netherlands centre for coastal research

Book of Abstracts

NCK Days 2021

March 25-26

Organized by:

NIOZ

UNIVERSITY OF TWENTE.

Preface

Welcome to the NCK Days 2021!

The NCK Days 2020 regrettably had to be cancelled a week before they would have taken place, but we are pleased to announce the program of the NCK days 2021, which will be an online event.

There is no substitute for meeting colleagues face-to-face, but still we will try to mimic real life by online random social encounters during the program!

The oral presentations are organized in parallel sessions. In addition, there are two plenary talks. Ana Colina Alonso (TUD/Deltares) will present an overview from a recent synthesis of the mud budget of the trilateral Wadden Sea. By way of virtual excursion, Sander Holthuijsen (NIOZ) will guide us on a tour through the SIBES project, the benthic sampling of the inter- and subtidal areas of the Dutch Wadden Sea, the fieldwork and the analysis.

Below you will find the abstracts, listed in alphabetical order of the first authors' names.

We wish you inspiring and enjoyable NCK Days 2021!

The organizing committee,

Theo Gerkema (NIOZ), Pieter Roos (University of Twente) and Julia Vroom (NCK/Deltares)

Program NCK days 2021

Thursday 25 March

12:45-13:00 digital walk-in

13:00-13:10 welcome, opening, remarks

13:10-14:05 parallel sessions 1A/1B/1C

14:05-14:40 social session

14:40-15:00 plenary talk:
Ana Colina Alonso (TUD/Deltares): Towards a Mud Budget for the Trilateral Wadden Sea Area

15:00-15:55 parallel sessions 2A/2B/2C

15:55-16:00 closure

Friday 26 March

12:45-13:00 digital walk-in

13:00-13:10 welcome, opening, remarks

13:10-14:05 parallel sessions 3A/3B/3C

14:05-14:40 social session

14:40-15:00 plenary talk:
Sander Holthuijsen (NIOZ): SIBES and Wadden Mosaic; No place to hide

15:00-15:45 parallel sessions 4A/4B/4C

15:45-15:50 closure

Parallel sessions on Thursday 25 March

SESSION 1A	SESSION 1B	SESSION 1C
Henk Schuttelaars (TUD):	Unze van Buuren (VU):	Marije Smit (W+B):
Morphodynamic Equilibria and Linear Stability in Tidal Estuaries: Influence of Coriolis and Planform Geometry	Spatio-temporal variability of suspended sand input in a coastal dune system, the Kennemerduinen (the Netherlands)	The impact of climate change scenarios on Belgian coastal policy
Wessel van der Sande (UT):	Christa van IJzendoorn (TUD):	Abdi Mehvar (UT):
Dune migration in estuaries: the effect of the gravitational circulation	Dune toe elevation increase outpaces sea level rise	A practical framework of quantifying climate change-driven environmental losses (QuantiCEL) in coastal areas
J. van Belzen (NIOZ)	Job Oude Vrielink (UT):	Joep van der Zanden (MARIN):
Double dykes and transitional polders as ecosystem-based solution in the Dutch southwestern delta	The rise of Spanjaards Duin: factors regulating sediment fluxes over an engineered foredune and adjacent dune slack	Design optimization of a multifunctional floating breakwater
Jill Hanssen (TUD):	Geert Campmans (UT):	Otto Ongkosongo (NWRC):
Most suitable creek locations	Modelling grain sorting processes in aeolian sediment transport: the grain scale	The Deformation of the former unique enchanting Citarum delta, Indonesia in the last four decades

SESSION 2A	SESSION 2B	SESSION 2C
Wouter Kranenburg (Deltares):	Greg Fivash (NIOZ):	Jorn Bosma (UU):
Salt intrusion in the Rhine Meuse Delta: Estuarine Circulation or Tidal Dispersion?	Flattening of accreting tidal flats will accelerate terrestrialization of estuaries, due to a positive feedback between channel formation and vegetation establishment	Mixed-sand behaviour of a back-barrier beach nourishment
Bouke Biemond (UU):	Muriel Brückner (UU):	Stuart Pearson (TUD):
Response of salt intrusion to spring-neap tides and other time-varying forcing	Benthic species as mud patrol - modelled effects of bioturbators and biofilms on large-scale estuarine mud and morphology	Characterizing the Suspended Sand and Mud Composition on Ameland Ebb-Tidal Delta using Combined Optical and Acoustic Measurements
Rutger Siemes (UT):	Jaco de Smit (NIOZ):	Anna-Maartje de Boer (WUR):
Modelling the role of estuarine wetland development on salt-intrusion	Quantifying the resilience of seagrass to climate change: combining in situ wave erosion experiments with data driven modelling	Reading where sand goes by how it glows: Development of luminescence sediment tracing methods
Gijs Hendrickx (TUD):	Jasper Leuven (RHDHV):	Jakob Wallinga (WUR):
Nature-based solutions to mitigate salt intrusion	Enhanced mud sedimentation to reduce turbidity and grow with sea-level rise	Introducing the TRAILS project: Tracking Ameland Inlet Living lab Sediment

Parallel sessions on Friday 26 March

SESSION 3A	SESSION 3B	SESSION 3C
Tosca Kettler (TUD): Simulating long-term cross-shore dynamics under various nourishment types at the Dutch coast	Oscar Franken (RUG): Wadden Mosaic: Understanding the ecological functioning of the subtidal Wadden Sea	Dirk Rijnsdorp (TUD): Free infragravity waves in the North Sea
Mostafa Saleh (IHE): Simple one-line and free-form coastline evolution models' forecasting ability enhancement using sequential data assimilation (Ensemble Kalman Filter)	Carmine Donatelli (NIOZ): The Dutch Wadden Sea as an event-driven system: statistical detection of spatio-temporal patterns in the salinity field and variability of the transport time scales	Joost Kranenborg (UT): Large-scale laboratory measurements of the pore pressure response to bichromatic waves in the swash zone
Anne Ton (TUD): Field observations of longshore transport on low-energy, non-tidal beaches	Bart Grasmeijer (Deltares): Effect of dredging scenarios on silt concentrations in the Wadden Sea near Holwerd	Vera van Bergeijk (UT): Wave overtopping forces at transitions on the crest and the landward slope
Bart Roest (KU Leuven): Estimating alongshore sand transport based on bathymetric survey data in dredged access channels	Ana Colina Alonso (TUD): The contribution of sand and mud to infilling of the Western Wadden Sea	Luuk Barendse (UT): Hydrodynamic modelling of wave overtopping over a block-covered dike

SESSION 4A	SESSION 4B	SESSION 4C
Chiu Cheng (NIOZ): Sediment shell-content diminishes current-driven sand ripple development and migration	Rik Gijsman (UT): Biophysical responses of mangroves to variations in hydrodynamic forcing: developing a sub-grid model approach	Weiqiu Chen (UT): Modelling of overtopping flow parameters at the seaward side of the dike crest
Abdel Nnafie (UU): Long-term morphodynamics of a coupled shelf-nearshore system forced by waves and tides, a model approach	Sebrian M. Beselly (IHE): Mud Volcano Induced Seasonal Mangrove-Mudflat Dynamics	Daan Poppema (UT): How the spacing and orientation of buildings shape local sandy deposition patterns
Janneke Krabbendam (UU): Modelling the observed evolution of tidal sand waves in the North Sea	Heike Markus-Michalczyk (NIOZ): Woody willow´s bending capacity reduces flow velocity during winter with possible implications for shoreline management and sediment control	Paran Pourteimouri (UT): How erosion and deposition patterns around a row of holiday cottages at the beach can be influenced by wind direction: A numerical study

Hydrodynamic modelling of wave overtopping over a block-covered dike

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Introduction

Physical wave flume tests have been done at the Delta flume of Deltares to determine the flow velocities u [m/s] and pressures P [kPa] on the landward slope of the dike. The crest and landside slope have been covered with Grassblocks, blocks developed by Hillblock that are installed between the clay and grass cover of the dike to reduce further erosion when the grass cover has eroded. The blocks have a permeable function which reduces the flow velocity and pressures along the landward slope. The stability of the blocks needs to be determined in expensive flume tests where not all hydraulic parameters can be measured and only limited wave conditions and configurations can be tested. The goal of this study is to develop a hydrodynamic model for overtopping flow over porous blocks and to calculate the forces on these blocks.

Methods

The setup as used in the physical test has been implemented in OpenFOAM, a computational fluid dynamics software package. Using the solver porousWaveFoam which is included in the waves2Foam toolbox, a porous layer on the crest and landside slope has been implemented which represents the permeable function of the Grassblocks. The resistance force F_p of this porous layer depends on the resistance coefficients α [-] and β [-]. Then the model has been run using different combinations for α and β based on research by Van Gent (1995) [α=200, β=0.8], Jensen et al. (2014) [α=500, β=2.0] and Losada et al. (2008) [α=1000, β=1.1].

Results

The modelled peak values are compared with the measured peak values for both u and P. Fig. 1 shows the flow velocity, where the resistance coefficients of Losada et al. performed best with NSE = 0.68, followed up by Jensen et al. (NSE = 0.65) and Van Gent (NSE = 0.05). The calibrated model can then be used to determine the forces that occurred on the blocks during the physical test.

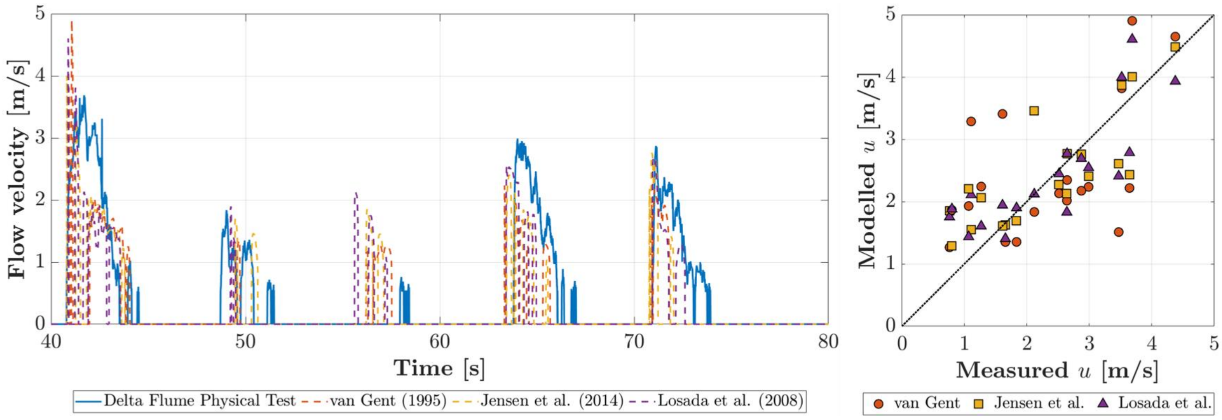

Figure 1: Measured and modelled peak values of flow velocity along the landside slope.

Acknowledgements

This research was funded by the Netherlands Organisation for Scientific Research (NWO), research programme All-Risk with project number P15-21.

References

Jensen, B., Jacobsen, N.G., & Christensen, E.D. (2014). Investigations on the porous media equations and resistance coefficients for coastal structures. Coastal Engineering, 84, 56–72.
Losada, I.J., Lara, J.L., & del Jesus, M. (2016). Modeling the interaction of water waves with porous coastal structures. Journal of Waterway, Port, Coastal and Ocean Engineering, 142(6).
Van Gent, M. R. A. (1995). Wave interaction with permeable coastal structures. Delft University Press.

Double dykes and transitional polders as ecosystem-based solution in the Dutch southwestern delta

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Introduction

Climate warming and sea level rise force us to rethink our water safety approach. The strategy we applied over the last centuries of building ever higher and wider dykes has it limits and does not resolve problems arising in the long run related to subsidence and salinization. We explored implementing double dykes with transitional polder in the Dutch southwestern delta as an Ecosystem-based alternative and link land-level rise modelling to costs/benefits-analyses and economic effects.

Method and results

By switching to double dykes for coastal defence, the water safety functions normally provided by a single dyke are redistributed between two dykes. First, an existing polder dyke landward from the seaward dyke is upgraded to serve as primary defence. Next, a tidal inlet is made in the seaward wave-breaking dyke so that the polder can be flooded by tides and can silt up. As the stability of the primary defence dyke improve over time due to the land-level rise in the transitional polder, the dykes do not need to be raised and strengthened as much in response to sea level rise as conventional dykes, saving construction and maintenance costs. The transitional polder can furthermore generate revenue when it is used for aquaculture, cultivation of saline crops or for recreation/tourism (nature development). Finally, when the ground is at the target level, the inlet can be closed, and the transitional polder put back into agricultural use.

Double dykes turn out to be much cheaper than conventional dykes and are competitive with overtopping-resistant dykes. However, transitional polders provide a myriad of functions and services which give them additional benefits and economic effects making them currently the most interesting option. Timely implementation is however greatly beneficial for its success, because sea-level rise and subsidence will downplay delivery of functions and benefits.

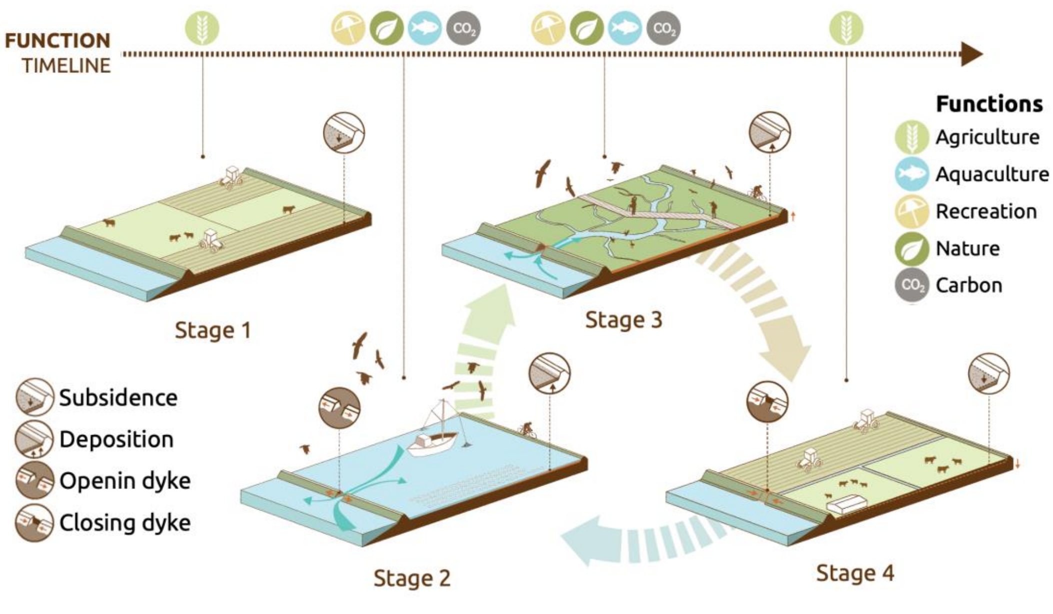

Figure: Concept of double dykes and functions of the transitional polder over time. Illustration by Defacto.

Wave overtopping forces at transitions on the crest and the landward slope

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Introduction

Wave overtopping on grass-covered dikes results in high hydraulic loads on the dike cover which may lead to erosion of the dike cover. Transitions in cover type and in geometry are vulnerable locations for dike cover erosion. Changes in bed roughness can create additional turbulence and geometric transitions can lead to impact of the waves. The effect of transitions on the forces of the overtopping wave are unknown, since these forces are hard to measure during this highly turbulent flow and measurement equipment damages the grass cover and thereby affects the flow. We developed a hydrodynamic model to calculate the forces of the overtopping waves and investigate the effects of transitions on these forces.

Methods

A 2DV model for the overtopping flow over the crest and landward slope is developed in the open-source software OpenFOAM (Van Bergeijk et al., 2020). The model requires the flow velocity and layer thickness as boundary conditions, which can be generated from the overtopping volume. The model output includes the flow velocity, pressure, shear stress and normal stress as function of time, cross-dike location and height. The dike geometry is varied to simulate various geometric transitions and the roughness height in the turbulence model is adapted to simulate changes in cover type.

Results

The model results show that changes in roughness have no significant effect on the pressure, shear and normal stress. The flow velocity increases from a rough to a smooth cover which is well presented by the friction coefficient in analytical models (Van Bergeijk et al., 2019). Geometric transitions, such as the transition from the crest to the landward slope and the toe, lead to a high peak in the modelled pressure. The dike geometry has a large affect on the overtopping forces, where both the maximum shear stress and maximum pressure along the slope increase with increasing slope steepness (Figure). Additional model simulations are currently performed in order to study why the pressure increases at geometric transitions and to study other geometric transitions such as erosion holes or vertical cliffs.

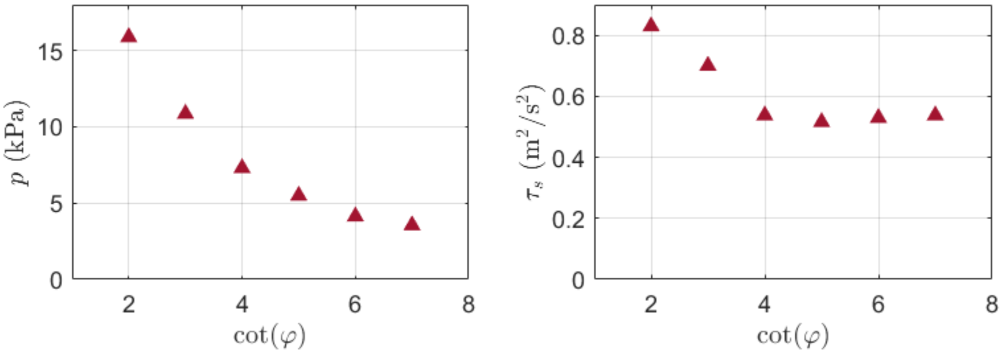

Figure: The maximum pressure p and the maximum shear stress τ_s as function of the slope steepness cot(φ) for an overtopping volume of 4000 l/m.

Acknowledgements

This research was funded by the Netherlands Organisation for Scientific Research (NWO), research programme All-Risk with project number P15-21.

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Van Bergeijk, V.M., Warmink, J.J. & Hulscher, S.J.M.H. (2020). Modelling the Wave Overtopping Flow over the Crest and the Landward Slope of Grass-Covered Flood Defences. *Journal of Marine Science and Engineering*. 8, 489

Van Bergeijk, V. M., Warmink, J. J., van Gent, M. R. A., & Hulscher, S. J. M. H. (2019). An analytical model of wave overtopping flow velocities on dike crests and landward slopes. *Coastal Engineering*, 149, 28-38

Mud Volcano Induced Seasonal Mangrove-Mudflat Dynamics

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Introduction

The Porong Delta in Indonesia has been experiencing a rapidly prograding delta along with mangrove expansion in 15 years. It was triggered by an extreme mud volcanic eruption called LUSI. This eruption was at a peak rate of up to 180,000 m^3/day in 2006 and declined to 50,000m^3 in September 2011. LUSI is still actively erupting at a considerably reduced rate. The diversion operation has been conducted since 2009 by storing and conveying the mudflow to the Porong River. This operation has increased sediment concentration and loads of the Porong River by a factor of three to four compared to pre-LUSI conditions. As a result, we observed the build-up of the delta lobes and the mangrove expansion. The Porong area has a tropical monsoon climate characterised by the wet and dry season. We observed the seasonal river discharge fluctuation that correlates with the seasonal pattern of mangrove expansion. The objective of this study is to analyse the seasonal mangrove dynamics in the cloud computing Google Earth Engine (GEE) by creating three-monthly mangrove and age class maps.

Methods

The random forest supervised classification in GEE was used to classify the mangroves. Our maps are more frequent than commonly produced annual mangrove maps. Based on these validated time series of mangrove extent maps, we further estimated the age of the forest and developed the age class map. The age class map was referenced to November 2019 and derived backward to 2009. Additionally, by taking advantage of the high-resolution Canopy Height Model (CHM) from previous study and this age map, a relationship of mangrove height dependent on stand age was setup.

Results

Our analysis shows a unique and high spatiotemporal resolution of mangrove extent maps. We observe a recession of the mangrove extent during the transition of dry to wet season and regrowth during the wet and dry season. Generally, the net development trend of the mangrove area is positive. We can see that the high-low signal amplitude differs in the period of 2013-2017 from that in 2018-2019. It is likely in the beginning, mangroves start growing on the newly deposited mud. Due to the presence of mangroves, sediment is deposited at the margin of the forest, thus creating the basin mangrove type in a certain area. Since the young mangroves are more sensitive to salt and drought, they might die under that condition. Therefore, we observe the seasonal pattern of recession and expansion of the mangrove forest.

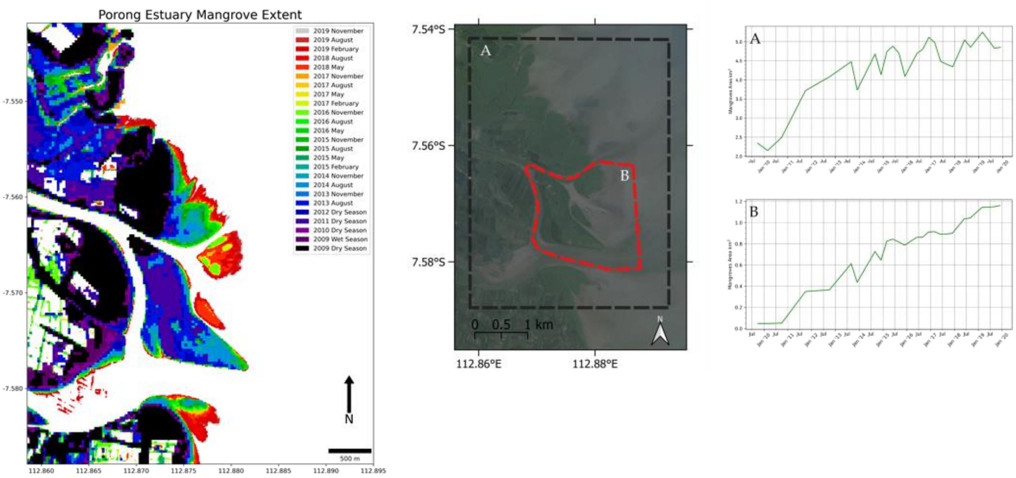

Figure: Porong Estuary mangrove extent from 2009-2019 (left figure) and time series of mangrove extent area development (right figure).

Response of salt intrusion to spring-neap tides and other time-varying forcing

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Introduction

Understanding and predicting salt intrusion in estuaries and deltas is an important scientific challenge, as trends and fluctuations in salt intrusion will have implications for fresh water intake, agriculture, etc. To gain fundamental knowledge about salt dynamics idealised models are being used, such as that of MacCready (2007), MC07. However, problems arise when these models are applied to situations with a high freshwater Froude number. In this study, an extended version of the MC07 model is used to study the response of salt to time-dependent forcing (spring-neap cycle, fresh water discharge and storm surges).

Methods

The model computes the subtidal currents and salinity in an estuary. The momentum balance is solved in the same (analytical) manner as in MC07, but the salt balance is solved with a Galerkin approach in space and a Cranck-Nicholson scheme in time. The Thames estuary is used as a prototype estuary to compare model output to observations. Specifically, assessment will be made of adjustment time scales, as well as the response of salt intrusion to the spring-neap cycle, time-variable fresh water discharge and to storm surges.

Results

Adjustment time scales, response characteristics and salinity patterns in an estuary will be presented for a larger part in parameter space than what can be captured by the MacCready (2007) model. Moreover, an analysis of the response times to various time-varying forcing agents will be presented.

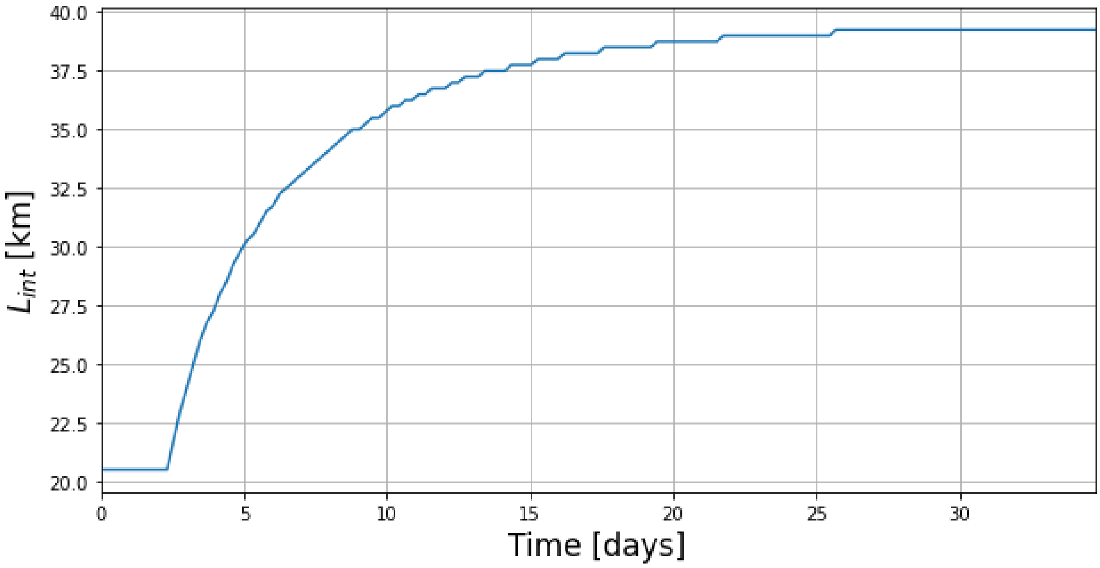

Figure: Example of the response of the salt intrusion length L_{int} to a sudden decrease in river discharge calculated by this model. For this setting, the MC07 model yields negative salinities in part of the domain.

References

MacCready, Parker. "Estuarine adjustment." Journal of Physical Oceanography 37.8 (2007): 2133-2145.

Reading where sand goes by how it glows: Development of luminescence sediment tracing methods

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Introduction

The ability to trace the movement of sediment in nature is key to predicting geomorphic change associated with a vast and diverse range of fluvial, coastal, and anthropogenic processes. In the Netherlands, a new coastal mega-nourishment project aims to maintain a portion of the North Sea coastline through sand deposition at the Ameland inlet ebb-tidal delta. How this nourishment sand will disperse and its geomorphic and ecologic impacts are not well known and will be assessed within our NWO funded TRAILS project. Luminescence, that is, the ability of sediment grains to store energy as trapped charge and release that charge as light upon (sun)light or heat exposure, presents a novel and largely undeveloped means of sediment tracing. While luminescence techniques are conventionally used for dating the burial age of sediments, luminescence itself may be an ideal sediment tracer because it is environmentally friendly, highly sensitive and strongly bound to sand grains, and does not interfere with sediment transport. Here, we develop the degree of charge evacuation ("bleaching") of luminescence signals as a means to trace coastal sediment dispersal. This will be applied to differentiate two populations of grains, nourished (figure: green symbol) and native (figure: yellow symbol).

Methods

A variety of luminescence signals can be obtained using different minerals and stimulation protocols, such as the infrared stimulated luminescence (IRSL) signal of feldspar grains. Focusing on a single feldspar grain, multiple signals can be extracted by repeated infrared stimulation at increasing temperatures, known as post-infrared IRSL (pIRIR). The higher temperature pIRIR signals are less light sensitive and therefore bleach more slowly than the IRSL and low-temperature pIRIR signals. We develop and apply a multiple elevated temperature (MET) measurement protocol to extract slow- (figure: turtle symbol) and fast-to-bleach (figure: hare symbol) signals from feldspar grains on a single-grain level.

Preliminary results

We offer a conceptual framework and will share preliminary results for how slow- and fast-to-bleach signals can be paired to reveal both provenance (deep time) and transport history (modern time) of sand grains, i.e. luminescence sediment fingerprinting. Our future work will vet and apply this framework to track sand of the Ameland inlet ebb-tidal delta nourishment. Broadly, our work will contribute to improved coastal engineering strategies and methodological advancements of the science of luminescence.

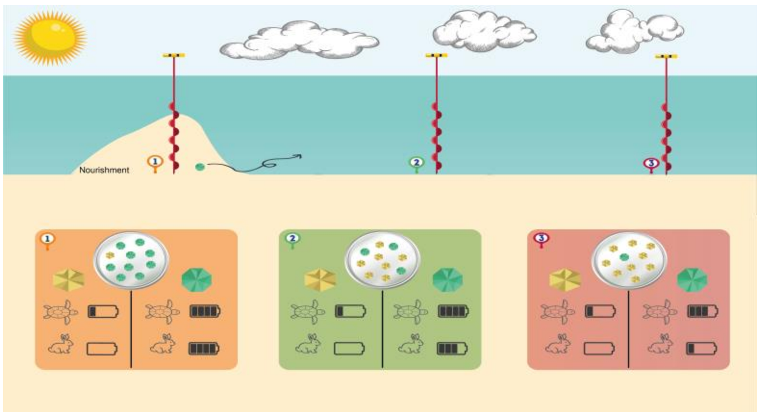

Figure: Conceptual overview of our study's principal. The augers indicate three sampling locations. The petri discs show native (yellow) and nourished (green) grains. The turtle indicates slow-to-bleach signals, whereas the hare indicates fast-to-bleach signals. The battery is an analogue for the degree of signal bleaching.

Mixed-sand behaviour of a back-barrier beach nourishment

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Introduction

Over the past decade or so, the traditional way of building hard engineering structures for the purpose of coastal protection has increasingly made way for both more adaptive and multi-purpose soft-solution alternatives [1]. A very recent example of this is the Prins Hendrikzanddijk (PHZD) at the island of Texel (Fig. 1). In 2006, the former asphalt-covered seawall was found to no longer meet the requirements for primary flood defences as set out in the Dutch Water Act [2]. A 5-Mm^3 beach nourishment was placed in front of the seawall for its reinforcement. Located in the lee of a barrier island. the PHZD nourishment is sheltered from most high waves, though tide/wave-driven currents in the area can be strong [3]. In addition to its complex spit-lagoon morphology, part of the PHZD beach was topped off with a protective wear layer consisting of relatively coarse and shell-rich sand, thus creating a valuable opportunity to closely study mixed-sand transport processes in a mixed-energy setting and evaluate the implemented design. This research therefore aims to unravel how the different sand fractions disperse as the PHZD evolves and to determine the processes involved.

Methods

As part of a four-year doctoral research, the dispersal and sorting behaviour of the mixed-sand fractions are monitored through ~3-monthly sampling of the intertidal beach and surf zone. Together with high-resolution records of the area's topo/bathymetry, these data will provide insights into the morphologic and sedimentologic behaviour of the nourishment. The first results show that, despite the low-energetic wave climate, the PHZD beach is already very much in motion: the initially created slopes are flattening out while the head of the spit is rapidly building out in the direction of the flood current (NE). Patterns of visibly distinct sediment fractions thereby occupy the surface. Second, cross- and longshore arrays of a variety of instruments will be deployed at the morphologically active parts of the beach for several prolonged periods to measure the local hydrodynamics and coinciding suspended-sediment and bed-load transport rates. Sophisticated instrumentation additionally allows to differentiate between the different size fractions in suspension. Finally, the acquired data and insights will be used to develop and extensively test an improved forecasting tool that will aid coastal engineers and policy makers worldwide in finding the best retrofit design for similar mixed-energy environments.

Figure 1: Bird's-eye view of the Prins Hendrikzanddijk nourishment at the island of Texel as seen from the east in November 2020. Source: Jan De Nul NV.

Acknowledgements

This work is part of the NWO-funded project named EURECCA (Effective Upgrades and REtrofits for Coastal Climate Adaptation), grant no. 18035.

References

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M. C. Buijsman and H. Ridderinkhof, "Long-term ferry-ADCP observations of tidal currents in the Marsdiep inlet," *J. Sea Res.*, vol. 57, no. 4, pp. 237–256, 2007, doi: 10.1016/j.seares.2006.11.004.

Benthic species as mud patrol - modelled effects of bioturbators and biofilms on large-scale estuarine mud and morphology

Muriel Z.M. Brückner[1*], Christian Schwarz[2], Giovanni Coco[3], Anne W. Baar[4], Márcio Boechat Albernaz[1], and Maarten G. Kleinhans[1]

Introduction

Benthic species that live within estuarine sediments stabilize or destabilize local mud deposits through their eco-engineering activities, affecting the erosion of intertidal sediments. Possibly, the altered magnitudes in eroded sediment affect the large-scale redistribution of fines and hence morphological change.

Methods

To quantify this biological control on the morphological development of estuaries, we numerically model i) biofilms, ii) two contrasting bioturbating species present in NW-Europe, and iii) their combinations by means of our novel eco-morphodynamic model. The model predicts local mud erodibility based on species pattern, which dynamically evolves from the hydrodynamics, soil mud content, competition and grazing, and is fed back into the hydromorphodynamic computations.

Results & conclusions

We find that biofilms reduce mud erosion on intertidal floodplains and stabilize estuarine morphology, whereas the two bioturbators significantly enhance inter- and supratidal mud erosion and bed elevation change, leading to a large-scale reduction in deposited mud and a widening of the estuary (Fig. 1). In turn, the species-dependent changes in mud content redefines their habitat and leads to a redistribution of species abundances. Here, the eco-engineering affects habitat conditions and species abundance while species interactions determine species dominance. Our results show that species-specific biostabilization and bioturbation determine large-scale morphological change through mud redistribution, and at the same time affect species distribution. This suggests that benthic species have subtly changed estuarine morphology through space and time and that aggravating habitat degradation might lead to large effects on the morphology of future estuaries.

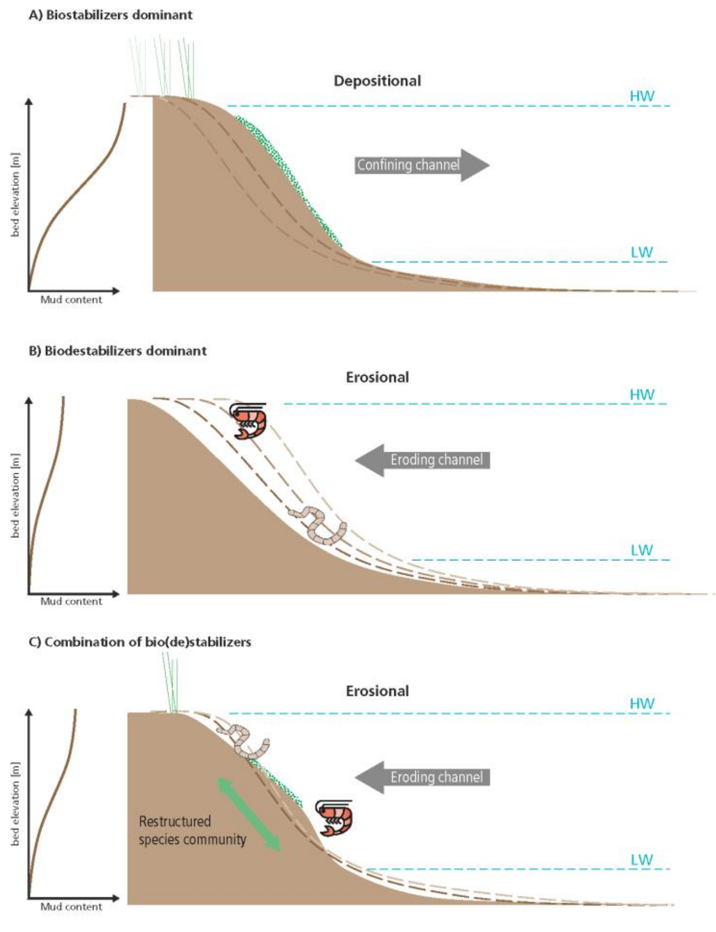

Fig. 1: Conceptual channel adaptation and mud content in an estuary dominated by biostabilization (A), biodestabilization (B), and a combination of biostabilization and -destabilization (C).

Spatio-temporal variability of suspended sand input in a coastal dune system, the Kennemerduinen (the Netherlands)

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Introduction

In the National Park Zuid Kennemerland, near the town of IJmuiden, five notches have been excavated in the foredune ridge to reactivate and promote aeolian transport of $CaCO_3$-rich beach sand towards the inland dune system. This project is executed to rehabilitate the rare (Natura2000 protected) coastal dune biodiversity and increase coastal safety (Arens et al., 2015). In recent research of Van Hateren et al. (2020) it was concluded that it is possible to differentiate between transport processes (bedload vs. suspended load) based on combined grain size and shape data in aeolian sediments. Since the start of the rehabilitation project (2013-present) sand transported in suspension has been trapped and collected every two weeks in sandtraps custom made by Arens Bureau for Beach and Dune Research. In this research we investigate the spatial and temporal changes in sediment flux and composition (grain size-shape distributions, carbonate content) of the aeolian suspension load trapped during one of those years (2017), which is part of the ongoing PhD research project of Unze van Buuren.

Materials and Methods

The sandtraps (n=15) are distributed in four coast-parallel north-south transects (A to D, ~1 km in a N-S and ~1.2 km in an E-W direction). Samples are analysed by dynamic image analysis (n=204), which provides grain size and shape distribution data, and thermo gravimetric analysis (n=128) which determines the carbonate content. The grain shape parameter used here is the aspect ratio, defined as the ratio of the minimal to the maximal Feret diameter of a grain.

Results and conclusions

The sand flux recorded in the sand traps show large spatial (down-wind), temporal (inter-annual) changes. For instance, trap A1, located on the foredune, has an annual flux of 1573 gr, while C1, ~700 m downwind of the fore dune, has an annual flux of 16 gr.
The grain size and shape distributions show the existence of two subpopulations: a coarse population with a modal size of ~350 µm, with a relatively low aspect ratio, and a fine population with a mode at ~210 µm, with a relatively high aspect ratio. Down-wind changes in composition are reflected by a reduction of the proportional contribution of the coarse population (size sorting: down-wind fining) and a decrease of the aspect ratio of especially the coarse population (shape sorting: down-wind increase of proportion of platy/elongated grains).
The carbonate content has an average of 7.5 wt% varying on a spatial and temporal scale. Beach sediments (source) and dune sediments in the shallow subsurface underneath the traps show a significantly lower carbonate content.
To fully understand the (positive) effects of a reactivated dune system and considering the fact that shell fragments are predominately platy particles, our results clearly illustrate the importance of understanding aeolian suspension load transport and sorting processes.


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Modelling grain sorting processes in aeolian sediment transport: the grain scale

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Introduction

Sediment in coastal dunes are often finer sediment grains than those observed at the beach. Because the sand from the beach is blown to the dunes, there must be sorting processes going on. However, most sediment transport models quantify sediment transport using a single grain size. The goal of this research is to gain insight in the sorting process of aeolian sediment transport by modelling sediment transport at the grain scale.

Methods

To model aeolian sediment transport at the grain level both the grains as well as the airflow needs to be described, similar to e.g. Durán et al. (2012). For the sediment dynamics the Discrete Element Method is used, which models every grains trajectory by the equations of motion. The airflow is modelled using a boundary layer model. Sediment grains experience accelerations through collisions with each other, by gravitational acceleration and by fluid drag forces. Similarly the drag forces accelerating the sediment grains causes the airflow to decelerate. To model the sorting processes in aeolian sediment transport the sediment grains in the bed have grain sizes following prescribed size distributions. By keeping the median grain size (D50) constant in the model simulations and varying the sediment distributions the sorting effect in various sediment compositions is investigated.

Results

The Figure shows a snapshot of particles in transport. Early results confirm that the median sediment grain, D50, indeed quantifies total sediment transport rates accurately for the sediment distributions tested. However, the grain sizes that contribute to the transport rates are generally the smaller grains.

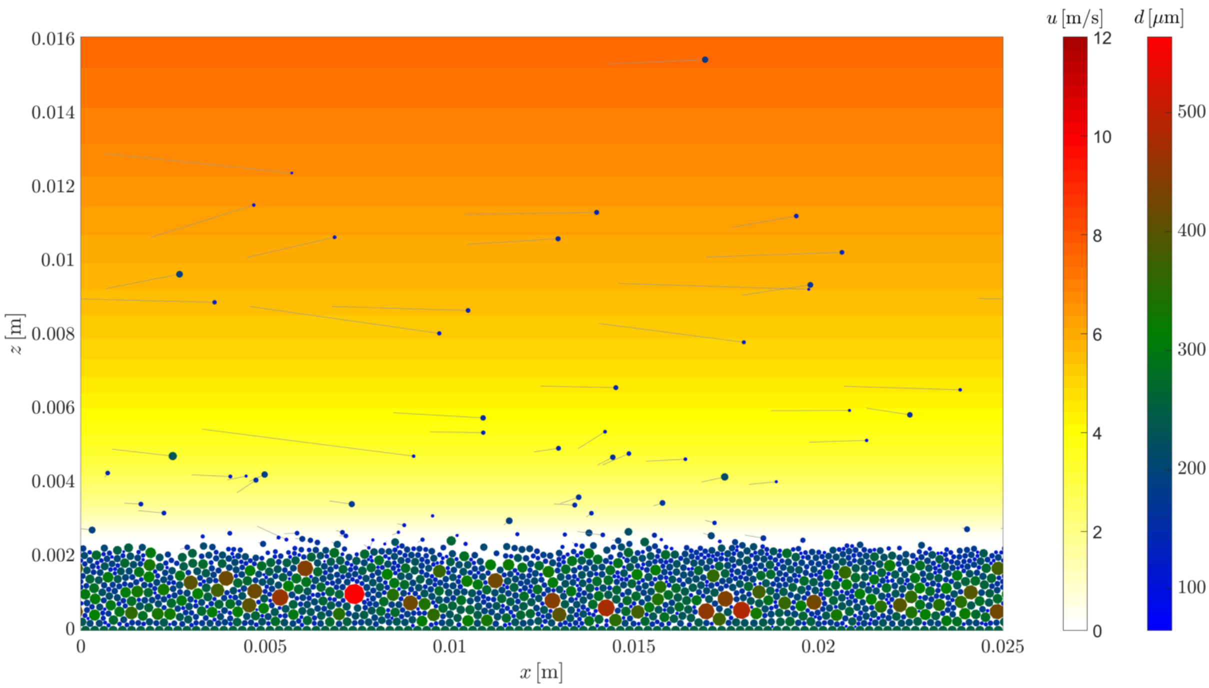

Figure: A snapshot of sand grains in wind-driven saltation transport. The background colour shows the horizontal wind speed u *in the boundary layer. The grains are coloured by their diameter* d*. The trailing tails indicate the velocity and direction of particle trajectories.*

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Modelling of overtopping flow parameters at the seaward side of the dike crest

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Introduction

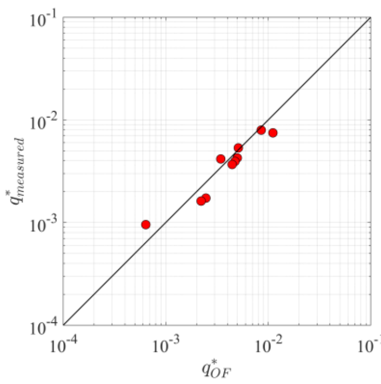
The overtopping flow on the crest and landward slope can cause erosion at the landward side of dikes, which can finally lead to dike breaching. Extreme flow velocities, layer thickness and volumes, which have a low probability of exceedance during a storm event, are usually used to characterize the wave overtopping flow. Some empirical equations are available to estimate the flow velocity and layer thickness. However, these empirical equations were derived based on experiments where only limited wave conditions and dike configurations were tested. It remains unclear if these empirical equations are applicable for cases that are outside of the tested ranges. Numerical modelling has become an important complementary tool to experiments. The objectives of our study are to set up a numerical model using OpenFOAM® that is capable of accurately predicting the overtopping flow parameters and to investigate the effects of berms and roughness on flow parameters.

Methods

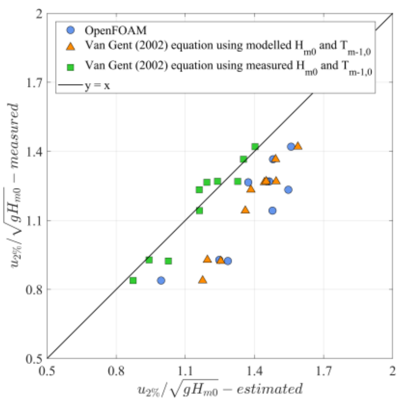
The waves2Foam toolbox was applied to generate irregular waves and the solver waveIsoFoam which is included in the waves2Foam was used to solve the model. The OpenFOAM model was validated by comparing the modelled overtopping discharges, flow velocities and layer thickness with the measured results from Van Gent (2002).

Results

Figure 1(a) shows the comparison between the modelled dimensionless average overtopping discharges with the measured ones with a NSE of 0.84. Figure 1(b) shows that the flow velocity predicted by the OpenFOAM model is slightly larger than the measured flow velocity. This overestimation is caused by the overestimation of the wave period given by the OpenFOAM model. Overall, the numerical model is capable of predicting the overtopping flow parameters with a good accuracy. The validated OpenFOAM model will be applied to investigate the effects of berms and roughness at the waterside edge of the crest on the overtopping flow parameters.



(a)



(b)

Figure: Model validation with (a) Measured versus modelled dimensionless mean overtopping rate and (b) Measured flow velocities and estimated ones using analytical equations and the OpenFOAM model.

Acknowledgements

The first author thanks the China Scholarship Council for providing the research grant. This work is also part of the All-Risk research programme, with project number P15-21, which is partly financed by the Netherlands Organisation for Scientific Research (NWO).

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Sediment shell-content diminishes current-driven sand ripple development and migration

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Introduction

Shells and shell fragments are biogenic structures that are widespread throughout natural sandy shelf seas. Their presence can affect the bed roughness and erodibility of the seabed, especially given their lower bulk density and significantly different shapes and sizes as compared to the surrounding siliciclastic sediment particles. An important consequence is the effect on the formation and movement of small bedforms such as sand ripples. However, despite the prevalence of shells, their direct influence on the geomorphological dynamics of sandy sediments has not been well-studied.

Methods and results

We experimentally measured ripple formation and migration using a mixture of natural sand and increasing volumes of shell material under unidirectional flow in a racetrack flume. Two separate experiments were conducted to (1) measure the equilibrium ripple dimensions and migration rates over a constant flow velocity, and (2) determine the incipient sediment motion over gradually accelerating flow.

Our experiments reveal the impacts of shells on ripple development in sandy sediment, thus providing information that was previously lacking. Shells expedite the onset of sediment transport while simultaneously reducing ripple dimensions and slowing down their migration rates. Moreover, increasing shell content enhances near-bed flow velocity due to the reduction of bed friction that is partly caused by a decrease in average ripple size and occurrence. This, in essence, limits the rate and magnitude of bedload transport. Given the large influence of shell content on sediment dynamics on the one hand, and the high shell concentrations found naturally in the sediments of shallow seas on the other hand, a significant control from shells on the morphodynamics of sandy marine habitats is expected.

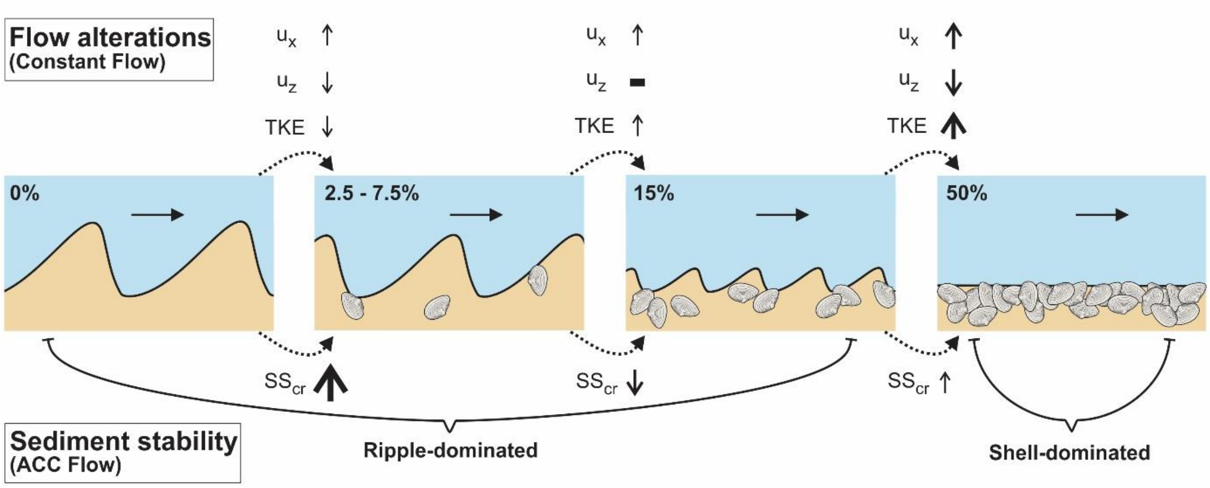

Figure: Conceptual figure showing how shells affect the hydrodynamic conditions, under flat and rippled-bed conditions. In the absence of ripples, shells effectively create roughness for the otherwise-flat bed. As the concentrations of shells increase and exceed a certain threshold, a density-dependent effect on near-bed flow attenuation can be observed, where the increasingly dense and immobile shell clusters exhibit a dampening behavior. TKE = turbulent kinetic energy; u_x = depth-averaged horizontal velocity; u_z = depth-averaged vertical velocity; SS_{cr} = critical shear stress.

Towards a Mud Budget for the Trilateral Wadden Sea Area

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The Wadden Sea is an extensive barrier-lagoon system covering Dutch, German, and Danish territory. Although being an important nature reserve, the area also provides important economic services. The area is strongly influenced by human interventions – especially by successive land claims in the past, and more recently, by facilitating economic development along the three main estuaries intersecting the tidal basins (the Elbe, Weser and Ems).

Recent estimates suggest that mud (<63 µm) deposits make up about 10-30% of the total volume of recent deposits in the Wadden Sea, thus playing a significant role in its sedimentary development. Fine sediments mainly deposit on intertidal mudflats fringing the coastline or tidal divides, providing among others important feeding habitat for migratory wading birds. Mud also deposits on the salt marshes, contributing to the important ecological services provided by these systems, and protecting the dikes and therefore the hinterland against flooding. It may significantly contribute to the basin's ability to keep up with Sea Level Rise (SLR), which implies that fine sediments may become an important commodity in the future, fuelling the need for a quantitative mud budget for the Wadden Sea.

This research presents the first attempt to establish a mud budget for the Trilateral Wadden Sea, providing detailed estimates for mud sinks, sources, and transport. It is based on a combination of existing literature, bathymetric charts, sediment composition maps, observed deposition rates, and dredging information. The total supply of mud to the Wadden Sea is estimated at 12.1-16.5×10^6 ton/yr. Mud is mainly deposited in areas where strong anthropogenic disturbances prevail, such as the Western part of the Dutch Wadden Sea (closure of the Zuiderzee), along the mainland, and in sheltered embayments. The total amount of mud depositing in the system (both naturally and through anthropogenic sediment extraction) is estimated at 10.8-11.3×10^6 ton/yr. This implies that currently the sediment supply is only 1.1-1.5 times larger than the net total sedimentation + extraction.

We show that mud is a crucial component in the morphodynamic behaviour and the sediment budget. On a large scale there is a constraint on the amount of mud that can be extracted from the system, especially considering the expected acceleration of SLR. Locally, enough mud may be available, but in time shortages may develop. Sustainable sediment management strategies including sediment extraction should account not only for the local impact, but also the large-scale, long-term implications.

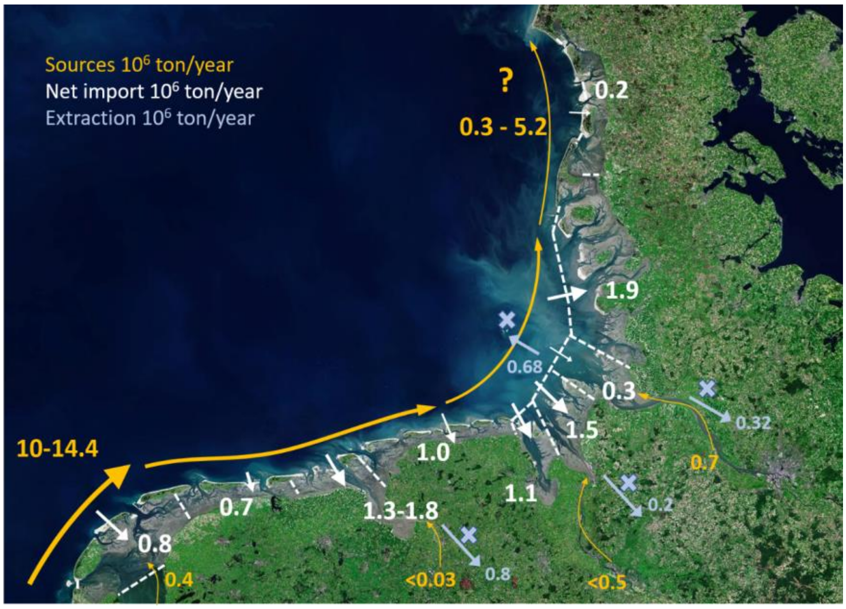

Figure 1: Conceptual figure of the mud budget for the Wadden Sea area (Oost, et al., 2021).

The contribution of sand and mud to infilling of the Western Wadden Sea

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Human interventions and climate change can severely influence the large-scale morphological development of tidal basins. This has implications on sediment management strategies, as well as on ecological and recreational purposes. Examples of heavily impacted tidal basins are those in the Western Dutch Wadden Sea: Closure of the *Zuiderzee* in 1932 still influences its morphodynamic development. Previous studies on the sediment budget did not differentiate between sand and mud fractions. However, understanding the contribution of both sediment types to the morphologic evolution is crucial for unravelling the processes responsible for the observed bathymetric changes.

This research presents a quantitative analysis of the post-closure sediment budgets, differentiating between sand and mud. Analysis of historical sediment composition data combined with bathymetry data revealed that the intervention caused a redistribution of sand and mud sedimentation. The responses of both sediment types differ spatially and temporally. The total infilling of the sandy basins over the last century was substantially caused by mud (~27 %, which is much larger than the average mud content in the bed). Initially, large mud volumes accreted in abandoned channels. At present, mud sedimentation along the mainland coast is still ongoing with nearly constant sedimentation rates over the past century, while the net import of sand significantly decreased over time and has been fluctuating around 0 over the last two decades.

SLR can be a major threat for the existence of the Wadden Sea with its current characteristics with extended tidal flats; these may drown if the sedimentation cannot to keep pace with SLR. We argue that for slow, gradual changes, both sand and mud sediments are likely to keep pace. For rapid changes — such as increased SLR rates — only the transport capacity of mud might be enough to compensate directly, as long as the sediment source remains sufficient. Consequently, mud contents in the basins would increase. The supply of mud is more than sufficient to keep pace with the current SLR rates.

This research shows the importance of distinguishing between the response of sandy and muddy sediments when analysing the morphodynamic impact of an intervention. We advocate collection of detailed sediment distribution data in the vicinity of large-scale past or future interventions, and use of this data in combination with available historic topographic data to understand the responses to and implications of interventions.

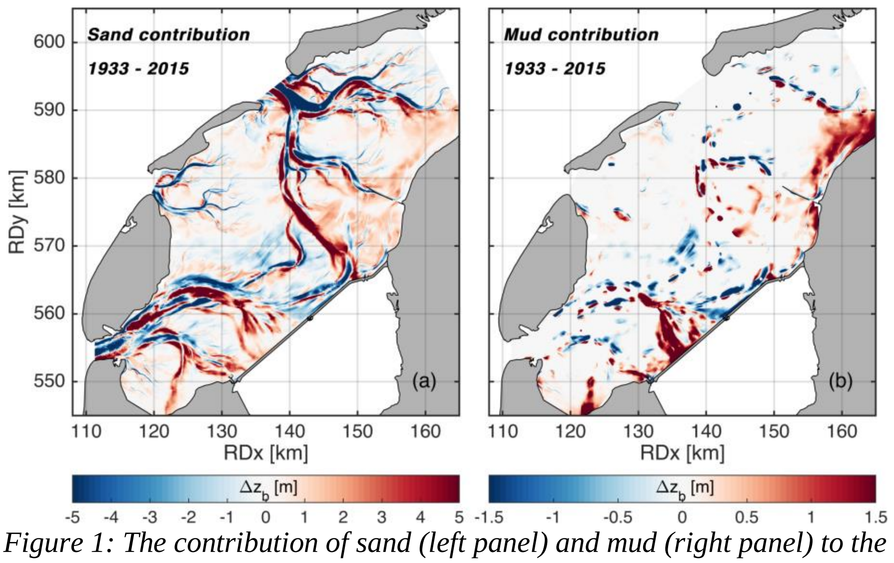

Figure 1: The contribution of sand (left panel) and mud (right panel) to the bed level changes of 1933-2015 inside the basins of the Western Dutch Wadden Sea (Colina Alonso, et al. (submitted)).

The Dutch Wadden Sea as an event-driven system: statistical detection of spatio-temporal patterns in the salinity field and variability of the transport time scales

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Two major agents in the movements of water and sediment in the Dutch Wadden Sea (DWS) are the tides and the wind. While the former is highly predictable, the latter is episodic in nature; the wind climate varies even strongly from year to year, and was previously shown to have a disproportionately large effect on the dynamics of the DWS. In the recently started LOCO-EX project, we use a 35-year long numerical simulation to study the hydrodynamics of the DWS from the perspective of an event-driven system. In this presentation, we first focus on salinity variability. In particular, we employ advanced statistical methods to detect events characterized by extreme salinity values since these episodes dramatically increase stress levels on organisms living in intertidal areas. In the second part of this talk, we analyze the system from a Lagrangian point of view to study the spatio-temporal variability of the transport time scales under different wind conditions. We focus especially on the residence time, in order to examine Lagrangian retention and episodes of strong flushing events between the DWS and its surroundings.

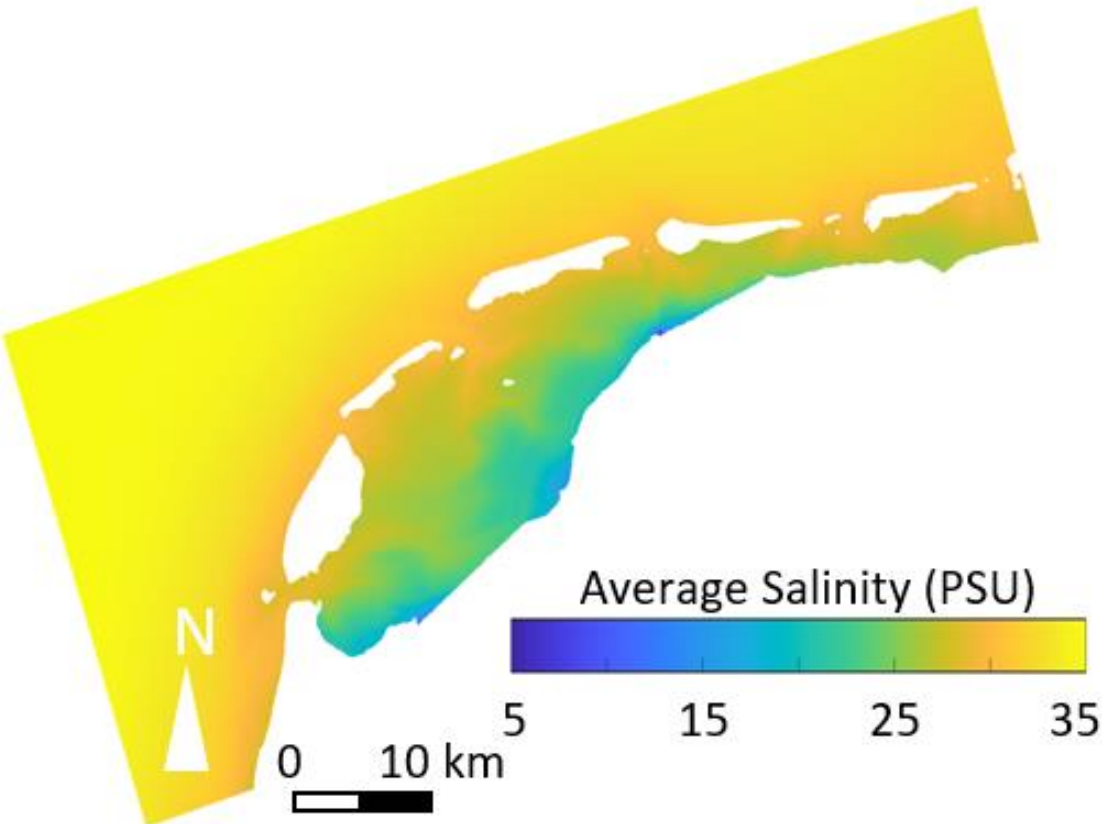

Figure: Long-term mean salinity distribution in the Dutch Wadden Sea.

Flattening of accreting tidal flats will accelerate terrestrialization of estuaries, due to a positive feedback between channel formation and vegetation establishment

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Introduction

Worldwide, estuaries have been intensively utilized as shipping-lanes to service the global supply chain. To maintain their function in service of port cities, major structural changes are taking place in estuaries that will ultimately impact in their ecological character. The rising and flattening of estuarine morphology, driven by human usage, has been forecasted to drive the evolution of tidal ecosystems toward widening vegetated zones encroaching upon an ever-narrowing band of tidal flats. This future scenario has significant consequences for protected species that rely on intertidal mudflats for food and habitat. In one heavily navigated estuary, the Western Scheldt (servicing the port of Antwerp), vegetation is not only expanding over the rising mudflat shelves, but is also occurring more frequently at lower elevations every year. This is indicative of the presence of additional feedback processes that aid the establishment of vegetation in previously inhospitable areas. In this study, we demonstrate how biogeomorphic feedbacks between vegetation and tidal drainage patterns are responsible for this accelerating terrestrialization process.

Methods

This is done through GIS analysis of semi-annual bathymetry and false color data of the Dutch Western Scheldt between 2004 and 2020.

Results

The appearance of small-scale drainage patterns on high intertidal flats commonly precedes the invasion of salt marsh vegetation via seedling-establishment. Here we demonstrate how the formation of these small-scale drainage patterns is becoming more likely as high intertidal mudflats progressively flatten into plateaus. Vegetation establishment is more likely to occur at low elevation in these well-drained patterned landscapes. The establishment of pioneer vegetation then leads to drainage pattern intensification and propagation, expanding the region hospitable to further establishment. This feedback process effectively allows the vegetation to step-stone deeper down the tidal gradient once initial establishment has occurred. Together, this suggests that whilst the raising of estuarine tidal flats in navigated estuaries increases linearly in time, the expansion of the vegetated areas in these environments will occur in the coming decades in sudden self-reinforcing events, as the threshold requirements in bathymetric elevation and slope for biological succession are suddenly met, and the vegetation-drainage feedback loop is set in motion.

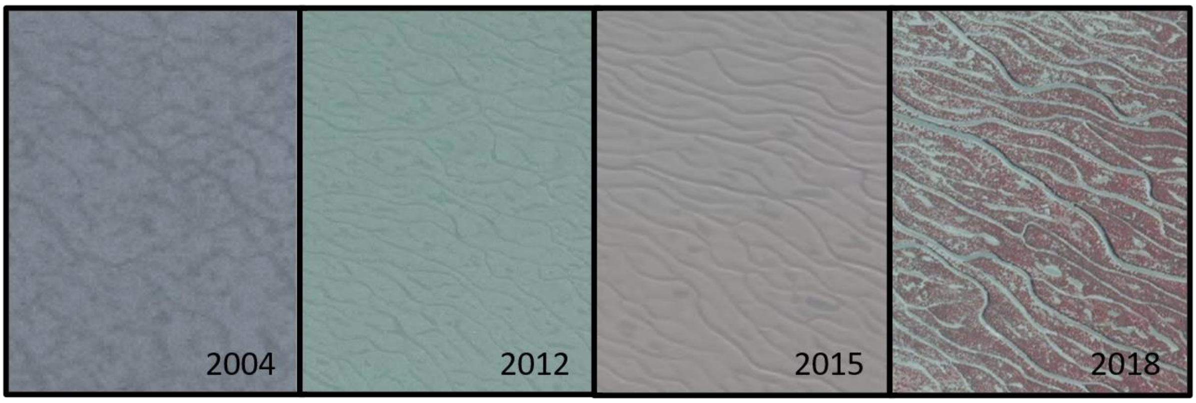

Figure: Mudflat channelization followed by vegetation expansion (in red, 2018) on Hoogeplaat in the Western Scheldt. Source: False color images, Rijkswaterstaat.

Wadden Mosaic: Understanding the ecological functioning of the subtidal Wadden Sea

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The Wadden Sea is of great ecological importance and supports many species of birds and fish. These species depend on a plethora of benthic invertebrate species living in and on the sediment. While the intertidal mudflats are relatively well studied, the biodiversity and food web structure of the subtidal Wadden Sea is relatively unknown. Yet, information on this subtidal component of the Wadden Sea is essential if we want to understand changes that occur due to climate change, natural and human disturbances. The Wadden Mosaic project aims to shed light on this hidden part of the Wadden Sea. We will map biodiversity and link the benthic communities to habitat characteristics. In addition, we will test the feasibility and effects of possible management actions: i) (re-)introducing hard substrates, ii) facilitating epibenthic shellfish beds, iii) explore restoration possibilities for subtidal seagrass meadows and iv) test the effectiveness of excluding human activities from designated marine protected areas. Here, we will present the first results from a large sampling campaign in which samples were taken throughout the Dutch Wadden Sea with a grid resolution of 1 km, resulting in data from 1394 samples. From each sample we analyzed sediment characteristics; identified, counted and weighted the benthic species; and for the dominant species the stable isotope ratios were analyzed to reconstruct the subtidal food web. Overall, the results from the project will improve our understanding of the ecological functioning of the subtidal Wadden Sea, and predict the effectiveness of management practices aimed at sustaining or increasing biodiversity.

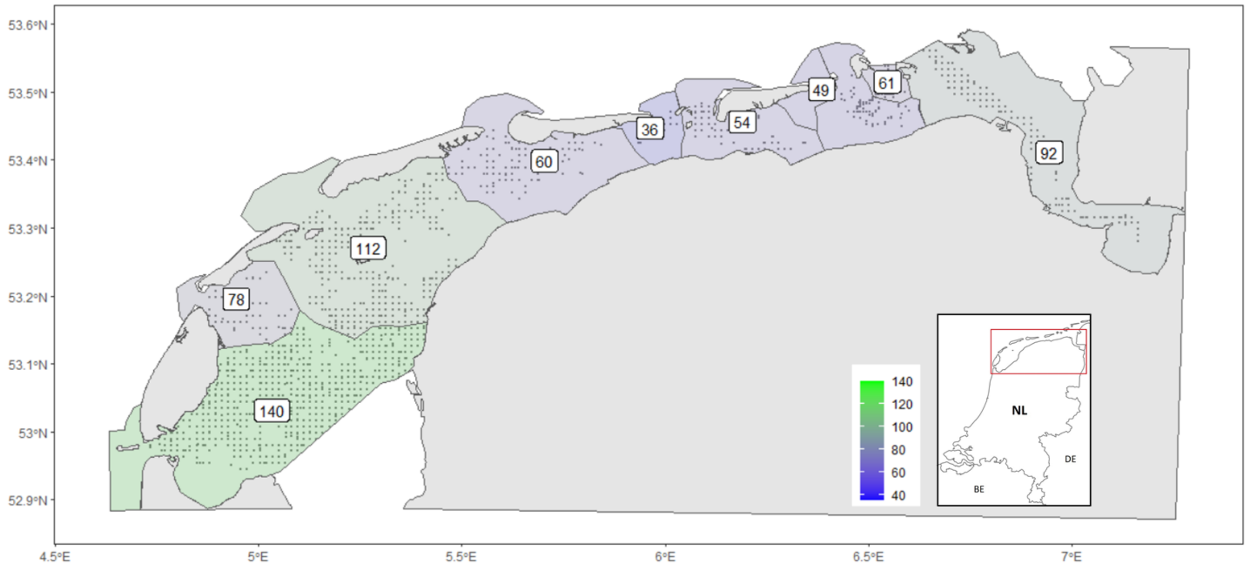

Figure: Observed species richness per tidal basin (numbers) and visualization of all sampling locations (grey dots) in the subtidal Dutch Wadden Sea.

Biophysical responses of mangroves to variations in hydrodynamic forcing: developing a sub-grid model approach

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Introduction

Mangrove forests can grow in the intertidal area of sheltered (sub)tropical shorelines. They can attenuate wave energy and stabilise shorelines, but they can also regenerate after storm impacts and adapt to changes in environmental conditions. These resilient and adaptive capacities of mangroves make them promising nature-based solutions for flood risk reduction in a changing climate. However, mangroves are also vulnerable ecosystems and (the persistence of) their flood risk reducing capacities may vary largely when environmental impacts or changes exceed their natural resilience. As a result, the implementation of mangroves as a solution for flood risk reduction requires a comprehensive understanding of how mangroves will respond to variations in environmental stressors such as hydrodynamic forcing. To date, process-based models to assess and predict biophysical responses of mangroves to hydrodynamic forcing are lacking. This study considers the development of a new numerical modelling approach to simulate hydro- and morphodynamic processes as well as biophysical interactions in mangroves.

Methods

The study combines the hydro- and morphodynamic model Delft3D Flexible Mesh (DFM) and an individual-based Mangrove Forest Development (MFD) model (Figure 1). The DFM model simulates the propagation of water levels and waves as well as resulting morphodynamics on a spatial grid. Simultaneously, the MFD model considers the establishment, growth and mortality of individual mangrove seedlings and trees on a sub-grid scale. The approach includes the interactions between the trees, hydrodynamics and morphodynamics through an online coupling between DFM and the MFD, while the development of the mangrove forest is based on tree-to-tree interactions.

Results and Outlook

The first results of the coupled DFM-MFD model provide insights in cross-shore mangrove forest dynamics along an elevation gradient, in response to varying inundation periods (Figure 1). Different stressors to mangrove development are currently being incorporated in the model. Future work aims at model calibration and validation through field measurements and remote-sensing observations to monitor seedling establishment and forest development, respectively. Eventually, this model will provide a useful tool to explore the response of mangroves to variations in hydrodynamic forcing on short (e.g. storms), medium (e.g. seasonality) and long timescales (e.g. sea level rise).

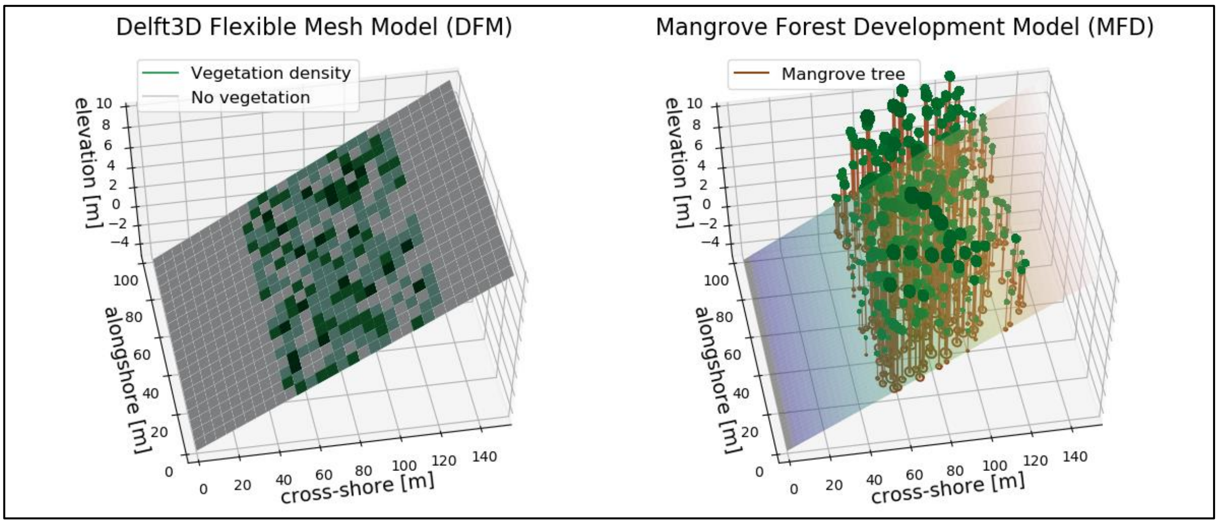

Figure 1: Mangrove vegetation represented in grid-based DFM model (left panel) and individual-based MFD model (right panel)

Effect of dredging scenarios on silt concentrations in the Wadden Sea near Holwerd

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Introduction

For optimal policy and management of the Wadden Sea, a numerical model is being developed that reproduces the characteristic properties of the mud dynamics in the system. The model has recently been applied to investigate the effect of different dredge disposal scenarios on silt concentrations in the Wadden Sea near Holwerd, which is the starting point of a ferry connection between the main land and the Ameland Wadden Island. The Holwerd-Ameland ferry connection has been in the public eye for years, because of the frequent delays of ferries and the sharp increase in maintenance dredging and high silt concentrations in the navigation channel (Figure 1).

Methods

First, the numerical model was calibrated such that it accurately reproduces measured concentrations of suspended particle matter (SPM) at twelve permanent measurement stations in the Dutch Wadden Sea. In a second calibration phase, model parameters were locally adjusted to reproduce observed sediment dynamics and siltation rates near the ferry terminal of Holwerd. The effects of dredging and disposal are quantified by comparing multiple model simulations, in which the dredging and disposal are switched on and off. In the current disposal strategy, part of the dredged sediment is released locally, and part is being brought to disposal sites. Model simulations with different disposal strategies reveal opportunities to optimize the dredge-disposal strategy.

Results

Model results suggest a negative feedback between dredging in the navigation channel and silt concentrations near Holwerd, because dredging reduces the availability of sediment for resuspension. On the other hand, the current disposal strategy leads to increased silt concentrations near Holwerd. Also, disposal increases the dredging volumes, since part of the disposed sediment redeposits in the navigation channel within several tidal periods.

Figure 1: Aerial photo of the southern part of the Holwerd-Ameland ferry connection near Holwerd, with brown coloured water indicating high turbidity in the navigation channel.

Most suitable creek locations

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Introduction

Worldwide, we observe creeks intersecting bare tidal flats at different latitudes and longitudes. Contrary, many tidal flats do not have such creeks. Simultaneously, there are bare flats with and without creeks in the same estuary. In this contribution, we study where and why creeks evolve on bare tidal flats.

Methods

We applied a spatial analysis and a numerical modelling approach to determine where and why creeks occur. Bare tidal flats are considered, bounded by a tidal channel and a dike or marsh edge. We sorted and selected (based on predefined criteria) areas with and without creeks based on high resolution historical aerial pictures of the Western Scheldt (WS) Estuary and Ems-Dollard (ED) Estuary. For each selected flat, creek locations were defined. We obtained multiple cross sections of each flat based from detailed LiDAR data sets of the estuaries. Each profile was fit to a mathematical formula that includes the shape parameters of the flat and related these characteristics to the occurrence of creeks.
Subsequently, flow velocities and bed shear stresses were calculated for varying flat shapes, using a 1D hydrodynamic model. The obtained results were related to the presence of creeks for different flat shapes.

Results

The tidal flats can be schematized by: a steep lower flat and mild upper flat, in between there is a curved transition zone. The analysed data set reveals that creeks occur at the transition zone between upper and lower flat. The flats with tidal creeks have a sharp transition between upper and lower slope (small transition zone).
From the 1D model follows: large flow velocities are found for mild upper slopes and locations around mean sea level.
Substituting the bed shear stress in an erosion formulation reveals that the tide-integrated erosion rate is highest at the transition zone. Hence, the highest probability for erosion and creek formation. Obtained results coincide with measurements from the field.

We conclude that creeks are found at the transition zone between the upper and lower flat on convex profiles because the flow velocities and erosion potential are highest.

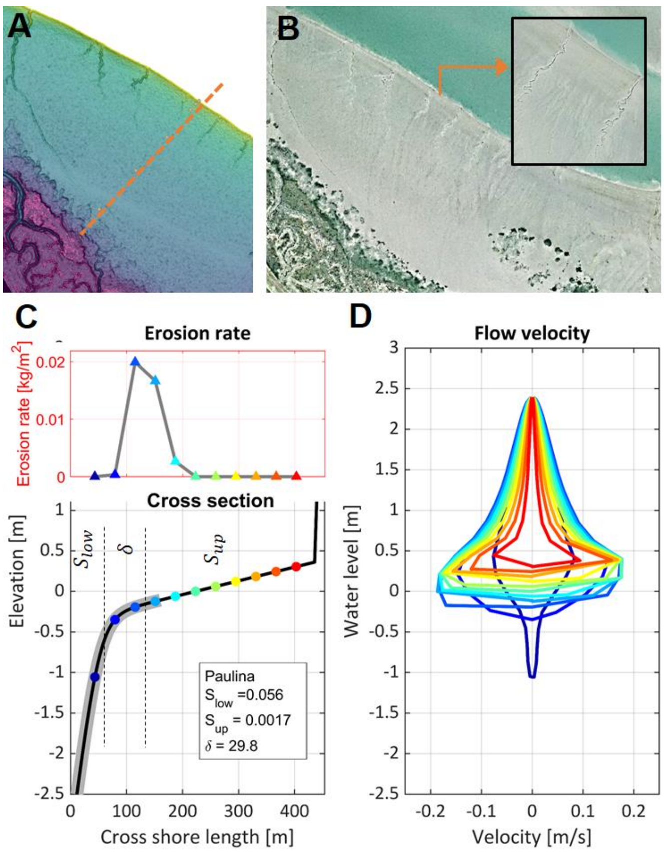

Figure 1: tidal flat Paulina (Western Scheldt). Panel A) LiDAR data with indication of transect. Panel B) Aerial picture. Panel C - low) Input numerical simulation. Cross section with indication of creek zone (grey), tidal flat parameters, observation points. Panel C - up) Erosion rate in observation points, during a tidal cycle. Panel D) flow velocities in observation points, during a tidal cycle.

Nature-based solutions to mitigate salt intrusion

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Introduction

Salt water intrusion is putting a substantial pressure on fresh water intakes and availability in estuaries around the world. Salt intrusion impacts are expected to increase due to climate change, because sea level is rising and droughts are expected to increase in frequency. Estuaries are densely populated areas with a high demand of fresh water, but are the first areas affected by salt intrusion. Closing off the estuary is the *status quo* solution to this issue. However, such hard measures have large negative side-effects for ecology and socio-economy. In this work, we explore the potential of nature-based solutions for the mitigation of salt intrusion-induced impacts in estuaries.

Approach

This PhD research starts off with a systematic analysis of the sensitivity of salt intrusion to variations in estuarine key parameters. These parameters are either forcing terms, e.g. tides and discharge, geometric terms, e.g. depth and width, or management terms, e.g. discharge distribution over tributaries. Based on a series of numerical model calculations, a set of potential nature-based solutions are identified. In this presentation, a number of options will be presented to the public, who are then invited to score the different types of solutions, assess their potential and propose alternative solutions themselves. All participants to the vote will receive the results of the analyses once these are ready.

The exercise will confront the public with the uncertainties associated with of this design choice, as well as provide a post-hoc evaluation of the quality of expert judgement. In the figure below, a sneak preview of two potential nature-based solutions to mitigate salt intrusion is presented.

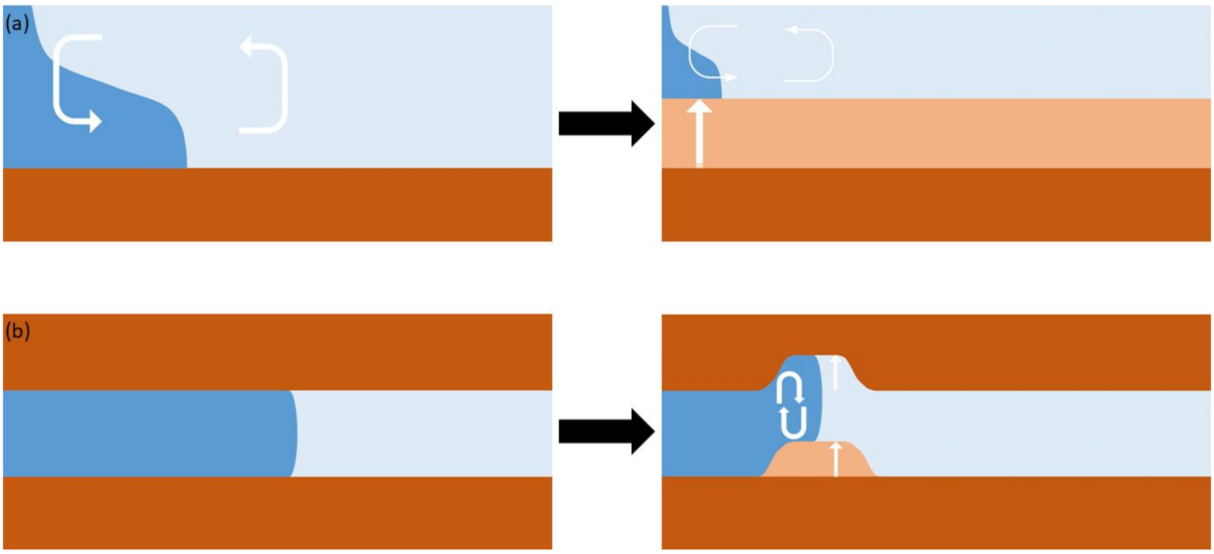

Figure: Two examples of nature-based solutions to mitigate salt intrusion. Dark blue colour indicates salt(er) water, light blue indicates fresh(er) water, and white arrows indicate estuarine modifications and circulations. (a) Reduce the water depth to limit the gravitional circulation, and thereby reduce the salt intrusion. (b) Insert meanders in the estuary to enhance lateral circulation, and thereby reduce the salt intrusion.

SIBES and Wadden Mosaic; No place to hide

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Introduction

The NIOZ has a long tradition of sampling benthic fauna across the Dutch Wadden Sea. Ever since the sixties we can be found in and on the mudflats. In 2008 the NIOZ has started with a large scale sampling effort covering the entire intertidal Dutch Wadden Sea. And since the beginning we have not only taken samples of the benthic life, but also of the sediment they live in. We now have a database with over 80.000 individual samples from the intertidal of which we know the benthic life and the sediment grain size distribution. In 2019 we combined forces with the Wadden Mosaic team to add 1400 samples from the subtidal.

Methods

As NIOZ we have our own Research Vessel "Navicula". Using this ship, as a work platform and refuge after a full day spent in rubber boats, we roam the Wadden Sea in spring and summer to take our samples. But fieldwork is only a small part of the total effort. We still must process the samples in the lab. Let me take you on a tour of the fieldwork and the lab effort.

Results

In taking a combined effort of over 6000 samples from the seafloor, covering the entire intertidal and subtidal Dutch Wadden Sea, there is no place to hide.

Figure 1: Box-coring form the Navicula back deck

Dune toe elevation increase outpaces sea level rise

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Introduction

The decadal development of coastal dunes is a result of the interplay between marine and aeolian processes. To date, it is unclear how this development is governed by short-term processes like storms and long term processes like sea level rise. Previous researches, have studied the decadal dune behavior by looking at specific geomorphological parameters. For instance, Ruessink and Jeuken (2002) used the cross-shore dune foot location and De Vries et al. (2012) used dune volume and beach slope. Here, we identify decadal trends in profile shape along the Dutch coast with an emphasis on the elevation of the dune toe. This parameter is expected to increase in elevation with sea level rise.

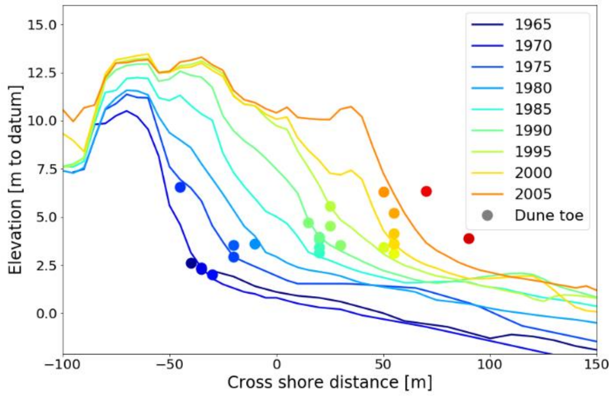

Figure 1: The development of the dune toe in a coastal profile from the JarKus dataset.

Methods

The extensive Jarkus database contains 200-250 m spaced profiles that have been measured yearly since 1965. Diamantidou et al. (2020) extracted the dune toe from this dataset using the second derivative method. These dune toes were filtered and analysed to study the decadal development. Figure 1 shows an example of the dune toe development in a coastal profile.

Results and discussion

The analysis of the dune toes results in the identification of several long term trends. It is found that the dune toe along the Holland coast increases linearly by 14 mm per year (Figure 2), and moves ±1.3 m seaward per year. A vertical translation of the coastal profile with sea level rise can be expected based on traditional concepts (e.g. by Bruun). However, the derived dune toe elevation increase is much larger rise than expected based on past sea level rise, which was only 1.9 mm/yr. Governing processes for this averaged behaviour remain unclear. A more detailed analysis of specific locations (e.g. nourished areas) might unravel specific governing processes.

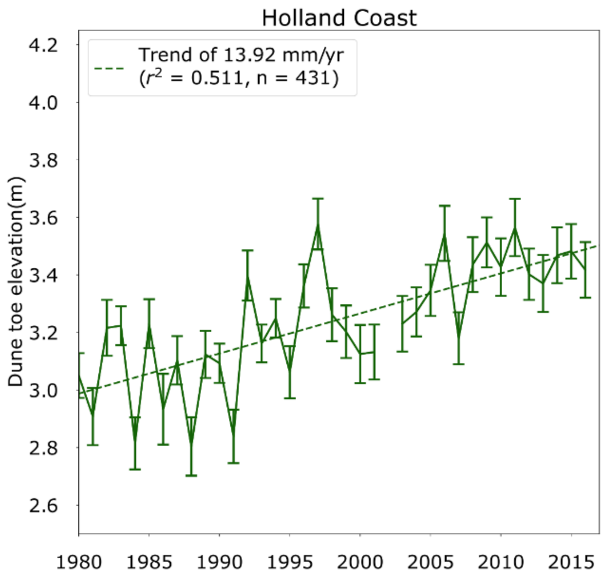

Figure 2: Dune foot and crest elevation through time.

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Modelling the observed evolution of tidal sand waves in the North Sea

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Introduction

Tidal sand waves are dynamic, rhythmic bedforms found all over the North Sea, which may interfere with offshore human activities, such as the construction and maintenance of cables and pipelines. For these activities, detailed information about the morphodynamic evolution of sand waves is necessary, but often lacking, due to coarse resolution of data. The use of 3D sand wave models could bridge this knowledge gap, but these models are computationally expensive. Therefore, the question arises whether less costly 2DV models are good alternatives and the objective of this study is to evaluate the performance of a 2DV model in hindcasting the evolution of observed tidal sand wave fields.

Methods

In this study, a 2DV Delft3D sand wave model based on the model Van Gerwen et al. (2018) is applied to three locations in the North Sea. At these locations, data of the Dutch Hydrographic Office of the Royal Dutch Navy are used to construct initial bathymetry profiles along the transects which are oriented perpendicular to sand wave crests. The model is forced with a combination of water levels and velocities, which are provided by the continental shelf model DCSM-Zuno v6 (Zijl et al., 2015). Van Rijn (1993) formulations are used to compute the bed load and suspended load transports.

Results & discussion

At all three locations, modelled transects are quite different from observed sand wave transects, even after model calibration (Fig. 1), indicating that 2DV models might not be sufficient for quantitative sand wave predictions on a decadal time scale. We are now comparing sand transports computed with a full 3D model with sand transports from the 2DV model to determine to what extent including this second horizontal dimension improves the accuracy of sand wave predictions.

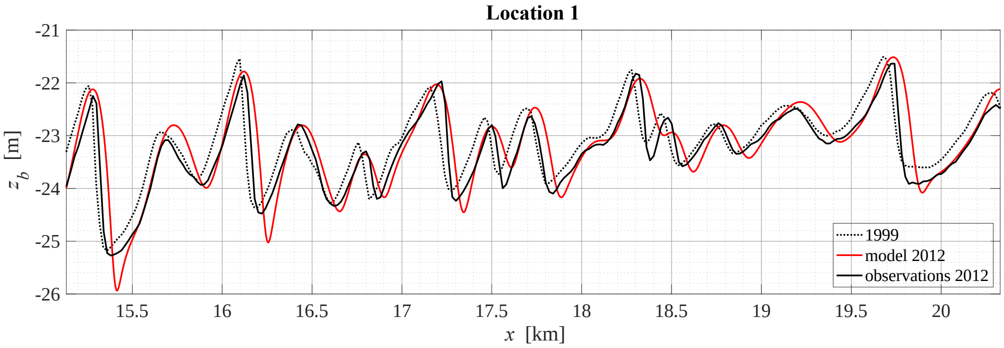

Figure 1: initial bed level profile from 1999 (black dotted line), observed bed level profile in 2012 (black solid line), modelled bed for 2012 (red line).

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Enhanced mud sedimentation to reduce turbidity and grow with sea-level rise

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Introduction

The Ems-Dollard estuary is characterised by a very high turbidity and is under pressure of sea-level rise and other human influences, similar to many other estuaries worldwide. The high turbidity reduces primary production, which disturbs the food web and decreases the ecological quality of the estuary. One of the measures that has been proposed to reduce the mud in the water column and to keep up with sea-level rise is enhancing the sedimentation process within the Dollard basin of the estuary. Here we investigate the potential of enhanced mud sedimentation for improving the water quality and thereby improving the ecological quality and growing with sea-level.

Methods

We designed ten potential measures to enhance mud sedimentation together with a team of experts from Dutch universities and knowledge institutes. The three most promising measures were selected based on a detailed qualitative analysis. These measures are: (1) create low energetic conditions with organic shapes of brushwood groynes (2) create a small lagoon by excavating a small part of the salt marshes (3) lower and rejuvenate salt marshes periodically. Subsequently, these three measures were implemented in a calibrated local Delft3D flow and wave model of the Dollard with a 100x100m grid. Boundary conditions are derived from a larger model of the entire Ems-Dollard estuary. Processes that steer the long-term autonomous evolution of the estuary, including for example sea-level rise, were also included in the model.

Results

Our results will show which measures are most promising for enhancing mud sedimentation and extracting mud from the water column. The model results will indicate the maximum sedimentation speed that can be reached per year when measures are taken, in contrast to the 0-1 cm per year without measures presently. Besides morphological modelling, we will also assess the ecological effects and costs of the proposed measures. Together this will lead to a choice for the most promising and cost-effective solution. Enhanced sedimentation measures can help drowning delta's and estuaries in the future, because it increases the capability to grow with sea-level rise.

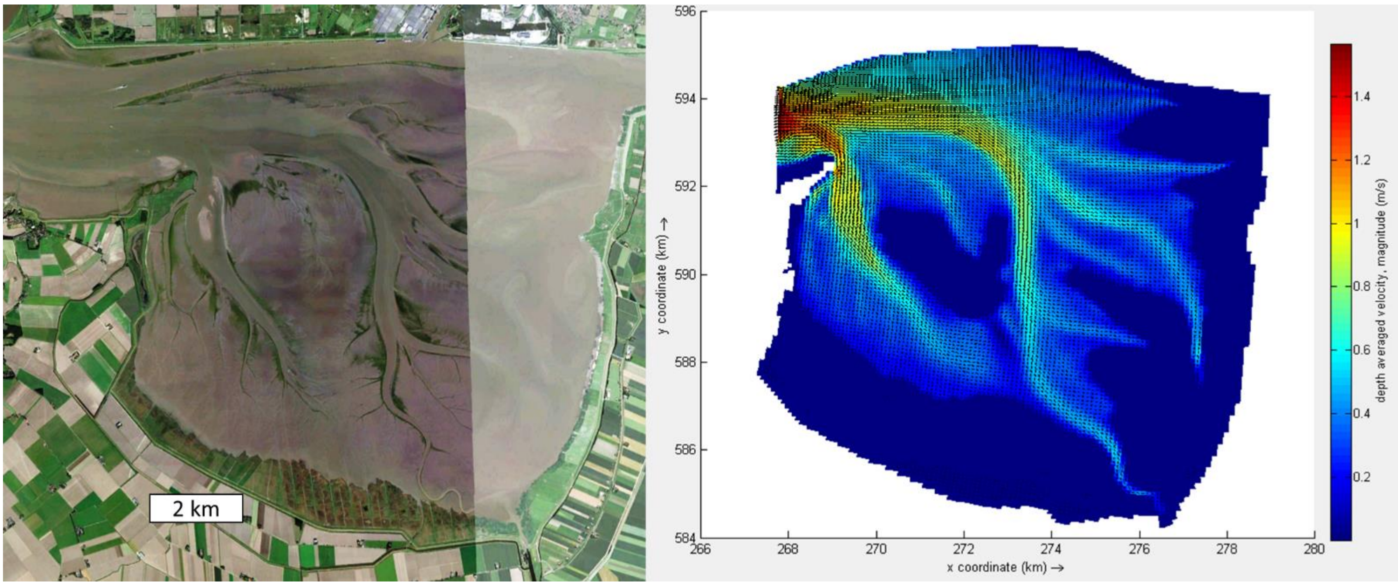

Figure 2 [left] Aerial photography of the Dollard basin along the Ems-Dollard estuary (source: google earth). [right] Example of model output with peak ebb flow velocities.

Long-term morphodynamics of a coupled shelf-nearshore system forced by waves and tides, a model approach

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Introduction

Sandy shelves often exhibit the presence of large-scale rhythmic bedforms, with longshore spacings of several kilometres, heights of tens of meters and which evolve on decadal and centennial time scales (Dyer & Huntley, 1999). Examples of such bedforms are the shoreface-connected and tidal sand ridges on the continental shelves of Long Island (New York, Duane et al., 1972) and the southern North Sea (Fig. 1). These bedforms are believed to strongly influence the nearshore wave patterns and thus its sediment transport and shoreline evolution (Schwab et al., 2013). Safak et al. (2017) found a persistent undulating shape of the shoreline in the vicinity of the Long Island shelf sand ridges, which they correlated to the presence of these ridges. However, despite the presence of offshore shelf sand ridges in many areas of the southern North Sea (Fig. 1), such a correlation does not seem to exist as the shoreline is rather straight in these areas. This suggests that other factors are of importance. A major difference between Long Island and the southern North Sea is that the former is subject to waves that predominantly are aligned with the shelf ridges, while the latter experiences waves that come from different directions. This difference in wave climate led to the hypothesis that shoreline undulations occur when shelf sand ridges are aligned with the direction of wave propagation. To test this hypothesis, the coupled morphodynamics of the shelf and the shoreline are studied for different wave conditions.

Methods

Simulations are carried out with a numerical shelf model (Delft3D-SWAN; Nnafie et al., 2020), which is coupled to a shoreline evolution model (Q2D-morfo; Arriaga et al., 2017). The Belgium coastal zone is selected as a study area (Fig. 1). The coupled model system is forced with tides and waves. Constant wave conditions (from the southwest or northwest), as well as more realistic wave conditions (time-varying wave heights, wave directions and wave periods) are considered. The simulations, which start from an initially longshore uniform and cross-shore sloping bottom, are run for 500 years.

Results

Model results show that sand ridges develop on the shelf, which resemble observed shelf sand ridges. When these ridges are aligned with the direction of wave propagation, strong shoreline undulations occur, while these undulations are weak when the wave direction changes in times. These results provide support for the hypothesis that the direction of wave propagation is of great importance for the coupled shelf-shoreline morphodynamic evolution.

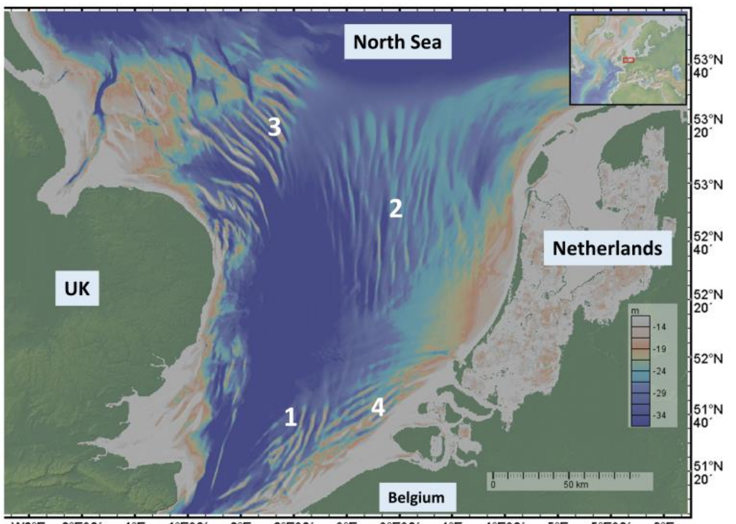

Figure 1.a) Bathymetric map of observed fields of tidal sand ridges (1, 2, 3) and shoreface-connected sand ridges in the North Sea (4).

Simulating long-term cross-shore dynamics under various nourishment types at the Dutch coast

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Introduction

Current coastal protection strategies in the Netherlands aim to maintain the coastline by the application of sand nourishment in various forms. Uncertainties in the rate and magnitude of sea level rise, as well as the desire to involve multiple coastal functions in future coastal protection strategies have risen the demand for the exploration of nourishment solutions that fit a larger geographical scale and a longer time horizon. Essential herein is insight in the morphological evolution of different designs and nourishment frequency, which can be supported by the quantification of key indicators such as beach width, beach slope and profile volume (e.g. Momentary Coastline position) with a morphological model. Present morphological models that have been developed to evaluate sandy profile evolution on a decadal timescale can roughly be subdivided as (semi-)empirical (e.g. Bruun rule, ShoreTrans (McCaroll et al., 2020), CS-model (Larson et al., 2016)) or physics-based (e.g. XBeach, Unibest-TC, Delft-3D). (Semi-)empirical models have a relatively low computational effort which is a major advantage. Major limitations are the large dependence on parametrization choices and the absence of morphological detail as desired by different stakeholders. Process-based models provide more detail, but require a relatively large computational effort as well as extensive site-specific calibration. There is no scientific consensus yet which strategy is best for decadal forecasts and planning future strategies. This research aims to compare presently available tools that can simulate morphological indicators relevant to decisionmakers.

Methods

As a first step, long-term profile models are examined to simulate transects with varying nourishment history along the Dutch coast, and compared to surveyed profiles (figure 1.). Several model approaches are applied on multiple transects spanning nearshore, beach and dunes. To reflect a variety of nourishment scenarios, Dutch coastal transects that have different nourishment histories are selected, including a (relatively) undisturbed profile, a frequently nourished profile and a profile on a mega scale nourishment. The model performance is tested by simulating the evolution of these locations over 30 years, and comparing these simulations to surveyed profiles.

Results

This model analysis offers insight in the strengths and weaknesses of the various model approaches. Model results show that model performance varies with time horizon as well as the output parameter investigated. These results underpin that the transition between model types needs to be further explored, with the objective to select a modelling technique that best supports the engineer and decisionmaker on different nourishment strategies.

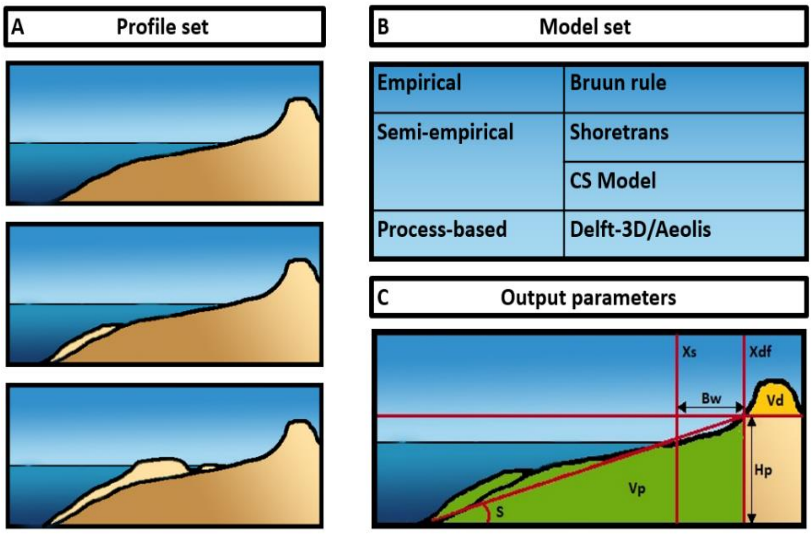

Figure 1. Overview of (A) cross-shore profile set, (B) model set and (C) investigated output parameters, including shoreline position Xs, dunefoot position Xdf, beach width Bw, dune volume Vd, profile slope S, profile volume Vp, profile height Hp.

Large-scale laboratory measurements of the pore pressure response to bichromatic waves in the swash zone

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Introduction

The swash zone is the dynamic coastal region where waves intermittently cover and expose the beach. These waves also induce fluctuations in groundwater levels through infiltration and exfiltration. The flow through the bed can have a mobilising or stabilising effect, and therefore influence the amount of sediment that is transported. Furthermore, strong pressure gradients can lead to bed fluidisation, which leads to large instantaneous suspension of sediments. To better understand these processes, new measurements of pore pressures under large-scale bichromatic waves were conducted in the Barcelona CIEM wave flume (for details see van der Werf et al., 2019). These unique measurements will help providing better insight into how subsurface flows and pressure gradients influence sediment transport, and ultimately morphodynamics, in the swash zone.

Results and outlook

In this work, we will present the data and initial findings. Figure 1 shows the pressure response to a bichromatic wave (H1= H2= 0.32 m, F1 = 0.31 Hz, F2 = 0.26 Hz). It shows that deeper pressure sensors show a more attenuated pressure signal. Furthermore, an analytical model for pore pressures could reproduce the measured results accurately (Pauli 2020). Future research focusses on the implications for sediment transport and how such implications can be implemented in numerical models.

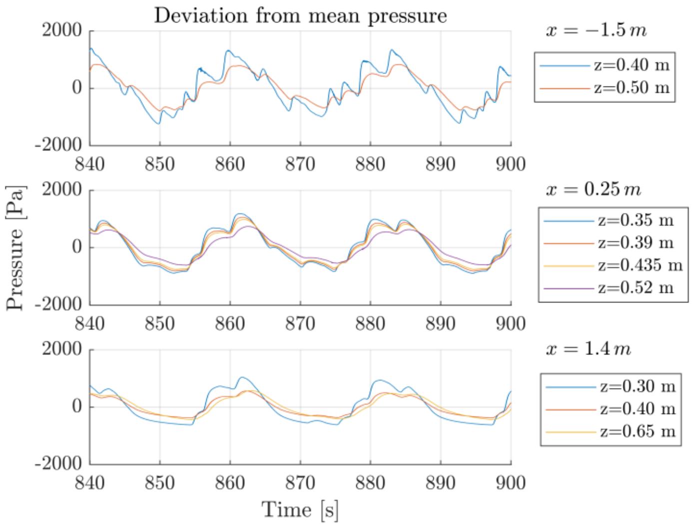

Figure 1: Measured pore pressure response at three different cross-shore locations and different burial depths z, below the initial beach profile. Here x is the landward position with respect to the still water line.

Acknowledgements

This work is part of the research program Shaping The Beach with project number 16130, which is financed by the Netherlands Organisation for Scientific Research (NWO), with in-kind support by Deltares. We also thank J. Alsina, I. Caceres and the supporting crew at CIEM for helping to perform the experiments.

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Salt intrusion in the Rhine Meuse Delta: Estuarine Circulation or Tidal Dispersion?

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Introduction

Salinity Intrusion through the Rotterdam Waterway puts a significant pressure on fresh water availability for drinking water and industry, and is expected to increase due to climate change (changing river discharge characteristics, sea level rise) and infrastructural developments (waterway deepening). In an open connection to sea, salt can intrude beyond the tidal excursion length due to the density driven estuarine exchange flow (gravitational circulation, Hansen and Rattray, 1965; Geyer and MacCready, 2014), but also due to tide driven dispersion, e.g. through tidal trapping in harbor basins and branches (Fischer, 1979), which are omnipresent in the Rhine Meuse Delta. In this study, we investigate the contribution of the various dispersion mechanisms in the Rhine Meuse Delta, to support design of effective salt intrusion mitigation measures.

Methods

The central method in this study is salt flux decomposition (see Lerczak et al., 2006). 3D-model results for salinity and flow at multiple locations along the Waterway and New Meuse have been decomposed into time-averaged and time-dependent and depth-averaged and depth-dependent components. From these components, the individual contribution of estuarine circulation related, time-dependent shear related, tidal oscillation related, and net flow (mostly run-off) related salt fluxes have been determined.

Results

From analysis of the salt flux contributions it was found that in the Rotterdam Waterway, the estuarine circulation related salt flux dominates over the tide related contribution most of the time, whereas tidal dispersion related fluxes dominate further upriver in the New Meuse. However, during surge events the contribution of the estuarine circulation reduces strongly, also in the Rotterdam Waterway. At these times, salt transport into the Rhine Meuse Delta is mainly produced by a temporal reversal of the net, tide-averaged flow, related to the large storage area in the system, and stratification vanishes almost completely. These results imply that measures aiming to reduce salt intrusion by enhancing vertical mixing in the Rotterdam Waterway can be expected to be effective most of the time. However, they likely have no effect on salt intrusion during surge events, which might be the more critical conditions.

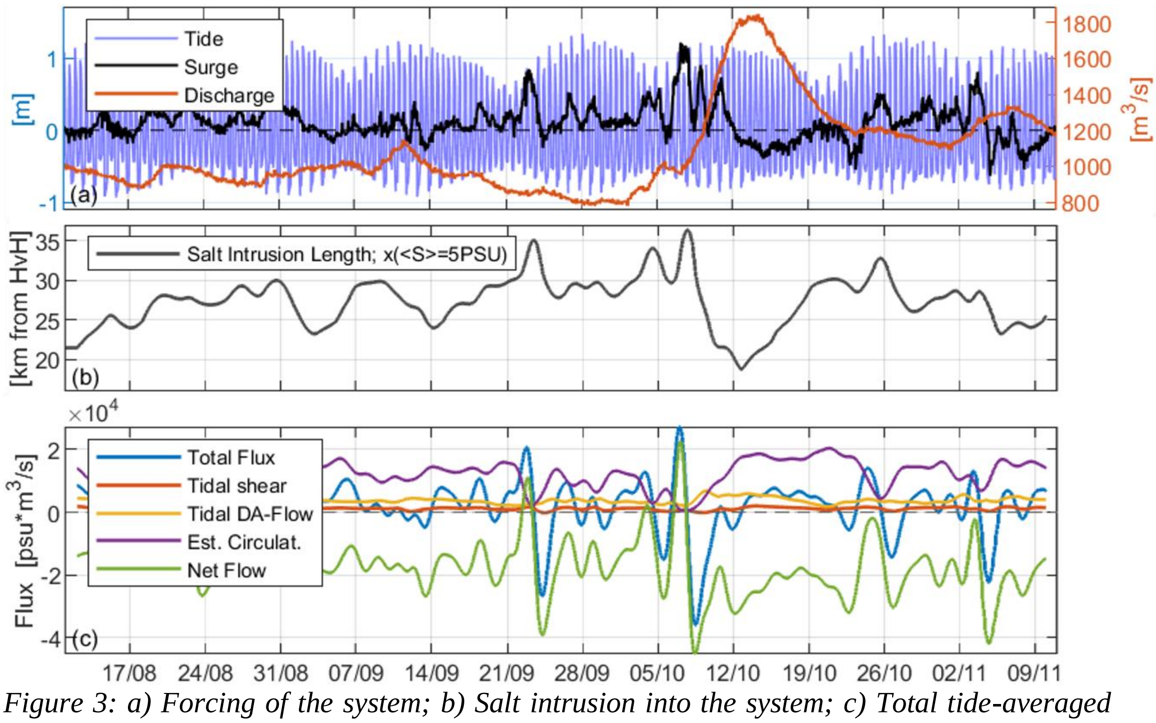

Figure 3: a) Forcing of the system; b) Salt intrusion into the system; c) Total tide-averaged salt flux (blue, positive is inward) and contributions of the individual salt flux components, for location Maassluis (Rotterdam Waterway).

Woody willow´s bending capacity reduces flow velocity during winter with possible implications for shoreline management and sediment control

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Introduction

Recent results indicated that SLR up to 2 m may induce large increases in tidal amplitude and state shifts to complete ebb dominance in tidal bays that may lead to enhanced sediment export according to a model of the European shelf downscaled to the eastern Scheldt (Jiang et al. 2020) with implications for shoreline management. Willow floodplain plantations are proposed as part of plans to create tidal wetlands for ecosystem-based flooding defence with high potential since they grow high in the intertidal. Willow forests characterize riparian floodplains in Europe up to the river mouth, e.g., in tidal wetlands along the Scheldt and Rhine-Meuse estuaries, Ems, Weser and the Elbe but are largely fragmented. However, the willow`s bending capacity and effects of living willows on flow velocity has to be studied.

Methods

First, we studied biophysical traits of two juvenile floodplain willow species in a mesocosm experiment with tidal flooding treatment in a climate chamber. Second, effects of living juvenile willows on flow velocity were studied during both summer and winter in a flume test series at NIOZ.

Results

Permanent and semi-permanent flooding of roots and periodic flooding of shoots reduced shoot length, biomass, and bending capacity but partial submergence did not affect shoot morphology or biophysical traits. Shoot diameter was larger for basket willow resulting in higher bending capacity but white willow showed more consistent results (Markus-Michalczyk et al. 2019). In the flume, flow velocity decreased within the leafy willow canopy but was less reduced above and below the canopy, whereas in winter, flow velocity inside leafless canopy was reduced but less reduced compared to summer. However, flow reduction above the canopy and near bed flow reduction is greater during winter when storm surges meanly occur. Generally, flow velocity was most reduced directly behind the willows and increased with vegetated test section length (Markus-Michalczyk et al. 2020).

Conclusion and Outlook

The willow may be a supplemental feature for shoreline management when applied high in the intertidal and directly in front of the dike. However, more research in the large flume and in the field is needed. Particularly, effects of harsh short time salinity increases (storm surges) on the willow should be studied.

Figure: White willow and Basket willow in front of the dike of Eastern Scheldt. Source: own resource.

A practical framework of quantifying climate change-driven environmental losses (QuantiCEL) in coastal areas

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Introduction

The impacts of Climate Change (CC) threaten the coastal wetlands and affect Coastal Ecosystem Services (CES) that are vital to human well-being. Quantification of the value of CC-driven environmental losses is scarce, especially in coastal areas of developing countries which have relatively low adaptive capacity to CC impacts. Addressing this knowledge gap, a practical framework to Quantify Climate change driven Environmental Losses (QuantiCEL) was developed and applied in coastal areas in Southeast Asia (i.e., Indonesia, Bangladesh, Sri Lanka). Using this framework, the likely physical impacts of climate-driven hazards (i.e., SLR-induced inundation, and coastline recession) on diverse ranges of ecosystems (i.e., mangroves, beach and dune systems, pelagic system) and provided goods and services (i.e., food provision; tourism; art and aesthetic values; provision of raw materials) were assessed for different impact scenarios in 2100, and corresponding damage values of CES were quantified in monetary terms.

Methods

The QuantiCEL framework (Mehvar et al., 2019) is based on an integrative socio-ecological-economic approach consisting of three coherent steps: (i) Economic valuation of CES by using the standard economic valuation methods; (ii) Identification of the CC-driven impacts on CES by determining hazards and the affected areas for each scenarios via digital elevation maps and satellite images, as well as using primary and secondary data; and (iii) Monetizing the impacts and quantifying the changes to the total CES value by linking the results of the previous two steps.

Results

The application of this framework for the selected case studies showed that, where the absolute loss value of CES by the end of the 21st century is concerned, food provision and tourism are the CES with higher loss values. However, art, amenity, and tourism are the highly affected CES where the percentage loss (by the end of the 21st century) relative to the present-day value of CES is concerned.

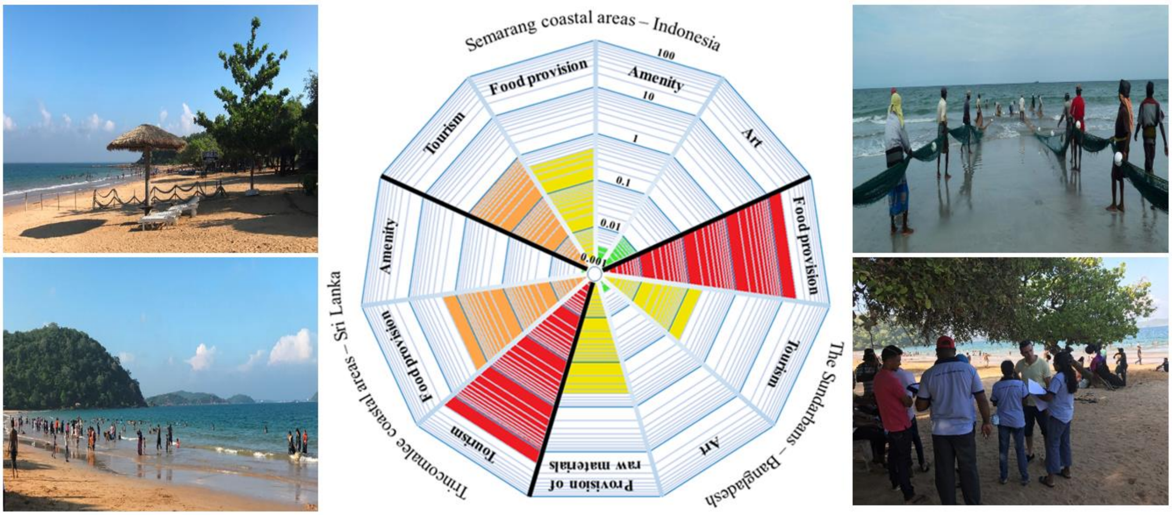

Figure: Photos taken during data collection phase; and schematic representation of the absolute loss value of CES in logarithmic scale, in million US$ (from 0.001 to 100) for the three case studies. 'Green' to 'dark red' colours represent low to extreme loss values.

References

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The Deformation of the former unique enchanting Citarum delta, Indonesia in the last four decades

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Introduction

The Citarum (Ci locally means water or river) is among the most discussed deltas in Indonesia, The river upstream passes Bandung city highland, and its present water is used to support the needs of Jakarta capital city, while some more portions are used for irrigation in the lower plain reaches. It was at least until some years after 1981 that the river had 8 distributaries, namely from SE to N are the Mati, Jaya, Gembong, Kuntul, and Belubuk which formed bird foot type delta, then to the N the Belubuk elongate delta, two mouths of Wetan cuspate delta in the NW, and finally the cuspate-arcuate Bungin delta in NE part. In 1965 the Jatuluhur dam (elevation 100 m) was installed, followed by Saguling (1985, 645 m) and Cirata (1987, 225 m) dams respectively and Curug weir (1988, 20 m) along the main river. The water is then dispered into the West, North, and East Tarum irrigation schemes. It is estimated that at present only about less than 20 % of its river discharge still flows to the former natural river mouths.

Ongkosongo (1984) has mentioned that an interdeltaic plain W of Bungin was indicated in subsiding state (Figure 1). This subsidence was also confirmed by many reports, such as those by Abidin *et al.* (2014) using, among others, InSAR remote sensing analysis. As a result of the aforementioned operated infrastructures and water flow dispersion, there seems to be a reduced sediment load and transport capacity. People also deliberately deforested and destroyed the former mangrove swamp into fishponds. As a result 4 distributaries i.e. the Jaya, Gembong, and two mouths of Wetan were abandoned, and the delta plains, except the Jaya, Kuntul and Belubuk were mostly severely eroded since the middle 1980's (Figure 2). The delta has become deformed and irregular, and it is estimated that this will more severely continue. In order to monitor further environmental degradation, it is suggested that the integrated coastal managers in charge should take proper actions at least with frequent serial remote sensing mapping as well as doing nearby sand replenishment, shore protection, and mangrove planting actions.

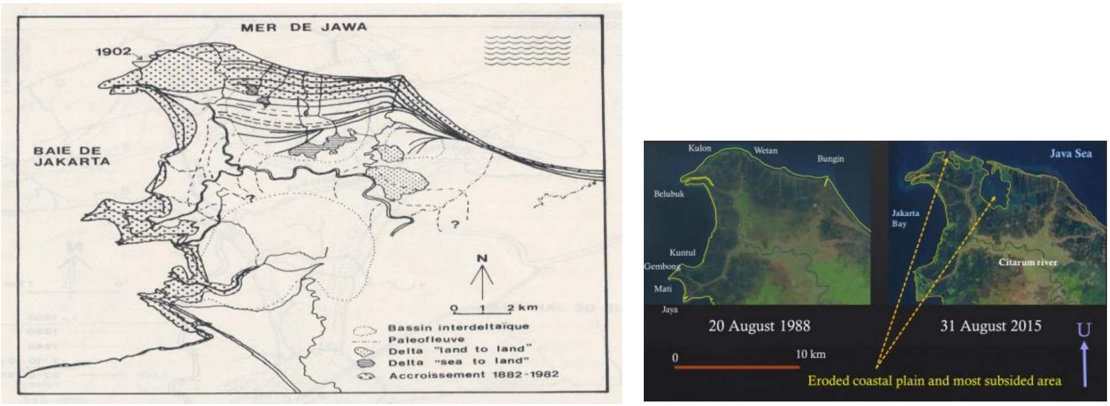

Figure left: The coastline changes of Citarum delta in 1881-1981 which shows accreted delta plain (shaded) (Ongkosongo 1984). Right: Deformation in the Citarum delta complex in the period of 1988 to 2015 which includes erosion and subsidence in some parts of the coastal plain.

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The rise of Spanjaards Duin: factors regulating sediment fluxes over an engineered foredune and adjacent dune slack

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Introduction

In 2009 a new dune-dune slack called Spanjaards Duin was constructed in front of the Delfland Coast. Spanjaards Duin was created as a compensation measure for the expected eutrophication of dune habitats due to increase in nitrogen deposition from use of the Rotterdam harbour expansion, Maasvlakte 2 (van der Meulen et al., 2014). Sediment fluxes shape the dune landscape and in doing so, affect establishment and growth of vegetation. Therefore, this study aims to identify and analyse which annual (meso-scale) sediment transport patterns develop in this engineered foredune-dune slack system.

Methods

The morphological development of the foredune-dune slack system was studied using 9 years of annual airborne LiDAR elevation data focusing on cross-shore profile evolution. Next, a process-based aeolian sediment transport model (AeoLiS) that included supply limiting processes, such as armouring (Hoonhout and de Vries, 2016), was calibrated and validated on the annual profile data set. It was used to simulate spatial patterns in aeolian sediment transport across the new foredune and in the adjacent dune slack based on one year of daily wind data. All simulated transport events were summed up to reveal how aeolian sediment transport behaved on an annual scale.

Results

The morphological analyses showed Marram grass, which had been planted in two strips along the top of the foredune, functions as a transport limiting factor and was a trigger for growth of the foredune (Figure 1). The annual-scale transport pattern derived from the simulations showed that under the prevailing wind climate this limited sediment supply to the dune slack. In addition, the dredged seabed sediment from which the area was constructed, contained shells and shell fragments leading to surface armouring in the dune slack. This limited the sediment entrainment, and hence functioned as a supply-limiting factor, which slowed down the deflation of the dune slack (Figure 1).

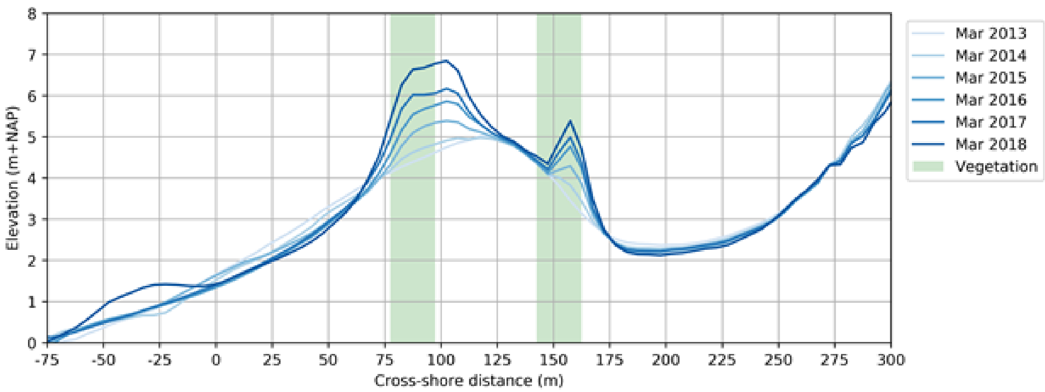

Figure 1. Observed evolution of alongshore-averaged elevation profiles.

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Characterizing the Suspended Sand and Mud Composition on Ameland Ebb-Tidal Delta using Combined Optical and Acoustic Measurements

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Introduction

Estimating the composition of suspended particulate matter (SPM) is essential to understanding and managing estuaries and coastal environments where both sand and mud are present. Optical and acoustic backscatter differ for suspended sand and mud, which makes it possible to estimate the relative sediment composition in mixed suspensions by using paired optical and acoustic instruments. We derive a sediment composition index (SCI) for mixed sand-mud suspensions via theory and laboratory experiments, and then apply it to in situ measurements from Ameland ebb-tidal delta (the Netherlands).

Methods

SCI is derived from the difference between optical and acoustic backscatter signals. This relationship was validated in a series of laboratory experiments where we found that SCI is negatively correlated with increasing relative sand content. Field measurements of hydrodynamics and suspended sediment at Ameland Inlet were obtained from August 29th to October 9th, 2017 as part of the *Kustgenese* 2.0 project. Using these data, we calculate SCI and put it into context with local hydrodynamics and seabed characteristics.

Results

In periods where wave influence is negligible, SCI is highly cyclical (Figure 1). SCI is lowest on Ameland ebb-tidal delta at flood tide when high bed shear stress can resuspend sand from the local seabed and due to the lower turbidity of water from the North Sea. SCI is slightly higher at ebb tide due to reduced sand suspension under lower velocities, and due to the advection of mud from the Wadden Sea. SCI is highest at slack water when local sand falls out of suspension, but mud remains. In periods with strong wave action, SCI is reduced by suspension of local sand.

Using SCI to estimate relative proportions of suspended sand and mud reduces the ambiguity of suspended sediment measurements in mixed-sediment environments. The index gives greater insight into the sediment dynamics of Ameland ebb-tidal delta, highlighting the presence of mud in an otherwise sandy setting. This index also provides valuable insights for the planning and analysis of future field measurements.

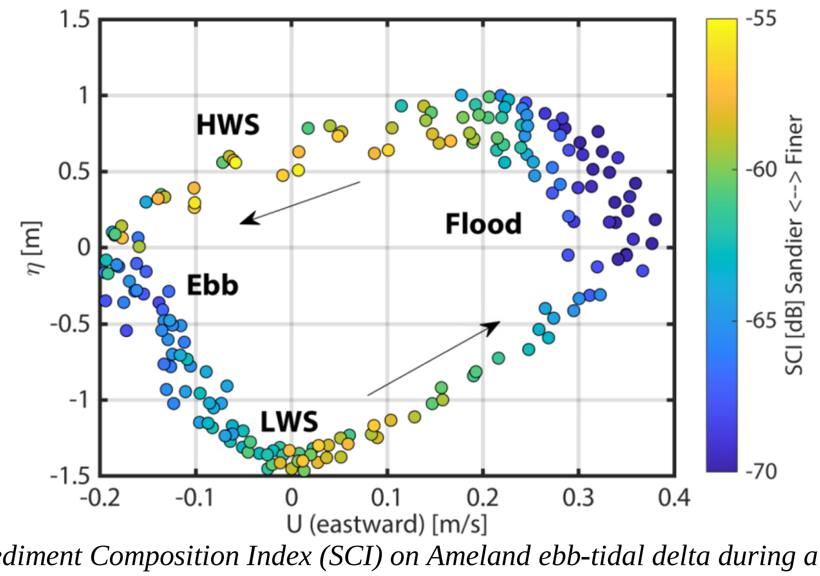

Figure 1: Sediment Composition Index (SCI) on Ameland ebb-tidal delta during a period with few waves (Sept 21-25, 2017) as a function of water level and current velocity. Lighter colours correspond to 30-minute bursts with a relatively stronger optical backscatter (and hence dominated by suspended mud), while darker colours correspond to bursts with a relatively stronger acoustic backscatter (and hence dominated by suspended sand).

How the spacing and orientation of buildings shape local sandy deposition patterns

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Introduction

Buildings at the beach, such as (holiday) houses or restaurants, can shape the development of the beach-dune system by affecting the wind field and wind-driven sand transport in their surroundings. In a recent study (Poppema et al., 2021), we found that buildings create deposition patterns around them, consisting of an upwind deposition area and two downwind deposition tails and with the deposition size depending on the wind-facing surface. However, that study only examined individual buildings that are placed perpendicular to the wind. Along the Dutch coast, buildings are often placed in rows, with a small distance in between buildings. In addition, the wind direction will often be at an oblique angle to a building. Therefore, we conducted a field experiment to determine the effect of building spacing and orientation on the aeolian deposition patterns around buildings.

Methods

During the experiment, cuboid scale models of buildings were placed on the beach at the Sand Motor. To determine the effect of building spacing, scale models were placed in groups of three, with gaps in between scale models ranging from 0 to 4 building widths (see figure 1). To determine the effect of building orientation, individual scale models were placed at various angles to the wind. In total, 34 configurations were tested. The deposition patterns around the scale models were measured after one day using structure-from-motion photogrammetry.

Results

Buildings with a spacing of more than 2 to 3 times the building width created similar deposition patterns as stand-alone buildings. Consequently, the deposition pattern per building group could then simply be regarded as the sum of individual building effects. For smaller gaps, fundamentally different airflow patterns developed, resulting in different deposition patterns behind the gaps, with the exact deposition pattern depending on the gap width. For the building orientation relative to the wind, oblique orientations created an asymmetry in the downwind deposition patterns.

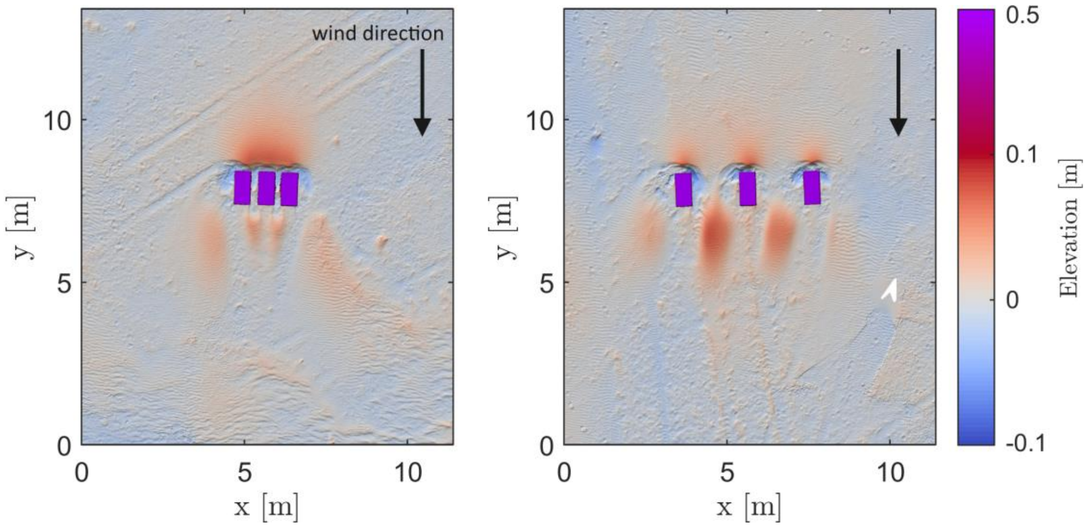

Figure 1: Deposition around two set-ups, with building spacings of 0.5 and 3 times the building width.

References

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How erosion and deposition patterns around a row of holiday cottages at the beach can be influenced by wind direction: A numerical study

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Introduction

The attractiveness of the coastal areas to people has led to the construction of buildings such as holiday cottages, restaurants, sailing clubs, recreational facilities and pavilions at the beach. These buildings change the local airflow patterns which, in turn, modify the sediment transport and erosion-deposition patterns around the buildings. On a longer time-scale, this can influence the functioning of the buildings and might need additional measures to smoothen the surface. In this research, we study how wind direction influences the flow regimes around a row of holiday cottages at the beach, to infer the erosion-deposition patterns.

Methodology

A numerical model is developed using OpenFOAM, which is an open-source computational fluid dynamics solver[1]. A three-dimensional computational domain with a row of ten buildings is modelled. The dimensions of the buildings are selected based on the real holiday cottages at the Kijkduin beach, the Netherlands (figure 1C). The distance between the buildings, d, is considered the same as each building's width. The logarithmic wind velocity profile is applied from left to right and the wind angle, θ, is defined as the angle between the wind direction and the x axis of the domain.

Results

The flow divergence patterns at $y = 0.25\, m$ show that for $\theta = 20^{\circ}$, the most significant depositions (figure 1B, blue shaded colors) are expected to occur in front of the upwind faces of the buildings. Further, small areas with sand accumulation are expected to develop just behind the leeward faces, which are extended as deposition tails. For $\theta = 40^{\circ}$, the wind facing sides increase and an additional deposition happens in front of the long side of the most upwind building. The deposition tails behind the buildings are formed parallel to the wind direction and they decrease in length with increasing wind angle. For $\theta = 80^{\circ}$, the deposition tails behind the buildings vanish and the most intensive erosion occurs very close to the long side of the first building (figure 1B, red shaded colors).

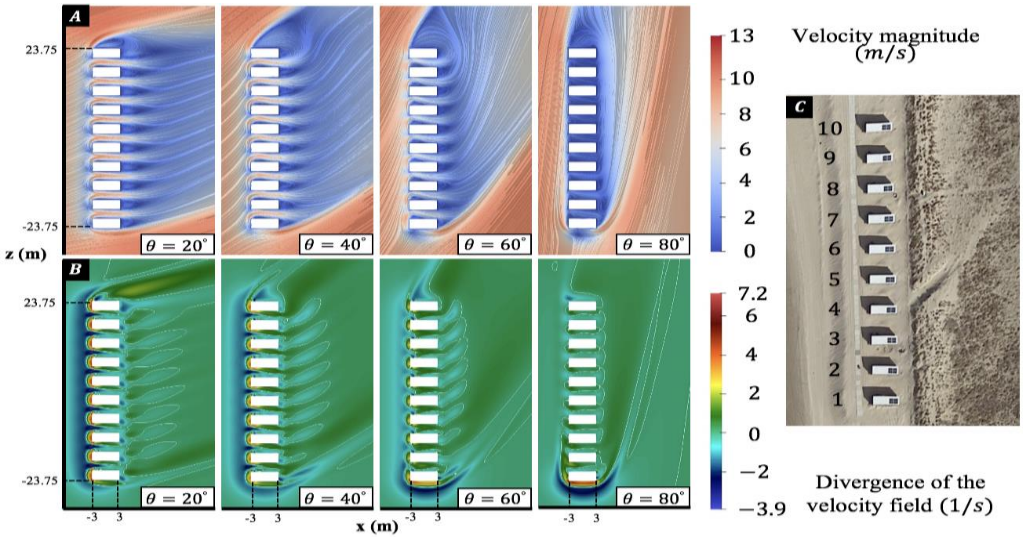

Figure 1: A) Horizontal velocity field around the buildings at y=0.25 m (white lines are streamlines), B) Erosion and deposition patterns close to the buildings inferred from velocity divergence at y=0.25 m (white lines are zero contours). C) A row of buildings at the Kijkduin beach, the Netherlands (source: google earth).

Acknowledgement

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Free infragravity waves in the North Sea

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Infragravity (IG) waves are surface waves with relatively long periods (20-200 s). Despite their relatively low height in deep water, they can increase substantially in height in coastal waters and contribute to the nearshore hydrodynamics, sediment transport and dune erosion. Recent analysis of measurements in the North Sea showed substantial bursts of IG energy during storm events (*Reniers et al., 2021*). Only part of this energy could be attributed to local forcing of bound IG waves by sea-swell waves. The objective of this study was to identify the source and origin of the remaining free IG (FIG) energy. We used the SWAN model to verify the hypothesis that this FIG energy originated at distant coasts, where it was radiated seawards after generation by the breaking of sea-swell in the surf zone.

We extended the SWAN model with a source of FIG energy along the shoreline bordering the North Sea (based on the approach of *Ardhuin et al., 2014*). This source is based on an empirical relationship between the IG wave height and two bulk sea-swell parameters (the significant wave height and the mean wave period), which showed a good correlation at several stations in oceanic waters (*Ardhuin et al., 2014*). After calibration, we used the model to hindcast four storm events that resulted in the largest FIG wave heights in the observational record (between 2010-2018).

We will show that SWAN was able to explain a significant part of the FIG height variability that was observed at three stations during the four storms (see below Figure for an example during storm Xaver). This suggests that a significant fraction of the FIG energy can be attributed to radiation from distant shorelines. We will present how the modelling allowed us to identify the major source of FIG waves, that these radiated FIG waves were able to cross the North Sea basin and reach adjacent shores, and explore the role of bottom friction. Along the shorelines, the shoreward directed FIG energy was found to be a combination of FIG radiated from remote beaches and locally radiated FIG waves that are trapped by refraction. At present, the contribution from these FIG waves is not included in coastal safety assessments with wave-resolving storm impact models (e.g., XBeach), and additional research is required to understand the impact of FIG waves on coastal safety.

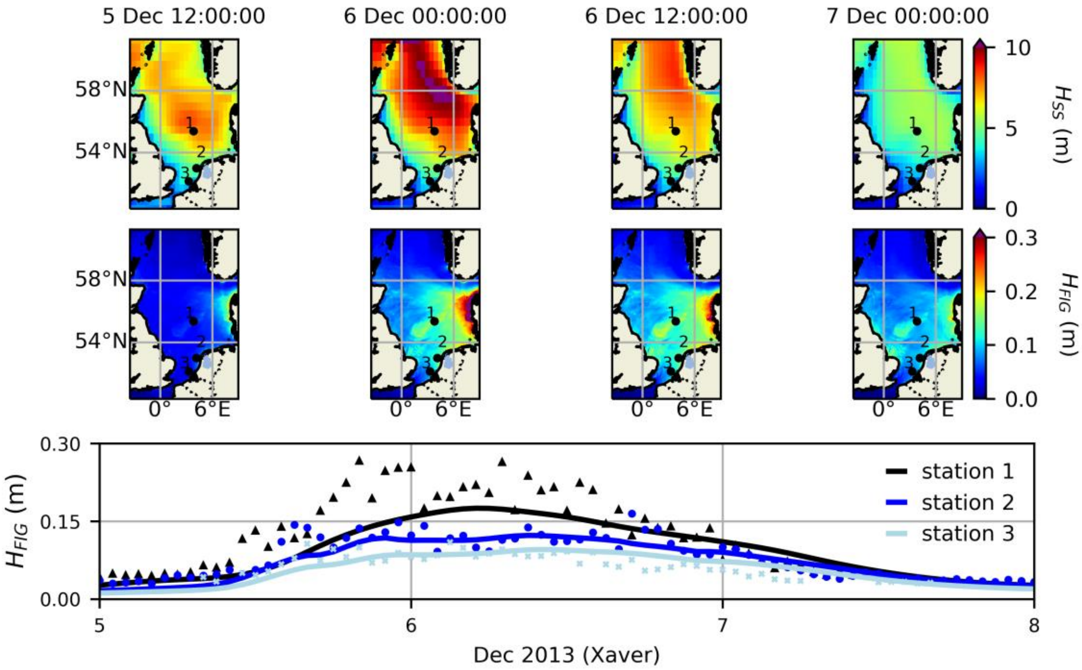

Figure: Time-stack of predicted sea-swell (top panels) and FIG (middle panels) wave heights. Predicted (lines) and measured (markers) FIG wave height at the three stations (bottom panel).

Reniers, A. J. H. M., et al. (2021). *JMSE*, *9*(2), 141.
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Simple one-line and free-form coastline evolution models' forecasting ability enhancement using sequential data assimilation (Ensemble Kalman Filter)

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Introduction

The main focus in this research is to implement the sequential data assimilation (DA) method, Ensemble Kalman Filter, in the free-form ShorelineS coastline evolution models (Roelvink, et al., 2020). ShorelineS is flexible and can simulate the effect of hard structures and river inlets, also can handle the splitting and joining of shorelines with distinctive sections. Although having all these advantages, it makes it quite challenging to apply DA in the model. So, experiments to a simple one-line model was implemented first. Then DA in ShorelineS was applied afterwards.

Methods

A quasi-transect approach was implemented: by sequentially transform the ShorelineS simulations onto a set of transects created across the shoreline ensemble members. The intersection points between transects and each ensemble member will be used in the EnKF assimilation process alongside with the model calibration coefficient, "B" coefficient. Several validation tests were made, for example: twin experiment and Pelnard-Considere-based groin test (for the simple model). While in ShorelineS, longshore dispersion of a beach nourishment test. In addition to, the application of the developed model in spits formation test using spread of high angle of wave incidence and a case study of the well-monitored, large-scale "Sand motor" nourishment in the Netherlands are in progress.

Results

Twin experiment and Pelnard-Considere-based groin tests on the simple model after adding data assimilation showed great improvements in model results' BSS values, and confirmed the suitability of EnKF in parameterization process. This was very encouraging to apply EnKF on ShorelineS. In longshore dispersion of a beach nourishment test on ShorelineS: "B" coefficient was successfully calibrated as shown in *fig (1.a)*. As a result, forecast results, presented in *fig (1.b)*, were significantly matching analytical solution, especially in presenting both erosion and accretion features.

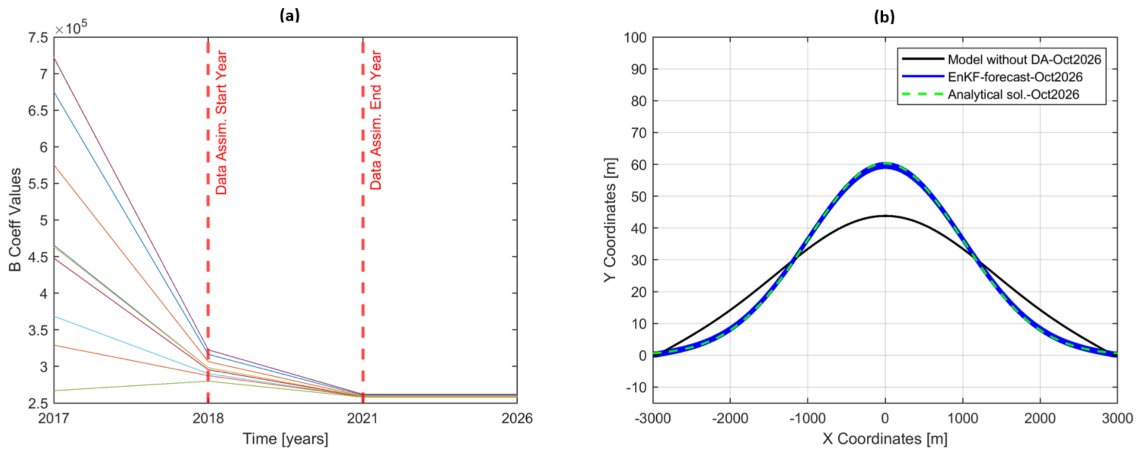

Fig (1.a) shows "B" coefficient calibration in different ensembles through time. Fig (1.b) shows comparison between ShorelineS model, with and without DA, forecasting results.

References

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Dune migration in estuaries: the effect of the gravitational circulation

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Introduction

Estuarine sand dunes are large-scale bedforms which are ubiquitous around the world. Their dimensions and dynamics are transitioning between those of marine sand waves and river dunes. Similarly, the driving mechanisms of estuarine sand dunes are a mixture of fluvial and marine hydrodynamic processes. Furthermore, there are also estuarine-specific processes that play a role, for instance the gravitational circulation. This residual circulation stems from the interaction between saltwater and freshwater, and it constitutes an upstream (landward) current near the bed, and a downstream (seaward) current near the water table. Here, we unravel the influence of the gravitational circulation on the migration of estuarine sand dunes.

Methods

We develop a process-based idealised model based on the shallow water equations which includes (a symmetric M2) tidal and river forcing, and a longitudinal salinity gradient which yields the gravitational circulation (figure 1a). Furthermore, we include a symmetric tide, and we neglect suspended sediment transport and the presence of cohesive sediments. Bed load sediment transport is modelled through a power law with a slope correction. With this model, we perform a linear stability analysis to find the mode that grows fastest from a flat bed (i.e. fastest growing mode, FGM) – which reveals the wavelength, growth rate and migration rate of the FGM.

Results

The wavelength and growth rate of the FGM are barely affected by the introduction of a longitudinal salinity gradient. Migration rate, however, shows large variations for changes in the salinity gradient. Figure 1b shows that migration direction reverses if the salinity gradient is strong and the residual river flow is weak. These results are in agreement with observations from the Gironde estuary (France), where Berné et al. (1993) found that the dunes reverse their lee sides to face the upstream direction (thus indicating upstream migration) during high discharge, which they attributed to the salinity field being pushed outward during high discharge, thereby increasing the salinity gradient at the sand wave field.

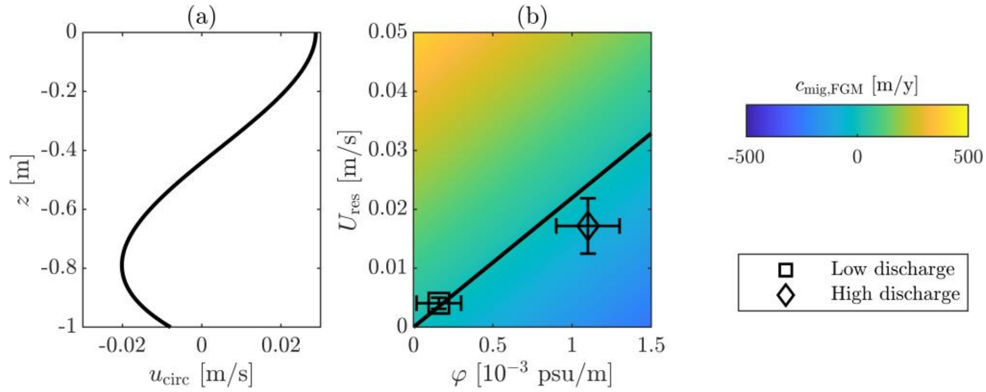

Figure1: (a) residual circulation stemming from the longitudinal salinity gradient and (b) migration rates of the fastest growing mode ($c_{mig,FGM}$), with the black line representing the zero migration contour, and the marker symbols showing representative discharge scenarios for the Gironde estuary.

Reference

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Estimating alongshore sand transport based on bathymetric survey data in dredged access channels

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Introduction

Alongshore sediment transport rates are important in sediment budget studies or design of coastal structures. Underestimated transport rates give rise to severe siltation updrift from cross-shore structures and severe erosion downdrift. Overestimates may lead to over-design and thus high costs. Currently, these estimates are generally obtained from sediment transport equations, morphodynamic numerical modelling or bathymetrical changes in accumulation areas (Vandebroek et al. 2017). However, alongshore transport is difficult to estimate from regular bathymetrical surveys, since only locations with gradients in the transport will provide information via volume changes. On a straight coastline the sediment will simply pass by.

Here an alternative data-based approach is proposed, studying an access channel suffering from repeated siltation. The recreational port of Blankenberge, Belgium, is connected to open sea via a short access channel. It is only separated from the beach trough two smooth low-crested breakwaters, and two open pile structures (“staketsels”). Sediment is easily transported over the breakwaters during mid to high-tide, silting up the access channel. Bypassing around the breakwaters also takes place (Teurlincx et al. 2009).

As the access channel effectively serves as a sediment trap it can be used to study alongshore sediment transport rates. The access channel is frequently dredged and even more frequently surveyed. It is therefore suitable to make estimates of sediment transport on the time-scale of weeks to months.

Methods

A large number of multibeam bathymetric surveys are available for the years 2016-2020, covering the access channel to the recreational port of Blankenberge. Volumes are derived in three distinct sedimentation zones to each side of the channel and in front of the entrance, providing timeseries of volume change. Surveys are inspected for dredging activities in the zones and the volumes corrected as necessary.

Results

Over the course of a week (6-14 February 2020), during the passage of storm Ciara, $12*10^3$ m^3 of sand was deposited in the access channel, which is similar to the entire month (7 January to 6 February) before. A period of calmer conditions (16 December 2019 to 7 January 2020) resulted in only $2.5*10^3$ m^3. These volumes could be scaled to annual transport rates of $5.5*10^5$, $1.5*10^5$ and $0.4*10^5$ m^3/year respectively in North East direction. Bypassed volumes were not yet included.

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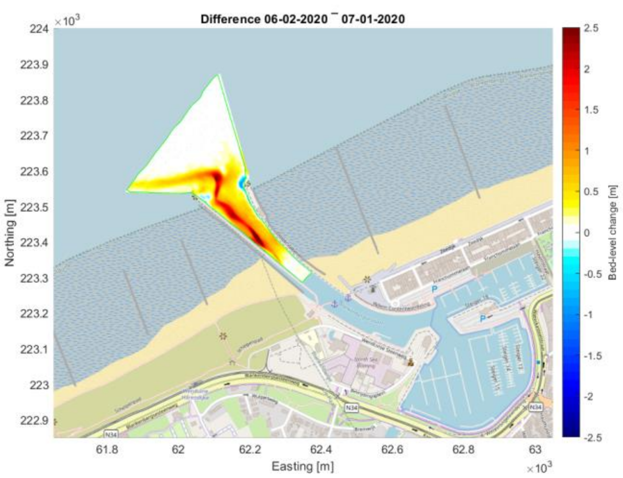

Figure: Blankenberge access channel, siltation during one month of winter conditions. Colours indicate accretion and erosion.

Morphodynamic Equilibria and Linear Stability in Tidal Estuaries: Influence of Coriolis and Planform Geometry

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Introduction

Complex bottom patterns are often observed in tidal basins, found in for example the Wadden Sea along the Dutch, German and Danish coast. These patterns consist of branching channel-shoal patterns, that often exhibit cyclic behavior. Using an idealised morphodynamic model, we aim at directly finding morphodynamic equilibria and assess their stability, with a specific focus on their sensitivity to Coriolis forcing and planform geometry.

Methods

The physics are modeled using the depth--averagerd shallow water equations, suspended sediment transport equation and the bed evolution equation. As a first step, the equations are scaled, using typical order of magnitudes for the various physical parameters. After scaling, a small parameter is identified, namely the ratio of the amplitude of the sea surface elevation and the water depth at the seaward side. This allows for an asymptotic analysis of the system of equations, resulting in a systematic solution method to obtain the various physical variables. Since the water motions and sediment transport take place on a much shorter timescale than the bed evolution, the bed is considered fixed on the fast hydrodynamic timescale. Only the tidally averaged divergences and convergences of the sediment transport result in a change of the bed profile on the long timescale. The model equations are discretized using the finite elements method, and morphodynamic equilibria are obtained using a continuation method: instead of integrating the equations in time, a solution of the equations is sought for such that there are no convergences and divergences of tidally averaged sediment transport. By including the Coriolis force and a general planform, results reported in the literature are extended.

Results

As an example, two equilibrium bed profiles are shown in the figure below: one for an exponentially diverging single tidal inlet (left panel) and one for a more realistic geometry (right panel). In both cases, the water depth at the seaward side (lefthand side) is maximum, while the undisturbed water depth vanishes at the landward side. In the equilibrium bathymetry shown in the right panel, the presence of a channel-shoal system is observed that is forced by the planform geometry.

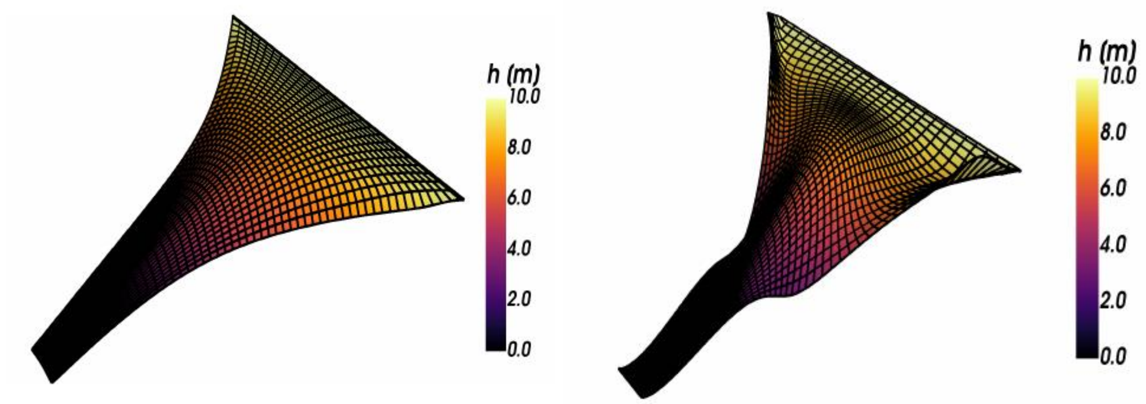

Figure 4 *Two examples of morphodynamic equilibrium in single inlet systems*

In this presentation, the influence of the planform geometry and Coriolis forces on the morphodynamic equilibria and their linear stability will be systematically analysed and the underlying physical mechanisms will be explained.

Modelling the role of estuarine wetland development on salt-intrusion

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Introduction

Estuaries are at the transition from the river to the ocean. During storm surges or river droughts, salt water can intrude far inland into the estuary, limiting freshwater availability. Wetlands are proposed to reduce estuarine salt-intrusion by increasing horizontal mixing of fresh- and salt water. Namely, their presence in an estuary can affect (horizontal) flow circulation, tidal trapping and tidal pumping, key processes for mixing of fresh- and salt water. Effective design of wetlands requires in-depth understanding of the natural processes, which involves the interplay of physical (hydrodynamics, sediment dynamics, morphology) and ecological (vegetation dynamics), processes acting on extensive spatial and temporal scales. We will develop a modelling framework that is able to evaluate wetlands to counteract salt intrusion, under long-term estuarine development. Hereby, we will focus on the spatial scale of the entire estuary. In addition, climate change (CC) impacts will be taken into account, e.g. sea level rise (SLR), altered river discharges and SLR driven basin infilling.

Methods

We created an idealized estuarine model, within the Delft3D-FM model (Figure). Herein, various wetland scenarios will be implemented, e.g. changing its location, width or vegetation characteristics.

First, present day simulations are performed, whereby hydrodynamic forcings will represent contemporary conditions within the Rhine-Meuse Delta (RMD). Ecomorphological development (morphological and vegetation development, in 2DH) will be simulated for 1 year, to study the impact of a wetland scenario on development of the entire estuary and vice versa. A population dynamics approach is included to enable vegetation growth/expansion and decay. In succession, salt-intrusion (3D) is simulated during extreme events (3 days) with return periods of 1 year, representing storm surges, river droughts or a combination of both. Validation of hydrodynamics and morphology will be performed by quantitative comparison within the RMD for a 1 year simulation. Simulated wetland development (also 1 year) is compared with modelling studies on dynamic wetland vegetation.

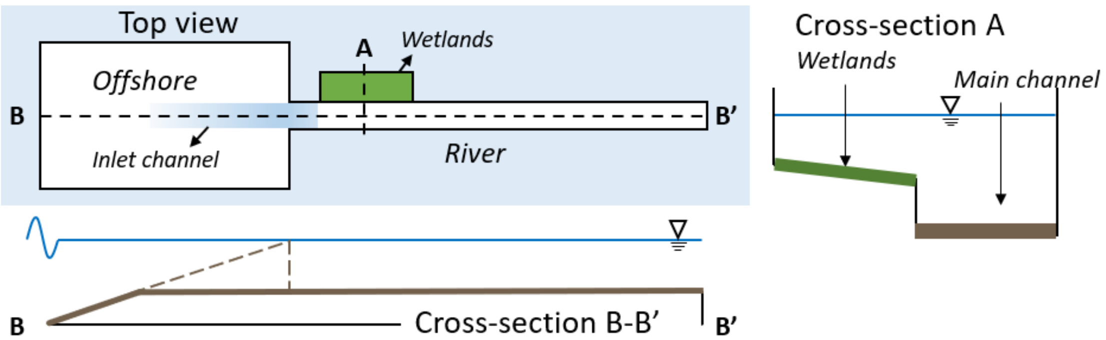

Figure: Schematic overview of the idealized estuarine model.

Next, CC impact on estuarine ecomorphology and salt-intrusion is assessed. The model is adjusted to represent future conditions by implementing CC projected hydrodynamic forcings and SLR modified bathymetry (Figure 2). Future simulations are performed of ecomorphology (1 year) and, in succession, salt intrusion during extreme events (3 days). These extreme events are also adjusted according to CC projections. The present day and future simulations are performed in parallel.

Expected results

- A modelling framework will be developed enabling us to predict the impact of a wide range of wetland scenarios on estuarine development and salt intrusion, under CC.
- Insights will be gained on estuarine wide development due to wetlands.
- Understanding on how this development affects salt intrusion will be improved.

The impact of climate change scenarios on Belgian coastal policy

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Introduction

Global climate changes are expected to affect local conditions like local water levels, waves and currents. Belgium has a 67 km long coastline with beaches, dunes, dikes, harbours and a variety of coastal defence structures like groynes and sea walls. The Belgian Coastal Policy focusses on 'soft solutions where possible and only hard structures where needed'. Based on the Masterplan Coastal Safety (www.https://afdelingkust.be/nl/masterplan-kustveiligheid), measures are currently implemented to withstand a sea level rise of 0.3 m in 2050, and 0.8 m in 2100. As the exact impact of climate change is unknow, there are various ways to deal with the uncertainty in sea level rise. Currently, the Flemish 'Complex Project Kustvisie' investigates the longterm effect of various climate scenarios on the coastal area and the subsequent possibilities for spatial use, measures and adaptations.

Methods

For a range of scenarios of sea level rise (SLR), with a maximum of 3 m, the impact on the local hydrodynamics is investigated. Possible adaptations are investigated and planned in an adaptive way. In later years (e.g. 2030 and 2050) the occurring conditions and new predictions will be used to adopt the coastal strategy.

Offshore conditions are transformed to nearshore conditions, combined with the occurring tides - which also change due to SLR. These local conditions are used in testing the current Belgian coastal defence, giving information on required extra dune volumes or strength of coastal defence structures. The space required to ensure coastal safety is combined with the space needed for other aspects like buildings, recreation, nature and economy. Solutions to meet the requirements for space are a combination of offshore constructions and measures on the beach and sea defences. An important aspect of these solutions are measures to reduce the offshore wave energy. The possibilities of solutions both offshore (reducing nearshore wave conditions) and nearshore are investigated for predefined sections of the coastline. This results in solutions strategies, which will be discussed with stake holders in order to come to preferred solutions. These will be designed in further detail at a later stage.

Results

The coastal area can be divided in several zones alongshore. Per zone the cross-shore impact and possibilities are investigated and discussed with stake holders. The location of the future coastline affects local functions and has implications for required coastal defence strategies (Figure 1). In the current project coastal engineers, spatial planners and policy makers collaborated to create a first set up for adaptive coastal management for the Belgian Coast, taking future changes into account. This process is ongoing.

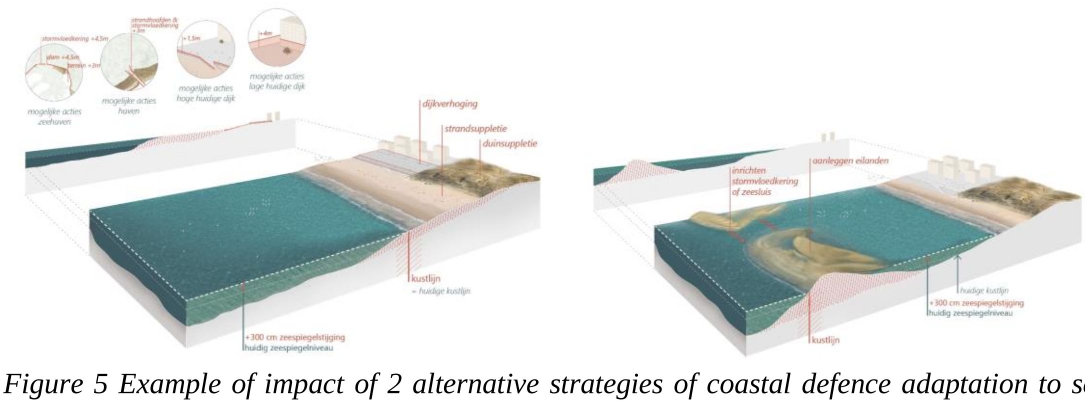

Figure 5 Example of impact of 2 alternative strategies of coastal defence adaptation to sea level rise.

Quantifying the resilience of seagrass to climate change: combining in situ wave erosion experiments with data driven modelling

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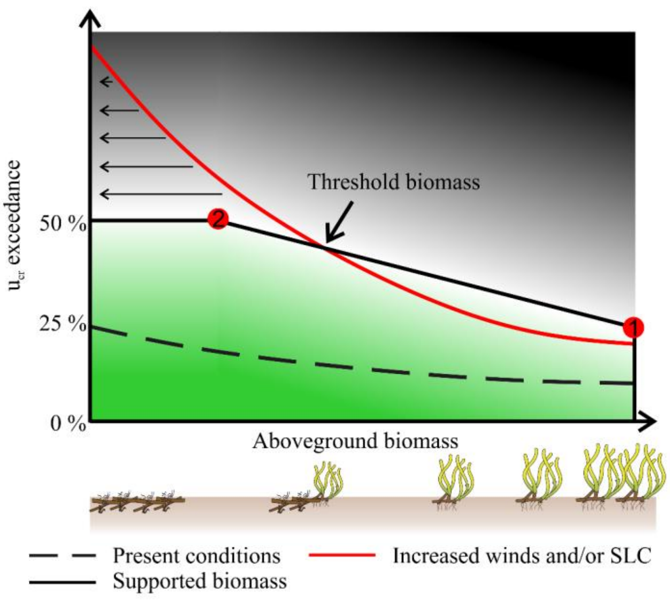
Introduction

Besides quantifying coastal protection services of nearshore biogenic habitats, there is also a need to quantify the persistence of these habitats under changing conditions in order to successfully implement Nature Based Solutions. Therefore we studied the stability of seagrass meadows. Seagrass meadows and bare sediment represent alternative stable states, with sediment resuspension dynamics being a key driver of system stability via the Seagrass – Sediment – Light (SSL) feedback. We explore the SSL feedback stability by quantifying the sediment stabilization by seagrasses, and using these measurements to calculate under which conditions seagrasses end up in a turbid environment.

Methods and results

We quantified sediment resuspension velocity thresholds (u_{cr}) in situ for a *Zostera marina* meadow growing in a sheltered bay in the Gullmars fjord in Sweden, using a field flume that induces near bed wave motion. u_{cr} was determined for three shoot lengths: full length, shoots clipped to 0.08m, and removed shoots, on both medium and fine sand. Comparing shoot removal with control measurements on bare sediment indicated that rhizomes did not influence u_{cr} of the top sediment layer. Overall, u_{cr} followed a positive linear relation with blade area, which was independent of sediment type when normalizing u_{cr} for the resuspension thresholds after shoot removal.

Comparing measured u_{cr} against calculated natural wave conditions showed that the seagrass meadow at the study site is presently not prone to light limitation. Changing the hydrodynamic conditions revealed that the effects of increasing storm frequency and magnitude only had a minor influence on the SSL feedback. Increasing average winds and lowering of the mean sea level, e.g. due to land uplift, had a much stronger influence. This was caused by the majority of turbidity events in the study site occurring under calm conditions, but with favourable wind direction. Increasing storm magnitude and lowering of the mean sea level however resulted in increasing differences between the turbidity levels of bare and vegetated sediments, increasing the bi-stability of the system and thereby increasing the risk of meadow collapse if biomass is reduced by other pressures.



Conceptual diagram showing how climate change can cause bi-stability and seagrass loss due to increased hydrodynamic pressure. The solid black line shows supported aboveground biomass under a given u_{cr} exceedance. Biomass starts to reduce at 25 % u_{cr} exceedance inside the seagrass meadow (point 1), and collapse occurs at 50 % u_{cr} exceedance (point 2). The dashed black and red line show the aboveground biomass – u_{cr} exceedance relations under present and potential future hydrodynamic conditions. Seagrass meadows become bi-stable when u_{cr} exceedance at zero biomass exceeds 50 %. Existing meadows may collapse at u_{cr} exceedance levels below 50 % due the nonlinear effect of biomass loss on u_{cr} exceedance.

Field observations of longshore transport on low-energy, non-tidal beaches

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Introduction

Hydrodynamic and morphological processes at low-energy or sheltered beaches can be significantly different compared to open, high-energy coasts. Ton et al. (2020) set up a conceptual model for morphological development of low-energy, sandy beaches in the cross-shore direction based on data from newly-constructed lake beaches. Next to this initial cross-shore profile readjustment, the data revealed additional sediment losses driven by gradients in the alongshore sediment transport rate. The goal of this research is to find out how longshore transports affect the sediment volume balance and how these transports are driven by hydrodynamic conditions typically found at low-energy coasts.

Results and Conclusion

Two densely monitored study sites at the Houtribdijk and the Marker Wadden, both located in the large shallow lake Markermeer, are used to study longshore transport in low-energy, non-tidal environments. In general both locations suffer from net erosion at the shoreline. At the Marker Wadden, sediment is deposited below 0.7 m below annual average water level over almost the whole length of the beach, except for coastline outcrop at -250 m (x-direction) (Fig. 1A). This beach experiences a net sediment loss, indicating longshore transport. Similar erosion around the shoreline is seen at the Houtribdijk, but the sedimentation below 0.7 m below annual water level is less uniformly distributed (Fig. 1B). Deposits occur mostly near the dams, also indicating longshore transport and possibly more intricate sediment transport patterns. By studying bathymetric surveys and corresponding hydrodynamic measurements, we deduced sediment transport pathways and their governing hydrodynamic conditions, showing the importance of wind and thus wave direction and external factors like dams.

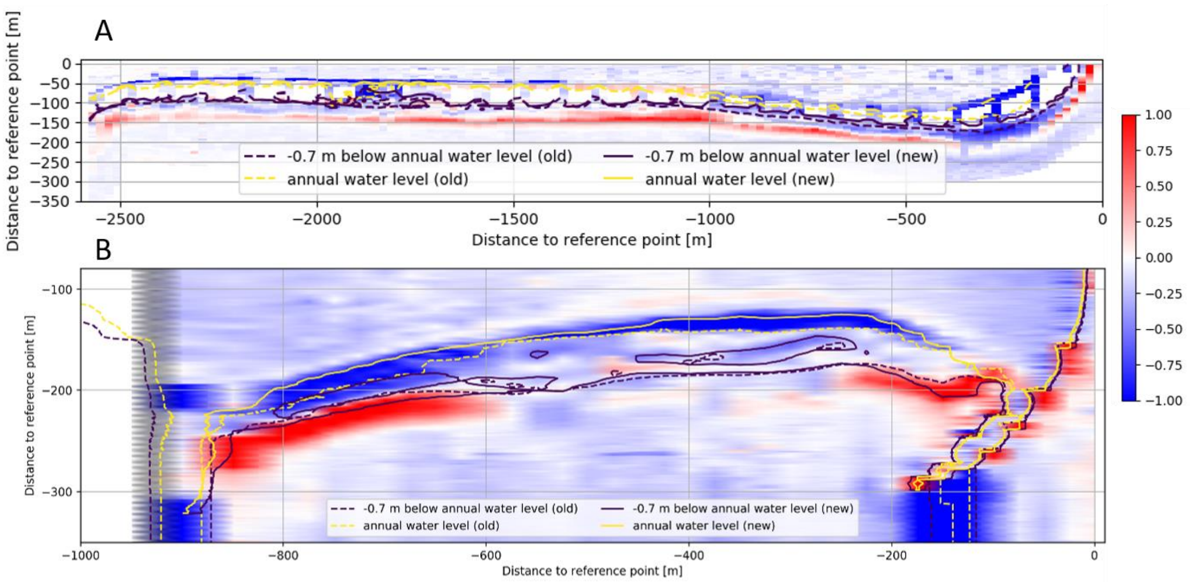

Figure 1: Sedimentation/erosion at Zuidstrand Marker Wadden (FL65), Oct 2019-Jul 2020 (A) and Houtribdijk (FL67), May 2019-Apr 2020 (B).

Acknowledgements

This research is part of the LakeSIDE project, which is funded by Rijkswaterstaat.

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Introducing the TRAILS project: Tracking Ameland Inlet Living lab Sediment

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Problem statement

Sand nourishment is now the preferred coastal management strategy in the Netherlands to prevent coastal erosion and drowning of intertidal areas of the Wadden Sea. Nourishments aim to enhance safety, while simultaneously promoting natural and recreational values. However, it is poorly understood how nourished sand is dispersed, and what the impacts are for diverse coastal functions like biodiversity, fisheries and safety.

Aim and objectives

The overall aim of our recently started TRAILS project is to develop, test and apply the instrumentation needed to predict effectiveness and off-site responses to (mega-)nourishments. Main objectives are:

- To create a fully operational Living Lab with all stakeholders to co-evaluate future nourishment strategies, based on a shared knowledge base (lead VHL).
- To develop and test novel luminescence-based methods to identify sand grains derived from a nourishment source and illuminate sediment pathways (lead WUR).
- To determine the effects of nourishments on benthic fauna, and identify and quantify the feedback mechanisms of the benthic community on sediment dispersal (lead NIOZ).
- To develop and test novel simulation approaches to trace pathways of different sediment types and predict sediment dispersal and morphodynamic responses to different nourishment strategies (lead TUDelft).
- To integrate insights gained from stakeholder, field and model approaches (lead Deltares).

We will focus on the recent Ameland inlet ebb-tidal delta nourishment (Fig. 1), which provides a unique opportunity to develop and test novel methods and to connect to stakeholders in this dynamic environment.

Funding and timeline

TRAILS is NWO funded through the ‘Living Labs in the Dutch Delta’ programme (Grant 17600). Research will be performed by two PhD candidates (WUR & NIOZ), a postdoc (TUDelft), their supervisors, and staff members of VHL and Deltares. The project has started late 2020 and is scheduled to be completed in 2025.

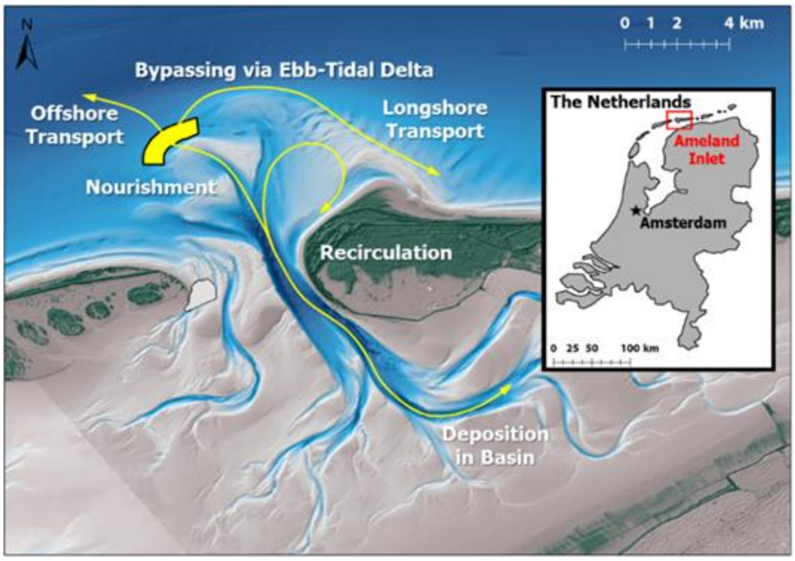

Figure: The location of the ebb-tidal delta nourishment within our Living Laboratory, with possible sediment transport pathways indicated.

Design optimization of a multifunctional floating breakwater

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Background

The attenuation of waves is essential to secure maritime operations and to protect coastal regions against erosion. Wave-attenuating breakwaters, which can be either fixed or floating, attenuate incident wave energy by means of wave reflection and/or wave dissipation through friction and wave breaking. Compared to fixed breakwaters, advantages of floating breakwaters include their applicability in more challenging environments (deep water, poor foundation), their reduced environmental impacts (minimum interference with water circulation and fish migration, minimum bottom disturbance, minimum visual intrusion), and their flexibility (can relatively easily be re-arranged) [1]. Disadvantages of are that their efficiency is typically limited for longer waves and that it is challenging to design a floating breakwater that is effective for a broad range of wave conditions. Within the present project, a new floating breakwater concept characterised by low hydrodynamic loads was developed.

Methods

The floater was designed for wave conditions typical for inland lakes or estuaries. In order to reduce the net hydrodynamics loads on the structure, the incident wave energy needs to be dissipated rather than reflected. An effective way to dissipate wave energy is wave breaking. The floating breakwater was therefore designed in the form of a parabolic beach that enforces incident waves to break. Within the project, first the floater was optimised through computational fluids dynamics (CFD) simulations. Next, a mooring layout was designed for shallow water conditions using wave diffraction and time domain simulation software. Finally, the design was tested in MARIN’s shallow water wave basin.

Figure: Waves breaking over the new floating breakwater design during scale model tests.

Results

Tests show that the breakwater reduces the incident wave energy by 40 to 80%. The breakwater is especially effective in attenuating relatively high waves, that are more likely to break, and relatively short waves, which are reflected. Compared to existing designs, the new breakwater design shows a more favourable balance between net wave loads on the structure and wave attenuation. The effect of additional surface roughness, representing, e.g., the effects of a grass or shellfish cover, was also tested. The additional roughness had little effect on the wave attenuation performance, but it did reduce the motions of the floater through an increased hydrodynamic damping.

Outlook

It is foreseen that the floating breakwater has potential as a stand-alone solution for shoreline protection, but also as a coupled module to reduce wave drift loads on larger floating structures (e.g., floating islands). The authors look forward to presenting the results at the NCK Days and are open for future collaborations.

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The Netherlands Centre for Coastal Research (NCK)

“Our network stimulates the cooperation and exchange of wisdom between coastal researchers from various research themes and institutes, making us all better.”

The Netherlands Centre for Coastal Research is a cooperative network of private, governmental and independent research institutes and universities, all working in the field of coastal research. The NCK links the strongest expertise of its partners, forming a true center of excellence in coastal research in The Netherlands.

Objectives

The NCK was established with the objectives:

- To increase the quality and continuity of the coastal research in the Netherlands. The NCK stimulates the cooperation between various research themes and institutes. This cooperation leads to the exchange of expertise, methods and theories between the participating institutes.
- To maintain fundamental coastal research in The Netherlands at a sufficiently high level and enhance the exchange of this fundamental knowledge to the applied research community.
- To reinforce coastal research and education capacities at Dutch universities.
- To strengthen the position of Dutch coastal research in a United Europe and beyond.

For more than 25 years, the NCK collaboration has stimulated the interaction between coastal research groups. It facilitates a strong embedding of coastal research in the academic programs and courses, attracting young and enthusiastic scientists. Several times a year, the NCK organizes workshops and/or seminars, aimed at promoting cooperation and mutual exchange of knowledge.

NCK is open to researchers from abroad and encourages exchanges of young researchers. Among the active participants are people from a lot of different institutes and companies.

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Historical context

Coastal research in The Netherlands has a long history. For many centuries, experience gained from the country's successes and failures in the struggle against the sea has been the major source of innovative knowledge. A more formal and systematic approach has developed over the last hundred years:

1920
An important step in the development of formalized knowledge was taken in the 1920s by the Nobel-prize laureate *Hendrik Lorentz*, who designed a computational scheme for assessing the tidal effects of the closure of the Zuiderzee. At the same time, with the founding of Delft Hydraulics, physical scale models became the favorite instrument for designing coastal engineering works. They remained so for a long time.

1953
The storm-surge disaster of 1953 provided a strong incentive for coastal research in support of the Delta Project, which entailed a drastic shortening of the Dutch coastline. The Delta Project profoundly affected the morphodynamics of the Rhine-Meuse-Scheldt delta; large parts of the system were transformed into what one might call a life-size hydraulic laboratory.

1965
In the 1960s, a monitoring program (JARKUS) was established to assess the evolution of the nearshore zone along the entire Dutch coast on a yearly basis. The resulting data base has revealed not only short-term fluctuations of the shoreline, but also large-scale structural trends. The JARKUS data set represents a key source of coastal information, particularly in combination with historical observations of Dutch coastline evolution that date back to 1840-1850. With no equivalent data set available worldwide, the unique JARKUS data base has inspired a wealth of coastal research programs throughout the years.

1985
The growing need for integrated coastal management during the second half of the 1980s triggered the development of a national coastal defense policy of 'Dynamic Preservation' (1990). It involved sustainable maintenance of the coast through 'soft' interventions (commonly nourishment of the beach and shoreface with sand taken from offshore), allowing for natural fluctuations. The basic principles were derived from a major research project for the systematic study of persistent trends in the evolution of the coastal system. This Coastal Genesis project - carried out by a multidisciplinary team of coastal engineers, physical and historical geographers and geologists - laid the ground for NCK.

1991
The successful multidisciplinary collaboration initiated during the Coastal Genesis project was institutionalized by means of the founding of the Netherlands Centre for Coastal Research (NCK). The NCK was initiated by the coastal research groups of Delft University of Technology, Utrecht University, WL | Delft Hydraulics and Rijkswaterstaat RIKZ. Early 1996, the University of Twente and TNO - Geological Survey of the Netherlands joined NCK (Deltares ‘inherited’ the Geological Survey Membership in 2008), followed by the Netherlands Institute for Sea Research (NIOZ, 1999), the Netherlands Institute for Ecology - Centre for Estuarine and Marine Ecology (NIOO-CEME, 2001), UNESCO-IHE Institute for Water Education (now IHE Delft Institute for Water Education, 2004) and Wageningen IMARES (now Wageningen University and Research, 2008). In 2017, the Geological Survey of the Netherlands rejoined NCK.

The NCK partners

TNO
Geological Survey of the Netherlands

The Netherlands Organisation for Applied Scientific Research (TNO) is a nonprofit company in the Netherlands that focuses on applied science. Established by law in 1932, TNO is a knowledge organization supporting companies, government bodies and public organizations with innovative, practicable knowledge. With 2,800 employees, it is the largest research institute in the Netherlands. The government has assigned various tasks to TNO in respect of information on the Dutch subsurface. TNO acts (internationally) as the Geological Survey of the Netherlands, which manages and models publicly available geological data and information. Its core expertise is the construction of voxel-based subsurface models that are highly suitable as input for decision-support systems. In addition, TNO has the legal task of making information on the Dutch subsurface available to Dutch society so as to enable the sustainable use and management of the subsurface and the mineral resources it contains. This information is needed to organizate the space above and below ground in a sustainable way.

More information
https://www.tno.nl/en/

Representatives
NCK Board of Supervisors: D. Maljers MSc
NCK Program Committee: S. van Heteren PhD

Delft University of Technology
Faculty of Civil Engineering and Geosciences

The Faculty of Civil Engineering and Geosciences is recognized as one of the best in Europe, with a particularly important role for the Department of Hydraulic Engineering. This department encompasses the Sections Fluid Mechanics and Hydraulic Engineering. Over the years, both have gained an internationally established reputation, in fluid dynamics in general; in coastal dynamics; in the fields of coastal sediment transport, morphology, wind waves, coastal currents. Mathematical, numerical modelling and experimental validation of these processes is at the forefront internationally. Recently, the development of field expertise has been an important focal point.

More information
http://www.citg.tudelft.nl/over-faculteit/afdelingen/hydraulic-engineering/

Representatives
NCK Directory Board: prof. S.G.J. Aarninkhof PhD
NCK Program Committee: B.C. van Prooijen PhD

Deltares
Applied research in water, subsurface and infrastructure

WL | Delft Hydraulics, GeoDelft, the Subsurface and Groundwater unit of TNO and parts of Rijkswaterstaat joined forces in January 2008 to form a new independent institute for delta technology, Deltares. Deltares conducts applied research in the field of water, subsurface and infrastructure. Throughout the world, we work on smart solutions, innovations and applications for people, environment and society. Our main focus is on deltas, coastal regions and river basins. Managing these densely populated and vulnerable areas is complex, which is why we work closely with governments, businesses, other research institutes and universities at home and abroad.

Enabling Delta Life
Our motto is Enabling Delta Life. As an applied research institute, the success of Deltares can be measured in the extent to which our expert knowledge can be used in and for society. For Deltares the quality of our expertise and advice is foremost. Knowledge is our core business. All contracts and projects, whether financed privately or from strategic research budgets, contribute to the consolidation of our knowledge base. Furthermore, we believe in openness and transparency, as is evident from the free availability of our software and models. Open source works, is our firm conviction. Deltares employs more than 800 people and is based in Delft and Utrecht.

More information
http://www.deltares.nl/en

Representatives
NCK Board of Supervisors: D.J. Walstra PhD
NCK Program Committee: prof. D.S. van Maren PhD, B. Huisman PhD

IHE Delft Institute for Water Education

IHE Delft Institute for Water Education is the largest international graduate water-education facility in the world and is based in Delft, the Netherlands. The Institute confers fully accredited MSc degrees, and PhD degrees in collaboration with partner universities. Based in Delft, it comprises a total of 140 staff members, 70 of whom are responsible for the education, training, research and capacity building programs both in Delft and abroad. It is hosting a student population of approximately 300 MSc students and some 60 PhD candidates. UNESCO-IHE is offering a host of postgraduate courses and tailor-made training programs in the fields of water science and engineering, environmental resources management, water management and institutions and municipal water supply and urban infrastructure. UNESCO-IHE, together with the International Hydrological Programme, is the main UNESCO vehicle for applied research, institutional capacity building and human resources development in the water sector world-wide.

After having been in existence for more than 50 years, IHE was officially established as a UNESCO institute on 5 November 2001 during UNESCO's 31st General Conference. Recently, IHE Delft signed a partnership agreement with UNESCO for the transition period from 2017 to mid-2018 when a decision on its category 2 status is expected. As from 1st January 2017, IHE Delft Institute for Water Education (formerly UNESCO-IHE) operates as a Foundation under Dutch law, working in in partnership with UNESCO. Throughout this period and once the new status is obtained, the Institute will continue to cooperate closely with the UNESCO Secretariat, the Science Sector and the International Hydrological Programme (IHP), and the Institute will remain a flagship institute in the UNESCO Water Family.

More information
https://www.unesco-ihe.org/

Representatives
NCK Board of Supervisors: J.A. van Dijk PhD
NCK Programme Committee: M. van der Wegen PhD

NIOZ
Royal Netherlands Institute for Sea Research

NWO-NIOZ Royal Netherlands Institute for Sea Research is the national oceanographic institute and principally performs academically excellent multidisciplinary fundamental and frontier applied marine research addressing important scientific and societal questions pertinent to the functioning of oceans and seas. Second, NIOZ serves as national marine research facilitator for the Dutch scientific community. Third, NIOZ stimulates and supports multidisciplinary fundamental and frontier applied marine research, education and marine policy development in the national and international context. The Netherlands Institute for Sea Research (NIOZ) aspires to perform top level curiosity-driven and society-inspired research of marine systems that integrates the natural sciences of relevance to oceanology. NIOZ supports high-quality marine research and education at universities by initiating and facilitating multidisciplinary and sea-going research embedded in national and international programs. We aim to generate the expertise and fundamental knowledge needed to underpin and improve longer-term sustainable and responsible marine management.

More information
www.nioz.nl/home_en.html

Representatives
NCK Board of Supervisors: prof. H. Brinkhuis PhD
NCK Program Committee: T. Gerkema PhD, prof. T.J. Bouma PhD

Rijkswaterstaat
Water, Traffic and Environment

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

As the executive body of the Ministry of Infrastructure and Water Management, Rijkswaterstaat manages the Netherlands' main highway and waterway network. Rijkswaterstaat takes care of the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. Its employees are responsible not only for the technical condition of the infrastructure, but also for its user-friendliness. Smooth and safe traffic flows, a safe, clean and user-friendly national waterway system and protection from flooding: that is what Rijkswaterstaat is about.

Participation in NCK

The participation of Rijkswaterstaat in NCK is covered by the service Water, Traffic and Environment (WVL). WVL develops the vision of Rijkswaterstaat on the main highway and waterway network, as well as the interaction with our living environment. WVL is also responsible for the scientific knowledge that Rijkswaterstaat requires to perform its tasks, now and in the future. As such, Rijkswaterstaat - WVL works closely with knowledge institutes. By participating in joint ventures and forming strategic alliances with partners from the scientific world, WVL stimulates the development of knowledge and innovation with and for commercial parties.

More information

http://www.rijkswaterstaat.nl/en/

Representatives

NCK Board of Supervisors: K. Portegies MSc
NCK Program Committee: G. Ramaekers MSc

University of Twente
Civil Engineering & Management

UNIVERSITY
OF TWENTE.

Since 1992, the University of Twente has had an educational and research program in Civil Engineering, which aims at embedding (geo)physical and technical knowledge related to infrastructural systems into its societal and environmental context. The combination of engineering and societal faculties makes the university particularly well equipped to run this program. Research of the section Water Engineering and Management (WEM) focuses on i) physics of large, natural, surface-water systems such as rivers, estuaries and seas; and ii) analysis of the management of these systems. Within the first research line WEM aims to improve the understanding of physical processes and to model their behavior appropriately, which means as simple as possible but accurate enough for the water-management problems that are considered. Dealing with uncertainty plays an important role here. An integrated approach is central to the water-management analysis, in which we consider not only (bio)physical aspects of water systems, but also the variety of functions these systems have for the users, the way in which decisions on their management are taken, and the translation of these decisions into practical applications. Various national and international research projects related to coastal zone management, sediment transport processes, offshore morphology, biogeomorphology and ecomorphodynamics have been awarded to this section.

More information
http://www.utwente.nl/ctw/wem/

Representatives
NCK Board of Supervisors: prof. K.M. Wijnberg PhD
NCK Program Committee: P.C. Roos PhD

Utrecht University
Institute for Marine and Atmospheric Research Utrecht IMAU

Universiteit Utrecht

The Institute for Marine and Atmospheric research Utrecht (IMAU) is hosted partly at the Faculty of Science and partly at the Faculty of Geosciences. The Institute's main objective is to offer an optimal, stimulating and internationally oriented environment for top quality fundamental research in Climate Dynamics and Physical Geography and Oceanography of the coastal zone, by integrating theoretical studies and extensive field studies. IMAU focuses on the hydrodynamics and morphodynamics of beaches and surf zones, shoreface and shelf, as well as on the dynamics of river deltas, estuarine systems and barrier islands. Research in coastal and shelf sea dynamics focuses on the interactions between the water motion, sediment transport and bottom changes in coastal seas and estuaries. Both sandy and mud-dominated coastal systems are investigated. The following approaches are used to gain more understanding of hydrodynamic and morphodynamic processes: collection and analysis of field observations, simulations with complex numerical models and interpretation of these results, development and analysis of idealized mathematical models. The Faculty of Geosciences studies the Earth: from the Earth's core to its surface, including man's spatial and material utilization of the Earth – always with a focus on sustainability and innovation.

More information
http://www.uu.nl/faculty/geosciences/EN/Pages/default.aspx
http://imau.nl/

Representatives
Board of Supervisors: prof. P. Hoekstra PhD
NCK Program Committee: M. van der Vegt PhD

Wageningen Marine Research

Wageningen Marine Research (WMR) explores the potential of marine nature to improve the quality of life. It is the Netherlands research institute established to provide the scientific support that is essential for developing policies and innovation in respect of the marine environment, fishery activities, aquaculture and the maritime sector. We conduct research with the aim of acquiring knowledge and offering advice on the sustainable management and use of marine and coastal areas. WMR is an independent, leading scientific research institute. We carry out scientific support to policies (50%), strategic RTD programmes (30%) and contract research for private, public and NGO partners (20%). Our key focal research areas cover marine ecology, environmental conservation and protection, fisheries, aquaculture, ecosystem-based economy, coastal zone management and marine governance. WMR primarily focuses on the North Sea, the Wadden Sea and the Dutch Delta region. It is also involved in research in coastal zones, polar regions and marine tropical areas throughout the world and in specific freshwater research. WMR has some 200 people active in field surveys, experimental studies, from laboratory to mesocosm scale, modelling and assessment, scientific advice and consultancy. Our work is supported by state-of-the-art in-house facilities that include specialist marine analysis and quality labs, outdoor mesocosms, specific field-sampling devices, databases and models. The Wageningen Marine Research quality system is ISO 9001 certified.

More information
http://www.wur.nl/en/Expertise-Services/Research-Institutes/marine-research/about-us.htm

Representatives
NCK Board of Supervisors: J. Asjes MSc
NCK Program Committee: M. Baptist PhD