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# Risk Based Coastal Flood Risk Analysis

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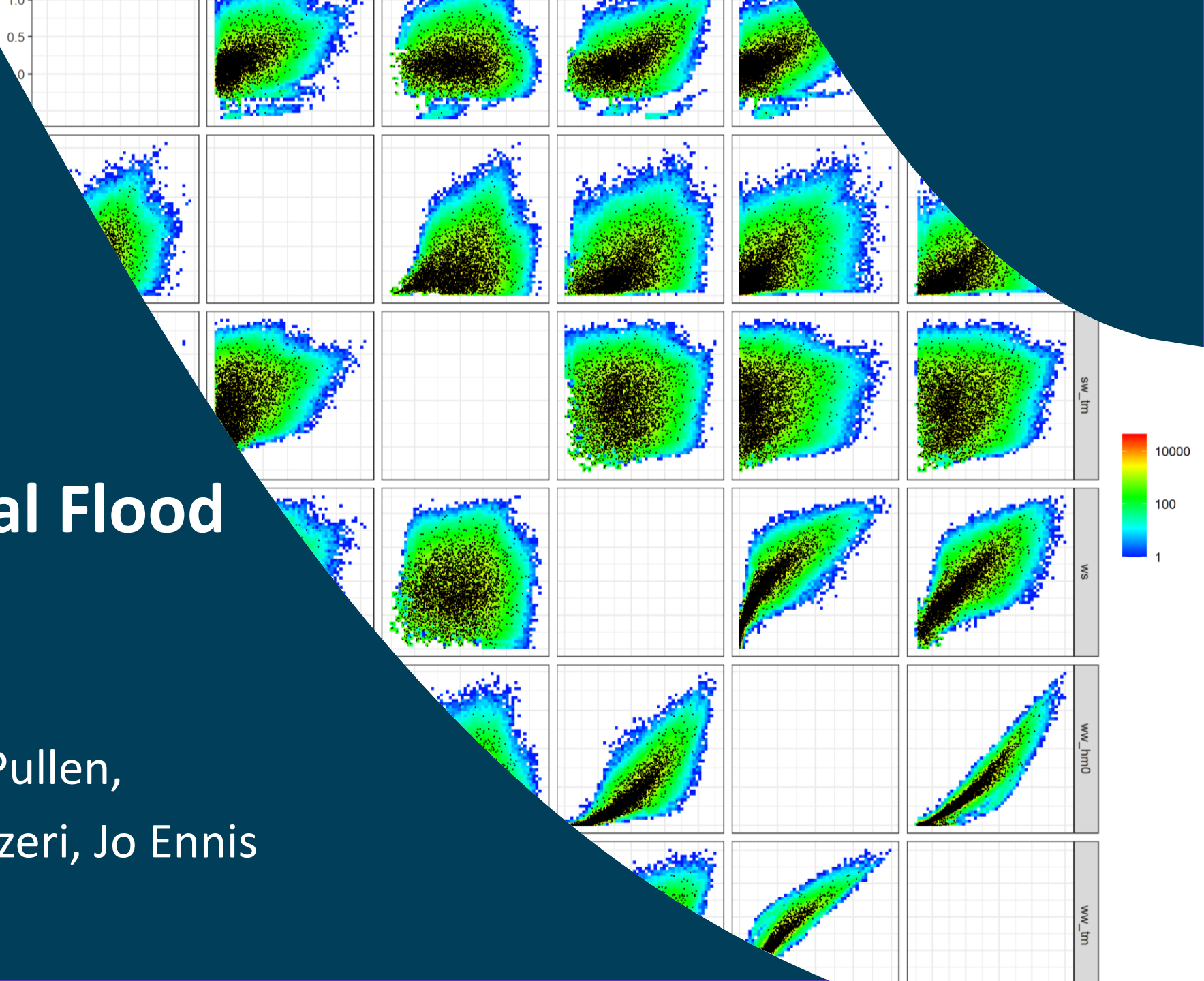
Simon Everitt, Mike Panzeri, Jo Ennis



# Outline of Talk

- Summary of a risk based approach to coastal flood modelling
  - Can be used for design and assessment of existing coastal structures/assets
- Limitations of original probabilistic approach
- Summary of new developments
  - addressing limitations of current method

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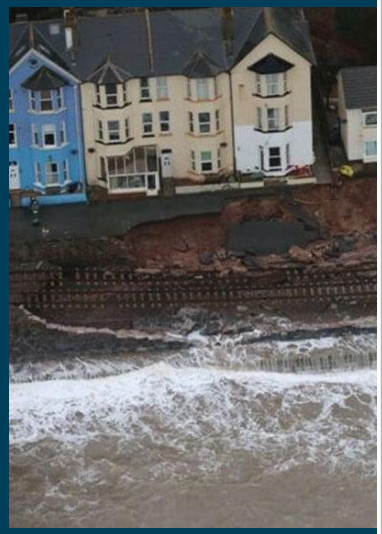
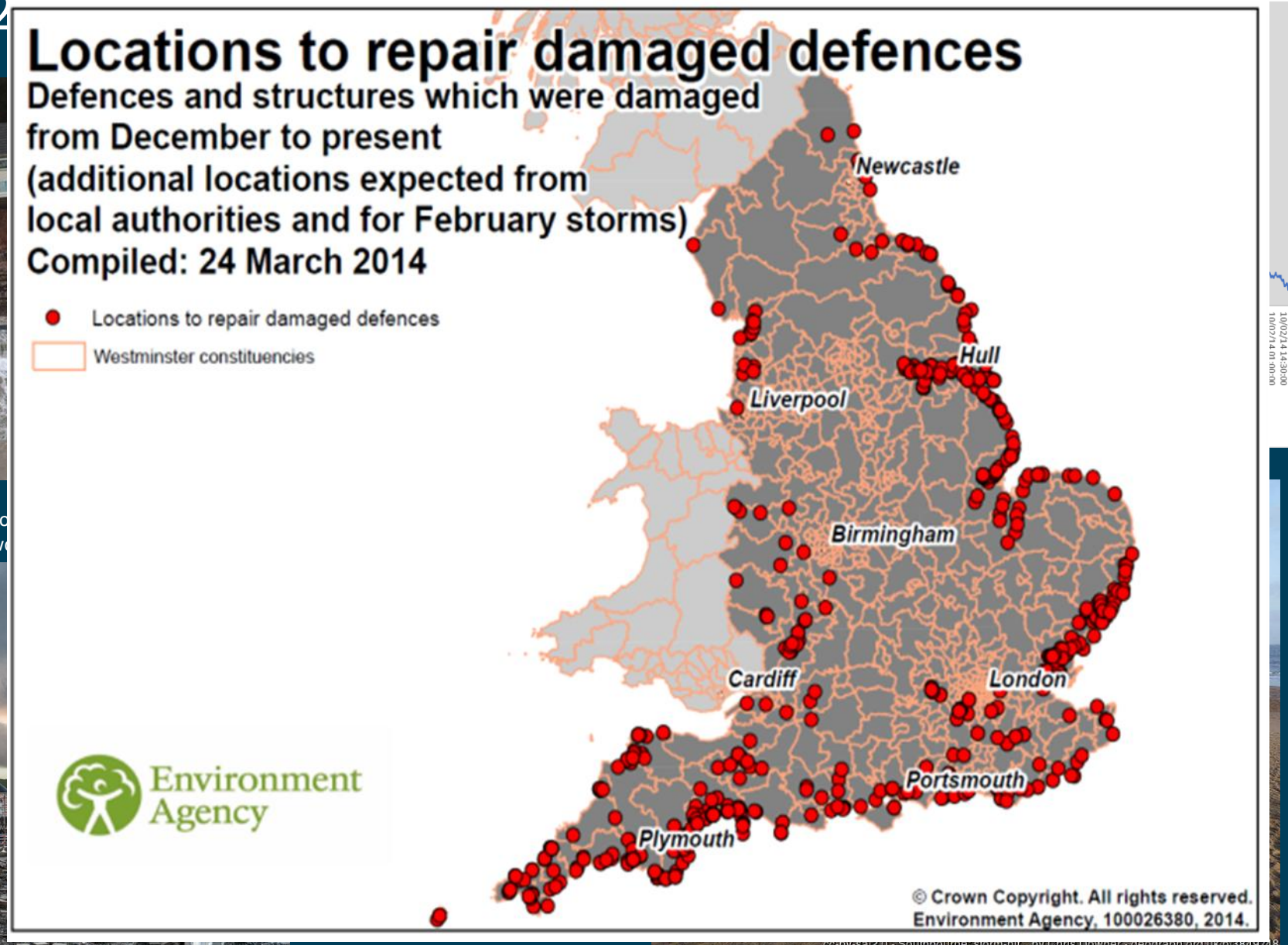
# Winter of 2013/2014 impacts



https://www.networkrail.co.uk/sto
since we reopened Dawlish - Netw















Southbourne
16th February

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Traditional Joint Probability curve methods

vs.

risk based multivariate approaches

Traditional bi-variate joint probability curve methods:

Considers the correlation between two parameters e.g. offshore wave height and water level –>

**The Cause = high waves and water levels**

Issues:

1. difficult to assign periods and directions to go with the offshore wave heights, and

2. can inherently lead to an underestimate of the return period of the nearshore response.

Multivariate method:

Considers many combinations of wave height (and associated period & direction) + water level are transformed inshore and the corresponding response is computed -> **The Effect = e.g. the Return Period of overtopping/runup/flood level**

Hames DP, Gouldby BP and Hawkes PJ (2020). Investigating the use of joint probability curves in coastal engineering practice. Proceedings of the Institution of Civil Engineers – Maritime Engineering 173(3): 68–78, https://doi.org/10.1680/jmaen.2019.12



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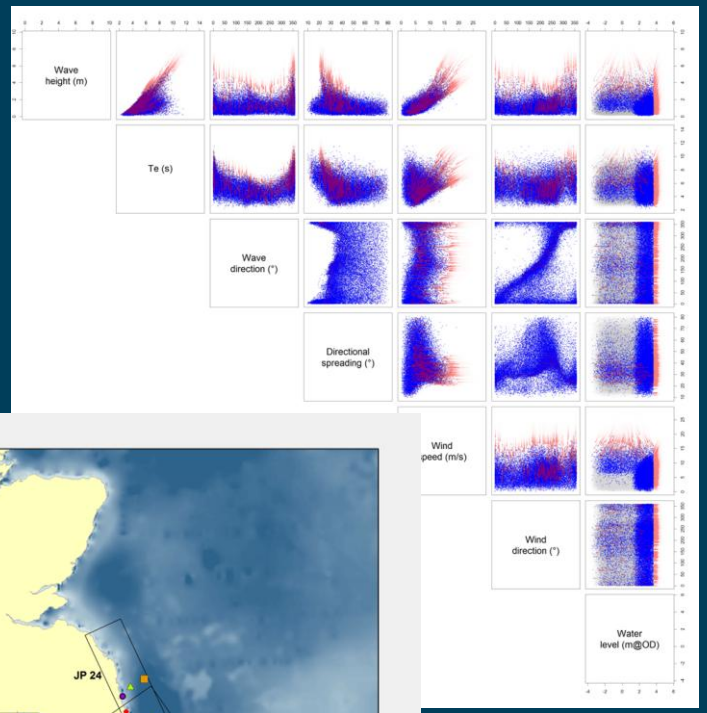
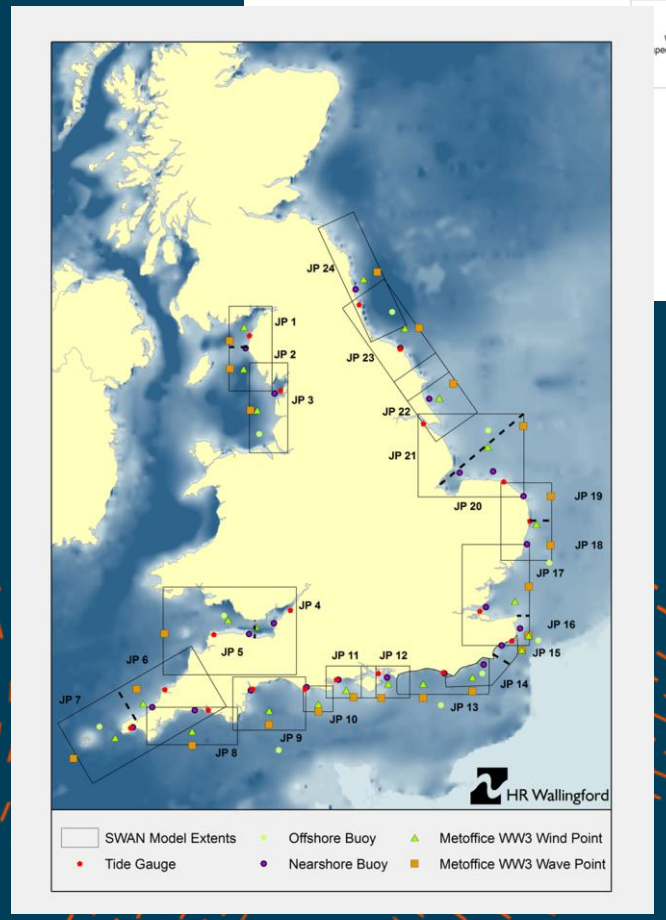
# Original method applied a multivariate extreme value analysis at a national level

Gouldby, B., Wyncoll, D., Panzeri, M., Franklin, M., Hunt, T., Hames, D., Tozer, N., Hawkes, P., Dornbusch, U. and Pullen, T., 2017, March. Multivariate extreme value modelling of sea conditions around the coast of England. In Proceedings of the Institution of Civil Engineers-Maritime Engineering (Vol. 170, No. 1, pp. 3-20). Thomas Telford.



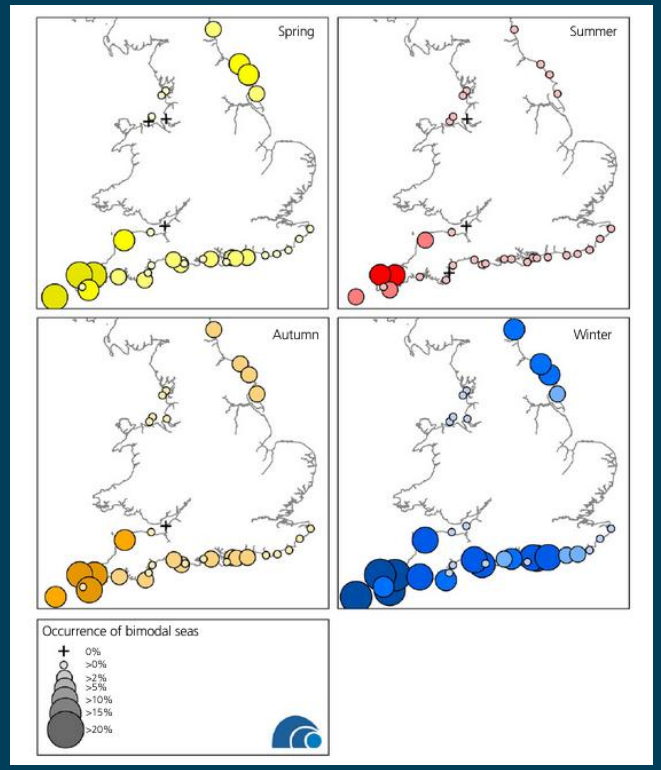

## Limitations of original method

- Baseline year 2014 – 10 years more data now available
- Peak values of variables – assumptions regarding storm shapes required
- Total sea used (i.e. bimodal/swell components not explicitly represented)
- Influence of storm clusters not included
- Climate change not included (UKCP18 update)

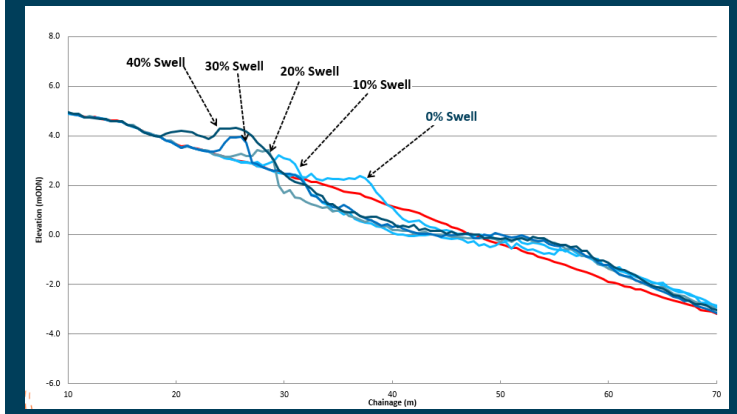


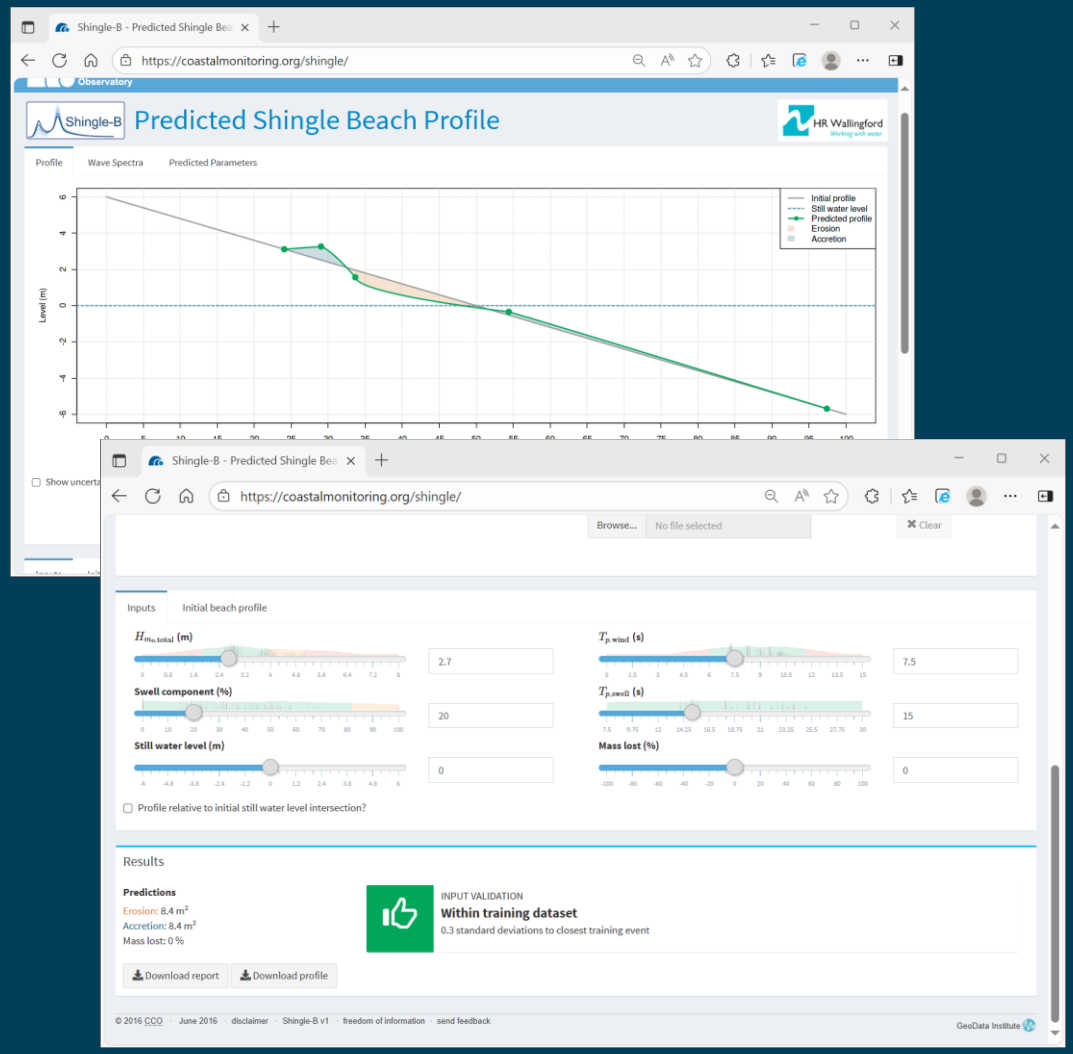
# Incorporating bimodality within coastal flood risk analysis

Modelling total sea carries the risk of underpredicting responses such as wave overtopping and runup




Channel Coast Observatory (2018)



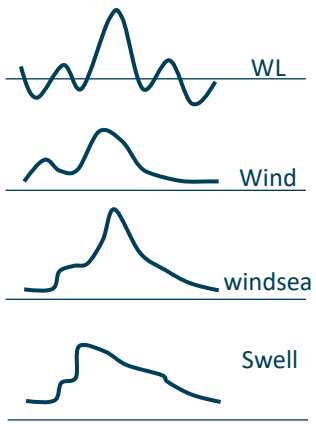




https://coastalmonitoring.org/shingle/

# Overview – Main steps of improved method

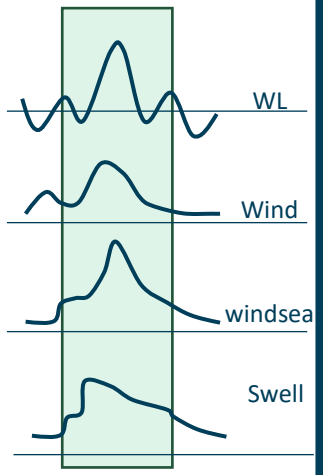
## Input time series data

Prepare input time series data for the modelled variables at the offshore location



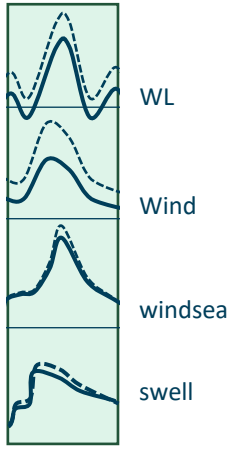

## Event extraction

Define storm windows and extract observed storm profiles



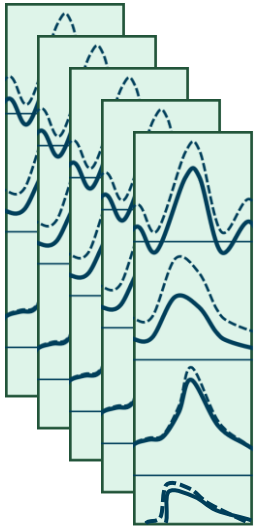

## Multivariate extreme value model

Use multivariate EV model (Heffernan-Tawn) to extrapolate variables to higher RPs



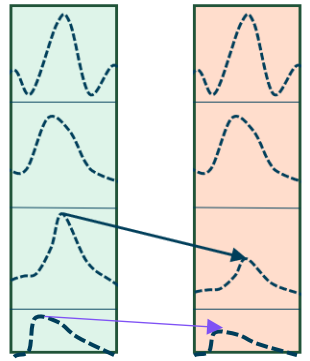

## Monte Carlo offshore datasets

Draw simulated synthetic storm profiles at the offshore location from the fitted EV model



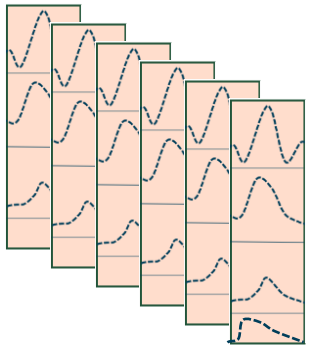
## Wave transform

Use SWAN to transform the offshore wave conditions to nearshore locations

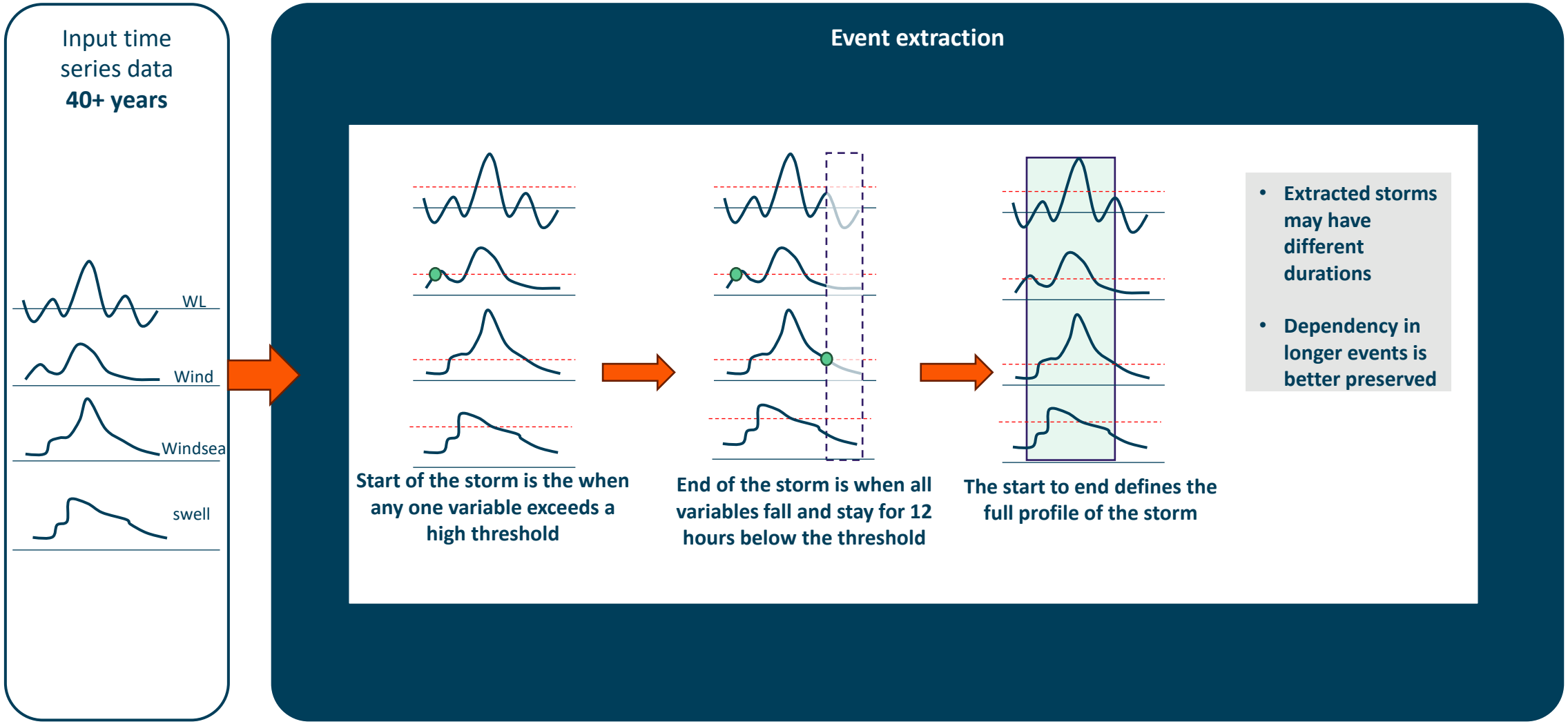


## Nearshore data and response

Produce the corresponding nearshore and response datasets



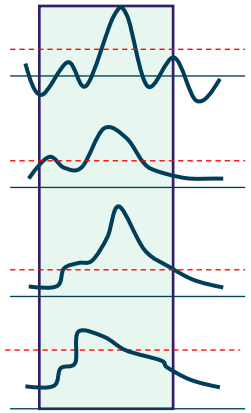
# Event extraction + definition of storm profiles



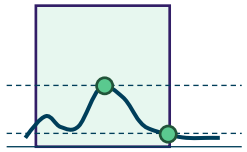

Smith, R.L. and Weissman, I. (1994). *Estimating the extremal index*. Journal of the Royal Statistical Society: Series B (Methodological), 56(3), pp.515–528.

# Multivariate extreme value model

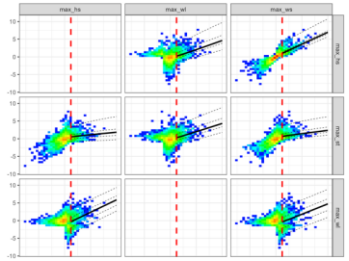
Extracted events



**Multivariate extreme value model**



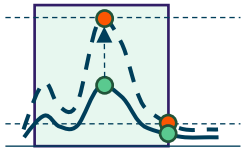
The storm profiles are parameterised by the **min and max** of each variable



**Heffernan-Tawn** model for the joint probability (JP) analysis

This model is used because it can

- handle more dimensions than alternatives, and
- capture all types of extremal dependences

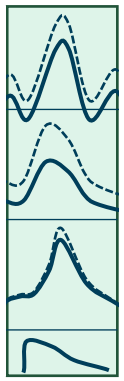


Simulate **new min / max** values and scale up the profile accordingly

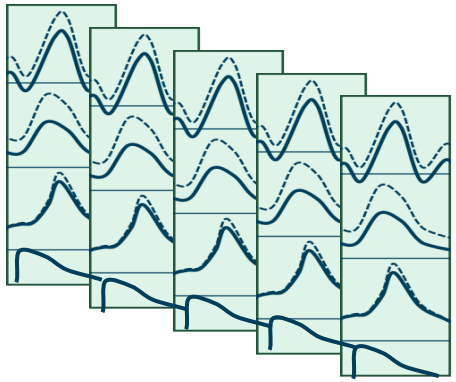
- Summary statistics (min / max) because of varying event duration

# Monte-Carlo simulation of offshore datasets, including appropriate climate allowances

Extrapolated profiles from the JP model

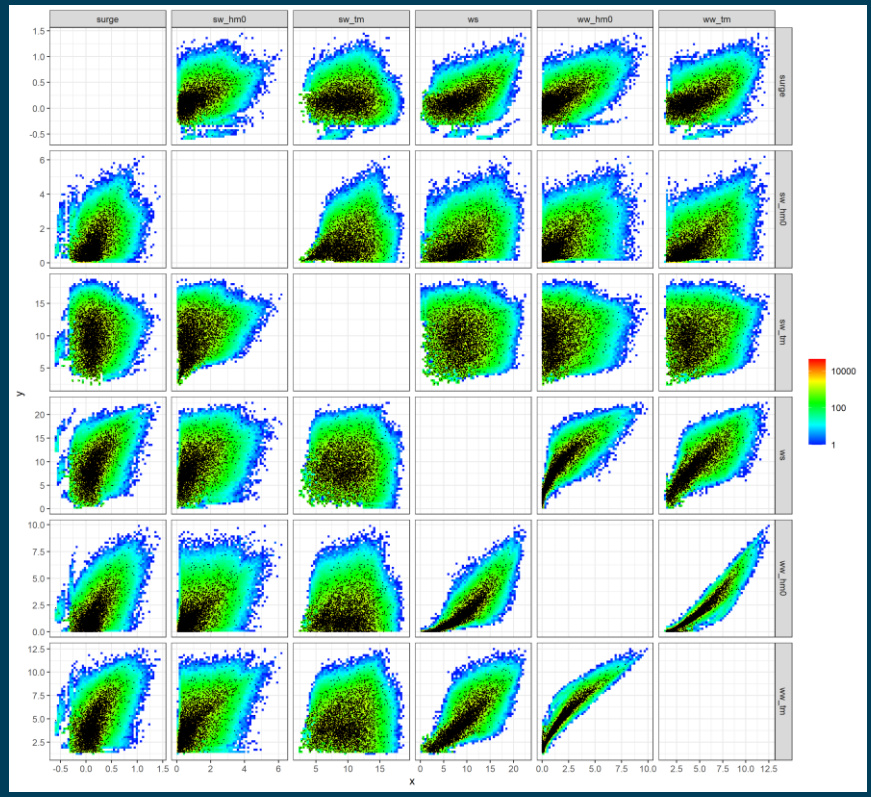



**Monte Carlo offshore datasets**



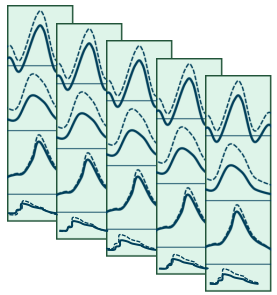
**Simulated storm profiles are adjusted further for climate change scenarios**

**They are combined into large samples (typically up to 100 times the target return period)**

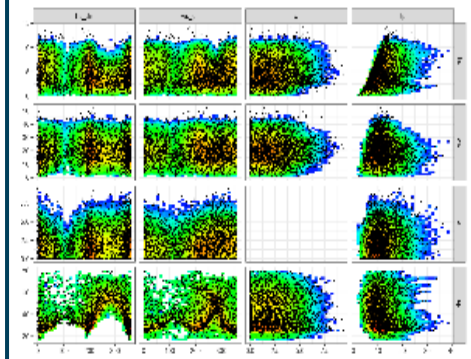


# Offshore to nearshore wave transformation

**Offshore datasets Including storm profiles of wind, water level, windsea and swell**



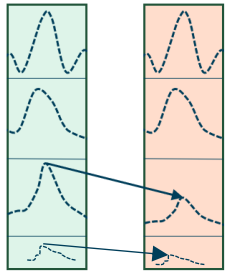
**Offshore to nearshore wave transformation**



**SWAN modelling assisted by Gaussian Process Emulators (GPEs)**

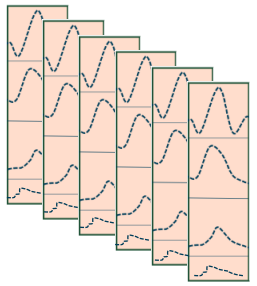
**GPEs trained with an optimally selected set of offshore wave conditions (MDA)**

**Dots** – training data
**Heatmap** – all simulations



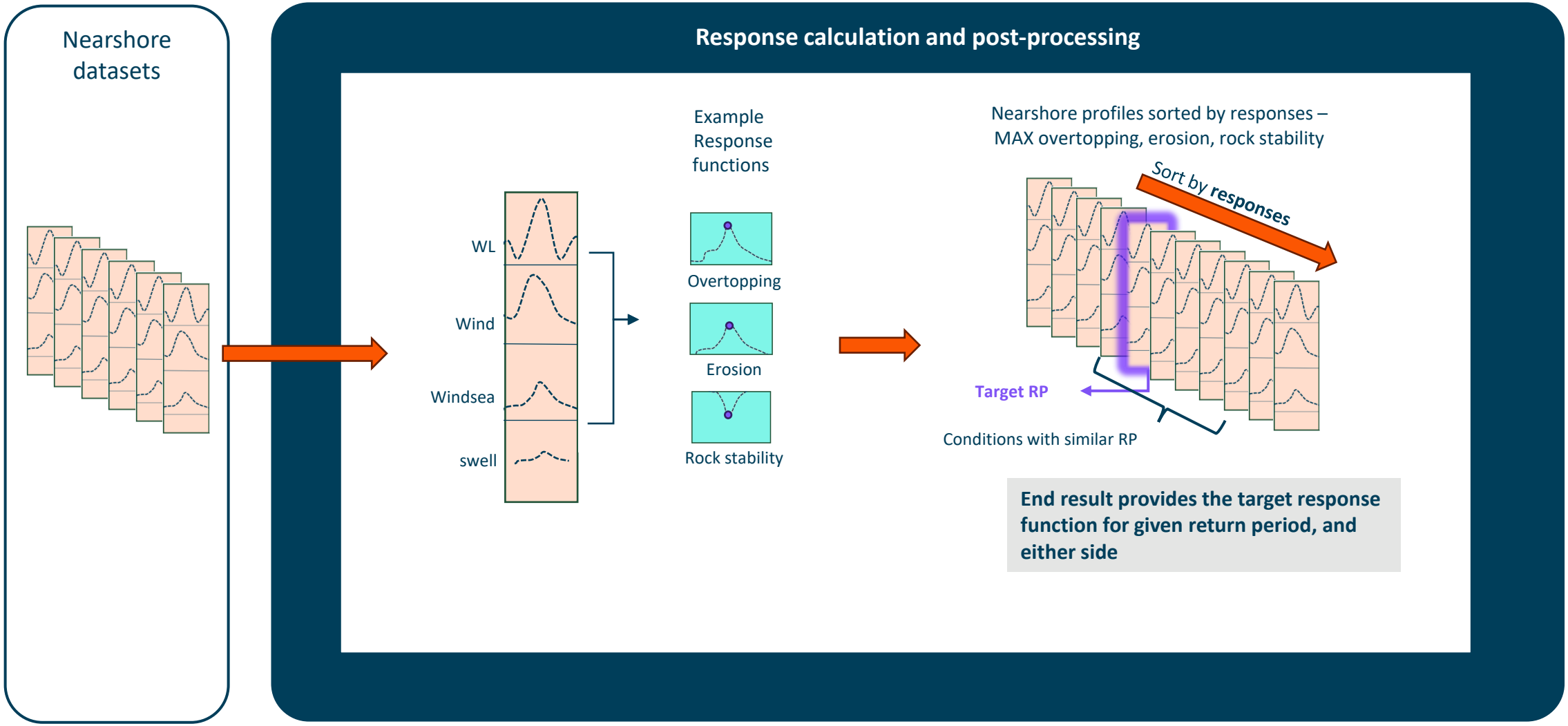
**Each offshore storm profile is transformed in whole to nearshore**

**SWAN Gaussian Process Emulator**



**Monte Carlo dataset of nearshore storm profiles**

# Response function and post-processing



## Summary of recent developments:

- Additional 10 years of data
- Multiple climate change scenarios (epochs and confidence intervals)
- Time evolution of variables within a storm (storm profiles)
- Wind-wave/swell (bimodal) explicitly considered
- Facilitates:
  - Traditional Deterministic Contours
  - Peak event analysis (i.e. as the original approach)
  - Dynamic flood inundation simulations using more realistic storm profiles

## Ongoing work includes :

- Consideration of the temporal dependence of storms (i.e. storm clusters), based on the extrapolated datasets in both a statistical sense and response)

Thank you for listening

Any questions?

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