

Approaches for Generating Long Term Nearshore Wave Climates

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Introduction

- Many coastal projects require **operational** (usually hourly time series) and **extreme** wave conditions in nearshore depths.
- Long-term offshore hourly data (covering decades) is usually obtained from regional or global hindcast models. The offshore data is usually analysed to provide extreme and operational conditions. The offshore data is then transformed to nearshore locations.
- Different approaches can be used to determine the operational and extreme nearshore waves.

Operational wave conditions are the typically occurring wave conditions used to investigate downtime in harbours or other marine operations, understand construction windows or model longshore sediment transport and associated shoreline changes. The wave conditions can be in the form of long term wave time series at the site or frequency statistics based on long term data.

Methods Presented to Generate Nearshore Wave Climates

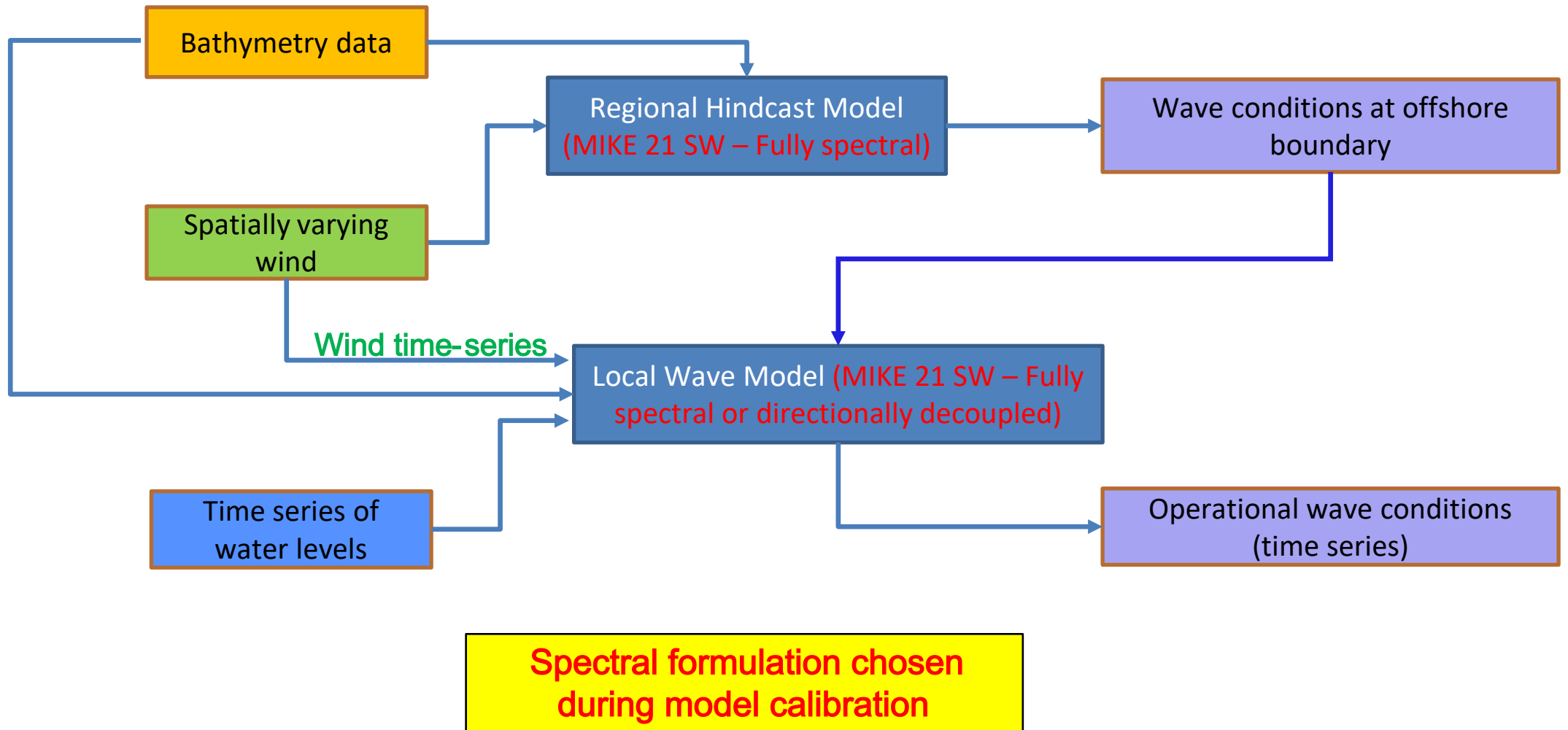
- For Operational Waves
 - Four methods
- For Extreme Waves
 - Two methods

Operational

Methods Commonly used

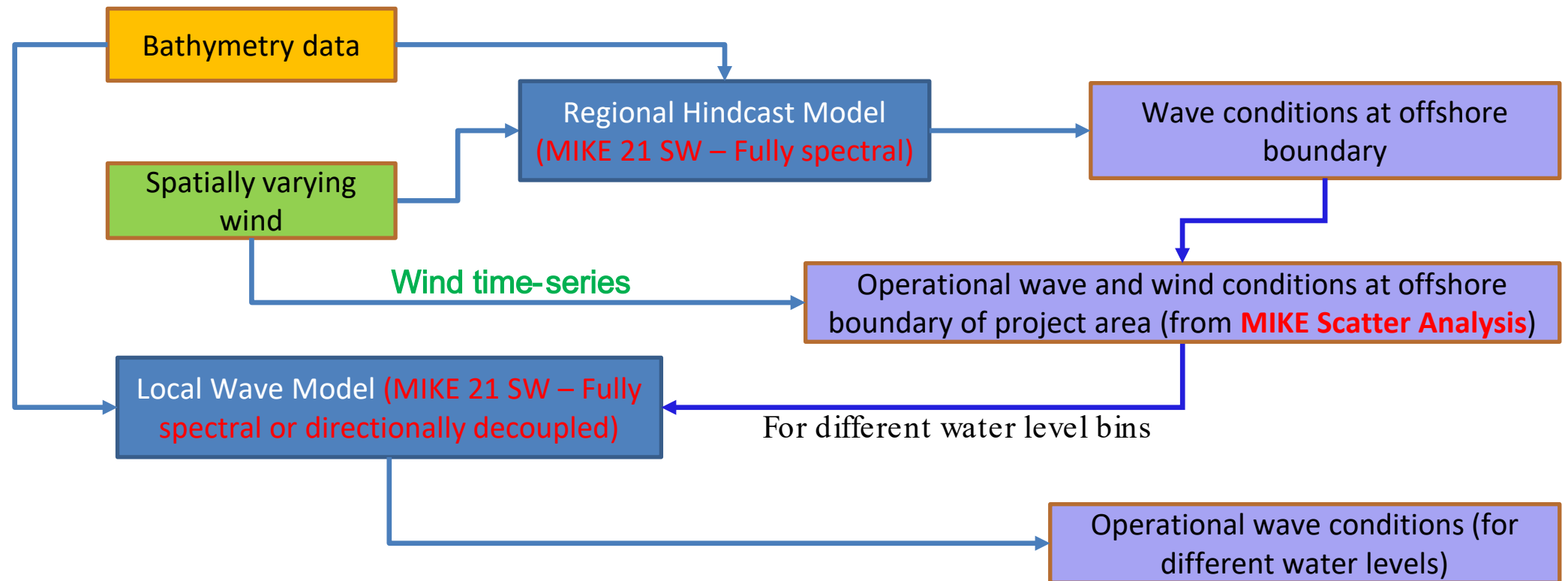
- Method 1-1: **Directly** transforming the long -term time series to the nearshore.
- Method 1-2: Transforming **binned** operational data from the offshore.
- Method 1-3: Transforming binned operational data from the offshore and using a **look-up table** to create nearshore time series.
- Method 1-4: Transforming a selected number of wave conditions in the offshore time series which is used together with a trained **emulator** to generate the long-term nearshore wave time series data.

Method 1 -1: Directly transforming the time series

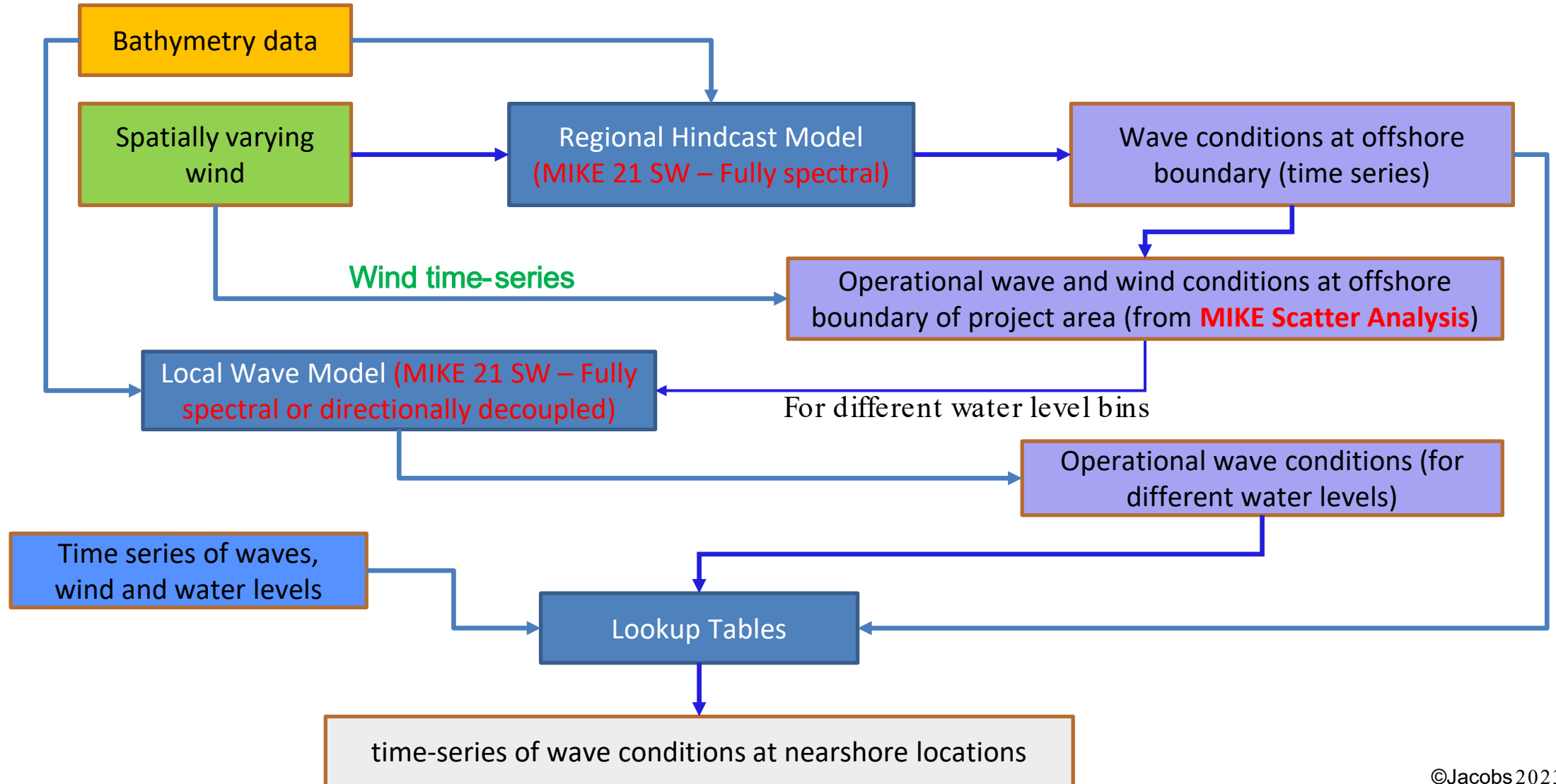


Method 1 -2: Transforming binned operational data

- Operational conditions can be used as input to **Littoral processes FM** but will not include any time series and thus only yearly averaged values can be determined.

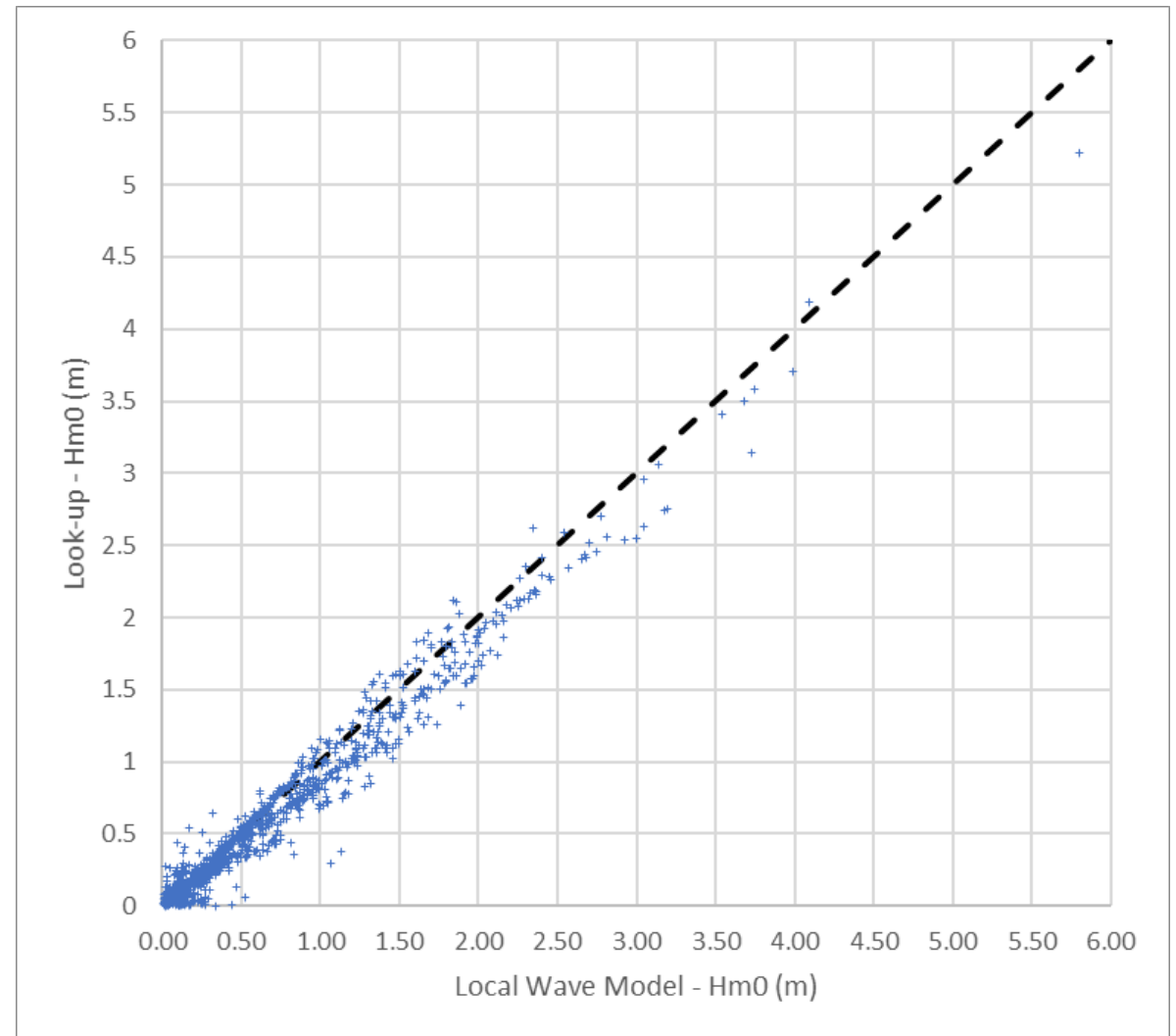


Method 1 -3: Transforming binned data and using a look-up table

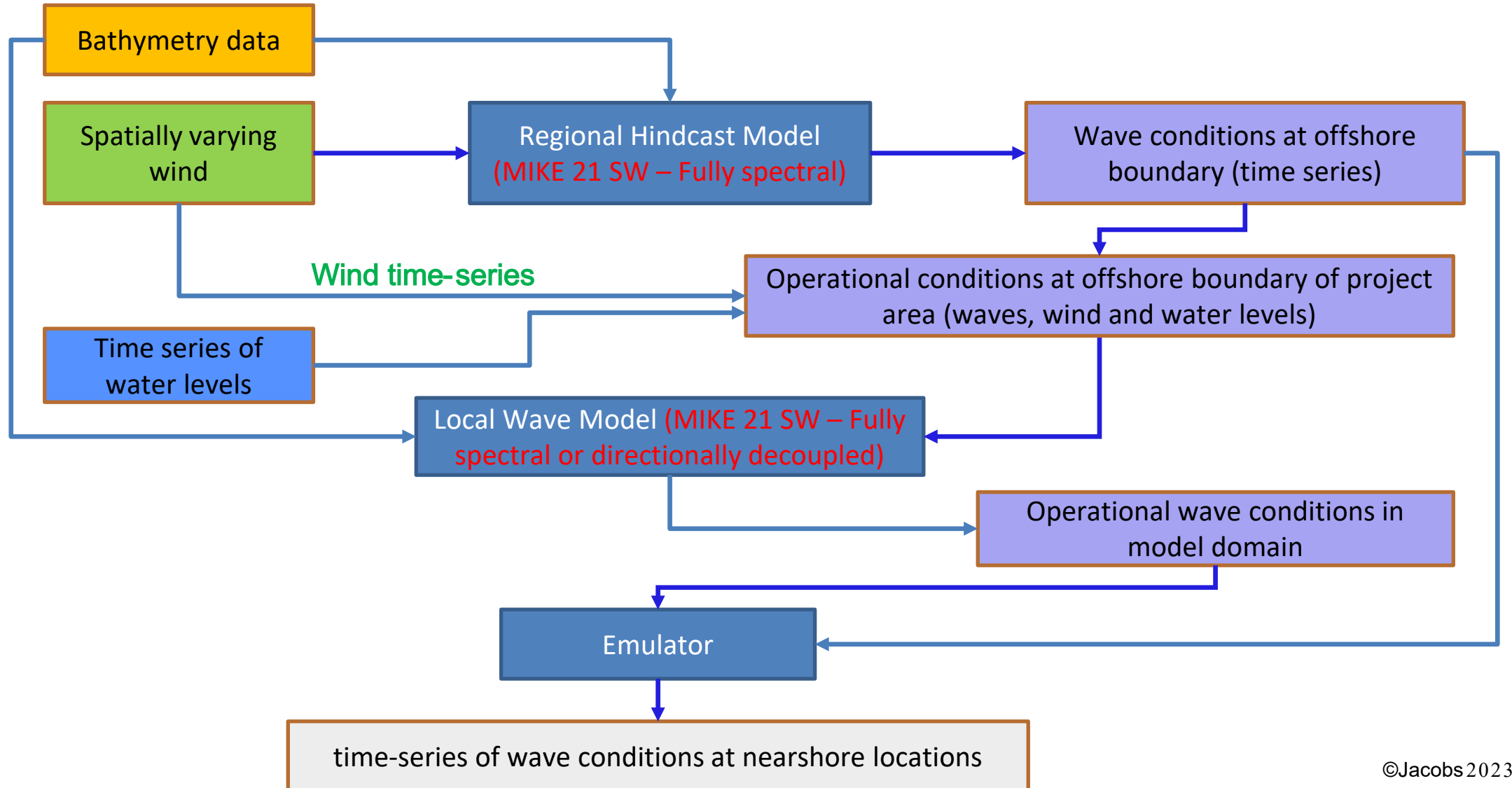


Example of results at a site

- Local wave model is Method 1-1 and Look-up is Method 1-3

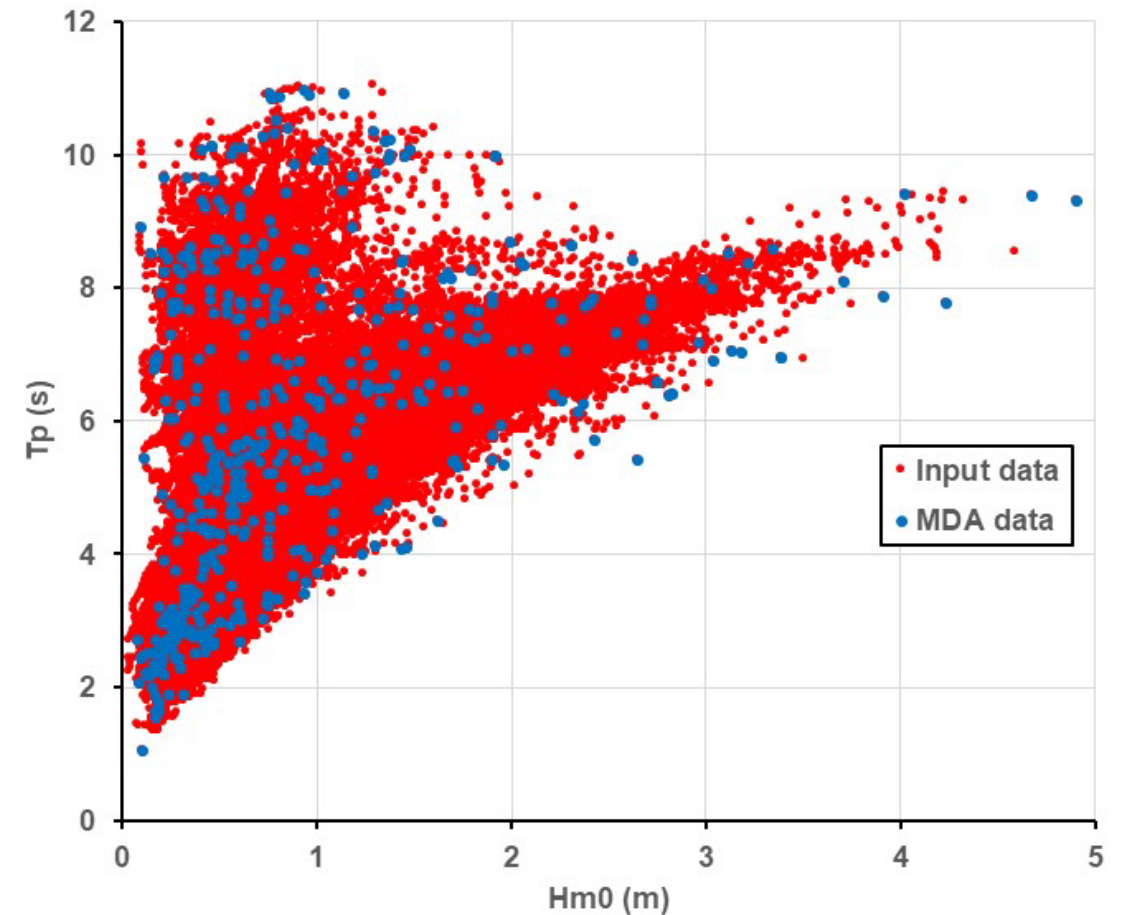


Method 1 -4: Transforming data using an emulator



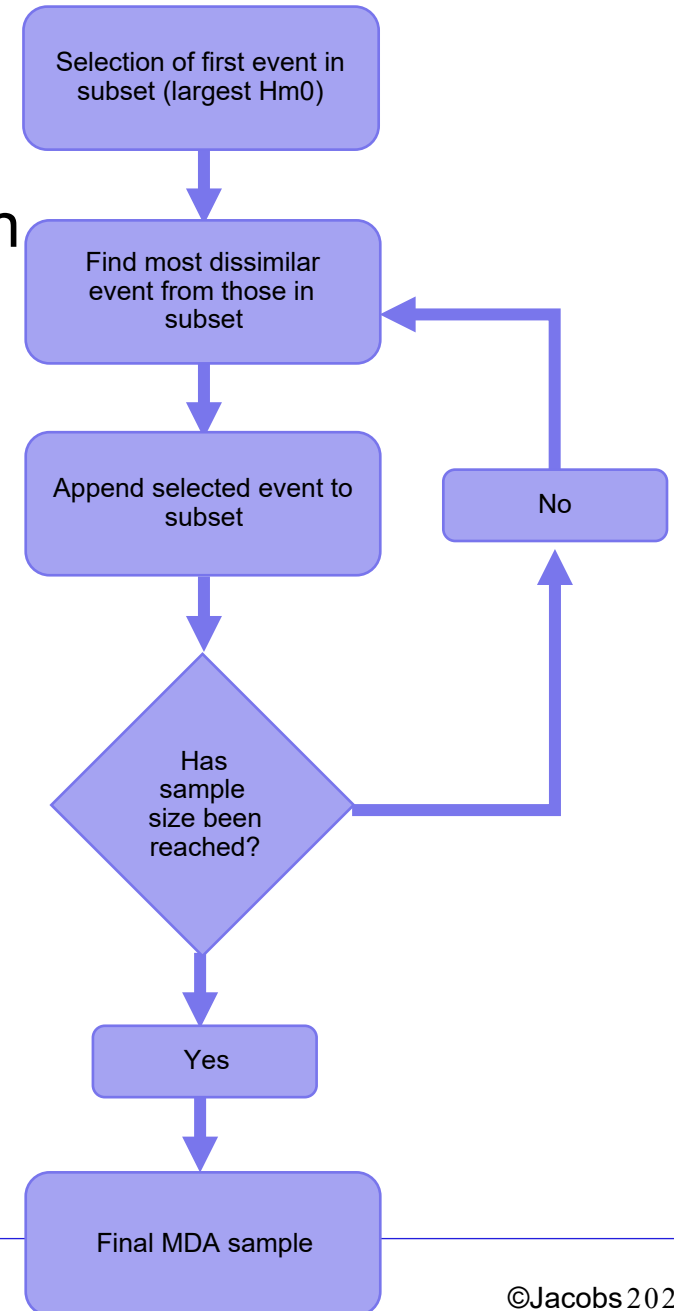
Emulator

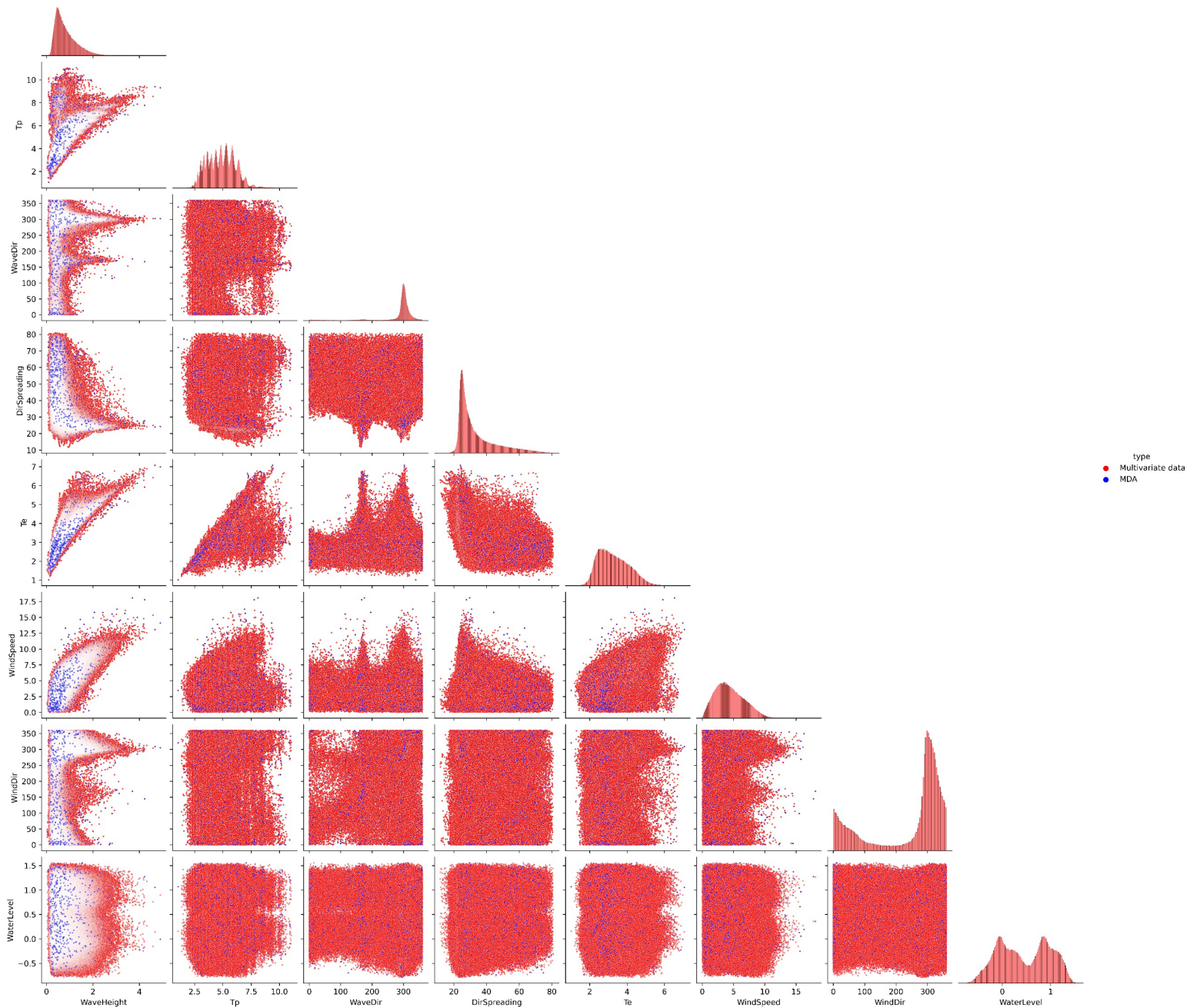
- The use of an emulator can be viewed as a more advanced look-up tool.
- Emulators are based on the Gaussian Processes (GP). Within the GP a kernel is a function that specifies the degree of similarity between variables given their relative positions in parameter space
- The first step for an emulator is the selection of the events to be used. The Maximum Dissimilarity Algorithm (MDA) is used for that purpose.



Maximum Dissimilarity Algorithm (MDA)

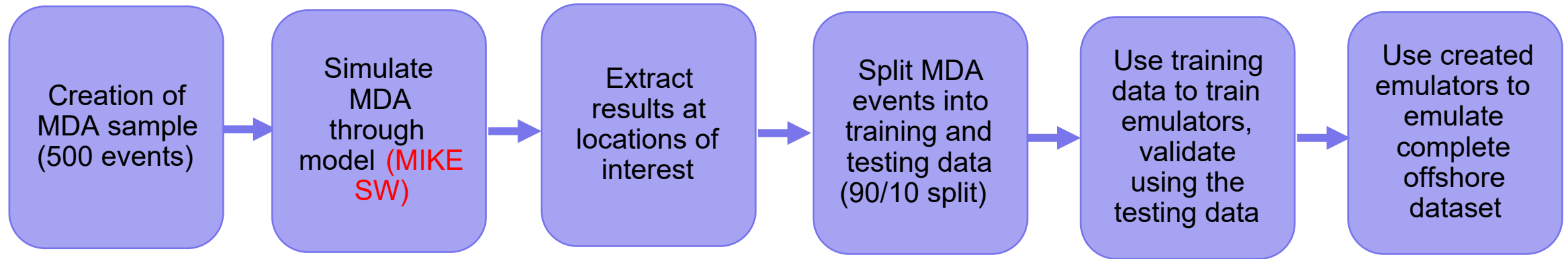
- The creation of an MDA sample starts with a single event in the subset selected from the main data sample (start with the largest H_{m0}).
- The next step is to select the most dissimilar event from this event and append it to the subset.
- Then, as the MDA runs through it iteratively loops over the events in the subset as it increases in size and then appends the next most dissimilar event to those already in the subset.
- The process continues until the desired number of events in the subset is reached (500-1000).





Emulation process

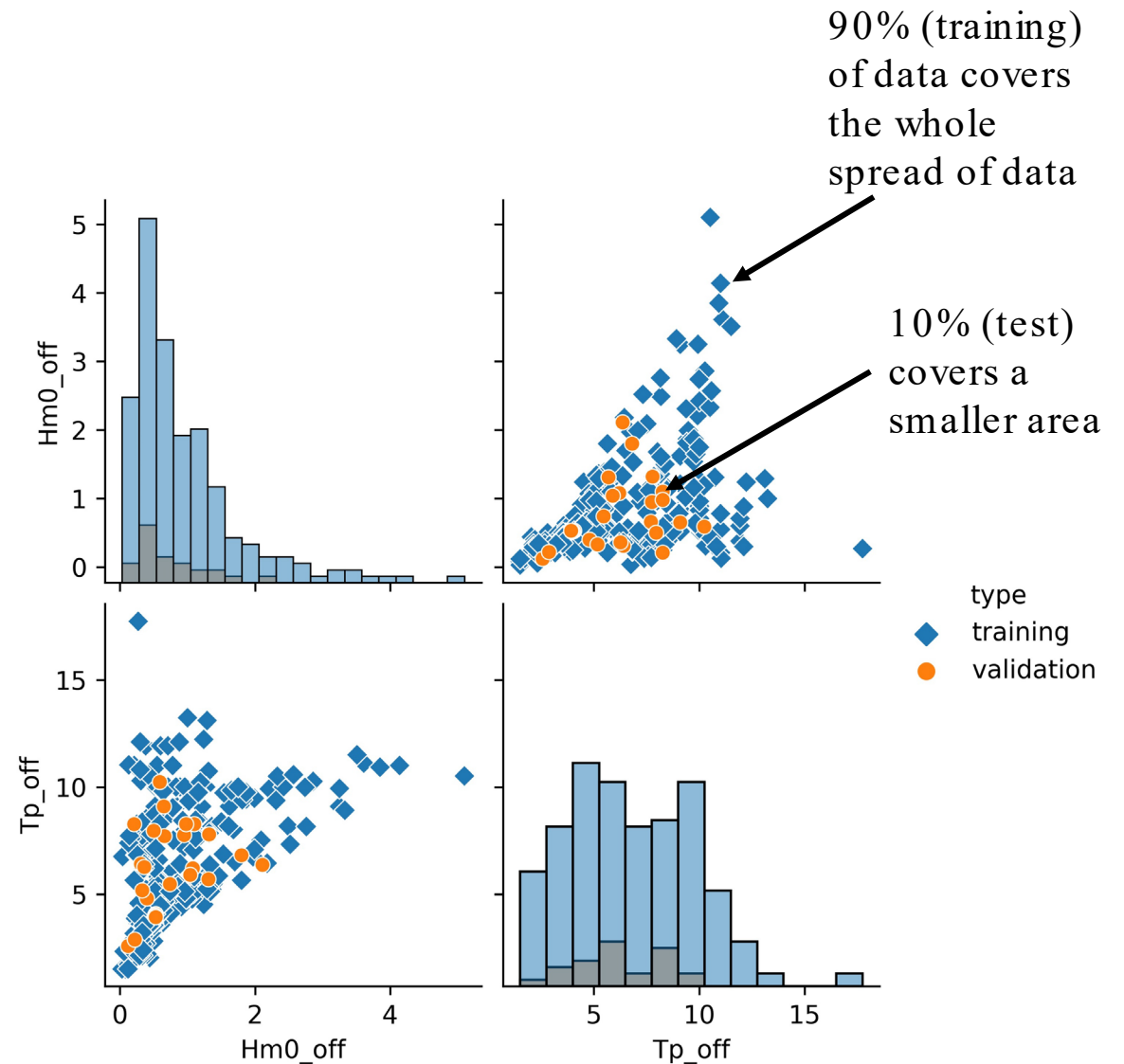
- The emulation process can be summarised in the following flow chart



Emulator can also be verified by comparing against a direct simulation for a short period.

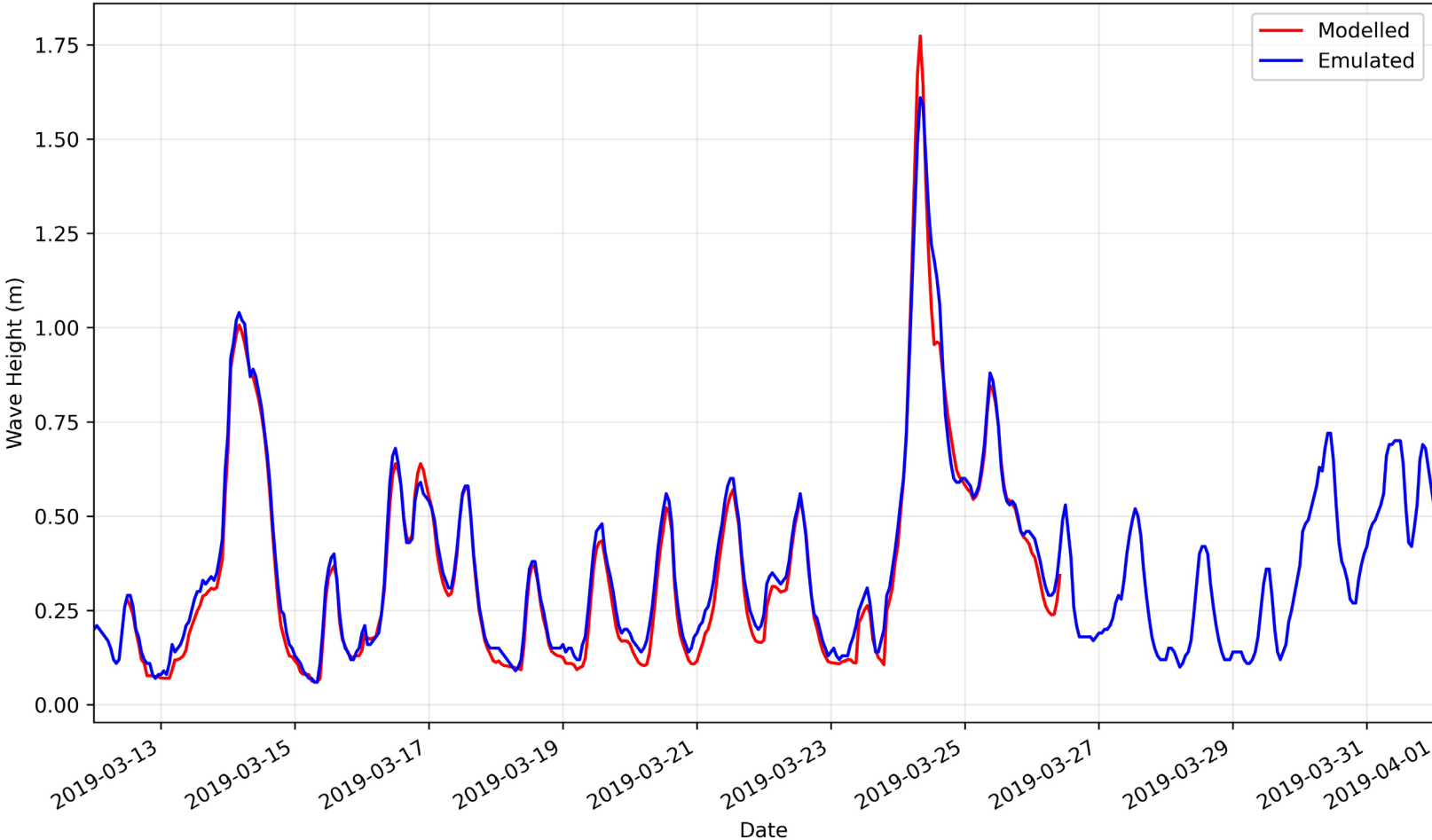
Splitting data 90/10

- Before emulating the MDA sample needs to be split into training and testing data
 - 90% of the data is used to train the emulators
 - 10% used to test/validate the created emulator
- 10% split taken from bottom 10% of MDA sample. This is so that the complete range of variables is represented in the 90% used to train



Sample of results at a project site

- Modelled is Method 1-1 and Emulated is Method 1-4



Comparison of methods

Method	Human effort	Computer effort	Accuracy	Output
1-1	Low	High especially for fully spectral	Same as calibration	Long term time series
1-2	Medium	Medium	Depends on bin sizes	Frequency table
1-3	Medium	Medium	Depends on bin sizes	Long term time series
1-4	Medium	Low	Depends on emulator training	Long term time series

Human effort:

Low	Below 8 manhours
Medium	24 to 40 manhours
High	More than 40 manhours

Computer effort:

Low	Less than 2 days
Medium	2 to 5 days
High	More than a week

Comparison of methods

Method	Approximations required	Advantages	Disadvantages
1-1	None	High accuracy	High computational effort
1-2	Binning of data and in some cases using correlations	Medium computational effort	No seasonal data can be obtained. Need to repeat for different water levels.
1-3	Binning of data and in some cases using correlations and use of lookup tables	Medium computational effort	Many cases simulated that cannot occur but required to fill the lookup table.
1-4	Emulator accuracy	Low computational effort	Effort in setting up emulator

Computer effort:

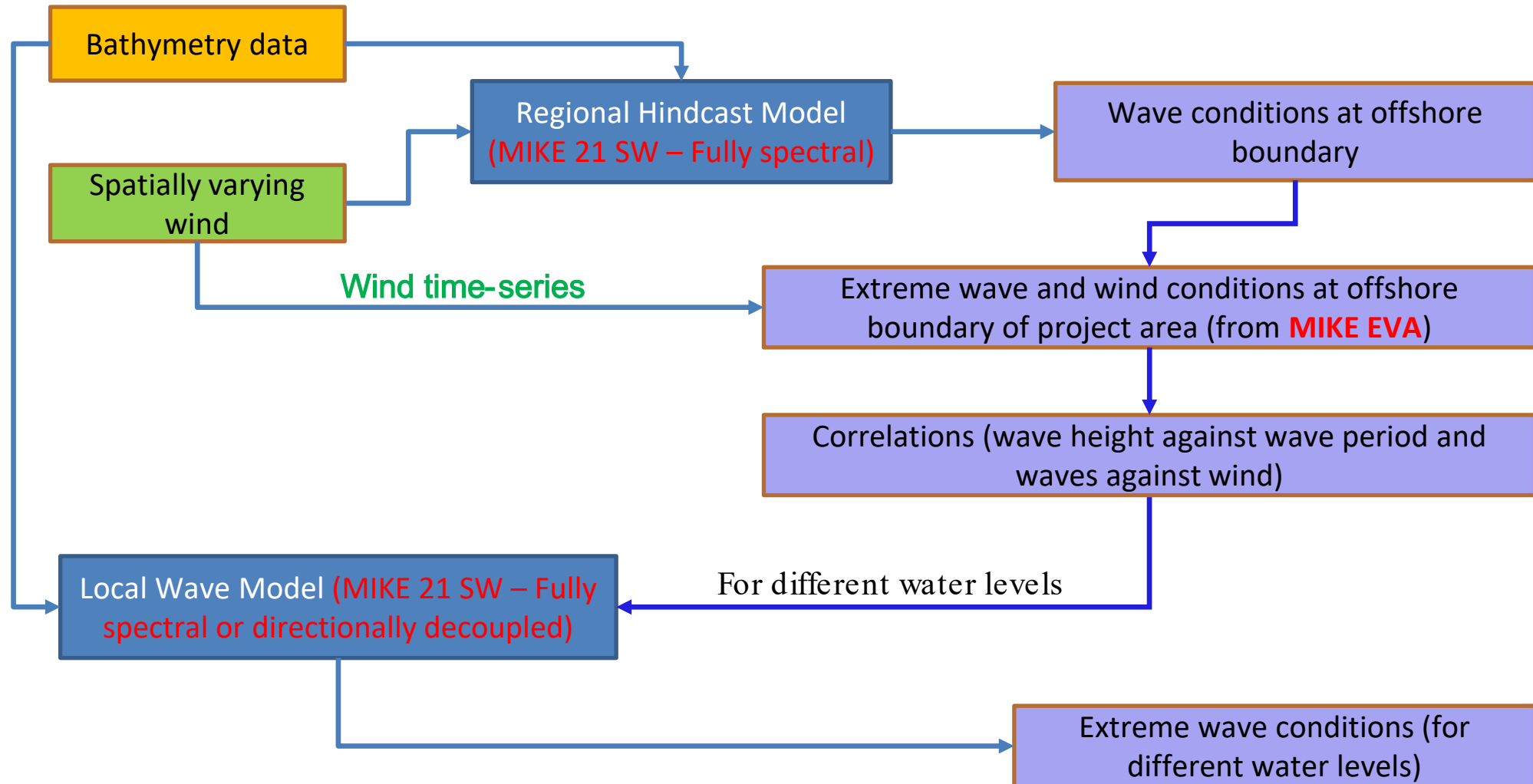
Low	Less than 2 days
Medium	2 to 5 days
High	More than a week

Extreme

Methods Used

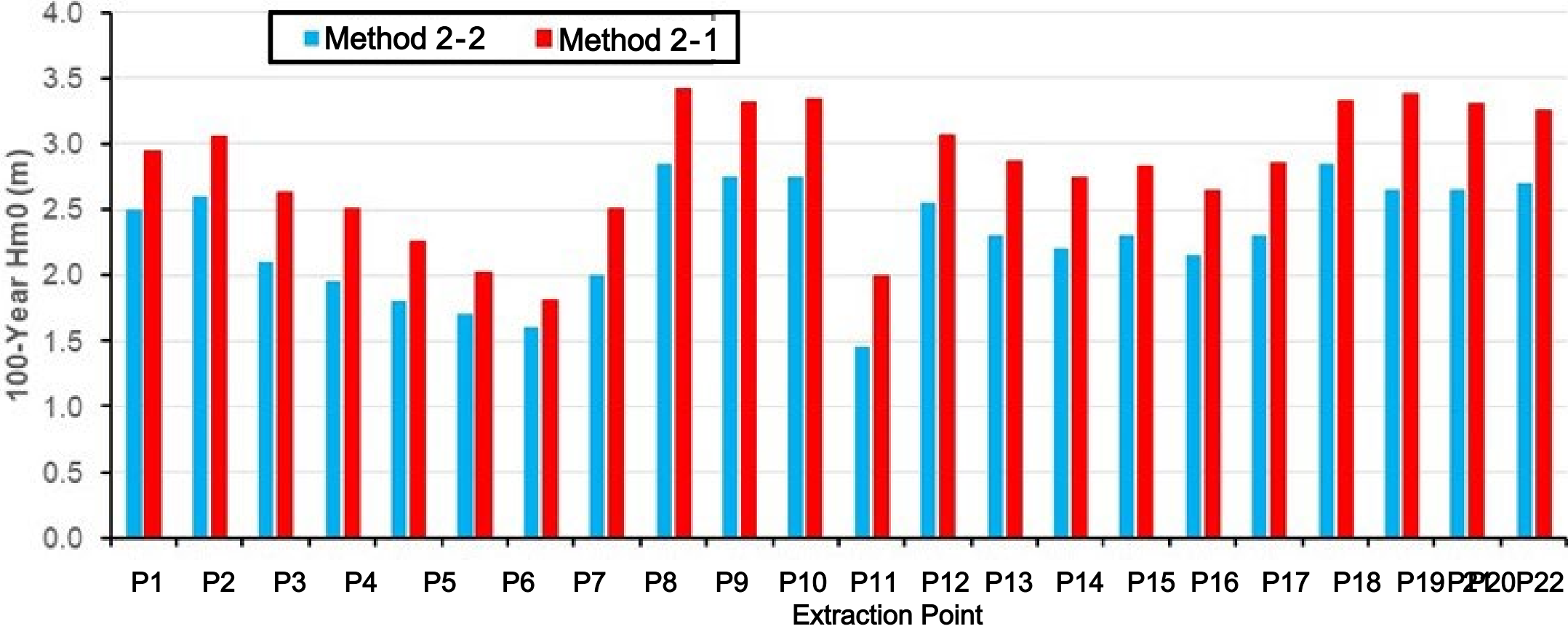
- Method 2-1: Transforming extreme offshore wave conditions directly.
- Method 2-2: Performing an Extreme Value Analysis (EVA) to the nearshore time series.

Method 2-1: Transforming extreme wave conditions



Sample for comparison

Emulator used to generate time series and extreme wind used with extreme waves



Comparison of methods

Method	Human effort	Computer effort	Accuracy
2-1	Low	Low	Difficult to quantify
2-2	Depends on method used to generate time series	Depends on method used to generate time series	Depends on accuracy of time series

Method	Approximations required	Advantages	Disadvantages
2-1	Fitted relations required for wave period and wind. Constant water level applied.	Minimal effort	Cannot study seasonal effects
2-2	Fitted relation required for wave period (associated with extreme wave heights). Generation of time series can be based on an approximation	Can study seasonal effects	More effort (generation of time series and EVA)

Conclusions

Conclusions

- For most projects, it is recommended to generate nearshore time series for the wave climate if offshore time series are available since more information can be obtained (seasonal variations etc).
- The use of emulators if properly trained will produce good results with less computational effort as compared to direct simulations.
- The effect of Sea Level Rise should be included in the training of the emulator.

Questions ?

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