Persistency analysis for four locations offshore Portugal

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Persistency analysis for four locations offshore Portugal

Description

IPMA commissioned Hermess B.V. to provide a persistency analysis for four locations offshore Portugal. Wind and wave parameters from offshore data were interpolated to the locations of interest. Offshore data is based on wind wave hindcast data for the period 1980– 2023, derived from our global hindcast with resolution 30’x30’.

Summary of deliverables

A summary of the deliverables is given below. These deliverables are described in more detail in subsequent sections of this Fact sheet.

Locations:	Lon	Lat	Site
	-9.15151	41.70758	Viana N
	-9.24216	40.97578	Leixoes
	-9.51020	40.15537	Figueira
	-9.62564	39.04862	Ericeira

The following metocean data are provided:

- Workable 12h weather windows for operable wind and wave conditions: tables and plots
- Expected dalay waiting for favorable weather windows for operable wind and wave conditions: tables and plots

Compliance and fitness for purpose

Where required, the data and methods proposed in this document comply with the relevant standards and guidelines (e.g. ISO 19901-1:2015[1], the ISO standard governing metocean activities for the offshore industry).The work was undertaken by a qualified metocean specialist and technically reviewed prior to issue.

Hermess provides a range of metocean services each with its own intended purpose. It is important that the end user appreciates the 'fitness for purpose' of any particular service in order to avoid results being used beyond their originally intended limits. Given the absence of local observation data, the data provided are deemed suitable for preliminary assessment of wind and wave conditions. For design purposes, it is recommended to use in-situ observations from near the study location for hindcast calibration.

Additional modelling, processing or analysis based on the conditions provided, the subsequent quality control and the further analysis of the data, will be the sole responsibility of the party performing such work.

If you are in any doubt as to the suitability of the information contained herein to your particular purpose, or if you wish to discuss alternative services, please contact us (info@hermess.nl) and an experienced metocean advisor will be pleased to assist you.

[1] ISO, 2015. Petroleum and Natural Gas Industries, Specific Requirements for Offshore Structures - Part 1: Metocean Design and Operating Conditions. ISO 19901-1:2015(E).

Locations

The project locations are shown in the figure below (yellow markers). For the wind and wave analysis, the grid model points nearest to the project location were selected and wind and wave parameters were interpolated to the locations of interest. The project locations are characterized in Table 1 and Figure 1.

Table 1 Location of interest and wave model grid points used for data delivery

Area	Lat	Lon	Depth (m)
Viana N	41°42’N	009°09’W	105
Leixoes	40°59’N	009°15’W	140
Figueira	40°09’N	009°31’W	150
Ericeira	39°03’N	009°38’W	100

Image source: Google Earth

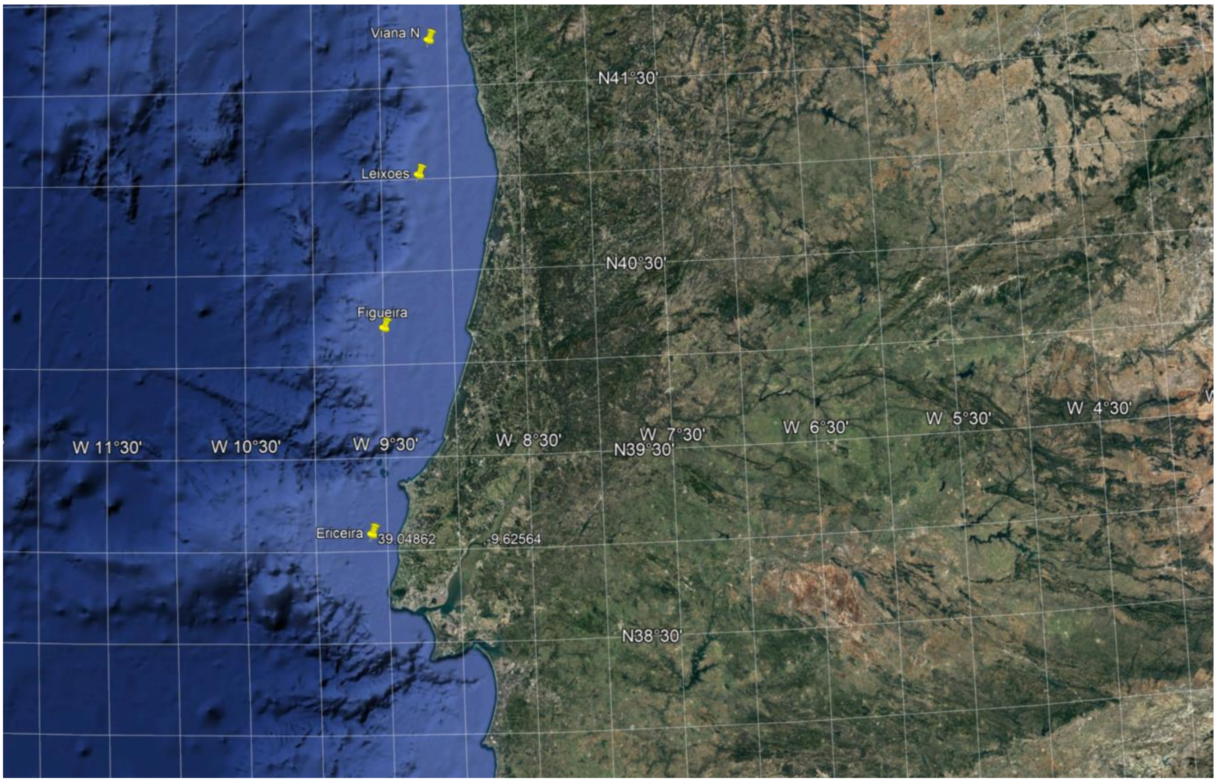

Figure 1 Locations of interest

Method

a) Offshore Hindcast Data

Hermess runs a 3rd generation wave prediction model based on the WaveWatch III code on a global grid as well as on several regional grids for hindcast and forecast purposes. The global model has a resolution of 0.5 degree. The model is forced by ERA5 wind-data obtained from ECMWF.

In addition to the global model several regional hindcasts were generated for the EU-shelf, the Mediterranean, the Black Sea, the Red Sea, the Persian Gulf, US East coast, Taiwan and Australia. Metocean conditions from these higher resolution regional hindcasts are used where appropriate.

For the present study we used data from the Global model with a resolution of 50km. All models provide 3-hourly time series of wave spectra and parameters covering a period of 45+ years (1979-near-present day, hindcast is updated monthly). For this study, hindcast data has been extracted for the years 1980-2023.

b) Calibration of Offshore Wave Data

Systematic errors between ambient significant wave height from the model and from the satellite are removed from the model assuming a linear error model. Satellite measurements (1992-2022) have been used to calibrate model hindcast significant wave height at the model point for the period (1980-2023).

Satellite observations were collected within radii of 20 to 40 km around the locations. The satellite data collected in such a small region in a single pass of the satellite are highly correlated. To account for this, we only use the nearest satellite sample from each pass. Model data are then linearly interpolated in time to form matched pairs of satellite measurement/modelled data that can be compared. Slope and intercept are computed per wave model grid point, using a least squares method on the sorted data. This calibration results in un-biased model significant wave height compared to satellite in-situ observations.

Observations of significant wave height and wind speed come from altimeters.

Figure 2 below shows the comparison between the probability of exceedance (PoE) of significant wave height from co-located altimeter observations and calibrated hindcast data for Viana N. Figure 3 shows a similar comparison for wind speed. Similar plots for the other locations are shown in Figure 4 till Figure 9.

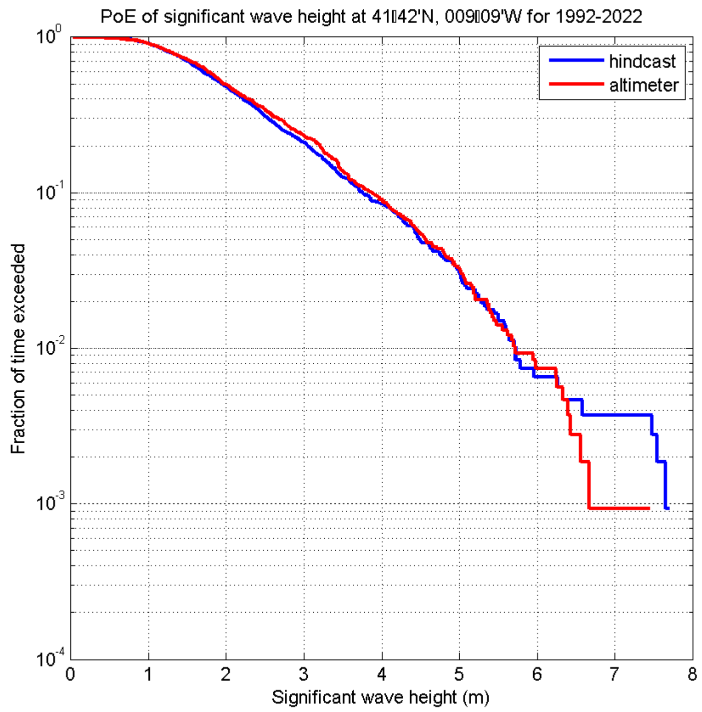

Figure 2 PoE of significant wave height from hindcast and altimeter at Viana N

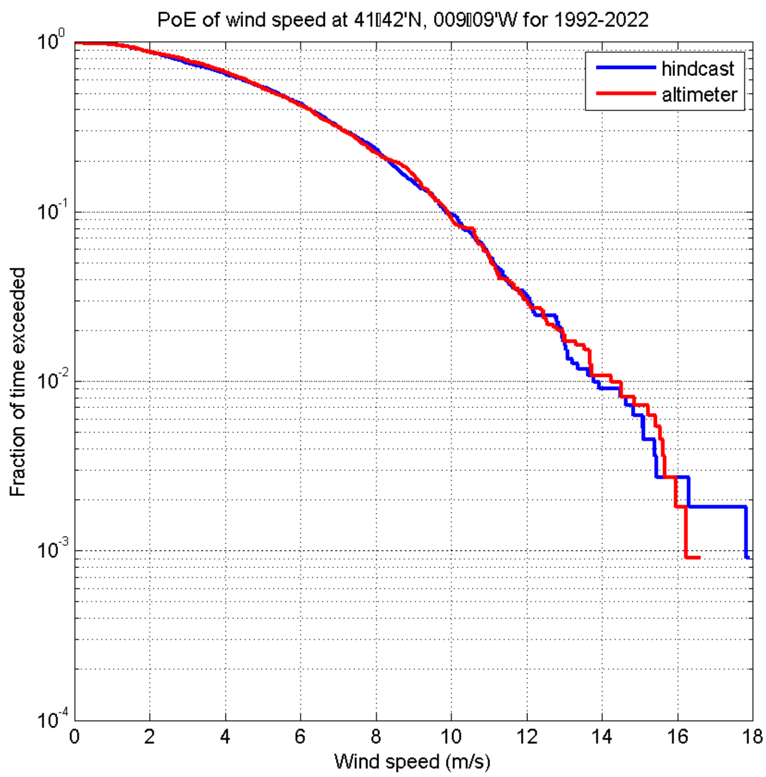

Figure 3 PoE of significant wave height from hindcast and altimeter at Viana N

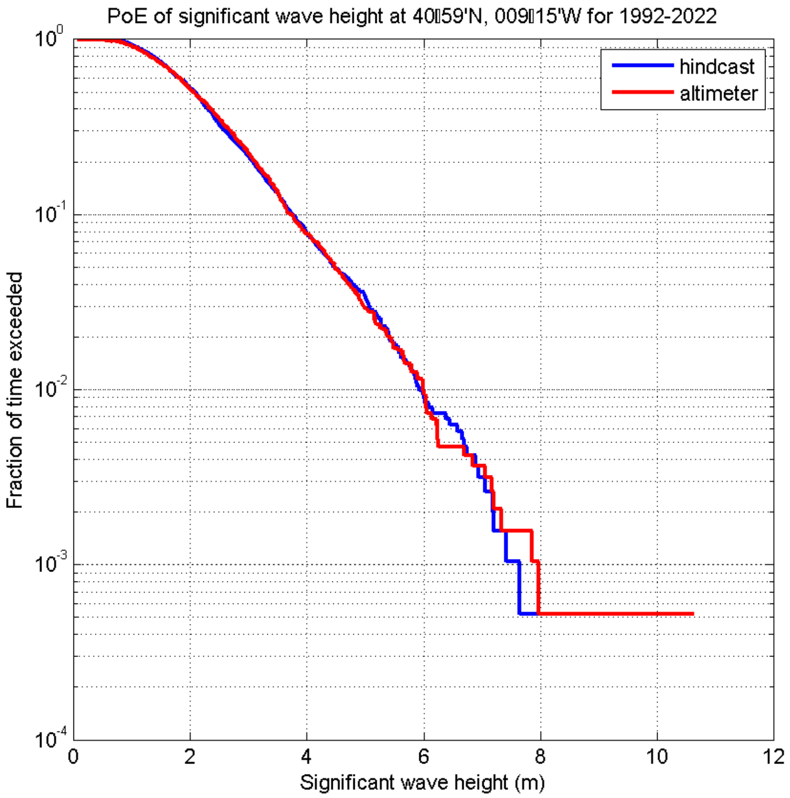

Figure 4 PoE of significant wave height from hindcast and altimeter at Leixoes

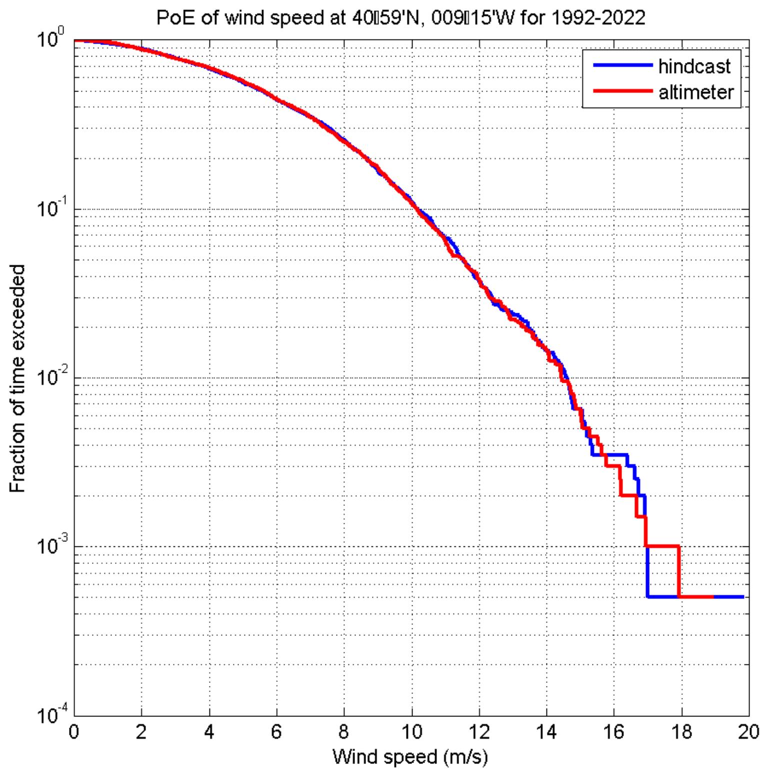

Figure 5 PoE of significant wave height from hindcast and altimeter at Leixoes

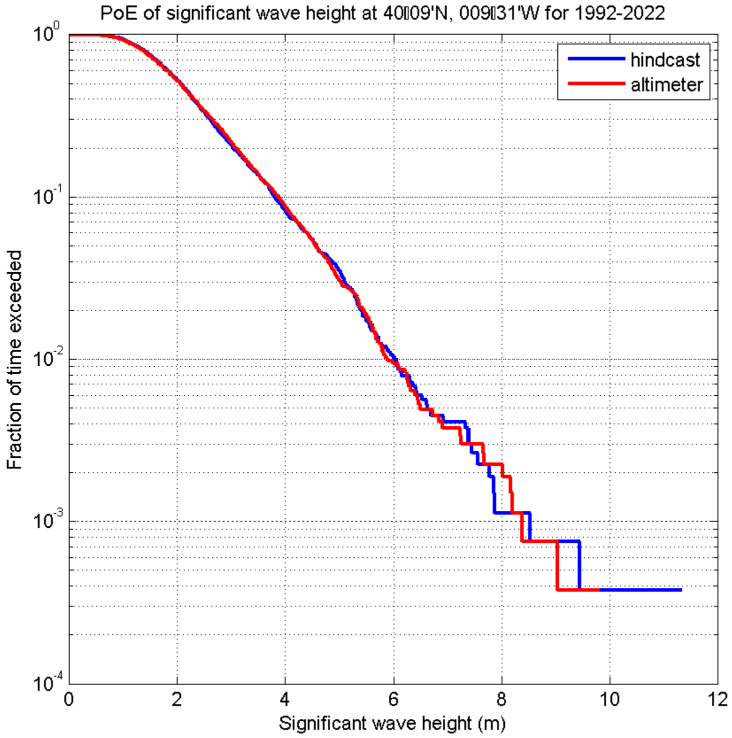

Figure 6 PoE of significant wave height from hindcast and altimeter at Figueira

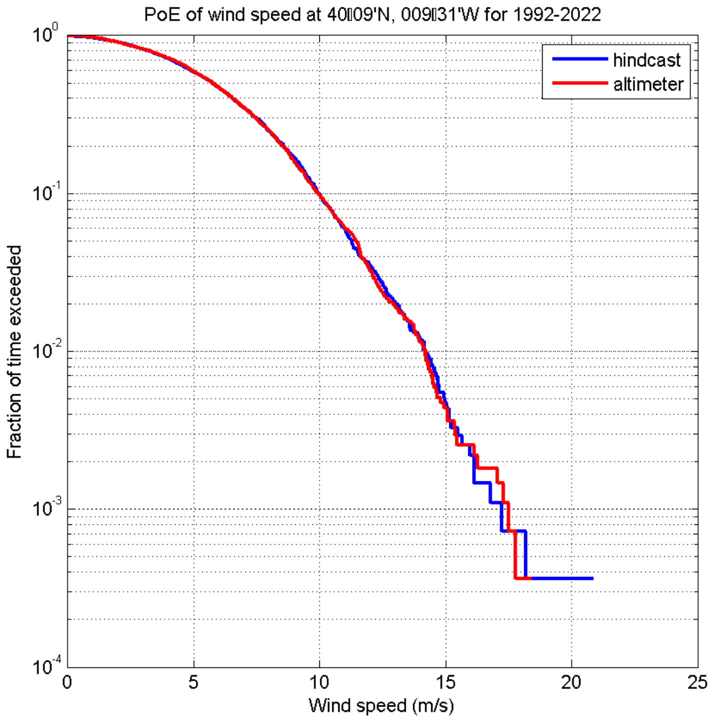

Figure 7 PoE of significant wave height from hindcast and altimeter at Figueira

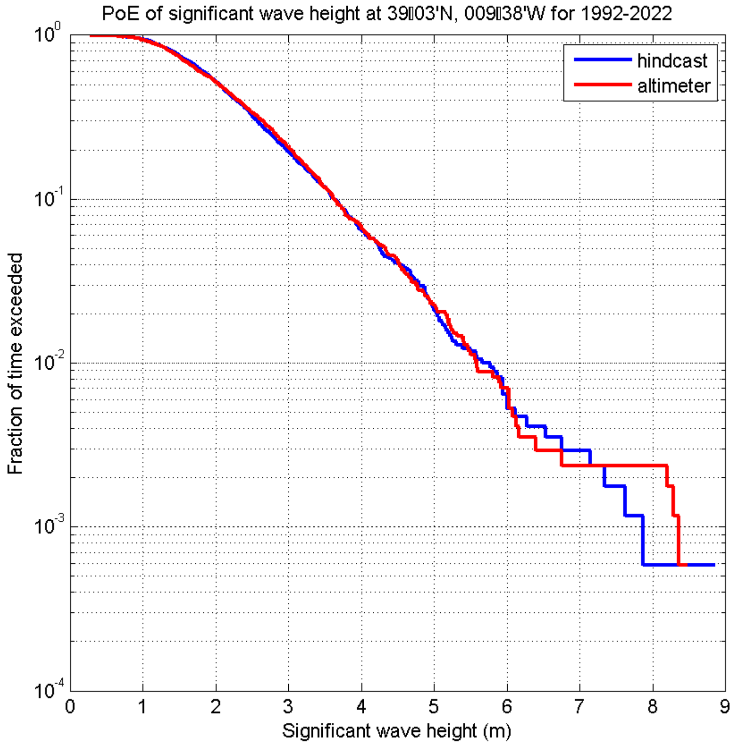

Figure 8 PoE of significant wave height from hindcast and altimeter at Ericeira

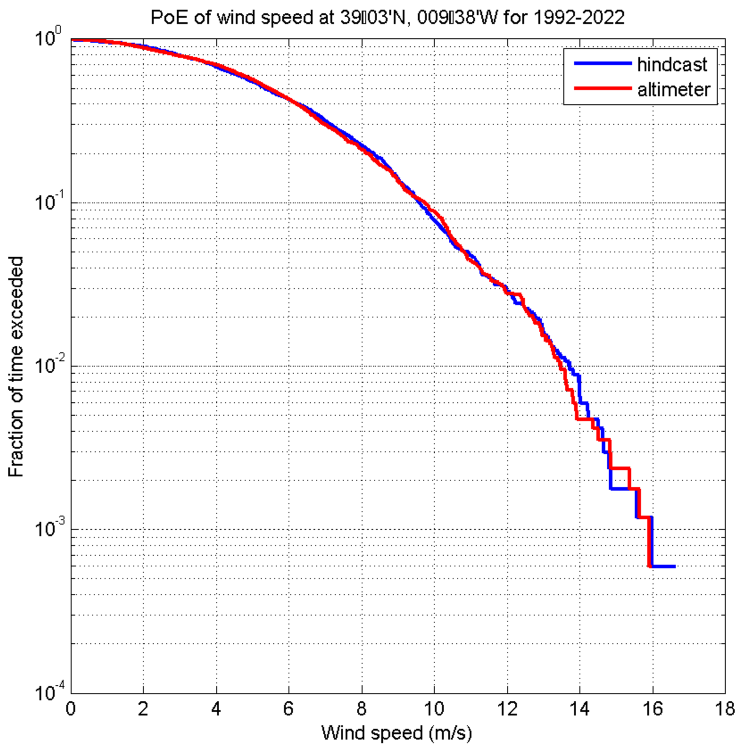

Figure 9 PoE of significant wave height from hindcast and altimeter at Ericeira

c) Persistency analysis

Based on operational constraints (thresholds) we compute the extent and the occurrence of 12 hour weather windows from the 3-hourly time series, covering the period January 1980 up to December 2023, at the output locations. A weather window is a continuous time interval with favourable conditions, i.e. a period of time where the values of the relevant wave and wind parameters remain continuously below the constraints.

For each month of the year, the persistency analysis results in:

- The fraction of time covered by workable windows;
- The number of workable windows;
- Expected delay due to unfavourable weather

Each parameter is averaged per month over all years as well as given for each year separately (inter-annual variation).

The constraints used in the analysis are listed in Table 2.

Table 2 Constraints used for the persistency analysis per case

	Limit Hs (m)	Limit u10 (m/s)
C1	**1.5**	**10**
C2	**2.0**	**12**
C3	**1.5**	**None**
C4	**None**	**10**
C5	**2.0**	**None**
C6	**None**	**12**

d) Deliverables

Persistency wind and wave

Persistency tables and plots are contained in the file **resultspersistency.zip**. The content of the persistency result files is explained below. The label ‘xxxxnyyyyye’ refers to the location of interest: xx°xx’N, yyy°yy’W

- **Window_tables_xxxxnyyyyyw.xlsx**- Tables of extent and number of windows

The tables list the fraction of workable days and the number of workable days per month against the years analyzed, including all-year averages. The first worksheet gives the monthly all-year average, minimum and the maximum. The other worksheets show the detailed inter-annual variation, one worksheet per window length.

- **Window_plots_xxxxnyyyyyw.xlsx**

This file contains the corresponding plots of extent and number of windows.

- **Delay_tables_xxxxnyyyyyw.xlsx**- Tables of delay

Tables for all window lengths, all wave height and wind speed limits. The tables list the mean time spent waiting for weather windows per month against the years analyzed, including all-year averages. The first worksheet gives the monthly all-year average, minimum and maximum. The other worksheets show the detailed inter-annual variation, one worksheet per window length analyzed.

- **Delay_plots_xxxxnyyyyyw.xlsx**

This file contains the corresponding plots of mean delay waiting for windows.

Frame of Reference

(a) Definitions and Notation

- **2D wave spectrum *S***
  The 2D spectral energy density describes how the variance of the sea surface elevation is distributed over spectral frequency and spectral direction. It is often referred to as real of full 2D wave spectrum. There are 30 spectral frequencies (equally distributed on a logarithmic axis between 0.0345 and 0.5481 Hz) and 24 spectral directions (centers of 15 degree wide bins) expressed in radians.
- **Quasi-2D / 1D wave spectrum**
  The 1D spectral energy density describes how the variance of the sea surface elevation is distributed over frequency f. It is often referred to as 1D wave spectrum. Together with the mean wave direction and the directional spread per frequency bin the 1D wave spectrum is also referred to as the quasi-2D wave spectrum. This is related to the fact that real 2D spectra can be simulated from quasi-2D spectra assuming a cosine-squared directional distribution of energy density based on the directional spread around the mean wave direction per frequency.
- **Spectral moment m_p**
  For any integer p, m_p is the integral over frequency f of f^p multiplied by the wave spectrum, with f frequency in cycles per unit time. Remark: m_0 is the total variance of sea surface elevation.
- **Wave height *H***
  This is the crest-to-trough wave height of an individual wave between two consecutive up-crossings of the still water level.
- **Significant wave height *Hs***
  Averaged wave height H of the 1/3 highest waves. Except on shallow water, *Hs* is accurately approximated by *Hm0*, defined as 4 times the standard deviation of the vertical surface displacement (4 times the square root of spectral moment m_0). In this report and in all result files, we approximated *Hs* by means of *Hm0*.
- **Principal wave direction *Hsd***
  The direction derived from the first-order directional Fourier moments (sine and cosine-weighted moments) of the directional wave spectrum. Wave direction is defined as “coming from”. It can also be defined for (a) limited range(s) of frequencies and represented as a function of frequency.
- **Wave period based on spectral moments $Tm_{p,q}$**
  $Tm_{p,q} = (m_p / m_q)^{1/(q-p)}$ with m_p and m_q spectral moments, and p and q two distinct integers. Here, $Tm_{-1,0}$ and $Tm_{0,2}$ are referred to as mean wave period (***Tm***) and spectral mean zero-crossing wave period (***Tz***) respectively.
- **Zero-crossing wave period T**
  Time elapsed between two consecutive up-crossings of the still water level.
- **Mean zero-crossing wave period *Tz***
  The average of the **zero-upcrossing period** *T* for a particular sea state. Tz is approximated by $Tz \approx Tm_{0,2}$ (see Moment-based wave period).
- **Peak wave frequency *Fp***
  This is the frequency where the wave spectrum reaches its maximum.
- **Peak wave period *Tp***
  The period corresponding to the frequency where the spectral density reaches its maximum.

- **Peak wave direction *Pd***
  This is the wave direction corresponding to the wave peak frequency.
- **Wave length λ**
  The horizontal distance between two consecutive up-crossings of the still water level in the direction of wave propagation.
- **Wave steepness parameter *s***
  A dimensionless parameter, defined as the ratio of significant wave height *Hs* to the deep-water wave length corresponding to the wave period $Tm_{-1,0}$, i.e., $s = (2\pi/g)\, Hs/(Tm_{-1,0})^2$
- **Directional spreading**
  This is the energy weighted mean directional spread of the total spectrum (**spreadd**) or the directional spreading at the peak frequency (**spreadp**).
- **Wind-sea**
  When using a steepness-based splitter, a spectral component (distinct peak) classifies as wind-sea if wave steepness *s*>0.03. Note that this “engineering” definition does not consider the wind; only wave steepness. Alternatively, a spectral peak classifies as wind-sea if its group velocity is less than the wind speed component in line with its direction, i.e. the component is still growing thanks to input of wind energy. Most splitters assume a single wind-sea peak but multiple wind-sea peaks are also possible. Corresponding wind-sea parameters such as ***Hs_sea***, ***Tp_sea***, etc. are found by applying the definitions of these parameters only to a particular wind-sea peak. Total wind-sea parameters can be found after summing wave energy over the wind-sea peaks. In this study we used our standard steepness-based splitter.
- **Swell**
  Any spectral component (distinct peak) that does not classify as wind-sea classifies as a swell component. Splitters may find multiple swell peaks. The corresponding swell parameters such as ***Hs_swl***, ***Tp_swl*** etc. are found by applying the definitions of these parameters only to that particular swell peak. Total swell parameters can be found by summing wave energy over all swell components. In this study we used our standard steepness-based splitter.
- **Wind speed u10 and wind direction *u10d***
  Sustained wind speed at 10m above the (sea) surface and associated direction. Wind direction is defined as “coming from”. “Sustained” means averaged over 1 hour.
- **Gravitational acceleration *g***
  On Earth, taken equal to 9.81 m/s^2

(b) Units and Conventions

- Spectral density (2D) is expressed in m2/Hz/rad; spectral density (1D) is expressed in m2/Hz/rad
- Units are expressed using the SI convention if not stated otherwise:
  - length or distance (wave height, surface elevation, water depth) in metres,
  - time (wave periods) in seconds,
  - speed in metres per second,
  - direction in degrees clockwise from North.
- Wind and (spectral) wave directions are defined as “coming from” relative to true north positive clockwise.
- Unless explicitly stated otherwise, co-ordinates are expressed in degrees latitude and longitude, assuming a WGS84 co-ordinate system.