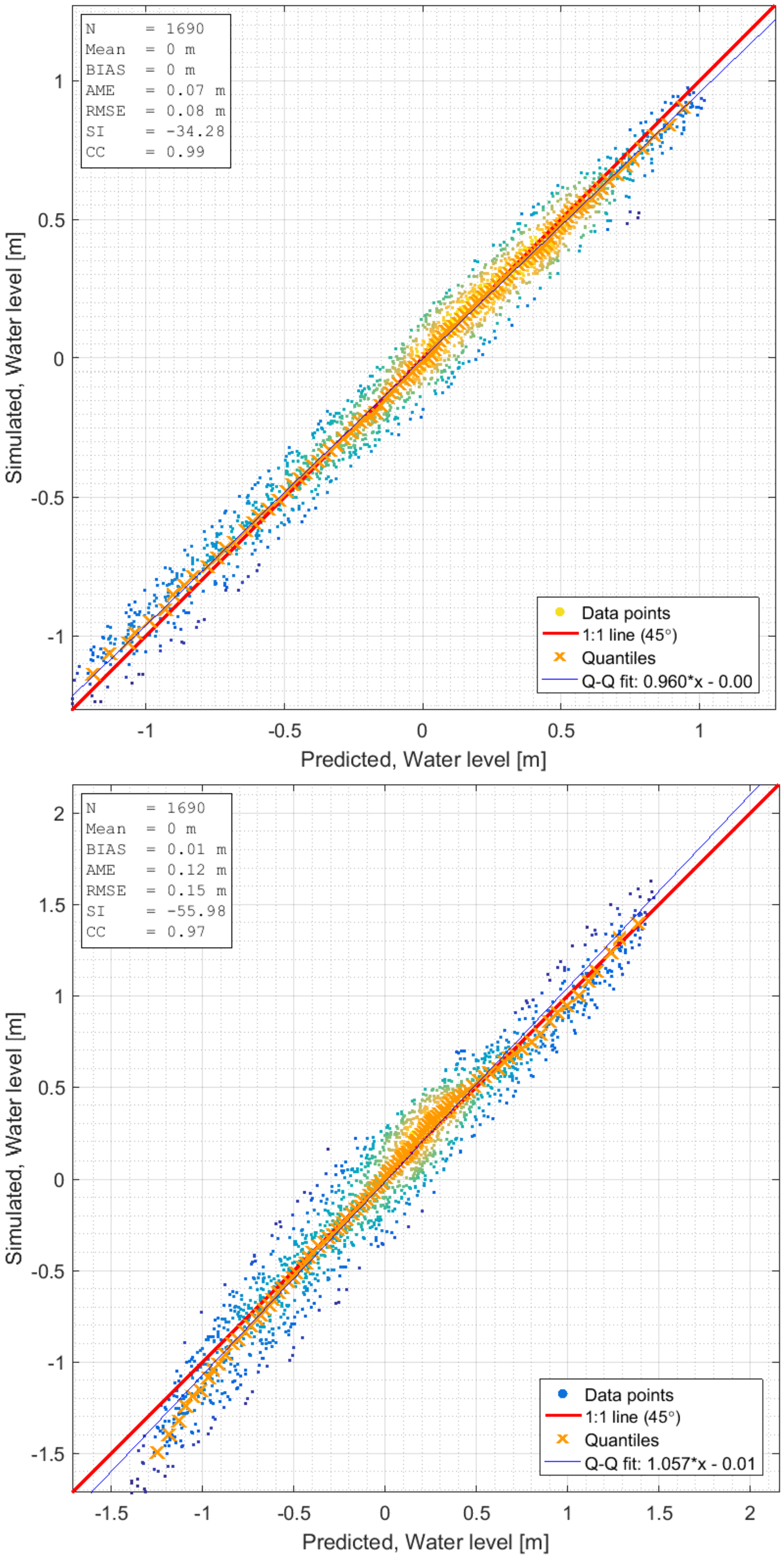
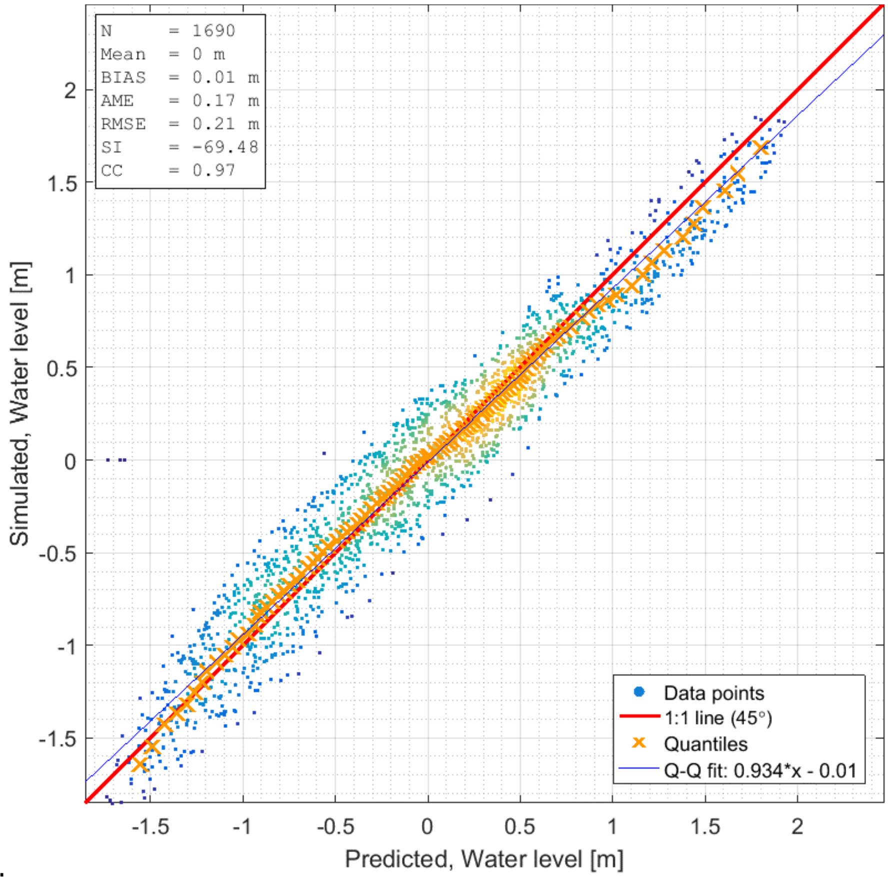


Figure 5.14 Scatter analysis showing the comparison between predicted and simulated water level at Veraval (Top) and Jafarabad (Bottom) for July 2016.



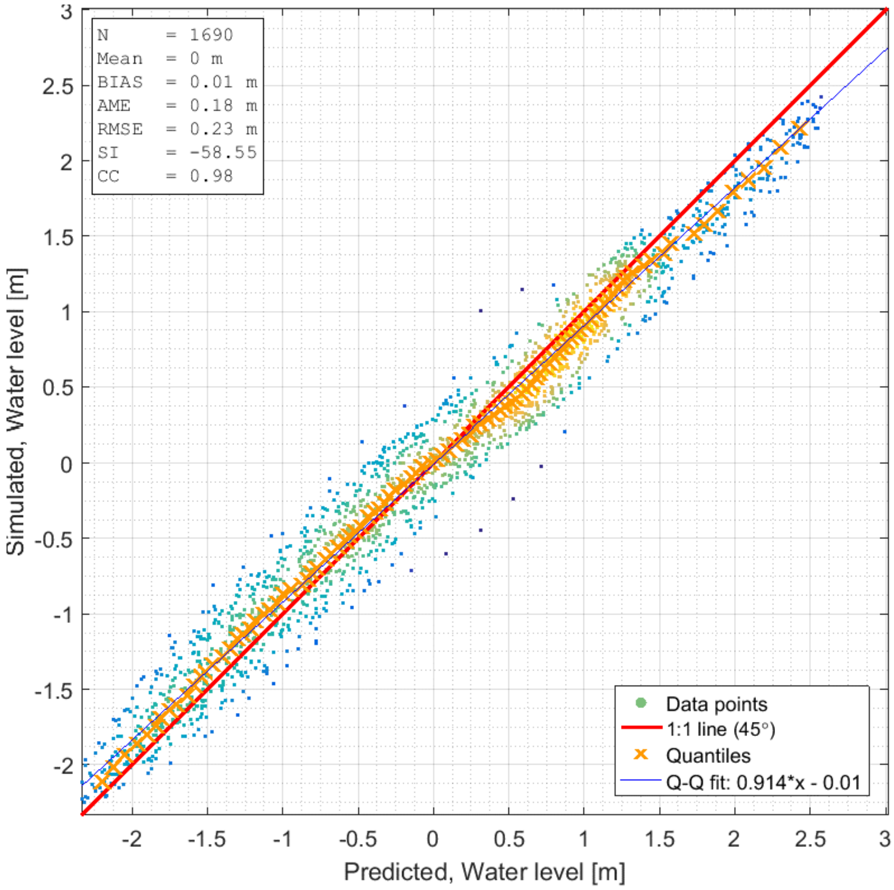


Figure 5.15 Scatter analysis showing the comparison between predicted and simulated water level at Pipavav Bandar (Top) and Dahanu (Bottom) for July 2016.

Table 5.4 Statistical analysis between predicted and simulated surface elevation at four locations

Port Location	No. of points, N	BIAS (m)	Average Mean Error, AME	RMSE (m)	Correlation coefficient, CC
Veraval	1690	0.00	0.07	0.08	0.99
Jafarabad	1690	0.01	0.12	0.15	0.97
Pipavav Bandar	1690	0.01	0.17	0.21	0.97
Dahanu	1690	0.01	0.18	0.23	0.98

Table 5.5 Root Mean Square Error (RMSE) between predicted and simulated surface elevation at four locations

Port Location	RMSE (m)	Tidal Range (Approx.)	RMSE (% of tidal range)
Veraval	0.08	2.2	4
Jafarabad	0.15	2.7	6
Pipavav Bandar	0.17	3.5	5
Dahanu	0.23	5.5	4

6 Wave Transformation Study

In order to derive the nearshore wave climate at the project site during normal wave conditions, a numerical wave model (MIKE 21 SW) has been setup. The following approach has been adopted.

- The model domain is chosen in such a way that its boundary will coincide with offshore NOAA points, Ref. /16/. The model domain consists of two boundaries i.e. West and South. Two NOAA points, one at the west boundary and another at south boundary is applied.
- The offshore NOAA hindcast wave data (windsea and swell parameters) are used to provide boundary conditions to the wave model.
- ECMWF varying wind field is used as forcing to the model.
- The spatially varying (2D) water levels of the MIKE 21 HD simulation is used in the wave model.
- Model results are calibrated using one month of wave measurements (significant wave height, mean wave period and peak wave direction) from two wave-rider buoys near the site, maintained by INCOIS (see Ref. /15/).
- The calibrated model is used to generate a five year continuous wave hindcast from 2010-2014 at the OWF.

A detailed description of the study is given below.

6.1 Wave measurements

In 1997, Department of Ocean Development (DOD), Govt. of India, established the National Data Buoy Programme (NDBP), unswerving to do systematic real-time meteorological and oceanographic observations to improve oceanographic services and predictive capability of short and long-term climatic changes.

In this context a number of buoys were deployed in both Bay of Bengal and Arabian Sea along the Indian coast ranging from deep water to shallow water.

Indian National Centre for Ocean Information Services (INCOIS), Govt. of India maintains the buoy database (see Ref. /15/).

These moored data buoys are floating platforms designed to carry a suit of sensors to measure meteorological and oceanographic parameters. The buoys are equipped with global positioning system, beacon light and satellite transceiver. The buoy data contains 3-hourly interval wave parameters.

For the present study, buoy data were procured at two locations from INCOIS as shown in Figure 6.1 and presented in Table 6.1. The following wave parameters are provided:

- Significant wave height, mean wave period, mean wave direction of total, windsea and swell waves
- Height of highest wave (total wave), H_{max} and wave period of the highest wave
- High frequency wave direction
- Peak wave period, zero crossing wave period, wave direction at spectral peak or Peak wave direction of the total wave.
- Directional spread at spectral peak
- Unidirectivity index (spectral bimodality index)

Table 6.1 Procured buoy data near the proposed OWF area

Buoy	Latitude/Longitude	Period
CB03	20.27802°N, 71.87767°E	19-05-2012 to 18-06-2012
SW02	16.95142°N, 71.11353°E	01-06-2008 to 01-07-2008

6.2 Offshore wave hindcast data (NOAA)

NOAA (see Ref. /16/) has been disseminating operational ocean wave predictions using the wave model WAVEWATCH III and operational NCEP products as input. The wave model suite consists of global and regional nested grids. The model result comprise of 3-hourly wave data (H_{m0}, T_p and direction of total, windsea and swell component).

For the present study, wave data at two offshore NOAA points were collected which will be used as boundary condition in the model, as shown in Figure 6.1.

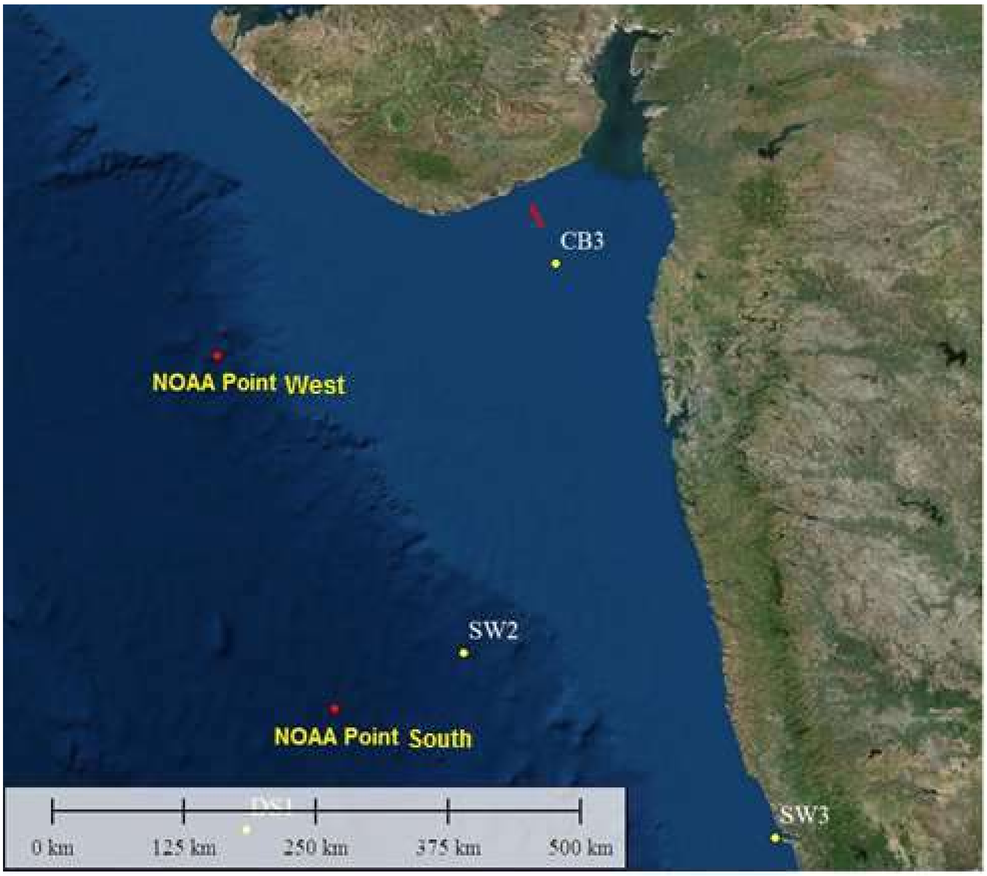


Figure 6.1 Wave rider buoys CB3, SW2 and SW3, selected NOAA hindcast points and project site (red) near the entrance to Gulf of Khambhat.

In order to check the reliability of boundary condition, NOAA hindcast wave data (South point) is compared with the nearest buoy (SW02) though it is 130km away. Figure 6.2 shows the comparison of rose diagrams of significant wave height of total, windsea and swell component between buoy SW02 and NOAA point south.

From the comparison of rose data of significant wave heights is seen that significant wave heights of NOAA data are higher than the SW02 buoy data for total and windsea component, whereas the NOAA data underestimates the swell component. The directional distribution fits well between NOAA data and SW02 buoy data for total and wind sea components. However, for the agreement of swell direction from NOAA and SW02 buoy data is not very good. The difference may be due to different methods applied for NOAA data and SW02 buoy data for separation of wind sea and swell. However, no further documentation has been found to justify this assumption.

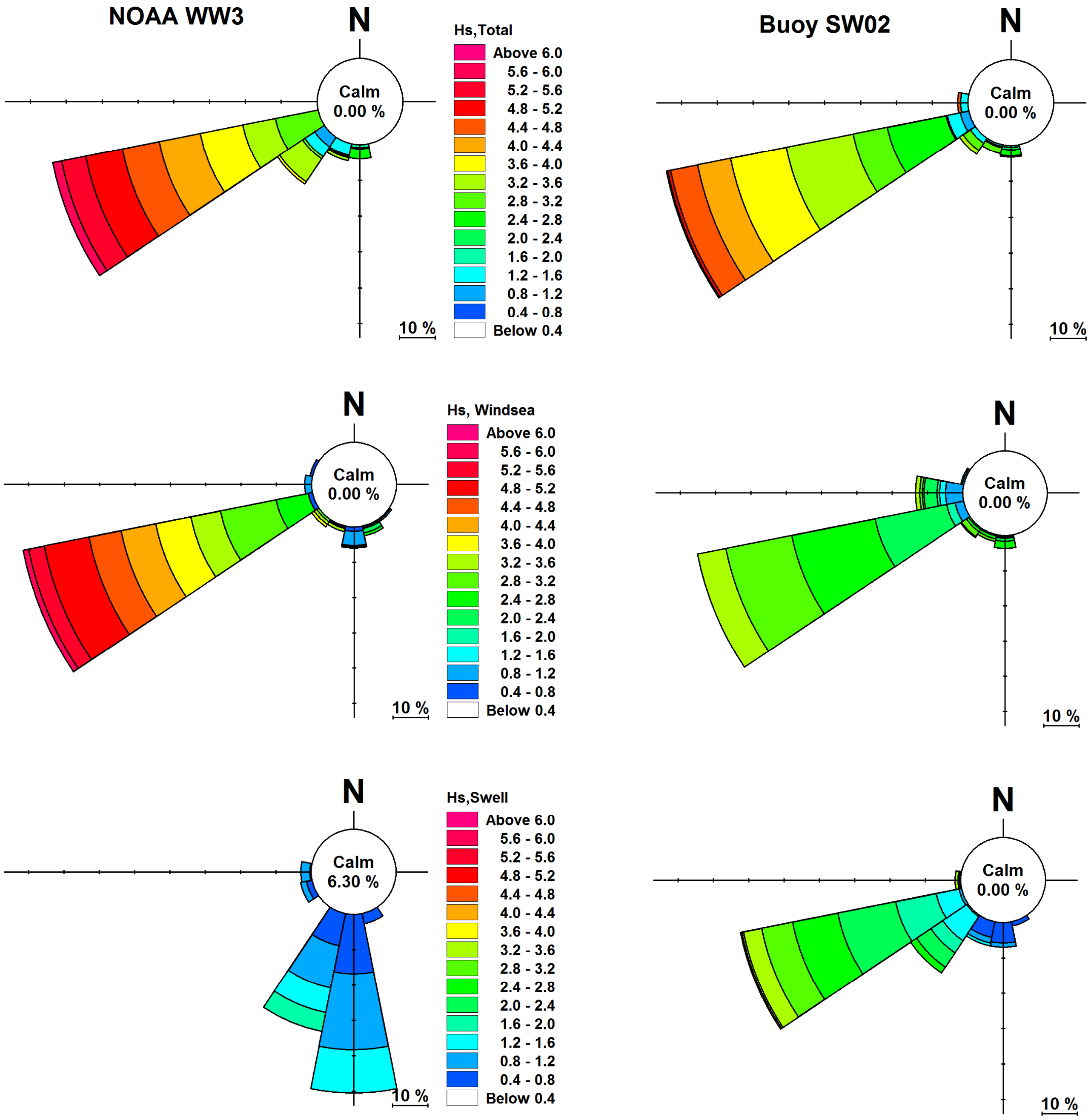


Figure 6.2 Wave rose diagram of significant wave height (Total, Windsea and Swell) for SW02 buoy and NOAA point South during June 2008

6.3 MIKE 21 SW (Spectral Wave)

MIKE 21 SW is a third generation time-dependent spectral wind-wave model based on unstructured meshes. It simulates the growth, propagation, decay and transformation of wind-generated waves and swells in offshore and coastal areas. The model includes the effects on wave growth by action of wind, interaction between waves with different frequencies and dissipation due to white capping. Furthermore, the model includes shallow water effects like shoaling due to varying depth and dissipation due to depth limited wave breaking and bottom friction.

The MIKE 21 SW includes two formulations;

Fully Spectral (FS)

The FS formulation is be used for wind-wave generation and propagation over long fetches and complex bathymetries where both wind-sea and swell are important.

Directionally Decoupled (DD)

The DD formulation is used for wind wave generation and propagation in small fetches and regular bathymetries.

In addition, the model can run in a quasi-stationary mode, which assumes fully developed sea states in all time-steps or in an in-stationary mode that will use the sea state of the previous time-step.

For the present study, the fully spectral (FS) and in-stationary formulation has been used to transfer the offshore wave conditions to the proposed OWF area.

6.4 Bathymetry

As mentioned in Section 5.4, C-MAP and ETOPO-2 data are used in the preparation of the bathymetry, as shown in Figure 6.3.

Figure 6.4 shows the flexible mesh bathymetry used in the model. The size of the triangular mesh elements varies from 1.4 km in deep waters to 700 m near the proposed OWF area. Figure 6.5 represents the bathymetry contours close to the project site. The offshore boundaries of the model domain are chosen in such a way that these coincide with the offshore NOAA output hindcast points (see Figure 6.6). The extension of boundaries is as follows

- South Boundary: 69°E, 16° 30'N - 73° 20' E, 16° 30'N (approx. 460 km)
- West Boundary: 69°E, 16° 30'N - 69°E, 22° 12'N (approx. 630 km)

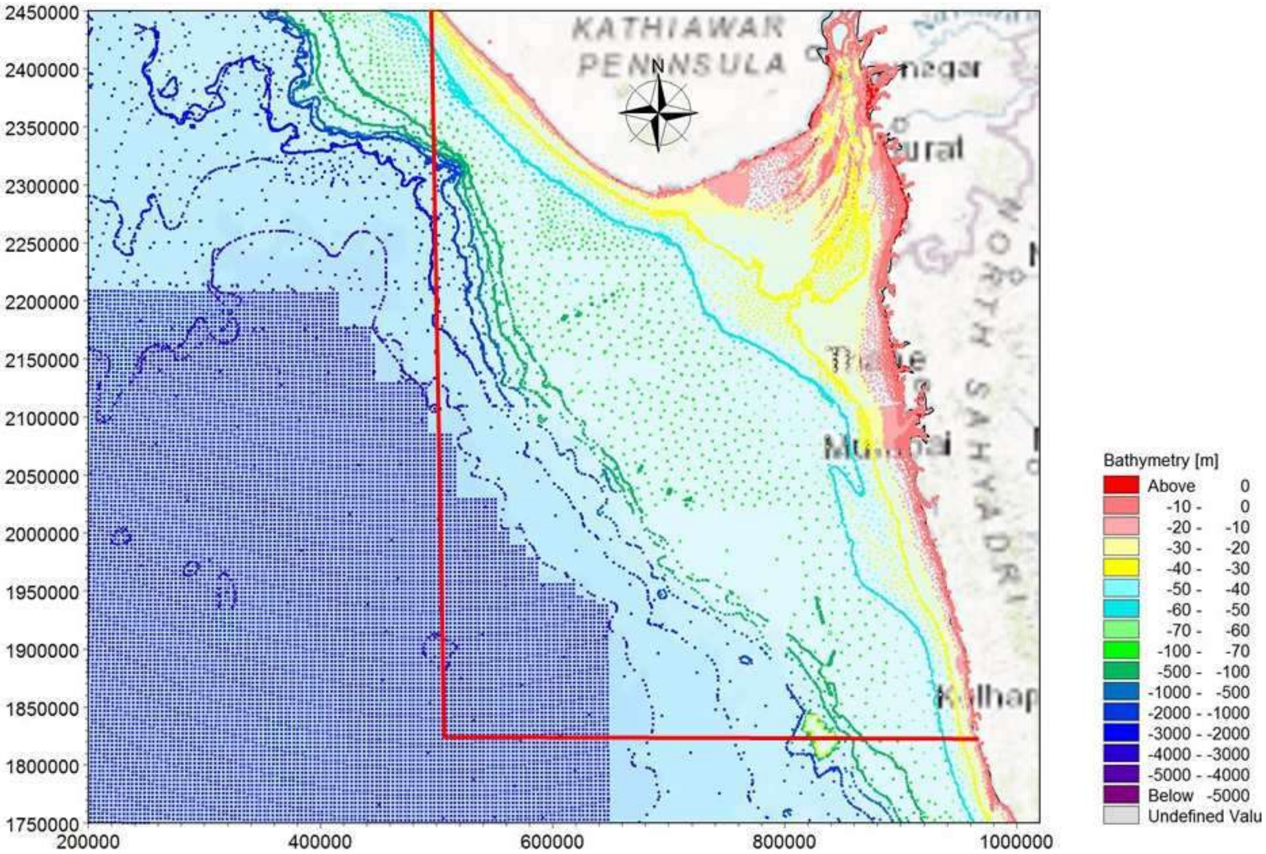


Figure 6.3 CMAP and ETOPO-2 datasets used to derive the bathymetry. Red lines show the extent of the model.

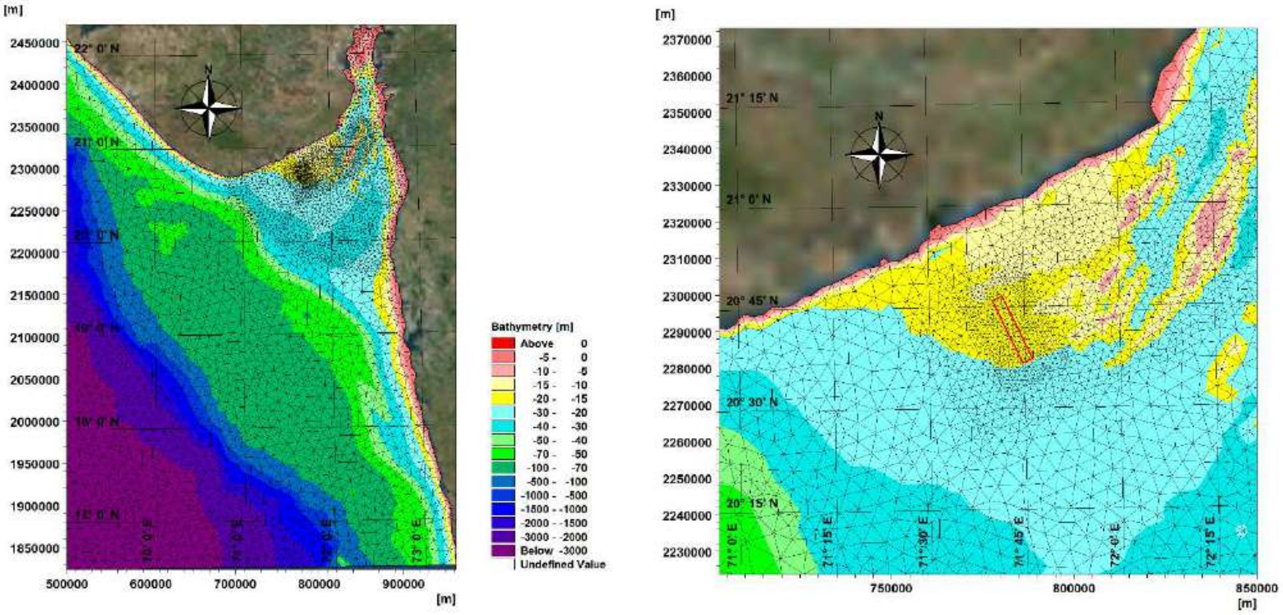


Figure 6.4 Flexible mesh used for the preparation of bathymetry (levels in m relative to MSL).

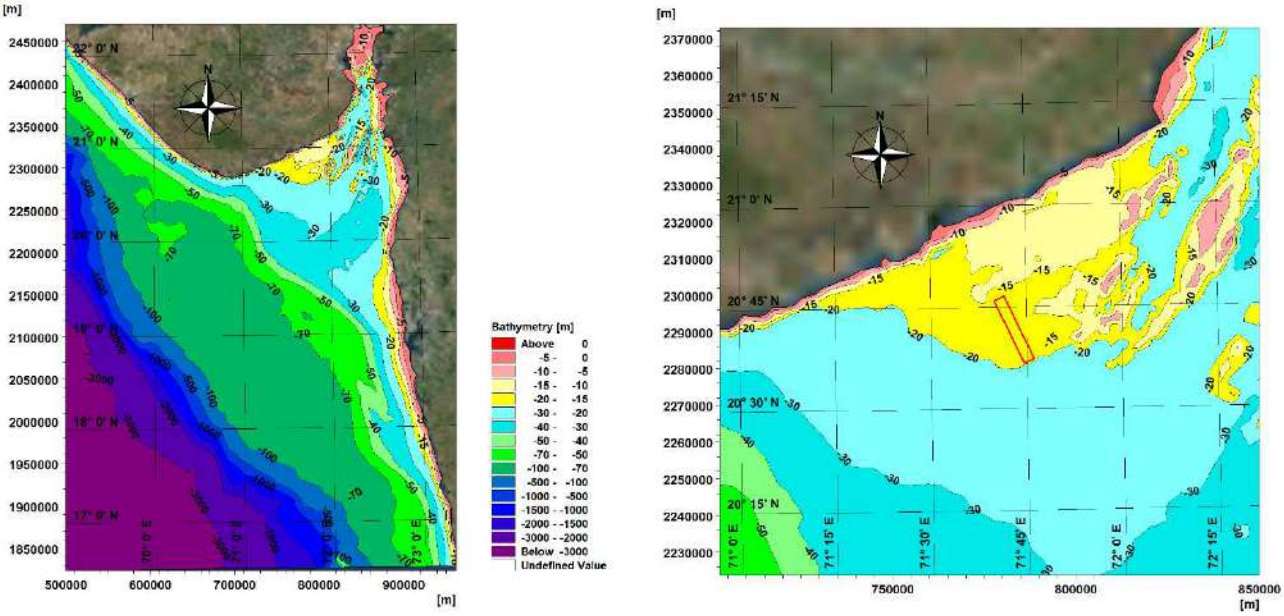


Figure 6.5 *Bathymetry contours near the proposed OWF area (levels in m relative to MSL).*

6.5 Input and Boundary conditions

The major input parameters to the SW model are the wind forcing and wave parameters at the boundary of the model bathymetry. The additional parameters, which influence the wave characteristics in the nearshore waters, are water level, wave breaking, and bottom friction.

The boundary wave conditions consist of significant wave height (H_{m0}), peak wave period (T_p), mean wave direction (MWD) and directional spreading index (n).

It is seen that the proposed site is influenced by both windsea and swell waves and hence combined effect of these two is important to derive the nearshore wave climate. In the model simulations, both windsea and swell wave parameters from the offshore NOAA output points are provided as boundary conditions along the two open boundaries i.e. S and W as shown in Figure 6.6. Wind speed and direction from the ECMWF ERA-interim hindcast (see Figure 5.3) is also applied as forcing on the model.

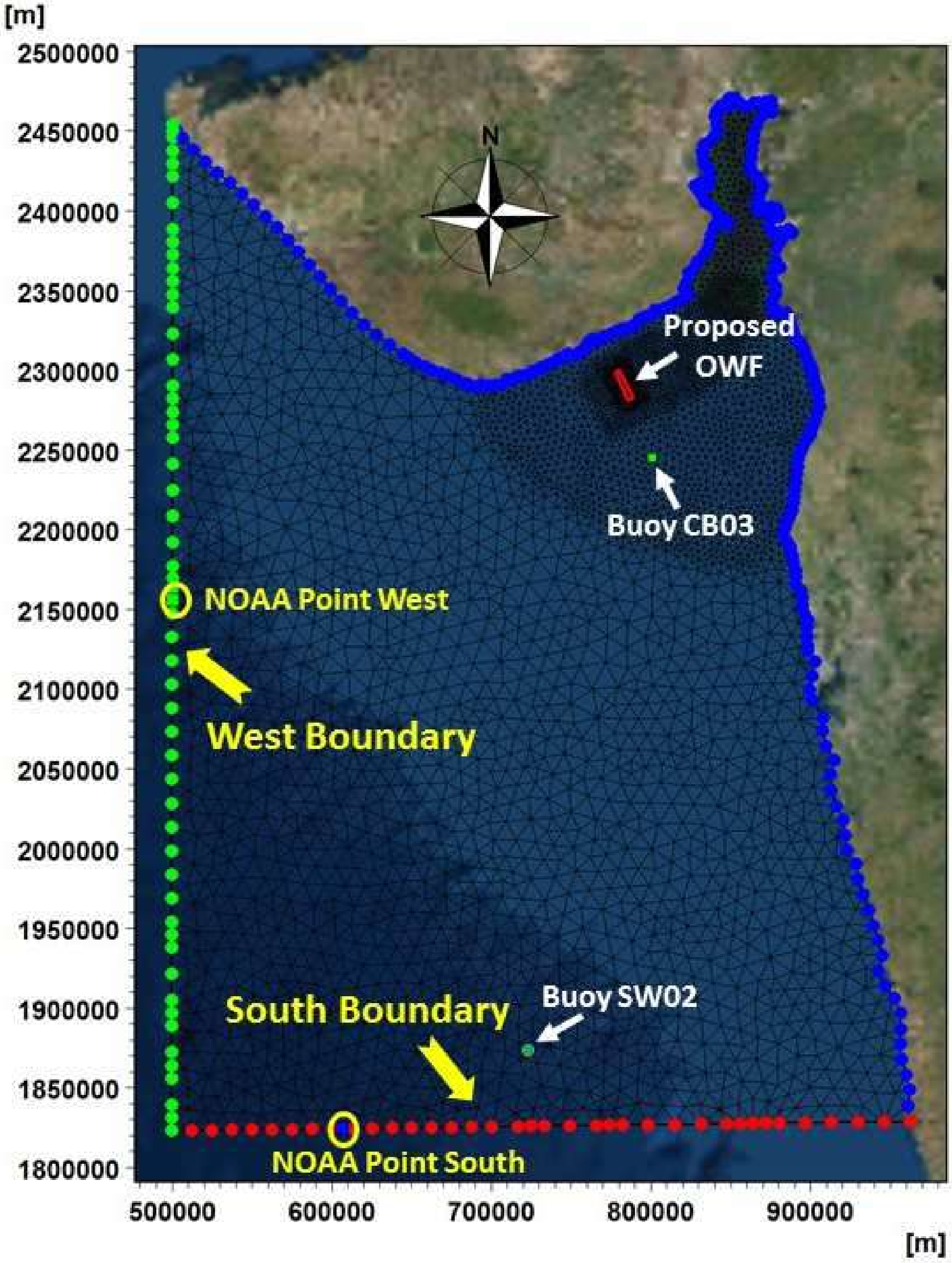


Figure 6.6 Two open boundaries coinciding with the offshore NOAA output points and the location of wave measurements in the model domain.

In addition to the offshore wave parameters and wind condition, the spatial variation of the water level is included from the MIKE 21 HD modelling.

6.6 Model Calibration

Model calibration is conducted against measured significant wave height, peak wave period and mean wave direction, procured at a wave rider buoy location (CB03) by INCOIS (see Section 6.1). The model calibration is carried out for a period of 1 month (18-05-2012 to 19-06-2012).

The wave model calibration consists of fine-tuning the model parameters until the model produces a good fit between the simulated and measured wave conditions at the measurement station.

Bottom friction coefficient and wave breaking parameters are the usually applied calibration parameters in the wave model. Model calibration is performed by changing bottom friction coefficient (Nikuradse roughness) and the wave breaking parameters (Alpha, γ) and dissipation coefficient C_{dis} (control the overall dissipation rate), $DELTA_{dis}$ (control the weight of dissipation in the energy/action spectrum), within recommended ranges and model executed for each of them.

Based on the above calibration, a constant value of 3.5 for C_{dis}, 0.5 for $DELTA_{dis}$ and 0.015 for bottom friction is used in the SW model.

Figure 6.7 and Figure 6.8 show the comparison between measured and simulated wave parameters at the measurement location CB03 (see Figure 6.6) for a period of 1 month. The comparisons between measured and simulated significant wave height and peak wave period are seen to be generally good, whereas the mean wave direction is not in good agreement. Table 6.2 shows the statistical parameters calculated for significant wave height and peak wave period at CB03 location. It is to be noted that measurements of wave directions are generally less reliable than other parameters, especially in mixed seas, and that the mean wave direction measured at buoy no. CB03 shows waves from all directions, which is quite unrealistic along a monsoon dominated coast with a very unidirectional wind climate.

Hence, it is concluded that the wave directions in the measurements are unreliable and that the calibration of the SW model is satisfying.

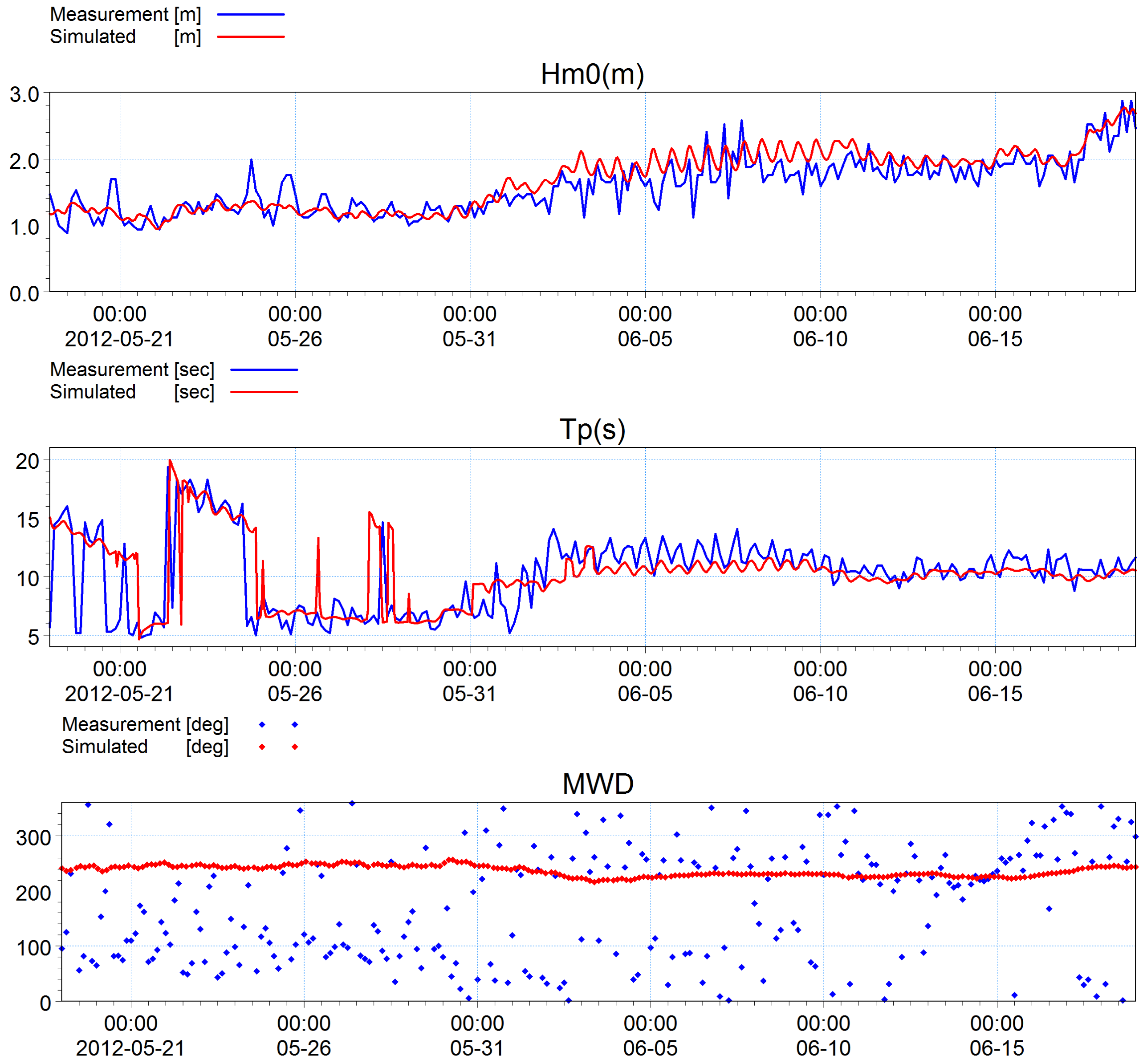


Figure 6.7 Comparison between the measured and simulated significant wave height (top), peak wave period (middle) and mean wave direction (bottom) at the CB03 location.

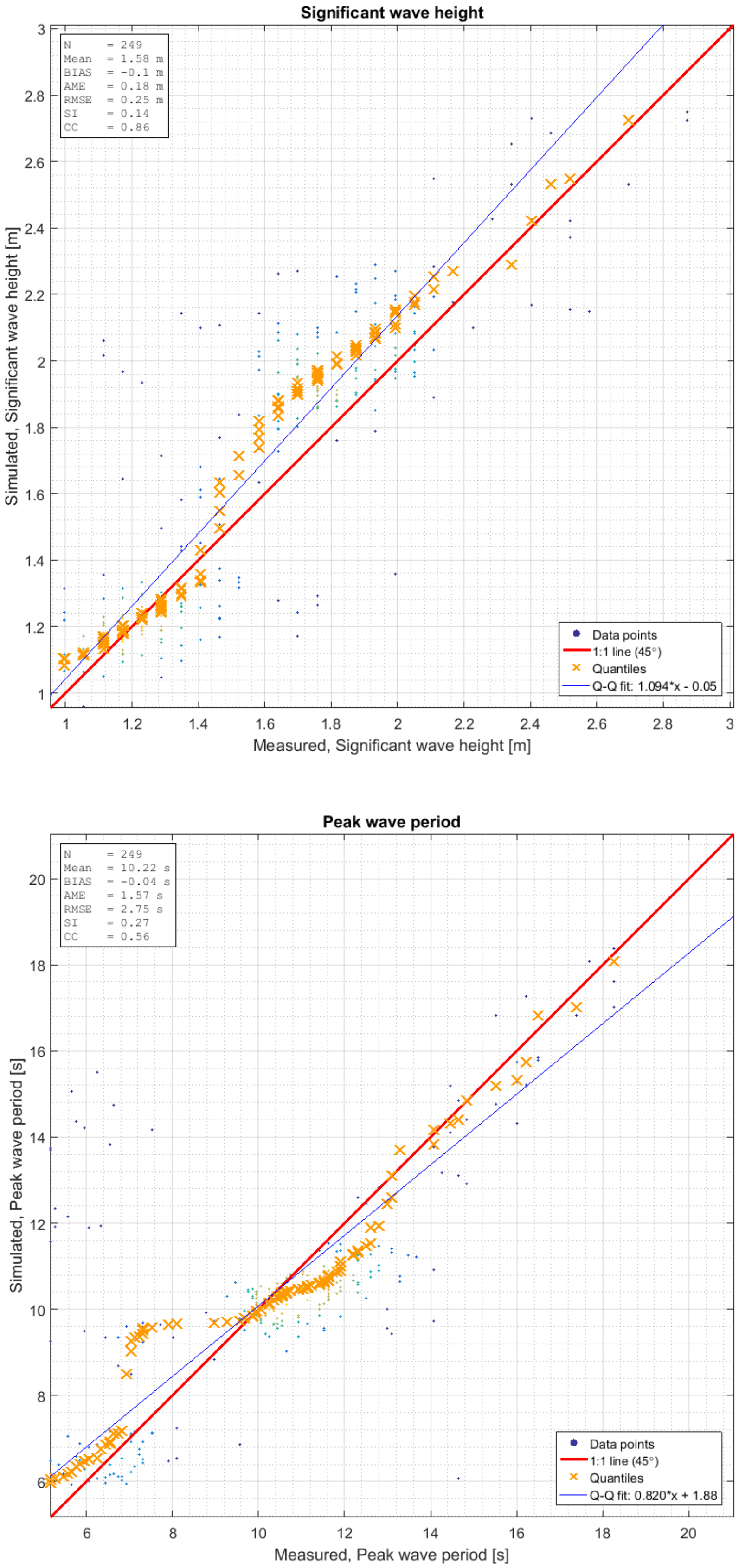


Figure 6.8 Scatter analysis showing the comparison between measured and simulated significant wave height (Top) and peak wave period (Bottom) at CB03 buoy location during May-June 2012.

Table 6.2 Statistical parameters calculated between measured and simulated wave parameters at CB03 buoy location

	RMSE	BIAS	AME	Correlation Coefficient
Significant wave height, H_{m0}	0.25 m	-0.1 m	0.18 m	0.86
Peak Wave Period, T_p	2.75 s	-0.04 s	1.57 s	0.56

7 Hindcast simulations

General details from the flow modelling and wave simulations are presented in this section.

7.1 Flow modelling

In order to assess the current pattern at the OWF-site, three points (i.e. P1, P2 and P3) in the proposed OWF are extracted from the MIKE 21 FMHD flow model. The water depths at the extraction points vary between 15 and 20m, as shown in Figure 7.1 and the coordinates are presented in Table 7.1. The rose plot comprising current speed and direction during 2010-2014 at these three locations are presented in Figure 7.2.

The result shows that currents in the OWF area are primarily driven by astronomical tide with little effect of wind condition. The flow predominantly being parallel to the coast, north-easterly during flood and south-westerly during ebb flow, as shown in Figure 7.3 and Figure 7.4. It is noticed that the intensity of current is higher during flood flow than the ebb flow in this region.

The simulated maximum and average current speed during 2010-2014 is shown in Figure 7.5. An average current speed of 0.6 m/s and maximum current speeds of up to 1.5 m/s are found near the proposed OWF area, see Table 7.2.

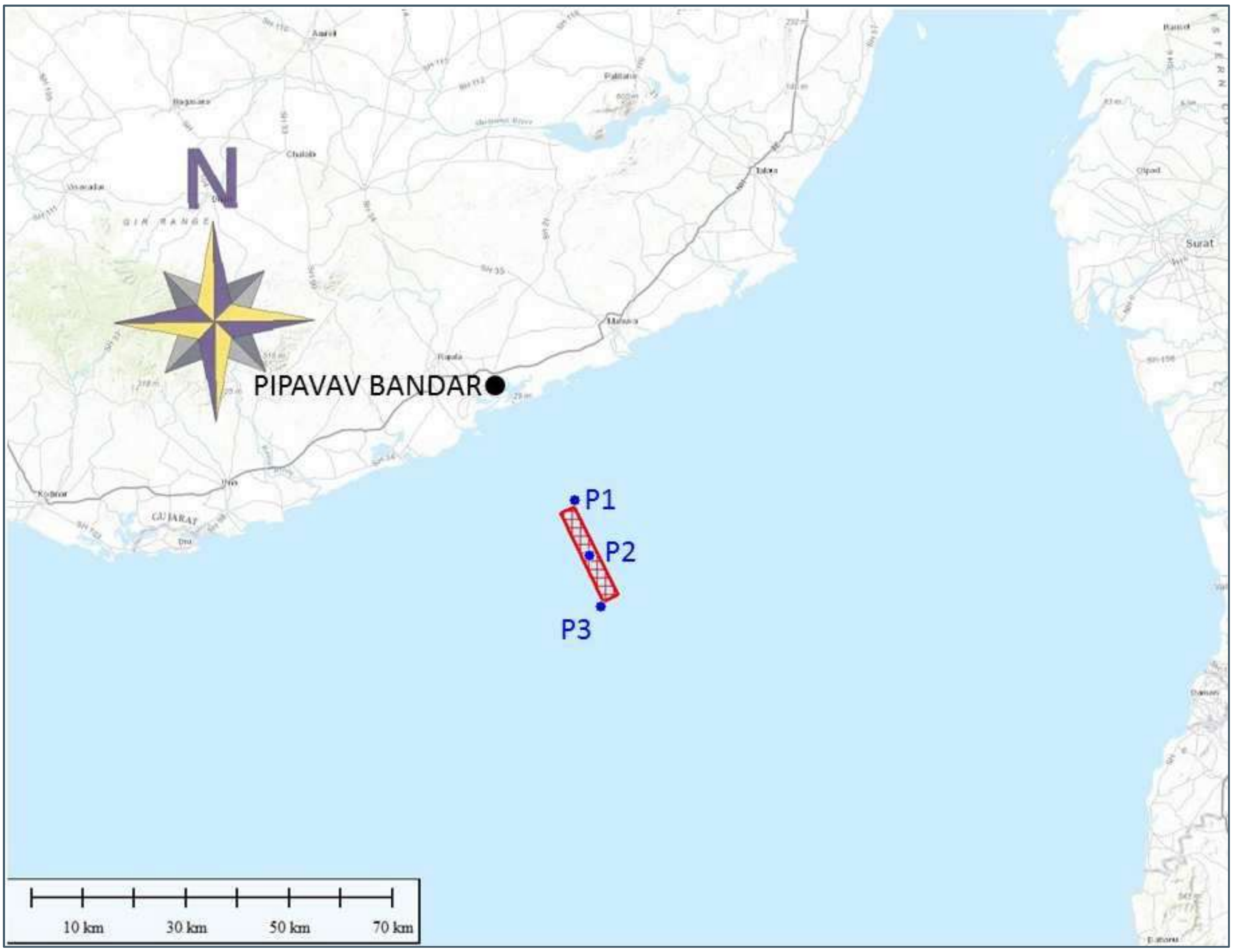


Figure 7.1 Extraction points (P1, P2 and P3) in the proposed OWF area.

Table 7.1 Locations of P1, P2 and P3 close to the proposed OWF.

Extraction points	UTM42, Easting [m]	UTM42, Northing [m]
P1	780428	2301062
P2	783217	2290278
P3	785314	2280430

Table 7.2 Current characteristics at point P1, P2 and P3 during 2010-2014

Extraction points	Mean Current Speed [m/s]	Maximum Current Speed [m/s]	Current direction, corresponds to Max current speed
P1	0.58	1.46	58°
P2	0.55	1.43	57°
P3	0.53	1.40	57°

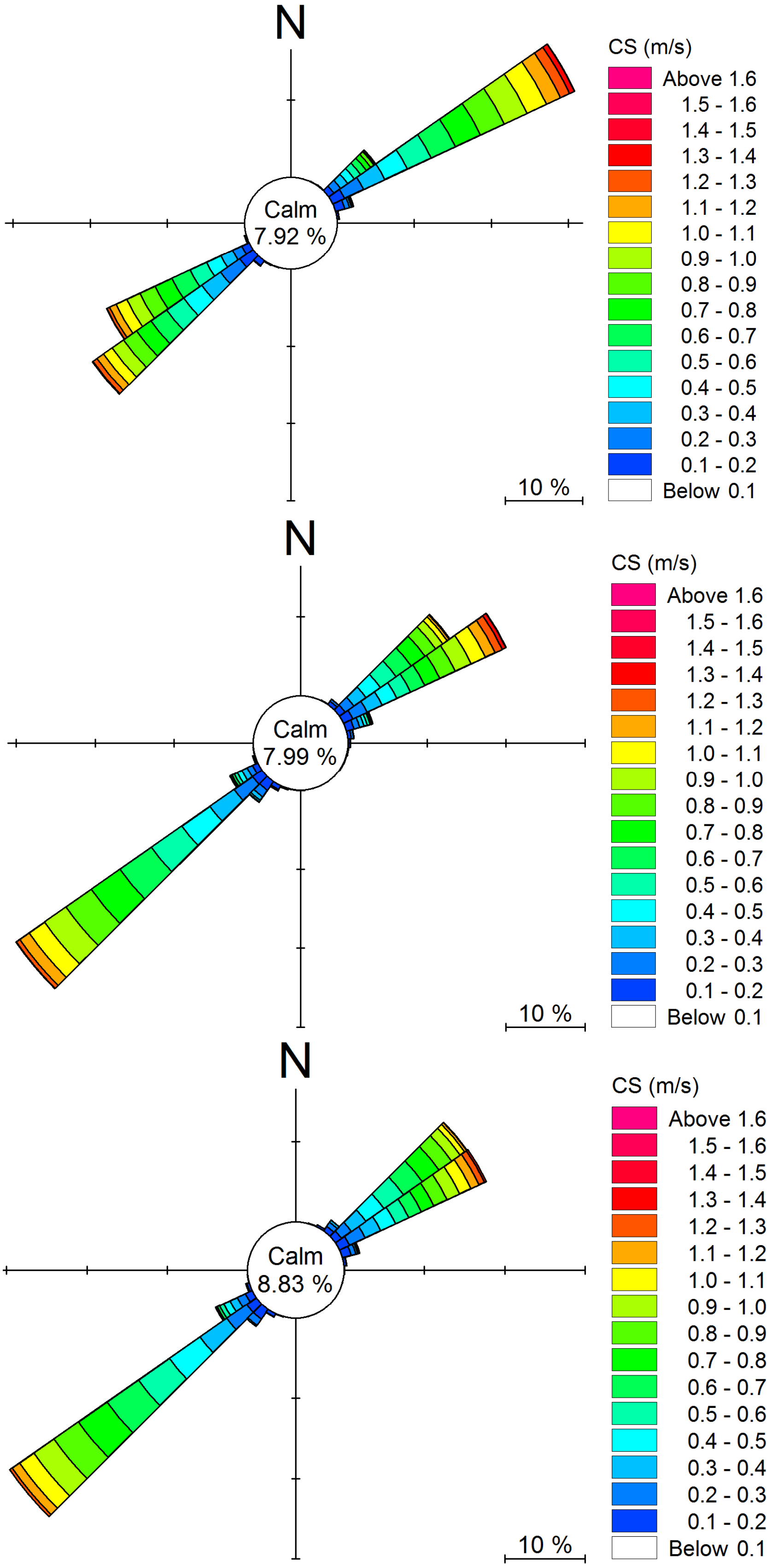


Figure 7.2 Rose plot of current speed at three locations (P1-Top, P2-Middle and P3-Bottom) in proposed OWF area

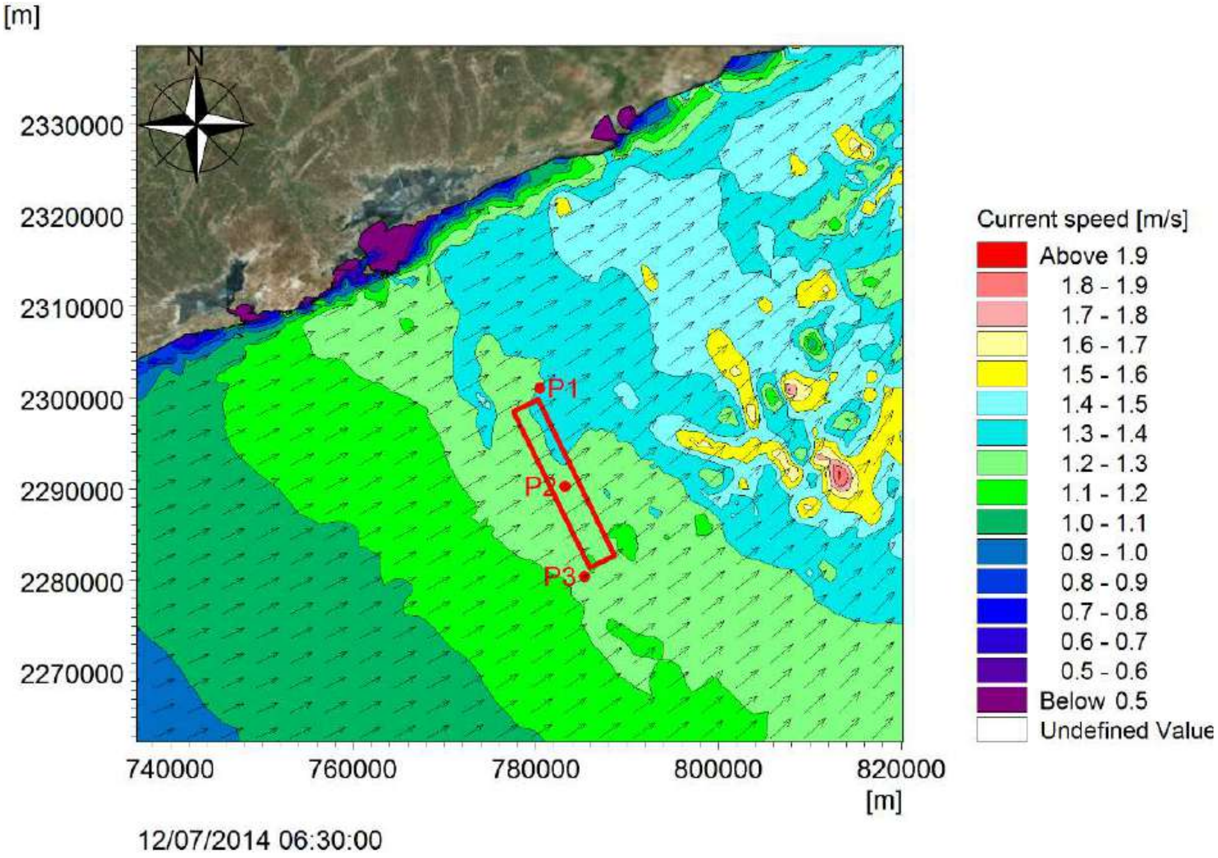


Figure 7.3 Flow characteristics during Flood flow

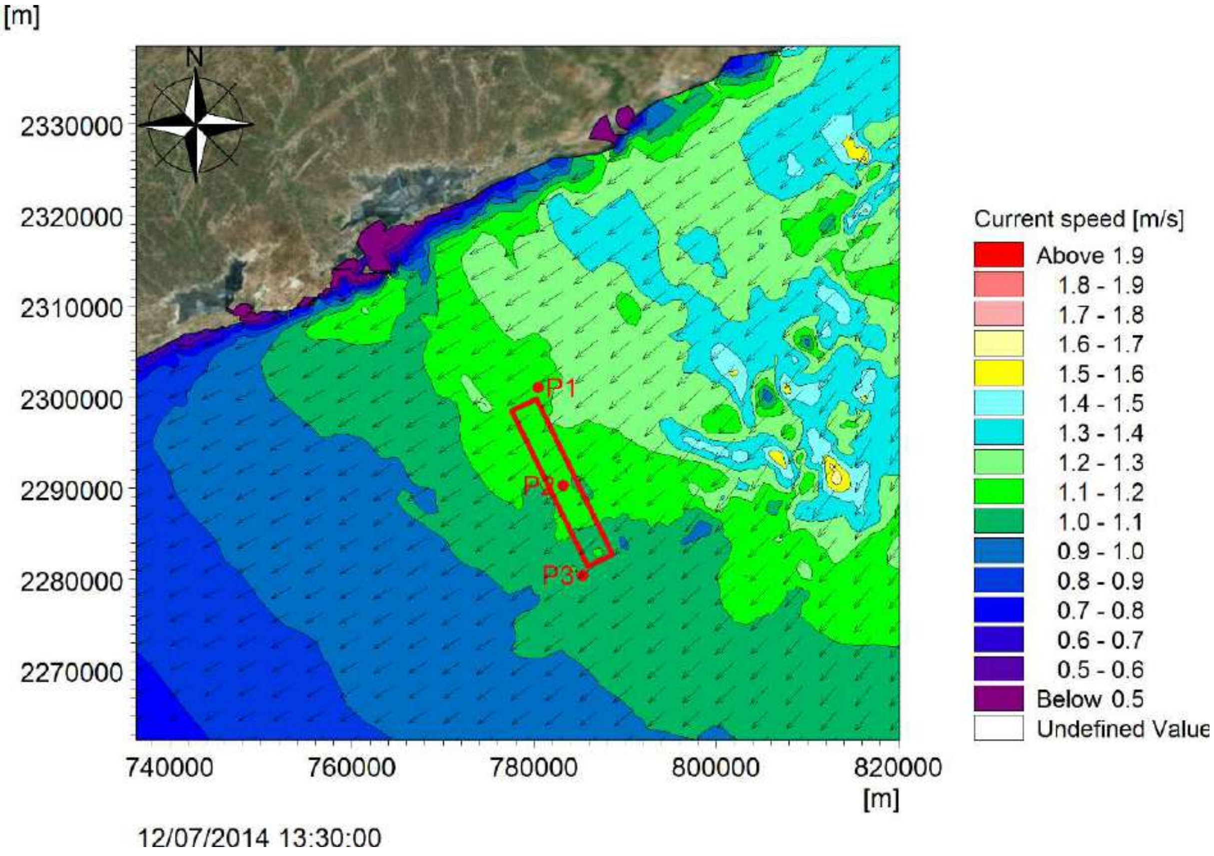


Figure 7.4 Flow characteristics during ebb flow

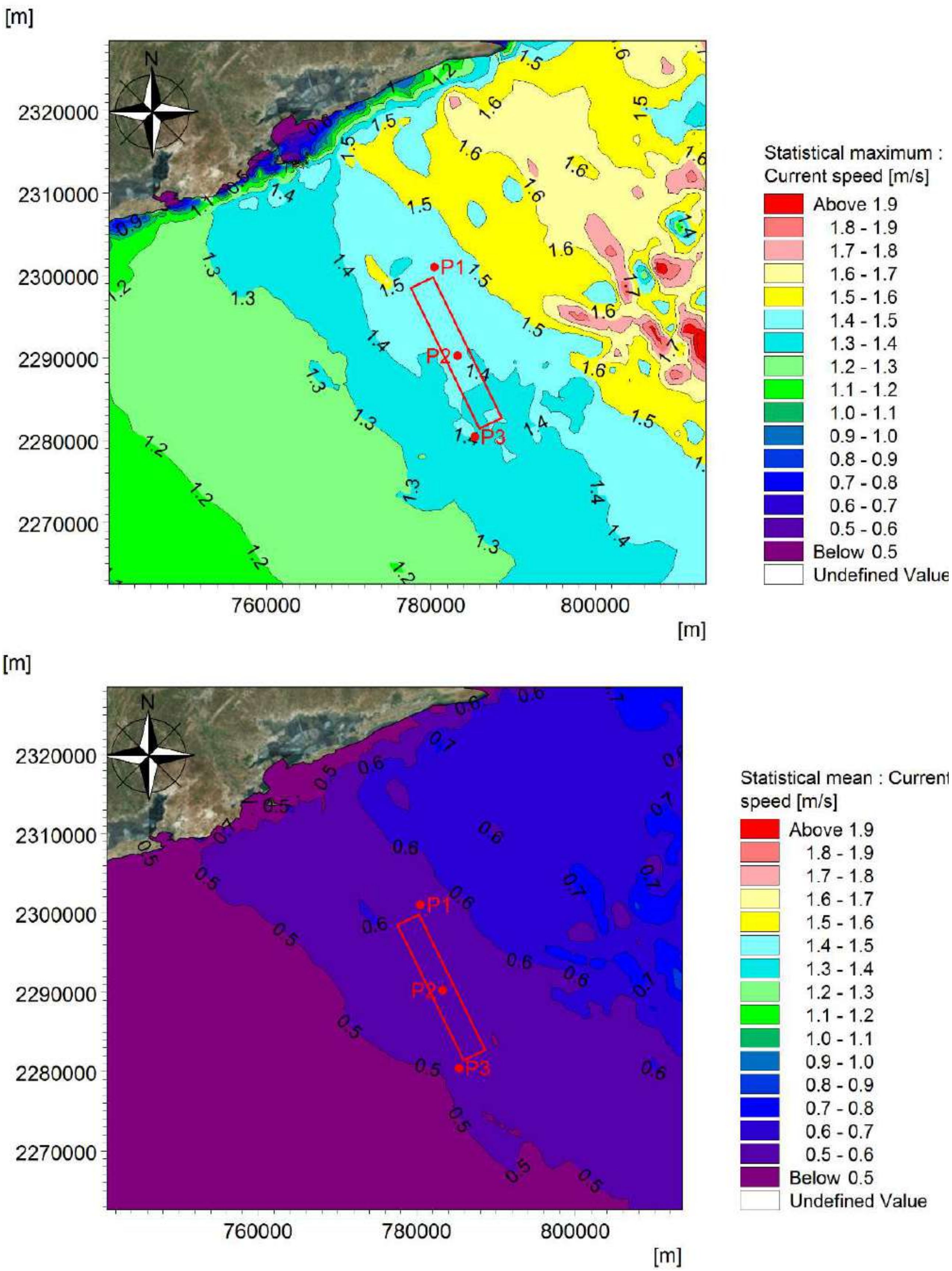


Figure 7.5 *Maximum (Top) and average (Bottom) current speeds near the proposed OWF area during 2010-2014*

7.2 Wave modelling

In order to establish nearshore wave climate at the project site, the calibrated wave model described above is used in the present study.

The results of nearshore wave transformation for a period of 5 years (2010 to 2014) are used to derive the nearshore wave climate at three locations (see Figure 7.1). The nearshore wave climate at these three locations in the form of wave rose plots of H_{m0} and T_p are presented in Figure 7.6 and Figure 7.7.

The rose plots show that the proposed OWF site is primarily exposed to waves from SW (225°), due to the exposure of the site during the southwest monsoon. The northeast monsoon has a minor effect due to the limited fetch towards NE.

Wave characteristics during the five year hindcast are presented in Figure 7.8 and Table 7.3. The model results shows an average significant wave height of 0.9-1m and maximum significant wave height of up to 2.7-3.1 m from SW in the proposed OWF area.

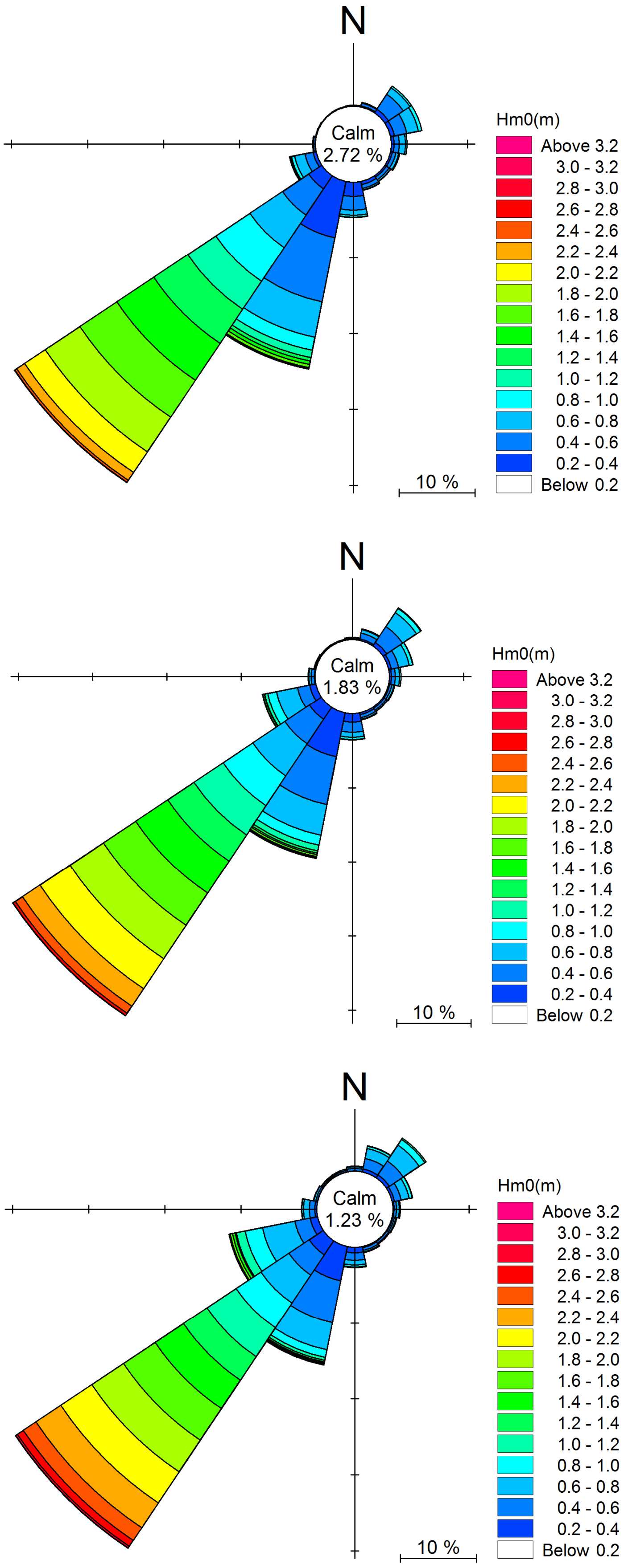


Figure 7.6 *Rose plots of significant wave height (H_{m0}) at three extraction points during 2010 to 2014; P1 (Top), P2 (Middle) and P3 (Bottom)*

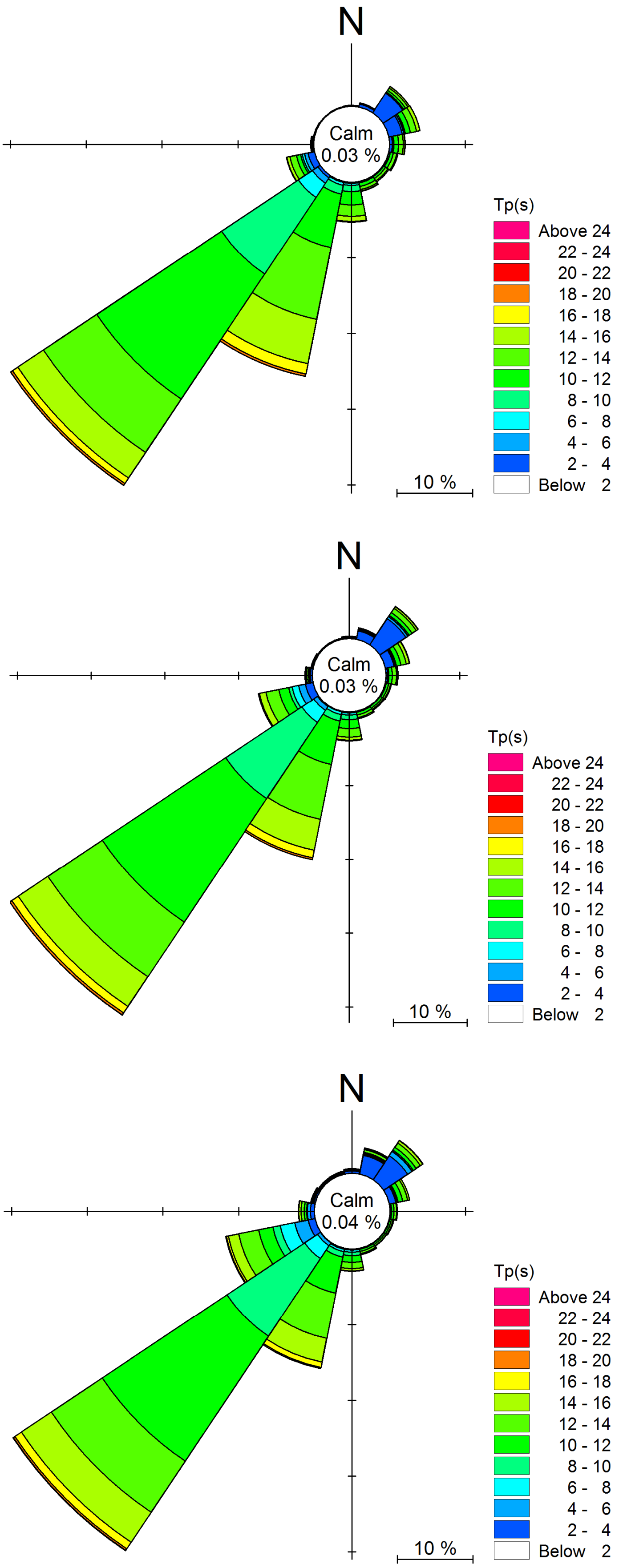


Figure 7.7 Rose diagram of peak wave period (T_p) at three extraction points during 2010 to 2014; P1 (Top), P2 (Middle) and P3 (Bottom)

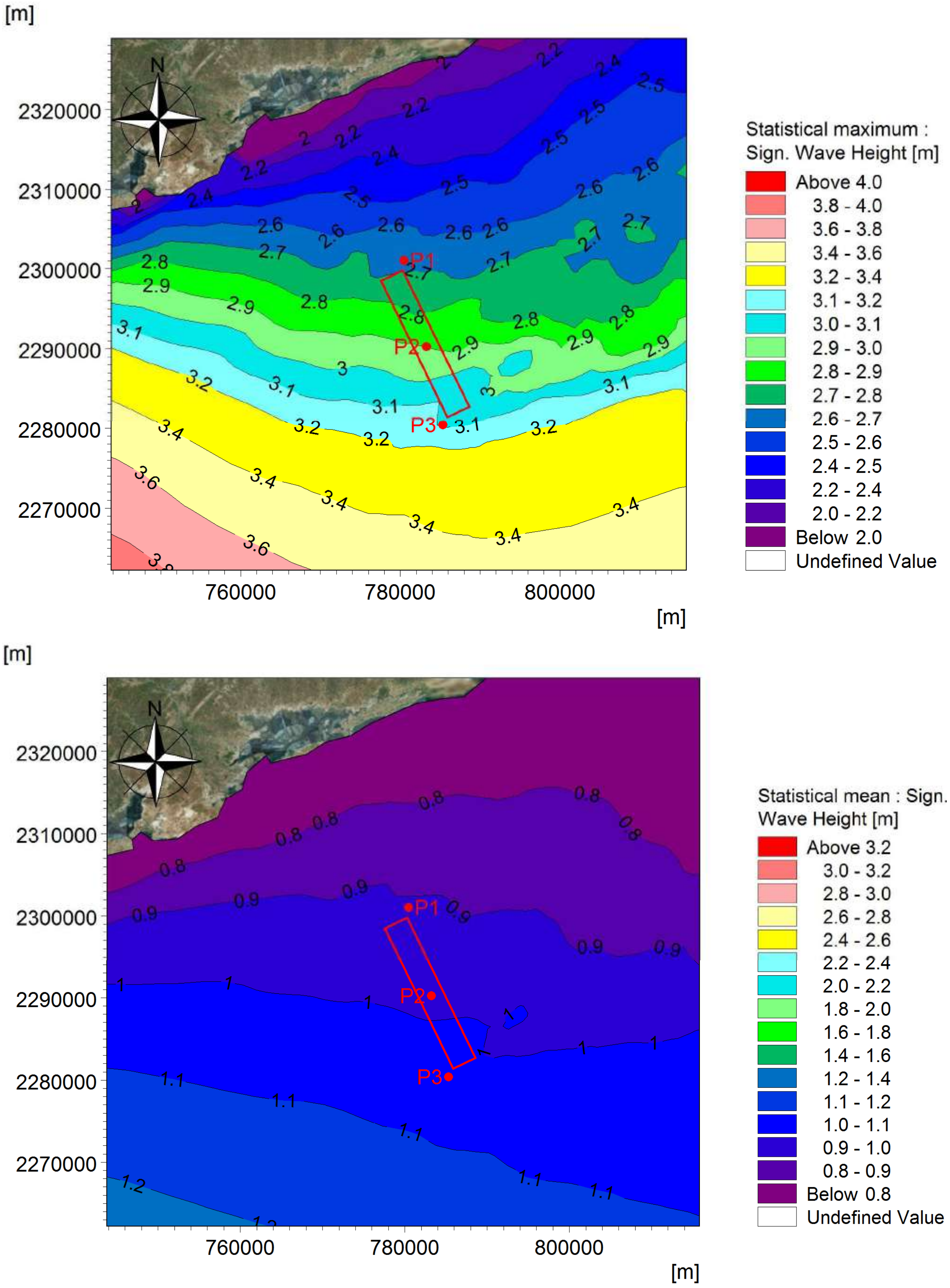


Figure 7.8 Maximum (Top) and average (Bottom) significant wave height near the proposed OWF area during 2010-2014.

Table 7.3 Wave characteristics at point P1, P2 and P3 during 2010-2014

Extraction points	Mean significant wave height [m]	Maximum significant wave height [m]	Peak wave period [s], corresponds to Max significant wave height	Wave direction, corresponds to Max significant wave height
P1	0.91	2.7	12.1	225°
P2	0.98	2.9	12.1	226°
P3	1.04	3.1	12.1	228°

8 Analysis

8.1 General

The following analysis is based on the hindcast modelling presented in the previous sections. The data analysis is performed in compliance with the specifications given in Ref. /3/.

Directional data are derived for the omni-directional case and per 12 directions centred on 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300 and 330º.

Additional specifications and clarifications are described below:

8.2 Operational wind conditions

The following analyses are made on the wind dataset:

- Wind rose and frequency tables
- Extreme value analysis is made on the wind speeds (omni and directional – with 30 degree sectors) to obtain 1, 5 and 10 years return period estimates
- Extreme events with 10 year return periods are also predicted based on cyclone study (see below)

8.3 Operational water level and current conditions

The following analyses are made of the hydrodynamic (MIKE 21 HD) hindcast dataset:

- 2D plots of peak water levels during spring and neap tides
- 2D plots of maximum and mean currents
- Current roses and frequency tables

- Extreme value analysis is made on the current speeds to obtain 1, 5 and 10 years return period estimates

- Extreme value analysis is made on the residual water levels - both high and low residual levels are considered. Output will be 1, 5 and 10 years return period estimates

- Extreme events with 10 year return periods are also predicted based on cyclone study (see below)

8.4 Operational wave conditions

The following analyses are made of the wave hindcast (MIKE 21 SW) dataset:

- 2D plots of maximum and mean wave parameters

- Wave roses and frequency tables

- Extreme value analysis is made to obtain 1, 5 and 10 years return period estimated of the significant wave height

- Extreme events with 10 year return periods are also predicted based on cyclone study (see below)

8.5 Cyclone conditions

The following additional analyses are made on basis of the cyclone simulations:

- Assess extreme significant wave height with average return periods of 10, 50 and 100 years

- Assess extreme water level and current speed with average return periods of 10, 50 and 100 years

9 Wind

9.1 General

The continuous ECMWF ERA-Interim reanalysis hindcast model time series of wind data from 2010 to 2014 (i.e. 5 years) from the position (71.6874°E, 20.7761°N) has been used for the analysis.

The ECMWF wind data are given as 3-hour average values at a height of 10 m above Mean Sea Level (MSL). However, as the desired reference period for data presentation of average wind speeds is 10 minutes, a conversion from 3-hour wind speeds must be made.

The conversion of the wind speeds from 3-hour average to 10-minute average is made using the relation from section 2.3.2.11 in Ref. /2/:

$$U(T,Z) = U_{10}\left(1 + 0.137ln\left(\frac{Z}{10}\right) - 0.047ln\left(\frac{T}{10}\right)\right)$$

In the above equation U_{10} is the 10-minute average wind speed at a height of 10 mMSL, Z is the reference height (in mMSL) and T is the average period (in minutes). The ratio between 10-minute average wind speed and 3-hour average wind speed at 10 m height above MSL thus becomes 1/0.864=1.157.

It is emphasized that this Metocean report does not constitute a full wind study, which would be required for wind turbine design or wind resource assessment. The analysis of the wind data carried out in this study is solely intended for foundation design.

9.2 Wind Rose

A rose plot of the U_{10} wind speed is given in Figure 9.1 and in Table 9.1 as relative values. The wind direction is defined as "coming from".

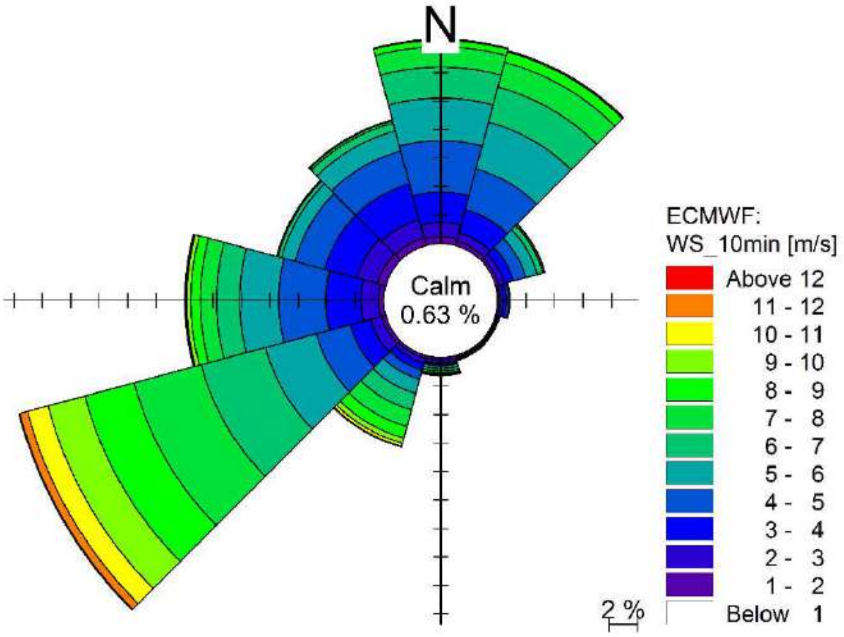


Figure 9.1: Rose plot of wind speed, U_{10}, 2010-2014.

Table 9.1: Relative distribution (in [%]) of wind speed, U_{10}, 2010-2014.

Direction	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	All
>12 m/s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.13
11-12 m/s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.55	0.04	0.00	0.00	0.64
10-11 m/s	0.01	0.00	0.00	0.00	0.00	0.00	0.06	0.23	1.52	0.09	0.00	0.00	1.91
9-10 m/s	0.06	0.10	0.01	0.00	0.00	0.00	0.05	0.38	2.68	0.30	0.00	0.00	3.59
8-9 m/s	0.48	0.75	0.03	0.00	0.00	0.01	0.05	0.84	3.58	0.65	0.01	0.06	6.46
7-8 m/s	1.41	1.81	0.11	0.00	0.00	0.03	0.15	1.21	4.88	1.14	0.07	0.16	10.97
6-7 m/s	2.17	2.53	0.40	0.02	0.02	0.04	0.18	1.20	4.68	1.63	0.28	0.56	13.70
5-6 m/s	2.99	3.42	0.85	0.06	0.02	0.03	0.19	1.03	3.69	2.73	0.97	1.47	17.45
4-5 m/s	3.60	2.93	0.91	0.17	0.03	0.03	0.10	0.66	2.47	3.31	2.16	2.41	18.79
3-4 m/s	2.14	1.71	0.66	0.25	0.06	0.03	0.11	0.52	1.48	2.49	2.35	2.58	14.37
2-3 m/s	1.01	0.60	0.42	0.23	0.09	0.09	0.19	0.35	0.82	1.25	1.50	1.34	7.90
1-2 m/s	0.47	0.31	0.20	0.13	0.08	0.11	0.19	0.18	0.29	0.36	0.60	0.54	3.46
< 1m/s	0.09	0.06	0.04	0.03	0.04	0.04	0.04	0.05	0.04	0.05	0.06	0.09	0.63
All	14.43	14.21	3.63	0.89	0.34	0.39	1.32	6.70	26.81	14.04	8.01	9.21	100

The scatter plot of wind speed conditioned on wind direction is shown in Figure 9.2.

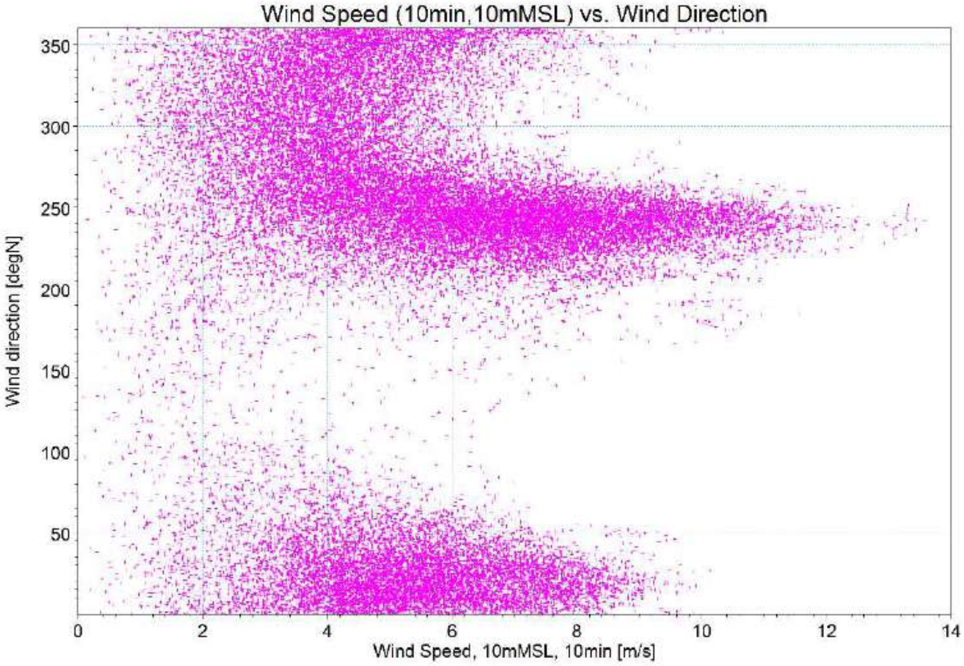


Figure 9.2: Scatter plot of wind speed, U_{10}, versus wind direction.

9.3 Statistics

The monthly statistical data of the wind speed are given in Table 9.2.

Table 9.2: Monthly and yearly statistical data of wind speed, U_{10} [m/s], 2010-2014

U_{10} [m/s]	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Maximum	10.14	9.59	9.28	10.24	12.40	12.57	13.08	13.73	13.44	8.40	8.93	10.33	13.73
Mean	5.55	4.84	4.40	4.61	6.07	7.24	7.69	6.67	5.22	3.43	4.45	5.24	5.46
St.Dev.	1.72	1.65	1.36	1.39	1.58	2.14	1.89	2.26	2.29	1.55	1.55	1.59	2.15
Counts	3720	3384	3720	3600	3720	3600	3720	3720	3600	3720	3600	3717	43821

The directional statistical data of the wind speed are given in Table 9.3.

Table 9.3: Directional statistical data of wind speed, U_{10} [m/s], 2010-2014

U_{10} [m/s]	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	All
Maximum	10.33	10.24	9.56	6.98	6.78	8.72	11.56	12.19	13.73	11.65	9.63	9.12	13.73
Mean	5.05	5.44	4.48	3.22	2.76	3.23	5.00	6.30	6.93	5.07	3.81	4.07	5.46
St.Dev.	1.66	1.64	1.55	1.27	1.61	2.19	2.70	2.21	2.19	1.86	1.28	1.39	2.15
Counts	6323	6229	1592	391	151	171	578	2938	11747	6152	3511	4038	43821

9.4 Extreme Value Analysis

The extreme value analysis of the wind speed is performed using the DHI MIKE Zero program EVA (Extreme Value Analysis). The extreme values are determined using a peaks-over-threshold (POT) method. A minimum requirement of time span between consecutive peaks is selected as 48 hours in order to ensure independence between consecutive peak values in the time series. An additional requirement stating that the minimum level between two consecutive peak values shall be below 70% of the minor of two consecutive events has also been imposed in order to only consider independent peak events (i.e. only one peak event from one storm).

The extracted peak values are fitted to a 3-parameter Weibull distribution using the maximum-likelihood method for parameter estimation. The location parameter, γ, is fixed at the threshold. Extreme values are then determined for average return periods of 1, 5 and 10 years.

A plot of the peaks-over-threshold data, the fitted Weibull distribution and confidence bands (based on 1 standard deviation) are given in Figure 9.3 for the wind speed. The Weibull parameters are given in Table 9.4.

The standard deviations of the extreme value estimates are determined on basis of Monte Carlo simulations. The key results of the extreme value analysis are given in Table 9.5. The results in Table 9.5 are presented as central estimates as well as standard deviation of the extreme wind speeds.

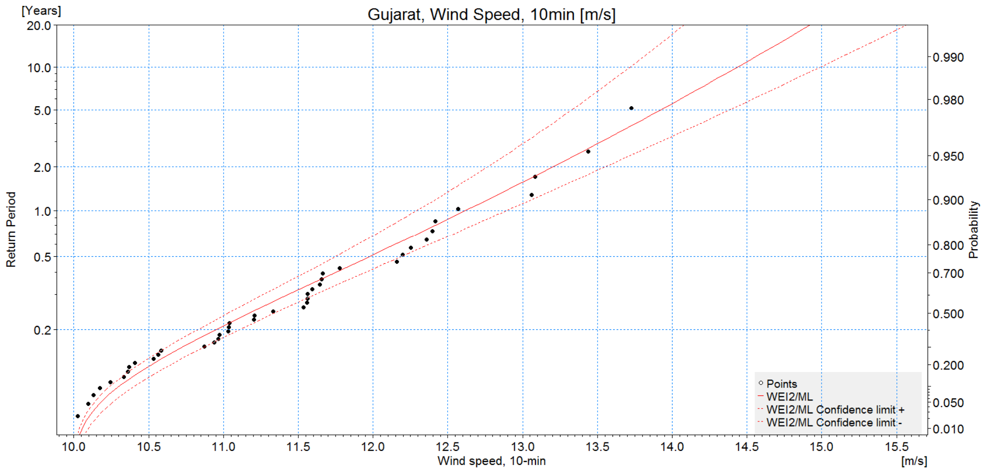


Figure 9.3 Weibull fit to peaks-over-threshold values of wind speed, U_{10}, 2010-2014.

Table 9.4: Weibull parameters from extreme value analysis of wind speed

Wind Speed, U_{10} [m/s]	Weibull Parameters		
	Scale, a	Shape, b	Location, γ
	1.521	1.391	10.0

Table 9.5: Extreme value analysis of wind speed, U_{10}, 2010-2014.

Wind Speed, U_{10} [m/s]	Return Period [Years]		
	1	5	10
Central estimate	12.6	13.9	14.4
Standard deviation	0.4	0.5	0.6

10 Waves

10.1 General

The continuous hindcast time series of hourly wave data from 2010 to 2014 (i.e. 5 years) from the data points P1, P2 and P3 was used for the wave analysis.

The main parameter to be analysed is the significant wave height, H_{m0}. The wave direction is defined as “coming from”.

10.2 Wave Roses

The rose plot of the significant wave height at the locations corresponding to points P1, P2 and P3 given in Figure 7.6. The wave directions used are Mean Wave Direction (MWD).

The distribution of the significant wave height as function of the MWD at points P1, P2 and P3 are given in Table 10.1, Table 10.2 and Table 10.3.

Table 10.1 Relative distribution (in [%]) of H_{m0} at Point P1

Direction	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	All
> 3.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8-3.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.6-2.8 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.03
2.4-2.6 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.17	0.00	0.00	0.00	0.38
2.2-2.4 m	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.54	0.71	0.00	0.00	0.00	1.27
2.0-2.2 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.77	1.49	0.00	0.00	0.00	3.27
1.8-2.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.02	3.74	1.91	0.00	0.00	0.00	5.67
1.6-1.8 m	0.00	0.00	0.00	0.00	0.00	0.00	0.01	4.79	1.42	0.00	0.00	0.00	6.22
1.4-1.6 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.97	1.41	0.00	0.00	0.00	6.39
1.2-1.4 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.15	1.79	0.00	0.00	0.00	5.94
1.0-1.2 m	0.00	0.00	0.04	0.00	0.00	0.01	0.02	4.32	1.23	0.00	0.00	0.00	5.62
0.8-1.0 m	0.00	0.04	0.63	0.26	0.13	0.06	0.31	4.93	2.51	0.03	0.00	0.00	8.90
0.6-0.8 m	0.03	0.37	2.08	1.12	0.44	0.28	1.19	7.09	3.84	0.16	0.03	0.03	16.67
0.4-0.6 m	0.16	1.09	3.03	0.89	0.59	0.58	3.04	10.10	2.46	0.33	0.10	0.08	22.46
0.2-0.4 m	0.02	0.34	0.77	0.44	0.30	0.50	3.03	8.00	0.98	0.06	0.01	0.01	14.47
< 0.2 m	0.00	0.00	0.08	0.07	0.08	0.11	0.87	1.11	0.39	0.02	0.00	0.00	2.72
All	0.21	1.84	6.64	2.78	1.53	1.54	8.51	55.74	20.35	0.61	0.14	0.11	100

Table 10.2 Relative distribution (in [%]) of H_{m0} at Point P2

Direction	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	All
> 3.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8-3.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.06
2.6-2.8 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.21	0.00	0.00	0.00	0.39
2.4-2.6 m	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.40	0.81	0.00	0.00	0.00	1.23
2.2-2.4 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	1.65	0.00	0.00	0.00	2.82
2.0-2.2 m	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.49	2.43	0.00	0.00	0.00	4.94
1.8-2.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.50	2.06	0.00	0.00	0.00	5.57
1.6-1.8 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.85	1.71	0.00	0.00	0.00	5.56
1.4-1.6 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.36	2.18	0.00	0.00	0.00	5.54
1.2-1.4 m	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.93	1.76	0.00	0.00	0.00	4.69
1.0-1.2 m	0.00	0.01	0.14	0.02	0.00	0.01	0.07	3.73	2.15	0.02	0.00	0.00	6.15
0.8-1.0 m	0.01	0.39	0.80	0.25	0.12	0.07	0.36	3.59	3.74	0.14	0.02	0.00	9.49
0.6-0.8 m	0.15	1.54	2.40	0.85	0.32	0.27	1.11	6.48	5.23	0.52	0.10	0.05	19.04
0.4-0.6 m	0.27	2.08	2.11	0.65	0.39	0.47	2.30	8.27	2.92	0.55	0.21	0.14	20.35
0.2-0.4 m	0.04	0.56	0.55	0.36	0.25	0.30	1.97	6.58	1.48	0.22	0.02	0.01	12.33
< 0.2 m	0.00	0.05	0.05	0.04	0.03	0.07	0.47	0.70	0.36	0.04	0.01	0.00	1.83
All	0.47	4.63	6.05	2.16	1.11	1.20	6.33	47.26	28.73	1.49	0.36	0.21	100

Table 10.3 Relative distribution (in [%]) of H_{m0} at Point P3

Direction	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	All
> 3.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03
2.8-3.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.21	0.00	0.00	0.00	0.30
2.6-2.8 m	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.19	0.76	0.00	0.00	0.00	0.97
2.4-2.6 m	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.50	1.57	0.00	0.00	0.00	2.08
2.2-2.4 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21	2.74	0.00	0.00	0.00	3.95
2.0-2.2 m	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.96	3.05	0.00	0.00	0.00	5.01
1.8-2.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.32	2.82	0.00	0.00	0.00	5.15
1.6-1.8 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.69	2.69	0.00	0.00	0.00	5.38
1.4-1.6 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.01	2.98	0.00	0.00	0.00	4.98
1.2-1.4 m	0.00	0.01	0.00	0.00	0.00	0.00	0.01	1.78	2.25	0.00	0.00	0.00	4.05
1.0-1.2 m	0.00	0.12	0.15	0.01	0.00	0.00	0.10	2.39	3.83	0.06	0.00	0.00	6.67
0.8-1.0 m	0.11	0.86	0.69	0.21	0.09	0.08	0.32	2.54	4.58	0.27	0.08	0.06	9.87
0.6-0.8 m	0.34	2.74	2.06	0.57	0.22	0.25	0.95	5.43	6.33	1.28	0.26	0.18	20.62
0.4-0.6 m	0.41	2.72	1.52	0.42	0.30	0.41	1.55	6.59	3.59	0.99	0.26	0.25	19.00
0.2-0.4 m	0.10	0.65	0.48	0.20	0.13	0.21	1.13	5.65	1.65	0.39	0.05	0.05	10.70
< 0.2 m	0.01	0.05	0.05	0.02	0.03	0.04	0.26	0.44	0.24	0.08	0.00	0.00	1.23
All	0.97	7.14	4.95	1.42	0.77	0.99	4.38	35.81	39.32	3.08	0.65	0.54	100

10.3 Statistics

The monthly statistical data of the significant wave height, Hm0, at points P1, P2 and P3 are given in Table 10.4, Table 10.5and Table 10.6.

The maximum significant wave height of 3.09 m at point P3 sea was observed on July 22th in 2010.

The directional statistical data of Hm0 at points P1, P2 and P3 are given in Table 10.7, Table 10.8 and Table 10.9.

Table 10.4 Monthly and yearly statistical data of significant wave height, H_{m0}. Point P1, 2010-2014

P1: H_{m0}	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Maximum, [m]	1.10	0.96	1.07	1.17	1.99	2.65	2.66	2.64	2.57	1.38	1.02	1.07	2.66
Mean, [m]	0.44	0.40	0.52	0.66	1.00	1.69	1.85	1.58	1.19	0.60	0.53	0.47	0.91
St.Dev., [m]	0.19	0.17	0.15	0.19	0.23	0.34	0.26	0.32	0.39	0.21	0.18	0.18	0.57
Count, [hr]	3720	3384	3720	3600	3720	3600	3720	3720	3600	3720	3600	3717	43821

Table 10.5 Monthly and yearly statistical data of significant wave height, H_{m0}. Point P2

P2: H_{m0}	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Maximum, [m]	1.19	1.01	1.11	1.24	2.07	2.83	2.90	2.88	2.77	1.49	1.06	1.12	2.90
Mean, [m]	0.48	0.44	0.56	0.71	1.06	1.82	2.02	1.71	1.27	0.63	0.55	0.51	0.98
St.Dev., [m]	0.21	0.18	0.15	0.19	0.23	0.38	0.29	0.35	0.43	0.22	0.18	0.19	0.62
Count, [hr]	3720	3384	3720	3600	3720	3600	3720	3720	3600	3720	3600	3717	43821

Table 10.6 Monthly and yearly statistical data of significant wave height, H_{m0}. Point P3

P3: H_{m0}	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Maximum, [m]	1.25	1.05	1.15	1.28	2.15	2.97	3.09	3.07	2.92	1.56	1.12	1.15	3.09
Mean, [m]	0.51	0.48	0.60	0.74	1.10	1.91	2.14	1.81	1.34	0.65	0.57	0.54	1.04
St.Dev., [m]	0.21	0.19	0.16	0.19	0.24	0.40	0.31	0.38	0.46	0.22	0.19	0.19	0.65
Count, [hr]	3720	3384	3720	3600	3720	3600	3720	3720	3600	3720	3600	3717	43821

Table 10.7 Directional statistical data of significant wave height, H_{m0}. Point P1

P1: H_{m0}	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	All
Maximum, [m]	0.69	0.87	1.10	0.97	0.90	1.02	2.38	2.66	2.64	1.00	0.69	0.69	2.66
Mean, [m]	0.50	0.52	0.58	0.58	0.53	0.46	0.44	0.99	1.16	0.56	0.52	0.51	0.91
St.Dev., [m]	0.08	0.12	0.17	0.18	0.19	0.19	0.22	0.58	0.61	0.16	0.10	0.10	0.57
Count, [hr]	90	807	2908	1219	672	675	3731	24425	8916	266	62	50	43821

Table 10.8 Directional statistical data of significant wave height, H_{m0}. Point P2

P2: H_{m0}	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	All
Maximum, [m]	0.82	1.06	1.19	1.08	1.05	1.06	2.55	2.87	2.90	1.12	0.87	0.80	2.90
Mean, [m]	0.57	0.57	0.63	0.59	0.54	0.50	0.49	1.05	1.23	0.58	0.57	0.55	0.98
St.Dev., [m]	0.12	0.15	0.18	0.19	0.19	0.19	0.25	0.63	0.65	0.18	0.15	0.11	0.62
Count, [hr]	205	2029	2650	947	486	525	2776	20711	12589	654	159	90	43821

Table 10.9 Directional statistical data of significant wave height, H_{m0}. Point P3

P3: H_{m0}	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	All
Maximum, [m]	0.92	1.25	1.15	1.00	0.93	1.07	2.66	2.97	3.09	1.18	0.99	0.97	3.09
Mean, [m]	0.59	0.62	0.63	0.62	0.56	0.53	0.53	1.03	1.32	0.59	0.60	0.59	1.04
St.Dev., [m]	0.15	0.17	0.18	0.19	0.19	0.19	0.28	0.66	0.68	0.19	0.16	0.15	0.65
Count, [hr]	424	3128	2167	622	338	434	1918	15691	17229	1349	283	238	43821

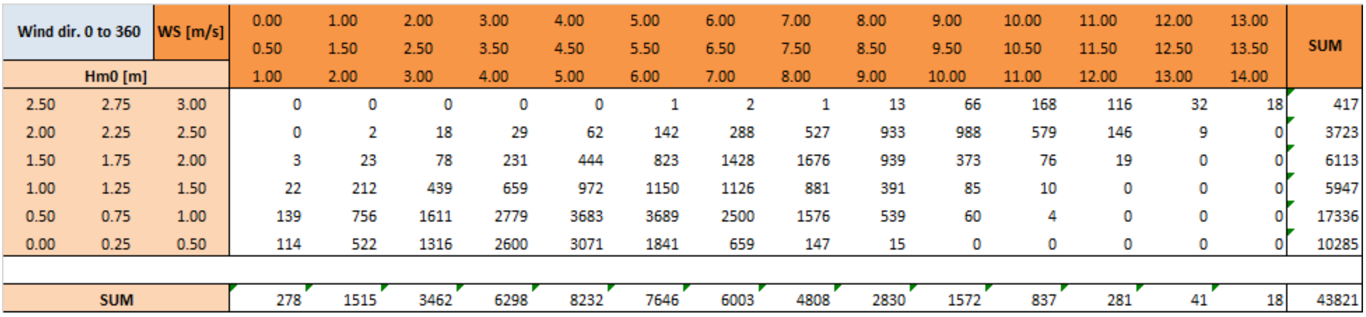
10.4 Scatter tables and plots

Scatter tables are produced on basis of the 5-year long time series of wind and wave data. The scatter tables are given with number of counts from the time series. The total number of data points (hourly) in the 5-year long time series is 43,821 (it is mentioned that the timestep in the original wind dataset is 3 hours).

The following scatter tables are given:

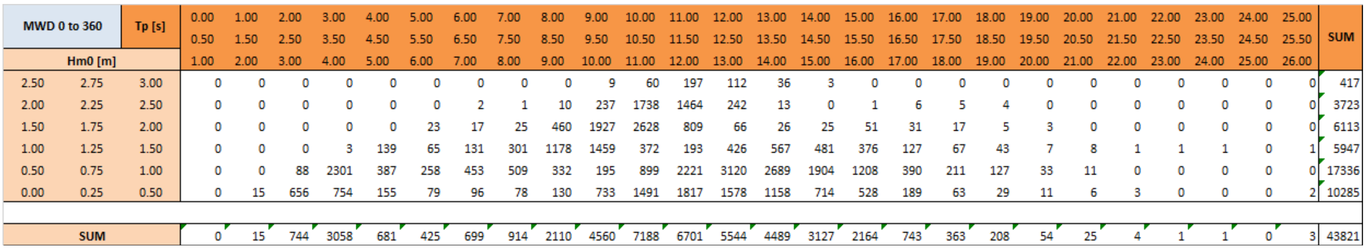
- Scatter table of H_{m0} vs. U_{10} in Table 10.10
- Scatter table of H_{m0} vs. T_p in Table 10.11
- Scatter table of H_{m0} vs. T_{02} in Table 10.12

Table 10.10 Scatter table of H_{m0} vs U_{10}



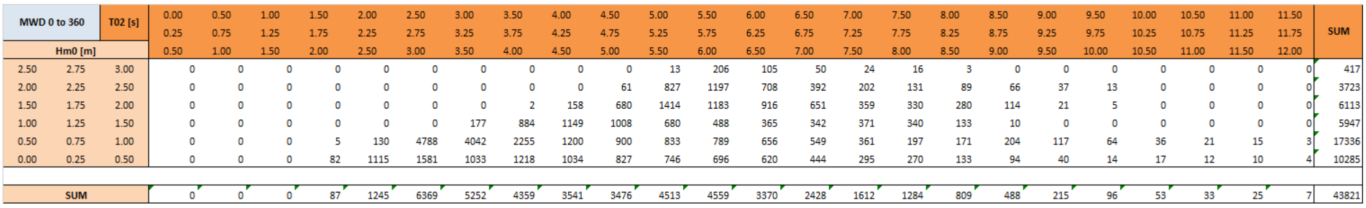
Wind dir. 0 to 360		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	1	2	1	13	66	168	116	32	18	417
2.00	2.25	2.50	0	2	18	29	62	142	288	527	933	988	579	146	9	0	3723
1.50	1.75	2.00	3	23	78	231	444	823	1428	1676	939	373	76	19	0	0	6113
1.00	1.25	1.50	22	212	439	659	972	1150	1126	881	391	85	10	0	0	0	5947
0.50	0.75	1.00	139	756	1611	2779	3683	3689	2500	1576	539	60	4	0	0	0	17336
0.00	0.25	0.50	114	522	1316	2600	3071	1841	659	147	15	0	0	0	0	0	10285
SUM			278	1515	3462	6298	8232	7646	6003	4808	2830	1572	837	281	41	18	43821

Table 10.11 Scatter table of H_{m0} vs T_p



MWD 0 to 360		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	9	60	197	112	36	3	0	0	0	0	0	0	0	0	0	0	0	417
2.00	2.25	2.50	0	0	0	0	0	0	2	1	10	237	1738	1464	242	13	0	1	6	5	4	0	0	0	0	0	0	0	3723
1.50	1.75	2.00	0	0	0	0	0	23	17	25	460	1927	2628	809	66	26	25	51	31	17	5	3	0	0	0	0	0	0	6113
1.00	1.25	1.50	0	0	0	3	139	65	131	301	1178	1459	372	193	426	567	481	376	127	67	43	7	8	1	1	1	0	1	5947
0.50	0.75	1.00	0	0	88	2301	387	258	453	509	332	195	899	2221	3120	2689	1904	1208	390	211	127	33	11	0	0	0	0	0	17336
0.00	0.25	0.50	0	15	656	754	155	79	96	78	130	733	1491	1817	1578	1158	714	528	189	63	29	11	6	3	0	0	0	2	10285
SUM			0	15	744	3058	681	425	699	914	2110	4560	7188	6701	5544	4489	3127	2164	743	363	208	54	25	4	1	1	0	3	43821

Table 10.12 Scatter table of H_{m0} vs T_{02}



MWD 0 to 360		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	13	206	105	50	24	16	3	0	0	0	0	0	0	0	417
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	61	827	1197	708	392	202	131	89	66	37	13	0	0	0	0	3723
1.50	1.75	2.00	0	0	0	0	0	0	0	2	158	680	1414	1183	916	651	359	330	280	114	21	5	0	0	0	0	6113
1.00	1.25	1.50	0	0	0	0	0	0	177	884	1149	1008	680	488	365	342	371	340	133	10	0	0	0	0	0	0	5947
0.50	0.75	1.00	0	0	0	5	130	4788	4042	2255	1200	900	833	789	656	549	361	197	171	204	117	64	36	21	15	3	17336
0.00	0.25	0.50	0	0	0	82	1115	1581	1033	1218	1034	827	746	696	620	444	295	270	133	94	40	14	17	12	10	4	10285
SUM			0	0	0	87	1245	6369	5252	4359	3541	3476	4513	4559	3370	2428	1612	1284	809	488	215	96	53	33	25	7	43821

The scatter tables for Hm0 vs. U_{10}, H_{m0} vs. T_p, and H_{m0} vs. T_{02} period are also determined per wave direction and per wind direction and are attached in Appendix A to Appendix F.

Various omni-directional scatter plots for data at point P2 are given in the following:

- Scatter plot of H_{m0} vs. U_{10} in Figure 10.1
- Scatter plot of H_{m0} vs. T_p in Figure 10.2
- Scatter plot of H_{m0} vs. T_{02} in Figure 10.3
- Scatter plot of H_{m0} vs. Total Water Level in Figure 10.4
- Scatter plot of H_{m0} vs. Residual Water Level in Figure 10.5

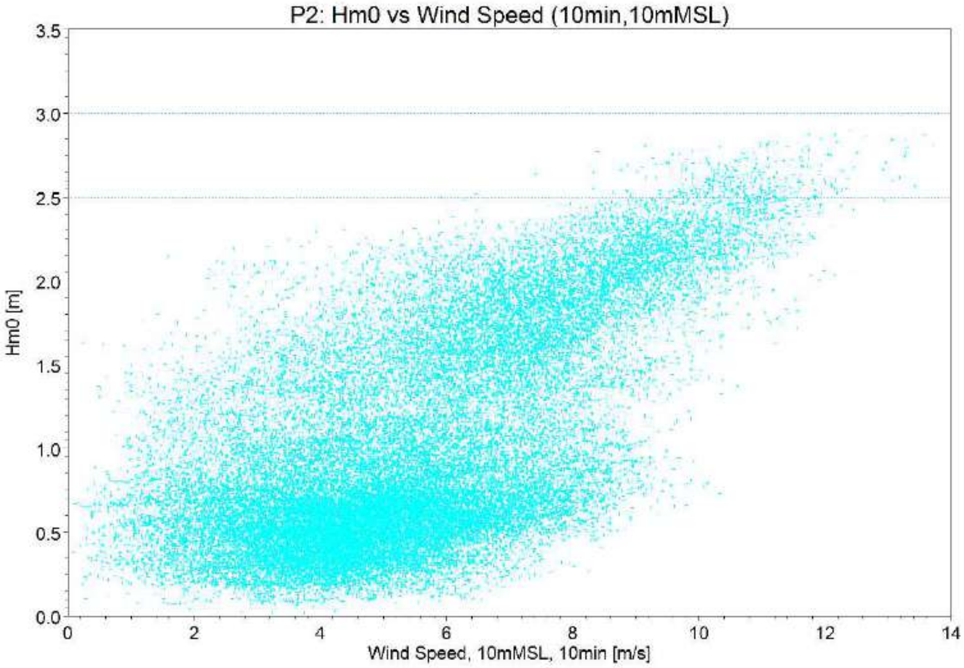


Figure 10.1 Scatter plot of H_{m0} vs. U_{10}

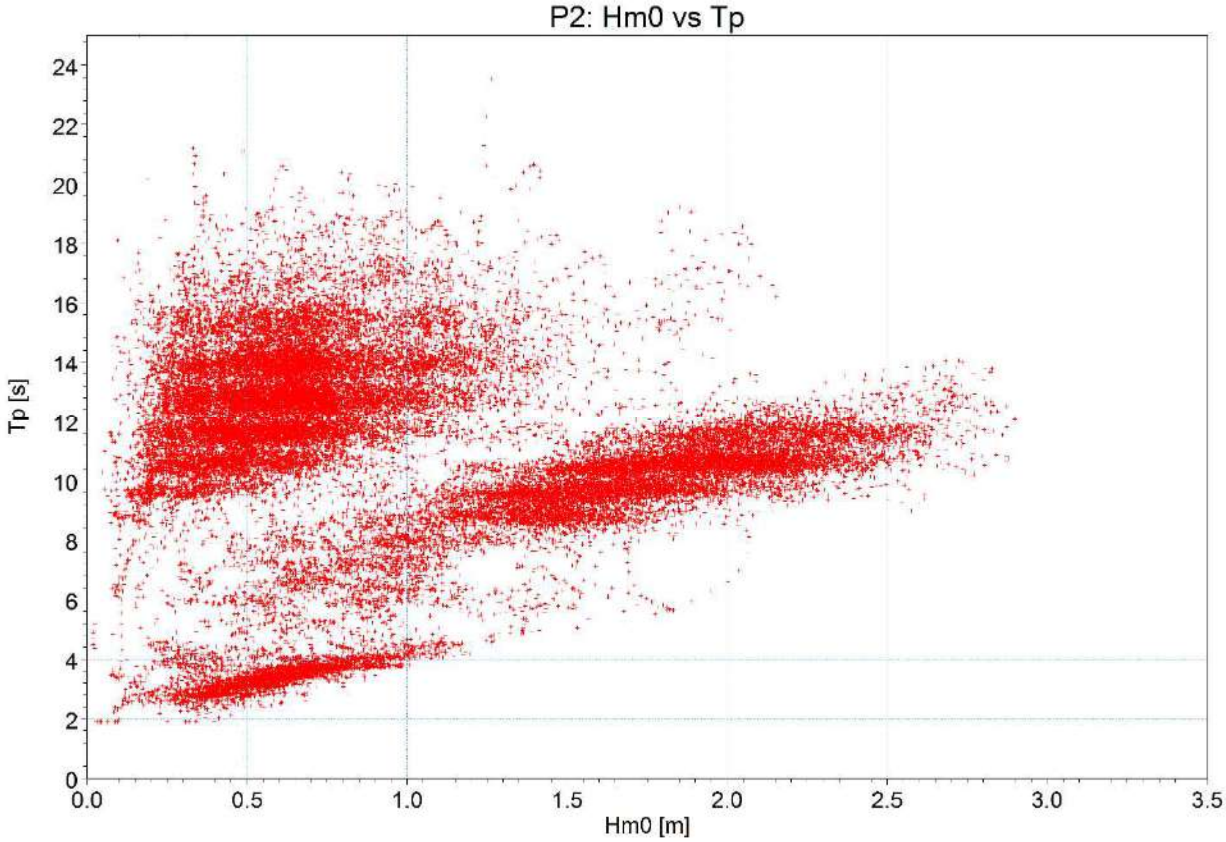


Figure 10.2 Scatter plot of H_{m0} vs. T_p

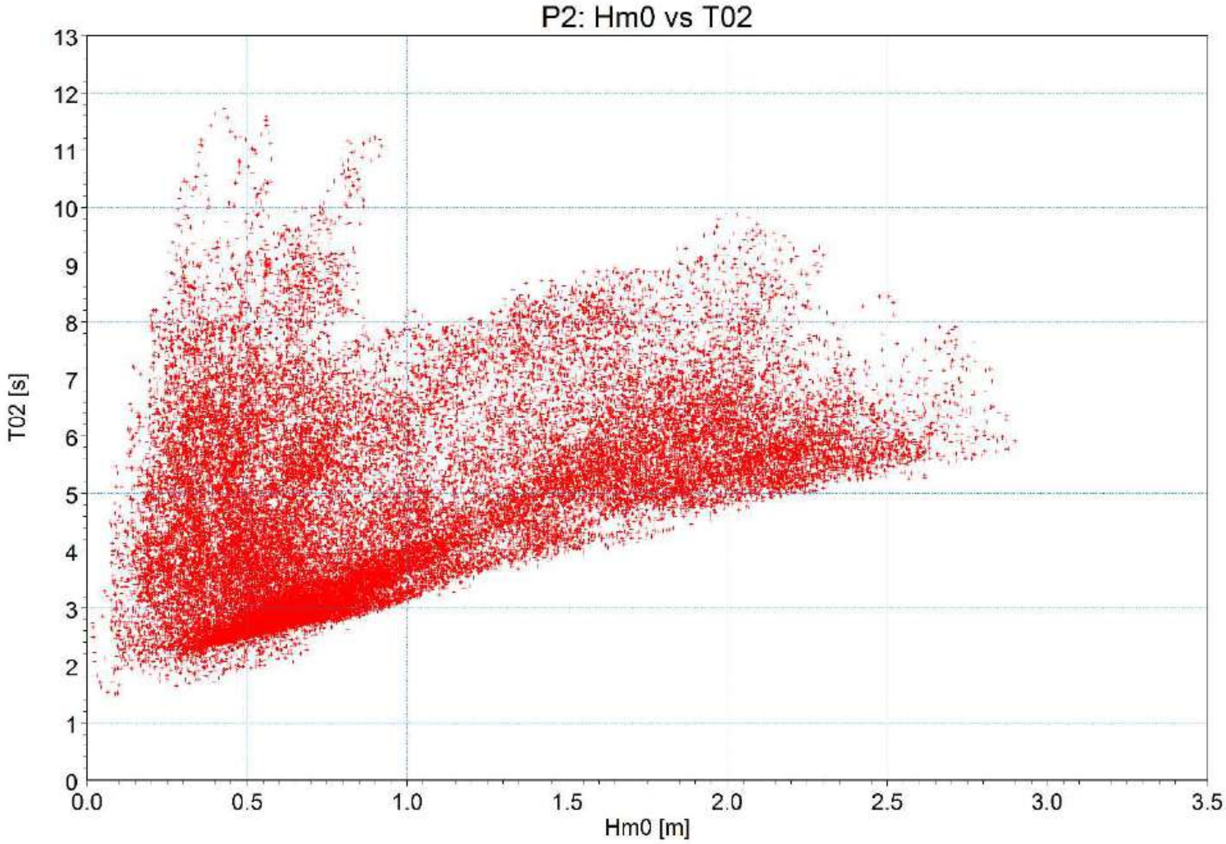


Figure 10.3 Scatter plot of H_{m0} vs T_{02}

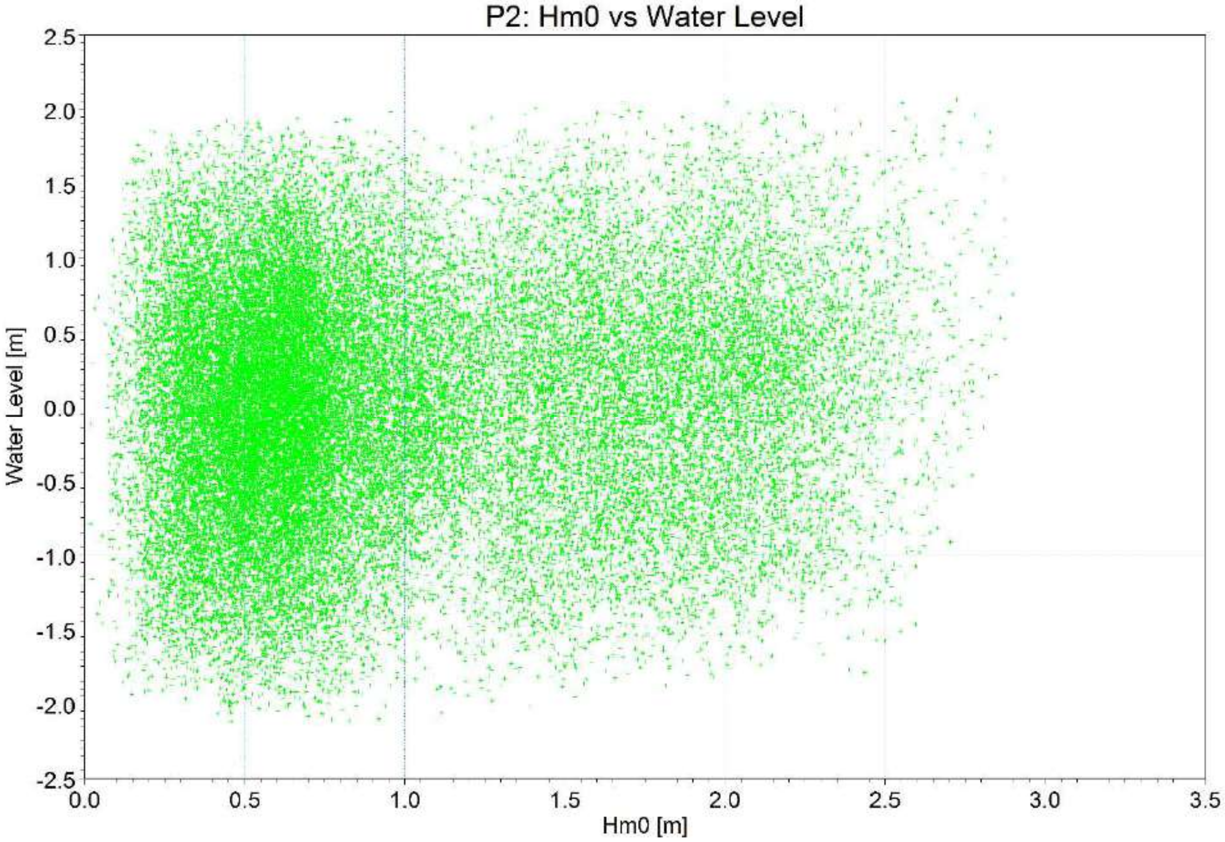


Figure 10.4 Scatter plot of H_{m0} vs Total Water Level

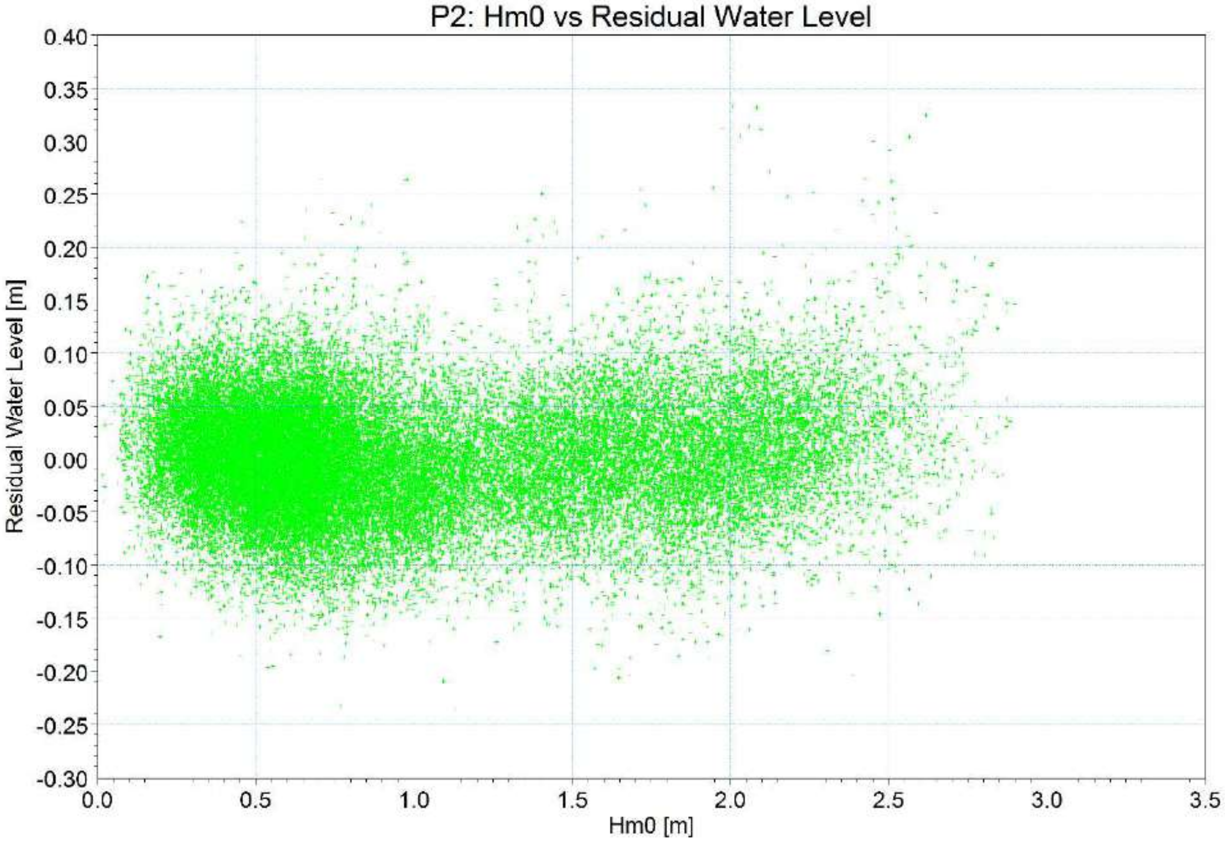


Figure 10.5 Scatter plot of H_{m0} vs Residual Water Level

10.5 Wind-wave misalignment

The misalignment between wind and mean wave directions are determined on basis of wind and wave directions for the 5 yr time series.

Scatter plots depicting the misalignment between wave and wind directions are given in Figure 10.6 for MWD at Point P2 and wind direction

The misalignment table for all wind speeds is given in Table 10.13 while misalignment tables for wind speed intervals of 1m/s are given in Appendix G.

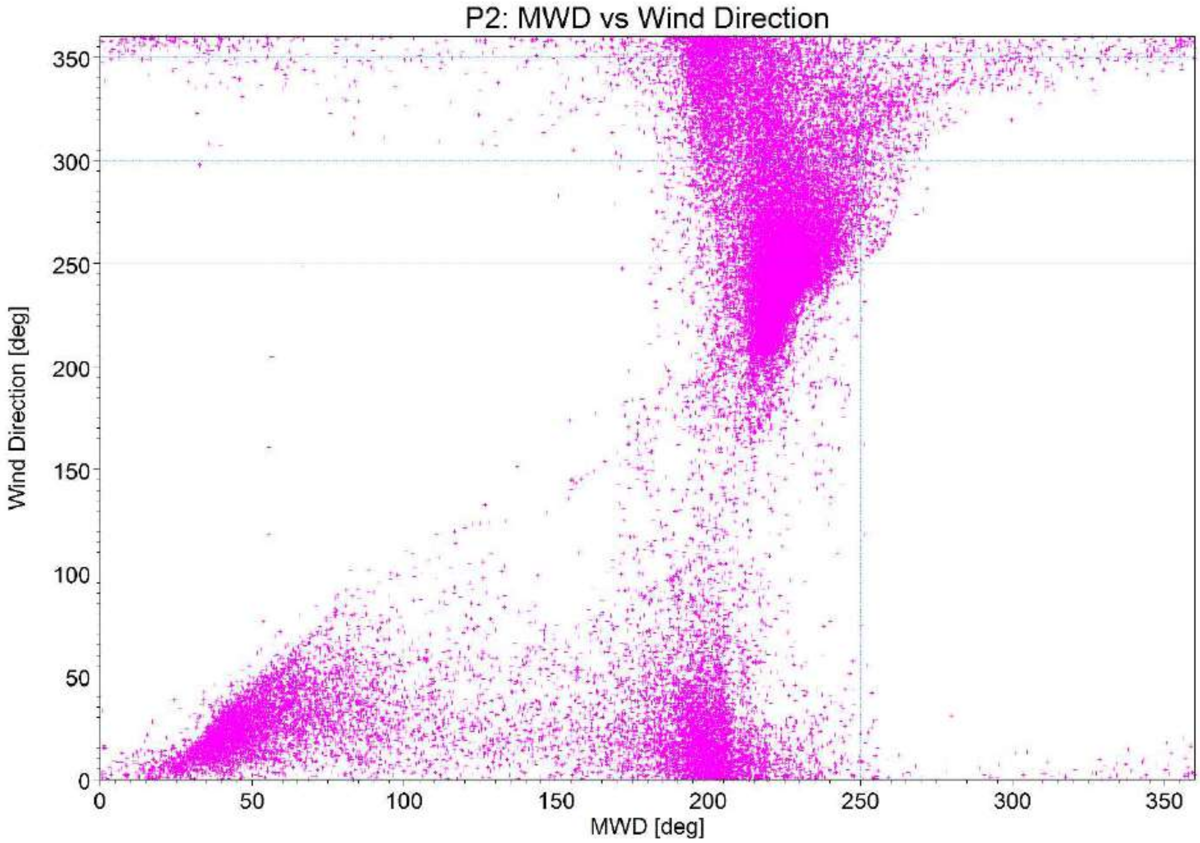


Figure 10.6 Scatter plot of MWD vs. Wind direction at Point P2

Table 10.13 Misalignment table of wind and mean wave directions for all wind speeds (given as total number of hourly counts during 5 years hindcast)

Wind direction [deg]	Point P2: Mean wave direction [deg]												
	0	30	60	90	120	150	180	210	240	270	300	330	All
0	194	986	332	149	110	139	852	2800	487	99	94	81	6323
30	8	1023	1896	485	221	219	930	1357	87	3	0	0	6229
60	0	5	398	246	94	104	312	417	16	0	0	0	1592
90	0	0	5	49	35	15	128	153	6	0	0	0	391
120	0	0	1	2	13	4	44	79	8	0	0	0	151
150	0	0	1	0	0	10	46	87	27	0	0	0	171
180	0	0	0	0	0	3	53	472	50	0	0	0	578
210	0	0	1	0	0	0	12	2700	225	0	0	0	2938
240	0	0	1	0	0	0	24	6145	5577	0	0	0	11747
270	0	0	0	0	0	1	43	2447	3606	55	0	0	6152
300	0	3	0	3	4	5	92	1793	1476	135	0	0	3511
330	3	12	15	13	9	25	240	2261	1024	362	65	9	4038
All	205	2029	2650	947	486	525	2776	20711	12589	654	159	90	43821

10.6 Severe Sea State (SSS)

According to Ref. /1/, section 3.3.4.4 the Severe Sea State (SSS) is characterised by a significant wave height, a peak period and a wave direction (the following data are however only given as omni-directional values). The SSS is associated with a concurrent mean wind speed. The significant wave height of the SSS, $H_{m0,SSS}$, is defined by extrapolation of appropriate site-specific metocean data such that the load effect from the combination of the significant wave height, $H_{m0,SSS}$, and the wind speed, U_{10}, has a return period of 50 years.

The calculation of $H_{m0,SSS}$ was made using the formulation from Ref. /3/, Annex G, and assuming that H_{m0} can be described by a normal distribution in each wind speed interval. The associated wind speed was taken as the 10-minute average wind speed at a height of 10 mMSL, U_{10}.

The associated peak wave period is based on a relation between H_{m0} and T_p derived on basis of Ref. /2/, Section 3.5.5.5 and assuming a peak shape parameter $\gamma=3.3$:

$$T_{p,SSS} = 3.96\sqrt{H_{m0,SSS}}$$

The maximum wave height, H_{max}, was determined as the Severe Wave Height, H_{SWH}, as defined in Ref. /3/, Annex G. Applying the Rayleigh distribution for the wave height distribution in the seastate leads to a ratio of 1.86 between H_{SWH} and H_{m0}.

The associated minimum and maximum individual wave periods are given by the following expression (cf. Ref. /1/, section 3.3.4.5):

$$11.1\sqrt{\frac{H_{m0}}{g}} \leq T_{H_{SWH}} \leq 14.3\sqrt{\frac{H_{m0}}{g}}$$

The resulting SSS are given in Table 10.14.

Table 10.14: Severe Sea State (SSS).

Wind Speed, $U_{3hr,10mMSL}$	$H_{m0,\,SSS}$	$T_{p,SSS}$	H_{SWH}	$T_{Hswh,min}$	$T_{Hswh,max}$
[m/s]	[m]	[s]	[m]	[s]	[s]
0-1	1.90	5.46	3.54	5.53	4.86
1-2	2.16	5.82	4.02	5.89	5.18
2-3	2.29	5.99	4.26	6.07	5.33
3-4	2.33	6.04	4.32	6.11	5.38
4-5	2.52	6.28	4.68	6.36	5.59
5-6	2.96	6.81	5.51	6.90	6.07
6-7	3.57	7.48	6.64	7.57	6.66
7-8	3.82	7.74	7.11	7.84	6.90
8-9	4.12	8.04	7.67	8.14	7.16
9-10	3.76	7.68	6.99	7.78	6.84
10-11	3.51	7.42	6.53	7.52	6.61
11-12	3.53	7.44	6.57	7.54	6.63
12-13	3.47	7.37	6.45	7.46	6.56
13-14	3.21	7.09	5.97	7.18	6.31

10.7 Extreme Value Analysis

The extreme value analysis of the significant wave heights is performed using the DHI MIKE Zero program EVA (Extreme Value Analysis). The extreme values were determined using a peaks-over-threshold (POT) method. A minimum requirement of time span between consecutive peaks is selected as 48 hours in order to ensure independence between consecutive peak values in the time series. An additional requirement stating that the minimum level between two consecutive peak values shall be below 70% of the minor of two consecutive events was also imposed in order to only consider independent peak events (i.e. only one peak event from one storm).

The extracted peak values are fitted to a 3-parameter Weibull distribution using the maximum-likelihood method for parameter estimation. The location parameter γ is fixed at the threshold. Extreme values are then determined for average return periods of 1, 5, and 10 years.

A plot of the peaks-over-threshold data, the fitted Weibull distribution and confidence bands (based on 1 standard deviation) are given in Figure 10.7 for H_{m0}. The Weibull parameters are given in Table 10.15.

The standard deviations on the extreme value estimates are determined on basis of Monte Carlo simulations.

The key results of the extreme value analysis are given in Table 10.16. The results in Table 10.16 are presented as central estimates as well as standard deviation of the extreme significant wave heights. The recommended values to be used for design purposes are also given.

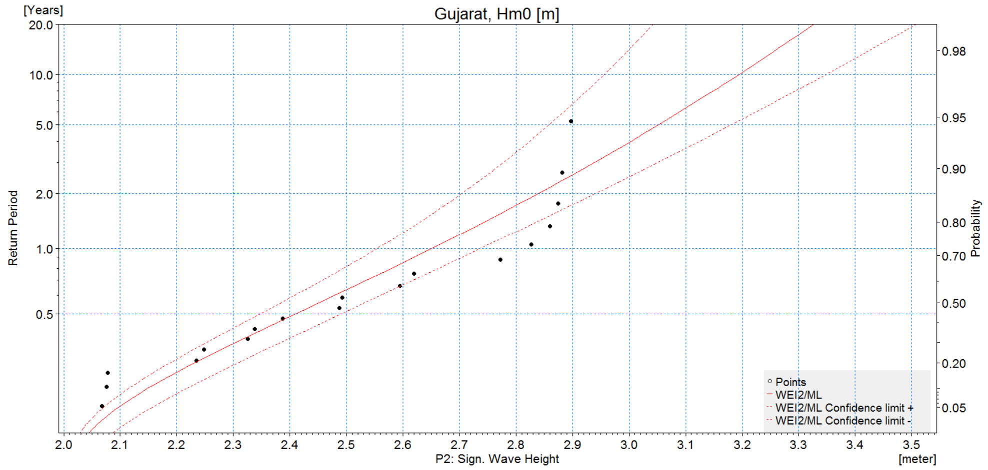


Figure 10.7: Weibull fit to peaks-over-threshold values of H_{m0}

Table 10.15: Weibull parameters from extreme value analysis of H_{m0}

H_{m0} [m]	Weibull Parameters		
	Scale, a	Shape, b	Location, γ
TOTAL SEA	0.561	1.688	2.000

Table 10.16: Results of extreme value analysis of H_{m0} at P2

H_{m0} [m]	Return Period [Years]		
	1	5	10
Central estimate	2.7	3.1	3.2
Standard deviation	0.1	0.2	0.2

From the Weibull fit to the peak values of Hm0 in Figure 10.7 is seen that the highest events are smaller than those by the fitted curve. The central estimates are therefore recommended to be applied as governing for operational conditions. Notice that the specific study of cyclone conditions leads to a significantly larger estimate of the 10-year return period value of H_{m0}.

The maximum wave height, H_{max}, associated wave period, T_{Hmax}, and associated crest height, η_{max}, are determined in the following.

Since the water depths correspond to intermediate water depth for the design wave conditions the following relationships for the maximum wave height, H_{max}, and associated period, T_{Hmax}, may be used (cf. Ref. /2/):

$$H_{max} = 1.86 H_{m0}$$

$$T_{Hmax} = 2.94\sqrt{H_{max}}$$

The associated wave crest height, η_{max}, is determined by a 25th order stream function wave theory using H_{max}, T_{Hmax} and a local water depth of 15 m (MSL). It is mentioned that MSL does not necessarily lead to the most onerous wave crest height. No current is included in the calculation.

The omni-directional extreme wave parameters calculated on basis of the recommended estimates of the extreme values of H_{m0} (from Table 10.16) are given in Table 10.17.

Table 10.17: Omni directional design wave parameters

Parameter	Return Period [Years]		
	1	5	10
H_{m0} [m]	2.7	3.1	3.2
H_{max} [m]	5.0	5.8	6.0
T_{Hmax} [s]	6.6	7.1	7.2
η_{max} [m]	3.0	3.6	3.8

From the scatter plot of H_{m0} versus the water level (total and residual) in Figure 10.4 and Figure 10.5 it is seen that there is almost no relation between the two quantities. This is due to the fact that the water level variation is highly dominated by tidal variation. It is suggested to associate design wave conditions with the most onerous water level for any design calculation. The most onerous water level does not necessarily have to be MSL.

10.8 Wave breaking

Based on the bathymetry presented in Figure 4.3 the seabed slope in the FOWPI area is assessed to be significantly smaller than 1%.

For a sloping seabed, the classification of breaking wave types is normally made through the non-dimensional parameter ξ_b, also known as the Iribarren number or the surf similarity parameter (cf. Ref. /2/):

$$\xi_b = \frac{m}{\sqrt{H_b/L_0}}$$

In the above formula H_b is the wave height at breaking, m is the seabed slope, $L_0=gT^2/2\pi$ is the deep water wavelength and T is the corresponding wave period.

According to Ref. /3/, Annex C.3 the breaking wave height may be estimated as:

$$H_b = \frac{b}{\frac{1}{h}+\frac{a}{gT_b^2}}$$

where

$$a = 44[1-\exp(-19m)]$$

$$b = \frac{1.6}{1+\exp(-19m)}$$

in which h is the water depth and T_b is the period of the breaking wave.

The wave data with a 10-year return period and a water depth of 15m are considered in this assessment.

Even for a conservatively large seabed slope of 1% the Iribarren number becomes significantly smaller than 0.4. Hence, based on the present data it is thus concluded that only spilling breaker types are expected in the FOWPI site.

11 Water Level

11.1 General

The continuous hindcast time series of hourly water level data from 2010 to 2014 (5 years) from the data point P2 has been used for the water level analysis.

The MIKE Zero tidal module is used for separation of the total water level into tidal and residual components.

11.2 Tidal Datums

A sketch showing the various tidal datums is given in Figure 11.1.

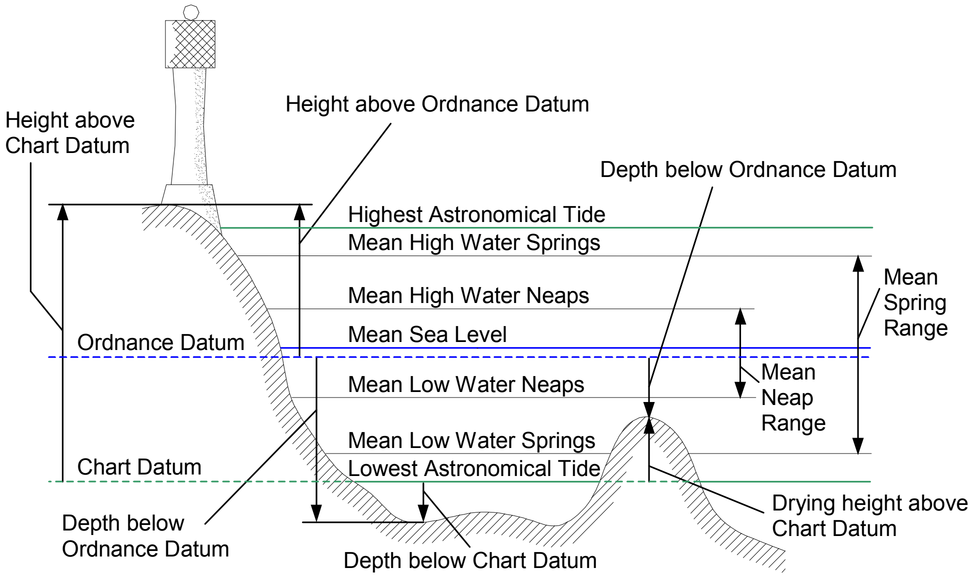


Figure 11.1: Illustration sketch of various tidal datums

The values of HAT (Highest Astronomical Tide), LAT (Lowest Astronomical Tide) and MSL (Mean Sea Level) are determined on basis of statistical values (maximum, minimum and mean) from the entire tidal water level time series. The remaining tidal levels are determined based on peak values during spring and neap periods during the entire tidal level time series. The derived tidal levels are given in Table 11.1.

Table 11.1: Tidal datums [m]

Tidal datum		Elevation [mLAT]	Elevation [mMSL]
HAT	(Highest Astronomical Tide)	4.12	2.01
MHWS	(Mean High Water Spring)	3.35	1.25
MHWN	(Mean High Water Neap)	2.64	0.54
MSL	(Mean Sea Level)	2.11	0.00
MLWN	(Mean Low Water Neap)	1.61	-0.50
MLWS	(Mean Low Water Spring)	0.83	-1.27
MLLWS	(Mean Lower Low Water)	0.64	-1.47
LAT	(Lowest Astronomical Tide)	0.00	-2.11

11.3 Statistics

The monthly statistical data of the Total and Residual high water level at point P2 are given in Table 11.2 and Table 11.3.

Table 11.2: Monthly and yearly statistical data of Total high water level [mMSL]. Point P2

Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Maximum, [m]	1.92	1.75	1.75	1.93	2.01	2.07	2.03	1.88	1.79	1.92	1.94	1.89	2.07
Mean, [m]	0.59	0.58	0.59	0.60	0.61	0.65	0.64	0.63	0.61	0.60	0.59	0.59	0.61
St.Dev., [m]	0.43	0.39	0.39	0.42	0.45	0.48	0.46	0.43	0.41	0.42	0.44	0.45	0.43
Count, [hr]	1807	1667	1834	1786	1923	2017	2099	2043	1925	1853	1780	1825	22559

Table 11.3: Monthly and yearly statistical data of Residual high water level [mMSL]. Point P2

Residual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Maximum, [m]	0.18	0.18	0.19	0.17	0.14	0.33	0.19	0.20	0.26	0.16	0.26	0.21	0.33
Mean, [m]	0.04	0.04	0.04	0.04	0.03	0.05	0.04	0.04	0.05	0.04	0.04	0.04	0.04
St.Dev., [m]	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.04	0.03	0.03
Count, [hr]	1505	1892	2069	1747	1212	2305	1826	1541	1889	1784	1932	1904	21606

The monthly statistical data of the Total and Residual low water level at point P2 are given in Table 11.4 and Table 11.5.

Table 11.4: Monthly and yearly statistical data of Total low water level [mMSL]. Point P2

Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Minimum, [m]	-1.97	-1.93	-2.04	-2.12	-2.11	-1.96	-1.80	-1.72	-2.04	-2.08	-2.07	-2.05	-2.12
Mean, [m]	-0.69	-0.67	-0.63	-0.59	-0.60	-0.61	-0.63	-0.63	-0.61	-0.58	-0.61	-0.66	-0.63
St.Dev., [m]	0.47	0.45	0.46	0.47	0.46	0.43	0.41	0.42	0.44	0.45	0.46	0.47	0.45
Count, [hr]	1913	1717	1886	1814	1797	1583	1621	1677	1675	1867	1820	1892	21262

Table 11.5: Monthly and yearly statistical data of Residual low water level [mMSL]. Point P2

Residual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Minimum, [m]	-0.24	-0.20	-0.18	-0.15	-0.17	-0.17	-0.20	-0.21	-0.16	-0.15	-0.20	-0.18	-0.24
Mean, [m]	-0.05	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.05	-0.04	-0.03	-0.04	-0.04
St.Dev., [m]	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Count, [hr]	2215	1492	1651	1853	2508	1295	1893	2178	1711	1936	1667	1812	22211

11.4 Extreme Value Analysis

The extreme value analysis of the residual water levels (high and low) was performed using the DHI MIKE Zero program EVA (Extreme Value Analysis). The extreme values are determined using a peaks-over-threshold (POT) method. A minimum requirement of time span between consecutive peaks was selected as 48 hours in order to ensure independence between consecutive peak values in the time series. An additional requirement stating that the minimum level between two consecutive peak values shall be below 70% of the minor of two consecutive events has also been imposed in order to only consider independent peak events (i.e. only one peak event from one storm).

The extracted peak values are fitted to a 3-parameter Weibull distribution using the maximum-likelihood method for parameter estimation. The location parameter γ is fixed at the threshold. Extreme values are then determined for average return periods of 1, 5 and 10 years.

A plot of the peaks-over-threshold data, the fitted Weibull distribution and confidence bands (based on 1 standard deviation) are given in Figure 11.2 for the High Residual Water Level and in Figure 11.3 for the Low Residual Water Level. The corresponding Weibull parameters are given in Table 11.6 and Table 11.7.

The standard deviations on the extreme value estimates were determined on basis of Monte Carlo simulations.

The key results of the extreme value analysis are given in Table 11.8 and Table 11.9. The results are presented as central estimates as well as standard deviation of the extreme residual water levels. The recommended values to be used for design purposes are also given.

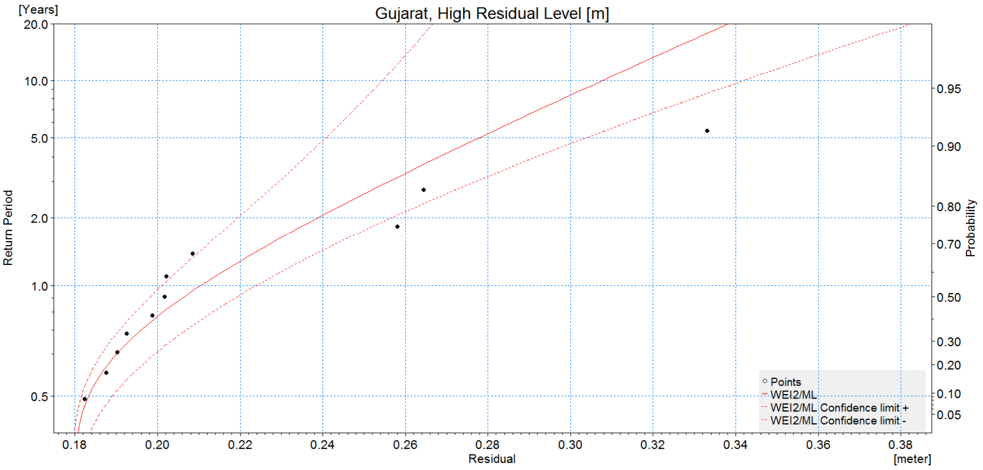


Figure 11.2: Weibull fit to peaks-over-threshold values of High Residual Water Level

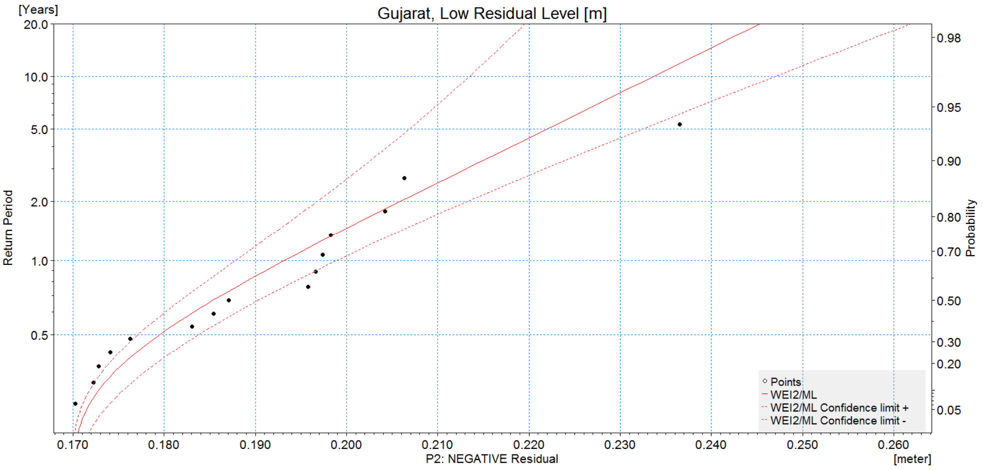


Figure 11.3: Weibull fit to peaks-over-threshold values of High Residual Water Level

Table 11.6: Weibull parameters from extreme value analysis of High Residual Water Level

High Residual Level [m]	Weibull Parameters		
	Scale, a	Shape, b	Location, γ
	0.039	0.950	0.180

Table 11.7: Weibull parameters from extreme value analysis of Low Residual Water Level

Low Residual Level [m]	Weibull Parameters		
	Scale, a	Shape, b	Location, γ
	0.021	1.115	0.170

Table 11.8: Results of extreme value analysis of High Residual Water Level (notice that for design purposes it is recommended to add one standard deviation to the central estimates)

High Residual Level [m]	Return Period [Years]		
	1	5	10
Central estimate	0.21	0.28	0.31
Standard deviation	0.02	0.03	0.04
Recommended value	0.23	0.31	0.35

Table 11.9: Results of extreme value analysis of Low Residual Water Level (notice that for design purposes it is recommended to add one standard deviation to the central estimates)

Low Residual Level [m]	Return Period [Years]		
	1	5	10
Central estimate	-0.19	-0.22	-0.23
Standard deviation	0.01	0.01	0.02
Recommended value	-0.20	-0.23	-0.25

11.5 Sea Level Rise (SLR)

The global mean sea level rise is assessed on basis of the results presented by IPCC (see Ref. /20/). Four emission scenarios from Ref. /20/ are presented in Figure 11.4.

An expected sea level rise of about 0.15 m in the coming 20 years and about 0.4 m in the coming 50 years can be derived from Figure 11.4. Although these estimates are associated with some uncertainty, it is recommended to add them to the water levels presented in this report in case of expected sea level rise should be taken into account.

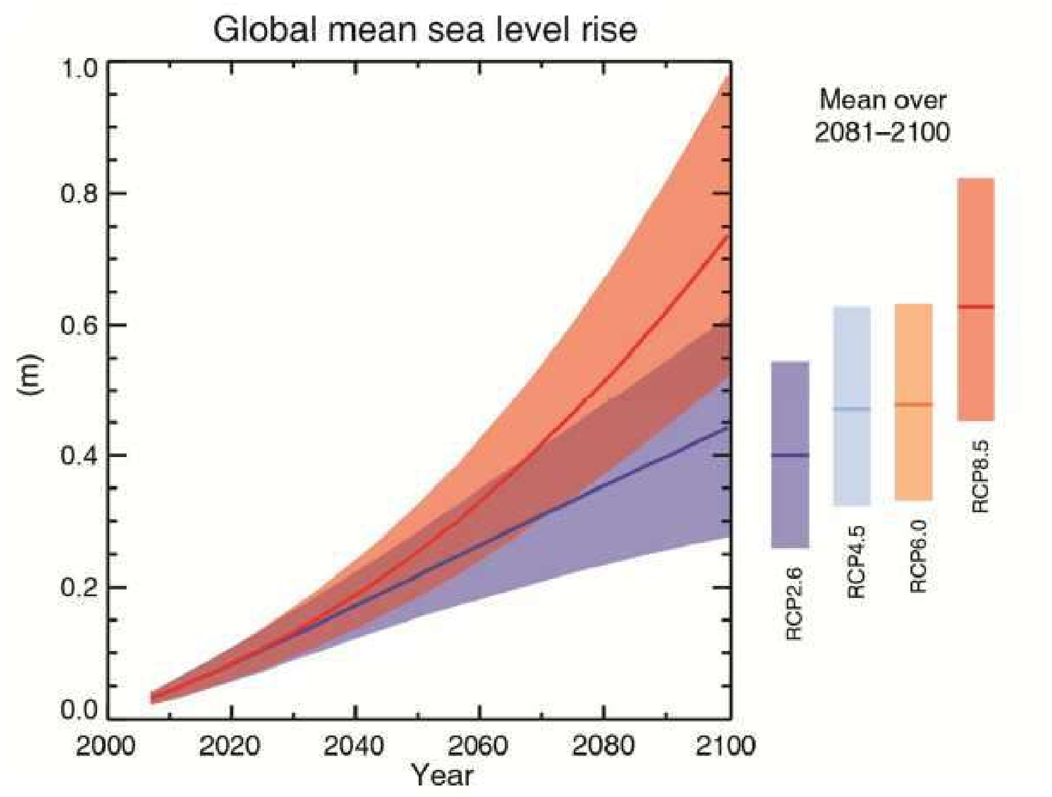


Figure 11.4 *Global mean sea level rise for four emission scenarios (RCP) until year 2100, cf. Ref. /20/*

12 Current

12.1 General

The continuous hindcast time series of hourly current data from 2010 to 2014 (5 years) from the data point P2 has been used for the current analysis.

The MIKE Zero tidal module is used for separation of the total current speed into tidal and residual components.

12.2 Statistics

The monthly statistical data of the Total and Residual current speed level at point P2 are given in Table 12.1 and Table 12.2.

Table 12.1: Monthly and yearly statistical data of Total current speed. Point P2, 2010-2014.

Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Maximum, [m/s]	1.35	1.35	1.41	1.42	1.42	1.40	1.38	1.37	1.43	1.42	1.40	1.36	1.43
Mean, [m/s]	0.56	0.56	0.56	0.55	0.54	0.54	0.55	0.56	0.56	0.55	0.55	0.55	0.55
St.Dev., [m/s]	0.32	0.33	0.34	0.33	0.31	0.31	0.32	0.34	0.34	0.33	0.32	0.31	0.33
Count, [hr]	3720	3384	3720	3600	3720	3600	3720	3720	3600	3720	3600	3717	43821

Table 12.2: Monthly and yearly statistical data of Residual current speed. Point P2, 2010-2014.

Residual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Maximum, [m/s]	0.13	0.14	0.17	0.10	0.10	0.12	0.15	0.17	0.15	0.10	0.10	0.15	0.17
Mean, [m/s]	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03
St.Dev., [m/s]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02
Count, [hr]	3720	3384	3720	3600	3720	3600	3720	3720	3600	3720	3600	3717	43821

12.3 Extreme Value Analysis

The extreme value analysis of the total and residual current speed is performed using the DHI MIKE Zero program EVA (Extreme Value Analysis). The extreme values are determined using a peaks-over-threshold (POT) method. A minimum requirement of time span between consecutive peaks is selected as 48 hours in order to ensure independence between consecutive peak values in the time series. An additional requirement stating that the minimum level between two consecutive peak values shall be below 70% of the minor of two consecutive events has also been imposed in order to only consider independent peak events (i.e. only one peak event from one storm).

The extracted peak values are fitted to a 3-parameter Weibull distribution using the maximum-likelihood method for parameter estimation. The location parameter γ is fixed at the threshold. Extreme values are then determined for average return periods of 1, 5 and 10 years.

A plot of the peaks-over-threshold data, the fitted Weibull distribution and confidence bands (based on 1 standard deviation) are given in Figure 11.2 for the Total Current Speed and in Figure 11.3 for the Residual Current Speed. The corresponding Weibull parameters are given in Table 11.6 and Table 11.7.

The standard deviations on the extreme value estimates are determined on basis of Monte Carlo simulations.

The key results of the extreme value analysis are given in Table 11.8 and Table 11.9. The results are presented as central estimates as well as standard deviation of the extreme significant wave heights. The recommended values to be used for design purposes are also given.

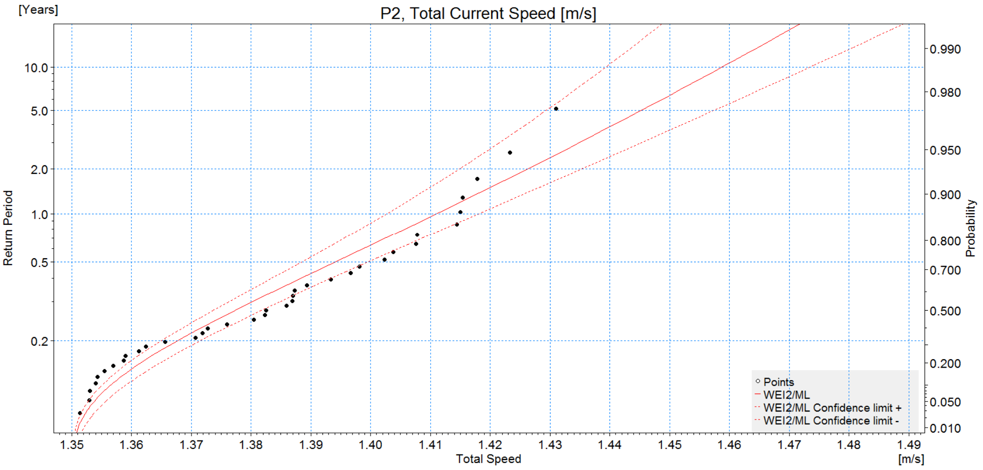


Figure 12.1: Weibull fit to peaks-over-threshold values of Total Current Speed

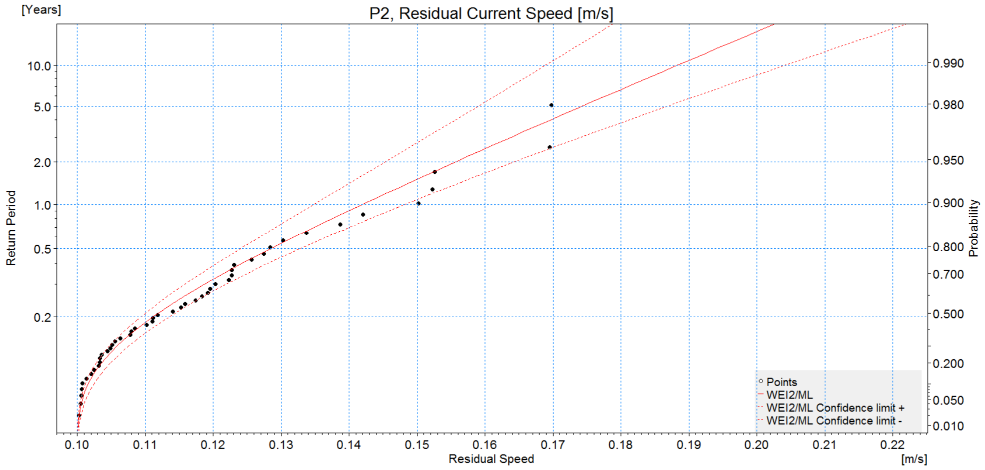


Figure 12.2: Weibull fit to peaks-over-threshold values of Residual Current Speed

Table 12.3: Weibull parameters from extreme value analysis of Total Current Speed

Total Current Speed [m/s]	Weibull Parameters		
	Scale, a	Shape, b	Location, γ
	0.036	1.321	1.350

Table 12.4: Weibull parameters from extreme value analysis of Residual Current Speed

Residual Current Speed [m/s]	Weibull Parameters		
	Scale, a	Shape, b	Location, γ
	0.018	0.942	0.100

Table 12.5: Results of extreme value analysis of Total Current Speed (notice that for design purposes it is recommended to add one standard deviation to the central estimates)

Total Current Speed [m/s]	Return Period [Years]		
	1	5	10
Central estimate	1.42	1.45	1.46
Standard deviation	0.01	0.01	0.02
Recommended value	1.43	1.46	1.48

Table 12.6: Results of extreme value analysis of Residual Current Speed (notice that for design purposes it is recommended to add one standard deviation to the central estimates)

Residual Current Speed [m/s]	Return Period [Years]		
	1	5	10
Central estimate	0.14	0.17	0.19
Standard deviation	0.01	0.02	0.02
Recommended value	0.15	0.19	0.21

13 Cyclone Conditions

13.1 General

The present chapter describes the results of hydrodynamic and wave conditions due to storm events corresponding to 10, 50 and 100 year return period at the proposed Gujarat OWF project area.

Data from Ref. /17/ (which is also given in Appendix H) reveal that the west coast of India has been struck by 27 cyclones during the period 1975 to 2015. The met-ocean condition during cyclones fare exceed the conditions caused by monsoons and tropical storms, and the random nature of the cyclone tracks in the region means that statistical the project site will inevitably experience the full-blown impact of a cyclone sometime in the near or fare future.

The following section describes the development of cyclonic design conditions at the project site.

13.2 Extreme wind speeds

13.2.1 Background

An internal COWI study on cyclone track information along the west coast of India resulted in a number of 27 cyclonic storms in the Arabian Sea during the period 1975 to 2015 (see Ref. /17/ and Appendix H).

During three of these cyclones the data reanalysis simulations given in Appendix H predict that the significant wave height near the OWF site will have exceeded 7.0m.

The tracks of these three historic cyclones are given in Figure 13.1 to Figure 13.3.

It is seen that all three tracks are approaching land from a south-westerly direction.

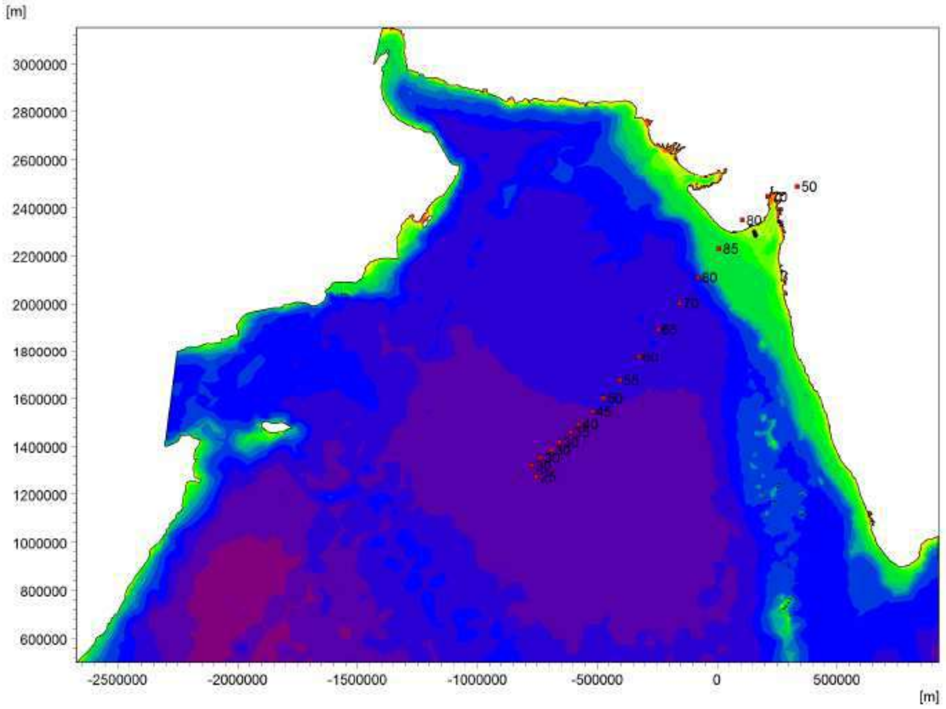


Figure 13.1 *Track for cyclone 04-09 November 1982 (cf. [1]). Reanalysis simulations show a maximum significant wave height at the OWF site of 7.7m. Colour codes indicate water depth (i.e. bathymetry)*

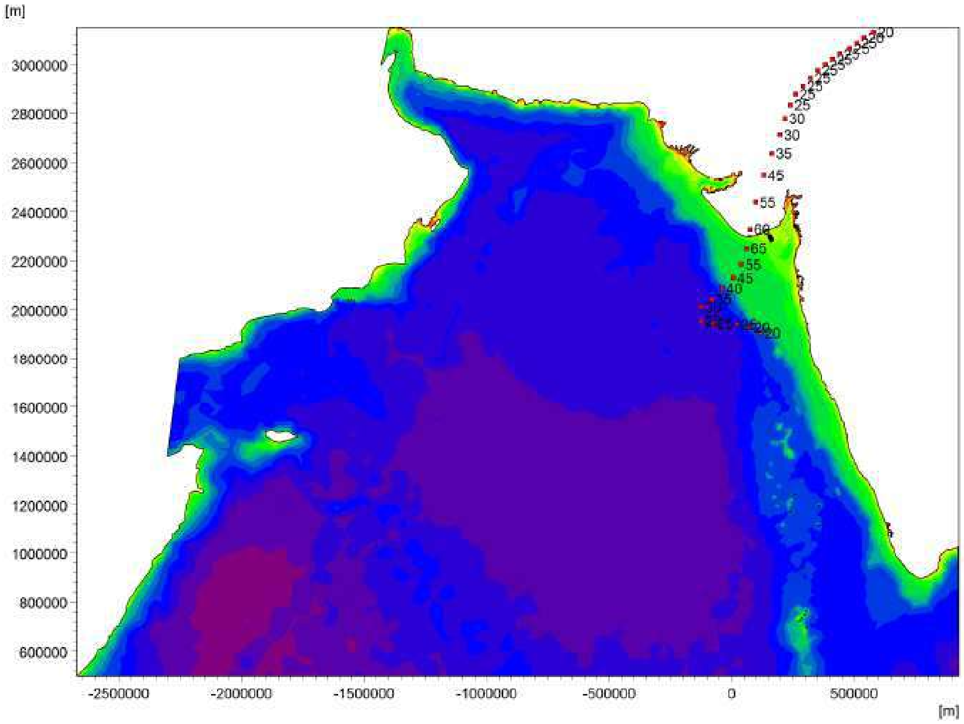


Figure 13.2 *Track for cyclone 15-25 June 1996 (cf. [1]). Reanalysis simulations show a maximum significant wave height at the OWF site of 7.4m. Colour codes indicate water depth (i.e. bathymetry)*

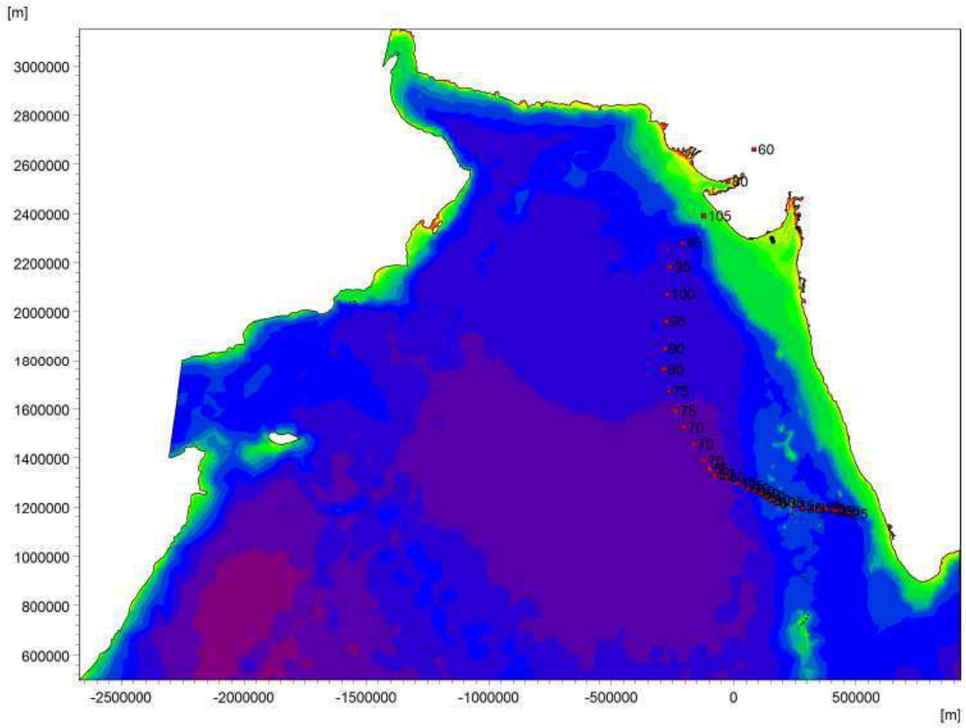


Figure 13.3 *Track for cyclone 01-09 June 1998 (cf. [1]). Reanalysis simulations show a maximum significant wave height at the OWF site of 7.0m. Colour codes indicate water depth (i.e. bathymetry)*

13.2.2 Extreme cyclonic wind hazard

The extreme cyclonic wind hazard is assessed by using the Tropical Cyclone Risk Model (TCRM) by Geoscience Australia (see Ref. /10/).

The results of the simulations provide the spatial variation of the cyclonic wind hazard for average return periods of 10, 50 and 100 years. Figure 13.4 to Figure 13.6 show 10, 50 and 100 year return period 3-second gusts wind speeds at height of 10 m above ground. Note that the TCRM model is mainly aimed for use at onshore areas and does therefore not provide wind speeds over the sea.

Figure 13.7 shows the return period extreme wind speeds (3-second gusts) at a location near Veraval, India (70.3°E, 20.9°N). The location of Veraval is also shown in Figure 5.1. The peak wind speeds (3-second gusts) corresponding to return periods of 10, 50 and 100 years are given in Table 13.1. The extreme wind speeds corresponding to 10-minute average period is converted from the 3-sec gust by applying a factor of 1/1.249=0.801 (cf. Ref. /2/, section 2.3.2.11), the results are given in Table 13.2.

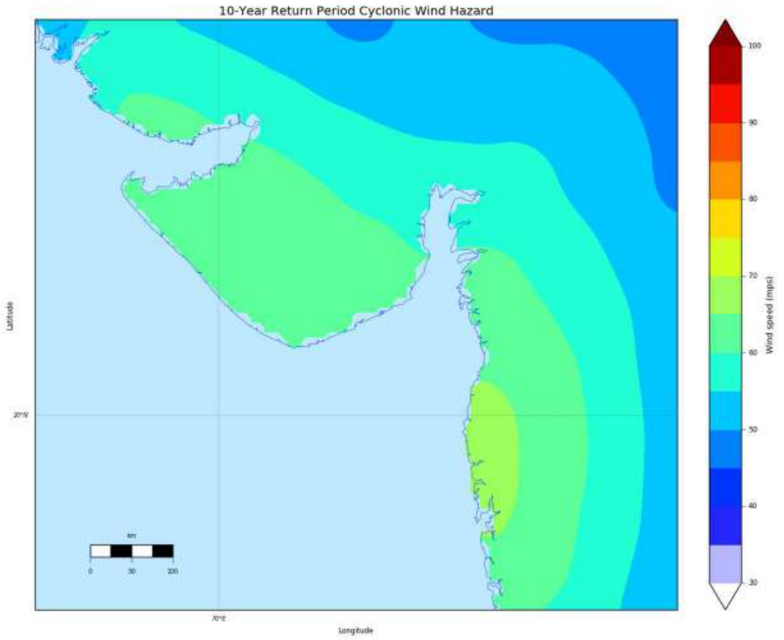


Figure 13.4 Gujarat Cyclone Wind Hazard: Wind speed corresponding to 3-second gust, 10 year return period

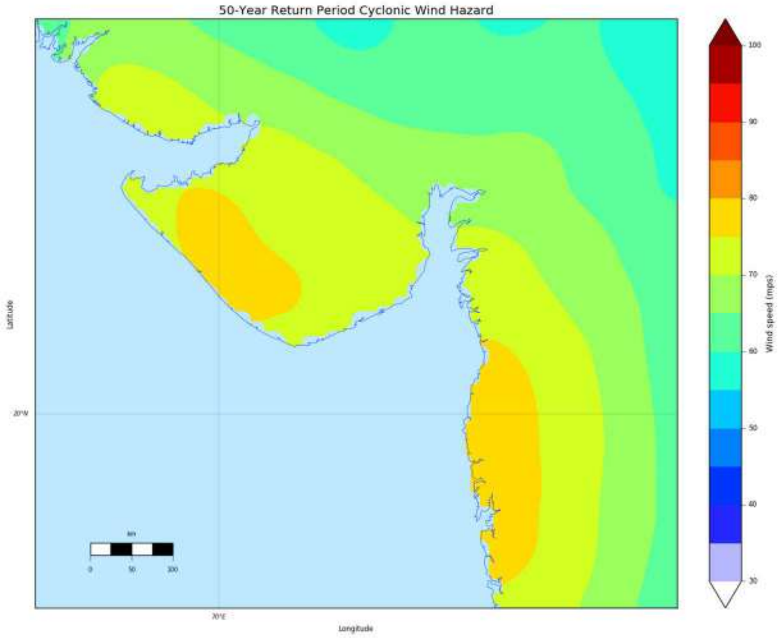


Figure 13.5 Gujarat Cyclone Wind Hazard: Wind speed corresponding to 3-second gust, 50 year return period

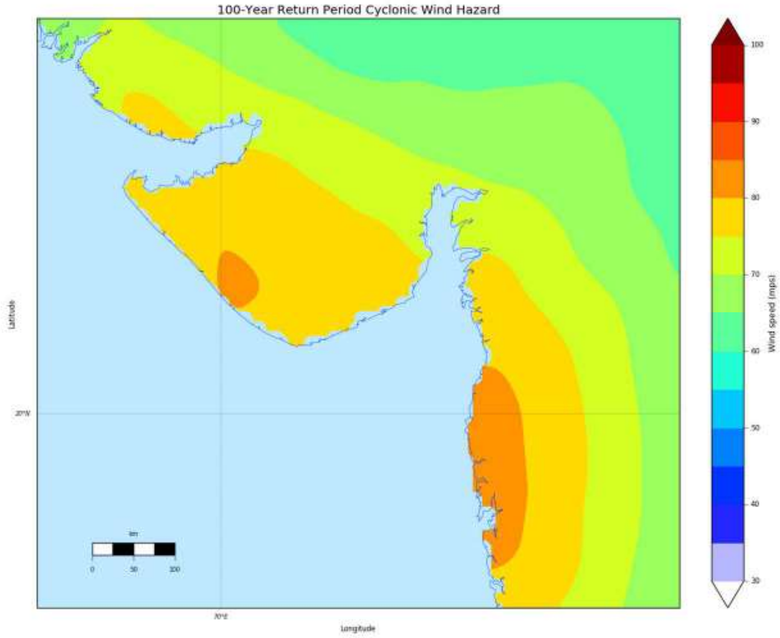
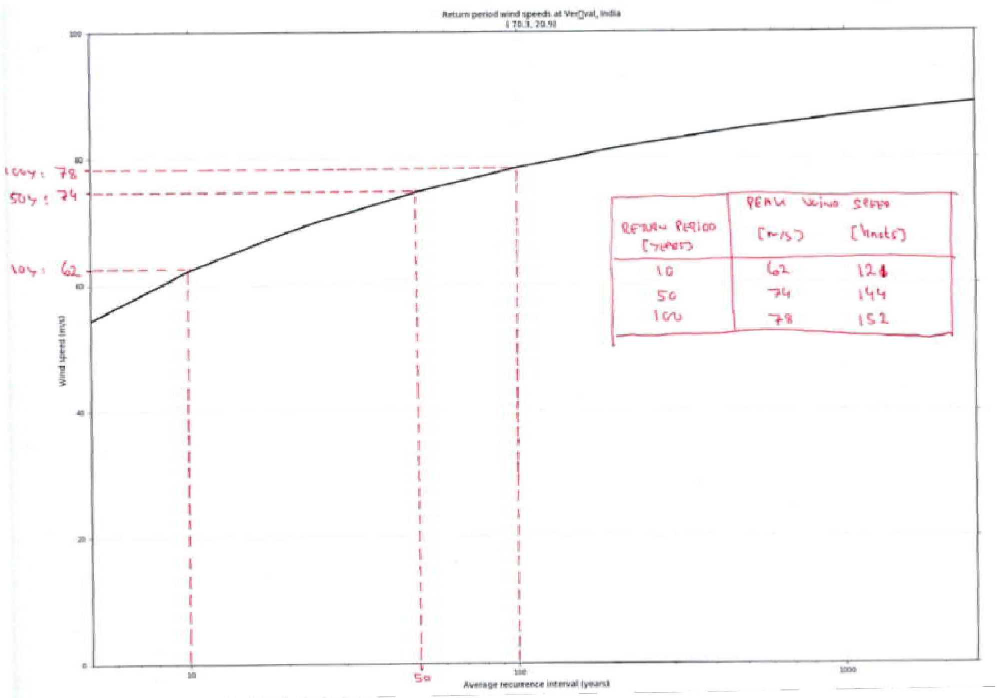


Figure 13.6 Gujarat Cyclone Wind Hazard: Wind speed corresponding to 3-second gust, 100 year return period



RETURN PERIOD [YEARS]	PEAK WIND SPEED [m/s]	[knots]
10	62	124
50	74	144
100	78	152

Figure 13.7 Return period 3-second gust wind speeds at Veraval, India (70.3°E, 20.9°N)

Table 13.1 Extreme peak wind speeds (3-second gust) at Veraval

Return Period [Years]	Peak Wind Speed (3-second gust)	
	[m/s]	[knots]
10	62	121
50	74	144
100	78	152

Table 13.2 Extreme peak wind speeds (10-minute average) at Veraval

Return Period [Years]	Peak Wind Speed (10-minute average)	
	[m/s]	[knots]
10	50	97
50	59	115
100	62	122

13.3 Selection of extreme events

For establishment of extreme conditions at the project OWF site, the cyclone track at 4-9 November 1982 was modelled with the wind speeds scaled to correspond return periods of 10, 50 and 100 year, so that the maximum wind speed during the simulation becomes equal to the ones given in Table 13.2

The selected "Tropical Cyclone 25-82" developed in the central Arabian Sea during the period 4-9 November 1982 (see Figure 13.8). The first Tropical Cyclone Formation Alert was issued on 4 November, followed by first warning on Tropical Cyclone 25-82 at 05 November. It continued to deepen until landfall on 8 November near Veraval (20.9°N 70.4°E) with sustained winds of 90 knots (46 m/s), leaving at least 50,000 homes damaged or destroyed and a death toll in excess of 341.

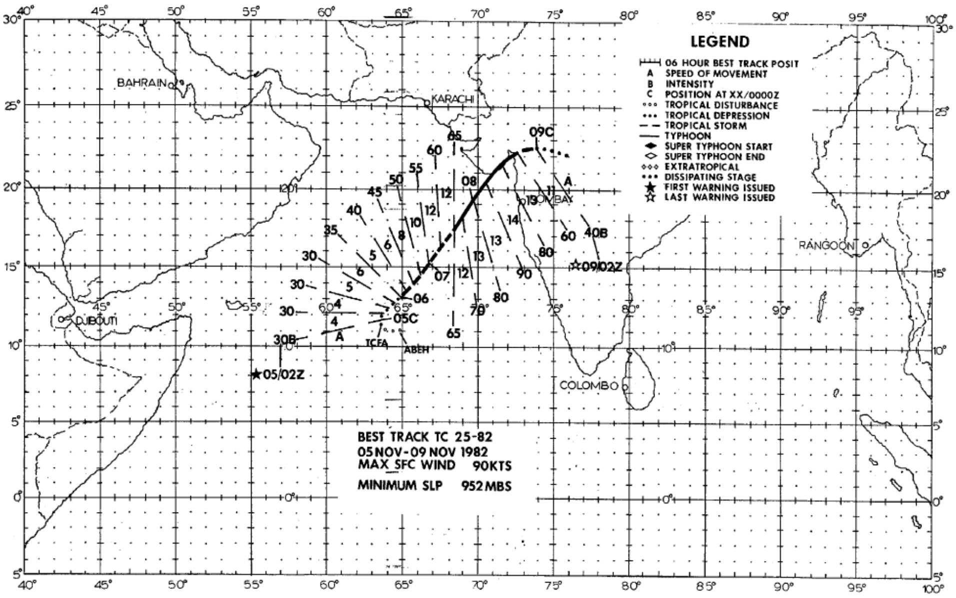


Figure 13.8 *JTWC track for 1982 storm (4 – 9 November) crossing Veraval coast with a maximum wind speed of 90 knots*

13.4 Hydrodynamic condition during storm events

The hydrodynamic conditions during the tropical cyclone (25-82) was modelled with the MIKE 21 HD FM model and using the setup presented in section 5.

The wind speed during the cyclone was scaled based on Table 13.2 to generate three artificial cyclones with 10, 50 and 100 year wind conditions. The artificial wind and pressure field was generated using the MIKE CYWIND tool of MIKE Zero, see Figure 13.9.

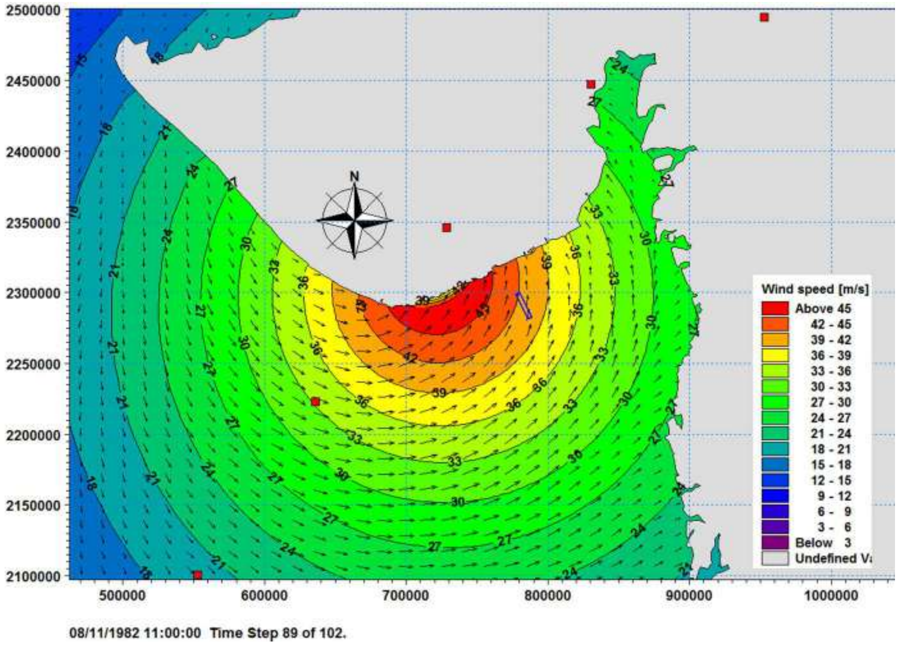


Figure 13.9 *Artificial cyclone wind field at 08/11/1982 11:00 for 10yr return period with a maximum wind speed of 97 knots using CYWIND tool. Red dots shows the track of the 1982 storm (4-9 November 1982).*

The calibrated Hydrodynamic model (including bathymetry and tide) as described in section 5 was used in the present simulation. The only other input provided to the hydrodynamic model is the artificial cyclonic.

During the 1982 cyclone, the anti-clockwise approach of the cyclone before the landfall results in a north-eastward wind over the project site (see Figure 13.9). Thus, a wind induced north-easterly current is generated at the proposed OWF area. Figure 13.10 to Figure 13.12 shows the current field surrounding the proposed OWF area during 10, 50 and 100 year return period events.

The surge heights and current speed during these three storm events were determined from the difference between the tide generated and combined effect of tide and wind generated. The maximum surge levels and current speed simulated during the passage of each of these three return period events at the point P3 are shown in Figure 13.13 and presented in Table 13.3. The location of three points (P1, P2 and P3) in the proposed OWF area between 15 and 20m water depth are shown in Figure 7.1 and Table 7.1.

The simulated surges are 2.72m, 3.26m and 3.32m for the 10, 50 and 100 year return period. The maximum surge current speed is 0.43 m/s, 0.53 m/s and 0.57 m/s for 10, 50 and 100 year return period.

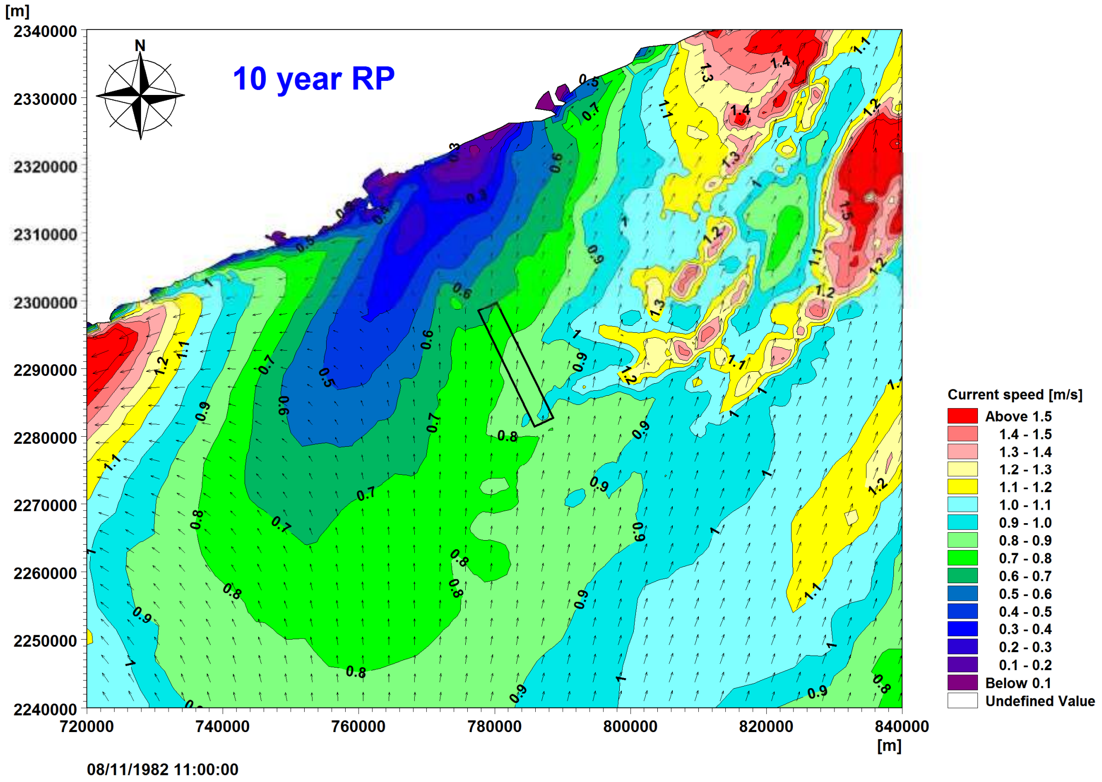


Figure 13.10 Current field during scaled 1982 storm (4-9 November) corresponding to 10 year return period

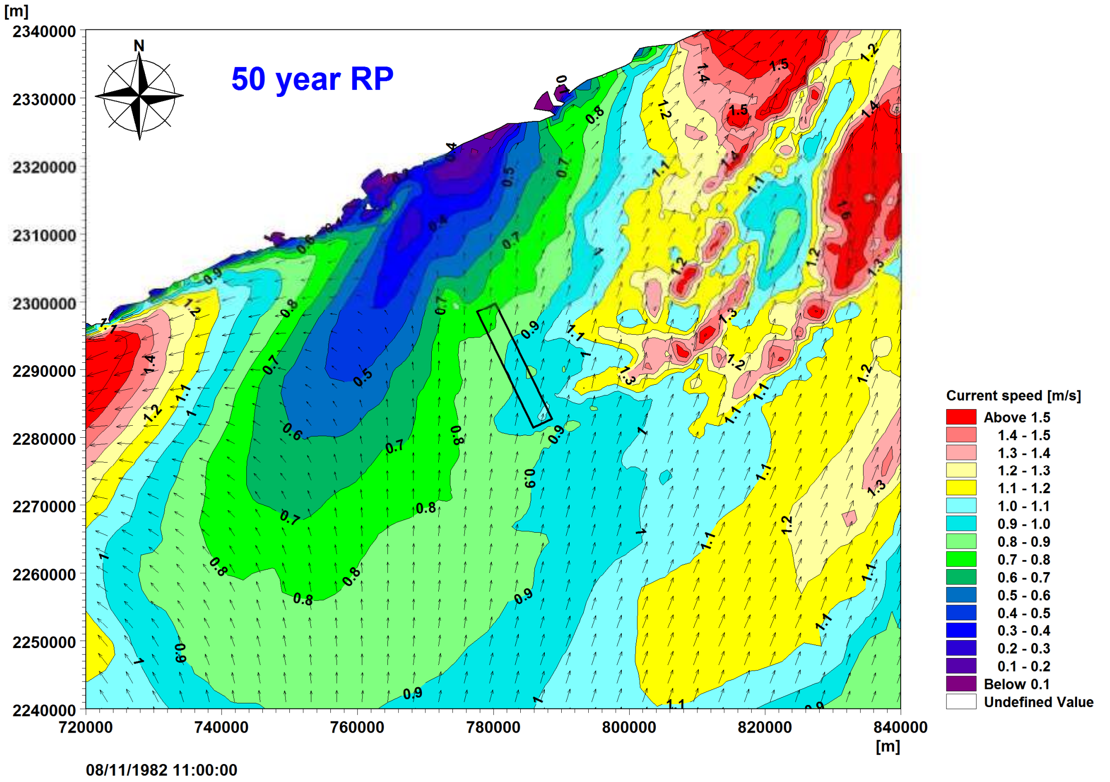


Figure 13.11 Current field during scaled 1982 storm (4-9 November) corresponding to 50 year return period

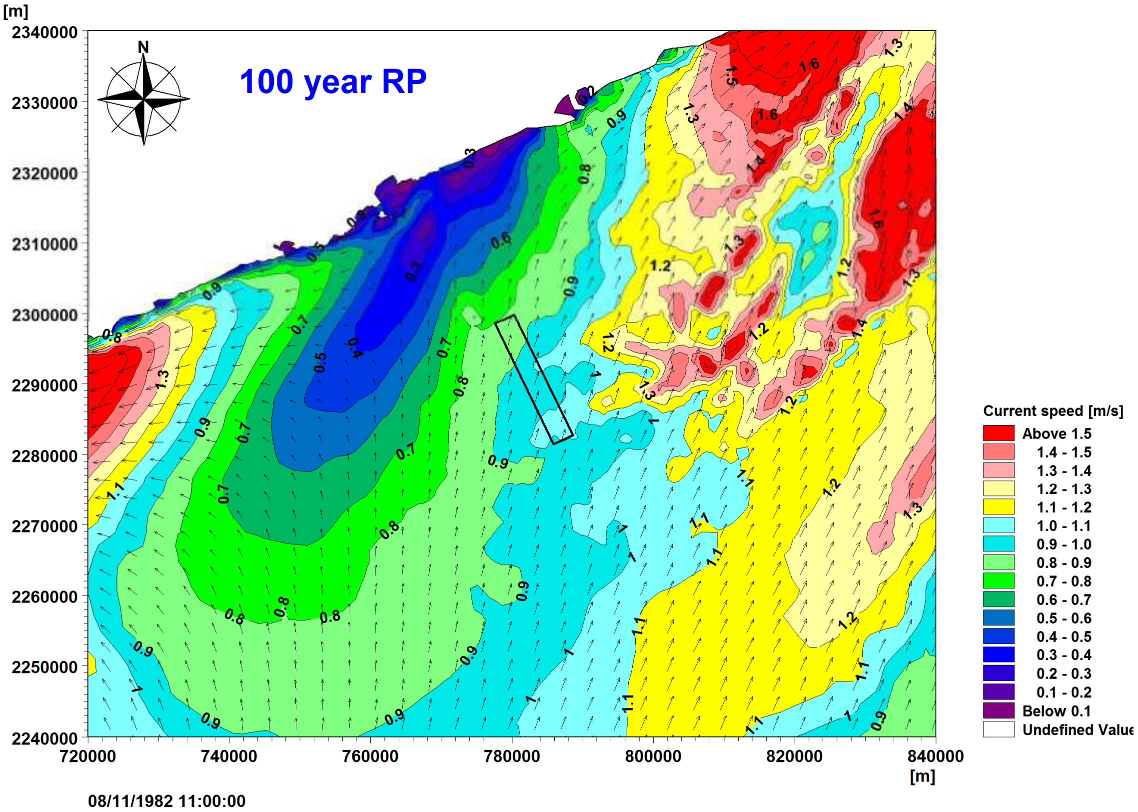


Figure 13.12 Current field during scaled 1982 storm (4-9 November) corresponding to 100 year return period

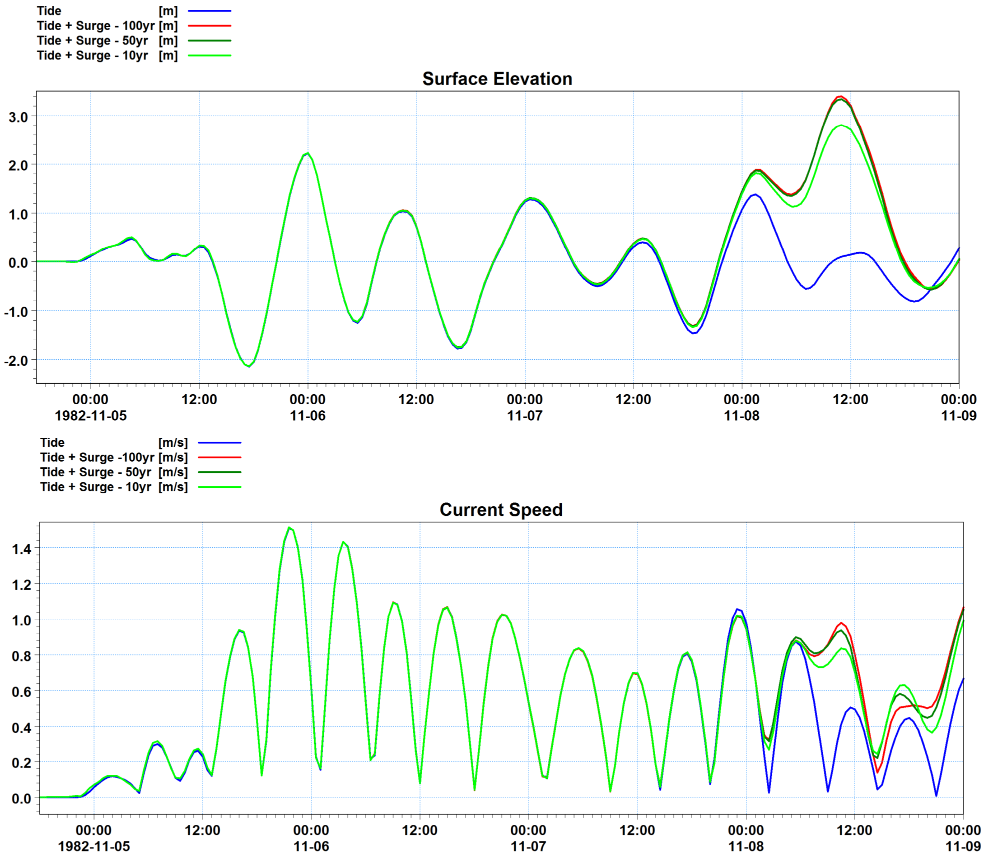


Figure 13.13 Simulated surface elevation (Top) and current speed (Bottom) during 10, 50 and 100 year return period storm events at the position P3 (785314 E, 2280430 N)

Table 13.3 Surge and current speed during various return periods at point P3

Return period [years]	Maximum Surge height [m]	Maximum Surge current speed [m/s]
10	2.72	0.43
50	3.26	0.53
100	3.32	0.57

13.5 Wave condition during storm events

Extreme wave conditions at proposed OWF area were established based on the three artificial cyclones described in section 13.4.

The wave conditions were established with the calibrated MIKE 21 SW wave model described in section 6. The main input parameters used in the simulation were the wind velocity components and spatial variation of the sea level during the three cyclones.

The wind velocity components were obtained with the MIKE CYWIND tool of MIKE Zero as described in Section 13.4. The surface elevation in the model area during the cyclone was based on the outcome of the hydrodynamic modelling discussed in Section 13.4.

The vector plot of simulated significant wave heights at the peak of the 10yr, 50yr and 100yr return period cyclone is presented in Figure 13.14, Figure 13.15 and Figure 13.16. The wave conditions at the extraction points at the site are presented in Table 13.4. The location of the extraction points is shown in Figure 7.1 and reported in Table 7.1.

It is seen that the maximum significant wave height for 10 year return period storm event varies in the range 7.5m to 9.1m at these locations, 7.8m to 9.5m for 50 year return period storm event and 7.9m to 9.5m for 100 year return period storm event. The largest waves are observed at the southern part of the project site (P3).

The peak wave period is seen to be slowly decreasing for increasing return period. This is considered to be due to wave breaking of the longer waves (i.e. larger wave periods) in the wave spectrum due to the relatively small water depth at the site. In this case an increasing significant wave height may be accompanied by a decreasing peak wave period.

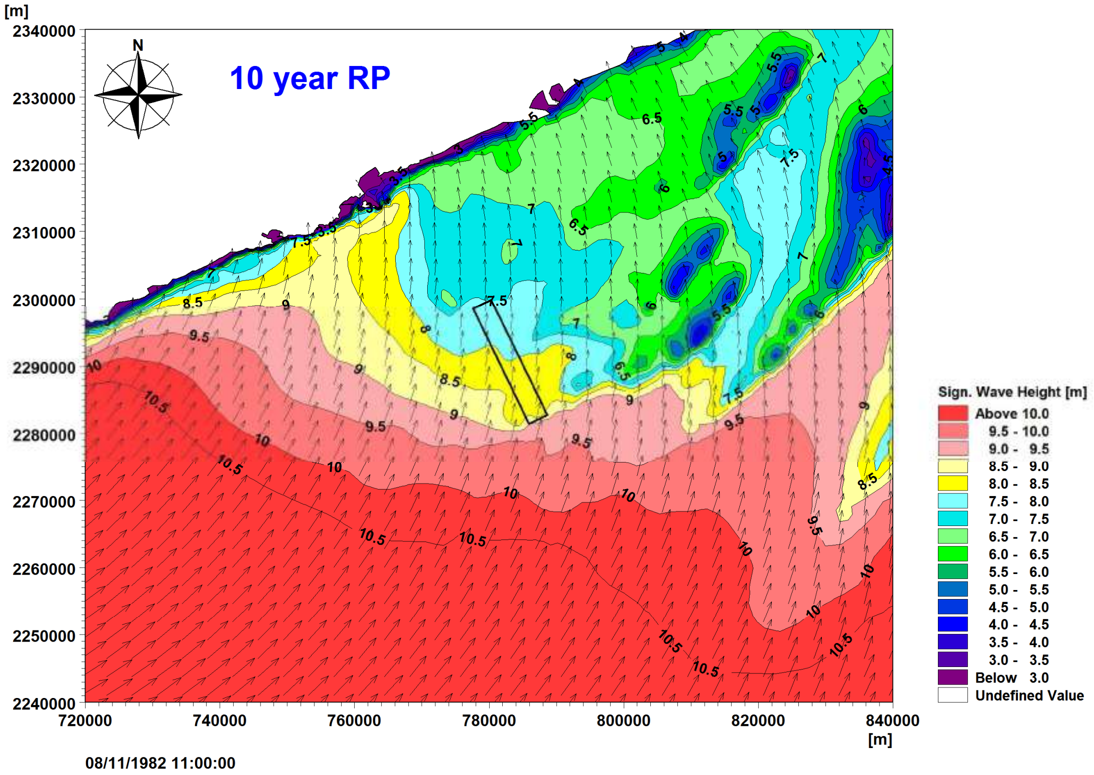


Figure 13.14 *Significant wave height and mean wave direction during scaled 1982 storm (4-9 November) corresponding to 10 year return period*

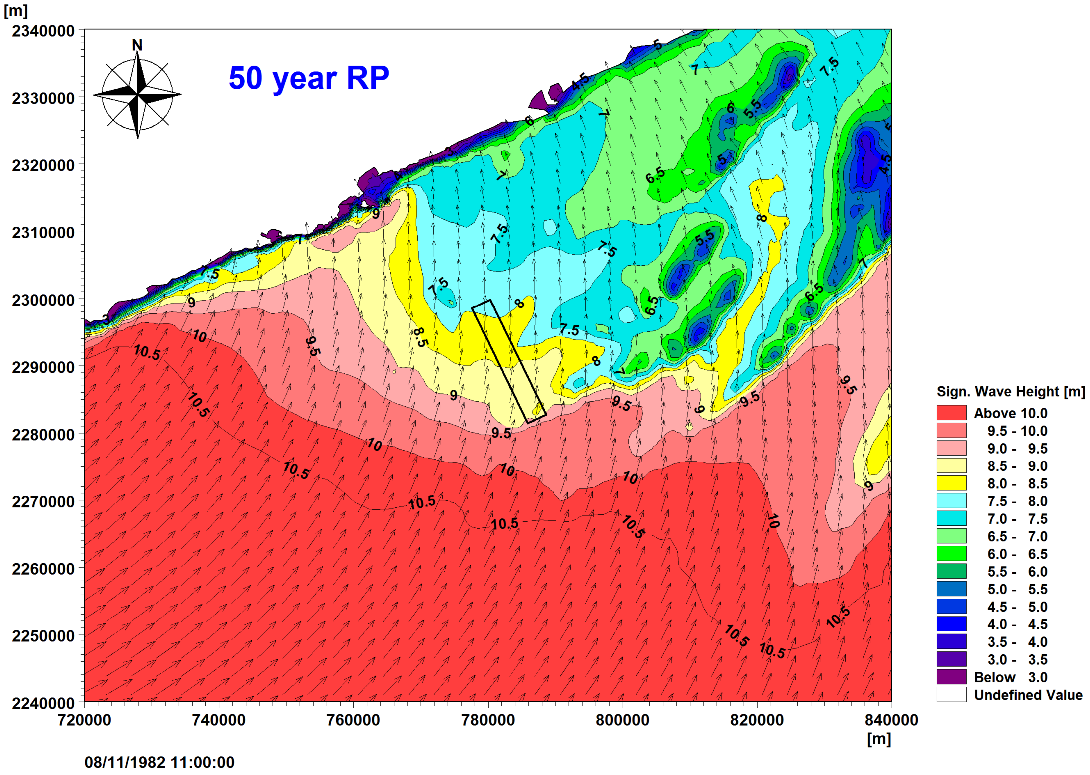


Figure 13.15 *Significant wave height and mean wave direction during scaled 1982 storm (4-9 November) corresponding to 50 year return period*

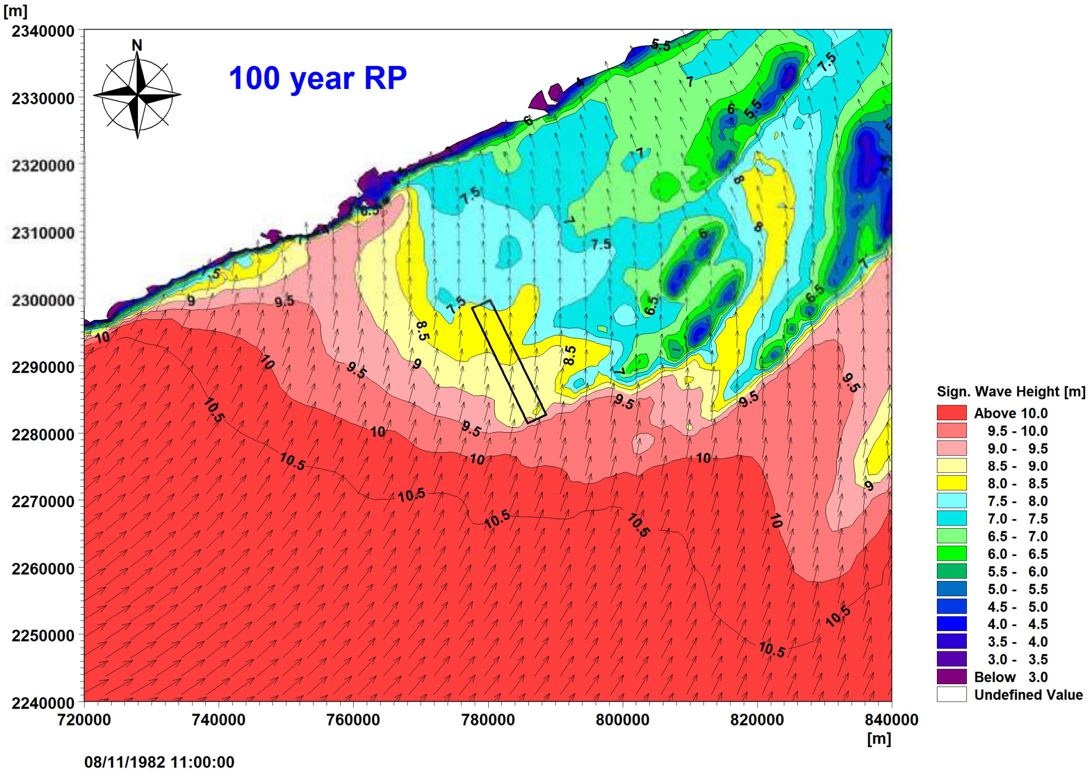


Figure 13.16 *Significant wave height and mean wave direction during scaled 1982 storm (4-9 November) corresponding to 100 year return period*

Table 13.4 Extreme wave conditions during various return periods at points P1, P2 and P3

Return period [years]	Maximum H_{m0} [m]			Peak wave period T_p [s] at time of maximum H_{m0}			Mean wave direction [Deg] at time of maximum H_{m0}		
	Point P1	Point P2	Point P3	Point P1	Point P2	Point P3	Point P1	Point P2	Point P3
10	7.5	8.1	9.1	11.2	14.9	15.0	180	187	193
50	7.8	8.4	9.5	11.0	12.7	14.9	180	187	193
100	7.9	8.5	9.5	10.8	12.4	14.6	180	186	193

Appendix A Point P2: Directional scatter tables: H_{m0} vs. U_{10} per wave direction (MWD)

MWD 345 to 15		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	0	0	2	19	37	60	25	6	3	0	0	0	152
0.00	0.25	0.50	0	0	0	0	1	23	20	7	2	0	0	0	0	0	53
SUM			0	0	0	0	3	42	57	67	27	6	3	0	0	0	205

MWD 15 to 45		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	2	2	0	0	0	0	4
0.50	0.75	1.00	0	0	0	0	7	113	390	537	321	45	1	0	0	0	1414
0.00	0.25	0.50	3	4	1	24	104	248	175	46	6	0	0	0	0	0	611
SUM			3	4	1	24	111	361	565	583	329	47	1	0	0	0	2029

MWD 45 to 75		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	7	40	15	1	0	0	0	63
0.50	0.75	1.00	0	0	0	4	111	517	688	534	126	4	0	0	0	0	1984
0.00	0.25	0.50	1	4	10	68	205	230	71	13	1	0	0	0	0	0	603
SUM			1	4	10	72	316	747	759	554	167	19	1	0	0	0	2650

MWD 75 to 105		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	2	5	0	0	0	0	0	0	7
0.50	0.75	1.00	0	0	3	17	159	262	172	42	2	0	0	0	0	0	657
0.00	0.25	0.50	0	1	12	73	118	69	6	4	0	0	0	0	0	0	283
SUM			0	1	15	90	277	331	180	51	2	0	0	0	0	0	947

MWD 105 to 135		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
0.50	0.75	1.00	0	1	6	26	85	90	66	15	0	0	0	0	0	0	289
0.00	0.25	0.50	0	2	24	48	65	42	11	2	1	0	0	0	0	0	195
SUM			0	3	30	74	150	132	77	19	1	0	0	0	0	0	486

MWD 135 to 165		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	4	1	0	0	0	0	0	0	0	5
0.50	0.75	1.00	1	2	7	40	90	80	25	6	2	0	0	0	0	0	253
0.00	0.25	0.50	0	11	43	69	77	48	17	1	1	0	0	0	0	0	267
SUM			1	13	50	109	167	132	43	7	3	0	0	0	0	0	525

MWD 165 to 195		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4
2.00	2.25	2.50	0	0	0	0	0	0	0	0	3	4	4	0	0	0	11
1.50	1.75	2.00	0	0	0	0	0	1	1	2	2	0	0	0	0	0	6
1.00	1.25	1.50	0	0	0	11	14	6	2	0	0	0	0	0	0	0	33
0.50	0.75	1.00	8	67	116	209	319	220	65	20	2	0	0	0	0	0	1026
0.00	0.25	0.50	11	100	260	469	522	255	66	13	0	0	0	0	0	0	1696
SUM			19	167	376	689	855	482	134	35	7	4	8	0	0	0	2776

MWD 195 to 225		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	1	2	1	12	46	62	20	4	1	149
2.00	2.25	2.50	0	2	18	29	62	135	246	353	429	300	123	24	1	0	1722
1.50	1.75	2.00	3	23	78	222	395	695	1027	932	432	162	43	12	0	0	4024
1.00	1.25	1.50	16	175	361	527	685	677	616	377	137	17	0	0	0	0	3588
0.50	0.75	1.00	105	613	1228	1733	1391	779	256	51	2	0	0	0	0	0	6158
0.00	0.25	0.50	89	343	756	1489	1488	674	206	24	1	0	0	0	0	0	5070
SUM			213	1156	2441	4000	4021	2961	2353	1738	1013	525	228	56	5	1	20711

MWD 225 to 255		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	1	20	102	96	28	17	264
2.00	2.25	2.50	0	0	0	0	0	7	42	174	501	684	452	122	8	0	1990
1.50	1.75	2.00	0	0	0	9	49	127	400	742	505	211	33	7	0	0	2083
1.00	1.25	1.50	6	37	78	121	273	463	505	486	206	51	9	0	0	0	2235
0.50	0.75	1.00	25	73	251	745	1434	1442	587	184	22	0	0	0	0	0	4763
0.00	0.25	0.50	9	52	208	320	399	198	51	17	0	0	0	0	0	0	1254
SUM			40	162	537	1195	2155	2237	1585	1603	1235	966	596	225	36	17	12589

MWD 255 to 285		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	4	6	0	0	0	0	0	10
0.50	0.75	1.00	0	0	0	5	80	143	150	75	15	1	0	0	0	0	469
0.00	0.25	0.50	1	5	2	38	69	36	20	4	0	0	0	0	0	0	175
SUM			1	5	2	43	149	179	170	83	21	1	0	0	0	0	654

MWD 285 to 315		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	0	0	3	14	40	38	15	1	0	0	0	0	111
0.00	0.25	0.50	0	0	0	2	15	11	13	7	0	0	0	0	0	0	48
SUM			0	0	0	2	18	25	53	45	15	1	0	0	0	0	159

MWD 315 to 345		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	0	0	2	10	24	14	7	3	0	0	0	0	60
0.00	0.25	0.50	0	0	0	0	8	7	3	9	3	0	0	0	0	0	30
SUM			0	0	0	0	10	17	27	23	10	3	0	0	0	0	90

Appendix B Point P2: Directional scatter tables: H_{m0} vs. U_{10} per wind direction

Wind dir. 345 to 15		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2
1.50	1.75	2.00	0	1	1	2	1	0	0	0	0	0	0	0	0	0	5
1.00	1.25	1.50	3	16	13	0	1	1	0	1	1	0	0	0	0	0	36
0.50	0.75	1.00	18	104	195	338	449	439	536	500	194	27	3	0	0	0	2803
0.00	0.25	0.50	18	87	234	596	1126	871	413	118	14	0	0	0	0	0	3477
SUM			39	208	443	937	1578	1311	949	619	209	27	3	0	0	0	6323

Wind dir. 15 to 45		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2
1.00	1.25	1.50	2	12	3	2	1	0	4	13	29	11	1	0	0	0	78
0.50	0.75	1.00	10	58	82	235	497	884	913	757	298	31	1	0	0	0	3766
0.00	0.25	0.50	13	64	178	511	788	614	193	22	0	0	0	0	0	0	2383
SUM			25	135	264	748	1286	1498	1110	792	327	42	2	0	0	0	6229

Wind dir. 45 to 75		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	1	7	3	2	5	5	1	0	12	6	0	0	0	0	42
0.50	0.75	1.00	8	35	72	121	255	312	171	49	1	0	0	0	0	0	1024
0.00	0.25	0.50	10	44	108	167	138	55	4	0	0	0	0	0	0	0	526
SUM			19	86	183	290	398	372	176	49	13	6	0	0	0	0	1592

Wind dir. 75 to 105		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1.00	1.25	1.50	1	8	7	7	7	4	0	0	0	0	0	0	0	0	34
0.50	0.75	1.00	8	30	31	49	39	18	10	0	0	0	0	0	0	0	185
0.00	0.25	0.50	4	19	62	53	30	3	0	0	0	0	0	0	0	0	171
SUM			13	58	100	109	76	25	10	0	0	0	0	0	0	0	391

Wind dir. 105 to 135		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	2	0	1	0	0	0	0	0	0	0	0	0	0	3
1.00	1.25	1.50	0	2	4	5	4	0	0	0	0	0	0	0	0	0	15
0.50	0.75	1.00	9	18	22	12	6	9	8	0	0	0	0	0	0	0	84
0.00	0.25	0.50	9	15	13	8	4	0	0	0	0	0	0	0	0	0	49
SUM			18	37	39	26	14	9	8	0	0	0	0	0	0	0	151

Wind dir. 135 to 165		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
1.50	1.75	2.00	0	0	4	1	0	0	2	2	1	0	0	0	0	0	10
1.00	1.25	1.50	0	7	2	0	3	2	0	1	0	0	0	0	0	0	15
0.50	0.75	1.00	7	25	32	7	4	9	14	8	2	0	0	0	0	0	108
0.00	0.25	0.50	10	17	3	3	4	0	0	0	0	0	0	0	0	0	37
SUM			17	49	41	11	12	11	16	11	3	0	0	0	0	0	171

Wind dir. 165 to 195		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	12	18	2	0	0	32
2.00	2.25	2.50	0	0	0	1	3	3	8	6	9	10	10	0	0	0	50
1.50	1.75	2.00	0	4	3	11	21	56	58	48	11	0	0	0	0	0	212
1.00	1.25	1.50	0	14	17	2	4	14	9	8	3	0	0	0	0	0	71
0.50	0.75	1.00	10	39	29	22	13	10	2	4	1	0	0	0	0	0	130
0.00	0.25	0.50	7	25	35	13	1	2	0	0	0	0	0	0	0	0	83
SUM			17	82	84	49	42	85	77	66	24	22	28	2	0	0	578

Wind dir. 195 to 225		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	1	8	12	23	2	0	0	46
2.00	2.25	2.50	0	0	7	13	21	73	77	101	123	71	36	9	2	0	533
1.50	1.75	2.00	0	5	10	63	119	226	285	291	163	73	40	11	0	0	1286
1.00	1.25	1.50	3	22	42	55	70	98	128	129	73	10	0	0	0	0	630
0.50	0.75	1.00	11	34	62	67	66	49	34	7	1	0	0	0	0	0	331
0.00	0.25	0.50	10	18	34	31	15	4	0	0	0	0	0	0	0	0	112
SUM			24	79	155	229	291	450	524	529	368	166	99	22	2	0	2938

Wind dir. 225 to 255		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	1	0	0	5	36	113	102	32	18	307
2.00	2.25	2.50	0	2	3	11	20	48	162	339	666	797	507	129	7	0	2691
1.50	1.75	2.00	0	2	39	104	201	414	878	1059	631	284	35	8	0	0	3655
1.00	1.25	1.50	4	33	108	217	366	554	666	594	249	58	9	0	0	0	2858
0.50	0.75	1.00	9	61	164	256	425	582	340	148	17	0	0	0	0	0	2002
0.00	0.25	0.50	6	31	45	59	69	20	4	0	0	0	0	0	0	0	234
SUM			19	129	359	647	1081	1619	2050	2140	1568	1175	664	239	39	18	11747

Wind dir. 255 to 285		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	2	0	0	6	14	10	0	0	32
2.00	2.25	2.50	0	0	6	2	10	14	37	78	134	109	26	8	0	0	424
1.50	1.75	2.00	0	3	13	43	83	119	204	267	133	16	1	0	0	0	882
1.00	1.25	1.50	4	34	120	221	386	354	265	131	18	0	0	0	0	0	1533
0.50	0.75	1.00	12	81	283	617	799	660	204	21	0	0	0	0	0	0	2677
0.00	0.25	0.50	7	38	126	206	174	49	3	1	0	0	0	0	0	0	604
SUM			23	156	548	1089	1452	1196	715	498	285	131	41	18	0	0	6152

Wind dir. 285 to 315		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	2	1	5	4	4	3	1	1	0	0	0	0	21
1.50	1.75	2.00	1	2	6	3	16	7	1	9	0	0	0	0	0	0	45
1.00	1.25	1.50	2	37	74	111	101	88	43	3	1	0	0	0	0	0	460
0.50	0.75	1.00	12	142	373	572	596	287	72	17	4	1	0	0	0	0	2076
0.00	0.25	0.50	11	80	203	344	230	40	1	0	0	0	0	0	0	0	909
SUM			26	261	658	1031	948	426	121	32	6	2	0	0	0	0	3511

Wind dir. 315 to 345		WS [m/s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
1.50	1.75	2.00	2	2	1	3	3	1	0	0	0	0	0	0	0	0	12
1.00	1.25	1.50	2	20	46	37	24	30	10	1	5	0	0	0	0	0	175
0.50	0.75	1.00	25	129	266	483	534	430	196	65	21	1	0	0	0	0	2150
0.00	0.25	0.50	9	84	275	609	492	183	41	6	1	0	0	0	0	0	1700
SUM			38	235	588	1132	1054	644	247	72	27	1	0	0	0	0	4038

Appendix C Point P2: Directional scatter tables: H_{m0} vs. T_p per wave direction (MWD)

MWD 345 to 15		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	18	56	0	0	0	2	6	0	2	3	22	17	13	9	4	0	0	0	0	0	0	0	0	0	152
0.00	0.25	0.50	0	0	29	6	0	0	1	0	0	4	5	5	2	0	1	0	0	0	0	0	0	0	0	0	0	0	53
SUM			0	0	47	62	0	0	1	2	6	4	7	8	24	17	14	9	4	0	0	0	0	0	0	0	0	0	205

MWD 15 to 45		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4
0.50	0.75	1.00	0	0	19	991	54	8	3	4	6	10	20	62	96	60	56	21	4	0	0	0	0	0	0	0	0	0	1414
0.00	0.25	0.50	0	4	272	231	1	1	1	2	5	7	32	22	12	7	8	4	1	0	1	0	0	0	0	0	0	0	611
SUM			0	4	291	1222	55	9	4	6	11	19	52	84	109	68	64	25	5	0	1	0	0	0	0	0	0	0	2029

MWD 45 to 75		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	2	49	1	0	0	0	5	1	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	63
0.50	0.75	1.00	0	0	22	873	75	7	12	9	6	51	124	168	201	210	116	87	14	6	3	0	0	0	0	0	0	0	1984
0.00	0.25	0.50	0	0	221	198	3	5	0	5	5	31	21	30	41	17	12	8	0	0	2	2	1	0	0	0	0	1	603
SUM			0	0	243	1073	127	13	12	14	11	87	146	198	243	231	128	95	14	6	5	2	1	0	0	0	0	1	2650

MWD 75 to 105		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	0	0	0	0	0	0	0	0	0	0	0	7
0.50	0.75	1.00	0	0	4	61	5	2	1	10	3	14	84	109	159	114	66	18	2	2	3	0	0	0	0	0	0	0	657
0.00	0.25	0.50	0	0	49	32	0	2	0	2	6	38	64	33	29	12	10	0	3	1	2	0	0	0	0	0	0	0	283
SUM			0	0	53	93	5	4	1	12	9	52	148	142	190	128	79	18	5	3	5	0	0	0	0	0	0	0	947

MWD 105 to 135		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
0.50	0.75	1.00	0	0	0	2	0	2	0	1	8	10	31	64	86	44	28	4	7	1	1	0	0	0	0	0	0	0	289
0.00	0.25	0.50	0	0	6	1	0	1	1	2	6	38	58	33	14	11	14	4	5	1	0	0	0	0	0	0	0	0	195
SUM			0	0	6	3	0	3	1	3	14	48	89	97	100	55	44	8	12	2	1	0	0	0	0	0	0	0	486

MWD 135 to 165		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5
0.50	0.75	1.00	0	0	0	0	4	3	0	0	3	0	25	48	77	47	27	12	6	1	0	0	0	0	0	0	0	0	253
0.00	0.25	0.50	0	0	0	0	0	0	3	1	10	49	62	46	30	27	25	9	4	1	0	0	0	0	0	0	0	0	267
SUM			0	0	0	0	4	3	3	1	13	53	87	94	107	74	53	21	10	2	0	0	0	0	0	0	0	0	525

MWD 165 to 195		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	11
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	6
1.00	1.25	1.50	0	0	0	0	0	0	0	5	8	8	11	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	33
0.50	0.75	1.00	0	0	0	0	5	46	49	51	24	17	70	144	203	198	106	87	25	1	0	0	0	0	0	0	0	0	1026
0.00	0.25	0.50	0	0	0	0	0	28	28	9	42	257	393	353	211	179	96	60	27	9	2	0	0	2	0	0	0	0	1696
SUM			0	0	0	0	5	74	77	65	74	282	474	506	426	377	203	147	52	10	2	0	0	2	0	0	0	0	2776

MWD 195 to 225		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	4	27	79	36	3	0	0	0	0	0	0	0	0	0	0	0	149
2.00	2.25	2.50	0	0	0	0	0	0	0	0	5	35	500	951	206	9	0	1	6	5	4	0	0	0	0	0	0	0	1722
1.50	1.75	2.00	0	0	0	0	0	11	4	5	254	979	1850	711	54	25	24	51	31	17	5	3	0	0	0	0	0	0	4024
1.00	1.25	1.50	0	0	0	0	13	4	4	82	559	889	298	137	292	410	381	304	106	58	35	4	8	1	1	1	0	1	3588
0.50	0.75	1.00	0	0	0	0	3	17	76	165	148	29	240	822	1367	1202	949	677	231	140	78	8	6	0	0	0	0	0	6158
0.00	0.25	0.50	0	0	1	1	17	6	13	26	26	233	711	1102	1083	800	469	364	133	47	22	9	5	1	0	0	0	1	5070
SUM			0	0	1	1	33	38	97	278	992	2165	3603	3750	3081	2482	1826	1397	507	267	144	24	19	2	1	1	0	2	20711

MWD 225 to 255		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	9	56	170	29	0	0	0	0	0	0	0	0	0	0	0	0	0	264
2.00	2.25	2.50	0	0	0	0	0	0	2	1	5	202	1238	505	33	4	0	0	0	0	0	0	0	0	0	0	0	0	1990
1.50	1.75	2.00	0	0	0	0	0	12	13	20	206	948	778	97	7	1	1	0	0	0	0	0	0	0	0	0	0	0	2083
1.00	1.25	1.50	0	0	0	1	75	60	127	214	611	551	62	56	130	150	92	65	21	9	8	3	0	0	0	0	0	0	2235
0.50	0.75	1.00	0	0	1	220	197	171	300	253	122	57	267	721	818	705	462	256	83	58	42	25	5	0	0	0	0	0	4763
0.00	0.25	0.50	0	1	40	191	113	32	48	26	27	67	135	179	139	94	72	73	13	4	0	0	0	0	0	0	0	0	1254
SUM			0	1	41	412	385	275	490	514	971	1834	2536	1728	1156	954	627	394	117	71	50	28	5	0	0	0	0	0	12589

MWD 255 to 285		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	7	0	0	0	0	0	0	0	0	0	0	10
0.50	0.75	1.00	0	0	3	61	42	1	10	8	3	6	34	73	62	71	57	23	13	2	0	0	0	0	0	0	0	0	469
0.00	0.25	0.50	0	5	12	91	20	2	1	1	0	6	8	3	5	7	5	6	3	0	0	0	0	0	0	0	0	0	175
SUM			0	5	15	152	64	3	11	9	3	12	42	76	67	78	63	36	16	2	0	0	0	0	0	0	0	0	654

MWD 285 to 315		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	13	24	1	1	2	4	1	1	2	6	19	12	18	6	1	0	0	0	0	0	0	0	0	0	111
0.00	0.25	0.50	0	2	16	3	0	1	0	3	2	3	1	8	6	1	2	0	0	0	0	0	0	0	0	0	0	0	48
SUM			0	2	29	27	1	2	2	7	3	4	3	14	25	13	20	6	1	0	0	0	0	0	0	0	0	0	159

MWD 315 to 345		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	8	13	1	0	0	2	2	0	0	1	10	9	6	8	0	0	0	0	0	0	0	0	0	0	60
0.00	0.25	0.50	0	3	10	0	1	1	0	1	1	0	1	3	6	3	0	0	0	0	0	0	0	0	0	0	0	0	30
SUM			0	3	18	13	2	1	0	3	3	0	1	4	16	12	6	8	0	0	0	0	0	0	0	0	0	0	90

Appendix D Point P2: Directional scatter tables: H_{m0} vs. T_p per wind direction

WindDir 345 to 15		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
1.00	1.25	1.50	0	0	0	0	0	0	0	0	5	12	5	3	0	0	5	4	0	2	0	0	0	0	0	0	0	0	36
0.50	0.75	1.00	0	0	46	446	8	22	37	44	53	31	153	296	558	447	358	193	73	23	12	3	0	0	0	0	0	0	2803
0.00	0.25	0.50	0	6	273	142	24	26	29	22	30	286	541	669	497	373	249	183	71	41	11	1	1	1	0	0	0	1	3477
SUM			0	6	319	588	32	48	66	66	88	329	701	973	1055	820	612	380	144	66	23	4	1	1	0	0	0	1	6323

WindDir 15 to 45		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1.00	1.25	1.50	0	0	0	2	31	1	0	0	5	12	4	3	4	7	7	2	0	0	0	0	0	0	0	0	0	0	78
0.50	0.75	1.00	0	0	20	1317	113	22	31	37	34	48	194	400	590	458	270	174	41	12	5	0	0	0	0	0	0	0	3766
0.00	0.25	0.50	0	2	241	278	21	17	19	19	27	171	381	387	287	228	151	89	55	6	2	2	0	0	0	0	0	0	2383
SUM			0	2	261	1597	165	40	50	56	66	231	579	792	881	693	428	265	96	18	7	2	0	0	0	0	0	0	6229

WindDir 45 to 75		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	18	0	0	5	4	4	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42
0.50	0.75	1.00	0	0	11	219	16	7	7	33	27	8	87	143	178	129	89	46	22	0	2	0	0	0	0	0	0	0	1024
0.00	0.25	0.50	0	0	42	51	3	5	6	11	14	38	95	68	89	32	23	22	5	4	11	6	0	0	0	0	0	1	526
SUM			0	0	53	270	37	12	13	49	45	50	188	216	267	161	112	68	27	4	13	6	0	0	0	0	0	1	1592

WindDir 75 to 105		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.00	1.25	1.50	0	0	0	0	0	0	0	0	3	13	12	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
0.50	0.75	1.00	0	0	1	21	3	5	3	19	6	6	8	30	32	30	10	11	0	0	0	0	0	0	0	0	0	0	185
0.00	0.25	0.50	0	0	15	7	0	3	3	0	5	17	30	32	14	18	17	5	5	0	0	0	0	0	0	0	0	0	171
SUM			0	0	16	28	3	8	6	19	14	36	50	69	46	48	27	16	5	0	0	0	0	0	0	0	0	0	391

WindDir 105 to 135		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	3	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
0.50	0.75	1.00	0	0	0	2	0	1	3	2	11	6	5	10	25	10	5	3	0	0	1	0	0	0	0	0	0	0	84
0.00	0.25	0.50	0	0	2	0	2	5	4	0	4	1	2	5	10	11	3	0	0	0	0	0	0	0	0	0	0	0	49
SUM			0	0	2	2	2	6	7	2	15	10	19	17	36	21	8	3	0	0	1	0	0	0	0	0	0	0	151

WindDir 135 to 165		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.50	1.75	2.00	0	0	0	0	0	0	0	0	2	1	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	6	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
0.50	0.75	1.00	0	0	0	0	4	18	30	4	3	3	0	6	16	7	0	8	1	1	6	1	0	0	0	0	0	0	108
0.00	0.25	0.50	0	0	1	0	2	1	4	1	3	1	2	1	9	4	6	1	1	0	0	0	0	0	0	0	0	0	37
SUM			0	0	1	0	6	19	34	5	8	11	14	12	25	11	6	9	2	1	6	1	0	0	0	0	0	0	171

WindDir 165 to 195		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	1	20	11	0	0	0	0	0	0	0	0	0	0	0	0	32
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	7	32	11	0	0	0	0	0	0	0	0	0	0	0	0	0	50
1.50	1.75	2.00	0	0	0	0	0	0	0	0	2	48	109	40	13	0	0	0	0	0	0	0	0	0	0	0	0	0	212
1.00	1.25	1.50	0	0	0	0	0	1	1	0	6	31	15	0	0	0	0	1	8	8	0	0	0	0	0	0	0	0	71
0.50	0.75	1.00	0	0	0	0	1	4	38	3	1	3	5	13	15	5	14	16	7	2	2	1	0	0	0	0	0	0	130
0.00	0.25	0.50	0	0	0	0	10	0	7	0	0	3	6	4	21	12	10	9	0	0	1	0	0	0	0	0	0	0	83
SUM			0	0	0	0	11	5	46	3	9	85	142	90	80	28	24	26	15	10	3	1	0	0	0	0	0	0	578

WindDir 195 to 225		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	21	22	3	0	0	0	0	0	0	0	0	0	0	0	46
2.00	2.25	2.50	0	0	0	0	0	0	2	0	3	9	87	346	77	8	0	1	0	0	0	0	0	0	0	0	0	0	533
1.50	1.75	2.00	0	0	0	0	0	9	3	5	96	325	586	239	10	1	2	8	2	0	0	0	0	0	0	0	0	0	1286
1.00	1.25	1.50	0	0	0	0	12	3	3	0	140	281	95	4	9	25	25	16	13	2	2	0	0	0	0	0	0	0	630
0.50	0.75	1.00	0	0	0	2	2	7	44	2	3	10	6	46	51	54	28	34	23	12	2	1	4	0	0	0	0	0	331
0.00	0.25	0.50	0	0	5	2	4	2	1	0	0	6	3	20	27	20	7	12	3	0	0	0	0	0	0	0	0	0	112
SUM			0	0	5	4	18	21	53	7	242	631	777	655	195	130	65	71	41	14	4	1	4	0	0	0	0	0	2938

WindDir 225 to 255		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	9	58	168	69	3	0	0	0	0	0	0	0	0	0	0	0	0	307
2.00	2.25	2.50	0	0	0	0	0	0	0	1	7	218	1422	907	124	5	0	0	4	2	1	0	0	0	0	0	0	0	2691
1.50	1.75	2.00	0	0	0	0	0	12	14	6	271	1212	1563	443	32	24	20	29	19	10	0	0	0	0	0	0	0	0	3655
1.00	1.25	1.50	0	0	0	1	64	49	110	128	515	615	130	131	288	334	244	144	48	20	18	7	8	1	1	1	0	1	2858
0.50	0.75	1.00	0	0	0	63	89	45	94	93	52	32	92	259	352	327	197	155	65	44	27	13	3	0	0	0	0	0	2002
0.00	0.25	0.50	0	0	9	32	8	4	2	0	0	14	28	22	51	32	25	6	0	0	0	0	1	0	0	0	0	0	234
SUM			0	0	9	96	161	110	220	228	845	2100	3293	1930	916	725	486	334	136	76	46	20	12	1	1	1	0	1	11747

WindDir 255 to 285		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	2	28	2	0	0	0	0	0	0	0	0	0	0	0	0	0	32
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	10	221	161	28	0	0	0	2	2	0	0	0	0	0	0	0	0	424
1.50	1.75	2.00	0	0	0	0	0	2	0	14	85	332	334	67	9	0	3	14	10	6	3	3	0	0	0	0	0	0	882
1.00	1.25	1.50	0	0	0	0	12	11	16	120	360	363	57	32	97	146	119	127	34	28	11	0	0	0	0	0	0	0	1533
0.50	0.75	1.00	0	0	1	148	67	72	90	150	45	24	109	361	497	415	328	221	60	44	37	8	0	0	0	0	0	0	2677
0.00	0.25	0.50	0	2	18	92	37	4	2	0	2	45	67	89	102	60	43	34	6	0	0	0	1	0	0	0	0	0	604
SUM			0	2	19	240	116	89	108	284	492	774	790	738	735	621	493	396	112	80	51	11	1	0	0	0	0	0	6152

WindDir 285 to 315		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	1	15	1	0	0	0	0	1	3	0	0	0	0	0	0	0	21
1.50	1.75	2.00	0	0	0	0	0	0	0	0	4	9	19	8	1	1	0	0	0	1	2	0	0	0	0	0	0	0	45
1.00	1.25	1.50	0	0	0	0	2	0	1	44	92	83	21	4	28	41	62	61	15	5	1	0	0	0	0	0	0	0	460
0.50	0.75	1.00	0	0	0	47	57	36	43	66	46	13	103	284	440	385	277	168	50	32	21	4	4	0	0	0	0	0	2076
0.00	0.25	0.50	0	5	13	82	12	2	4	4	10	49	104	177	173	143	60	52	13	4	0	1	1	0	0	0	0	0	909
SUM			0	5	13	129	71	38	48	114	152	154	248	488	643	570	399	281	78	43	27	5	5	0	0	0	0	0	3511

WindDir 315 to 345		Tp [s]	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	SUM
			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	25.50	
Hm0 [m]			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
1.00	1.25	1.50	0	0	0	0	0	0	0	4	48	36	7	4	0	14	19	21	9	2	11	0	0	0	0	0	0	0	175
0.50	0.75	1.00	0	0	9	36	27	19	33	56	51	11	137	373	366	422	328	179	48	41	12	2	0	0	0	0	0	0	2150
0.00	0.25	0.50	0	0	37	68	32	10	15	21	35	102	232	343	298	225	120	115	30	8	4	1	2	2	0	0	0	0	1700
SUM			0	0	46	104	59	29	48	81	134	149	387	721	665	661	467	315	87	51	27	3	2	2	0	0	0	0	4038

Appendix E Point P2: Directional scatter tables: H_{m0} vs. T_{02} per wave direction

MWD 345 to 15		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	0	1	6	131	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	152
0.00	0.25	0.50	0	0	0	7	21	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53
SUM			0	0	0	8	27	156	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	205

MWD 15 to 45		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
0.50	0.75	1.00	0	0	0	1	19	1276	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1414
0.00	0.25	0.50	0	0	0	16	418	177	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	611
SUM			0	0	0	17	437	1453	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2029

MWD 45 to 75		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63
0.50	0.75	1.00	0	0	0	2	23	1572	387	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1984
0.00	0.25	0.50	0	0	0	16	287	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	603
SUM			0	0	0	18	310	1872	450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2650

MWD 75 to 105		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
0.50	0.75	1.00	0	0	0	0	21	393	243	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	657
0.00	0.25	0.50	0	0	0	15	60	206	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	283
SUM			0	0	0	15	81	599	252	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	947

MWD 105 to 135		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0.50	0.75	1.00	0	0	0	0	16	75	198	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	289
0.00	0.25	0.50	0	0	0	4	41	123	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	195
SUM			0	0	0	4	57	198	226	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	486

MWD 135 to 165		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
0.50	0.75	1.00	0	0	0	0	9	34	182	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253
0.00	0.25	0.50	0	0	0	0	29	98	133	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	267
SUM			0	0	0	0	38	132	315	36	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	525

MWD 165 to 195		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	4
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	3	8	0	0	0	0	0	0	0	0	0	0	0	11
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	6
1.00	1.25	1.50	0	0	0	0	0	0	0	4	5	4	8	12	0	0	0	0	0	0	0	0	0	0	0	0	33
0.50	0.75	1.00	0	0	0	0	7	33	122	260	191	97	45	66	59	39	44	28	12	16	5	0	0	0	1	1	1026
0.00	0.25	0.50	0	0	0	0	16	78	224	292	201	178	192	180	115	109	54	34	7	13	3	0	0	0	0	0	1696
SUM			0	0	0	0	23	111	346	556	397	279	245	262	191	148	98	62	19	29	8	0	0	0	1	1	2776

MWD 195 to 225		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	15	44	47	24	16	3	0	0	0	0	0	0	0	149
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	13	76	367	444	310	179	128	89	66	37	13	0	0	0	0	1722
1.50	1.75	2.00	0	0	0	0	0	0	0	0	51	271	613	723	711	571	340	328	279	111	21	5	0	0	0	0	4024
1.00	1.25	1.50	0	0	0	0	0	0	10	270	621	621	459	331	263	302	276	301	129	5	0	0	0	0	0	0	3588
0.50	0.75	1.00	0	0	0	0	1	57	358	833	796	688	653	661	549	480	317	169	159	188	112	64	36	21	14	2	6158
0.00	0.25	0.50	0	0	0	1	14	66	287	669	735	616	548	516	505	335	241	236	126	81	37	14	17	12	10	4	5070
SUM			0	0	0	1	15	123	655	1772	2203	2209	2349	2613	2516	2045	1377	1178	785	451	207	96	53	33	24	6	20711

MWD 225 to 255		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	13	191	57	3	0	0	0	0	0	0	0	0	0	0	264
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	48	751	827	256	82	23	3	0	0	0	0	0	0	0	0	1990
1.50	1.75	2.00	0	0	0	0	0	0	0	2	107	409	801	459	200	80	19	2	1	3	0	0	0	0	0	0	2083
1.00	1.25	1.50	0	0	0	0	0	0	82	608	520	382	213	145	102	40	95	39	4	5	0	0	0	0	0	0	2235
0.50	0.75	1.00	0	0	0	0	4	861	2161	1134	213	115	135	62	48	30	0	0	0	0	0	0	0	0	0	0	4763
0.00	0.25	0.50	0	0	0	2	113	400	352	250	98	33	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1254
SUM			0	0	0	2	117	1261	2595	1994	938	987	1919	1684	663	235	137	44	5	8	0	0	0	0	0	0	12589

MWD 255 to 285		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
0.50	0.75	1.00	0	0	0	0	12	228	229	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	469
0.00	0.25	0.50	0	0	0	9	87	71	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	175
SUM			0	0	0	9	99	299	247	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	654

MWD 285 to 315		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	0	1	6	80	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111
0.00	0.25	0.50	0	0	0	8	19	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48
SUM			0	0	0	9	25	101	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159

MWD 315 to 345		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.75	1.00	0	0	0	0	6	48	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60
0.00	0.25	0.50	0	0	0	4	10	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
SUM			0	0	0	4	16	64	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90

Appendix F Point P2: Directional scatter tables: H_{m0} vs. T_{02} per wind direction

WindDir 345 to 15		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	5
1.00	1.25	1.50	0	0	0	0	0	0	2	0	0	0	0	2	0	5	10	11	5	1	0	0	0	0	0	0	36
0.50	0.75	1.00	0	0	0	3	51	1094	427	133	96	86	133	140	121	158	94	50	60	81	38	15	15	6	2	0	2803
0.00	0.25	0.50	0	0	0	41	446	479	337	377	365	328	271	199	194	153	98	80	46	31	14	5	4	9	0	0	3477
SUM			0	0	0	44	497	1573	766	510	461	414	404	341	315	316	202	141	116	115	52	20	19	15	2	0	6323

WindDir 15 to 45		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
1.00	1.25	1.50	0	0	0	0	0	0	55	3	1	0	0	2	2	0	6	7	1	1	0	0	0	0	0	0	78
0.50	0.75	1.00	0	0	0	1	53	2152	763	123	101	92	64	73	71	67	44	33	31	53	15	17	7	1	2	3	3766
0.00	0.25	0.50	0	0	0	24	393	459	170	148	160	149	167	173	204	146	69	45	29	23	16	3	2	0	3	0	2383
SUM			0	0	0	25	446	2611	988	274	262	241	231	248	277	213	119	85	62	78	31	20	9	1	5	3	6229

WindDir 45 to 75		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.00	1.25	1.50	0	0	0	0	0	0	18	3	2	3	4	1	0	0	3	5	2	1	0	0	0	0	0	0	42
0.50	0.75	1.00	0	0	0	1	13	399	262	79	58	24	28	41	37	27	19	13	11	6	2	2	0	2	0	0	1024
0.00	0.25	0.50	0	0	0	2	49	100	35	34	39	27	43	55	43	39	27	17	5	9	0	0	0	1	1	0	526
SUM			0	0	0	3	62	499	315	116	99	54	75	97	80	66	49	35	18	16	2	2	0	3	1	0	1592

WindDir 75 to 105		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
1.00	1.25	1.50	0	0	0	0	0	0	0	0	5	2	0	7	1	0	10	5	3	1	0	0	0	0	0	0	34
0.50	0.75	1.00	0	0	0	0	3	41	16	23	12	16	12	23	21	8	5	3	0	1	1	0	0	0	0	0	185
0.00	0.25	0.50	0	0	0	0	8	34	21	8	9	12	20	29	6	5	6	7	3	2	0	0	0	1	0	0	171
SUM			0	0	0	0	11	75	37	31	26	30	32	59	28	13	21	15	6	5	1	0	0	1	0	0	391

WindDir 105 to 135		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	3
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	2	5	0	2	2	2	1	1	0	0	0	0	0	0	15
0.50	0.75	1.00	0	0	0	0	0	1	15	12	4	4	10	3	9	12	7	5	1	0	0	0	0	1	0	0	84
0.00	0.25	0.50	0	0	0	0	1	4	4	7	5	7	4	8	1	2	5	0	0	0	0	0	1	0	0	0	49
SUM			0	0	0	0	1	5	19	19	9	11	16	16	10	16	14	7	4	2	0	0	1	1	0	0	151

WindDir 135 to 165		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	4	2	0	0	0	0	0	0	0	10
1.00	1.25	1.50	0	0	0	0	0	0	0	0	0	0	4	1	1	0	4	3	2	0	0	0	0	0	0	0	15
0.50	0.75	1.00	0	0	0	0	0	0	20	16	7	8	21	1	5	18	5	4	1	1	0	0	0	0	1	0	108
0.00	0.25	0.50	0	0	0	0	0	2	2	2	3	5	5	7	3	1	3	1	1	1	0	0	1	0	0	0	37
SUM			0	0	0	0	0	2	22	18	10	13	32	10	9	19	13	12	7	2	0	0	1	0	1	0	171

WindDir 165 to 195		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	6	15	8	3	0	0	0	0	0	0	0	0	32
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	4	14	7	6	13	1	1	4	0	0	0	0	0	50
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	1	5	60	32	21	22	28	32	11	0	0	0	0	0	0	212
1.00	1.25	1.50	0	0	0	0	0	0	0	0	2	8	12	12	13	7	9	2	5	1	0	0	0	0	0	0	71
0.50	0.75	1.00	0	0	0	0	1	2	9	8	15	18	26	7	18	12	1	1	6	6	0	0	0	0	0	0	130
0.00	0.25	0.50	0	0	0	0	0	1	1	26	3	9	9	19	1	4	4	3	0	1	0	1	1	0	0	0	83
SUM			0	0	0	0	1	3	10	34	20	36	52	102	84	66	50	50	44	20	4	1	1	0	0	0	578

WindDir 195 to 225		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	1	7	17	8	13	0	0	0	0	0	0	0	0	46
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	12	15	95	93	82	72	58	49	32	20	5	0	0	0	0	533
1.50	1.75	2.00	0	0	0	0	0	0	0	0	26	115	225	188	221	166	86	96	105	47	11	0	0	0	0	0	1286
1.00	1.25	1.50	0	0	0	0	0	0	2	37	100	126	77	74	48	29	42	73	22	0	0	0	0	0	0	0	630
0.50	0.75	1.00	0	0	0	0	0	9	33	97	64	31	22	33	12	8	5	4	2	8	0	0	0	1	2	0	331
0.00	0.25	0.50	0	0	0	0	3	9	9	40	14	0	5	13	0	0	7	10	0	1	0	1	0	0	0	0	112
SUM			0	0	0	0	3	18	44	174	204	284	344	404	381	302	220	254	178	88	31	6	0	1	2	0	2938

WindDir 225 to 255		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	11	183	86	18	8	0	1	0	0	0	0	0	0	0	307
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	49	706	954	525	250	98	51	30	15	6	7	0	0	0	0	2691
1.50	1.75	2.00	0	0	0	0	0	0	0	2	91	440	968	730	547	373	185	168	98	39	9	5	0	0	0	0	3655
1.00	1.25	1.50	0	0	0	0	0	0	79	677	670	482	298	182	117	114	106	96	36	1	0	0	0	0	0	0	2858
0.50	0.75	1.00	0	0	0	0	0	146	597	642	206	128	85	74	58	25	13	9	1	6	6	0	1	5	0	0	2002
0.00	0.25	0.50	0	0	0	0	14	55	31	64	21	10	10	10	3	3	3	3	3	0	2	2	0	0	0	0	234
SUM			0	0	0	0	14	201	707	1385	988	1109	2078	2133	1336	783	413	327	169	61	23	14	1	5	0	0	11747

WindDir 255 to 285		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	2	22	6	0	0	0	2	0	0	0	0	0	0	0	32
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	106	143	76	51	19	9	6	11	2	1	0	0	0	0	424
1.50	1.75	2.00	0	0	0	0	0	0	0	0	41	122	214	199	104	86	61	30	22	2	1	0	0	0	0	0	882
1.00	1.25	1.50	0	0	0	0	0	0	11	150	301	296	218	145	126	84	83	83	36	0	0	0	0	0	0	0	1533
0.50	0.75	1.00	0	0	0	0	0	404	731	616	302	219	110	96	91	36	31	6	2	7	11	7	4	2	2	0	2677
0.00	0.25	0.50	0	0	0	2	63	146	109	110	44	21	28	20	16	11	9	8	3	7	1	1	1	0	0	4	604
SUM			0	0	0	2	63	550	851	876	688	658	678	625	419	268	203	136	71	27	15	9	5	2	2	4	6152

WindDir 285 to 315		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	1	0	2	7	0	1	5	5	0	0	0	0	0	21
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	2	0	5	12	5	4	2	8	7	0	0	0	0	0	0	45
1.00	1.25	1.50	0	0	0	0	0	0	4	13	59	88	45	35	43	68	59	30	13	3	0	0	0	0	0	0	460
0.50	0.75	1.00	0	0	0	0	0	226	595	302	168	149	176	167	99	55	56	24	8	9	25	11	4	0	2	0	2076
0.00	0.25	0.50	0	0	0	7	53	140	104	134	123	76	66	46	51	25	20	37	16	3	0	0	3	0	5	0	909
SUM			0	0	0	7	53	366	703	449	350	315	287	254	205	155	146	93	46	27	30	11	7	0	7	0	3511

WindDir 315 to 345		T02 [s]	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	SUM
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	10.25	10.75	11.25	11.75	
Hm0 [m]			0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00	
2.50	2.75	3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	2.25	2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
1.50	1.75	2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	4	0	0	0	0	0	0	12
1.00	1.25	1.50	0	0	0	0	0	0	6	1	9	3	20	22	14	33	37	23	7	0	0	0	0	0	0	0	175
0.50	0.75	1.00	0	0	0	0	9	314	574	204	167	125	146	131	114	123	81	45	48	26	19	12	5	3	4	0	2150
0.00	0.25	0.50	0	0	0	6	85	152	210	268	248	183	118	117	98	55	44	59	27	16	7	1	4	1	1	0	1700
SUM			0	0	0	6	94	466	790	473	424	311	284	270	226	211	162	129	88	47	26	13	9	4	5	0	4038

Appendix G Wind-wave misalignment tables conditioned on U_{10}-wind speed (10-minute average, 10mMSL)

All Wind Speeds

	Mean wave direction [deg]												
Wind dir. [deg]	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**All**
0	194	986	332	149	110	139	852	2800	487	99	94	81	6323
30	8	1023	1896	485	221	219	930	1357	87	3	0	0	6229
60	0	5	398	246	94	104	312	417	16	0	0	0	1592
90	0	0	5	49	35	15	128	153	6	0	0	0	391
120	0	0	1	2	13	4	44	79	8	0	0	0	151
150	0	0	1	0	0	10	46	87	27	0	0	0	171
180	0	0	0	0	0	3	53	472	50	0	0	0	578
210	0	0	1	0	0	0	12	2700	225	0	0	0	2938
240	0	0	1	0	0	0	24	6145	5577	0	0	0	11747
270	0	0	0	0	0	1	43	2447	3606	55	0	0	6152
300	0	3	0	3	4	5	92	1793	1476	135	0	0	3511
330	3	12	15	13	9	25	240	2261	1024	362	65	9	4038
All	205	2029	2650	947	486	525	2776	20711	12589	654	159	90	43821

Wind Speed: 0-1 m/s

	Mean wave direction [deg]												
Wind dir. [deg]	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**All**
0	0	1	0	0	0	0	2	29	7	0	0	0	39
30	0	2	0	0	0	0	3	16	3	1	0	0	25
60	0	0	0	0	0	1	3	13	2	0	0	0	19
90	0	0	0	0	0	0	2	11	0	0	0	0	13
120	0	0	0	0	0	0	1	16	1	0	0	0	18
150	0	0	1	0	0	0	2	13	1	0	0	0	17
180	0	0	0	0	0	0	0	14	3	0	0	0	17
210	0	0	0	0	0	0	0	20	4	0	0	0	24
240	0	0	0	0	0	0	1	17	1	0	0	0	19
270	0	0	0	0	0	0	2	18	3	0	0	0	23
300	0	0	0	0	0	0	2	19	5	0	0	0	26
330	0	0	0	0	0	0	1	27	10	0	0	0	38
All	0	3	1	0	0	1	19	213	40	1	0	0	278

Wind Speed: 1-2 m/s

	Mean wave direction [deg]												
Wind dir. [deg]	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**All**
0	0	0	0	0	0	2	43	144	18	1	0	0	208
30	0	2	0	0	0	6	23	92	11	1	0	0	135
60	0	0	0	0	2	1	20	57	6	0	0	0	86
90	0	0	0	0	0	1	10	42	5	0	0	0	58
120	0	0	1	0	0	0	4	27	5	0	0	0	37
150	0	0	0	0	0	0	6	33	10	0	0	0	49
180	0	0	0	0	0	0	4	64	14	0	0	0	82
210	0	0	1	0	0	0	6	64	8	0	0	0	79
240	0	0	1	0	0	0	8	104	16	0	0	0	129
270	0	0	0	0	0	0	9	124	22	1	0	0	156
300	0	1	0	1	0	0	16	217	25	1	0	0	261
330	0	1	1	0	1	3	18	188	22	1	0	0	235
All	0	4	4	1	3	13	167	1156	162	5	0	0	1515

Wind Speed: 2-3 m/s

	Mean wave direction [deg]												
Wind dir. [deg]	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**All**
0	0	1	2	1	5	5	75	310	44	0	0	0	443
30	0	0	3	5	5	16	71	143	21	0	0	0	264
60	0	0	0	3	7	11	45	112	5	0	0	0	183
90	0	0	1	1	6	4	47	40	1	0	0	0	100
120	0	0	0	1	1	1	10	24	2	0	0	0	39
150	0	0	0	0	0	0	1	28	12	0	0	0	41
180	0	0	0	0	0	0	2	62	20	0	0	0	84
210	0	0	0	0	0	0	3	123	29	0	0	0	155
240	0	0	0	0	0	0	14	308	37	0	0	0	359
270	0	0	0	0	0	1	16	420	111	0	0	0	548
300	0	0	0	2	4	5	38	462	147	0	0	0	658
330	0	0	4	2	2	7	54	409	108	2	0	0	588
All	0	1	10	15	30	50	376	2441	537	2	0	0	3462

	Wind Speed: 3-4 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	0	30	60	90	120	150	180	210	240	270	300	330	All
0	0	11	17	15	7	27	177	604	76	3	0	0	937
30	0	9	38	30	33	39	230	352	17	0	0	0	748
60	0	0	8	29	17	28	77	128	3	0	0	0	290
90	0	0	1	9	12	4	37	46	0	0	0	0	109
120	0	0	0	0	1	0	17	8	0	0	0	0	26
150	0	0	0	0	0	0	3	4	4	0	0	0	11
180	0	0	0	0	0	0	5	38	6	0	0	0	49
210	0	0	0	0	0	0	0	195	34	0	0	0	229
240	0	0	0	0	0	0	1	535	111	0	0	0	647
270	0	0	0	0	0	0	13	680	395	1	0	0	1089
300	0	2	0	0	0	0	31	622	355	21	0	0	1031
330	0	2	8	7	4	11	98	788	194	18	2	0	1132
All	0	24	72	90	74	109	689	4000	1195	43	2	0	6298

	Wind Speed: 4-5 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	0	30	60	90	120	150	180	210	240	270	300	330	All
0	3	58	66	51	31	55	317	860	111	12	7	7	1578
30	0	49	183	140	70	74	304	448	18	0	0	0	1286
60	0	2	66	65	30	27	120	88	0	0	0	0	398
90	0	0	0	17	16	3	28	12	0	0	0	0	76
120	0	0	0	0	1	0	9	4	0	0	0	0	14
150	0	0	0	0	0	1	9	2	0	0	0	0	12
180	0	0	0	0	0	3	8	28	3	0	0	0	42
210	0	0	0	0	0	0	2	254	35	0	0	0	291
240	0	0	0	0	0	0	0	734	347	0	0	0	1081
270	0	0	0	0	0	0	3	665	761	23	0	0	1452
300	0	0	0	0	0	0	2	365	537	44	0	0	948
330	0	2	1	4	2	4	53	561	343	70	11	3	1054
All	3	111	316	277	150	167	855	4021	2155	149	18	10	8232

	Wind Speed: 5-6 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	0	30	60	90	120	150	180	210	240	270	300	330	All
0	36	191	82	50	34	27	159	554	126	25	14	13	1311
30	3	161	514	171	63	68	236	271	11	0	0	0	1498
60	0	3	149	97	28	33	43	19	0	0	0	0	372
90	0	0	2	13	1	3	4	2	0	0	0	0	25
120	0	0	0	0	6	0	3	0	0	0	0	0	9
150	0	0	0	0	0	1	9	1	0	0	0	0	11
180	0	0	0	0	0	0	8	76	1	0	0	0	85
210	0	0	0	0	0	0	1	416	33	0	0	0	450
240	0	0	0	0	0	0	0	968	651	0	0	0	1619
270	0	0	0	0	0	0	0	328	850	18	0	0	1196
300	0	0	0	0	0	0	3	82	306	35	0	0	426
330	3	6	0	0	0	0	16	244	259	101	11	4	644
All	42	361	747	331	132	132	482	2961	2237	179	25	17	7646

	Wind Speed: 6-7 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	0	30	60	90	120	150	180	210	240	270	300	330	All
0	54	272	88	19	23	19	60	253	67	32	35	27	949
30	3	292	553	108	40	14	58	35	6	1	0	0	1110
60	0	0	116	43	10	3	4	0	0	0	0	0	176
90	0	0	1	9	0	0	0	0	0	0	0	0	10
120	0	0	0	1	4	3	0	0	0	0	0	0	8
150	0	0	0	0	0	4	10	2	0	0	0	0	16
180	0	0	0	0	0	0	2	74	1	0	0	0	77
210	0	0	0	0	0	0	0	491	33	0	0	0	524
240	0	0	0	0	0	0	0	1287	763	0	0	0	2050
270	0	0	0	0	0	0	0	148	556	11	0	0	715
300	0	0	0	0	0	0	0	24	82	15	0	0	121
330	0	1	1	0	0	0	0	39	77	111	18	0	247
All	57	565	759	180	77	43	134	2353	1585	170	53	27	6003

	Wind Speed: 7-8 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**All**
0	65	290	63	13	9	2	19	44	34	26	31	23	619
30	2	293	451	29	10	2	5	0	0	0	0	0	792
60	0	0	40	9	0	0	0	0	0	0	0	0	49
90	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	3	5	3	0	0	0	0	11
180	0	0	0	0	0	0	6	58	2	0	0	0	66
210	0	0	0	0	0	0	0	501	28	0	0	0	529
240	0	0	0	0	0	0	0	1069	1071	0	0	0	2140
270	0	0	0	0	0	0	0	57	440	1	0	0	498
300	0	0	0	0	0	0	0	1	18	13	0	0	32
330	0	0	0	0	0	0	0	5	10	43	14	0	72
All	67	583	554	51	19	7	35	1738	1603	83	45	23	4808

	Wind Speed: 8-9 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**All**
0	27	144	14	0	1	2	0	2	4	0	7	8	209
30	0	185	140	2	0	0	0	0	0	0	0	0	327
60	0	0	13	0	0	0	0	0	0	0	0	0	13
90	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	1	1	1	0	0	0	0	3
180	0	0	0	0	0	0	6	18	0	0	0	0	24
210	0	0	0	0	0	0	0	358	10	0	0	0	368
240	0	0	0	0	0	0	0	626	942	0	0	0	1568
270	0	0	0	0	0	0	0	7	278	0	0	0	285
300	0	0	0	0	0	0	0	1	0	5	0	0	6
330	0	0	0	0	0	0	0	0	1	16	8	2	27
All	27	329	167	2	1	3	7	1013	1235	21	15	10	2830

	Wind Speed: 9-10 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**All**
0	6	18	0	0	0	0	0	0	0	0	0	3	27
30	0	29	13	0	0	0	0	0	0	0	0	0	42
60	0	0	6	0	0	0	0	0	0	0	0	0	6
90	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	4	18	0	0	0	0	22
210	0	0	0	0	0	0	0	166	0	0	0	0	166
240	0	0	0	0	0	0	0	341	834	0	0	0	1175
270	0	0	0	0	0	0	0	0	131	0	0	0	131
300	0	0	0	0	0	0	0	0	1	1	0	0	2
330	0	0	0	0	0	0	0	0	0	0	1	0	1
All	6	47	19	0	0	0	4	525	966	1	1	3	1572

	Wind Speed: 10-11 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**All**
0	3	0	0	0	0	0	0	0	0	0	0	0	3
30	0	1	1	0	0	0	0	0	0	0	0	0	2
60	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	8	20	0	0	0	0	28
210	0	0	0	0	0	0	0	91	8	0	0	0	99
240	0	0	0	0	0	0	0	117	547	0	0	0	664
270	0	0	0	0	0	0	0	0	41	0	0	0	41
300	0	0	0	0	0	0	0	0	0	0	0	0	0
330	0	0	0	0	0	0	0	0	0	0	0	0	0
All	3	1	1	0	0	0	8	228	596	0	0	0	837

	Wind Speed: 11-12 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	0	30	60	90	120	150	180	210	240	270	300	330	All
0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	2	0	0	0	0	2
210	0	0	0	0	0	0	0	20	2	0	0	0	22
240	0	0	0	0	0	0	0	34	205	0	0	0	239
270	0	0	0	0	0	0	0	0	18	0	0	0	18
300	0	0	0	0	0	0	0	0	0	0	0	0	0
330	0	0	0	0	0	0	0	0	0	0	0	0	0
All	0	0	0	0	0	0	0	56	225	0	0	0	281

	Wind Speed: 12-13 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	0	30	60	90	120	150	180	210	240	270	300	330	All
0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	1	1	0	0	0	2
240	0	0	0	0	0	0	0	4	35	0	0	0	39
270	0	0	0	0	0	0	0	0	0	0	0	0	0
300	0	0	0	0	0	0	0	0	0	0	0	0	0
330	0	0	0	0	0	0	0	0	0	0	0	0	0
All	0	0	0	0	0	0	0	5	36	0	0	0	41

	Wind Speed: 13-14 m/s												
	Mean wave direction [deg]												
Wind dir. [deg]	0	30	60	90	120	150	180	210	240	270	300	330	All
0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0	0	0	0
240	0	0	0	0	0	0	0	1	17	0	0	0	18
270	0	0	0	0	0	0	0	0	0	0	0	0	0
300	0	0	0	0	0	0	0	0	0	0	0	0	0
330	0	0	0	0	0	0	0	0	0	0	0	0	0
All	0	0	0	0	0	0	0	1	17	0	0	0	18

Appendix H Cyclone Hindcast Study

COWI DK

GUJARAT OWF

CYCLONE HINDCASTING STUDY

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CONTENTS

1 Introduction

Cyclone track information along the west coast of India published by India Meteorological Department (IMD), [Ref 1] and Joint Typhoon Warning Centre (JTWC), [Ref 2], were compiled to establish the database of depressions and cyclones those affect the proposed Offshore Windfarm site in the state of Gujarat, India.

2 Cyclone database

India meteorological department (IMD) has a database containing approximately 1500 tracks for cyclones and depressions that were generated and evolved in Indian seas from year 1891 to 2007. IMD has classified the low-pressure systems in Indian seas as depressions and cyclones based on the intensity of

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wind speed as shown in Table 2-1.

However, the wind and atmospheric pressure information for cyclones before 1990 are not furnished in IMD database. Therefore, cyclone data from the year 1975 to 1990 were extracted from the Joint Typhoon Warning Centre (JTWC) database to generate data on cyclones and depressions in the present study.

Table 2-1 Classification of cyclonic disturbances based on maximum wind speed on sea surface

Type of Disturbances	**Maximum sustained with wind speed**
Low pressure area	<17 knots
Depression	17-27 knots
Deep depression	28-33 knots
Cyclonic storm	34-47 knots
Severe Cyclonic storm	48-63 knots
Very severe cyclonic storm	64-119 knots
Super cyclonic storm	>120 knots

3 Wave hindcast study

COWI has undertaken a cyclone wave hindcast study to simulate the extreme waves off Gujarat Coast, during the passage of the cyclonic storms those occurred in Arabian Sea, using an in house Arabian Sea wave model. COWI's Arabian Sea model has been used for several studies along the west Coast of India.

The MIKE 21 SW, model developed by DHI Denmark, was used to simulate the cyclone generated waves. The fully spectral formulation, which can simulate waves generated by complex wind fields during storms, was used for the wave hindcast study.

3.1 Bathymetry of the Arabian Sea

An unstructured mesh bathymetry was generated using data from MIKE C-MAP and ETOPO2 database. The computational mesh covering the entire Arabian Sea, used for wave hindcast study is presented in Figure 3-1. The area extends from latitude 4° to 26°N and from longitude 48° to 79°E. The whole domain is covered by four kinds of mesh sizes. All along the Indian coast, the mesh size is 1.5km up to 20m water depth, beyond which the size progressively increases to 40 km for the outermost area of the model.

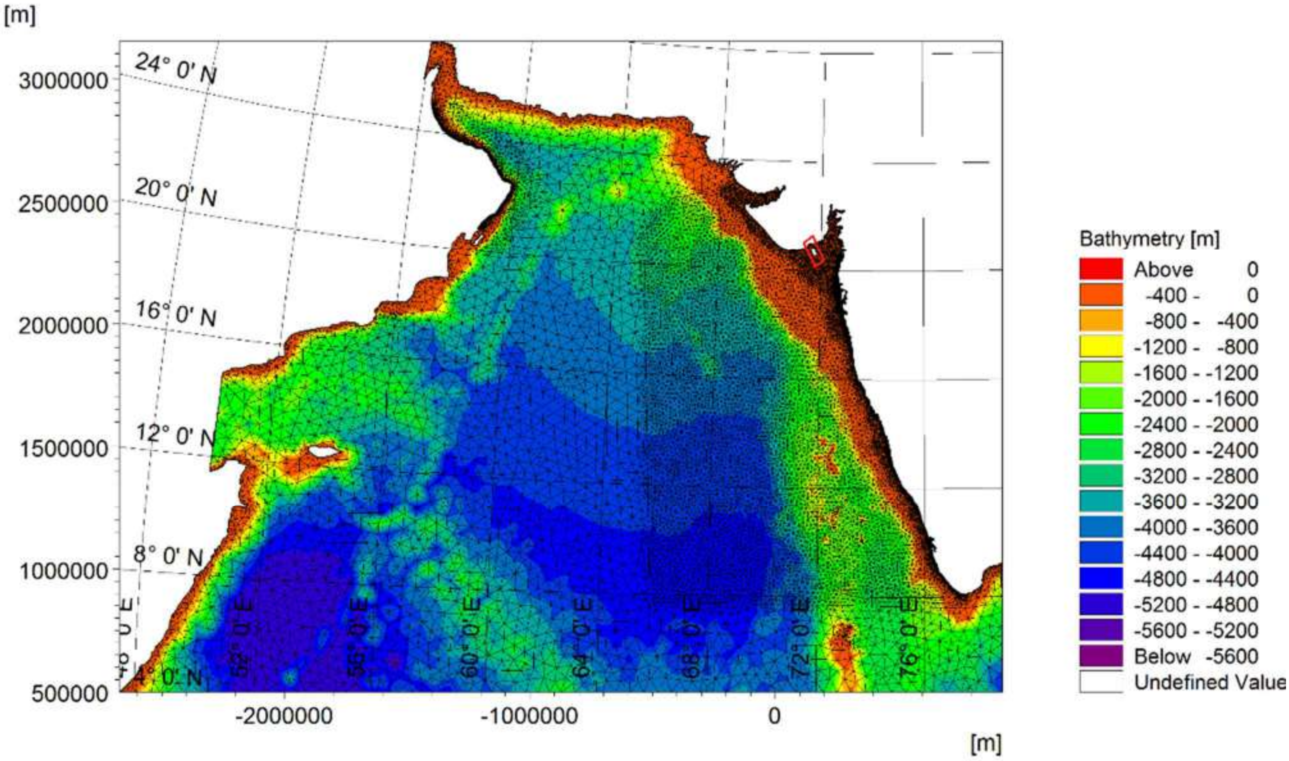

Figure 3-1 Arabian Sea mesh used for cyclone wave hindcast study; Rectangle (red colour) shows the Proposed OWF at Gujarat.

3.2 Input data

The cyclonic storm data for the period 1975 to 2015 were used to simulate cyclonic generated waves. Table 4-1 shows the 27 storms (15 storm with maximum wind speed > 63 knots and 12 storms with maximum wind speed between 34 to 63 knots) within a radius of 200km to the OWF location, which were simulated for establishing the extreme wave climate.

It shall be noted that for some of the cyclone tracks, central pressure data are not available. The method proposed by Atkinson and Holliday, [Ref 3], was used to obtain the pressure drop for cyclones, using the reported sustained maximum wind speeds, for each storm.

4 Extreme wind and wave at proposed OWF Location

The results of the wave hindcasting simulations for the 27 storms at a location (20m depth) close to the proposed OWF were used to extract the extreme conditions. The extraction location is presented in Figure 4-1. The tracks of the all 27 cyclones are presented below.

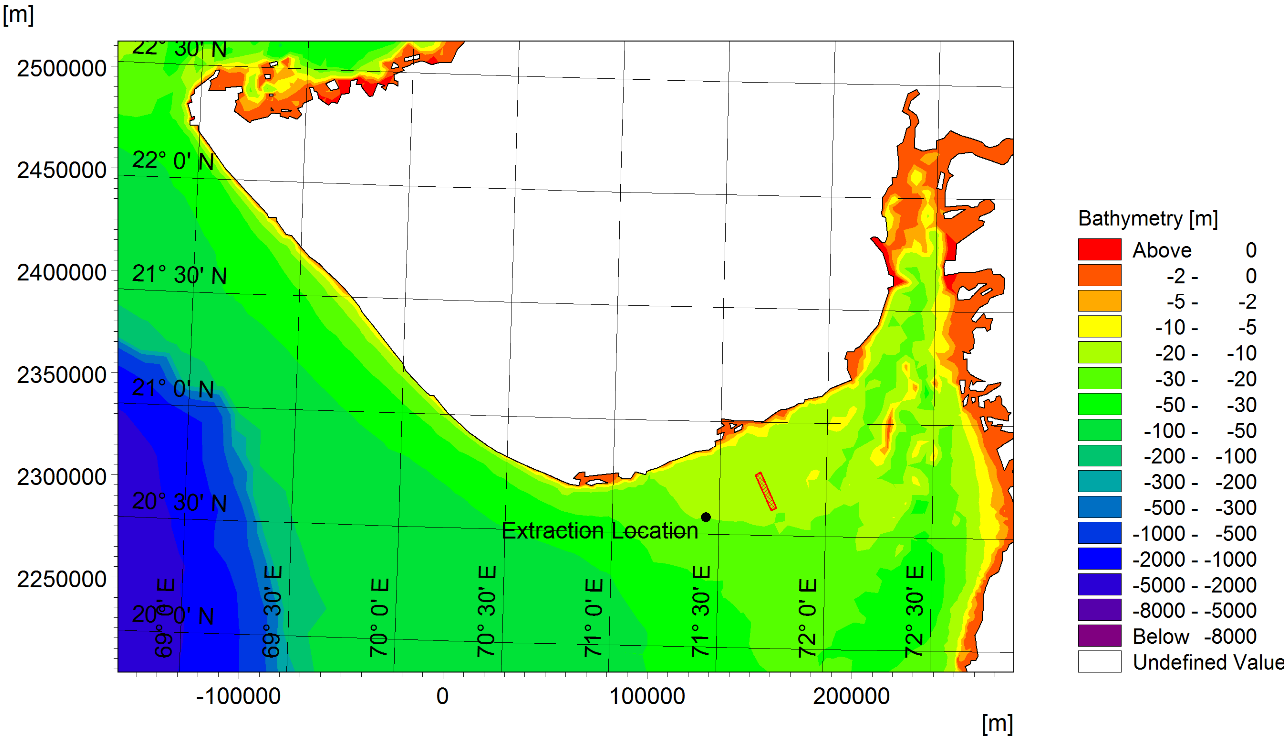

Figure 4-1 *The location (Black dot) selected for extraction of the storms; Red hatched area is the proposed OWF.*

Table 4-1 Cyclonic storms in the Arabian Sea for the period 1975-2015, and simulated extreme wave heights and wind speeds at a location near proposed OWF

No	Year	Date	U_{max} (knots)	Place of passing	Wave height Hs(m) [20m]	Est.wind speed (m/s)
1	1975	19-24 Oct	80	Porbandar	6.4	19.5
2	1975	01-11 May	95	Off Karnataka	3.9	7.2
3	1977	13-22 Nov	110	Mangalore coast	3.5	4.6
4	1978	03-13 Nov	80	Gulf of Kutch	2.7	5.3
5	1979	13-17 Nov	40	Off Mumbai	3.1	12.0
6	1980	12-19 Nov	35	Off Karnataka	1.5	7.0
7	1981	25 Oct-02 Nov	60	Porbandar	4.3	13.2
8	1982	04-09 Nov	85	Porbandar	7.7	40.4
9	1985	28 May-1 Jun	50	Kutch coast	3.4	11.8
10	1989	07-13 Jun	35	Near Porbandar	2.1	11.3
11	1993	09-16 Nov	80	Gulf of Kutch	3.5	5.4
12	1995	11-18 Oct	50	Off Maharashtra	1.6	7.0
13	1996	15-25 Jun	65	Porbandar	7.4	31.8
14	1996	20-28 Oct	65	Porbandar	5.1	17.7
15	1998	01-09 Jun	105	Porbandar	7.0	20.5
16	1998	11-17 Dec	65	Off West Coast	2.8	5.6
17	1999	15-21 May	110	Kutch coast	5.5	12.2
18	2001	21-29 May	110	Kutch coast	5.5	12.1
19	2004	01-03 Oct	40	Off Porbandar	1.2	6.4
20	2007	21-26 Jun	50	Near Porbandar	0.7	7.9
21	2007	31 May-08 Jun	140	Offshore	3.1	5.8
22	2009	09-11 Nov	50	Maharashtra Coast	1.2	2.0
23	2010	31 May-06 Jun	125	Porbandar	2.7	10.0
24	2011	09-12 Jun	35	Veraval Coast	3.2	17.3
25	2014	25-30 Oct	115	Offshore	3.8	3.0
26	2014	10-13 Jun	55	Offshore	1.9	5.5
27	2015	07-11 Jun	55	Offshore	1.1	7.4

4.1 Cyclone Tracks

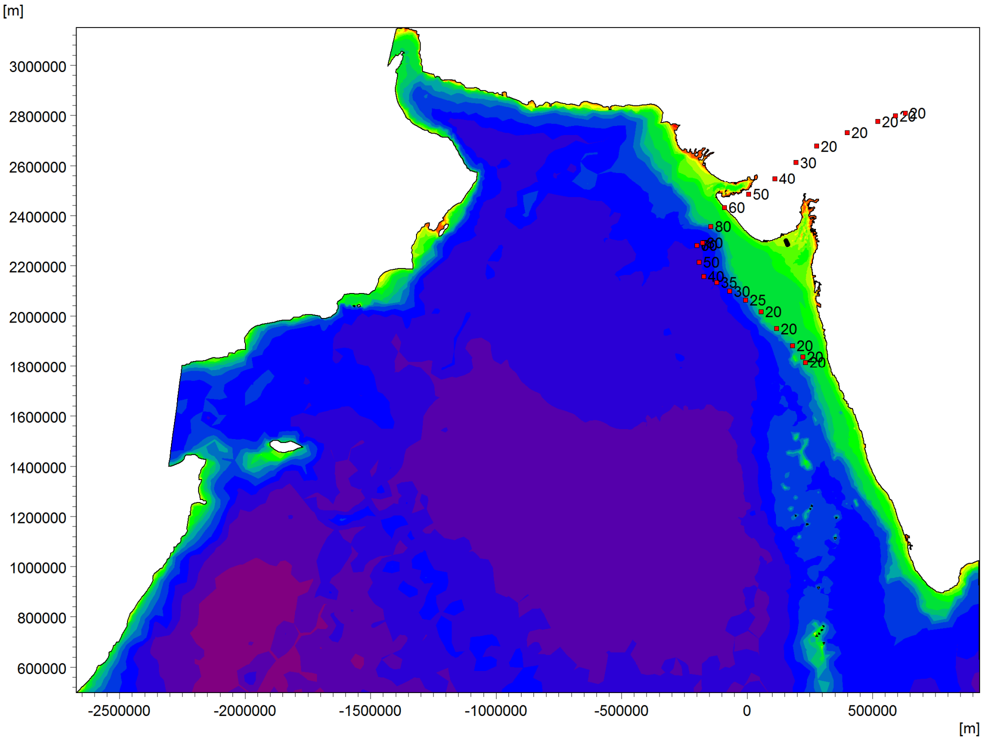

Figure 4-2 Track for 1975 storm (19-24 Oct) crossing Porbandar with a maximum wind speed of 80 knots.

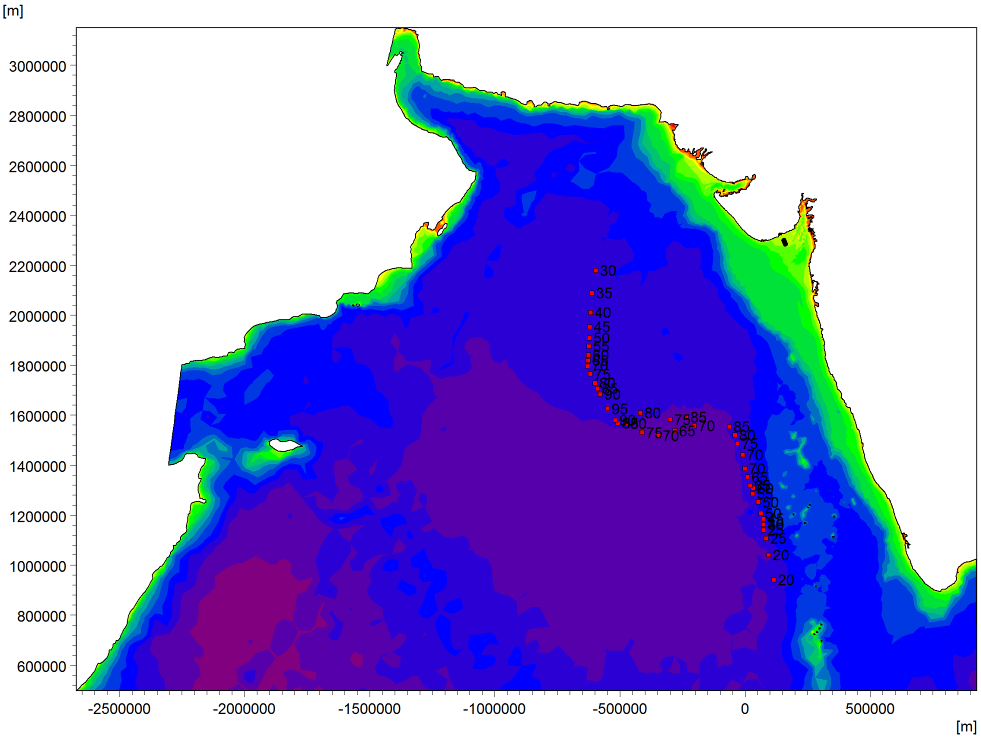

Figure 4-3 Track for 1975 storm (01-11 May) off Karnataka with a maximum wind speed of 95 knots.

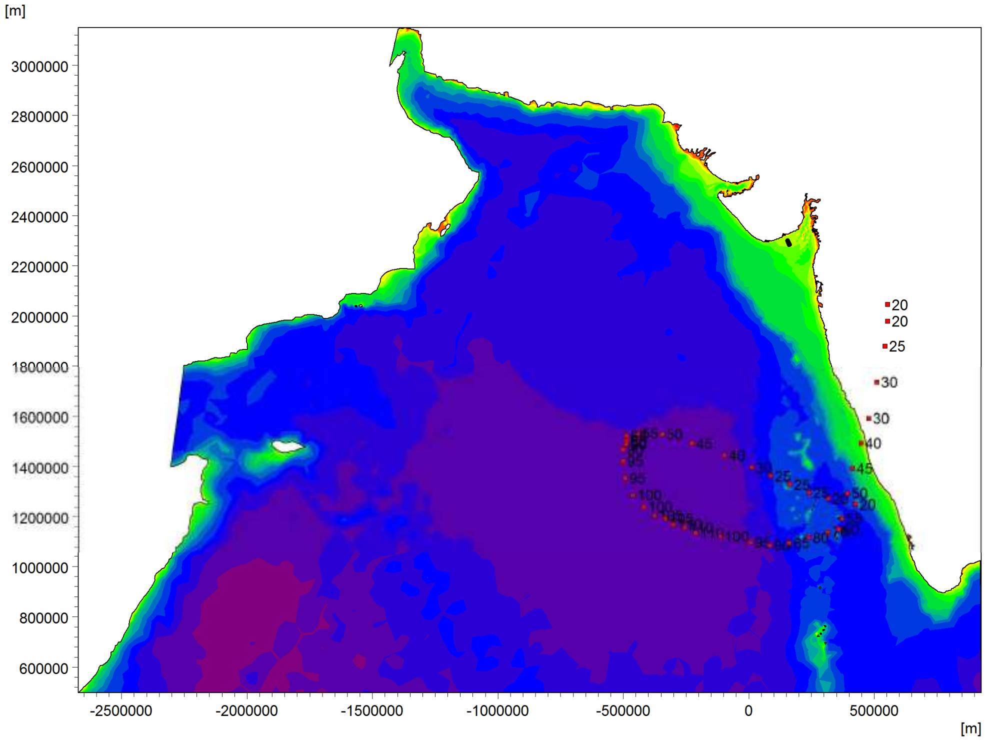

Figure 4-4 *Track for 1977 storm (13-22 Nov) crossing Mangalore with a maximum wind speed of 110 knots.*

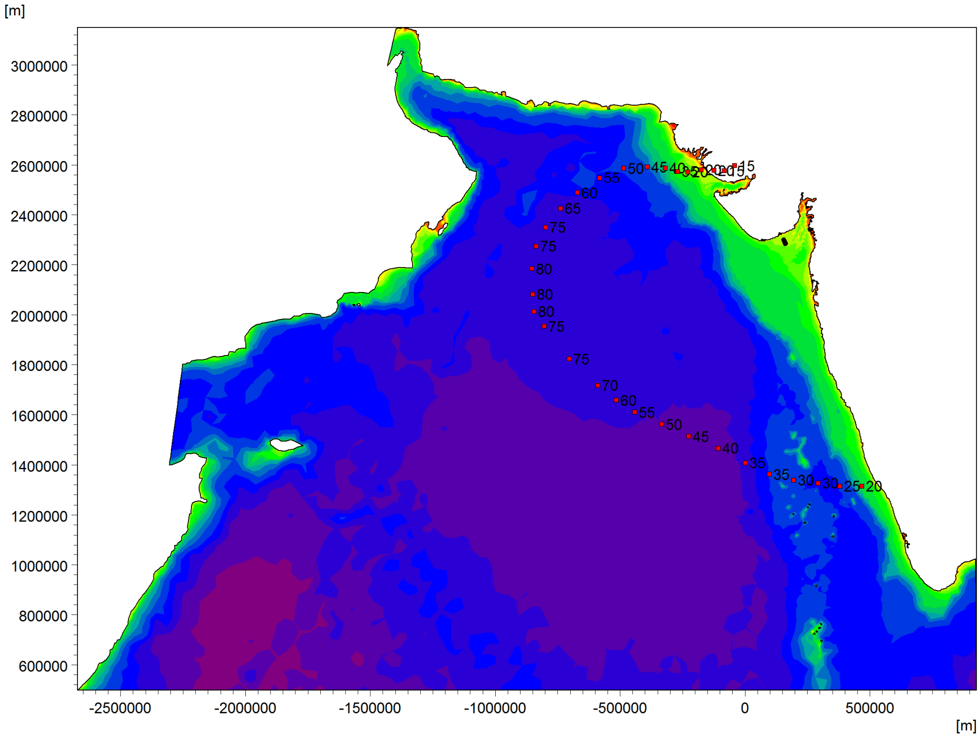

Figure 4-5 *Track for 1978 storm (03-13 Nov) crossing Gulf of Kutch with a maximum wind speed of 80 knots.*

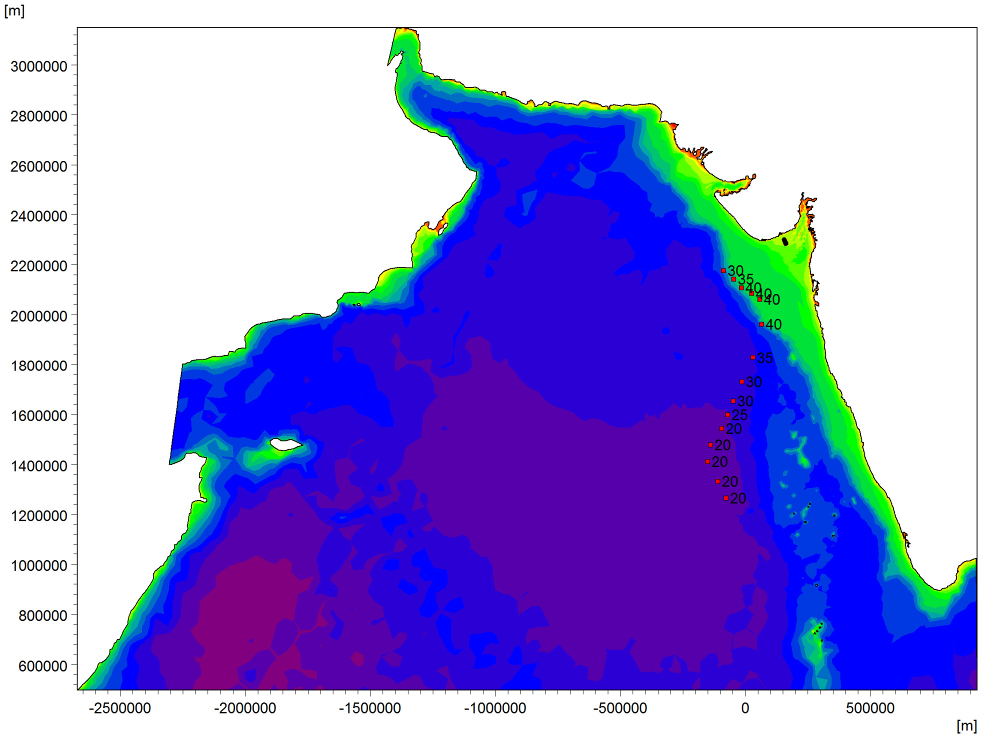

Figure 4-6 Track for 1979 storm (13-17 Nov) off Mumbai with a maximum wind speed of 40 knots.

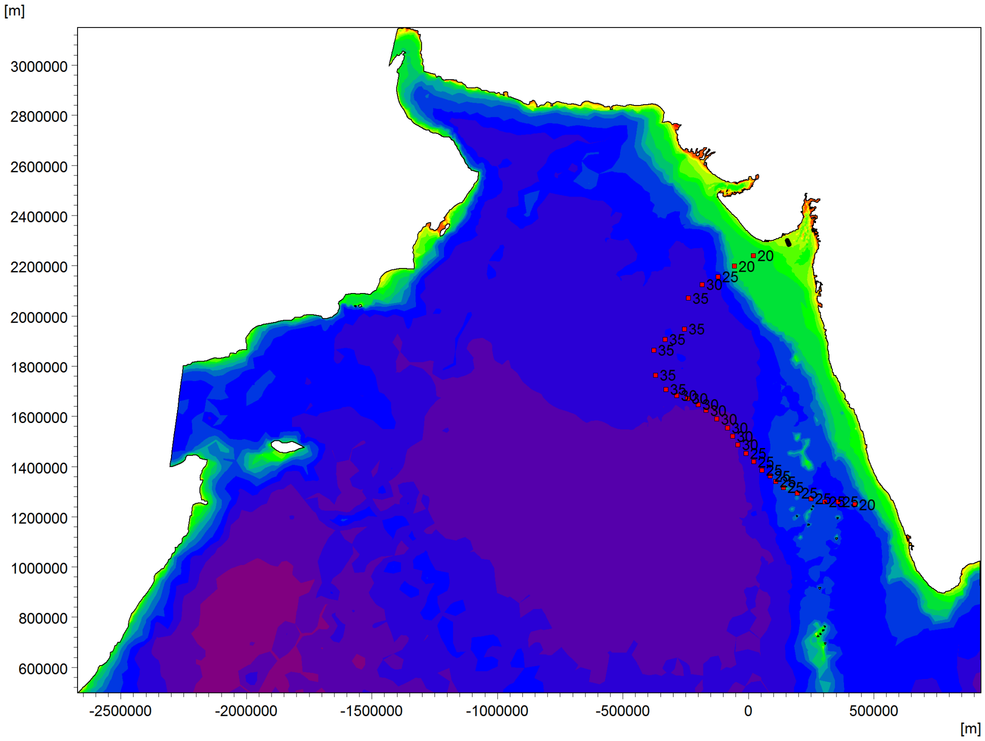

Figure 4-7 Track for 1980 storm (12-19 Nov) off Karnataka with a maximum wind speed of 35 knots.

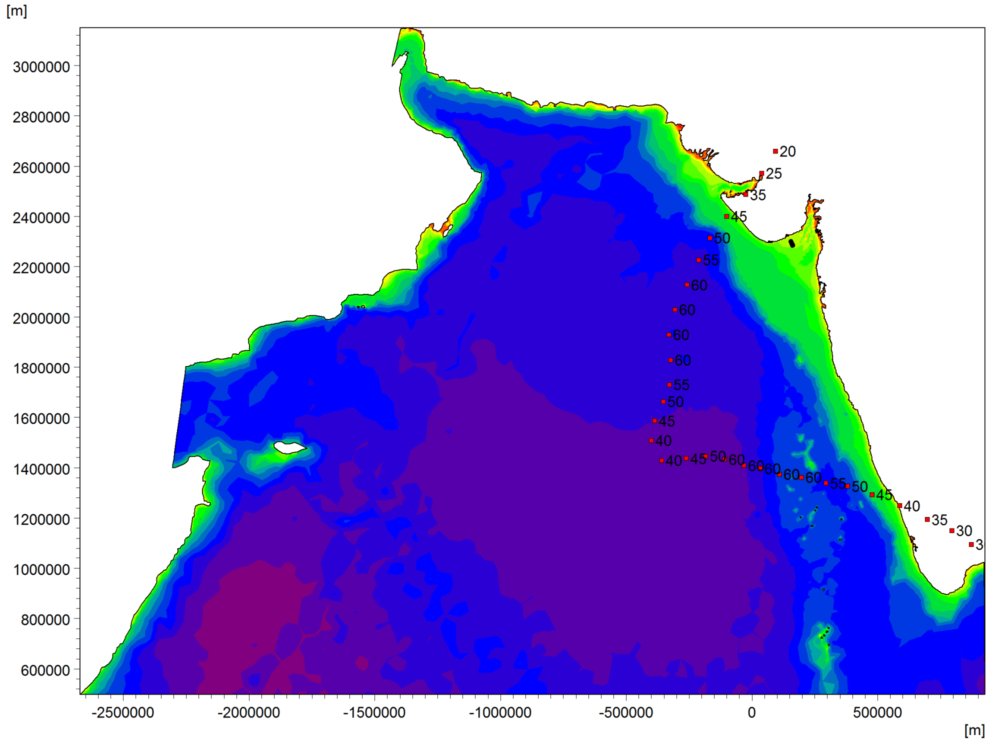

Figure 4-8 *Track for 1981 storm (25 Oct-02 Nov) crossing Porbandar with a maximum wind speed of 60 knots.*

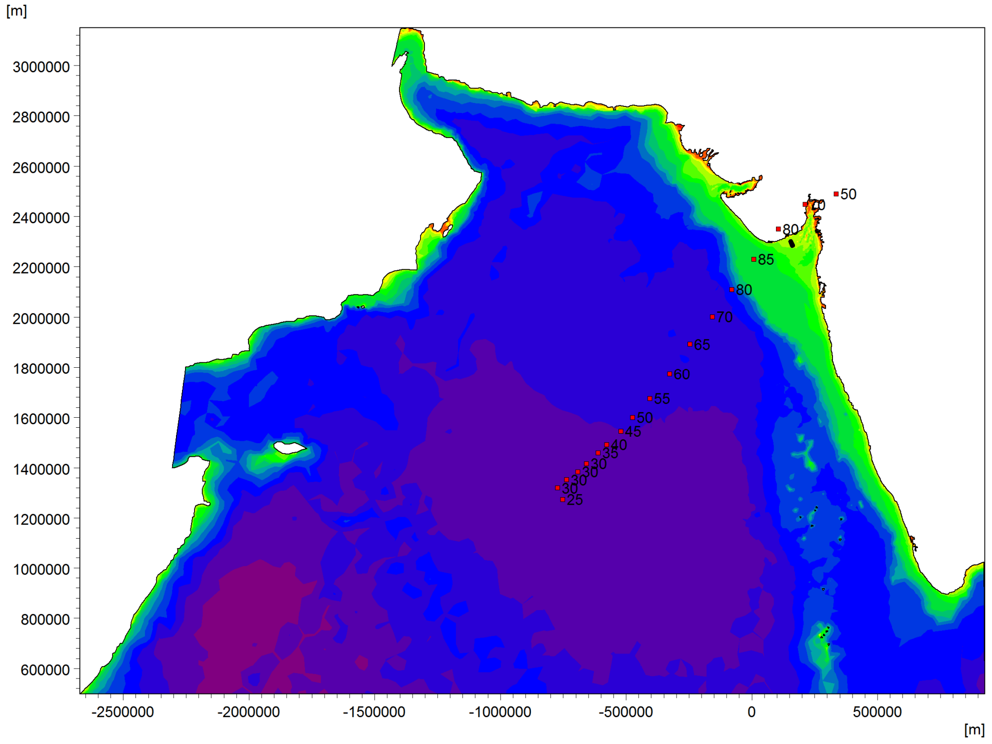

Figure 4-9 *Track for 1982 storm (04-09 Nov) crossing Porbandar with a maximum wind speed of 85 knots.*

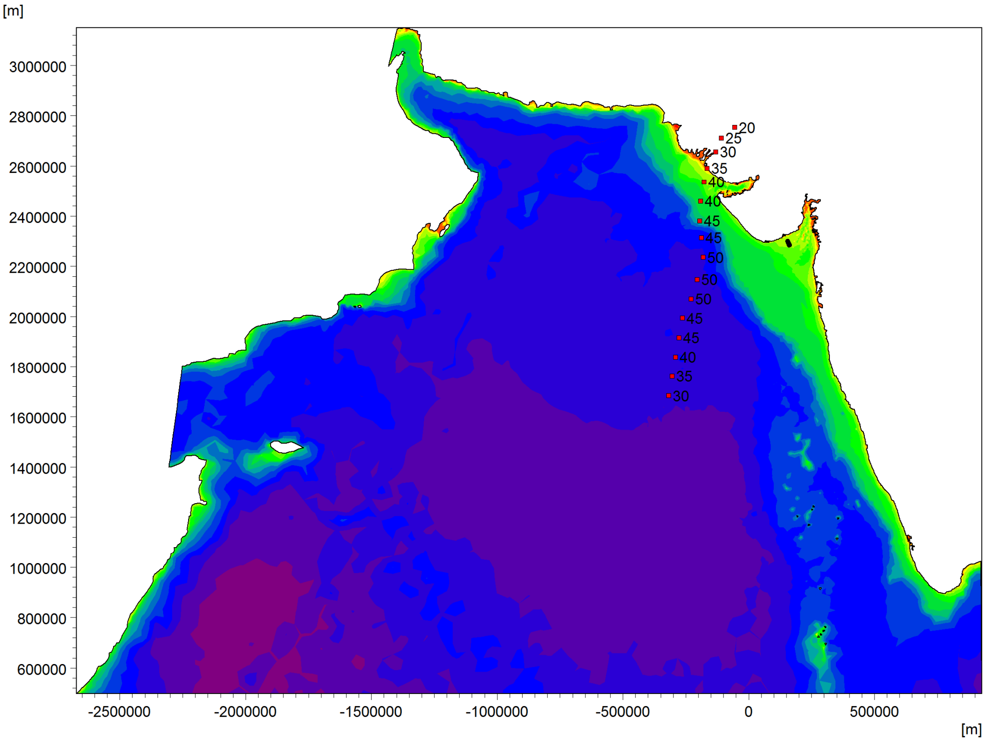

Figure 4-10 Track for 1985 storm (28 May-01 Jun) crossing Kutch Coast with a maximum wind speed of 50 knots.

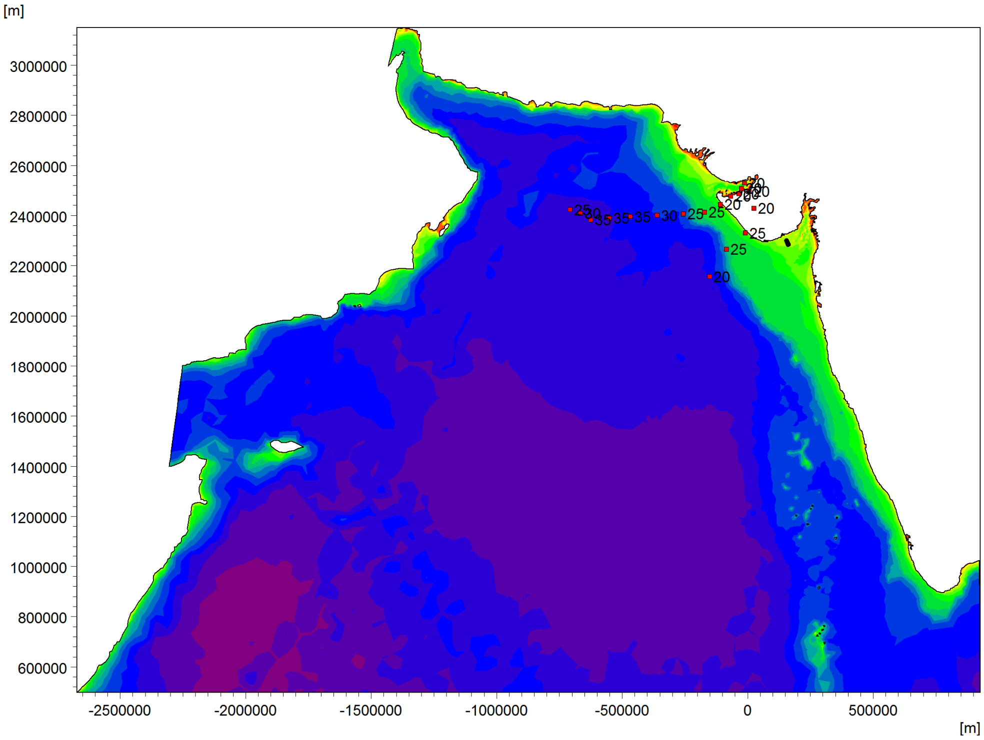

Figure 4-11 Track for 1989 storm (07-13 Jun) crossing near Porbandar with a maximum wind speed of 35 knots.

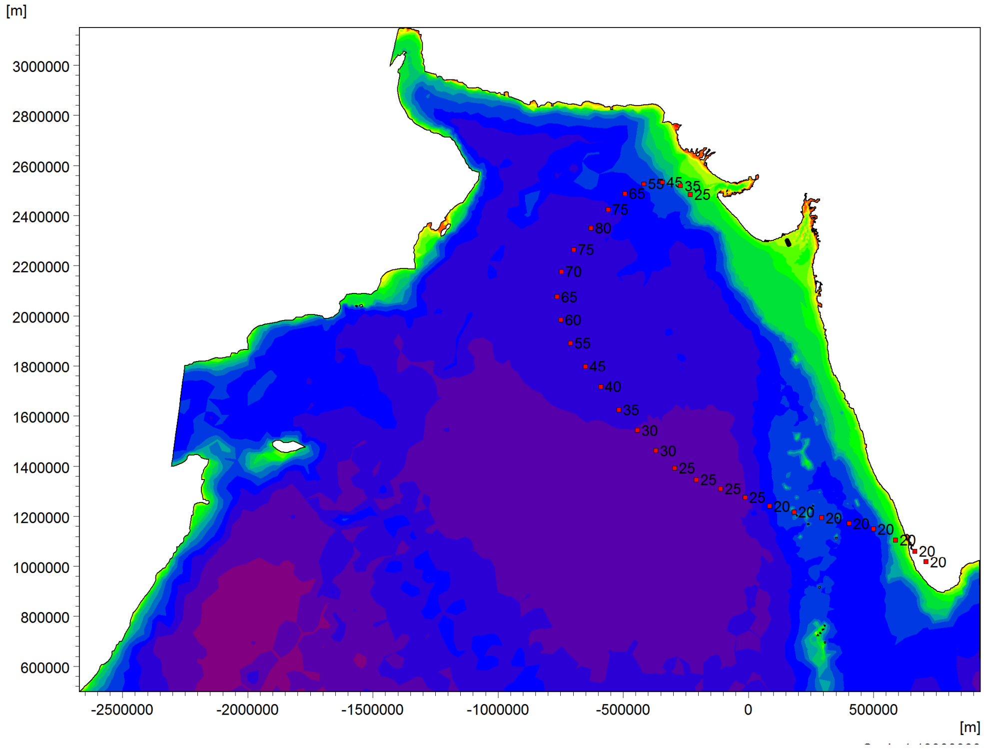

Figure 4-12 Track for 1993 storm (09-16 Nov) crossing Gulf of Kutch with a maximum wind speed of 80 knots.

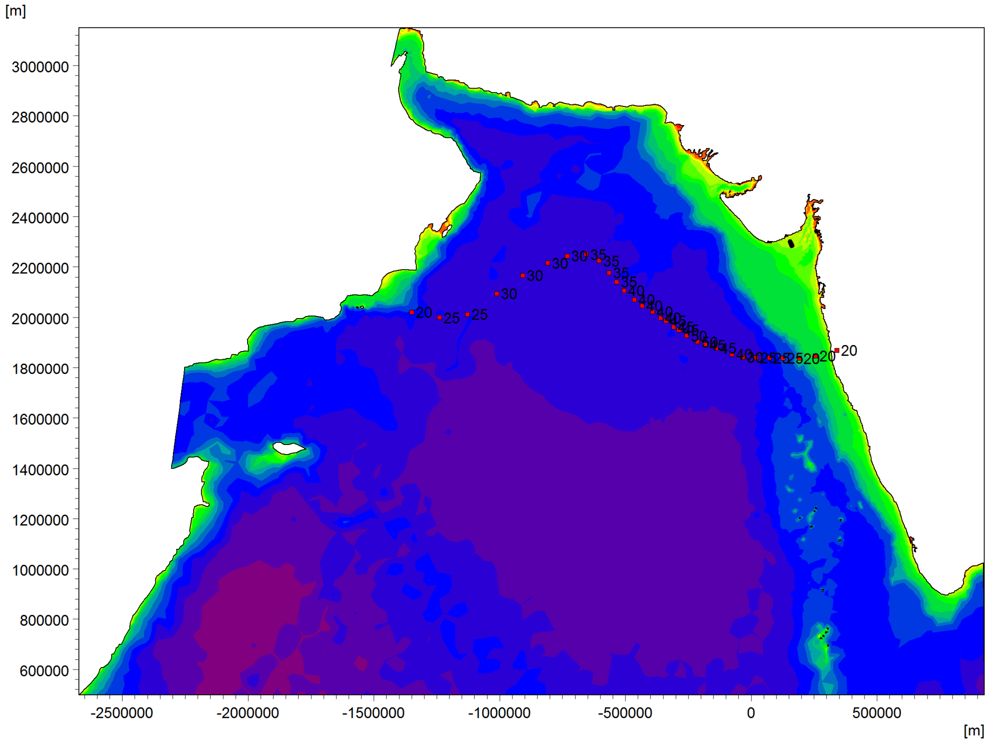

Figure 4-13 Track for 1995 storm (11-18 Oct) off Maharashtra with a maximum wind speed of 50 knots.

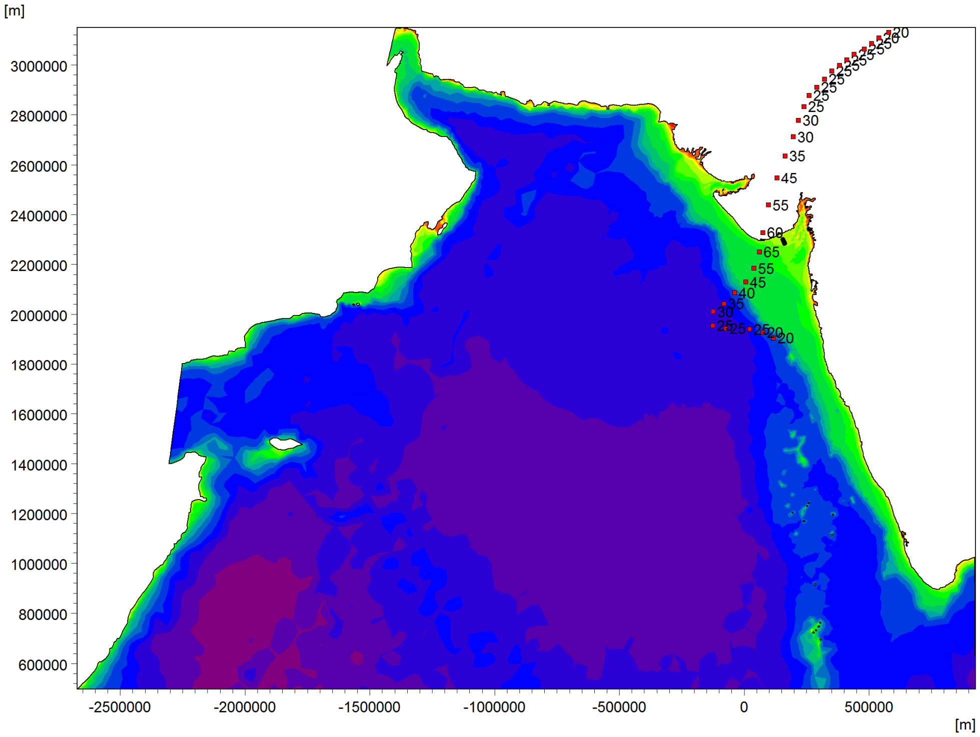

Figure 4-14 Track for 1996 storm (15-25 Jun) crossing near Porbandar with a maximum wind speed of 65 knots.

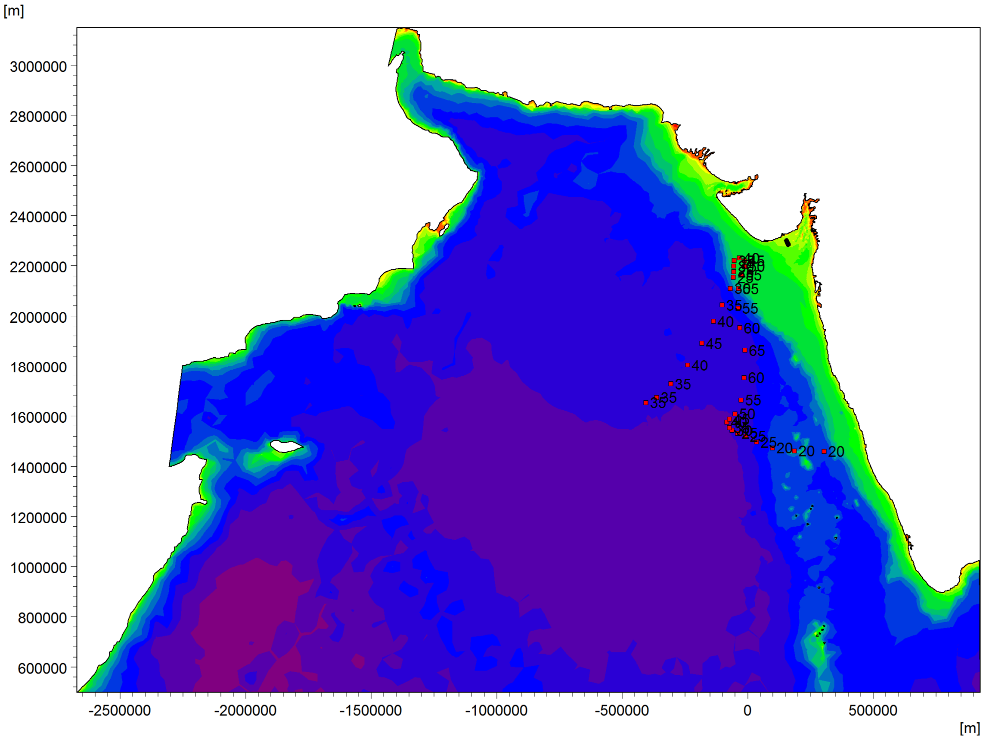

Figure 4-15 Track for 1996 storm (20-28 Oct) off Porbandar with a maximum wind speed of 65 knots.

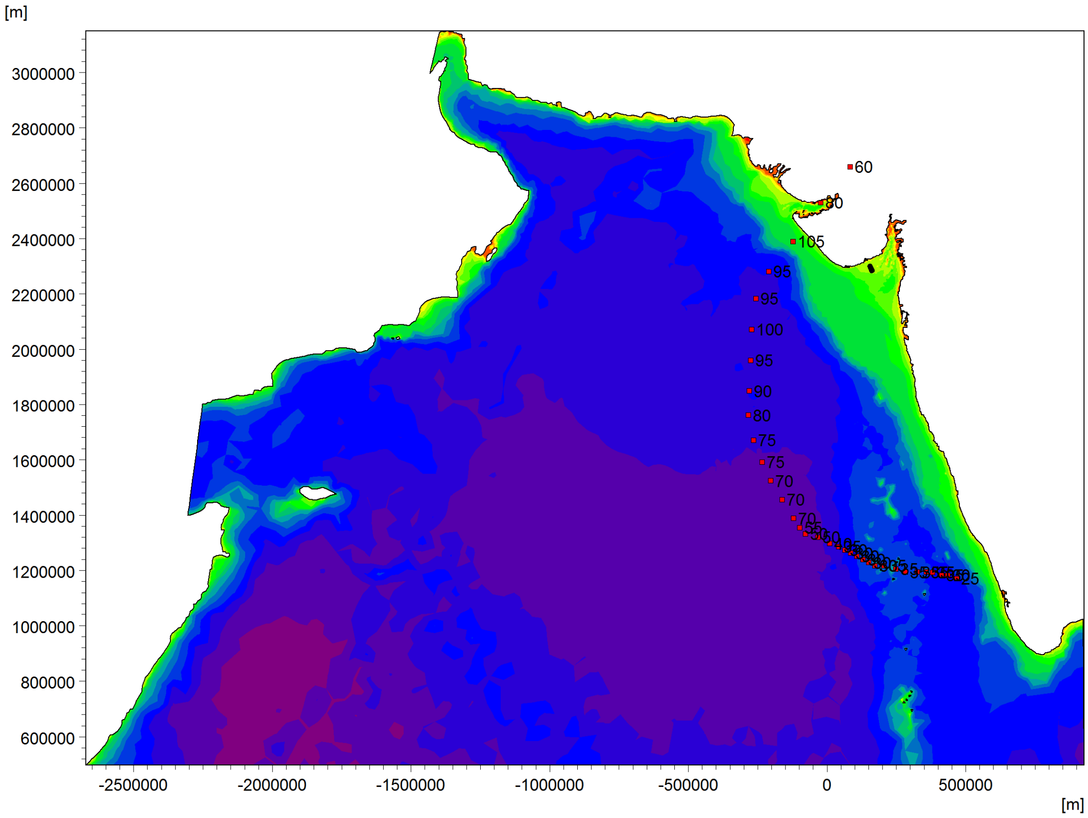

Figure 4-16 Track for 1998 storm (01-09 Jun) crossing Porbandar with a maximum wind speed of 105 knots.

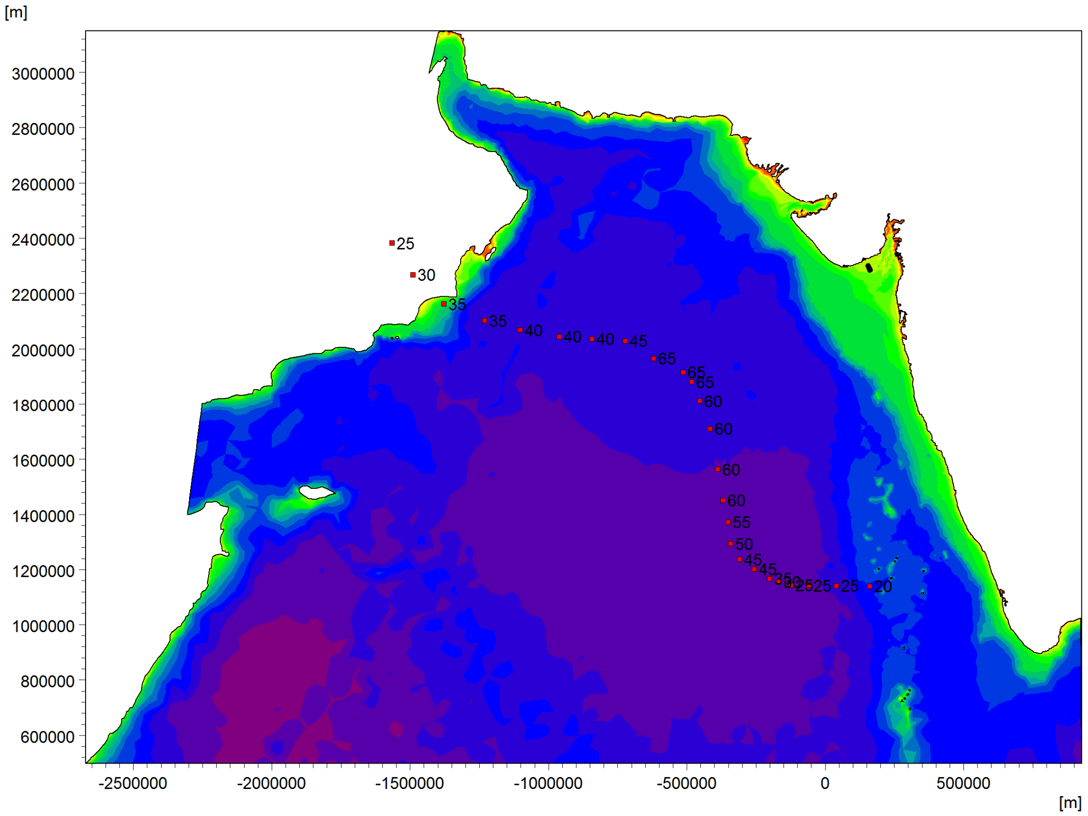

Figure 4-17 Track for 1998 storm (11-17 Dec) off west coast with a maximum wind speed of 65 knots.

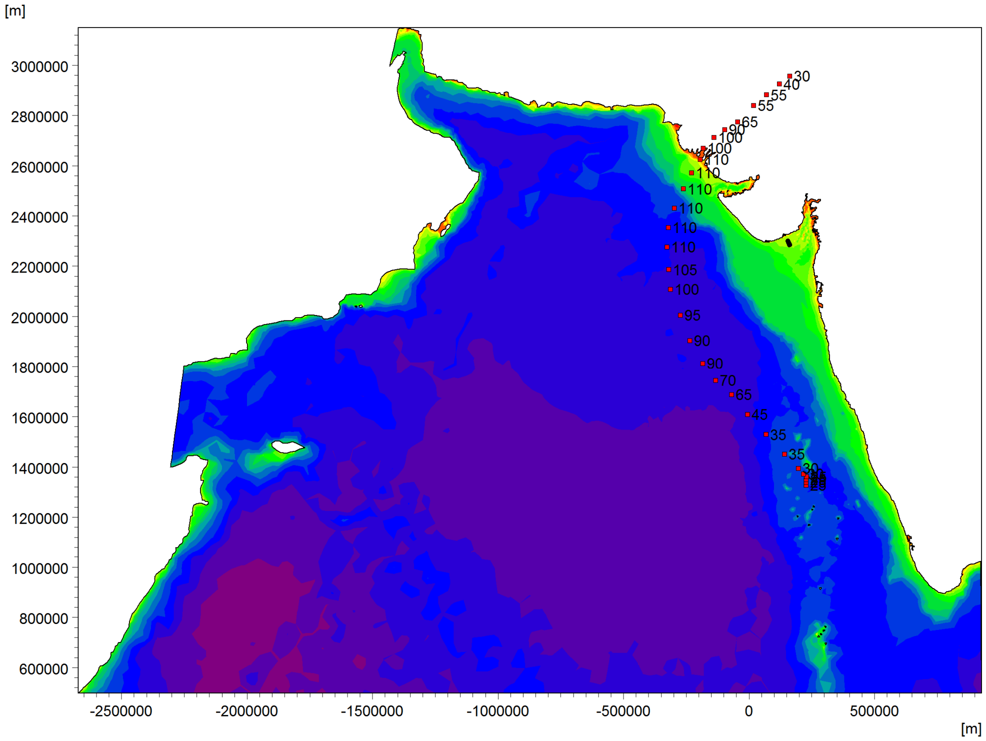

Figure 4-18 Track for 1999 storm (15-21 May) crossing Kutch coast with a maximum wind speed of 110 knots.

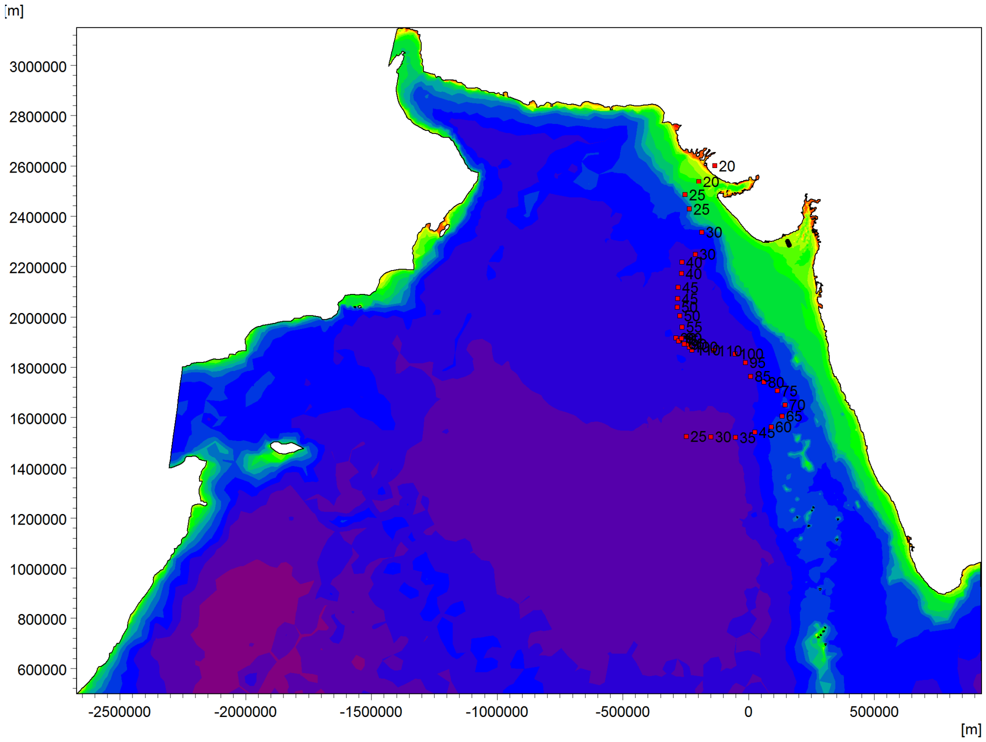

Figure 4-19 Track for 2001 storm (21-29 May) crossing Kutch coast with a maximum wind speed of 110 knots.

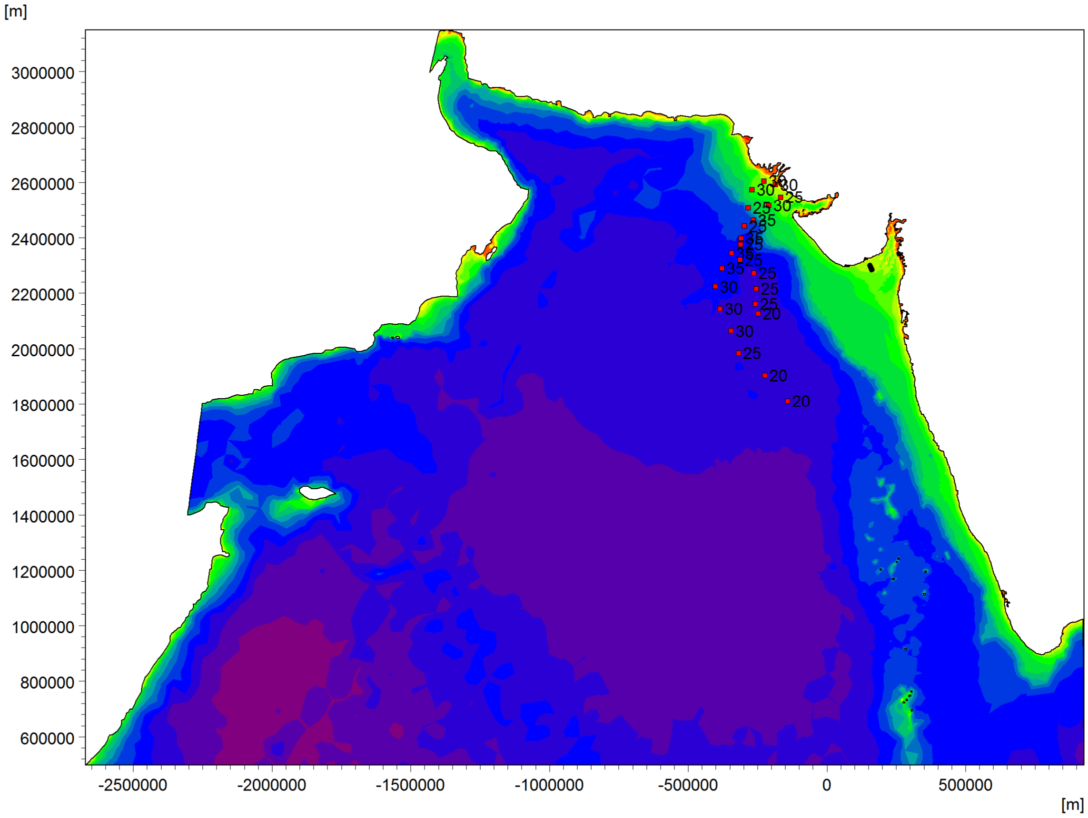

Figure 4-20 Track for 2004 storm (01-03 Oct) off Porbandar with a maximum wind speed of 40 knots.

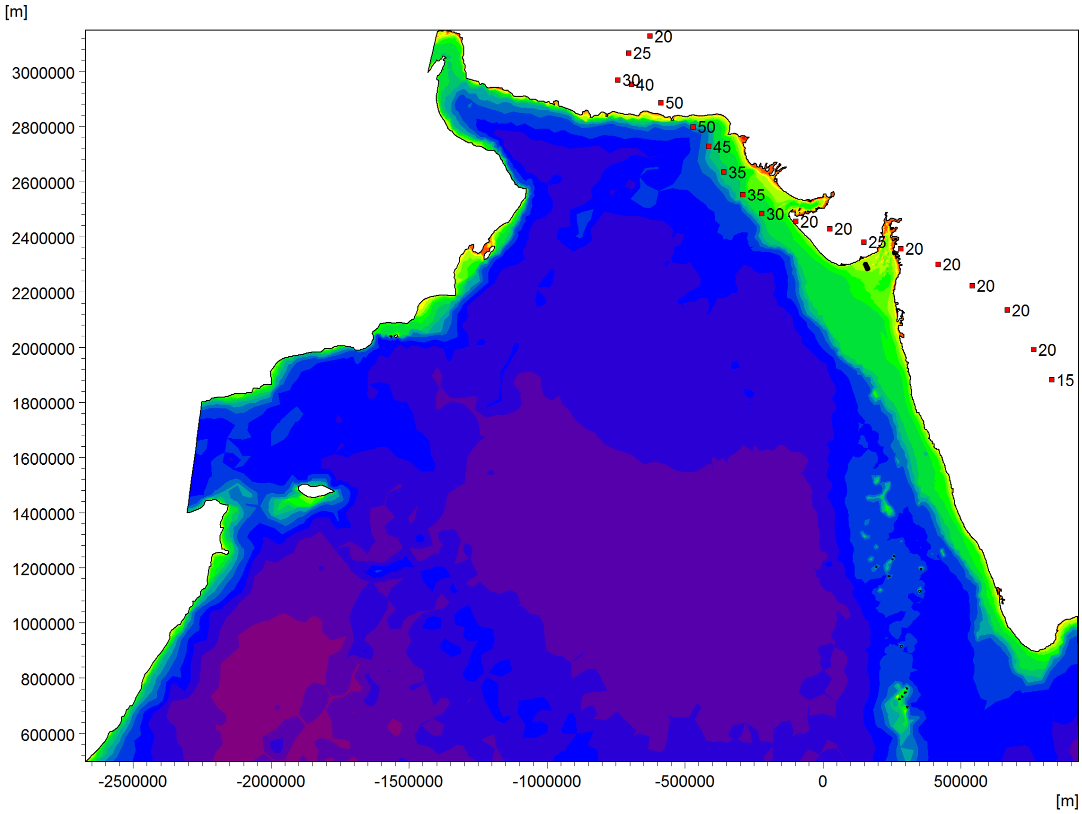

Figure 4-21 Track for 2007 storm (21-26 Jun) near Porbandar with a maximum wind speed of 50 knots.

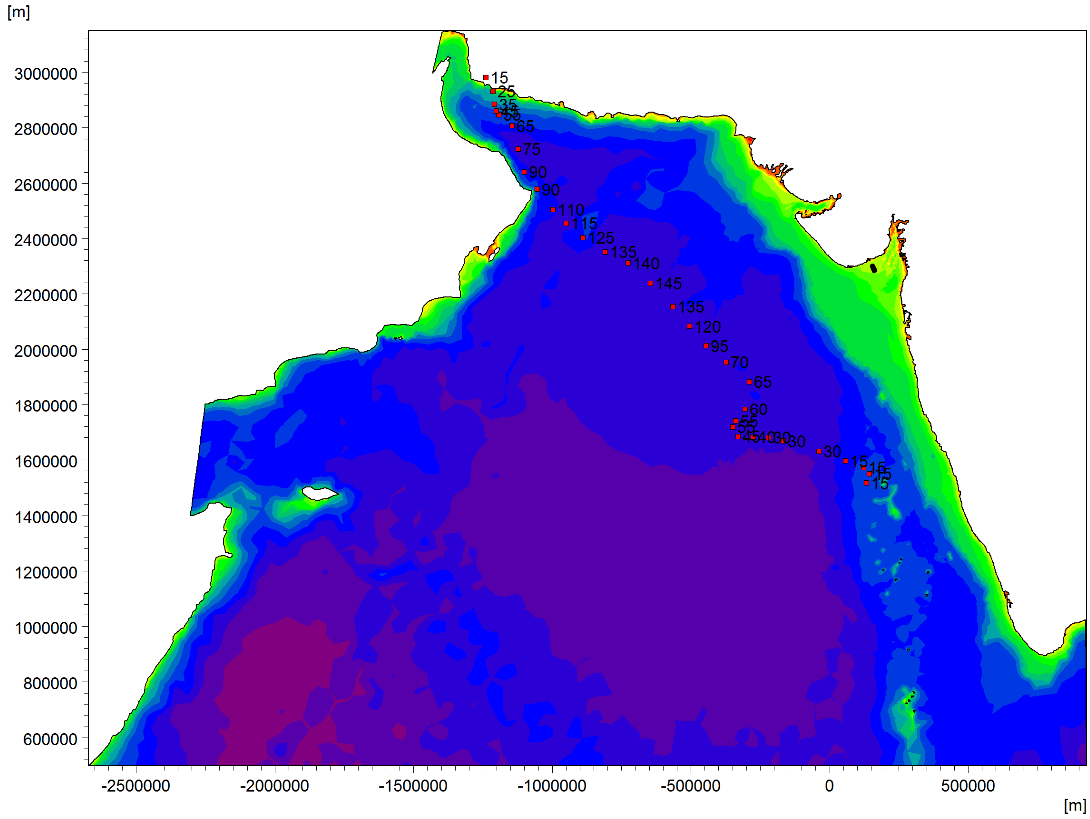

Figure 4-22 Track for 2007 storm [GONU] (31May-08Jun) moving offshore with a maximum wind speed of 140 knots.

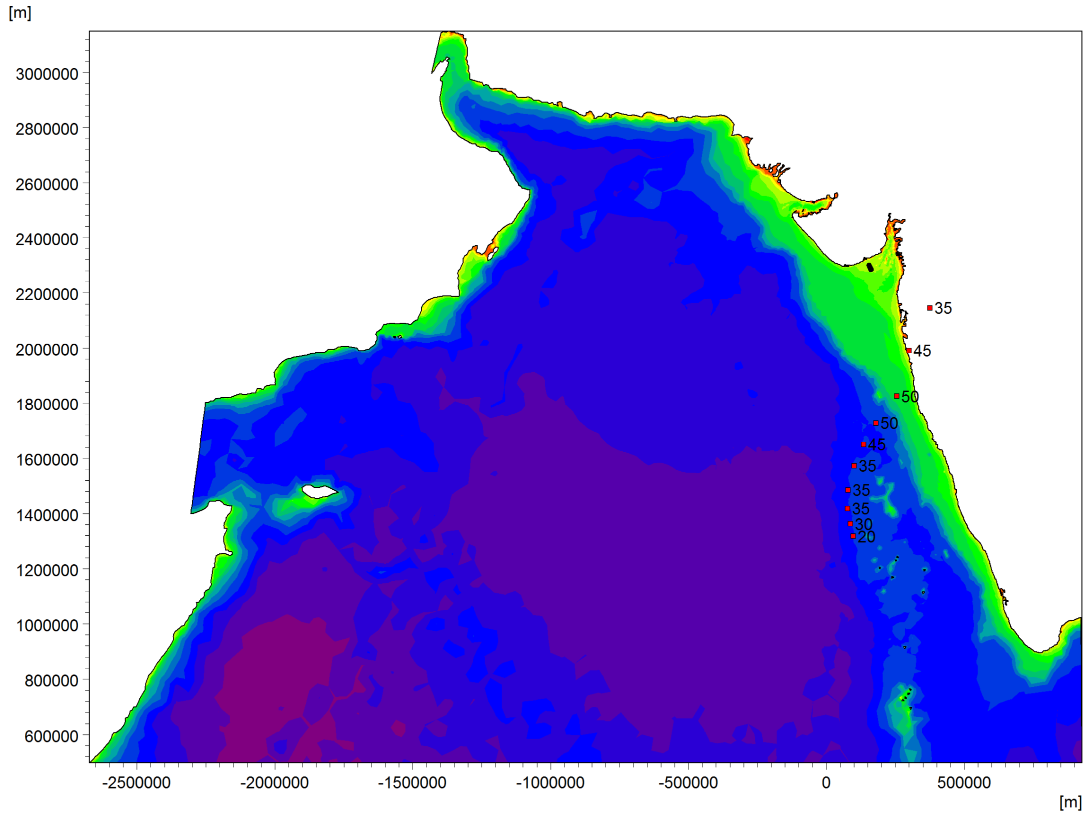

Figure 4-23 Track for 2009 storm (09-11 Nov) crossing Maharashtra with a maximum wind speed of 50 knots.

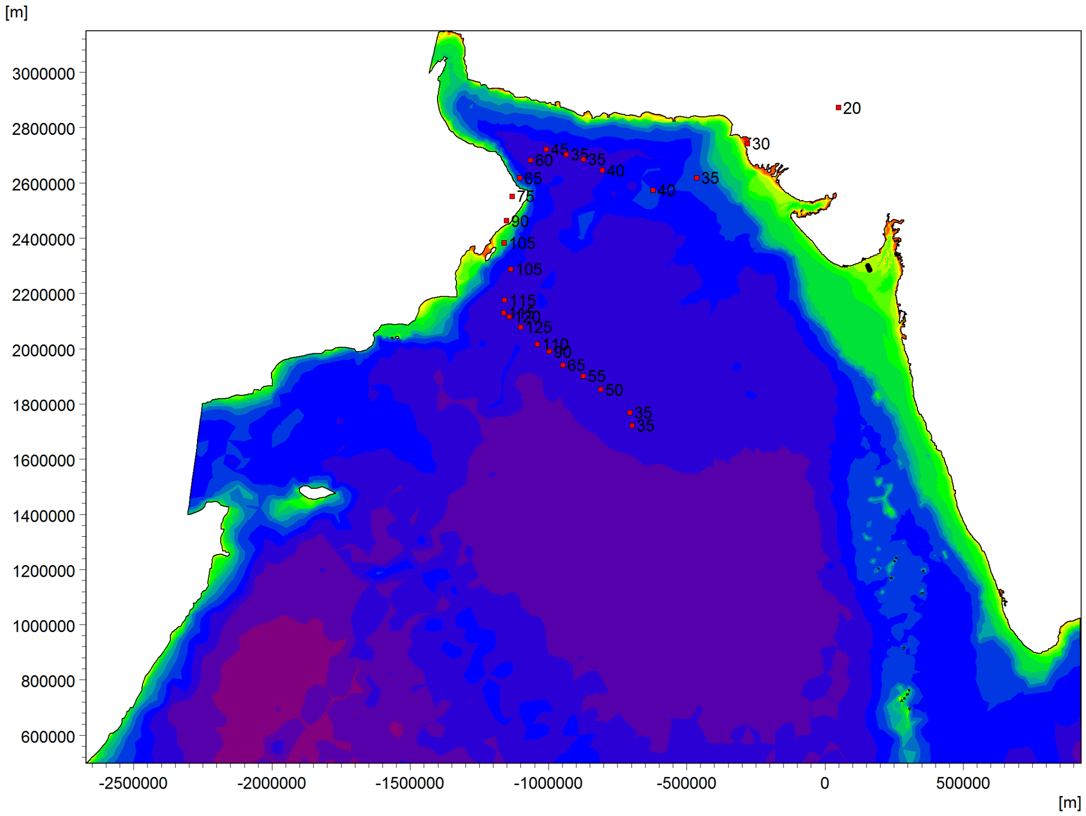

Figure 4-24 Track for 2010 storm (31May-06 Jun) crossing north of Porbandar with a maximum wind speed of 125 knots.

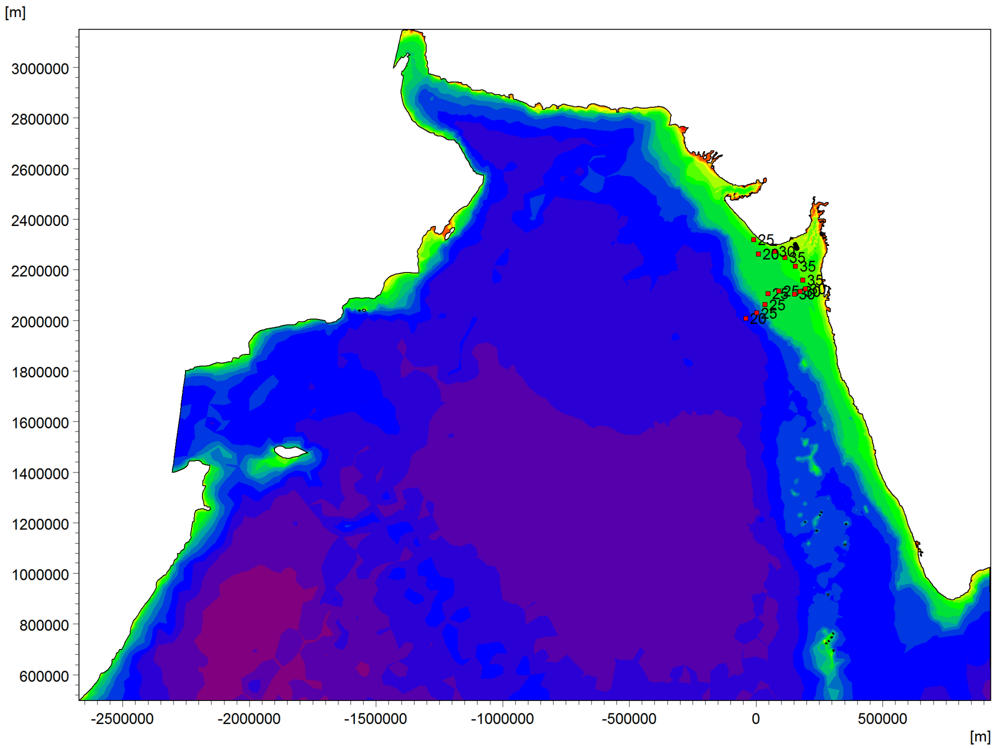

Figure 4-25 Track for 2011 storm (09-12 Jun) crossing Veraval coast with a maximum wind speed of 35 knots.

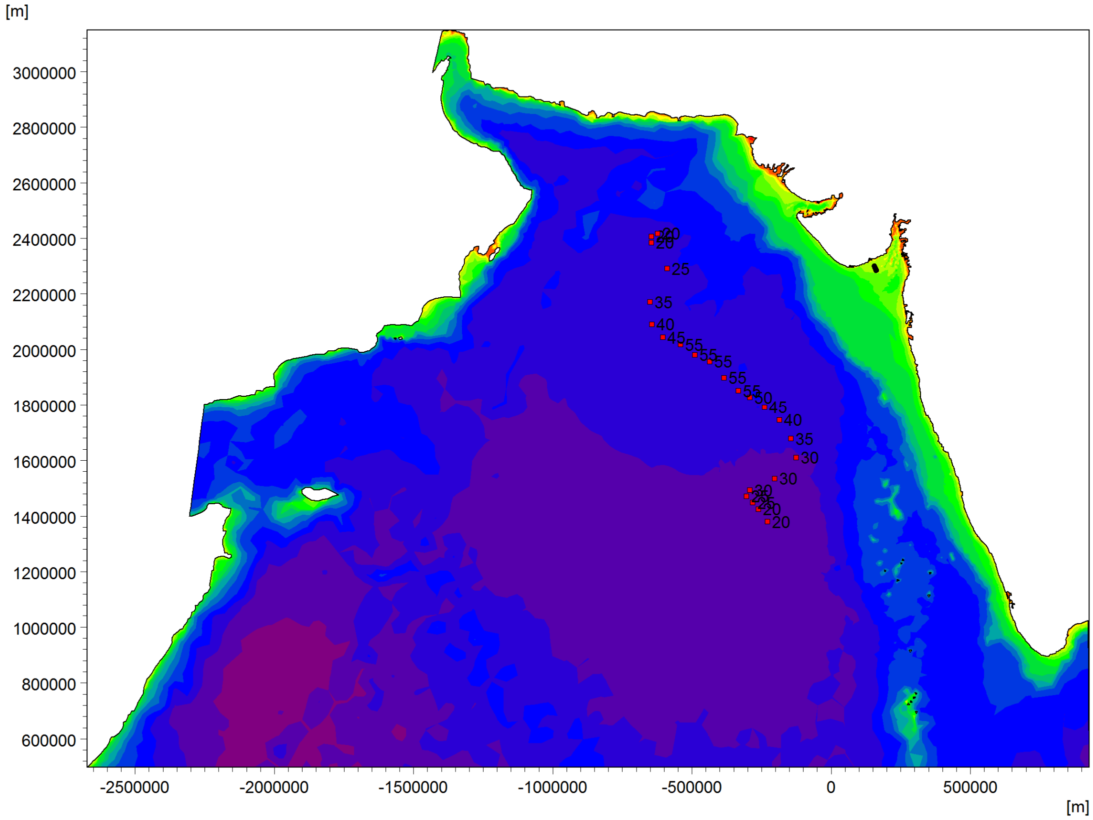

Figure 4-26 *Track for 2014 storm (10-13 Jun) moving offshore with a maximum wind speed of 55 knots.*

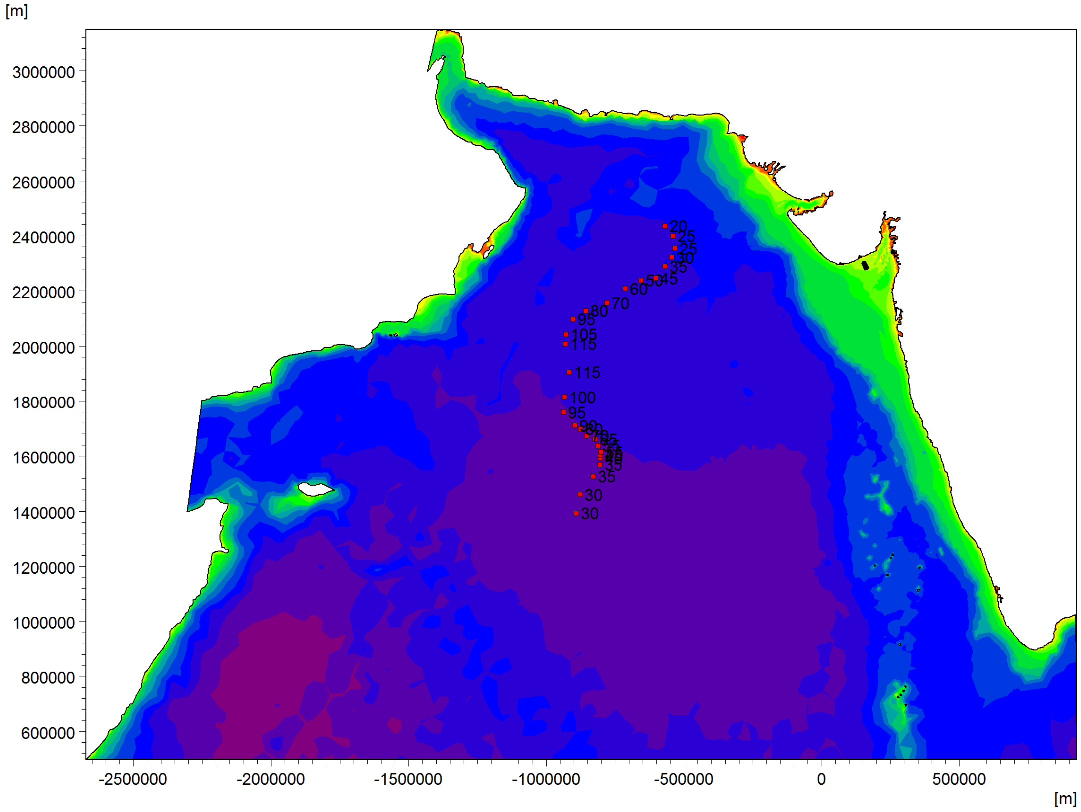

Figure 4-27 *Track for 2014 storm (25-30 Oct) moving offshore with a maximum wind speed of 115 knots.*

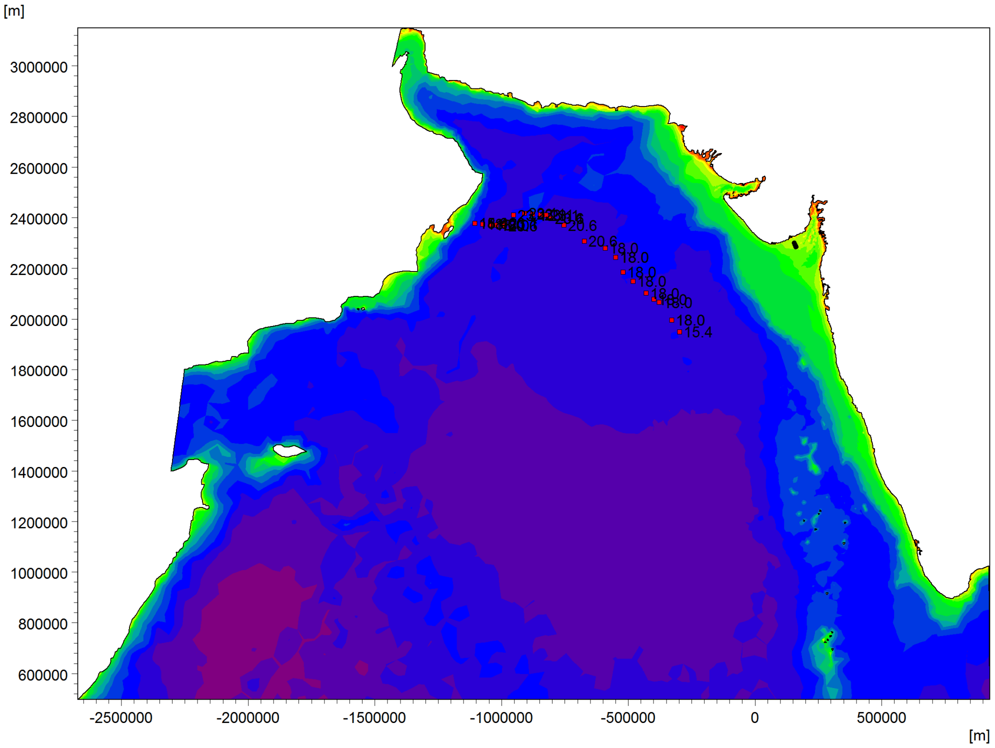

Figure 4-28 Track for 2015 storm (07-11 Jun) moving offshore with a maximum wind speed of 55 knots.

5 References

Ref 1 *Tracks of cyclones and depressions in the Bay of The Bengal and Arabian sea 1891-2007, IMD E-Atlas June 2008*

Ref 2 *Joint Typhoon Warning Centre, 2008. Tropical cyclone best track data, Hawaii, USA.*

Ref 3 *Tropical Cyclone Minimum Sea Level Pressure/ Maximum Sustained Wind Relationship for the Western North Pacific, GARY D. ATKINSON AND CHARLES R.HOLIDAY April 1977.*

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