ASSESSMENT OF THE EFFECT OF SHOREFACE NOURISHMENTS USING AUTONOMOUS BAR BEHAVIOR

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Abstract: This paper focusses on shoreface nourishments ability to contral the safety at a coast by controlling the position of the duneface. A very challenging task is to determine the net effect of coastal protection, because the atutonomous behavior must be known before hand. It is very seldom that there a multiple surveys before a costal protection scheme is implemented, in order to determine this. But in this paper it has been the case. The analysis shows a very positive net effect of a shoreface nourishment. The effect son safety and morphology are even larger than can be explained, which has risen new research questions.

Motivation

For normal sized nourishments (not mega) it is cheapest do nourishments at the shore face. Under severe storm surges dune erosion can occur, leading to an unacceptable risk. Shore face nourishments can be designed to prevent dune erosion, and the focus on this work is to find the optimal way. Vital for any assessment of the effect of any coastal protection is to be able to assess the net effect, i.e. the effect of the coastal protection where the autonomous behavior is extracted. Therefore the autonomous behavior must be known, which is a major challenge on the Danish west coast is.

Research questions

In this research there are three research questions. 1) What is a coast autonomous behavior? 2) Is it possible to extend the length of the outer bar downstream? 3) Can a shore face nourishment control the dune face at a erosional hot spot?

Methodology

3 coastal stretches are selected for the analysis of the autonomous behavior; they are all within 45 km of a nearly straight eroding sandy barrier coast. The northern most (transect 5350) is completely naturally behaving without any human interventions. The southernmost (transect 5760) has been completely naturally behaving for many years without any human interventions. The last

years shore face nourishments has been carried out. The middle stretch (transect 5450) has been impacted by regular nourishments. The stretches are being surveyed annually. The survey lines ranges from approximately 15 m depth to the dunes. The longshore distance between transects are approximately 1 km.

The profile for each transect is plotted in a time stack graph for the period 1957 to 2017. For each profile the bars are shown with a thick coloured solid line. The rest of each profile is shown with a solid black line if shoreface nourishment has been carried out, and a dashed line if beach nourishments have been carried out.

For each transect crosshore position of the bar(s) is determined and it is analyzed whether there is a trend/cyclicity in the bar(s) position and other indicators. The analysis is supplemented with local surveys, where transects are spaced 200m longshore, and are surveyed several time a year. The local surveys are project specific survey that has a project limited timespan of relatively few years.

The observed trends is used to define the autonoumous behavior, which is used analyzing the net effect of shoreface with a special focus on the dune face.

Shore face nourishment

At the southern most coast a very long (12,775m) shoreface nourishment of approximately 730.000 m^3 (57 m^3/m) was completed in 2011, while the shoreface nourishment in 2011 of approximately 310,000 m^3 (400 m^3/m) was only 775 meters long. It was planned to be placed at the downstream end of the outer bar where a local dune erosion hotspot has been present, see Figure 1. Both shoreface nourishments were placed on the shoreface of the outer bar. The depth at the bar top is approximately 5 m, while it is approximately 3 m at the bar top of the second bar.

Figure 1. Bars morphology and placement of 2011 shoreface nourishment.

It is seen from figure 1, than prior to the nourishment there was a distinct long and low outer bar, and that the second bar, which is higher than the outer bar, is missing, because of the cyclicity of the bar system at that specific coast. The second bar regenerates further to the left, which is in the down stream direction.

Hydrodynamic forcing

Waterlevel and wavedata have been monitored throughout the survey period to be able to include variation in the hydrodynamic impact/forcing on the analyzed coastal stretch. Waterlevels are recorded every 10 min. at the breakwater of a harbor north 11 km upstream the nourishment area. Wavedata are recorded in 20 min time periods every 3 hours. Based on these data the total energy flux Etot, the longshore energy flux Elong, and the crossshore energy flux Ecross is calculated using equation 1-3.

$$E_{tot} = \frac{1}{8}\,\rho\, g\, H_{m0}^2 \qquad (1)$$

$$E_{long} = E_{tot}\,\sin\alpha \qquad (2)$$

$$E_{cross} = E_{tot}\,\cos\alpha \qquad (3)$$

The hydrodynamic impact variation in time is shown on figure 2.

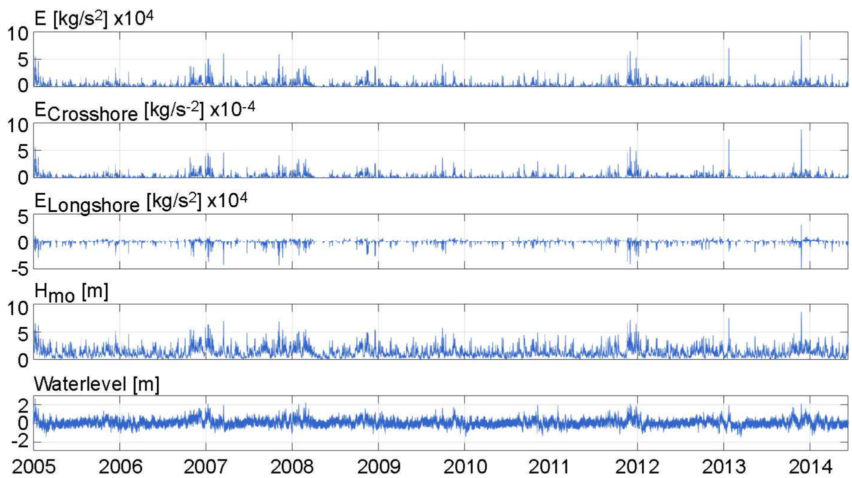

Figure 2 From above total energy flux, crossshore energy flux, longshore energy flux, Significant waveheight and waterlevel.

In general a clear seasonal variation is seen, but it is also clear that the energy flux during a storm season vary. The winter 2006-07, 2007-08 and 2011-12 have been especially energetic. One of these is just after the shoreface nourishment took place in 2011. It is also clear that the net and gross longshore energyflux is of the same magnitude, showing that waves are predominantly coming from a westerly and northwesterly direction.

Results

We start focusing on research question 1, determine the autonomous behavior. In figure 3 a time stack of a representative transect for each coastal stretch are presented with arrows indicating bar movement. It is clearly seen that the bars all moves offshore and in the same direction in average. Figure 1 is also showing that the trends are not linear, and varies both with time and space. Table 1 shows the derived offshore migration, lifetime and speed for each defined bar before shoreface nourishments took place.

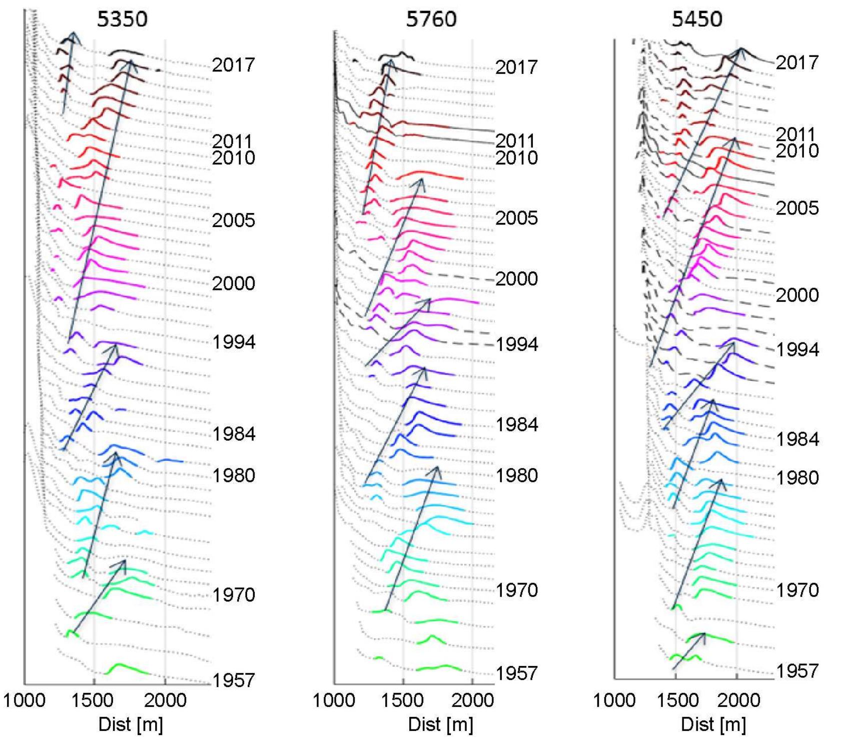

Figure 3. Time stack of profiles

From table 1 it is seen that in the area with no nourishments the offshore migration distance is shorter than the other two areas, which is mainly because of bar 2, which moved significantly shorter than the rest of the bars. The lifetime is approximately the same for all bars, while the migration speed for the area without nourishments is lower than the two other areas.

Table 1. Derived bar morphology parameters

	No nourishments Line 5350			Some beach nourishments Line 5760			Many beach nourishments Line 5450		
	Offshore migration [m]	Life-time [years]	Speed [m/year]	Offshore migration [m]	Life-time [years]	Speed [m/year]	Offshore migration [m]	Life-time [years]	Speed [m/year]
Bar 1	708	10	71	708	14	51	667	14	48
Bar 2	375	12	31	833	12	69	541	10	54
Bar 3	750	12	63	875	8	109	958	11	87
Bar 4	833	26	32	791	13	61	1167	20	58
Mean	667	15	49	802	12	73	833	14	62

Now the focus is on the coast where the southern most profile 5760 is located. The coast is a sandy almost natural evolving coast. There has only been minor beach nourishments until 2010.

A 4.8 km long coast including the shoreface nourishment has been studied in detail to answer the research questions. The analysis will be based on surveys in transects with a spacing of 200 m. The survey period is from 2005 until 2014 and the density of survey varies because the research aim in the beginning of the survey period were different than in this paper.

Now we look into the research question 2, whether it is possible to elongate a bar downstream. The volume in the outer shoreface has been calculated in 7 boxes. One (Nour) that includes the nourishment. Two upstream, north of the nourishment (N1, N2) and four downstream, south of the nourishment (S1, S2, S3 and S4). The volume changes in time from 2005-2014 can be seen on figure 4. The vertical grey lines indicate the time of nourishments in 2010 and 2011.

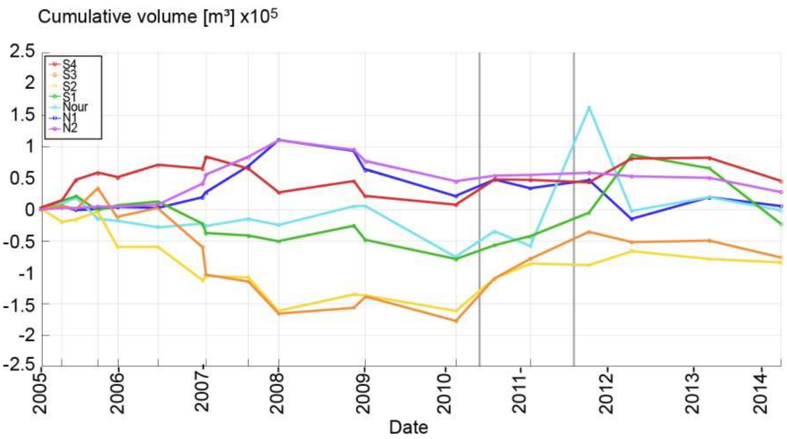

Figure 4. Cumulative volume evolution from 2005-2014 for the outer shoreface

Figure 4 shows a general loss of volume before the nourishments. The first nourishment in 2010 has stopped this trend. Especially in the nourishment box and downstream (S1-S3) a gain in volume can be seen, which is partly due to a sediment transport alongshore at the outer bar. The total volume in the offshore boxes seems have increased more than the nourishment volumes.

As a check the total sediment volume in the 4.8 km long box from -6- -7 depth to dune top. Figure 5 shows the total volume changes from 2005 to 2014. The vertical grey lines indicate the time of nourishments in 2010 and 2011.

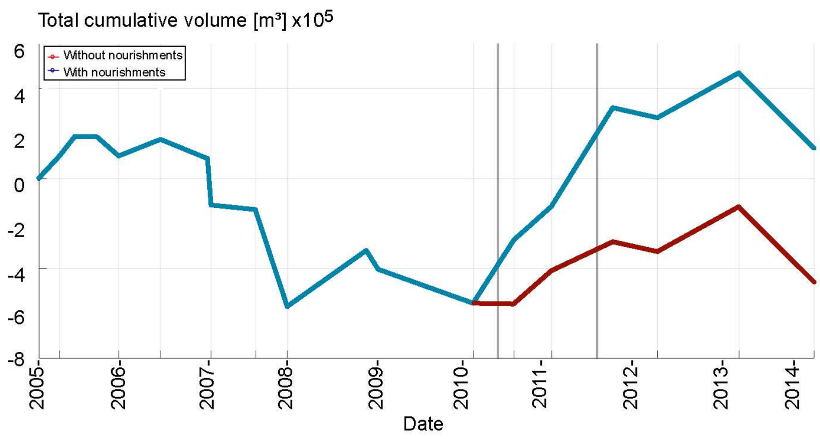

Figure 5. Total volume in the active profile on the 4.8 km long coast including the shoreface nourishment. Red line is the measured volume reduced by the volume of the shoreface nourishment.

At first it is seen that the total volume decrease in time from 2005 to 2010. The linear trend is 157,000 m^3/year corresponding to a profile retreat of 2 m/year. From 2010 to 2014 the volume increases and even more than the nourished volume. If the measured trend before the nourishment started is extrapolated from 2010 to 2014 the total volume would have been -1,200,000 m^3. The measured net volume is -450.000 m^3.

What is causing this significant change in trend? There are several possible explanations. The two most obvious ones is 1) The survey lines seaward limit is at approximately 6 m depth, and it is known that sediment transport takes place on deeper water, causing an onshore supply og sediment. 2) Due to the cyclic longshore behavior of the bars there is more sediment being transported longshore into the box than is transported out of the box.

Research question 3 focus on the shoreface nourishment effect of safety against erosion and flooding, expressed in the position of the duneface. In the Building with nature project a set of coastal state parameters (CSI's) are defined, and three of these describes the position of the duneface. These are position of upper dune, mid dune and lower dune level. There are 2 others on the beach mean high water level MHWL, and mean low water level MLWL. The position of these 5 CSI's just shorewards of the shoreface nourishment is shown in figure 6.

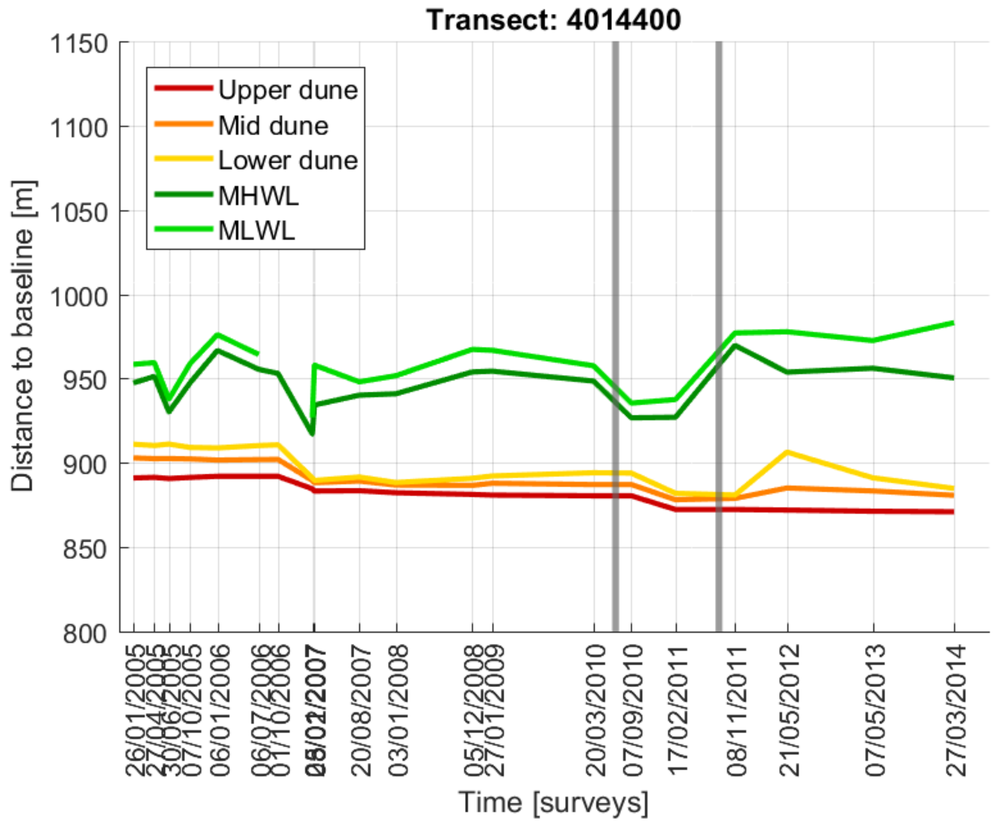

Figure 6 Crosshore movement of coastal state indicators just shoreward of the shoreface nourishment. Grey lines indicate shoreface nourishments. MHWL is mean high water line and MLWL is mean low water line.

The figure shows a typical dune behavior on this type of sandy coast. The slope of the dune expressed by the distance between the lower, mid and high dune is suddenly being steeper due to dune erosion. The position of the high duneface is constant while the lower dune is building up causing a more gentle slope. It is however seen that the position of the dune positions indicated a huge positive effect of the shoreface nourishment, despite of the huge energy flux that hit the coast in the winter just after the nourishment was finished (figure 2).

Conclusion and further work

The autonomous behavior of the bar system at coast has been determined. It is described by the offshore migration, migration speed and lifetime. It has made it possible to determine the net effect of a shoreface nourishment on the position of the duneface and on morphology. It is shown that the shoreface nourishment has been able to control an erosional hot spot, even under a very energetic storm season. However the results has shown a much larger net effect than expected, especially the volume in the coastal system is much larger than expected. It is not yet possible to identify the cause of this very positive effect.

These analysis will be compared with similar shoreface nourishments on coasts in Germany, The Netherlands and Belgium trying to determine the net effect of shoreface nourishments at varying coastal environments. The results is going to be used to upscale the findings to generalized guidelines to use a building with nature concept as shoreface nourishment to control the risk of erosion and flooding on sandy coast in the world.

Acknowledgements

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