

ORCA

Analysis, classification and transformation of metocean data

Deltares systems



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The design of marine structures, such as offshore structures, wind parks, coastal structures, etc, generally starts with a metocean study in which the mean, operational and extreme environmental conditions that the structures will have to withstand are determined. The detail and extent of the required metocean conditions (waves, water level, temperature, currents and wind) are, however, study dependent. On the other hand, most of the studies involve data validation, determination of normal and extreme metocean conditions and offshore to nearshore transformations of data.

Deltares often carries out metocean studies for a varied spectrum of clients such as project developers, governments, local businesses, contractors, oil and gas producers, etc and has been working on a method to standardize the execution of metocean studies, by developing guidelines along with a MATLAB tool, called ORCA, which integrates the main aspects of analyzing metocean data.

General

Deltares frequently carries out metocean studies. These studies involve quite a lot of statistical analyses, which are for a great part carried out using an in-house MATLAB tool called ORCA (metOcean data tRansformation, Classification and Analysis). At the moment, there are four functionalities available on the ORCA tool. Each functionality deals with certain aspects of data analysis, namely:

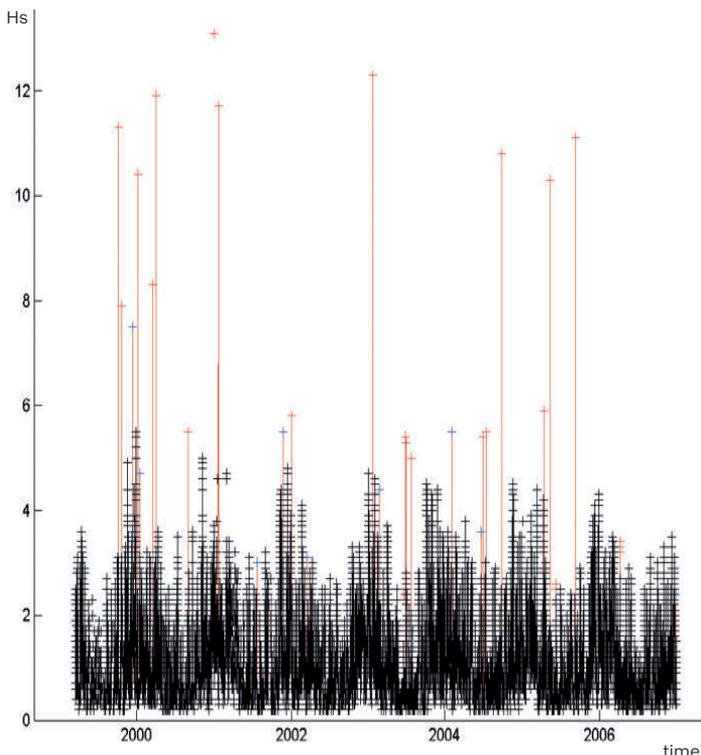
- Data validation- Procedures necessary for the determination of a “good dataset”. Consisting of, among others, procedures for reading of different data, analysis of gaps in time series, data visualization, data comparison and error statistics and plots, and data correction.
- Normal conditions- Procedures necessary to the determination of mean climates, including persistence statistics, i.e. estimates such as average durations of metocean events with specific characteristics (e.g. fair or severe weather). Consisting of, among others, procedures for data classification, creation of wave roses, data transformation and definition of mean climate scenarios.
- Extreme conditions - Procedures for extreme value analysis. Consisting of, among others, procedures for the collection of peaks-over-threshold data, the collection of annual maxima data, definition of optimal threshold for the estimation of the generalized Pareto distribution parameters, return value estimation, fitting of statistical distributions.
- Sea State analysis - Procedures for sea state analysis. Consisting of, among others, procedures for fitting of different spectral forms to discrete spectral data, estimation of sea state wave statistics (e.g.: number of waves, H1%).

Graphical User Interface & Toolbox

There is currently a GUI available with which the most important analyses available in the ORCA Data Validation, Normal Conditions and Extreme Conditions functionalities can be carried out. The remaining functionalities are available as MATLAB code and there are exemplary scripts and guidelines available on how to use them. When a client is only interested in the GUI then he requires no MATLAB since the GUI is available in a platform independent format.

Data validation

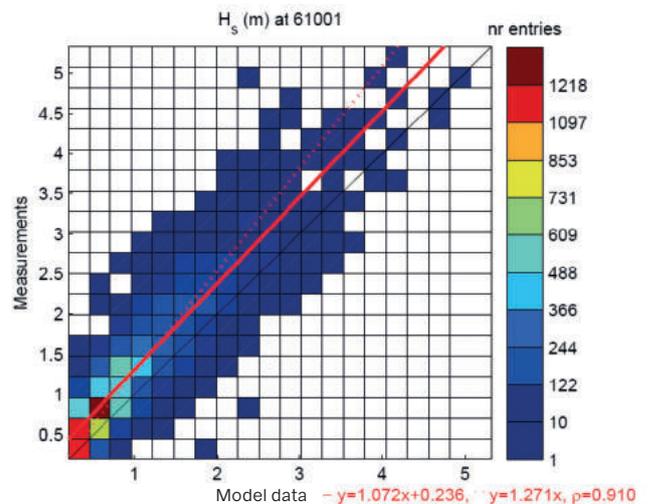
Each metocean study starts with a dataset of either measured or modelled quantities. The dataset is the basis of the study. It is therefore very important to know how the set looks like and what its quality is. Are the measurements reliable? What is the source of the measurements? Has the measuring device been operational during the entire period covered by the dataset, or does the dataset show gaps in the measurements? Is the numerical model reliable? Have the numerical results been validated and calibrated? Etc.



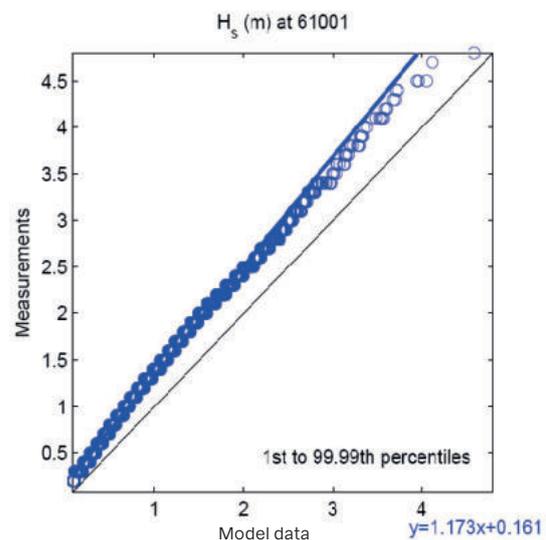
Example of a dataset from which outliers have been removed.
Red: original dataset, black: dataset without outliers

ORCA's first tool answers some of these questions. The Data Validation Tool can be used to inspect and improve datasets. It consists of three parts:

- A **Data QA module** that checks and adjusts the consistency of the dataset itself. This module can read datasets of various formats, visualize the quantities in the dataset (e.g. in plots of time series), identify and fill gaps in the data during the period covered by the dataset, remove outliers, etc.
- A **Data Comparison module** that compares the data with data from another dataset (e.g. model data with buoy measurements) and corrects the data if necessary.
- The **Error statistics module** that can be used for error analyses. Spatial error analyses being also included.



Example of a scatter plot including fitted trend lines



Example of quantile plot including fitted trend line

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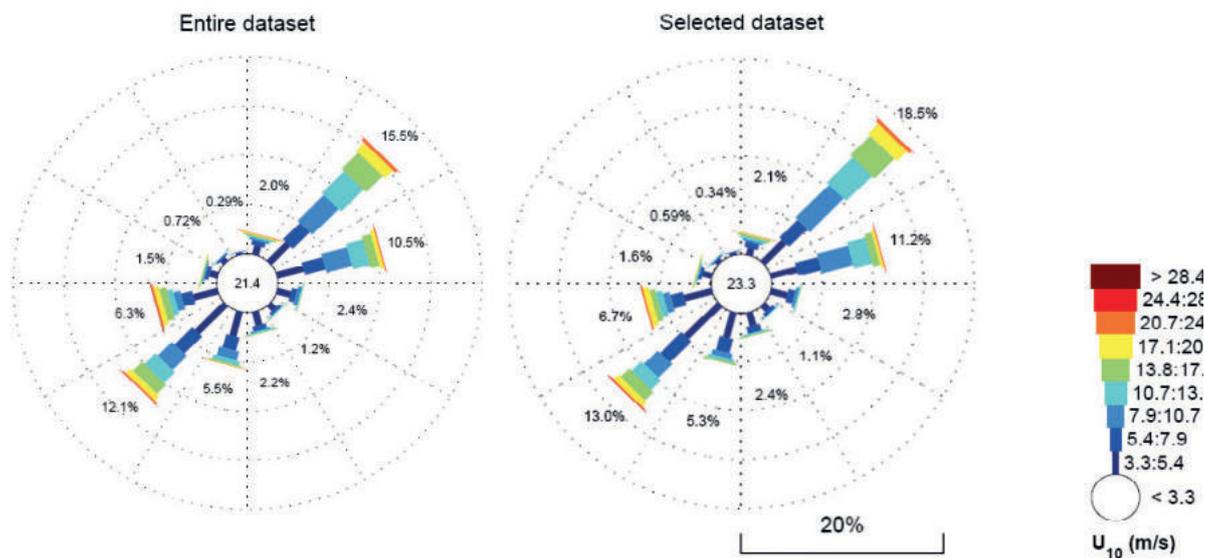
Normal conditions

With the Normal Conditions functionality of ORCA mean climates can be determined on the basis of time series of metocean variables. A mean climate can be determined and represented in a number of ways. For instance as standard bivariate distributions (joint occurrences of, for instance, wind speed and direction within certain classes) or as multivariate and multidimensional mean conditions.

ORCA offers three possibilities to represent a mean climate:

- By means of roses;
- By means of joint occurrence tables,
- By means of multivariate means per multi-dimensional condition.

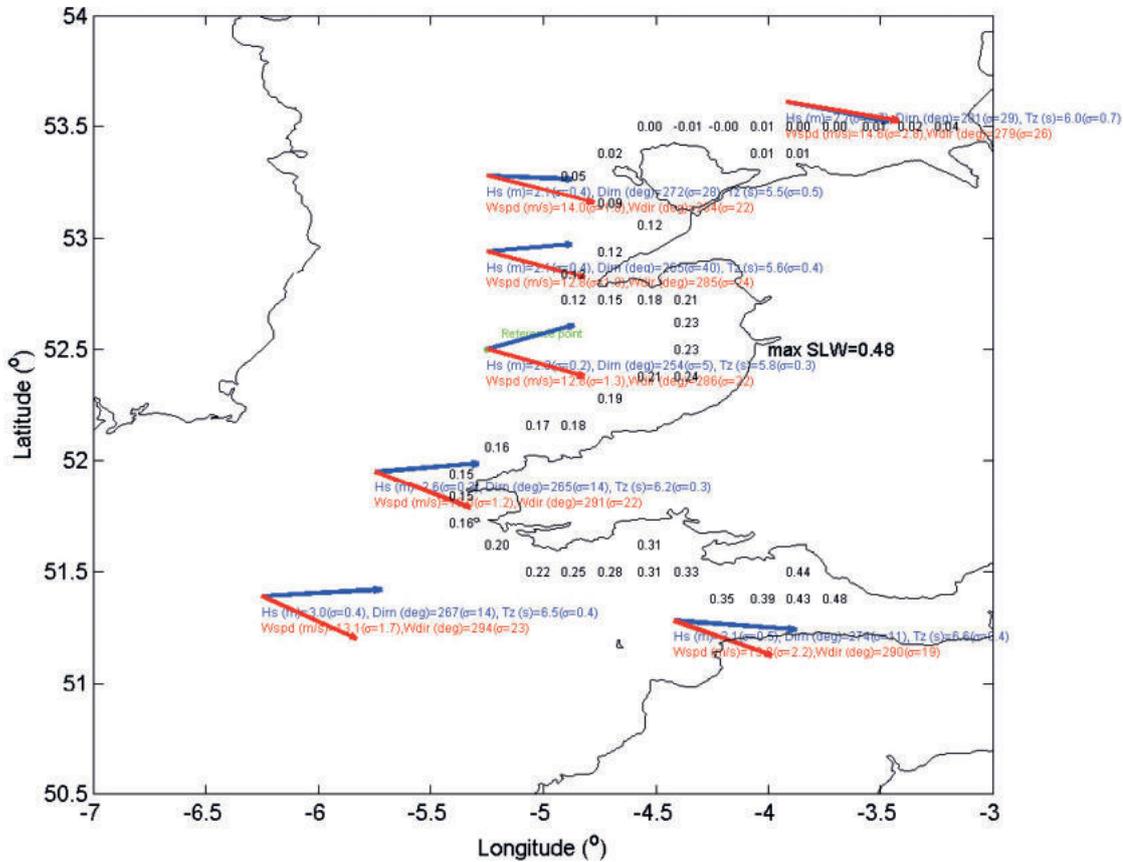
The first possibility is used to visualize the mean climate of a certain directional variable at one or more locations, see for an example of wave roses below.



Example of wind roses. The bar lengths indicate the occurrence percentages. Directions are to the centre of the roses. The numbers in the centre of the roses are the percentage of occurrences in the lowest class.

| | | Mean wave direction (°N) | | | | | | | | | | | | |
|---------------------|-------------|----------------------------------|-------|-------|--------|---------|---------|---------|---------|---------|---------|---------|-------|---------|
| | | 345-15 | 15-45 | 45-75 | 75-105 | 105-135 | 135-165 | 165-195 | 195-225 | 225-255 | 255-285 | 285-315 | | 315-345 |
| Wind direction (°N) | >345.0 | 223 | 13 | 4 | 2 | 4 | 4 | 4 | 26 | 179 | 92 | 150 | 397 | 1096 |
| | 315.0-345.0 | 139 | 20 | 5 | 4 | 7 | 5 | 7 | 93 | 401 | 331 | 582 | 758 | 2354 |
| | 285.0-315.0 | 29 | 11 | 4 | 2 | 4 | 4 | 4 | 42 | 503 | 697 | 714 | 243 | 2257 |
| | 255.0-285.0 | 20 | 11 | | 4 | 2 | 11 | 13 | 95 | 1105 | 1215 | 309 | 71 | 2857 |
| | 225.0-255.0 | 20 | | 5 | 4 | | 9 | 4 | 201 | 1971 | 544 | 115 | 27 | 2901 |
| | 195.0-225.0 | 9 | 4 | | | 4 | 7 | 53 | 800 | 1543 | 152 | 60 | 24 | 2656 |
| | 165.0-195.0 | 9 | 4 | 2 | 9 | 11 | 53 | 189 | 1215 | 838 | 119 | 38 | 20 | 2507 |
| | 135.0-165.0 | 20 | 5 | 13 | 22 | 86 | 243 | 372 | 650 | 600 | 92 | 51 | 40 | 2194 |
| | 105.0-135.0 | 49 | 15 | 26 | 113 | 366 | 304 | 218 | 467 | 549 | 90 | 49 | 20 | 2266 |
| | 75.0-105 | 60 | 110 | 210 | 450 | 185 | 124 | 88 | 300 | 547 | 90 | 53 | 53 | 2271 |
| 45.0-75.0 | 150 | 339 | 412 | 167 | 44 | 53 | 38 | 167 | 461 | 93 | 53 | 70 | 2046 | |
| 15.0-45.0 | 428 | 326 | 102 | 40 | 26 | 15 | 11 | 117 | 339 | 93 | 121 | 189 | 1806 | |
| 345.0-15.0 | 534 | 82 | 18 | 9 | 5 | 7 | 15 | 62 | 337 | 145 | 212 | 604 | 2031 | |
| | | 1693 | 939 | 802 | 825 | 743 | 840 | 1014 | 4235 | 9374 | 3752 | 2509 | 2516 | 29242 |
| | | 0 ≤ ws < 5 m/s (29% of the time) | | | | | | | | | | | Total | |

Example of a joint occurrence table of wind direction and wave direction (a so-called misalignment table) for wind speeds lower than 5 m/s. The number of occurrences add in this example to 100,000 (resolution of up to one thousandth of a percentage point) and the tables presents 29.242% of the data (29,242 occurrences).



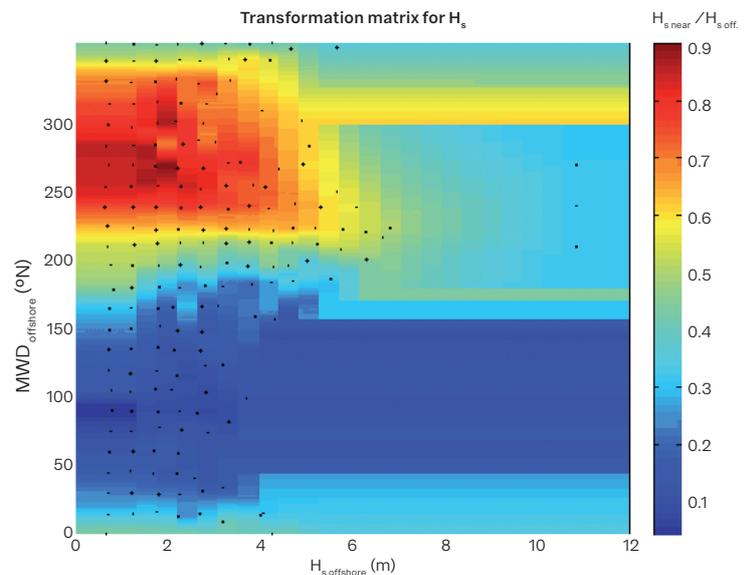
Example of a scenario plot. Mean values (and standard deviations) of the wave parameters (in red), wind parameters (in blue), and water levels (in black and only means) in several locations for when the mean wave direction is between 247°N and 262.5°N the significant wave height is between 2 and 2.5 m and the wind direction is between 187°N and 7.5°N at the reference location (see green).

The second possibility is useful when the precise number of occurrences is needed, see figure on previous page.

With the third possibility, the climate is represented as a (multivariate) number of mean conditions, each representing one (multi-dimensional) class. Such a set of mean conditions is called a “scenario”. In the bi-dimensional and bivariate case a scenario could be the mean values of the significant wave height (H_s) and mean wave direction (MWD) data falling in the bi-dimensional class $0.5\text{m} < H_s < 1.0\text{m}$ and $165^\circ\text{N} < \text{MWD} < 195^\circ\text{N}$, which could be $H_s = 0.9\text{m}$ and $\text{MWD} = 183^\circ\text{N}$. Scenarios are, however, generally defined using several variables at a number of locations. An example of a scenario is given above.

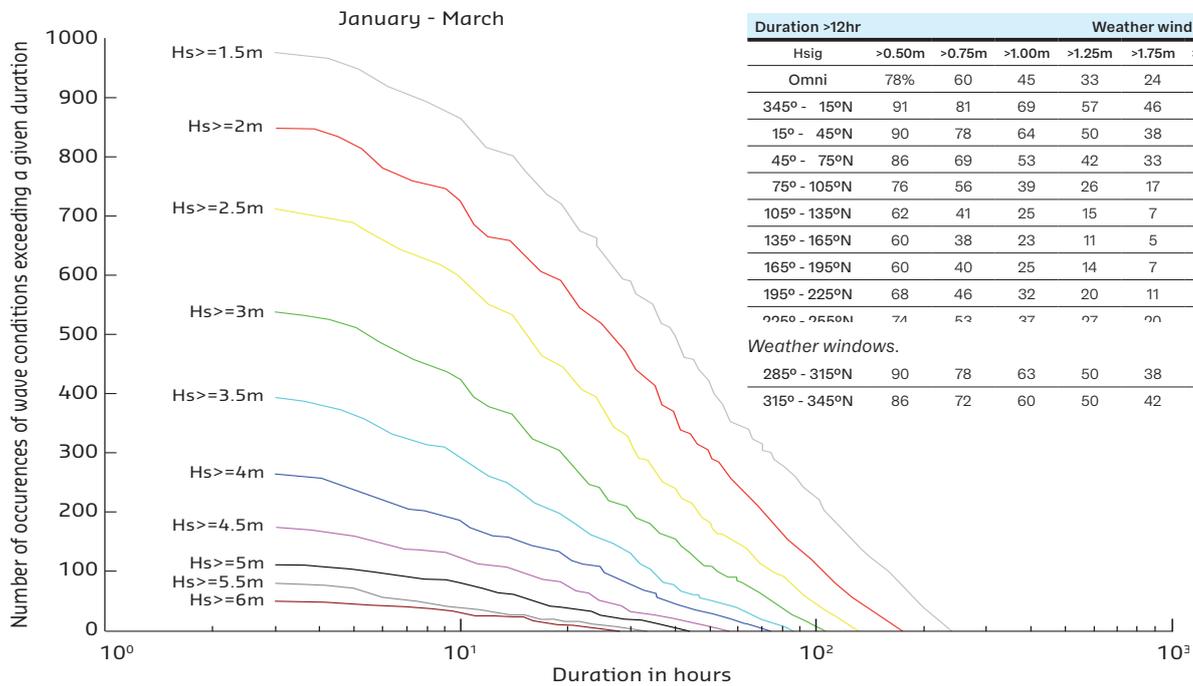
Furthermore, the ORCA Normal Conditions functionality contains a transformation tool that allows, for instance, the computation of nearshore time series of wave parameters on the basis of an offshore time series and scenario computations. This is done by means of non-parametric regression.

Moreover, the ORCA Normal Conditions functionality also allows the computations of persistence statistics.



Example of a transformation matrix

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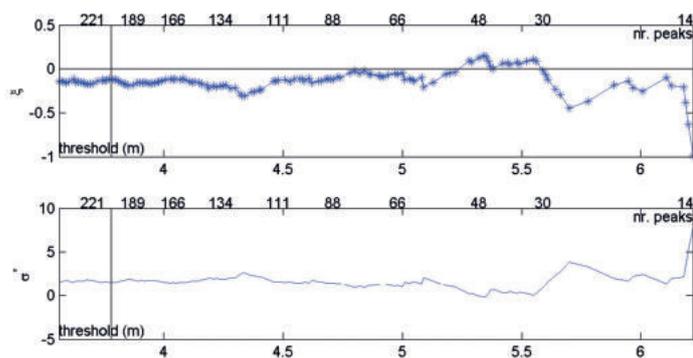


Example of a persistence statistics plot

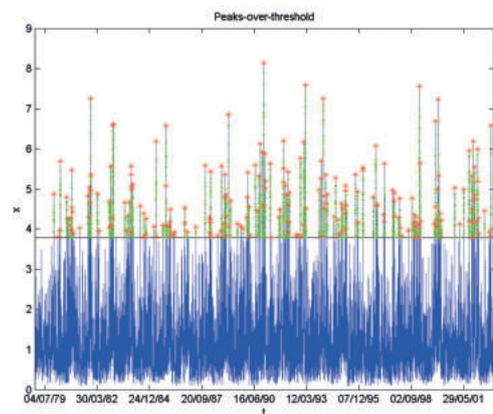
Extreme conditions

This ORCA functionality deals with extreme value analysis and includes the possibility to carry out the following analyses:

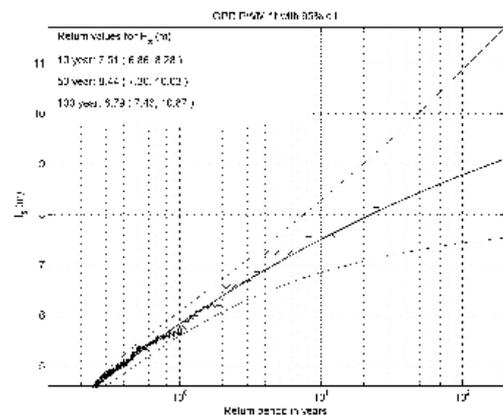
- collection of peaks-over-threshold data,
- collection of annual maxima data,
- determination of the optimal threshold for the estimation of the generalized Pareto distribution parameters,
- return value estimation,
- fitting of statistical distributions,
- bivariate analysis,
- uncertainty (confidence intervals) estimation.



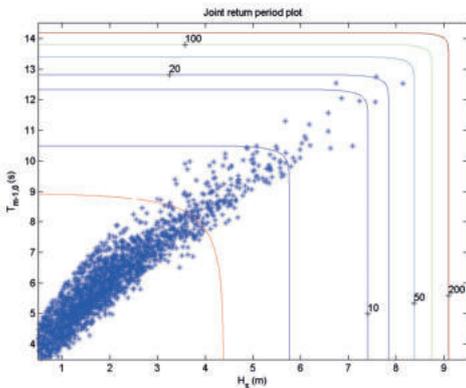
Example of a threshold plot. The threshold suggested by the automatic procedure (3.8 m) is indicated by the vertical lines.



Example of peaks-over-threshold plot. Blue: all values. Green: values higher than the chosen threshold (3.8 m). Red: the maximum values of independent events (more than 48 hours apart)



Example of a return value plot.



Example of a joint return value plot of significant wave height (H_s) and mean wave period ($T_{m-1,0}$).

Sea State analysis

This ORCA functionality deals with sea state analysis. There are two types of analyses that can be currently carried out:

I Spectral analyses

- Creation of a wave spectrum given certain integral wave parameters;
- fitting of a parametric spectrum to a computed wave spectrum.

II Individual wave height analyses

- Estimation of extreme individual wave heights in a given sea state;
- computation of the crest height of a given extreme wave height;
- computation of joint occurrences of individual wave heights and mean wave direction from significant wave height and mean wave direction joint occurrence tables.

Manual

ORCA comes with a digital manual, which contains all necessary information to use the graphical user interface. Furthermore, guidelines are available for the MATLAB toolbox. These manuals are available in pdf-format.

System requirements

The advised minimum requirements are a configuration consisting of:

| | Minimal |
|------------------|--------------------------------------|
| Operating System | Windows 10 (20H2) |
| Processor: | i5-5300u CPU 2.3GHz or higher |
| RAM | 16 GB or higher |
| Harddisk | 250 GB HDD (for saving model output) |

The Matlab Toolbox of ORCA has been tested in Matlab version R2021b

For this software package, node locked and floating licences can be issued. For more information on how to purchase this package please contact: software@deltares.nl or visit our website: www.deltares.nl/software

Support

Deltares systems tools are supported by Deltares. A group of 70 people in software development ensures continuous research and development. Support is provided by the developers and if necessary by the appropriate Deltares experts. These experts can provide consultancy backup as well.

| | 345-15 | 15-45 | 45-75 | 75-105 | 105-135 | 135-165 | 165-195 | 195-225 | 225-255 | 255-285 | 285-315 | 315-345 | |
|---------------|--------|-------|-------|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| >13.00 | 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 |
| 12.00 - 13.00 | 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 |
| 11.00 - 12.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 |
| 10.00 - 11.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.2 | 0.6 |
| 09.00 - 10.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.7 | 0.4 | 1.3 |
| 08.00 - 09.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.5 | 1.4 | 0.9 | 2.9 |
| 07.00 - 08.00 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 1.2 | 2.9 | 1.9 | 6.4 |
| 06.00 - 07.00 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 3.0 | 6.2 | 4.2 | 14.6 |
| 05.00 - 06.00 | 0.8 | 0.3 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.2 | 2.0 | 7.7 | 13.2 | 9.6 | 34.4 |
| 04.00 - 05.00 | 2.3 | 1.0 | 1.1 | 1.1 | 0.1 | 0.0 | 0.1 | 0.7 | 6.6 | 20.6 | 29.1 | 22.6 | 85.2 |
| 03.00 - 04.00 | 7.2 | 3.4 | 3.8 | 5.2 | 0.8 | 0.1 | 0.4 | 2.9 | 22.4 | 56.3 | 67.3 | 56.5 | 226.5 |
| 02.00 - 03.00 | 26.4 | 12.7 | 15.6 | 24.5 | 6.3 | 1.6 | 3.0 | 13.4 | 76.8 | 156.6 | 169.7 | 158.9 | 665.4 |
| 01.00 - 02.00 | 127.2 | 60.5 | 81.7 | 117.9 | 51.3 | 17.5 | 24.3 | 64.6 | 270.1 | 444.0 | 490.9 | 555.2 | 2305.3 |
| 00.00 - 01.00 | 606.0 | 315.7 | 337.4 | 426.8 | 256.8 | 114.5 | 113.5 | 208.5 | 651.4 | 983 | 1099.9 | 1543.5 | 6657.0 |
| | 770.3 | 393.7 | 440.0 | 575.8 | 315.3 | 133.8 | 141.3 | 290.2 | 1030.2 | 1673.4 | 1881.8 | 2354.2 | 10000.0 |

Individual wave height and mean wave direction joint occurrences table.

Total



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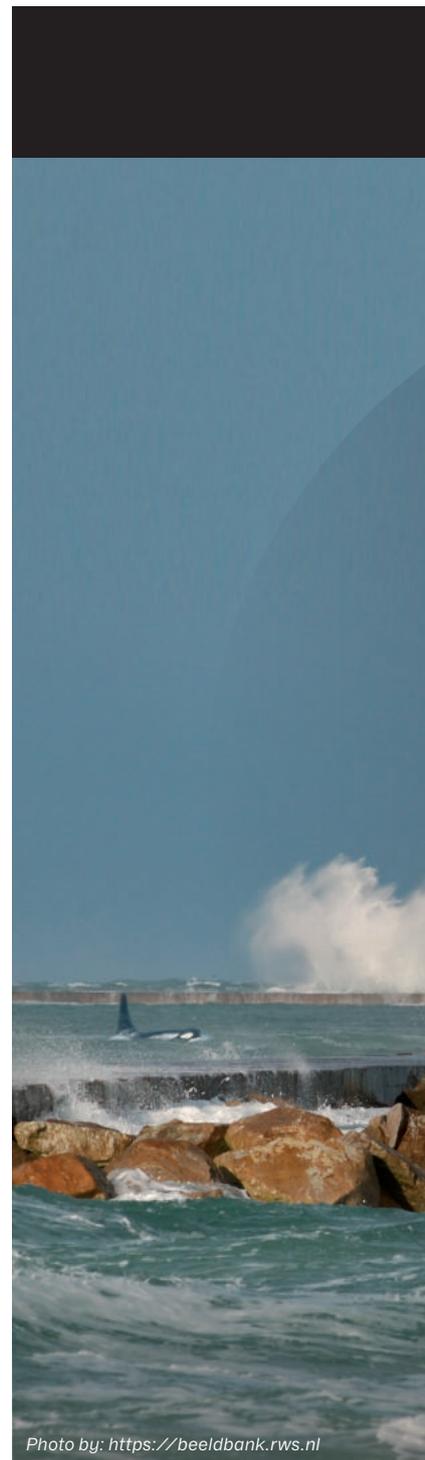


Photo by: <https://beeldbank.rws.nl>