Coastal domain analysis for geo-coastal assessment in Great Britain

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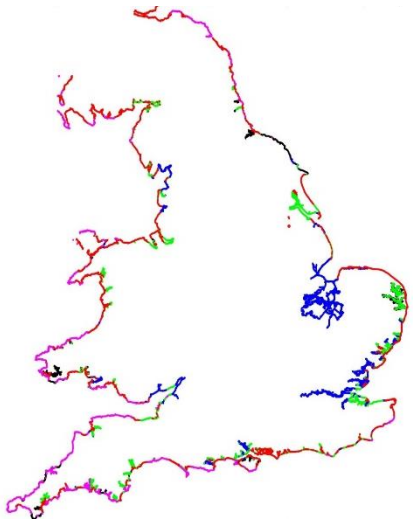


Background

- Coastal erosion and flooding are an increasing issue in the UK and pose a threat to people living and working in coastal environments, as well as threatening coastal infrastructure and assets.
- The geomorphology of the UK's 11,000 mile long coastline is highly varied, from steep, hard cliffs to weak, easily erodible cliffs and wide flat estuaries.
- The geology of the UK is also very diverse, leading to variability in the cliff structure, lithology and rock properties which significantly influence the geomorphology of the coastline and it's susceptibility to erosion and flooding.
- This variability is challenging to represent and consider in a modelling environments, and consequently geological influences are often under-represented in coastal modelling and management planning.

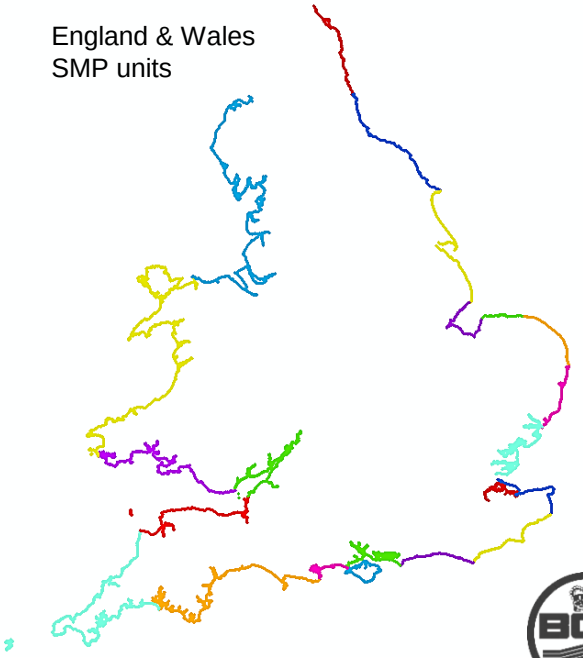
Coastal Management

- In the UK various attempts have been made to manage the coastal environment, particularly to prevent coastal erosion and flooding. Much of this infrastructure is add-hoc, old, poorly maintained or abandoned as management efforts have changed over time.

- In England and Wales, the responsibility for coastal management is split between the Environment Agency which manages the flood risk and Local Authorities which manage erosion. To assist with coastal management the coastline of England and Wales is split into 22 units and a Shoreline Management Plan (SMP) has been developed for each. These provide a route-map for decision makers to identify the most sustainable approaches to managing coastal risk in the short, medium and long term.

- In Scotland the Dynamic Coast Project holds an evidence base of national coastal change via the National Coastal Change Assessment (NCCA), which summarised the past 130 years of coastal change, and projects forwards to 2050.

- BGS currently contributes our geological expertise towards coastal hazard management through the Coastal Vulnerability Dataset. This provides a number of layers, including Cliff Susceptibility to Erosion, Foreshore Geomorphological Environment and Inundation Potential, which offer users easy-to-use datasets to interpret the potential interdependencies of coastal hazards. The Coastal Domains dataset, currently in development, will enhance this toolkit.



Coastal Domains

- A coastal domain is a segment of coastline that possesses a character defined by the sum of its basic morphological (e.g. platform, barrier, estuary…) and geological (e.g. soft cliffs, hard cliffs, structure…) properties and behaviour.

- Domains could be defined manually by coastal experts, however this is only suitable for local-scale assessment. There can also be inconsistencies between experts, bias, and may not be effective at considering all the data available.

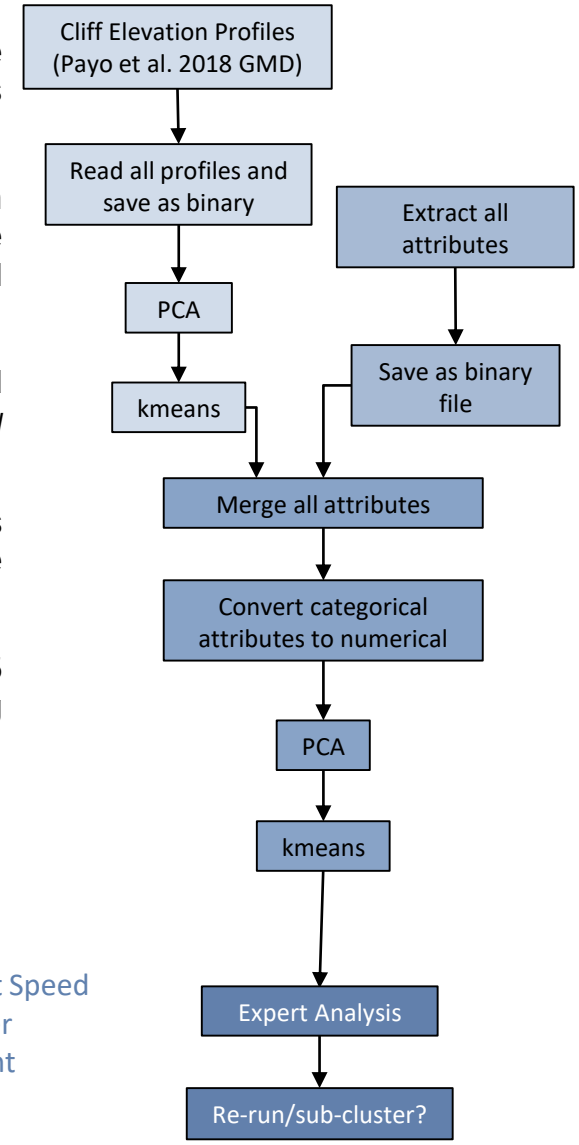
- To combat this we have developed an semi-automated approach using partitional clustering methods. This enables us to consider a large number of variables and combines data available within the existing BGS Coastal Vulnerability Dataset, including lithology, cliff strength, foreshore environment and inundation, with additional open source datasets, such as wave power and height, tide height and tidal current speed.

- This is the first time this method has been applied nationally in the UK and it will provide a new benchmark for describing the coastline and coastal change which is not bound by administrative districts.

- The coastal domains dataset will be made available as part of the BGS Coastal Vulnerability Dataset and will assist in making more informed decisions when considering coastal management.

Method

- Elevation profiles orientated perpendicular to the coastline were derived using the NEXTMap® DTM at 5m intervals around the entire UK, using the automated cliff metrics extraction algorithm (see Payo et al. (2018) https://www.geosci-model-dev.net/11/4317/2018/.)
- Principle Component Analysis (PCA) was used to reduce dimensionality (using elevation values and cliff metrics). The first 4 Principle Components explained 99% of the variability. Using the scores over the principle components we used the partitional clustering function 'kmeans' for 5 clusters.
- Shoreline points at 5m intervals were used to extract all other coastal attributes and joined with the elevation profile clusters. *(At present time, Scotland north of Edinburgh is excluded from the rest of the analysis while some attributes are finalised).*
- Some attributes are categorical and were converted to numerical by sorting the values alphabetically. To ensure the min and max values for all attributes are of the same order, the log10 value for some attributes was used.
- A PCA analysis of all attributes was used to reduce dimensionality and finds that 5 PCA's explain 90.7% of the variability. Consequently, we used the partitional clustering function 'kmeans' for 5 clusters.
- Expert analysis of results determined that further sub-clusters are useful.
- Clustering attributes used:



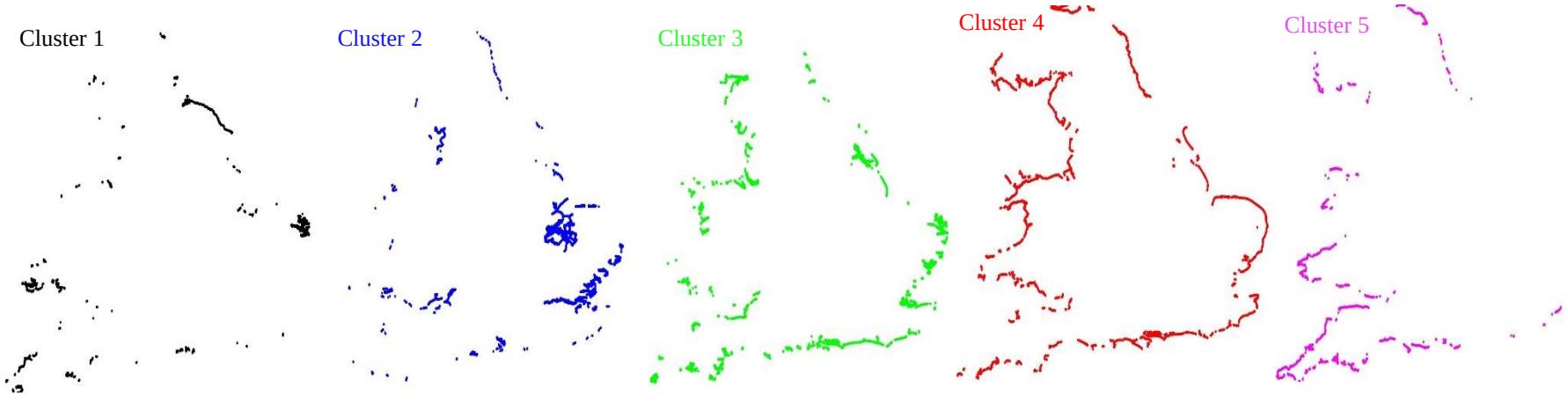
BGS Datasets;

- CVD Erosibility Score
- LEX-RCS Code
- Backshore Lithology
- Foreshore Environment
- Inundation Potential
- Potential Subsidence Rate

Open Access Datasets;

- Cliff Elevation Profiles
- Intertidal Zone Width
- Mean Spring tide Range
- Mean Neap Tide Range
- Mean Spring Tide Current Speed
- Annual Mean Wave Power
- Annual Mean Wave Height
- Cliff Top Elevation

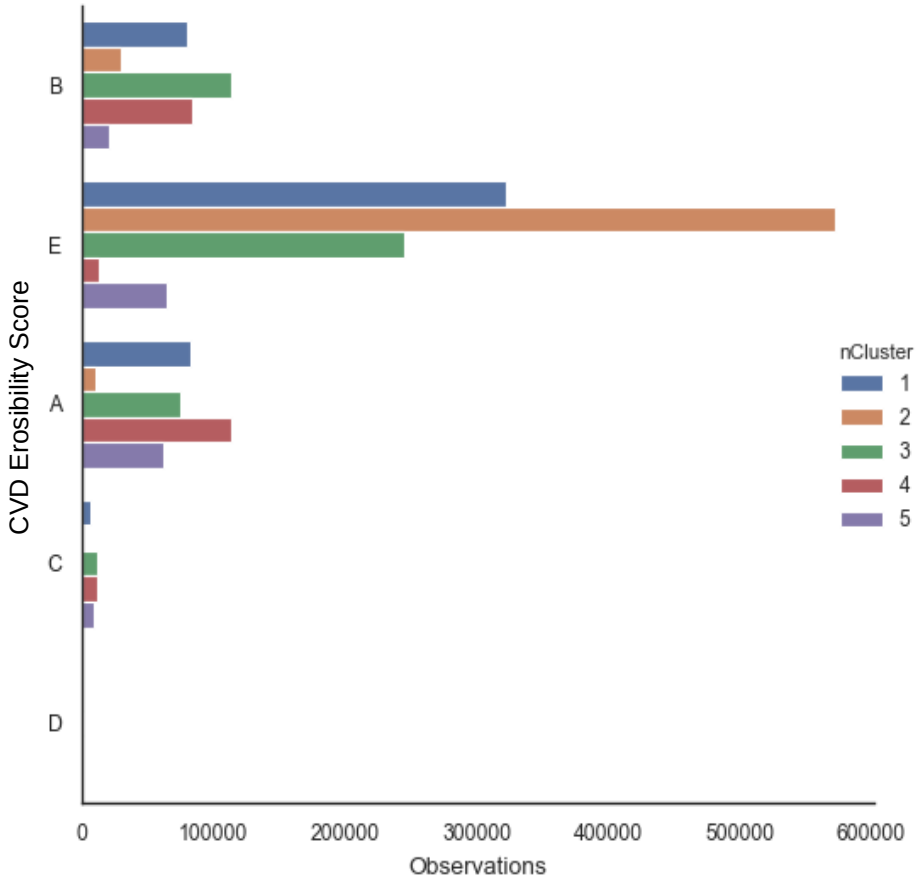
Clustering Results

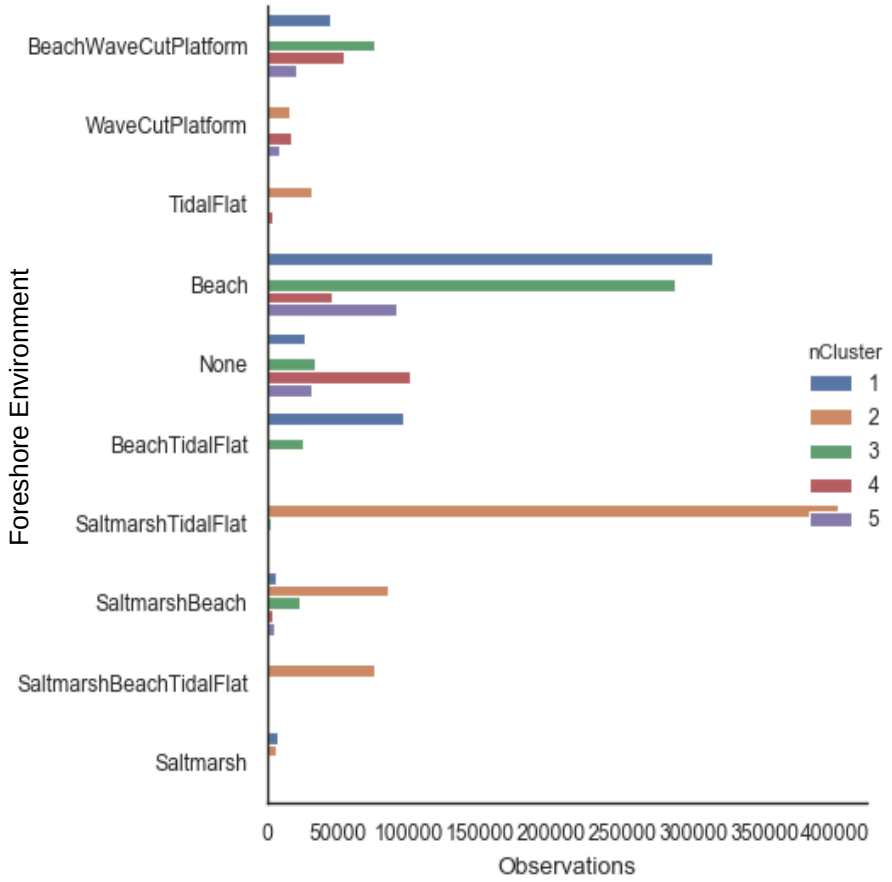


- The maps above show the extent of the clusters (1-5) along the UK coastline. These have been assessed by a team of geo-environmental scientists at BGS, using summary plots of the input attributes to help create a narrative for each cluster and to determine the success of the analysis. (examples of these plots can be found on following slides).

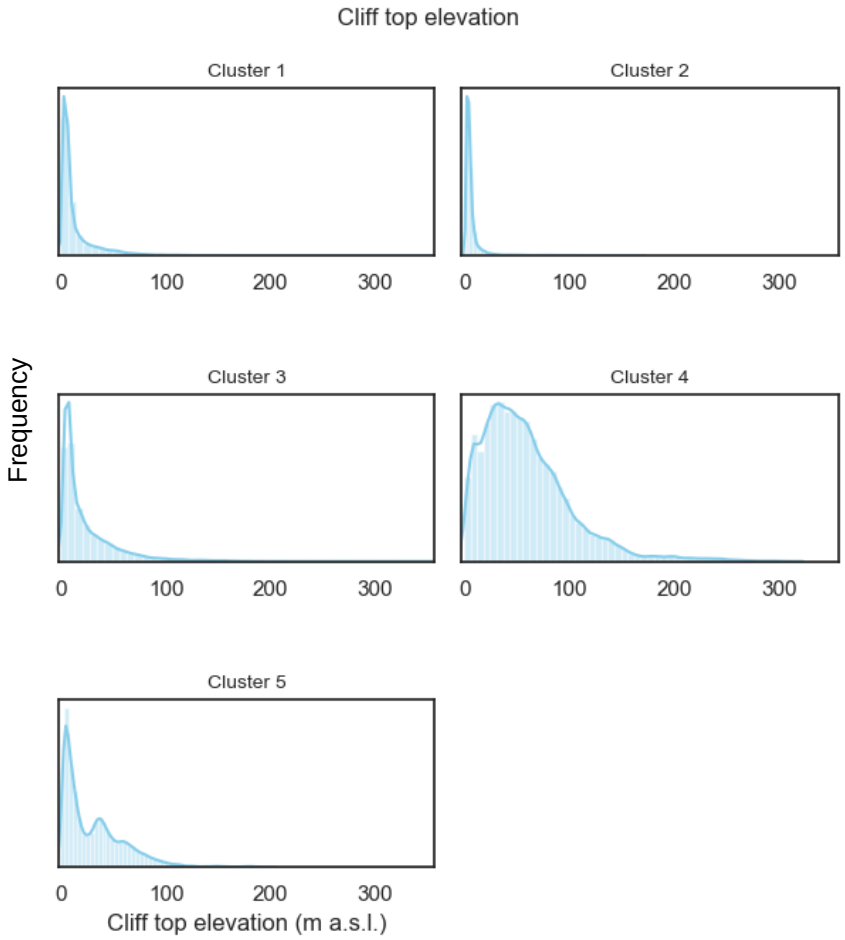
- By examining the input attributes a number of observations can be made;
  - Cluster 1 – predominantly stretches of the coast with low or flat relief and wide intertidal and coastal zones which are backed by low, weak and easily erodible cliffs.
  - Cluster 2 – predominantly stretches of the coast very wide intertidal zones, high tidal ranges and either low or no cliffs. Where the cliffs are present they are usually weak and erodible.
  - Cluster 3 – dominated by beach environments with a moderately wide intertidal zone and backed by no cliffs or by low-medium height cliffs which are commonly weak and easily erodible.
  - Cluster 4 – predominantly stretches of the coast with narrow or no intertidal zone, which when present is either a narrow beach or wave-cut platform, frequently high wave power and wave heights and backed by moderate-high, cliffs which are commonly more resistant to erosion.
  - Cluster 5 – consists of stretches of the coast commonly with narrow intertidal zones, which when present is either a narrow beach or wave-cut platform, and is subject to moderate-high wave power and wave height, and backed by cliffs of variable height and strength.

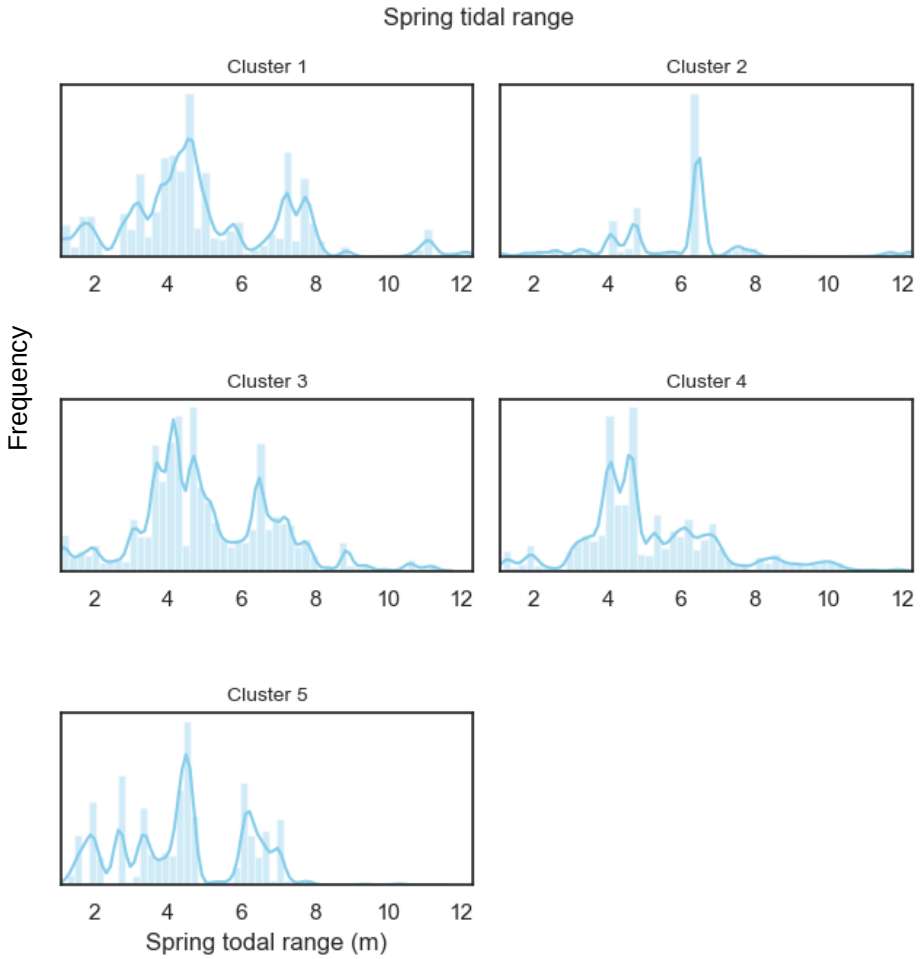
Attribute examples by cluster





Attribute examples by cluster





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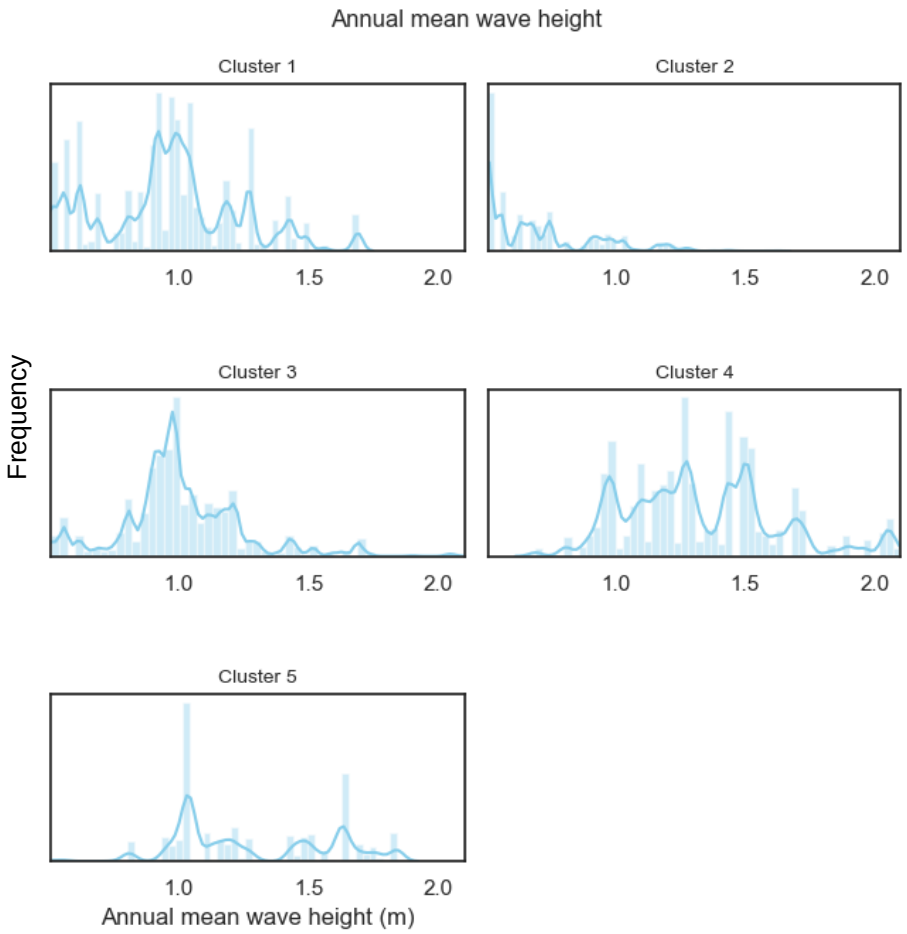
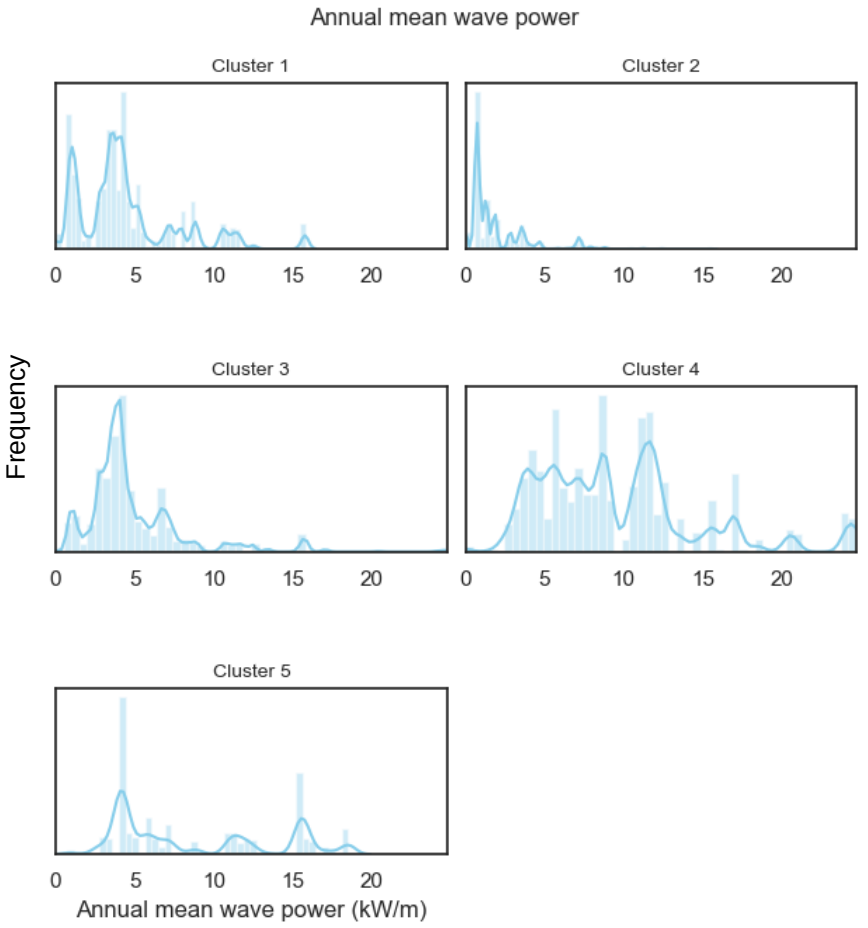
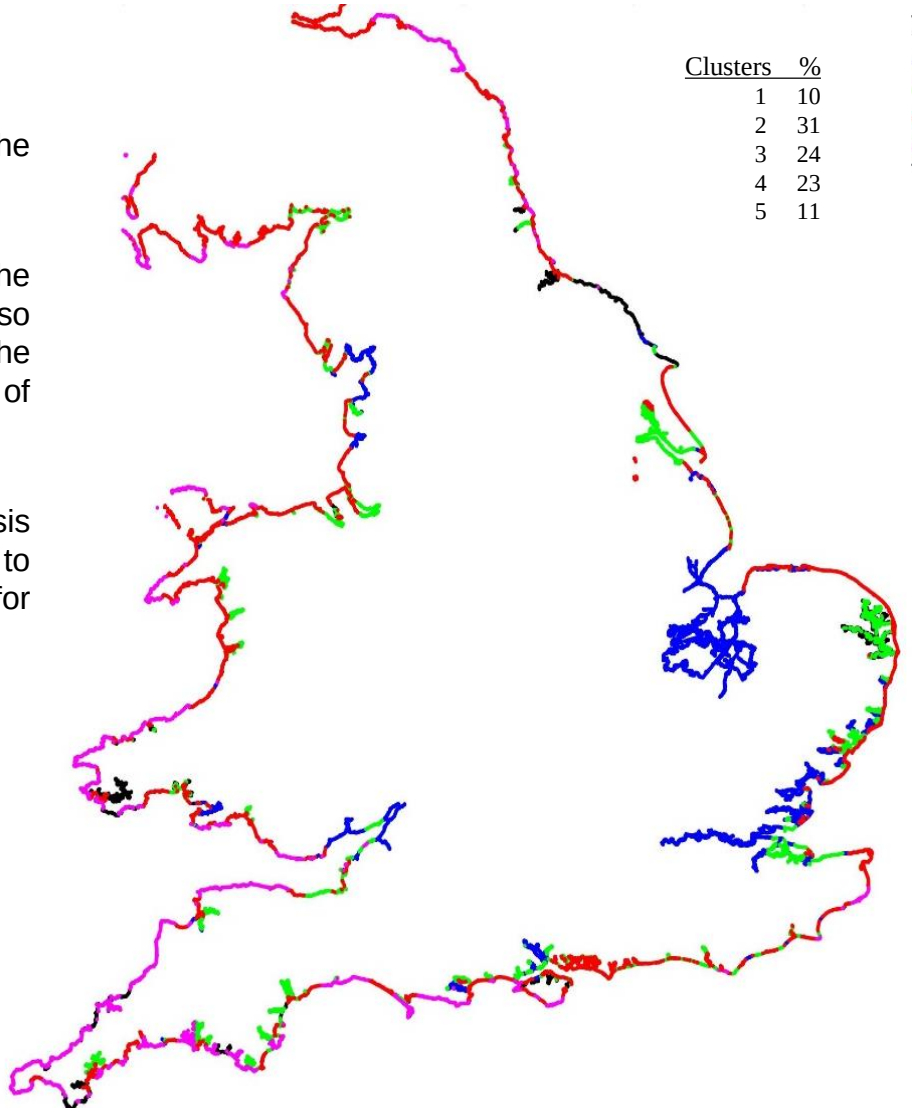




Where Next?

- Completion of other datasets to enables us to add the whole of Scotland into the analysis.
- Re-assess the number of clusters – some of the clusters have wide ranges in some attributes so perhaps there is room for more clusters, or perhaps the clusters which account for the larger percentages of the coast need sub-clustering.
- Expert elicitation of the input attributes and analysis results to build a narrative behind each cluster and to convey the detail in an easy-to-use format for practitioners.



Applications

- The Domains data will allow coastal practitioners to identify regions of the UK coast which have similar characteristics. Applications include;
  - Allowing users to interpret interdependencies of erosion, flooding, habitat and other vulnerabilities
  - Identifying similar coastal environments throughout the UK to understand coastal change and influencing attributes as well as risks from climate change and sea level rise
  - Identifying stretches of coast where similar management policies/practises can be employed and shared
  - Identifying ideal environments or coastal features around the coast for development of infrastructure/industries
  - Inputting into resilience planning strategies and climate adaptation