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Abstract

This research is focused on creating visualization methods for the dynamics in the Shoreface. For this it uses the JARKUS dataset. This JARKUS data contains the height measurements by high precision bathymetry of the dunes, beach and underwater shoreface. In order to show the development of the height elevation over time for the period 2000-2010 the research focuses on the location of areas with a lot of dynamics. This research only focuses on the north coast of Ameland. The Dutch practise of water management is an important factor for the analysis and visualization of the dynamics. This research targets to add value by elaborating on the location of the dynamics and not on the coastal profiles.

The objective of this study is to develop and test a visualization to show the morphologic dynamics of the shoreface. Where there are options to focus on line or field object this report is focused on the evolution of the height dynamic of point locations. The problem to tackle is how to *visualize the dynamics of the shoreface morphology*. The fact that the research is focused on the underwater dynamics leads to a difficulty. The area is highly influenced by several natural and artificial processes. Where the land morphology is seen to be quite solid, the dune, beach, and shoreface are constantly developing. Also the multidimensional aspect of the JARKUS data is of influence on the research.

The questions that are central in this research are:

1. What morphologic features in the shoreface are of interest?
2. What dynamics are present in the shoreface of north Ameland?
3. How to visualize the dynamics of the shoreface?
4. How are the dynamic visualizations understood?

The research starts with a literature review of the coastal morphological phenomena and dynamics to answer the first research questions. The first question is about the morphological features that exist in the shoreface of the Dutch coast. This is followed by the identification of the dynamics of the shoreface and the processes that influence the situation on Ameland. It is identified that the morphological features in the shoreface that are of interest on de mid-term timescale are the longshore bars and rip channels. The development of these elements under the influence of the natural and artificial circumstances can be shown by displaying the dynamics in height over time.

The second part of the research, question three and four, focus on a more practical approach. First there is elaborated on the influence of different graphic parameters on the perception of maps. Then in order to visualize the data, the JARKUS data has been preprocessed. This includes, interpolating the coastal profiles, normalization, and classification of the data, and the transforming of the raster to a vector dataset with point data. The resulting visualizations are coded with the use of the CARTO library and the TORQUE function. The JavaScript libraries of these products are used and adjusted to create the animated maps. The creation of digital and animated maps is one of the possibilities that digital mapping allows and is analysed under the circumstances of perception and change blindness. Mapping theories indicate that new visual variables arise when the maps are created for digital purposes and not only for print only maps. One of these is the blinking that is used for the maps. Next to the blinking variable the maps are created with variation on the aggregation method, spatial resolution, colour use, and size. This results in eighteen visualizations. Three of the visualisation are presented in an usability test to check whether the expectations meet the reality. The test made clear that some maps are better to be used in the identification of the dynamics in an area and others are better to identify a spatial-temporal pattern. The testing of the visualizations leads to the conclusion that: A blinking map can help in the identification of the locations of the dynamics and in the identification of the spatial-temporal pattern. It however still remains a difficult task to use the correct graphic variables to display the development over time. Based on the visualization of the height dynamics a step is made to fill the research gap of the analysis of the dynamics of underwater morphological objects.

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Throughout the research I have had some moments where I thought: how will I ever finish this project? It was growing way out of scope and there were so many possibilities to work out and go into. I have learned that it is difficult to make some decisions but that it is necessary to remain an overview into the extent of the research.

TABLE OF CONTENTS

ABSTRACT **3**

ACKNOWLEDGEMENTS **4**

LIST OF TABLES & FIGURES **7**

TABLES 7
FIGURES 7

CHAPTER 1 - INTRODUCTION **8**

1.1 INTRODUCTION 8
1.2 CONTEXT 8
Visualization to Whom *9*
Visualization of What *9*
Visualization How? *9*
1.3 RESEARCH QUESTIONS 10
1.4 READING GUIDE 10

CHAPTER 2 - THEORETICAL FRAMEWORK **11**

2.1 JARKUS DATA 11
2.2 UNDERWATER SHOREFACE MORPHOLOGY 12
2.3 SHOREFACE DYNAMICS 13
2.4 VISUALIZATION METHODS 15
2.4.1 Static maps *15*
2.4.2 Dynamic and animated maps *15*
2.4.3 Virtual Geographic Environments (VGE's) *15*
2.4.4 Online Mapping *16*
2.4.5 Graphs *16*
2.4.6 Harmonization of the data *16*
2.4.7 Interpolation methods *17*
2.4.8 Perception blindness *18*
2.4.9 Bertin's image theory *18*
2.5 CONCLUSIONS 20

CHAPTER 3 - METHODOLOGY **21**

3.1 VISUALIZATION OF THE DYNAMICS 22
3.1.1 Preparation of the data *22*
3.1.2 Visualization Scripts *24*
3.2 EVALUATION OF VISUALIZATION METHODS 27

CHAPTER 4 - VISUALIZATIONS & USABILITY EVALUATION **29**

4.1 VISUALIZATIONS 29
4.1.1 Aggregation method *29*
4.1.2 Spatial resolution *29*
4.1.3 Marker size variation *30*
4.1.4 Colour variation *31*
4.1.5 Combined colour and marker size variation *32*
4.1.6 Blinking element *33*
4.2 USABILITY EVALUATION 34
4.2.1 Identification of the dynamics *34*
4.2.2 Spatial-Temporal pattern *35*

CHAPTER 5 - CONCLUSIONS **36**

5.1 CONCLUSION 36
5.2 DISCUSSION, REFLECTION, RECOMMENDATIONS 37

6. BIBLIOGRAPHY **40**

7. APPENDICES **45**

7.1 MODEL BUILDER IMAGES 46
7.2 FILE NAME EXPLANATIONS 48
7.3 EXAMPLE CARTO SCRIPT 49
7.4 ALL IMAGES OF THE RESULTS 51
7.5 USABILITY TEST RESULTS 58

List of Tables & Figures

Tables

Table 2.1.1	*The different measurement techniques and periods*	*p. 12*
Table 3.1.1.1	*Harmonization example*	*p .23*
Table 3.1.1.2	*Reclassification*	*p. 23*
Table 3.1.2.1	*Visualisation parameters and variables*	*p. 26*
Table 3.2.1	*Allowed answers for the first question per map*	*p. 28*
Table 3.2.2	*Allowed answers for the second question*	*p. 28*
Table 3.2.3	*Percentage of a certain class in a certain area*	*p. 28*
Table 4.2.1	*What dynamics are visible in an Area according to the respondents*	*p. 34*
Table 4.2.2	*What spatial-temporal patterns is visible in an Area according to the respondents*	*p. 35*

Figures

Figure 2.1.1	*Cross-section of the coastal profile (Minneboo, 1995)*	*p. 11*
Figure 2.3.1:	*Situation on the North-West side of a Ameland*	*p. 14*
Figure 2.4.1:	*Example of the JARKUS data (Deltares, 2016)*	*p. 17*
Figure 3.1	*Conceptual model*	*p. 21*
Figure 3.1.1.1	*Examples with (left) and without (right) data harmonization*	*p. 23*
Figure 3.1.2.1	*Visualization Structure*	*p. 24*
Figure 3.1.2.1	*Code example of colour and marker size for the 50x50m grid in a selection of the research area*	*p. 25*
Figure 3.1.2.2	*Code example of the blinking effect*	*p. 26*
Figure 4.1.1.1	*50x50 Visualization with a cumulative aggregation method using marker size variation and 50x50 grid*	*p. 29*
Figure 4.1.2.1	*Linear visualization of a part of the area with use of marker size and colour variation using a 50x50 grid*	*p. 30*
Figure 4.1.2.2	*Linear visualization of a part of the area with use of marker size and colour variation using a 10x10 grid*	*p. 30*
Figure 4.1.3.1:	*Linear visualization of a part of the area with a variable marker size using a 50x50m grid*	*p.30*
Figure 4.1.3.2:	*Linear visualization of a part of the area with no use of variation in the visual variables using a 50x50m grid*	*p.31*
Figure 4.1.4.1:	*Linear visualization of a part of the area with a variable colour use using a 50x50m grid*	*p.31*
Figure 4.1.4.2:	*Linear visualization of the whole area with a variable colour use using a 50x50m grid*	*p.32*
Figure 4.1.5.1:	*Linear visualization of the total research area with use of colour and marker size variation using a 50x50 grid*	*p.32*
Figure 4.1.6.1:	*Visualization of the total research area with use of colour and marker size variation using a 50x50 grid*	*p. 33*

Chapter 1 - Introduction

1.1 Introduction

In the Netherlands water management is a crucial element of the daily life. Controlling the water can be seen as an important part of the Dutch culture. In order to manage the water properly a lot of data in needed and the Dutch coastline is monitored very closely for a long period of time. Since 1963 the monitoring is done in a structured way based on fixed measurement points along the coast, so called transects. The height measurements of the transects are stored in a public database called the JARKUS data (*'Jaarlijkse Kustmetingen'*). This JARKUS data contains the height measurements by high precision bathymetry of the dunes, beach and underwater shoreface. It is used to create a profile of the coastline. The use of bathymetry allows for the analysis of the dynamics of the shoreface (Bakker, 2013). The JARKUS data is a time series dataset with annual measurements for more 53 years. By combining the measurements for all transects a full coastal profile is created. The coastal profile is of importance for the protection of the hinterland. All the elements of the coastal zone are of influence on the water management. Changes are monitored, predictions are made and the area is controlled. The shoreface, the part of the sea that begins from the coastline until approximately one kilometre sea inwards, is not visible because it is underneath the seawater. This does not mean that there are no important elements in this submarine area. Currents, tidal flows and waves influence the area and change the morphologic pattern of the seabed. Being able to make a good analysis of these patterns can help in the creation of models and to make predictions for future coastal profile developments and management tactics. The objective of the study is to develop and test a visualization to show the morphologic dynamics of the shoreface given the JARKUS time series data.

To create this visualization first the broader background of the problem is explained and the research questions are discussed. This is followed by a literature framework where some of the key concepts are worked out. After which the used methodology is discussed leading to the results and ending with the conclusions and discussion.

1.2 Context

The dynamic structure of the coast can be predicted based on historic developments and spatial models. In order to create these models the situation has to be measured. Typically applications to monitor the development of the earth environment create large amounts of data. This also is the case when monitoring the Dutch coastal profile. The results are for instance saved in the JARKUS data that is central in this research. The large amounts of data describe the changes in time and space of a certain physical phenomenon. This data can be observed and analysed but this requires visualization methods to make it more easily comprehensible. Especially the temporal aspect of the data gives need for innovative ideas and methods (Koussoulaka, 2013, pp 243-245).

So Visualization methods are needed but what exactly is meant by this? An interesting question about visualization is stated by Koeman: 'How do I say What to Whom'. This question can be used for defining visualization methods (Koeman, 1971; Koussoulaka, 2013). The targeted use of the map is the critical factor in creating visualizations. So it is necessary to know for whom the map is created, who are the users. The second crucial element of a map is the what. What is the map about and what information does it need to give (Koussoulaka, 2013). Visualization as defined in the Geographic Information Science & Technology Body of Knowledge relates to the visual display of geographical information. It encompasses the problems and ideas of cartography and involves the communication of the geographical information and geospatial analysis results. Visualization not only comprises in cartography but also in other domains (Dibiase, 2006). In definition al the map creations can be seen as a way of visualization. In essence the whole cartography domain is about visualizing information (Maceahren, 1997). According to Kraak (2010) visualization is applied with four different objectives.

These are: to explore, to manipulate, to synthesize, or to present the data in well-designed maps under the rules of the cartography design discipline. Thus in order to create visualization or answer the 'How' in Koeman's question, first the whom and what parts have to be filled in.

Visualization to Whom

As just mentioned the Who part of the visualization question is a very important one before coming to the how part. The who part are the users of the data. Users can be distinguished on how they want to use the map, what information do they want to obtain from the map. This depends on what information is important for the function that the users has. It is useful to know the educational level or capabilities of the users with the respect to maps and the information task.

Several different types of users can be interested in the development of the coastal zone. This could for instance be the locals that are interested in the development of the coast in order to know where dangerous gullies are. Otherwise these could be researchers that are interested in the development of coastal zones. Or policy makers that are required to make choices about the water management. The target group for this research is those with some experience in GIS with the capabilities to understand maps but that do not have expert knowledge about the processes and the area. This leads to the question of How do I say What to "experienced mappers with no background in the research area".

Visualization of What

The second variable part is the What. This needs to be determined before starting to make any visualization. Based on the JARKUS data several options can be chosen. Visualizations can be focused on the extraction of morphological objects, such as gullies and show their presence and location or their development over time. Another option is to focus on the actual height of the surface and the development over time. Or to focus on the locations where a lot of change is present. The last one is central in this study. So the question can be extended to: How do I say "Where on the Northshore of Ameland are the points with a lot of height dynamics" to "experienced Mappers with no background in the research area". This part will be elaborated on further in later parts of the report.

Visualization How?

Under the influence of computer technology the possibilities for visualizations of (geographic) information are ever increasing, from basic static representations with the use of simple symbols, to more advanced options. These increased possibilities combined with an increased popularity of maps and an increased demand for virtualizations of information allow to broaden the perception of the where question of the geographic features in the daily life (Lin, 2013). In order to let the viewer really understand what is shown the designer needs to make decisions on the visualizations. The Mapmaker needs to determine what the map is trying to tell, not everything can be visible in a single map. Choices have to be made and some kind of cartographic grammar followed. In addition to the representation of spatial information an extra dimension makes the situation more complex. In this case the temporal aspect creates a more difficult situation as the traditional graphic variables need to be changed to show the change over time (Kraak, 2010, p. 154). These new variables can be dynamic when a digital map is created. Some general ways to present spatial information are discussed in the section about visualization methods (2.3). The use decisions on the use of the visual variables leads to the final part of the visualization question: How? This is the main objective in this study and the How part of the visualization question as given by Koeman is the product of this study.

The **objective** of this study is to develop and test a visualization to show the morphologic dynamics of the shoreface. The **problem** to tackle in this research is how to *visualize the dynamics of the shoreface morphology*. It is interesting to have a research on this topic because existing reports mainly focus on the analysis of coastal profiles. Based on the visualization of the height dynamics a step might be made to fill the research gap of the analysis of the dynamics of underwater morphological objects. This report is focused on the evaluation of the height dynamic of point locations. Extended research can go into the gap to look at contour line or field objects to study the visualization techniques of morphological development of the shoreface. The fact that the research is focused on the underwater dynamics leads to a difficulty. The area is highly influenced by several natural and artificial processes. Where the land morphology is seen to be quite solid, the dune, beach, and shoreface are constantly developing. Just like the dunes in a desert, the underwater morphology is subject of a lot of dynamics.

1.3 Research Questions

To come to solution to the research problem and to fulfil the research objective some research question are thought out:

5. What morphologic features in the shoreface are of interest?
6. What dynamics are present in the shoreface of north Ameland?
7. How to visualize the dynamics of the shoreface?
8. How are the dynamic visualizations understood?

The first question is about the morphological features that exist in the shoreface of the Dutch coast. It is based on a literature review about (underwater) morphological features and an analysis of the JARKUS data.

The second research question analyses on the dynamics of morphological features in the area. It is for instance focused on the movement of the features, the emergence or disappearance of the features, or the change in size of the features.

The third question discusses ways to visualize change. Based on the theories and visualization rules relevant options are picked and some visualization of the features are created. The final goal is to test the visualizations of the features in order to compare the different visualization methods. The approach to answer the research questions and a conceptual model of the coherence between the researches questions are discussed in the third chapter of this report.

1.4 Reading Guide

In the next sections of this report first (chapter 2) there is elaborated on the relevant principles of underwater morphology, its dynamics, and principles of Geo-visualization. This leads to a broader understanding of the concepts that are of interest. In the following Chapter 3 the methodology is worked out. It explains the approach of the research, which steps are performed and which choices are made to create the morphological visualizations. The used variables, and preparation steps are explained. Chapter 4 is about presenting the results visualization and discussing the influence of the used visual variables. This all is followed by the last chapter containing the conclusions, discussion and recommendations.

Chapter 2 - Theoretical Framework

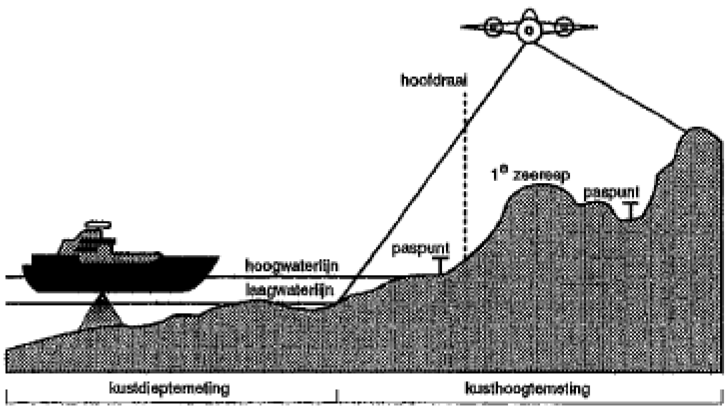
This chapter elaborates on the most important concepts involved in this research. First of all the JARKUS-dataset is described then Geomorphological underwater features of the shoreface are discussed and thirdly the relevant dynamics of these features are worked out. After that a comparison between different visualization methods of (dynamic) geo-information is made. This all is followed by some conclusions on how this information involves the research. The answers to the first two research questions can be found in this chapter.

2.1 JARKUS data

The JARKUS data file is openly available and consists of yearly measurements of the Dutch coast. The data contains the height measurements by high precision bathymetry of the dunes, beach and underwater shoreface. These measurements are combined in transects to create a full coastal profile. These measurements are performed along lines on the coast. The dataset contains information of the coastline since 1965 till now. The goal of the measurements is to be able to use the data to determine the coastline location, to test for security, to study the development of the Dutch coast on the long term and for recommendations regarding coastal management (Minneboo, 1995). The dataset is split in 17 separate areas ('kustvakken') and uses a transects-method ('raaien'). All transects have a unique number. The measurement system consist of a main transect, a straight line with nods, that follows the coastline. Each 250 meter this main transect is crossed by a perpendicular lying measurement transect.

The measurements consist of two variations, the height and the depth measurements, respectively the dry and the wet area of the coast. This is visible in figure 2.1.1.

Figure 2.1.1 Cross-section of the coastal profile (Minneboo, 1995)



There has been some development in the way the measurements are performed (Table 2.1.1). As a result of the evolution of measurement techniques at this moment three different time periods are identified (Wiegmann, 2002). It is important to know the differences in order to determine the usability of a comparison of the elevation from two different time periods.

Table 2.1.1 The different measurement techniques and periods (Wiegmann,2002).

Measurement type	Period
System with radio-positioning and water level	1979 - 1990
System with GPS-positioning and water level	1990 - 2000
System with RTK*-positioning without water level	2000 - Now

**: Real Time Kinematic.*

The most common errors have been eliminated due to the evolution of the measurement systems. There are however three breaks in the data when a new method was introduced. Wiegmann (2002) states that it is not relevant to compare the seabed from the first period with the latest period. This because there has been too much development in the precision of the depth measurements. Since the upcoming of GPS-positioning the precision has improved significantly. The other big difference in the precision of measurements is the use of the water level in the calculations. This is a known source of errors in the earlier years of data collection and there have been corrections of the data. These however do not cover all errors (Wiegmann, 2002*).* The latest period has been selected to be used in this research.

2.2 Underwater shoreface morphology

The details of the morphological features that together form the shoreface are discussed here. It is used to provide an answer for the first research objective to identify the morphological features of the shoreface.
The Dutch coast consists of sand that, under the influence of wind, currents, and waves creates the seabed morphology (Stronkhorst et al, 2010). This natural process is always trying to create a balance. However a real balance is never created, there can be a dynamic balance. There are movements of sand along the coast in a lengthwise way and in a traversed way towards the coastline. Rijkswaterstaat tries to control the sand in order to keep the coastline at the position where it is located now. Human built structures and actions, like sand nourishments, can influence the coastal profile (Van de Rest, 2004). The current policy of coast containment is focused on natural dynamics. In order to maintain the coastline most of the times sand nourishments are used. Sand from the deeper sea is dredged and dumped on the shoreface or the beach and then in a natural way transported along the coast (Dynamisch Kustbeheer, 2016; Rijkswaterstaat, 2000).

Morphological there are four zones of the Dutch coast to identify: The flat seabed, the underwater shore, the (wet and dry) beach and the dunes. Along the coast there is a huge differentiation between the sizes of the different zones. The border between the flat seabed and the underwater shore is determined based on de slope; the location where the slope increases above 1:1000 (Stolk, 1989). On the flat seabed along the Coast of the Netherlands there are two large areas with sand ridges. These ridges are several kilometres long and are between 14-30 meters below NAP. Some of these ridges are connected with the underwater shore (Stolk, 1989). The underwater shore in general starts from -20 meter NAP and has an increasing slope towards the coastline (Mid-Holland shore area from -15 NAP). In the Wadden area in the north and the Delta area in the south the underwater shore is characterized by outer deltas, which exists of sand plates and tidal channels, at the locations of estuaries. In the higher parts the underwater shore typically has several breaker ridges (“brandingsruggen”). The most landward breaker ridge is also part of the ‘Zwin’-morphology of the wet beach and is above the water level during the ebb-tide (Stolk, 1989).

The morphological features that together form the wet beach area of the shoreface are: sandbanks, channels (‘Zwinnen’), rip channel or gullies (‘Muien’) and channel-potholes (‘Zwin-kuilen’). The sandbanks, or longshore bar/ridge, are accumulations of sand on the seabed (Shepard, 1963). They differentiate in size and height and lay parallel to the beach. The sandbanks distinguish themselves by a gradually rising slope on the sea side and a more abrupt end on the beach side. Commonly several sandbanks are present next to each other (Wikipedia, 2016a;

de Zeebaars, 2016). The space between two banks is called a channel pothole ('Zwin'). The deepest area of a channel is called a 'Zwin-kuil'. 'Zwinnen' are typically the spaces between de banks parallel to the beach. The areas cross lying on the beach and between the ends of the sandbanks are called gullies ('Muien'). Through these gullies there is a lot off transport of water, leading to the fact that the heads of the sandbanks can be rigid. The flowing water cuts in the sand. This is especially the case when sandbanks are close to each other; the speed of the water is then higher (Shepard, 1963; Wikipedia, 2016b; de Zeebaars, 2016).

A possible technique to extract features from height data is presented by Wood (1996). Wood uses curvature to identify morphological features, peaks and ridges. (De Smith, 2009) This could be applicable on the JARKUS data to identify specific gullies and ridges. When such a method is used the breakers and channels can be identified and possibly processed over time. A time series of the contour line development could help by tracing the features over a certain timespan. Or the features can be identified as an object by creating fields in the area based on cells with the same value to identify features with the same height. To extract features over time is complicated. Another way of analysing the morphological dynamics of the shoreface is by looking at the locations with change in height. This is a point or cell based approach and this research focuses on the visualization of these locations with high dynamics. This can be used to see change and might assume the movement of certain features. The focus lies on the visualization of dynamics and not on precisely defined objects, such as the mentioned longshore bars or rip channels.

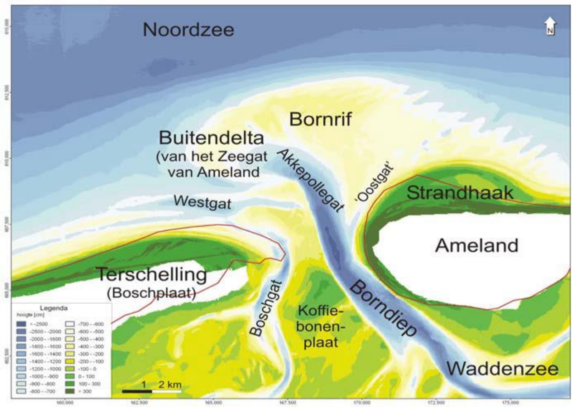
2.3 Shoreface dynamics

As the previous section discussed the question about what morphological features are present in the shoreface area this section discusses the question about the movements of the features. What are the dynamics of the morphological features in the shoreface?
Already mentioned is the fact that the shoreface changes under the influence of wind and water in a natural and artificial way. These are movements along the coast come in a lengthwise and a width direction). These depend on the currents and the weather and create sand waves along the coast with continuous moving erosion and sedimentation zones (Van Vliet, 1994). As the result of the currents and natural conditions the underwater morphological features change. These changes can be identified as movement, or pulsing of the longshore bars and gullies. Pulsing in this case means the growth or decline of a certain feature in a certain year. Naturally it is also possible that features appear or disappear over time. Different time and spatial scales are applicable on changes in underwater shoreface morphology (Stolk, 1989).

On the long term (centuries) influences as seabed rise and climate change are of relevance for the coastal profile. These are not measurable with the JARKUS data. On the Mid-term (± 10-100 years) the natural coast development is also determined by cyclic processes like moving sand waves and relocating rip channels. Some sand waves move an approximate 45 meter each year. The tidal flows create ablation and sedimentation zones along the coast. The fluctuation of these circulations is over an order of several years. Next to the natural changes there is the human interaction (Van Vliet, 1994). This human interaction also influences the area on the mid-long-term and is present in the way of coastal management. On the short term the sand nourishments and direct meteorological influences are most important. These lead to a direct change in the coastal profile (Stolk, 1989). This change in the coastal profile can change on a daily bases on small scale. These very small changes cannot be identified with the JARKUS data. On a somewhat larger scale of at least a year these effect are identifiable with The JARKUS data. The development of a large sand plate as a result of sand nourishments can be followed using the JARKUS data. By following the height changes the movement of such a sand plate can be identified. Also by comparing the height with the height of previous years areas with a lot of dynamic, i.e. change compared to the base measurement, can be identified. The focus in this research is on the location of dynamic and the movement of these locations with high dynamics. This is not based on the exact features that are present on the shoreface but on the surface height changes compared to the base year. So in general the dynamics of the morphological features are discussed but how is the situation on the north side of Ameland?

The mid-long term timeframe of several years is the most interesting for this project. As the JARKUS measurements are only taken once a year the influence of a specific storm to the underwater surface and features aren't be measured. Only an index could be made about the "storminess" of a certain year. The short term natural effects of developing certain gullies that sometime only last for days are not within the scope of this research. The mid-term dynamic focuses on the movement of the more solid elements, the larger gullies and breakers. In de mid-long term the movement of these elements along the coast can be identified. Every year there is dynamic in the area. In general one can speak of a West-East longshore movement of sand along the north coast of Ameland, as is the case for the whole Dutch coastline (van Vliet, 1994). The specific system that is present on Ameland is influenced by the presence of the Waddenzee and the so called Zeegat van Ameland with the Borndiep channel between Terschelling and the west side of Ameland. In this channel a tidal flow is influencing the circulation and development of the morphology on Ameland. There are a lot of researches to the dynamic and development of this channel (Cleveringa, 2005). Every channel of the Wadden-islands has a unique situation. Over time there have been a lot of researches to these channels as it is an important part of the natural dynamic of Ameland. The exact situation of the channel will not be discussed here but it is necessary to know of its presence because of its influence on the coast of Ameland. The North-West area of Ameland is described as a sand plate with a hook and the offshore presence of the Bornrif (Cleveringa, 2005). A part of the beach hook is the most westward part of the research area. The hook on the North-West side of Ameland moves slowly South-Eastward. Under influence of the Bornrif and the Borndiep the West-East flow is in a circular manner along the hook. The tidal flow breaks on the north side of Ameland and leads to an erosion zone on this location. For this reason the influence of the Borndiep is researched often to create appropriate coastal management techniques. The developments of the Borndiep and Bornrif influence the north coast of Ameland. Since 1992 the result is a netto accumulation of sand along the rest of the coastline (Oost, 2001). Except for the part where the beach hook is attached to the north side shore. In this area just east of the beach hook an erosion zone is present (Cleveringa, 2005). This ablation zone moves eastward under the influence of changing situations in the estuary and the eastward position of the beach hook under the influence of the natural process of passing sedimentation waves. On the long term the longshore drift of the deeper sea leads to a new sediment wave that attaches to the sand plate on the north-West of Ameland (Oost, 2001). So to wrap it up, in general there is a West-East longshore movement and a cross-shore tidal movement. The developments on the north shore of Ameland are influenced heavily by the developments of the estuary and channel to the West of Ameland. Just east of the hook typically there is an erosion zone present and sand from the hook and the sand plate is deposited further east along the coast. The dynamics as discussed in this section what is to be visualizated. It can be seen as what of Koeman's visualization question.

Figure 2.3.1: Situation on the North-West side of a Ameland



2.4 Visualization methods

For visualizations it is important that the users understand what is presented. In order to achieve this, a map should have the correct amount of information. Both too little and too much information are of no good for the informative value of a map. When taking into account the temporal aspect and including patterns into a map there is a serious risk of overkilling the user with information. For this reason it in important to select the right amount of information and cartographic techniques (Blok, 2005). This section discusses several options to visualize the dynamics of the morphological features. Along the route of the evolutionary process of Geographic Information Systems as discussed by (Lin, 2013).

2.4.1 Static maps

As the human understanding of the world around develops the presentation of this develops accordingly. The first and traditional way of displaying spatial information is by displaying a static map that presents elements of information. Such a map can be used to identify where something is located. Especially after the development of digital static map the popularity of its use increased and delivered a basic tool for the understanding of geographic features (Lin 2013,). The presentation of information as a static map in essence becomes atemporal, as the map doesn't change over time. In a single map, visually different values can be used to present a change over time. To fully perceive the change over time it would be possible to create a series of maps showing the development of the information on the map. In a more elaborate way the series of maps can be combined in an animation to show movement of spatial features (Kraak, 2010, p. 154).

2.4.2 Dynamic and animated maps

Because of the development of the digital static map, the maps have gained functionality. The development of digital Geographic Information Systems allow for analysis of the data behind the static maps. It is possible to make digital dynamic or animated maps. There is a development to the information behind the map as the mapping and analytical capabilities have increased (Lin, 2013). This results in the creation of dynamic maps. A dynamic map reacts on changes to input or selection by interaction with the users. The animated map is a digital map with the data visualization and presentation created beforehand. The difference in terminology as followed in this research is in the amount of interaction. In an animated map only the play/pause controls are available where a dynamic map is fully interactive. Dynamic maps function as an extension on the presentation of geographical information because of the interactive nature. Interaction means the change of the visualization in an almost instantaneous way by the control of the user. This requires the right hardware, software and data. Very common interaction is the selection and transformation of data. The change in visualization of the represented information can also be part of the interaction (Dibiase, 1994). The interaction allows an analyst to create the map(s) with only the relevant part data. This process however requires a time investment by the analyst (Dibiase, 1994). Animations on the other hand take time to express the changing elements of the environmental variables in a sequence of representations. The user sees the information as is and can only control the time of the animation.

2.4.3 Virtual Geographic Environments (VGE's)

The next step in the process of the evolution of the GI-systems as described is that of a data driven approach to one that focusses on the scientific added value (Goodchild, 2009). As there has been a shift of the classical map that shows the locations of map to a GI-system, where there is more room for the data behind the map and spatial analysis, the current step is the one to the dynamic model and the inclusion of the fourth dimension: time. The world has to be modelled as a dynamic system and (Lin, 2013). Lin sees the development of Virtual Geographic Environments as the solution. The VGE's are more technologically advanced dynamic visualizations. They are used for multidimensional visualization, dynamic phenomenon simulation, and public participation (Lin, 2013). It uses augmented reality in the physical world to allow the users to really experience the information. The public can feel the visualized world as real and visit the history and even the future based on spatial models. By combining multiple dimensions this can lead to a better understanding of the influences leading to an environmental situation and eventually might help to contribute to the (digital/physical) environment by feedback. Feedback can be provided via systems that focus on Participatory GIS or Public Participation GIS systems (Lin, 2013).

In the case of coastal profiles the effects of storms or sand nourishment projects could be virtually presented. Collaboration between different domains can be the basis of new decision making and experiments. A multidiscipline project between Meteorologists, geographers, decision makers, scientists etc. could give interesting results. This technique is very new and the possibilities are promising for future visualizations.

2.4.4 Online Mapping

Creating digital maps means that the map can be spread out among users easily. This can be achieved by providing the dataset as is via a server, or as a map representation. A server is needed which provides the data and scripts, which tell the computer what to do with the data and how to present this to the users. Where static maps can be distributed as images, more dynamic and especially the interactive maps ask for more coding. The first part of online mapping: the data offering, comes in a variety of ways. Commonly known (geo-) webservices are: the Web Map Service (WMS) that just provides the map image which is coded on the server side. The Web Feature Service (WFS) which allows for coding and mapping on the user side. And the Web Processing Service (WPS), which allows users to process and edit the dataset by using software on the server. Web services are an easy and often low-cost ways to offer geospatial data over the web (Peterson, 2012).

The second part of online maps is the code that the internet browser, service, or software on the user side uses that translates the data to the wished image. The code is located on a server and can be accessed via a webadress. Two examples of browser based code to via geospatial data are Leaflet (Agafonkin, 2017) and Openlayers (2017). These are both open source JavaScript libraries for the mapping of geospatial data. Basically it tells the user's computer where to find the data and how to load and visualize it. The combination of web-services allows the combination of data from several sources to create mash-ups of data and new layer based maps (De Longueville, 2010). Another JavaScript library is Carto. This is an open source tool aimed at the dynamic visualization of Geo-spatial data, which provides open to use functionality and server space. It includes an online builder with limited free functionality, but also provides the option to load the JavaScript library separately and to use its possibilities as fits the project best. Carto provides WFS functionality for the uploaded datasets and includes SQL functionality to query the data (CARTO, 2017). It is possible to combine multiple JavaScript libraries when they are interoperable. The use of standards as provided by the Open Geospatial Consortium (OGC, 2017) ensures the interoperability of Carto with for instance Leaflet to visualize and create a digital map. Within Carto the GeoJson file format is used (CARTO, 2017). This project uses the capabilities of Carto and Leaflet to create the visualization of the shoreface dynamics.

2.4.5 Graphs

Graphs can, in addition to maps, help to visualize spatial data, especially in the case of dynamic data with a temporal aspect. These graphs can be an addition to the map and show different variables for the same geographic location (Kraak, 2010).

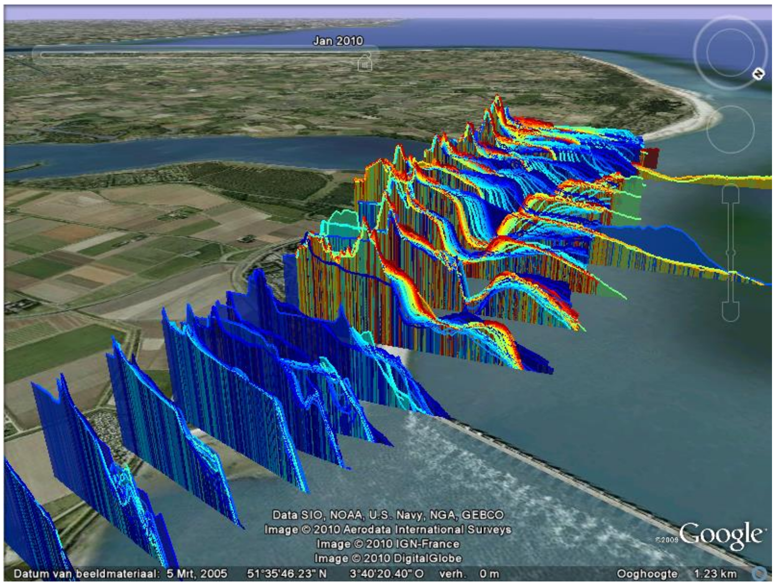
2.4.6 Harmonization of the data

In the appearance of morphological patterns the observation position and the time of the observation matters (Wassink, 1999). To be able to visualize the shoreface morphology the data needs to be harmonized. The negative values for the heights underwater should be changed to positive values through harmonization. The methodology that is used to perform this harmonization is described in section 3.3.

2.4.7 Interpolation methods

The JARKUS data is available as coastal profiles, i.e. measurement points along lines (Figure 2.4.1). For this research the data needs to be interpolated in order to cover the area and identify features. Interpolation is the creation of a spatial surface based on spatially distributed data points with a certain attribute (z) value. This z value can be elevation but also any other attribute with a variable spatial distribution (Fotheringham, 2000, p43). Important note is that interpolation methods provide a method of estimating the value of the unknown (De Smith, 2009). Several interpolation methods exist that will be shortly discuss.

Figure 2.4.1: Example of the JARKUS data (Deltares, 2016)



The discussed methods are based on the assumption of local influence. The nearby point values influence the values of the surface. The first method is the inversed distance weighing (IDW). The IDW is based on the assumption that the value for a certain location can be estimated by creating a weighted average of the points within a certain distance. These weighs are most of the time inversely proportional to the distance. IDW is a common interpolation method, but has some shortcomings such as the local shape mispredictions and the appearance of local extrema at the data points.

The natural neighbour interpolation technique predicts the value of an unsampled point based on the average of the nearest neighbour values. The weights depends on a variable combination of data input points weighted on area or volumes instead of distance. The natural neighbour interpolation results in a smooth surface that passes through the data points. This type of interpolation allows for the calculations of derivatives of the surface and is typically used for topographic, bathymetric, and geophysical data (Sibson 1981; Esri, 2017).

Another interpolation technique is the triangulated irregular network (TIN). This method is based on triangulation of the data points to estimate the unknown values. This is an especially fast method which allows for an easy implementation of structures or borders. However the Tin seen as the simplest and least accurate method is, it is regularly used in visibility analyses and dynamic visualizations because of its effective representation of the surface.

A fourth method of interpolation is Kriging. Kriging is a geostatistical based technique and can be used with several different functions (spherical, exponential). It is modelled after covariance in order to statistically predict values. It's most important positive point is the statistical correctness and ability to predict uncertainty in the spatial distribution. It however performs less on smoothness and local geometry. Commonly used in mining, geochemistry and geology.

Fifth is the spline technique, which creates a raster surface with minimum curvature created with the derivates and minimum sum of the deviations from the data points. It includes several ways to create a stiffer or a more elastic surface depending on the formula used and whether tension is taken into account or not (Mitas, 1999, p 483-486).

In this project there is chosen to use the natural neighbour interpolation method. This method is chosen, because of it smoothness of the surface, easy appliance and the fact that it is commonly used in cases of bathymetric datasets. Also In this research the focus is on the visualization itself and less on the most perfect statistical representation of the facts. Several more elaborated interpolation methods do exist but these are not discussed because they do not fit within the scope of this research.

2.4.8 Perception blindness

The capacity of the readers/users to understand the (map-) image that is presented is limited. The human brain has a maximum capacity to take in information. Too much information can lead to an uncomprehensive map. The visualization of change is often a serious amount of information. As it is difficult to include time in GIS, the result is often a series of snapshots. These snapshots store information from one variable at any point in time. In this case this is the elevation data. When developments over more than one time step and a large area are shown this will lead to perception problems. It can be hard for the user to see the change, because it is so overwhelming or on the other side because there is a lack of information and the user is not triggered enough to notion any changes (Simons & Chabris, 1999; Simons & Rensink, 2005). This leads to change blindness; this is the concept that the difference between two different images is not being noted. Neither of the images shows the proof of the change. The user has to perceive the change based on its memory of the image.

A related and more specific perceiving problem is the problem where users fail to see completely visible objects because their attention is focused on other parts of the map, events or tasks. This problem is referred to as inattentional blindness. This second problem is often accounted when the attention of the users is focused on one task or area of the map and they don't consciously see other elements. When questions are asked about those elements they often can't be answered. In the essence inattentional blindness is a form of change blindness as it covers the fact that a certain change or element in the image was not noted. It is however more specifically focused on the fact that, opposite from change blindness, the memory of an earlier stored state in the memory is not necessarily to compared, it is more the failure to see it at all (Simons, 2007).

Several visualization techniques and variables exist in order to focus attention on certain elements. Using unexpected outstanding colours, movements or flashes will surely divert the attention to that position. Typically there is a quick general perception of a situation and a more slow detailed perception (Rensink et al, 1997). Focusing observers on one element can distract them from other elements and will lead them unable to report on those matters, so the inattentional and change blindness should always be kept in mind.

2.4.9 Bertin's image theory

As already concluded the JARKUS data is a multivariate or multidimensional dataset. This is exactly where the difficult part lies. The difficulty with multidimensional data is the ability of the observer to perceive the image in an instant. A solution in order to visualize the multidimensional data is to present more than one representation of the same data, but this still leaves the observer with the need to combine several images to come to a conclusion or perception of the data or processes. More common is the use of coding the data dimensions into non-spatial features using combinations of visualization variables. Bertin (1967) defines six variables: size, brightness, texture, colour, orientation, and shape. Bertin says that representations should create a single image and optimize the efficiency of this image. The image is efficient when the observer is able to immediately extract the information.

In Bertin's image theory marks are used to show the correspondence between two main components and an invariate component. The visual variables are divided into two classes, planar and retinal. The planer variable is the spatial dimension and the retinal variable a non-spatial variable (colour, shape, orientation etc.). Bertin puts a limit to the amount of components that can be used in an image: three for diagrams and two for networks or maps. The second planar variable that is present in a diagram cannot directly be interchanged with an additional retinal variable (Green, 1998).

The length of a visual variable is of importance, the amount of steps in the data should not exceed the perceivable amount of steps for the used visual variable. There is also the organizational level of the data. The choice for a visual variable depends on the level of perception required, i.e. nominal, ordered, or ratio scale.

The image theory of Bertin's is an important factor in creating maps and images. Visualization is based on the factor that data is transformed into an image by certain (computer) algorithms. This image should lead to insights for the observer. These insights are based on the (immediate) perception of the image by the observer. Green (1998) creates a link between Bertin's Image theory and the science of visual perception and elaborates on the matter. Green includes the visual variables motion and flickering in the theory of Bertin. And he claims that the limits that Bertin states are not true and more visual variables can be included with the image still being effective and immediately perceived. Green bases its addition on the linking of several visual search and image segmentation theories (Cleveland, 1984; Abarbanel, 1993; Woods, 1991). The theory of Bertin aligns with these researches on the terms automatic, preattentive, and immediate to create the efficient image.

The most important additions from Green to Bertin for this case are the introduction of two new visual variables, Motion and Flicker. Where Bertin focused on print-only variables these two computer possibilities are added. Motion can be split in two sub-variables, velocity and direction. They are both selective variables as humans automatically select moving objects as a single element. The observer is able to select those with the same and differing motions. Also the Flicker variable consists of two sub variables, frequency and phase. The frequency is the speed of the flicker cycles and the phase is the status or moment of the cycle, on or off. It is possible to show elements in the same time or in a follow-up order, in-phase or counter-phase. Where motion direction and flicker phase are only possible with a selective order. The velocity and frequency can also be used for ordered and, when scaled, quantitative data perception (Green, 1998).

Other authors also include several more visual variables since the possibilities of on-screen display and animations have grown. For instance MacEachren (1992) elaborates on the use of colour saturation and focus (contour crispness, fill clarity, fog and resolution/transparency) in order to map uncertainty. Borgo (2013) mentions the use of graphical variables in order to create well-functioning glyph-based visualization elements. Kraak (1999, p171) mentions the development of the technical possibilities and the fact that Bertin was negative over animation because of the additional dimension it would give. Research has shown that this is not the case and the observer of an animation would not necessarily have less understanding off the image then with a static image. DiBiase et al (1992) introduces the dynamic variables duration, order and rate of change and MacEachren (1994) has added frequency, display time and synchronisation to the list of dynamic variables (Kraak, 1999).

Blok (2005) agrees with the idea that a visualization of the data on its own is not enough, it is about creating an impression in the mind of the observer. Animation can be a more effective way to achieve this, but only because it might include information about the steps between major changes. Blok also mentions the problem of change blindness because of the too high information density in animated maps. Where for the static map and Bertin's graphical variables the immediate perception is most important, in order to see change and patterns in animated maps, focussed attention is also required. Without attention change will be noticed but patterns won't be extracted by the observer. Attention seems to temporarily allow for the tracking of object in time and space. However the attention can only be directed to a limited amount of items at any time (Blok, 2005). Blok also identifies several visual variables that can be used in digital mapping, especially for the dynamic mapping which includes the temporal dimension. Dynamic visualizations methods are those methods that can only be observed in the temporal dimension of a running animation. Blok mentions some possibilities to show emergence or disappearance of elements using dynamic visualization methods. Blinking/flashing, Highlighting, different colour (tone) use. This research focuses on the use of such a dynamic visualization method, the Blinking, or as Green identifies it Flickering. However Blok uses it as a method to show the emergence or disappearance of an object in this case it is used to show dynamics and to identify a spatial-temporal pattern.

The CARTO product, which is used, is focused on this kind of dynamic visualization methods, especially the Torque functionality. Where this function follows the classic use, as seen by Blok, in order to show the appearance and focussing on points that weren't there before. This research tries to find out whether it can be used in a situation with continuous data presence for all the points. An animated digital map with time controls is needed for this. The exact method that is used for the visualization is discussed in the next chapter.

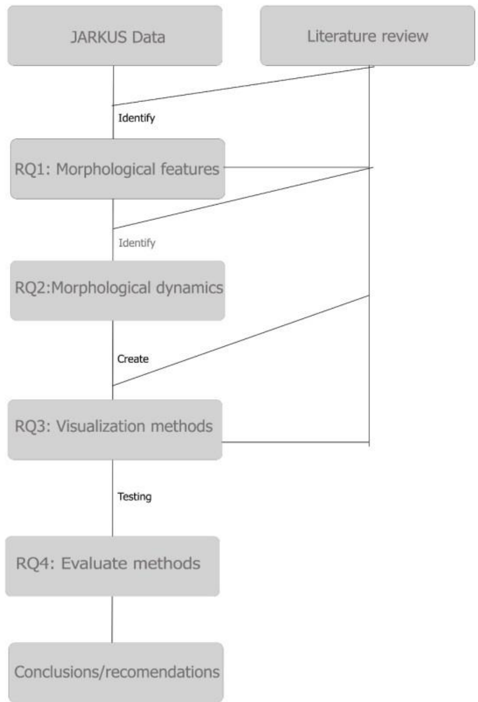
2.5 Conclusions

This chapter began with the explanation of the JARKUS data. This was followed by the description of the underwater morphological features. The answer to the first research question was found. The morphological features of interest in the shoreface are longshore bars (sandbanks) and rip channels. After the discussion of the morphological elements the dynamics in the shoreface and the research area are discussed. Leading to the conclusion that under influence of developments in the westward channel and the arrival of sand from the west, an overall West-East longshore current is present and a cross shore tidal flow influences the shoreface on the north of Ameland and creates erosion and sedimentation zones. This zones influence the location of longshore bars and rip channels with an overall West-East spatial-temporal pattern. On the east of the beach hook an erosion location is present. This answers the second research question about the dynamics of the shoreface. The What of the visualization question became clear. The visualization should present the locations of dynamics and show a spatial-temporal pattern. The fourth item was the explaining of some visualisation methods and potential visualization techniques or variables. These techniques are of importance to the how of the visualization question, as the exactly used method follows, the visualization is an animated map with time control that uses some classical graphical variables and a new dynamic visualization method in the temporal dimension.

Chapter 3 - Methodology

In this chapter the used methodology is explained. The choices that are made based on the reviewed literature and a conceptual model is presented. First of all the limitations in time and are place set. This is followed by the research question which leads to a step by step approach, sections (3.1 & 3.2). The intended way of working is that for each research question the results are input for the next objective. The base of the research is the literature review as presented in chapter 2. The approach (see figure 3.1) is to first investigate the JARKUS data, secondly to research the morphological features and their dynamics, thirdly to develop a method to visualize these dynamics and fourth to evaluate these visualizations and compare them to be able to come to conclusion over the use of the visualization and recommendations for further studies.

Figure 3.1: Conceptual model



The study is limited to the use of the JARKUS data. From the available data the part is selected for the period 2000-2010. This is data is gathered with the most recent measurement technique as described in section 2.4. The dataset that is used was already prepared for the correct location and contains the part of the Dutch coast on the north side of Ameland. This area is used as the total research area, from which as small part on the east side is used for a more detailed view. The goal is to create a visualization framework for the area of the north coast of Ameland which could be applied for the rest of the Dutch coast.

From the research questions as presented in the first part of this report two are already answered within the Theoretical Framework (sections 2.2 & 2.3). The methodology on how to create the visualization and the evaluation of these visualizations should provide material to find the answers for the two remaining questions. The first question that remains answering is how to visualize the dynamics? The method for this are discussed in the next part of this chapter and the results are presented in section 4.1. After the explanation on how to create the visualizations also the method to answer the remaining research question of how the evaluate how the dynamic visualizations are understood is explained, for which the results are presented in section 4.3.

3.1 Visualization of the Dynamics

To visualize the dynamics several steps are performed. As you can expect this starts with the data preparation, followed by the visualization scripting. The data preparation is performed in three steps: Creating an elevation surface, Create change surface, Create Point data.

3.1.1 Preparation of the data

The data preparation is performed in ArcMap and the tools present in that software program. The model builder in ArcMap is an important factor in the data preparation process. It allows for automated performance of the tools. The models that are used can be found in Appendix 7.1. The input datasets are the JARKUS data with points for each row. First the selection for the years 2000-2010 is made. And the research zones picked. One zone as the total research area and one smaller zone on the east side of the area for a more detailed analysis.

Create elevation surface raster

The next step in the data preparation was to interpolate the JARKUS transect data into a digital elevation surface for each year (see appendix 7.1: model 1). For each of the years a separate surface and dataset is created. The Natural Neighbour tool is used to perform the interpolation (see section 2.3 Interpolation methods). The cell size variable in the tool for the interpolation was set to 10x10 meters and to 50x50 meters. This interpolated elevation surface is rounded to a 1 decimal digit precision with the use of the raster calculator tool. This in order to not assume an exact elevation precision and to keep the data manageable. To remain with data with a workable size and processing speed the whole interpolated surface is split in smaller areas by the extract by mask tool. This uses a mask area to cut out a certain section of the total area. This step is especially necessary for the files with a 10x10 meters cell size.

Create change surface raster

The elevation surfaces that are created for each of the years and areas are iterated in the model (see appendix 7.1: model 2), i.e. each file is loaded, and the actions are performed and then repeated for the next file. The model that is used can perform the action for each selection of years and each chosen interval. In this case the interval is 1 year and the total period is 2000 – 2010. The change raster is created by the Raster Calculator tool. It calculates the change between a certain year and the base year (2000). The formula used is:

*Change Value = (("Year X Elevation Surface" + 100) / ("Elevation surface year 2000") + 100)) * 100*

The new value for change is the product from a division of the selected year by the base year multiplied by a 100. To harmonize the data and overcome problems with negative and positive values to both the raster surfaces a value of 100 is added. The result of this process is a raster dataset with a value in each cell corresponding to the relative change on that location.

Example Harmonization of data effect

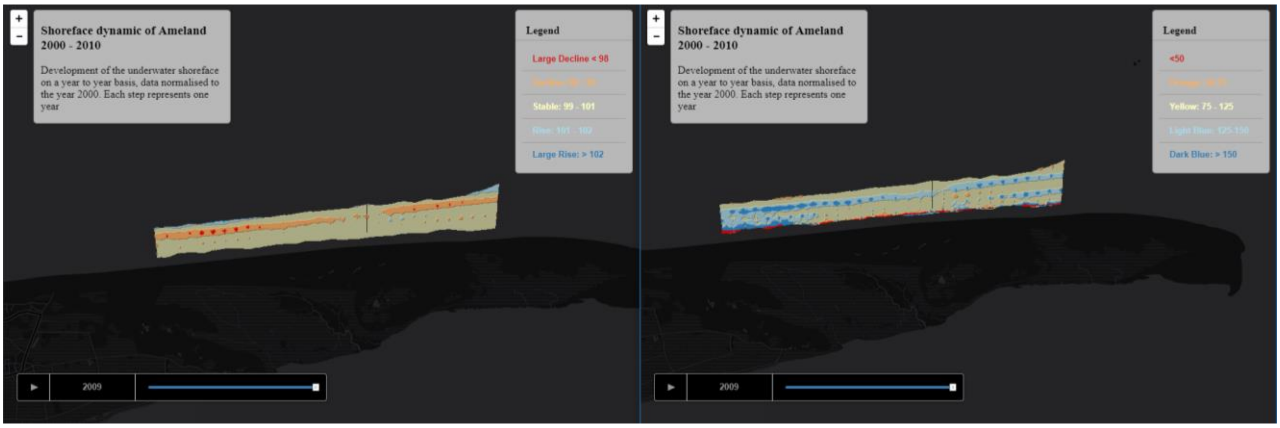
Data harmonization is necessary because otherwise the calculation of the normalised change leads to wrong interpretation of the visualization. The problem that is at hand is shortly discussed with the help of figure 3.1.1.1 and table 3.1.1.1. The problem is divided into two sub problems: Distinction between negative and positive values, and the extreme change values. First the negative values problem. The elevation surface contains mainly negative values, as the area underneath the sea level is researched. Dividing negative values by other negative values leads to a positive value and on the other hand dividing a negative value by a positive value results in a negative change value, where a rise of the area is the real case. In that way it is impossible to see a correct result in a diverging way. The effect of a visualization with and without the data correction are presented in figure 3.3.1. On the left the corrected image is visible. There is a clear red area visible, indicating a decline in elevation. On the right side of the image the uncorrected visualization is presented. Here a clearly blue image is visible, indicating the exact opposite: an elevation rise in the area.

Table 3.1.1.1: Harmonization example

Height in meter		Calculated value	
2000	**2001**	**uncorrected**	**corrected**
1	-1.5	-150	97.52
-1	-1.5	150	99.49
-1	1.5	-150	102.53
0.1	1.5	1500	101.40
1	2.4	240	101.49

Then the second part of the problem, the extreme values. The uncorrected image shows more areas with a large change than the corrected image. This is the results of the division of elevation values that are very small, i.e. close to zero. So even when the change is the same in absolute way, in one case the normalised change is extremely high (1500) and in the other case much lower (240). Comparison between areas is made impossible in that way. The harmonization is thus very important for a correct representation of the normalised values.

Figure 3.1.1.1 Examples with (left) and without (right) data harmonization



Create point dataset

The end from the previous step is the input for the final step of the preparation of the data (see 7.1: model 3). Because the Torque function of Carto only works with point feature the data needs to be transformed. The tool raster to point does this. But before the transformation takes places, each raster surface is reclassified. The classification is based on the Standard deviation for all years for the total area but rounded to a whole number (0.87 to 1). The 6 classes now indicate a Small positive/negative change (3 & 4), Medium change (2 & 5) and Large change (1 & 6). This classification is chosen to minimize the complexity of the data but to still maintain its meaning (Heywood, 2010).

Table 3.1.1.2: Reclassification

Old values	New values
< 98	1
98 - 99	2
99 - 100	3
100 - 101	4
101 - 102	5
> 102	6

Now the raster cells are transformed to point data and extra attribute fields are added:

- Date Field → indicate the time step
- Ordinal Field → medium and large change
- Ordinal Field → large change only

The final step of the pre-processing of the data is to merge the datasets for all the years into one dataset containing all the data to be visualized.

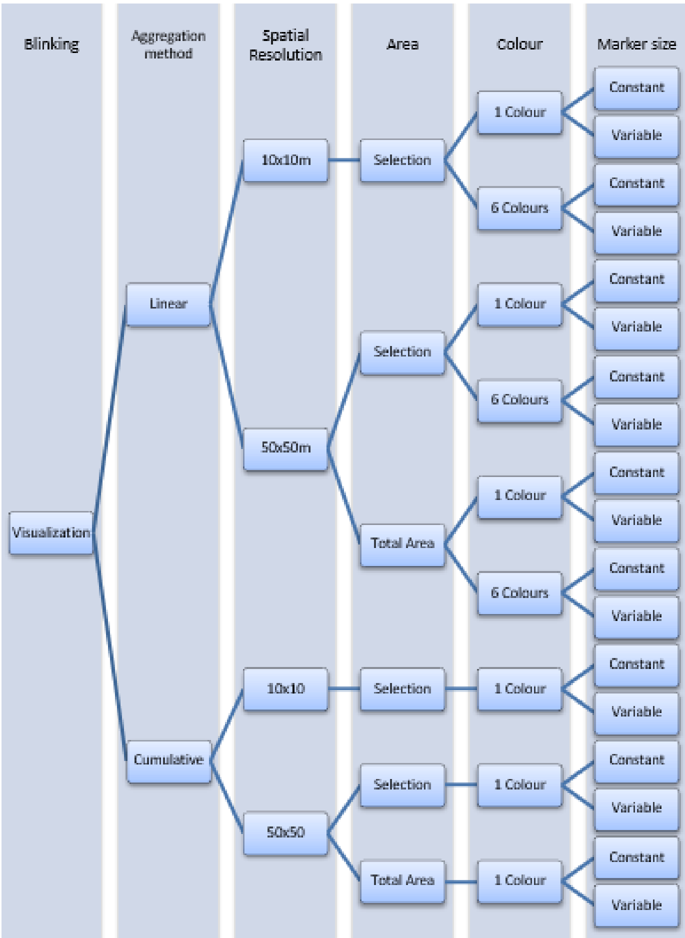
3.1.2 Visualization Scripts

The visualizations of the shoreface dynamics are built using the CARTO and Leaflet functionality. It uses JavaScript libraries, web languages and web services. The data is uploaded on the CARTO server. The scripting takes places in several scripts in html. Several options to perform this are possible: The visualization can be changed trough only transforming the corresponding .css files. Or to create a .html for each of the visualizations. In this case the second method has been followed.

One of the functions in CARTO is the Torque technique. This allows for visualizations over time. Typically the Torque technique is used to present new elements or a travelled route. An example of the Torque use is the mapping of Twitter tweets locations (Carto, 2017). The Torque technique however is not created for the use that is requested in this project. It isn't created to show the development of an area where for each moment in time a value exists. In combination with CARTO's ability to visualize elements in different ways based on their value and the temporal element of the torque functionality this project creates the visualizations. The classical Torque functionality is only available for point data. Naturally there are ways to overcome this problem and find a solution for presentation of lines or objects, this however is not within the scope of this project and leaves room for additional visualizations.

The visualization scripts create the maps based on the assigned values of graphic and spatial variables. Figure 3.1.2.1 shows which visualizations are created. In the end there are eighteen maps. The influence of all the variables are discussed in this section of the report, first those that are variable and later also the constant variables are explained.

Figure 3.1.2.1: Visualization framework



Aggregation method

Torque functionality allows for two ways of visualizing data over time: linear or cumulative. This is the so called aggregation function. The linear way shows for each timeframe the data as is coded for that time step only.

The cumulative way calculates the values of the point and sums the values for all previous time steps. When a classification is applied to the data the cumulative presentation leads to unwished results. A standard sum of the values is not correct as it's not a ratio scale but an ordinal scale, which cannot be quantified. In the preparation of the data ordinal variables of change are added in order to allow for the cumulative visualization of the data. The ordinal variable allows to sums the moments with change in a certain point.

Spatial resolution

The visualizations are made for two different kinds of spatial resolution. This is already performed in the preparation of the data. The elevation raster is built with a 10x10 meters grid cell size and a 50x50 meters grid cell size. For the visualization script this means that different input data is used for the visualization. The spatial resolution is of big influence on the loading time of the points. The uploaded dataset with all points for the whole area with a spatial resolution of 50x50 meter is 14Mb and contains an approximate of 125.000 points. The dataset for the smaller area with a 10x10 meter cell size is already 39 Mb and contain more than 340.000 points. The small cell size datasets of 10x10 meter requires a lot more processing capacity than the 50x50 meter datasets. CARTO uses SQL to retrieve the data from the server and analyse it on the client side. This doesn't require a lot of processing on the server side but requires processing capabilities on the user side. For this reason the 10x10 meter data is only used in a selection of the total research area.

Area

Visualizations are created for two areas. Some are created for both the whole research area and the selection where some are only created for a part of the area. This is due to processing capacities. The zoom level is adjusted for the maps with a selection of the area. Where in the maps for the total research area a zoom level of 12 is handled, in the map with more precision the zoom level is 14.

Colour

The visual variable colour is used in two different ways. Some maps are only made with the points in one colour (White) and the other maps are made with the use of six different colours. For each class a different colour is used on a diverging colour scale, from red to blue. The red colour is used for the decline areas and the blue colour for the rising parts. To create the visualization in each of the visualization scripts the points are coded (figure 3.1.2.2) to be displayed in a certain colour based on their value.

Figure 3.1.2.1: Code example of colour and marker size for the 50x50m grid in a selection of the research area

```
//Size and Colour differentiation
  [value = 1] { marker-width: 5;      marker-fill: #d60606;   marker-line-width: 2;}    //dark red
  [value = 2] { marker-width: 2.5;    marker-fill: #fdae61;   marker-line-width: 1;}    //orange
  [value = 3] { marker-width: 1;      marker-fill: #fee090;   marker-line-width: 0.5;}  //yellow
  [value = 4] { marker-width: 1;      marker-fill: #e0f3f8;   marker-line-width: 0.5;}  //light blue
  [value = 5] { marker-width: 2.5;    marker-fill: #abd9e9;   marker-line-width: 1;}    //blue
  [value = 6] { marker-width: 5;      marker-fill: #2c7bb6;   marker-line-width: 2;}    //dark blue
```

Marker size

For the marker size variable there is also the distinction between changing and constant use in the maps. There is however an extra addition in the variety of the marker size based on the spatial resolution. In the more detailed maps with a smaller cell size the used constant marker size is 1 pixel and the variable values are: 0.5px; 1px; 2.5px. This leads to bigger marker sizes for the classes with high dynamics and smaller markers for the areas with less change. In the maps with a larger cell size the constant marker size is 3px and the variable values are: 1px; 2.5px; 5px (see the example code in figure 3.1.2.1). The value for the marker is the amount of pixels of the diameter of the marker. The marker sizes have been chosen to limit the overlapping of points in the constant situation. In the variable situation overlapping markers are used for areas with high dynamics.

Blinking

The blinking of the elements is reached by coding a different visualization for the same element in a different display frame (figure 3.1.2.2). This leads to the effect that the element on a certain moment is more present in the first frame than in the following moment. In the code the Frame-offset element is used. The frame-offset is the amount of frames the element is visible after its first presentation. To achieve this blinking the variable marker line is used. The size of the marker line depends on the size of the marker itself. De blinking is created by showing a thicker line on the first view than in the second view. The value for the line size in the second frame (offset = 1) is half of the original line size.

Figure 3.1.2.2 Code example of the blinking effect

```
//Blinking: offset line width half of normal line width
#layer[value = 1]{   [frame-offset=1] {  marker-line-width: 1;     }   }
#layer[value = 2]{   [frame-offset=1] {  marker-line-width: 0.5;   }   }
#layer[value = 3]{   [frame-offset=1] {  marker-line-width: 0.3;   }   }
#layer[value = 4]{   [frame-offset=1] {  marker-line-width: 0.3;   }   }
#layer[value = 5]{   [frame-offset=1] {  marker-line-width: 0.5;   }   }
#layer[value = 6]{   [frame-offset=1] {  marker-line-width: 1;     }   }
```

Constant variables

As discussed in the theoretic framework there are a lot of possibilities to present data as a map by using visualization variables. This leads to a huge amount of possibilities to create maps and to test the effectiveness of the use of different variables. This project aims to test the visualization of shoreface dynamics using blinking elements and the variable graphic variables colour and marker size. Table 3.1.2.1 shows a matrix of variables that influence the visualizations. Some variables in this project are kept constant, these are: blinking speed, classification, time step, and time period. Although it would be possible to change these variables in order to not overdo the project these are kept constant. Further projects can focus on changes in these variables to analyse visualizations of the dynamics and spatial-temporal patterns.

Table 3.1.2.1 Visualisation parameters and variables

Spatial Parameters	**Graphic parameters**					**Temporal parameters**	
	Blinking Speed	Spatial Resolution	Classification of Change	Colour	Marker size	Time step[4]	Total time period[5]
Cell/Point *(Raster/vector)*	*Constant* 22 Frames in 11 seconds	*Variable* 10x10m, 50x50m	*Constant* Normalised Six classes	*Variable* No colour & Six colours	*Variable* Not & Variable	*Constant* 1 year	*Constant* 2000 - 2010

3.2 Evaluation of visualization methods

An evaluation of the visualization is needed to draw any conclusion on the functionality. The last research question of this project is focused on this task to analyse how the visualizations are understood. Do the visualizations of the area provide insight in the dynamics of the shoreface? Is the user capable of perceiving information out of the map by interactively using the presented product? There are several possibilities to do an usability analysis depending on some restrictions such as time and budget (Usability Net, 2017). The goal of the usability test is to test a level appropriateness to a purpose (Brooke, 1997). Options to test the usability can be user or expert based. For instance the test can use a user questionnaire, interviews or focus groups. In general the questionnaire is the least budget and time (Usability Net, 2017).

To test the usability of the interactive maps a user test is performed. This test is a questionnaire which is used to perform a combination of the subjective assessment and the diagnostic evaluation. Both of these methods are commonly used in post-release testing. It is an efficient method which requires limited time and recourses. The subjective assessment shows how the user feels about the tested software. To limit the subjectivity of the test standardized questionnaires are commonly used. When using a subjective satisfaction assessment there are two possible scenarios: A questionnaire to be filled in after a testing session or a sent message including a questionnaire which is used to test the experience of the product (Usability Net, 2017). The second scenario is applicable for this situation. The participant are sent a digital questionnaire with which the experience and satisfaction of the user is investigated.

Satisfaction in this case, is the ability to perceive and analyse the information presented in the map by interactively using the map. This satisfaction evolves out of the effectiveness and efficiency of the product. However because of the nature of the product in this case, the possibilities of a precise test on the effectiveness and efficiency are limited. The functionality of the product is such straight forward in use that a usability test on this is a bit superfluous. An elaborate performance test procedure, with strict testing scenarios, to uncover all technical problems is not within the scope of the project. It would be nice to for instance see a heatmap of the mouse use above the map or to track eye-movement but these both require considerable resources and user participation.
The focus is to answer the research question about the functionality in order to detect dynamics and a spatial-temporal movement pattern. The second point is to analyse whether it is possible to make a general assumption of the technique of using these visualization techniques to be used in other cases with visualizations of dynamics.

Usability test questionnaire:
The questionnaire is conducted using surveymonkey.com (2017). A free to use questionnaire website focused on student researches. As it seems impossible to embed the scripts for the visualizations in existing questionnaire tools a separate webpage is created to combine the maps and the questionnaire tool. The test is distributed between GIMA students only. For GIMA students can be assumed they have enough technical and mapping experience. The test is distributed for a timespan of a week. The participants are asked to answer questions using three interactive animated maps:

1.	***Linear map*:**	Total research area 50x50meter cell size with colour and size differentiation
2.	***Linear map*:**	Total research area 50x50meter cell size with only size differentiation
3.	***Cumulative map:***	Total research area 50x50meter cell size with only size differentiation

There is chosen to use the maps with a spatial resolution of 50x50 meters because of the processing speed and the possibility to include the whole research area. As already mentioned even one zone of the 10x10meters resolution requires more resources to load than the whole area of the larger spatial set. Two matrix questions are presented for each map. There is no indication for the year the participant has to look at, the whole time period can be assessed as the time controls are included. All the maps are divided into five zones. The questions need to be answered for every zone and for the total area. The first question to answer for each map was is: What would you say about the dynamic in each Area? The options to choose from are presented in table 3.2.1. The outcomes of this question are used to evaluate whether the user is capable of identifying the locations of dynamic in the blinking maps.

Table 3.2.1: Allowed answers for the first question per map

Map 1	Map 2	Map 3
Large Decline	High Dynamics	High Dynamics
Decline	Some Dynamics	Dynamics
Small Decline	Stable	Small Dynamics
Small Rise		Stable
Rise		
Large Rise		

Table 3.2.2: Allowed answers for the second question

All maps
West-East
East-West
South-North
North-South
No movement

Only in the first map there is distinction in colour so this has the most elaborate answer possibilities. Colour allows for the distinction of the dynamic in rise and decline. The other maps use next to the blinking only marker size, so only a distinction is the amount of dynamic is to be given. When looking at the actual situation present in a certain Area the following situation is the case:

When looking at the statistics in the areas for all the years, Area A and Area B can be identified as the areas with a small rise and in all the other areas and the total area a small decline is measured. Because of the normalisation and the fact that an animated map is created it is more interesting to look at the actual situation in 2010 (table 3.2.2).

Table 3.2.3: Percentage of a certain class in a certain area

Year 2010	Area A	Area B	Area C	Area D	Area E	Area Total
Class 1	15.2	0.0	0.5	3.7	5.4	4.2
Class 2	**25.3**	2.4	16.6	12.9	10.9	12.8
Class 3	21.6	13.0	**55.6**	**65.4**	**55.6**	**42.1**
Class 4	23.0	**47.2**	20.8	14.5	21.2	26.2
Class 5	6.9	23.0	5.8	3.1	6.7	9.7
Class 6	8.0	14.3	0.7	0.4	0.1	5.0

This shows that in Area A there is a declining situation (25%) and a serious presence of the Large decline (15%). In Area B the opposite is the case with serious presence of the large Rise (14.3). The other areas show a situation of small decline. This situation can be combined with the results of the questionnaire to see the performance of the visualization. The Area A is part of the hook where erosion is present and Area B is the eastward Area where the described sedimentation zone is present (section 2.3).

The second question of the questionnaire is: Identify a spatial-temporal pattern for each Area. The users are asked to select an answer (Table 3.2.2) for each of the areas and for the Total. Based on the assumption that is retrieved from the literature and discussed in the theoretical framework (section 2.3) a West-East movement is expected. The participants are asked to identify the spatial-temporal pattern for each area to analyze the performance of the visualizations.

The outcomes of the test are evaluated by looking at the statistics of the most given answer. There is analysed which answer is most commonly given and there is checked whether this answer is the only answer or whether there are multiple views given by the participants. By interpreting these answers and the unanimity of an answer conclusion can be drawn about the usefulness of the used visualization to present the dynamics and the spatial-temporal pattern in the area.

Chapter 4 - Visualizations & Usability evaluation

This chapter discusses the results of the visualizations and the evaluation of these with the help of the usability test. The method to create the visualizations is described in chapter 3. In the appendix (7.4) the complete overview of all created visualizations is added. This chapter will explain the effects of the change in visual variables based on examples. The question is how the changed visual variables reflect to the image and the representation of the dynamic of the shoreface.

4.1 Visualizations

In section 3.1.2 an elaborate overview of all the visualizations that were to be created is given. The different used visual variables are discussed and the table (3.1.2.1*)* shows all relevant variables. In the coming section the same structure is handled as in the methodology where for each of the visual variables and the blinking the result is presented with a description of the effect of such a visualization and expectations for the evaluation. The focus lies on the question whether the locations of dynamic be identified and the question in what way a spatial-temporal pattern can be identified.

4.1.1 Aggregation method

The distinction between the aggregation methods leads to different visualizations. The linear method means that for every single time step the whole presentation is updated, the cumulative method reminds the previous values and sums them up. This leads to a presentation based on the previous visualization. When looking at the figure (4.1.1.1) the cumulative representation is shown. The bright spots in this image show the locations where the sum of the dynamic is high. These bright spots are the result of the coding. Based on a higher cumulative value for a location a large marker is shown. When you compare the location of these areas with figure (4.1.2.1) with the linear representation of the same area you see that the locations are quite the same. Where the linear view does show areas with small dynamics the cumulative image does not show these. The cumulative aggregation method can be used to identify the locations of the dynamics. It might also be possible to use the cumulative aggregation method to show a pattern. A spatial-temporal movement pattern can be identified as a bright spots that extent in a direction.

Figure 4.1.1.1: 50x50 Visualization with a cumulative aggregation method using marker size variation and 50x50 grid

4.1.2 Spatial resolution

Variation in spatial resolution leads to mainly the same visual results as the other variables have been adjusted accordingly. For instance the marker size has been adjusted in order to keep a relevant and distinctive map. Also the zoom level is increased so the details are visible. The differentiation of the maps with different spatial resolution is mainly focused on the handling of the data, the processing speed and the total area that can be processed at the same time. To be able to compare the results between the spatial densities, also a version of the 50x50 meters is created for the smaller research area as is explained in the methodology. The main difference between the options in spatial resolution is the level of detail that is visible (Figure 4.1.2.1 & 4.1.2.2). Both options can be used to identify the locations of dynamics and a spatial-temporal pattern, but the scale that can be researched is different.

Figure 4.1.2.1: Linear visualization of a part of the area with use of marker size and colour variation using a 50x50 grid

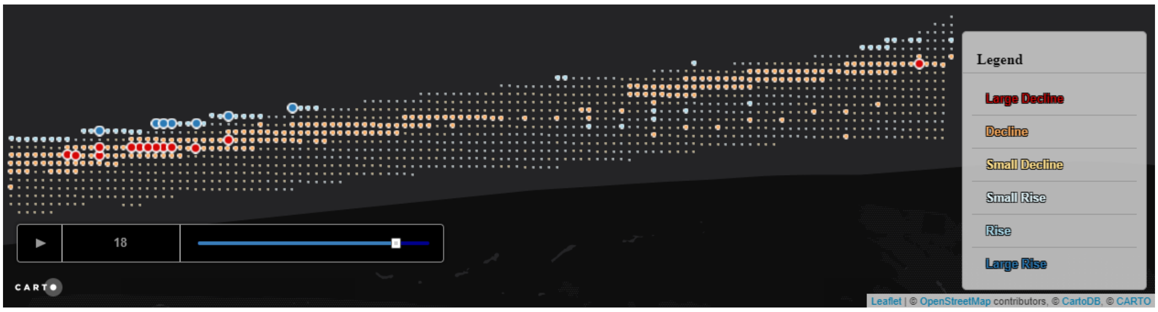
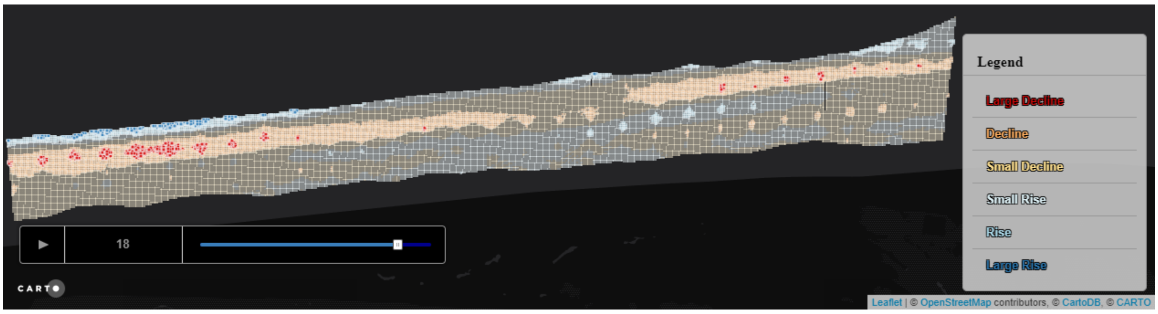


Figure 4.1.2.2 Linear visualization of a part of the area with use of marker size and colour variation using a 10x10 grid



4.1.3 Marker size variation

The variation in marker size is one of the variables that influence the image. Using the marker size is useful for making clear where the locations with high dynamics are. The figure 4.1.3.1 shows that when using solely the marker size variation there becomes a differentiation visible between areas with high dynamics and those areas where less dynamics are present. In the figure (4.1.3.1) on the top left side of the area the spots with high dynamics are located, identifiable by the bigger white spots. In the second figure (4.1.3.2) all markers have the same size and it is not possible to see any distinction between the spots with high or low dynamics.

Figure 4.1.3.1: Linear visualization of a part of the area with a variable marker size using a 50x50m grid

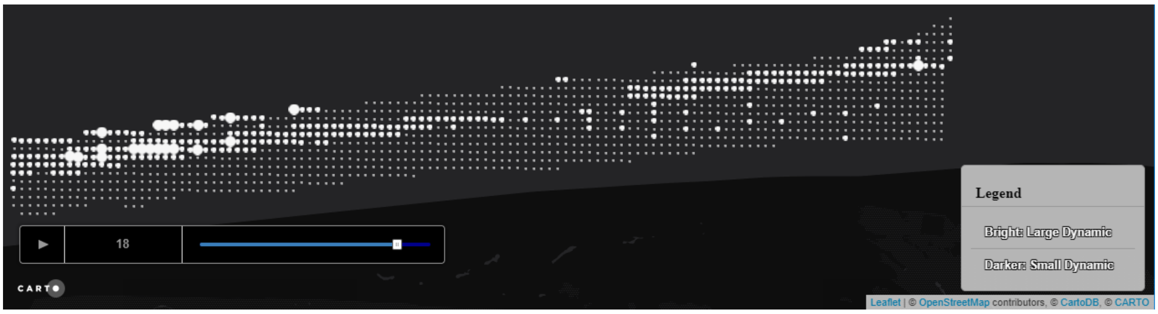
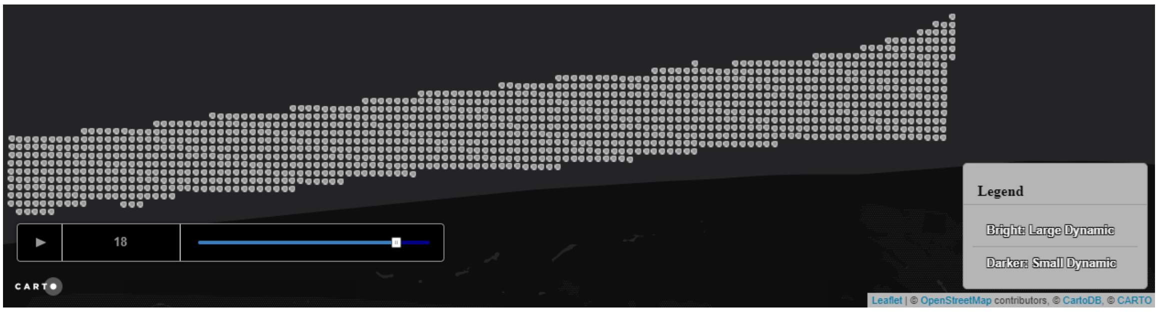


Figure 4.1.3.2: Linear visualization of a part of the area with no use of variation in the visual variables using a 50x50m grid



When comparing the situation over time, the movement of the bigger white spots, that identify areas with high dynamics, can indicate the directions of a spatial-temporal pattern. However with the use of only marker size it is not possible to say anything about the character of this pattern. It is not possible with only marker size to make a distinction between a rising and a declining area. In combination with the variable colour it seems that marker size can help to focus on the locations with high dynamics.

4.1.4 Colour variation

How does the visual variable colour influence the visualization? The use of colour as visual variable allows for a more extensive interpretation of the map. The different colours not only show the locations where high dynamics are present it even helps to identify a diverging pattern. On the figure (4.1.4.1) is visible that there is a declining area (dark red) on the left. Slightly above this area there is an area visible with a high rise (dark blue colour). This could indicate the presence and movement of sandbanks and channels. The use of colour also seems to help in identifying the spatial-temporal pattern of the movements. With the knowledge of the areas that rise or decline the movement can be identified. This is tested in the usability test and the result is discussed in section 4.2. Especially when looking at the image of the whole study area (figure 4.1.4.2) the locations and dynamics become clear by the use of colour. Area A can be identified as an area with a (large) decline, and Area B is clearly a rising area. This rising area can be identified as a part of the West-East dynamic in the area where a cyclic pattern is visible of sand that comes from the beach hook and accumulates on the north beach.

Figure 4.1.4.1: Linear visualization of a part of the area with a variable colour use using a 50x50m grid

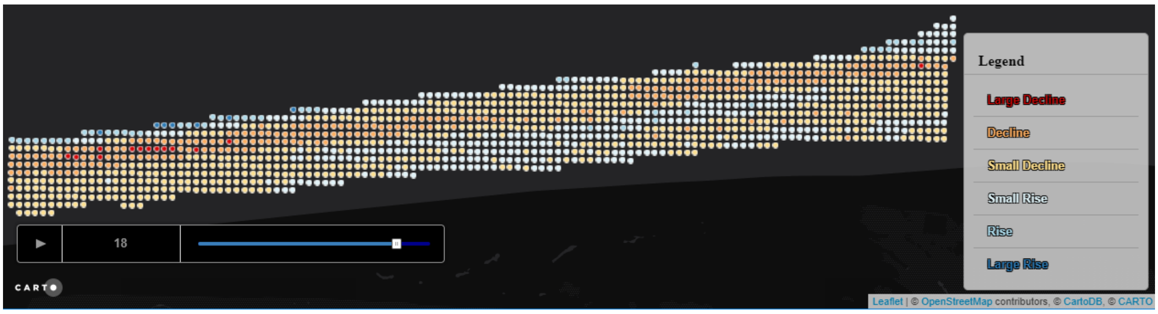
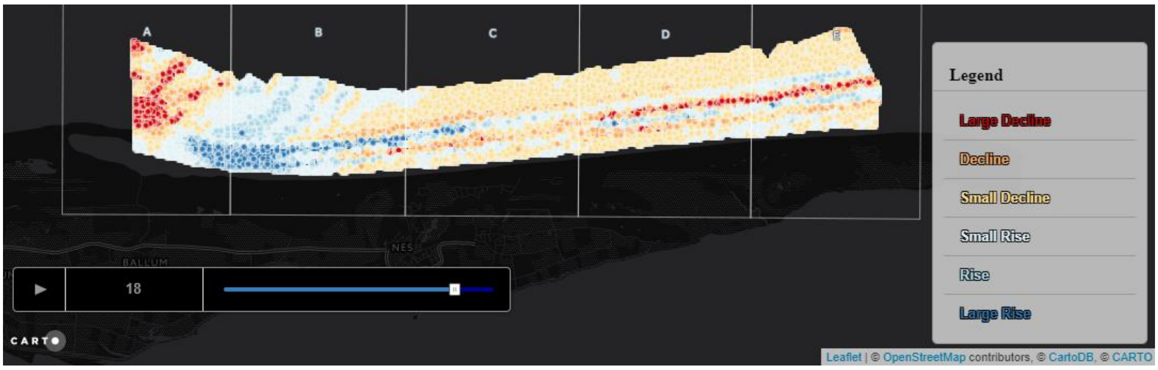


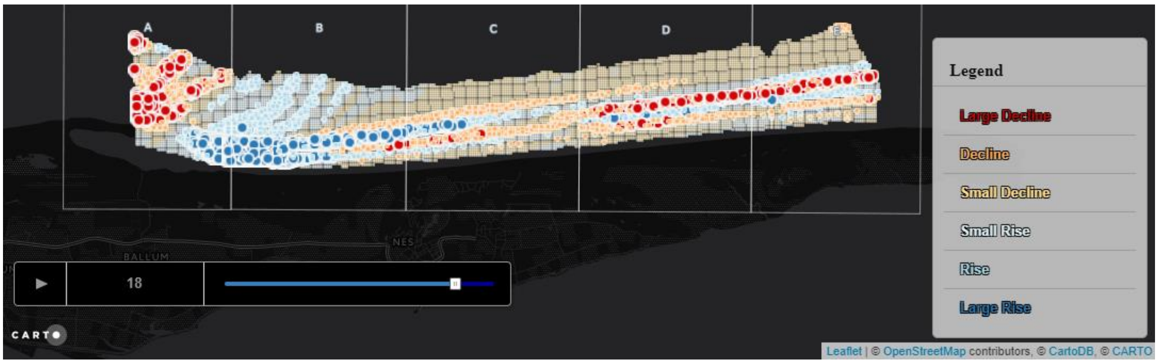
Figure 4.1.4.2: Linear visualization of the whole area with a variable colour use using a 50x50m grid



4.1.5 Combined colour and marker size variation

It has become clear that both the marker size and the colour variation help to show the location with dynamics and in some way help to discover a spatial-temporal pattern. It is also possible to combine these two visual variables and create a double coded map. The result of this is visible in the previous figure 4.1.1.1, 4.1.1.2 and in the figure underneath 4.1.5.1. The combination of the both graphic parameters seems to have a clarifying effect on the image. Where for the total area with only colour variation the figure (4.1.4.2) has points with no hierarchy, the variation in marker size creates some kind of hierarchy in the points. By hierarchy is meant that the focus is more triggered to certain elements with high dynamic instead to all the points. The visualization with the combination of both the visual variables changing seems to give a clear presentation of the location with high dynamics. So does the situation in area A (figure 4.1.5.1) seem to present a large decline, in area B a large rise and in area C clearly a more stable situation with smaller dynamics.

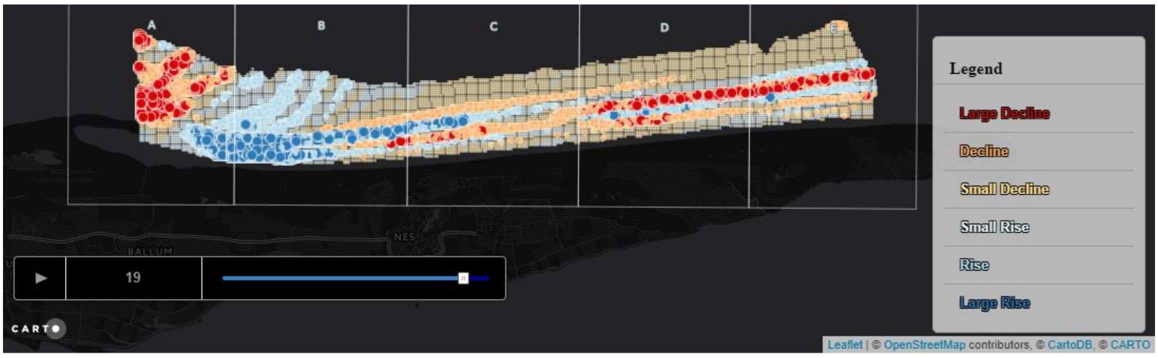
Figure 4.1.5.1: Linear visualization of the total research area with use of colour and marker size variation using a 50x50 grid



4.1.6 Blinking element

The version with both colour and size distinction seems to be the most appropriate way to show the dynamic and the pattern. Blinking is unfortunately not very presentable as a static analogue map but when comparing the frame 18 and 19 the effect of the blinking becomes visible. The clear white line that is visible around the markers in figure 4.1.5.1 is not that clear anymore in frame 19 (figure 4.1.6.1).

Figure 4.1.6.1: Visualization of the total research area with use of colour and marker size variation using a 50x50 grid



The Blinking element in the maps with no colour (only white), does not come forward very clear. This is because of the fact that both the marker-line, which creates the blinking element and the marker itself are the same colour. A distinction is difficult to make, the blinking moment provides an image with more white. An option is to select two different (complementary) colours or -tones to make it clearer. The blinking element in the maps with no marker size variation seems to be a superfluous addition because all the blinking is the same and a distinction for the classification is not made. The purpose of the blinking elements to focus on a specific element does then not work. As this is not the case it might even be distraction or even be creating more blindness. In the maps where there is a distinction in the marker size the blinking element seems to help to focus on the locations with higher dynamics as the Blinking elements are more visible because of a thicker marker line.

4.2 Usability evaluation

The usability test is performed on those maps with the highest perception assumption. Especially the combined map with both colour and marker size variation is expected to be useful in identifying dynamic locations and spatial-temporal patterns. As the colour use influences the perception of the map seriously it is interesting to also include a linear map with only marker size variation in order to test the possibilities of this graphic parameter. The third map that is included is to test the difference between the linear and the cumulative aggregation method.

The usability test was set out in the GIMA-students group on a Wednesday. A first reminder was sent on the second day which led to the bigger part of the responses. A reminder was also sent on Monday but this only led to one more response. As was expected most of the people responded or immediately or not at all anymore. With a total response of 15 the statistical quality is not as high as was hoped for but most of the results show a clear pattern. The questions about the first map were answered by all participants; the second by 14 and the last two questions about map 3 were answered by 12 respondents. The average completion time was 10 minutes. The exact result to all of the questions can be found in appendix 7.5. The test is discussed per question.

4.2.1 Identification of the dynamics

As is explained in the methodology, three visualizations are shown for which the respondents have to answer two questions. The goal is to test to see whether the user of the map can see the locations of the dynamics, and is able to identify a spatial-temporal pattern. The first question about map 1 gives quite clear answers, however with a little doubt sometimes in the exact amount; Area A and E are both seen as areas with a “large decline” but are followed closely, only 1 and 2 responses difference, by the option “decline”. The situation in Area A aligns with the pattern that is identified in the methodology (section 3.2). Here Area A was identified as an area with a “decline” in the area, with the presence of a “large decline”. It is understandable that these two options are given, especially because the differentiation in marker size focuses more on the large dynamics. This is probably also the reason that in Area E a larger decline is identified than is truly present based on the statistics.

The answers for the first question with map two are quite unanimous. Interesting is that in map 1 for area E there is chosen for a “large decline” but only for “some dynamics” at Map 2 and for the third map no distinctive answer is given. The influence of clear blinking and colour variation seems to create a more extreme interpretation of the visualization.

Map 3 shows a lot of differentiation between the answers for the first question. In the question about Map 3 Area A and B are clear, 91% for high dynamic, but the other areas are open for interpretation. The respondents choose in Area C and Total Area for both the options “high dynamics” and ”dynamics” evenly. In Area D there was only one more response for “dynamics”, which with this amount of respondents should count as a draw between the two options. And for Area E the response was almost evenly distributed between the three options of dynamics; high, normal, small.

Table 4.2.1: What dynamics are visible in an Area according to the respondents

Area	Map 1	Map 2	Map 3
A	Large Decline	High dynamics	High dynamics
B	Large Rise	High dynamics	High dynamics
C	Small Decline	Some dynamics	X
D	Decline	Some dynamics	X
E	Large Decline	Some dynamics	X
Total	Small Decline	High dynamics	X

X: no distinctive answer

The results of question one indicate that the use of a linear map allows for a better perception of the locations of dynamics than the cumulative map. The cumulative maps lead to more discussion under the participant. Also the answers indicate that the use of colour in the blinking map can lead to a more extreme interpretation of the map.

4.2.2 Spatial-Temporal pattern

Then the results of the second question of the usability test. This question asks the participant to identify a spatial-temporal movement pattern for each of the areas. For the map with both colour and marker size differentiation it is difficult for the participant to identify a movement pattern. For Area A & B there is a clear identification for a West-East movement, more than 60%. However for all the other areas and the total area both the West-East movement and the East-West moment score equally. Interesting is that for the second map all the areas get a clear West-East movement indication, 50% till 85%. This visualization seems to show a more constant idea of what is going on in the area. Some participants also see a south to north movement, this especially in area D. Also the answers about the third map are too diverging to point to a certain direction of the spatial-temporal movement pattern. The division is between the west-east, south-north or no movement options.

Table 4.2.2: What spatial-temporal patterns is visible in an Area according to the respondents

Area	Map 1	Map 2	Map 3
A	West-East	West-East	West-East
B	West-East	West-East	West-East
C	X	West-East	No movement
D	X	West-East	X
E	X	West-East	X
Total	X	West-East	X

X: no distinctive answer

The results of the second question indicate that the maps 1 and 3 are not very suitable for the identification of a spatial-temporal pattern in the area. Only in a few sub areas the pattern could be identified, in the others the participants see to many different options. Map 2 with only marker size differentiation

To arrive at some conclusion about the usability test: The use of colour and marker size in a linear visualized blinking animated map can be helpful in the presentation of the locations of dynamics and the identification of these dynamics. It can however lead to a more extreme interpretation of the real situation. It is however a good way to display a diverging scale and focus on the parts with the higher values. This kind of map is, against the expectations, however not very suitable for the identification of a spatial-temporal pattern.

A linear visualized blinking map with only the use of the visual variable marker size is suited for both the identification of locations with dynamics and for the identification of a spatial-temporal pattern. The cumulative visualization is only effective in the areas with a very clear spatial-temporal pattern and extreme dynamics. It is in this version not very suitable to present dynamics in the shoreface.

Chapter 5 - Conclusions

This last chapter is divided into three subdivision; the conclusions with the summary of the answers to the research questions, a discussion and reflection of the followed procedure a choices, and recommendations for further research.

5.1 Conclusion

In order to complete the research objective*: to develop and test a visualization to show the morphologic dynamics of the shoreface*, the visualization question as stated by Koeman is brought into the project. In the introduction of this report this question is clearly worked out. The question explains that for a useful map one should know the users, know what the message of the map is and define a method to create the map. This project has mainly focuses on the “what” and “how” of this question.

First known was that the JARKUS-data was the basepoint for the visualization of the dynamics in the shoreface. Because this dataset was not known before the project started the data had to be researched and the possibilities identified. This led to the understanding that the JARKUS data could be used in the presentation of dynamics in the shoreface. Where previous researches often focused on the presentation of the developments of the coastal profile this project is focused on the presentation of the locations of the dynamics and to try to show a spatial-temporal pattern.

The analysis on how to visualize elements led to the understanding that there are a lot of possibilities to visualize the dynamics. Especially with the development of technical capabilities and digital mapping the classical cartographic grammar that can be used for static maps is overgrown. Nowadays there are a lot of possibilities with interactive animated maps that even seem to develop to augmented reality. But before going too far in this part of the conclusion and directly continue to the how. First the first part of the research should be discussed.
The first part of the research was mainly about a literature review to find the answers to the first two research questions. Where intentionally the goal was to extract the morphological features and show the developments over time this later changed to the visualization of the dynamics. This was the result of limitations in tools and resources, and choices made to fit the research within a certain scope.
The morphological features that are identified as to be of relevance in the underwater shoreface are the rip channels, gullies and potholes, and longshore bars. These can be identified within the JARKUS data. Other smaller elements of the short term morphology can’t be identified by the JARKUS data, as is also for the really long term morphological elements.

By mentioning these time periods there is already made a bridge to the second research question. This question asks what the dynamics of the identified morphological features are. The literature identifies the pulsing of morphological features like longshore bars and rip channel, the movement along or cross shore of the features and the emergence and disappearance of these features. For the visualisation of the dynamics in the shoreface and the identification of the spatial-temporal pattern the height development of certain areas is the most interesting. An analysis of the situation at Ameland concludes that the north coast is influenced greatly by the so called Zeegat Ameland on the west side of the island. Also the West-East longshore current from the Dutch coast influences the coast of Ameland. The combination of these two phenomena leads to the existence of a beach hook just to the west of the research area. The presence of this hook leads to a lot of dynamics in the western part of the research area where a lot of height changes can be detected. In this area clear erosion- and a sedimentation zones can be identified. The what of the visualization question thus became the visualization of the locations with dynamics in the shoreface of north Ameland.

Next came the second part of the project: an extensive search on how to visualize these dynamics. More literature and tools where researched to decide that the visualization was to use Blinking elements and to test whether these blinking elements could present the dynamics of the shoreface and possibly help in the perception of a spatial-temporal pattern.

The temporal aspect of the data creates extra difficulties as there are problems with change blindness and the capabilities of the users' perception. The presented map should not have too little to show but certainly also not too many. The blinking elements are planned to be used to help focus on the locations with a lot of dynamics. In the end there is chosen to create visualizations that have blinking and are variable in certain visual variables. The changing visual variables are: spatial resolution, colour and marker size. The tool to create the visualization is the CARTO library with especially the TORQUE functionality. However this is not directly created for this kind of work the temporal aspect was essential for the visualizations. This TORQUE function also introduced an extra element to be tested. How would the aggregation function influence the visualizations? In the end a total of eighteen visualizations are created. These visualizations are an answer to the "How" of Koeman's' question and the method is the answer to the third research question.

This leaves the project with the final research question: How are these visualizations understood? In order to get an answer to this question the usability test is performed. The participants fit the who part of Koeman's question, as they are experienced with maps but do not have expert knowledge of the processes in the shoreface. The usability test led to the conclusion that the map with both variation in colour and in marker size was good to show the users the exact dynamics, with a little side note that it created a focus on the parts with a lot of dynamics. This presentation turned out to be less useful for presenting a spatial-temporal pattern. The tested map with only marker size variation turned out to be more effective in the identification of the spatial-temporal pattern. This map can also be used for the identification of the locations with a lot of dynamics, but without the distinction in the exact character of the dynamics. The third map that was tested was a cumulative visualization of the dynamics of the shoreface. Although the expectations where that this would be a solid way to present the data it turned out that it left to much room for different interpretations of the dynamic and the spatial-temporal pattern.

To conclude the morphological features in the shoreface that are of interest on de mid-term timescale are the longshore bars and rip channels. The development of these elements under the influence of the natural and artificial circumstances can be shown by displaying the dynamics in height over time. A blinking map can help in the identification of the locations of the dynamics and in the identification of the spatial-temporal pattern. It however still remains difficult to use the correct graphic variables to display the development over time.

5.2 Discussion, Reflection, Recommendations

In the research a set of visualizations are created based on variation in the visual variables. There was chosen for some variables to remain constant and others to be variable. One of these constant variables is the blinking speed. There have been experiments to influence the blinking speed by creating multiple frame-offsets However by doing this the total timeline went wrong and it created a chaotic situation. The use of the TORQUE functionality and the knowledge about it were insufficient to create images with different blinking speed. The idea behind this different blinking speed was to focus more attention on the blinking elements with high dynamics.

For some of the maps the expectations were higher than comes out of the usability test. This can be influenced by the limited amount of people that has participated in the test or by the information that is provided in the test. Additional questions about the maps and about the users ideas of the map might be helpful to get more clarity about the interpretation of the map. The broad target group of people with some experience in GIS with the capabilities to understand maps but that do not have expert knowledge about the processes and the area means that the exact population size of the research is unknown. The test sample is taken in an population of GIMA-students of at least 100. For the GIMA students is assumed they have enough technical and mapping experience and no expert experience with the research topic and area. With this group as the population size, a sample size of 49 is needed to reach a confidence level of 95% with an margin of error of 10% (Creative Research Systems, 2017). The confidence interval, or margin of error, is the radius around the sample results. The correct value for the total population can be assumed to be within this margin. (Wikipedia, 2017). Based on the 15 responses and the percentage to guess the right answer the confidence interval can be calculated. In this case the average of 4.5 anwser options per question means a percentage of 22.2% chance to guess the correct answer. With a 95% confidence level and the sample size of 15. This means that the confidence interval is 21.03% (Creative Research Systems, 2017). Any anwser of the sample results thus has an margin of 21.03% above and below the test result to be statistically correct.

The maps that surprised in their performance in the usability test were the cumulative map and the map with both colour and marker size variety. Where for the cumulative map the expectations for it were to give a good understanding of the dynamics, this was not very clear. Possibly it was better to use a different colour than white and include a tone effect based on the cumulative value. The research also only shows a cumulative map for all the change classes, there is an possibility to only show the highest change classes but due to time restriction and the total amount of visualizations this map wasn't created. The initial goal for the cumulative map was to create a diverging effect. This was tried by using some complicated SQL functionality in the scripts to create a distinction between decline and rise and show this distinction using colour effect. However some examples in other projects showed methods on how this was possible, the project didn't succeed in creating those visualizations. One might also try to load the rising and declining points as different layers and create an overlay on the map. This isn't tested in the project as it is not recommended to include multiple TORQUE layers in one map but it leaves an interesting window for further experiments.

The map with both colour and marker size variation turned out to be not very successful in the discovering of a spatial-temporal pattern. It was expected that especially this map was useful for this purpose as it included the distinction between rising and declining areas. It however turned out that it was probably too detailed and the user of the map was a bit overwhelmed by all the variety. It would be an interesting addition to create a fully interactive product where the user can select the data and the visualizations itself. The approach to use a base year and create a data normalisation should then be revised. The creation of all the data cannot happen on the fly. This is also part of the reason there was chosen for a constant time step interval of 1 year. It would especially be a fun part to make a combination of a map with contour lines and the points in one map and take a look on the dynamics in that way and experiment with the potential of such a map. It has already been mentioned several times but the extension of the research from point data to one of lines or objects and to visualize these in a blinking interactive map, is open.

Some parts of the research could have been handled differently. There might have been more attention to the users of the map. Now there is chosen for a neutral user, but when there had been contact with for instance Rijkswaterstaat on what they would like to see in a map of the dynamics, the relevance of the research could have been higher. The goal for the user could have received more attention.

Another thing that could have been worked out deeper is the blinking element. Now all maps that are created have the same blinking based on the size of the marker. Some different coding in the visualization scripts would have led to a more interesting analysis on the blinking. There might have been looked at differentiation in the blinking elements in maps with no marker size variation based on the value of a point. This would however have led to a new load of visualizations and it would have been necessary to limit the variation on other variables.

Where Bertin's theory of graphical variables is the more classical print-only theory, this research includes some parts of the new visual variables as discussed by Blok (2005), Kraak (2010), and Green (1998). They noticed the elaboration of the available techniques and include new digital visual variables to create interactive and animated maps. The new element that is tested is the blinking or flickering, which has added an extra visual variable to the maps. Bertin's theory was that there could only be two retinal variables. The research uses two classical visual variables, colour and size, and includes a third, blinking. The research can be seen as an extension on the research to graphic perception as there was already proposed by Green, Blok, and Kraak. The project adds to the blinking functionality the presentation of dynamics where it is especially identified as a tool to be used to show emergence or disappearance of features. The research allows room to extent more on the principles as identified by Dibiase (1992). These are the variables duration, order, and rate of change. These variables can be useful in the presentation of dynamics by differentiation in blinking duration or time step interval. This aligns with the possibility to experiment with the variables duration or frequency from McEachren (1994). Next to the fact that the research leaves room for more testing and experimenting with the graphic or temporal parameters it also leaves room for more elaborate testing of the effect of blinking on the image perception in a preattentive or attentive way. An extensive test to the reaction of the users in order to analyse the results of blinking on the (pre) attentive perception of the users as is mainly discussed by Bertin and Blok. The users can be tested to do some specific task with focus on an certain area and then analyse the result of the blinking element. In the research field of dynamics of the shoreface the visualizations provide an new view to the existing research (Deltares, 2016; Rijkwaterstaat (2000; Dynamisch Kustbeheer, 2016; Cleveringa). Where those researches are focused on the classic graphic parameters the project provides a new way to display the dynamics in a more interactive animated way.

Concluding it can be said that the project succeeded in creating some nice visualization of the dynamics of the shoreface using interactive animated maps with blinking element. Due to time and resources constraint there are some limitations to the research, but it leaves room for further analysis and the creation of more visualizations.

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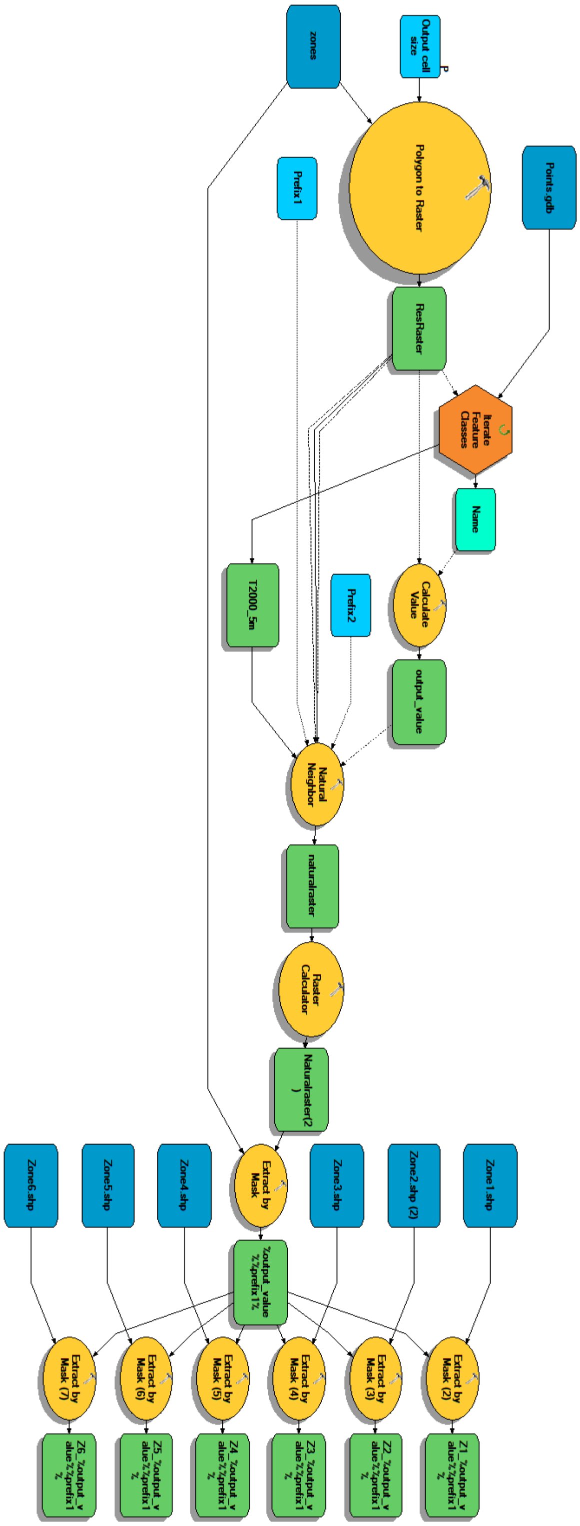
7. Appendices

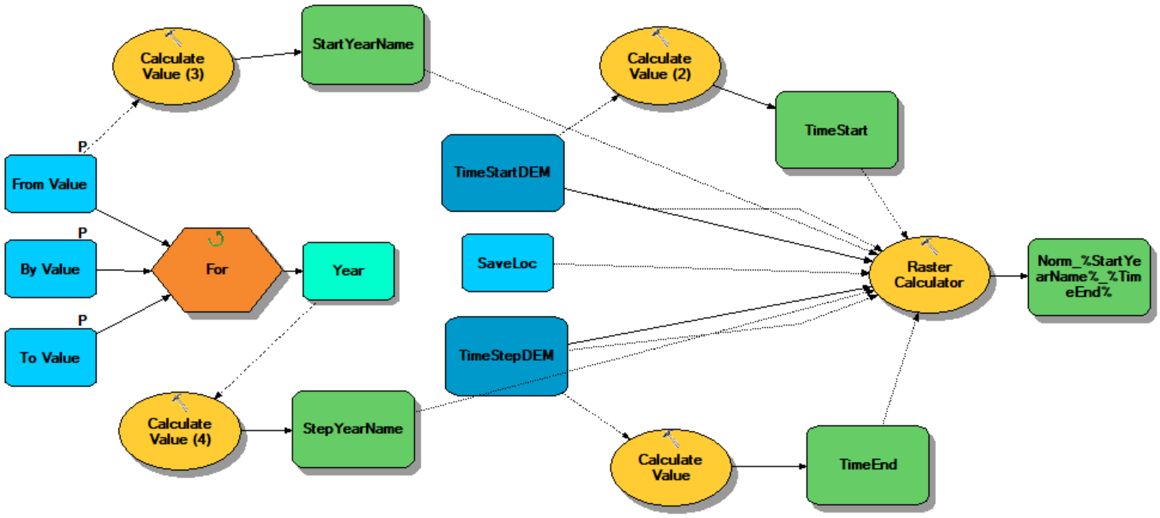
7.1 Model builder scripts
7.2 File name explanations for the visualization scripts
7.3 Examples of the Carto scripts
7.4 Images of all visualizations
7.5 Results of the usability test

7.1 Model builder images

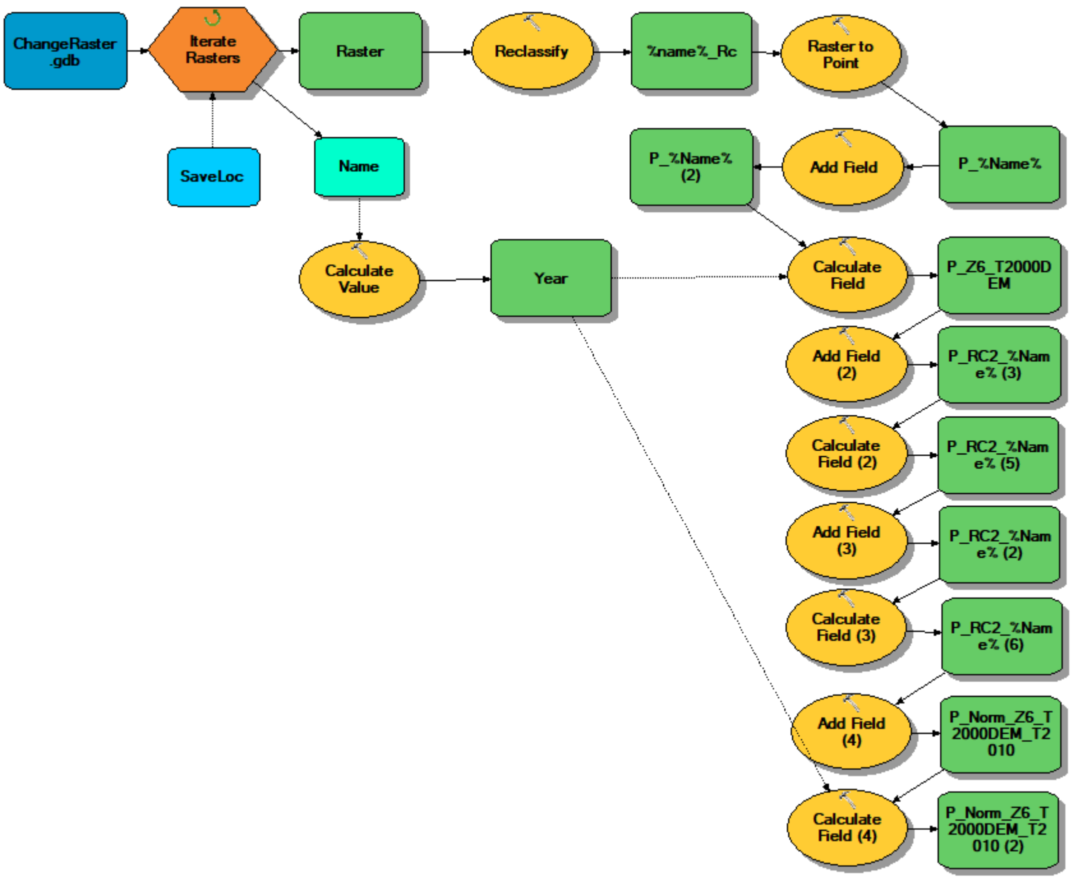
Model 1: Create Dems Model



Model 2: Create Normalized Change Rasters



Model 3: Reclassify the value of change Rastercel and add date field



7.2 File name explanations

The filenames that are used in the accompanying files of this report are

Coding used in the names of Visualization scripts, databases and images

YS/NS	- A script or image with or without variation in marker size
YC/NC	- A script or image with or without variation in marker size
Z0/Z6	- The Whole research area or a selection of the research area
10m/50m	- The spatial resolution of 10 or 50m
Linear	- The linear aggregation method is used
Cumulative	- The Cumulative aggregation method is used
10y	- The period of ten years
B125	- The Ordinal variable for medium and large change is used

7.3 Example Carto Script

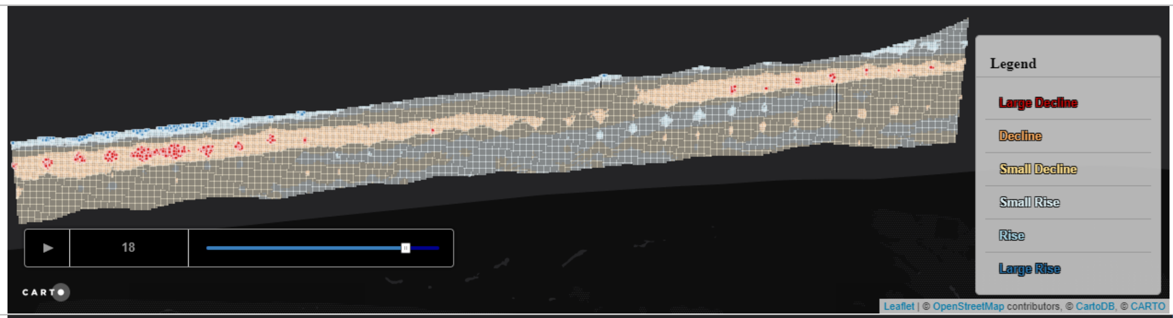
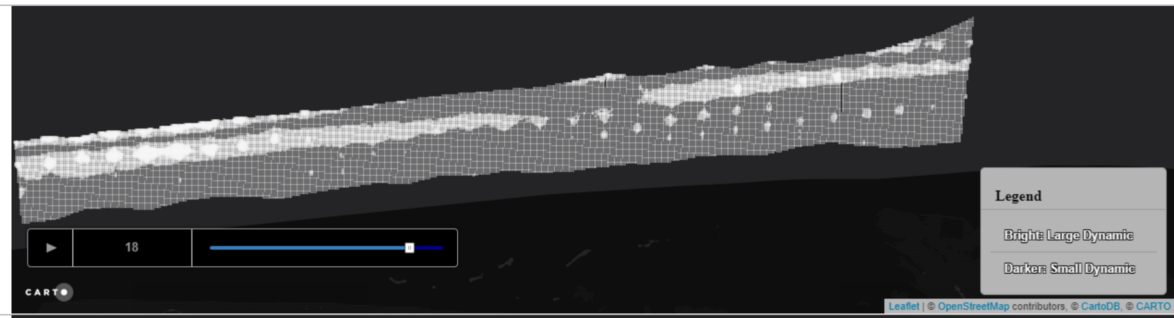
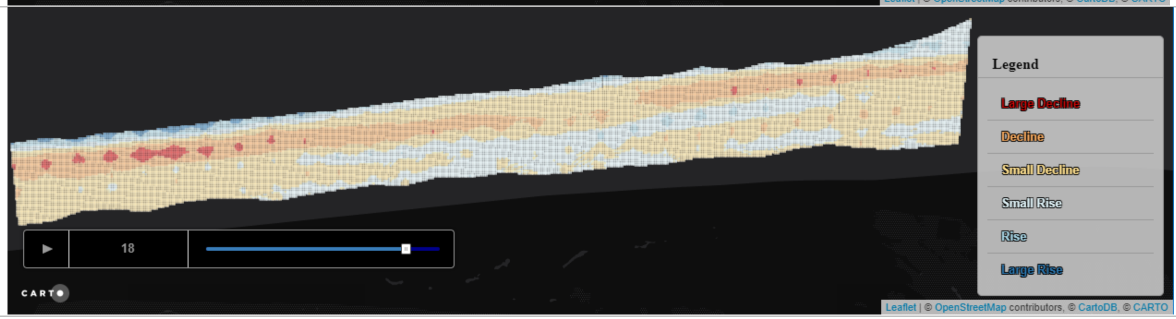
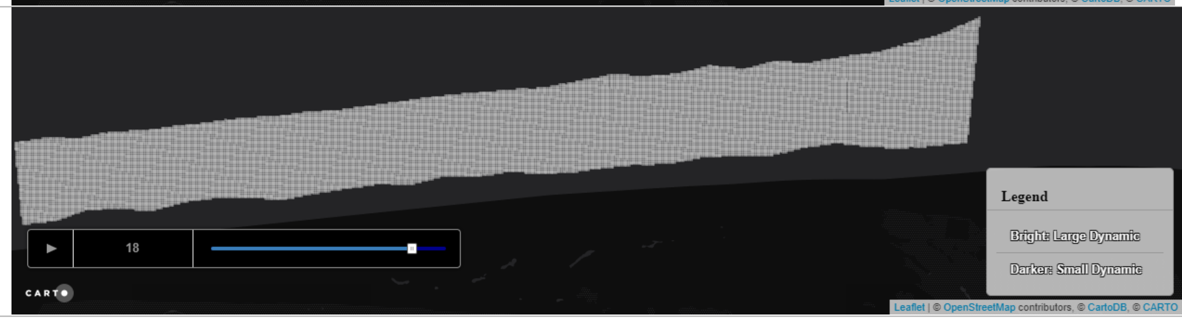
```
<html>
  <head>
    <title>Shoreface Ameland Visualisation</title>
    <meta name="viewport" content="initial-scale=1.0, user-scalable=no" />
    <meta http-equiv="content-type" content="text/html; charset=UTF-8"/>
    <link rel="shortcut icon" href="https://carto.com/favicon.ico" />
    <style>
    <script type="cartocss/text" id="cartocss">
    /** torque visualization */

    Map {
    -torque-frame-count:22;
    -torque-animation-duration:11;
    -torque-time-attribute:"yearb";  // year for the real timestamp or yearb for the integer years
    -torque-aggregation-function: "CDB_Math_Mode(grid_code)";
    -torque-resolution:1;
    -torque-data-aggregation:linear;
    }

    #layer{
      comp-op: source-over;
      marker-fill-opacity: 1;
      marker-line-color: #f7f7f7;
      marker-line-width: 0.5;
      marker-line-opacity: 1;
      marker-type: elipse;
      marker-width: 3;
      marker-fill: #f7f7f7;

    //Size and Colour differentiation
      [value = 1] { marker-width: 5;     marker-fill: #d60606;  marker-line-width: 2;}   //dark red    #d60606
      [value = 2] { marker-width: 2.5;   marker-fill: #fdae61;  marker-line-width: 1;}   //orange      #fdae61
      [value = 3] { marker-width: 1;     marker-fill: #fee090;  marker-line-width: 0.5;} //yellow      #fee090
      [value = 4] { marker-width: 1;     marker-fill: #e0f3f8;  marker-line-width: 0.5;} //light blue  #e0f3f8
      [value = 5] { marker-width: 2.5;   marker-fill: #abd9e9;  marker-line-width: 1;}   //blue        #abd9e9
      [value = 6] { marker-width: 5;     marker-fill: #2c7bb6;  marker-line-width: 2;}   //dark blue   #2c7bb6

     //Blinking: offset line width half of normal line width
     #layer[value = 1]{   [frame-offset=1] {  marker-line-width: 1;     }    }
     #layer[value = 2]{   [frame-offset=1] {  marker-line-width: 0.5;   }    }
     #layer[value = 3]{   [frame-offset=1] {  marker-line-width: 0.3;   }    }
     #layer[value = 4]{   [frame-offset=1] {  marker-line-width: 0.3;   }    }
     #layer[value = 5]{   [frame-offset=1] {  marker-line-width: 0.5;   }    }
     #layer[value = 6]{   [frame-offset=1] {  marker-line-width: 1;     }    }
   }

    </script>
```

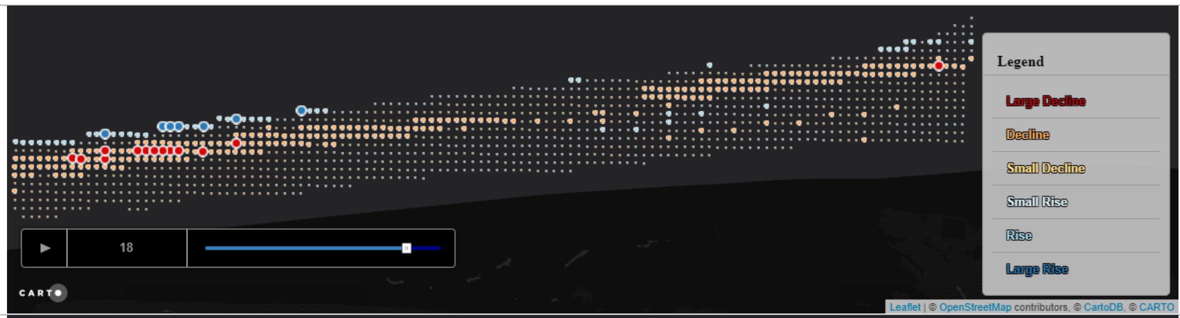
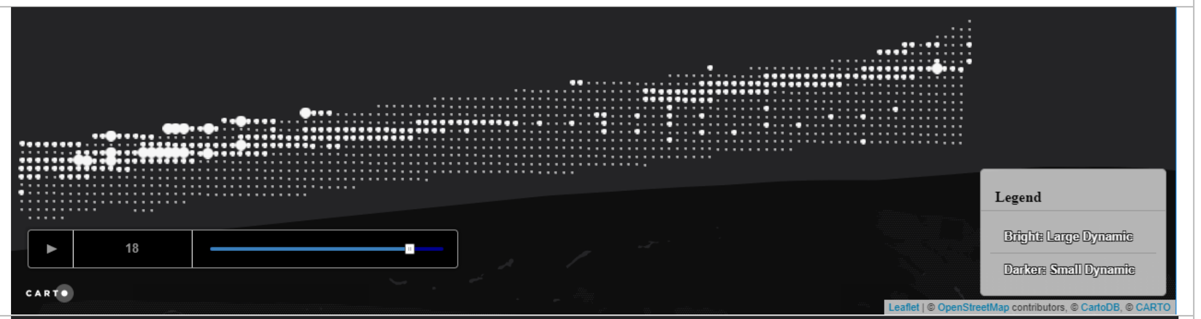
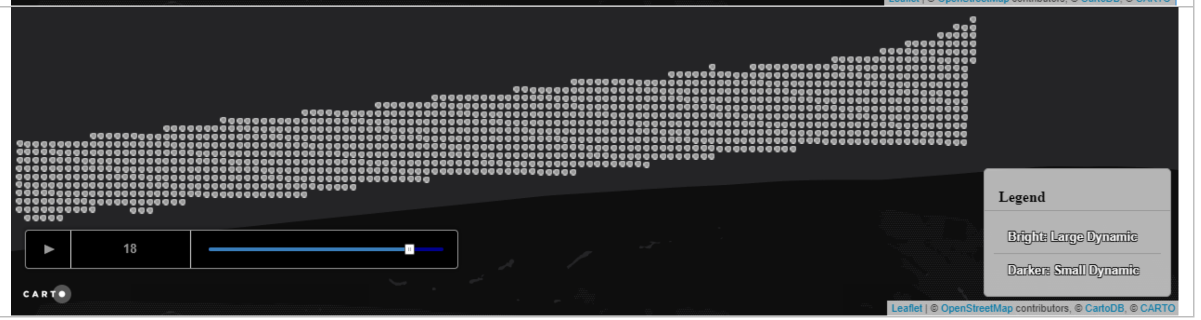
```
<script src="https://cartodb-libs.global.ssl.fastly.net/cartodb.js/v3/3.15/cartodb.js"></script>
<script>
  function main() {
      var layer = L.tileLayer('http://{s}.basemaps.cartocdn.com/dark_all/{z}/{x}/{y}.png', {
          attribution: '&copy; <a href="http://www.openstreetmap.org/copyright">OpenStreetMap</a> contributors, &copy; <a href="https://carto.com/attributions">CartoDB</a>'
      });
      var map = new L.map('map', {
          scrollWheelZoom: false,
          center: [53.473,5.8875], // Ameland
          zoom: 14
      });
      map.addLayer(layer);
      var tableName = "E_Linear_10y_50m";
      var userName = "wvdhulst";
      var layerSource = {
          type: 'torque',
          options: {
              query: "SELECT * FROM " + tableName,
              user_name: userName,
              cartocss: $("#cartocss").html()
          }
      }
      cartodb.createLayer(map, layerSource, {https: true})
        .addTo(map)
        .done(function(layer) {
            var torqueLayer = layer;
            var slider = map.viz.timeSlider;
            torqueLayer.pause();
            torqueLayer.on('load', function() {
                torqueLayer.play();
            });
            slider.formatter(function(d) {
            var year = d.getUTCFullYear().toString();
            console.log(year + " hoi");
             return d.getUTCFullYear();
            })
            // pause animation at last frame
            torqueLayer.on('change:time', function(changes) {
                if (changes.step === torqueLayer.provider.getSteps() - 1) {
                    torqueLayer.pause();
                }
            });
            //console.log(torqueLayer.getTime());
        })
        .error(function(err) {
            console.log("Error: " + err);
        })
        };
  window.onload = main;
</script>
```

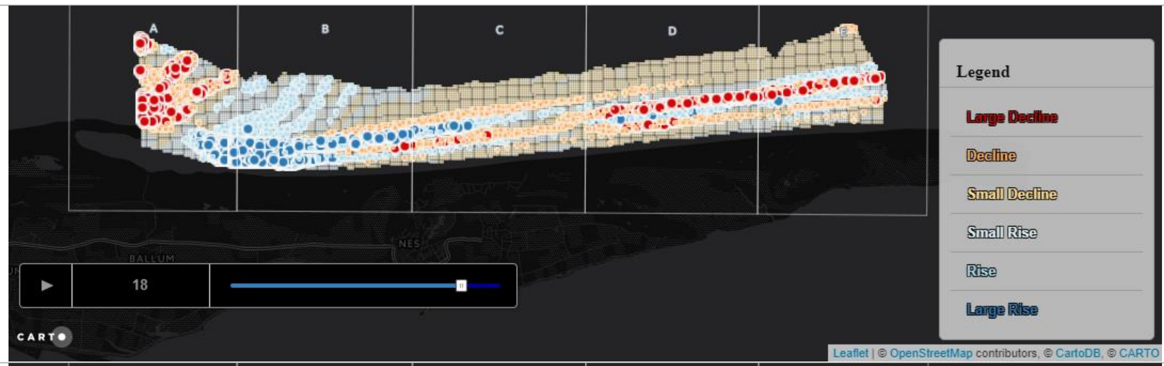
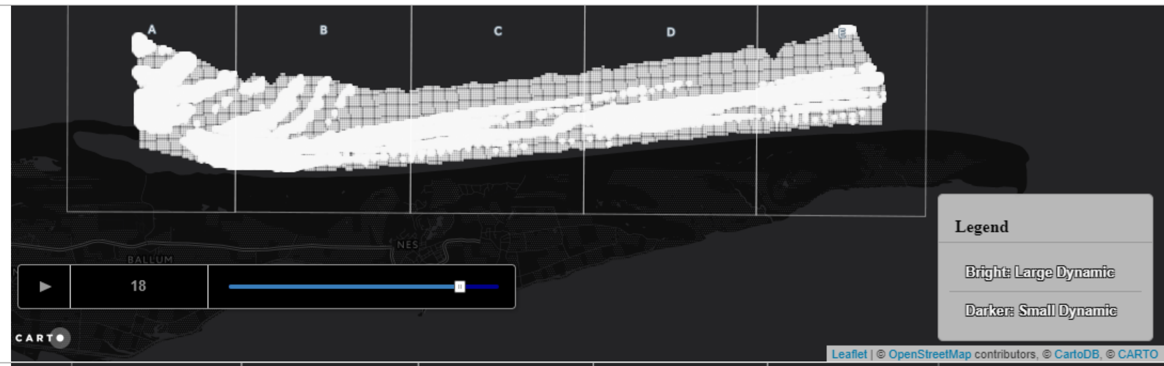
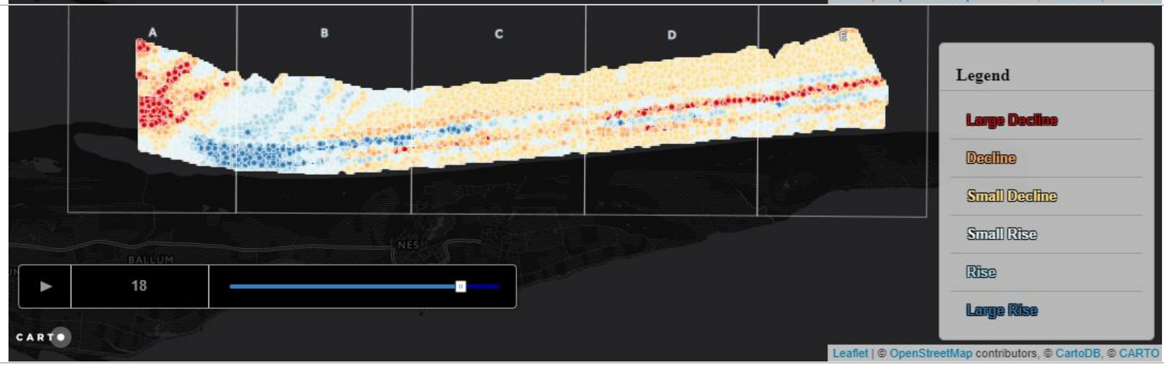
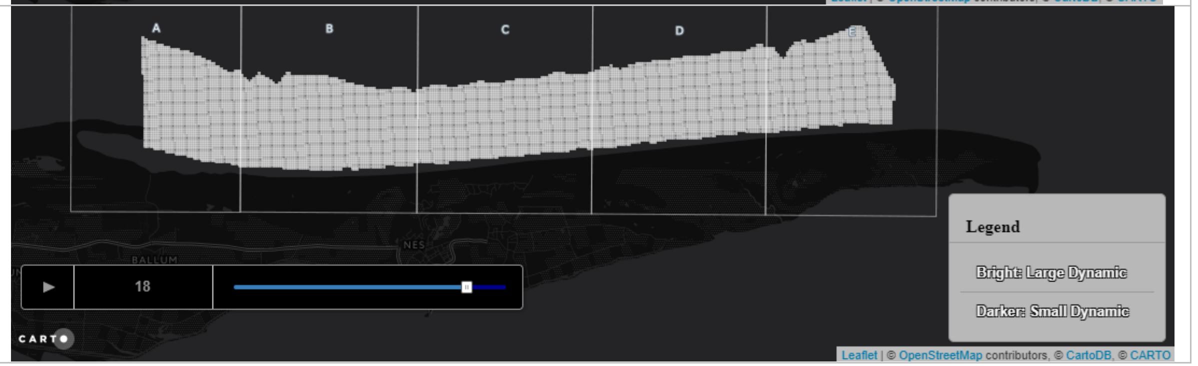
7.4 All Images of the results

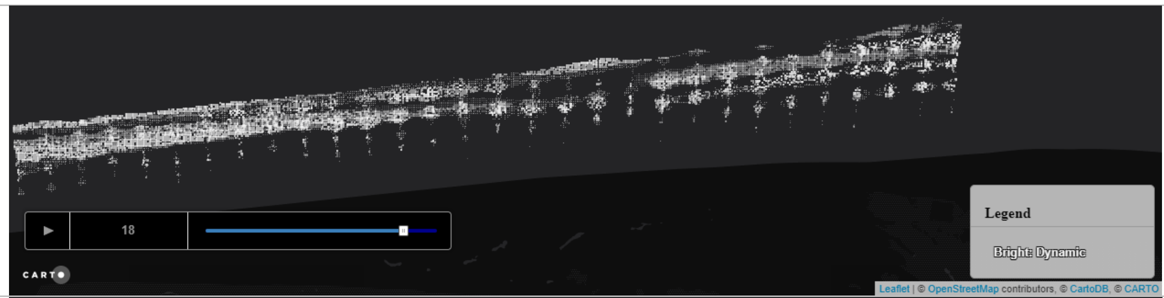
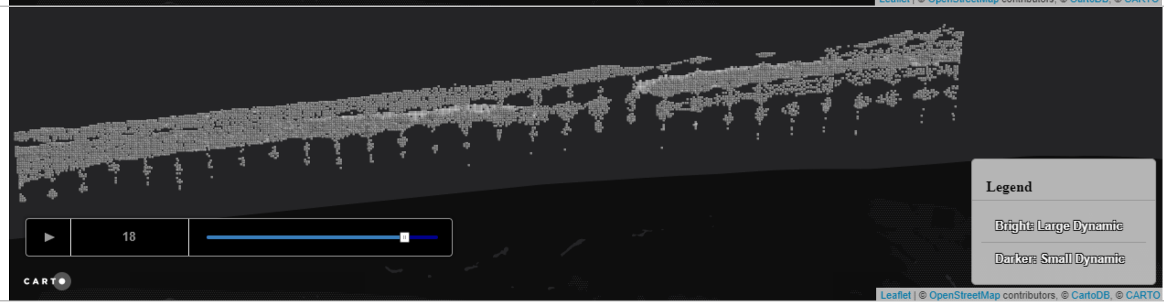
Index:

1. Linear 10x10 part of the research area
2. Linear 50x50 part of the research area
3. Linear 50x50 total research Area
4. Cumulative 10x10 part of the research area
5. Cumulative 50x50 part of the research area
6. Cumulative 50x50 total research area

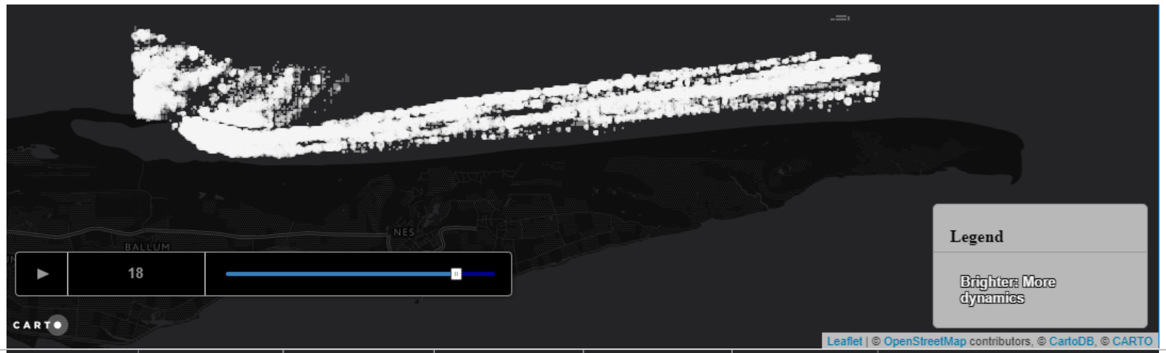
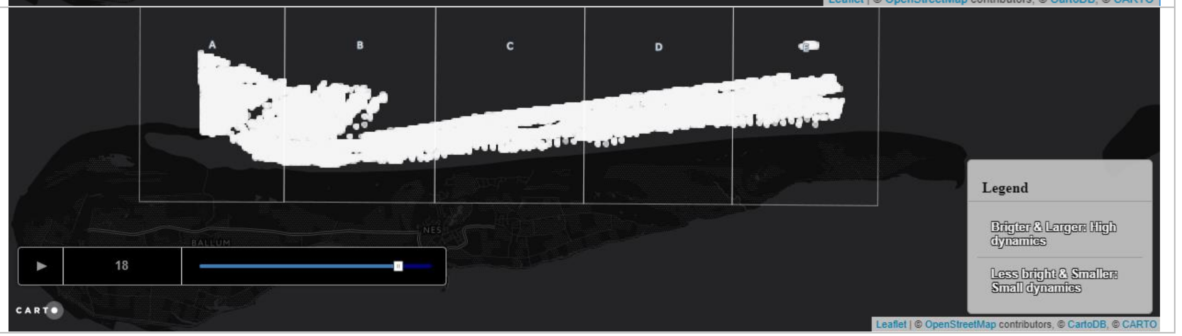
<table>
<tr><th colspan="4">Linear Visualizations of a part of the research area</th></tr>
<tr><td>Spatial scale</td><td colspan="3">10 x 10 meters (Selection of the research are only)</td></tr>
<tr><td>Classification</td><td colspan="3">Normalized to Year 2000: 6 Classes</td></tr>
<tr><td>Timescale</td><td colspan="3">2000 - 2010, 1 year steps</td></tr>
<tr><td></td><td></td><td colspan="2">Colour variation</td></tr>
<tr><td></td><td></td><td>Yes</td><td>No</td></tr>
<tr><td>Size variation</td><td>Yes</td><td>
</td><td>
</td></tr>
<tr><td></td><td>No</td><td>
</td><td>
</td></tr>
</table>

Linear visualizations of a part of the research area			
Spatial scale	50 x 50 meters (Selection of the research area only)		
Classification	Normalized to Year 2000: 6 Classes		
Timescale	2000 - 2010, 1 year steps		
		Colour	
		Yes	No
Size variation	Yes		
	No		

Linear visualization of the whole research area			
Spatial scale	50 x 50 meters (Total research Area)		
Classification	Normalized to Year 2000: 6 Classes		
Timescale	2000 - 2010, 1 year steps		
		Colour	
		Yes	No
Size variation	Yes		
	No		

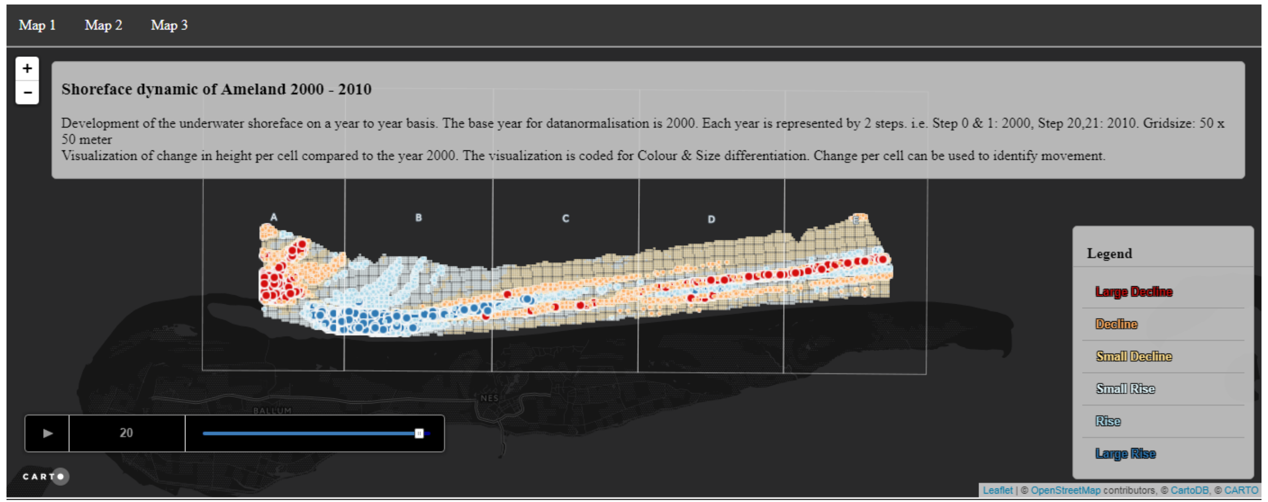
Cumulative visualization of a part of the research area		
Spatial scale	10 x 10 meters (Selection of the research area)	
Classification	Normalized to Year 2000: Ordinal change	
Timescale	2000 - 2010, 1 year steps	
		Colour
		No
Size variation	Yes	
	No	

Cumulative visualization of a selection of the research area		
Spatial scale	50 x 50 meters (Selection of the research area only)	
Classification	Normalized to Year 2000: Ordinal	
Timescale	2000 - 2010, 1 year steps	
		Colour
		White
Size variation	Yes	
	No	

<table>
<tr><th colspan="3">Cumulative visualization The total Research Area</th></tr>
<tr><td>Spatial scale</td><td colspan="2">50 x 50 meters (Total Research Area)</td></tr>
<tr><td>Classification</td><td colspan="2">Normalized to Year 2000: Ordinal</td></tr>
<tr><td>Timescale</td><td colspan="2">2000 - 2010, 1 year steps</td></tr>
<tr><td rowspan="2"></td><td></td><td>Colour</td></tr>
<tr><td></td><td>No</td></tr>
<tr><td>Size variation</td><td>Yes</td><td>
</td></tr>
<tr><td></td><td>No</td><td>
</td></tr>
</table>

7.5 Usability test results

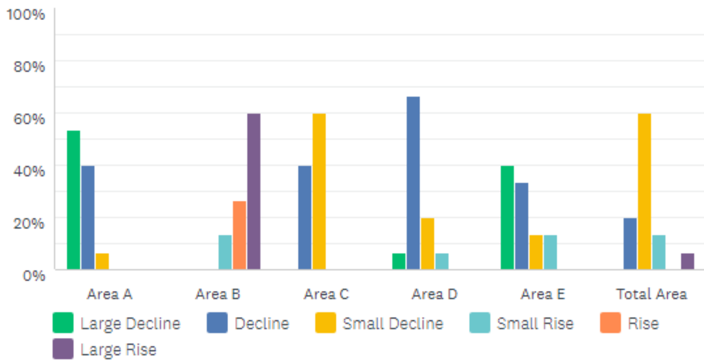
Map 1 Linear visualization with colour and marker size variation



Question 1:

What would you say about the dynamic in each Area

Beantwoord: 15 Overgeslagen: 0

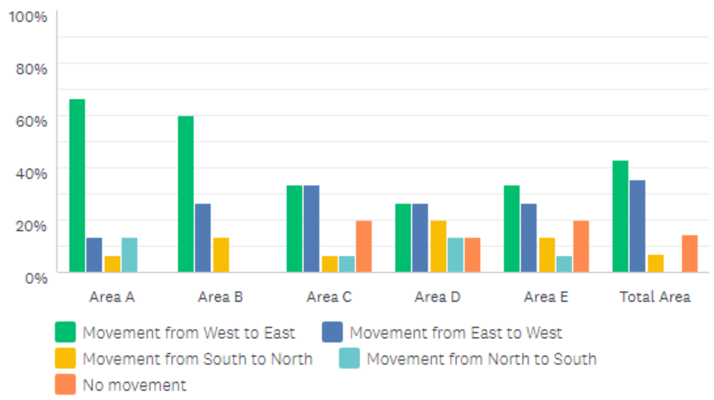


	LARGE DECLINE	DECLINE	SMALL DECLINE	SMALL RISE	RISE	LARGE RISE	TOTAAL
Area A	53,33% 8	40,00% 6	6,67% 1	0,00% 0	0,00% 0	0,00% 0	15
Area B	0,00% 0	0,00% 0	0,00% 0	13,33% 2	26,67% 4	60,00% 9	15
Area C	0,00% 0	40,00% 6	60,00% 9	0,00% 0	0,00% 0	0,00% 0	15
Area D	6,67% 1	66,67% 10	20,00% 3	6,67% 1	0,00% 0	0,00% 0	15
Area E	40,00% 6	33,33% 5	13,33% 2	13,33% 2	0,00% 0	0,00% 0	15
Total Area	0,00% 0	20,00% 3	60,00% 9	13,33% 2	0,00% 0	6,67% 1	15

Question 2:

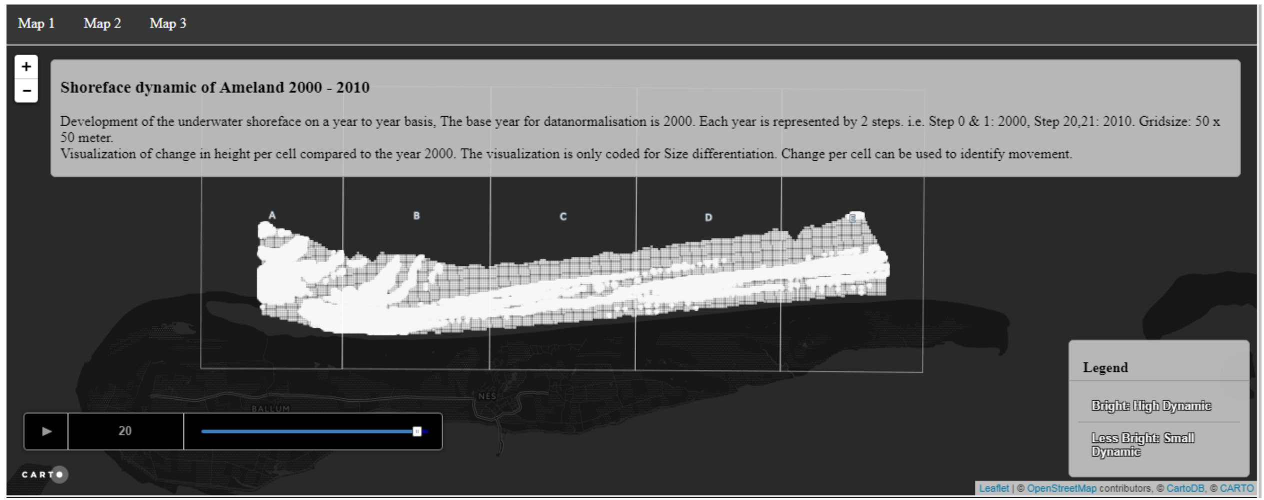
Identify a spatial-temporal pattern for each Area.

Beantwoord: 15 Overgeslagen: 0



	MOVEMENT FROM WEST TO EAST	MOVEMENT FROM EAST TO WEST	MOVEMENT FROM SOUTH TO NORTH	MOVEMENT FROM NORTH TO SOUTH	NO MOVEMENT	TOTAAL
Area A	66,67% 10	13,33% 2	6,67% 1	13,33% 2	0,00% 0	15
Area B	60,00% 9	26,67% 4	13,33% 2	0,00% 0	0,00% 0	15
Area C	33,33% 5	33,33% 5	6,67% 1	6,67% 1	20,00% 3	15
Area D	26,67% 4	26,67% 4	20,00% 3	13,33% 2	13,33% 2	15
Area E	33,33% 5	26,67% 4	13,33% 2	6,67% 1	20,00% 3	15
Total Area	42,86% 6	35,71% 5	7,14% 1	0,00% 0	14,29% 2	14

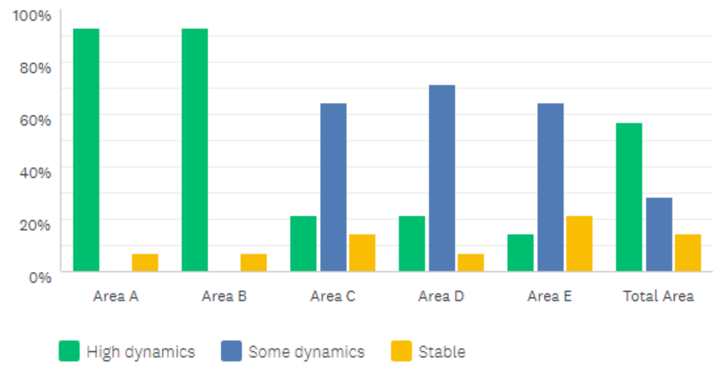
Map 2: Linear visualization with only marker size variation



Question 3:

What would you say about the dynamic in each Area

Beantwoord: 14 Overgeslagen: 1

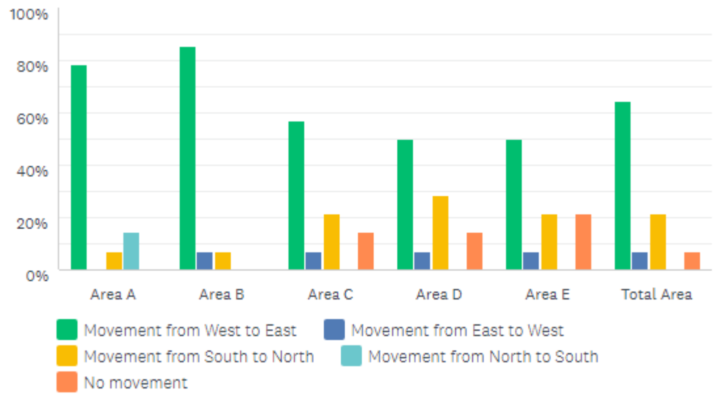


	HIGH DYNAMICS	SOME DYNAMICS	STABLE	TOTAAL
Area A	92,86% 13	0,00% 0	7,14% 1	14
Area B	92,86% 13	0,00% 0	7,14% 1	14
Area C	21,43% 3	64,29% 9	14,29% 2	14
Area D	21,43% 3	71,43% 10	7,14% 1	14
Area E	14,29% 2	64,29% 9	21,43% 3	14
Total Area	57,14% 8	28,57% 4	14,29% 2	14

Question 4:

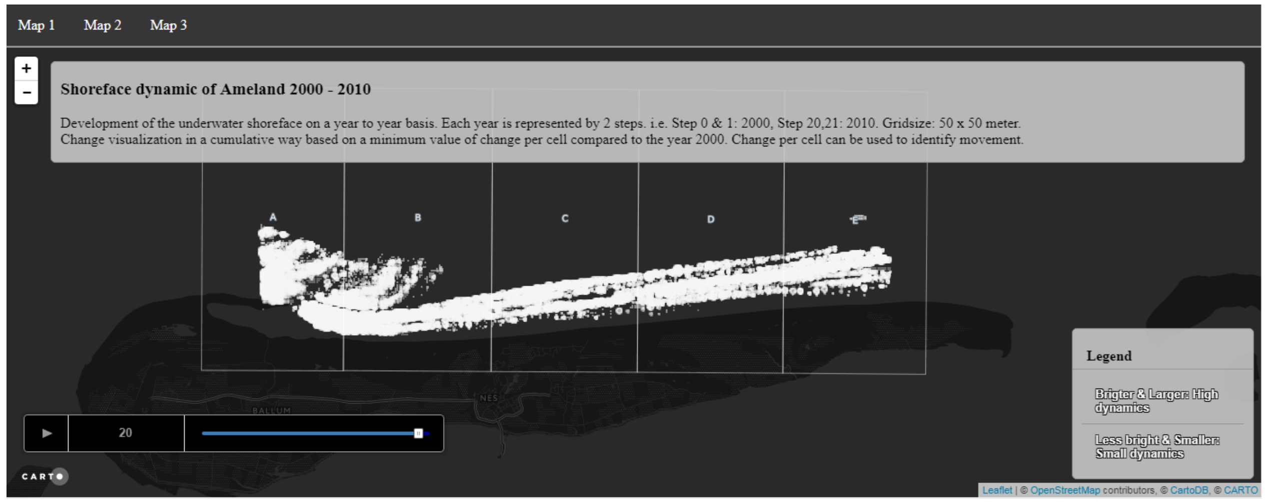
Identify a spatial-temporal pattern for each Area.

Beantwoord: 14 Overgeslagen: 1



	MOVEMENT FROM WEST TO EAST	MOVEMENT FROM EAST TO WEST	MOVEMENT FROM SOUTH TO NORTH	MOVEMENT FROM NORTH TO SOUTH	NO MOVEMENT	TOTAAL
Area A	78,57% 11	0,00% 0	7,14% 1	14,29% 2	0,00% 0	14
Area B	85,71% 12	7,14% 1	7,14% 1	0,00% 0	0,00% 0	14
Area C	57,14% 8	7,14% 1	21,43% 3	0,00% 0	14,29% 2	14
Area D	50,00% 7	7,14% 1	28,57% 4	0,00% 0	14,29% 2	14
Area E	50,00% 7	7,14% 1	21,43% 3	0,00% 0	21,43% 3	14
Total Area	64,29% 9	7,14% 1	21,43% 3	0,00% 0	7,14% 1	14

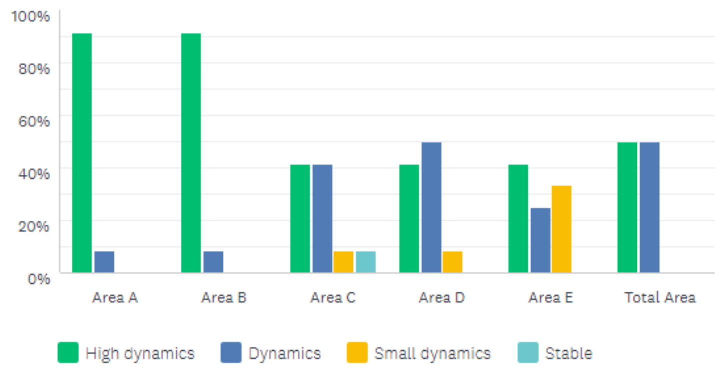
Map 3: Cumulative visualization with marker size variation



Question 5

What would you say about the dynamic in each Area

Beantwoord: 12 Overgeslagen: 3

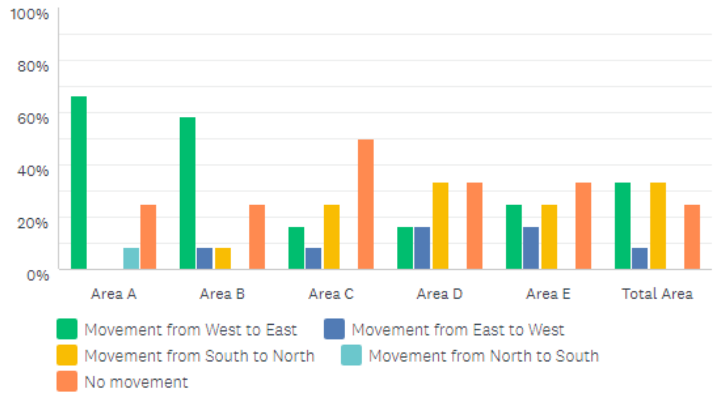


	HIGH DYNAMICS	DYNAMICS	SMALL DYNAMICS	STABLE	TOTAAL
Area A	91,67% 11	8,33% 1	0,00% 0	0,00% 0	12
Area B	91,67% 11	8,33% 1	0,00% 0	0,00% 0	12
Area C	41,67% 5	41,67% 5	8,33% 1	8,33% 1	12
Area D	41,67% 5	50,00% 6	8,33% 1	0,00% 0	12
Area E	41,67% 5	25,00% 3	33,33% 4	0,00% 0	12
Total Area	50,00% 6	50,00% 6	0,00% 0	0,00% 0	12

Question 6:

Identify a spatial-temporal pattern for each Area.

Beantwoord: 12 Overgeslagen: 3



	MOVEMENT FROM WEST TO EAST	MOVEMENT FROM EAST TO WEST	MOVEMENT FROM SOUTH TO NORTH	MOVEMENT FROM NORTH TO SOUTH	NO MOVEMENT	TOTAAL
Area A	66,67% 8	0,00% 0	0,00% 0	8,33% 1	25,00% 3	12
Area B	58,33% 7	8,33% 1	8,33% 1	0,00% 0	25,00% 3	12
Area C	16,67% 2	8,33% 1	25,00% 3	0,00% 0	50,00% 6	12
Area D	16,67% 2	16,67% 2	33,33% 4	0,00% 0	33,33% 4	12
Area E	25,00% 3	16,67% 2	25,00% 3	0,00% 0	33,33% 4	12
Total Area	33,33% 4	8,33% 1	33,33% 4	0,00% 0	25,00% 3	12