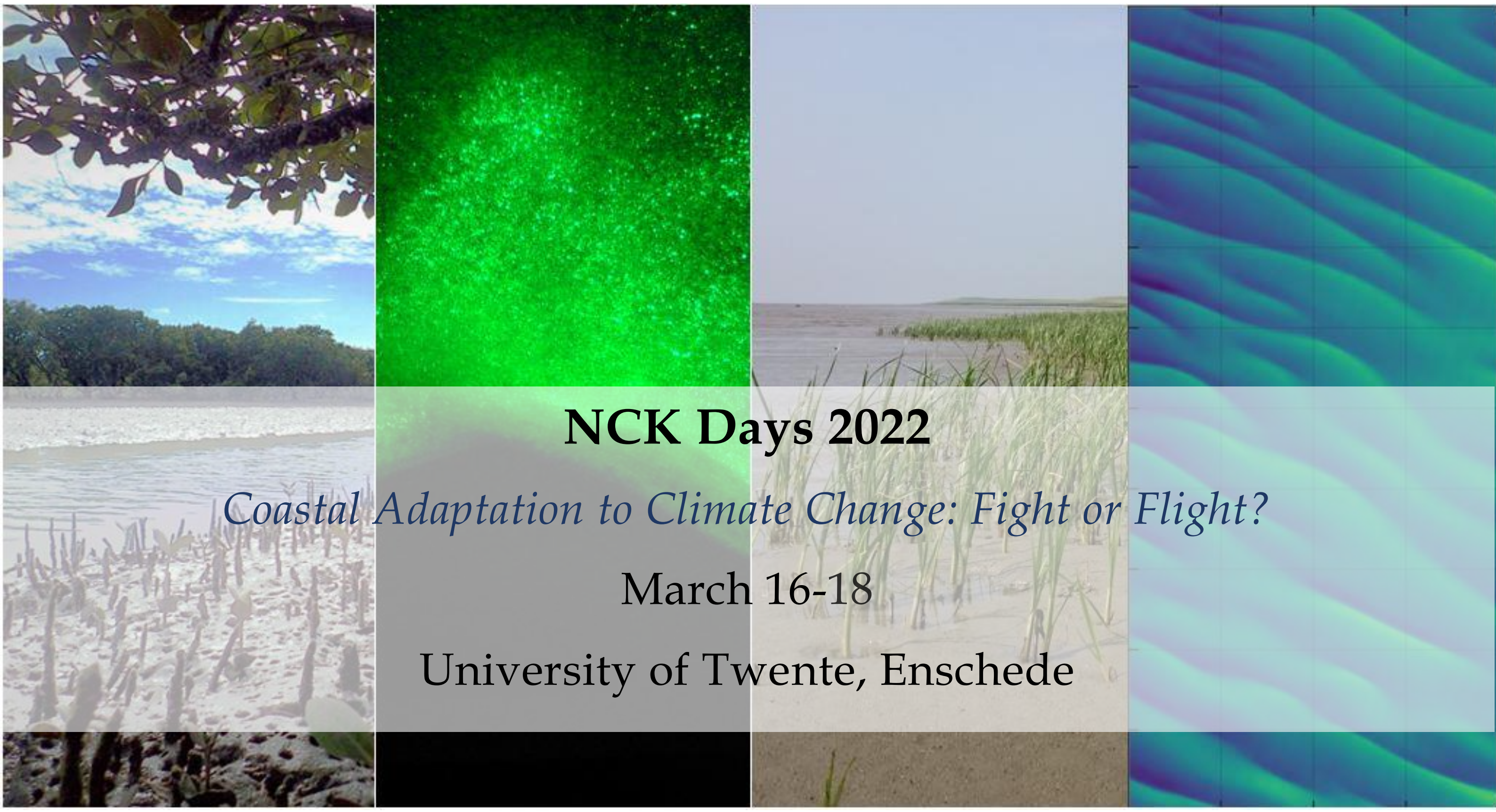
netherlands centre for coastal research

Book of Abstracts



NCK Days 2022

Coastal Adaptation to Climate Change: Fight or Flight?

March 16-18

University of Twente, Enschede

Organized by

UNIVERSITY OF TWENTE.

These NCK Days are supported by:

Contents

Preface

On behalf of the Water Engineering and Management (WEM) department of the University of Twente we warmly welcome you to the NCK days 2022 in Enschede!

This year's meeting is a special edition for two reasons. It is the first real-life NCK conference after the last-minute cancellation in 2020 and the 2021 online-edition, related to the COVID-19 pandemic. Furthermore, we celebrate the 30th anniversary of the Netherlands Centre for Coastal Research. The FC Twente football stadium offers the perfect conference venue for this special event.

The past is honored during the field trip (Wednesday 16 March). We will visit the Waterloopbos that used to be a famous open air laboratory, in which WL|Delft Hydraulics (now Deltares) developed and tested many hydraulic structures, including the Delta works. We will also visit the Schokland UNESCO World Heritage site, which is a former island in the Zuiderzee.

The future is reflected in the theme of the NCK Days 2022 'Coastal Adaptation to Climate Change: Fight or Flight?' and through the 34 oral and 38 poster presentations by mainly young coastal researchers.

We have invited three keynote speakers who will address the conference theme from different angles. On Thursday (17 March), Ad van der Spek will kick-off with a reflection on the History & Future of the NCK. The same day, Alice Lefebvre will present the latest insights into the geomorphology of subaqueous dunes, which is crucial to construct offshore wind farms, enabling the energy transition. On Friday (18 March), Gonéri le Cozannet will discuss the conference theme from the perspective of the IPCC 6th Assessment report.

We would like to thank the following organizations for sponsoring the NCK days 2022: NWO, JM Burgerscentrum, Arcadis, Boskalis, HKV, Nortek, Svašek Hydraulics, Waddenacademie & Waterproof.

We truly hope that you will enjoy these NCK days and that this meeting will reinforce the collaborations within the NCK community and will strengthen the productivity of Dutch coastal research.

The organizing committee,

Weiqiu Chen
Johan Damveld
Trang Duong
Erik Horstman
Dominique van der Meché
Anke Wigger-Groothuijs
Pim Willemsen
Jebbe van der Werf

UNIVERSITY OF TWENTE.
Water Engineering & Management

Enschede, March 2022

About NCK

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 centre 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 sufficient 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 20 years, the NCK collaboration continues to stimulate the interaction between coastal research groups, which in the past had often worked more isolated. It facilitates a strong embedding of coastal research in the academic programmes and courses, attracting young and enthusiastic scientists to the field of coastal dynamics. Several times a year, the NCK organises workshops and/or seminars, aimed at promoting cooperation and mutual exchange of knowledge. NCK is open to researchers from abroad and exchanges of young researchers are encouraged. Among the active participants we often find people from a lot of different institutes and companies.

Organisation

The NCK Programme Committee establishes the framework for the activities to be organised by NCK. These include for instance the theme for the annual coastal symposium ("The NCK Days") and the topics for the seminars ("Theme days"). The Programme Committee gathers twice a year. Since 1998 a part-time Programme Secretary has been appointed. The Programme Secretary is also the main contact person for the NCK.

As of April, 2020, the NCK Programme Committee consists of:

- B.C. van Prooijen PhD. (Delft University of Technology, Chairman)
- J. Vroom MSc. (Programme Secretary NCK, c/o Deltares)
- G. Ramaekers MSc. (Rijkswaterstaat)
- B. Huisman PhD. (Deltares)
- D.S. van Maren PhD. (Deltares)
- P.C. Roos PhD. (University of Twente)
- T. Gerkema PhD. (Royal Netherlands Institute for Sea Research, NIOZ)
- M. van der Wegen PhD. (IHE Delft)

- M.J. Baptist PhD. (Wageningen Marine Research)
- M. van der Vegt PhD. (Utrecht University – IMAU)
- S. van Heteren PhD. (TNO Geological Survey of the Netherlands)

The NCK Programme Committee and the Programme Secretary are supervised by the NCK Directory Board. As of April 2020, the Directory Board consists of:

- D.J. Walstra PhD. (Deltares, Chairman)
- J. Vroom MSc. (Programme Secretary NCK, c/o Deltares)
- M.E. Busnach-Blankers MSc. (Rijkswaterstaat)
- prof. S.G.J. Aarninkhof PhD. (Delft University of Technology)
- prof. P. Hoekstra PhD. (Utrecht University - IMAU)
- prof. K.M. Wijnberg PhD. (University of Twente)
- prof. H. Dolman PhD. (Royal Netherlands Institute of Sea Research NIOZ)
- prof. J.A. van Dijk PhD. (IHE Delft)
- J. Asjes MSc. (Wageningen Marine Research)
- D. Maljers MSc. (TNO Geological Survey of the Netherlands)

NCK partners

The Netherlands Centre for Coastal Research is a cooperation between the following partners:

Every partner has a representative in the Programme Committee and the Directory Board.

Historical Context

Ad van der Spek & Jebbe van der Werf

Coastal research in The Netherlands has a long history. For many centuries, experience gained from the 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 (1927, now Deltares), 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 nearshore evolution along the entire Dutch coast on a yearly basis. The resulting data base has revealed not only short-term shoreline fluctuations, 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.

1980
The growing need for integrated coastal management during the second half of the 1980s as well as the impact of the hurricane on 25th of January and the violent storm on 26th of February 1990 triggered the national coastal defense policy '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 that systematically studied 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.

1992
The NCK was initiated by the coastal research groups of Delft University of Technology (TUD), Utrecht University (UU), WL | Delft Hydraulics (now Deltares) and Rijkswaterstaat RIKZ. Early 1996, the University of Twente (UT) and *Rijks Geologische Dienst* (later: TNO-NITG, TNO - Geological Survey of the Netherlands) joined NCK (Deltares 'inherited' the TNO - 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; now part of NIOZ), IHE Delft Institute for Water Education (2004) and IMARES (now Wageningen University and Research, 2008). In 2016, the TNO - Geological Survey of the Netherlands rejoined NCK.

2011

In 2011 the Sand Motor pilot mega-nourishment was constructed between Ter Heijde and Kijkduin, South Holland coast. The Sand Motor is a 128 ha hook-shaped peninsula, spanning 2.4 km along the coastline and extending up to 1 km offshore, with a total nourishment volume of 21.5 million m^3. It was created following the principles of Building with Nature: currents, wind and waves are gradually spreading the sand along the coast and into the dunes. Many researchers from various universities and knowledge institutes have been closely monitoring the development of the Sand Motor since its construction. As such, it is an important driver for coastal research and innovative coastal maintenance.

The table below gives a time line of the NCK in general, and the NCK days in particular since 1991. It is incomplete; additions very much welcome!

Year	Organizer	Venue	Excursion	Specials
1991-1995	Various meetings, workshops & symposiums			NCK initiated by Rijkswaterstaat RIKZ, TUD, UU & WL | Delft Hydraulics, fall 1991 NCK officially founded on 11 August 1992
1996	RIKZ	Stadskasteel Oudaen, Utrecht		Rijks Geologische Dienst & UT joined NCK First official NCK days!
1997-1999	various	Zandvoort		NIOZ joined NCK
2000	TNO-NITG	Zandvoort		
2001	NIOZ	Texel		NIOO-CEME joined NCK
2002	TUD	Vlissingen		10th anniversary NCK! Start of tradition: NCK days in March
2003	NIOZ	Texel		
2004	NIOO-CEME	Yerseke		UNESCO-IHE joined NCK
2005	UT	Enschede		
2006	IHE	Kijkduin		
2007	NCK	IJmuiden		3rd NCK lustrum!
2008	Deltares	Delft	Prinsenhof, TUD experimental facilities	WUR joined NCK
2009	WUR	Texel	De Hors	
2010	UU	Westkapelle	Het Zwin	
2011	NIOZ	Texel		
2012	UT	Enschede	Ems-Dollard estuary	20th anniversary NCK!
2013	TUD	Kijkduin	Sand Motor	
2014	IHE	Delft	Maasvlakte-2	Mini Symposium in honor of Jan Mulder’s retirement

2015	RWS	Schoorl	Hondbossche & Pettemer Dunes	
2016	Deltares	Brouwersdam	Westenschouwen	TNO - Geological Survey of the Netherlands rejoined NCK
2017	WUR	Royal Netherlands Naval Institute, Den Helder	Boat trip Marsdiep, Razende Bol	5th NCK lustrum!
2018	TNO-Geological Survey of the Netherlands	Teylers Museum, Haarlem	Geological walk through Haarlem	100-year geological mapping anniversary
2019	UU	Zuiderzeemuseum, Enkhuizen	Marker Wadden	First time no hard copy Book of Abstracts
2020	NIOZ	Texel	Prins Hendrik Zanddijk	Last-minute cancelled due to Covid19
2021	NIOZ & UT	online		First (and hopefully last) online event

Program NCK Days 2022

Wednesday 16 March 2022		
Excursion: Waterloopbos & Schokland		
08:00	Meeting at Railway station Enschede Kennispark	
08:15	Bus departs from Enschede Kennispark	
09:45	Meeting at railway station Zwolle Centraal zuidzijde (Hanzelaan in front of grand café Lubeck)	
10:00	Bus departs from Zwolle Centraal	
10:30	Arrival Waterloopbos (Voorsterweg 34, Marknesse)	
13:15	Lunch (at Proeflab)	
14:15	Bus departs from Waterloopbos	
14:30	Arrival Schokland (intersection Vluchthavenpad/Oude Emmeloorderweg, Schokland)	
16:30	Bus departs from Schokland	
18:00	Arrival Enschede Kennispark	
20:00-22:00	**Ice-breaker** *Stanislaus Brewskovitch, Stadsgravenstraat 59, Enschede*	
Thursday 17 March 2022		
08:30-09:15	**Registration**	
09:15-09:30	**Opening** *Suzanne Hulscher & Jebbe van der Werf*	
09:30-10:00	**Keynote 1: History & Future of NCK** *Ad van der Spek (Deltares & Department Physical Geography, Utrecht University)*	
10:00-10:05	**Poster Session 1 - Intro**	
10:05-11:00	**Poster Session 1 & Coffee Break**	**Page**
1 A classification of salt transport regimes in narrow estuaries, with application to the Rotterdam Waterway ***Yoeri Dijkstra***		53
2 Barrier islands face a gradual path toward drowning under most sea level rise scenarios ***Laura Portos-Amill***		54
3 How turbating lugworms and stabilizing seagrasses shape the morphology of a Wadden Sea tidal basin ***Sanne Vaassen***		55
4 Assessing short-term estuarine development after large-scale interventions: An idealised model study ***Rutger Siemes***		56
5 Settings of exploratory process-based modelling of estuarine sand dunes ***Dieuwke Maas***		57
6 Benthos-sand interactions in the context of an ebb-tidal delta nourishment ***Tjitske Kooistra***		58
8 Quantification of morphological changes on ebb-tidal deltas using satellite derived bathymetry ***Feliks Raap***		59
9 Modeling mud-induced wave damping with Delft3D and SWAN-Mud ***Bram Loef***		60

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14:12-14:24	New Techniques for Mapping Ebb-Tidal Delta Morphodynamics and Stratigraphy ***Stuart Pearson***	26
14:24-14:36	How is the cross-shore shape of tidal flats affected by accommodation space, hydrodynamic and sediment characteristics? ***Jill Hanssen***	27
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15:42-15:54	Field observations and model simulations of longshore transport on low-energy, non-tidal beaches in lake Markermeer ***Anne Ton***	31
15:54-16:06	Large-scale laboratory experiments: Beach slope influence on sediment transport processes in the swash zone at event scale ***Sara Dionisio Antonio***	32
16:06-16:18	Depth-resolved modelling of water and sediment fluxes in the swash zone ***Joost Kranenborg***	33
16:18-16:30	Unravelling 10 years morphology of the Sand Motor and Delfland coast ***Bas Huisman***	34
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18:00-21:00	**Dinner**	
Friday 18 March 2022		
08:30-09:00	**Registration**	
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09:12-09:24	The fate of sediment from source to sink in two different tidal flat environments ***Jianwei Sun***	36
09:24-09:36	Lagrangian transport time scales in the Dutch Wadden Sea: variability due to wind forcing ***Jeancarlo Fajardo Urbina***	37

17 Storm surges in an idealized tidal channel: a power criterion for the unsteady bed shear stress ***Giordano Lipari***		87
19 Development of luminescence imaging to trace Wadden Sea nourishment sand ***Anna-Maartje de Boer***		88
20 Wide Green Dike (WGD) concept for grass revetment under coastal conditions ***Henrike Maris***		89
21 What are ecological and societal benefits of different coastal nature-based solutions? ***Annelies Boerema***		90
11:00-11:30	**Keynote 3: Coastal adaptation to climate change and sea-level rise: what is new in the IPCC 6th Assessment report?** *Gonéri le Cozannet (BRGM, French Geological Survey)*	
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12:18-12:30	Modelling sediment dynamics around buildings in a cellular automaton model ***Daan Poppema***	44
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13:42-13:54	Exploring System-based Nourishment Strategies for Texel Southwest ***Stefan Pluis***	46
13:54-14:06	The influence of foreshore dimensions on dike breach consequences: a flume study ***Kim van den Hoven***	47
14:06-14:18	The wave overtopping flow over grass-covered flood defences ***Vera van Bergeijk***	48
14:18-14:30	Enabling dynamic modelling of global coastal flooding by defining storm tide hydrographs ***Job Dullaart***	49
14:30-14:42	Improvements and validation of XBeach for the safety assessment of the Dutch coast: Part 1, hydrodynamics ***Robert McCall***	50
14:42-14:54	Improvements and validation of XBeach for the safety assessment of the Dutch coast: Part 2, morphodynamics ***Robbin van Santen***	51
15:00-15:30	**Closure & Awards**	
15:30-16:30	**Drinks**	

Conference locations

1. Accommodation

Fletcher Hotel De Broeierd
Hengelosestraat 725, Enschede
www.fletcherhotelenschede.nl
Located close to the conference venue!
- a 10-minute walk to the venue

Upark Enschede
De Veldmaat 8, Enschede
Located on UT campus!
https://www.uparkhotel.nl/nl

Intercity hotel Enschede
Willem Wilminkplein 5, Enschede
Located in town, next to the railway station!
- direct trains to the conference venue (10 min)
https://www.intercityhotel.com/nl/hotels/alle-hotels/nederland/enschede/intercityhotel-enschede

2. Ice-breaker

The icebreaker will take place at Stanislaus Brewskovitch, Stadsgravenstraat 59 (https://www.stanislausbrewskovitch.nl/) in Enschede. This venue is in walking distance from the Enschede railway station.

3. Conference venue + Dinner

The NCK days 2022 will take place in Hatrans Plaza in the Grolsch Veste (https://fctwente.nl/de-grolsch-veste/), Colosseum 65 in Enschede. The conference venue is conveniently located next to the Enschede Kennispark railway station. The dinner will also take place in the Grolsch Veste.

Excursion

On Wednesday we will visit two exciting locations that give an insight in the history of the NCK and the water engineering practice in the Netherlands in general.

The first part of the excursion will be at the 'Waterloopbos'. This was the famous open air laboratory, in which WL|Delft Hydraulics have developed and tested many different hydraulic structures, such as the Delta works. After a delicious lunch (included), a guided tour by former employees of the laboratory will show us all the old scale models in the forest.

The tour starts around 10:00 am at the NS station Zwolle, where you will be picked up. After the tour we will drive directly towards Enschede. We aim to be in Enschede well on time for dinner, and the icebreaker.

The second stop will be at the Schokland World Heritage site, which is an former island in the middle of the Noordoostpolder. A guided tour will show us the geological, archaeological and ecological remnants of the former island.

Keynote speakers

Dr. Ad van der Spek

Deltares & Department Physical Geography, Utrecht University

Dr. Ad van der Spek is a senior marine geologist specialising in long-term coastal morphodynamics. He has been working with Deltares, TNO and the Geological Survey of The Netherlands RGD for over 30 years, e.g., on reconstructing the Holocene coastal evolution of The Netherlands, and participated in both national and international research projects. He represented Deltares in the Netherlands Centre for Coastal Research NCK and works as senior researcher at the Physical Geography department of Utrecht University. He is lecturing and supervising PhD and MSc students at Utrecht University, UNESCO-IHE and the Coastal Engineering Section of Delft University of Technology. His research supports the Dutch national coastal nourishment policy and he is a member of the Netherlands Expertise Network for Flood Protection ENW. His research interests include coastal sedimentology, long-term coastal morphodynamics, reconstruction of coastal evolution, dynamics of beach barriers and tidal basins, seabed dynamics, biogeomorphology and large-scale catchment-to-coast sediment budgets.

Keynote 1: History and future of NCK

This year we celebrate 30 years of NCK. NCK was founded to continue the fruitful collaboration in coastal research in the Netherlands that was established by the Kustgenese project in the 1980’s and 1990’s. Looking back, we can conclude that it has been successful in that and hopefully we can continue this in the coming decades. The presentation will address the history of coastal research in the Netherlands and our present position, and will sketch an impression of the future.

Dr. Alice Lefebvre

MARUM, University of Bremen, Germany

Dr. Lefebvre research focusses on the interaction between hydrodynamics, geomorphology and sediment dynamics with a particular interest on bedforms. Alice studied geology and oceanography at the University of Bordeaux (France) and Southampton (UK). In 2009, she received a PhD in coastal oceanography at the National Oceanography Center, Southampton. Since then, she has been working at MARUM – Center for Marine Environmental Sciences, University of Bremen, Germany. Her primary interest is the complex interaction between hydrodynamics and large dune fields, in rivers, estuaries, tidal inlets and shallow continental shelves. For this, she has worked with field data and numerical modelling.

Dr. Alice Lefebvre is also a mother of 3 children. Through her position in the collective of Equal Opportunities Officers at MARUM, she promotes principles of Equity, Diversity and Inclusion.

Keynote 2: Geomorphology of subaqueous dunes

The talk will focus on dunes found in shallow waters (rivers, estuaries, tidal inlets and continental shelves). Using examples of her research, Alice will describe how dunes interact with the flow, creating varying morphologies, and why it is relevant to study them.

Dr. Le Cozannet (Gonéri)
BRGM (French Geological Survey), France

Gonéri Le Cozannet is research engineer at BRGM, the French Geological Survey, since 2006. His main research interest focusses on the impacts of sea-level rise and climate change for coastal risks, including erosion and flooding. He currently coordinates the H2020-CoCliCo project, aiming at establishing a broad scale climate service for adaptation to future coastal flood risks in Europe. He is Lead Author of the 6th assessment report of the IPCC (Working Group 2 on impacts, vulnerability and adaptation).

Keynote 3: Coastal adaptation to climate change and sea-level rise: what is new in the IPCC 6th Assessment report?

Sea-level rise and climate change represent a major threat for coastal communities and ecosystems during the 21st century and beyond. The 6th assessment report of the IPCC represents a major update in this area. For the first time, WG1 extended medium confidence sea-level projections up to 2150 and delivered low-likelihood scenarios involving a collapse of the Antarctic ice-sheet. Furthermore, WG1 reassessed related hazards such as high-tide and coastal flooding, salinization, erosion and land losses, and WG2 focused on impacts, vulnerability and adaptation to changing coastal risks. This presentation will build upon these reports to propose research avenues relevant to coastal adaptation.

Abstracts of oral presentations

Of the NCK Days 2022

Initial development of an artificial dune:
Dune-in-front-of-a-dike site Ostend Oosteroever - Belgium

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Introduction

During strong wind conditions, wind-blown sand accumulates on the local Spinoladijk, blocking an important access road to a leisure beach club. Cleaning this dike is labour-intensive, expensive and unsustainable. To mitigate the sand nuisance, a dune-in-front-of-a-dike solution was implemented. The traditional sea dike is strengthened with the aid of a nature-based solution by creating an artificial dune seawards of the seawall. Benefits are a higher level of coastal safety and at the same time a more natural vision and higher ecological and socio-economical values. There are still some knowledge gaps in arranging such solutions (Rizvi and Riel, 2020). In this study, we want to identify specifically the optimal plant density to protect the dike from sand nuisance, and how these plants are best arranged.

Methods

To find out how dunes can be deployed as a coastal protection measurement by using a dune-in-front-of-dike concept, a new engineered dune was built at Ostend Oosteroever, Belgium. A dune of 2400m² was divided in six zones (1-6) of 20x20m² each with a different density (6, 9 and 15 plants/m²) and planting strategy (regular, clustered and staggered) (Figure 1). By weekly monitoring the topographical changes on 12 cross-shore profiles (two per zone) combined with monthly drone surveys, conducting aeolian transport measurements and simultaneously measuring wind conditions, the effect of density and planting strategy during the initial months (January-April 2021) of dune development is studied.

Results

Results show a clear difference in cross-shore profile development for the different zones, in which the influence of the density is much more prominent than the pattern. Deposition occurs higher and over a shorter distance with increasing density. At the end of April, zone 4 (9 plants/m² staggered) had the most growing potential (no deposition across the last 2.50m in landward direction). The overall volume of sand accumulated in the dune area is increasing in time and is independent of density and planting strategy, hence completely governed by the aeolian sand supply from the beach. The largest volume change corresponds to the strongest wind conditions (6-8m³/m dune growth at the end of April).

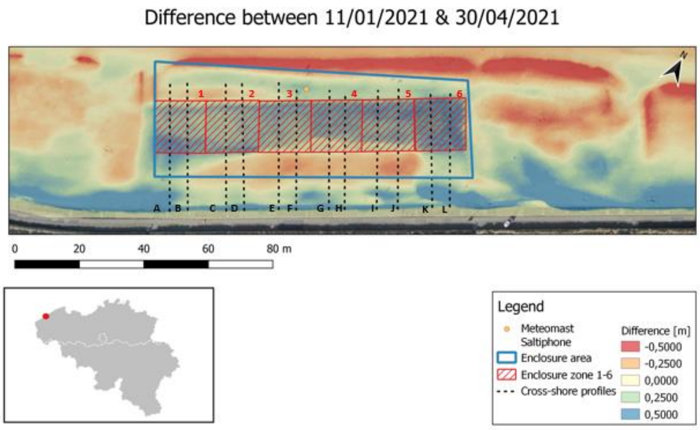

Figure 1: Dune-in-front-of-a-dike pilot site at Ostend Oosteroever, Belgium divided in 6 zones and 12 cross-shore monitoring profiles.

References

Rizvi, A.R., Riel, K. Van, 2020. Nature Based Solutions for Climate Change Adaptation – Knowledge Gaps.

Predicting multi-monthly growth of an artificial dune

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[1]Hydraulics and Geotechnics, Department of Civil Engineering, Bruges Campus, KU Leuven, Spoorwegstraat 12, 8200 Bruges, Belgium.
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Introduction

An understanding of aeolian sediment transport processes and its interaction with vegetation is crucial for predicting the development of coastal dunes. Coastal managers are getting convinced of building with nature concepts, such as dunes in front of dikes, for coastal protection. For an optimal design of these artificial dunes, a fundamental knowledge of morphological changes is required. Despite many decades of research, we remain unable to accurately predict aeolian sediment transport as input for dune growth and the subsequent dune development. Commonly used aeolian sand transport models compute sand transport rate with bed shear velocity to power two or three, where shear velocity is calculated based on time-averaged wind velocity measurements. However, the bed shear velocity is generally estimated too large leading to overprediction of sediment transport rates. In this study, we investigate the predicting ability of a modified Bagnold transport model (Van Rijn & Strypsteen, 2020) including sub-models for bed roughness and shear velocity by exploring a multi-monthly dataset of wind characteristics and dune growth of an artificial dune.

Methods

We incorporate detailed measurements of wind variables (speed, direction) and vegetation into the modified Bagnold model and compare them to high-resolution topographic datasets (drone surveys and ED-pins). Wind transformation is applied to replicate wind conditions on the beach from a nearby regional meteorological station. All measurements are gathered during an ongoing field campaign that started in February 2021 at the 120x20m² dune-in-front-of-a-dike in Oosteroever, Belgium.

Results

Results provide field evidence demonstrating the prediction accuracy of aeolian sediment input to the dune (Figure 1). Local measurements of bed shear velocity leads to significant overprediction of dune growth. Sub-models for bed roughness and bed shear velocity lead to more realistic values and better predictions of dune growth. Transformation from regional to local beach conditions is essential to predict dune growth. Dune growth is influenced by supply limitations and vegetation trapping efficiency.

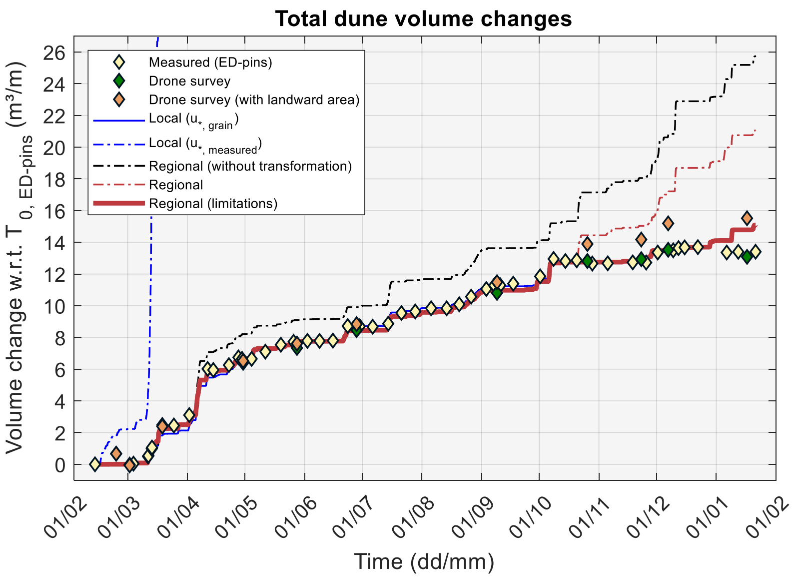

Figure 1: Multi-monthly dune growth in Oosteroever, Belgium and corresponding predictions.

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Understanding retreat and expansion of salt marshes by modelling the variability of the salt marsh edge under influence of waves and sediment availability

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Introduction

Salt marshes can provide coastal protection when included in a Nature-based Flood Defence. The magnitude of the protection by the marsh strongly depends on the lateral extent of the salt marsh, and thereby the potentially dynamic location of the salt marsh edge. This study systematically assesses the influence of daily occurring mild weather conditions including waves and sediment availability on the biophysical development of the salt marsh, and retreat and expansion of the marsh edge.

Methods

50 year dynamics of the salt marsh and marsh edge were simulated by a biogeomorphological model (Willemsen et al., 2022). Parameter settings were derived from salt marshes in the Western Scheldt. Hydrodynamics and morphodynamics were computed by the numerical Delft3D-Flexible Mesh model (D3D-FM) and were coupled with a vegetation growth module, computing the population dynamics balance equation (Temmerman et al., 2007) in Python. D3D-FM and the vegetation growth module were coupled by the Basic Model Interface (Peckham et al., 2013), enabling biophysical interaction. Scenarios were forced without waves, waves of 0.05, 0.10 and 0.15m high with sediment concentrations (SSC) of 10mg/L. Vice versa, other scenarios were forced with SSC of 10, 25 and 50mg/L with waves of 0.10m.

Results & conclusions

Both simulated patterns and variability at the marsh edge resembled field observations. The marsh edge expanded at low wave forcing (0.00m; 0.05m) and retreated at higher wave forcing (0.10m; 0.15m) (Fig. 1). With higher wave forcing the marsh edge was found at lower elevations, indicating an unhealthy system due to vegetation mortality, suggesting the importance of response time of vegetation to physical stress. Still the salt marsh with higher wave forcing was able to expand with increasing sediment supply.

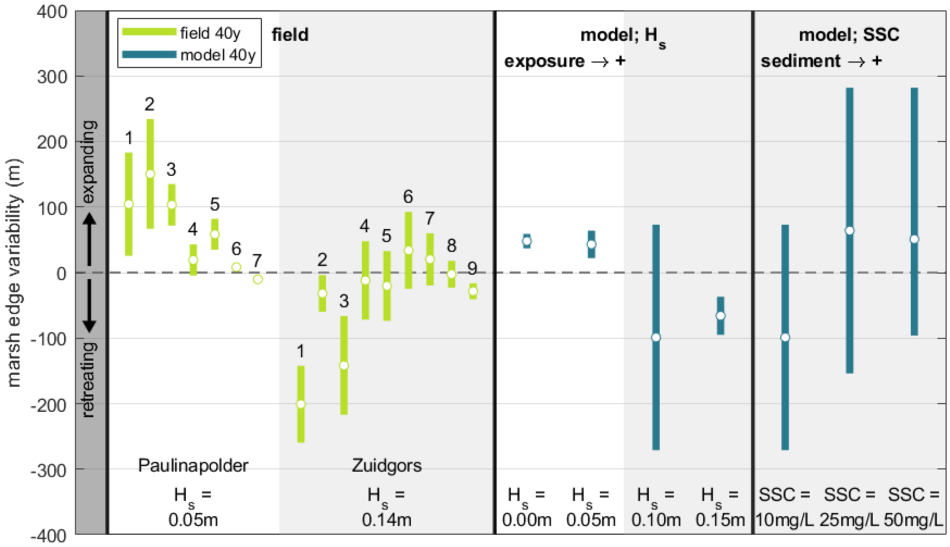

Figure 1: Variability of the marsh edge, i.e. mean location (white marker) and standard deviation (bar); from field data in the period 1975-2015 and from simulations. Transect numbers are showed above the bars. Simulations with an SSC of 10mg/L are sorted with an increasing wave exposure; simulations with a wave height of 0.10m are sorted with an increasing sediment availability.

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Intertidal flat alterations enhance their ecological value

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Introduction

Humans have actively shaped the coastline for thousands of years to suit their needs to the detriment of coastal ecosystems. Recently, managed realignment initiatives have been pursued to help protect against sea level rise, but also to make existing habitat more attractive to macrobenthos which perform vital ecosystem services. In creating or modifying intertidal areas, we can affect the physical characteristics of the ecosystem and trigger a diversification in ecological characteristics. This requires understanding the abiotic and biotic relationships within the intertidal system, and how the physical components drive the biological components.

We present three case studies of habitat modification to increase the intertidal flat's ecological value. In Knuitershoek and Baalhoek, groins were built to reduce the water flow and encourage sediment accretion. In nearby Perkpolder, old farmland was inundated to create a new tidal flat. We analysed the development of these three areas to better understand how hydrodynamics and sediment characteristics drive the benthos communities in managed realignments.

Methods

Extensive monitoring of the developing geomorphology and macrobenthos community was carried out at Knuitershoek, Baalhoek and Perkpolder from 2015 until 2020. In addition, hydrological models were created to show the difference in current velocities before and after the interventions. We used linear models to search for correlations between abiotic characteristics (Figure 1) and multivariate statistical methods to better understand which abiotic characteristics best explained the trajectories of the benthos communities.

Results

Groins at Knuitershoek and Baalhoek lowered current velocities which led to the gradual increase in bed level. The abundance and biomass of the benthic macrofauna at Knuitershoek, Baalhoek, and Perkpolder increased after the interventions. Though the relationships between the abiotic characteristics where similar at the three sites (Figure 1), the composition of the resulting macrobenthos communities differed.

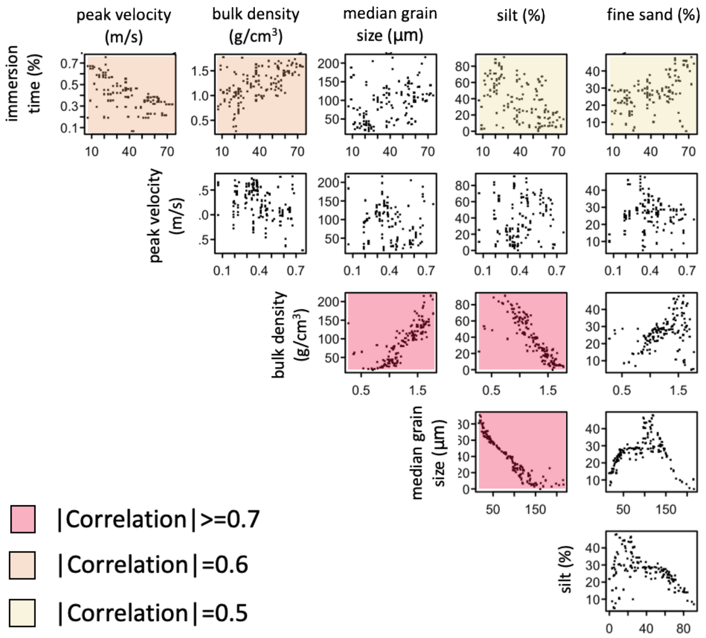

Figure 1: Correlations between hydrology (peak velocity), morphology (immersion time) and sediment (bulk density, median grain size, silt and fine sand components) at the intertidal flats.

Simulation of the Mangrove-Mudflat Dynamics with A New Coupled Individual-Based Mangrove-Morphodynamic Model

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Introduction
Mangrove ecosystems have complex ecogeomorphic interactions between the hydrodynamic forcing (tides and waves, river runoff), sediment transport, morphological development, groundwater discharge, nutrient supply, and the mangrove dynamics itself. Several studies found that the species-specific survival of the mangroves depends on the competition in soil nutrient and light availability in space (resources), the stress in salt, pH, and hydrogen sulphide (regulators), and flooding patterns (hydroperiod). These factors are essential to the mechanistic understanding of mangrove dynamics. Few models have been developed that spatially explicitly simulate the life cycle of the mangroves to the environment, such as FORMAN (1998), KIWI (2000), MANGRO (1995), and MesoFON (2014). However, to our knowledge, studies including a morphodynamic feedback loop between the mangroves and their bed are lacking. In this research, we propose a coupling of the spatially explicit mangrove dynamics model (MesoFON, including the recruitment, establishment, growth, and starvation of individual trees) and the morphodynamic model Delft3D Flexible Mesh (Delft3D-FM).

Methods
The modelling is based on the three-monthly offline coupling of the hydromorphodynamic model Delft3D-FM with the mangrove model MesoFON. MesoFON is an Individual-Based mangrove forest dynamic Model (Java-based) that takes advantage of the fields-of-neighbourhood (FON), while the competition for above/below-ground resources is dealt with separately. The offspring production depends on the tree growth and rises with tree ontogeny. The coupling is designed as a series of information exchanges between a grid cell based hydrodynamic state and the environment, forcing the mangroves' growth and biophysical properties in a feedback loop.

Results
In the present work, we focus on the proof of concept of the coupling. We employed a schematized funnel-shaped estuary with a delta in the middle—to represent the Porong Delta, in Sidoarjo, Indonesia—with a single mangrove species population of different ages. The current model approach incorporates flooding patterns and salinity, as the environmental stressor, affecting the propagules production and tree competition. Model results show the schematized 11-year morphodynamic development as well as individual mangrove dynamics.

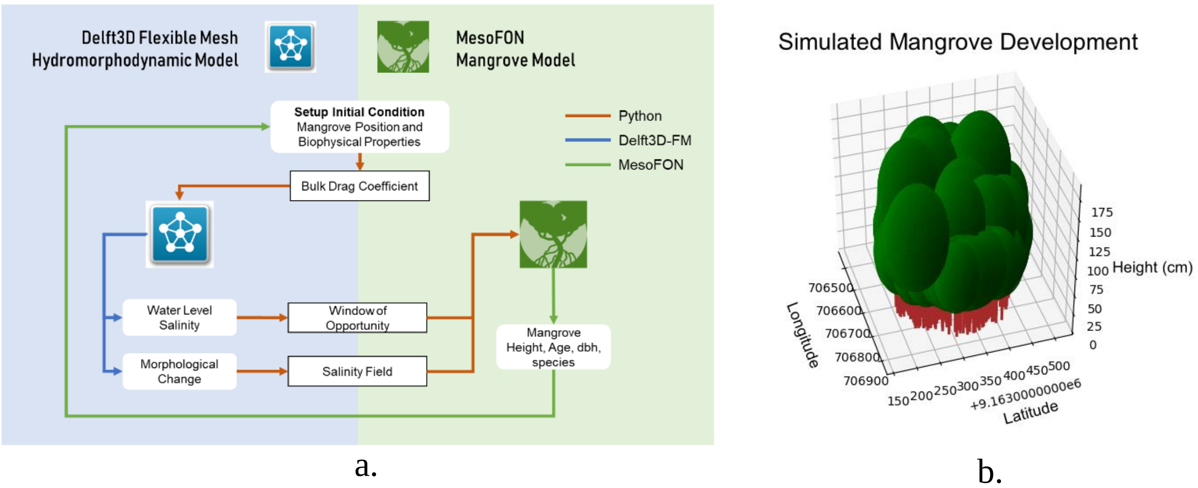

Figure 1: (a) Schematic of the coupling approach described the information exchange and key parameters, and (b) simulated individual mangrove development due to competitions and environmental forcing variations.

Estuarine sensitivity to salt intrusion mitigation measures

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Introduction

Deltas are among the most densely populated and heavily utilised regions, where crucial functions, e.g. freshwater availability and water safety, strongly relate to the natural dynamics of the system. Especially when developing nature-based solutions for safeguarding these essential functions, a thorough understanding of estuarine dynamics is required.

Method

In this study, a sensitivity analysis has been carried out using an idealised estuary focusing on the salt intrusion length. The idealised estuary is parametrically designed using key parameters, such as river discharge and water depth. Subsequently, Delft3D Flexible Mesh is used to determine the salt intrusion length for various estuarine layouts. To limit the computational costs of this exploratory study, machine learning techniques have been used to choose samples wisely. At last, the data is fitted to a regression model to gain insights into the sensitivity of the salt intrusion to the various input parameters by analysing the regression coefficients.

Preliminary results

The first results align with knowledge from literature: There is a clear and strong dependence of the salt intrusion length on the river discharge and channel cross-section (see Figure). In addition, the convergence of the estuary and the occurrence of tidal flats have a clear influence on the salt intrusion.

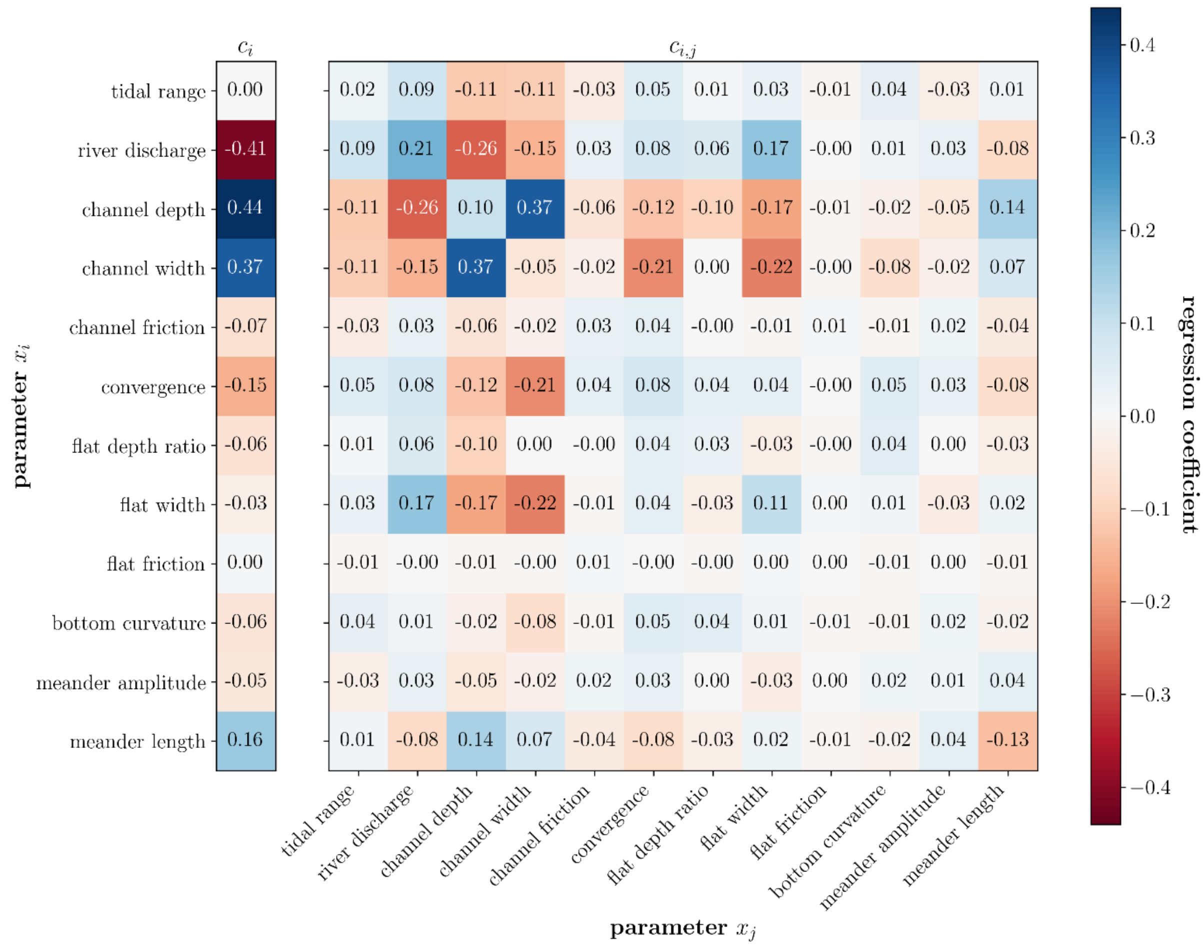

Figure 1: The regression coefficients of the regression model, where a darker shading indicates a higher sensitivity of the salt intrusion to the parameter. The regression model includes linear and quadratic dependencies.

Multi-fraction sediment sorting and entrainment at the Prins Hendrikzanddijk

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Introduction

Since the 1990's sand nourishments are increasingly used to improve coastal safety at the wave-dominated North Sea coast. Generally, the nourished sediment is kept similar to the naturally occurring sediment and in most cases consists of well-sorted sand. However, recently, sandy beaches are also used to strengthen dikes in regions that are not wave-dominated. The Prins Hendrikzanddijk (PHZD) is an example of such a sandy retrofit, located on leeward side of the Dutch barrier island of Texel. Additionally, a layer of coarse sediment was added on top of that particular beach in order to limit erosion. This has resulted in a complex spatiotemporally varying sediment composition in a mixed wave-current environment. It is expected that this combination of factors results in highly variable and complex sediment entrainment and transport processes, which are not yet fully understood. This research focusses on the temporal variability in the sediment composition and how this affects sediment entrainment and suspended transport at the PHZD.

Methods

During a 6-week (SEDMEX; mixed SEDiments in Mixed Energy eXperiment) field campaign in early autumn at the PHZD, instruments were deployed at 6 alongshore locations, of which two had additional instruments in the cross-shore. The collected data consist of measurements on waves, currents and sediment (composition and transport). A total of approximately 150 sediment samples were collected in the intertidal area at different cross-shore locations and over varying time intervals. Wave and current shear stresses were used to identify when the various sediment fractions could have been in motion. This was then compared to concentration measurements derived from Optical Backscatter Sensors (OBS).

Results

The collected sediments show a distinct variability of the grain-size distribution over time in response to the waves and tides. It is observed that sediment is primarily entrained by wave stirring and transported by tidal currents. The presence of shells and large mineral grains suggest influence of hiding-and-exposure effects. However, the large temporal variability in the grain-size distribution indicates that these mechanisms are not constant over time.

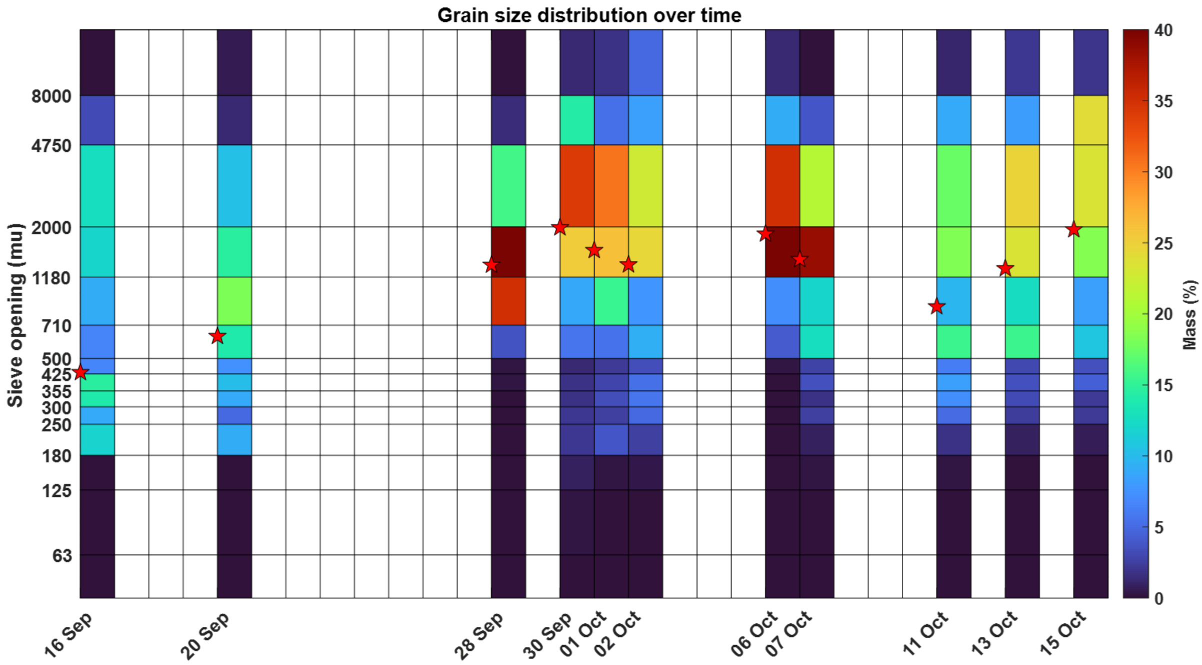

Figure 1: The grain-size distribution over time. The red stars indicate the D_{50} of the sediment sample which were collected just below the low mean water line.

Morphodynamic Equilibria in Double-Inlet Systems

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Introduction

Tidal basins are connected to the outer sea by one or more tidal inlets. In this presentation, we focus on so-called double inlet systems, i.e., tidal inlet systems with two connecting channels. A typical example is the Marsdiep-Vlie system. Using an idealised morphodynamic model, we aim at directly finding morphodynamic equilibria of double inlet systems and assess their stability. For unstable configurations, the linear stability mechanism will be presented.

Methods

The depth--averagerd shallow water equations, suspended sediment transport equation and the bed evolution equation are used to model the morphodynamics of the double inlet system. This system of equations is analysed using an asymptotic analysis in a small parameter, the ratio of the tidal amplitude of the undisturbed water depth. 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. After discretizing the model equations using the finite elements method, morphodynamic equilibria are found using a continuation method: this is a method to directly obtain solutions of the equations sought for such that the tidally averaged sediment transport is constant in the tidal inlet system.

Results

As an example, the width-averaged equilibrium bathymetry is calculated using the characteristic parameters of the Marsdiep-Vlie system. In Fig.1, left panel, the blue solid line represents the width-averaged depth obtained from observations, while the orange line is the width-averaged depth, found with the idealised model. The main characteristics (i.e., a very deep section close to the Marsdiep inlet and a tidal high when moving into the basin) are qualitatively reproduced. This equilibrium is analysed by assessing the various sediment transport contributions (Fig.1, right panel), showing that there is a tidally averaged sediment transport directed from the Marsdiep inlet to the Vlie inlet, even though the prescribed tidally averaged water transport is from the Vlie to the Marsdiep inlet.
In this presentation, the sensitivity of morphodynamic equilibria to forcing conditions and their linear stability will be systematically discussed.

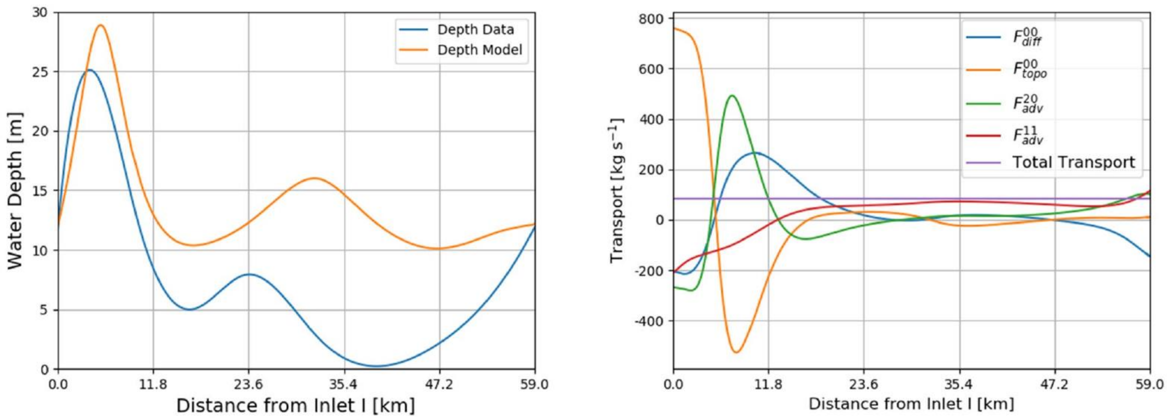

Figure 1: Morphodynamic equilibrium (left panel) and associated sediment transport contributions in a double inlet system with the characteristics of the Marsdiep-Vlie system.

New Techniques for Mapping Ebb-Tidal Delta Morphodynamics and Stratigraphy

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Introduction

To adapt the Dutch coast to climate change, a key source of uncertainty lies in the dynamics of the Wadden Island and Sea system. In particular, ebb-tidal deltas form a key component of coastal sediment budgets, exerting a strong influence on adjacent shorelines. Nourishing these deltas has been proposed as a potential solution for maintenance of the Wadden coast, but there is still a need to better describe and quantify the evolution of ebb-tidal deltas. To leverage the availability of high-resolution bathymetric surveys, we propose two approaches for generating new insights into the shoal bypassing process and preservation potential of ebb-tidal deltas.

Methods

The first approach is derive a conformal map of Ameland ebb-tidal delta, placing it in polar coordinates centred at the inlet. Shoals and channels on the delta tend to rotate in a clockwise direction around the inlet, so this approach collapses the morphodynamic behaviour into a timestack for better visualization and analysis. The second approach takes the differences between successive bathymetries to derive a decadal scale (1975-2020) stratigraphic model.

Results

Here we clearly visualize the shoal bypassing process and repeated rotation of channels and shoals around the inlet from updrift to downdrift coasts. Together, these techniques provide new perspectives on ebb-tidal delta dynamics and preservation potential which can be readily applied to other locations with detailed bathymetric data. These findings are useful on short timescales for coastal management (e.g., for planning sand nourishments) but also on much longer timescales (e.g., for interpreting stratigraphy in ancient rock records).

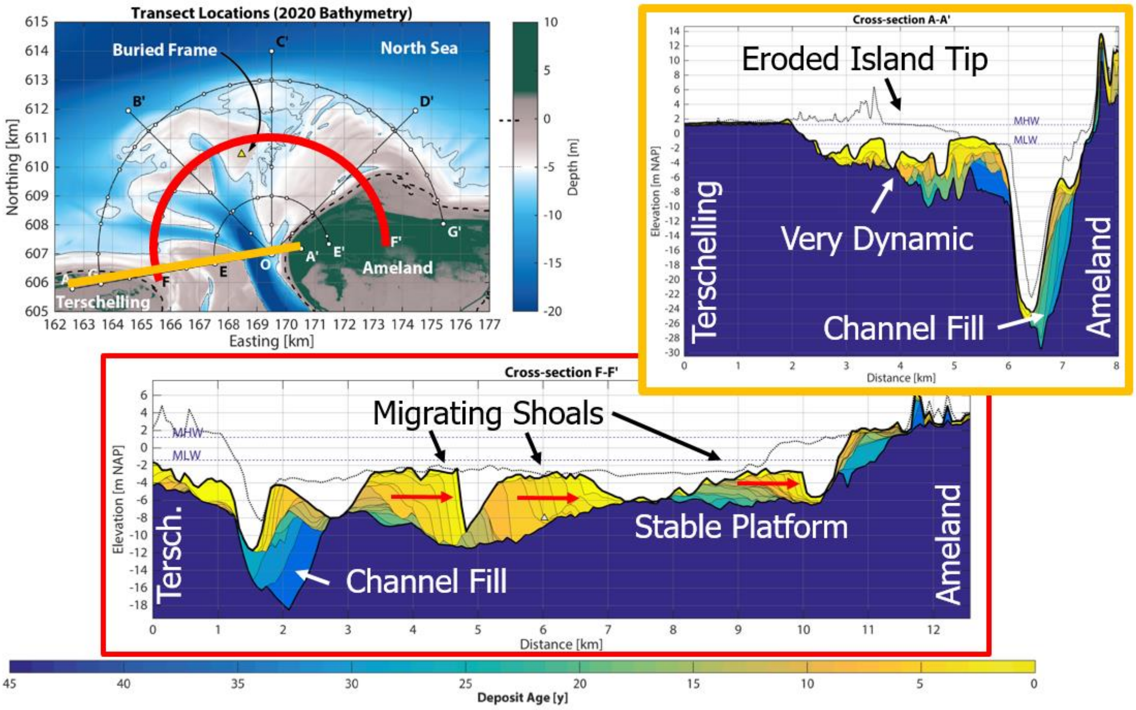

Figure 1: Stratigraphic profiles across Ameland Inlet (A-A') and through the ebb-tidal delta (F-F'). Darker colours represent old deposits, and lighter colours represent more recent deposits.

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How is the cross-shore shape of tidal flats affected by accommodation space, hydrodynamic and sediment characteristics?

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Introduction

The natural evolution of tidal flats is affected by human interference worldwide, (e.g., coastal squeeze, dredging and disposal (van Dijk et al., 2019)). Managing these tidal flats requires understanding how the morphology of tidal flats responds to human interference. Current research often describes the flat shape qualitatively as convex-up and concave-up for accreting and eroding flats, respectively. However, several processes have been identified to affect the shape of different parts of a tidal flat (Maan et al., 2018). A tool that describes the cross-shore tidal flat shape quantitatively does not exist yet. In this research, we develop a model to predict the cross-shore flat shape while taking into account the effects of the accommodation space (area between dike and tidal channel), as well as the hydrodynamic and sediment characteristics.

Methods

A tool is developed to systematically analyse the cross-shore shape of tidal flats in the Western Scheldt. The cross-shore profiles are deduced from bathymetry data of the intertidal and subtidal area for the past two decades. Then, three zones are defined for each cross-shore profile: the lower flat, upper flat, and the transition zone of the tidal flat in between. Based on a shape function for the bed level, we quantify the flat shape parameters of each element: the length, elevation and the slope of the lower and upper flat.

Results

Our tool automatically extracts numerous cross-shore profiles along the entire estuary for multiple years (Figure 1). Figure 1B shows the evolution of one transect over time. The results show that parts of a tidal flat erode or accrete independent from each other. Also, not every tidal flat fits into the category of convex-up or concave-up. This highlights the importance of evaluating different parts of the cross-shore tidal flat profile separately. We are able to fit the mathematical expression to the cross-sections and obtain the flat shape parameters. Next, we combine this spatial and temporal datasets with hydrodynamic and sediment data to evaluate relations between physical forcing mechanisms and changes in the shape parameters. This tool to assess tidal flat shape changes contributes to a better understanding of the tidal flat evolution.

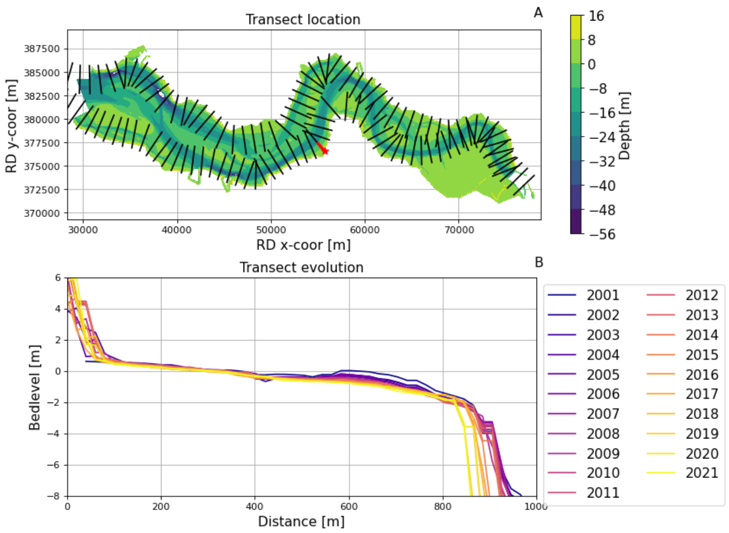

Figure 1: A) overview of the intertidal and subtidal area in the Western Scheldt and derived cross-section (red). B) Evolution of a cross-section in the past decades

Maan, D. C., van Prooijen, B. C., Zhu, Q., & Wang, Z. B. (2018). Morphodynamic Feedback Loops Control Stable Fringing Flats. *Journal of Geophysical Research: Earth Surface*, *123*(11), 2993–3012. https://doi.org/10.1029/2018JF004659

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Regime shifts in river deltas

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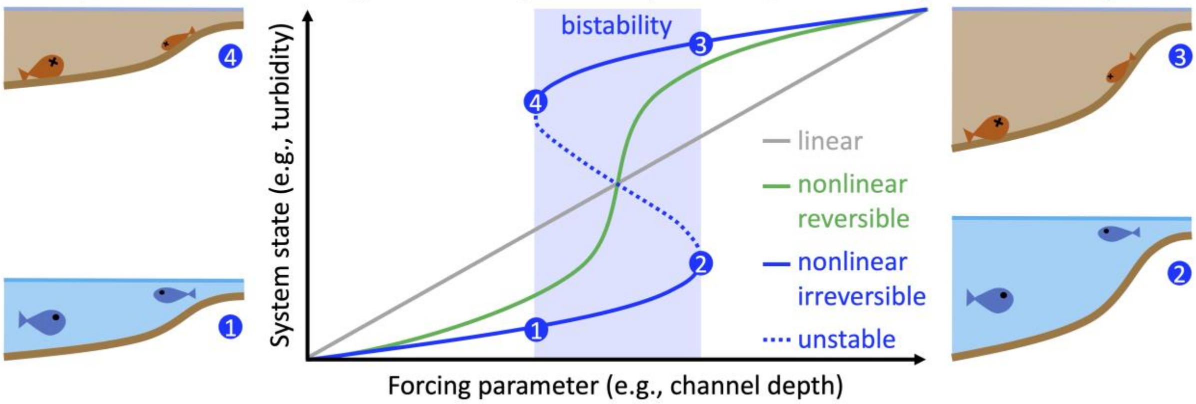
Introduction

River deltas harbor invaluable ecosystems as well as many of the world's largest cities and are hotspots for economic activity. This necessitates accurate prediction of the response of delta biogeomorphology to future scenarios of changes in sea level, wave climate, river discharge dynamics and anthropogenic forcing. Valuable insights have come from long-term model predictions performed with high-complexity simulation models. Such models often predict a gradual adjustment of biogeomorphic equilibrium to changing forcing conditions. On the other hand, a growing number of studies, based on strongly idealized models, indicate the presence of tipping points where delta systems may undergo irreversible regime shifts to an alternative stable state. Examples include estuarine (hyper)turbidity, delta channel instability and ecosystem emergence or collapse. However, field observations to support either the predicted absence or presence of irreversible regime shifts in river deltas remain scarce.

Review approach

Our study reviews the existing research on reversible (single equilibrium) and irreversible (multiple equilibria) transitions in delta biogeomorphology. We propose how to bridge the apparent gap between high-complexity models, which accurately capture reversible morphodynamic adjustment to small changes in forcing but are unpractical to probe wide parameter ranges for the presence of irreversible regime shifts, and idealized models, which have contrasting characteristics. We discuss (the lack of) existing field data to support morphodynamic model predictions and specify which field measurements would be needed to provide more conclusive evidence. Specific attention is given to early warning indicators for regime shifts, such as spatial patterning and critical slowing down, and which of these signals could be picked up in delta systems. Finally, we illustrate how the design of human interventions, such as channel dredging, beach nourishments and ecosystem restoration, requires fundamental knowledge of a delta's natural resilience, as lower resilience implies higher susceptibility to irreversible regime shifts.

Conceptual illustration of a hypothesized regime shift (reversible/irreversible) in river delta systems



A synthetic representative tidal signal for long-term morphological modelling

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Current tidal input reduction approaches applied for accelerated morphological simulations aim at capturing the dominant tidal forces in a single or double representative tidal cycle, often referred to as a "morphological tide". The existing methods may provide appropriate boundary conditions to simulate representative residual transport fluxes and the resulting morphological changes of the tidal channels. However, heavily simplified tidal signals fail to represent the tidal extremes. They poorly represent intertidal areas, which exert a major impact on the development of tidal asymmetry and the associated residual transport fluxes.
Here, we aim to develop a generic method to construct a synthetic representative tidal signal that incorporates tidal extremes. Such a synthetic cycle should adhere to several criteria to make it applicable for long-term (i.e. subdecadal) accelerated simulations. The synthetic signal should: (1) represent the original signal, particularly preserving asymmetries present in the original signal; (2) be exactly periodic, to ensure coherency between consecutive cycles and to control the relative phasing with other types of forcings (e.g. wind, waves, discharge); and (3) remain valid during the long-term simulations in which the bathymetry in the modelling domain changes shape.
The starting point for the construction of the synthetic signal is a fortnightly modulation of the semi-diurnal tide to represent spring-neap variations, while conserving periodicity. Diurnal tides and higher harmonics of the semi-diurnal tide are included to represent the asymmetry of the tide. The amplitudes are then scaled to give a best fit to the full tidal signal. Statistical measures of the synthetic signal show that it gives a better representation of the amplitude variation and asymmetries present in the original signal, compared to existing approaches of tidal input reduction. A hydrodynamically validated depth-averaged model of the Ems estuary (The Netherlands) demonstrates the effects of different tidal input reduction techniques on residual sediment transport patterns. Adopting the new approach, the shape of the tidal wave is better represented over the entire length of the estuary, and inundation of shallow parts of the basin is modelled in closer resemblance to the real-world intertidal dynamics.

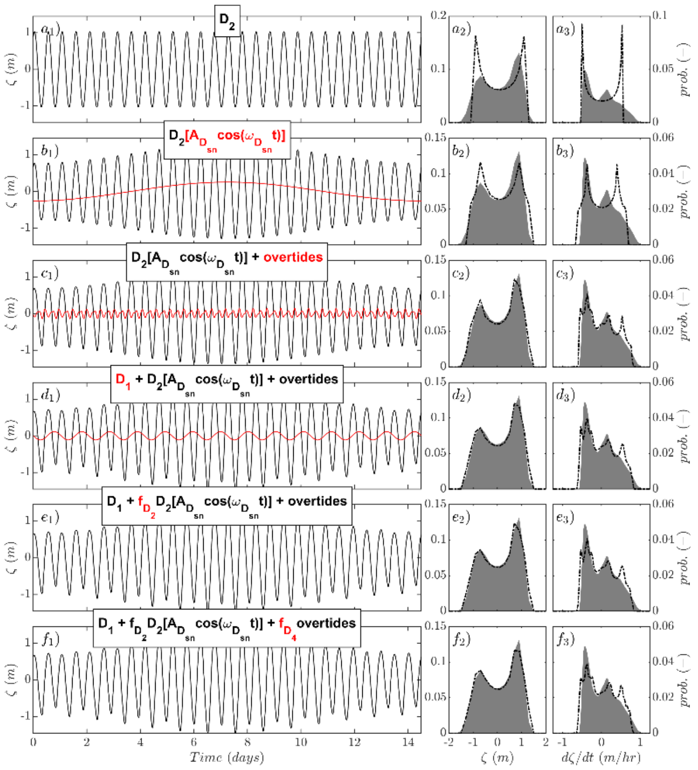

Figure 1: Step-wise construction of the synthetic spring-neap cycle; showing time series (left) and histograms of the synthetic signal (dotted lines) and the full tidal signal (gray patches).

Spatial variability in hydrodynamic conditions and its implications for sand transport along a nourishment in mixed wave-current conditions

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Introduction

Increased sea levels and more frequent storms due to future climate change will increase the vulnerability of coastal communities. Hard engineering structures are traditionally applied to offer coastal safety and reduce coastal erosion for years. However, hard structures are not flexible and adaptation to future conditions becomes increasingly costly while the ecological sustainability of the structures is low. Therefore, implementing soft solutions (often with sand) has been increasingly considered even in areas where hard-based structures are present.

In this context, the Prins Hendrik Zanddike (PHZD) is a recently applied nourishment at the lee side of the barrier island Texel in the Western Wadden Sea (HHNK & Witteveen+Bos, 2016). Contrary to most nourishments, the PHSD is situated in a complex mixed wave/current energy system where it is sheltered from large waves while strong tidal currents prevail (Buijsman & Ridderinkhof, 2017). Moreover, a large variety of grainsizes was used including a armouring top-layer consisting of very coarse sand and (fragmentated) shells. It is known that alongshore variety of hydrodynamic conditions leads to preferential sand transport due to difference in sediment entrainment of various grainsize classes in wave-dominated climate (Huisman et al., 2016). These observations on the other hand, lack in mixed energy settings. The aim of this research is to identify alongshore variation of waves and currents and its implication on sand transport.

Methods

Between 7 September and 19 October 2021, a field-campaign, under the name SEDMEX, was conducted in the inter- (-0.75 m +NAP) and subtidal (-1.45 m +NAP) zone. Herein, 5 pressure sensors and 6 Acoustic Doppler Velocity sensors were deployed in 6 cross-shore arrays (fig. 1a). This resulted in a near continuous dataset of waves and currents for 39 days covering multiple spring-neap tidal cycles and various (stormy) wind conditions. The data is converted into a timeseries of 10 minutes averaged wave and current properties. Hereafter, the bed shear stresses (current, waves and combined respectively) were calculated for various grain sizes.

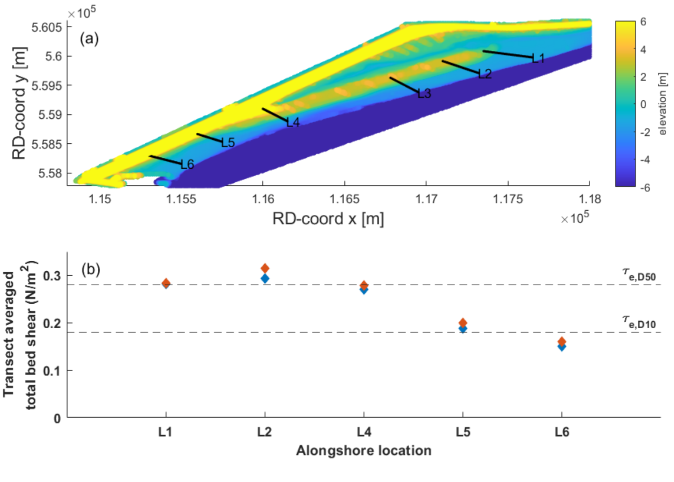

Figure 1: Positions of cross-shore arrays and local morphology (a). Averaged total bed shear stress for the different (b) The dashed horizontal lines indicate the critical bed shear stress for erosion for D_{10} and D_{50}.

Results

Our results indicate that waves are locally generated and scale with wind speed and direction. The sheltering effect by a harbour jetty accounts for most of the alongshore variability. The current magnitude also decreases with proximity to the jetty. Consequently, alongshore variation in bed shear stresses are observed (fig. 1b) leading to alongshore sediment entrainment gradients.

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Field observations and model simulations of longshore transport on low-energy, non-tidal beaches in lake Markermeer

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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 currents driven by waves and large-scale lake circulations affect the longshore transport.

Results and Conclusions

Alongshore volume changes at the Houtribdijk could convincingly be related to the longshore transport capacity based on ADV flow measurements. Model results show that large-scale wind set-up driven currents make up, up to 90% of the nearshore current. This shows that wave driven longshore currents may have an effect, but minor compared to the wind set-up driven currents. Concluding, our analysis has shown that the design and implementation of sandy beaches and foreshore in confined lake environments cannot be achieved without considering the effect of large-scale, wind-driven flow circulations on nearshore sediment losses.

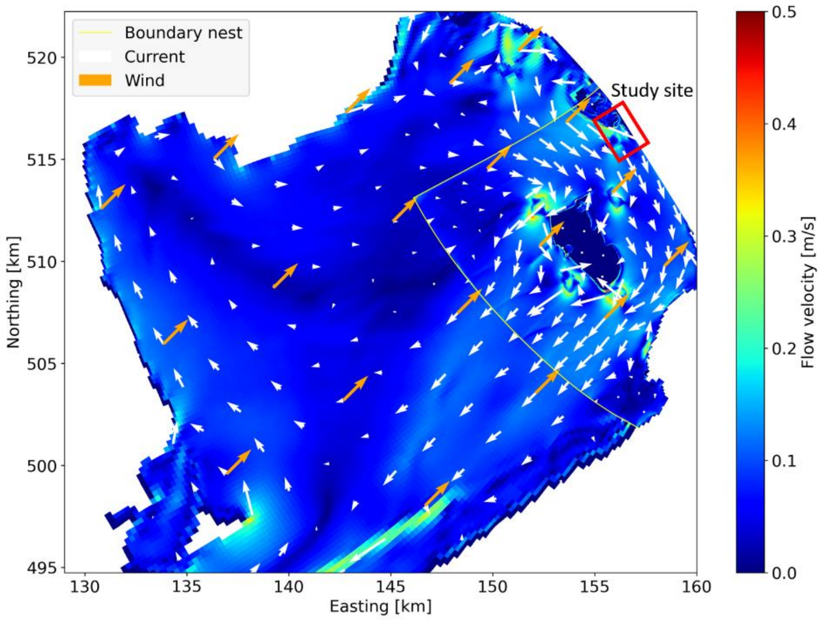

Figure 1: Delft3D model results of total Markermeer model and nest of Houtribdijk site and Marker Wadden for southwestern wind.

Acknowledgement

This research is part of the LakeSIDE project, which is funded by Rijkswaterstaat. We want to thank contractors Boskalis and van Oord for supplying us with bathymetric data.

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Large-scale laboratory experiments: Beach slope influence on sediment transport processes in the swash zone at event scale

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Introduction

The swash zone is the highly dynamic boundary between the beach and the surf zone. Swash processes strongly affect shoreline evolution as they determine whether sediment is either stored on the upper beach or transported offshore. The erosive/accretive nature of a single swash event has been attributed to a combination of several processes such as interactions between the surf and swash zone or local wave-swash interactions occurring in the outer swash. However, the effect of the beach slope on the intra-swash scale dynamics is still unclear. The present research focusses on understanding the effect of beach slope on intra-swash hydrodynamics and sediment transport processes in the swash zone through a series of large-scale wave flume experiments.

Methods

Laboratory experiments were conducted in the large-scale CIEM wave flume at the Universitat Politécnica de Catalunya (Barcelona, Spain). In these experiments erosive bichromatic wave series with groups of 4 waves (equivalent to random time series with H_s=0.65 m and T_p=3.5s) were produced in consecutive runs with each wave group repeating every two group periods (T_R=2T_g=28s) in order to produce distinct types of swash interactions. The same sequence was reproduced for two different bed slopes of 1:15 and 1:25. The beach profile consisted of medium sand with D_{50} = 0.25 mm.

Results

Results have shown that the swash zone on the 1:15 slope was shorter with shorter swash excursion and greater water depths, while on the 1:25 slope the swash zone was wider but shallower (Fig. 1). The three types of wave-swash interactions (wave capture, weak and strong wave-backwash interaction) were identified in both slopes but they did not occur at the same cross-shore location. Furthermore, observed velocities indicate stronger wave-backwash interactions on the 1:15 slope. Based on the present results, it is hypothesized that the stronger interactions on the 1:15 slope lead to a net offshore-directed sediment transport, while the weaker interactions on the 1:25 slope lead to a net onshore-directed sediment transport. Intra-swash sediment concentrations are being analyzed to investigate the proposed hypothesis.

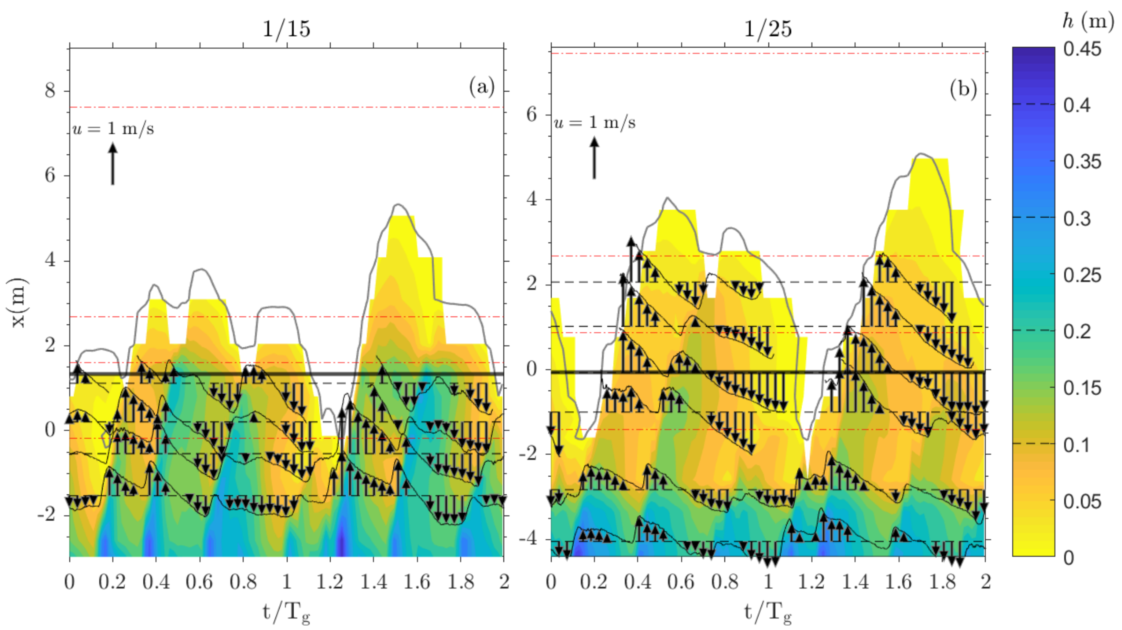

Figure 1: Water depths (contours) and cross-shore velocities (vectors) in the swash zone for (a) 1:15 slope and (b) 1:25 slope. The dash-dotted lines in red represent the limits between the upper swash, mid swash, lower swash and inner surf. The solid black line represents the shoreline location.

Depth-resolved modelling of water and sediment fluxes in the swash zone

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Introduction

Most models used to study the morphodynamics in the swash-zone are based on a depth-averaged approach (e.g. XBeach). However, such models have difficulties in reproducing the complex dynamics in the swash zone, such as the overturning shape of a breaking wave, or the depth-dependency of the suspended sediment flux. Depth-resolving models, although being computationally more expensive, do not have these inherent drawbacks, and thus they are useful tools to better understand such processes. The knowledge these models provide could subsequently be fed back to improve the faster depth-averaged models.

Model study

In this study, we present our initial findings of a depth-resolving model for hydrodynamics and sediment transport, based on the Reynolds Averaged Navier-Stokes (RANS) equations (implemented in OpenFoam). These findings use an extended version of the model by Jacobsen et al., (2012) and is applied to the laboratory experiments of van der Zanden et al., (2019). These experiments feature bichromatic waves which repeat every two wave-groups, and with a wave height of H=0.6 m. Figure 1 shows the cross-shore water and sediment fluxes, averaged over four wave groups. These results show a clear vertical dependency in both the sediment and water fluxes. Furthermore, at certain cross-shore locations, the near-bed sediment flux direction is opposite to that of the water flux (e.g. at x = 70 m). At the conference, we will show the demonstrate the use of depth-resolving models, and the importance of these vertical structures for the swash zone sediment transport.

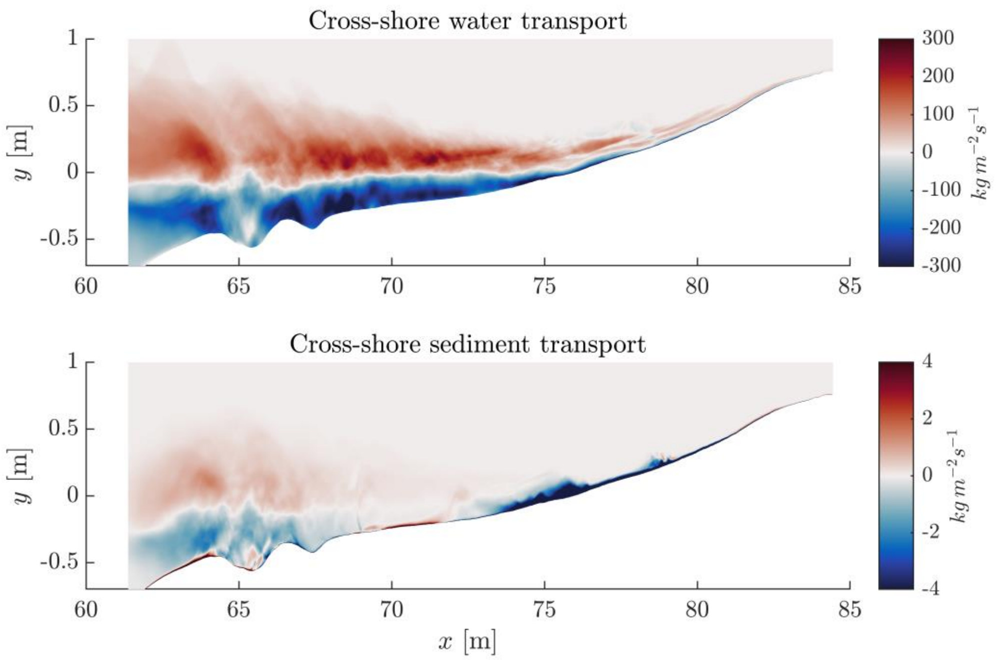

Figure 1: Cross-shore water and sediment fluxes averaged over four wave groups. Here red means onshore transport and blue means offshore transport.

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Unravelling 10 years morphology of the Sand Motor and Delfland coast

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Introduction

The Sand Motor is the most distinguishable sand nourishment that has been introduced in the last 10 years. Its sheer size of 21 million m^3 and ability to support also natural and recreational functions (Huisman et al., 2021a) is making it a landmark development that can even be seen from space.

Unique data collection

The Sand Motor bathymetry has been monitored extensively using jetski surveys, quad surveys, lidar planes, benthos surveys, salt and sandspray catchers, vegetation surveys and groundwater gauges. This has resulted in an impressive data set which provides us with the opportunity to investigate every detail of the development of the Sand Motor (Huisman et al, 2021a/b).

Analyses and findings

A large number of analyses have been made of the morphological changes over the 10-year timespan of the Sand Motor, which among others provided us with a detailed insight in the sediment balance of the Delfland coast and local embryonal dune growth. Locally the Sand Motor has spread its sand surprisingly over a relatively small area (60% within 1.5 km) as a result of wave-driven transport. The balance of the larger area could also be closed, showing a net northward transport of approximately 100,000 m^3/yr at Scheveningen, although this varies substantially per year. Noticeable is the dune growth at the Sand Motor (14 m^3/m/yr), which is rather similar to the rest of the Delfland coast (13 m^3/m/yr) due to catchment of sand by the lagoon. Also, the lagoon entrance was very dynamic.

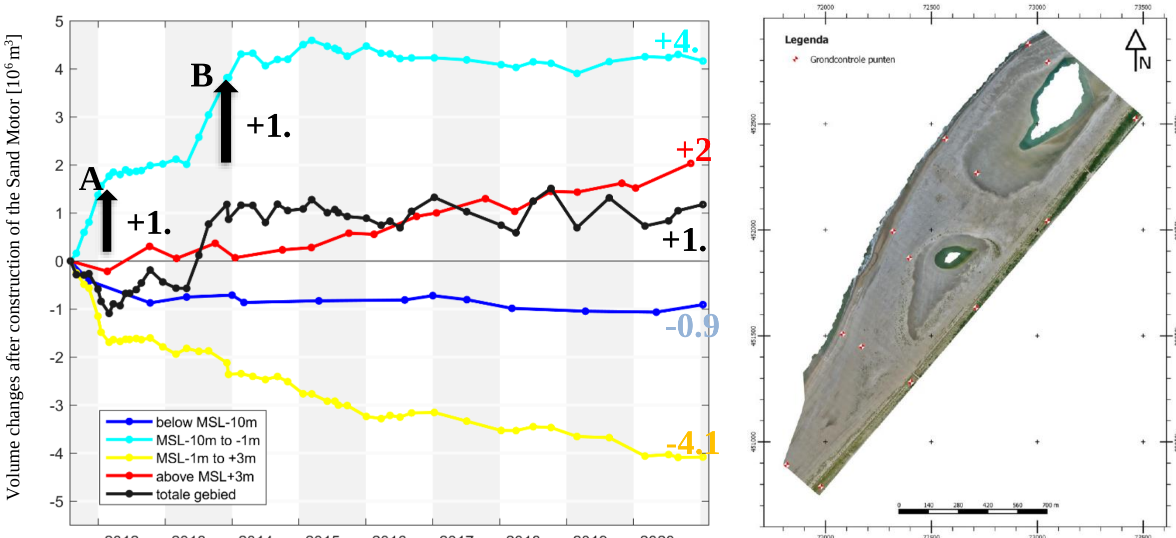

Figure 1: Temporal development of the sediment volume of cross-shore regions of the Delfland coast (left) and Lidar / ortho-photo of the Sand Motor using a drone (at dm resolution).

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MUSA – Physical experiments to quantify Mud-Sand interactions in determining erosion parameters

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Much is known about the rheological behavior of the individual muddy and sandy sediments. However, the interaction between mud and sand in determining erosion and deposition processes remains limited. Consequently, the available formulations to predict sediment transport and bed evolution in mud-sand environments, such as estuaries and tidal basin, remains rather uncertain and inaccurate. In the MUSA-research project, we aim to increase our understanding on the combined effects of mud and sand by means of fieldwork campaigns and physical experiments. For this 124 sediment samples were collected from the tidal harbor of Noordpolderzijl (Wadden Sea) and from the intertidal flats of the Western Scheldt estuary, both sites located in the Netherlands. Based on the mud-sand percentages and dry bulk density 15 samples were selected, for which flow-flume experiments were performed to determine the critical shear stress for erosion over a wide range of mud-sand combinations. The samples covered a wide range of sand percentages between 2 and 90% and dry bulk densities between 400 and 1300 kg/m³. In total 18 flow-flume experiments were performed varying 3 to 4 dilutions per sample, in addition to the original sample. The critical shear stress necessary to erode increased up to 1.5-2 N/m² for intermediate percentages of mud-sand and medium to high bulk densities. This increase was particularly observed for mud-samples with higher percentages of clay over silt, due to the cohesive properties of clay. For the lower bulk densities, e.g. <400 kg/m³, and higher sand contents (low cohesion properties) no clear correlation was observed between the critical shear stress and composition or density. Values were in the range of 0.3-1.0 N/m² converging to analogue Shields mobility value. In conclusion, we found that intermediate percentages of mud-sand combined with medium to high dry bulk densities (800-1200 kg/m³) require higher shear stress to initiate erosion in comparison with pure mud and pure sand. These finding are in agreement with the theoretical background and previous research based on the fact that the cohesive properties of mud, especially clay, and higher bulk densities require more energy to be eroded in comparison with sandy and low-density sediments (van Ledden, 2003). However, here we show that intermediate percentage sand-mud mixtures require higher energy to start erosion in comparison with the mud and sand rich end-members.
This research is the initial phase of the MUSA-project. In the future we will expand the scope with current-waves experiments, field work and more comprehensive analysis before incorporating the finding on sediment transport formulations and numerical models.

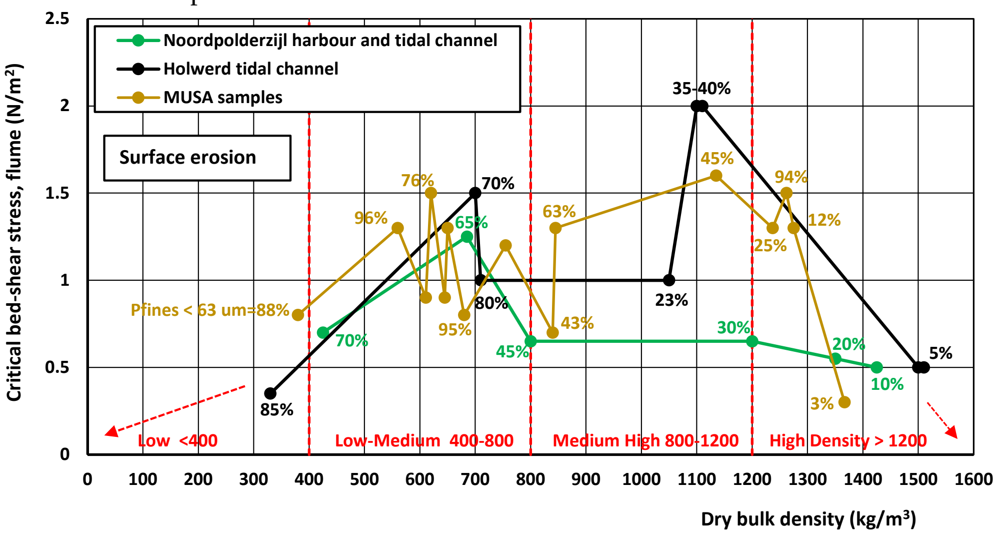

Figure 1: Critical bed-shear stress for surface erosion as function of dry density and percentage of fines.

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The fate of sediment from source to sink in two different tidal flat environments

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Introduction

The dynamic processes in tidal flats environment are considerably changing under the impacts of human interventions and climate change (Fagherazzi et al., 2020). In order to determine whether salt marsh can keep pace with these changing conditions, we identified the dynamic processes and also quantified the contribution of the sediment sources in an accreting and an eroding integrated tidal flat system. We found that the sediment routings are completely different in these two systems, and the sediment availability could be the main factor leading to the differences, which sheds light on the possible responses of tidal flat systems to the changing conditions due to human interventions and climate change in the future.

Methods

Two summer field campaigns were conducted in Paulina Saltmarsh (Fig. 1b) and in Chongming (Fig. 1c). Water depth, velocity, bed level change and SSC were measured at the same time in a marsh creek and in the adjacent mudflat in Chongming, and in the mudflat, the marsh creek, the marsh edge and the inner marsh in Paulina Saltmarsh.

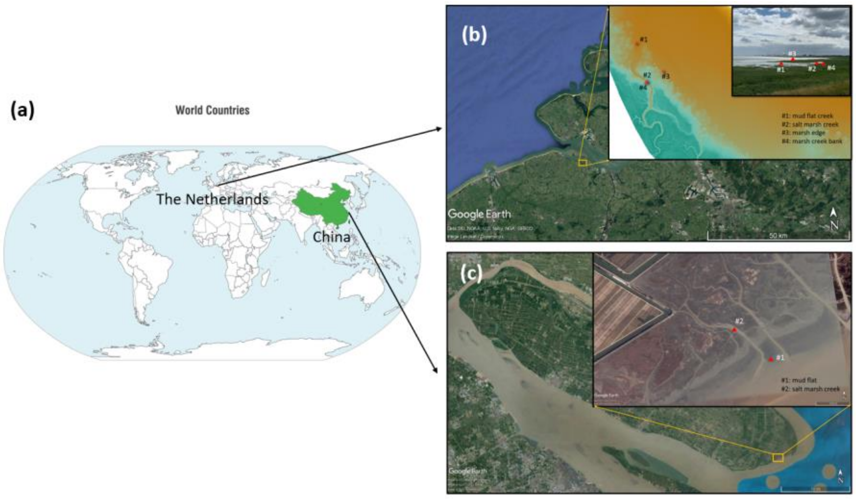

Figure 1: (a) World map indicating the locations of the Netherlands and China; (b) Measuring locations in Paulina Saltmarsh in the Netherlands; (c) Measuring Locations in Chongming Island in China (Red triangles represent the exact measuring locations).

Results

The measurements show net accretion of the Chongming Island system and net degradation in the Paulina system. In both cases the tidal creeks play a key role. In Chongming, the sediment fluxes indicated that the creeks transport sediment, that was mainly from sea and was resuspended from the main channel, towards the marsh. This was even often the case for conditions with a net outflow of water through the creeks. In Paulina, the creeks transport sediment from the marsh towards the creeks. The comparison between an eroding system and an accreting system indicates the essential role of sediment availability for salt marshes in keeping pace with changing conditions due to human interventions and climate change (SLR).

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Lagrangian transport time scales in the Dutch Wadden Sea: variability due to wind forcing

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Introduction

In the past, dynamical processes in the Dutch Wadden Sea (DWS) used to be viewed as mainly driven by the tides. Hence, previous Lagrangian studies in the DWS focused on the effects of tides on transport or on the relationship between mean Lagrangian statistics (e.g. the residence time) with ecological parameters. In recent years, it has been recognised that the DWS is strongly affected by the wind, with storms having a disproportionately large impact, as well as a high interannual variability. Therefore, the goal of this research is to link the variability of the Lagrangian transport time scales in the DWS with the wind forcing.

Methods and Results

We employed a 36-year (1980-2015) simulation based on an offline coupling of the General Estuarine Transport Model (GETM) and the Lagrangian model "Parcels". The GETM configuration for the DWS is based on a realistic 3D setup described by Duran-Matute et al. (2014) and Gräwe et al. (2016); while Parcels provides around 300 million trajectories of particles initially released inside the DWS (~ 13 000 particles every 12.42 h for 36 years). For the analysis and due to a strong wind anisotropy, we divided the wind energy into eight sectors (following Gerkema and Duran-Matute, 2017).

During stormy winter (DJF) seasons, which are mainly characterized by intense southwesterly (SW), westerly (W) and sporadic but still energetic southerly (S) wind events, the system is flushed (in terms of the residence time) about two weeks faster than during calm summer (JJA) seasons (Figure 1). An annual cycle is evident with its amplitude largely modulated by the variability of the dominant wind directions (SW, W, S). The lowest values of the residence time occurred during the energetic winters of 1983, 1990, 1995, 2000 and 2007; while the highest ones took place in the summers of 1984 and 1989. We reconstructed the times series of the spatially averaged residence time using an exponential fit with the sum of the energy of the dominant wind directions as predictor. This reconstruction matches the numerical data with a correlation of 0.94 and an error of 1.3 days. Finally, the variability during the winter seasons is explained, to a large degree, by North Atlantic atmospheric patterns.

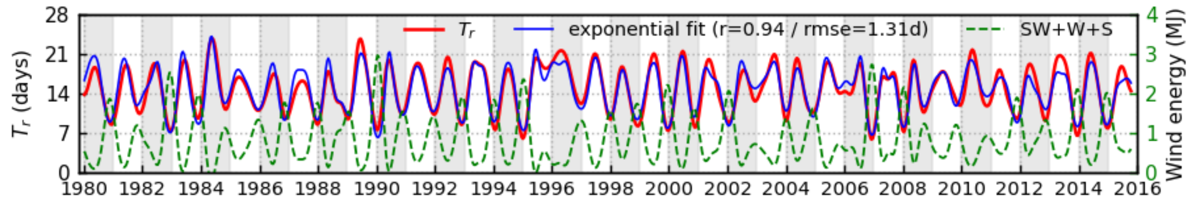

Figure 1: Spatially averaged, low-pass filtered (periods > 0.5 years) residence time and its reconstruction using the wind energy of the dominant wind sectors (W, SW, S) as predictor. The residence time is depicted with red, the reconstruction with blue and the wind energy with green.

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Long-term earth observation of spatial and temporal variability of Suspended Particulate Matter (SPM) related to river discharge and winds in the Scheldt Estuary

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Introduction

Estimating suspended particulate matter (SPM) is a key factor to interpret sedimentary exchanges between land and sea. SPM is most likely be impacted by changes in weather and climate, for example in reaction to variations in river discharge and wind characteristics. Yet, the linkages between wind and river discharge and the role these have on local dynamics and spatial-temporal patterns of estuarine SPM are, to date, largely unknown.

Methods

This study uses 37 years (1984-2020) of atmospherically corrected remote sensing reflectance data from Landsat 5, 7, and 8 to investigate SPM with winds and river discharge in a turbid estuary (see Figure 1). From these data we establish a long time series of satellite-derived SPM for the Scheldt Estuary, The Netherlands. SPM was estimated using a generic algorithm applied to the near-infrared band Additionally, a time series of river discharge and wind speed were used to assess the potential effects of these two coastal drivers on the spatial and temporal variability of SPM. In principle, such approach can provide quantitative and qualitative evaluation of SPM dynamics at high spatial resolution.

Results

The observed spatial and temporal patterns between SPM and river discharge and SPM and wind speed which correlate best at daily and monthly timescales, reveal the complex importance of these two drivers for the Scheldt Estuary system. Our study also demonstrates the usefulness of applying the high-resolution Landsat data to capture where river discharge and wind speed mostly affect SPM within the Scheldt Estuary although quantitative evaluations of SPM dynamics can be significantly limited by cloud coverage and/or low temporal resolution (16-day overpass). Finally, studies of synoptic variability and the hydrodynamics would assist in better understanding of SPM behaviour driven by river discharge and wind speed at strategic locations, which are further determined by spatial correlations.

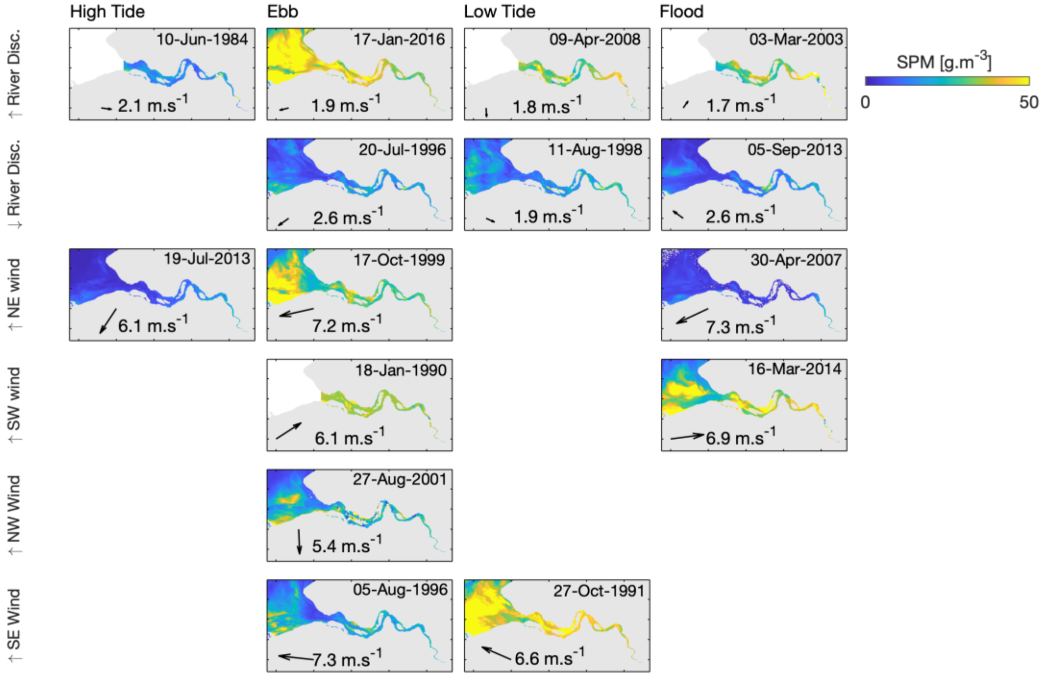

Figure 1: Examples of spatial SPM variability under multiple river discharge and wind configuration

Estuarine recovery time after a freshwater pulse

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Introduction

Freshwater pulses, during which the freshwater discharge by rivers exceeds three times its long-yearly average value for no longer than one month, are common features in many estuaries around the world. These events cause a strong (temporary) downstream shift of the salt intrusion, having implications for the freshwater availability around the estuary. An important aspect is the recovery time, which is the time it takes for the estuary to reach equilibrium again after the freshwater pulse. Values of this quantity widely vary between observations. For example, Valle-Levinson et al. (2002) found 10 days for the Chesapeake Bay (USA), whilst Gong et al. (2007) reported four months for York River estuary, which is located in the same area. To understand the mechanisms determining this recovery time, an idealised model is employed.

Methods

The idealised model solves the width-averaged subtidal (simplified) equations of motion for an estuary, coupled to the salt balance. This model extends earlier model approaches to estuarine unsteadiness such that it is also capable to handle high river discharge events. A set of simulations is conducted where the idealised case of a freshwater pulse in an estuary is considered. The effect of the background state of the estuary, the peak river discharge and the duration of the pulse on the recovery time is quantified.

Results

The effect of the background state of the estuary expresses itself through the background river discharge. A larger background river discharge leads to a smaller recovery time (Fig. 1). The (somewhat surprising) dependence on tidal strength will also be shown and discussed. The recovery time is insensitive to the peak river discharge and the duration of the pulse. These findings can be explained by studying the different processes driving the recovery.

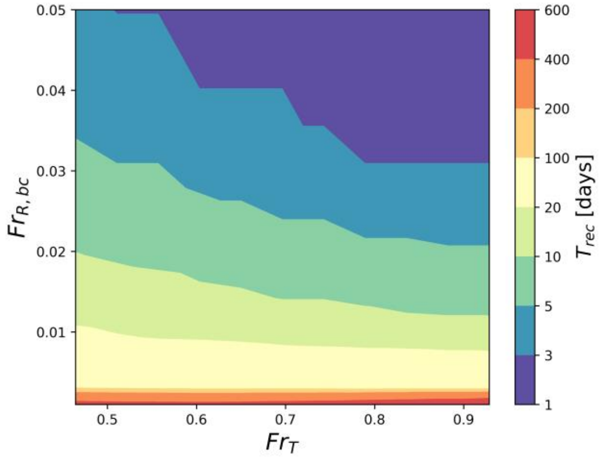

Figure 1: Regime diagram of recovery time T_{rec} versus tidal Froude number (Fr_T, which is a measure of the strength of the tides) and background freshwater Froude number ($Fr_{R,bc}$, which is a measure of the strength of the river discharge after the pulse).

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Providing instant feedback in coastal citizen science: automated geo-rectification of smartphone images and shoreline detection

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Introduction

Coastal areas are recreational hotspots where people actively engage with their environment. To occasional visitors, the coast may appear relatively static, but regular beachgoers are often aware of the ever-changing sea, beach and dunes. Monitoring and assessment of coastal dynamics relies on high-frequency observations, which are time-consuming or costly. Engaging the public in the collection of such observations provides a cost-effective method to acquire observational data. At the same time, this ‘citizen science’ approach provides an opportunity to raise awareness of coastal dynamics and to engage the public in our ongoing coastal research. With this contribution we aim to (1) give an overview of the ongoing coastal citizen science efforts at Utrecht University and (2) outline how we process smartphone-collected photos of the beach to provide instant feedback to users.

Approach

We build upon the methodology used within the international CoastSnap (Harley et al., 2019) network, where users (“citizens”) contribute by submitting smartphone photos of shoreline positions through the CoastSnap app, e-mail or social media, at fixed photo points. In our approach, users are directed to a custom-built webpage (www.coastsnap.nl) by scanning a QR-code, where they can directly shoot and submit their uncompressed photo file. After, they are instantly rewarded with the result of their processed image (figure 2). To provide this instant feedback on shoreline positions, we automated the georectification and shoreline detection using machine learning and object detection. The existing MATLAB routines were converted and extended to Python, to make the CoastSnap approach even more accessible and interoperable for other citizen science initiatives. The source code will be made publicly available. We currently run four CoastSnap locations using this approach (at Egmond, Petten, Noordvoort and the Prins Hendrikzanddijk on Texel), and aim to include other sites and coastal features of interest.

Figure 1: (a) The CoastSnap station at Egmond aan Zee (NL), (b) a received photo file, taken from the mount, and (c) the automatically processed image with the shoreline indicated in red.

References

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A global remote-sensing assessment of the mobility of coastal dunes

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Introduction

Over the last decades, many coastal dunes have lost their natural geomorphologically dynamic character due to spatial extension of vegetation. This "greening" may not only affect adversely the resilience of the dune systems to climate change, but already puts at risk their ecological diversity. Whether dune greening is acting globally is largely unknown. The aim of this work is to detect and assess the change in vegetation cover over time at a large number of dune sites worldwide from Landsat satellite imagery, and to correlate the identified trends with the main climatic variables such as temperature, precipitation and wind speed in order to examine the drivers of the change.

Methods

The Climate Engine App (http://climateengine.org/) has been used to retrieve the multitemporal time series of the Normalized Difference Vegetation Index (NDVI; Landsat 4, 5, 7 and 8) and those of the climatic variables (temperature, precipitation, wind speed) for the period between 1984 and 2021. This has been done for 186 individual dune sites, geographically distributed as (Fig. 1): Europe (69); South America (33); North America (31); Africa (20); Oceania (29); and Asia (4). The first step in the data analysis was to identify significant annual trends using the Mann-Kendall statistical test and quantify them using the Sen's slope estimator. A statistically significant positive NDVI trend reflects greening. Finally, linear correlation analysis was applied to determine the dependence between greening and temporal changes in the climate variables.

Results

The performed trend analysis of the NDVI time series showed that positive (greening) trends are indeed dominant (87.1%) on a global scale, as compared to a few dune areas (9.1%) with negative trends where the aeolian process dominates the stabilization, and sites with no change (3.8%) (Fig. 1). We also found that larger NDVI increases are associated with denser average vegetation cover (i.e., greener sites). About 63% of all significant changes have accelerated over the second half of the studied period. The vegetation trends are not statistically related to the trends in the climatic variables ($p > 0.05$). This was additionally corroborated by a multiple regression analysis, which showed a lack of dependence on any of the climatic variables. Possible explanation is that the current climate is sufficiently warm and wet for dune greening and that changes in the climate variables are not relevant, or that other local or regional factors (e.g., atmospheric pollution; decline in rabbit numbers) contribute to the greening.

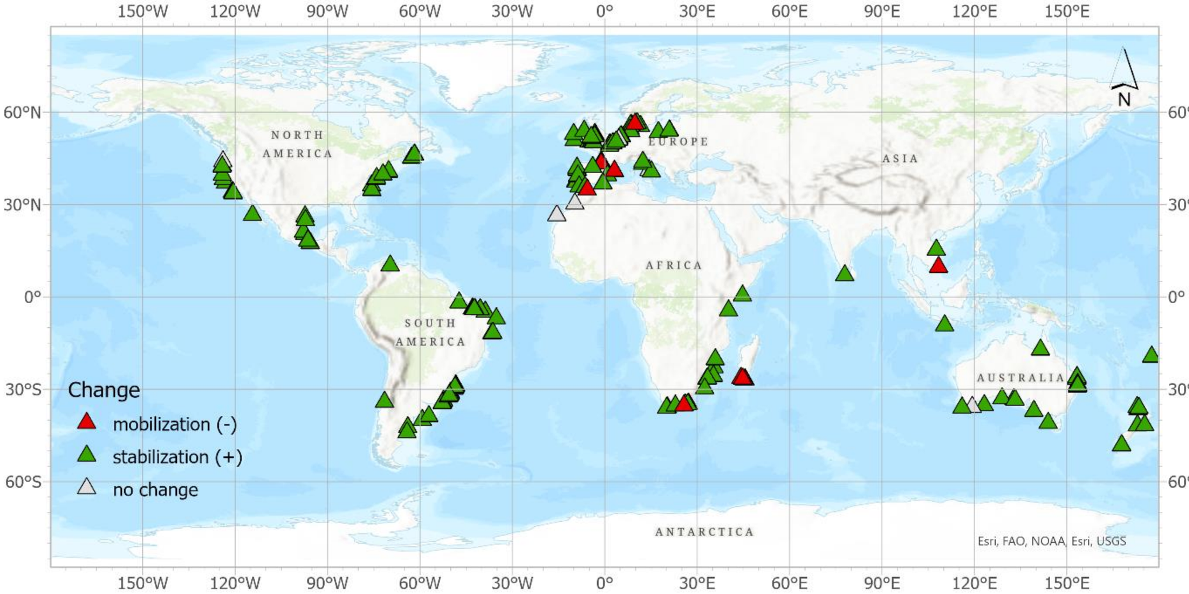

Figure 1: Dune dynamics based on the Mann-Kendall trend analysis using the NDVI signals.

Sediment balance of the Noord-Holland coast

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Introduction

The open Dutch coast consists of sandy beaches, which are continuously changing as a result of wave-driven longshore transport, tide-driven transports and sea level rise. Sand nourishments are placed at regular intervals to maintain the position of the coastline and compensate any deficits in the sediment balance. A re-evaluation of the sediment balance is very relevant, as the last effort was undertaken decades ago by *Van Rijn (1997*).

This study uses the yearly bathymetric surveys of the Dutch coast as measured by Rijkswaterstaat (referred to as the 'Jaarlijkse Kustmetingen' or JarKus) from 1965 till the present day. These data consist of cross-shore transects with a 250 meter alongshore spacing for the nearshore area. The offshore section is measured five-yearly up to 3 km offshore with an alongshore spacing of 1 km, also referred to as '*doorlodingen'*.

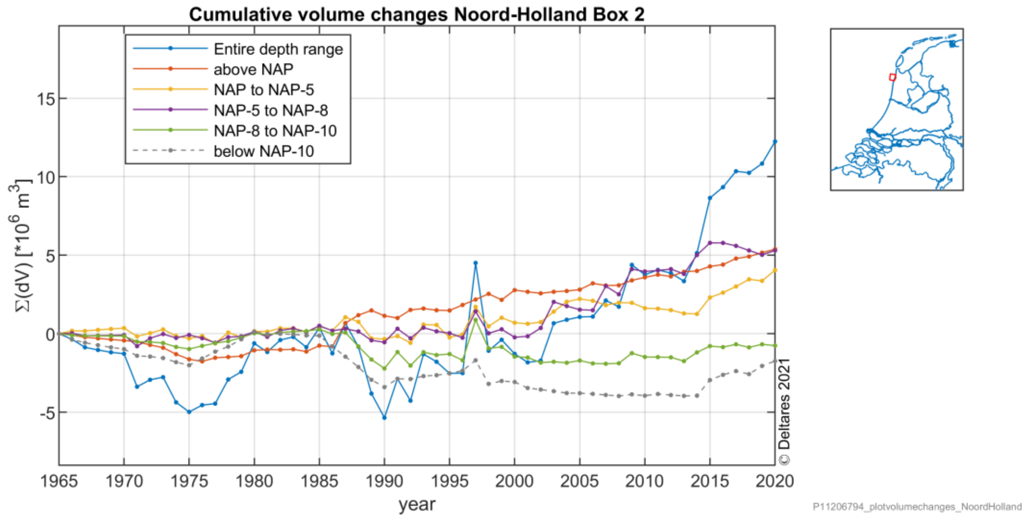

Figure 1: Example of cumulative volume changes in a box along the Noord-Holland coast

Method and results

Building on the work of *Van Rijn (1997)*, we made a sediment budget model for the Noord-Holland coast by interpolating the cross-shore JarKus profiles in time and space on a regularly spaced grid to assess the sediment volume changes and trends per depth range over the past decades. Analyses were made for various depth-ranges and alongshore regions, which gives us a prime insight in the cross-shore influence zone of the nourishment program and general cross-shore behaviour of nourishments. Figure 1 shows an example of volume changes per depth range.

The results for the nearshore zone show the relevance of beach and shoreface nourishments for the preservation of the North-Holland coast, which generally is accretive. Erosive trends are observed typically in the more seaward section of the profile beyond 8 meter water depth. The observed sediment volume changes here are to be further interpreted in relation to transport computations by *Grasmeijer et al. (2022)*, which gives us insight in expected future development of the region. Our study does not only quantify trends, but also explores a methodology for combining data sources in a sediment balance.

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Building the socio-biophysical cognitive model of sandy anthropogenic shores (SAS) in the Netherlands.

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Introduction

Sandy Anthropogenic Shores (SAS) are coasts formed by moving large amounts of dredged sand from offshore to near the coast, with natural processes such as waves, wind, and currents used to spread the sand and reinforce the foredune for coastal safety. At the same time, wider beaches and lagoon features provide new space for human activities and habitats. The Sand Motor is an example of SAS on the Dutch North Sea coast near The Hague. Previous studies of SAS in the Netherlands have mainly addressed the biophysical and social aspects separately, ignoring their interactions as part of a unified socio-natural system. We aim to map this complex socio-bio-physical system based on the experience and knowledge of policymakers and managers.

Methods

We applied a participatory modelling process (Gray et al., 2018) to explore the socio-biophysical system of SAS. We started with semi-structured interviews with various stakeholders in relevant management organizations. After analyzing the interviews, we derived the preliminary list of concepts related to each SAS's function and clustered them into different categories. In the next stage, we ran a workshop with selected stakeholders. During the workshop, we validated the concepts and updated them by presenting the identified primitive concepts and using the adaptation pathways approach to track the pathways between aims and actions.

Results

Figure 1 shows the general framework of the socio-biophysical system on SAS based on the identified concepts' categories (stakeholders (goals and management actions), functions, and biophysical system (elements and processes)) developed by stakeholders. In general, this conceptual model can provide a guideline for developing a quantitative computer model of the socio-biophysical system in SAS. This is the aim of the next stage of this research.

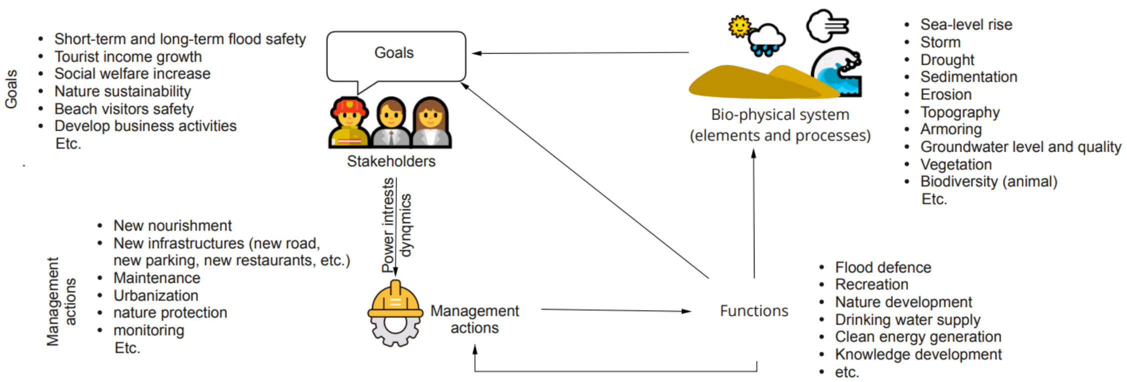

Figure 1: the general framework of the socio-biophysical system on SAS

References

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Modelling sediment dynamics around buildings in a cellular automaton model

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Introduction

Buildings in sandy environments alter windblown sediment transport and morphology in their surroundings. So far, morphodynamic cellular automaton (CA) models like Dubeveg (Keijsers et al., 2016) have only been used to study natural dune dynamics. However, buildings introduce anthropogenic effects to these natural landscapes. We extend these CA models with building effects and use this to examine how building-induced morphological patterns interact with natural bedform dynamics.

Methods

CA models like Dubeveg are based on a grid with discrete slabs representing elevation. Probabilistic rules determine slab erosion and deposition, based on the presence features such as dunes or vegetation. For the sediment transport dynamics around buildings, additional rules are needed. Therefore, we developed new rules that represent sideward sediment transport around buildings and the deceleration (deposition) and acceleration (scour) of sediment around buildings. Model results are then compared to field experiments. Next, longer-term simulations of up to 15 years are used to explore how morphological features around buildings interact with natural bedform dynamics.

Results

The simulated deposition and erosion patterns show good agreement with field experiments. They reproduce the shape and location of morphological patterns, for configurations with both single buildings and building groups (Figure 1). Model results further demonstrate that building-induced effects interact with local bedform dynamics and can alter the shape, growth and migration of sand dunes.

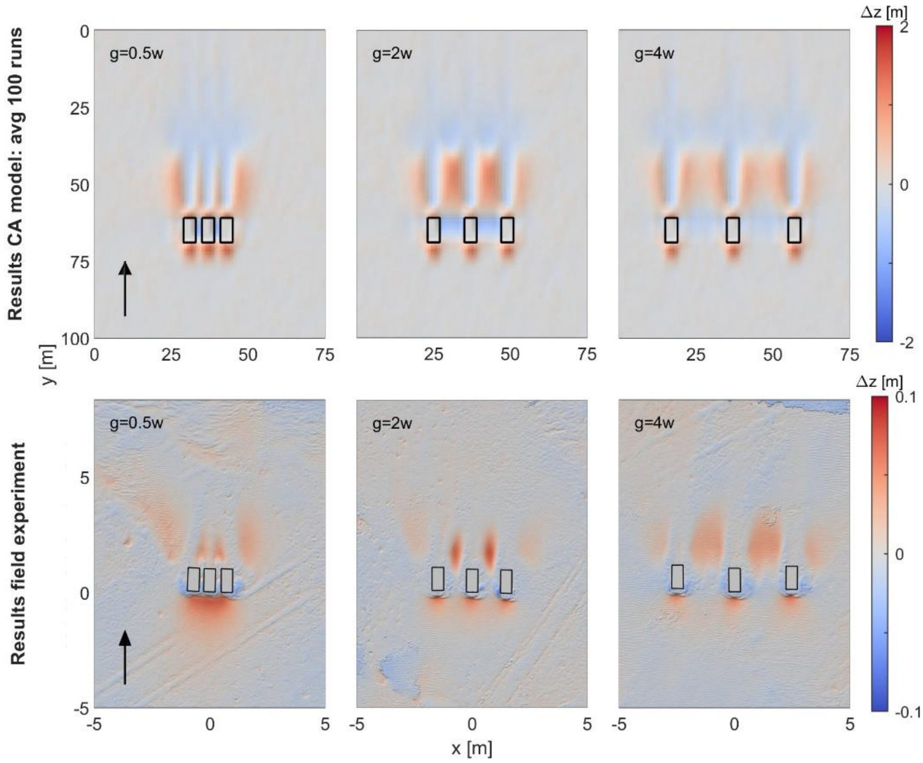

Figure 1: Comparison of bed level change: CA results (top row) vs field observations (bottom row)

References

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Geomorphological evolution of excavated foredune notches

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Introduction

Many foredunes along developed coasts have been managed into densely vegetated, uniform and stable ridges of sand to strengthen their role as sea defence. It is increasingly feared that such foredunes are less resilient to erosion under climate change (e.g., rising sea levels) relative to present-day conditions. The dense vegetation blocks the sand exchange between the beach and the backdunes and accordingly, prevents the backdunes from growing with sea-level rise. The excavation of gaps through the foredune, termed notches, is nowadays increasingly applied as a nature-based solution to restore the natural sand pathway into the backdunes and to improve their natural values with the overarching aim of advancing climate adaptation. The geomorphological evolution of notches is, however, not well understood, especially on the time scales of years. This prevents understanding what factors contribute to success (long-term mobility) or failure (rapid closure) of foredune notches.

Methods

We analyse the geomorphic evolution of five notches in the foredune near Bloemendaal - one of the largest dune restoration projects in NW Europe - since their excavation in the 2012/2013 winter using 24 digital elevation models (DEMs) derived from airborne lidar and drone surveys. Nineteen of these DEMs are associated with an RGB orthomosaic.

Results

The orthomosaics and DEMs of Difference illustrate that up to 280-m long and more than 7-m thick depositional lobes formed landward of the notches, while the notches persistently eroded through alongshore widening and steepening of the lateral walls (Fig. 1). Both the deposition and erosion volume, computed inside the region bounded by the azure blue line in Fig. 1c, increased approximately linear with time (33,500 versus 17.500 m^3/y). The larger deposition than erosion volume is due to the throughput of wind-blown beach sand, highlighting that the notches facilitated highly efficient onshore sand pathways into the backdunes during the entire examined time period. In more detail, the data also suggest that the notches oriented with the dominant wind direction (the upper two notches in Fig. 1) were more efficient in facilitating this onshore transport than notches with other orientations.

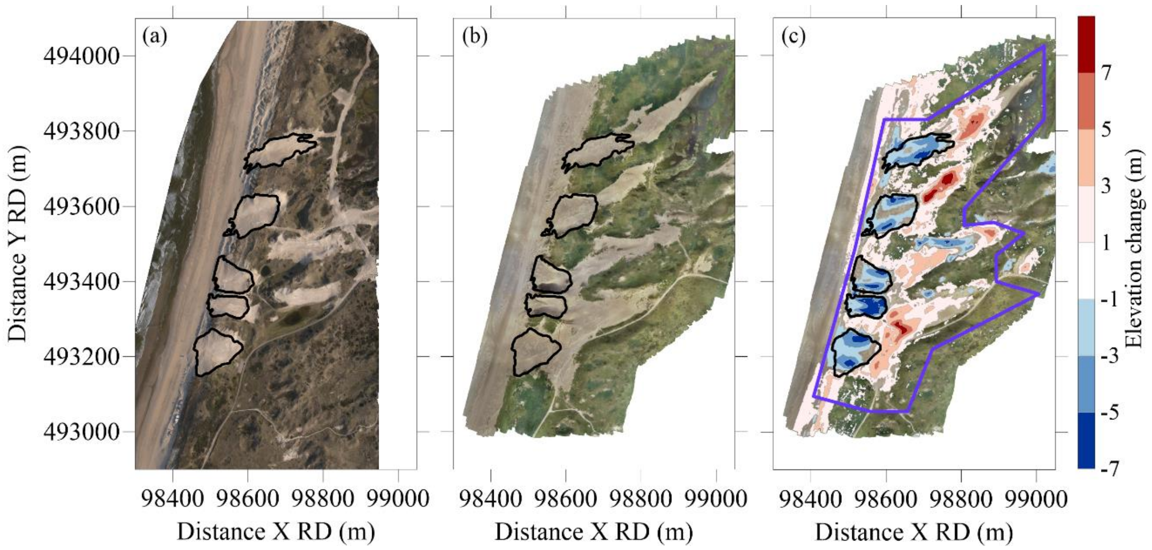

Figure 1: Orthomosaic (a) shortly after excavation (May 2013) and (b) after 8.5 years (October 2021), (c) and the DEM of Difference for the same time period (red = deposition; blue = erosion) overlain on the October 2021 orthomosaic. Black lines in all panels are the initial (May 2013) notch outlines. The azure blue line in (c) outlines the region for which erosion and deposition volumes were computed.

Exploring System-based Nourishment Strategies for Texel Southwest

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Introduction

In 1990 a new policy framework of 'dynamic coastal preservation' was adopted in The Netherlands (Ministerie van Verkeer en Waterstaat, 1990). This policy framework encompasses the introduction of coastal sand nourishments to prevent structural coastal erosion and to keep the coastline (dynamically) in place. Rijkswaterstaat is the responsible authority for the planning and execution of these sand nourishments ever since the start of 'dynamic coastal preservation' in 1990.
One of the most intensively nourished sites along the Dutch coast is Texel Southwest, located between JarKus transect ('raai') 900 - 1269 (Figure 1). This area is characterized by structural erosion due to the presence of Texel Inlet (Elias & Van der Spek, 2017). Therefore, since 1990 more than 7,500,000 m^3 of sand has been nourished to maintain the coastline. Recently, Rijkswaterstaat and Deltares collaborated in exploring system-based nourishment strategies for Texel Southwest that make use of coastal processes in order to reduce coastal erosion. These system-based nourishments can serve as an addition or alternative to the common practice of beach nourishments at Texel Southwest.

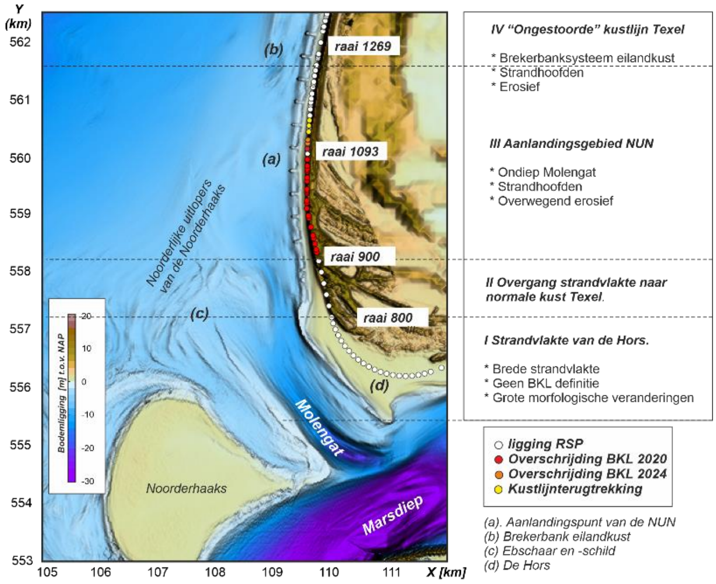

Figure 1. Morphological processes along the coast of Texel Southwest (Source: Elias et al., 2020).

Results

Four alternative nourishment strategies were identified and modelled, including: 1) extending the breaker bar system from JarKus transect 1269 in southward direction), 2) nourishing the Noordelijke Uitlopers of the Noorderhaaks ('NUN' in short), 3) XL beach nourishment between JarKus transect 900 - 1269, and 4) blocking the Molengat tidal channel along the tip of Texel Southwest. Research by Elias et al. (2021) suggests options 2 and 4 have potential to optimize the nourishment scheme at Texel Southwest by respectively reducing wave-driven erosion ('breaker bar effect') and reducing tidal action.

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The influence of foreshore dimensions on dike breach consequences: a flume study

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Introduction

Climate-proof coastal protection includes flood protection by dikes and foreshores. Historical data and initial modelling show the presence of a foreshore limits the chance and consequences of a dike breach (Zhu et al., 2020). We aim to provide quantitative lab evidence for the influence of foreshore dimensions on polder inundation during a dike breach.

Methods

A dike breach event was simulated in a scaled flume. Inside the flume, a sea, dike and polder area were created (details in Figure 1). A foreshore was placed in front of the clay dike. Foreshores differed in height (3.5 cm for low marsh and 5.0 cm for high marsh), width (15, 30, 45, or 60 cm), and material (sand or TRESPA). Sae level was kept constant at 10 cm, without waves. The dike had a fixed breach of 5.0 cm wide. A total of 24 runs were conducted, including two control runs without a foreshore. Data was collected using depth sensors for water depth monitoring and cameras for visual observation.

Results

Preliminary results show that in a lab setting the presence of a foreshore reduces water flow into a polder during a dike breach (Figure 1). Reduced flow velocity and discharge lead to slower polder inundation. This gives more evacuation time for a dike breach with foreshore compared to a dike breach without a foreshore. Mainly foreshore height is important, while differing foreshore width has little influence. Further analysis will be presented to show it is useful to connect the foreshore and dike for climate-proof flood protection, even in case of a dike breach.

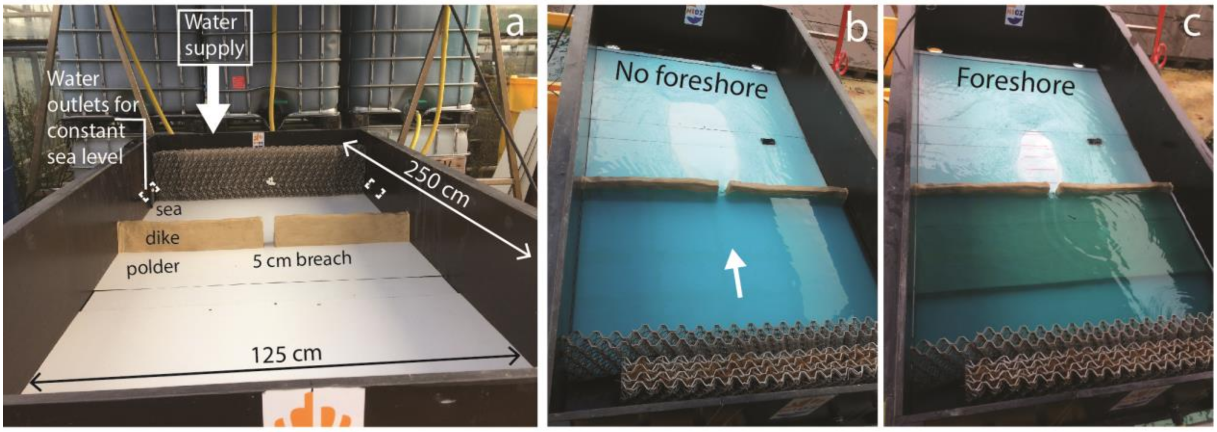

Figure 1: Flume set-up (a). Water flows from the sea into the polder and is stored underneath the flume. Compared to a dike without a foreshore (b), foreshore presence (c) reduces flow velocity and discharge into the polder during a dike breach (image courtesy: Kim van den Hoven).

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The wave overtopping flow over grass-covered flood defences

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Introduction

Grass-covered flood defences are globally used as coastal protection. Wave overtopping is one of the main failure mechanisms of these flood defences. During storms, waves can flow over the crest and accelerate along the landward slope resulting in high hydraulic loads that can lead to erosion of the cover (Figure 1). Climate change can increase the amount of wave overtopping and decrease the strength of the grass cover. For example, higher design water levels are expected due to sea level rise while increasing droughts in summer reduce the strength of the grass cover and underlying clay layer. Therefore, it is important to develop tools for wave overtopping that can take both changes in the load and the strength into account to assess the safety of grass-covered flood defences.

Methods

We developed a numerical model to simulate the overtopping flow over grass-covered flood defences in OpenFOAM (Van Bergeijk et al., 2022). Separate overtopping volumes are simulated to identify important hydraulic processes and locations of high hydraulic load. The numerical model is used to develop formulations for the hydraulic load that can be used in a probabilistic framework to calculate the failure probability of grass-covered flood defences. In this framework, the distribution for the grass cover strength was adapted to study the effect of reduced cover strength due to droughts.

Results

Two important hydraulic processes were identified. Firstly, the flow can separate at the landward crest line resulting in high normal forces at the reattachment location. Secondly, high flow velocities at the toe result in high shear forces. Therefore, the upper slope and the toe are vulnerable locations for cover erosion by overtopping waves. The probabilistic calculations showed that a good grass cover is extremely important to protect the flood defence against erosion. Damages to the grass cover can increase the failure probability by a factor 3000 for flood defences with a long fetch length as is the case for coastal flood defences (Van Bergeijk et al., 2021). The developed methods can be used to study innovative covers to make coastal defences more climate proof such as flower rich species or geogrid.

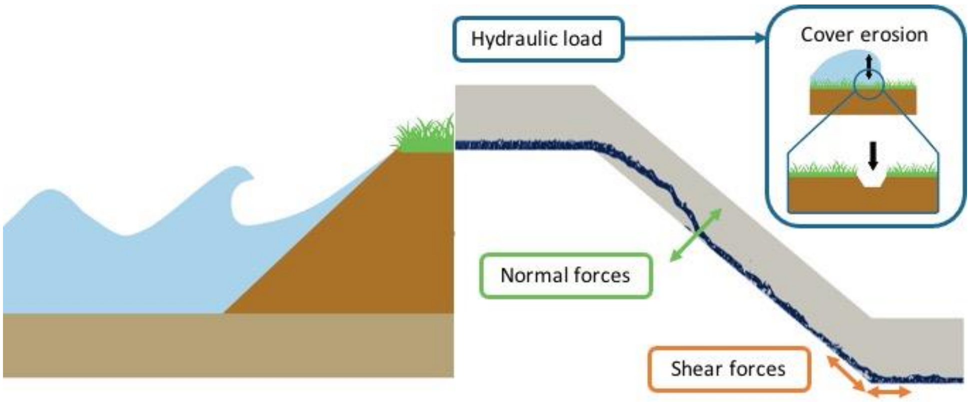

Figure 1: Model simulation of the overtopping wave indicating locations of high hydraulic load.

Acknowledgements

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Enabling dynamic modelling of global coastal flooding by defining storm tide hydrographs

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Introduction

Coastal flooding is driven by strong winds and low pressures in tropical and extratropical cyclones that generate a storm surge, and high tides. The combination of storm surge and the astronomical tide is defined as the storm tide. Currently over 600 million people live in coastal areas below 10 m elevation worldwide which is projected to increase to more than 1 billion people by 2050 under all Shared Economic Pathways. Towards the end of the 21st century these growing coastal populations will be increasingly at risk of flooding due to SLR. To gain understanding into the threat imposed by coastal flooding and identify areas that are especially at risk, now and in the future, it is crucial to accurately model coastal inundation and assess the coastal flood hazard.

Method

There are three main types of inundation models with complexity levels ranging from simple, to semi-advanced to advanced. Models capable of simulating inundation at the global scale follow a simple static approach. These models, often referred to as bathtub models, delineate the inundation zone by raising maximum water levels, that correspond to a return period, on a coastal DEM and select all areas that are below the specified water level height. The main limitations of this type of model is that they implicitly assume an infinite flood duration and do not capture relevant physical processes. Regional comparisons have shown that dynamic inundation models are much more accurate than static models in terms of flood extent and depth, and they can provide information on the flood duration.

Results

In this study we develop a global dataset of storm tide hydrographs. These hydrographs represent the typical shape of an extreme sea level event at a certain location along the global coastline (Fig. 1) and can be used as boundary conditions for dynamic inundation models. This way we can move away from static to more advanced dynamic inundation models. To assess how different assumptions used for generating hydrographs influence the inundation extent and depth we perform a sensitivity analysis for several coastal regions.

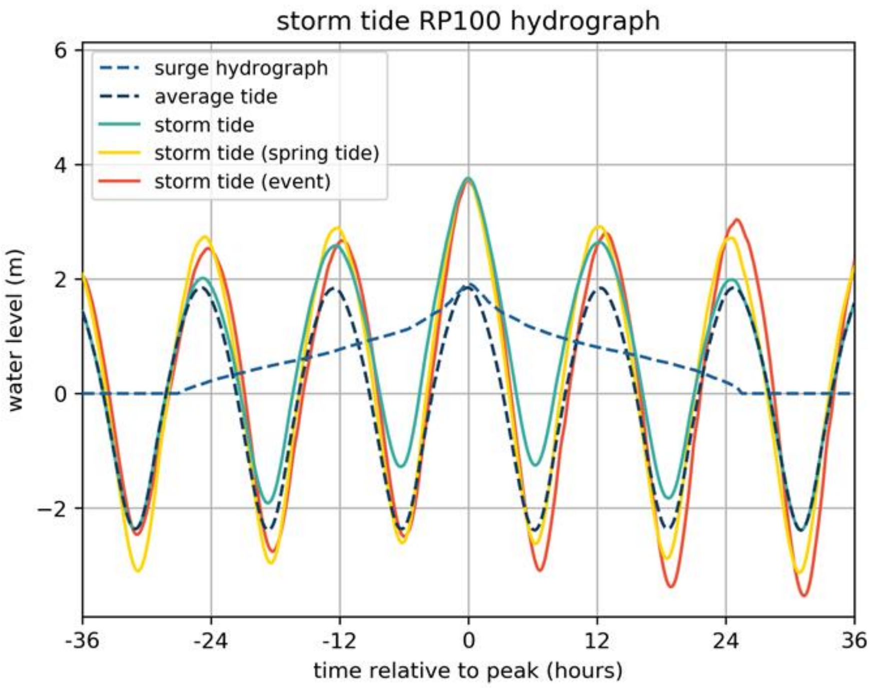

Figure 1: Hydrograph of the 1-in-100 year storm tide event at La Rochelle, France

Improvements and validation of XBeach for the safety assessment of the Dutch coast: Part 1, hydrodynamics

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Introduction

Dunes and beaches protect large stretches of the Dutch coast against flooding. As prescribed by the Dutch Water Law, the Dutch dune coast is periodically assessed to ensure an acceptable level of flood risk. This safety assessment methodology is currently being updated within the framework of the program BOI (Assessment and Design of Flood Defences) to utilize the process-based storm impact model XBeach, instead of the empirical dune erosion model DUROS+. As part of this work, improvements to XBeach model formulations have been made, and extensive validation has been carried out using laboratory and field data.

Model improvements and field validation

One of the advantages of the XBeach model over DUROS+ is its ability to simulate both incident-band and infragravity-band hydrodynamics. As a key driver of dune erosion during storms, it is imperative that the XBeach model represents infragravity waves well in settings relevant to the Dutch safety assessment.

Alongside the development of modelling guidelines and default model parameters, the 1D XBeach formulations were also improved to better represent infragravity waves in directionally-spread seas. While computationally cheaper than their 2DH equivalents, 1D models suffer from the assumption of alongshore uniformity in hydro- and morphodynamics. This assumption presents well-known challenges for application in complex coastal areas. However, an additional, lesser-known challenge presents itself in XBeach (in common with wave flume experiments), in that the 1D assumption of alongshore uniformity in the (instantaneous) hydrodynamics leads to strong transfer of energy from the incident wave band to the infragravity wave band, and hence a substantial overestimation of nearshore infragravity wave energy relative to field conditions. This subsequently leads to overestimation of dune erosion and overwash. To allow for the application of 1D XBeach models in the safety assessment, we have validated a heuristic approach that allows us the model to mimic the effect of wave directional spread on infragravity wave energy and provide better estimates of dune erosion. This approach was subsequently validated using field observations of nearshore hydrodynamics.

We look forward to presenting these developments and their validation at the NCK conference.

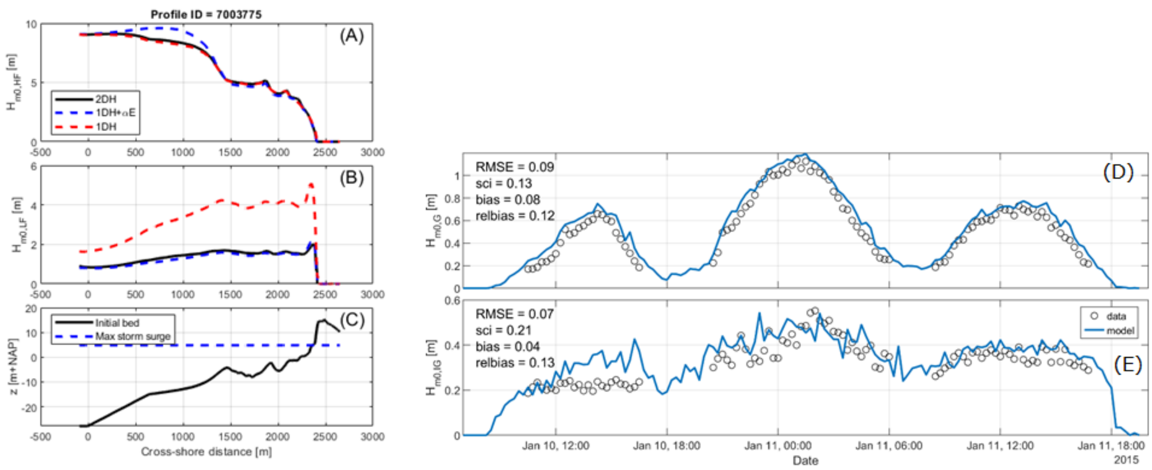

Figure 1: Comparison of 2DH (black), uncorrected 1D (red) and corrected 1D (blue) simulated wind wave (A) and infragravity wave (B) transformation on coastal profile (C). Comparison of 1D corrected (blue) and observed (circles) wind waves (D) and infragravity waves (E) in field validation case.

Improvements and validation of XBeach for the safety assessment of the Dutch coast: Part 2, morphodynamics

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Introduction

Dunes and beaches are an integral part of the primary sea defences along the Dutch coastline. The existing (and legally embedded) methodology for dune safety assessments is built around the empirical 1D model Duros+. The applicability of this model, however, is limited for coastal areas with more complex bathymetry, multiple dune rows and/or the presence of coastal structures. As part of the national program BOI (Assessment and Design Instrument for flood defences) a renewed instrument is being developed, based on the model XBeach, for assessing, designing and maintaining dunes.

Calibration and validation of XBeach

One of the initial steps in developing the new dune assessment instrument is the calibration and the validation of the new core model, XBeach. A new set of model parameter settings has been derived based on both laboratory experiments and field data. To ensure consistency in the setup of XBeach models for the purpose of a dune safety assessment BOI-specific guidelines and procedures have been developed (e.g. for schematisation of coastal profiles). As part of the study also some model improvements have been implemented and tested. Related to the morphodynamic processes, for example, the grain size sensitivity of XBeach has been improved. Based on the new BOI-settings and developed guidelines for model setup, multiple field cases are considered to validate XBeach and to gain insight in the accuracy of the model.

For the validation study a series of Dutch and international field cases was selected based on availability of data and representativeness of the local situation (profile, grain size, storm conditions, erosion volumes). For each of the selected cases one or more coastal transects are considered for which (1D) XBeach models are set up in accordance with the new guidelines and the BOI model settings. The results of the model simulations are used for the validation of the modelled hydrodynamic and morphodynamic processes. In total, nine case studies and more than 60 transects are considered for a successful quantitative comparison between model results and observational data.

We look forward to presenting the results of the morphodynamic field validation at the NCK conference.

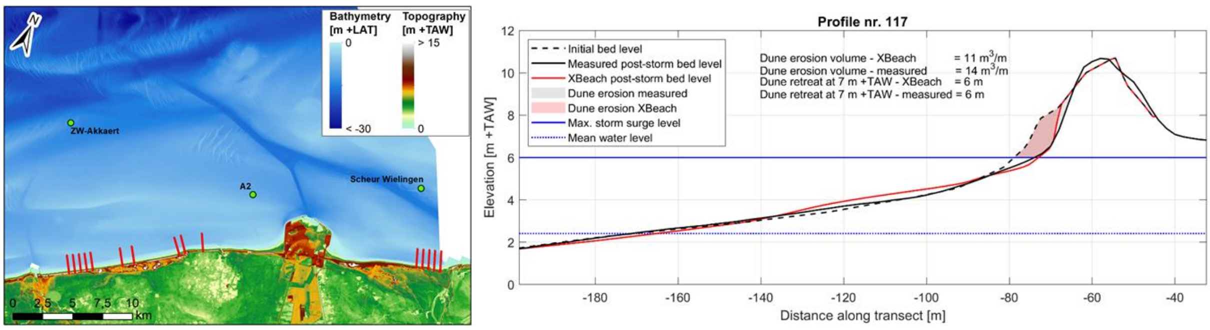

Figure 1: Example of input and output data of one of the morphodynamic validation cases: dune erosion along the Flemish Coast during the Sint Nicholas storm (2013).

Towards a renewed instrument for dune safety assessments

The calibration and validation of the BOI-version of XBeach is the first step towards the intended new instrument for assessing the sandy Dutch coasts. The formal safety assessment aims at estimating the probability of flooding, therefore also a semi-probabilistic method is being developed for dunes. The calibrated XBeach model, the semi-probabilistic method and a set of updated guidelines and procedures jointly support the future assessment, design and maintenance of dunes along the Dutch coastline.

Abstracts of poster presentations

Of the NCK Days 2022

A classification of salt transport regimes in narrow estuaries, with application to the Rotterdam Waterway

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Introduction

The distribution of salt in an estuary continuously adapts to the various processes that import and export salt. Tidally-averaged, these transport processes are categorised as subtidal processes or tidal covariance (hereafter 'tidal processes'). Analysis of salt transport in various estuaries has shown that either subtidal or tidal processes can be dominant. The various subtidal and tidal transport processes each have a different sensitivity to changing forcing parameters (e.g. tides, river discharge, sea level) and geometry (depth or width). Hence, to understand how the salt intrusion responds to climate change, it is important to understand which mechanisms dominate the salt transport.

There is currently no comprehensive theory that describes the relative importance of subtidal and tidal processes as a function of the estuarine parameters, such as depth, width, river run-off or tides for general estuaries. Therefore, the aim of this contribution is to construct a classification that shows the relative importance of subtidal and tidal transport processes across a large range of estuarine parameters, where we focus on width-averaged processes.

Methods

The classification is derived from a systematic analysis of a process-based model. The model is purpose-built to allow for studying a very large number of model configurations (>40.000 experiments) covering a wide range of estuarine conditions. For each model experiment, the salt balance is analysed. For validation, the classification is applied to the Rotterdam Waterway to conclude which salt transport processes dominate.

Results

We find that the salt transport is dominated by one of seven salt transport balances, or *regimes* (Fig 1a). The dominant regimes are described as a function of four dimensionless parameters. During the presentation, we will explain two specific regimes: one dominated by subtidal density-driven flow (green in Fig 1) and one dominated by tidal flow (red in Fig 1).
Application to the Rotterdam Waterway shows this estuary features multiple regimes (Fig 1b), with import dominated by subtidal regimes in the seaward part and a tidal regime in the landward part.
These results are confirmed by a direct decomposition of the salt flux in a 3D SIMONA model.

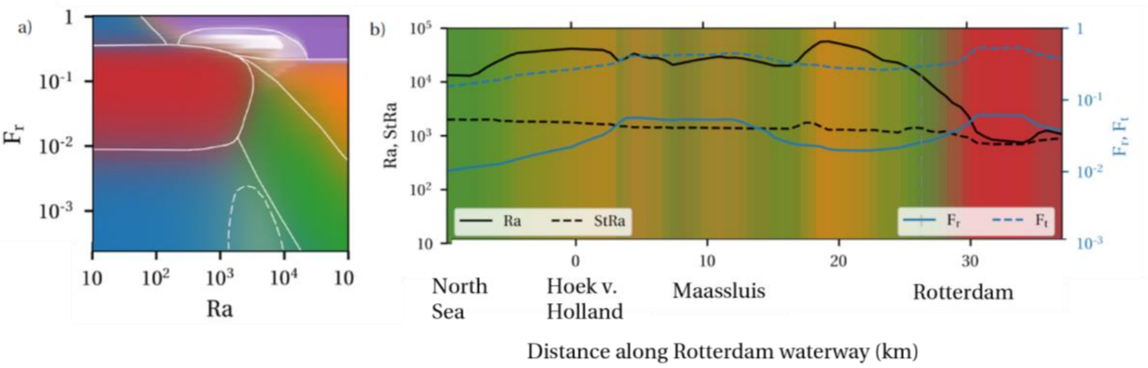

Figure 1: a) A slice of the classification scheme. Each colour indicates a regime that dominates the salt balance for given parameters. Here plotted are two of the four estuarine parameters: Fr (measuring fresh water discharge) and Ra (measuring mixing). For example, the green/orange regimes are dominated by subtidal density-driven flow, while the red regime is dominated by tidal flow. b) parameter values for the Rotterdam Waterway during low discharge, with colours matching those in the classification. A transition from subtidal regimes (green/orange) to a tidal regime (red) is observed.

Barrier islands face a gradual path toward drowning under most sea level rise scenarios

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Introduction

Interrupted barrier coasts, which comprise 10% of the world's coasts, consist of low-lying islands interrupted by inlets. Understanding their spatio-temporal behaviour and evolution is of great importance from an ecologic and socioeconomic point of view. Under moderate rates of sea level rise, barrier islands can survive by migrating onshore. However, the increasing sea level rise (SLR) rates that are expected to take place during the 21st century and beyond may cause an increasing proportion of barrier island chains to be below sea level. The present study looks at barrier island drowning timescales and spatial scales under different SLR scenarios, between the years 2000 and 2300.

Methods

Simulations were performed using the BRIE model (Nienhuis et al., 2019), an idealised model including overwash as well as inlet and shoreface morphodynamics. Runs consisted of 2000 years for model spin-up with a constant SLR rate of 2 mm/yr, and 300 years for system evolution under a SLR defined by the different IPCC scenarios (RCP2.6, RCP4.5 and RCP8.5). For all scenarios we assessed the transformation of tide-driven inlets toward SLR-driven inlets, which together sum up to be a barrier fraction below sea level.

Results

Simulations performed under different SLR scenarios and different values of wave height and tidal amplitude highlight the vulnerability of these systems under extreme conditions (see Figure 1). Results also show that the relation between fraction of barrier island that was drowned and sea level depends on SLR scenario. Thus, barrier system evolution strongly depends on the rate of SLR and its time dependence, and not only on the sea level at a given time.

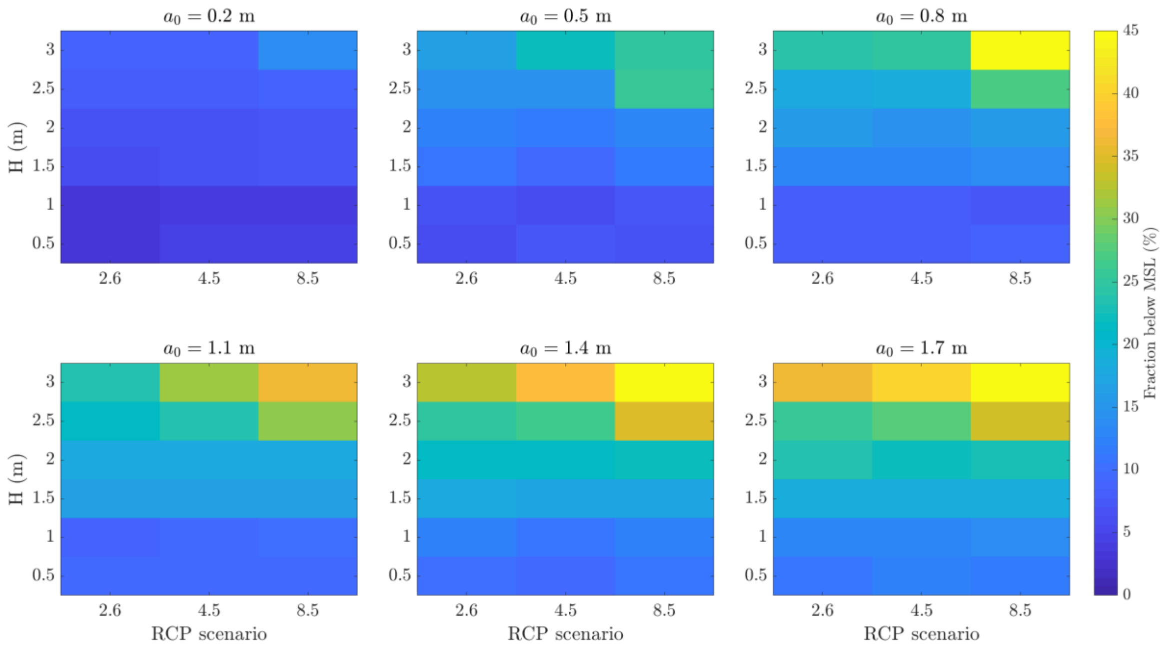

Figure 1: *Temporal mean (years 2000-2300) of alongshore fraction of the barrier that was drowned, for different values of tidal amplitude (a_0), wave height (H) and RCP scenario.*

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How turbating lugworms and stabilizing seagrasses shape the morphology of a Wadden Sea tidal basin

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Introduction

Biostabilizers and bioturbators determine the shape of tidal morphology on different scales through their effects on flow and sediment erodibility. While previous research has mainly focused on the effect of these species small-scale morphology, we still lack understanding of how the species interact with their habitat and affect the morphology on the scale of entire tidal basins.

Methods

To better understand how contrasting species determine coastal morphology, we model the effects of the destabilising lugworm (*Arenicola Marina*) and a stabilising seagrass species (*Zostera Noltii*) on the morphology of a tidal basin. The domain was inspired by a Wadden Sea tidal basin. We use a novel numerical model that couples Delft 3D with a species code which accounts for growth and mortality of both species based on environmental parameters and competition (Brückner *et al.*, 2019, 2021).

Results

We found that the lugworm erodes the tidal flats and promotes sedimentation in the tidal channels, whereas seagrass increases the elevation of the tidal flat and promotes erosion of the tidal channels.

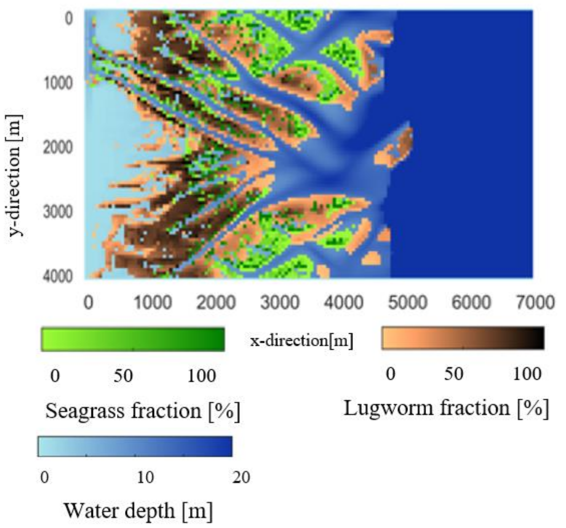

Figure 1: The distribution of Zostera Noltii (green) and Arenicola Marina (brown) overlain on the bathymetry of the tidal basin model domain (blue) for a scenario where competition between the two species is considered.

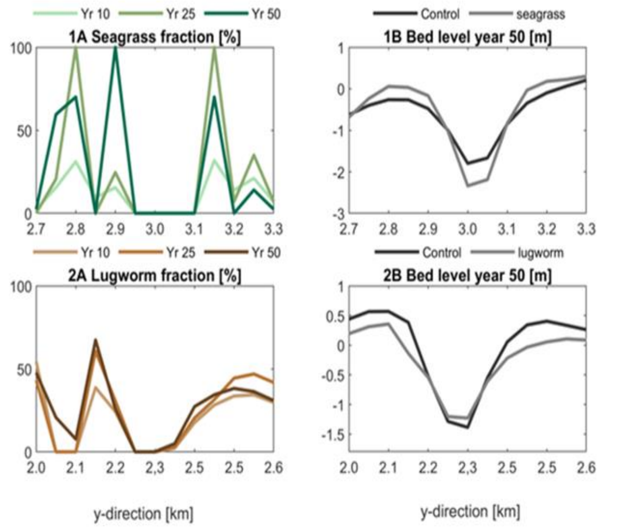

Figure 2: Cross-sections (A: x = 2000, y = 2500, B: x = 2500, y = 2800) of a tidal channel are shown next to the species fractions along these cross-sections. Where seagrass tends to promote erosion of the channel bed, lugworms initiate channel bed elevation.

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Assessing short-term estuarine development after large-scale interventions: An idealised model study

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Introduction

Estuarine regions are at the interface between rivers and seas. To allow shipping, and to ensure safety from flooding and freshwater availability, estuaries worldwide undergo many anthropogenic changes. Human interventions are desired to improve the current system and prepare for future threats, such as sea-level rise or sediment starvation. However, there is limited knowledge on the impact of large-scale human interventions on the development of the entire estuarine system. In this study, the aim is to explore the short-term (1 year), morphological response of estuaries to two large-scale intervention, and their impact on each other: 1) inter-tidal land reclamation, a nature-based solution increasingly recognised for its potential for flood safety, sediment trapping and ecosystem services (Temmerman et al., 2013) and; 2) Channel deepening, an intervention often applied within estuaries, e.g. to allow larger ships to enter the ports. To this end, an idealised morphological model is developed. In addition, by developing and applying a novel, generic approach to assess vegetation changes, the study aims to also gain insight into trends for vegetation development within the inter-tidal zone.

Methods

An idealised morphological model is developed in Delft3D-FM (2DH), representing a part of the Rhine-Meuse Delta (RMD), consisting of a coastal zone and estuarine channel (Figure 1). Firstly, the model is calibrated and validated to gain confidence in its ability to represent the RMD system. Next, large-scale interventions are implemented. Land-reclamation is implemented by creating vegetated intertidal zones. Hereby, a global dataset of salt marsh extent (Balke et al., 2016) is used to determine the area of the inter-tidal zone suitable for vegetation. Channel deepening is implemented (but also undeepening of the channel) by a uniform change in channel depth. Model simulations are performed using hydrodynamics for a representative year, including tides, seasonally varying waves and river discharge, to assess how these interventions affect short-term (eco-)morphological development of the estuarine system.

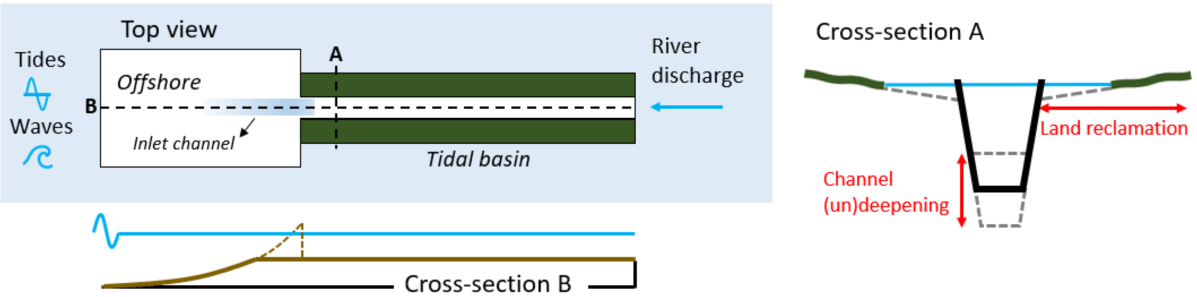

Figure 1: Graphical representation of the idealised estuarine model and the human interventions implemented within the model. The model is forced with tides and seasonally varying waves at the coast, and by a seasonally varying river discharge at the river boundary.

Results

The model is validated with observed hydrodynamic timeseries (water levels and waves) and observed annual morphological trends. Large-scale interventions are implemented, first in isolation and after that in combination. This way, the model helps us 1) to identify the (eco-)morphological impact of both types of interventions, locally and on the estuarine scale, and 2) to arrive at management strategies on how to deal with these large-scale human interventions in the RMD system.

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Settings of exploratory process-based modelling of estuarine sand dunes

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Introduction

All over the world, large-scale rhythmic bedforms can be found, one example being estuarine sand dunes. Estuarine sand dunes are influenced by both marine and fluvial processes. But they are also affected by estuarine-specific processes, like gravitation circulation. To understand the dynamics of the development of estuarine sand dunes, Van der Sande et al. (2021) developed a linear process-based model. This process-based model describes the initial development of estuarine sand dunes from a flat bed, and is based on shallow water equations forced by tide, river and a longitudinal salinity gradient. They choose their parameter settings to represent the Gironde Estuary. However, these parameters vary for different estuaries and locations within an estuary. Here, we investigate how the model parameters influence the characteristics of the Fastest Growing Mode (FGM), being growth rate, wavelength and migration rate.

Methods and results

We divide the parameters in two types: environmental parameters (water depth, depth-averaged M2 tidal velocity amplitude, depth-averaged river flow velocity, grain size and salinity gradient) and model parameters (drag coefficient, slip parameter, slope correction factor in the sediment equation and the bed load exponent). This is done to discern between natural variation and model uncertainty. The second step is to perform a one factor at the time (OFAT) sensitivity analysis.. This analysis shows the influence of different environmental and model parameters on the characteristics of the FGM. The range in each parameter is set based on a literature review. For example, the depth-averaged M2 tidal velocity amplitude ranges between 0.1 and 2 m/s, the effect of this change on the predicted sand dunes is presented in Figure 1. Thirdly, we investigate the combined sensitivity of the environmental parameter ranges and the model parameter ranges on the characteristics of the FGM. Lastly, we apply the model to explain variability between two cases: the Elbe and Scheldt estuary and the original used Gironde estuary .

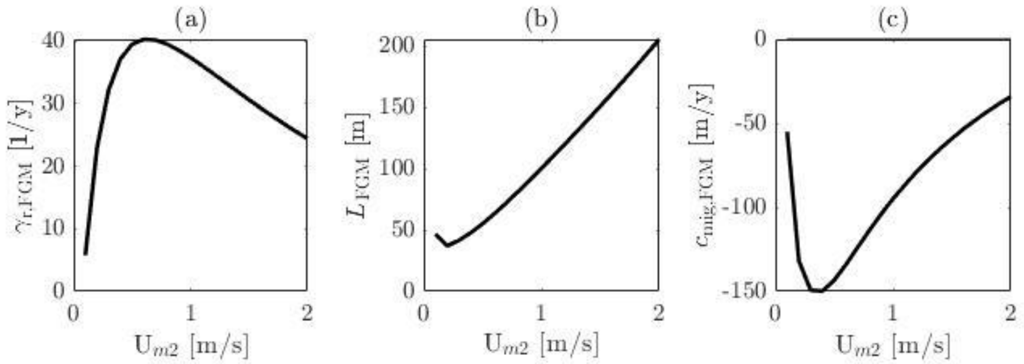

Figure 1: The effects of the depth-averaged M2 tidal velocity amplitude changes on the FGM properties. a) growth rate, b) wavelength, c) migration rate. This figure is an example of one of the OFAT analyses..

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Benthos-sand interactions in the context of an ebb-tidal delta nourishment

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Introduction

The Dutch Wadden coast is, like many coastlines worldwide, threatened by erosion. To ensure coastal safety, currently regular beach and foreshore nourishments are applied. For maintaining the long-term sediment balance of the coastline and tidal basins, new nourishment techniques are being developed. In this context, a pilot nourishment of 5 million m^3 sand was placed on the Ameland ebb-tidal delta. The project TRAILS (Tracking Ameland Inlet Living lab Sediment) aims to investigate transport pathways of the nourished sand within the ecological and social context. Since benthic fauna form a key link in the Wadden Sea ecosystem, and are strongly associated with their sediment habitat, their response to the nourishment cannot be overlooked. Therefore, we will dive into the far-field ecological implications of this ebb-tidal delta nourishment. Vice versa, fauna can alter sediment stability and composition by their activity or the structures they create, and hereby affect sand transport.

Approach

Using timeseries on benthic community composition from the ebb-tidal delta, subtidal and intertidal Wadden Sea, the temporal - seasonal and inter annual - variability of the benthic community will be quantified, to provide a context for effects of the nourishment. We will link benthic community composition to environmental gradients within the inlet system and map species sensitivity to sandification over the tidal basin. Additionally, we will investigate the bioengineering by benthic fauna through field, flume and mesocosm experiments. We will map bioturbation over the inlet system and experiment with bioturbators to determine their role in sand transport, reworking and the development of the nourishment. Physical structures such as bivalve shells can diminish bedload transport. To link this to community composition, we will test how shell shape and size affect sand transport in flume experiments. Interdisciplinary approached are developing in collaboration with the other work packages within the TRAILS project (modelling sand transport pathways and tracing sand using optically stimulated luminescence).

We will give an overview of objectives and approaches, and present preliminary results on the distribution of bivalve shells, and benthic community composition and variability over the tidal inlet.

Figure 1: Snapshots of the seafloor in the Ameland tidal inlet (own pictures).

Quantification of morphological changes on ebb-tidal deltas using satellite derived bathymetry

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Abstract
Ebb tidal deltas are subaqueous accumulations of sediment caused by the deceleration of ebbing currents seaward of a tidal inlet. On these deltas, sandy shoals cyclically form and migrate towards the coast, thereby transporting large volumes of sand to the adjacent beaches. A detailed understanding and subsequent monitoring of these environments have important implications for coastal management. Automated monitoring methods for quantifying morphological patterns can help to speed up and standardise the analysis, contributing to timely updates on the state of the coasts and important trends. Previous studies, such as Gaudianao & Kana (2001) and Ridderinkhof et al. (2017), have manually quantified the characteristics of the shoals based on aerial photographs and satellite images. Owing to low temporal resolution, the results still contain large uncertainties. Furthermore, the manual nature of the analysis renders the results subjective and is time-consuming. Within the last several years, an automated methodology was developed at Deltares to derive subtidal and intertidal bathymetry based on satellite images. The satellite-derived bathymetry (SDB) product provides large spatial coverage, enabling morphological analyses in areas with little or no in-situ bathymetric data. In this project, the satellite-derived bathymetry is used to quantify lifetimes, periods and migration speeds of sandy shoals on ebb-tidal deltas of different systems. Results that will be presented include 1. supplementation and enhancement of greatly researched systems such as the Vlie inlet (Waddenzee, the Netherlands) and Breach inlet (east US coast) 2. analysis of a system where little is known about its dynamics (Eierlandsegat, the Netherlands). Phenomena of interest, such as bypassing events, can be captured within SDB due to its sufficiently high temporal resolution (see Fig. 1). Through computer vision methods, shoals can be isolated, allowing for their behaviour to be quantified through time and space. Finally, the reliability of the method is assessed by comparing the results with in-situ bathymetry and earlier research.

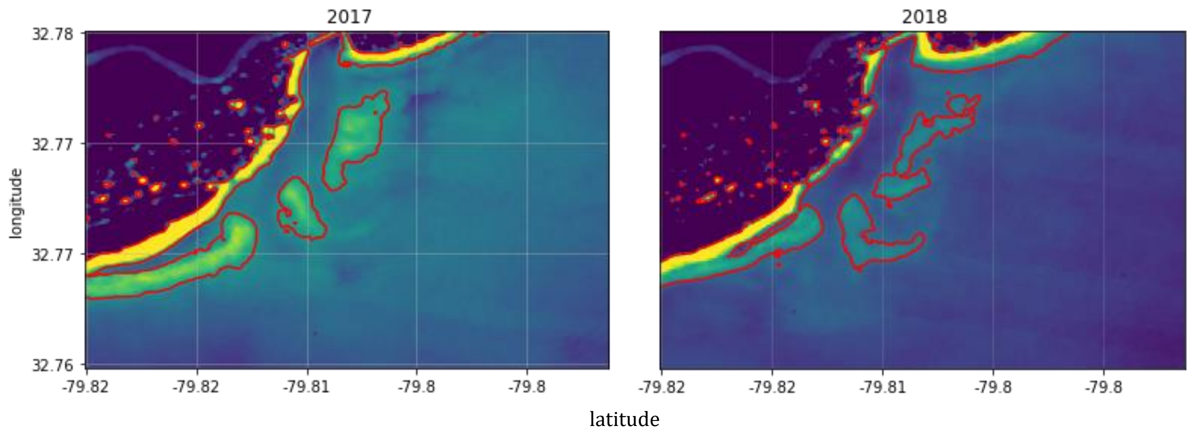

Figure 1: SDB images of bypassing event of shoals near Breach Inlet (east US coast) in 2017 and 2018. Morphodynamic features are isolated and contoured in red. The shoals are formed at the mouth of the inlet in the north and migrate towards the south where they in the end attach to the beach.

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Modeling mud-induced wave damping with Delft3D and SWAN-Mud

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Introduction

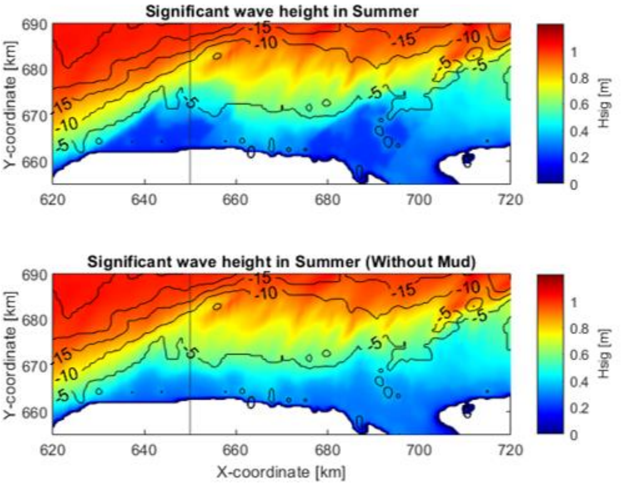
Fluid mud is suspended cohesive sediment on top of the consolidated bed. The fluid mud is generated by an external force that liquefies the bed sediment. When the water in the overlying layer is in motion, it experiences energy dissipation due to the fluid mud. In field experiments a large decrease in significant wave height was observed for beaches with fluid mud compared to beaches without this mud (Wells & Coleman, 1981). Often this fluid mud forms mudbanks in front of a shore, alternating with areas without mud, the interbank area. Different formulations for dissipation of wave energy due to fluid mud are implemented in the model SWAN-Mud, but experience with these formulations is limited. The goal of this study is to learn more about the mud-induced wave damping as a function of mud and wave characteristics . To reach this aim, various idealized model simulations were first set up in which mud and wave characteristics were varied; the model was then applied on a case study for the Suriname coast.

Methods

At the onset of this study we corrected an error in the dispersion relationships embedded in SWAN-Mud. In order to test different mud characteristics, experiments for a 1D-setting (transects) were performed, based on Kranenburg (2008). A 2D experiment with an idealized mudbank was conducted for different wave heights, periods and directions at the boundaries of the domain, as well as for different wind speeds and directions. For the Suriname experiments the same wave characteristics have been tesed. These wave and wind characteristics were based on the ERA-5 model data set, and represent summer, winter and storm conditions.

Results

After updating SWAN-Mud, results for the imaginary wavenumber (which measures the rate at which wave height exponentially decreases when wave propagate through the domain.) correspond to analytical solutions of the dispersion relationships. With the updated model we could observe the influence of the mudbanks on the incoming waves (Fig. 1). A transect taken from Fig. 1 (see Fig.2) shows that the total dissipation increases steeply at the seaward side of the mudbank during the summer, winter and storm conditions; this peak is not present when there is no mudbank. For all scenarios with mudbanks the onshore wave height is therefore considerably smaller compared to the situation without mudbanks. This is also visible in Figure 1 by the darker blue colors at the locations of the mudbanks.



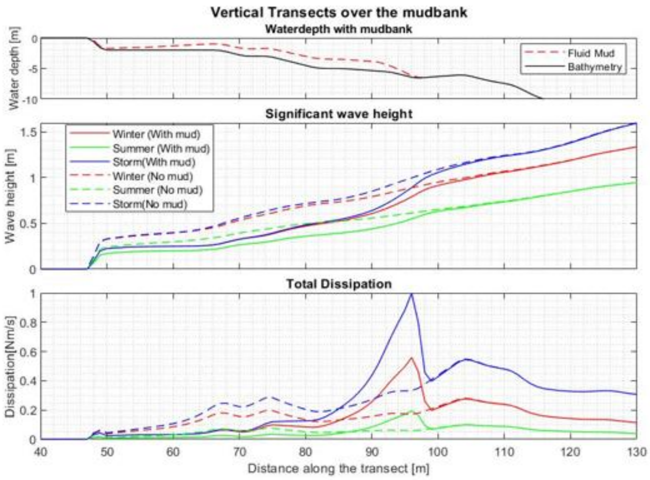


Figure 1 (left): The Significant wave height at the coast of Suriname for Summer scenario. The top one includes two mudbanks, the bottom one is without mud. The transect of fig.2 is indicated with the black line. Figure 2 (right): Three different scenario's (summer, winter and a storm) are modelled for the coast of Suriname, the results of a transect over the mudbank are shown. The situations are modelled with and without mud.

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Image-based beach state classification using convolutional neural networks (CNN)

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Introduction

Subtidal sandbars are ubiquitous features in the nearshore zone of many sandy coasts, and unravelling their dynamics is crucial to the understanding of nearshore sediment pathways. Wave breaking and wave-driven currents constantly rearrange nearshore sediment into complex patterns leading to the development of sandbar morphology, ranging from shore-parallel ridges of sand to an alongshore alternation of shore-attached bars and rip-channels. Wright and Short (1984) created a widely used beach state classification scheme, in which they distinguish a total of six beach states with distinct sandbar configurations. Recognition and classification of these beach states is not trivial and hitherto involved manual classification or pre-defined image features. The tremendous progress in data-driven learning in image recognition over the past years has led to a first automated classification of single-barred beach states from video (Argus) imagery (Ellenson et al., 2020), using a convolutional neural network (CNN). We build upon this work to extend the classification of single-barred beach states to double-barred beaches. The objective of this study is to perform a multi-class classification of beach states for the inner and outer bar separately.

Methods

To make our CNN model we used the pretrained network ResNet50 with transfer learning from a natural image dataset, ImageNet. Our data consisted of labelled images from the single-barred beaches Narrabeen (Australia) and Duck (US), as used by Ellenson et al. (2020), complemented with over 9 years of daily images of the double-barred beach of the Gold Coast (Australia). We implemented various combinations of the data to train, test and validate the performance of each model for the detection of Wright and Short's (1984) beach states.

Results

Adding the inner and outer bar data separately to the single-bar trained CNN increased model performance (up to an F1-score of 0.88). For the double-barred beach it mattered which of the two bars was used for training the model; training with outer (inner) bar data led to higher performance for the outer (inner) bar detection. During the NCK days, we will present our CNN model evaluation and analysis, as well as valuable insights that can be extended to the design of high performance detection and classification systems for other imaging tasks in the coastal domain.

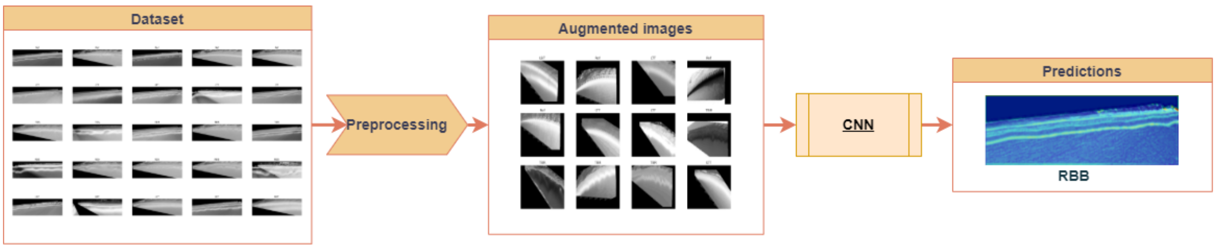

Figure 1: CNN in action

References

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Exploration of the dynamics of mega nourishments with a cellular automata model

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Introduction

At sandy coastlines nature-based solutions have been applied for several decades already, through ongoing sand nourishments for maintaining coastal flood protection. Recently, the scale of sand nourishments has been upscaled significantly, significantly modifying the original coastal landscape. Examples of such mega nourishments are the Sand Motor (SM) and Hondsbossche Dunes (HD). Cellular Automata (CA) models are a promising tool to study the beach-dune morphology that emerges at such mega nourishments from the combined effects of aeolian processes, hydrodynamic processes, groundwater dynamics and vegetation dynamics, as well as the biophysical interactions between these dynamics. However, a realistic representation of mega nourishments with CA models is not yet possible. The aim of this study is to extend an existing CA model to allow for the long-term development of mega nourishments.

Methods

We extend an existing CA model for the combined development of Dunes, Beaches and Vegetation (DuBeVeg) (Galiforni Silva et al., 2018) by including longshore sediment transport and coastline retreat, sand armouring of the beach, and the formation of beach scarps due to wave action. The newly included physical processes were combined with aeolian, hydrodynamic, groundwater, and vegetation dynamics that were already represented in the model. The model was evaluated for a schematized version of the SM, by comparing the shape and typical scale of the simulated dunes with the real dunes that have developed on the SM since its construction in 2011.

Results & Outlook

The preliminary results show that the processes added to the model, combined with the previously included processes, can produce realistic predictions of the development of the SM. The Gaussian function that is implemented to represent longshore transport (Arriaga et al., 2017) can successfully represent the retreat of the SM in a 10-year simulation (Figure 1). Dune shapes, dimensions and spacing simulated by the model also agree with the dune formation observed at the SM over the past 10 years: embryo dunes have an average spacing of about 30 m, aligned with the prevailing wind direction, and an average height of about 1 m. These results indicate that the extended DuBeVeg model can be used to assess the realization of the intended goals of mega nourishments for different configurations and scenarios, e.g. permanent vs. transient nourishments, or different shapes and dimensions of the initial nourishment.

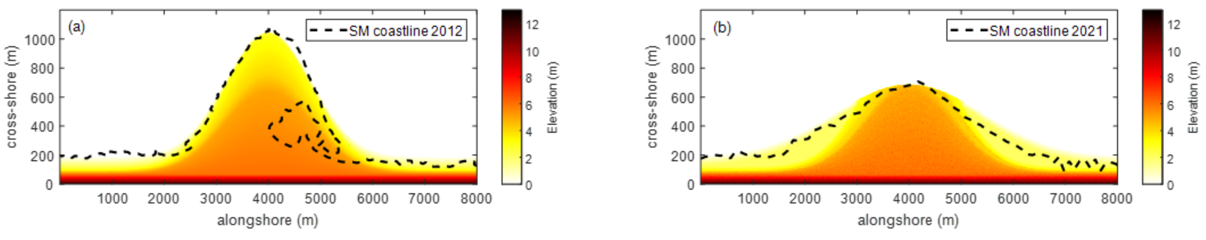

Figure 1: The extended DuBeVeg model of the SM: (a) initial topography, (b) final topography after a 10-year simulation.

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How vertical grain size layering at the beach surface affects aeolian sediment transport

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Introduction

Aeolian sediment transport determines the growth and development of coastal dunes. Many factors, including grain size, influence the amount of sediment transported towards the dunes. Recently, it was shown that significant variations in vertical grain size layering occur at the millimetre scale on the beach (van IJzendoorn et al., 2022). It is expected that this layering could affect the aeolian sediment transport towards the dunes. However, vertical grain size variability at this scale is typically not accounted for in grain size sampling or when predicting aeolian transport. This study uses a numerical model to investigate how different vertical sequences of fine and coarse sand layers affect aeolian transport.

Methods

Cases with varying vertical grain size layering were used as input for the numerical aeolian sediment transport model Aeolis (Hoonhout and de Vries, 2016). The beach surface used in the calculations was 100 m long, and a 10-minute constant wind speed was imposed. The grain size layering at the beach surface was represented by 5 layers, consisting of either fine (250 µm) or coarse (500 µm) sand. Here, we display two scenarios in which the vertical placement of a coarse layer varied (Figure 1). Constant wind speeds of 5, 10, and 25 m/s were applied. The aeolian sediment transport was calculated to determine the effect of the varying vertical grain size layering and wind speed.

Results and discussion

The results show that vertical grain size layering can directly affect the amount and timing of aeolian transport. At a wind speed of 5 m/s, no transport occurred in scenario 1 because the wind was not strong enough to mobilize the top layer of coarse sand. However, in scenario 2, transport did occur because fine sand was available at the surface. At 10 m/s, the wind moved coarse sand from the top layer in scenario 1. Thus, fine sand became available near the surface, and the transport increased through time. On the contrary, for scenario 2, the fine sand depleted over time, and the presence of coarse sand decreased the transport. At 25 m/s, both the fine and coarse sand was easily mobilized and transported by the wind, resulting in similar transport for scenarios 1 and 2. These simplified academic cases are expanded to real-world scenarios to estimate the effects of grain size layering on the total aeolian sediment transport towards the dunes on yearly timescales.

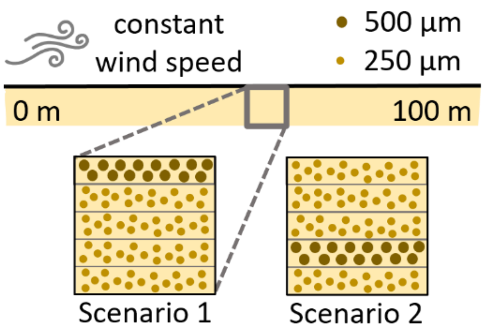

Figure 1: The vertical grain size layering as implemented in scenario 1 and 2 in Aeolis.

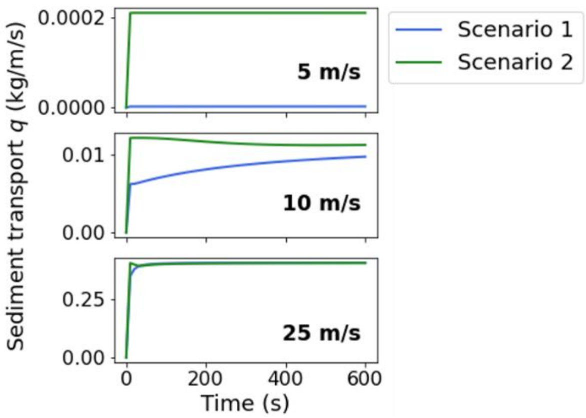

Figure 2: Aeolian transport (at x = 100 m) calculated using Aeolis for scenarios 1 and 2.

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Detecting coastline change drivers from a combination of satellite radar altimetry and optical remote sensing (Terschelling, the Netherlands)

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Introduction

Coastline migration can have several causes with one of them being increased or decreased inundation due to changes in absolute sea level. A second factor are vertical land movements, e.g. subsidence due to the extraction of ground material or uplift as a delayed response to the last ice age, leading to changes in relative sea level and therefore also influencing the extent of inundated areas. Apart from these geometrical effects, morphological processes including those resulting from human intervention are influencing the position of a coastline. Changes in relative sea level height can additionally alter the morphodynamic response. Coastal zones, and particularly their coastlines, are therefore influenced by a combination of absolute sea level changes, vertical land movements and morphological changes.

Methods

We are investigating ways to separate these three groups of influences on changes in coastal geometry from each other. For this, we will analyse coastal sea-level heights from multi-mission radar altimetry in combination with other height datasets like tide gauge measurements, GNSS observations and land elevation data from LiDAR airborne surveys and bathymetry from shipborne multibeam and single beam surveys. We aim at resolving vertical land motion by combining these datasets. Series of snapshots of coastal land-water interfaces will be extracted from optical remote sensing images using Sentinel-2 and Landsat data. Add a sentence about the combination.

Results

In this contribution, we will show preliminary results and perspectives for a case study for the barrier island Terschelling (the Netherlands). First, we will show an accuracy assessment of the retracked altimetry products. With the GNSS observations it will be possible to compare sea-level heights from altimetry with tide gauge measurements, which will help us to quantify sea-level changes in the vicinity of the coast. Furthermore, we will investigate how well the optical remote sensing images used for coastline extractions can be matched with the passes from radar altimeters in time and space. In future research, comparison of coastlines extracted from images with coastlines obtained from topographic heights can give us insight into coastline changing processes.

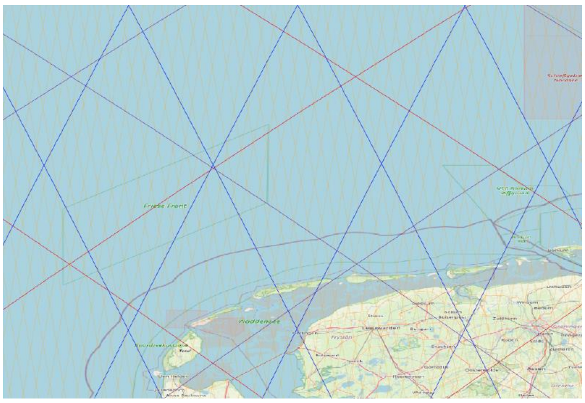

Figure 1: Altimetry ground tracks in the study area. Red: Jason-1, -2, -3 and Topex/Poseidon (reference orbit). Purple: Jason-1 and Topex/Poseidon (interlaced tracks). Blue: Envisat. Yellow: CryoSat-2. Source: TU Delft RADS database.

Developing a generic framework for coupled modelling of foreshore, beach and dune interaction

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Introduction
The development of coastal systems is the result of interacting marine, aeolian and ecological processes. The coastal zones in which these processes are active are often studied and modelled independently, although feedbacks between processes can be critical for coastal development. Coupled models that cross the land-sea division can increase our knowledge on complex morphodynamic interactions, and therefore have the potential to improve predictions of morphological and ecological development at the foreshore, beach and dunes.

Methods
In this work, we introduce the initial developments of a generic framework for coastal model coupling, which is inspired on the WindSurf framework (Cohn et al. 2019). Earlier frameworks focused on coupling specific numerical models, limiting the number of included processes and therefore application range. We aim to develop a flexible, user-oriented framework, that allows for the coupling of a wider variety of process-based models to expand the usability. The coupled models run in parallel using the BMI (Basic Model Interface), which allows for integration of models written in different programming languages. Coupling between different grids and numerical schemes can introduce additional challenges.

Results
The basic operations and benefits of a coupled modelling approach are shown with a demonstration case. Examples of included processes are hydrodynamic erosion, supply-limited aeolian transport and sediment sorting. During future development, we aim to make to model capable of robust simulations of morphologic evolution at time scales of storms, seasons and decades through describing interactions of the aeolian, marine, and ecological parts of the coastal system. This is vital for providing better designs of coastal infrastructure and management strategies considering future challenges for coastal communities.

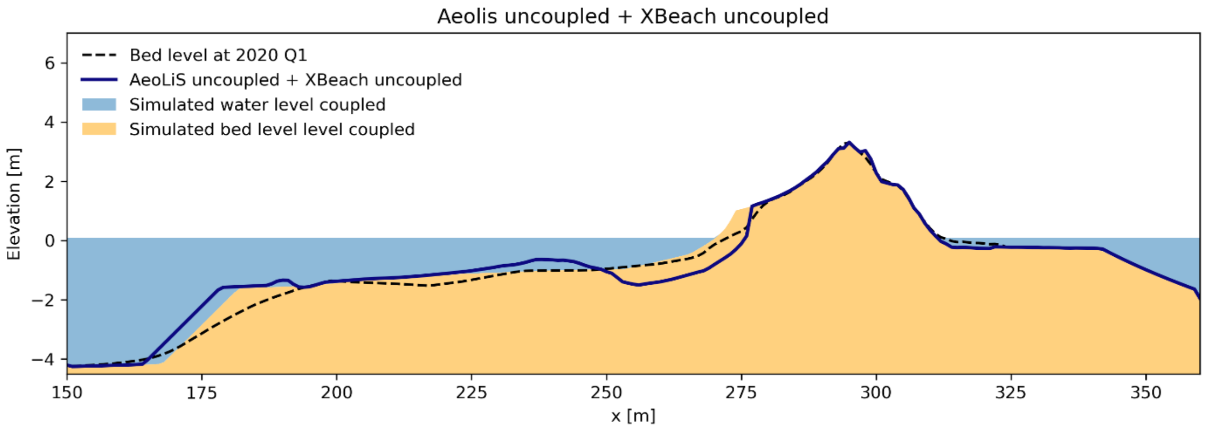

Figure 1: Comparing morphological development after 2 years (dry and wet) at the Marker Wadden between 1) the superposition of two stand-alone models (blue line), 2) a coupled model simulation (yellow patch) and 3) the observed bed level (black dotted line).

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Sandbanks on non-erodible layers: Grow or go?

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Introduction

Tidal sandbanks are large-scale marine bedforms observed at the bottom of shallow seas such as the North Sea and the Irish Sea. They are large-scale rhythmic bottom features with lengths of tens of kilometres, widths of kilometres, and heights of tens of metres (de Swart & Yuan, 2019). Due to their large size, they are of interest for marine ecosystems, and economic activities like wind farms and sand extraction. Process-based models have explained their growth as a free instability of the flat bed (Hulscher et al., 1993), and have shown that sandbanks may evolve towards an equilibrium under unrestricted sediment supply (Roos et al., 2004). Our understanding may not apply to areas with a non-erodible substrate, such as sandbanks on the Belgian Continental Shelf. It is not yet known how the non-erodible layers affect the morphodynamic evolution of the sandbanks, their equilibrium height and shapes as well as their capacity to recover from sand mining. Therefore, we introduce a non-erodible layer in a process-based model to understand how it affects sandbank evolution.

Methods

We have introduced an entrainment limiter in the modelling framework by Roos et al. (2004) to simulate the impact of non-erodible layer. Our model includes nonlinear hydrodynamics, sediment pick-up and deposition, and stirring of sediment by wind waves. The topography (Fig. 1) varies in one dimension only. The entrainment limiter is applied to the sediment pick-up function in areas where the hard layer is exposed or nearly exposed. The limiter decreases gradually within a buffer layer such that the sediment pickup function is continuous and numerical stability is improved.

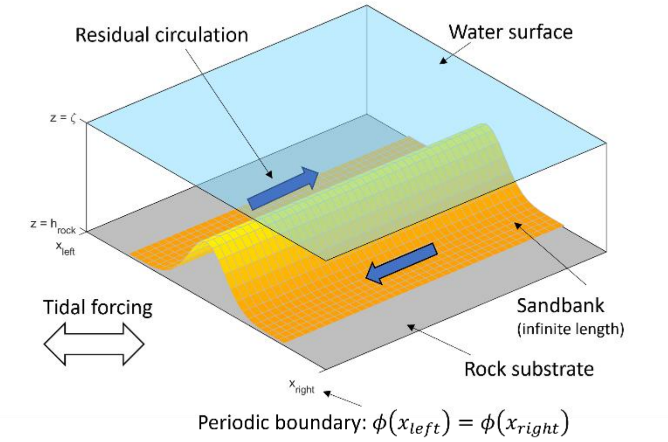

Figure 1: Model domain including sandbank topography. The yellow-orange bank represents the 1-D sandbank topography. The grey plane represents the non-erodible substrate.

Results

Our focus lies initially with the evolution of the cross-sectional shape h(x) and its equilibrium profile $h_{eq}(x)$. The crest height is limited by the presence of a non-erodible layer. Furthermore, its ability to recover from sand extraction may be reduced. Our results give insight in the dynamics of sandbanks on non-erodible layers, thus supporting sand extraction strategies in areas where sand supply is limited.

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Footprint: effects of offshore wind farms on sediments in the Coastal North Sea

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Introduction

In the coastal North Sea (NS), tidal forces cause the formation sandwaves, bedform structures of up to 10 meters in height and hundreds of meters long, which migrate several meters per year. Variations in physical parameters and food availability along these bedforms provide a high heterogeneity of habitats on a small spatial scale (i.e. the length of the sandwaves), and thus sandwaves house a surprisingly high amount of species (Damveld et al, 2018). The construction of offshore windfarms (OWFs) in areas where these bedforms are present, as is planned in the Dutch sector of the NS, will lead to cascading effects both during the construction phase (immediate impact) and the operational phase through alterations of local currents and sediment transport (chronic impact) (Rivier et al., 2016). In turn, migrating bedforms might lay bare the power cables present in OWFs.

The NWA project Footprint

In Footprint we aim to study and model this interplay between dynamic bedforms and hard structures, as this has both economic and ecosystemic relevance. In order to learn more about the interactions between OWFs and their environment, a field sampling campaign around the Dutch-Belgian OWF aggregation on either side of the border will take place come summer 2022 (Figure 1). In this campaign three research vessels will collaborate to study the hydrodynamic patterns, water column suspended matter characteristics, and sediment oxygen consumption, in and around the OWFs, and on the sandwave fields present in this area. This data will eventually be used to create realistic models of OWFs in a sandwave setting.

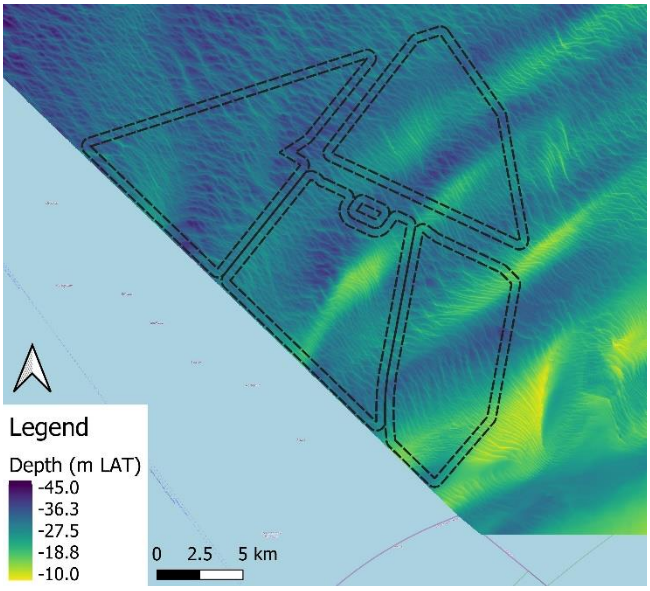

Figure 1: Bathymetric chart of the Borssele OWF area near the Dutch-Belgian border, location of the 2022 summer sampling campaign in the Footprint project.

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An efficient multi-scale modelling framework for assessment of coastal flood events

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Flood risk in coastal areas is projected to increase with climate change, affecting more coastal communities and their economies (Hinkel et al., 2014; Vousdoukas et al., 2016). An accurate estimation of risk is essential to reduce the potential impact of extreme flood events. Recent studies have focused on improving the simulation of extreme sea levels at large scales (Muis et al., 2016; Vousdoukas et al., 2016). However, the inundation mapping derived from those water levels is usually done using simple static approaches that can lead to an overestimation of flood extents (Hinkel et al., 2021; Vousdoukas et al., 2016). This research provides a step forward towards global-scale modeling of coastal inundation due to tropical cyclone events. We are developing a model framework to rapidly and realistically simulate flood hazard in any coastal region. The framework will incorporate three main improvements compared to previous approaches: (1) use of a multi-scale modelling approach that allows for the use of global models and datasets for local flood hazard assessments at high-resolution; (2) move from simple static inundation models towards more physically-based approaches; and (3) move from homogeneous return periods towards event-based modeling. For this purpose, we use the Oceanographic Multipurpose Software Environment which enables model coupling across different spatial scales and physics. Refined local models are nested in the Global Tide and Surge Model for a better representation of the extreme sea levels driven by tropical cyclones. Next, we will combine the water levels with SFINCS and the Synthetic Tropical cyclOne geneRation Model (STORM) to map inundation for a large number of tropical cyclone events. Here we will present the validation of the framework for two historical coastal flooding events.

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Effects of sea level rise on the maintenance of the Dutch coast

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Introduction

Sea level rise affects coastal safety. Until 2050, current coastal management strategies as described in the Delta programme suffice, but uncertainties arise on longer time scales. On the one hand, it is unknown to what extent the melting of ice on Antarctica will accelerate sea level rise in the Netherlands. On the other hand, it is not yet clear up to when we can maintain our current coastal management strategies, and which options there are for long-term strategies, at least up to 5 m of sea level rise. Therefore, the research programme Sea Level Rise was set up. One of the main goals of this programme is to develop knowledge that can improve our decision-making on the long-term maintenance and development of the Dutch coast with respect to coastal (flood risk) management.

Methods

The research programme comprises five tracks. One of these tracks (track 2) contains a study of the effect of sea level rise on the current coastal management strategy, including stress tests of the current flood risk management strategies. This track considers the impact of different values of sea level rise (0.5, 1, 2, 3 and 5 m, Figure 1) for three themes: on the natural process of the sandy coastal system, on levees and artificial structures (flood risk management), and on fresh water systems (water supply). For each of these themes, in 2022 we will determine the physical impact of sea level rise on our current flood risk management strategies of the Dutch Delta programme. For example, for the sandy coast the sediment demand is determined for the various levels of sea level rise, followed by a study on how this affects the nourishment volumes. After this, in 2023-2024, we will explore what options are available for continuing the current strategy.

Results

Together with regional authorities, each theme has set up its own research agenda. For the themes of flood risk management and water supply, modelling has already started. The sandy coast theme will first consult various experts in the field, in order to determine the main research priorities. At the NCK days, we will present the preliminary outcomes and current research agenda. Our aim is to find synergy with NCK partners in how they are addressing similar issues in their work.

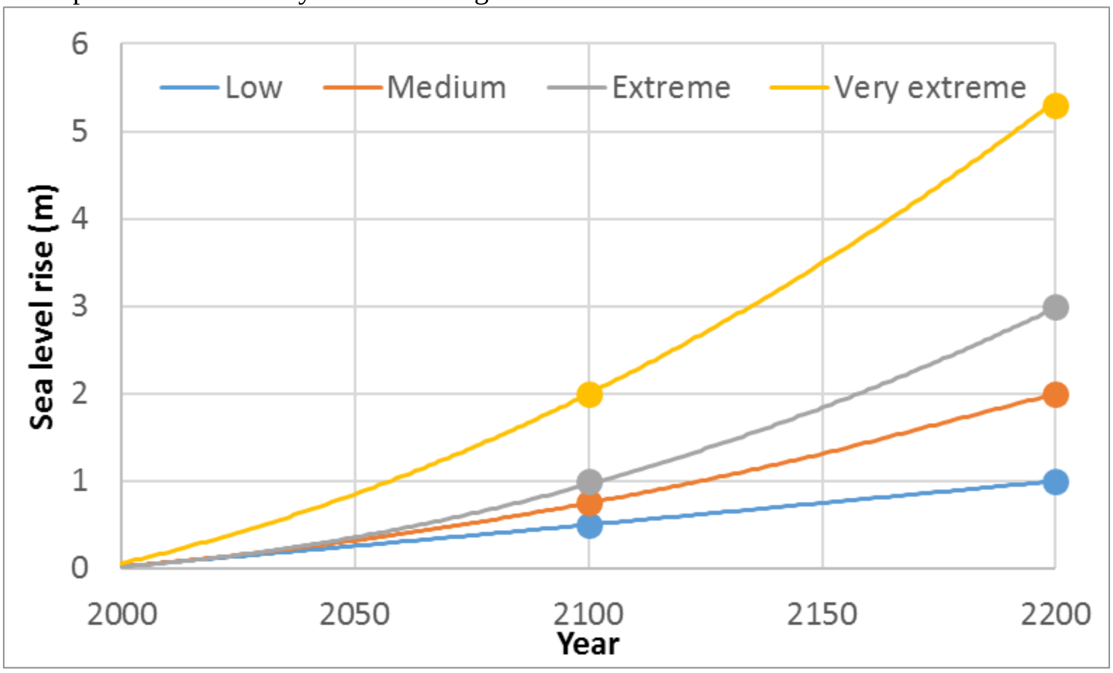

Figure 1: Sea level rise timelines (lines) and values (dots) as used in the Research programme Sea Level Rise

Modelling pioneer vegetation establishment at constructed salt marshes from seasons to decades

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Introduction

In the era of ongoing sea level rise, Nature-based Solutions (NbS) that capture sediments and grow with rising sea level can be more cost-effective and sustainable compared to conventional coastal protection measures that are designed at a fixed height. Therefore, hybrid solutions including salt marshes in front of dikes are gaining ground. The challenge of predicting the outcomes of such NbS projects lies in the fact that relations between implemented management measures and the mechanisms that facilitate establishment of pioneer vegetation are largely unknown.

Methods

In this study we implement newly obtained monitoring data on the establishment of salt marsh pioneer vegetation in a dynamic equilibrium theory model for morphological salt marsh development (DET-ESTMORF) (Hu et al,, 2015). Vegetation growth of the pioneer species *Salicornia* was monitored during one growing season on a salt marsh (Marconi, Delfzijl, the Netherlands) that was constructed in 2018 by elevating the bed and implementing brushwood dams. By simultaneously measuring inundation and bed level change, thresholds for vegetation establishment were identified, which were used to extend DET-ESTMORF with the ability to simulate vegetation establishment. This extended model was then used to predict short- and long-term vegetation establishment in NbS under the influence of implemented management measures (brushwood dams and elevation of the bed level) and predicted sea level rise.

Results and conclusions

Model simulations showed that implementation of a brushwood dam on this specific salt marsh does not have a significant effect on the extent of vegetation coverage during one growing season (Figure 1a, green bars denote vegetation extent), because of the high bed level already present and consequently limited erosion. However, simulations showed that there is increased sedimentation landward of the dam compared to a no dam scenario, highlighting the adaptive capacity of the measure. Predicted sea level rise might result in an increasing retreat of the vegetation boundary the coming decades (Figure 1b). Furthermore, elevation of the salt marsh bed enhances vegetation establishment greatly as the vegetation boundary before the construction works in 2018 reaches only a distance of 5 m from the landward boundary (Figure 1b, light green bars).

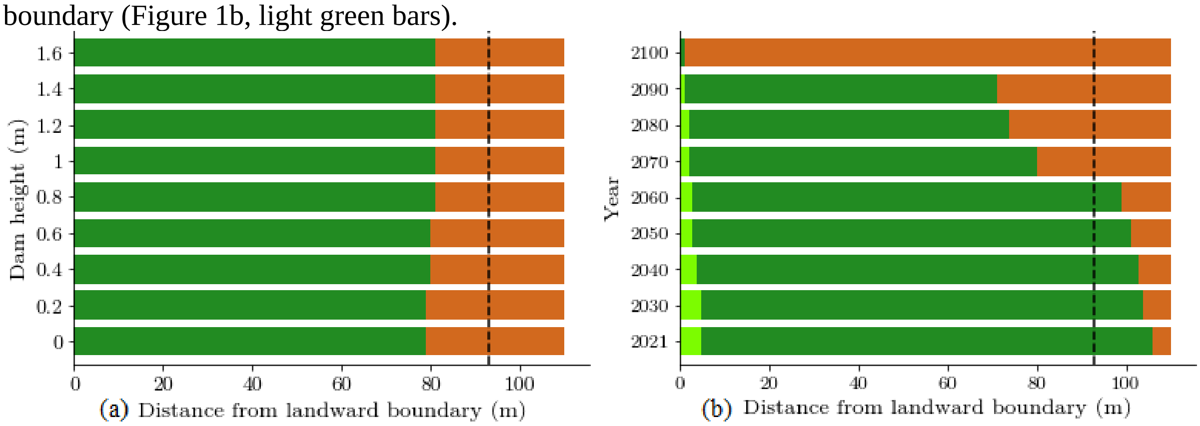

Figure 1: (a) Extent of vegetation coverage (green bar) after one growing season for different dam heights (dam located at black dotted line). (b) Long-term establishment taking into account predicted sea level rise under the intermediate GHG emission scenario (7.6 mm year). Light green bars represent the predicted vegetation coverage before the bed was elevated in 2018 to facilitate salt marsh formation.

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The effect of SIPS on estuarine sand dunes: a stability approach

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Introduction

Estuarine sand dunes are large-scale bedforms situated in hydrodynamically complex environments with tidal flow and river discharge as main drivers. Furthermore, the density difference between fresh and salt water gives rise to various types of tide-averaged circulations which are aggregated in the term estuarine circulation. These circulations are characterized by landward flow near the bed and seaward flow near the surface. One of these circulations is the gravitational circulation, which is induced by a baroclinic pressure gradient resulting from a longitudinal salinity (density) gradient – its effect on sand dunes has been the subject of past research (Van der Sande et al., 2021). Here, we investigate the influence of another type of circulation on estuarine sand dunes: tidal straining circulation. This circulation is induced by varying stratification between ebb and flood tide due to a mechanism referred to as Strain-Induced Periodic Stratification (SIPS). Stratification reduces the vertical mixing of momentum and as such affects the flow, resulting in a circulation pattern similar to gravitational circulation.

Methods

We present an idealized process-based morphodynamic model which is extended to account for variations in vertical mixing through the eddy viscosity, which is parameterized as a function of the gradient Richardson number (and thus as a function of the local vertical density gradient). The vertical density gradient is expressed in terms of the squared Brunt-Väisälä buoyancy frequency, which is imposed on our local model domain as a periodic function of time only. This is incorporated in a 2DV shallow water model and combined with a bed-load sediment transport formulation and a bed evolution equation. A stability analysis of the flat bed then reveals the emergence of sand dunes.

Results

We impose the squared Brunt-Väisälä buoyancy frequency as a periodic function with maximum value $N^2_{\max}$ and frequency equal to the M2 tide. In Figure 1, we vary $N^2_{\max}$ (i.e. the buoyancy frequency at maximum stratification) to show its influence on the properties of the Fastest Growing Mode (FGM). Migration rate (right panel) drops when introducing the SIPS mechanism and then tends to a constant for all tested nonzero values. Most strikingly, the wavelength of the FGM drops when introducing stratified conditions. This suggests that bedforms in partially-mixed estuaries have shorter wavelengths.

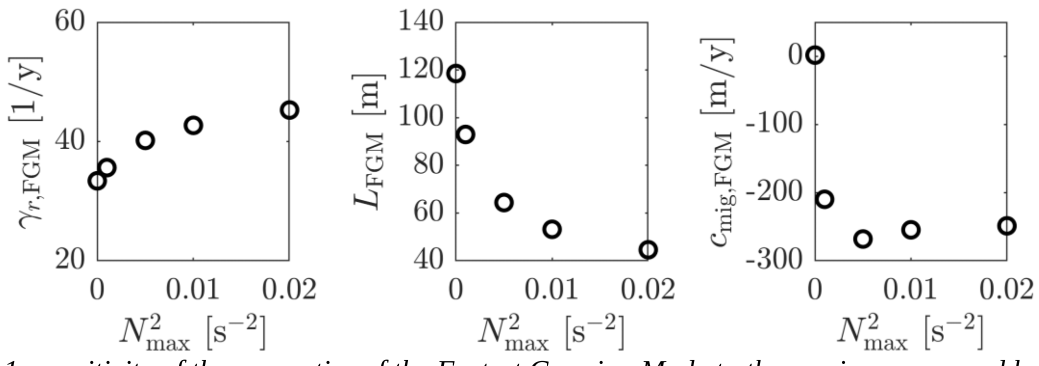

Figure 1: sensitivity of the properties of the Fastest Growing Mode to the maximum squared buoyancy frequency. Left panel: growth rate, middle panel wavelength and right panel migration rate.

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Feedbacks between Estuarine Morphology and Mangrove Dieback and Recovery in the Gulf of Carpentaria, Australia

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Introduction

Mangrove forests are valuable ecosystems, but in rapid decline due to various threats such as extreme climate events and sea level rise. One recent example of a large-scale mangrove dieback event in the Gulf of Carpentaria, Australia has raised great concerns in society while its causes and consequences remain poorly studied (Duke et al., 2017). To understand the impacts of such dieback events and assess mangrove tree recovery, the bio-geomorphological feedbacks between mangrove dynamics and the estuarine morpho- and hydrodynamics is unraveled using simulations with a bio-morphodynamic model.

Methods

A bio-morphodynamic model (Xie et al., 2020) was used to simulate the settling, growth and mortality of mangrove trees dependent on inundation and competition. The effects of tides, river discharge, sand and mud conditions in Delft3D runs resemble the Leichhardt estuary in the Gulf of Carpentaria. The simulations are based on four phases including processes of the estuary development, mangrove establishment, dieback due to a decrease in sea level & river discharge, and mangrove recovery (Fig. 1).

Results

The results show that mangrove dieback can be triggered by a sea level drop and river discharge decrease. The mangrove dieback has effects on the morphology and hydrodynamics of the estuary: the absence of vegetation leads to channel infilling, decreased sedimentation in the previously vegetated areas and increased flow velocity in the vegetation loss areas (Fig. 1a). The simulations also suggest that the recovery of the mangrove tree distribution is slow (Fig. 1b). Considering the likelihood of further disturbance events, a full recovery within the life cycle of mangrove trees seems unlikely.

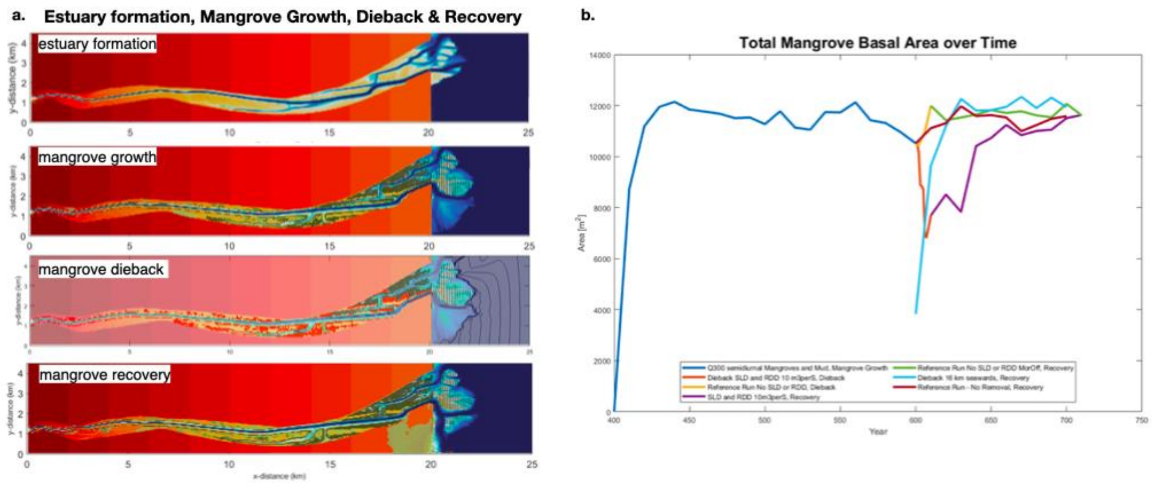

Figure 1: Mangrove behaviours during dieback and recovery processes. a) Bio-morphodynamic model simulations in 4 phases, b) mangrove basal area over three phases.

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The relationship between linearized 3D and 2DH models in tidally dominated estuaries

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Introduction

Estuaries are important features that can be found all around the world. Accurately estimating the water level in such systems is of crucial importance. However, the highly dynamical nature of estuaries makes modelling the water motion particularly challenging. Even though the increase in computational power allows the use of complex 3D models to analyse this water motion, depth-averaged 2DH models are often used. The reason for this is twofold: firstly, they are much faster than their 3D counterparts and secondly, the results obtained with a 2DH model are considered adequate for many applications.

This implicitly assumes that the depth-averaged results from a 3D model and those obtained using a 2DH model are the same. Even though some efforts have been made to compare both 3D and 2DH results to measurements (Marinone, 2000), no systematic analysis is presented in the literature, not even for the linearized tidal dynamics. Focusing on the linearized dynamics, the main aim of this contribution is to investigate if it is possible to consistently parameterise 3D effects in a 2DH model such that both models describe the same depth-averaged dynamics, e.g., resonance, transport and water levels, and (if possible) to derive this parametrisation.

Methods

As a first step we restrict ourselves to the linearized water motion. To obtain an exact reduction from a linearized 3D model to a 2DH model an analytical approach is necessary. We start with the linearized three-dimensional shallow water equations, see e.g. Kumar (2018). For the water motion consisting of a single tidal constituent, i.e., a harmonic signal, the vertical structure can be obtained analytically, see Winant (2007). Using this analytical vertical solution we are able to derive an exact closure relationship between the velocity at the bed and the depth-averaged velocity, resulting in an exact reconstruction of depth-averaged 3D results in a 2DH model. In addition, using advanced mathematical techniques, we are able to extend this result to non-harmonic models, i.e., models solving the tidal dynamics using time-stepping techniques.

Results

The exact reduction culminates into a new friction formulation for both harmonic and non-harmonic 2DH models that parameterises the effect of 3D dynamics. That is, given the 3D parameters, an *exact parameterisation* for the 2DH parameters is found such that their depth-averaged dynamics are the same. For harmonic models, the three most striking features of this new friction formulation are that the friction coefficient has an *amplitude* that depends in a complex way on the local water depth and tidal frequency, a *phase (shift)* relative to the depth-averaged velocity and that it depends on *both depth-averaged velocity components.* For non-harmonic models, it additionally shows that the friction felt by the system depends not only on the instantaneous velocity but also on *the velocities in the past*. During the presentation, we illustrate the effects of using this friction formulation on the water motion in a typical estuary by comparing it with results obtained using more commonly applied friction formulations.

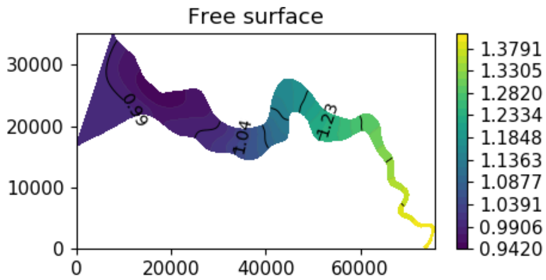

Figure 1: The absolute value of the free surface of the M2 tidal constituent in the Scheldt estuary.

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Residual sediment transport in a stratified estuarine channel

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Introduction

After major storm surge protection works in the Rhine-Meuse Delta, referred to as the Delta Works (Vellinga et al., 2014), the New Waterway has become the only remaining open channel connecting the estuary to the North Sea. Like in many harbour areas, continuous deepening of this channel for navigation purposes has led to strong stratification and often salt wedge conditions, which likely has a strong impact on the marine sediment import. The sediment balance for various fractions is highly uncertain (Cox et al., 2021). Based on field measurements and sediment transport modelling, we aim to unravel the mechanisms controlling residual sediment fluxes in highly stratified estuarine channels, by focusing on the New Waterway.

Methods

A measurement campaign was set up consisting of two 13-hour surveys, one during spring tide and one during neap tide. Flow was monitored continuously based on a vessel-mounted ADCP, at an along-channel transect (~3 km) and a cross-channel transect (~300 m). A measurement frame was equipped with a LISST-100x, a Seapoint turbidity meter and a CTD probe. Suspended sediment samples are collected every hour at three depths, next to water temperature, salinity and turbidity.

Results

The ADCP-measurements show a clear distinction in flow magnitude and direction between the upper fresh water layer and lower saline layer, confirming the high degree of stratification especially during neap tide. After low water slack, most suspended sediment is found in the lower half of the water column. Suspended sediment concentrations (SSCs) increase during the flood acceleration phase, suggesting local resuspension during this phase of the tide. When reaching high water slack, SSCs decrease with flow velocity. At high water slack, the ADCP-backscatter profiles indicate settling of the suspended sediment on top of the pycnocline. During the ebb phase, SSCs increase again, and the water column is better mixed compared to the flood phase. Preliminary results of the grain size analysis indicate coarsening of the suspended sediment at the end of the flood acceleration and ebb acceleration phases. Ongoing analysis of these data and numerical modelling of SSC will provide more insight in the suspended sediment transport processes under various degrees of stratification.

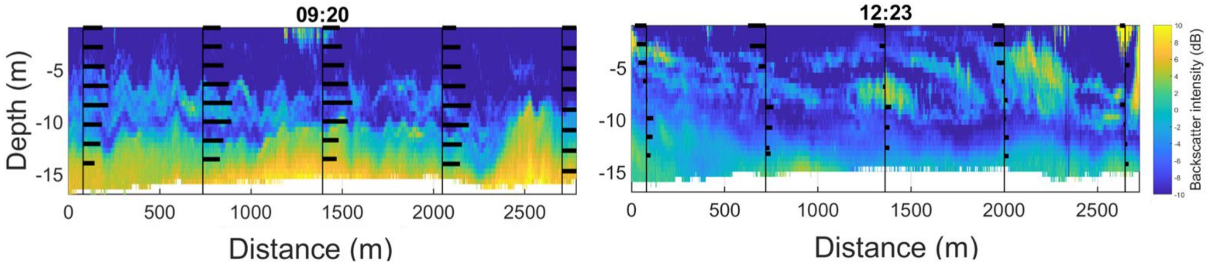

Figure 1: Two flow- and backscatter profiles recorded along the New Waterway during neap tide. Left panel: during the flood phase, sediment is concentrated in the lower half of the water column and the velocity maximum is located around the pycocline as observed in De Nijs et al. (2011). Right panel: around HWS, suspended sediment settles around the height of the pycnocline.

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Hydrodynamic conditions on an accreting intertidal flat in the Western Scheldt

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Abstract

In the mesotidal Western Scheldt estuary in the Netherlands intertidal bars are accreting much faster than local sea level rise. To understand which processes underlie this rapid accretion a 6-month field campaign was conducted in 2019 on one fast accreting intertidal bar with the aim to identify the relevant hydraulic conditions. During this field campaign current velocities were measured at 16 different locations in the channel with Teledyne Workhorse 1200 kHz instruments and on the intertidal bar with Nortek Aquadopp Profiler 2MHz instruments. During monthly field visits the bed level was recorded with Leica GPS-1200 system (NedPos) .

The validated data shows patterns of spatial and temporal differences between different locations (Fig. 1). MP1, which is located in the western part of the channel, is flood dominant, while MP2, which is located in the east in a more shallow region in the channel, is ebb dominant. Therefore coarse sediment will most likely be transported onto the tidal bar in the western part, while the finer sediments will be deposited in the eastern part. Current speeds above the 95th percentile during the flood period at both locations are caused by storm conditions. Noticeable for MP2 is that the current speed is for a large part of the time around 60 cm/s. This effect depends on the water depth and therefore we assume that local morphology contributes to it. Further analysis will verify the agreement of measured flow velocities with idealized models intertidal flats (Friedrichs and Aubrey, 1996) and will quantify the role of wind and wave effects on the sediment transport between the channel and the intertidal bar. Furthermore, the 14 other measurement locations will be analysed.

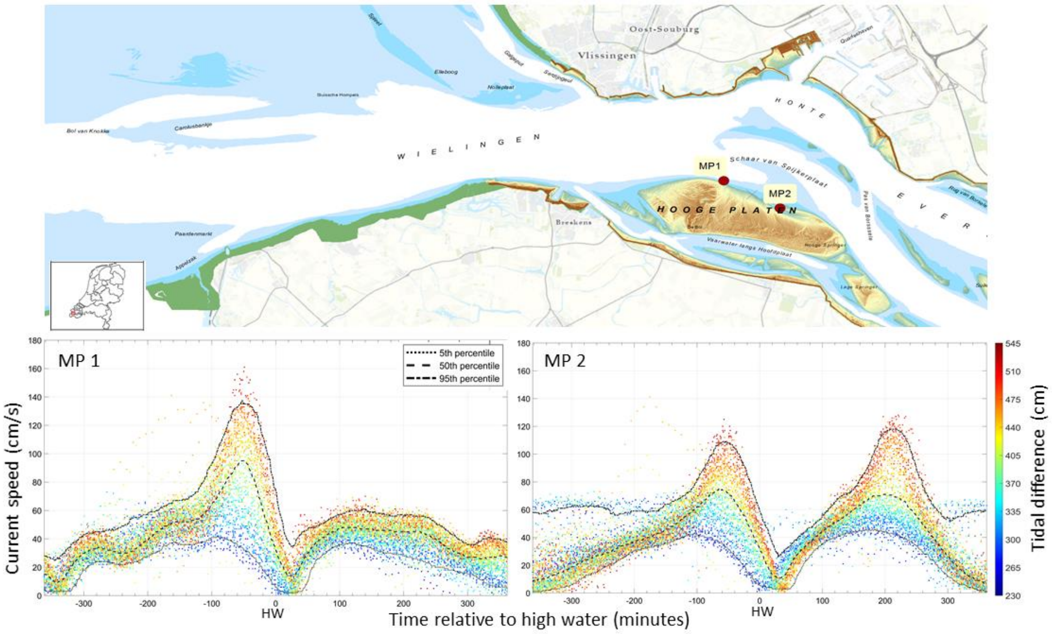

Figure 1: An overview of two locations and an example of the measured current velocity in the lowest cell at these locations during the measurement campaign in 2019.

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Salt dispersion at two tidal channel junctions: Data analysis

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Introduction Tidal channel junctions play a key role in the distribution of water throughout estuarine networks. Accurate modelling of these systems, for example to predict salt intrusion, is of great importance. However, the dominant mechanisms driving salt exchange between junction branches are hard to estimate due to strongly three-dimensional flow and salinity dynamics, caused by tidal phase differences and complex geometries. To better understand the three-dimensional nature of salt transport at junctions, here we analyse two 13-hour field surveys, which were conducted in 2014 and 2015 at two tidal channel junctions in the Rhine-Meuse delta (Figure 1). Each of the junction branches was traversed once per hour, with ADCP (Acoustic Doppler Current Profiler) and CTD (Conductivity, Temperature, Depth) sensors being used to measure flow and salinity, respectively, in the branch-cross sections.

Methods ADCP velocity data are analysed using an adjusted sigma – layered computational grid as proposed by Vermeulen et al. (2014), after which CTD salinity data are interpolated. Dominant tidal constituent amplitudes and phase differences are estimated, both between junction branches and within individual branches. Thereafter, salt transport fluxes are decomposed by separating flow and salinity in constant and varying components with respect to the vertical, temporal and lateral dimension, yielding a salt flux decomposition which allows for separation of coexisting salt transport mechanisms. In particular, fractions of tidally averaged, net longitudinal salt transport caused by correlations between lateral flow and salinity shear, are estimated.

Results Preliminary results indicate that the tidal flow is strongly sheared across the junctions. Both junctions show tidal phase differences between the branches of up to 1,5 hours, with the southern junction showing an additional large lateral phase difference within the western branch, the Hartel Canal, of up to 2,5 hours. Differences between the junction dynamics may partly be attributed to differences in degrees of bed discordance (Fig. 1, upper right). Tidal asymmetries and associated oscillating salinity gradients are likely to influence salt transport to a larger degree than stratification, turbulence or subtidal gravitational circulation. However, due to nonlinear interactions, these phenomena are not entirely separable. Results indicate that parametrisations of dispersion coefficients and nodal point relations, currently used to model salt exchange at tidal channel junctions, may have to be improved to more accurately model the impact of complex flow patterns at channel junctions on longitudinal salt transport in one-dimensional modelling.

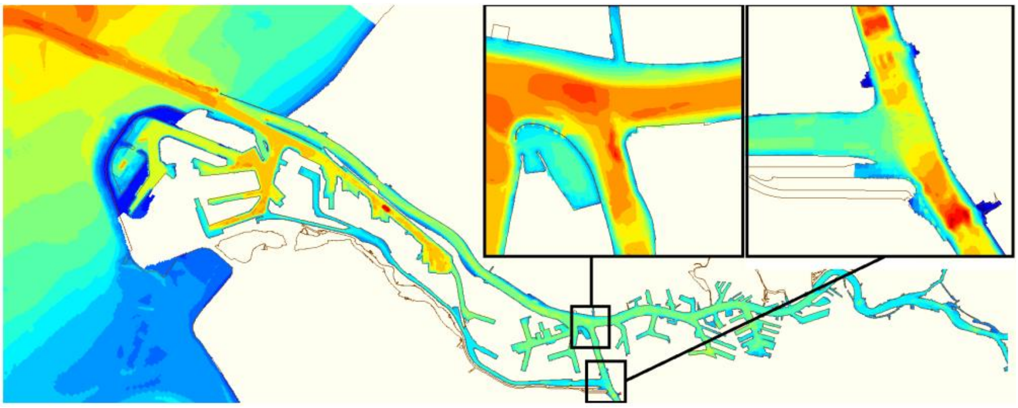

Figure 1: Locations and bathymetry of the two tidal channel junctions in the Rhine – Meuse delta. The Old/New Meuse – Rotterdam Waterway junction for the survey of September 2015 (north) and the Old Meuse – Hartel Canal junction for the survey of August 2014. Figure from Port of Rotterdam, 2014.

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Sediment bypassing at Ameland inlet and the role of an ebb-tidal delta nourishment

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Introduction

A large part of the Dutch coast, the barrier islands in the Wadden Sea included, would be eroding if the deficit in the total sediment budget was not compensated for through nourishments. Ebb-tidal deltas have an important function within the coastal system that make them of interest for coastal defence as a source and transport path for sand to the back-barrier basins and the island coastlines. As part of the Kustgenese 2.0 project, a pilot nourishment of 5.5 million m^3 has been placed on the Ameland ebb-tidal delta. Improved understanding of sediment bypassing processes and the interaction with a nourishment is needed for strategic placement of nourishments in the future.

Methods

The high-frequency bathymetric dataset available at Ameland inlet between 2005 and 2020 is analysed and used to model the tide- and wave-driven transport pathways with to SedTRAILS to determine how sediment bypassing works under natural circumstances and under the influence of a nourishment. Insights are combined in a series of conceptual models which illustrate sediment bypassing behaviour.

Results

The conceptual models (example in Figure 1) show that the formation and growth of a series of ebb-shields on the western side of the ebb-tidal delta plays an important role in sediment bypassing. Their development gradually results in transport pathways connecting the western side of the ebb-tidal delta to the major transport pathway along the ebb-delta front, which forms a direct connection to the Ameland coast in 2017. The influence of the pilot nourishment on sediment bypassing processes is limited, adding volume to the system but not altering the existing transport pathways. Transport pathways show that sediment from the nourishment eventually reaches the Ameland coast and is unlikely to feed the Terschelling coast or the tidal basin. This is valuable knowledge for the future sustainable coastal management of Ameland inlet, which can also be extended to other inlets.

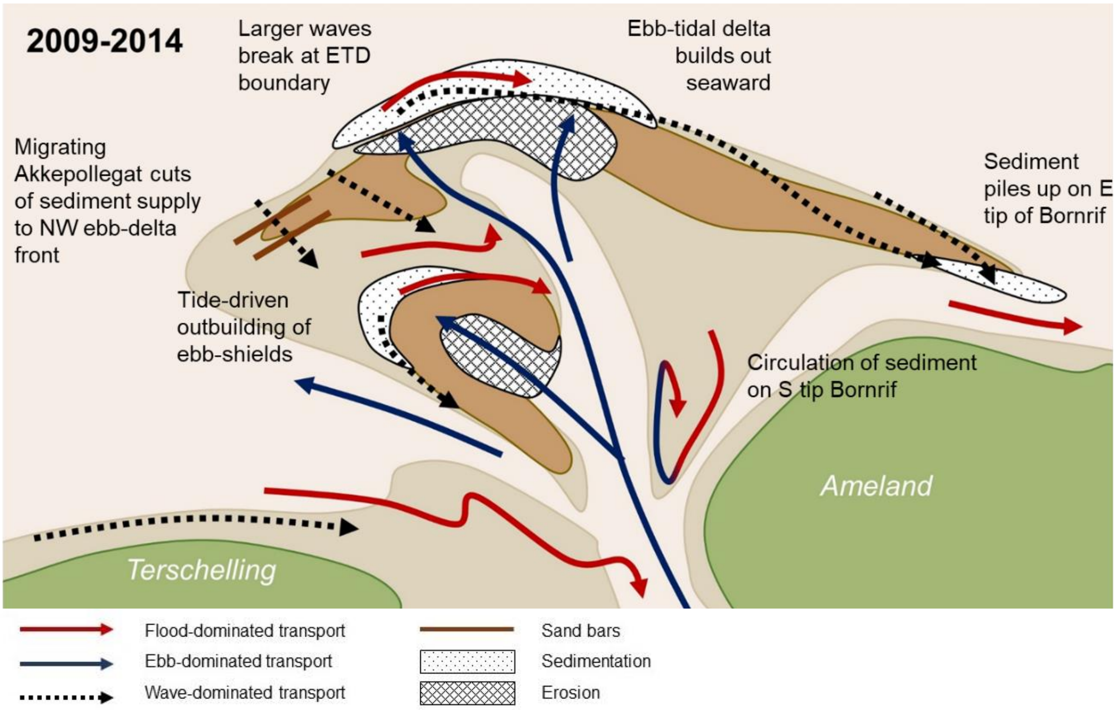

Figure 1: Conceptual model illustrating sediment bypassing behaviour during ebb-shield growth from 2009 to 2014, including residual transports (arrows) and areas of sedimentation and erosion (shaded).

Numerical modelling of aeolian sand transport on moist beach in different scales

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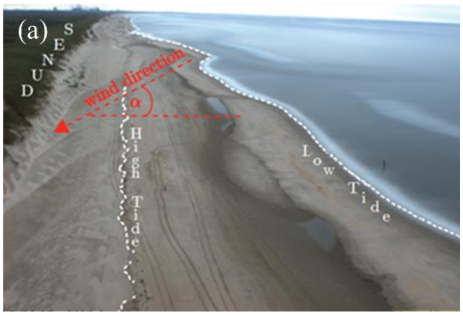
Introduction

In coastal areas, aeolian sand transport has significant spatio-temporal variability, as a result of varying beach surface properties. Surface moisture is one of the most important factors limiting the sand supply (Figure 1 (a)). To understand the intrinsic variability of sand transport over short spatial and temporal scales, it is necessary to study the effect of moisture on the grain-scale dynamic behaviours. Moisture between the sand grains can influence the sand transport by increasing the threshold velocity for transport and reducing the transport rate remarkably (Neuman and Scott, 1998), hence change the bed form patterns. This study aims to investigate the effect of surface moisture on the sand transport mechanism on the grain scale and then upscale the description to the transport variability on an engineering scale.

Methods

On the grain scale, an explicit coupling between discrete element modelling (DEM) and RANS description will be adopted to simulate the sand particle movement under the influence of wind flow. Two important processes in aeolian transport will be studied, the aerodynamic entrainment and the impact mechanics in the saltation transport mode (Figure 1 (b)). The open-source package MercuryDPM will be used and this includes a liquid bridge model that can simulate the fluid between the particles. From the grain-scale simulations, an initiation function and a splash function incorporating the moisture effect will be derived and applied in the meso-scale modelling. The functions, which are capable to describe the particle initiation and the impact process in the near-bed layer, can reduce the computational cost drastically, as only the saltating particles (no bed particles) need to be modelled. The meso-scale modelling will be implemented by direct particle modelling coupled with a RANS fluid model in order to capture the influence of moisture content on the transport characteristics in a larger scale. Then an erosion function will be developed based on the relation of erodibility and the bed moisture content measured from meso-scale simulations, making it possible to upscale to an engineering-scale continuum model.



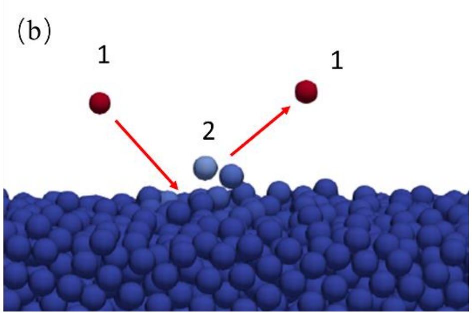


Figure 1: Different scales of sand transport: (a) Beach-dune system (Duarte-Campos et al., 2018); (b) Impact process in MercuryDPM simulation (Blue particles have zero velocity and red ones have high velocities; 1- impact particle, 2 – ejected particles).

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Sediment transport and sorting processes at a back-barrier beach nourishment

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Introduction

Sand nourishments are increasingly applied to more sheltered systems (e.g., Perk et al., 2019), where the morphodynamics are driven by mixed (tides and waves) forcing. Here, sand deposits are usually retrofitted to inadequate, hard flood defences to act as a buffer against erosion of such infrastructure. Introducing different grain sizes into a system results in more complex, differentiated sediment transport, as coarser fractions are mobilised at different moments and places than finer fractions (McCarron et al., 2019). By focussing on a nourishment on the leeward side of a barrier island, we aim to find quantitative answers to the questions when and how the mixed-sediment composition changes and what implications that has for the morphologic evolution of the area.

Methods

This research is based on the 6-week SEDMEX field campaign in autumn 2021 at the 3-km long Prins Hendrikzanddijk, a retrofit nourishment on the island of Texel (Fig. 1). We deployed long- and cross-shore arrays of instruments (Fig. 1) that measured a range of parameters such as pressure, flow velocity, suspended sediment concentration and bedforms. These measurements were further complemented by almost daily bed-level measurements and spatiotemporally extensive sets of sediment samples.

Results

Wave heights (H_{m0}) ranged up to 0.6 m, while tidal currents frequently reached velocities up to 0.5 m/s. Wide grain-size distributions, sometimes revealing multi-modality, characterised the top 5-6 cm of the bed almost everywhere. The D_{50} varied temporally and spatially, both in the cross- and longshore directions, often hand in hand with changes in bed level and beach-step position after a period of increased wave activity. Furthermore, transient patterns of surfacing coarse and shell-rich material often characterised the intertidal beach surface. We will further elaborate on our findings at the conference.

Figure 1: The Prins Hendrikzanddijk with the instrument locations during the SEDMEX campaign.

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Effect of waves, tides and spatial heterogeneity of bed sediment on sediment transport and initial erosion-deposition patterns at a new dike in a mixed-energy coastal environment

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Introduction

The placement of sandy beaches in front of dunes is increasingly used as coastal protection in favour of hard engineering structures along sandy coasts. These so-called soft-solutions are often economically and ecologically more sustainable as these structures are adaptable and can self-repair after storm events. Until recently, all of these soft solutions were constructed on wave-dominated coasts. However, this approach has started to be used to improve weak flood defences, such as dikes and dams, in regions that are not necessarily wave-dominated. In 2019 an artificial sand dike was constructed at the back-barrier side of the Dutch island of Texel, the Prins Hendrikzanddijk (PHZD; Perk et al., 2019). As this coastal defence structure lies in a mixed wave-tide environment, it is important to assess the role of different drivers (waves, tides, wind) and processes (suspended load, bed load) on the sediment transport under the range of environmental conditions encountered in such environments (e.g. spring-neap tides, fair weather, storms). Moreover, the spatial heterogeneity of the artificially placed bed sediment should be taken into account for the understanding of both the morphological and ecological impact of such sandy interventions (Figure 1; Huisman et al., 2018). This study aims to characterise how the hydrodynamic boundary conditions and bed sediment composition influence the sediment transport patterns at the PHZD through numerical modelling.

Approach

Results will be shown of simulations performed with a calibrated Delft3D-SWAN model of the PHZD area. For the calibration, data were used that were collected during a 6-week field campaign (SEDMEX; mixed SEDiments in Mixed Energy eXperiment) in September-October 2021. Relevant model parameters, forcing input and initial bed composition will be systematically varied to evaluate their individual influence in sediment transport patterns.

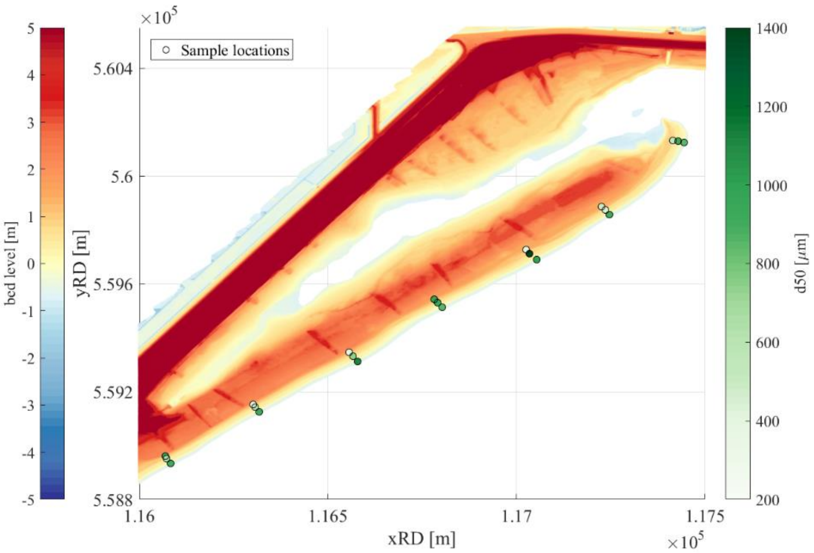

Figure 1: Bed level of the northern part of the Prins Hendrikzanddijk (wadden coast of Texel). The green shaded circles indicate the d50 of sediment samples collected during the pilot field campaign.

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Grain size evolution and armour layer development at mega nourishments

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Introduction

In the last decade, there has been a tendency towards larger-scale nourishments to enhance coastal safety and reduce the environmental impacts of frequent nourishments. The Sand Motor and Hondsbossche Dunes are examples of so-called mega nourishments, where natural processes are used to redistribute the sediment both in the longshore and cross-shore direction.

One desired mechanism is that sand is transported by the wind over the beach into the dune area, reinforcing the existing dunes and stimulating new dune formation. However, sediment sorting processes due to grain-size-selective pick-up and deposition influence sand availability for aeolian transport (Hoonhout & de Vries, 2017). If the beach rarely is overwashed by waves, armour layers may develop with coarse material that impedes the aeolian transport (Strypsteen et al., 2021).

This study investigates how sediment sorting and armour layer development are influenced by the fill material, nourishment design, and sediment transport processes at the mega-nourishments Hondsbossche dunes and the Sandmotor.

Methods

About 100 sediment samples were collected along 25 cross-shore transects at each of the Sandmotor and Hondsbossche dunes mega nourishments. The samples were sieved to determine their grain size distribution. Local trends of the grain size characteristic parameters, such as median grain size and sorting, were investigated by correlation analysis.

Results

The results revealed considerable grain size variability both in the longshore and cross-shore direction (Figure 1). In general, the coarsest samples and largest variability were found in the morphologically dynamic intertidal area. Aeolian transport processes have sorted the sediment across the nourishments so that the finest and most well-sorted sediments are found in the aeolian deposits in the dune areas. Eroding parts of the beaches generally display coarser sediments than accreting parts, which may locally influence the aeolian transport rates towards the dunes. Knowledge about sediment sorting processes at mega nourishments - how they relate to different management strategies and fill material - can be used to optimize the design of mega nourishments and promote dune build-up.

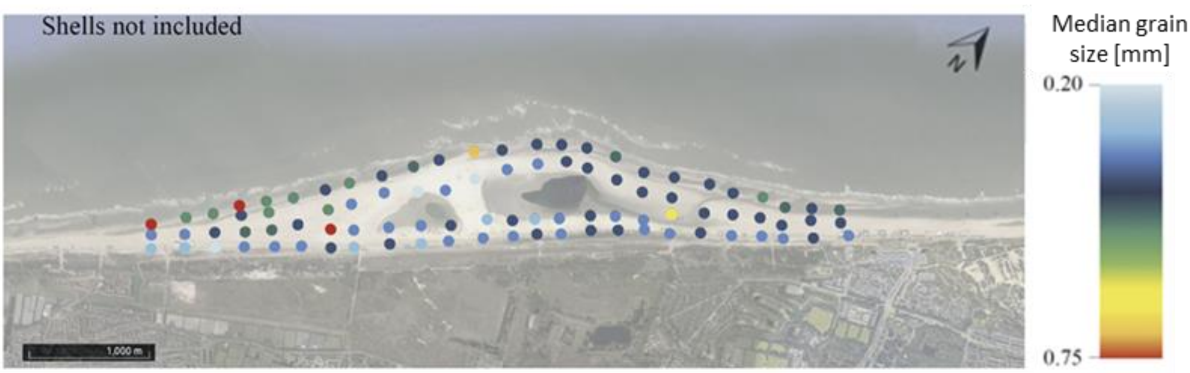

Figure 1: Median grain size of the surface sediments at the Sandmotor.

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Field observations of wave reflection during dune attack

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Waves propagating onshore can reflect at the beach and propagate back offshore. Wave reflection is frequency dependent with lower frequencies reflecting stronger than higher frequencies. Furthermore, steep slopes enhance reflection. As a result, reflection patterns can change substantially when waves start to reach the steep dune face during storm surge. For example, reflection of higher frequencies will become more important, influencing run-up patterns and thus water levels at the dune. Measurements of wave transformation and reflection during dune attack are limited along the Dutch coast as the water level only reaches the dune foot under intense storm events, which are challenging conditions for instrument deployment. Here, we present a field data set with three dune attack events (November 2021, December 2021 and January 2022) collected during the RealDune/REFLEX measurement campaign at the Sand Motor. Dune attack was ensured by constructing two artificial dunes near the high water line, designed to erode during moderate storms and therefore allowing to measure several dune erosion events. The two dunes (each 5.5 m high, 150 m long and 7 m wide) are fronted by a substantially different bathymetry and beach topography and differ slightly in coastline orientation due to the curvature of the Sand Motor. Pressure and velocity were measured across instrument arrays at each dune. In addition, beach and dune evolution was captured with stereo photography, sonar, and line-scanning LiDAR. At the conference, changes in time- and frequency-dependent reflection during the three dune attack events will be presented.

Figure 1:Aerial picture of field site with red lines indicating the two dune crests (top left), instrument array at RealDune/REFLEX campaign (bottom left) and runup on dune face during storm (right).

Acknowledgments: The RealDune and REFLEX projects are financially supported through TKI Deltatechnologie existing of Rijkswaterstaat, Witteveen en Bos, Arcadis, STOWA, Deltares, Nortek and TU Delft. We acknowledge Pieter van der Gaag, Arie van der Vlies and Arno Doorn for technical support during the field campaign.

Interaction between vegetation and aeolian sediment transport in coastal dune systems, a modelling approach

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Introduction

Coastal beach and dune systems are the most effective natural line of defence against coastal flooding in low elevation coastal zones, such as the Belgian Coast. Maintaining, enlarging and creating dunes have been suggested as one of the effective approaches considering nature based solutions in climate adaption projects (e.g. Vlaamse Regering, (2017)).

Restoration, maintenance or the creation of these systems require understanding of aeolian sediment transport. Understanding this process and estimating the amount of sediment transported by the wind will help in predicting beach and dune evolution on short (storm) and long (decadal) timescales and enable in designing better and more efficient maintenance, adaptation and dune design plans to ensure the resiliency of the dunes (Strypsteen et al., 2019).

In this study we assess the aeolian transport along the Belgian coast by first comparing two numerical models and thereafter the influence of vegetation.

Results

We observed that two commonly used numerical aeolian sediment transport models (i.e. Aeolis and Duna) are largely similar when looking at sediment transport rates along a schematized profile.

Moreover, when using Aeolis to simulate aeolian sediment transport along a coastal profile it was found that vegetation has a considerable impact on the transport rates. In the case of vegetation we observed a decrease in transport rates, potentially leading to sedimentation in the area of vegetation. For the case without vegetation an increase in aeolian sediment transport at the dune area was found, leading to potential erosion of the dune area.

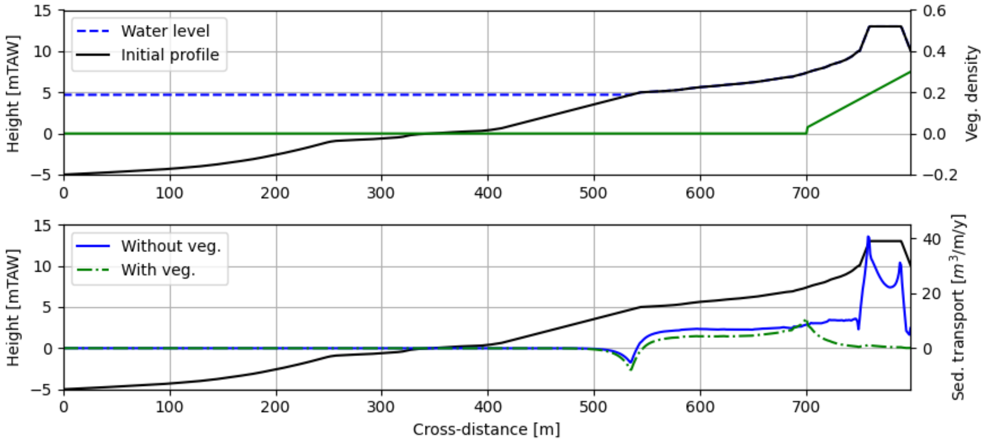

Figure 1: Annual aeolian sediment transport for a typical cross-shore profile along the Belgian coast for a scenario with vegetation and a scenario without vegetation

Acknowledgement

The authors want to acknowledge "Vlaamse Overheid, MOW – Afdeling Maritieme Toegang" for the financing of this study as part of the project of Vlaamse Regering, (2017).

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Decadal morphological evolution of the Belgian west-coast

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Introduction

The western part of the Belgian coast between the French border and Nieuwpoort/River Yser (14 km) is characterised by a wide dune area, which is interrupted by sea dikes in coastal towns (6 km). The beach is wide with multiple intertidal bars. Only a few groynes are present near Koksijde and Nieuwpoort-Bad. Regarding coastal management and safety, a sediment budget is determined for this part of the Belgian coast. This zone requires limited maintenance. Anthropogenic influences include beach reshaping for recreational purposes, beach nourishment and dredging. An important morphological feature is the *Trapegeer-Broersbank*, a large sand bank that is obliquely connected to the shoreface at Koksijde (Verwaest et al. 2020).
The Belgian coast is among the best monitored worldwide. Timeseries of volumes are available for the past four decades, furthermore data of nourishment and dredging volumes are available (Houthuys & Roest, 2019). Therefore it is possible to discern between observed volume changes and autonomous behaviour, provided that nourishments and dredging operations do not significantly alter coastal behaviour.

Methods

Time series per coastal section are aggregated alongshore to present the large-scale volumetric development. Volumes are determined for supra- and intertidal area (topo), shoreface and sea-bed (below the depth of closure). Nourishment and dredging volumes are cumulatively subtracted from the observed timeseries to obtain autonomous behaviour (Houthuys & Roest, 2019).

Results

The dune area steadily gains sediment. Two larger nourishments for coastal protection were installed since 2012, increasing the positive sediment budget of dunes and beach (Figure 1). Dredging of the Nieuwpoort access channel takes place continuously and sediments are dumped outside this zone, which is the main cause of the decreasing shoreface sediment budget. Volumetric changes are not uniform alongshore. Shoreward migration of the *Trapegeer-Broersbank* and tidal channel *Potje* do not influence the large-scale sediment budget, but lead to local erosion and deposition.

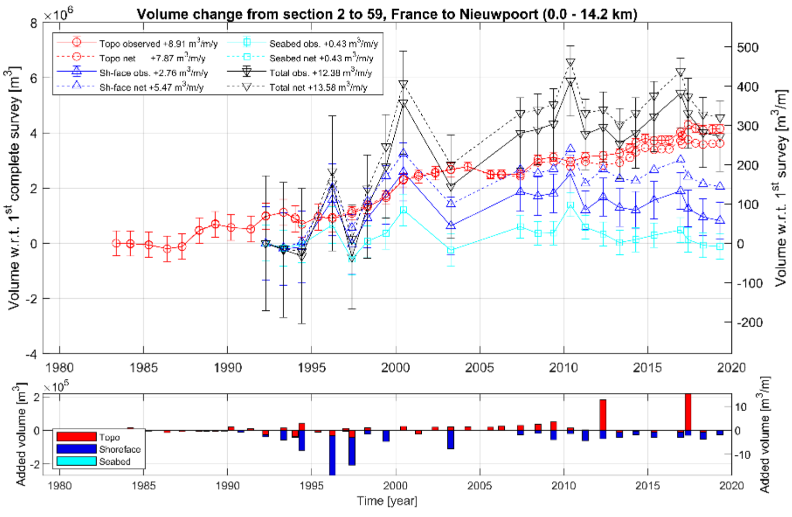

Figure 1: Volumetric changes of the Belgian West Coast. Beach and Dune volumes (red) steadily increase, while Shoreface volumes (blue) show a slow decrease in the last decades. Observed (full lines) and 'autonomous' volumes (dashed lines).

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Exploring the potential of the Nortek Eco, an affordable and portable current profiler

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Introduction

ADCPs, widely used for measuring water motions in the water column, are associated with large investments, complex programming, demanding deployment operations, and extensive data processing. Nortek's Eco was designed to overcome these barriers with a ready-to-use, portable current profiler at an accessible price point (Velasco et al., 2020). Designed for applications in relatively shallow waters, the Eco is suitable for sampling tidal currents, wind driven circulations and rip currents in coastal areas and estuaries. It can be deployed on foot with its mounting frame or released from a dock, floating platform, or small vessel with the Eco pop-up buoy system (Figure 1). Study questions include: Is the Eco an accessible instrument for the inexperienced user? What are the viable potential uses of a simplified instrument with minimal user input requirements?

Methods

To explore this question, deployments were carried out at the Prins Hendrikzanddijk at the island of Texel as part of the SEDMEX field campaign of the TU Delft and Utrecht University. A range of high-end instrumentation installed along the beach was used for validation. The Eco was deployed in the 20 m deep tidal channel Texelstroom with the buoy, and with the mounting frame at the shallow underwater platform close to the beach. One of the nearshore deployments encompassed the subject of research into an emerging salient, a geomorphic feature formed by accretion in the lee side of an offshore shallow zone.

Results

The study showed that current profiles can easily be obtained with the Eco due to built-in deployment options, lightweight form, and a user friendly interface for programming and data processing. Its limited size enabled deployments with small weights (<50 kg), thus enabling deployment by one or two persons without specialized vessels. While high-end instrumentation allows for advanced configurations and high resolution measurements, the Eco's portability and flexibility enable spontaneous deployments, without the need for prior experience in ADCP observations. It proved to be the right instrument to capture flow patterns around the salient that emerged outside the range of the installed measurement arrays. Short, investigative deployments can be made to scout out conditions to optimize future campaigns. Hence, the instrument can be a valuable tool for dedicated applications in coastal and estuarine studies.

Figure 1: The Nortek Eco deployed at the field site using its tripod bottom mount and buoy system.

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Shifting Sands: Developing new measurement methodologies in GIS to analyse the spatial variability of tidal sand wave migration on the Netherlands Continental Shelf

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Tidal sand waves are large-scale bed features that occur in sandy, shallow seas, such as the Netherlands Continental Shelf (NCS). Their significant dimensions and dynamic behaviour makes them relevant to many offshore activities. Despite the abundance of observational studies quantifying sand wave migration, large-scale, shelf-sea wide analyses are lacking. This research aims to gain insight in the spatial variability of sand wave migration on the NCS.

To facilitate this large-scale analysis, an appropriate migration detection method was developed in a GIS. Two methods were tested: Pairs of Source and Target Points (PSTP) and Spatial Cross Correlation (SCC). PSTP measures the distance and angle between vectorised crest and trough lines. SCC locates the two most correlated points in consecutive bathymetries and measures the distance and angle between them. PSTP was found most suitable for a large-scale analysis as its procedure is more transparent and the input parameters need less changing between different analyses.

Regarding migration direction, three distinct patterns were revealed (Figure 1 left). First, virtually all sand waves north of Rotterdam migrate towards the north/north-east. Second, bilateral reverse migration to the north-east or south-west occurs on the flanks of the Zeeland Banks and the Brown Ridge. Third, the sand waves in the south-western corner of the NCS migrate to the north-east and south-west. Average migration rates south of the Wadden Islands typically range between 0-3 m/year. Near the Wadden Islands, average migration rates typically range between 2-8 m/year. Distinct spatial patterns were revealed. First, migration rates are lowest in the south-west of the NCS and increase in north-eastern direction. Furthermore, migration rates are generally highest near the coast and on top of ridges and sandbanks (Figure 1 right).

This research has shown that PSTP, SCC, and GIS in general, are suitable for analysing sand wave migration. The obtained migration data can be used for studying the role of parameters and processes governing sand wave migration. The colour plots provide insight in the spatial variability of sand wave migration at an unprecedented coverage. These insights are valuable for offshore infrastructure planning, optimising hydrographic re-survey policies, dredging and mine hunting strategies.

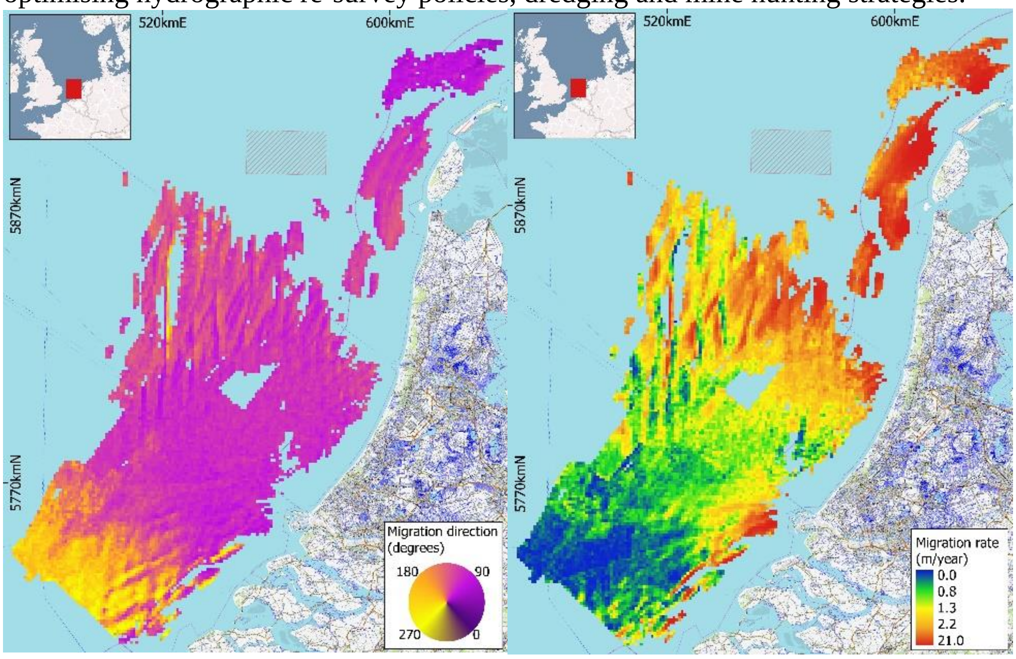

Figure 1: Left: Average migration direction (degrees) per square kilometre. Right: Average migration rate (m/year) per square kilometre.

Storm surges in an idealized tidal channel: a power criterion for the unsteady bed shear stress

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An unsteady friction coefficient for the bed-shear stress

The nonlinear dependency of bed shear stress on flow speed complicates the modelling of time-varying shallow flows, like tides and storm surges. Lorentz's linearisation circumvents nonlinearity in tidal flows thanks to a steady friction coefficient r established with a criterion of *tide-averaged energy equivalence* (Lorentz, 1922). Idealized models of sandbank and tidal dynamics in channel networks have used this linearisation successfully. However, this approach is not suited to storm surges because of their episodic and irregular forcing pattern. Here, we introduce and illustrate the amplification of Lorentz's energy criterion to an *instantaneous power criterion* (Roos et al, 2021). As a result, an unsteady friction coefficient $r(t)$ can adjust to the temporal development of natural wind-driven flows.

A semi-analytical solution in an idealized channel

This novel bed-stress parametrisation is applied to the flow in an idealised channel, closed at one end, forced by a time-varying surface elevation at its mouth and by a time-varying wind stress over its free surface, as sketched below. The cross-sectionally averaged, linearised shallow-water equations are solved analytically in the frequency domain and nested in an iterative procedure to determine $r(t)$.

The verification of the modelling approach

An accurate finite-difference solution of the linearised shallow-water equations retaining the quadratic bed shear stress has been used as numerical benchmark. A forcing from the Xavier storm, on the *Sinterklaas* day of 2013, is used to mimic a natural event. The comparisons, previewed below, show that the proposed approach captures accurately qualitative and quantitative aspects of surge dynamics such as the height and timing of the peaks, sloshing, and the friction-induced tide-surge interactions. The RMSEs of the predicted velocity and bed shear stress deviate from the benchmark minimally too.

Therefore, the computationally fast methods of linear analysis can be applied to processes having a nonperiodic temporal variability. The approach can be extended to complex setups such as channel networks. The impact of the small-amplitude approximation for storm surges simulations and the deviation with respect to a fully nonlinear friction term are subjects of following investigations.

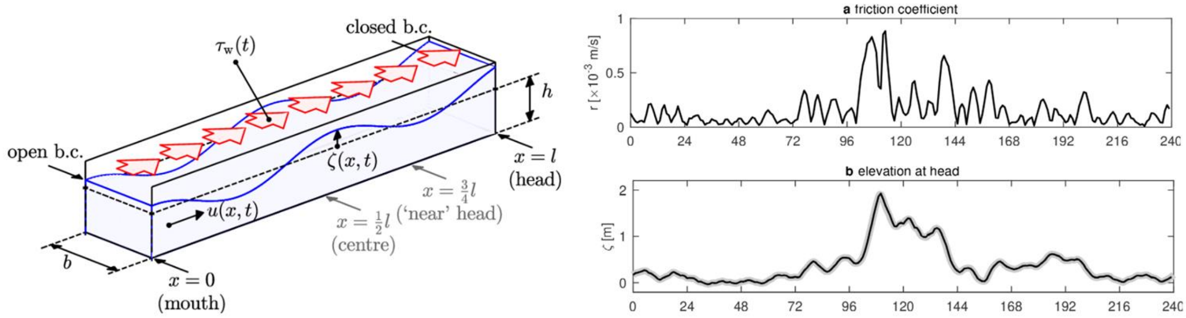

Figure 1: Left: schematic of the channel domain, forcing and boundary conditions. Right: temporal development of the unsteady fiction coefficient r(t) *and of the water level at the channel head as forced by a wind stress signal from the* Sinterklaas *storm; the background grey line is the nonlinear benchmark solution; time is in hours.*

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Development of luminescence imaging to trace Wadden Sea nourishment sand

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Introduction

Luminescence is a powerful tool for dating the burial age of sediments, and it has potential applications for sediment tracing. The method uses light sensitive signals that accumulates in grains while buried, and a main assumption for dating is that the targeted signal has been reset by light exposure (e.g., during transport) prior to burial. Insufficient signal resetting (i.e., poor bleaching) is undesired for luminescence dating but can be of value for luminescence tracing. As different luminescence signals reset at different rates, comparison of these signals yields information about the duration and mode of transport (Reimann et al., 2015). Within our NWO funded TRAILS project, we develop and validate novel luminescence tracing methods and apply them to trace the dispersion of the nourished sands in the Ameland inlet of the Wadden Sea on a basin- and site-scale. The rationale of our approach is that nourished and native grains can be distinguished by different luminescence signal resetting related to their different source and transport histories.

Methods

The principle of native and nourished grain differentiation depends on signal resetting of slow- and fast-to-bleach luminescence signals of feldspar sand grains. Infrared stimulated luminescence (IRSL) and low-temperature post-infrared IRSL (pIRIR) signals are more light-sensitive and bleach more readily than higher temperature post-infrared IRSL (pIRIR) signals. We use a novel luminescence imaging system, which stimulates 100 grains simultaneously and images the resulting luminescence signals with an electron multiplying charge-coupled device (EMCCD) instead of conventional grain-wise stimulation and photon counting with a photomultiplier tube (Kook et al., 2015). EMCCD application has the advantage that it enables repeated measurements without user interference, and it may provide extreme low-level light detection for dimmer signals. The EMCCD camera also enables us to explore the slow-to-bleach thermoluminescence (TL) signals of single-grains.

Preliminary results

The EMCCD enables imaging of luminescence from nourished and native Wadden sea sand grains (figure 1), and results indicate that luminescence fingerprints of both populations are indeed different.

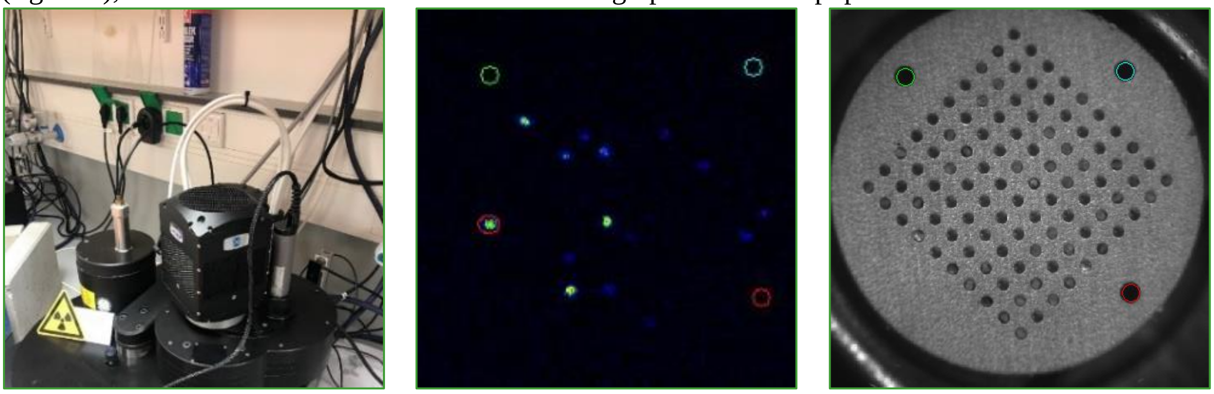

Figure 1: EMCCD camera (left), image of sand grains emitting luminescence (middle) and sand grains mounted on a measurement disc (right).

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Wide Green Dike (WGD) concept for grass revetment under coastal conditions

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The dike along the Dollard estuary in the northeast of the Netherlands has a grass cover. This revetment is not sufficiently strong for the local hydraulic stormconditions. Traditional dike strengthening leads to the replacement of grass with a hard revetment. An alternative under investigation is the "Wide Green Dike" (WGD) concept: a grass-covered dike with an erodible outer slope. To reduce erosion a gentle slope of 1:7, naturally merging into the salt marsh located in front is designed. The advantage of the WGD concept is that it's easily adaptable (add clay) to future challenges, such as sea level rise.

The WGD needs to comply with the national flood safety standards to make it a feasible alternative. Current assessment methods and instruments don't include the strength of the clay layer. In the case of the WGD the grass cover of the dike is allowed to fail during normative conditions. Furthermore the underlaying clay layer is experienced to erosion. Using a clay erosion model the thickness of the clay layer has been designed. This model is based on existing models developed by Deltares (W.J. Klerk, R. Jongejan, 2016). The depth of the erosion profile (d_e in Fig. 1) relates to the thickness of the clay layer. This is the minimum thickness of the future clay layer in the design of the pilot dike.

The strength of the Dollard clay has been carried out in a series of experiments in the "Deltagoot" (P. van Steijn, M. Klein Breteler, 2021) (Fig. 2). Using the results of the experiments, the equations for calculating the erosion volume and the erosion profile has been slightly changed. The experiments confirmed the idea that not the thickness of the clay layer was normative, but the development of the erosion which eventually leads to failure of the crest (Fig. 3). This means that as long as the clay layer is sufficiently thick, the amount of erodible clay between initiation and crest determines the strength.

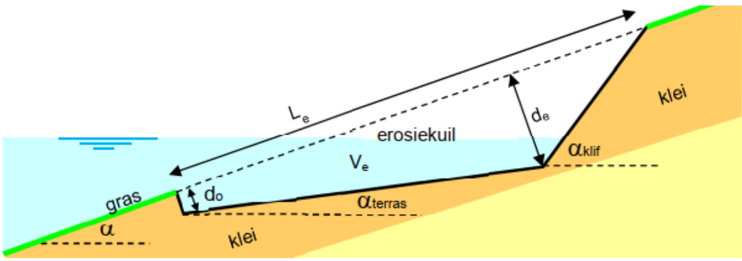

Figure 1: Sketch of the erosion profile with starting depth (d_0, terrace and cliff) (P. van Steijn, M. Klein Breteler; 2021)

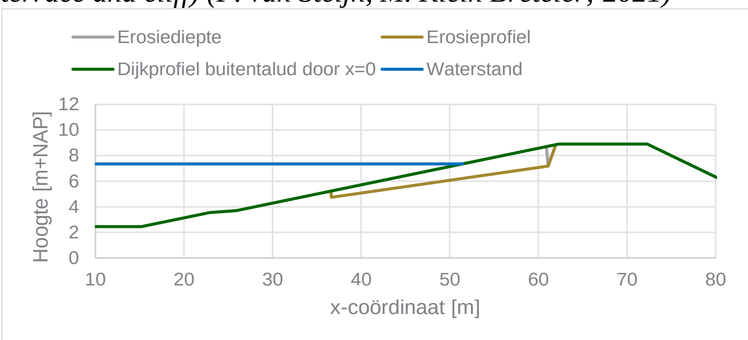

Figure 3: Erosion profile along the dike, where the crest is reached by the erosion profile

Figure 2: Erosion profile in the "Deltagoot" (Deltares) (P. van Steijn, M. Klein Breteler; 2021)

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What are ecological and societal benefits of different coastal nature-based solutions?

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Introduction

Mainstreaming nature-based solutions into coastal management and policy making requires an in depth understanding of the coastal flood defence contribution of such measures as well as their additional societal benefits. Our aim was to demonstrate the added value of nature-based measures in the land-sea interaction zone of the Belgian coast.

Methods

We investigated six nature-based coastal solutions (Figure 1) compared with a hard reference scenario with a grey dike. First, the coastal Safety Tool, developed by IMDC, was applied to assess the magnitude of each measure required to protect against a sea level rise of +1.5m. Second, for each scenario, a series of ecological and cultural services were quantified besides coastal safety. Third, our evaluation was presented to local governments to start a discussion about their (practical) considerations or possible resistance for implementing nature-based measures.

Results

Although not all coastal nature-based measures provide full coastal protection, we found evidence of the added value of combining soft and hard measures (resulting in a reduction of the required dike height). Furthermore, we found evidence that the required dune height can be 1 meter lower than the required dike height in order to protect against the same rise in sea level of +1,5m.

The ecosystem services analysis showed the added value of all nature-based measures compared to the hard reference dike (Figure 1), with moderate added benefits for sand measures (nourishments) and the highest gains for measures with plants and animal species (dune vegetation, reef species).

From our discussions with local governments, we learned that there is an overall willingness to rethink today's coastline but only if all current user functions are integrated, with many practical considerations (e.g. accessibility, maintenance), and much attention for communication to the local stakeholders.

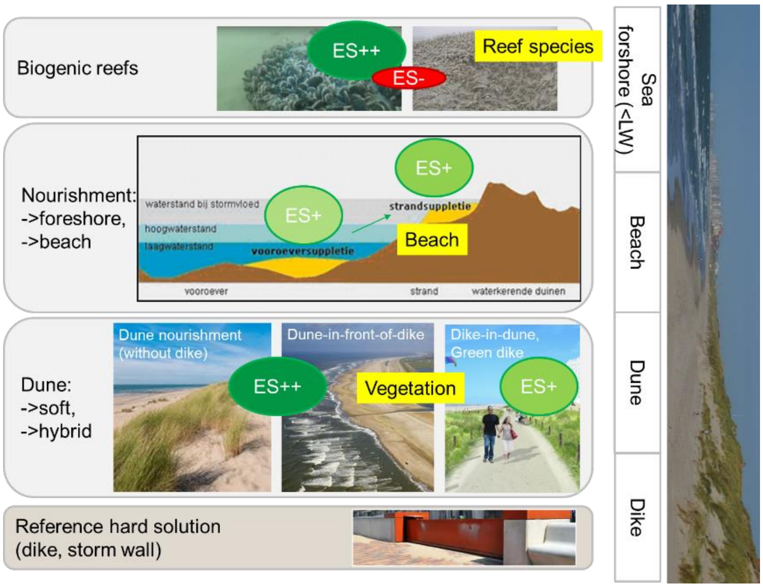

Figure 1: Overview of the range of nature-based coastal solutions and their contribution to ecosystem services (ES) compared to the reference hard solution

Acknowledgement

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