EXPLORING SPATIO- TEMPORAL WAVE PATTERN USING UNSUPERVISED TECHNIQUE

Rohana, N.A.[*], Yusof, N., Uti, M.N., and Md Din, A.H.

Geoinformation, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, Johor, Malaysia – tikahrohana88@gmail.com, norhakim@utm.my, amihassan@utm.my, nizam1694@gmail.com

KEY WORDS: Significant wave height, Spatio-temporal patterns, clustering, Satellite altimetry

ABSTRACT:

The sea waves are the up and down movements of water in the sea. The various heights of sea waves are known as significant wave heights. Each type of wave has their own characteristics based on their significant wave heights. The aim of this research is to explore spatio-temporal wave patterns and their effects on Tok Jembal coastal areas. For this study, the monthly wave data were obtained from the satellite altimeters that have been processed using Radar Altimeter Database System (RADS). The Self Organizing Map (SOM) method was used to extract the spatio-temporal wave height patterns from the monthly wave height data. From the clustering results, six number of clusters were extracted and then each of these clusters was categorized into specific type of wave heights. In addition, time series of Landsat satellite images were used to observe the coastal changes at Tok Jembal areas. Finally, we analyzed the effects of spatio-temporal wave patterns towards the occurrences of coastal erosion along the coastal areas. This study has discovered that the wave heights along the coastal areas fall in slight category and showed less effects on the erosion. From the visual interpretation of time- series images (10 years gap) also proved that the erosion can be considered as moderate. Overall, this study could benefit the coastal management especially for shoreline monitoring where early action can be taken when there are signs of erosion along the coast.

1. INTRODUCTION

Waves at the surface of the ocean are among the most impressive sights that nature can offer. From the shore, we can notice that the waves are changes all the times. It is mainly caused by wind blowing across the surface of the ocean (Kudela, 2006). Waves form as wind blows over the surface of open water in ocean, causing the waves to moves in various directions, wavelength, height and period. Hence, these behaviors will be resulting different types of wave patterns (Balasubramanian, 2016). Each of the wave patterns has their own characteristics which can be grouped according to the wave height in meter (Table1).

Table 1: Type of Wave Patterns (MetService)

No.	Height (m)	Types	Image
1.	No Wave	Calm (Glassy)	
2.	0 – 0.2	Calm (Rippled)	
3.	0.2 – 0.5	Smooth	
4.	0.5 – 1. 25	Slight	
5.	1.25 – 2.5	Moderate	
6.	2.5 - 4	Rough	

https://doi.org/10.5194/isprs-archives-XLII-4-W16-543-2019

7.	4 - 6	Very Rough	
8.	6-9	High	
9.	9-14	Very High	
10.	14+	Phenomenal	

The first type of wave is glassy with 0 m of wave height and the sea condition of this type is flat. The wave height for the second type of wave ranges from 0 – 0.1 m and the sea condition is ripples without crests. For this type, the sea has small wavelets with crests of glass appearing but not breaking. The slight type of wave has wave heights ranging from 0.5-1.25m where there are large wavelets found on the surface of the sea with the crests beginning to break. For the wave heights of 1.25 – 2.5 m, this type is called moderate with fairly frequent whitecaps occurring and the waves are small with breaking crests, while a rough type of wave has wave heights of 2.5 – 4m.

The very rough type of wave has wave heights ranging from 4 – 6 m and the sea heaps up. Some foam that occur from the breaking waves is blown into streaks along the wind direction. As for the high type, the waves have breaking crests and blown along the wind direction while the very high type of wave has very large patches of foam that can be spotted which cover most of the sea surface. Lastly, the phenomenal type of wave consists of huge waves with the sea completely white with foam and spray. Due to the various characteristics of waves over time and space, hence, it is important to understand how the waves generate their movement as well as their effects to the environment especially along the coastal areas. Thus, spatio-temporal of wave patterns can be used to characterize the waves' behavior across the large ocean surface.

Clustering is one of the unsupervised methods that divide a dataset into groups or cluster. Each group consists of members that are similar as possible to one another while different groups are dissimilar from one another (K.Popat, 2012). There are several methods in clustering technique such as hierarchical, k-means, spectral clustering, self-organizing map (SOM) and density-based clustering. In this study, we have used clustering technique for exploring spatio-temporal wave patterns. The extracted wave patterns can give a great benefit especially to the coastal management for understanding the changeability of wave behavior. Furthermore, the clustering results can be converted into geographical maps for visualizing their distribution over space and in time. From these maps, we are able to monitor the wave behavior that leads to a better understanding of their impacts to the surrounding areas. Understanding wave pattern is essential because wave is one of the primary source that lead to coastal erosion (York, 2015). Therefore, extracting patterns over space and time from wave data can represent specific wave characteristics.

However, wave is highly changeable over space and time, thus identifying wave characteristics is challenging, and yet essential task. Previously, most studies have focused only on spatial patterns for mapping waves. (Sparavigna, 2012) have used satellite images to visualizing wind wave patterns. This study has used image processing methods with high resolution data to identify the type of waves. (Barbariol et al., 2016) have used self-organizing map (SOM) technique for clustering wave patterns, however this technique do not provide geographical mapping to visualize the wave patterns distribution. Other study such as (Fourie, June 2015) have shown the impact of sea wave by identifying the shoreline changes from year 2003 – 2014 due to the coastal erosion.

However, specific study on wave impact to coastal erosion using clustering technique is limited. Therefore, a specific clustering technique was proposed in this study and focused on these following objectives; 1) to identify spatio-temporal of wave patterns using unsupervised geospatial technique, 2) to characterize the spatial-temporal waves patterns into wave categories and visualize them over space and time, and 3) to correlate the obtained wave patterns with shoreline changes (i.e. erosion) in selected coastal areas.

The finding of this study could provide benefit to the coastal management application through analyzing the changeability of wave patterns and their impact to the shoreline changes. In addition, the generated wave patterns can cover large areas, which could facilitate the coastal management to monitor changes that occur along the shorelines. The finding also helps the coastal management to alert public if the coastal area is unsafe for conducting activities.

2. METHODOLOGY

This study comprises of four main phases. First, the wave data were produced from the satellite altimeter using RADS program. In phase 2, Self Organizing Map (SOM) method was used to perform the spatio-temporal clustering. Then, in phase 3 we characterized the generated wave clusters into spatio and temporal components. Finally, these wave patterns were visualized in time-series of geographical maps and analyzed their effect to coastal erosion.

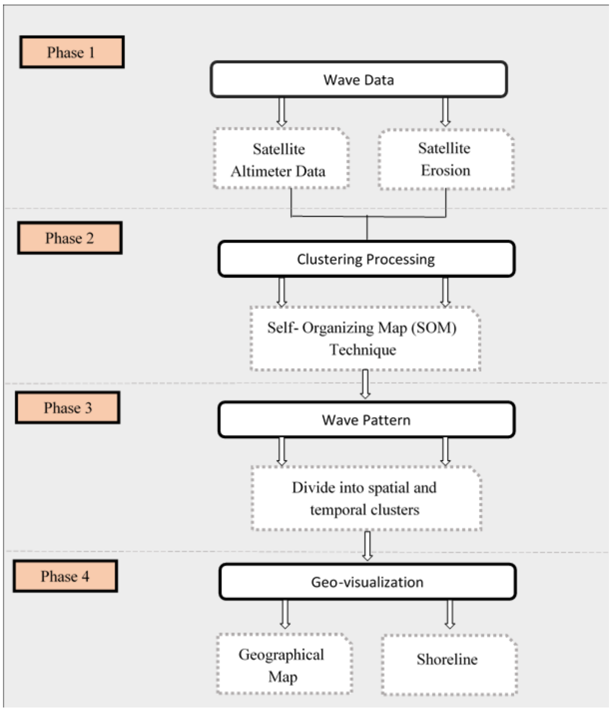

Figure 1: Flow Chart

2.1 Wave Data Preparation

Wave data can be collect and measured with different approach such as from the laser altimetry, acoustic altimetry and radar altimetry. For this research, we focused on remote sensing technique which is laser altimetry. Radar Altimeter Database System(RADS) is a system produce by NOAA laboratory with the collaboration of Delft Institute for Earth-oriented Space Research (DEOS) for satellite altimetry.

For this study, RADS software is used to process the satellite altimeter data (Naeije et al., 2000). The RADS software extracted the wave data from a single mission altimetry data and stored them into daily and monthly resolutions. The satellite images of the study area are downloaded from the USGS website in four consecutive years, 2005, 2006, 2017 and 2018. For this study, Tok Jembal Beach, Terengganu was selected to specifically observed the impact of wave patterns on the coastal erosion occurrences.

2.2 Clustering Process

In this study, the SOM method was used for extracting wave patterns. For this, MiniSOM was used for producing the spatio-temporal wave patterns. MiniSOM is a python based implementation of the SOM and it is.

An open source package that is compatible with python 3.5 and above. To use this MiniSOM, the monthly wave data were organized into a 2D matrix for each month. The row and column of this matrix are representing the samples and monthly wave data, respectively. There are several parameters need to be comprise the element of x and element of y which is the row, column and dimension of the number data itself.

2.3 Spatio-Temporal of Wave Patterns

The obtained clusters in each month represent the spatio-temporal wave patterns in the study area. These wave patterns were further analyzed to gain insight of wave behavior. Next, we computed the mean wave height for each of the generated clusters in order to determine the type of wave category.

For visualization purpose, these clusters were assigned with discrete colors. Figure 2-13 shows the cluster maps for each month. For instance, the computed means for each cluster is referred to the wave categories in Table 1.

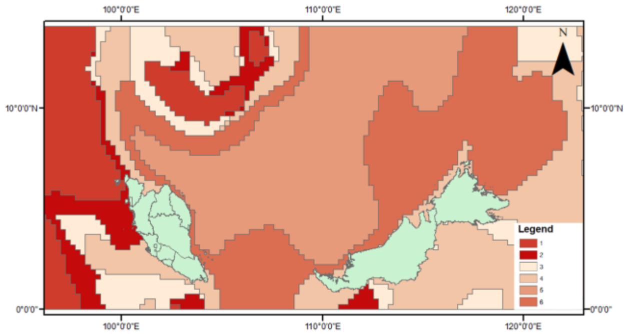

Figure 2: Map of Cluster on South China Sea in January

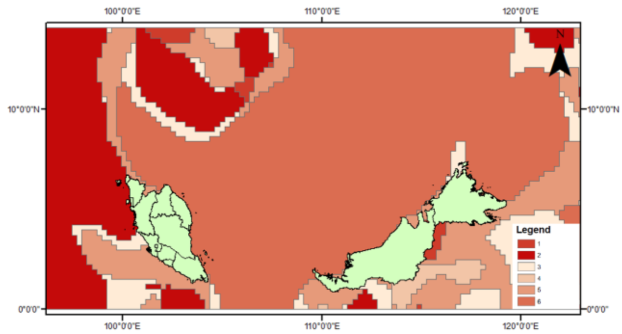

Figure 3: Map of Cluster on South China Sea in February

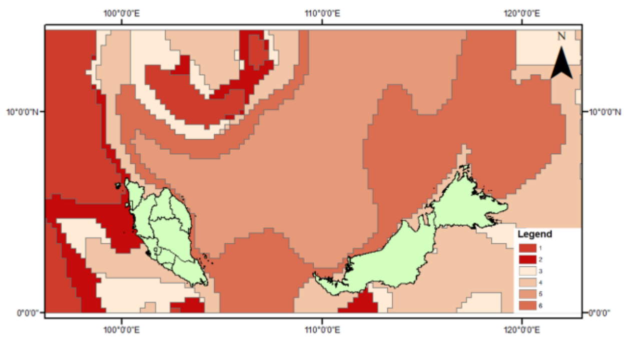

Figure 4: Map of Cluster on South China Sea in March

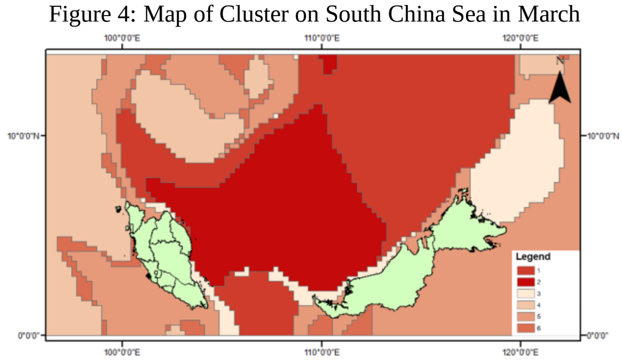

Figure 5: Map of Cluster on South China Sea in April

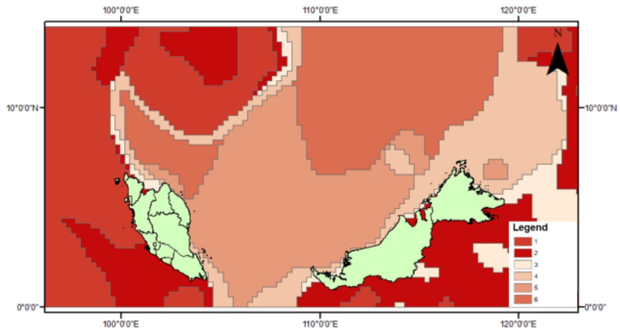

Figure 6: Map of Cluster on South China Sea in May

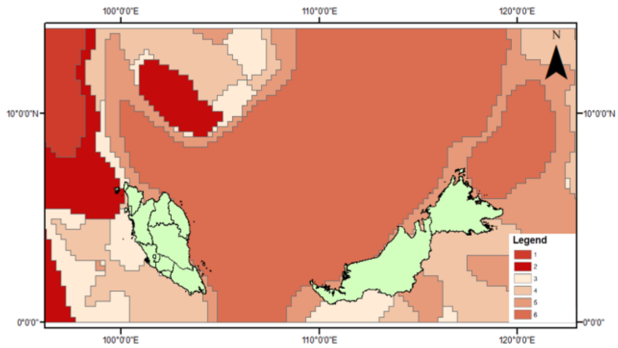

Figure 7: Map of Cluster on South China Sea in June

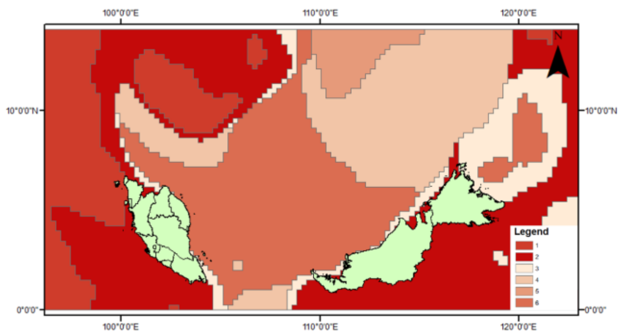

Figure 8: Map of Cluster on South China Sea in July

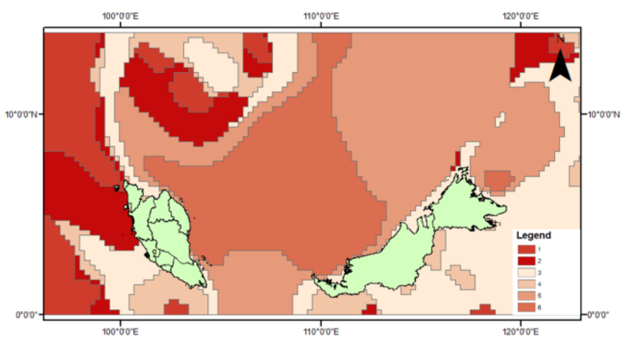

Figure 9: Map of Cluster on South China Sea in August

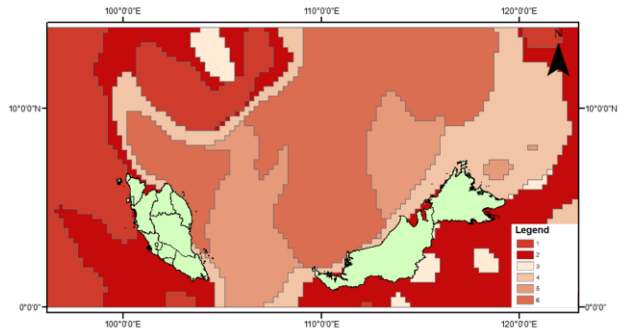

Figure 10: Map of Cluster on South China Sea in September

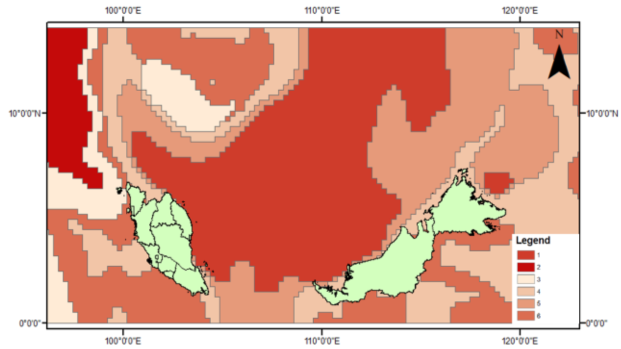

Figure 11: Map of Cluster on South China Sea in October

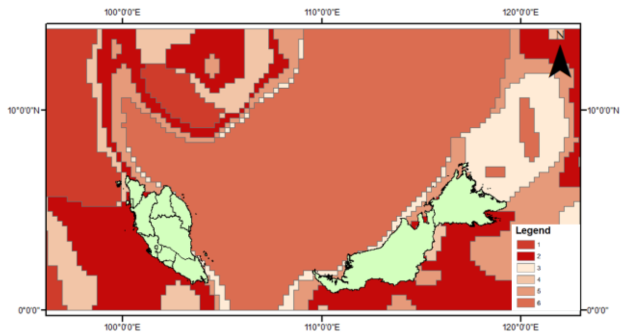

Figure 12: Map of Cluster on South China Sea in November

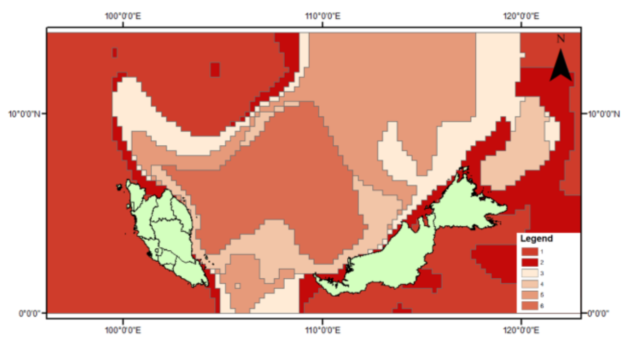

Figure 13: Map of Cluster on South China Sea in December

2.4 Geo-Visualization

Geo–visualization is used for visualizing the spatial and temporal components of wave patterns. The generated geo-visualization can aid users to interpret the wave characteristics based on the geographical phenomena that are visible from the patterns. Next, the generated wave patterns maps were intersected with the selected coastal area for identifying the effect of wave patterns to shoreline erosion at Tok Jembal.

3. RESULTS AND ANALYSIS

The results obtained from the clustering process are shown in Table 2. Table 2 shows all the average wave height based on the wave clusters. Each cluster is referred with the types of wave in Table 1. From Table 2, we can observed that cluster 1 to cluster 4 are belong to slight categories. Even though these clusters have a similar characteristic, their spatial distributions are located at difference spots. For cluster 5 and cluster 6, they are considered as moderate wave category. The highest average values in cluster 5 are in January, March and December. For cluster 6, highest average wave heights are in January, February and December. This quite similar wave behaviour is due to east coast monsoon that occurred between mid-October until the end of March.

Table 2: Time Series Cluster

Month/Cluster	1	2	3	4	5	6
January	0.828806	0.76969	0.787942	0.900236	1.960061	1.333368
February	0.661833	0.758009	0.779071	0.8224	0.823663	1.316907
March	0.796435	0.728931	0.746615	0.840917	1.141806	0.873411
April	0.873411	0.741061	0.772187	0.846655	0.764337	0.790333
May	1.039992	0.798549	0.701456	0.650308	0.604532	0.754222
June	0.754222	1.344976	1.344976	0.896632	0.737809	0.78691
July	1.444671	0.812048	0.749984	1.124343	1.304615	0.785478
August	1.472	1.011739	0.783364	0.842167	1.015087	0.885467
September	1.210955	0.809037	0.720889	0.764372	0.806717	1.008566
October	1.142603	1.107125	1.177694	0.79147	0.949072	0.80432
November	0.961655	0.811322	0.860618	0.862182	0.823132	1.451086
December	0.830583	0.925159	1.373024	1.452472	2.1595	2.018804

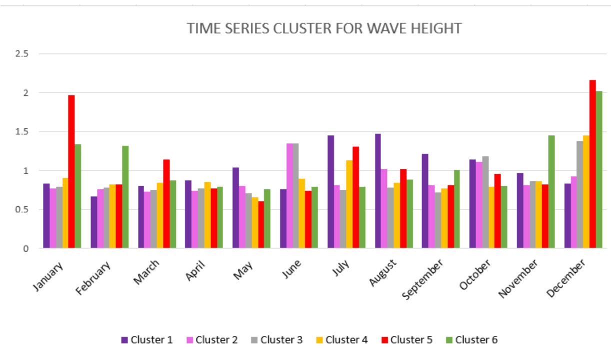

Figure 15: Time Series Cluster Plot

The figure 16 show the evidence of erosion occurrences in year 2005, 2006, 2017, 2018 and 2019 respectively. Comparison between these years is shows in table 3. Between 2006 and 2017, we have identified a large change on the shoreline where the offset from the original shoreline is 18.16m. This offset may be effected by the construction of Sultan Mahmud Airport that was started in 2005 until 2008.

Year	Offset(m)	Difference
2005	86.448508	-
2005-2006	89.692973	3.244465
2006-2017	107.854632	18.161659
2017-2018	111.551494	3.696862
2018-2019	113.659813	2.108319

Table 3: Comparison of shoreline changes from 2005 to 2019

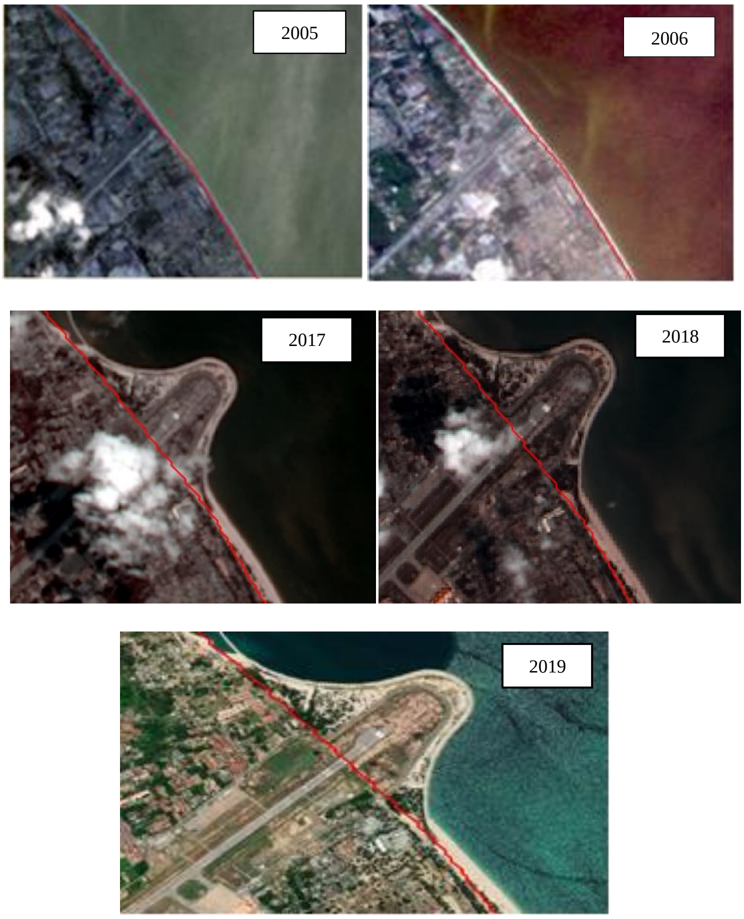

Figure 16: Satellite Image in 2005 to 2019

In Table 4 shows the result of time series wave clusters for Tok Jembal Beach. This study focused on Tok Jembal Beach because there were several erosion studies have been conducted at this study are (Yanalagaran, 2018). After we analyzed the wave patterns in Tok Jembal Beach, we found that the average heights for wave patterns are not too high throughout the year. The highest wave height over the time series is in cluster 6 which is 1.6m height and belong to moderate category. This event is mostly due to east coast monsoon that occurred from mid-October to the end of March. Figure 17 shows time series of wave patterns along the shoreline in Tok Jembal Beach. The highest wave was recorded in December (Figure 17). Figure 18 shows the wave patterns distribution in Tok Jembal Beach.

Table 4: Time Series Cluster for Tok Jembal Beach

Month/Cluster	1	2	3	4	5	6
January					1.510111	1.206
February						1.102
March					0.85	0.791
April	0.541	0.597889				
May				0.6865	0.5158	
June						0.580636
July						0.7085
August					0.774667	0.689778
September					0.6614	0.6164
October	0.7745				0.71	
November						1.0818
December				1.33325		1.682

https://doi.org/10.5194/isprs-archives-XLII-4-W16-543-2019

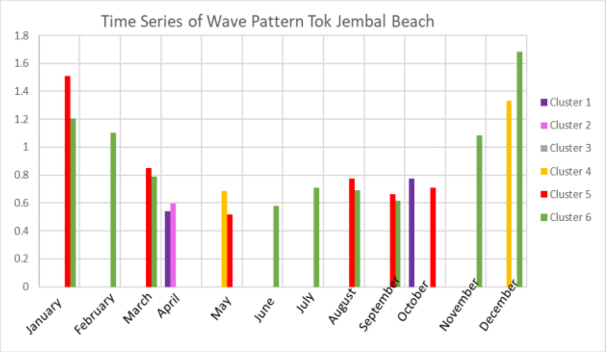

Figure 17: Time Series of Wave Patterns at Tok Jembal Beach

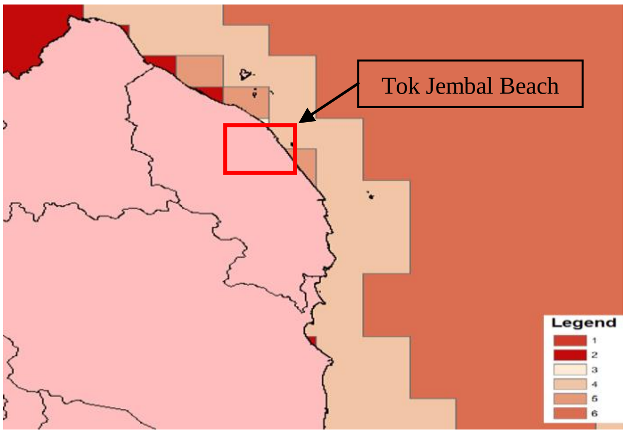

Figure 18: Cluster Map in December for Tok Jembal Beach

4. CONCLUSION

From this study, we have identified that the wave heights are mainly belong to slight and moderate categories throughout the study period. Furthermore, based on Table 3 we can observed the coastal erosion that occurred at Tok Jembal Beach only experience slightly changes according to the shoreline offset from the reference shoreline boundary. Besides wave, this erosion may also influenced by the rapid development that was established around the coastal area.

ACKNOWLEDGEMENTS

The authors wish to acknowledge TU Delft Radar Altimeter Database (RADS) and ICF research grant (vote number R.J130000.7901.4S142) for funding this study.

REFERENCES

Balasubramanian, 2016 The ocean waves.

Barbariol, F., Falcieri, F.M., Scotton, C., Benetazzo, A., Carniel, S., Sclavo, M., 2016. Wave extreme characterization using self-organizing maps. Ocean Science 12, 403-415.

Fourie, June 2015. The influence of wave action on coastal erosion along Monwabisi Beach, Cape Town.

K.Popat, S., 2012. An Overview On Clustering Methods
Kudela, 2006. Ocean Waves.

Naeije, M., Schrama, E., Scharroo, R., 2000. The Radar Altimeter Database System project RADS. 2, 487-490.

Sparavigna, T., 2012. Internal waves and vortices in satellite images Department of Applied Science and Technology.

Yanalagaran, R., 2018. Assessment Of Coastal Erosion Related to Wind Characteristics In Peninsular Malaysia.

York, G., 2015 Coastal Processes and Causes of Shoreline Erosion and Accretion.

Revised August 2019