Measuring coastal erosion with the help of the local population in Myanmar

Additional thesis MSc. Coastal Engineering

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Abstract

Coastal erosion in Myanmar causes the coastline to retreat, which increases the flood risk for those who live near the coast. Lack of data about the coastline retreat makes it difficult to design proper flood protection measurements (UNFCC 2007). Since Myanmar is a relative poor country traditional measuring techniques, such as laser mapping, are not applicable. Therefore, the rate of erosion was measured with the help of citizen science. A new method was tested, in which measurements were performed with the help from the camera in a smartphone. Pictures were taken from a point of reference on the beach. With the help of triangular symmetry the distance from the participant to the reference was determined. With the help of CTD divers and Xtides, the effect of the tides was included in the measurements as well. This resulted in beach width measurements over time. A decreasing trend in beach measurements indicated erosion of the beach, as expected. The method has proven to be useful for measuring erosion for less developed countries, such as Myanmar. When the method is compared to the existing project Sandwatch (Cambers,2009), the advantage is that it easier to participate, since no additional tools are needed and the measurements can be performed at any time.

Contents

1 Introduction

In Myanmar great damage is caused by coastal erosion each year (ESCAP 2015). An example of this can be seen in Figure 1. Additionally, coastal erosion makes the coastal regions more vulnerable to the occurring typhoons. However, nearly no data is available on the coastline so far. With a coastline of almost 2000 km long coastal erosion is definitely a topic of interest for Myanmar. More importantly, there have been several reports of sand mining (Myanmar Times, 2015). Sand mining is the withdrawal of sand from the beach. It is a direct cause for coastal erosion. Mainly in developing countries sand mining is dealing great damage to its beaches (Coastal Care, 2017).

Figure 1: Citizens of Myanmar who lost their house to the ocean.

1.1 Problem statement

Knowing where and how much coastal erosion takes place is of vital essence in order to prevent it or to react on it. Coastal erosion causes the coastline to retreat. Coastal erosion is the reduction of sand mass of the beach. In order design mitigation measures data is required about the coastline. In many well developed countries this data is gathered every year. However, the methods used to gather this data can be quite costly. As a consequence this data is often not present in developing countries, which are most vulnerable to natural hazards (UNFCC 2007). Knowledge about the coastline can help to mitigate the effects of the coastal erosion, by setting the boundary conditions for the design of mitigation measures.

1.2 Citizen science

Citizen science is the involvement of the public in scientific research. The participants contribute in collecting data for a specific research. The advantage of citizen science is that for gathering the required data not a lot of financial resources are necessary. Also citizen science projects create more awareness among the community about certain subjects. More awareness among the community is part of the solution for many environmental problems (UWE 2013). It is a relatively new methods of gathering data. Lately it has become more popular since the great availability of consumer technology, such as smartphones.

An example of a successful citizen science project to measure coastal erosion is Sandwatch. The project is funded by UNESCO and the measurements take place mainly in the Caribbean. In this project students are invited to measure several different properties of the beach. The instructions are given in publically available videos. The measurements can be carried out with very simple tools, so it is easy to participate. The data is then gathered in an online database, which is also publically accessible. As a result of participating in the project the students also gained more knowledge about the dangers and risks of living near the ocean. The project started in 2001 and has been running ever since. A lot of data about the coastline has been gathered since the start of the project (Cambers, 2009).

In the United States there is funding for citizen science along different coastlines. Here the desired locations are marked on Google maps and the pictures made by the user are automatically uploaded through their smartphone app (iCoast, 2014). The obtained data is used to validate existing coastal models. Also participants are actively requested to make these pictures directly after big storms, in order to study the impact of these storms (Earthsciweek, 2017). For the same project the participants are asked to answer certain questions about aerial coastal pictures from before and after the storm. The questions ask about the present structures and the damage that is visible after the storm.

1.3 Research goals

The main goal of this research is to develop a method to measure coastal erosion with the help of citizen science. The local population should be able to perform these measurements, to keep the costs low. This way the local population will become more aware of the causes and consequences of coastal erosion. Also the method should not cost a lot of resources, so it can still be applied in developing countries as well.

Since the time available for this research is limited, coastal erosion cannot be measured in this specific research. The timescale over which coastal erosion becomes visible is around a year or longer, due to seasonal variation. Since this research only lasts for about two months, the effectiveness of the method will be tested on the tides instead. The same data that is required to measure coastal erosion can be used to determine the ebb-tidal cycle. The main research question in this research is:

- How accurate can coastal erosion be measured with the help of citizen science?

To answer this question the following two sub-questions will be answered:

- How accurate can the tides be measured with the help of citizen science?
- How well do these tidal measurements correspond with the existing predictions about the tides?

1.4 Background information

For this research Ngapali beach is chosen as the research location, since this is one of the locations where sand mining takes place. Ngapali beach is located in the Rakhine state in Myanmar, as can be seen on Figure 2. With its pristine white beaches it is one of the most important beaches for tourism of Myanmar.

Figure 2: Location Ngapali Beach in Myanmar

Ngapali is an attractive place for tourists, because of the beautiful beaches. Therefore guesthouses and resorts have been built in the area. For the construction of these guesthouses and resorts sand is needed. Traditionally, the sand from the beach is used for construction in this area. Snce 2010 a different party came to power in Myanmar, opening up the borders to the tourist industry. This has led to an increase of construction in Ngapali, in order to accommodate the increase in tourists. The amount of sand that is removed from the beach for the construction has increased. An example of the magnitude of the stolen sand can be seen on Figure 3.

Figure 3: Large quantity of illegally mined sand at Ngapali beach. All the sand behind the first trees has been removed from Ngapali beach.

This causes significant damage to the beach. Trucks are driving up and down the beach, as can be seen on Figure 4. According to the local hotel owners the erosion of the beach started as soon as the sand mining started. Therefore is of high importance that the sand mining stops completely as soon as possible. According to the local population the sand mining has been made illegal a couple of years ago. Unfortunately, the laws are not being enforced.

There is an alternative for the sand mining in the area present. The sand from the river can be used for construction. In fact, the sand from the river results in higher quality concrete, since it doesn't contain salt. The beach sand does contain salt, which can cause corrosion or cracks in the concrete (A. Bandyopadhyay, 2016). The price of the sand of the river is in fact lower as well. The main reason that people still use the sand of the beach is the lack of education. Most people are unaware about the damage they are causing towards the beach and therefore continue to use this sand. Another reason is that no license is required for the stealing of the sand from the beach. This means anyone can start up a "business" selling the sand from the beach.

Figure 4: A truck is being filled up with beach sand

Efforts of local hotel owners to create more awareness seem to be working. Throughout the whole village posters are placed with instructions on sustainable tourism, as can be seen on Figure 5. The government is becoming more aware of the consequences of sand mining as well. It is illegal to do sand mining and the government is putting more effort into it to stop it. There are some projects being built with river sand at the moment. Investment companies are trying to show themselves from their best side, using the river sand instead of the beach sand.

Figure 5: Poster to create more awareness about sand mining

1.4.1 Signs of erosion

The effect of erosion already becomes visible on the beach. The roots of the palm trees have become visible, as can be seen on Figure 6**.** According to the local population the roots have only been visible since a couple of years. Also some of these trees have fallen down, because of the lack of support of its roots. It shows how the height of the beach has been reduced over the years.

Figure 6: Roots of the palm tree become visible

Another indication of erosion is the sudden need to build walls around the hotels on the beach. One of the hotels was struck by a big flood a couple of years ago, causing a lot of damage to all the electrical wires under the ground. It seemed that the water was getting a lot closer to the shore than before. To prevent the flooding from happening in the future the hotel owner built a wall at the beachside of the hotel, as can be seen on Figure 7. Now all the hotel owners copied him and also built a wall at the beachside of their compounds. The problem with these walls is that they limit the size of the beach, which influences the natural growth of the beach. Naturally, the beach size decreases in the rainy season and increases in the dry season. The incoming waves reposition the sand on the beach slope. However, when the wave is broken on the wall, it is prevented from repositioning the sand on the beach and the size of the beach decreases even further. At some of the hotels there is nothing left from the beach at all. Another effect that increases the rate of erosion is the reflection of waves. Since the reflected wave causes an increased wave height, the rate of erosion will increase.

Figure 7: Wall from one of the hotels on the beach

Also note that the wall on Figure 7 is poorly constructed and holes become visible at the base of the wall. This is the case for many of the hotel walls and many of them have cracks in them or even collapsed completely.

2 Method

The coastal retreat is measured with the help of citizen science. In Figure 8 all the different steps of the method are shown.

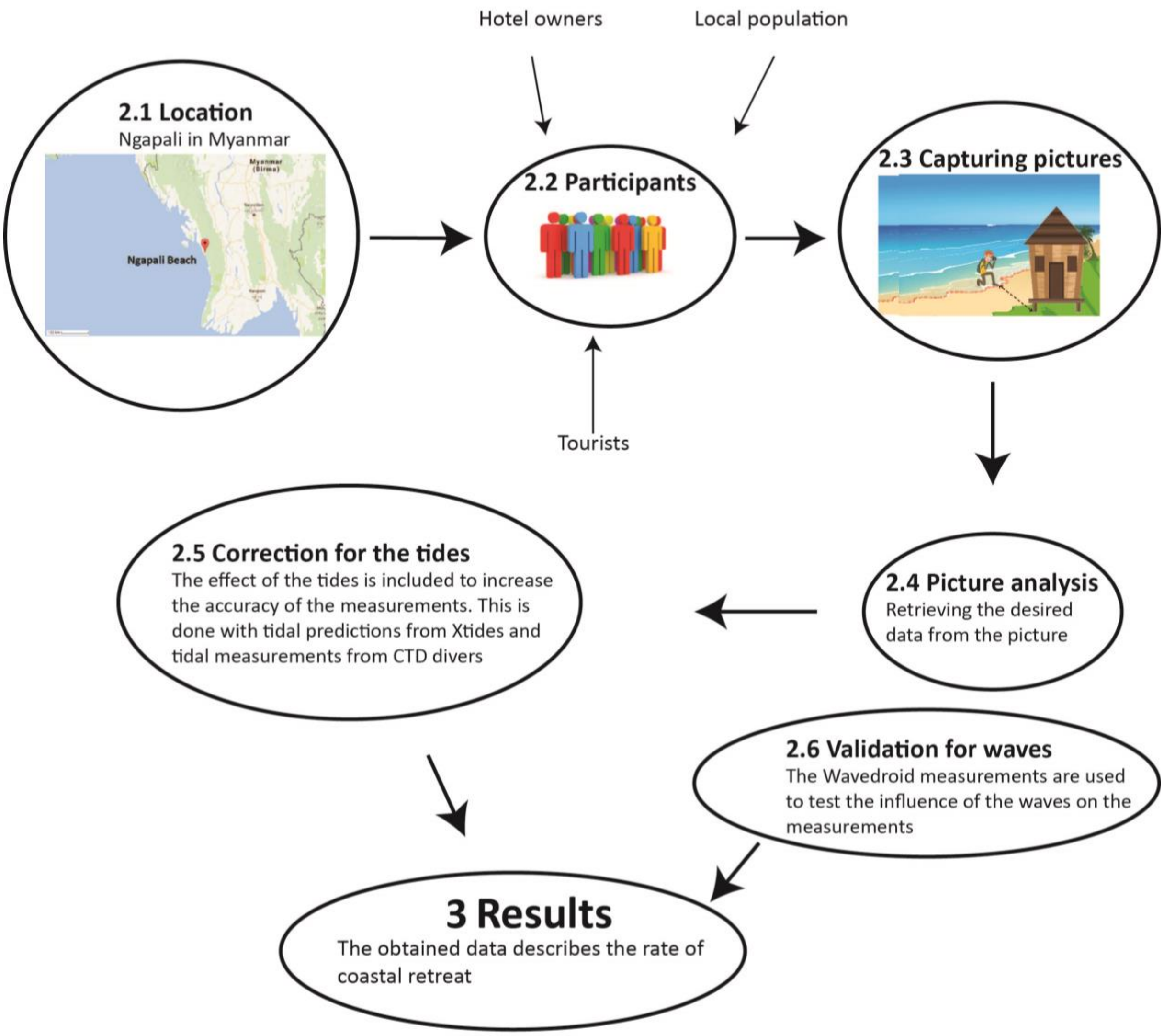


Figure 8: Overview method

2.1 Location measurements

The measurements were performed at two different locations in Ngapali. The locations are shown on Figure 9. On location 1 most measurements were taken during the time I was there. For location 2 I received more measurements when I had left the location.

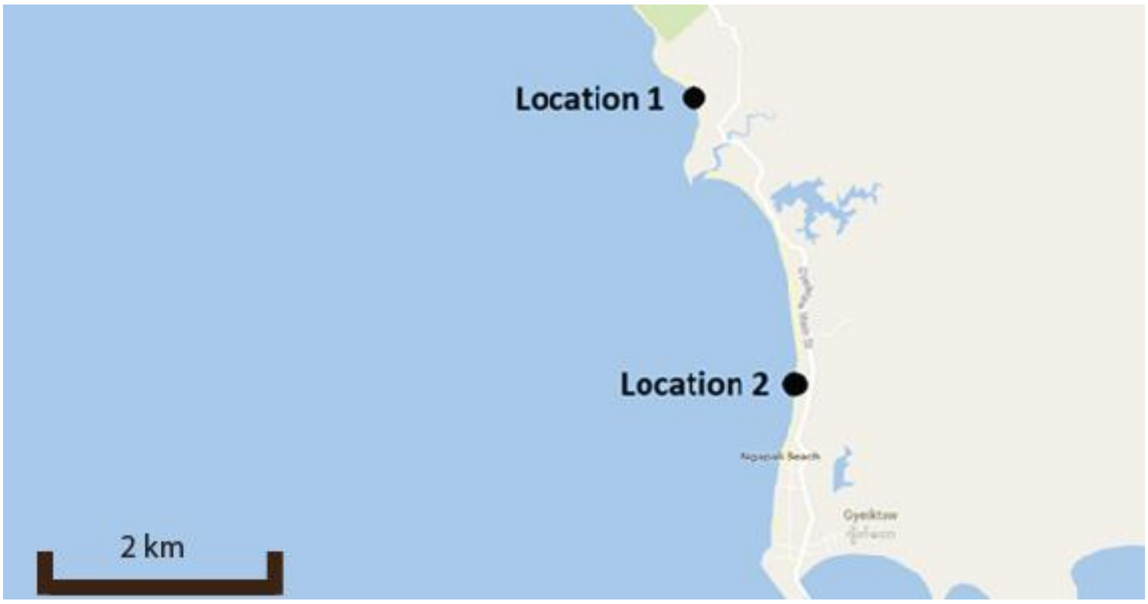


Figure 9: Map with the location of the measurements indicated.

2.2 Participants

The measurements were performed by different groups of participants. The participants all participated voluntary. For this research the participants was divided in the following groups:

Tourists
Ngapali beach is one of the most touristic beaches in Myanmar. Therefore, a lot of tourists are present in the area. The main reason for the tourists to come to Ngapali is the beach.

Locals
Since there is a lot of tourism present in the area, a lot of locals work in the hotels or restaurants located at the beach. Indirectly, their income is dependent on the amount of tourists that visit the beach.

Hotel owners
The hotel owners benefit the most from the beach. The beach is the main reason people come to Ngapali. If the size of the beach reduces, this could influence the income of the hotel owners directly.

The different groups were approached in two different ways: directly and indirectly. The tourists and locals on the beach were approached on the beach by myself and were asked to participate in the project. A flyer with the image of Figure 10 was shown to illustrate the instructions. The hotel owners were also asked to participate by instructing their staff to take the pictures regularly.

2.3 Taking the pictures

The measurements were made with a smartphone, which means almost anyone can participate in the project. The idea was to invite people who are present on the beach to make these measurements. This is a cost effective method to gather the required data. Also it contains an educative factor. The participants became more aware of the environmental problems around them. I participated in taking the pictures myself as well.

The focus in the instructions lied in the importance of the sand-mining to stop in order to preserve the current beach state. Also it was made clear that this research could convince the local authorities to take more action, and each measurement helps to get closer to this goal. Emails containing the pictures could be send to a special email address. Each email was replied with gratitude and also the retrieved data was included. This way the participant could see what the pictures are being used for. A Facebook page is available where they can find more information about the project (www.facebook.com/ngapalibeacherosion).

Indirectly the tourists were also informed by posters throughout all the hotels near the coast. Posters with instructions for participation were placed in all the hotels near the coast. The poster is included in Appendix B.

Equation 1 is used to measure the size of the beach. In order to determine the size of the beach, the pictures are taken facing towards the beach. The photographer is positioned at the spot where the waves just reach. This is illustrated on Figure 10. When the size of for example the palm tree is known, the distance between the photographer and the palm tree can be determined with Equation 1.

Figure 10: Instruction on how the picture should be taken

As a reference point a yellow wooden plate was used, as can be seen on Figure 11.

Figure 11: Automatic picture processing

2.4 Picture analysis

The pictures were analysed in order to obtain the width of the beach. First the general theory will be discussed, after which it will be applied on the obtained pictures.

2.4.1 General theory behind the picture analysis

It is possible to determine the distance from the photographer towards a certain object, when the real size of the object is known, plus some properties from the used camera. The relation used to determine this distance is based on triangle similarity, which applies here since the picture taken is a scaled down version from the reality. Equation 1 can be used to determine the width of the beach. A more complete derivation of Equation 1 is included in Appendix A.

$$distance\ to\ object\ (m) = \frac{focal\ length(m) * real\ width\ (m) * image\ width\ (pixels)}{object\ width\ (pixels) * sensor\ width\ (m)}$$

Equation 1: Determining the distance to the object

All the different parameters are explained below. Also the different parameters are illustrated in

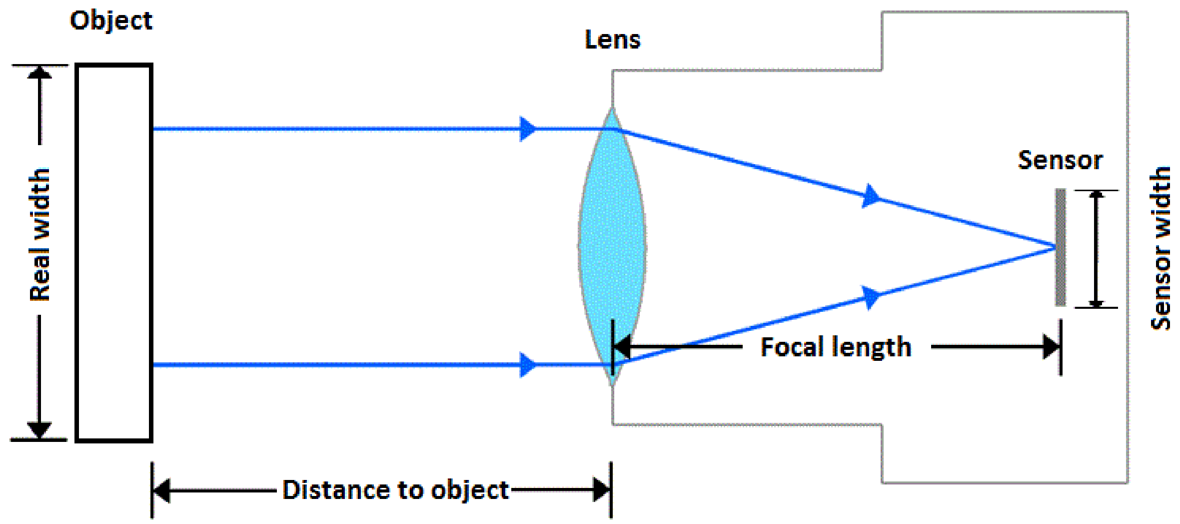


Figure 12. In this case the width of the parameters is chosen. It is also possible to determine the distance to the object with the height of the different parameters.

focal length (m) = Distance between sensor and lens.
real width (m) = Real width of the object.
image width (pixels) = Width of the complete image.
object width (pixels) = Width of the object inside the image.
sensor width (m) = The width of the sensor is a fixed property of the used camera.

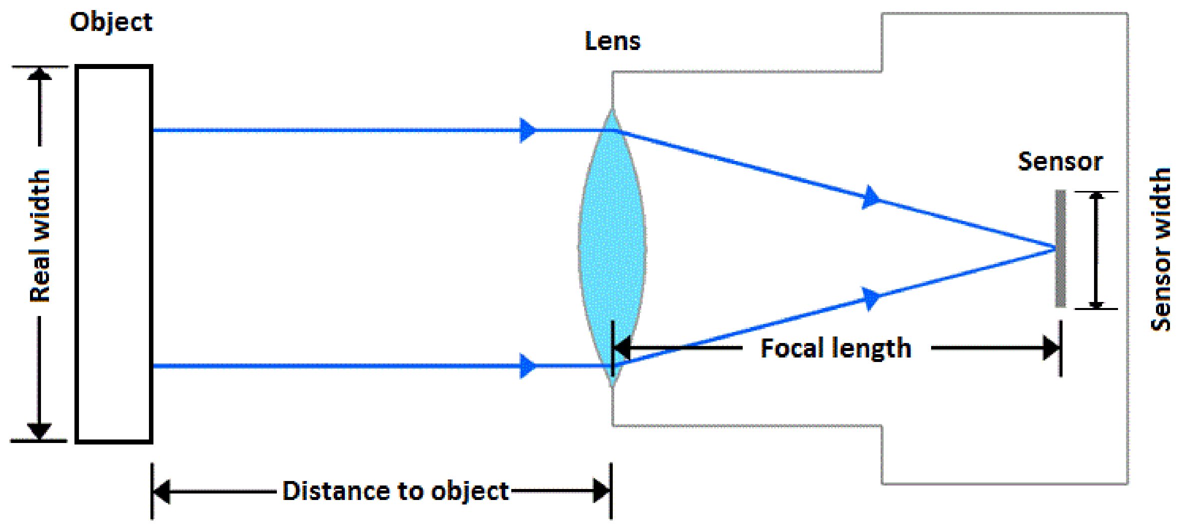


Figure 12: Illustration of the different parameters

The real width of the object has to be measured on site. The object width in pixels was manually measured in the picture or it can be automatically measured with an image recognition script. The image width is included in the resolution of the picture.

The focal length and the sensor width have to be determined in a different way. These are fixed properties from a camera, but are *different for each camera*. This means that these properties can differ for two cameras of the same model. Therefore it is important to determine the focal length and sensor width for each camera. This was done with the same relation as described before, but now the distance from the photographer to the object was also measured. The relation is shown in Equation 2.

$$\frac{focal\ length(m)}{sensor\ width\ (m)} = \frac{real\ width\ (m) * image\ width\ (pixels)}{object\ width\ (pixels) *\ distance\ to\ object\ (m)}$$

Equation 2: Determining the camera properties

Since the focal length and sensor width are both used in Equation 1 as well, the relation between the focal length and the sensor width is sufficient and the parameters weren't computed individually.

2.4.2 Analysing the obtained pictures

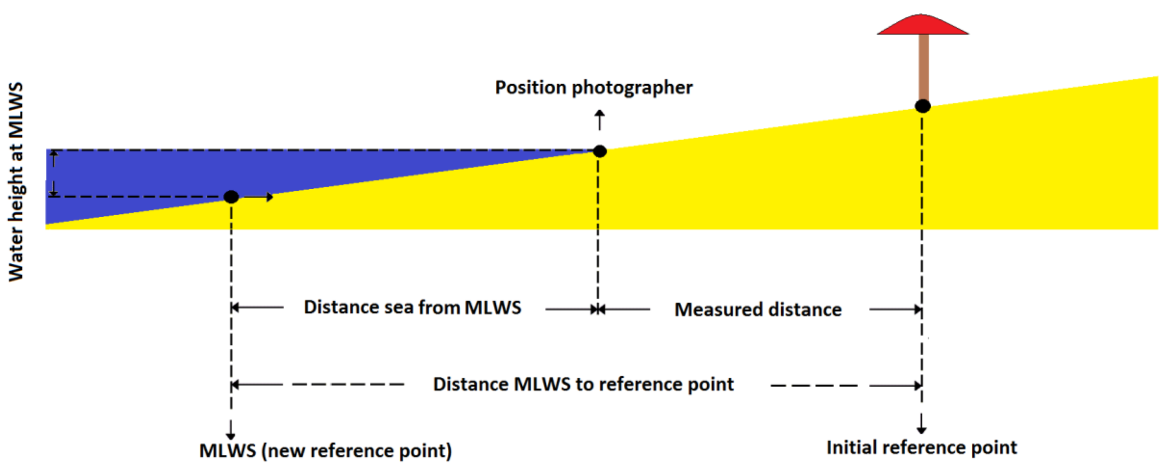
Once all the pictures were collected, they were processed in order to find the distance from the photographer to the object. Additionally, the horizontally measured distance by pictures was transformed into a vertical water elevation, so the results of the different methods can be compared.

2.4.2.1 Reference point for the measured distance

The reference point for all three methods was set at the Mean Low Water Spring tide (MLWS). The reference point for the pictures measurements was initially set on land. In the case of the example of Figure 13 the parasol was the initial reference point. The measurements were adjusted in such a way that the reference point was moved to MLWS. All the different distances are displayed in Figure 13.

First the distance from the initial reference point to MLWS was determined by taking a picture when the tide is lowest, either with full or new moon. Then, each measured distance was subtracted from the distance MLWS to the initial reference point. This resulted in the distance the sea reaches in land from MLWS. When this distance is multiplied by the slope of the beach, the water height at MLWS is the result. Note that only one low spring tide was used, the results could be improved by taking the mean of several low spring tides. Also note that the small angle assumption is applied. This implies that the beach slope is small enough to assume that the diagonal and horizontal length of the beach are approximately the same.

Figure 13: Cross section beach with measurement definitions



2.4.2.2 Measuring the pixels in the picture

The pictures were manually processed, as well as automatically processed. Manually processing means the amount of pixels of the object is measured with a digital measuring tape in for example Microsoft Paint or Adobe Photoshop. The amount of pixels of the yellow plate, shown in Figure 11, was measured.

It is also possible to measure the amount of pixels automatically with Python. The Python library OpenCV contains a lot of tools to automatically recognize objects and perform actions on them. The yellow plate was easily recognisable by the Python script.

The code, which is included in Appendix C, first removes everything that is not the colour yellow. Then the remaining pixels are transformed to either black or white. Subsequently, edges are fit around any shapes and a rectangle is drawn around the largest surface, in this case the yellow sign. Note that the picture is processed completely automatic. This was very helpful processing large quantities of pictures. The results are nearly as accurate as manually measuring the pixels of the object. The difference between in the two methods is in the order of centimetres.

2.4.3 Accuracy of the obtained beach measurements

The accuracy of this method was determined with a field experiment. Several pictures were taken from an object and the distances to the object were determined with Equation 1. Additionally, the distances to the object were measured with measuring tape. The results are displayed in Table 1.

Real distance (m)	Measured distance with pictures (m)	Difference (m)
30	30.20754286	-0.207542857
28	28.25649889	-0.256498886
27	27.1673833	-0.167383298
26	26.15910928	-0.159109278
25	25.07345455	-0.073454545
20	19.854723	0.145276995
10	9.997768322	0.002231678

Table 1: Accuracy measurements obtained from pictures

This results in average error of approximately 20 cm. This error is most likely caused by imperfect calibration of the camera and inaccuracies in measuring the exact amount of pixels of the object.

Note that this accuracy applies to Equation 1 only. When the distance between the sea and an object is measured, an additional error is present because of the waves and due to the face that the sea doesn’t reach the land in a straight line. Also an error may be introduced by the user, when the instructions are not followed up perfectly.

2.5 Correction for the tides

Since the tides cause a variation of the beach width of about 20 meters per day, the accuracy is increased when the effect to the tides are included. Tides are in general quite constant and predictable if enough tidal measurements have been performed in the past. Two different methods were used to determine the effect of the tides. With the CTD divers the tidal variation was measured on location. These measurements were compared to existing tidal predictions for the location from

Xtides. Since Xtides predictions are available for any time, these are more suitable to apply the correction. The CTD divers measurements could only be used for the period they were actually deployed, which was a period of one month.

2.5.1 CTD divers tidal measurements

For the increasing of the accuracy of the measurements the water depth over time is measured with the help of two CTD divers. A CTD diver measures the absolute pressure over time with the help of pressure sensors. In order to measure the water depth of the sea one diver is placed at the bottom of the sea and one diver is placed above the water level. The difference in pressure between the two divers is the water pressure. The water depth can be computed from the measured pressures with the relation described in Equation 3.

$$Water\ depth = 9806.65 \frac{P_{diver} - P_{baro}}{\rho * g}$$

Equation 3: Determine the water depth from the measured pressures

In which:

P_{diver} (cmH20) =	Absolute pressure at the bottom of the sea
P_{baro} (cmH20) =	Atmospheric pressure
ρ (kg/m^3) =	Density of the sea water, 1025 kg/m^3
g (m/s^2) =	Gravitational acceleration, 9.81 m/s^2

The diver that measures the absolute pressure at the bottom of the sea is set up in such a way that it measures the pressure every second and saves the average of these values over a minute during timespan. This way the effect of the waves is cancelled out as much as possible.

The diver that measures the atmospheric pressure is set up in such a way that it measures and saves the pressure every minute. It is located approximately 1 kilometre from the other diver, since it is not possible to place it directly above the sea water. Instead it is placed at land. It is assumed that the difference in atmospheric pressure over the distance is negligible.

The diver can determine the pressure with an accuracy of around 2.5 cm. This means that the maximum error of the two divers combined is 5 cm. This is by far the most accurate method of the three methods.

2.5.2 Predictions of tides with Xtides

For the prediction of tides the open source tidal prediction software Xtides is used. Xtides uses an algorithm to compute the tides, which is also used by the National Ocean Service in the U.S (David Flater, 2006). The algorithms make use of tidal harmonics, which are obtained from measurements of the water level over a period of around one year. For Ngapali the closest station is Andrew Bay, which is about 5-10 km from Ngapali, as can be seen on Figure 14. The tidal station Andrew Bay is a subordinate station, which means the measurements of the water level are performed over a shorter period of time and are partly based on another station, for which more data is available. This slightly decreases the accuracy of the predictions of this station. Tidal predictions by Xtides are available up to the year 2037.

Figure 14: Location station

The accuracy of the prediction of the high and low tide for this station is approximated to be around 30-60 minutes, according to the developer of the program (David Flater, 2006).

2.6 Measuring the wave height with the Wavedroid

The wave height is measured in Ngapali with the help of the Wavedroid. The measurements of the wave height could help to gain more insight in the accuracy of the measurements with pictures. The Wavedroid can measure several wave properties with the help of the accelerometer inside an Android phone (Wavedroid, 2017). The measured parameters are the significant wave height (Hs), wave period (Tp), wave directions and spectral moments. The Wavedroid is deployed about 500-1000m from the coast. The deployed Wavedroid is displayed on Figure 15.

The accuracy of the Wavedroid is determined with earlier tests in Durban, South-Africa (Wavedroid, 2017). The accuracy for each property is as follows:

Significant wave height:	± 7 cm
Average wave period:	± 0.5 s
Wave direction :	± 15 degrees

Figure 15: Picture of the deployed Wavedroid

3 Results

The width of the coastline, after compensation for the tides, is shown in Figure 16 and Figure 17 for location 1 and 2 respectively. A negative trend is clearly visible for both locations, which indicates a retreating coastline. This could be caused by structural coastal erosion, but it could also be caused by seasonal effects. In the wet season erosion is expected due to heavy rainfall and higher waves. During the dry season aggradation is expected due to milder weather and wave conditions. The measurements were taken in the transition from dry to rainy season.

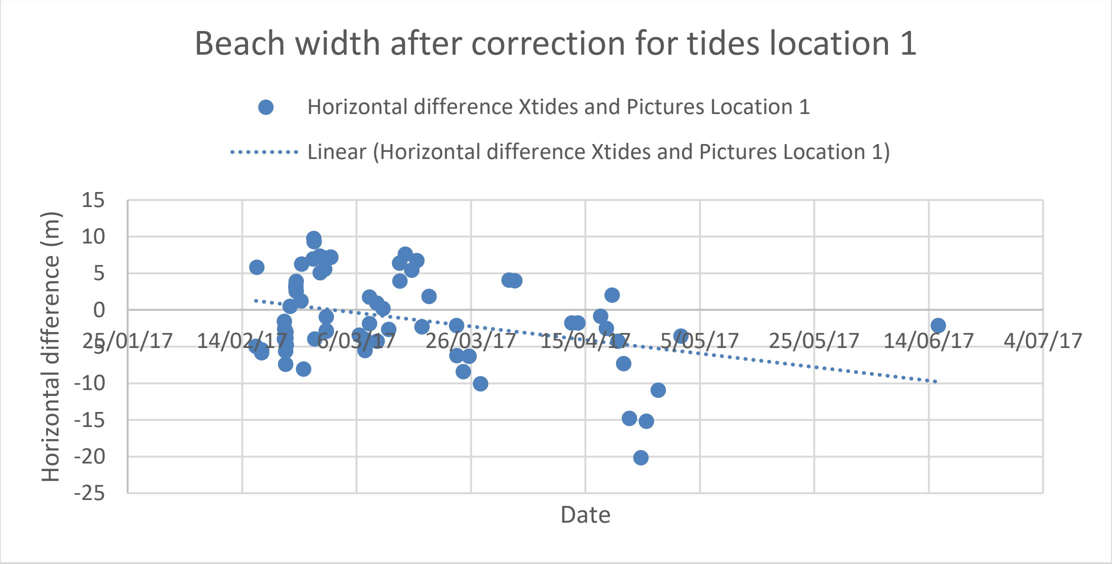


Figure 16: Beach width after correction for tides location 1

For Location 2 the negative trend is about three times smaller than for location 1. The difference between the two methods could be either caused by more erosion on Location 1 or due to inaccuracies in the Xtides prediction, or both. Further research could show this.

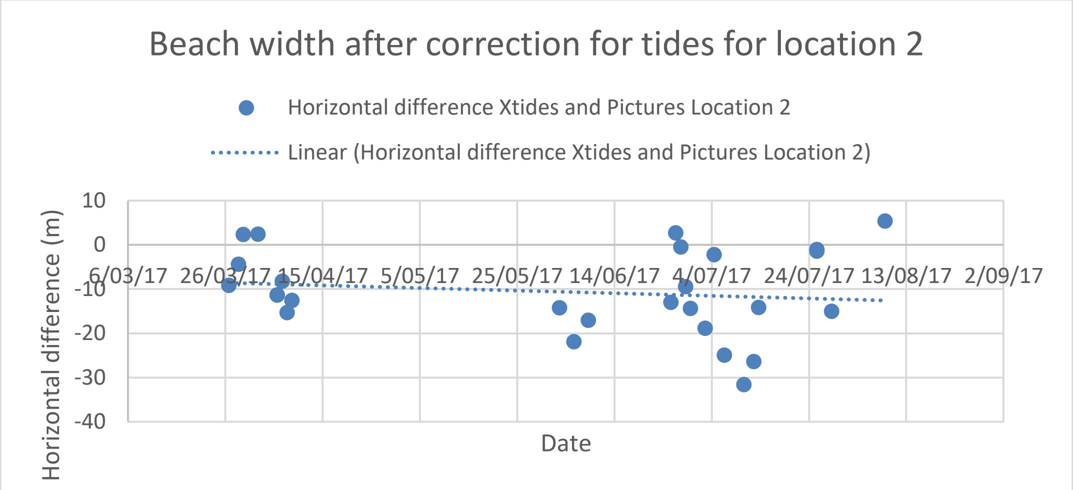


Figure 17: Beach width after correction for tides for location 2

3.1 Response participants per group

The response of the different groups was very different. The response of the tourists and locals was very low. However, the response of the hotel owners seems promising. In a period of six months time a total of 70 measurements have been performed.

Tourists

The tourists were mostly enthusiastic when approached and said to be willing to co-operate. However, only very few actually participated in the measurements. The posters in the hotels got no response at all, although some people did visit the related Facebook page. Also it took a lot of time to calibrate each camera. It is not very time efficient to use a specific camera for only very few measurements.

Locals

The language barrier made it very difficult to explain the purpose of the measurements and the research. The problem of the sand-mining was sometimes understood, but the link to the measurements with pictures was very difficult to explain. Although they were very friendly and willing to help, the response in this group was extremely low. Also some technical problems were present. Many locals did not have a smartphone advanced enough to take a picture and then send it by email.

Hotel owners

Most of the hotel owners are already aware of the problem of sand-mining and were willing to help. All the hotel owners helped with the spreading of the posters with instructions. More importantly, two hotel owners offered to take pictures on a regular basis for a couple of months. They instructed one of their staff members to take the pictures regularly.

3.2 Correction for the tides results

In order to obtain more accurate measurements, a correction for the tides was applied with CTD divers and Xtides. The CTD divers are assumed to be more accurate, since these measurements took place at the same time the pictures were taken. The predictions of Xtides are based on measurements in the past.

3.2.1 CTD divers measurements

The CTD divers measured the water depth with accuracy in the order of centimetres. This provides very detailed measurements of the tides at Ngapali. The result of one spring-neap tidal cycle is displayed on Figure 18.

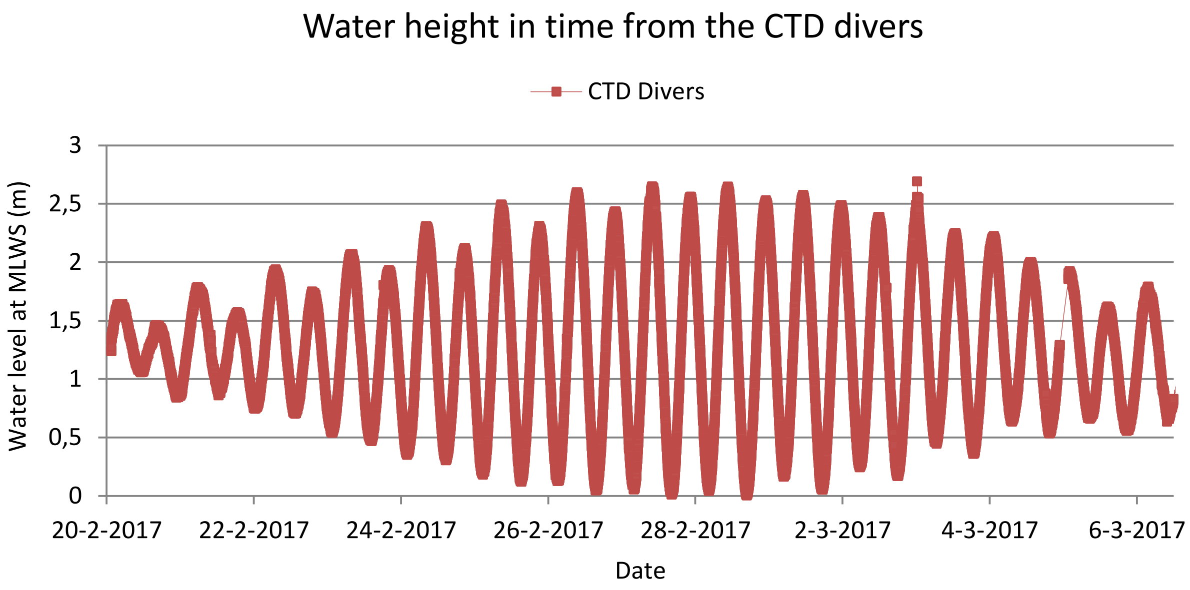


Figure 18: CTD divers one spring-neap tidal cycle

As the reference point the lowest measured water depth was chosen, since this point represents the MLWS. Note that only one low spring tide was used to determine MLWS. The results could be improved by taking the mean of several low spring tides.

3.2.2 Optimization of the Xtides predictions

The tidal prediction software Xtides provides the water heights caused by the tides in Ngapali up to the year 2037. The predictions of Xtides are compared to the measurements of the CTD divers, which are assumed to be more accurate. The result is shown in Figure 19.

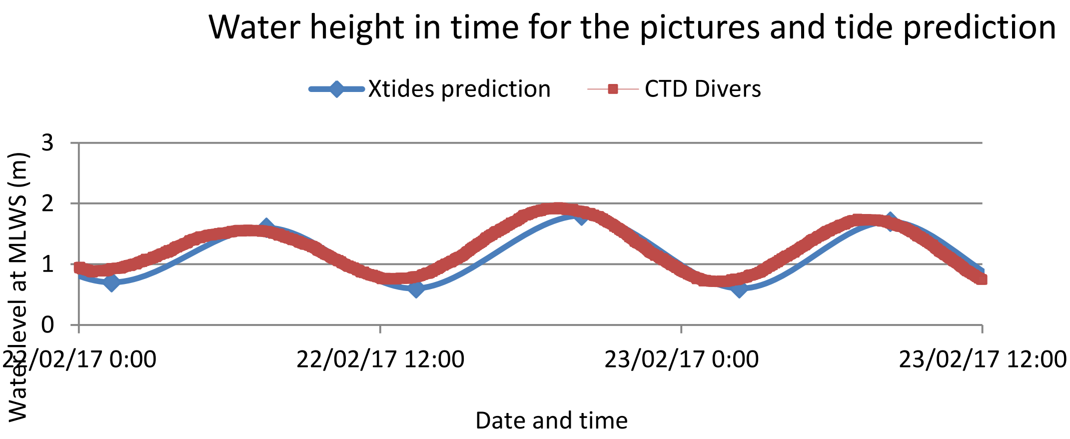


Figure 19: Tidal prediction compared to CTD diver measurements

There seemed to be a consequent error in the timescale of the prediction, resulting in an average difference of 0.3 meters. When a correction of 53 minutes is applied, the prediction is a lot more accurate. This can be seen in Figure 20. The average absolute difference between the CTD divers and Xtides predictions now becomes 0.1 meter.

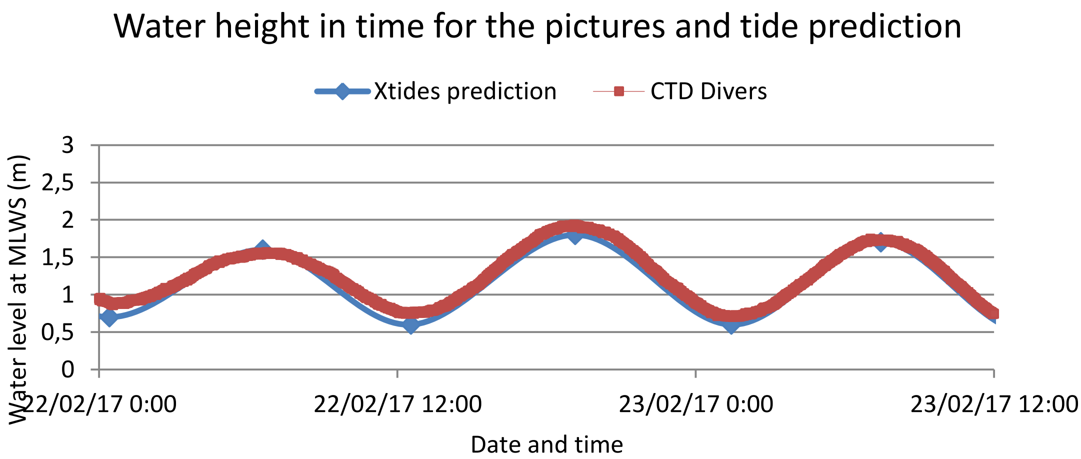


Figure 20: Adjusted tidal predictions compared to CTD diver measurements

There also seems to be a difference in the amplitude of the water level between the two methods. The CTD diver measurements are subtracted by the Xtides predictions, as shown as in Figure 21. There seems to be a negative trend in the difference between the two methods, while one would expect the trend would be horizontal. The average measured water level by the CTD diver slowly decreases over time, while the average predicted water level by Xtides slowly increases in time. This could be caused by missing tidal coefficients in the Xtides model.

This temporal variation is caused by negative trend present in the CTD divers measurements. Since this trend is not present in the Xtides measurements, the difference between the methods show a negative trend. This implies that comparison between the Xtides method and the measurements with the pictures will lead to an underestimation of the erosion. More research should be done in order to see if this trend continues to increase in time or not.

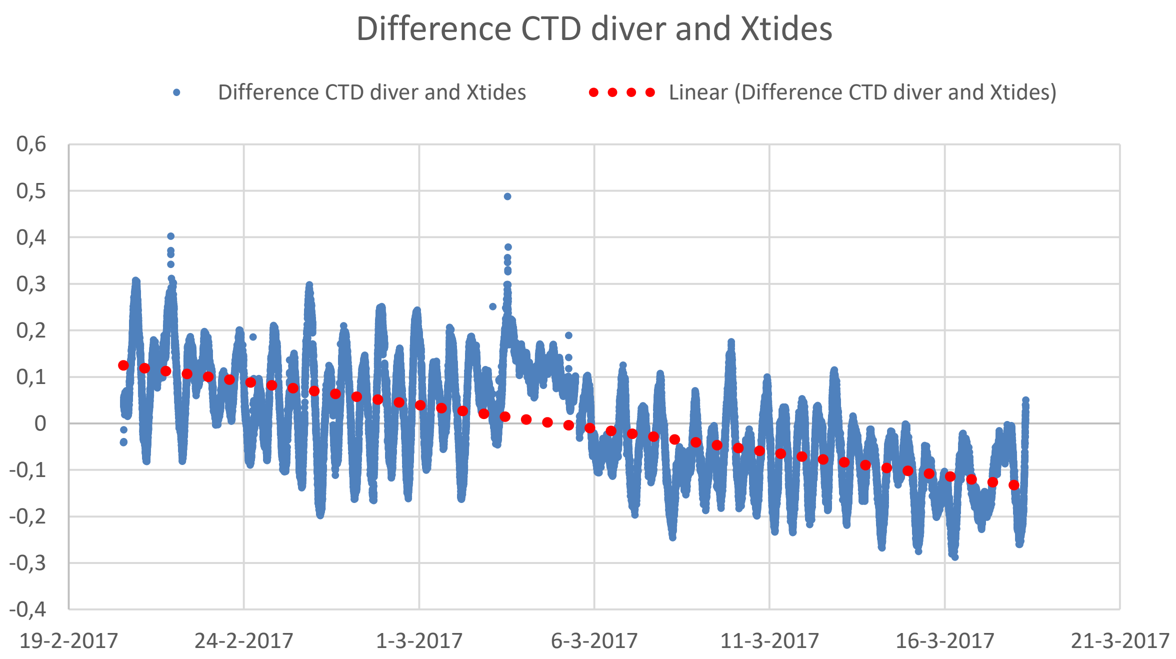


Figure 21: The CTD diver water levels are distracted by the Xtides water levels

3.3 Accuracy measurements

In order to gain more insight in the accuracy of the performed measurements, the obtained measurements from the pictures are displayed as a water height together with the CTD divers measurements and Xtides predictions in Figure 22. The water depth is displayed with respect to the Mean Low Water Spring tide (MLWS). The green dots seem to be on the red and blue line, which indicates a similar measurement for those specific times. The average difference between the measurements from the pictures and both the Xtides predictions and CTD divers is around 0.1 meters and the relative error is 10-15%.

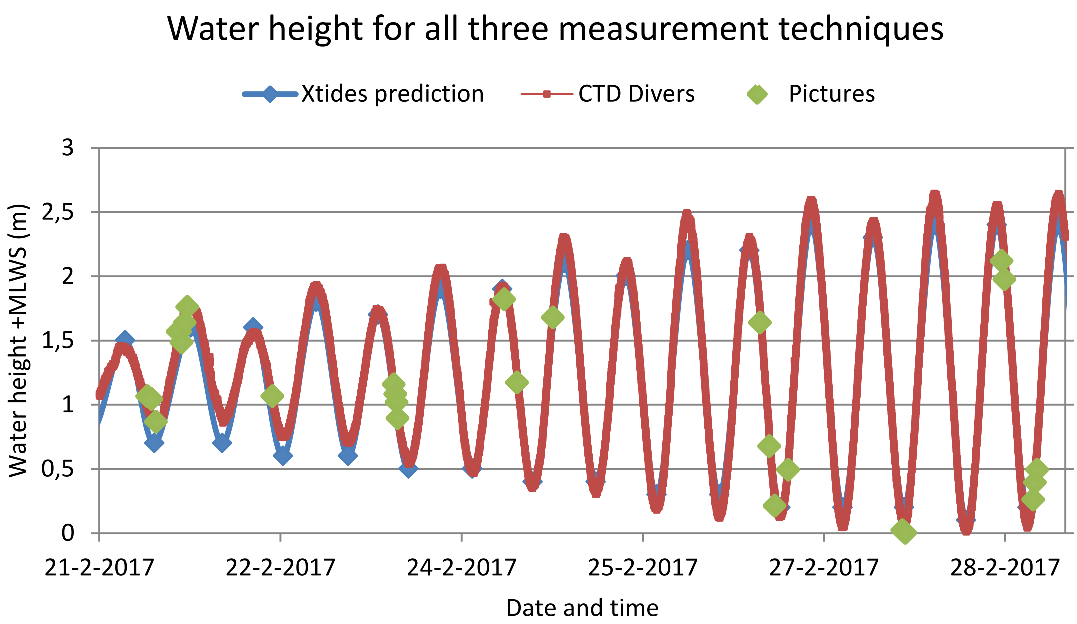


Figure 22: Overview different measurement techniques for a period of one week

3.3.1 Influence variation of tides

The influence of the variation of the tides on the measurements were also researched, as shown on Figure 23. The different colours give an indication when the measurement was taken; with high, low or middle tide. There seems to be no significant difference in error for the different tides.

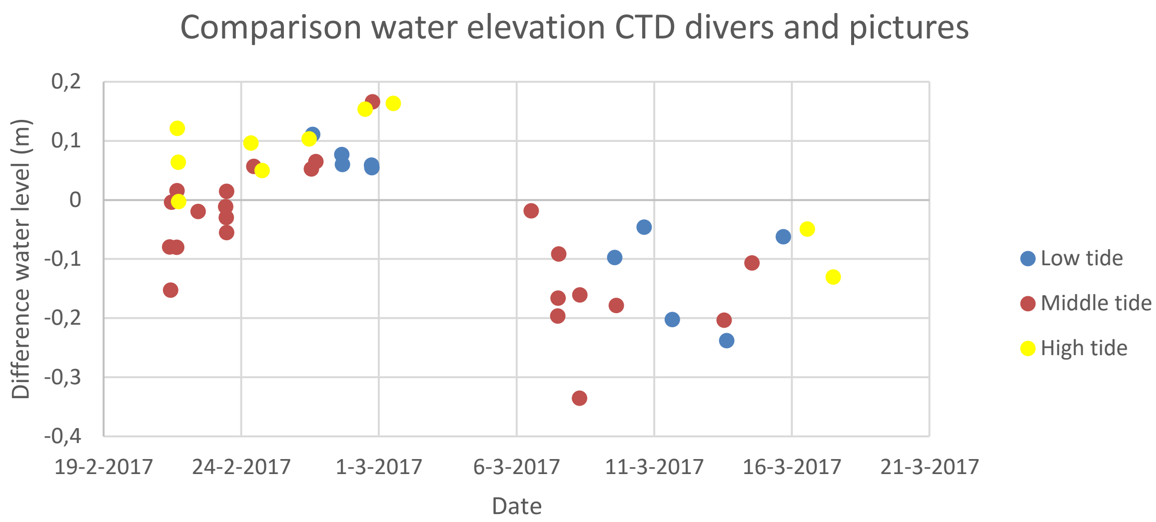


Figure 23: Comparison of the water elevation of the measurements of the CTD divers and the pictures measurements. The average difference is 0.1 meter

3.3.2 Influence waves

The significant wave height is measured with the Wavedroid, to see if the wave height influences the accuracy of the pictures measurements. The wave climate clearly shows a difference in significant wave height between the morning and afternoon, as shown on Figure 24. Between approximately 11:00 and 20:00 the significant wave height becomes much larger compared to the rest of the day.

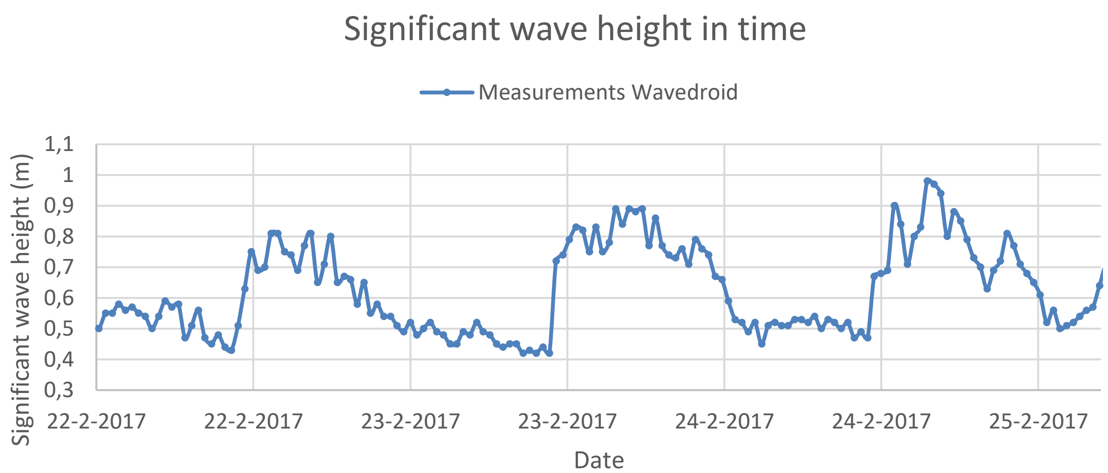


Figure 24: Significant wave height over a period of three days

In Figure 25 the measurements made with low waves are displayed blue, and the ones with high waves red. Although the measurements with the low waves are limited, there seems to be no significant difference between the measurements with the high and the low waves. This might be different in the rainy season, when the waves are usually higher.

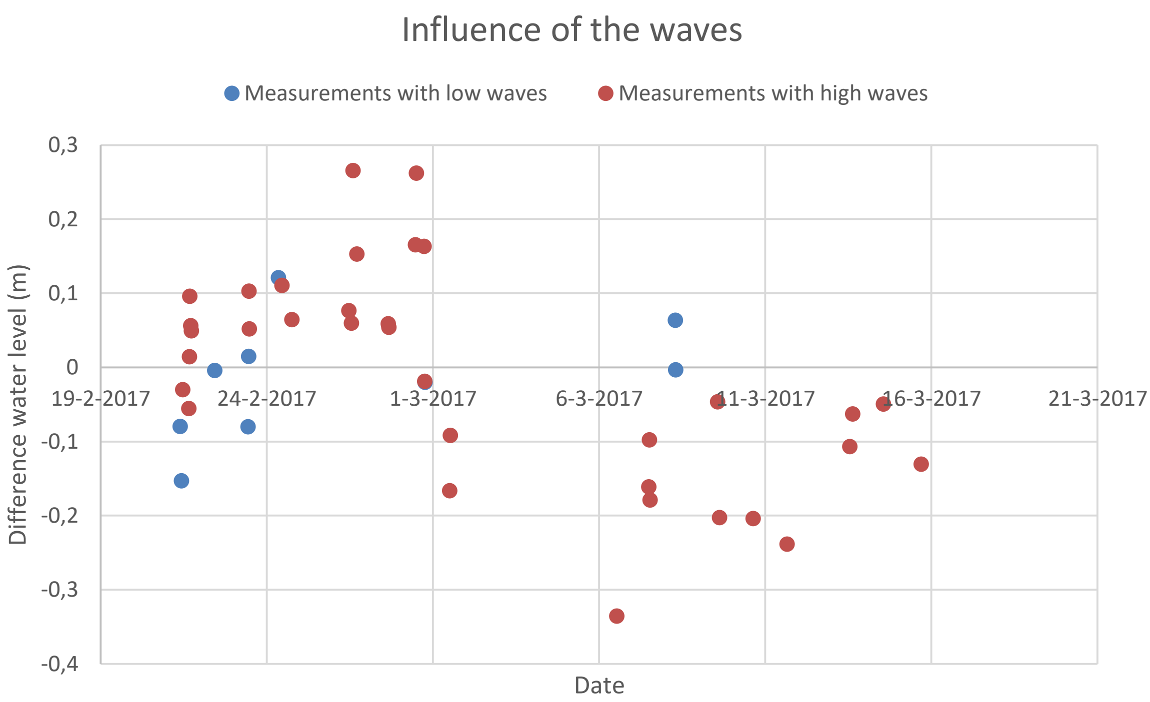


Figure 25: Measurement with low waves compared to measurements with higher waves

4 Discussion

The main research goal was to see if the tides and also coastal erosion can be measured with the help of the local population. The method to do this was by taking pictures of a specific object on the beach. The results seem to be promising and confirm that this is indeed possible. Different groups have been approached in different methods. Some methods were more effective than others. It appeared to be very hard to include the people from Myanmar, who are just visiting the beach, in the research. The language barrier and the lack of quality smartphones made it very difficult for this group to participate. Also the Western tourists were not so easy to motivate, partly because it was difficult to explain how coastal erosion exactly works. The hotel owners, however, were very helpful and willing to participate. Also they had enough staff to ensure that the pictures were taken regularly. The staff working in the hotels are all from Myanmar, so this way the people from Myanmar were still included. A big advantage was that the staff spoke decent English. Another advantage was that the same camera was being used for the measurements each time, which saves a lot of time calibrating the cameras. This also greatly improves the reliability of the method, since calibrating the camera correctly increases the accuracy greatly. The facebook page did get a lot of likes, 211 in total, although it didn't result in more submission of pictures.

In future measurements it is recommended to contact the local hotel owners or other parties who have direct benefits of the beach. This seems by far the most effective approach in obtaining the required pictures to measure erosion. In total 70 pictures were received in a period of 6 months with the help of the hotel owners.

The accuracy of the pictures method was also high enough to validate the tides and possibly measure erosion. The accuracy is 2.1 meters, which allows coastal erosion to be detected in an early stage. The Xtides did have to get adjusted to get more accurate results, without the adjustment the accuracy was nearly double with 4 meters. This is something to keep in mind when performing this method on a different location. A more accurate tidal prediction can greatly improve the accuracy of the measurement of erosion.

The presented method approached the measurement of coastal erosion in a different way than previous researches which results in certain advantages and disadvantages. The advantage towards the methods used by Sandwatch (Cambers, 2015), is that it is easier to participate since no extra tools such as measuring tape are required. Also the time of measurement is irrelevant. This does introduce an extra inaccuracy however.

In the iCoast project (iCoast, 2014) the pictures could only be used qualitatively, while for this research the pictures were mainly used quantitatively. This results in a more detailed description of the coast and more accurate prediction of coastal erosion.

The method is more than ten times more accurate than remote sensing techniques that make use of satellite imagery. These type of techniques are limited to the scale of the spatial scale of the satellite which is 30 meters for the Landsat images (Michalowsca et al., 2016).

A negative trend is the width of the beach was found, which indicates coastal erosion. Coastal erosion is a very slow process, which becomes visible over several years. Also the seasons influence the rate of erosion. The rainy season starts in May and traditionally the coast erodes in this period. The months after the rainy season, starting with October, coastal aggradation usually occurs. Therefore, it is too early speak of structural erosion. However, in the time the measurements took place erosion did take place. Measurements over a longer period of time could show if structural erosion takes place as well.

5 Conclusions

The method has proven to be a valuable addition to existing methods to measure coastal erosion in countries with limited resources. The method can determine the beach with an accuracy of two meters and can detect coastal erosion in early stages. The method works especially well when the local population benefits directly from the beach, for example for hotel owners. Limitations of the method are the reliability of accurate tidal predictions and a lack of participation of other visitors of the beach.

6 Recommendations

The methods can be improved in different areas. Here are some of the main recommendation for future research listed.

- For Ngapali beach the measurements should continue over a longer period of time in order to determine if structural erosion takes place.
- The Xtides model should be validated with CTD divers again, in order to determine if the accuracy has stayed the same or changed.
- A more effective way to approach more hotel owners could greatly improve the amount of participants of the research. For example as part of an ecological government program.
- Tourists and locals were not easily motivated to participate. Also there were problems with the calibration for the cameras. Another approach should be looked for in order to include these groups as well.
- It would be interesting to test the pictures method in a different country to see if more people are willing to participate. This could give more insight in the language or cultural barriers.
- The tidal predictions were now improved with the help of the CTD divers. Since these are quite costly a different method to obtain the most accurate tidal predictions is desirable.

7 Literature

- Bandyopadhyay, 2016. Use of sea sand as fine aggregate in concrete making. URL: http://www.nbmcw.com/crushing-mining/35318-use-of-sea-sand-as-fine-aggregate-in-concrete-making.html.
- Cambers, 2009. Carribean beach changes and climate change adaptation.
- Coastal Care, 2017. URL: http://coastalcare.org/sections/inform/sand-mining/
- David Flater, 2006. XTide. URL: http://www.flaterco.com/xtide/.
- ESCAP, 2015. Disasters in Asia and the Pacific: 2015 Year in a review.
- Liu S. et al., 2014. USGS iCoast – Did the coast change? Designing a crisis crowdsourcing app to validate coastal change models. Proceedings of the ACM Conference on Computer Supported Cooperative Work.
- Michalowska et al., 2016. Temporal satellite images in the process of automatic efficient detection of changes of the Baltic sea coastal zone.
- Myanmar Times, 2015. Fears for future of Ngapali Beach as authorities permit sand excavation. URL: http://www.mmtimes.com/index.php/in-depth/13497-fears-for-future-of-ngapali-beach-as-authorities-permit-sand-excavation.html.
- UNEP, 2006. Marine and Coastal ecosystems and Human wellbeing: A synthesis report base on the findings of the millennium ecosystem assessment. Nairobi, Kenia, UNEP.
- UNFCC, 2007. Climate Change: Impacts, vulnerabilities and adaptation in developing countries.
- UNISDR, 2013. Global assessment report on disaster risk reduction. Tech. rep., United Nations International Strategy for Disaster Risk Reduction.
- UWE, 2013. Science for Environment Policy In-depth Report: Environmental Citizen Science.
- Wavedroid, 2017. URL: http://www.wavedroid.net/

8 Appendix A

According to triangle similarity Equation 4 applies:

$$\frac{distance\ to\ object\ (m)}{real\ width\ (m)} = \frac{focal\ length\ (m)}{object\ width\ (m)}$$

Equation 4: Triangle similarity

Since the object width in the picture is in pixels, the amount of pixels have to be translated in the amount of meters, which is shown in Equation 5:

Equation 5: Translation pixels to meters

$$object\ width\ (m) = \frac{sensor\ width\ (m) * object\ width\ (pixels)}{image\ width\ (pixels)}$$

This results in the final equation, shown in Equation 6.

Equation 6: Distance to object

$$distance\ to\ object\ (m) = \frac{focal\ length(m) * real\ width\ (m) * image\ width\ (pixels)}{object\ width\ (pixels) * sensor\ width\ (m)}$$

9 Appendix B

NGAPALI BEACH NEEDS YOUR HELP!

Ngapali beach is one of the most beautiful beaches in Myanmar, which attracts many tourists each year. Unfortunately the beach is in danger, because people are stealing sand from the beach to use it for construction, so called "sand-mining". This can be seen on the image at the right. The sand-mining is causing the beach to get smaller and smaller each year. When it continues like this in a couple of years there will be nothing left of the beach in Ngapali! Then nobody will come to Ngapali anymore and many people in Ngapali lose their jobs!

ABOUT THE RESEARCH PROJECT

The aim of the research is to study the coastal erosion in Ngapali and find out how quickly the beach erodes (for example: 1 meter per year). The result of this research could be of great help convincing the local authorities to take direct action against the sand-mining. A collaboration between the Myanmar Maritime University and the Technical University Delft has made this research possible. The research is being performed by Dutch researchers from the TU Delft.

WHAT YOU CAN DO

Anyone with a smartphone can participate in the research. It is very easy to participate and it won't cost much time.

1. Walk from any hotel/restaurant on the beach in a straight line towards the sea
2. Position yourself at the point where the seawater just reaches the land as shown on the image
3. Take a picture of the hotel/restaurant
4. Send the picture towards the email address as below OR post the picture on the Facebook page. Also include the name of the hotel/restaurant.

EMAIL: ngapalibeacherosion@gmail.com

HOW IT WORKS

Each pictures can be seen as a measurement of the beach size. When enough measurements are made it can be seen that the beach is getting smaller and by how much.

LIKE US ON FACEBOOK (www.facebook.com/ngapalibeacherosion)

Visit the **Facebook** page to see how your picture is being used! You can find the page by searching for "**Ngapali beach erosion**". More information about the sand-mining can be found there as well.

THANK YOU!

Thanks to your help Ngapali beach will hopefully remain as beautiful as it is now!

TU Delft

10 Appendix C

```
# -*- coding: cp1252 -*-
import cv2
import numpy as np
import imutils
import PIL.Image
import os
import csv


def distance(image,img):

    #Read the time
    exif_data = img._getexif()
    date = exif_data[36867]
    date = date[0:16]
    date = date[8:10] + "/" + date[6:7] + "/" + date[0:4] + date[10:16]

    #Resize image
    #image = imutils.resize(image, height = 1000)

    #Adding a color mask to the image
    hsv = cv2.cvtColor(image, cv2.COLOR_BGR2HSV)
    lower = np.array([14, 178, 153], dtype = "uint8")
    upper = np.array([35, 255, 255], dtype = "uint8")
    mask = cv2.inRange(hsv, lower, upper)
    output = cv2.bitwise_and(hsv, hsv, mask = mask)

    #Apply grayscale, blur, threshold and edges
    grey = cv2.cvtColor(output, cv2.COLOR_BGR2GRAY)
    grey = cv2.blur(output, (7, 7), 0)
    (T, thresh) = cv2.threshold(grey, 20, 255, cv2.THRESH_BINARY)
    edged = cv2.Canny(thresh,0,0)

    #Dilation
    kernel = np.ones((3,3),np.uint8)
    edged = cv2.dilate(edged,kernel,iterations = 1)

    #Apply contours
    (cnts, _) = cv2.findContours(edged.copy(), cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)

    #Find the contour with the largest area
    areas = [cv2.contourArea(c) for c in cnts]
    max_index = np.argmax(areas)
    cnt=cnts[max_index]

    #Draw a bounding rectangle to largest area
    x,y,w,h = cv2.boundingRect(cnt)
    cv2.rectangle(image,(x,y),(x+(w-6),y+h),(0,0,0),8)

    #Compute distance to object
    focalsensor = 1.41
    realheight = 0.87
    objectheight = h-6
    dis = focalsensor * realheight * image.shape[0] / (objectheight)

    return h, date

source = "C:\Users\Aspire\Google Drive\Python\geel"
os.chdir(source)
row = 0

for root, dirs, files in os.walk(source):
    data_array = np.zeros((len(files),2),dtype=object)
    for file_name in files:
        image = cv2.imread(file_name)
        img = PIL.Image.open(file_name)
        data = distance(image,img)
        data_array[row,0] = str(data[1])
        data_array[row,1] = data[0]
        row = row + 1
        print str(data[1])

#Save data to file
with open("C:\Users\Aspire\Google Drive\Python\output.csv", "w") as f:
    writer = csv.writer(f, lineterminator='\n')
    writer.writerows(data_array)
```