MODELLING STORM IMPACT ON COMPLEX COASTLINES WESTKAPELLE, THE NETHERLANDS

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Regular dune safety assessments in the Netherlands are presently based on a 1D model approach, which is insufficiently applicable for more complex coastal areas with structures, tidal channels or spatially strong varying bathymetry. These situations require more advanced methods to assess the safety in dune areas. In this study a 2DH XBeach model (Roelvink et al., 2009) is applied as a demonstration for a complex coast, and a comparison is made with results obtained from a 1D model approach, using 1D XBeach and 1D DurosTA (Steetzel, 1993). For this specific test-case the coastal area near Westkapelle (in the south-western part of the Netherlands) is selected, since this location is considered to be 'complex' for regular safety assessment studies. The near-shore zone is characterized by a (spatially) strongly varying bathymetry, due to the presence of tidal flats and channels, and a strongly curving coastline. Moreover, the Westkapelle-area is protected by both coastal structures and sandy dunes, such that transition zones exist, which are difficult to assess with a 1D model approach. It is demonstrated that a 2DH model approach enables detailed analysis of the effect of alongshore processes on (dune-) erosion. From model comparisons it is concluded that significant differences are found between simulated erosion-volumes for 1D and 2DH models, when considering the impact of normative storms on complex coastlines.

Keywords: storm impact modelling; dune erosion; safety assessment; complex coastline; Westkapelle; XBeach; DurosTA; DUROS+.

INTRODUCTION

In the Netherlands sandy dunes are an integral part of the sea defences that protect the hinterland from flooding. The sandy coastlines require safety assessments on a regular basis since the morphology of dunes and foreshore is dynamic. For the Dutch coast these assessments are performed by applying relatively simple 1D calculation methods for dune erosion, which have been extensively validated with (large scale) physical models. However, the applicability of the currently used approach for safety assessments is limited when considering more complex coastlines. Therefore, in this study a 2DH model approach is tested for simulating storm impact along a more complex coastline where alongshore processes may not be ignored.

The 1D dune erosion approach is used as a quick and well-supported way to monitor the state of the sea defences along the coastline. Yearly-measured bathymetry along a large number of so-called JarKus transects provide (reasonably) up-to-date input for dune erosion modelling and the related safety assessments. The 1D approach for these safety assessments works particular well for coastal stretches with a gently sloping foreshore and a more or less alongshore uniform bathymetry, which correspond to the assumptions inherent in the laboratory tests. The Dutch coast, however, (also) consists for a substantial part of more complex coastal areas, with for example the presence of strongly curved coastlines, deep near-shore tidal channels, or transitions between dikes and dunes. In those complex situations the applicability of a 1D model approach is doubtful, since by definition no alongshore effects are considered (or, only incorporated in a very schematized manner).

Figure 1 indicates for which coastal areas along the Dutch coast the regular 1D approach is applicable, and for which areas an advanced method (i.e. 2DH approach) is preferred. For the central part of the `Holland Coast` (except for locations with coastal structures) the simple 1D dune erosion models are applicable since the foreshore is gently sloping and reasonably uniform alongshore. However, for the `Wadden Coast` in the northern part and the `Delta Coast` in the south-western part of the Netherlands more complex, spatially varying, foreshores are found. The presence of these complex areas impedes a straightforward application of 1D dune-erosion models. It is conducted that up to 40% of the dunes cannot or should not be assessed with a 1D model approach.

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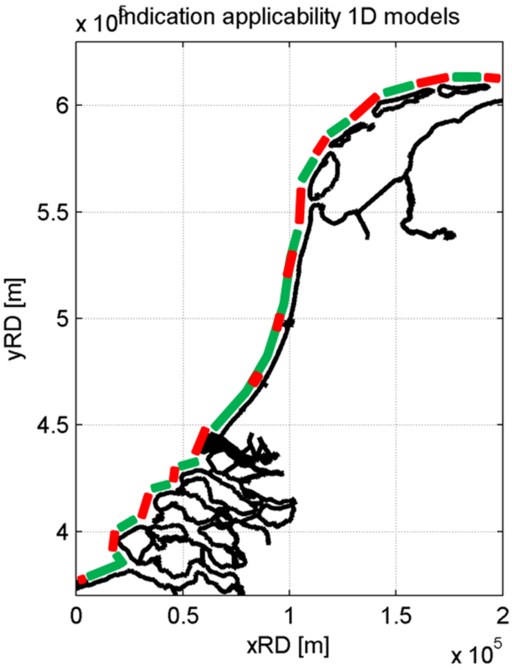

Figure 1 **Indication of areas where 1D dune-erosion models are applicable (green) / are not applicable (red) for safety assessments. Distinction is based on the complexity of the bathymetry and the presence/absence of coastal structures.**

For areas with complex coastlines a 2DH approach might be a more suitable alternative to determine possible safety issues during (normative) storm conditions. The use of 2DH dune erosion models enables a more sophisticated method to incorporate near-shore hydrodynamics and morphodynamics due to alongshore variations in bathymetry, wave field or flow velocity. These processes hypothesized to have a significant effect on the amount of dune erosion and therefore it seems important to account for these aspects in safety assessments.

This study focuses on the application of a 2DH numerical dune erosion model for a so-called complex coastal area along the Dutch coast. Morphodynamic simulations of normative storm-conditions applied to a 2DH coastal domain are used to demonstrate the results and advantages of a more sophisticated approach for dune-erosion modelling.

OBJECTIVE OF STUDY

The main objective of the study is to demonstrate the possibilities of the numerical 2DH model XBeach (Roelvink et al., 2009) to assess storm impact at complex coasts. Based on a specific coastal area the effects of alongshore non-uniformities are studied in detail. The results of the 2DH model are compared to results of a regularly used 1D dune-erosion model: DurosTA (Steetzel, 1993).

STUDY AREA

The study-location selected for the test-case is situated near Westkapelle, in the south-western part of the Netherlands (see Figure 2). This area is characterized by the presence of several features that typically impede the application of a regular 1D model approach, and is therefore particularly suitable for this demonstration-case with a 2DH model. Examples of complex features in the area of Westkapelle are:

- Deep tidal channel
- Coastline curvature
- Transition between sea-dike and dune-area
- Dune-foot protections

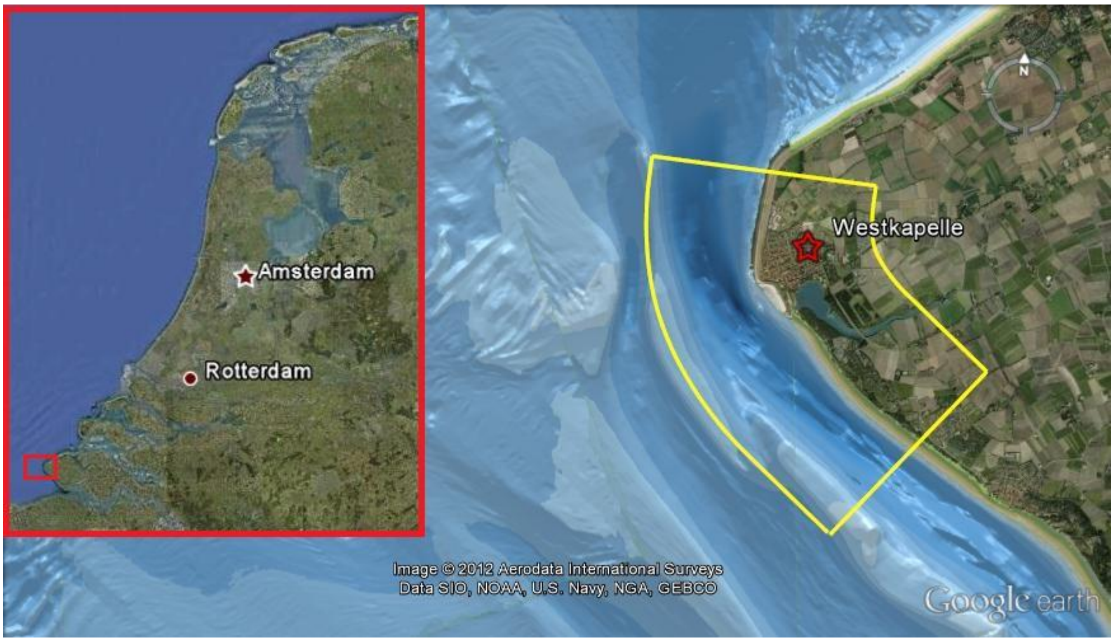

Figure 2 Overview of study-area near Westkapelle in the Netherlands. Recent bathymetric data is presented as well, to show the complexity of the near-shore seabed. The area consists of several tidal channels and shoals that influence the hydrodynamics in the coastal zone. *Source: Google Earth.*

From Figure 2 it is clear that the coastal area near Westkapelle is quite challenging for morphological modelling. The (alongshore) non-uniformities of the bathymetry and the strong local coastline curvature are caused by the presence of two large estuaries on both sides of the area (Western Scheldt and Eastern Scheldt). Just seaward of these inlets large outer deltas are formed with subsequent series of shoals and tidal channels. In front of the coast near Westkapelle a very deep (> 40 m) tidal channel has formed, close to the shoreline. Further seaward also some shallow flats are found that absorb most of the wave energy before waves are reaching the beach area.

The combination of a strong coastal curvature and the presence of a tidal channel enhance alongshore sediment transports and gradients therein such that the area is vulnerable to erosion. The coastline is protected against (structural) erosion by a sea dike (`Westkapelse Zeedijk`) and a stretch of dune-foot protections. These coastal structures are shown in Figure 3, which is an aerial photograph of Westkapelle area. The photo also shows that wooden groins are present at the inter-tidal beach, used to reduce alongshore transport-gradients during daily conditions.

The specific area-of-interest for this study is the `central` beach between the coastal structures (as indicated in Figure 3). This beach is located between two structures, the tidal channel is located just a couple of hundred meters offshore, and the dunes are positioned relatively far landward. This location is often referred to as ‘Het Gat van Westkapelle’, because at this location a dike breach was forced during the Second World War, in order to try to flood the hinterland. Behind the dunes a creek is found (not visible in Figure 3), which is one of the remains of the breach. The dune area that is now present at the former breach location is the result of the efforts to close the breach. Apart from sand also concrete rumble and remains of the former dike are expected to be found below the beach.

The central beach area is a typical example of a dune-area for which it is expected that it cannot be assessed by a 1D model approach, due to the complex geometry of the area and the presence of the structures and the tidal channel. Therefore, this study focusses on this beach area to simulate the impact of normative storm-conditions.

Figure 3 **An aerial photograph of the coastal area near Westkapelle, the Netherlands. The 'Westkapelse Zeedijk' (sea-dike) is located in the back, and another coastal structure is situated in the front. In-between the beach is present near 'Het Gat van Westkapelle'. *Source: Rijkswaterstaat, www.kustfoto.nl*.**

MODEL SETUP

A 2DH XBeach model is built for the coastal zone near Westkapelle to demonstrate the possibilities to assess dunes in complex areas. In order to study the effects of alongshore varying processes on the morphological impact during normative storm conditions, a two-dimensional curvilinear grid is constructed. The curvilinear grid-definition is used to ensure that the cross-shore gridlines are more or less perpendicular to the initial coastline, despite the strong curvature. The boundary of the model-domain is presented in Figure 2 by the yellow line. Within the presented domain a non-uniform grid-size distribution is applied such that the highest spatial resolution is found in the area-of-interest: the central beach between the coastal structures. By using this approach a substantial reduction of the total number of grid-cells, and the computational times, is achieved.

Using recently measured data of bathymetry and topography a detailed bed level schematisation is made. Some additional modifications are applied to the bed level data in order to ensure a constant bed level at the offshore model boundary, and to ensure a realistic water depth for the inland creek behind the primary sea-defences. The bathymetric input for the 2D XBeach model is presented in Figure 4. Related to the bed level input for the sandy layer, also a non-erodible layer is defined to include the coastal structures in the model setup. Both the sea-dike and the dune foot protections are schematized, based on available design drawings.

The hydraulic forcing for the storm-impact simulations is associated with the normative storm conditions for the area near Westkapelle. These conditions have a typical combined return-frequency of '1/4.000 per year', and are prescribed in the HR2006. The maximum storm surge level is defined at NAP +4.9 m, and the maximum significant wave height in the tidal channel is estimated at 3.65 m, with a corresponding peak (wave) period of 12.2 s. By default, the angle of (offshore) wave attack is set at 270^{o}N, in order to impose pre-dominant westerly waves. Since in both models, XBeach and DurosTA, time-dependent boundary conditions are required, the prescribed maximum storm conditions are converted to representative time-series. These time-dependent storm conditions are constructed following the approach of `standard storms`, as described by Steetzel, 1993. The typical storm duration is thereby set at 30 hours, and the storm surge is combined with a tidal amplitude of 1.7 m. The model-input for the offshore hydraulic forcing is presented in Figure 5.

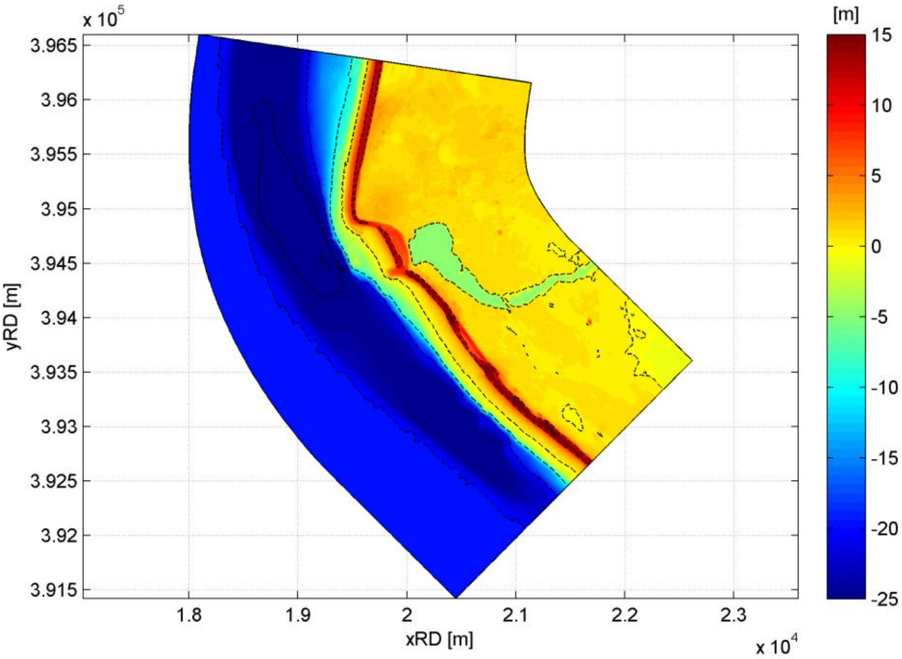

Figure 4 Bathymetric input for 2D XBeach model. The contour lines indicate the NAP -30 m, NAP -20 m, NAP -10 m, NAP +0 m, NAP +10 m and NAP +20 m lines, as a reference.

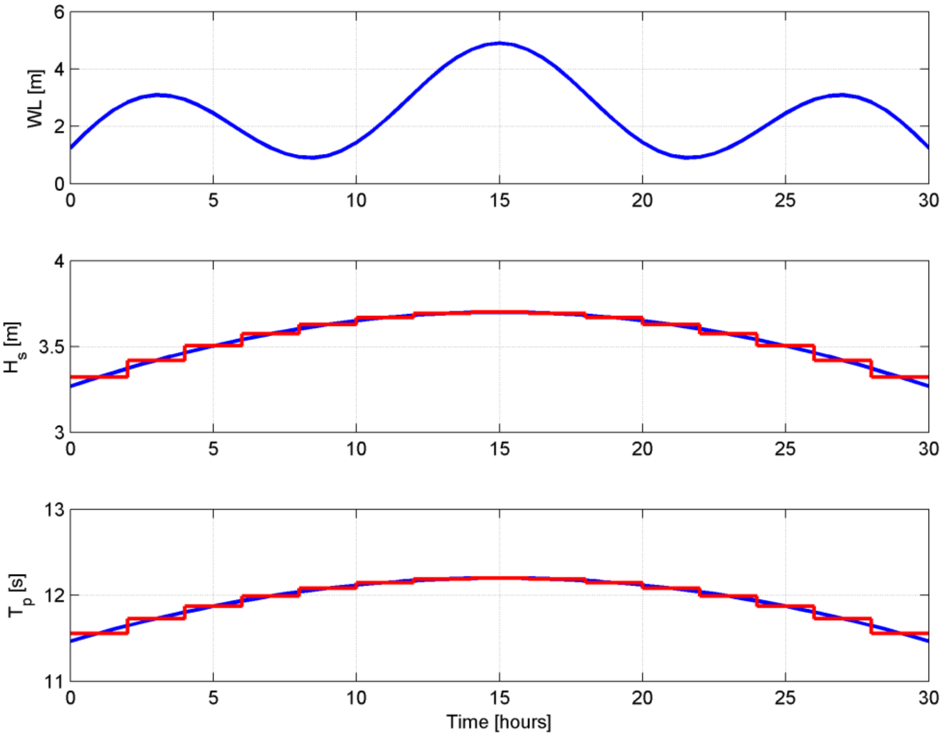

Figure 5 Time-series of hydraulic boundary conditions for XBeach and DurosTA. These conditions represent the normative storm conditions in the study area near Westkapelle.

In this study comparisons are made between XBeach 2DH, XBeach 1D en DurosTA. The input definitions for the 2DH domain are used to generate a large series of 1D cross-shore models, to be used for model-comparisons. For each cross-shore gridline in the 2DH domain a separate 1D model is constructed, resulting in a total of more than 150 transect models; for both XBeach 1D and DurosTA. The bed level definition and structural definition of each transect is based on the model-input of the 2DH XBeach model. The hydraulic forcing of the transect models is identical to the presented time-series in Figure 5. For the 2DH model a westerly wave attack is imposed at the entire offshore domain-boundary, whereas for the transect models two options exist. The first option is to impose normal wave incidence for each individual transect (left panel of Figure 6), and the second option is to impose westerly waves, such that the relative wave angles for individual transects are determined by the transect-orientation (right panel of Figure 6). In this paper results are considered for the latter option: westerly wave attack, and thus oblique wave incidence for the transect models.

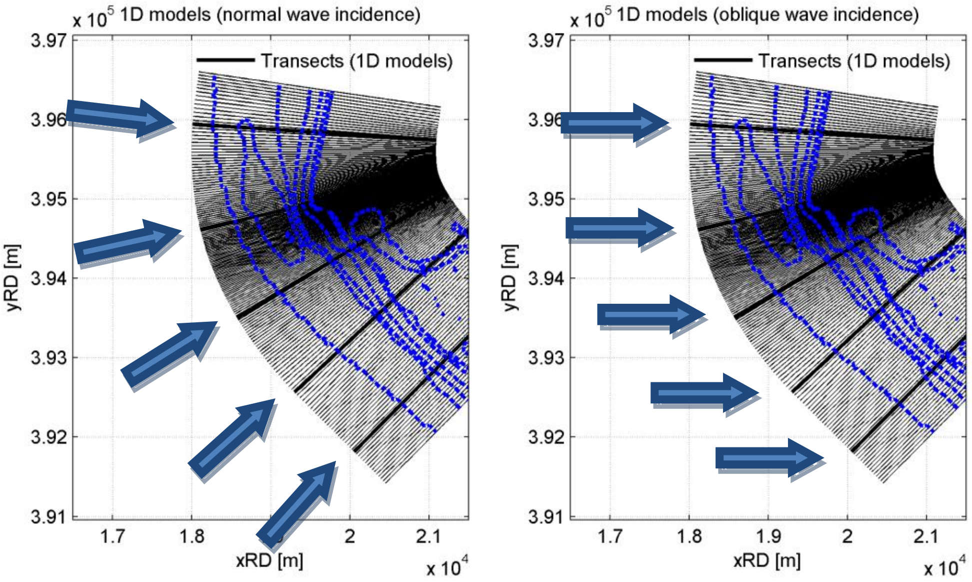

Figure 6 Illustration of two types of input for the direction of wave attack. Left panel: normal wave incidence for all individual 1D transects. Right pane: westerly waves are imposed, so the relative wave angles are determined by the orientation of each individual transect.

For all considered models (XBeach 1D/2DH and DurosTA) the default parameter settings are applied for the storm-impact simulations. The only important exception is the *morfac* parameter for XBeach that enables a reduced calculation time by scaling the hydrodynamic timescale relative to the morphological timescale by a given factor (here: *morfac* = 10). Another important difference between XBeach and DurosTA is that the first model generates wave-groups and (bound) long waves at the offshore boundary, based on a JONSWAP type of wave spectrum. DurosTA does not resolve long waves and their effect on dune erosion, during storm-impact simulations.

RESULTS

A 2DH XBeach model is used to simulate storm impact on the complex coastline near Westkapelle, for normative conditions. The model results are used to analyse the simulated amount of dune erosion and the spatial distribution of erosion- and deposition- areas in the near-shore zone. Similar simulations are performed by a large series of adjacent transect models (both XBeach 1D and DurosTA) in order to study the differences between a 1D and a 2DH model approach. The primary objective of the model comparisons is to gain insight in the effects of alongshore processes on the amount of dune erosion, in areas with significant alongshore variations in the bathymetry.

This paper presents results for one specific cross-shore transect and for one area-of-interest at the location of the central beach in-between the coastal structures. In Figure 7 the defined output locations are presented by the red lines within the overall model-domain of Westkapelle.

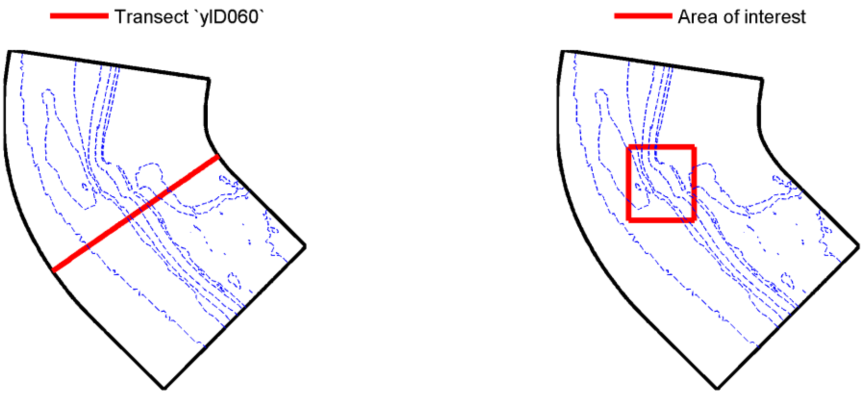

Figure 7 **Defined locations of the reference transect *ylD060* and the `area-of-interest` near the central beach in-between the coastal structures, near Westkapelle.**

Analysis of cross-shore profiles

Before starting a detailed volume-balance analysis, first the morphological development of an individual cross-shore transect is considered for comparison of the different models. The coastal stretch around this transect is located south of the central beach and is protected by a dune foot protection. Just in front of the coastline a tidal channel is present. The channel has a typical depth of about 25 m, and the landward side of the channel is located at a distance of less than 200 m from the waterline.

Figure 8 presents the model results for transect *yID060*. It is clearly shown that the coastal structure prevents the dune face from eroding. Most of the bed level changes occur seaward of the construction. The results of the different model runs are very similar for this specific situation. DurosTA and XBeach 1D produce similar erosion-profiles, but the amount of erosion is somewhat larger for the first model and DurosTA also simulates, in contrast to XBeach, some erosion above the dune foot protection. The most substantial difference is found just landward of the tidal channel (at x = 1500 m), where deposited sediment is found for both 1D cases, while no deposition is simulated by the 2DH model. It turns out that alongshore processes cause a net downstream transport of eroded sediment in this area. In fact, the amount of erosion is similar in all cases, but a 1D approach ‘forces’ offshore-directed transport that results in deposition near the tidal channel, while alongshore processes in the 2DH model cause alongshore redistribution of the eroded sediment.

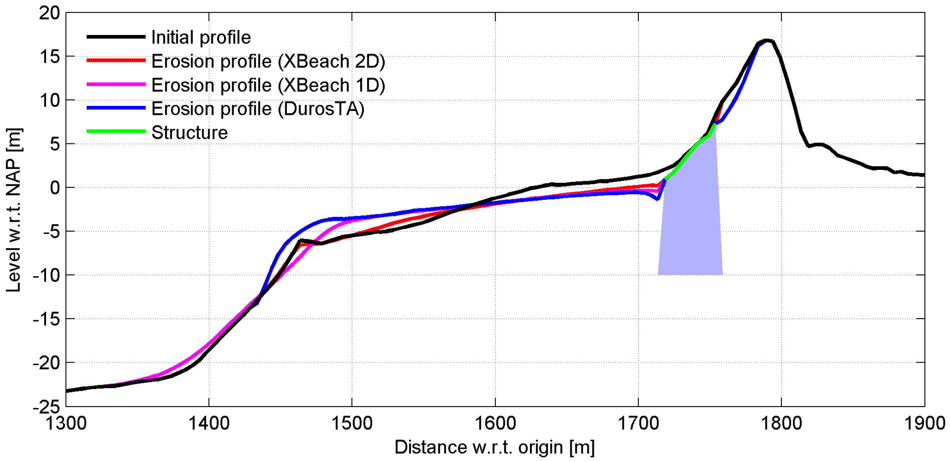

Figure 8 **Pre-storm and post-storm profiles for reference transect `*ylD060*`, for three different models (DurosTA, XBeach 1D, XBeach 2D).**

Analysis of spatial patterns of erosion and deposition

In order to study the effects of a 2DH approach on storm impact in more detail, spatial patterns of erosion and deposition are considered. For the 2DH model bed level differences are calculated for the pre-storm and post-storm situations, which results in a typical sedimentation-/erosion map. For the transect models an additional step is required in order to generate a spatial representation of the 1D model results. For each grid-cell of each individual transect, the bed level changes are determined and converted to world coordinates. From the obtained data a spatial representation is made, that is comparable to the 2DH model results. In Figure 9 the simulated bed level changes are presented for each of the considered models (both 1D and 2DH). In the figure, the initial bathymetry is added as contour lines, for spatial referencing. The reddish colours represent areas where the post-storm bed level is higher than the pre-storm bed level, thus: deposition areas. The bluish colours indicate the areas where erosion occurs.

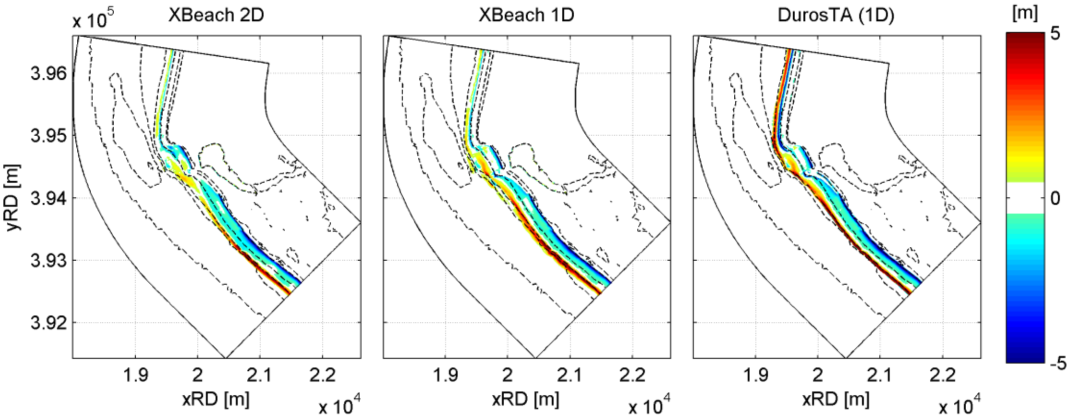

Figure 9 Bed level changes, as result of 30h of simulation with normative storm conditions and westerly waves. A comparison is made between XBeach 2D, XBeach 1D and DurosTA. Reddish colours indicate deposition areas and bluish colours are associated with erosion patterns.

From Figure 9 it is concluded that both similarities and differences are found between the three presented panels. Overall, the largest deposition areas are found for DurosTA, followed by XBeach 1D. Compared to XBeach 1D, DurosTA simulates larger scour holes in front of the sea-dike in the northern part of the model domain, which results in larger erosion- and deposition- volumes in that specific area. The overall results for the southern dune area are very similar for both 1D models. As shown in Figure 8 the models' behaviour for sandy dune profiles shows good agreement between DurosTA and XBeach.

When focussing on the differences between XBeach 1D and XBeach 2DH it is concluded that the overall erosion patterns are similar. However, the alongshore processes in the 2DH model result in differences in the location, and size of the deposition areas. As a first guess it is stated that a certain amount of sediment is removed from the model domain, during the normative storm period, and it is probably transported in south-easterly direction. The net loss of sediment is a consequence of the strong coastal curvature that causes flow divergence.

A more detailed view on the erosion- and deposition patterns is provided in Figure 10. In this figure the area-of-interest near the central beach (see right panel of Figure 7) is considered to assess the morphological effect of alongshore processes around the coastal structures. It can be seen that dune-erosion occurs in the dune area landward of the central beach. Moreover, the original beach profile is reshaped due to erosion processes.

The figure also confirms the previous statement that DurosTA predicts larger erosion (and deposition) in front of coastal structures. This yields for both the sea-dike and the headland-shaped structure south of the central beach. Apart from the absolute erosion volumes, the erosion- and deposition patterns are obviously similar for both 1D models, since eroded sediment is transport along individual transects by definition.

The effect of alongshore transport gradients is nicely shown when comparing the results of XBeach 2DH (left panel) and XBeach 1D (middle panel). In the northern part of the central beach, just south of the sea-dike, only erosion patterns are found and no deposition occurs. Due to the local geometry combined with westerly waves, a net south-eastward transport of sediment is generated that moves eroded sediment from the northern part of the central beach to the southern part of the beach and beyond.

The south-eastward directed sediment transport causes relative large erosion volumes in the upper part of the central beach, resulting in a larger retreat of the dunes. In contrast, the sediment supply from the northern part of the beach reduces the amount of erosion in the southern part. Moreover, a large part of the eroded sediment from the beach-area is transported further southward, bypassing the fortified 'headland' in the south. As a consequence, effectively no erosion volumes are found for the 2DH simulation in front of the dune foot protection (see lower-right corner of Figure 10).

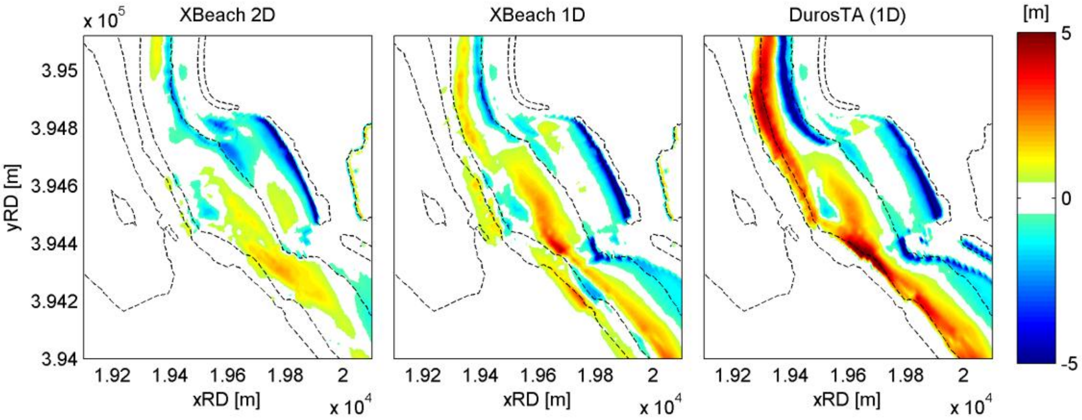

Figure 10 Bed level changes in *area-of-interest*, as result of 30h of simulation with normative storm conditions and westerly waves. A comparison is made between XBeach 2D, XBeach 1D and DurosTA. Reddish colours indicate deposition areas and bluish colours are associated with erosion patterns.

From Figure 9 it is concluded that the large-scale patterns of erosion and deposition are only slightly affected by alongshore processes during normative storm conditions. However, on a more local scale (Figure 10) non-uniformity of the near-shore bathymetry and geometry, and coastline curvature, alongshore sediment transport (-gradients) can affect on the amount of (dune-) erosion. In order to quantify the differences between the 1D and the 2DH model approach, a more detailed volume analysis is performed for the coastal area of Westkapelle.

Analysis of alongshore distribution of sediment volume-changes

In this study a method for sediment volume analysis is proposed to study the differences between the results of the 1D and 2D models, in a more quantitative way. The analysis focusses on the alongshore distribution of volume changes along individual transects. As such, for each cross-shore profile in the model domain (and thus also: each grid-row of the 2D model) the amount of erosion and the amount of deposition is determined. Based on the combined information for all transects, the alongshore variations of volume changes are studied (see *Van Thiel de Vries et al., 2010* for a comparable approach).

In Figure 11 three panels show the results of performed volume analysis. The horizontal axis of each panel represents the normalized position (of all cross-shore transects) along the coastline in the model domain. The left side of the graph corresponds to the southern extent of the domain and the right side represents the area in the north, near the sea-dike. Below the three panels of Figure 11 the contour-lines for NAP +0 m and NAP +10 m are drawn as spatial reference (*note*: these lines are plotted w.r.t. the normalized coastline). The dashed vertical lines in the panels indicate the extents of the central beach area. The `+` -shaped markers indicate the typical alongshore grid size, and thus the amount of data points in the graphs. The highest resolution is found in the central beach area.

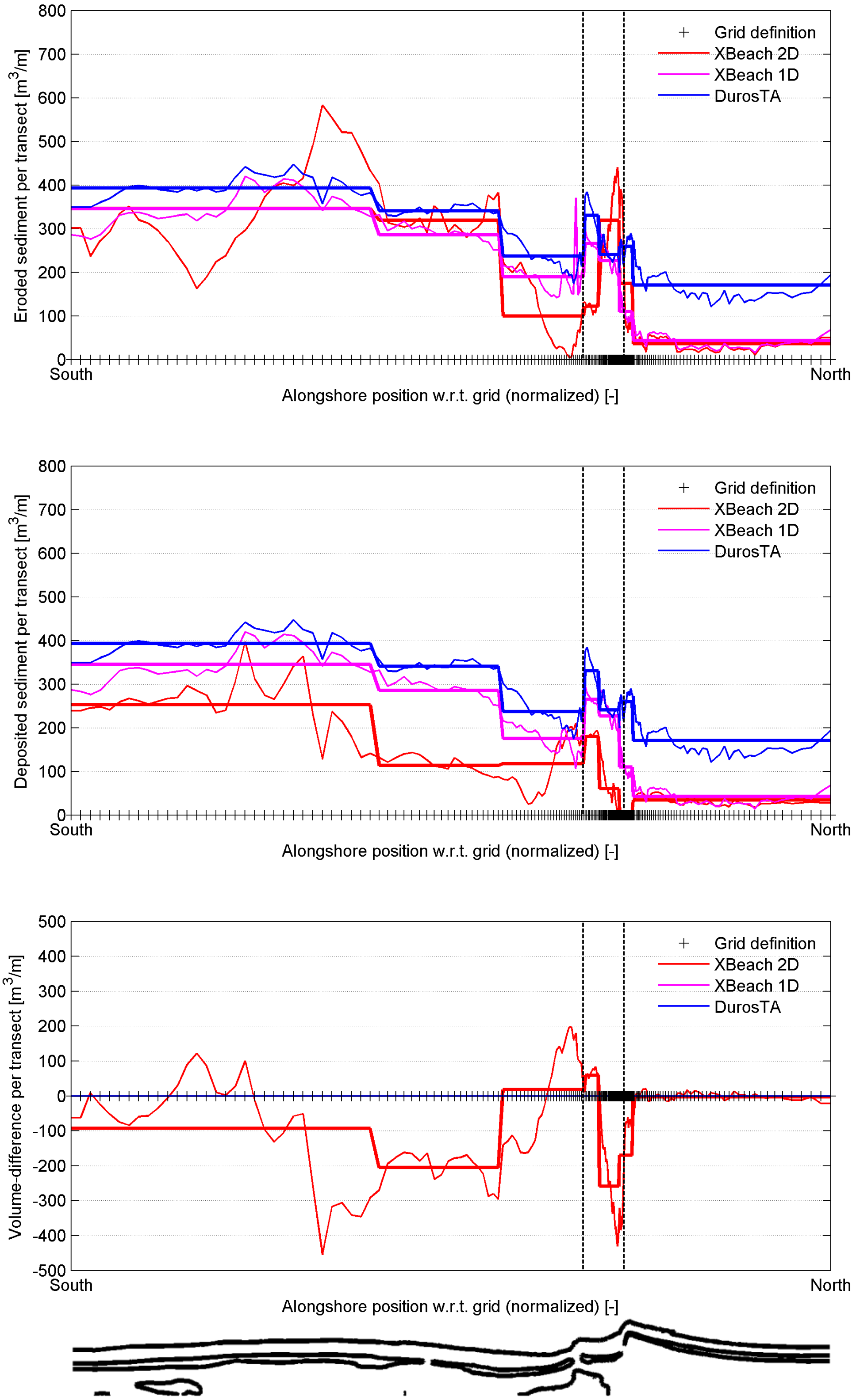

Figure 11 Results of volume-analyses. For a large series of transects along the coastline the total amount (per cross-shore profile) of eroded sediment (top panel), deposited sediment (middle panel) and net volume changes (bottom panel) are presented. The results are alongshore distributions of sediment volume changes, for simulations with normative conditions and westerly waves.

The upper panel of Figure 11 shows, for each model, the total amount of simulated erosion along the coastline near Westkapelle, per cross-shore transect (thin lines). The thick horizontal lines represent section-averaged values of the simulated erosion volumes. The middle panel of the figure presents the simulated amount of deposition per transect and the lower panel shows the net volume changes along the coastline for each cross-shore profile. By definition, the net volume differences (= deposition minus erosion) are zero for the 1D models, but alongshore processes in the 2DH model enable sediment redistribution along the coastline.

From the figure it is concluded that the alongshore variation of the estimated amount of erosion is more or less the same, for DurosTA and XBeach 1D: 350 – 400 m^3/m for the southern dune area. Overall, DurosTA predicts somewhat larger erosion volumes, but the results give good confidence in the behaviour of both models. The largest difference between both 1D models is found at the right side of the graph, where the sea-dike is present: 40 m^3/m for XBeach versus 180 m^3/m for DurosTA. These differences are caused by the fact that DurosTA simulates much larger scour holes at the toe of a structure. As a consequence of the 1D model approach presented (deposition) volumes in the middle panel are identical to the (erosion) volumes in the upper panel.

Comparing the 1D results with the results of the 2DH XBeach model, some interesting differences are found. The upper panel in Figure 11 shows that alongshore processes play an important role in simulating (dune) erosion along this coastal stretch. In particular for areas with an alongshore non-uniform bathymetry significant volume-differences are found along the coastline. Within the considered model domain two locations are identified where alongshore effects are clearly visible. First, a clear southward shift of sediment is simulated in the area around the central beach. Especially the northern part of the beach area lost a substantial amount of sediment, which contributes to downstream locations, even beyond the coastal structure south of the beach. A second, less expected, location where the effects of alongshore sediment transport gradients are obviously visible is a small coastal stretch in the center of the considered dune area. Due to coastline curvature, flow divergence is generated that results in a net loss of sediment in that area.

It is also noted that in Figure 11 the effects of gradients in the alongshore transport rate are visible; for the (southern) dune area. On average, negative volume-differences are found in a large part of the dune area, which means that varying transport rates are present. When a zero-gradient alongshore transport is considered, the amount of inflow and outflow in an area remains constant and thus independent of the transport rate. In this case flow divergence causes alongshore differences in transport rate thus resulting in a net volume loss.

A summary of the above presented results of the volume-change analysis is presented in Figure 12. This figure shows the combination of total eroded sediment volume, total deposited sediment volume and net volume changes, along the coastline of Westkapelle. Again, the vertical dashed lines in the graph and the black contour lines below the figure are presented for reference purposes. The central beach area is, for example, located at about 2/3 of the horizontal axis.

Figure 12 shows the same information as the three panels of the previous figure (except for the section-averages), but provides a quick overview of all relevant information. The figure suggests that the net volume losses in the southern part of the model domain (left in figure), are mainly caused by the reduced amount of deposited sediment, since the erosion volumes are quite similar for the 1D and 2D results. However, the peaks in erosion volumes do influence the distribution of net volume changes on a local scale. In other words, the *large-scale* sediment losses at the foreshore that are simulated with the 2D model are related to reduced deposition volumes, but the most significant *local* sediment losses in the 2D results are mainly caused by enhanced erosion(-rates) relative to the 1D results, due to combined cross-shore and alongshore processes. Two clear examples of this are found in the central part of southern dune area, and the northern part of the central beach area.

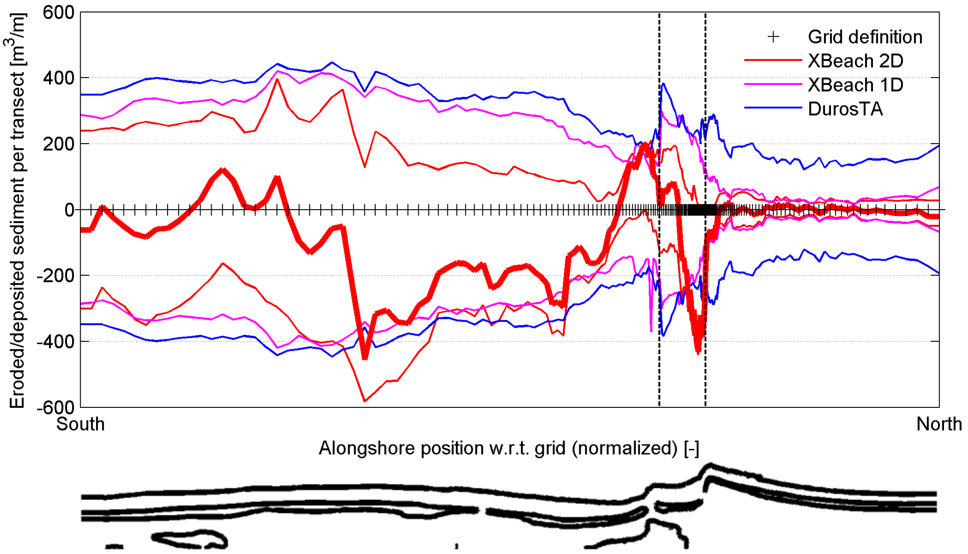

Figure 12 Combined results of volume analyses. For each model the total amount of deposition and erosion is presented per transect (thin lines). The net volume change (per transect) for the 2D XBeach model is shown as the thick red line. Note that, by definition, yields that erosion = deposition for 1D models.

One of the two locations where a significant effect of 2D storm-impact modelling is found is the central beach area in-between the coastal structures in the area. In Figure 13 a detail is presented of the data in Figure 12. The dashed vertical lines in both graphs represent the same part of the coastline, the left dashed line indicates the southern extent of the beach (near the fortified 'headland') and the dashed line on the right side indicates the northern extent of the beach, and thus the southern tip of the sea-dike. From this figure is it clear that two-dimensional effects do play an important role in redistributing sediment during normative storm conditions. At the northern part a net sediment loss is simulates that is compensated further southward, near the fortified headland. But, even more interesting is that the absence of deposited sediment in the northern part results in *extra* erosion. While DurosTA and XBeach 1D predict erosion volumes of about 200 m^3/m, XBeach 2D predicts up to 400 m^3/m. In the southern part of the beach these numbers are reversed: less erosion for XBeach 2D due to the relatively large sediment supply from upstream.

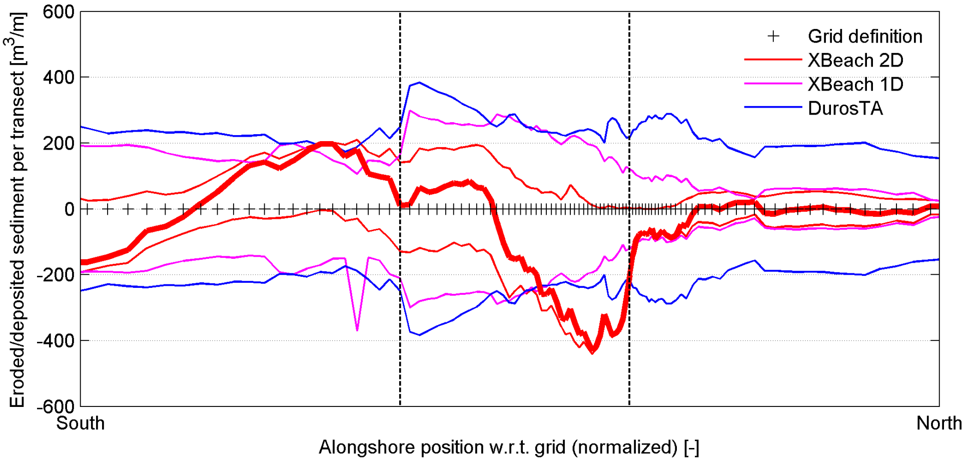

Figure 13 Combined results of volume analyses, for area-of-interest: `central beach area`. For each model the total amount of deposition and erosion is presented per transect (thin lines). The net volume change (per transect) for the 2D XBeach model is shown as the thick red line.

CONCLUSIONS

The main objective of this paper is to demonstrate the possibilities of 2DH storm impact modelling for complex coastal areas. A test-location near Westkapelle is selected that is characterized by rather complex features for dune erosion modelling, such as a deep near-shore tidal channel, dike/dune transitions, a strongly curved coastline, and alongshore varying bathymetry. In this specific location a regular 1D modelling approach for storm impact is considered to be doubtful due to the limited capability to include alongshore variation in processes that can affect the cross-shore storm profile evolution. Therefore a 2DH XBeach model is set-up for the coastal area near Westkapelle. This model setup is used to simulate the effects of normative storm impact, and a westerly wave attack.

In order to interpret the results of the 2DH XBeach model, a large number of 1D dune erosion models is set-up as well. Both XBeach (1D) models and DurosTA models are considered. The 1D models are built for each cross-shore gridline in the 2DH model domain, such that a series of subsequent transects (in alongshore direction) covers the entire model domain. The comparison of the results of the 1D and the 2DH approach is based on simulations with normative storm conditions and westerly waves.

Based on the results of the storm-impact simulations several analyses are performed in order to compare the different models. First individual cross-shore profiles are studied, then spatial patterns of erosion and deposition are considered and finally a more detailed analysis of the alongshore distribution of erosion volume, deposition volume and net volume change is performed. The most important conclusions are:

1. The results of the 1D and 2DH model simulations are very similar when considering the larger-scale erosion-patterns and the typical erosion- and deposition- volumes, for parts of the domain with more or less uniform near-shore bathymetry.
2. On smaller scales and in areas with a complex geometry, substantial effects of alongshore processes are found: i.e. local peaks in the simulated amount of dune-erosion due to local geometry and net sediment losses due to flow divergence.

This demonstration-case showed that the storm impact model XBeach is a good alternative for the more regularly used model DurosTA when considering complex coastal areas for safety assessments. Using a 2DH model approach provides additional insight in the hydrodynamics and morphodynamics during severe storm conditions, compared to the regular 1D approach. At this moment it is suggested to use XBeach in combination with a regular model, like DurosTA, for the assessment of (complex) coastal areas. The main reason for suggesting a *combined* application is that the formal regulations for assessing (Dutch) coastlines are not intended to be used with 2DH models. In addition, guidelines should be developed that focus on a proper translation from process-based model results to robust safety indicators; regarding the handling of uncertainties in the process of assessing dune areas. This also holds for the use of process-based *1D* models, like DurosTA.

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