netherlands centre for coastal research

Book of Abstracts

NCK Days 2019

March 20-23

Zuiderzee museum – Enkhuizen

Sponsored by:

Netherlands Organisation for Scientific Research

Organized by:

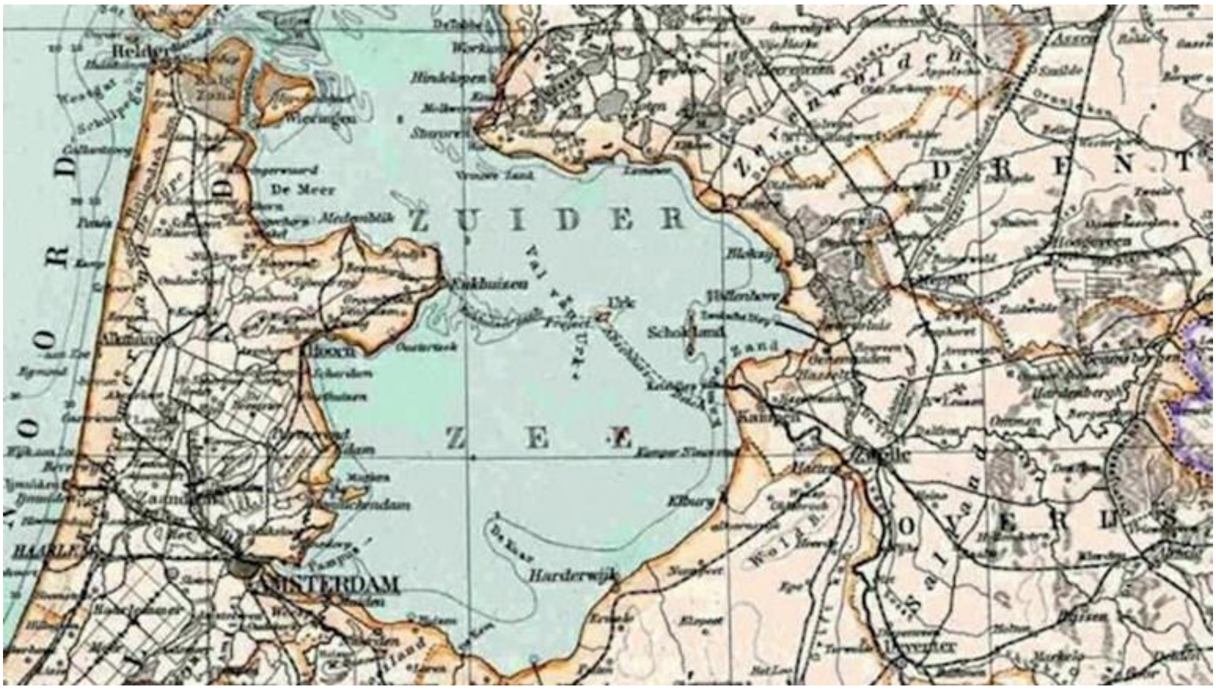
Utrecht University

Contents

Preface

Welcome to the 27th NCK Days!

This year's NCK Days are organized by Utrecht University. We have decided to organize the NCK-days in the Zuiderzee museum in Enkhuizen. Although Enkhuizen is not a coastal city anymore, we all know it used to be up till 1927, when the Zuiderzee was turned into Lake Ijssel. This strongly impacted people living in this area and strongly impacted the morphodynamics of the Wadden Sea. The Zuiderzee museum shows how people used to live in this area before closure of the Zuiderzee.



This year we invited two keynote speakers, highlighting the past and the future of Zuiderzee area. Albert Oost, together with Yftinus van Popta, will discuss how the Zuiderzee area evolved morphologically and how this impacted the people in the area. Petra Dankers will discuss the future of the area and explain how water quality in Markermeer deteriorated and how in the end the Marker Wadden were designed and constructed.

During the conference there is ample time to discuss your work and you will also have time to visit the Zuiderzeemuseum. On Thursday afternoon there will be a guided museum tour. On Saturday the 23rd of March, there is a possibility to visit the Marker Wadden area.

We thank NWO for sponsoring and wish you inspiring and enjoyable NCK days 2019!

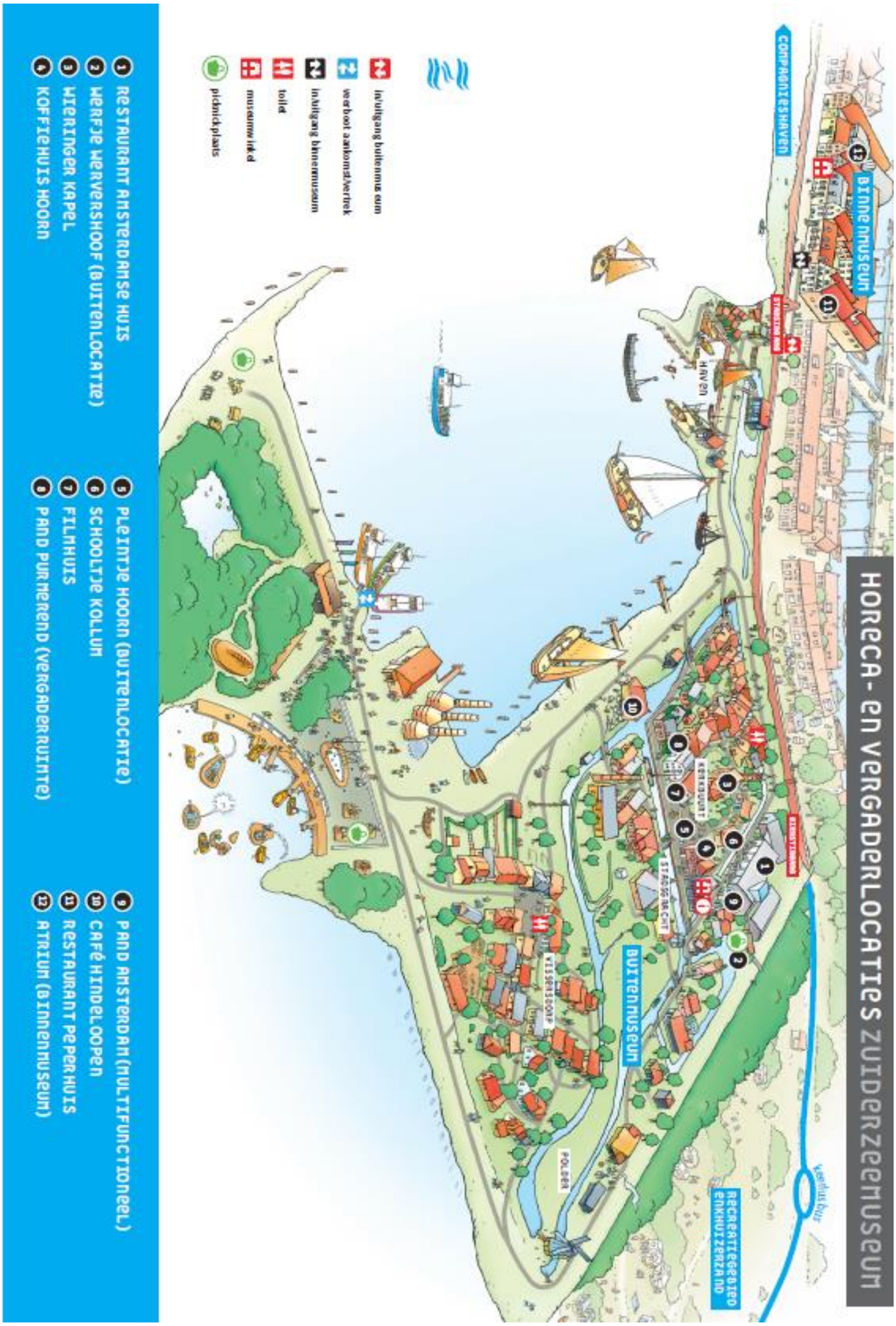
The organizing committee,

Laura Brakenhoff and Maarten van der Vegt

Conference locations

Important locations for this conference are shown on the map on the next page.

- Wednesday March 20: the ice-breaker takes place in **Peperhuis, Wierdijk 22, Enkhuizen,** indicated by number 11 on the map.
- Thursday March 21 & Friday March 22: the conference takes place in **Amsterdamse Huis**, nr 1 on the map. Go to the '**Dienstingang**', address is **Kooizandweg 2, Enkhuizen**. You can park your car in the recreational area near the Dienstingang. Note that the 'Stadsingang' is closed, since the museum will not be open to the public.
- The conference dinner on Thursday takes place in **Peperhuis, Wierdijk 22, Enkhuizen,** indicated by number 11 on the map.
- Information on Marker Wadden excursion will be sent to the people that signed up.



Map of the Zuiderzee Museum.

The Netherlands Centre for Coastal Research (NCK)

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

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

Objectives

The NCK was established with the objectives:

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

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

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

Organization NCK

Netherlands Centre for Coastal Research

Secretariat:
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secretary@nck-web.org
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The Board of Directors of NCK consists of:
- *prof. J. Kwadijk PhD. (Deltares, Chairman)*
- *J. Vroom MSc. (Program Secretary NCK, c/o Deltares)*
- *K. van der Werff MSc. (Rijkswaterstaat)*
- *prof. S.G.J. Aarninkhof PhD. (Delft University of Technology)*
- *prof. P. Hoekstra PhD. (Utrecht University - IMAU)*
- *prof. S.J.M.H. Hulscher PhD. (University of Twente)*
- *prof. H. Brinkhuis PhD. (Royal Netherlands Institute of Sea Research NIOZ)*
- *prof. J.A. van Dijk PhD. (IHE Delft Institute for Water Education)*
- *J. Asjes MSc. (Wageningen Marine Research)*
- *M. van der Meulen PhD. (TNO - Geological Survey of the Netherlands)*

The NCK Program Committee consists of:
- *A.J.F. van der Spek PhD. (Deltares, Chairman)*
- *J. Vroom MSc. (Program Secretary NCK, c/o Deltares)*
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- *B.C. van Prooijen PhD. (Delft University of Technology)*
- *K.M. Wijnberg PhD. (University of Twente)*
- *D.S. van Maren PhD. (Deltares)*
- *T. Gerkema PhD. (Royal Netherlands Institute for Sea Research, NIOZ)*
- *prof. T.J. Bouma PhD. (Royal Netherlands Institute for Sea Research, NIOZ)*
- *prof. J.A. Roelvink PhD. (IHE Delft Institute for Water Education)*
- *M.J. Baptist PhD. (Wageningen Marine Research)*
- *M. van der Vegt PhD. (Utrecht University)*
- *S. van Heteren PhD. (TNO - Geological Survey of the Netherlands)*

Historical context

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

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

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

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

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

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

The NCK partners

TNO
Geological Survey of the Netherlands

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

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

Representatives
NCK Board of Supervisors: M. van der Meulen PhD
NCK Program Committee: S. van Heteren PhD

Delft University of Technology
Faculty of Civil Engineering and Geosciences

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

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

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

Deltares
Applied research in water, subsurface and infrastructure

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

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

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

Representatives
NCK Board of Supervisors: prof. J. Kwadijk PhD
NCK Program Committee: A.J.F. van der Spek PhD, D.S. van Maren PhD

IHE Delft Institute for Water Education

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

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

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

Representatives
NCK Board of Supervisors: J.A. van Dijk PhD
NCK Programme Committee: prof. D. Roelvink PhD

NIOZ
Royal Netherlands Institute for Sea Research

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

More information
www.nioz.nl/home_en.html

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

Rijkswaterstaat
Water, Traffic and Environment

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

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

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

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

Representatives
NCK Board of Supervisors: K. van der Werff MSc
NCK Program Committee: G. Ramaekers MSc

University of Twente
Civil Engineering & Management

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

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

Representatives
NCK Board of Supervisors: prof. S.J.M.H. Hulscher PhD
NCK Program Committee: K.M. Wijnberg PhD

Utrecht University

Institute for Marine and Atmospheric Research Utrecht IMAU

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

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

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

Wageningen Marine Research

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

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

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

Program NCK Days 2019

Wednesday 20 March

20.30 Icebreaker at Peperhuis (Zuiderzeemuseum)

Thursday 21 March

08.30 Registration at Amsterdamse Huis

09.00 Opening

09.10 Keynote:
Petra Dankers: *From mud pool to birds paradise: how did we get from here to there?*

09.40 Session 1: Aeolian transport and dunes
Vincent van Zelst: *Impact of nourishments and foredune management on dynamics in the foredune*
Marije Smit: *The effect of aeolian processes on the Hondsbossche Dunes*
Bart van Westen: *Aeolian modelling of coastal landform development*
Corinne Böhm: *Effect of vegetated foredunes on wind flows and aeolian sand transport*

10.40 Poster pitches:
Glenn Strypsteen: *Aeolian sediment input to the Belgian coastal dunes*
Jakolien Leenders: *Can Dune Growth keep up with Aeolian Losses and Sea Level rise? A study at the Hondsbossche Dunes*
Daan Poppema: *Scale experiments on Aeolian deposition patterns around buildings on the beach*
Paran Pourteimouri: *CFD modeling of airflow over urbanized beaches and the impact of built environment on aeolian sediment transport*
Bob Smits: *The Dynamic Vegetation Module: A Process-Based Modelling Tool for Biogeomorphological Systems*
Giovanni Cecconi: *Tidal regeneration*
Inger Bij de Vaate: *Effects of salt marsh pioneer species-assemblages on emergence of intertidal channel networks*
Alejandra Gijón Mancheño: *Morphodynamic effects of bamboo and brushwood structures for mangrove habitat restoration*
Jill Hansen: *Hidden bio-geomorphological transitions on intertidal flats*
Silke Tas: *Chenier dynamics at an eroding mangrove-mud coastline in Demak, Indonesia*
Alissa Albrecht: *Analyzing the effects of saltmarshes on nearshore wave processes with XBeach*
Erik Horstman: *Tidal Currents in a Mangrove Creek System Quantified*
Stijn Odink: *Long-term marsh growth and retreat in an online coupled hydrodynamic, morphodynamic and ecological model*
Long Jiang: *Potential tidal responses to future sea-level rise in the Oosterschelde*
Hesham Elmilady: *Understanding the long-term morphological evolution of estuarine shoals and the potential impact of sea level rise: A small-scale fundamental approach*
Steven Weisscher: *The effect of mud and vegetation on shaping net infilling estuaries*

Said Alhaddad: *Large-Scale Experimental Investigation of Breaching Flow Slides*
Vera van Lancker: *Transnational and integrated long-term marine exploitation strategies*
Sicco Kamminga: *Bed depth measurements from an ADCP at the right place and time*
Sytze van Heteren: *A new geological overview map of the Kingdom of the Netherlands*
Jelte Stam: *Using vintage seismic data for modern-day geological mapping*

11.00 Coffee/tea break

11.20 Session 2: Estuaries
Wout van Dijk: *Effect of dredging and disposal on multi-channel estuaries*
Sepehr Eslami: *Tidal propagation and salt intrusion in the multi-channel estuarine system of the Mekong Delta, Vietnam*
Karl Kästner: How do Tides Propagate up Rivers with a Sloping Bed?
Pim Willemsen: *Long-term wave attenuating capacity of foreshores: a case study in the Westerschelde*

12.20 Lunch

13.30 Session 3: Tidal Flats & cohesive sediments part 1
Qing He: *Mudflat-creek sediment exchange in intertidal environments*
Roeland van de Vijsel: *Intertidal drainage patterns as indicator for biostabilising ecosystem development*
Lodewijk de Vet: *The Timing of Events Matters for the Eco-Morphology of Intertidal Flats*

14:15 Poster session + Tea & coffee

15:30 Session 3: Tidal flats & cohesive sediments part 2
Irene Colosimo: *Winds of Opportunity: the influence of wind on tidal flat accretion*
María Barciela Rial: *Consolidation and drying of slurries at the Marker Wadden: An overview*
Mick van der Wegen: *MFlat explores wave-induced morphodynamics on intertidal mudflats*

16.30 – 18.00 Excursion: Guided tour through the Zuiderzee museum

18.00 – 21.00 Drinks & dinner at Peperhuis

Friday 22 March

08.30 Registration at Amsterdamse Huis

09.00 Keynote:

Albert Oost: *The Development of the Western Wadden Sea due to the opening of the Marsdiep and Zuiderzee area*

09.30 Poster pitches

Yorick Broekema: *Field and Laboratory Observations of Laterally Non-Uniform Flows Over a Streamwise Depth-Increase*

Arjan van den Broek: *Modelling the transport of organic matter in offshore sand wave fields*

Janneke Krabbendam: *Modelling the past evolution of observed tidal sand waves: model set-up*

Gerben Hagenaars: *Pan-European coastline-migration map based on satellite data 2007-2016*

Vassia Dagalaki: *Quantifying coastline change uncertainty using a multi-model aggregation approach*

Arjen Luijendijk: *The Evolution of Modelling Coastal Evolution*

Bart Roest: *Where does the sand go? A morphological study of the Belgian coast*

Anna Kroon: *Model uncertainty in predicting coastline response of Building with Nature designs*

Ioanna Saxoni: *Morphological evolution of submerged mounds under hydrodynamic forcing*

Mohamed Ghonim: *Recent developments in numerical modelling of coastline evolution: advanced development and evaluation of ShorelineS coastline model*

Sara Dionísio António: *Large-Scale Sediment Transport Experiments in the Swash Zone*

Joost Kranenborg: *Numerical modelling of the swash zone*

Timothy Price: *Quick Reaction Force Egmond aan Zee: measuring the alongshore variability in storm erosion*

Stephanie Janssen*: Dike and Foreshore Joint Stakeholder Action – A Waddencoast case study*

Robert Zijlstra: *Long term coastal management on the Wadden Islands: how to incorporate large scale morphodynamics?*

Abdel Nnafie: *Modeling the morphodynamics of tidal inlet systems: Delft3D-FM vs. Delft3D*

Sicco Kamminga: *Observation of ice flow around Ameland with an x-band radar*

Ana Colina Alonso*: Analysing the large-scale impact of the Afsluitdijk on the sediment patterns in the western Wadden Sea*

Koen Reef*: The influence of basin geometry on the long-term morphological evolution of barrier coasts*

ShengZhuo Xu: *The effect of tidal basin connectivity and waves on sediment transport patterns in the Ameland Inlet*

Jaap Nienhuis: *Feedbacks between overwash deposition and flood-tidal deltas*

10.00 Poster session & Coffee/tea break

11.15 Session 4: Tidal inlets

Gennadii Donchyts: *Automated extraction and fusion of the intertidal and subtidal bathymetry from the Landsat and Sentinel satellite data*

Roy van Weerdenburg: *Exploring the relative importance of wind for exchange processes around Ameland Inlet*
Laura Brakenhoff: *Local bedform patterns on the Ameland ebb-tidal delta*
Klaas Lenstra: *The effect of ebb-tidal delta nourishments on cyclic channel-shoal dynamics*

12.15 Lunch

13.15 Movie session

13.45 Session 5: Nearshore 1 – Surf zone and shoreline
Bjarke Eltard-Larsen: *Simulation of surf zone kinematics over a breaker bar using a stabilized RANS model*
Filipe Galiforni Silva: *Modelling the effects of storm surges on sand flats: case study in Texel (NL)*
Vera van Bergeijk: *An analytical model for dike cover erosion by overtopping waves*
Grace Molino: *Hydrodynamic factors influencing beach profiles in shallow, low-energy lakes: a case study in the Markermeer and IJsselmeer*

15.00 Coffee/tea break

15.15 Session 6: Nearshore 2 – Large-scale vs long-term
Carola van der Hout: *A new estimate for the alongshore SPM transport along the Dutch coast*
Sam de Roover: *Evaluation of uncertainty associated with projections of climate change-driven coastline variations in Japan*
Wessel van der Sande: *Modeling of long-term shoreface morphodynamics under sea-level rise*
Lennart Keyzer: *Response of tropical shallow bays to sea-level rise*

16.15-16.30 Closure; Best presentation and poster award

Abstracts of oral and poster presentations in alphabetical order

ANALYZING THE EFFECTS OF SALTMARSHES ON NEARSHORE WAVE PROCESSES WITH XBEACH

A.M. Albrecht[1,2]*, C.H. Lashley[1], J.D. Bricker[1], C.M. Ferreira[3]
[1] Delft University of Technology, [2] Fulbright U.S. Student Program, [3]George Mason University
*alissa.m.albrecht@gmail.com

Figure 1 Aerial view of the Chesapeake Bay study site. Source: Google Earth

Motivation

As climate change causes sea levels to rise, coastal communities must continue to improve their flood defense systems to withstand wave activity created by extreme storm events. Energetic waves can reach shore and cause dangerous flooding, the risk of which will increase with rising seas. To defend coastal communities, new flood control methods are being explored. One such method is using vegetated foreshores like salt marshes to attenuate wave energy before the waves reach the shoreline.

The approach of using salt marshes as flood control can be applied to the northeastern United States (US), an area that is at an increasing risk for storm-related flooding as warmer temperatures cause both an increase in large storms in the Atlantic Ocean and an increase in sea levels. This project will focus on the northeastern coast of the US and create a two dimensional model of a study site in the Chesapeake Bay, seen in Figure 1, using the XBeach numerical model. The site has previously been modeled by Baron-Hyppolite (2018) using SWAN, a wave phase-averaged model. Modeling in XBeach will extend this project to include a wave-group resolving analysis of the site.

Aims

The model of the study site will be used to evaluate the extent that XBeach accurately predicts wave propagation over shallow vegetated foreshores. It will also be used to study the effect of salt marsh vegetation characteristics on wave attenuation in the foreshore.

Figure 2 Aerial view of the study site vegetation, with sensor locations in red. E2EM1P represents a salt marsh. Source: Google Earth and National Wetlands Inventory

Methods

The XBeach model has been created using field data from collaborators at George Mason University (GMU) in Virginia taken during a series of storm events between September 24th and October 2nd of 2015. GMU provided pressure gauge data, ADCP data, bathymetry, and vegetation characteristics. Boundary conditions for the XBeach model are taken from the ADCP and pressure gauge data.

The model will be validated by comparison to GMU site data taken at four locations along a transect. After validation, the site will be modelled with a base vegetation setup based on the GMU vegetation survey and the National Wetlands Inventory map shown in Figure 2. Then, following the approach used by Hu et al. (2015) the stem height and density of this base vegetation will be varied from 50% to 200% in 25% intervals. Preliminary results will be presented.

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LARGE-SCALE EXPERIMENTAL INVESTIGATION OF BREACHING FLOW SLIDES

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Introduction

A flow slide occurs when a large, subaqueous soil mass is destabilized and accelerates down slope, then eventually redeposits as a milder slope. This phenomenon poses severe risk for subaqueous structures and flood defenses along coastlines and riverbanks, which is able to undermine an entire hydraulic structure, resulting in significant unwanted consequences.

Breaching is a gradual, retrogressive failure of a steep subaqueous slope, greater than the angle of repose. This type of failure usually takes place in densely-packed sand due to its dilative behaviour under shear. Breaching flow slides are accompanied by the generation of turbidity currents. This current is driven by excess density versus the ambient fluid; it may increase erosion of the sand surface, picking up more sediment into suspension, thereby increasing speed and erosion potential.

Measurements of breaching-generated turbidity currents are substantial for understanding the interaction between the turbidity current and the slope surface, and validation of numerical models. However, such measurements are scarce in the literature. Therefore, laboratory experiments are planned to be conducted in the water lab of Delft University of Technology.

Methods

An experimental setup was designed specifically for the purpose of studying breaching flow slides (see Figure 1). A densely-packed fine sand deposit up to 1.5m high is constructed with a selected slope, steeper than the angle of repose. This slope is created and supported by a removable confining wall. The deposit is emplaced layer by layer and compacted using a vibrator needle to ensure that the sand porosity is homogeneous and the sand is dense. Breaching is initiated by quickly removing the confining wall from the breaching tank, leaving the deposit at an unstable slope.

Figure 1 3D diagram of the experimental setup

Results and Outlook

The experimental setup has been recently constructed. As yet, two preliminary experiments have been conducted to check the functionality of the setup. The preliminary results and observations show that the sand erosion rate increases in the downstream direction of the slope due to acceleration of the turbidity current. We will conduct a series of experiments with different slope angles in the near future. We plan to obtain velocity and concentration measurements of turbidity currents to understand the coupling of the breaching process and the associated turbidity current.

CONSOLIDATION AND DRYING OF SLURRIES AT THE MARKER WADDEN: AN OVERVIEW

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Introduction

Sediment is becoming scarce and fine sediments are progressively used for reclamation projects. Therefore there is an increasing need to use cohesive fine sediments (mud) for land reclamation and nature building. These sediments exhibit larger deformations and consolidation time than sandy sediment, and are therefore more challenging building materials to use. The MarkerWadden (Lake Markermeer, The Netherlands) is one of the first projects using fresh soft mud (with a low-strength and high water content) for wetland construction.

In the research, the material properties of natural sediment from the Markermeer were determined and, the consolidation, drying and undrained shear strength was studied for varying solid compositions. Furthermore, the influence of vegetation and drainage during consolidation and drying was investigated.

Methods

The material parameters (of the previously characterised different sediment compositions) were determined with settling and Seepage Induced (SIC) tests. Further, multiple experiments were performed to study the behaviour of Markermeer sediment during the different construction phases (Figure 1). To study the consolidation behaviour under loading, Constant Rate of Strain (CRS) and Incremental Loading (IL) tests were performed. The undrained shear strength was studied with the Fall cone test. The commercial Hyprop device was used to determine the water retention curves (WRC) of the different sediments, therefore characterising their drying behaviour. Finally, a new set-up was designed to study the consolidation and drying under the influence of vegetation and drainage.

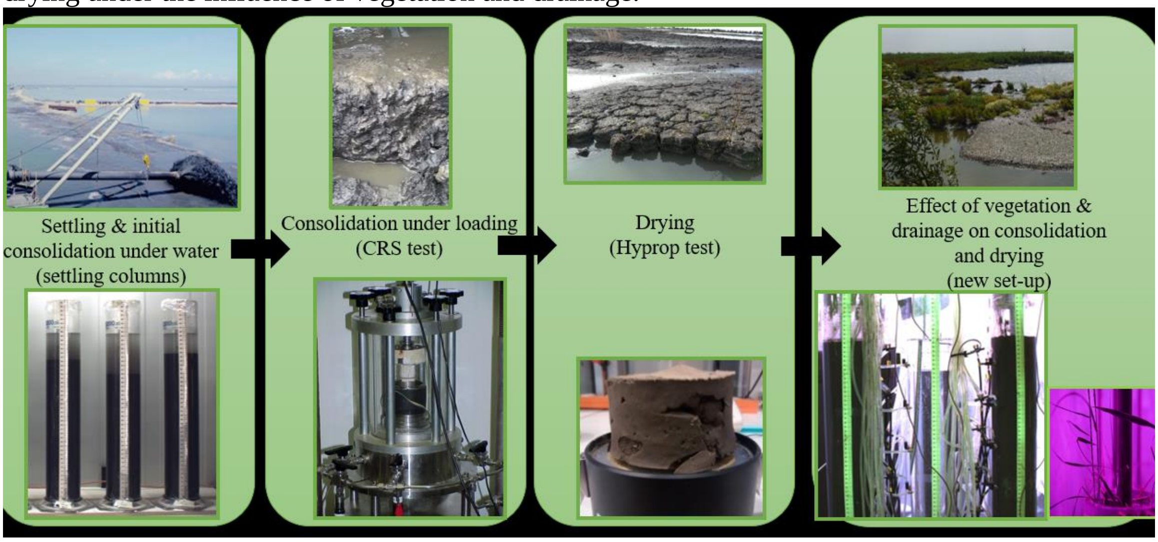

Figure 1 Some of the physical processes taking place during the construction of a wetland such as the Marker Wadden (top) and different experiments performed to study the response of the different sediments (bottom)

Results

The behaviour of sediment samples was dominated by the fine fraction for sediments below 70% sand. The results showed a strong influence of the type and degree of oxidation of the organic matter (thus not only of the amount) on the mechanic behaviour of the sediment. This effect was observed during all stages (settling, consolidation and drying). The vegetation induced high gradients and day-night pore pressure differences induced by plants as well as the change on the hydraulic conductivity of the sediment.

The results provide insight on the factors affecting the mechanical behaviour of mud. Therefore they provide engineering tools for Building with Mud projects, such as the quantification of plant drainage, while putting in relevance the importance of a multidisciplinary approach herein.

AN ANALYTICAL MODEL FOR DIKE COVER EROSION BY OVERTOPPING WAVES

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Introduction

Earthen dikes and dams are vulnerable for cover erosion by overtopping waves. Transitions in geometry and cover type can lead to more cover erosion because they increase the hydrodynamic load by creating extra turbulence and decrease the cover strength. The effect of transitions on the overtopping flow and the dike cover erosion along the dike profile is unknown. For that reason, we developed a coupled hydrodynamic-erosion model to study the effects of transitions and find the most vulnerable spot for cover erosion along dike profiles.

The Analytical Model

The analytical model couples the velocity formulas of Van Bergeijk et al. (subm) and the erosion formulas of Hoffmans (2012) to calculate the maximum overtopping flow velocity and the dike cover erosion along the dike crest and the adjacent landward slope for one wave. The analytical model is applied to a river dike with a road on the crest at Millingen a/d Rijn where an overtopping experiment was performed (Figure 1). The maximum flow velocity decreases along horizontal parts of the profile and increases on the slopes. The road does not erode and the grass cover only erodes when the critical flow velocity of 4.5 m/s is exceeded. The erosion depth is maximal at the end of the landward slope where the flow velocity is highest.

The Effect of Transitions

To study the effect of transitions on the dike cover erosion, the erosion model needs to be adapted to account for the extra turbulence created by the transitions and the reduced cover strength around transitions. Preliminary results showed that berms and revetments on the landward side reduce the flow velocity significantly and might be effective measures to reduce the dike cover erosion. Better understanding of the erosional effects of transitions can lead to improved dike design and assessment.

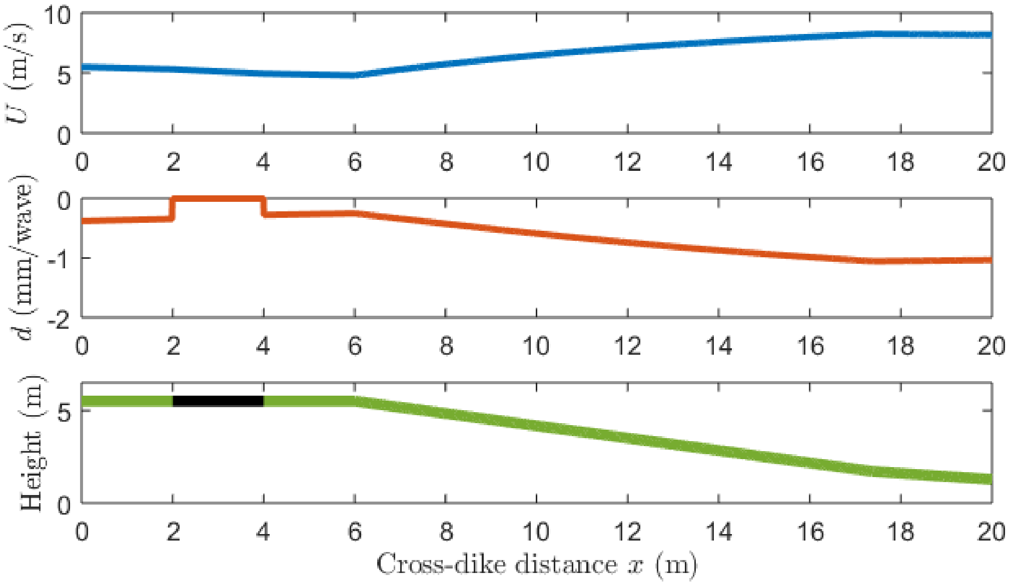

Figure 1: The flow velocity U, the erosion depth d and the cross-dike profile. The dike is covered in grass (green) with a road on the crest (black) and a transition in slope steepness around x=17.5 m.

Acknowledgements

This work is part of the research programme All-Risk, with project number P15-21, which is (partly) financed by the Netherlands Organisation for Scientific Research (NWO).

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EFFECTS OF SALT MARSH PIONEER SPECIES-ASSEMBLAGES ON EMERGENCE OF INTERTIDAL CHANNEL NETWORKS

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Introduction

Salt marshes form a natural barrier between land and sea. They can protect the coast from effects of climate change through attenuating storm surges, and accreting with rising sea level (Constanza et al., 1997). The effectiveness of salt marshes in doing this, is closely related to their channel networks (Leonardi et al., 2018), which is in turn influenced by their vegetation cover. Previous research suggests a dual effect of vegetation on marsh topography, where vegetation favours stabilization of sediment, yet also promotes erosion and channel incision (Schwarz et al., 2014). Past models used simplified vegetation properties to predict salt marsh channel development, disregarding the effect of various species-dependent growth forms (varying in space and time) on abiotic processes. The aim of our research is to investigate the effects of a set of common salt marsh species and their interactions on sediment stabilization and channel initiation.

Methods

To assess the long-term effect of vegetation on topography, we made use of a coupled biogeomorphologic model (based on van Oorschot et al. 2016, Brückner in prep.). This model couples vegetation development to Delft3D, which was set up using M2 forcing on a linear sloping bed. Species colonization was implemented by random establishment and growth modelled through species-specific growth and mortality functions. Here, the model allowed to consider both physical plant properties and spatio-temporal variation in growth. In this study we focused on three species that dominate NW European salt marshes: *Spartina anglica, Puccinellia maritima* and *Salicornia procumbens.* Their effect on topography was investigated for (i) each species respectively, (ii) species-assemblages and (iii) species shifts potentially occurring due to climate change or species invasions.

Results

Our results demonstrate the importance of species-dependent vegetation properties in shaping the resulting marsh topography. Both *Spartina* and *Puccinellia* induce significant channel incision, while *Salicornia* does not lead to topographic change. Species assemblages resulted in comparable topographies, but with reduced channel development compared to the most spatially dominant species in the assemblage. Vegetation cover also enhances tidal asymmetry and hence influences the direction of net sediment transport. In both species shift-scenarios, the pre-shift channel network eroded because of an initial drop in vegetation cover under the new species, implying reduced protective capacity of the marsh.

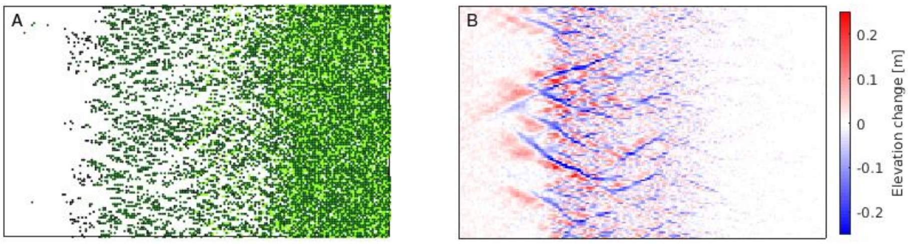

Figure 1: Vegetation distribution (A) and related bed level change (B) after 20 years of simulation. Colours in (A) depict different species: Spartina (dark green), Puccinellia (light green) and Salicornia (black).

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Effect of vegetated foredunes on wind flows and aeolian sand transport

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Introduction

Coastal foredunes are important for coastal safety (de Winter, Gongriep and Ruessink, 2015) and constitute habitats with a high biodiversity (Everard, Jones and Watts, 2010; Miller, 2015). Foredunes form due to a complex interplay between wind, morphology, vegetation and aeolian sediment transport (Hesp, 1988; Davidson-Arnott *et al.*, 2018). They form through plants establishing on the bare beach able to trap sediment transported by the wind. The sediment eventually builds up and the dune morphology is altered starting from low embryo dunes which eventually become high prominent foredunes. Wind, Sediment transport and plants are thus important determinants for the foredune development and shape. There is great interest in improving the predictive capacity of foredune development (Davidson-Arnott *et al.*, 2018) for both environmental significance and coastal safety, particularly in light of a projected increase in erosion events in future.

Methods

To study the controls of foredune growth on high, densely vegetated foredunes, field data was collected during a period of five weeks in Egmond aan Zee, the Netherlands. Foredunes were approximately 20 m high with steep slope (1:2) and dense cover of European marram grass (*Ammophila arenaria*). Wind velocity, direction and turbulent kinetic energy (*tke*) were measured across the foredune, while sand transport was recorded on five selected days. Moreover, vegetation surveys were done across three transects, which were complemented with sedimentation data from LIDAR elevation maps.

Results

Depending on the incident wind direction, the wind flow changes in both magnitude and direction. Generally when flowing across the foredune, the wind first decelerates and is deflected towards the alongshore direction, followed by acceleration up to 310% and turning to perpendicular onshore. Highly oblique flows were deflected up to 38° towards cross-shore direction at the crest. The *tke* was directly proportional to the wind velocity exhibiting its biggest magnitude at the crest, but relatively it was largest at the dune foot and on the slope. Aeolian transport decreased substantially across the foredune. Sediment fluxes at the upper dune foot increased first to 328% and subsequently decreased towards the dune crest. Sediment transport fluxes varied for different days in response to wind velocity and direction determining the maximum available fetch. The vegetation assays showed that the foredune was covered densely with European marram grass (20-100%), reaching its maximum at the crest. A comparison between vegetation cover and sedimentation throughout the field campaign revealed a strong influence of vegetation of foredune morphology. Highest sedimentation rates were related to vegetation cover between 5-50%. The study showed that the foredune has large influences, both on wind characteristics as well as on transport.

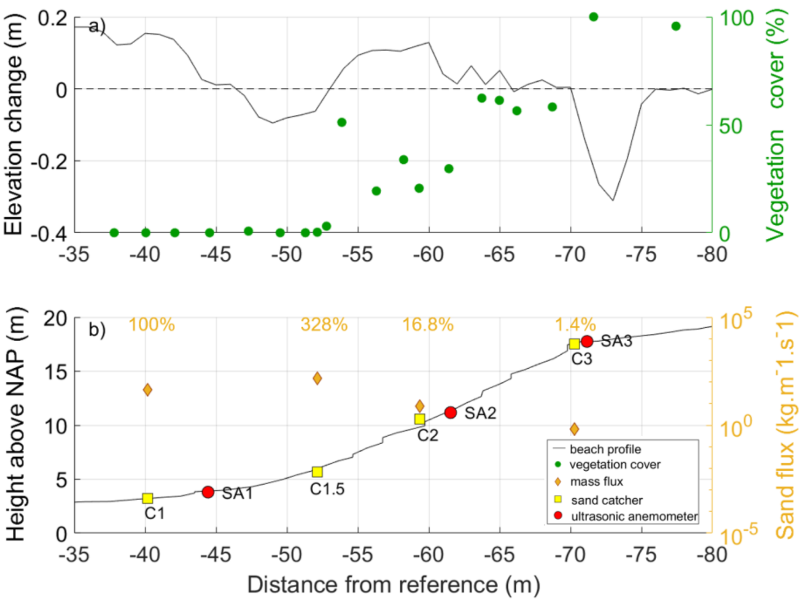

Figure 1. Relationship between mean sand transport, vegetation cover and morphology for main study transect with a) vegetation cover (%) and elevation change (m); b) sand flux ($kg.m^{-1}.s^{-1}$) and dune profile with position of sand catchers (Cs) and ultrasonic anemometers (SAs).

LOCAL BEDFORM PATTERNS ON THE AMELAND EBB-TIDAL DELTA

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Introduction

Ebb-tidal deltas are subtidal bodies of sand, located seaward of tidal inlets. They are affected by both waves and currents and contain a wide variety of bedforms. Since these bedforms influence bed roughness and sediment transport, it is important to understand their dynamics. This can help in improving predictions of sediment transport and hydraulic resistance used by models like Delft3D. Recently developed predictive formulas for bedform geometry have not yet been tested for the complex hydrodynamic conditions of ebb-tidal deltas. The present study analyses the spatio-temporal behaviour of small-scale bedforms on an ebb-tidal delta and relates these to the hydrodynamic forcing.

Methods

In September and October 2017 four frames were installed on the Ameland ebb-tidal delta, which measured amongst others wave heights, current speeds and bedforms. The bedforms were measured hourly on a small spatial scale of 2x2 m with a horizontal resolution of 1 cm by a 3D profiling SONAR. Grain sizes near the frames were determined through box core samples.

Results

Figure 1A shows the bedforms at 6.5 m water depth on the outer shoal for one moment in time. The grain size near this frame was 185.8 µm. The bedforms shown in Figure 1A are highly three-dimensional, indicating the combined influence of both waves and currents. At this moment in time, the wave- and current-related Shields parameters were approximately the same (θw = 0.06 and θc =0.05; red dot in Figure 1B). The associated bedform classification is 'mixed wave-current ripples'.

Figure 1B also shows predicted bedform types as a function of the wave- and current- related Shields parameters for all other moments during the measurement campaign on the same location. It is visible that most of the time, both waves and currents were important here, although waves are a little more dominant. The associated ripple types are mixed wave-current ripples and hummocks (Kleinhans, 2005). All bedform patterns measured by the four Sonars through time will be classified, in order to find a relation between waves, currents and bedform types.

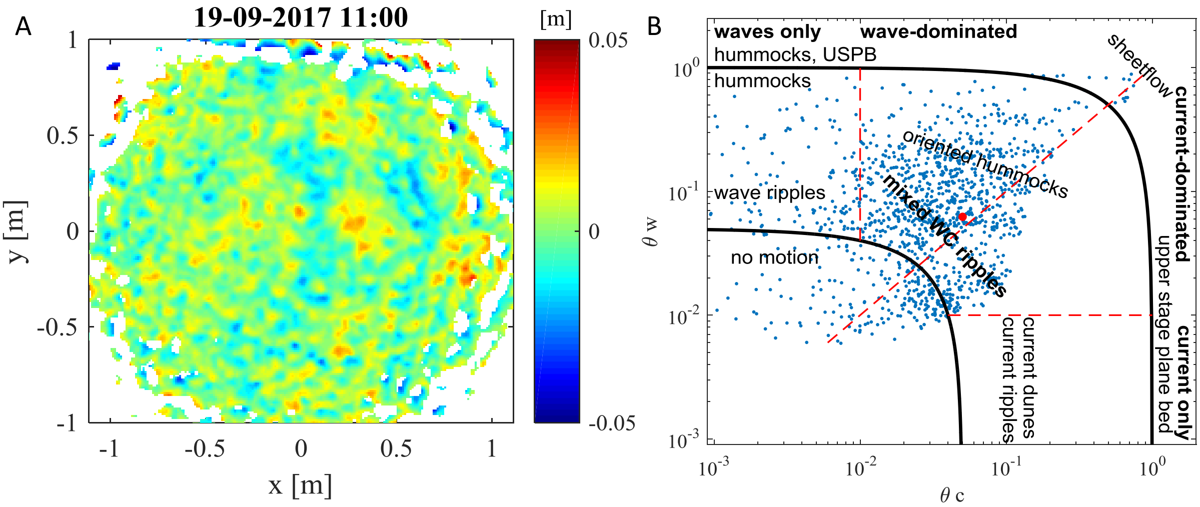

Figure 1. A: typical example of bedforms as measured on the outer delta shoal. B: Nondimensional wave- (θw) and current- (θc) related Shields parameters throughout the measurement period and predicted bedform types. Red dot indicates the moment visualized on the left. Red lines indicate transition between wave-, wave-current, and current-dominated ripples. Black lines indicate thresholds for ripples vs flat bed and sheetflow. (Lines reproduced after Kleinhans, 2005)

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Modelling the transport of organic matter in offshore sand wave fields

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Large parts of the sandy seabed of shallow seas are covered with rhythmic bed patterns. These bed patterns result from the complex interaction among hydrodynamics, seabed topography and sediment transport. The most dynamic bed patterns are tidal sand waves which generate in several years' time, may grow up to 25% of the water depth, have wavelengths of hundreds of meters and migrate at a speed of several meters per year. Moreover, sand waves are inhabited by benthic macrofauna which are invertebrate animals that are > 0.5 mm in size. Broadly speaking, most of them can be divided into two major feeding groups. The deposit feeders ingest large volumes of sediment to consume the organic material and microbes. Suspension feeders, on the other hand, filter organic matter from the overlying water column.

Collectively, these feeding processes can have significant consequences on the sediment dynamics. Insight in the transport of organic matter in sand wave areas is scare, and is important to understand to link the biological and physical processes (and vice versa). Therefore, the aim of this study is to understand the transport of organic matter in a sand wave field. To this end, we combine (i) a numerical sand wave model (van Gerwen et al, 2018) and (ii) a biogeochemical model (Soetaert et al, 2016).

Results show that reversing flow currents during slack tide are causing the organic matter to be transported over distances greater than one sand wave. Conversely, during flood and ebb flow the organic matter accumulates on the lower slopes and in the troughs of the sand waves. A recent field campaign, as part of the SANDBOX program, collected both physical and biological data in a sand wave field near Texel. These field data agree generally well with the results of this modelling study.

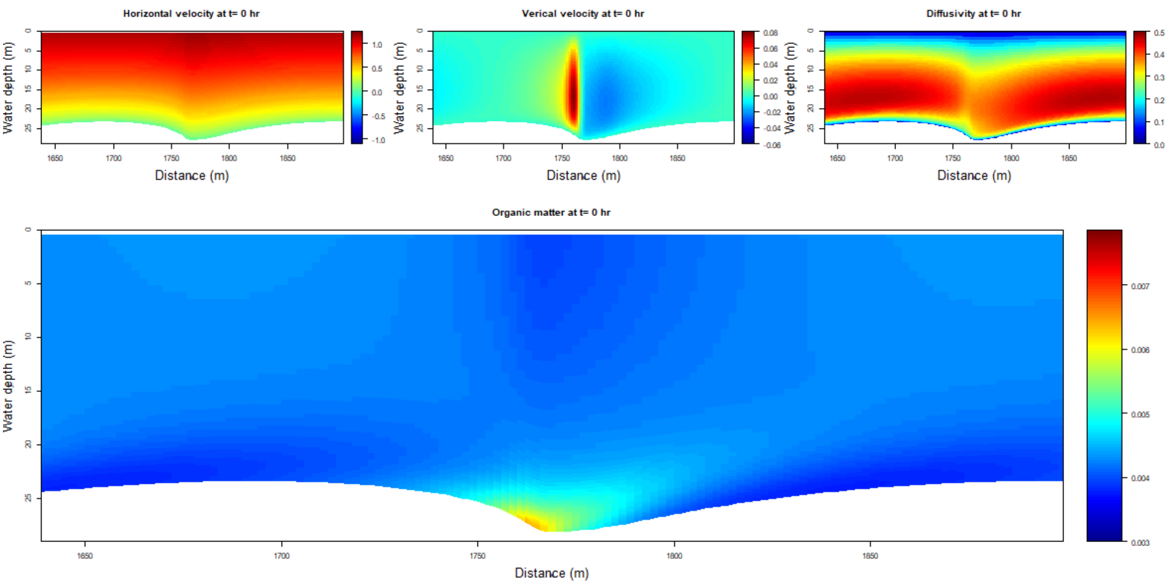

Figure 1 Flood values for (a) horizontal velocity, (b) vertical velocity, (c) vertical diffusivity and (d) organic matter concentration.

Acknowledgement

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FIELD AND LABORATORY OBSERVATIONS OF LATERALLY NON-UNIFORM FLOWS OVER A STREAMWISE DEPTH-INCREASE

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Located in the South-Western delta of the Netherlands, the Eastern Scheldt storm surge barrier is one of the most well-known flood defense structures of the Netherlands. It is 9 km long and has a semi-open structure, consisting partly of dams (+/- 6 km) and partly of gates (+/- 3 km) to maintain a tidal saline-water habitat in the Eastern Scheldt estuary. At both sides of the barrier, a bed protection is applied with a length of 500-600 m in streamwise direction, and downstream of this bed protection large-scale local erosion (scour) has developed. These so-called scour holes may become a potential threat to the stability of the barrier. A fundamental understanding of the local flow phenomenology is lacking, making future development and mitigation measures hard to determine.

Observations of Broekema et al. (2018) have shown that the flow adjacent to the barrier and the scour holes have characteristics of a tidal jet, that is, large velocity differences over the width of the inlet were present. It is exactly this combination of non-uniformity in the horizontal plane in combination with the increasing flow depth plane that gives rise to a highly complex flow field which, at times, may cause a self-amplification of the scouring process. To understand these flow patterns, a series of flow experiments were performed in the hydraulic laboratory of the Delft University of Technology. Archetypal horizontally non-uniform flow fields, like mixing layers, jets and wakes were investigated, and key observations of these flows will be discussed. Key characteristics from these flows include:

- The slope induces a redistribution of the flow in the horizontal plane. In many cases, a strong convergence of flow towards the high-velocity side(s) of the domain was observed (Figure 1).
- In some cases, this convergence leads to a suppression of vertical flow separation through a reduction in adverse pressure gradient.

It will be demonstrated that slope-induced changes of the flow can have large consequences for hydraulic loading, like for instance bed shear stress and drag. Results of these studies are not only applicable to the Eastern Scheldt storm surge barrier, but transcend to many other applications where similar flow fields are expected to occur.

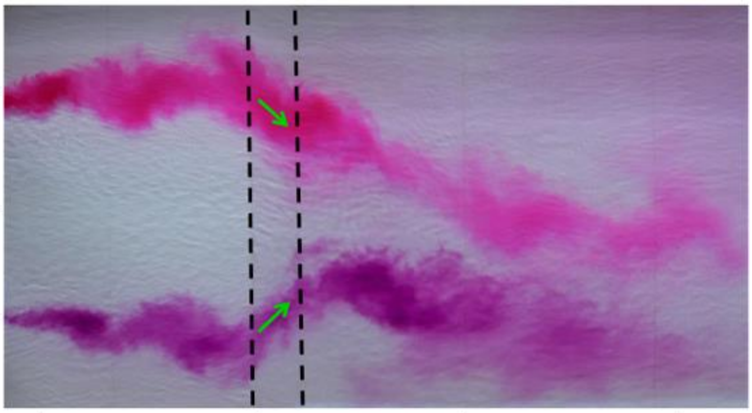

Figure 1 Convergence of flow over a sloping section in the horizontal plane. The black-dotted lines denote the position of the slope. The water flows from left to right, and the high flow-velocities are concentrated in the centre of the domain. On the interface between the high and low velocities, mixing layers are developing, visualized by the purple ink. Because of the shallowness of this experiment, large-scale (quasi-)2D coherent structures may be recognized in the mixing layers. Taken from Van de Zande (2018).

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TIDAL REGENERATION

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Introduction

During the last 20 years the 224 arches of the bridge connecting Venice with inland has been clogged by 2m reefs of oysters (*Crassostrea gigas*) till the elevation of mean high tide. This has produces stagnation of the water, siltation of the navigation channels, risk of anoxia and an excess of turbidity. All these factors are impeding the growth of bio structuring habitat. A bottom-up co-produced project with the reuse of oysters and dredged sediments for increasing tidal flushing in the open waters and the retention of pollution and sediments in the Osellino and Dese Delta has been developed and submitted to the EU LIFE-BIODIVERSITY 2018 Program for co-financing.

Methods

Using a hydrodynamic model, we have found the possibility of inducing a residual current across the bridge reopening only few arches together with tentative channels that we foresee will expand naturally under the tidal flow. Also, with a limited amount of dredging we have demonstrated the possibility of retaining nutrients and turbidity inside the delta of Dese and Osellino river increasing the depuration of water entering the open lagoon and increasing also the accretion capacity of the salt-marsh wetlands, with a greater increase of C=2 trapping and adaptation to sea level rise.

Results

Presentation of the dredging for tidal flushing and the delta retention works together with the simulation of their effects with a 2-D hydrodynamic model. The possibility to install a vegetated floating mattress for wave dumping and water depuration instead of oyster shoals will be discussed comparing the effects and costs of the two solutions.

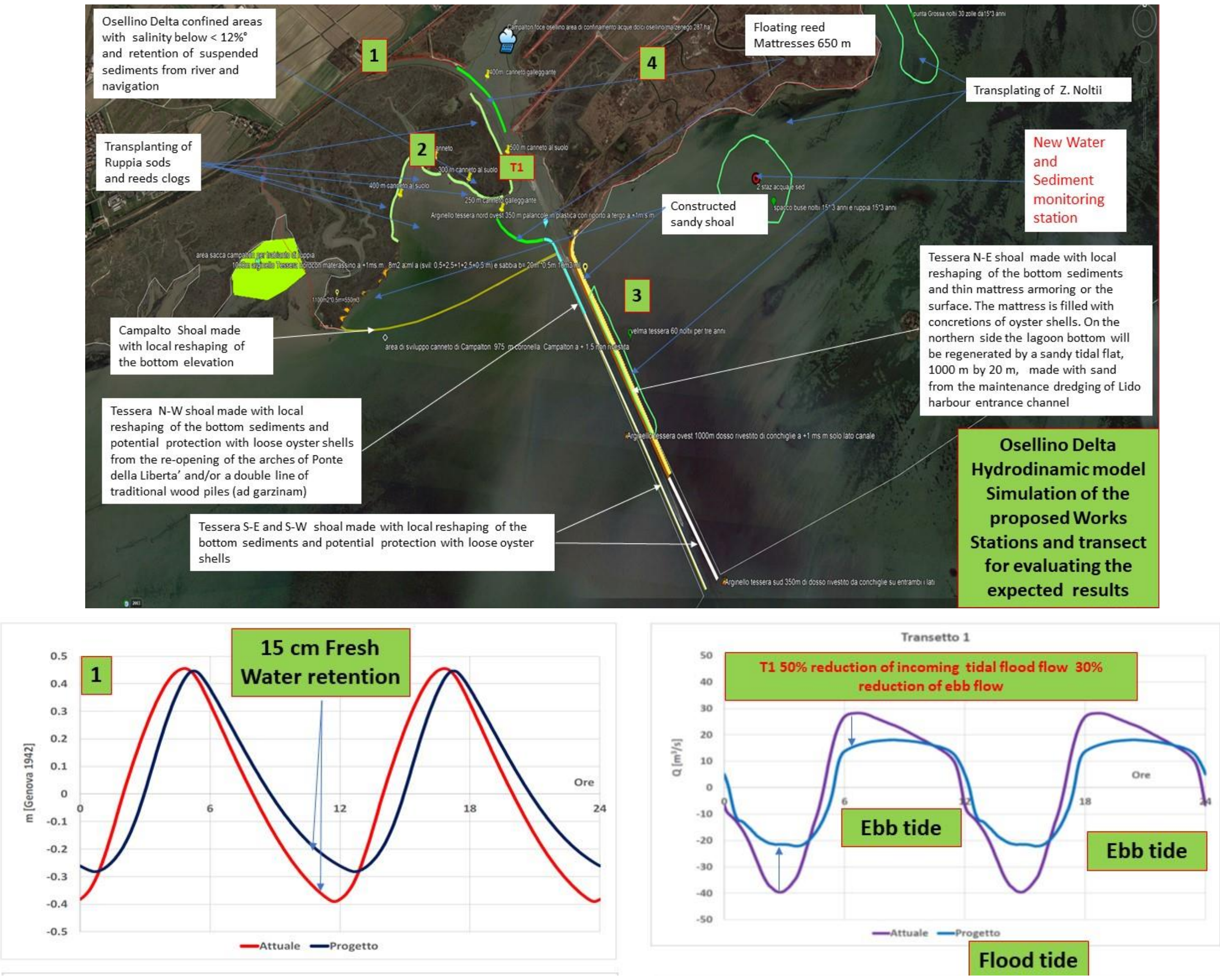

Figure 1 The retention structures at the Osellino Delta and the effects on water levels.

ANALYSING THE LARGE-SCALE IMPACT OF THE AFSLUITDIJK ON THE SEDIMENT PATTERNS IN THE WESTERN WADDEN SEA

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Introduction

Deltas are under pressure by climate change and increasing human activities, resulting in changes in abiotic and biotic factors. Especially when these pressures exceed certain thresholds, these changes may be abrupt or even irreversible (i.e., regime shifts). This research focuses on large-scale regime shifts in the morphology of the Dutch Wadden Sea. Its diverse morphological features were initially formed under a temperate climate and sea level rise, strongly influenced by human activities later on. The significance of anthropogenic interferences for the large-scale morphological development of the Wadden Sea compared to its natural sediment dynamics is still largely unknown.

Previous studies have determined short- and long-term effects on the sedimentation and erosion patterns after the closure of the Zuiderzee. However, little is known about which sediment fractions caused the changes in the sediment budget. In this research, we therefore investigate and link the morphological evolution of the Western Wadden Sea (WWS) in terms of bed level changes to changes in the distribution of sand and mud in the sediment.

Preliminary results

Analysis of long-term field data reveals that the human interventions led to large sedimentation rates in parts of the WWS. Surprisingly, the distribution of sand and mud has not changed substantially. An exception is found in the channels in front of the Afsluitdijk: they used to be predominantly sandy, but the closure triggered a rapid siltation leading to a large accumulation of mud (see Figure 1). Mud-dominated areas tend to coincide with areas where net deposition rates are large. A first estimate of the mud contribution to overall sedimentation suggests that 24% of the total sediment deposition volume since the closure consists of mud. Besides, it is striking that the ratio of the gross mud deposition volume to the gross mud erosion volume is consistently larger than the same ratio applied to the sand fraction.

Burning questions for further research

Former sediment budget studies have suggested a balance between the large-scale sedimentation of the Wadden Sea basins and erosion of sand along the Dutch coast. Our results, indicating a significant contribution of mud to the sedimentation, reject this and seem to reveal a lack of balance. Establishing a realistic sediment balance for both sand and mud in the Wadden Sea area requires a better understanding of the sand-mud patterns and their transport pathways. We plan to further research these patterns and investigate the processes that determine the mud content by combining analysis of field data with idealized models and detailed process-based numerical simulations.

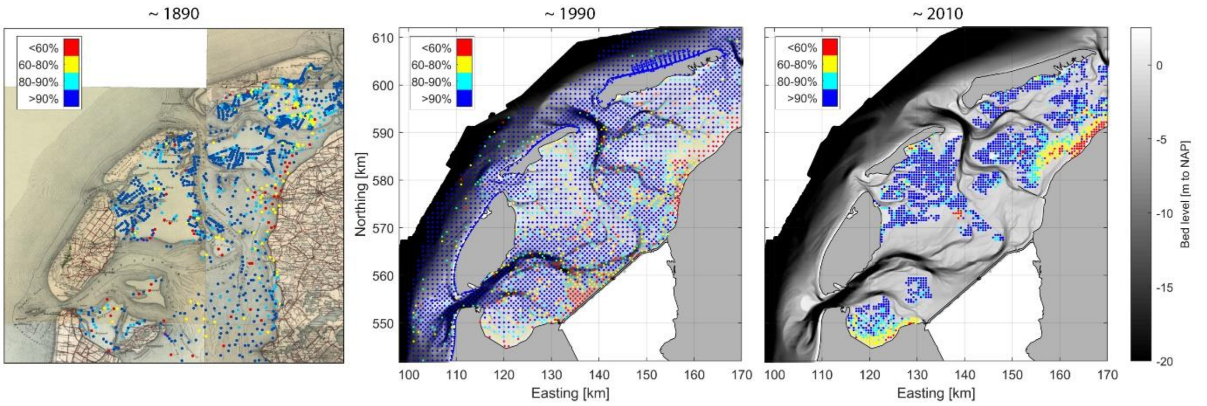

Figure 1: Evolution of the sediment types in the Western Wadden Sea. The colours indicate the sand fraction.

Funded by the Royal Netherlands Academy of Arts and Sciences (KNAW) within the framework of the Programme Strategic Scientific Alliances between China and the Netherlands.

Winds of Opportunity: the influence of wind on tidal flat accretion

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Introduction

The Windows of Opportunity for salt-marshes to develop on a bare mudflat depend on the emergence inundation regime and hydrodynamic conditions. We argue that the mudflat can only accrete to a adequately high level if four conditions are met: (1) sufficient sediment available; (2) a long enough mudflat inundation time; (3) sufficient sediment deposition and (4) consolidation of the bed. We analyse the effect of different hydrodynamic forcing on the four conditions, and we compare the effects of deterministic (tide) vs stochastic (wind) input.

Methods

Three field campaigns were set up on a muddy intertidal flat, in the Wadden Sea, close to Harlingen. Two transects with a reciprocal distance of 5 km were selected and two frames were deployed on each transect. Each frame had 1-2 ADVs, 1 ADCP, 2-3 OBSs and 1 wave logger. Continuous measurements were carried out over at least 30 days at a high frequency (8 Hz), during 2 spring seasons and 1 winter season. This provided a rich data set covering diverse meteorological conditions.

Results

Based on the extensive dataset, we identified the four different conditions necessary for the bed-level accretion. The data suggest that the wind has an eminent role in all four conditions. For example, Figure 1 shows the high correlation between sediment concentration and wind speed (condition 1). We observe that wind has a strong influence on the high water (HW) and low water (LW) levels, determining the conditions of submergence or emergence of the upper flat zone (condition 2 and 4). Eventually, wind-waves reduce the opportunity for deposition (condition 3), with maximum wave heights occurring during HW, when the slack water should give opportunity for sediment settling.

Conclusion

The stochastic component of the hydrodynamic forcing is crucial for the bed level to accrete to a sufficient level to achieve salt marsh development. Furthermore, the temporal succession in which the four conditions are fulfilled is essential for a successful accretion. We conclude, therefore, that the Windows of Opportunity for bed level increase are strongly influenced, in some conditions entirely controlled, by wind.

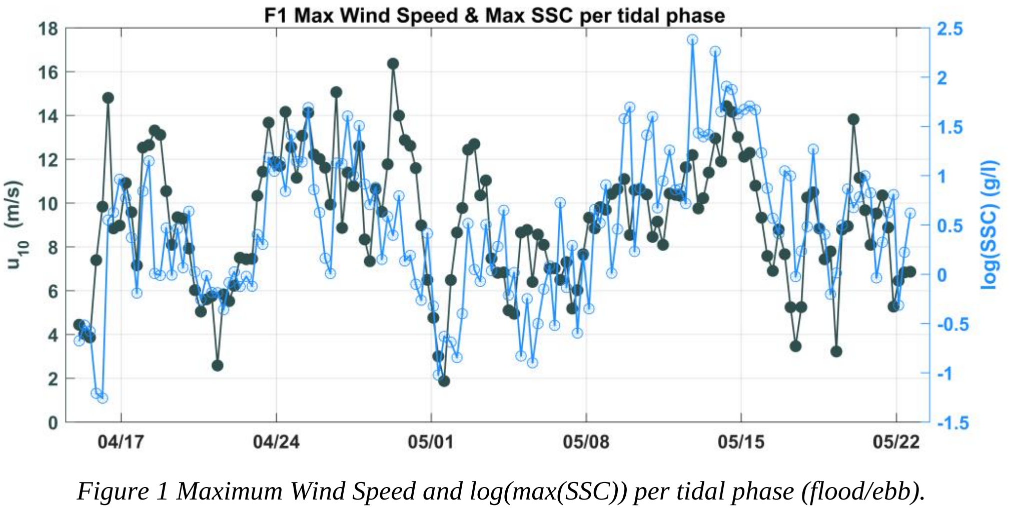

Figure 1 Maximum Wind Speed and log(max(SSC)) per tidal phase (flood/ebb). Location: F1, the frame installed at MLW (i.e. -1m MSL).

QUANTIFYING COASTLINE CHANGE UNCERTAINTY USING A MULTI-MODEL AGGREGATION APPROACH

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Introduction

Morphodynamic process-based models are widely used to estimate coastline position change and support the decision-making process for adaptation/mitigation measures. However, the outputs of these models are characterised by uncertainty originating from, among other sources, forcing variability and parameter imprecision. Currently, this uncertainty is mostly assessed qualitatively, using sensitivity analyses for computationally intensive models, while fully probabilistic analyses have been applied to single, computationally less expensive models. Yet, no approach has been presented in literature for the quantification of the uncertainty in coastline change estimates under the joint effect of different physical processes that are simulated using different models. This gap is addressed in this study.

Methods

A case study in Anmok beach, South Korea is considered, focussing on relevant processes acting upon future coastline positions, and their respective timescales. Delft3D and UNIBEST-CL+ models are respectively used to simulate the impact of a small-scale intervention and large-scale coastline dynamics. Firstly, empirical distributions of coastline change are derived using the selected models associated with the different physical processes. Subsequently, a Monte Carlo convolution approach is applied to aggregate the derived probability distributions. The method is used to quantify the effects of alternative human interventions on the cumulative coastline change probabilities.

Results

This method allows us to obtain information that was previously unavailable: quantified estimates of coastline change uncertainty under the combined effect of different physical processes simulated with the different models. The advantages of the studied aggregation approach include speed, ease of implementation and comprehensibility. The results of the case study (Figure 1) allow us to assess which intervention design preforms best, based on the aggregated distributions of coastline change, reflected against a set of probabilistic indicators. These indicators can be defined to quantify the effectiveness of different intervention designs. Finally, this method constitutes the first step towards risk-based intervention planning and assessment.

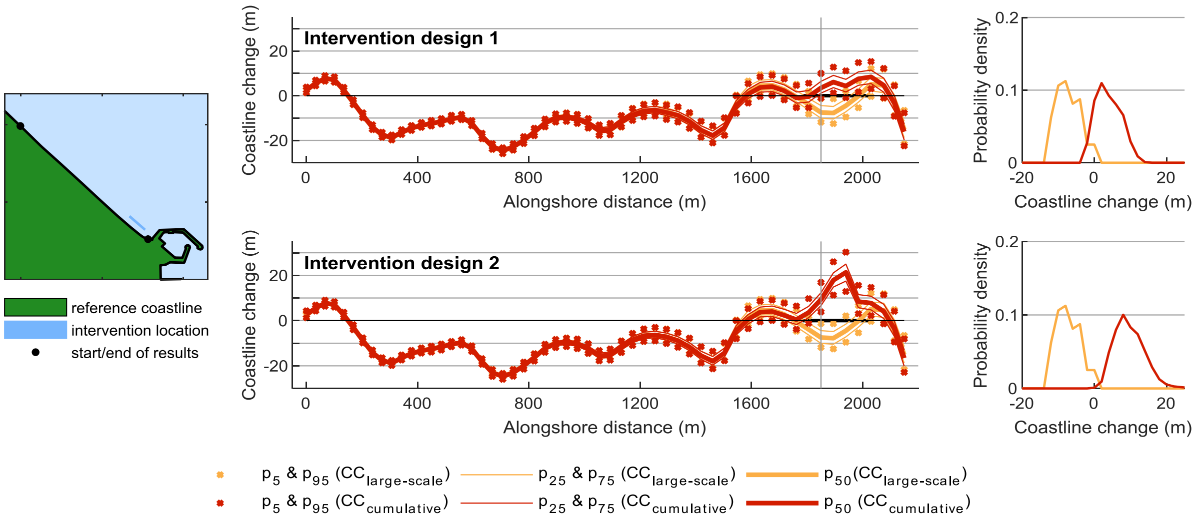

Figure 1.Overview of Anmok beach (left panel), alongshore distribution of coastline change percentile estimates for two alternative intervention designs (centre panels), probability distributions of coastline change for one location (left panels) marked by the grey vertical line on the centre graphs. Red indicates the effect of the large- scale processes, while yellow indicates the combined effect of the large-scale processes and intervention impact.

From mud pool to birds paradise: How did we get from here to there?

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It all started in 1975 with the closure of the Houtribdijk. Once meant to become a polder, the need of fertile land decreased and Lake Marken became an established fact. The muddy soils of the lake, in combination with the shallow depth, were a perfect combination to create a mud pool with low ecological value. At least, that was the general opinion. Research on the real reason of the high turbidity in the lake had yet to start.

Already in the late nineties, people started dreaming of ecological improvement of the Lake system. At that time, the first ideas about creating a large ‘Oermoeras’ came to play. A large wetland that would provide space for many birds and fish and at the same time would help in reducing the turbidity in the lake.

In 2010, an extensive 6-year long research program started. Focus of this research program was on understanding the Lake Marken biotic and abiotic system, finding the cause of the high turbidity in the lake and experiment, in the field, with measures to improve the resilience and sustainability of the ecosystem. One of these measures was creating a ‘mini’ Oermoeras. Now known under the name Ierst (old Dutch for ‘the first’). Ierst can still be seen when travelling along the Houtribdijk.

6 Year is a long time, especially for policy makers. They had no time to wait for scientists to come up with an answer on causes of turbidity and possible solutions. They needed action and measures. The idea of creating Markerwadden fitted perfectly in the wishes and expectations of policy makers. We all know how this ended, Markerwadden is a fact and in the future possibly functions as the long desired large Oermoeras. It does improve the ecosystem and is a haven for birds because of its quietness and the many gradual land-water boundaries it provides in a lake with so many hard boundaries. Whether the Markerwadden also decreases the turbidity in the lake, remains to be seen.

EFFECT OF DREDGING AND DISPOSAL ON MULTI-CHANNEL ESTUARIES

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Introduction

Estuaries are characterized by intertidal bars, i.e. shoals, that are encompassed by ebb and flood channels forming a multi-channel system. Division of the flow at channel junctions into the main and side channels indicates that the estuary consists of asymmetric bifurcations. While disturbances, such as shoal margin collapses (Van Dijk et al., 2019 – *JGR-ES*) only have a near-field effect on erosion and deposition at individual channel scale, disturbances have a far-field effect on elevation jumps and flow division at the channel junctions. Tidal asymmetry is produced by the distortion of the propagating tidal wave. We expect, therefore, that a disturbance will migrate differently through the flood- and ebb-dominated channels. Our aim is to determine how dredging and disposal affect the channel network, the tidal asymmetry, and the bifurcation asymmetry of channel junctions.

Methods

Bathymetry of the Western Scheldt (The Netherlands) since 1955 was analysed to determine tidal and bifurcation asymmetry. A Delft3D schematization of the Western Scheldt was used to isolate the effect of dredging and disposal strategies. A novel channel network extraction tool was applied to quantify the changes in the channel network, the tidal asymmetry, and the bifurcation asymmetry among the main, side and connecting channel scales.

Results

The tidal asymmetry in the Western Scheldt, represented by peak velocity ratio and period of flood-ebb ratio, shows that the duration of the ebb flow increases with increased flow current. Disposal strategy determines the development of the tidal asymmetry. The ebb period becomes longer and stronger in case dredged sediment is disposed in the side channels. Model results show that dredging affects the bifurcation asymmetry. Dredging of the main channel leads to an increased elevation jump between the high-order channel and the bifurcating channel. We expected that the bifurcating channels would close off because the increase in elevation jump. However, both channels remained open because the bifurcation angle increased. Bifurcations become less stable with dredging, which is indicated by a decrease in the number of ebb and flood channels in the channel network. The decrease in channel numbers co-exist with the amalgamation of intertidal shoals (Leuven et al., 2016 – *ESR*). Side and connecting channels become shallower, increasing the elevation difference within the estuary.

Conclusions

We conclude that dredging and disposal affect the stability of bifurcations by increasing the ebb period and decreasing the peak velocity ratio. The stability of bifurcations is important as it is an indicator for future reduction in the number of channels and thus threatens the sustainability of the multi-channel system. This ultimately affects the area of tidal flat and the biodiversity in the Western Scheldt.

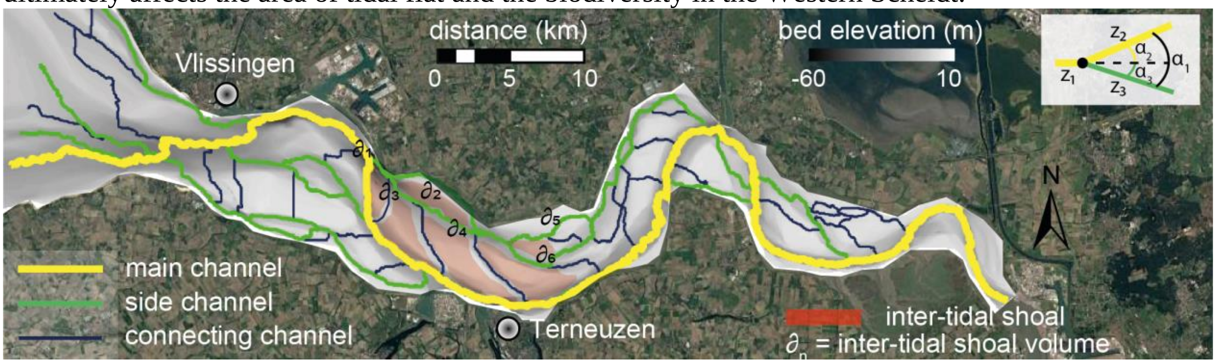

Figure 1 Extracted channel network and intertidal shoal volumes for the Western Scheldt. Right top corner shows how the bifurcation asymmetry is measured, the example indicates a symmetric bifurcation, in which the angle and bed elevation among branch 2 and 3 is equal.

LARGE-SCALE SEDIMENT TRANSPORT EXPERIMENTS IN THE SWASH ZONE

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Introduction

The swash zone is the region near the shoreline that is alternatively covered and exposed by incident waves running up and down the beach face. Swash zone processes determine whether sand is stored on the upper beach or is transported offshore, and thus strongly affect shoreline evolution. Measurements of swash hydrodynamics and sediment concentrations are needed to be able to quantify and understand sediment fluxes near the shoreline. The Shaping The Beach research project aims to develop a new parameterization for sand transport in the swash zone, through a combination of detailed laboratory experiments and advanced numerical modeling.

Research plan

The present PhD project focuses on the hydrodynamics and sand transport processes in the swash zone through a series of laboratory experiments in the large-scale CIEM wave flume. This research aims to improve the understanding of swash zone sand transport processes, in particular the role of cross-shore sand advection. These experiments will shed new detailed insights in bedload and suspended sand transport processes in the swash, and also in net sand transport rates for a wide range of swash conditions. The results from these experiments will be used to develop a new practical parameterisation for swash zone sand transport for application in morphodynamic models.

Methods

The laboratory experiments will be conducted in the large-scale CIEM wave flume at the Universitat Politècnica de Catalunya (Barcelona, Spain). Two types of experiments will be conducted: the "TRANS" experiments focusing on quantifying the net sand transport across the swash zone for a wide range of swash conditions; and the "PROC" experiments focusing on the hydrodynamic and sand transport processes across the inner surf and swash zone. These experiments involve a series of sophisticated instrumentation such as LIDAR and conductivity concentration sensors to measure sheet-flow concentrations and velocities (CCM+, CCPs) (Figure 1).

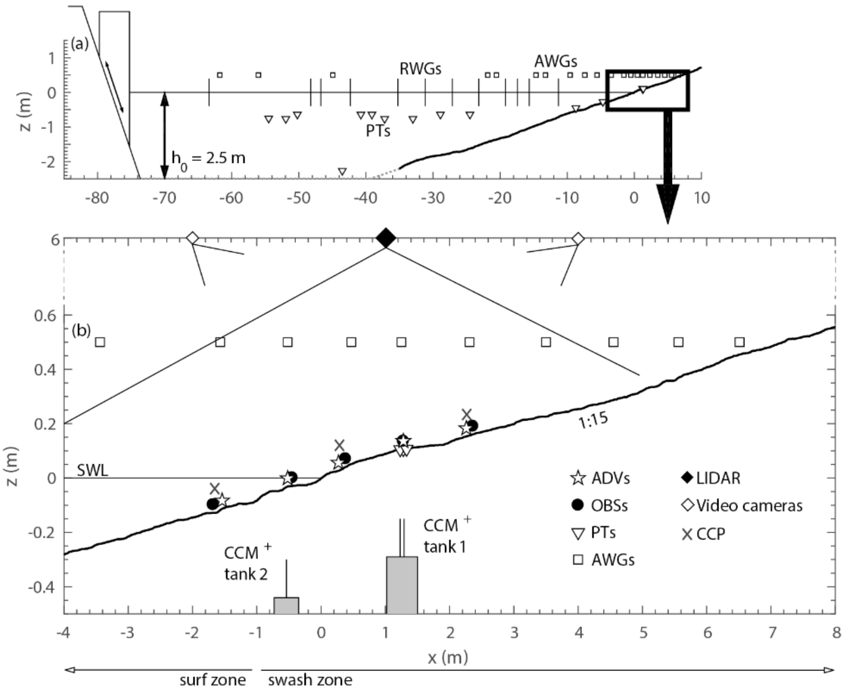

Figure 1 Preliminary experimental set-up in the Barcelona large-scale wave flume.

Acknowledgements

Shaping The Beach (2018-2023) is a NWO-TTW funded research project (no. 16130), with in-kind support by Deltares.

AUTOMATED EXTRACTION AND FUSION OF THE INTERTIDAL AND SUBTIDAL BATHYMETRY FROM THE LANDSAT AND SENTINEL SATELLITE DATA

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Monitoring of the intertidal and subtidal bathymetry at large spatiotemporal scales using traditional surveying methods is a challenging and costly task. Well established methods of remote sensing and increasing frequency of freely available satellite data enable automated monitoring of intertidal and subtidal bathymetry. A number of methods exist to extract intertidal bathymetry by combining the observed water masks with the water level data simulated by intertidal numerical models and local water level measurements. At the same time, the light attenuation in a water column, observed by optical satellite sensors, can be used to estimate water depth, providing a way to estimate subtidal bathymetry. In this research, we will discuss how both these methods can be combined to generate a consistent intertidal and subtidal bathymetry data.

The algorithm based on water occurrence for intertidal waters and optical reflectance for the subtidal region has been applied in Dutch open waters, providing promising insights. The use of tidal variability and empirical optical characteristics enabled to characterise depth in the intertidal and some of the subtidal areas. Furthermore, the method makes use of variability in bottom reflectance detected by the satellite as that is covered by different water columns. A great advantage in the estimation of satellite-derived bathymetries is the high temporal frequency of sampling provided by the satellite sensors, addressing the need for data on short-duration morphological changes.

The results of this research were used to improve the European Marine Observation and Data Network (EMODnet) bathymetry. The research was supported by the European Commission and the Dutch Ministry of Infrastructure and Water Management.

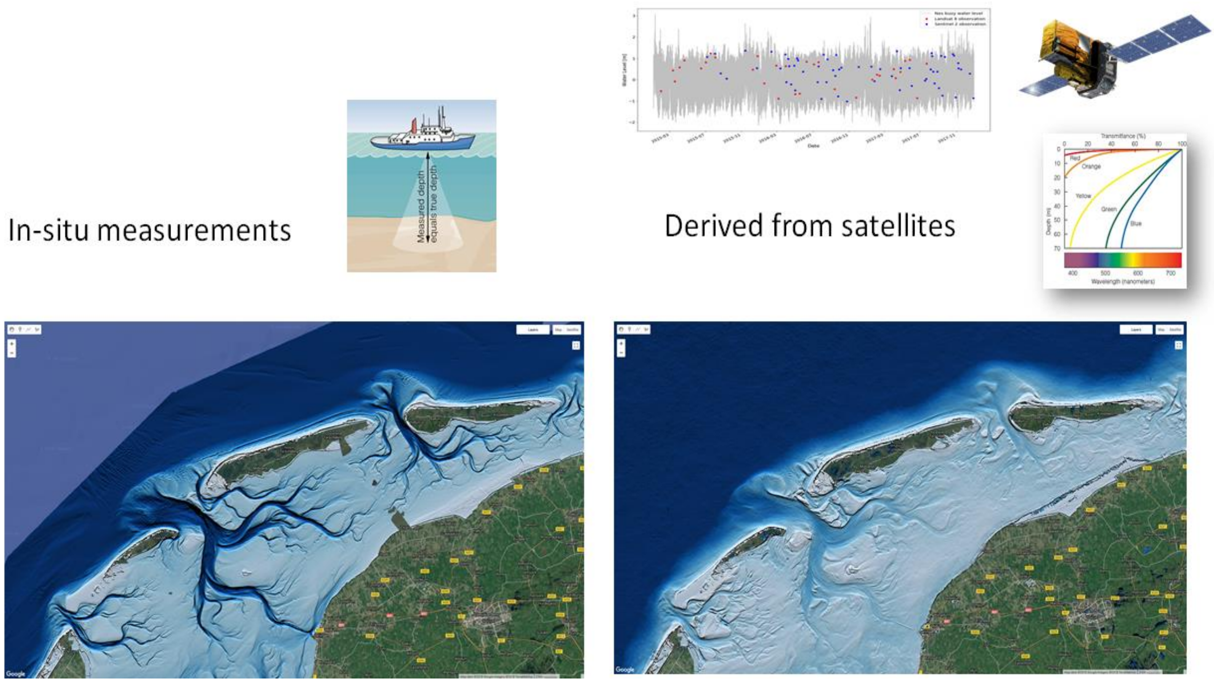

Figure 1 Vaklodingen Bathymetry (de facto in-situ data source for Dutch waters) on the left and Satellite-Derived Bathymetry on the right. Source: https://earthengine.google.com.

Understanding the long-term morphological evolution of estuarine shoals and the potential impact of sea level rise: A small-scale fundamental approach

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Intertidal shoals are a vital component of the estuarine environment. Ensuring their sustainability requires an understanding of how such systems will react to sea level rise (SLR). In this study, we apply the Delft3D process-based numerical model to investigate mechanisms that govern the long-term morphological development of estuarine sandy shoals and their ability to cope with predicted SLR. The developed model describes a 2D, small-scale, high resolution (10×15m), setup which represents a channel-shoal system inspired by conditions in the Western Scheldt Estuary (The Netherlands). A flat shoal bathymetry (Figure 1a) is subjected to semi-diurnal tidal forcing and wave action until it reaches a state of tidally averaged morphodynamic equilibrium (Figure 1b). This equilibrium state represents the current estuarine morphology and shows good agreement with observations. We perform a forecast by imposing different SLR scenarios on the generated bathymetry for a century representing the period from 2000-2100.

Our results show that shoal accretion starts with channel bank deposition which propagates landwards towards the landward margin. Tidal currents drive levee formation while wave action limits the levee height by increased bottom shear stresses. In the modeled equilibrium state and under constant wave conditions, levees don't exist. Fluctuations in wave forcing enhances levee formation which suggests that the presences of such features in estuaries is an indication of an evolving bathymetry. Shoals accrete in response to SLR (Figure 2). However, a phase lag in bed level response results in accretion rates lower than the SLR rate eventually leading to the loss of intertidal area and an increase in shoal inundation frequency. This lag is at its lowest near the channel and increases gradually towards the estuarine margins. Systems with higher tidal energy, sediment supply and wave action cope better with SLR. Simulations assuming a sudden halt of SLR after 2100, showed that bed levels continue to adapt until the profile reaches a new state of equilibrium. The time scale at which stability is achieved ranges between decades to centuries depending on the forcing conditions.

The implemented small-scale approach allowed us to perform several sensitivity runs for different forcing conditions and parameter settings. Contrary to the common situation, developing a stable small-scale fundamental setup for a sandy channel-shoal system presented a challenging task due to the boundary effects. The knowledge developed in this study serves a first step towards realizing the limits and the possibility of modeling such systems on a large scale comprising an entire estuarine system while providing a good representation of intertidal shoals development.

Keywords:
Sea level rise, intertidal, shoals, estuary, long-term, morphological development, small scale, fundamental setup, Delft3D, process-based model, Western Scheldt.

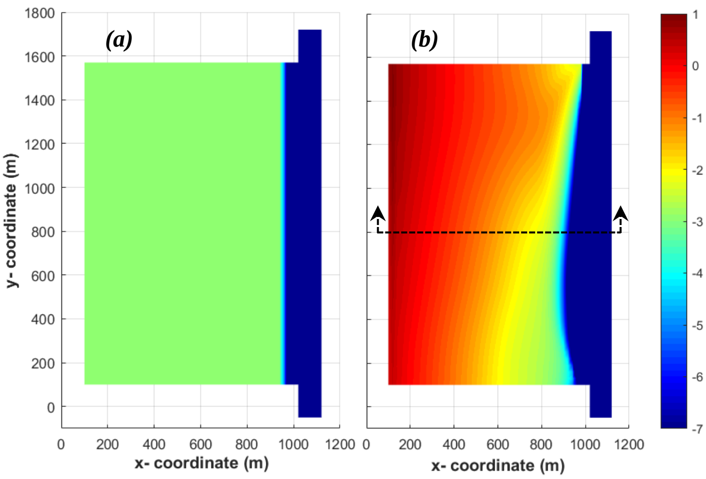

Figure 1. Left panel (a) shows the initial bathymetry and the right pane (b) shows the equilibrium bathymetry for the Western Scheldt forcing conditions.

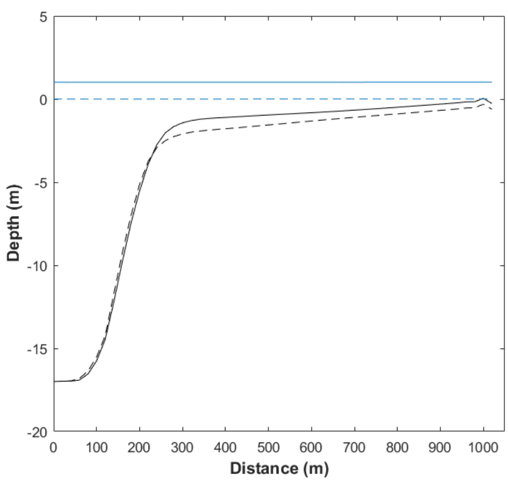

Figure 2. Cross-section showing the bed levels (Black) and mean water level (Blue) for the equilibrium state (Dotted line) and after 100 years of a 1 m SLR (Solid line).

Simulation of surf zone kinematics over a breaker bar using a stabilized RANS model

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Introduction

Accurately predicting cross-shore sediment transport remains a challenging task as it comprises many physical processes, which are often comparable in magnitude, but vary in terms of sign. Numerical wave tanks using Reynolds-Averaged Navier-Stokes (RANS) turbulence models can potentially resolve many of these processes, and may be used as powerful tools to study the detailed sediment transport processes, which are often difficult to measure in the laboratory and field. In past studies using RANS models to simulate waves, there has been a tendency to overestimate turbulence, however. This problem was solved by Larsen and Fuhrman (2018), where significant improvements in predicted turbulence levels and undertow profiles for a simulated model scale experiment were demonstrated. In this work, the new model will be used to simulate a large-scale experiment with a special focus on hydrodynamic processes relevant for cross-shore sediment transport, such as wave boundary layer flow, undertow and turbulence.

Methods and Results

A recent experimental campaign conducted in a 100 m long wave flume involving bichromatic waves breaking over a fixed bar (van der Zanden et al., 2019) will be simulated using the OpenFOAM solver waves2FOAM (Jacobsen et al. 2012), combined with the model by Larsen and Fuhrman (2018).

Figure 1 shows a comparison between the experimental and modelled undertow. The model importantly captures the transition in the vertical undertow structure going through the outer surf zone (54 m< x < 60 m), where the undertow goes from having largest negative velocities far from the bed to having largest negative velocities near the bed. This could not be achieved using a standard RANS model. The model results will be compared in detail with experimental results for water surface elevations, velocities and turbulence, and implications for cross-shore sediment transport will be discussed (to be presented).

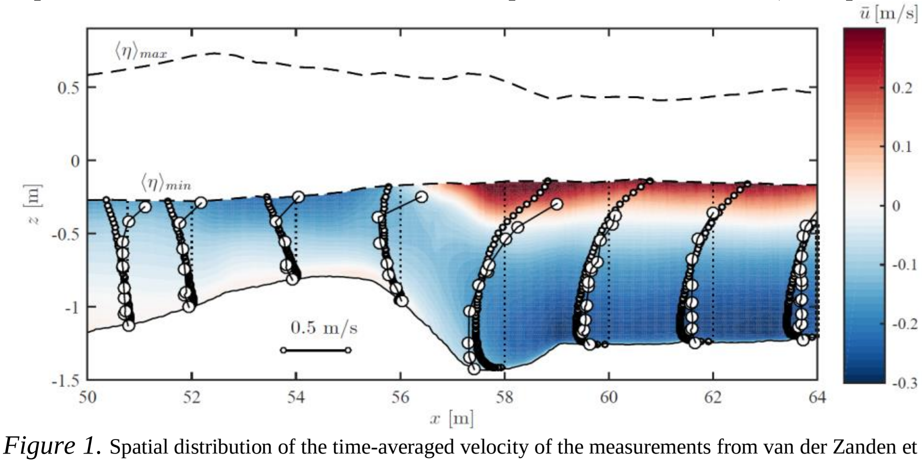

Figure 1. Spatial distribution of the time-averaged velocity of the measurements from van der Zanden et al. (2019) (large circles) and from the model (small circles and colored velocities)

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TIDAL PROPAGATION AND SALT INTRUSION IN THE MULTI-CHANNEL ESTUARINE SYSTEM OF THE MEKONG DELTA, VIETNAM

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Introduction

The low-lying and rapidly urbanizing Mekong Delta is experiencing land subsidence rates in the order of 1-4cm/yr, in response to excessive ground water extraction, that are exceeding sea level rise. Furthermore, sand mining is changing channel geometries; hence, tidal propagation is changing in the estuarine channel system. By accelerated dam construction further upstream in upper and lower Mekong basins, sediment supply has declined, resulting in coastal, channel and bank erosion. All above mechanisms contribute to increased salt intrusion, which is portrayed in the land-use change (e.g. agriculture to aquaculture) and record numbers of salt intrusion events.

Methods

we analyse a noble dataset of 20-year record of water level (*e.g.* see *Figure*), discharge and stationary salinity measurements and extract trends of tidal deformation and saline water intrusion. Furthermore, by application of an extensively calibrated 1D-2D coupled Mekong-wide barotropic model (in D-Flow Flexible Mesh), we explain the observed trends and link those trends to shifts in the upstream regime. The observed salinity trends could be physically explained and related to water level and discharge observations, by application of commonly-used salinity models.

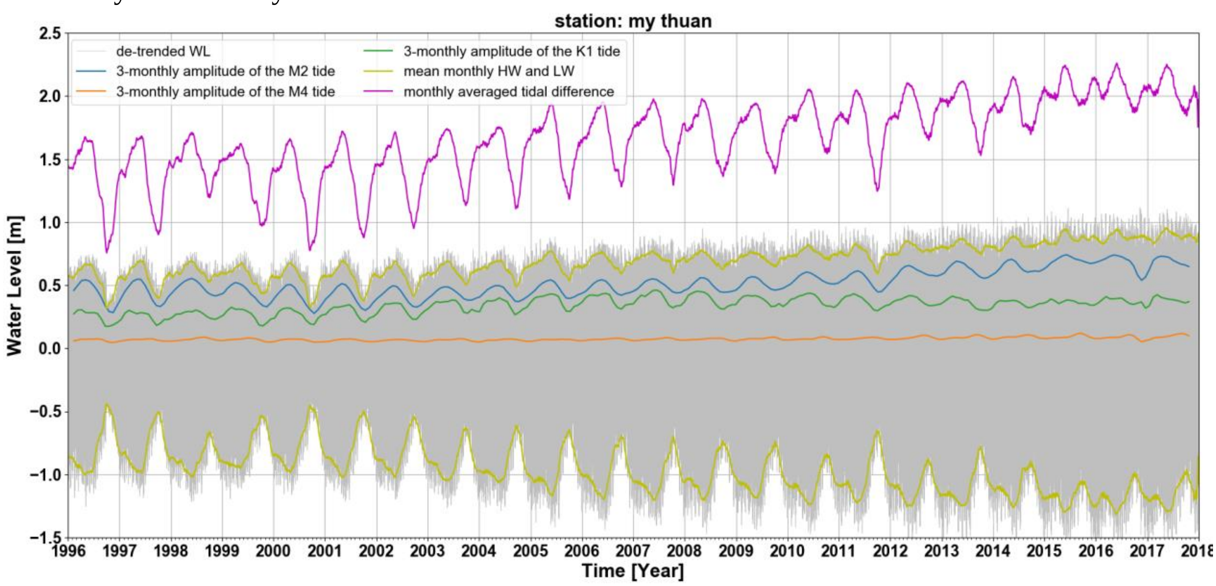

Figure 1. The observed historical variation of de-trended, tidal water level, M2, M4 & K1 variations, and tidal difference at a measurement station in the Mekong Delta

Results

Our analysis shows an increase in salt intrusion and tidal amplitudes along several branches. The in-depth analysis of the model results and studying the short-term processes revealed a crucial role for subtidal water level in temporal variation of freshwater in the multi-channel estuarine system. In studying the long-term processes, the model was used to provide additional argumentation that the changes in tidal characteristics are related to morphological changes in response to anthropogenic processes. The observed trends and the modelled physical reveal that anthropogenic activities out-pace global climate change effects on the region. The fate of this mega delta solely depends on bold, integrated, inter-disciplinary and trans-boundary governance and management measures that require immediate actions.

MODELLING THE EFFECTS OF STORM SURGES ON SAND FLATS: CASE STUDY IN TEXEL (NL)

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Introduction

Marine supply of sand can control the development and morphology of coastal dunes. However, processes that control the sediment transfer between sub-tidal and the supra-tidal zone are not fully understood, especially in coastal settings such as sand flats close to inlets. Wijnberg et. al. (2017) hypothesize that storm surge events may induce sediment deposition on sand flats, so that this may influence dune development. The objective of this study is to identify storm surge conditions on which deposition on sand flats occur and discuss the relation between the supra-tidal deposition and sediment supply to the dunes. To reach the goal, we use the sand flat called “De Hors”, in the island of Texel (NL), as a case study.

Methods

We use the numerical model XBeach to simulate 12 frequent storm conditions that reach the Texel inlet. For all scenarios, we used default values, followed by a validation check. From the simulations, we relate bed level change on the flat with local hydrodynamic characteristics (i.e. *Hrms*, *u* and *v* convergence, max water level) and general storm conditions, in order to check which processes would explain most of the bed level change and whether there is a relation between storm characteristics and storm-induced supra-tidal deposition.

Results and Discussion

Supra-tidal sand deposition occurred in 10 out of 12 scenarios, disposed most of the times in a clear shore-parallel north-south patch above mean spring high tide level (Figure 1). The deposited amount is correlated with storm energy, with stronger storms leading to more sedimentation onto the sand flat. Most deposition occurred at the beginning of the inundation phase, with most of the sediment being transported from regions below MSHTL and deposited above such elevation. This suggests that storm surges may act as a mechanism of sediment transfer between sub-tidal and sub-aerial zones on sand flats. Furthermore, prediction of the yearly amount of deposited sand based on water level data suggest that over time, the amount of sand deposited may be significant in terms of supply for dune growth, which is in agreement with Wijnberg et. al. (2017).

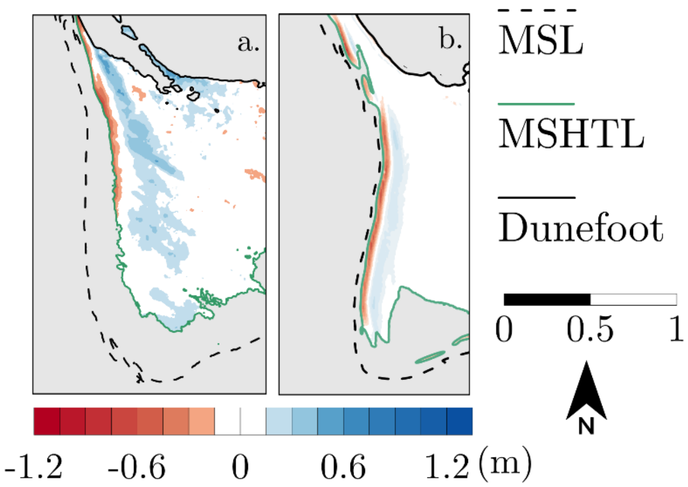

Figure 1: a. Elevation difference map from LiDAR data between 1998-1999. b. Example of elevation difference map from one simulation scenario.

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RECENT DEVELOPMENTS IN NUMERICAL MODELLIMG OF COASTLINE EVOLUTION: ADVANCED DEVELOPMENT AND EVALUATION OF SHORELINES COASTLINE MODEL

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Coasts were naturally created in balance without any issues, however, coastal erosion became one of the critical problems that many coastal regions suffer, mainly because of human intervention. Specialists started developing different coastline models in order to simulate coastline change, and the first one-line model was developed by Pelnard-Considère in 1956 (Dean, 2003). ShorelineS is a new shoreline simulation model introduced by (D. Roelvink, 2017) to overcome the severe limitations of existing coastline models. The model includes many unique features; the model describes coastlines as strings of grid points that can move around, expand and shrink freely without a refiner. It can have multiple sections such as islands and lagoons, where spits and other features can be developed; they may break up or merge as the simulation continues.(Roelvink et al., 2018).

Recently, the model has been developed to give more accurate coastline behavior near structures and to match the analytical solutions. Sand bypassing around structures has been introduced; it may take place when the up-drift side of the structure is filled with sand or just after the construction of the structure.

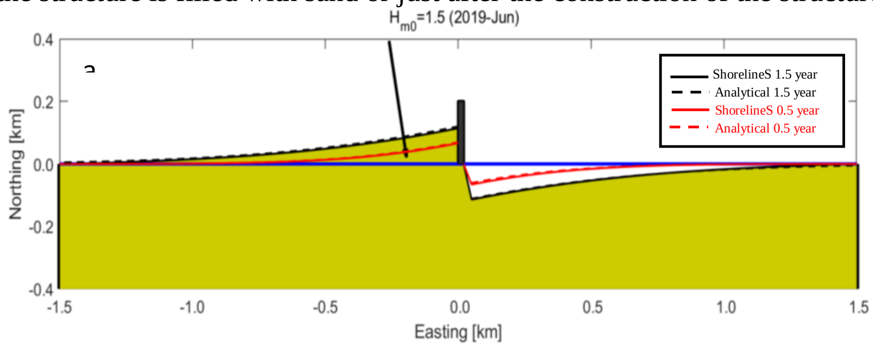

Figure 1. ShorelineS result compared to Pelnard-Considère analytical solution near a single groin.

Simulating dune foot evolution for beaches, where dunes are located either in long-term periods or after storms is a new feature being introduced to the model in the meanwhile. Dune foot may move seaward due to the Aeolian transport or landward due to wave attacks.

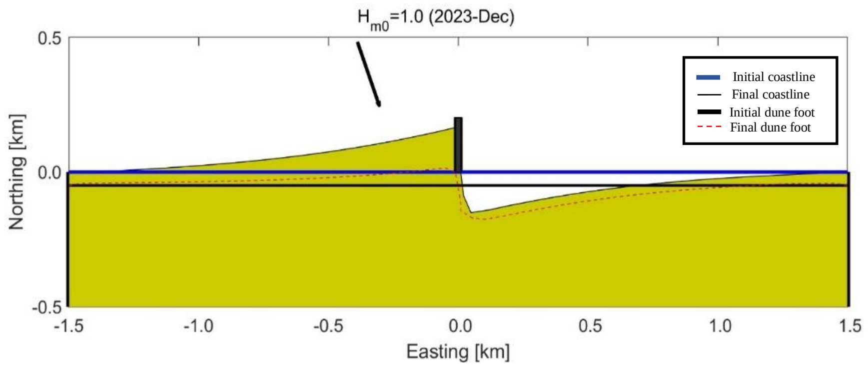

Figure 2. Initial and final coastline and dune foot location after 5 years.

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MORPHODYNAMIC EFFECTS OF BAMBOO AND BRUSHWOOD STRUCTURES FOR MANGROVE HABITAT RESTORATION

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Introduction

Mangrove vegetation attenuates waves and currents, reduces erosion and enhances sediment deposition (Horstman et al., 2017). It may consequently be a natural tool to combat land subsidence and relative sea level rise, provided that there is enough sediment supply in the system (Horstman et al., 2015).

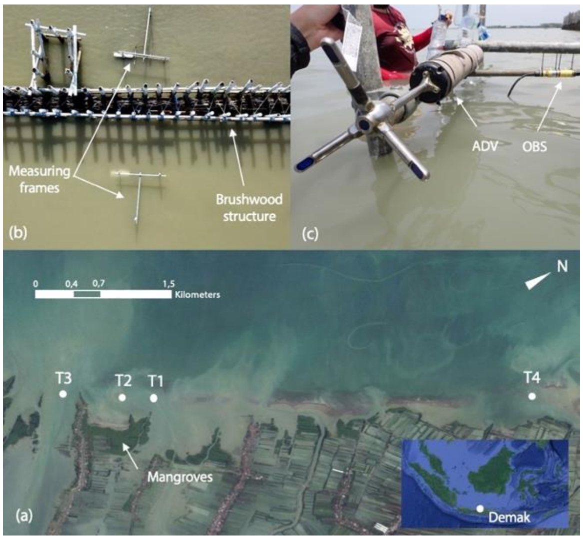
In the area of Demak, Indonesia, mangrove removal to build aquaculture ponds has resulted in high erosion rates and flooding at the coast. Different types of brushwood and bamboo structures have been built in Demak by the Ecoshape consortium, in order recover the mangrove habitat and enhance natural colonization. The structures reduce wave energy at their lee, providing a calm environment where sediment can settle and mangrove seedlings can establish. However, the current designs were based on engineering judgment, and have provided variable success rates.

Optimizing restoration efforts requires a deeper knowledge of the mangrove habitat, and of which structure designs could reproduce the required physical environment. The present work aims to improve the understanding of the second point; how bamboo and brushwood structures affect the morphodynamic processes, considering different structure configurations and varying hydrodynamic conditions.

Methods

Field measurements were conducted in Demak between November and December of 2018. Measuring frames were placed in front and behind permeable structures, at four different locations (Figure 1).

Each frame contained an Acoustic Doppler Velocimeter (ADV), and an Optical Backscatter sensor (OBS), which monitored the effect of the structures on the morphodynamics. The bathymetries and sediment properties were also regularly measured at each transect.



Results

The collected hydrodynamic data will provide information on the rate of wave energy dissipation and reflection produced by different structure configurations.

Parameterizations of the hydrodynamic processes will be derived, in order to implement the structures in larger scale models.

The measurements will also be used for model validation, in order to assess the structure performance over longer timescales. These findings will help develop design tools which can be applied in future restoration efforts.

Figure 1. (a) Location of the monitored transects in Demak. (b) Close-up of transect T4, where instruments were attached at two steel frames. (c) Picture of a Nortek ADV and Campbell OBS in one of the frames.

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PAN-EUROPEAN COASTLINE-MIGRATION MAP BASED ON SATELLITE DATA 2007-2016

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Introduction

Traditionally, coastline-migration maps have been made using field-monitoring data, supplemented locally by analyses of aerial photography. The EMODnet Geology coastline-migration map is a good example. It provides an overview of our current knowledge and is useful in transnational coastal-zone management. At the same time, it is far from perfect. First, it combines monitoring series from different time periods and at varying spatial scales, necessitated by an overall scarcity of data. Second, it includes data gaps as many remote regions have never been surveyed. Third, the coastline is not a single line that is easily and consistently recognized and used. Along sandy coasts, one can map the low-tide line, the high-tide line and the dune foot, and each of these indicators may behave differently through time. Along bluff and cliff coasts, one can map the bluff/cliff top and base, or the actual low- or high-water line some distance away. When part of a bluff or cliff collapses and thus recedes landward, its rubble accumulates at the base, moving the water line seaward.

Approach

The public availability of satellite data and new analytical tools for processing big data, such as the Google Earth Engine, enable us to look at coastline migration in a new way. Scripts for automated detection of the land-water boundary generate numerous data points for each part of the European coastline. When averaged by year and analyzed for a decadal period, these data points form the basis for a new pan-European coastline-migration map that covers a consistent time period relevant for present-day coastal-zone management, eliminates data gaps, and portrays a single coastline indicator that is assumed to correspond to the mid-tide land-water boundary.

Result and outlook

As part of EMODnet Geology, tens of thousands of transects with a spacing of 500 meters were analyzed, giving a map resolution of 1:1,000,000 at maximum zoom level, and generalized for online viewing at larger scales up to a pan-European view (Figure 1). As the pixel resolution of individual satellite images is about 10 meters, the precision of the method is still limited. Calculating annual averages from multiple measurements made within a single year reduces this uncertainty, and validation for sandy coastlines with beaches shows the method's accuracy. For bluff, cliff and muddy coasts, such validation and further analysis still need to take place. Now published as an EMODnet web service on the EMODNET Geology Portal (https://www.emodnet-geology.eu/map-viewer/), we are keen to invite all users to evaluate our satellite-based output with corresponding field-monitoring data.

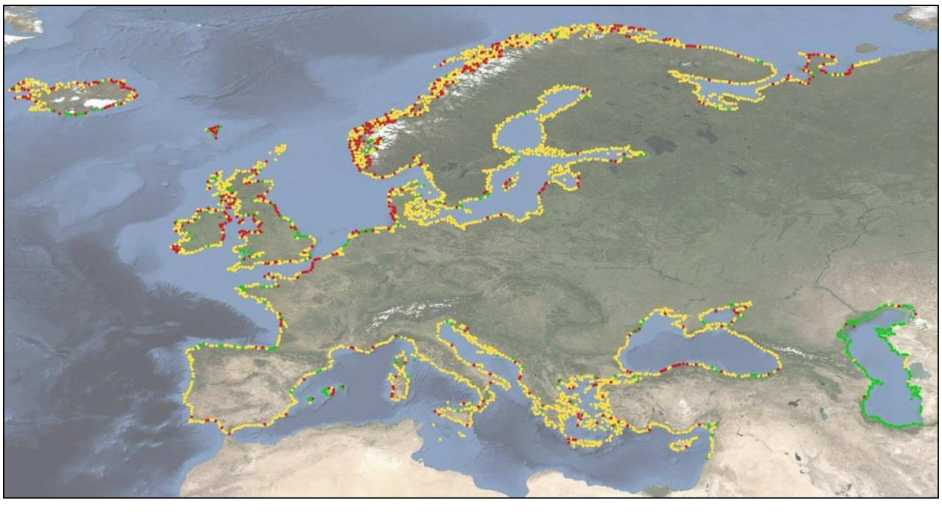

Figure 1 Zoomed-out view of the EMODnet data product at a pan-European scale. Accretion is denoted in green, stability in yellow, and erosion in red.

HIDDEN BIO-GEOMORPHOLOGICAL TRANSITIONS ON INTERTIDAL FLATS

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Intertidal flats provide essential services, like habitats for a range of species and forming a part of the coastal defence system. They are however vulnerable for climate change and human interferences. Large scale changes in hydrodynamic and sediment conditions influence the intertidal flats. In reverse, small scale bio-geomorphology determines the large scale habitat structure and functioning (Weerman, 2011), leading to complex feedback mechanisms between morphology, hydrodynamics and ecology. It is a major challenge to unravel the interconnected dynamics of estuaries in order to quantify the consequences of human interventions and climate change in estuaries.

Different morphological features like channels, gullies and pools in a variety of shapes and patterns can be found on tidal flats (Figure 1). Their influence on the hydrodynamic conditions, sediment fluxes and water storage is highlighted by Whitehouse et al. (2000), but the mechanisms controlling the origin and fate of the features are not well known. Different studies found relations between factors determining the profiles of mudflats. In a classification analysis, Dyer et al. (2000) described these correlations in 13 estuaries in North West Europe based on 20 environmental parameters.

In this PhD research we aim at deriving insight in tipping points and feedback loops governing the morphological features. Relations between development of morphological features and the mudflat or estuary will be used as a generic predictive tool for estuarine development. We will study multiple sites in various estuaries (Western Scheldt, Eastern Scheldt, Humber, Yangtze, Waddensea and Ems-Dollard) having different environmental conditions. Spatial and temporal variations of morphological features are analysed based on historical data (e.g. satellite imagery, hydrodynamic conditions, sedimentology and estuary shape). New data will be gathered from field measurements. This will require advanced technology to measure flow conditions in the gullies with water depths smaller than 0.2 m. We are developing a method using adjusted laboratory instruments in the field.

These insights in the generation and development of these morphological features will be essential to predict the fate/future of intertidal flats for future climate change scenarios and to evaluate management strategies.

Figure 1: Humber estuary – Pattern of channels on the intertidal flat

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MUDFLAT-CREEK SEDIMENT EXCHANGE IN INTERTIDAL ENVIRONMENTS

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Intertidal environments, including bare mudflats, tidal creeks, and vegetated salt marshes, are of significant physical and ecological importance in estuaries. Understanding water motion and sediment transport in mudflats and tidal creeks is fundamental to understand intertidal morphodynamics in intertidal environments. To explore dynamic interactions between tidal creeks and mudflats, we conducted field campaigns monitoring water depths, tidal currents, waves, suspended sediments, and bed-level changes at sites in both mudflats and tidal creeks in the Yangtze Delta for a full spring-neap tidal cycle. We saw that under fair weather conditions, the bed-level changes of the tidal creek site displayed a contrary trend compared with those of the mudflat site, indicating the source-sink relationship between tidal creek and mudflat. During over-marsh tides, the tidal creek site with relatively high bed shear stresses was eroded by 35mm whereas the mudflat site was accreted by 29mm under low bed shear stresses. To the contrast, during creek restricted tides, deposition occurred in the tidal creek site by 20mm under low bed shear stresses whereas erosion occurred in the mudflat site by 25mm under relatively high bed shear stresses. Over a spring-neap tidal cycle, the net bed level changes were -15mm (erosion) and 4mm (deposition) in tidal creeks and mudflats, respectively. These results suggested that there were alternated erosion-deposition patterns in spring and neap tides, and a sediment source and sink shift between mudflats and creeks. We found that the eroded sediments in mudflats were transported landward into tidal creeks and deposited therein in neap tides, and these newly deposited sediments would be resuspended and transported to surrounding marshes (over-marsh deposition) at spring tides. The coherent sediment transport and associated erosion-deposition pattern within the mudflat-creek system at spring-neap tidal time scales thus played a fundamental role in intertidal morphodynamic development. These findings suggest that management and restoration of intertidal ecosystem need to take the entire mudflat-creek-marsh system as a unit into consideration rather than focusing on single elements.

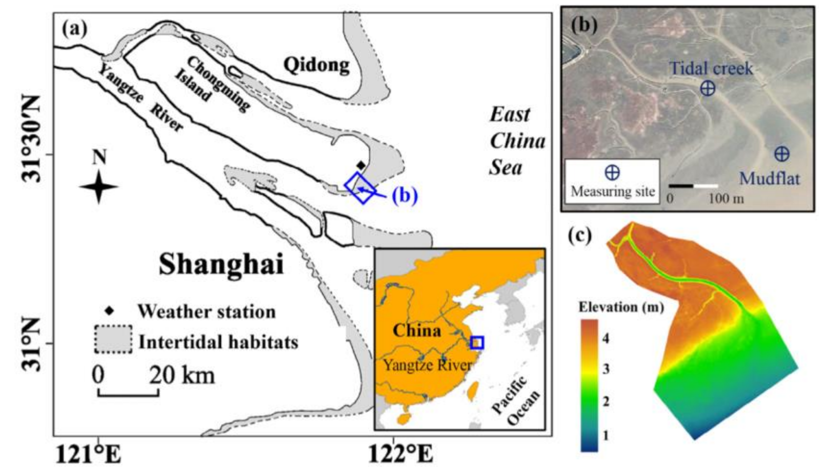

Fig. 1. Map of the Yangtze Estuary, location of Eastern Chongming weather station (a) and a view of the study site and locations of the two measuring sites (b), and Digital elevation model of the study area derived from Terrestrial Laser Scanning data collected in August 2016 (c).

A NEW GEOLOGICAL OVERVIEW MAP OF THE KINGDOM OF THE NETHERLANDS

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Geological mapping

Systematic government-commissioned mapping of the Dutch subsurface dates back to 1918, when the Geological Survey of the Netherlands was founded by Cornelis Lely. Each geological survey in the world has a similar task: offering insight into the distribution of geological resources and the presence of geological risks. After one hundred years, our national mapping program is alive and kicking, although we now focus on 3D subsurface modeling rather than on 2D mapping. Our models provide new geological explanations and predictions for an ever-increasing application portfolio. Nevertheless, a traditional map (Figure 1) still has value. It tells an exciting and compelling story of change spanning millions of years, showing how sea, rivers, wind, ice sheets, vegetation and man have shaped our part of northwestern Europe.

An illustrated story of the North Sea subsurface

Soft young layers in the North Sea cover much firmer formations – highly suitable for pile foundation in construction – dating back to the ice ages. Because of glacial overburdening, some of these Pleistocene units are so dense that pile design requires extra care. A landward-shifting coastline driven by Holocene sea-level rise explains why we find coarse river sediment close to the seabed offshore Rotterdam, a potential source of sand and gravel for concrete and masonry. A vast network of drowned tidal channels in the north contributes to lateral subsurface heterogeneity. Closure of former inlets dissecting an originally open coast has left clayey channel fills that should be avoided where wind farms are planned, especially close to the present coastline. Buried soils and peat layers mark drowned Stone Age landscapes that represent and are home to valuable cultural heritage. And finally, 'unlimited' offshore sand resources for shoreface and beach nourishment are in fact regionally finite when composition and non-extractible covers are taken into account. Managing and fixing our delta and its coastline, needed for socio-economic reasons, is a work of the ages that requires all geological knowledge available.

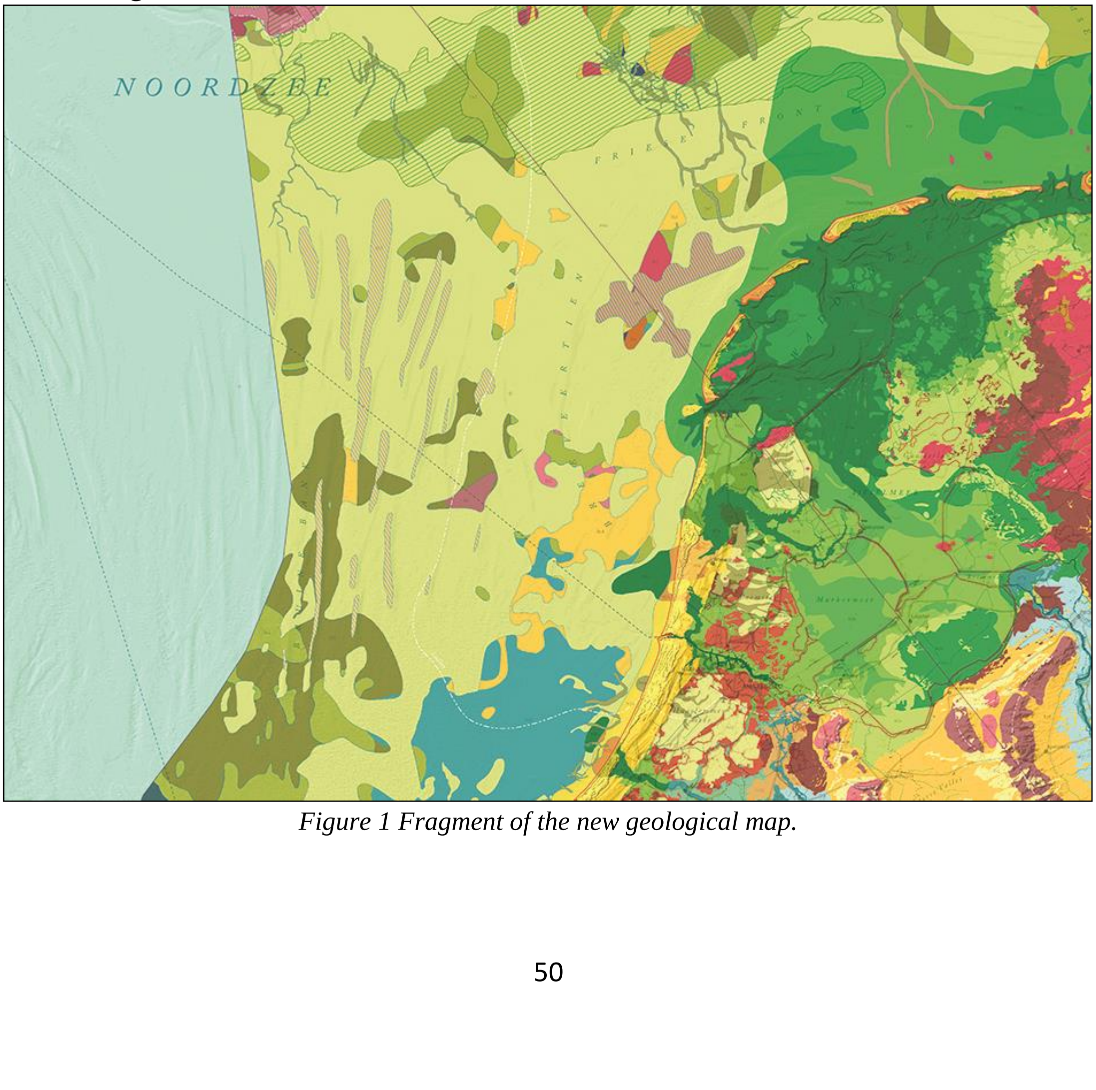

Figure 1 Fragment of the new geological map.

Tidal Currents in a Mangrove Creek System Quantified

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Introduction

Aboveground root structures are ubiquitous in mangrove forests and provide substantial drag to currents and waves propagating through these systems. Creeks can improve the hydraulic conductivity of mangrove systems, providing low-resistance conduits for the tidal prism to propagate into and out of the intertidal area. Consequently, the presence of creeks in mangroves may reduce the total attenuating capacity of the system, while improving the transport of suspended and dissolved matter. In this work we address the effect of mangrove vegetation on the tidal hydrodynamics in an ephemeral creek catchment with no terrestrial fresh water input, located in the Whitianga estuary in New Zealand.

Methods

A series of acoustic instruments was deployed throughout the creek channel and within the mangrove forest, monitoring spatial changes in the velocity profiles over a 10-day period covering spring and neap tides. Suspended sediment concentrations were monitored synoptically at part of these stations. Spatial data on the elevation, vegetation and sediment properties of the site were collected simultaneously in order to provide quantitative insight into the drivers of the observed tidal dynamics.

Results

As in previous field studies, we observed an asymmetry of the tidal currents in the mangrove creek, with up to 3x greater ebb-tidal current speeds due to a delayed discharge from the vegetated flats surrounding the creek. The tidal amplitude was also attenuated up the creek, with a significantly slower inland propagation of the low tide than the high tide.

Within-creek drag coefficients, estimated by balancing pressure gradients and (vegetation-induced) friction, were large ($O(10^{-2})$) and increased notably upon inundation of the vegetated flats as well as with distance up the creek. Agreement in the fitted parameters deteriorated for bank full stages of the creek at the mudflat in front of the mangroves, but improved for water levels exceeding the creek banks inside the mangroves.

Maximum ebb velocities in the creek were found to correlate directly with the tidal prism, whereas the maximum flood velocities correlated with the tidal prism scaled to the relative width of the channel. Maximum ebb and flood velocities were also in reasonable agreement to those predicted using a simplified momentum balance for long, shallow, non-convergent estuaries with abundant intertidal fringes. Combined, such simple approximations could reduce the need for field data when quantifying tidal transport rates, and spatial changes therein, through similar mangrove systems.

Figure 1 Low tide at the creek entrance of the mangrove-lined creek system studied in this work.

A NEW ESTIMATE FOR THE ALONGSHORE SPM TRANSPORT ALONG THE DUTCH COAST

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Introduction

SPM passing the Southern Bight mainly originates further ‘downstream’ of Dover Strait and by cliff erosion in that area. Along the continental coast of the Southern Bight, the alongshore transport of SPM is estimated to be 22 Mton/yr on average, but can fluctuate by a factor of two. We will focus on a part of the route of SPM through the southern North Sea where concentrations were found to be high: in the turbidity maximum zone (TMZ), which stretches between 0.5 and 3 km from the coastline.

Methods

A dataset from a lander frame located in the middle of the TMZ forms the basis of this work. It was situated 1.2 km off the coast near Egmond, for the project ‘Monitoring and Evaluation Program Sand mining’ commissioned by the *La Mer Foundation*. The research has been done in the framework of the *BwN NTW3.2* project. Attached to the frame were four SPM concentration sensors, one near-bed point velocity sensor, a CTD and an upward looking ADCP. The SPM concentration at the top of the frame is used as a continuous calibration to convert the acoustic backscatter of the ADCP to SPM concentrations. Thereby the transport of SPM is estimated for the whole water column. The length of the timeseries is March – October 2011 and January – July 2012.

Results

It appears that the residual transport per tide is strongly correlated with the wind speed and the wind direction (Figure 1A), in such a way that the northward-southward division lies perpendicular to the axis of the Southern Bight rather than to the local coastline orientation (Figure 1 – right). Southwesterly winds result in higher northward transport (red colours), than the northerly winds generate southward transport (blue colours). The data in Figure 1A does not encompass a full year. We developed a statistical model based on wind direction sectors and wind speed, to calculate the yearly transport for the 10-year wind record 2004-2013. The average SPM transport in the 2.5 km wide TMZ is then 2.75 Mton/yr, with 2010 and 2011 as extremes: 1.75 and 3.25 Mton/yr, respectively.

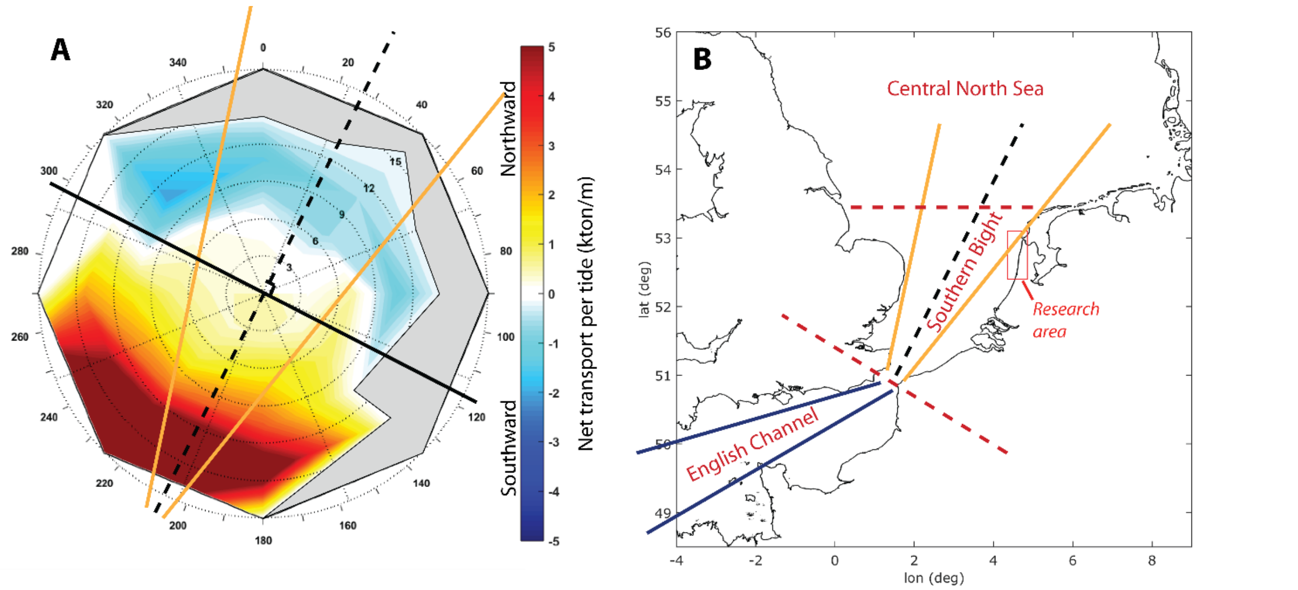

Figure 1. A. Median per wind sector of the net transport per tide (radial distance is wind speed).There is no data for the grey part. On top of the graph the orientation lines from the Southern Bight are sketched. B: Map and sketch of the English Channel – Southern Bight - Central North Sea orientation, along with the research area.

IMPACT OF NOURISHMENTS AND FOREDUNE MANAGEMENT ON DYNAMICS IN THE FOREDUNE

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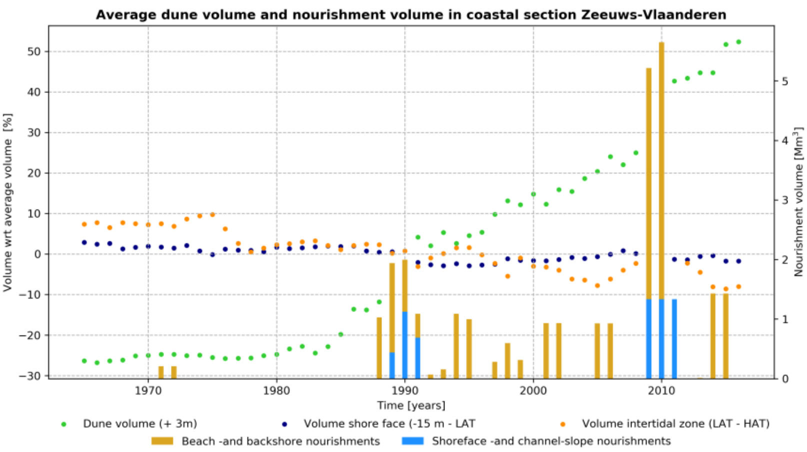
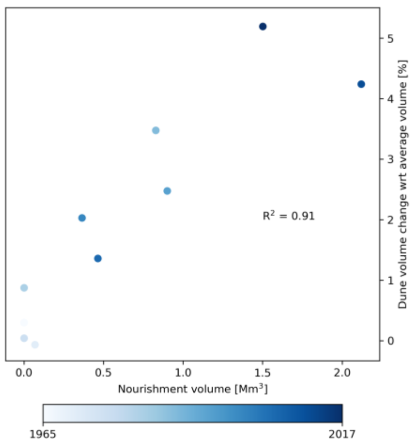
Dune management has traditionally stabilized foredunes to protect the hinterland against flooding. As a result of these static ‘sand dikes’, however, the biodiversity of the dune landscape was limited. Dynamic dune management allows and stimulates ‘dynamic foredunes’, where sand transport towards the backdunes is restored leading to a more diverse dune landscape and long-term coastal safety, because dunes can grow with a rising sea level. Both coastline management (nourishment) and foredune management potentially influence foredune dynamics, but the underlying relations are not fully understood. Here, we evaluate the role of nourishments and foredune management on dune volume and foredune dynamics. This research is part of the ongoing programme Natuurlijk Veilig, initiated by Rijkswaterstaat (www.natuurlijkveilig.nl).

We calculated sand budgets of the foreshore, the intertidal zone (including the beach) and the dune area along the entire Dutch coastline using coast-normal transects (Jarkusraaien) based on EO data from 1965 to 2017. Next, we categorized foredune dynamics based on the five ‘response types’ (RT) from stable (1) to dynamic (5) (Arens et al. 2010) using surface elevation (differences) maps and aerial imagery for the periods 1988-2008, 2008-2013 and 2013-2017. Foredune management data (Löffler and Veer, 1999; Löffler and Van der Togt 2018) and nourishment data (Rijkswaterstaat) are projected on the coast-normal transects. The relationship between nourishment and dune management on one hand, and foredune volume and dynamics on the other are analysed for 17 coastal sections (‘kustvakken’).

Our results show an average increase of dune volume between 1965-2017 of 8.2 (σ =9.4) m^3/m/year. During the same period an average nourishment volume of 31.7 m^3/m/year is supplied. Over time, a slight increase of the RT is observed, due to an increase of dynamics at the front and at the top of the foredune. The percentage of dynamic managed foredunes are increased from 11% in 1990 to 51% in 2017. According to our analysis, nourishment and foredune volume are correlated (R_{av}^2=0.61). In addition, we found a clear correlation between foredune management and the corresponding RT. Insight in the effects of nourishments and foredune management are crucial to come up with effective integral coastal management approaches, which allow coastal safety and ecological development to go hand-in-hand.





Dike and Foreshore Joint Stakeholder Action – A Waddencoast case study

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Introduction

By including foreshores in flood risk reduction strategies, actual safety levels are better understood, while safety issues and dike construction costs may be reduced. Moreover, dike authorities are legally bound to consider foreshores and enter into agreements with neighbouring stakeholders. Nevertheless, dike-foreshore coalitions do not occur naturally. Diverging stakeholder interests and responsibilities, and historical factors often lead to fragmentation in dike-foreshore management inhibiting joint action. Along the Friesland Waddensea coastline, POV-Waddenzeedijken[1] (POV-W) initiated a research project aimed at improving dike-foreshore cooperation using innovative approaches.

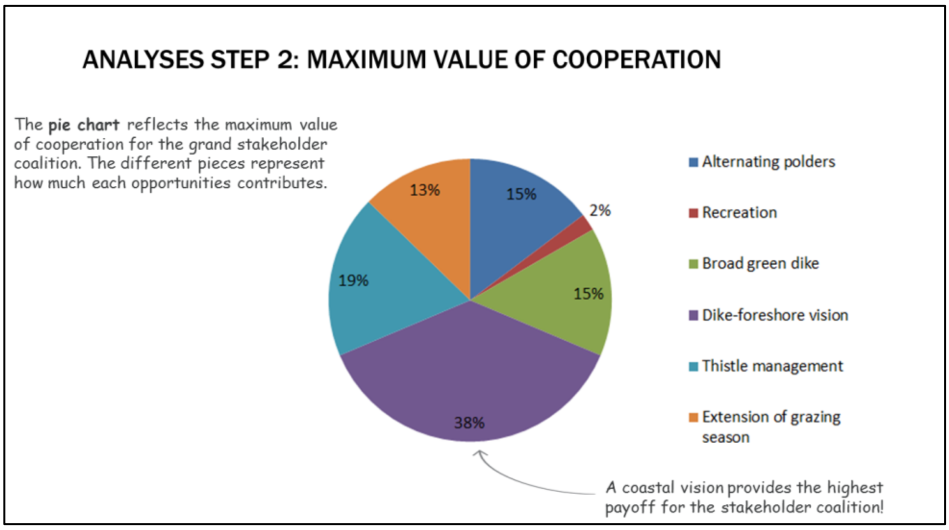
Methods

Recognizing the challenge of dike and foreshore cooperation, BE SAFE[2], developed a participatory tool to help stakeholder establish the added value of joint action. This tool is informed by the theory of cooperative games which provides concepts to assess the value of cooperation and ways to distribute the gains. In cooperation with POV-W, this tool was applied in the region 'Noard-Fryslân Bûtendyks' in the period April - October 2018.

Results

Two workshops were organised in July and October, in which five local stakeholders participated. After an excursion and sharing ambitions and current work methods, stakeholders explored potential joint dike-foreshore initiatives in the first workshop. A total of 8 opportunities for cooperation were identified. Each stakeholder valued these opportunities, by indicating whether achieving their (organisational) goals would become easier or more difficult when opportunities were to be realised. Researchers analysed these values and reported the results in the second workshop (see figure). Based on the analyses stakeholders defined two cooperative pilots and started working on a shared vision.

Application of the participatory tool 'added value of joint action' resulted in joint dike-foreshore initiatives. At the same time lessons for tool improvement were learned.



[1] The 'Project Overstijgende Verkenning' Waddenzeedijken comprehends 12 research projects for innovative dike concept along the Waddensea. More info: pov-waddenzeedijken.nl/

[2] An interdisciplinary NWO supported project aimed at how and how much foreshores can contribute to flood risk reduction. More info: www.citg.tudelft.nl/be-safe

POTENTIAL TIDAL RESPONSES TO FUTURE SEA-LEVEL RISE IN THE OOSTERSCHELDE

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Introduction

Sea-level rise (SLR) poses flooding risks to estuaries and coastal bays around the world. SLR not only changes mean water levels but also can modify local tidal dynamics. Understanding the SLR-induced local tidal changes is essential to planning coastal defense activities. Shifts in tidal regimes may modulate the direction and amplitude of sediment transport.

Methods

An existing Oosterschelde hydrodynamic model was coupled with a European shelf model (Idier et al., 2017). The latter models water levels and current velocity for 0 m to 2 m SLR scenaios; they were used as a boundary condition to drive the local domain, assuming no coastal flooding.

Results

The simulated water level in the baseline scenario agrees relatively well with observations at tidal gauges. SLR up to 2 m (possibly reached by 2100 or 2200) would submerge all tidal flats in the Oosterchelde and increase the tidal range, high water, and tidal currents, which are more responsive than the adjacent North Sea. With SLR up to 2 m, it is likely that tidal asymmetry (flood dominance) would be reduced, contributing to a decline in landward bedload sediment transport. Turnover time in the Oosterschelde would be mostly shortened with SLR-induced stronger tidal flushing. SLR also alters the local flushing characteristics by modulating the residual current field. Approaches and findings in this study have implications for understanding the local impacts of SLR on the Dutch coast as well as in global estuaries and coastal bays.

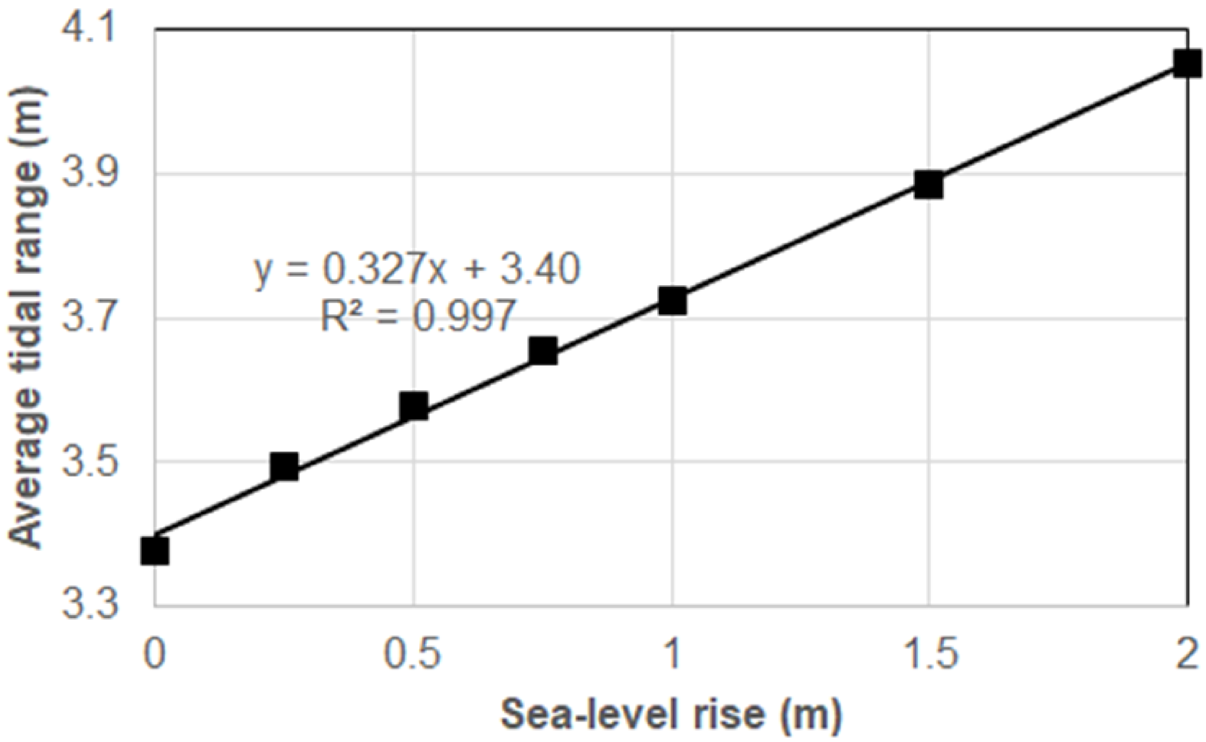

Figure 1 Simulated spatially average tidal range in the Oosterschelde in the SLR scenarios. The line denotes the linear regression between the average tidal range and SLR amplitude.

OBSERVATION OF ICE FLOW AROUND AMELAND WITH AN X-BAND RADAR

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Introduction

In the cold winter of 2017/2018 considerable amounts of ice were formed in the Dutch part of the Wadden Sea and in the tidal inlets, connecting the relatively shallow Wadden Sea with the adjacent deeper North Sea, where no ice was formed. The aerial photograph shows the formation of sea ice near the Island of Ameland., Fig 2.. Given the possible threats of such large ice formation to e.g. shipping and recreation the authorities would like to have a real-time surveillance technique that continuously (24/7) outlines the extent and movement of the ice sheets.

Fig 1: Aerial image with the beach in front and a patch of ice in the back.

Methods

In order to continuously observe the extent and flow of ice the X-band radar on the lighthouse of Ameland was selected. The processing computer that acquires radar data stores raw images every 1.5 seconds. These raw images are then averaged over a time window of approximately 1 minute, containing 42 images. This averaging process effectively removes all rapidly changing features e.g. due to surface waves. Consequently, only the semi-permanent and persistent sea surface structures remain like e.g. bottom induced features and ice. The ice is visible in the VV polarized radar images as deep black areas indicating that their radar backscatter properties are low. This is illustrated in the averaged radar image, Fig. 2. One of the ice patches is indicated with the red arrow.

By combining the average images into a series (in the order of several hours) a video has been made that clearly shows the flow of ice in the Ameland Tidal Inlet, around the western part of Ameland.

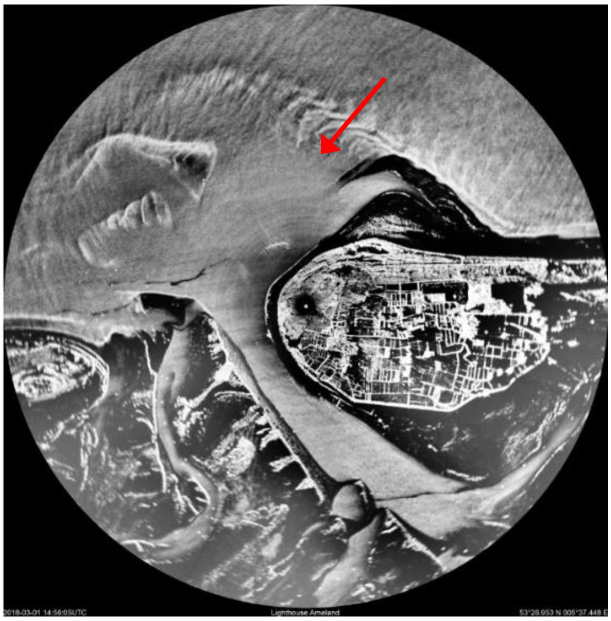

Fig 2: Averaged radar image of the Ameland inlet. One of the ice patches is indicated with a red arrow.

Results

Results in the form of a time-lapse video and still images will be presented. These results will be compared with aerial photographs. It will be shown that these images are able to effectively monitor the extent and flow of ice.

BED DEPTH MEASUREMENTS FROM AN ADCP AT THE RIGHT PLACE AND TIME

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Introduction

Measurements of currents need good bathymetric data. Especially in dynamic environments the bed depth at the position of the ADCP and at the time of the measurements is of importance for further use of the data of measured currents directly and for estimating the discharge in a river or tidal channel.

The local depth could be obtained from bathymetric measurements with echo sounders. That is however not done at the same time. A separate echo sounder could be installed at the same vessel but that carries the risk of acoustic interference. Current ADCPs for coastal and oceanic measurements measure with four slanted beams each having an offset compared to the position of the instrument and are not optimally configured for detecting the bed due the angle of the beam with the bed and lack of dynamic range.

A different problem is that for sediment measurements the cells or bins are large and data close to the bed is lacking.

The goal is to design an ADCP that measures bed depth directly below the instrument, has sufficient dynamic range and can be used for sediment measurements.

Methods

We propose a 1 MHz ADCP with an extra acoustic beam that is directed vertically downwards. This extra beam measures depth directly below the ADCP. The acoustic pulse is short compared to the acoustic pulse that is being used for current measurements and bottom tracking. The short pulse results in a sharp return from the bed and a precise and accurate depth estimate. The acoustic transducer has a wide bandwidth, allowing for sophisticated processing techniques.

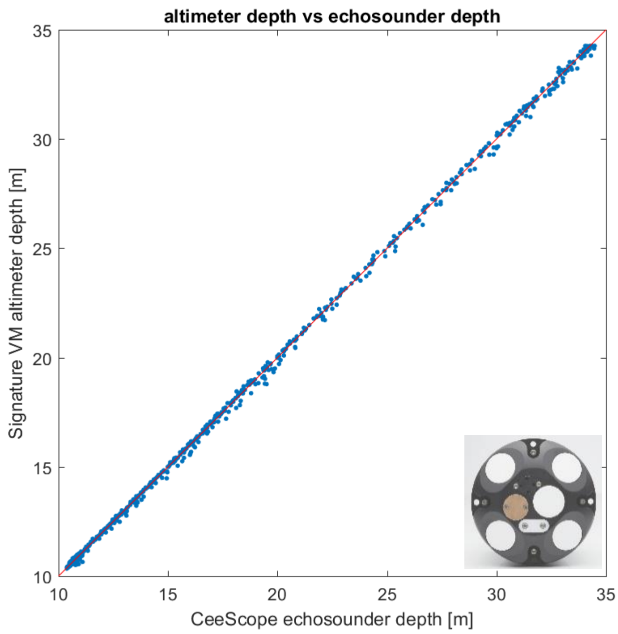
The ADCP can, using the same vertical beam, produce high resolution scientific echograms from 10 cm below the ADCP to the bed.

Results and conclusions

Depth measurements using this ADCP have been carried out in the Marsdiep in The Netherlands. The results have been evaluated against an echo sounder that was mounted on the same vessel. The echo sounder was positioned as far away as possible to limit interference.

The accuracy of the measured depth is better than 1% of the depth.

We conclude that the method works well. Further validation in different circumstances will be performed. The method will be implemented in ADCPs with different frequencies.



How do Tides Propagate up Rivers with a Sloping Bed?

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Keywords: tides, river delta, river discharge, bed slope

Tidal rivers are conceptualized as narrow channels along which the cross-section geometry remains constant and the bed is horizontal. As the tide propagates upriver, it is damped by friction and the amplitude decreases exponentially (Figure 1d, dashed) (Friedrichs, 2010). The strength of the damping increases with the river flow (Godin, 1991). At the river mouth, the tidally averaged water level changes little throughout the year. However, further upstream, the water depth seasonally varies with the river discharge. Our observations from the Kapuas River, Indonesia (Figure 1a), show that the water surface forms a backwater profile when the river flow is low, so that the depth gradually decreases into the upstream direction (Figure 1b). This influences how the tide propagates so that the amplitude does not decrease exponentially anymore (Figure 1c). We analyze this phenomenon theoretically and reveal several so far overlooked aspects of river tides, which are particularly relevant for low river flow (Figure 1d, solid). In the downstream part of the tidal river, depth-convergence compensates frictional damping so that the tidal range is higher than expected. Farther upstream, frictional damping is strong due to the shallow depth. This rapidly attenuates the tide. The tide effectively does not propagate beyond the point where the bed reaches sea level. This also applies to the overtide and the subtidal water level setup.

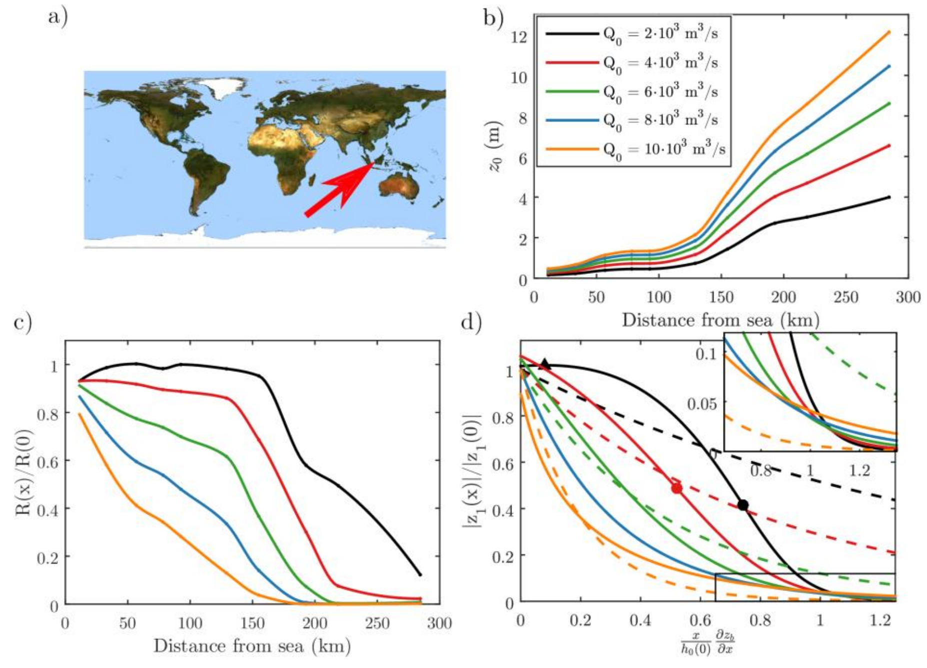

Figure 1: Location of the Kapuas Delta in Indonesia (a), Observed tidally averaged water level (b) and tidal admittance (c) along the Kapuas River, tidal admittance as predicted with a conventional model that ignores the bed slope (d, dashed) and by the extended model that incorporates backwater effects (d, solid)

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Kästner, K., Hoitink, A.J.F., 2019. Effects of a sloping bed on the propagation of tides up-river. Submitted to J. of Fluid Mechanics

RESPONSE OF TROPICAL SHALLOW BAYS TO SEA-LEVEL RISE

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Introduction

Tropical shallow bays in the Caribbean, like Orient Bay and Galion Bay in Saint Martin, are often sheltered by coral reefs and covered with seagrass meadows. The ecosystems are linked through biological, chemical and physical processes. They provide valuable services such as habitat for many animals, tourism and coastal protection. But the system is threatened by climate change. Due to rising water temperatures and ocean acidification, coral reefs are not likely to keep up with sea-level rise. This will lead to a change in hydrodynamics, which might affect again the seagrass. This study focuses on how the change in hydrodynamics will impact the system. Due to the interdependency, the response of one of the elements might lead to a collapse of the entire system and the resulting loss of services. Shown is how the ecosystems stabilize the system and mitigate the impact of sea-level rise.

Methods

Within D-Flow FM a 2D depth-averaged hydrodynamic model has been set up for Orient Bay and Galion Bay, Saint Martin. The model is forced with the tide and average wind- and wave-conditions and includes vegetation. Using this model, the change in hydrodynamics due to 0.87 m sea-level rise is calculated. The dominant forcing is identified and the impact is related to the response of coral reefs to climate change. Next, the change in seagrass distribution is predicted using a statistical analysis. In this way it will be shown that ecosystems are able to mitigate the impact of sea-level rise.

Results

A wave-driven circulation is found in the bays. The water depth above the reefs mainly determines the hydrodynamics inside the bays. Therefore, the change in hydrodynamics will depend on the response of coral reefs to climate change in general. When the reefs are able to keep up with sea-level rise, the change in hydrodynamics is limited. But in other cases, there will be a significant change in hydrodynamics. In Orient Bay, this will lead to a shift in the seagrass distribution. But on the scale of the entire bay, it is expected that the ecosystems are able to withstand the sea-level rise and valuable services are not lost. The key to conservation of the bays and its functions is preserving the reefs.

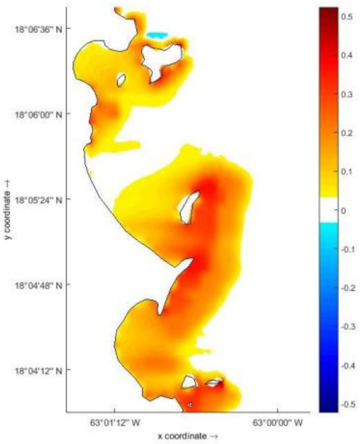

Figure 1 Change in RMS wave height [m]

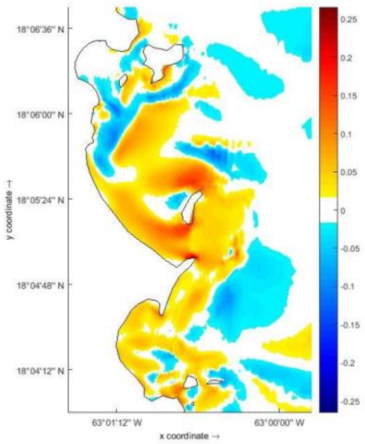

Figure 2 Change in flow velocity [m/s]

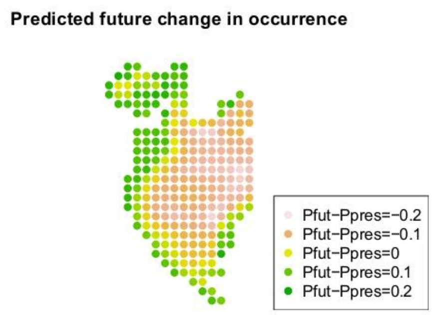

Figure 3 Change in probability of seagrass occurrence [-]

MODELLING THE PAST EVOLUTION OF OBSERVED TIDAL SAND WAVES: MODEL SET-UP

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Introduction

Tidal sand waves are rhythmic bed forms located in many coastal seas. These bed forms have heights up to ten meters and migration rates of several meters per year. Due to their dynamic nature, sand waves can uncover buried cables and pipelines, thereby making them subject to risk of damage. This study aims at developing a new numerical 2DV model (Delft3D) to simulate the past evolution of tidal sand waves on a decadal timescale (hindcast study). In particular, the effect of imposing different types of boundary conditions (time series of currents, water levels and Riemann invariants) on sand wave evolution is investigated. Simulations are conducted for a period of ten years, whereby an observed sand wave field is used as an initial bathymetry. Model results show that imposing time series of Riemann invariants at one boundary and of water level at the other yields the best agreement with bed level observations.

Methods

The study area consists of a 45.5 km transect located between two measuring buoys in the North Sea which were deployed by offshore survey service Fugro in future wind parks Hollandse Kust Zuid (HKZ) and Hollandse Kust Noord (HKN). In this area, bathymetrical surveys were performed by the Netherlands Hydrographic Office of the Royal Netherlands Navy both in 2000 and 2010. For a certain transect, the bed level observed in 2000 is used as model input and the model output is compared with the measured bed level in 2010. The tidal flow is forced with velocity and water level timeseries measured by the two buoys. These timeseries were imposed in four different ways: (1) Riemann invariants at both open boundaries (RR); (2) depth averaged velocity at one and water level timeseries at the other boundary (Uζ); (3) a water level time series at both boundaries ($\zeta\zeta$) and (4) a Riemann invariant at one and water levels at the other boundary (Rζ). Other model settings are a horizontal grid spacing of 10 m, 50 vertical sigma layers of decreasing thickness towards the bed, a hydrodynamic time step of 6 s and a morphological run time of 10 years with a morphological acceleration factor of 100.

Results

Figure 1 shows the observed bed level of 2000 (black dotted line) and 2010 (black solid line). The different colors correspond to modelled bed levels resulting from forcing with different boundary conditions. The red line corresponds to the best model result, i.e. this modelled bed level is closest to the observed bed level of 2010 in terms of sand wave length, height, shape and migration and corresponds to tidal flow forced with one Riemann invariant and one water level time series.

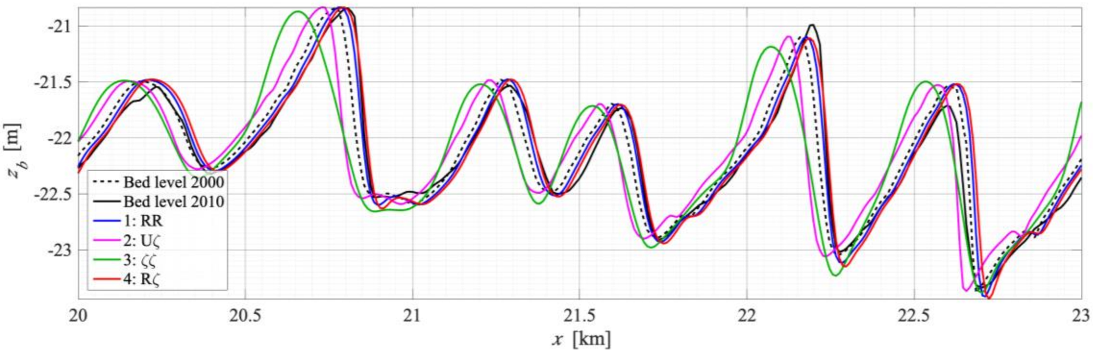

Figure 1. Bed level z_b measured in 2000 and 2010 (dashed and solid black lines, respectively) over x, and simulated z_b for the different types of boundary conditions: 1. two Riemann invariants (RR, blue); 2. depth-averaged velocity and water level time series (Uζ, magenta); 3. two water level time series ($\zeta\zeta$, green); 4. Riemann invariants (Rζ, red).

NUMERICAL MODELLING OF THE SWASH ZONE

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Introduction

The swash zone is the highly dynamic boundary between the sea and the beach where waves run up and down the beach. In the swash zone, the highly unsteady and turbulent flows lead to large sediment transport rates and morphological change. Understanding the processes driving the transport and morphological change is therefore of vital importance to better understand the long-term development of beaches. To investigate these processes, numerical models are important tools. However, these models still have difficulty reproducing accretive wave conditions and overpredict erosion. These model shortcomings will be addressed in the recently started NWO-TTW research project *Shaping the beach* with the aim of understanding cross shore swash zone processes. At the conference the methodology of this research project will be presented.

Figure 1: Swash zone of a sandy beach, source: pixnio.com

Methods

The first step of the research is a literature study to identify important processes, study cases and suitable models. In the present PhD project, two numerical models will be used to analyse swash zone processes and improve sediment transport formulations. These models are the depth resolving OpenFOAM model and the depth averaged XBeach model. The OpenFOAM model will be applied to understand the fundamental swash processes for these cases. The OpenFOAM results will then be used to improve depth averaged sediment transport formulations used in XBeach. Both models will be validated with detailed data on swash zone flow and sand transport processed from controlled, large-scale laboratory experiments.

Results

The main expected result is an improved understanding of the processes driving cross shore sediment transport in the swash zone. This will also lead to an improved sediment transport formulation to be used in XBeach.

Acknowledgements:

This project and Shaping The Beach (2018-2023) is an NWO-TTW funded research project (no. 16130), with in-kind support by Deltares. It is a collaboration between the University of Twente, Delft University of Technology and Deltares with in total 2 PhD Researchers and 1 Post-Doctoral Researcher.

MODEL UNCERTAINTY IN PREDICTING COASTLINE RESPONSE OF BUILDING WITH NATURE DESIGNS

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Introduction

The Building with Nature (BwN) design philosophy (de Vriend et al, 2015) uses natural dynamics and resources as adaptive coastal protection. Consequently, the degrees of freedom and therewith the uncertainty of the state of the system increase by allowing these natural dynamics. Thus, evaluating this state at a certain point in time requires a different approach than in case of a more traditional coastal protection. Over the past decades several probabilistic frameworks have been developed to allow for the effects of natural dynamics in coastal modelling (Callaghan et al., 2013; Baart,2013; Ruggiero et al., 2010; Baquerizo and Losada, 2008; Ranasinghe et al.,2012). However, these methods can give a false sense of confidence when ignoring model uncertainty, introduced by these frameworks. We investigate the importance of model uncertainty in the prediction of coastline response of a BwN solution under stochastic wave forcing.

Methods

We make a stochastic prediction for the Sand Engine, a peninsula shaped nourishment of 21 million m^3. The stochastic method runs a one-line model numerous times with varying wave input and settings, using a Monte Carlo procedure. In this stochastic prediction we include model uncertainty and wave climate variability. The model uncertainty is obtained using a GLUE approach on model-observation discrepancies and, the wave climate variability is based on a bootstrapping procedure of historical observations. As a result, both of these uncertainties are obtained on observational data rather than estimates of variances.

Results

The stochastic prediction results in a confidence probability distribution of losses at the sand engine. Comparing the bandwidth against observations for the same period shows that we are able to represent the variance in the volume losses at the Sand Engine (Figure 1). Results show that the importance contributions varies with the time scales considered.

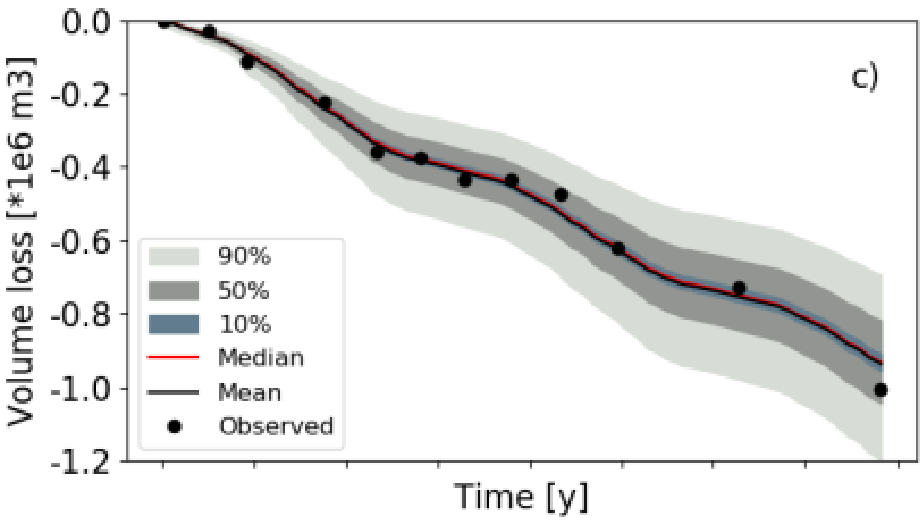

Figure 1 Stochastic forecast of volume loss compared to observed volume loss for the period of June 2015 to January 2018.

TRANSNATIONAL AND INTEGRATED LONG-TERM MARINE EXPLOITATION STRATEGIES

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Context

Mineral and geological resources are non-renewable on time-scales relevant for decision-makers. The sustainable management of these invaluable resources requires a thorough and careful balancing of available quantity and quality versus rapidly changing societal and economical needs. The need for such an approach is recognized in the EU's Raw Materials Initiative, which highlights the optimization of the geological knowledge base as a key element in ensuring sustainable supplies from within the EU borders. Comprehensive knowledge on the distribution, composition and dynamics of geological resources therefore is the backbone of long-term strategies for resource use in a rapidly changing world.

Results

As a world's first, a trans-border geological knowledge base is now available for the Belgian and southern Netherlands part of the North Sea comprising volumetric 3D pixel ('voxel') models of its subsurface (Figure 1), environmental impact models accounting for geological boundary conditions, a geological data portal, and a voxel-based decision support module on marine aggregate extraction. The newly developed tools assist in the preparation of long-term adaptive management strategies, and in scientifically underpinning new legally binding measures to optimize and maximize long-term exploitation of aggregate resources within sustainable environmental limits. Such measures feed into policy plans that are periodically evaluated and adapted (e.g. Marine Spatial Planning and the Marine Strategy Framework Directive, the environmental pillar of Europe's Maritime Policy).

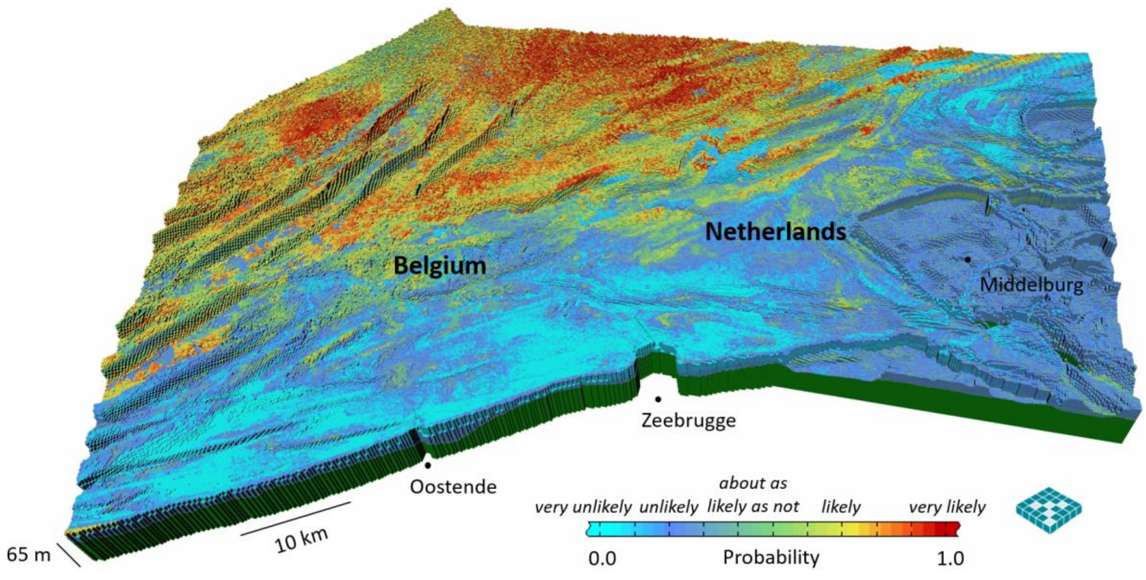

Figure 1 Transnational voxel model of the subsurface offshore Zeeland and Flanders, with probability of medium sand. This surficial view emphasises the top voxel representing the seabed sediment, but also shows the vertical succession of voxels at the coastline (edge of the model), with green representing non-extractable old clay at the base, covered by Pleistocene and Holocene sediment of different size.

Can Dune Growth keep up with Aeolian Losses and Sea Level rise? A study at the Hondsbossche Dunes

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Introduction

In 2015 the coastline between Camperduin and Petten (NL) was reinforced because the sea defence did not comply to the Dutch safety standards anymore. A soft sandy solution was chosen to improve the flood safety and spatial quality (Figure 1). A natural barrier of 36 million cubic metres of sand on the seaside of the dike was built. After construction, a three-year interdisciplinary study was carried out in the area to monitor the development of nature and morphology and the perception of this development. The aim of the monitoring was to learn about efficient sand-nourishment with added value for nature and leisure.

One of the research questions in the study comprised whether optimisations can be pointed out at the design and construction of a sandy nourishment, specifically with respect to aeolian sediment loss and sea level rise. In the design and construction of the dune and the safety profile for the Hondsbossche Dunes aeolian loss over a period of 20 years and climate change over a period of 50 years was compensated for with a total volume of about 1,8 Mm^3 of sand. Was, in view of the current processes, this necessary or is it likely that the natural process of dune growth will adequately compensate for the aeolian loss over the next 20 years, and sea level rise and soil subsidence over the next 50 years?

Methodology

Dune growth rates, beach erosion rates and wind data were analysed for the monitoring period to study the morphological development. This was based on 9 laser altimetry measurements (LiDAR) and aerial photographs of the zone above the waterline. Also half-yearly site visits were conducted. The ecological development was monitored and literature study was done. Morphodynamic calculations were done with XBeach and Duros+ .

Figure 1: Satellite imagery of the coastline between Camperduin and Petten (NL) A) Hondsbossche and Pettemer sea dike (December 2013) B) Hondsbossche Dunes a few months after construction (June 2015) and C) Hondsbossche Dunes 2 years after construction (June 2017) Source: Google Earth Pro.

Results

In the analysis it was taken into account that the dune growth during the monitoring period, the period shortly after construction of the dunes, is expected to be higher than the coming years. Based on the analysis it is expected that aeolian deposition in the entire area of the Hondsbossche Dunes is large enough to offset the aeolian sediment loss for the next 20 years and relative sea level rise for the next 50 years. In hindsight, construction of the compensation volume for aeolian losses and sea level rise for the next 50 years would therefore not have been necessary.

A boundary condition for this result is a constant or growing profile below 3 m + NAP (foreshore, intertidal area, beach). This fits within the current safety policy of the coastal zone in the Netherlands in which the coastline as determined in 1990 is maintained by regular nourishments. Under this condition (maintaining the coastal zone below 3 m + NAP), aeolian deposition can compensate the sea level rise to a speed of 1 m per century.

In new projects with sandy nourishments it is advised to use the most up-to-date forecasts on sea level rise, to consider the sea level rise that has occurred up to that point and weighing up whether additional compensation for sea level rise is necessary or an adaptive policy is preferred.

THE EFFECT OF EBB-TIDAL DELTA NOURISHMENTS ON CYCLIC CHANNEL-SHOAL DYNAMICS

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Introduction

Sedimentation of the Dutch Wadden Sea during the last century was a direct result of human interventions, such as the construction of the Afsluitdijk and the closure of the Lauwerszee. Most of the sediment was supplied by the ebb-tidal deltas, which had a significant loss in sediment volume. Accelerated sea level rise will cause an additional need for sediment in the Dutch Wadden Sea, but it is unlikely that the remaining ebb-tidal deltas can deliver this. Therefore, mega nourishments (~$20 \cdot 10^6$ m^3) of ebb-tidal deltas are considered and in 2018 a nourishment of ~$5 \cdot 10^6$ m^3 has been implemented at the ebb-tidal delta of Ameland. However, the question is how ebb-tidal deltas will respond to these nourishments. For example, will the sediment indeed be transported into the tidal basin and does this depend on the location of the nourishment? Furthermore, many ebb-tidal deltas show a cyclic pattern of shoal formation, migration and attachment to the downdrift coast and it is highly uncertain how this cyclic evolution is affected by nourishments.

Methods

Here, we studied the long-term (>years) morphological effect of nourishments on cyclic channel-shoal dynamics. Using an idealized geometry and simplified forcing in Delft3D/SWAN, we implemented and studied the morphodynamic evolution of ebb-tidal deltas for a wide range of possible nourishments, varying in size, location and phase of the cyclic behavior. We compared our results with a base case model simulation without nourishment which showed clear patterns of channel-shoal dynamics resembling those observed in the Wadden Sea.

Results

Our results show that the nourishments accelerate the natural cyclic behavior, where different nourishment locations show different effects. Nourishing the updrift shoal reduces the period between successive shoal attachments by 30% (see figure 1), whereas this is only 15% if the nourishment is placed in one of the channels. Surprisingly, most of the nourished sand remained in the updrift side of ebb-tidal delta, even during the channel and shoal migration. This indicates that the nourished sediment causes morphological changes by adjusting the patterns of sediment transport rather than directly feeding the shoal that attaches to the downdrift island. As a result, the volume of the ebb-tidal delta is higher than in the base case model simulation, even after several shoal attachments. Furthermore, any nourishment initially results in additional sediment transport into the tidal basin. However, this effect is limited to the first cycle of the modeled channel-shoal dynamics.

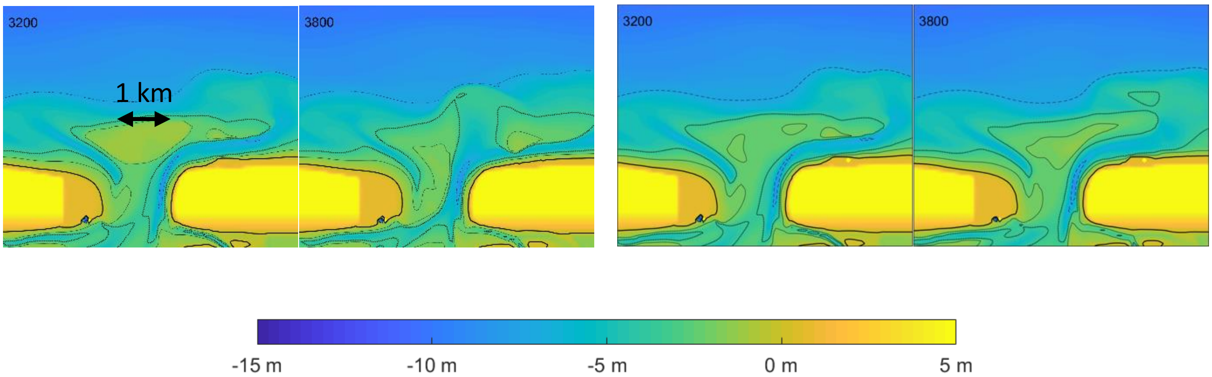

Figure 1. Depth obtained in model simulation with (left) and without (right) nourishment at the updrift shoal at the moment of nourishment placement (3200 modeled days) and 600 days hereafter. It can be seen that the nourished ebb-tidal delta is close to shoal attachment and new channel has formed, whereas the base case is still in the preceding phase of channel rotation and shoal growth.

THE EVOLUTION OF MODELING COASTAL EVOLUTION

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A common measure to mitigate erosion along sandy beaches is the implementation of sand nourishments. The design and societal acceptance of such a soft mitigating measure demand information on the expected evolution at time scales from storms to decades. Process-based morphodynamic models are increasingly applied to obtain detailed information on the temporal behaviour.

This research will highlight the advances made in morphodynamic predictions of complex sandy interventions over the last decade. We adopt the Sand Motor as a case study to illustrate the evolving performance of morphodynamic predictions in a quantitative manner. We start our assessment with the 20-year predictions conducted for the EIA in 2008 before the construction of the Sand Motor. This prediction is followed by the key findings of the predictions with a first-year calibrated model using data. In addition, the relative contribution of the most relevant nearshore processes is derived. Next, we will demonstrate a novel morphodynamic acceleration technique that allows for resolving the morphodynamics from storm to decadal time scales in one simulation. The 40-year predictions reveal an interesting impact of the Sand Motor on the overall behaviour of the Delfland coast. Finally, we present an integrated model that seamlessly predicts the morphodynamics in both the subaqueous and subaerial domains of the Sand Motor. Decadal predictions illustrate the need to be able to resolve the marine and aeolian processes simultaneously in one modelling framework. Especially when dynamics of coastal landscapes are subject of interest.

Combining the above-mentioned developments has led to a unique, open-source, process-based landscaping tool for (complex) sandy systems. This modelling framework will stimulate further collaboration within the NCK community; extensions into dune dynamics and vegetation development are already planned. Moreover, this work demonstrates the evolution from mono- to interdisciplinary forecasts of coastal evolution.

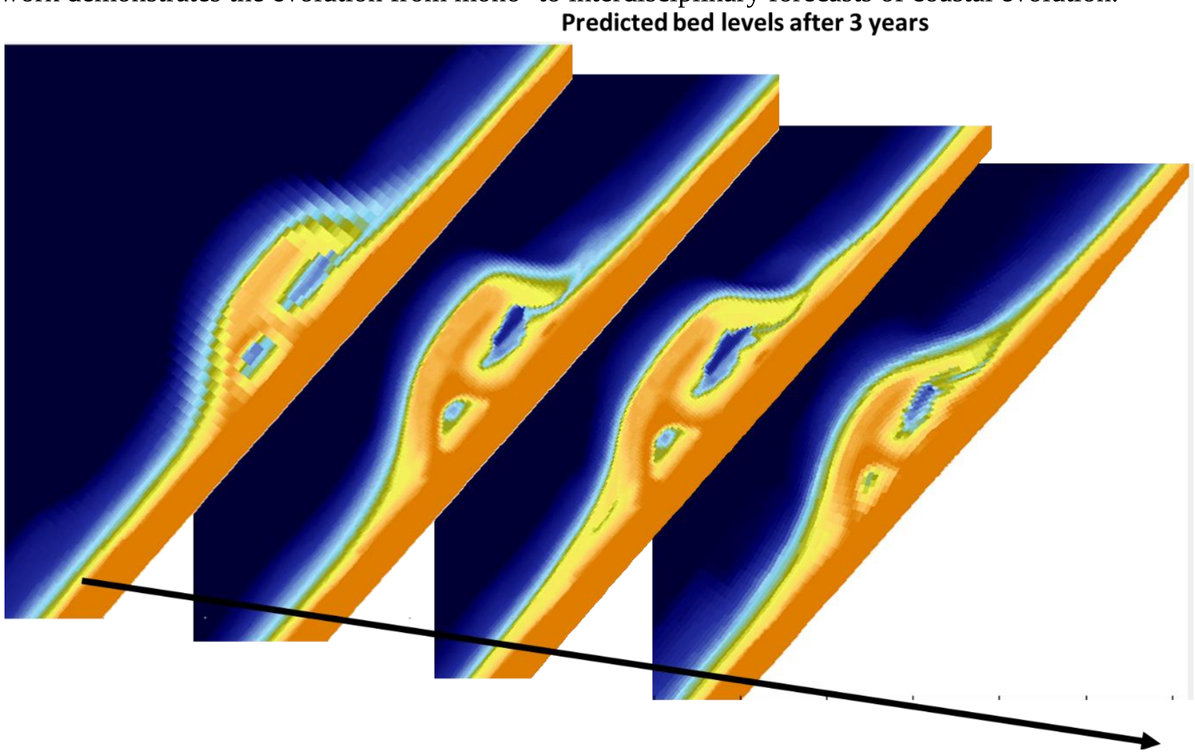

Figure 1 The evolution of model predictions for the Sand Motor evolution

Hydrodynamic factors influencing beach profiles in shallow, low-energy lakes: a case study in the Markermeer and IJsselmeer

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Introduction

As sea level continues to rise and intense storms become more frequent across the globe, coastal populations have begun to implement various defense mechanisms to protect major population areas and valuable infrastructure. Over the last decade the Netherlands has pioneered nature-based flood defense mechanisms, such as sandy foreshores, as an alternative to traditional hard structures, such as sea walls and breakwaters. These methods are widely thought to be more effective and cheaper as they can adapt to changing climactic conditions. However, this strategy requires additional validation before it can be relied upon in lakes, since studies of hydrodynamics and morphology in these systems lag behind that of high-energy ocean coasts. As a result, a pilot project has been implemented at the Houtribdijk. The pilot sandy foreshore was placed in front of the dike to study its effect on reducing wave heights approaching the dike from the Markermeer side. This study looks at coastal profiles in the Markermeer and the IJsselmeer which are analogous to the Houtribdijk pilot foreshore to better understand the sediment transport processes influencing profiles in low-energy, non-tidal locations.

Methods

To determine the impact of hydrodynamic conditions on the beach profile, we measured beach profiles of 11 sites in December 2018 (for example see Figure 1). Four of these sites, located in the Markermeer, were measured previously in 2005 for a master thesis project (Van der Weij, 2005). In the spring, we will revisit all 11 sites to compare seasonal changes in beach profile. The 4 sites also studied by Van der Weij (2005) will be further analyzed for changes on a decadal time scale. Additionally, sediment samples were taken at each location for a better understanding of the influence of sediment properties on beach profile.

Results & Conclusions

Preliminary results at the study sites show that wind and storms create steep slopes and rotate the exposed beach while the underwater platform remains relatively stable, a phenomenon also seen at the pilot project. This indicates that wind and wave direction strongly influence beach long-shore and cross-shore profiles. Sediment type also likely plays a role in the profile form based on the fall velocity of the sediment present at each site. Ultimately, this research aims to inform future nature-based design so that it can be effectively implemented throughout the Netherlands and vulnerable coastal areas around the world.

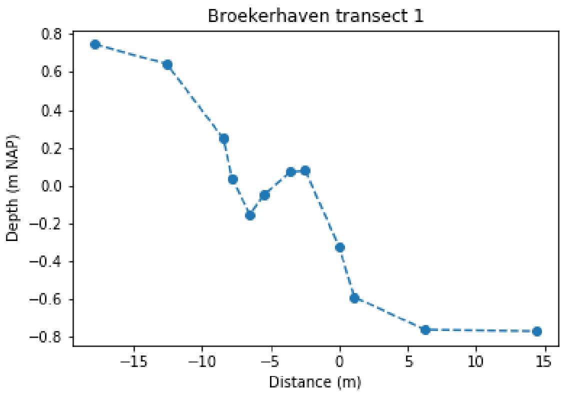

Figure 1. Left: cross-shore profile taken at Broekerhaven, one of the study sites in the Markermeer. Right: measuring beach cross-shore profile with hand-held GPS in the IJsselmeer.

FEEDBACKS BETWEEN OVERWASH DEPOSITION AND FLOOD-TIDAL DELTAS

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Introduction

Barrier islands can migrate landward in response to sea level rise by transporting sediment to the back barrier, either through flood-tidal delta deposition, or via storm overwash. Our understanding of these processes over decadal to centennial time scales, however, is limited and poorly constrained.

Methods

Here we use a new barrier inlet environment (BRIE) model combined with remote sensing to quantify potential overwash and flood-tidal delta deposition rates. The BRIE model integrates existing overwash and shoreface formulations (Lorenzo-Trueba and Ashton, 2014) with alongshore sediment transport (Ashton and Murray, 2006), inlet stability (de Swart and Zimmerman, 2009), inlet migration, and flood-tidal delta deposition (Nienhuis and Ashton, 2016). Within BRIE, inlets can open, close, migrate, merge with other inlets, and build flood-tidal delta deposits. We use 34 years of remote sensing observations of barrier island change to parameterize overwash fluxes. The model accounts for feedbacks between overwash and inlets through their mutual dependence on barrier geometry.

Results

Model results suggest that when flood-tidal delta deposition is sufficiently large, barriers require less storm overwash to move landward and aggrade during sea level rise. In particular in micro-tidal environments with high alongshore sediment transport, tidal inlets are effective in depositing flood-tidal deltas and constitute the majority of the landward-driven sediment flux.

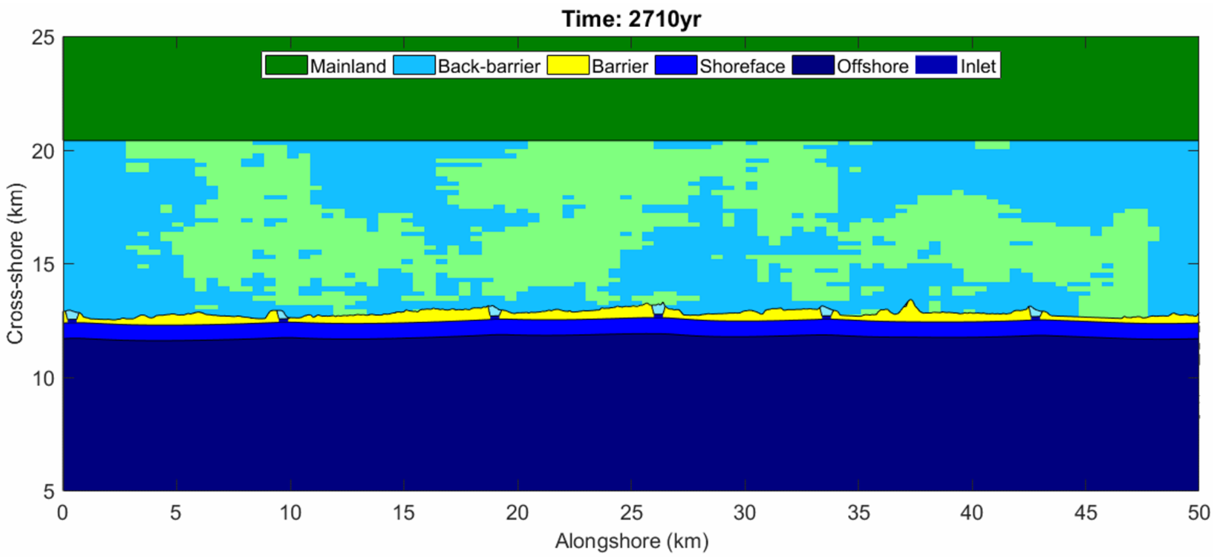

Figure 1: BRIE model showing inlets along a barrier island chain.

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Modeling the morphodynamics of tidal inlet systems: Delft3D-FM vs. Delft3D

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Introduction

The performance of the new flexible mesh (FM) morphodynamic numerical model Delft3D-FM in simulating morphology on long time scales (order years to decades) is verified by running this model for the case of a tidal inlet system. Results from this model are compared with Delft3D, which has been proven successfully in simulating the morphology of tidal inlet systems. As a benchmark, the Delft3D-FM should be able to simulate a seaward located ebb-tidal delta that is connected to a complex branching pattern of tidal channels inside the basin (Figure 1). This test case is adopted from the work by Ridderinkhof *et al.*, 2014, who studied effects of the length of the back-barrier basin on the sand volume and spatial symmetry of ebb-tidal deltas using Delft3D.

Methods

Simulations with Delft3D-FM and Delft3D are carried out for the same configuration as that used by Ridderinkhof et al., 2014. The model domain consists of a rectangular open sea and a back-barrier basin, which are connected to each other by a narrow tidal inlet. The model, which starts from an initially flat bed, is forced by a propagating tidal wave with three harmonic constituents (M_2, M_4 and M_6). The used sediment transport equation is the Engelund-Hansen total load formulae.

Results

The formation of an ebb-tidal delta seaward of the tidal inlet is well captured by the Delft3D-FM model (Figure 2). However, the simulated bottom pattern in the back-barrier basin does not feature a clear formation of a tidal channel network. Moreover, bottom patterns grow too fast (order weeks to months), which is likely due to a high numerical diffusion that is generated in the model.

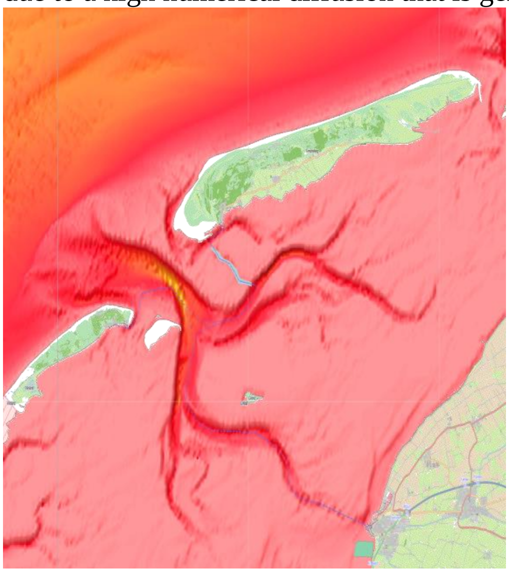

Figure 1 Map of an ebb-tidal delta and a tidal channel network in the Wadden Sea.

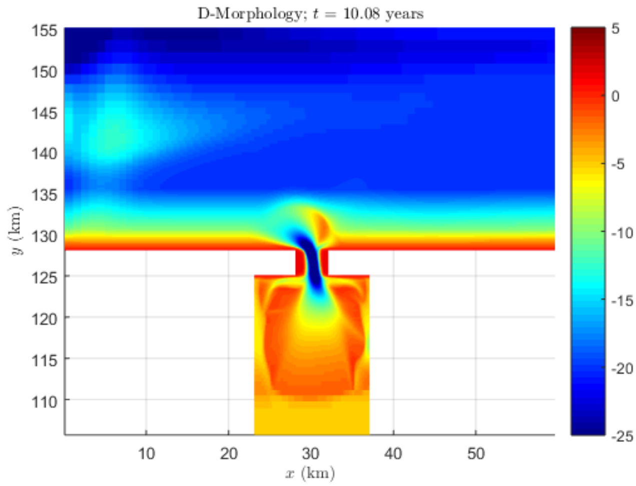

Figure 2. Simulated bottom pattern with the Delft3D-FM.

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Long-term marsh growth and retreat in an online coupled hydrodynamic, morphodynamic and ecological model

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Nature-based coastal protection solutions such as salt marshes are able to complement conventional solutions. Salt marshes are able to grow with sea level rise by actively trapping sediments and creating belowground biomass, and their wave attenuating capacity is proven. Furthermore, salt marshes are widely recognized as pristine ecosystems that provide habitat to a unique and wide range of flora and fauna. Their possible use as a nature-based way of flood protection plus the recognition of the ecological value of these ecosystems has led to multiple salt marsh creation and restoration projects. However, salt marshes are also known as dynamic ecosystems, and significant changes in total covered area over time scales of decades have been observed in the past (Van der Wal et al., 2008). Both, growth and retreat have been registered at marshes in close proximity (a few kilometres only). Recent field work and model results suggest that the magnitude of (short term) hydro- and morphodynamics may be indicators for the long-term marsh growth and retreat. A better understanding of the physical processes driving the long-term evolution of these ecosystems may be valuable knowledge for efficient coastal management.

A dynamic vegetation model setup in Python was coupled to a hydro- and morphodynamic model (D-flow Flexible Mesh) in order to unravel the long-term marsh dynamics. The dynamic vegetation model consists of a combination of two existing vegetation modelling approaches. Establishment of pioneering vegetation was modelled by the Windows of Opportunity theory (Poppema, 2019). Growth and decay of vegetation was based on the population dynamics theory. For each grid cell, the vegetation was updated every several timesteps, depending on the hydro- and morphodynamic conditions in that grid cell. The relative contribution of wind waves and tides influences the cross-shore development of the profile, whereas the rate of actual establishment of vegetation affects the lay-out of the salt marsh.

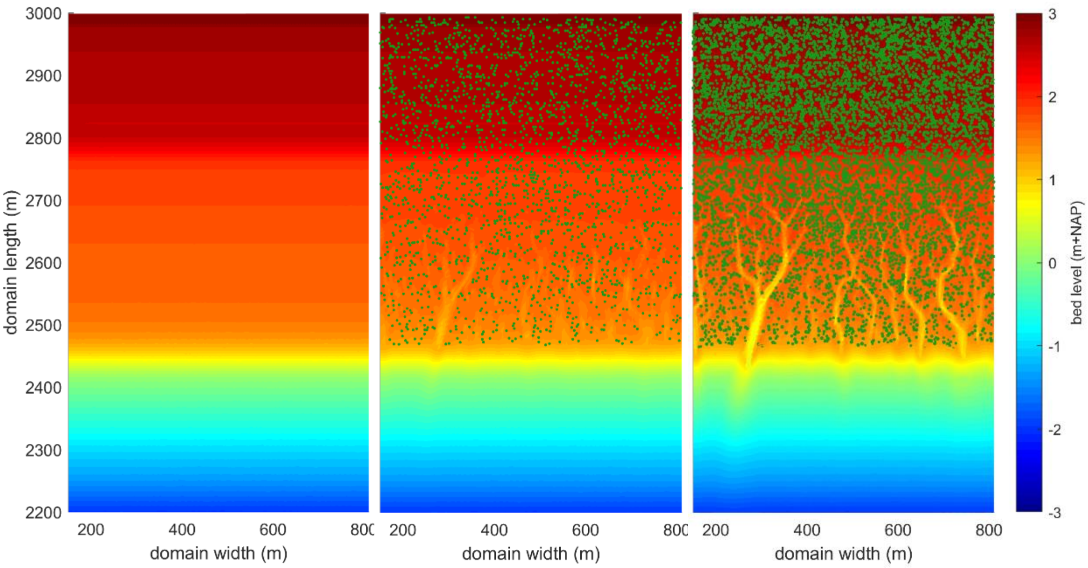

Figure 1 Modelled salt marsh evolution. From left to right: initial bathymetry, vegetation and ecology after 40 years, vegetation and ecology after 80 years

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THE DEVELOPMENT OF THE WESTERN WADDEN SEA DUE TO THE OPENING OF THE MARSDIEP AND ZUIDERZEE AREA.

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Introduction

The westernmost inlet of the Wadden Sea, the Marsdiep, is a relatively young tidal system if compared to the other Dutch inlets. This might also explain the present-day relatively large depth of the system.

Situation up to ca. 1000 A.D.

At the dawn of historical times, the Zuiderzee region consisted of several river-fed lakes, described as Flevo Lakes (*Lacus Flevo*) and largely uninhabited peatlands (Van Bavel, 2010). The lakes gradually increased in size due to erosion. The peats extended N of the present-day IJsselmeer area and functioned as a barrier between the North Sea and the lakes. The waterway to the W, the Oer-IJ closed around 200 BC and limited drainage of the lakes (Vos, 2015). Throughout the Roman period and Early Middle Ages, the lakes were (partially) drained by the Vlie tidal inlet, as can also be deduced from the name *Lacus Flevo*, at least since 400 BC or perhaps even since 700-1000 BC (Vos, 2015; Van Zijverden, 2017). Given the fresh water conditions and the lack of strong tides in the lakes, fresh water must have drained towards the Vlie tidal inlet via a stream, which is mentioned *Nakala* in historical sources. Calculations learn that this channel was at least some 10-20 km long and of limited width. Such a situation may well have existed up to the 8th century AD as the Vita Boniface (754-768 AD) indicates. By that time, the name of the region changed from *Lacus Flevo* into *Almaere*, meaning ‘all lakes’ and suggesting larger fresh water basins. The Vlie system was most likely an estuary.

The *Maresdeo*p (817 AD) indicates either a “marsh stream” or a “sea deep”, leaving it unclear how the situation was. However, up to at least 800 AD the coast between Den Helder and Texel was probably situated some 10 km more to the W (Schoorl, 1973). Tides came up to Den Helder, but 4.5 km to the E the area was inhabited in the 8th, 9th and in the 11th-12th century (Woltering, 1998).

1000-1500 the formation of the Zuiderzee

As the erosion of the seaward protruding coast of Texel-Den Helder continued, the Marsdiep itself also retreated in a landward direction. This will have made the peaty landscape E of it more vulnerable to flooding. The Marsdiep inlet might have been situated at its present location around 1220 AD or earlier, but had a small tidal volume (Oost et al., 2003). Salt water reached the Balgzand area around 1200 AD. Somewhere between probably 1150 and 1300 AD the Vlie system was contacted which originally may have reached westward up to Wieringen. The expansion of the Marsdiep to the E led to strong changes in the western Wadden Sea and the Zuiderzee area, as oxygen-rich salt waters driven by tides, waves and storm surges burned the peat and drained and eroded it.

Due to the expansion of the Marsdiep the Aelmere became directly connected to the sea instead of via a stream. Initially, this must have led to high current velocities and strong erosion. During the expansion in the backbarrier of the Marsdiep the tides may have been amplified as they met the land on about a quarter tidal length, which added to the erosion. By the end of the Early Middle Ages, pioneers entered the vast peatlands of the Zuiderzee region and started large-scale reclamation and cultivation works. It had a negative impact upon the peatlands, resulting in compaction, dehydration and increased vulnerability against marine erosion. Between at least the 12th to 14th century heavy floods scourged the large vulnerable land areas, resulting in marine ingression and formation of the Zuiderzee (Vos, 2015; Van Popta, 2017; Van Popta *et al.*, in prep.). Land loss occurred at a large scale in a.o. the Wieringermeer area, the Hoornse Hop, near Amsterdam, the Noordoostpolder region and south of the IJsseldelta. New research by Van Popta (2017) and Van Popta & Benders (in prep.) demonstrates the positive and negative consequences of these landscape dynamics: multiple settlements drowned (*e.g. Nagele, Marcnesse, Venehusen*) while important maritime trade routes were established (*e.g.* Rhine - IJssel – Zuiderzee – North Sea – Baltic Sea). At the same time the area became brackish marine. Erosion continued throughout the Late Middle Ages, but was limited by the construction of dikes from the 13th century onwards.

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SCALE EXPERIMENTS ON AEOLIAN DEPOSITION PATTERNS AROUND BUILDINGS ON THE BEACH

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Introduction

Dunes provide protection against flooding and a high ground to live on. At the same time, the beach and dunes form an attractive area for recreation. This leads to the presence of buildings like restaurants and (holiday) homes at the land-sea interface. These buildings affect wind-driven sand transport and thereby shape the development of the dunes. Currently, there is an increasing demand for sea-side buildings on the beach and a lack of knowledge on the effect they have on the beach-dune system. Therefore, this research aims to understand the effect of buildings at the beach-dune interface on sediment transport and beach-dune morphology. In this contribution, we focus on determining the erosion and deposition patterns around buildings, using scale experiments on the beach.

Methodology

Scale models of buildings were constructed by stacking cardboard boxes into cuboid bodies of various sizes and shapes. During the experiment, the wind speed and direction were recorded, as well as the occurrence of sand transport at different elevations above the bed. The sedimentation and erosion patterns around the objects were measured using structure-from-motion photogrammetry. All around the models, photos were taken from a height of approximately 5 metres. These photos were computationally combined to form a digital elevation model (DEM) and orthophoto (a distortion-free top view).

Results and outlook

The experiments, conducted in Autumn 2018 at the Sand Motor in The Netherlands, suggested that the building width and height are more important than the length parallel to the wind. Further processing of the data is needed to determine the sedimentation and erosion patterns around buildings in a more quantitative manner and describe the dependency on building size and shape. In addition, the experiments will provide insight on how small the scale models can be for further experiments using configurations of multiple objects. Smaller scale models allow for more flexibility, but can potentially introduce scaling effects or change the physical processes. Therefore, a middle ground has to be found, that balances small-scale flexibility and full-scale representativeness of real-world effects.

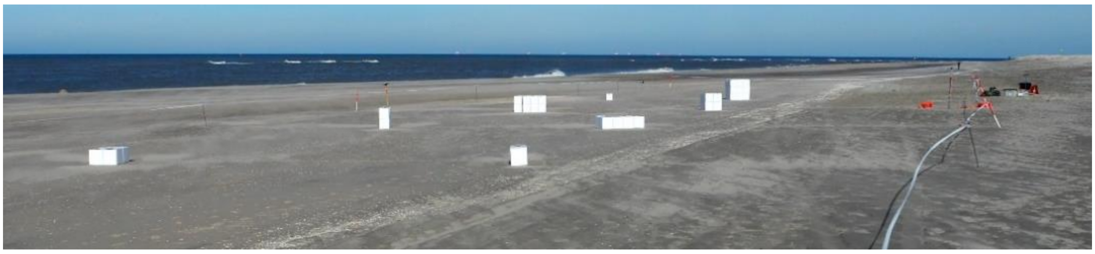

Figure 1: Photo of one of the set-ups, testing the effect of building width and height in October 2018

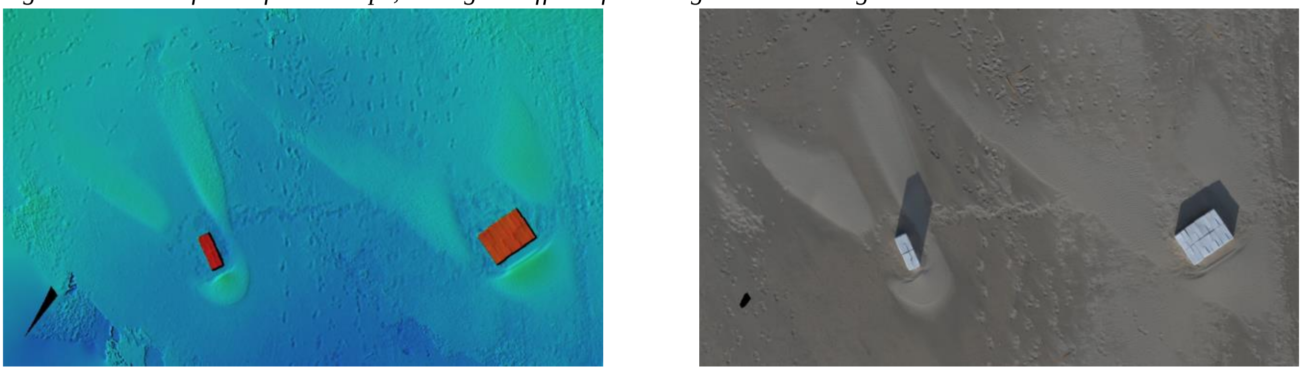

Figure 2: Digital elevation model (left) and orthophoto (right) of the sedimentation pattern around two of the models in figure 1. Model size 32x100x70 cm (left model) and 128x100x35 cm (right model).

CFD MODELING OF AIRFLOW OVER URBANIZED BEACHES AND THE IMPACT OF BUILT ENVIRONMENT ON AEOLIAN SEDIMENT TRANSPORT

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Introduction

Coastal urbanization is rapidly developing in many countries around the world. Rapid urbanization in coastal zones has the potential to affect the local airflow patterns. The impact of airflow variations on coastal dunes are still not fully known. In meteorology, the atmospheric boundary layer (ABL) can be defined as the lowest portion of the atmosphere that is directly influenced by the presence of the Earth's surface. The airflow characteristics in the ABL are strongly dependent on the underlying roughness elements such as buildings, structures, trees and vegetation. Therefore, the resulting airflow perturbations due to urbanization impact the surrounding environment and the adjacent aeolian dunefield. There have been relatively few studies addressing the geomorphological impact of urbanization on aeolian dune dynamics. Hernández-Calvento et al. (2014) implemented an urban airflow model into a geomorphological context and investigated the human-induced changes in aeolian landforms using aerial photographs and LiDAR surveying. Smith et al. (2017) numerically illustrated the direct impact of successive stages of urbanization on aeolian dunefield dynamics. To the best of the authors' knowledge, this study is the first of its kind investigating the effect of different construction patterns on dunefield behaviour. The main objective of this project is to understand the effect of the buildings and their configuration, including geometry, orientation, spacing as well as their distance to the dunefield on aeolian sediment transport.

Methodology

In recent years, the application of computational fluid dynamics (CFD) to study a wide variety of processes in the atmospheric boundary layer (ABL) has progressively increased. In this project, an opensource CFD modeling software, OpenFOAM, in combination with a sediment transport model will be deployed for the simulation of the airflow over urbanized environment and to investigate the morphodynamics of the aeolian dune systems. First, the model will be validated with the field measurements from Poppema et al (2019) who experimentally studies the impact of built environment on the morphological development of the beach-dune system in the Sand Engine along the coast of South Holland (Figure 1). Then, the model will be utilized to investigate the effect of different building patterns along the coast on the aeolian sediment transport and the dunes migration.

Figure 1 Study site (Sand Engine).
Source: www.zandmotor.nl.

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. **QUICK REACTION FORCE EGMOND AAN ZEE:**
MEASURING THE ALONGSHORE VARIABILITY IN STORM EROSION

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Introduction

Along wave-dominated coasts, sandy dunes can erode severely during extreme storms. The volume of eroded dune sand has been observed to vary strongly alongshore. Recent observations show that this alongshore variation in dune erosion may relate to alongshore depth variations of nearshore crescentic sandbars, where shallower areas supposedly reduce the wave attack on the dune. On the other hand, other observations suggest that the pre-storm dune morphology may provide an alongshore-variable sand buffer against wave attack, leading to alongshore-variable dune erosion. The latter suggests that alongshore-variable dune erosion does not require alongshore variability in wave attack. Despite observations of alongshore-variable dune erosion and morphological coupling within the sandbar-beach-dune system, concurrent measurements of the nearshore wave field are lacking. With our research, we aim to quantify the alongshore variability in the wave field reaching the dunes during storms, and investigate its correlation with alongshore-variable (changes in) bed levels.

Methods

During the winters of 2017/2018 and 2018/2019 we deployed 7 pressure sensors spaced 250 m apart, along a 1.5-km stretch of beach on the Dutch coast (Egmond aan Zee). All sensors were located above the high tide water level, each at different elevation levels (maximum 1 m difference). We monitored marine forecasts for approaching storms, and deployed 7 additional pressure sensors 40 m seaward of each initial pressure sensor before the storm surge arrived. During the study period the sensors were submerged several times during storm surges of 1-2 m. Full bathymetric (sonar-equipped jetski) and topographic (mobile laser scanner) surveys were done before and after the storms.

Results

The bed level measurements show a distinct alongshore variability in morphological response to storms across the entire bar-beach dune system. At the meeting we will present our wave data analysis obtained during storm surges and aim to discuss our measurement strategy.

Figure 1 Dune erosion near Egmond aan Zee, observed after the storm of 8 January 2019 (photo: T.D. Price).

THE INFLUENCE OF BASIN GEOMETRY ON THE LONG-TERM MORPHOLOGICAL EVOLUTION OF BARRIER COASTS

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Introduction

Barrier coasts are important for coastal safety, ecology, tourism, and economy. They consist of a back-barrier basin connected to a larger sea/ocean through multiple tidal inlets. Using an exploratory model based on Escoffier's approach (1940), Roos et al. (2013) found equilibrium configurations and reproduced the observed patterns of inlet spacing in mesotidal multiple inlet systems (Stutz and Pilkey 2011). They adopted a strongly schematized geometry of the back-barrier basin: rectangular and of uniform depth. However, this does not reflect the spatial variation in back-barrier basin width that is commonly observed in e.g. the Wadden Sea.

Methods

To investigate the effect that a spatial variation in back-barrier basin has on the long-term morphological evolution of barrier coasts, we extend the model of Roos et al. (2013) to allow arbitrary geometries to be included in the model. A first test with a conically shaped basin shows that where the barrier coast is wider, more and larger inlets are present. The opposite holds for the narrower part of the basin. An example model run is shown in Figure .

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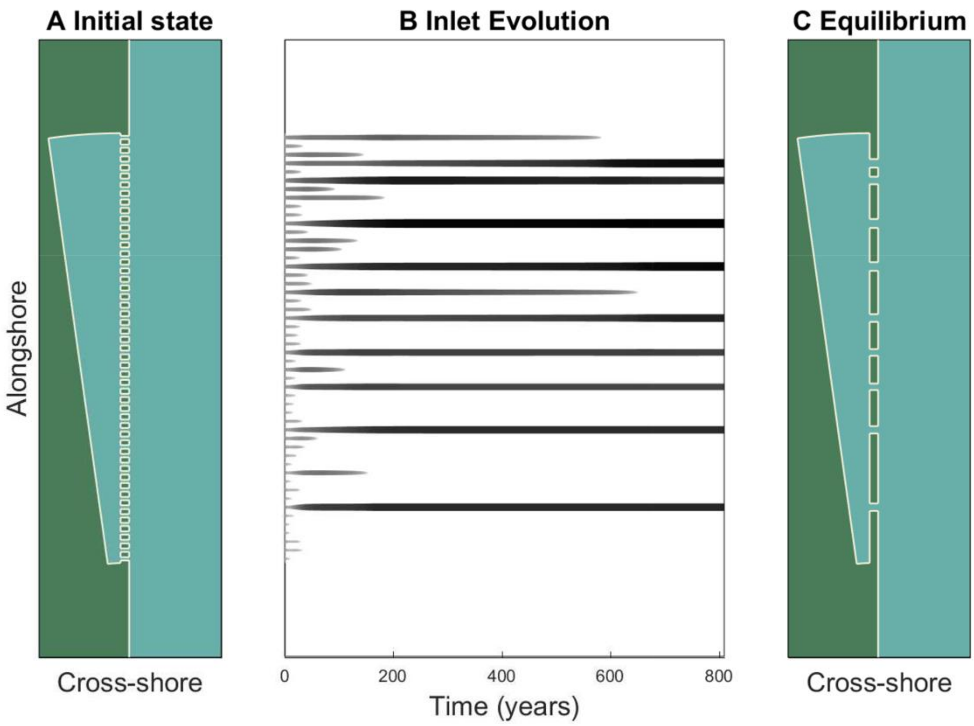

Figure 1: Example run showing the evolution of a barrier coast from a saturated coast with many open inlets (A), evolving over time (B) towards an equilibirum state with 9 open inlets (C).

WHERE DOES THE SAND GO? A MORPHOLOGICAL STUDY OF THE BELGIAN COAST

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The Belgian coast is a 65km long, macro-tidal, sandy coast. This coast fringes a low-lying coastal plain, which is protected against flooding by dunes and dikes. Since the 1970's beach nourishments are implemented for the purpose of coastal safety, as well as maintenance of the recreational beach. Nowadays sand nourishments are the preferred way of coastal protection. However, several locations along the coast struggle with structural erosion and require very frequent re-nourishment.

In this study, the morphology of the Belgian coast is investigated. The volume changes of the Belgian coast have been investigated using a dataset spanning the entire coast from the dunes to 1.5km offshore. The data cover the years from 1992 to 2018 for the whole coast, and locally earlier.
Changes in volumes are presented both as observed and corrected for artificial works such as dredging and nourishments. To correct for these artificial works, the cumulative added volume is subtracted from the observed volumes in the respective areas. The remaining signal is then an estimate of the autonomous morphological behaviour of the coast.

As opposed to what is usually thought, the Belgian coast is not erosive everywhere. Instead, large differences in morphological behaviour are found along the coast (Figure 1). It is expected that the Flemish banks and associated tidal channels contribute to this differential behaviour.
Large accretional areas are found on both sides of the Zeebrugge breakwaters and west of Nieuwpoort, where a sand bank connects to the coast. Erosional hotspots are the areas of Knokke-Zoute and Wenduine. Tidal channels close to the shore are thought to be the cause of this structural erosion. In these erosional areas, nourishments are used to keep up the beach volumes.
In general, the area above the low water line is observed to be accretive. Yet, after corrections for nourishments, only holds about half of the coast shows accretion. The rest is compensation by beach nourishments. The sub-tidal area is merely erosive, and accretion is only found near Zeebrugge and west of Nieuwpoort.

Closer inspection of the accuracy of the investigated data must point out at what rate the coastal volumes are evolving and which trends are significant.

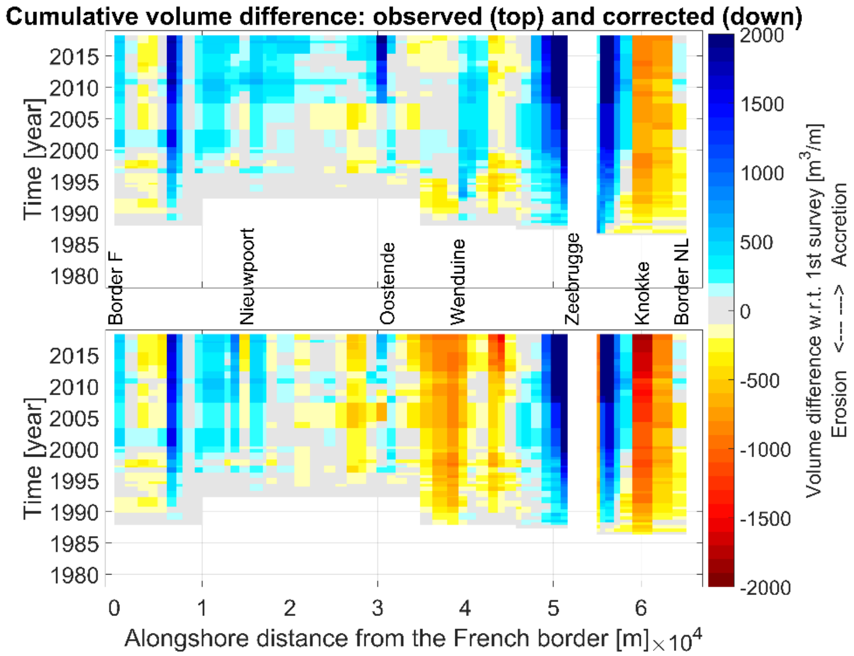

Figure 1 Time stack of cumulative volume differences along the Belgian coast. Cold colours indicate accretion, warm colours erosion. Top panel: observed values, bottom panel: after corrections for artificial works.

EVALUATION OF UNCERTAINTY ASSOCIATED WITH PROJECTIONS OF CLIMATE CHANGE-DRIVEN COASTLINE VARIATIONS IN JAPAN

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Introduction

In Japan, projections of future beach erosion (up to 2100) have been estimated using the Bruun rule[3]. However, Bruun rule-derived coastline projections[4] are difficult to use in coastal hazard risk assessment, because they are deterministic and uncertainty from storms is not included[5,6].

The research goal was to quantify uncertainty related to sea level rise and storm definition in the Bruun rule-derived future shoreline positions in Japan, by comparing these projections with the results of Probabilistic Coastal Recession (PCR) models[7].

Methods

Three sites in Japan were considered for this research. These were sandy beaches with (almost) no hard structures. Four different sea level rise (SLR) scenarios[8] were used in the setups of PCR models. Empirical cumulative distribution functions (ECDFs) describing coastal recession exceedance probabilities were produced with the PCR model results. Two ECDFs were made per data set based on annual maximum landward shoreline positions (R_{max}) and shoreline positions derived from 5-year trend lines (R_{trend}). Exceedance probabilities for Bruun estimates were derived with these ECDFs (Figure 1).

Results

For 2100 and the most severe SLR scenario, the exceedance probabilities derived with the ECDFs for R_{max} for Bruun rule estimates were: 49% and 44% with the two PCR models for site 1; 18% and 77% with the two PCR models for site 2; and 43% with the single PCR model for site 3.

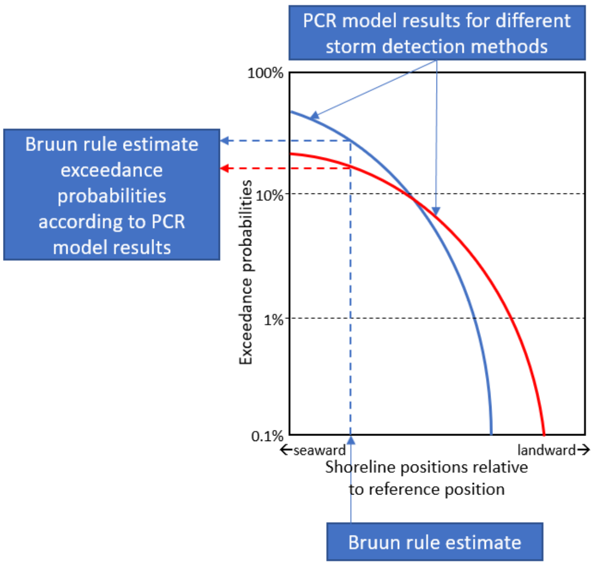

Figure 1. Explanation of the comparison of Bruun rule estimates with PCR model results. The example shown are hypothetical results of a PCR model and Bruun rule calculation for one site for one SLR scenario for one particular year.

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MODELING OF LONG-TERM SHOREFACE MORPHODYNAMICS UNDER SEA-LEVEL RISE

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Introduction

Coastlines are expected to retreat due to a globally accelerating sea-level rise. To anticipate future land loss, it is important to know how coastal zones will react to a rising sea, both now and on the long term. Here, we present a morphodynamic model that describes the transient development of a sandy wave-dominated shoreface. We then subject this model to sea-level rise to study how this affects the coast.

Methods

Our morphodynamic shoreface evolution model is based on descriptions of wave-induced sediment transport mechanisms, consisting of a slope-induced component directed offshore, and onshore-directed components resulting from shoaling of waves (Bowen, 1980). Assuming alongshore uniformity, these descriptions of sediment transport are coupled to bed development through the Exner equation (following Ortiz and Ashton, 2016). This results in a PDE bounded by the shoreline and a point (far enough) offshore. The onshore boundary is a moving boundary obeying a so-called Stefan condition as done by Swenson et al. (2005). Furthermore, a parametrized onshore overwash flux is added to the model formulation to represent back-barrier sediment deposition, which is widely recognized as the driving mechanism behind barrier beach persistence (Lorenzo-Trueba and Ashton, 2014).
Discretization of the model is done through a finite difference scheme; the Stefan condition is implemented through a fixed grid method that treats the shoreline boundary as an auxiliary variable. This numerical implementation results in short computation times (~10 minutes) for long simulation periods (~1000 years).

Results

Model simulations support earlier findings from Wolinsky and Murray (2009) by showing that the long-term retreat rate of the boundary depends on the regional slope and only initially follows the Bruun rule (Bruun, 1962). Over time, this results in faster retreating coast for shallow regional slopes (Figure 1) and slower retreating coasts for steep regional slopes (Figure 2) than predicted by the Bruun rule, although adjustments between short-term and long-term trajectories take significant (> 1000 yr) timescales to manifest, even for rapid rates of sea-level rise.

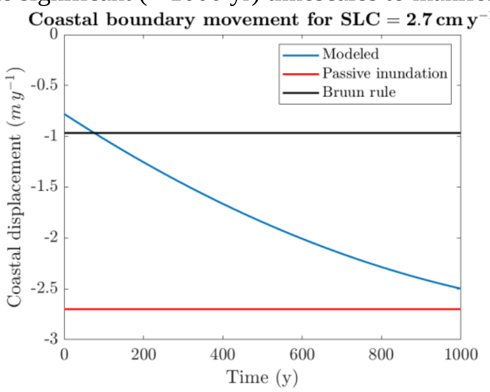

Figure 1: Boundary retreat rate for a shallow regional slope (0.01 m/m)

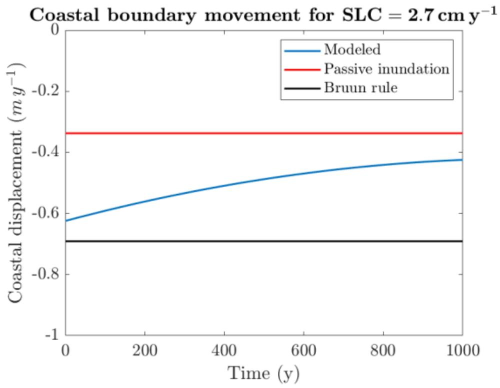

Figure 2: Boundary retreat rate for a steep regional slope (0.08 m/m)

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MORPHOLOGICAL EVOLUTION OF SUBMERGED MOUNDS UNDER HYDRODYNAMIC FORCING

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Rising sea levels, and changes in storm patterns owing to climate change threaten coastal areas with erosion. A variety of protective measures exist to stall erosion, among which nourishments are ever gaining popularity. However, despite the wide application of nourishments, the hydrodynamics around nourishments are not fully understood. To achieve a better understanding of sediment movement at the vicinity of nourishments, MODEX (MOrphological Diffusivity EXperiment) was conducted in May/June 2018 (Figure 1) with the aim to establish a link between the imposed hydrodynamic forcing and observed morphodynamic response of a sandy mound in shallow water.

Figure 1: Left: The tested sand mound. Right: Impression of the mound after an experiment.

Here, observations from nine tests of hydrodynamic conditions on the sandy mound of (water column) velocities and bathymetry data are presented, to show the relationship between mound diffusion and incident wave, current, and combined wave-current conditions. The chosen aspect to express the hydrodynamics is flow energy, as it allows the comparison between the different conditions. In particular, a measure of the energy of the flow related to the maximum occurring velocity is used, $\overline{U_{max}}^2$.

The observations show a linear relationship between mound height reduction rate and flow energy, irrespective of whether the energy is owing to waves or currents. The same holds for the migration rate of both the mound footprint and peak. An inverse linear relation is found between post-experimental mound footprint shape (length/width ratio) and flow energy. Regarding footprint area changes, no uniform relation can be established for all the hydrodynamic conditions. The observations seem to follow a parabolic rule with flow energy under waves, while a linear relationship is apparent under current, and combined conditions. Finally, within the flow type subgroups the cases may comply fully to the general (linear) relationship or show different behaviour locally (cluster or spread).

The established relationships show that a mound is expected to lower more quickly and move downstream further with increasing flow energy, regardless of the kind of conditions that it is imposed to. All those measures of morphological change scale with the flow velocities in the water column. However, the spreading of the mound (in terms of footprint area) follows different relationships depending on the hydrodynamic conditions, as is shown from the two occurring relations. All the above refer exclusively to the flume scale and the experimental conditions. Possible implications for field scale nourishments will be discussed.

THE EFFECT OF AEOLIAN PROCESSES ON THE HONDSBOSSCHE DUNES

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Introduction

The mega nourishment of foreshore, beach and dunes (36 Mm^3) at the Hondsbossche and Pettemer Sea Defence in The Netherlands was monitored for 3 years from 2015-2018. The aim of this Ecoshape innovation project was to increase understanding of how aeolian processes shape a constructed dune and how this can be applied to optimise the design and create additional value such as coastal safety, ecological development and optimal spatial integration.

Methods

For this purpose a monitoring program was set up which included 9 laser altimetry measurements and aerial photographs of the zone above the waterline, covering the entire project area, including some of the adjacent coastline. Also, half-yearly site visits were conducted and the ecological development was monitored. Dune growth rates, beach erosion rates and wind data were analysed for this period.

Results

It was found that the average dune growth rate over the first three years is 33 m^3/m^1/year. Important sources of the sand that blows into the dune area are the shallow foreshore and the intertidal beach as over 50% of the sand originates in those areas. The dune growth rates vary along the nourishment which is explained by the orientation of the dune foot with respect to the dominant wind direction, the beach width and the sediment grain size.

It was observed that most sand is captured in the dune foot and on the seaward side of the dune. This area quickly evolves in a natural looking area with fresh and healthy vegetation. It is this dynamic zone where, in future projects, the aeolian evolution can be directed by planting variable patches of vegetation, applying a variable geometry or adding willow screens. This can prevent dynamics if required for coastal safety or to reduce hindrance, but it also offers opportunities to stimulate dynamics at locations where this is desired.

In combination with the Dutch coastal policy of maintenance the dune growth means that the coastal area becomes safer and is able to keep up with sea level rise.

Figure 1 Aerial photographs of central part with dune valley, showing evolution of dune area over two years. The view is Northward, with the North Sea (not visible) and beach on the left side.

THE DYNAMIC VEGETATION MODULE: A PROCESS-BASED MODELLING TOOL FOR BIOGEOMORPHOLOGICAL SYSTEMS

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Introduction

More and more research is being carried out on the interaction between hydrodynamic systems and ecosystem responses, some of it presented at previous NCK conferences. Process-based modelling of these systems can help to gain insight into various applications related to flooding, wave attenuation, erosion, sedimentation, landscape development and ecosystem services. Key issues for modelling of such complex systems are computation time, interactive exchange of parameters and trade-offs between user-friendliness and reproducibility. Deltares has developed a new model instrument that can be applied to study feedbacks between hydrodynamics, sediment transport and ecosystem responses. This standardised Dynamic Vegetation Module simplifies numerous ‘personal’ scripts, whilst allowing flexibility for various applications. Thus far, formulations for vegetation dynamics have been developed for several vegetation types (i.e. river floodplains, mangroves, sea grass and salt marshes). Furthermore, the module could potentially be applied to simulate the dynamics of other types of biota.

Methods

Requirements for the new module are computation time, coherency and interactive exchange of parameters at variable ecological time step. In the Dynamic Vegetation Module the vegetation development is simulated in Python based on formulations for vegetation establishment, growth and decay. A Basic Model Interface (BMI) allows communication with any selected BMI compatible hydrodynamic model (e.g. Delft3D FM and XBeach) directly via memory, as well as running of single or multiple time steps[1]. Utilising this concept, the Python module continuously communicates with the hydrodynamic model to obtain flow parameters (e.g. water levels, velocities, shear stresses, bed levels) and then computes the vegetation response based on these physical parameters. Next, it communicates the updated vegetation parameters to the flow model to continue the hydrodynamic simulation.

Case study

The development of *Spartina Anglica* at the Plaat van Valkenisse[2] (figure 1), was modelled as case study. The initial vegetation presence is modelled by a random field. Growth and decay are simulated based on bed level change, inundation time and a diffusive growth function. The results (figure 2) compare favourably to the actual development based on satellite images.

Figure 1: Patch of Spartina Anglica at Plaat van Valkenisse (Western Scheldt)

Applications

The Dynamic Vegetation Module has already been applied to study the development of a river floodplain[3], the influence of sea level rise on a mangrove coast in Guyana[4] and the feedbacks between seagrasses and suspended sediment in the Rødsand lagoon, Denmark[5]. Currently, our tool is being used to research the interaction of a seagrass-coral reef system in Saint Martin and salt marsh development under influence of tides and waves based on the Windows-of-Opportunities concept in the Western Scheldt.

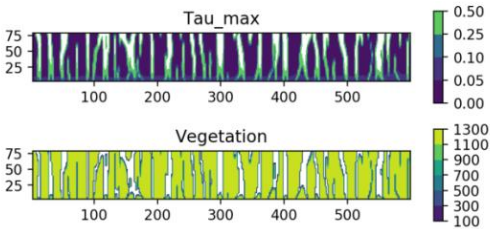

Figure 2: Resulting maximum bed shear stress and vegetation density using the Dynamic Vegetation Module

[1] Source: http://github.com/csdms/bmi;

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USING VINTAGE SEISMIC DATA FOR MODERN-DAY GEOLOGICAL MAPPING

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Results

The Geological Survey of the Netherlands has a large archive with historical North Sea data. A vast volume of vintage seismic data recorded in the 2nd half of the 20th century is recorded on paper scrolls. These data are commonly of very high quality and can be the only available seismic information for particular areas. They give valuable insights into the geological architecture and distribution of sediment type in the North Sea subsurface. Over the past years, we scanned all paper sections to make them available for further digital processing. A method to transform these scanned images to a digital seismic format (SEG-Y) has been optimized and tested for several datasets. In the SEG-Y format the historical data now fit the "create once, use many times" principle and can easily be included in modern-day mapping and modelling programs. The aim for the near future is to make these datasets easily accessible for the public through our open-access portal, helping users in science, government and industry to increase their understanding of the North Sea.

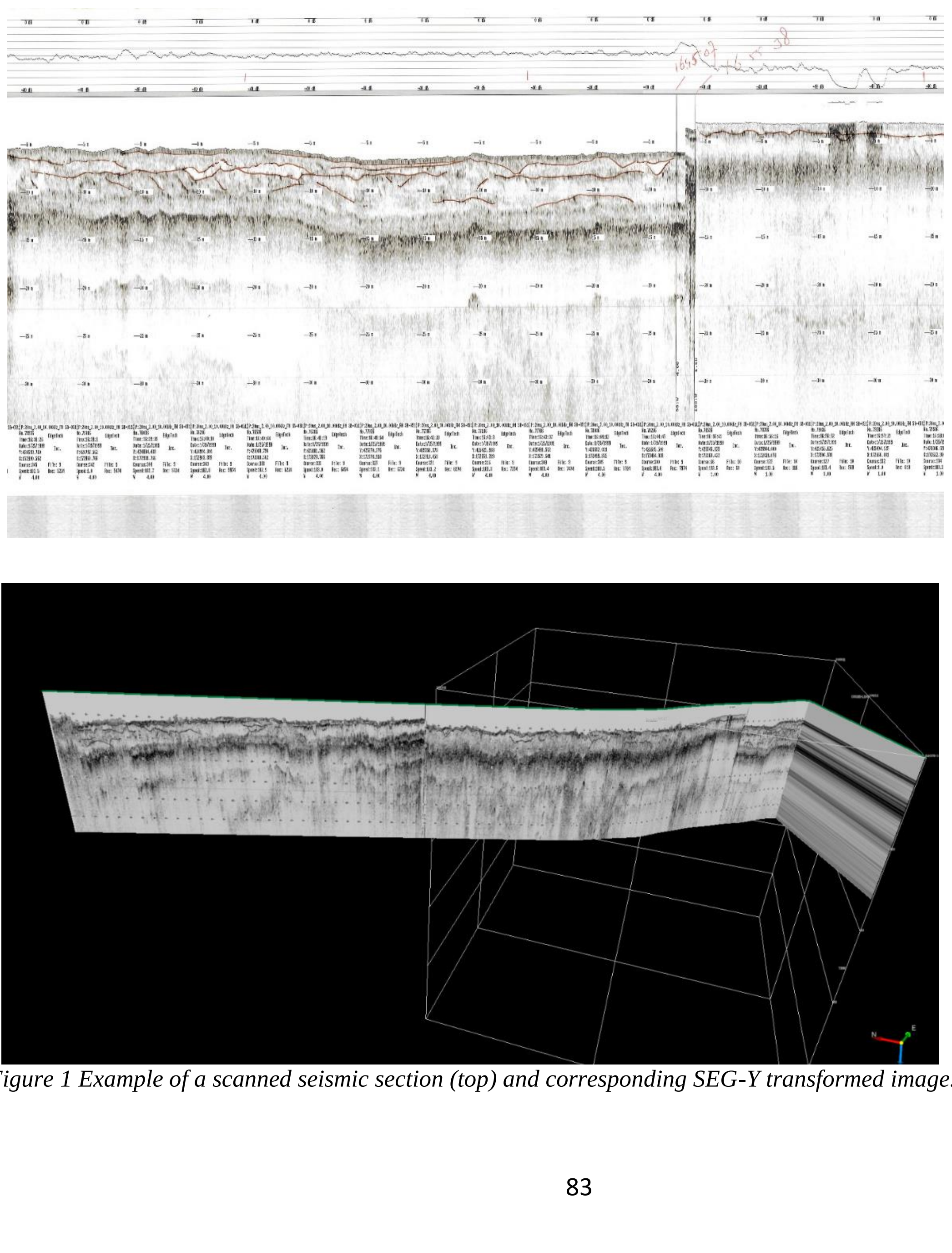

Figure 1 Example of a scanned seismic section (top) and corresponding SEG-Y transformed image.

AEOLIAN SEDIMENT INPUT TO THE BELGIAN COASTAL DUNES

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Sediment input by wind to the adjacent coastal dune system at the decadal timescale is usually predicted by incorporating hourly wind speed and direction data measured at standard meteorological stations into sediment transport equations. Variations in aeolian sediment input to the dunes, along the Belgian coast, were calculated based on a modified Bagnold model using representative values for mean grain size and coastal orientation. The modified Bagnold model is validated by aeolian field campaigns carried out since 2016. These potential sediment calculations were related to dune volume changes for the period 2000-2017. Since the 1970's, LiDAR surveys are performed along the 65 km Belgian coast to monitor beach, foreshore and dune. Depending on the amount of aeolian sediment input and dune erosion, dune volume changes over time. Worldwide, dune volume is an important factor for coastal safety which provide protection for the hinterland against storms. Dune volume changes along the Belgian coast are generally between -50 and +50 m³/m (Figure 1). Between each survey there is considerably longshore variability in dune volume change. Furthermore, large differences in dune volume change are found between each year. Dune volume change along the Belgian coast mainly show a positive linear trend in time (dune growth). It is found that half of the coastal sections with dune growth have correlation coefficients larger than 0.9. This indicates that a large part of the dune volume data is well represented using a linear model in time. For the period 2000-2017, the wind regime consists of a fairly balanced mix of moderate (85% of winds are below 8 m/s) onshore, offshore and shore-parallel winds. Wind speeds between 8-10 m/s take the largest portion of the total sediment transport. The mean direction of potential transport over all years is 260 ± 14° to the North (southwest), indicating that the direction is fairly constant. For some years potential transport is up to 3 times larger than other years. Aeolian sediment input to the dunes varied between 0 and 16 m³/m. However, no significant relation is found between dune behaviour and potential sediment transport on yearly to decadal timescale. Due to transport limiting factors, wind forcing alone is not sufficient to explain the year-to-year variability in dune growth rates at the Belgian coast.

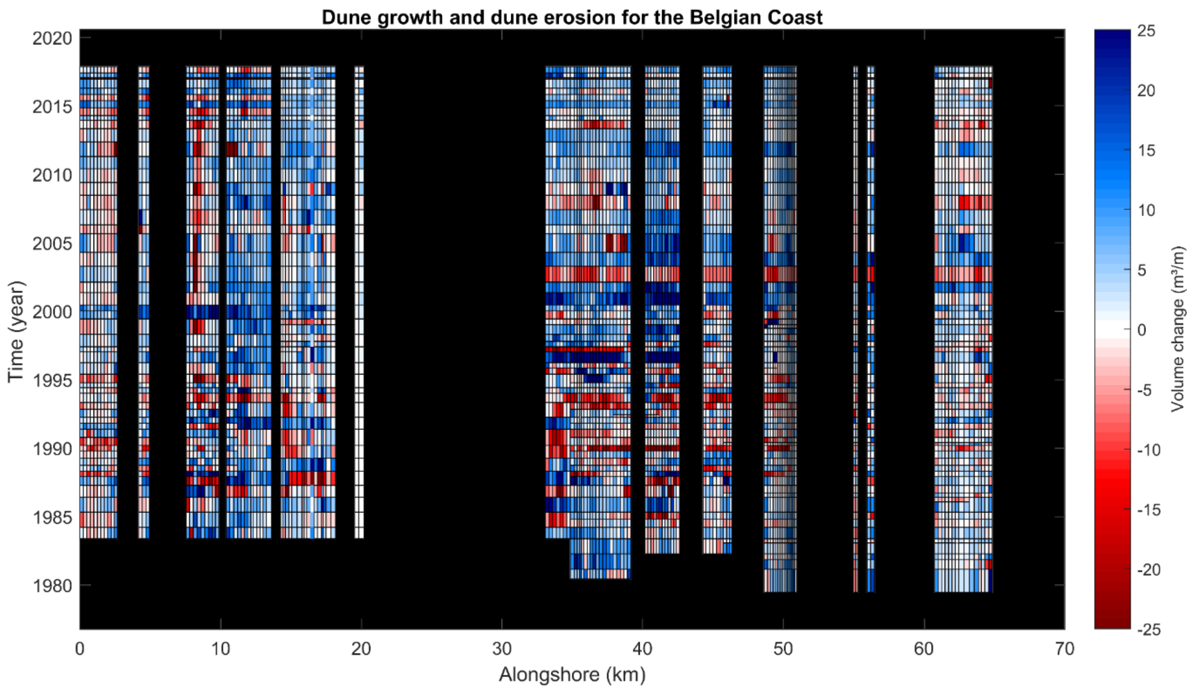

Figure 1 Dune growth and dune erosion along the Belgian coast since the start of the LiDAR measurements. The columns represent the coastal sections with presence of vegetated dunes.

CHENIER DYNAMICS AT AN ERODING MANGROVE-MUD COASTLINE IN DEMAK, INDONESIA

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Introduction

The erosion of mangrove-mud coasts is a serious problem worldwide, affecting millions of people in their daily life. For example, income drops of 60-80% and halving of commercial sea fishing over a period of 5-10 years have been reported in eroding areas of Java, Indonesia, largely attributed to the loss of mangrove spawning and sheltering grounds (Manumono, 2008).

This research focuses on the role of cheniers in the dynamics of mangrove-mud coasts. A chenier is defined as a beach ridge, resting on silty or clayey deposits, which becomes isolated from the shore by a band of tidal mudflats (Augustinus, 1989). A GIS study by van Bijsterveldt (2015) shows that the presence of cheniers has a positive effect mangrove vegetation. Cheniers create shelter, in which mangrove vegetation can recover. However, cheniers can be extremely dynamic and little is known about the dynamics of cheniers in this area: what is the origin of the sand, how are cheniers formed, how will cheniers evolve?

Figure 1: Drone photo of a chenier in front of the Demak coastline (Indonesia, December 2018) (Tas, 2018)

This poster will focus on four hypotheses on the chenier dynamics: (i) Cheniers are formed by wave action during periods of reduced sediment supply (the classical mechanism, in which cross-shore processes are dominant); (ii) Cheniers are formed as a river mouth spit and are transported alongshore (longshore processes dominant); (iii) Cheniers are created during extreme events; (iv) Cheniers are created in response to changes in tidal prism.

Methods

During a field campaign between October and December 2018 in Demak, Indonesia, one chenier was intensively monitored (hydro- and morphodynamics). This data will be used to set up and validate a numerical model (Delft3D), which will be used to systematically test the hypotheses. First, a 2DV model will be set-up (one cross-section, perpendicular to the coastline) and validated with data from a field campaign carried out between October and December 2018 in Demak, Indonesia. This 2DV model will be subsequently simplified to test hypotheses (i) and (iii). In a next step, the model will be extended to a 3D model, such that hypothesis (ii), (iii) and (iv) can be tested through additional numerical experiments.

Results

The numerical model will give a range of conditions under which each mechanism can occur. This could help explain the chenier dynamics any given coastline, and predict how cheniers will evolve under changing boundary conditions in the future.

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The Timing of Events Matters for the Eco-Morphology of Intertidal Flats

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Introduction

The impacts of storms on the hydrodynamics in estuaries are generally of shorter duration than on open coasts, as the boundaries limit the fetch lengths. In these storms, the waves coincide with the wind events generating them. Also without meteorological influences, the water levels and flow velocities vary substantially over hours. In this research, we show the importance of timing of events within the tidal cycles, explaining strong spatial inhomogeneous impacts on estuarine intertidal flats.

Methods

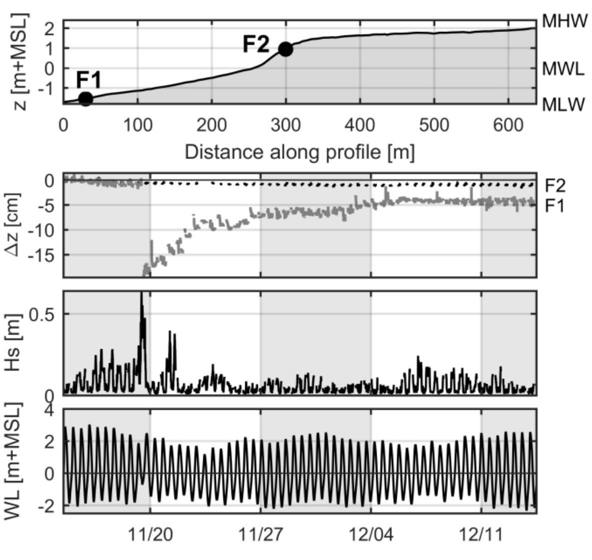
We employed two frames (see F1 and F2 in Figure 1) on an intertidal flat in the Western Scheldt (near Ellewoutsdijk). Each frame was equipped with instruments measuring hydrodynamics (ADV, ADCP and wave logger), sediment concentrations (OBSes) and bed level changes (ADV). This one-month dataset was complemented by our 1.5 years EMERGO field campaign on benthos, grain sizes, waves, flow and bed level changes that also covered this site.

Morphodynamic response

The morphodynamics during the one-month measurement campaign was dominated by the impact of a single storm, which lowered the bed with 20 cm at F1. This was in big contrast to the almost negligible impact at F2. These substantial differences in impact are explained by the timing of the storm: (I) the peak of the storm coincided with low water during which F1 was submerged with a limited water depth (~1m) for 4 hours, implying the waves to have a large impact for a long duration; and (II) the wind generated a flow of 1 m/s at F1. The combination of these hydrodynamic adjustments due to the storm imposed the large impact. When by the rising water level also F2 submerged, the wind and waves were already substantially reduced. Within days, half of the impact at F1 was already recovered. However, a net impact of 5 cm remained.

Impact on ecology

The local impact of a storm depends highly on its timing within the tidal cycle. Even though intertidal flats may recover substantially on short time scales, long-term consequences may persist. These affect also benthic communities. This is supported by relations between our benthic data and wave measurements. The impact on ecology is likely to exceed the morphological recovery timescale, especially for events with large changes in bed level. These insights have direct implications for the long-term modelling of intertidal flats, and the prediction of the evolution of its benthic species.



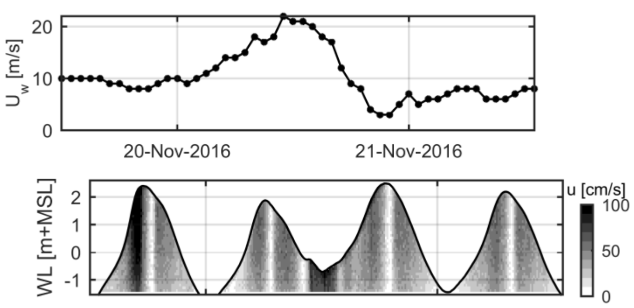


Figure 1 – Top left: the cross-section of the intertidal flat with the position of the measurement frames. Bottom left: the measured bed level changes at F1 and F2, the wave heights measured at F1 and the water level. Right: The water level with velocity magnitude over the water column, as measured at F1 during the storm, with the wind speeds over this time frame.

INTERTIDAL DRAINAGE PATTERNS AS INDICATOR FOR BIOSTABILISING ECOSYSTEM DEVELOPMENT

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Introduction and methods

Estuaries are changing rapidly due to climate change and direct human interventions, urging for indicators of critical transitions causing loss or recovery of valuable biostabilising ecosystems (e.g., algal biofilms, vegetation). Self-organisation theory provides an indicator framework based on spatial patterns that can be observed in many natural systems. We lay the foundations for deriving an intertidal indicator system by constructing an idealised numerical model that couples the dynamics of water flow, morphology and biostabilisers.

Results

Model simulations show that self-organisation due to one scale-dependent feedback explains a wide range of intertidal drainage structures. This scale-dependent feedback consists of a local positive feedback due to sediment biostabilisation and a scour-induced long-range negative feedback. These feedbacks create regularly spaced, linear drainage channels around biostabilised banks. Weak feedbacks (e.g., when sediment cohesion in the system is low) create a flat drainage landscape. Stronger feedbacks create steeper channel banks, inducing flow and hence a secondary drainage pattern across these primary channel banks. This “cascade” of scale-dependent feedbacks can hence form complex drainage morphologies (Figure 1).

Implications

Our results point out the degree of drainage pattern complexity (flat, linear, higher-order) as an important indicator for intertidal ecosystem transitions, as its biostabilisers strongly rely on drainage. Moreover, our findings may provide insight in how landscapes formed in biofilm-dominated ecosystems in the Precambrian and how they changed through geological time, after the evolution of higher plants.

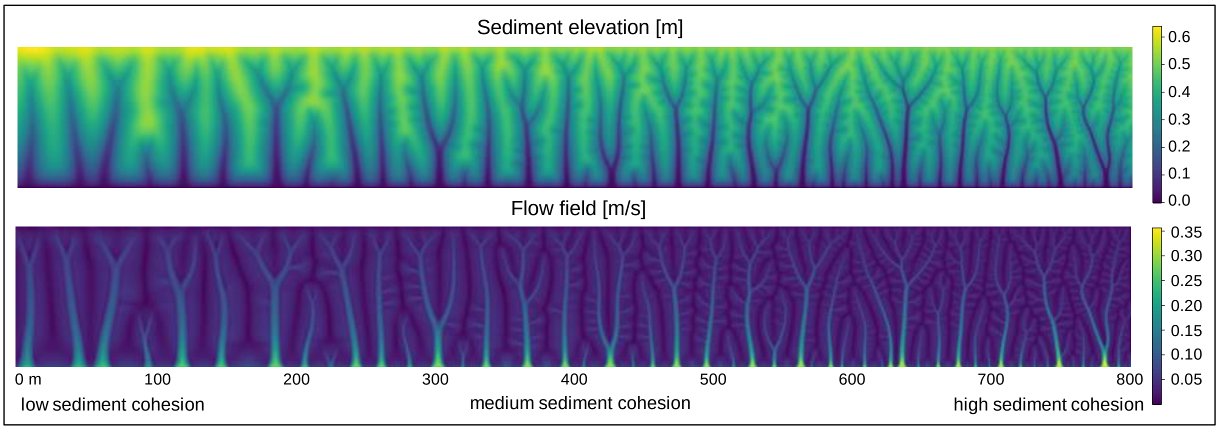

Figure 1 Top view on simulated drainage topography (m) and flow speeds (m/s) along a gradient of (to the right) increasing sediment cohesion. Outflow occurs through the lower boundary; the other boundaries are closed.

EXPLORING THE RELATIVE IMPORTANCE OF WIND FOR EXCHANGE PROCESSES AROUND AMELAND INLET

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Introduction

As part of the Kustgenese 2.0/SEAWAD programme, we aim to quantify the exchange of water and sediment between the North Sea and the Wadden Sea. This knowledge is essential to forecasting the sediment budget of the Dutch coastal system in relation to sea level rise and - in response - to optimize nourishment strategies. In this particular research we study how wind forcing and the connectivity of tidal basins in the Wadden Sea affect the exchange of water and sediment through Ameland Inlet.

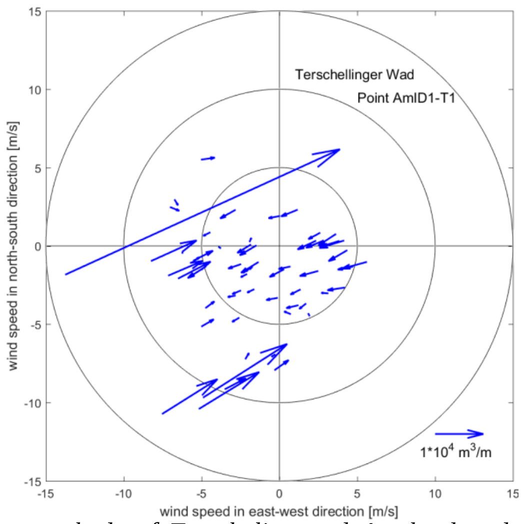
Methods

This study combines field observations with Delft3D modelling. Field observations were obtained during a 40 days field campaign around Ameland Inlet in fall 2017. Flow velocities were measured in Ameland Inlet's main channel (i.e. Borndiep) and at three observations points on each of the watersheds of Terschelling and Ameland. The coupled Delft3D-SWAN numerical model is used to unravel the contribution of different forcing mechanisms (i.e. waves, wind, surge and tides), and to extend the measurements in space and time.

Results and conclusions

The direction and magnitude of residual flows over the watersheds of Terschelling and Ameland depend on the wind forcing in relation to the orientation of the watersheds. During calm wind conditions, residuals are directed towards the west of the watersheds. Stronger winds from the west-southwest generate a residual flow towards the east (Figure 1). The magnitude of wind-driven residual flows over the Terschelling watershed can exceed the mean tidal prism of Ameland Inlet. The residual discharge per tidal period over Ameland watershed is only 25-30% of the residual discharge over Terschelling watershed. This leads to residual flows through Ameland Inlet.

Due to the flow over the watersheds, Ameland Inlet experiences a residual outflow in 2017 (Figure 1). The seasonal variations in wind forcing lead to seasonal variations in the residual flow through Ameland Inlet. The combination of residual outflow with high waves on the ebb-tidal delta during strong wind conditions has large consequences for the sediment exchange through Ameland Inlet.



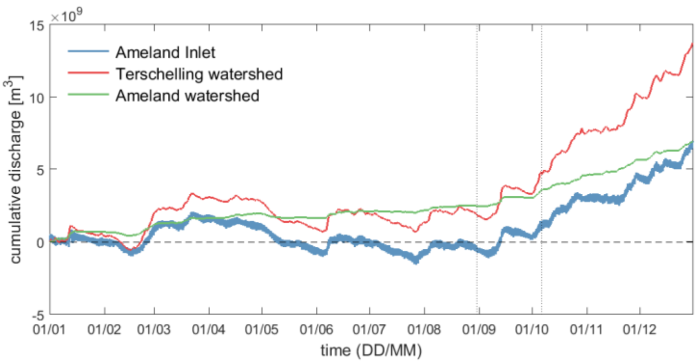


Figure 1. Left: Direction and magnitude of the residual discharge for every tidal period during the field campaign (i.e. the arrows) in relation to the tide-averaged wind conditions (i.e. the position in the wind rose), as measured at an observation point on the Terschelling watershed. Right: Time series of residual discharge over the watersheds of Terscheling and Ameland and through Ameland Inlet in 2017, based on Delft3D modelling results. Eastward (watersheds) and northward (inlet) flow are considered positive. The vertical dotted lines indicate the timespan of field observations.

MFlat explores wave-induced morphodynamics on intertidal mudflats

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Intertidal mudflats are key features sustaining a vital estuarine environment and protection of estuarine hinterlands against wave induced flooding. Their bed is shaped by hydrodynamic forcing of waves and tides, sediments and surrounding planform of channels, marshes (mangrove belts) and levee systems. It is essential to develop a better understanding on governing processes and forcing sensitivities to assess mudflat response to changing environmental conditions such as changing prevailing sediment concentrations, land reclamation works and sea level rise.

We developed an open source matlab code (MFlat) including an along-shore momentum equation, a cross-shore mass equation, the advection diffusion equation for sediment transport and a wave energy equation that allows for a straightforward computation of cross-shore mudflat morphodynamics, similar but less complex and more accessible than Delft3D. MFLat allows the inclusion of channels adjacent to the mudflat so that complex channel-shoal dynamics can be studied.

Model results show skill full development towards equilibrium cross-shore channel-mudflat profiles including both along-shore and cross-shore tidal flow. Similar to observations, the equilibrium mudflat bed show considerable sediment dynamics and large wave induced sediment concentrations during a tidal cycle, albeit that the tide residual effect is zero. In addition, we assessed the impact of extreme storm events and wave climatology on the equilibrium profile. The mudflat profile is remarkably resilient on changing wave forcing conditions. Observations show mainly erosion patterns at the edge of the channel-mudflat. The model shows similar patterns and recovery equilibrium conditions within 100 days after a 1 day extreme wave event. Wave climatology is imposed via the well-known mormerge approach (applied on sandy beaches), where multiple wave conditions are run in parallel on an evolving bed merging the impact of the multiple wave conditions. Preliminary modelling results show the impact of sea level rise on a variety of mudflat configurations, where mudflats react with inertia and slowly drown under all sea level rise scenarios.

Keywords:
Mudflats, wave climatology, estuarine morphodynamics, process-based modeling.

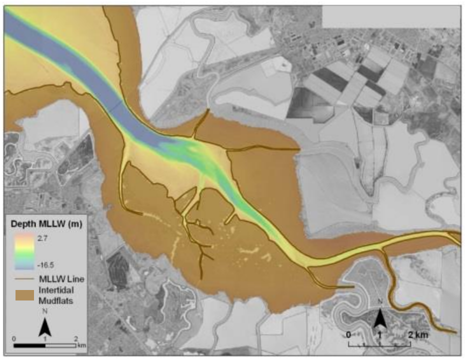

Figure 1. Location of modeled transect in South San Francisco Bay

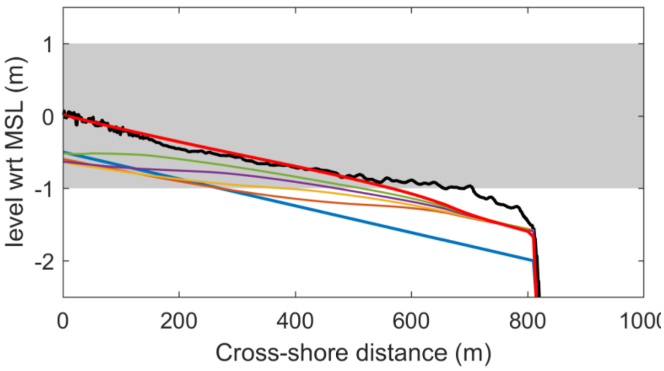

Figure 2. Cross-section showing observed bed level (black) and morphodynamic development towards an equilibrium state after 100 years (colored lines).

THE EFFECT OF MUD AND VEGETATION ON SHAPING NET INFILLING ESTUARIES

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Introduction

Stratigraphic records show that many Holocene estuaries were infilled and closed off from the sea, but how is unclear. Yet, understanding how to build and raise land to keep up with future sea level rise is urgently needed. Current understanding of estuaries and analogies with rivers suggest that mud and vegetation play a key role in this process by elevating bars and confining flow. We aim to unravel experimentally how these local processes affect the filling up of entire estuaries, and what the resulting stratigraphy becomes.

Methods

We used a 20 m long by 3 m wide tilting flume (the www.uu.nl/Metronome) to simulate complete tidal systems developing from an initially long rectangular basin with barrier islands. Tidal flow was driven by periodical tilting of the flume, which favoured ample and realistic sediment transport in both the flood and ebb direction. Tilting was done asymmetrically such that sediment was net imported (flood asymmetry; M2+M4), which is in contrast to former exporting systems simulated in the Metronome. We ran three experiments, one with only sand, a second with sand and mud, and a third with sand, mud and vegetation. Mud was simulated as crushed walnut shell, which was added to the river discharge and at the tidal inlet. Sprouts of three species with different colonising strategies simulated natural vegetation. The experiments were run for 10,000 tidal cycles, and the following data were acquired: time lapse imagery, bathymetry maps for every 100 to 1,000 tidal cycles, and stratigraphic cross-sections.

Preliminary results

Mud in the infilling estuaries with perpetual channel-shoal migration was deposited on top of bars and in abandoned channels, reduced overall dynamics due to its cohesivity, and its preservation potential increased in the landward direction. Vegetation effectively trapped most fluvial mud, resulting in considerable topographic variation on the fluvial bayhead delta, and strongly reduced bar mobility. Vegetation colonised both muddy and sandy tidal bars, suggesting that mud is not a prerequisite for vegetation settlement in estuarine environments. Peat layers formed in the stratigraphic record by vegetation burial. The large-scale effect of mud and vegetation is lower dynamics, especially in the upstream part of the estuary, and faster local accumulation, effectively narrowing the estuary (Fig. 1).

This research was funded by the European Research Council (ERC Consolidator grant 647570 to MGK). We would also like to thank the technical staff of Physical Geography for their support.

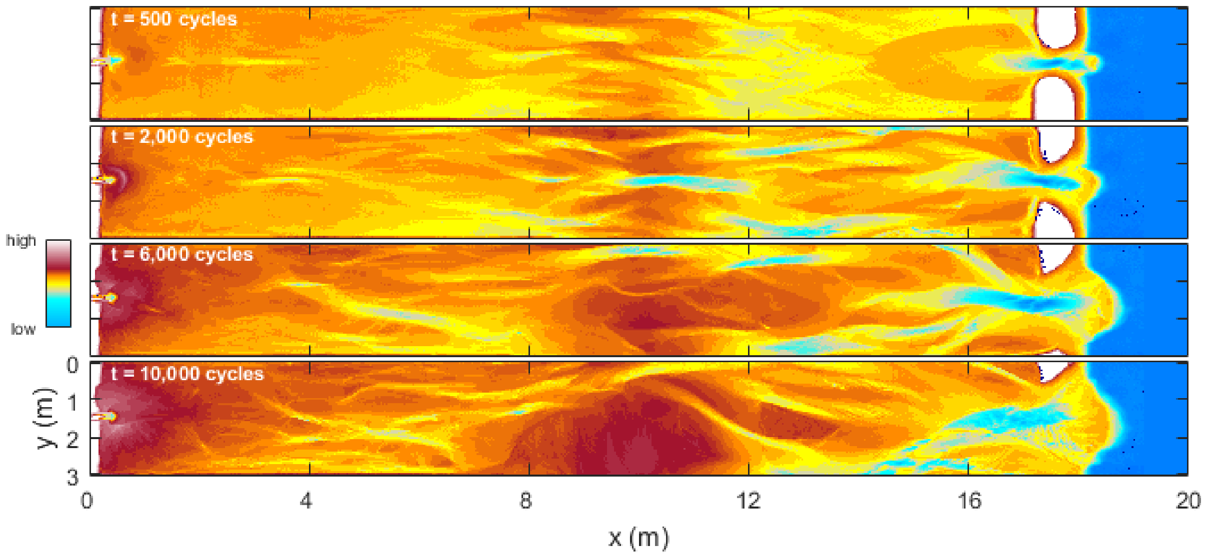

Figure 1 Morphological development of experiment sand+mud. Elevation is not yet calibrated.

AEOLIAN MODELLING OF COASTAL LANDFORM DEVELOPMENT

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Introduction

Coastal dunes serve as a first line of protection against flooding by the sea. In the recent past, the interest in secondary services provided by coastal dunes, such as ecological values and recreation, has increased. To manage and maintain the coastal as an attractive area that combines these services, the natural dynamics must be understood. In view of this, numerical models with quantitative predictive capabilities on the development of coastal dunes provide a useful tool for coastal zone managers. Several models related to aeolian sediment transport and dune development are currently available, but none of these individual models is currently used for engineering purposes. The aim is to improve the current aeolian modelling state of the art by coupling capabilities from different existing models, developing a modular aeolian transport model with quantitative predictive capabilities for dune development.

Methods

We have combined model formulations of three aeolian transport and dune models. The *AeoLiS* model (Hoonhout and de Vries, 2016) is a process-based aeolian sediment transport model with spatiotemporal varying sediment availability, capable of simulating both supply- and transport-limited situations. Coastal Dune Model (*CDM*) (Durán and Moore, 2013) does contain dune building processes including a quantitative description of turbulent flow fields over smooth hills, a continuum saltation model and avalanching. In cases where beach dune vegetation dynamics are significant, Dune-Beach-Vegetation (*DUBEVEG*) (De Groot, 2012) provides a practical implementation of vegetation dynamics. The supply-limited approach from *AeoLiS* is combined with the dune development processes and general formulas for vegetation growth and their influence on the shear stresses from *CDM*. Vegetation parameters as vertical growth, sediment burial tolerance, germination and lateral expansion are adapted from *DUBEVEG*. To reproduce the influence of the sea, marine sediment supply in the intertidal zone and the mechanical erosion of sediment and vegetation during extreme events are implemented as well.

Results

The combined model is now capable of simulating barchan dunes (Figure 1a) and parabolic dunes (partly). The inclusion of seed germination and lateral vegetation expansion causes the growth of randomly located hummocks, creating embryonal dune fields (Figure 1b). The modular structure of the model makes it possible to couple it to hydrodynamic-, groundwater- or vegetation-models, with the eventual possibility to simulate complete coastal areas. The model can potentially be used to determine the influence of tidal ranges, storm frequencies, armoring, salinity and precipitation on dune building processes. This will result in a greater insight in the general behavior of coastal systems, including the evolution of embryonal dune fields as well as foredune characteristics like maximum height and auto cyclic formation of transversal dunes. On the other hand, the model can also be used during more practical situations such as computing recovery times of coastal dunes after extreme events or for the creation of artificial blowouts.

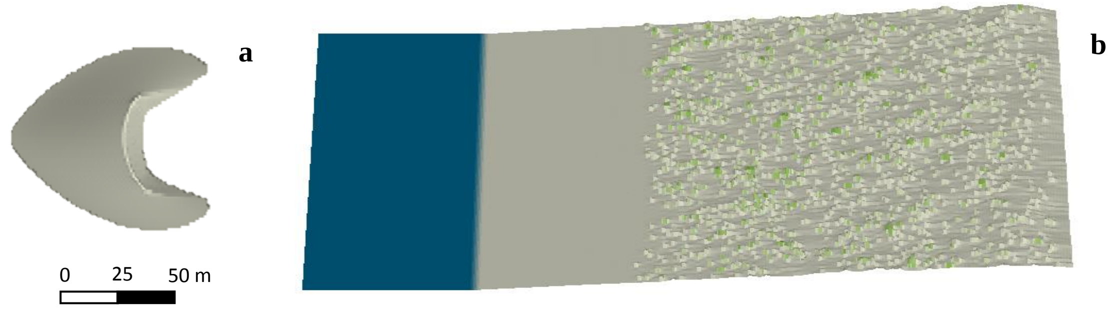

Figure 1 Simulation results of the coupled approach of (a) barchan dunes and (b) embryonal dune field.

LONG-TERM WAVE ATTENUATING CAPACITY OF FORESHORES: A CASE STUDY IN THE WESTERSCHELDE

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Dikes with foreshores (salt marshes and tidal flats) in front of it are proposed as sustainable and cost-effective solutions for coastal defence in the Scheldt estuary (Broekx et al., 2011). Within the Westerschelde, bed level measurements indicate a stable salt marsh and a relative stable or accreting tidal flat on time scales of months to a single year (Willemsen et al., 2018), thereby providing a sustainable coastal defence measure. However, the reliability of the wave attenuating capacity of foreshores in the Westerschelde on the design life time of coastal defence infrastructures (50 years) is not known and implementation is therefore hampered (Bouma et al., 2014). This study aims to quantify the long-term (50+ years) wave attenuating capacity of foreshores in the Westerschelde.

The wave attenuating capacity of eight foreshores in the Westerschelde was assessed using SWAN (Simulating WAves Nearshore; Vuik et al., 2016), over the past 60 to 70 years. Bathymetrical data stored in the "Vaklodingen" was converted to transects parallel to the design wave direction (i.e. direction from where the highest waves possible occur). Vegetation was assigned to the higher parts of the transects, starting at Mean High Water Neap and represented by an appropriate Nikuradse roughness length (Vuik et al., 2019). The wave attenuating capacity for all transects was assessed for specific design conditions (recurrence time of 1/10000 year).

The wave attenuating capacity under design conditions over the past 50+ years shows spatial variability over a single foreshore (Fig. 1). The spatial variability at the southern shores of the Westerschelde is larger than at the northern shores. In general, the wave attenuating capacity at the southern shores is larger. Although natural dynamics affect the shape and environmental settings of foreshores, foreshores consistently contribute to coastal safety over the design lifetime of coastal defence infrastructures.

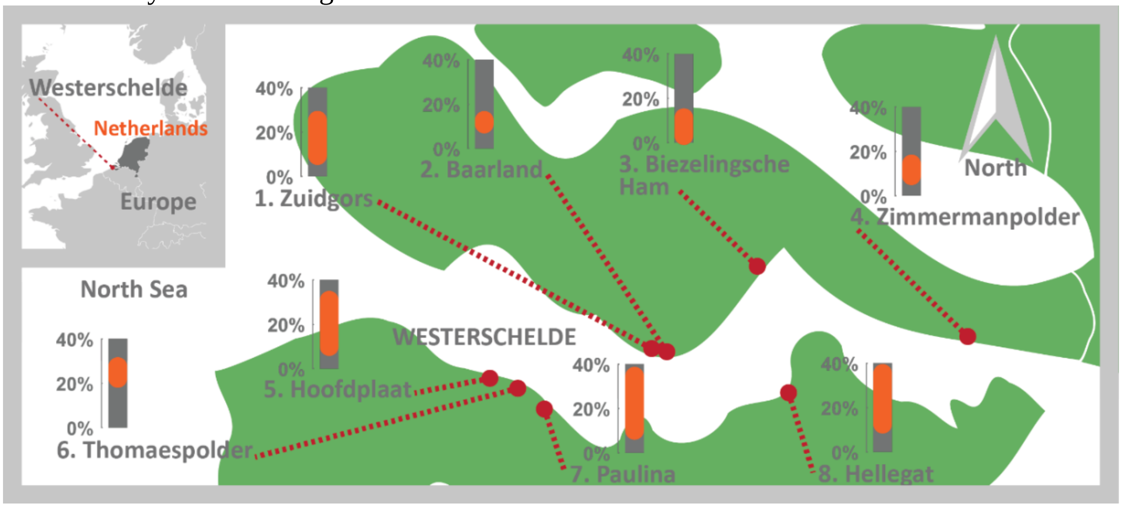

Figure 1. Minimum wave attenuation for eight foreshores in the Westerschelde. The minimum wave attenuating capacity of every transect is summarized per foreshore (orange bar).

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THE EFFECT OF TIDAL BASIN CONNECTIVITY AND WAVES ON SEDIMENT TRANSPORT PATTERNS IN THE AMELAND INLET

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Introduction

Ameland Inlet has recently been studied intensively because of the mega nourishments (~20×10^6 m^3) of its ebb-tidal deltas that are being considered. Therefore, to understand how such nourishment will behave, a good understanding of the sediment transport patterns and its spatial and temporal variability is needed. In a recent study (Lenstra et al., 2019) we showed that sediment transport patterns in Ameland Inlet not only depend on wave and tide conditions, but also strongly depend on the different phases of its cyclic evolution. However, we neglected the effect of wind and assumed the Ameland Inlet to be an isolated system where the tidal watersheds could not be flooded. The latter is realistic during calm weather conditions, but during storms the exchange of water over the tidal watersheds can be quite large. In this study we present results on the effect of wind and basin connectivity on estimated sediment transport patterns in Ameland Inlet based on the results from a high resolution model including the effects of winds, waves and flooding of tidal watersheds.

Methods

We set up a model in Delft3D/SWAN with two-way coupling (domain decomposition) between a high-resolution Ameland Inlet grid and a medium coarse grid Wadden Sea grid. Boundary conditions for the tides and waves were based on a North Sea continental shelf model and wave buoy data, respectively. We included effects of wind growth because waves in the Wadden Sea are to a large extent determined by local wind growth. Wind and pressure input came from WRF and HIRLAM data. Wind forcing was schematized by binning the wind events into 5 main directions and studying for each direction an extreme scenario and a quiet scenario in the year 2007, 2011 and 2012.

Results

The model shows that wind force and connectivity with adjacent basin can alter the flow and the sediment transport significantly. For example, as shown in Figure , during the strong NW storms, roughly 80% of water is imported into the basin via its western watersheds and the rest 20% flow through the Westgat. Besides, the eastern watershed was the main exit of water during the storm while Borndiep become dominant in exporting water after the storm. In terms of sediment transport, Westgat contribute to almost 80% of the sediment transport during the storm while only 10% of the sediment is transported through the western watersheds. The export of a small volume of sediment can be observed via eastern watersheds. To sum up, the system accumulates the sediment during a strong NW storm. During the presentation we will also discuss the results of other wind directions and magnitudes and present the weighted mean sediment balance of Ameland Inlet and compare it with previous estimates.

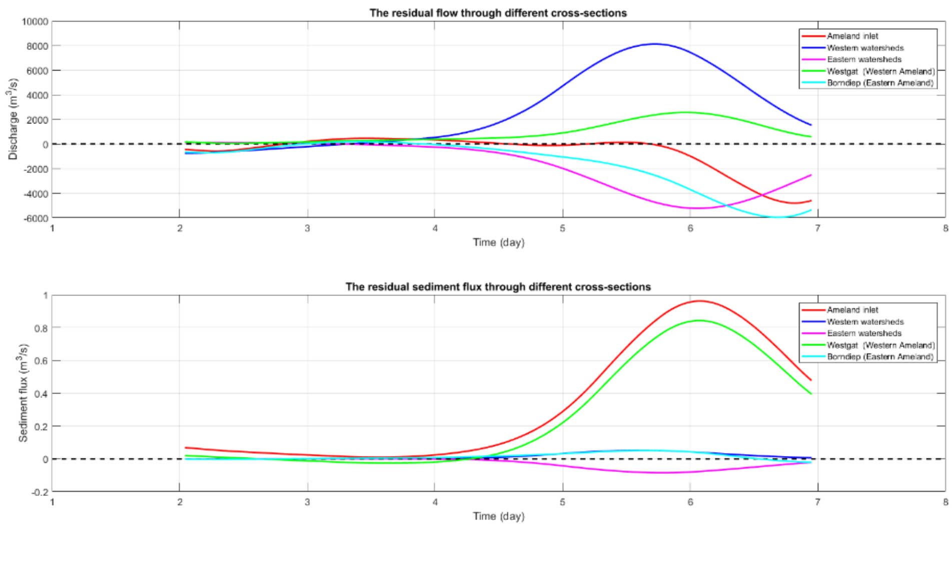

Figure 1 The time-series of residual flow and sediment transport through 5 cross-sections of Ameland Inlet.

LONG TERM COASTAL MANAGEMENT ON THE WADDEN ISLANDS
HOW TO INCORPORATE LARGE SCALE MORPHODYNAMICS?

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Introduction

The tidal inlets of the Wadden Sea are characteristically governed by large scale dynamic processes. Annually the gross sediment transport in these area's is many millions of cubic meters. The net sediment transport rates are considerably smaller but still very significant (eg. Elias et al., 2018). These dynamics have an impact on the coast of the Wadden Sea Islands (see figure 1). Working against these dynamics requires relatively large nourishment efforts. Fully embracing all dynamics may result in considerable land loss. This has consequences for the use of the coast. And there is uncertainty on whether it will be regained in the future. In this poster presentation we will show examples of the challenges for coastal zone management in these area's.

We will especially elaborate on:

- Large spatial scale and long time scale morphodynamics versus the use of a fixed reference coastline, the basiskustlijn (BKL);
- Spatial Planning and Coastal Management;
- Effectiveness of coastal management actions and sustainability;
- Need for system understanding.

To further optimize and adjust the Dutch coastal policy and sand nourishment practice, Rijkswaterstaat (part of the Ministry of Infrastructure and Water) coordinates multiple research programs. Co-operation with NCK on these programs is essential. With this poster we aim to inspire NCK for future collaborations.

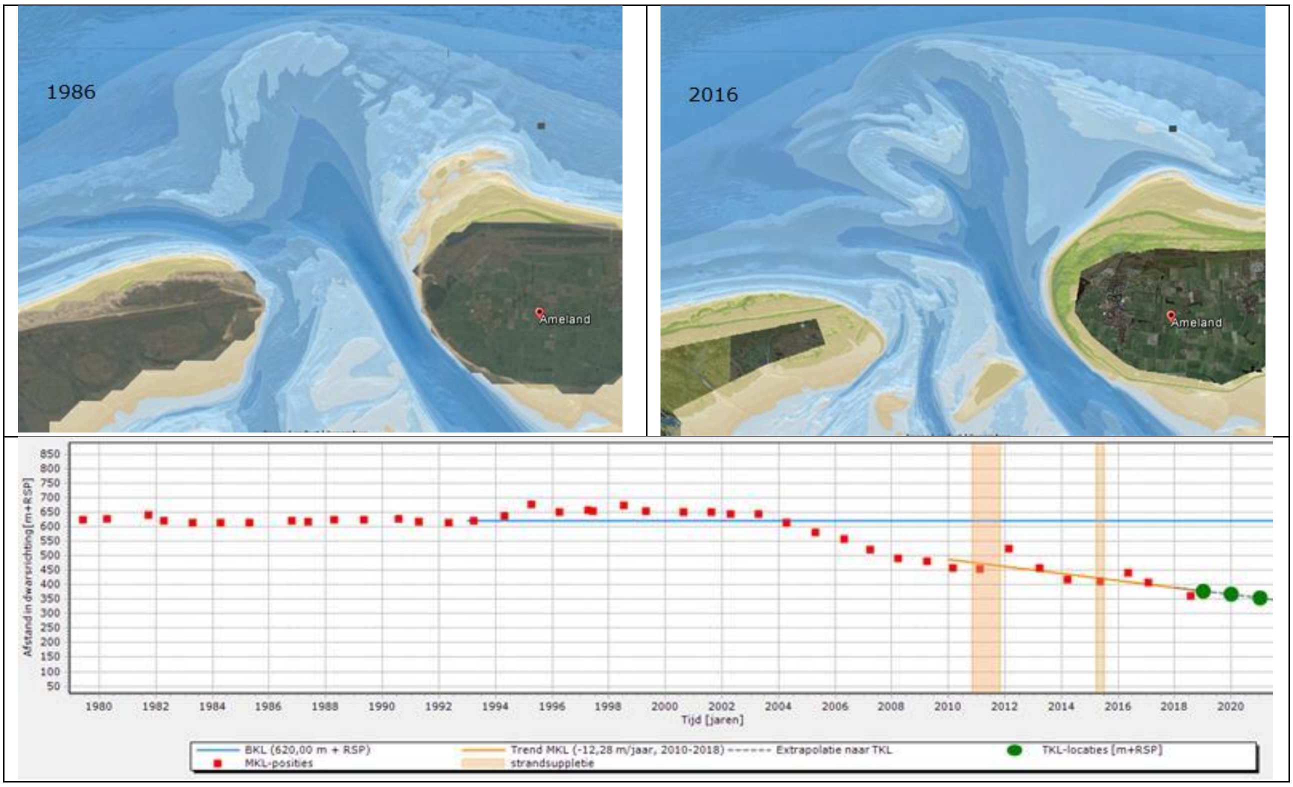

Figure 1 Example of large scale changes: bed topography in the Amelander Inlet System (top: 1986 and 2016) and the (calculated) coastline position in a transect at Ameland (TKL) (below).

Reference: Elias et al. 2018, Understanding the present-day morphodynamics of Ameland inlet