netherlands centre for coastal research

Book of Abstracts

NCK Days 2020

March 18-20

NIOZ - Texel

Sponsored by:

Organized by:

Contents

Preface

Welcome to the NCK Days 2020!

The NCK Days 2020 are organized by the NIOZ, the Royal Netherlands Institute for Sea Research. The venue for the conference is also the NIOZ, on the island of Texel. Created 144 years ago as a zoological station, the NIOZ has evolved into a multidisciplinary institute studying the oceans, shelf seas, and coastal waters, supported by marine technology facilities, including research vessels.

An excursion is organized to the nearby Prins-Hendrik Zanddijk at the southeast coast of Texel, which has recently been reinforced in an innovative way, featuring a seaward sandy extension with dunes and marshes.

We are pleased to welcome as invited speakers Ulf Gräwe (IOW, Germany), who has recently carried out a multi-decadal hydrodynamical study on the Dutch Wadden Sea, and will share first results with us, and Aimée Slangen (NIOZ, EDS, Yerseke), a lead author on the forthcoming IPCC AR6 report, who will speak about sea level projections.

During the conference there will be ample time to discuss your work, to visit the posters, and you will also have the opportunity to visit the Marine Technology and SIBES laboratories at the NIOZ.

We thank NWO for sponsoring this conference and wish you inspiring and enjoyable NCK Days 2020!

The organizing committee,

Theo Gerkema and Nina Aalberts

Program NCK Days 2020

WEDNESDAY 18 MARCH

13:30-15:30 **Excursion to Prins-Hendrikdijk** – start & end at NIOZ main entrance
Guide: Joël Verstoep (HHNK), with Matthieu de Schipper (TUD) and Timothy Price (UU)
15:30-17:45 **Sprint-workshop (SEAWAD data)** @Noordzeezaal, NIOZ
organized by Laura Brakenhoff (UU) and Rinse Wilmink (RWS)
20:00-22:00 **Icebreaker** @Restaurant Lindeboom, Den Burg
22:00 *Bus transport from Den Burg Elemert to De Koog (via Hotel De Pelikaan)*

THURSDAY 19 MARCH

8:30 *Bus transport from De Koog, via Hotel De Pelikaan, Den Burg Elemert (8:45), to NIOZ (9:00)*

9:00-9:30 registration & coffee @Entrance hall
9:30-9:40 opening @Oceaanzaal

SESSION **ESTUARIES AND TIDAL BASINS**

9:40-10:10 **Ulf Gräwe** (IOW, Warnemünde): *Variability of residual water flow in the western Dutch Wadden Sea* (keynote)
10:10-10:25 **Yoeri Dijkstra** (TUD): *A unifying approach to subtidal salt intrusion modelling in tidal estuaries*
10:25-10:40 **Arya Iwantoro** (UU): *Determining morphological stability of tidally-influenced bifurcations*
10:40:11:05 poster pitches (see below)
11:05-11:45 coffee break + posters @Entrance hall

11:45-12:00 **Laurie van Gijzen** (TUD): *Fine sediment transport pathways and connectivity in San Francisco South Bay*
12:00-12:15 **Jasper Leuven** (RHDHV): *Enhanced mud sedimentation to reduce turbidity and grow with sea-level rise*
12:15:12:30 **Ymkje Huismans** (Deltares): *Sediment redistribution mechanisms in deep pits of the Western Scheldt*
12:30-14:00 lunch + posters @Entrance hall

SESSION **ABIOTIC-BIOTIC RELATIONSHIPS**

14:00-14:15 **Johan Damveld** (UT): *Tidal sand waves and benthic organisms: observations and modelling of bio-physical interactions*
14:15-14:30 **Loreta Cornacchia** (NIOZ): *Vegetation-driven creek complexity promotes efficient sediment delivery in salt marshes*
14:30-14:45 **Thomas van Veelen** (Swansea Univ., UK): *Modelling wave damping by flexible salt marsh vegetation*
14:45-15:00 **Mariska Hendriks** (WMR): *A large-scale field experiment on salt marsh construction*
15:00-15:15 **Gijs Hendrickx** (TUD): *Predicting the survival of coral reefs*
15:15:15:30 **Sebrian M. Beselly** (IHE): *Drone-based 'Structure-from-Motion' (SfM) photogrammetry analysis of mangrove dynamics in the prograding delta in Porong, Indonesia*

15:30-16:15 coffee break + posters @Entrance hall

SESSION **AEOLIAN TRANSPORT AND DUNES**

16:15-16:30 **Daan Poppema** (UT): *The effect of building geometry on aeolian deposition patterns: a field experiment*

16:30-16:45 **Christa van IJzendoorn** (TUD): *Are the Dutch dunes keeping up with sea level rise?*

16:45-17:00 **Job Oude Vrielink** (UT): *The impact of roughness elements on sediment fluxes in coastal dunes and dune valleys, solving the puzzle for Spanjaards Duin*

17:00-18:00 drinks @Canteen NIOZ

18:00-20:00 dinner @Canteen NIOZ

20:15 *Bus transport from NIOZ to Den Burg Elemert and De Koog (via Hotel De Pelikaan)*

POSTERS THURSDAY SESSIONS:

1 Zaiyang Zhou (TUD): *Lateral flow and sediment transport due to groynes' effects in a channel-shoal system*

2 Wouter Kranenburg (Deltares): *Salt intrusion in the Rhine Meuse Delta: Estuarine circulation or tidal dispersion?*

3 Ana Colina Alonso (TUD): *Understanding sand-mud interaction and its large-scale impact on tidal basins*

4 Maeve Daugharty (Nortek): *High resolution echo sounder data from water surface to sea bed*

5 Paul Donkers (TUD): *Influence of wind on estuarine circulation and sub-tidal salinity distribution*

6 Henk Schuttelaars (TUD): *Morphodynamic equilibria and linear stability in tidal estuaries: Influence of Coriolis and planform geometry*

7 Donald Schuurman (UU): *Impact of local cross-sectional area reduction by tidal barrage placement on estuarine hydro- and morphodynamics*

8 Steven Weisscher (UU): *Building and raising land: mud and vegetation effects in infilling estuaries*

9 Rutger Siemes (UT): *Modelling consequences of artificial structures on salt marsh dynamics in the Wadden Sea*

10 Roel de Goede (TUD): *Regime shift in sediment concentrations in the Loire estuary*

11 Maurits Groenewegen (TUD): *Morphological development of the Bollen van de Ooster: A potential hazard for Goeree-Overflakkee?*

12 Vera van Bergeijk (UT): *Hydrodynamic modelling of wave overtopping flow over grass-covered dikes*

13 Quirijn Lodder (RWS): *On the importance of net sediment transport capacity to Dutch Coastal Management*

14 Aaron Lynch (WUR): *Influences of nutrient availability and precipitation on the growth of dune-building grasses*

15 Sasja van Rosmalen (WUR): *Plant-sediment-human interactions along anthropogenic sandy shore*

16 Marijn Gelderland (UT): *Living on the edge: quantifying physical dynamics controlling mangrove fringe dynamics*

17 Muriel Brückner (UU): *Modelling of interactions between bioturbation and mud distribution reveals effects on large-scale estuarine morphology*

18 Johan van de Koppel (NIOZ): *Building virtual estuarine ecosystems*

19 Floris van Rees (Deltares): *Mangrove seedling survival in fluid mud and sand*

20 Hans van Hateren (VU): *Identifying sediment transport mechanisms from grain size-shape distributions: application to an active coastal dune system (Kennemerduinen, the Netherlands)*

21 Sander Vos (TUD): *Scan Experiment 2020*
22 Unze van Buuren (VU): *Spatio-temporal aeolian sand dispersal patterns in a coastal dune system, the Kennemerduinen (the Netherlands)*
23 Paran Pourteimouri (UT): *Modelling airflow patterns around beach houses using computational fluid dynamics*
24 Yaron Huberts (UU): *The impact of storms, wind and vegetation recovery on washover development on Rottumeroog, studied using high-resolution satellite imagery*
25 Eleftheria Kragiopoulou (IMDC): *Estimating aeolian sand transport along the Belgian coast*
26 Roula Dambrink (NWO/TTW)

FRIDAY 20 MARCH

8:30 *Bus transport from De Koog, via Pelikaan, Den Burg Elemert (8:45), to NIOZ (9:00)*

SESSION **SHOREFACE DYNAMICS**
9:15-9:30 **Bas Huisman** (Deltares): *Sand redistribution mechanisms of shoreface nourishments: data, models and processes*
9:30-9:45 **Bart Grasmeijer** (Deltares): *Modelling of annual sand transports at the Dutch lower shoreface*
9:45-10:00 **Evelien Brand** (VU Brussel): *Intertidal beach morphodynamics of the tide-dominated Belgian coast*
10:00-10:25 poster pitches (see below)
10:25-11:15 coffee break + posters @Entrance hall

11:15-11:30 **Anne Ton** (TUD): *Morphological development of sandy beaches in low-energy, non-tidal environments*
11:30-11:45 **Joost Kranenborg** (UT): *A depth-resolving model for intraswash hydrodynamics and sediment transport*
11:45-12:00 **Sebastiaan Haverkate** (UU): *Nearshore bar dynamics of a nourished coast with respect to a neighboring natural coast (Egmond aan Zee)*
12:00-12:15 **Marlies van der Lugt** (Deltares): *Morphodynamic modelling of barrier island response to hurricane forcing*

12:15-13:30 lunch + posters (+ excursion labs 13:00-13:30) @Entrance hall

SESSION **SEA-LEVEL CHANGE AND COASTAL MANAGEMENT**
13:30-14:00 **Aimée Slangen** (NIOZ): *Global and regional sea-level projections* (keynote)
14:00-14:15 **Floortje Roelvink** (Deltares): *Coral restoration for coastal hazard risk reduction*
14:15:14:30 **Hesham Elmilady** (IHE): *Investigating the long-term morphological evolution of intertidal shoals and SLR impact*
14:30-14:45 **Richard Marijnissen** (WUR): *The sensitivity of a dike-marsh system to sea-level rise – A model-based exploration*
14:45-15:00 **Nadia Bloemendaal** (IVM-VU): *Estimation of global synthetic tropical cyclone hazard probabilities using the STORM dataset*
15:00-15:15 **Jaap Nienhuis** (UU): *For which sea-level-rise rate will barrier islands drown?*

15:15-15:30 awards, closure
15:45 departure to ferry

POSTERS FRIDAY SESSIONS:

1 Abdel Nnafie (UU): *Modelling shelf morphodynamics and shoreline change using a two-coupled model system*
2 Ype Attema (Svasek): *XBeach modelling of Maasvlakte 2 coastal morphology aimed at predicting long term impact of on-the-beach wind turbines*
3 Laura Brakenhoff (UU): *The effects of bedform roughness on hydrodynamics and sediment transport in Delft3D*
4 Joep van der Zanden (MARIN): *Design optimization of a multifunctional floating breakwater*
5 Stuart Pearson (TUD): *Sediment connectivity: a framework for analyzing coastal sediment transport pathways*
6 Giordano Lipari (TUD): *Meshfree simulations of wave breaking on the foreshore*
7 Rikke van der Grinten (Nortek): *Extensive monitoring campaign at sandy lake beaches of Houtribdijk and Marker Wadden*
8 Alex Ionescu (TUD): *Large observed grain size variability around the Sand Engine*
9 Geert Campmans (UT): *Modeling tidal sand wave dynamics in response to dredging interventions*
10 Roeland de Zeeuw (Shore M&R): *Tendering and measurement innovation in integral monitoring of extremely shallow water embankments and bed level classification: Monitoring sandy reinforcement Houtribdijk*
11 Timothy Price (UU): *The EURECCA project: How will waves and tides spread the sand mixture of the Prins Hendrikzanddijk?*
12 Bart Roest (KU Leuven): *Growing dunes, eroding shoreface*
13 Filipe Galiforni Silva (UT): *Ebb-shoal dynamics and its influence on the adjacent beach-dune system in Texel (NL)*
14 Martienke Baaij (WUR): *Role of salt marsh vegetation in sedimentation and modelled wave attenuation (the Slufter, Texel)*
15 Maarten Prins (VU): *Identifying sediment transport mechanisms from grain size-shape distributions: application to a secondary tidal inlet system (de Slufter, Texel, the Netherlands)*
16 Petra Goessen (HHNK): *Slufter Texel – combined search for change indicators*
17 Job Dullaart (IVM-VU): *Creating a global database with return periods of extreme sea levels caused by tropical and extratropical cyclones*
18 Lars de Ruig (IVM-VU): *Evaluating reforms of the National Flood Insurance Program by integrating human behavior in a coastal flood risk analysis*
19 Bob Smits (Deltares): *Can the Demak mangrove-mud coast keep up with relative sea level rise?*
20 Martijn Peters (UT): *The effect of the slope angle on the failure of the grass revetment due to wave impact*
21 Roeland van de Vijsel (NIOZ): *Multi-stability due to biogeomorphic feedbacks: implications for saltmarsh restoration*
22 Koen Reef (UT): *How do tidal divides affect the morphological evolution of tidal inlets?*
23 Frank Kok (RWS): *Effective monitoring campaigns*
24 Pär Persson (CAB, Sweden): *Coordination of coastal management and policymaking*
25 Rena Hoogland (RWS): *How relative is relative sealevel change?*

Abstracts Oral Presentations Thursday

(in order of presentation)

Variability of residual water flow in the western Dutch Wadden Sea

U. Gräwe
Leibniz-Institute for Baltic Sea Research, ulf.graewe@io-warnemuende.de

Introduction

The western Dutch Wadden Sea (wDWS) is a region of intertidal flats located between the chain of Wadden Islands and the Dutch mainland. The residual circulation in the wDWS has been previously studied through numerical simulations, measurements, and analytical models. However, all three methods are far from perfect. The analytical models are limited due to their implied assumptions. Numerical model investigations lack sufficient spatial resolution or time coverage. The measurements (for instance in the Marsdiep Inlet) are challenged by the high level of uncertainty due to the needed post processing to convert ADCP measurements into volume fluxes. In this study, I conducted a numerical hindcast covering the period 1979-2018. This will allow studying the monthly and annual variability of the residual water exchange in wDWS in a consistent fashion.

Methods

All results are obtained from three-dimensional numerical simulations carried out with the General Estuarine Transport Model (GETM), at a horizontal resolution of 200m and with terrain-following vertical adaptive coordinates with 25 layers. The setup is nearly identical to the one of Duran.Matute et al. 2014. The model run covers the period 1979-2018. The data analysis is based on 20 minutes snapshots of transects over the inlets and watersheds.

Results

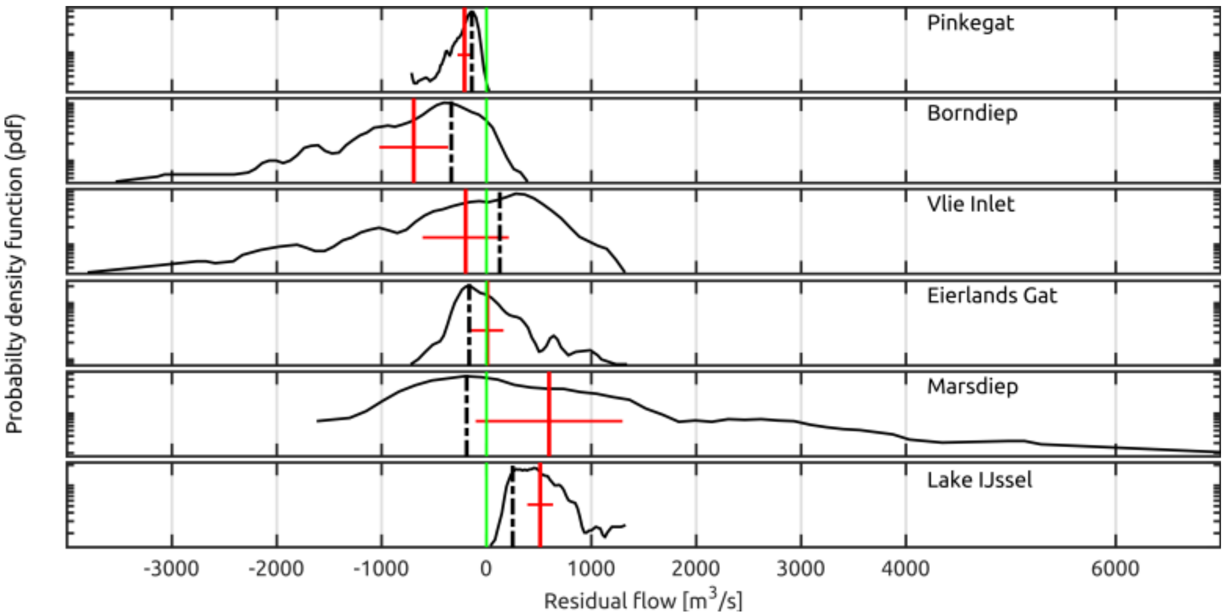

Figure 1 Probability density functions of monthly residual flows through selected tidal inlets. Positive flow indicates a transport into the Wadden Sea. The vertical red line marks the mean value; the black dashed-dotted line the median. The horizontal red line indicates the standard deviation. The analysis is done for the period 1979-2018.

The analysis of the monthly residual flow through selected tidal inlets indicates that the average flow through the Marsdiep is positive (Figure 1). Thus, the residual flow points into the direction of the Wadden Sea. The other inlets show a net export of water volume. Whereas the average flow varies between -500 and +500 m^3/s, especially Marsdiep, Vlie Inlet and Borndiep can show monthly residual flows exceeding the ten-fold of the mean. Moreover, all three inlets show a pronounced skew distribution.

Duran-Matute, M., Gerkema, T., de Boer, G. J., Nauw, J. J. & Gräwe, U. Residual circulation and freshwater transport in the Dutch Wadden Sea: a numerical modelling study. *Ocean Sci.* **10**, 611–632 (2014).

A unifying approach to subtidal salt intrusion modelling in tidal estuaries

Y.M. Dijkstra[1]*, H.M. Schuttelaars[1]
[1] TU Delft, Delft Institute of Applied Mathematics

Introduction

The salinity structure in estuaries is classically described in terms of the salinity structure as well-mixed, partially mixed, or salt wedge. The existing knowledge about the processes that result in such salinity structures comes from highly idealised models that are restricted to either well-mixed or partially mixed cases or salt wedge estuaries. Hence, there is still little knowledge of the differences in dominant processes driving these different types of salinity structures and the estuarine parameters at which a transition from one such structure to another is found.

Methods

As an important step toward a unified description of processes driving well-mixed, partially mixed, and salt wedge estuaries, we developed a fully nonlinear subtidal width-averaged model that is applicable to all these salinity structures. The model was run for a straight uniform rectangular channel for a large range of model parameter values representing the entire estuarine parameter space.

Results

We identified four salinity regimes, resulting from different balances of dominant processes: (1) a dispersion dominated regime; (2) the Chatwin regime, dominated by gravitational circulation; (3) the Chatwin regime with salinity front, similar to regime 2 but with a distinctive salinity front dominated by momentum advection; and (4) a fully momentum advection-driven salt wedge regime. It is shown that each regime is uniquely determined by two dimensionless parameters: an estuarine Froude and Rayleigh number, representing fresh water discharge and tidal mixing, respectively. This results in a classification of the regimes in terms of these two parameters (Figure 1).

Furthermore, analytical expressions to approximate the salt intrusion length in each regime are developed. These expressions are used to illustrate that the salt intrusion length in different regimes responds in a highly different manner to changes in depth of fresh-water discharge. Finally, we show that there are only very weak relations between the process-based regime of an estuary and the salt intrusion length and top-bottom stratification.

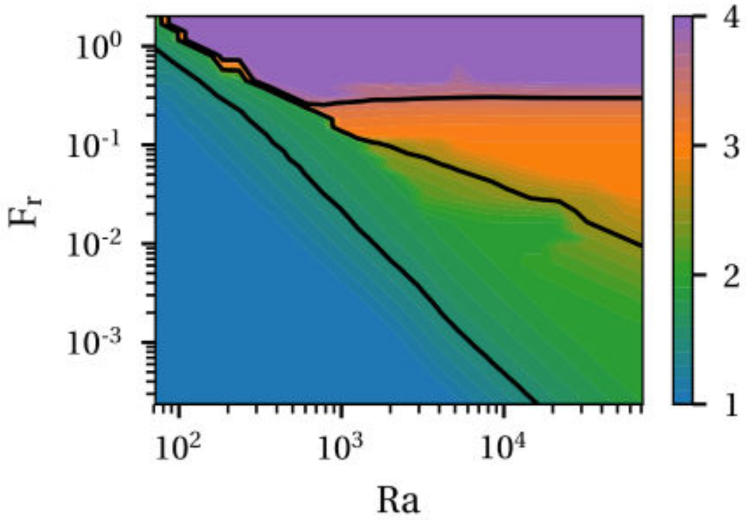

Figure 1 The four regimes (indicated by colours) dominated by transport due to (1) dispersion, (2) gravitational circulation, (3) momentum advection at a distinctive salinity front, (4) advection in a salt wedge. The regimes are plotted in the parameter space of the fresh water Froude number (Fr; indicating discharge) and the estuarine Rayleigh number (Ra; indicating mixing).

Determining morphological stability of tidally-influenced bifurcations

A.P. Iwantoro[1]*, M. van der Vegt[1], M.G. Kleinhans[1]
[1] Utrecht University, a.p.iwantoro@uu.nl, m.vandervegt@uu.nl, m.g.kleinhans@uu.nl

Introduction

The morphology of river bifurcations often evolves asymmetrically, resulting in an avulsion (i.e. unstable bifurcations). Observations suggest that bifurcations in tidally influenced systems are stable. Here we study the morphological evolution of bifurcations in the range from river- to tide-dominated systems.

Methods

We developed a 1D numerical model that solves the 1D shallow water equations, sediment transport and the sediment mass conservation equation for a system consisting of one upstream channel and two downstream branches. The sediment division at the bifurcation includes both bed-load and suspended load transport and can cover the changing flow directions in tidal systems. The division of bed-load at the junction was affected by both cross-channel flow and transverse bed slopes, while for suspended load, it is only affected by cross-channel flow.
To analyse the stability of the bifurcations, identical branches were initially defined. Then a small depth difference between branches was prescribed. When this depth asymmetry grows in time the system is unstable, when it decays it is stable. The channel configuration and other model settings were based on observed bifurcations. In shown results, the Shields number was varied by varying the D50 in the range of sandy material (0.1-1 mm) and the width-to-depth ratio was varied in the range between 10 and 50 by varying the width while keeping the same discharge per unit width.

Results

Based on four sets of simulations with different tidal influence (Fig. 1), we conclude that tides cause a wider range of condition for which stable bifurcations can occur. From these results, we proof that tides can counteract the avulsion process that would occur in river-dominated deltas. Using this new model, we can start analyzing how different combinations of tide and river forcing determine the morphological stability of bifurcations, and how this depends on the geometry of the bifurcation.

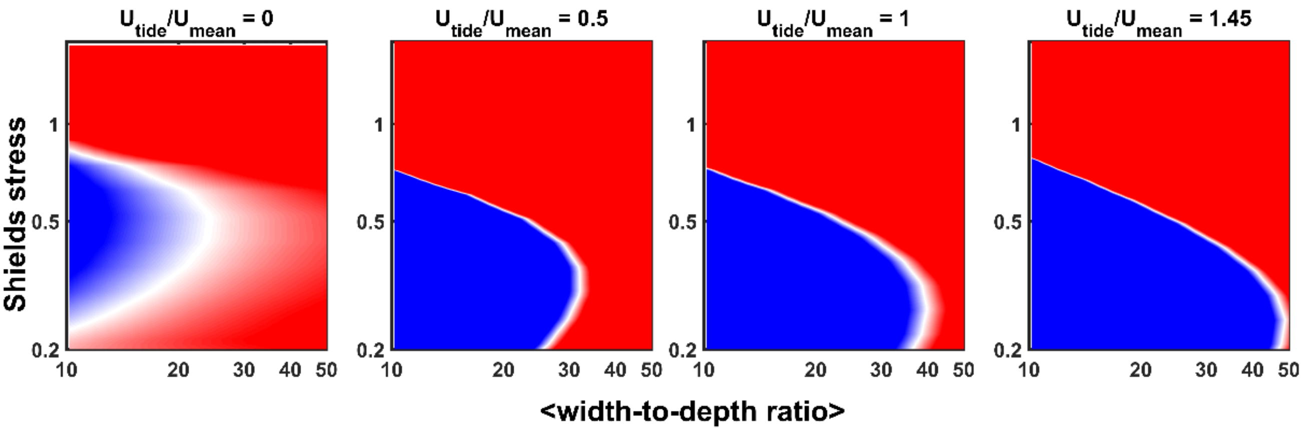

Figure 1 Stability of bifurcations for fluvial influenced (Utide/U0 at the bifurcation = 0) and fluvial-tidal influenced cases with channel slope = 3e-5. Red and blue indicates unstable and stable condition, respectively. Utide and Umean are tide-induced and tidally averaged flow magnitudes at the junction, respectively.

Fine sediment transport pathways and connectivity in San Francisco South Bay

L. van Gijzen[1,2*], P.M.J. Herman[1,2], M. van der Wegen [1,3] , B.C. van Prooijen[2], S.G. Pearson[1,2]
[1] Deltares, [2] Delft University of Technology, [3] UNESCO-IHE
Laurie.vangijzen@deltares.nl

Introduction

San Francisco Bay is one of the largest estuaries of the US Pacific Coast with an area of 4000 km^2. It consists of two hydrologically disti
nctive sub-embayments North Bay and South Bay. South Bay is unique as it does not experience the freshwater flushing typical for estuaries. It experiences the largest freshwater input during a regime of reverse estuarine circulation during Winter, when the entire Bay becomes fresher following peak discharges from the northern rivers. Hence both saline and freshwater enter from Central Bay through the same entrance. South Bay is dealing with increased risk of inundation due to the combination of sea level rise and land subsidence and a deteriorating water quality.
Understanding sediment pathways within South Bay and sediment exchange at its entrance can support the development of management strategies dealing with turbidity depended algae blooms and the development of salt marshes as a measure against sea level rise. Additionally, by understanding the current factors controlling fine sediment dynamics, future implications of climate change can be better predicted. Though San Francisco Bay is the topic of much research, a process-based model with a model domain covering the entire Bay is a novel approach to analyse fine sediment dynamics in South Bay.

Methods

A Delft3D-DELWAQ buffer layer model was calibrated against a newly available combination of local high-frequency suspended sediment concentration (SSC) measurements and two-monthly, depth varying SSC measurements across the entire 145 km length of the Bay. Subsequently the method of Sediment Connectivity was applied to analyse sediment pathways and net sediment fluxes in South Bay. Sediment Connectivity is an approach that uses network analysis to quantify sediment fluxes based on a schematization of San Francisco Bay into 17 segments. Large data sets of spatial and temporal output were reduced to a 17x17 adjacency matrix permitting a more straightforward analysis and the application of different statistical metrics unavailable in more traditional approaches.

Results and implications

Calibration enabled the model to better capture seasonal and episodic variations in SSCs across the Bay. Connectivity analysis uniquely revealed key dominant pathways, which agree well with literature. Additionally, it unveiled intra-basin transport pathways, regions of erosion and sedimentation and an indication of the varying controlling forcings during the year. Finally, this study acts as a proof of concept for the Sediment Connectivity method that could be applied in other estuaries.

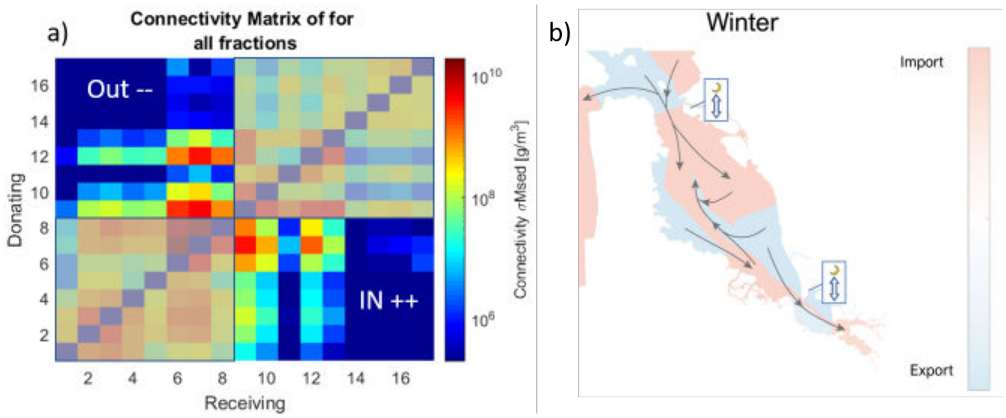

Figure 1 a) Connectivity Matrix for SFB in Spring indicating the incoming fluxes and outgoing fluxes with respect to South Bay during Winter (dec-feb). Each row represents outgoing fluxes from a certain segment and each column incoming fluxes. b) Concept Diagram with a schematization of the sediment fluxes, regions of import and export in Winter, with the tide being dominant in the sediment exchange at the South Bay entrance.

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

J.R.F.W. Leuven[1,2]*, B. de Vries[1], D.S. van Maren[3], C. Schmidt[4], P. Dankers[1]
[1] Royal HaskoningDHV, jasper.leuven@rhdhv.com, bente.de.vries@rhdhv.com, petra.dankers@rhdhv.com
[2] Wageningen University & Research, jasper.leuven@wur.nl
[3]Deltares, bas.vanmaren@deltares.nl
[4]Rijkswaterstaat WVL, charlotte.schmidt@rws.nl

Introduction

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

Methods

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

Results

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

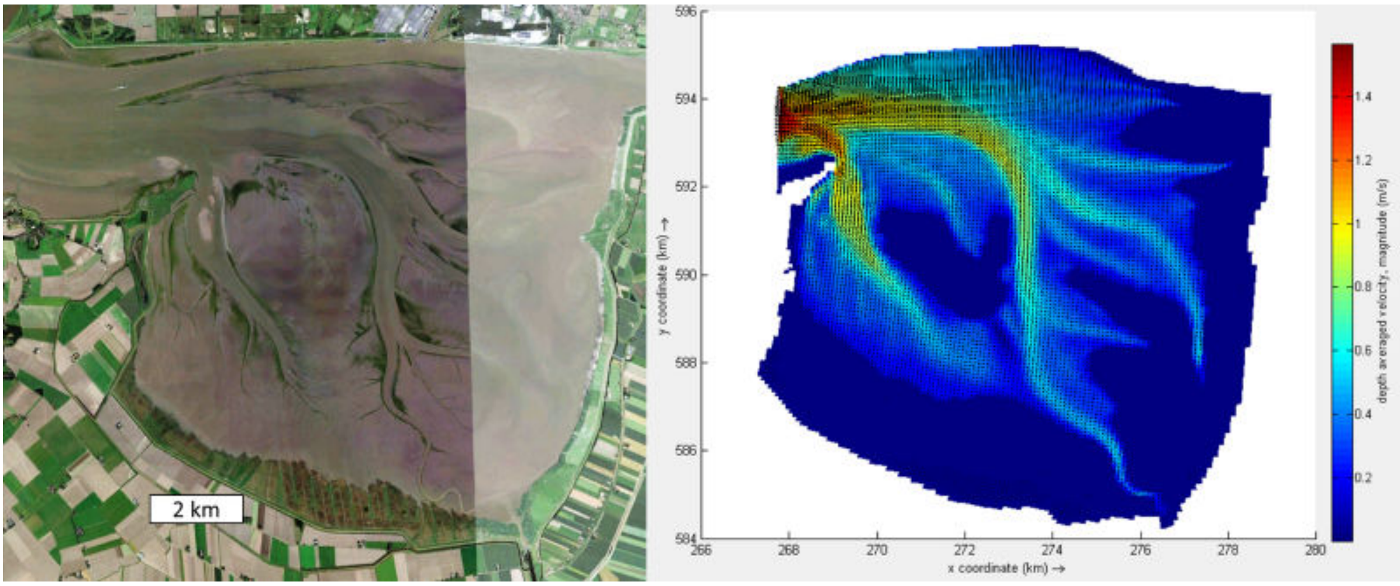

Figure 1 [left] Aerial photography of the Dollard basin along the Ems-Dollard estuary (source: google earth). [right] Example of model output with peak ebb flow velocities.

Sediment redistribution mechanisms in deep pits of the Western Scheldt

Y. Huismans[1]*, B. Huisman[1], A. Colina Alonso[1,2], H. van der Vegt[1], M. van der Wegen[1,3]
[1] Deltares, Ymkje.Huismans@deltares.nl, Bas.Huisman@deltares.nl, Helena.vanderVegt@deltares.nl
[2] TU Delft, A.ColinaAlonso@tudelft.nl
[3] IHE Delft, M.vanderWegen@un-ihe.org

Introduction

The Western Scheldt has a large ecological value and is classified as Natura 2000 area. The estuary is furthermore of large economic interest as it provides an important navigation route. To maintain the navigation route, dredging is carried out. The dredged sediment is disposed back into the system, in the side- and main channels and on the edges of tidal flats. To optimize the disposal strategy for both ecology and dredging efforts, a strategy is being considered in which a large part of the sediment is disposed in deep pits in the main channel. In this study, the effects on the morphological developments are investigated.

Methods

The study focusses on the sediment dynamics around the pit of Hansweert, one of the largest pits. This site serves as a pilot location. In the past years, three times 1 Mm^3 of sediment is disposed in this pit. The hydrodynamics and sediment dynamics have been closely monitored by e.g. ADCP measurements, 42 multibeam surveys and sediment samples. To analyse the morphodynamic response to the disposal, three methods are combined. First, multibeam surveys are used to track the volume changes in each sub-domain. Secondly, detailed 3D hydrodynamic modelling is carried out to understand the local flow patterns and predict the impact on short-term sediment transport (hours to days). Thirdly, 2D morphodynamic modelling is applied to infer how the sediment spreads on a larger scale (kilometres) and timeframe (years), once it has left the pit.

Results

The analyses show that the sediment transport is flood dominated (directed to the east). After the disposal of sediment, all sediment leaves the pit within several months to a year. Most sediment is transported towards the inner bend (~80-95%). Model results and bed level measurements suggest that a large share of this sediment is transported in suspension. From the inner bend, sediment is either transported eastward towards the "Drempel van Hansweert" or flows back into the pit via a flow slide. Due to accretion of the inner bend, the flow cross section decreases, which is compensated by erosion in the adjacent channel and outer bend. About 5 to 20% of the sediment is transported in other directions. Delft3D indicates this sediment can end up further away in low energy areas, but effects are relatively small in comparison to the natural changes in the estuary. Similar morphological processes are expected to play a role for other bends of the Western Scheldt. These findings enhance our understanding of the physics of estuaries and support policy decisions on the sustainable management of the system.

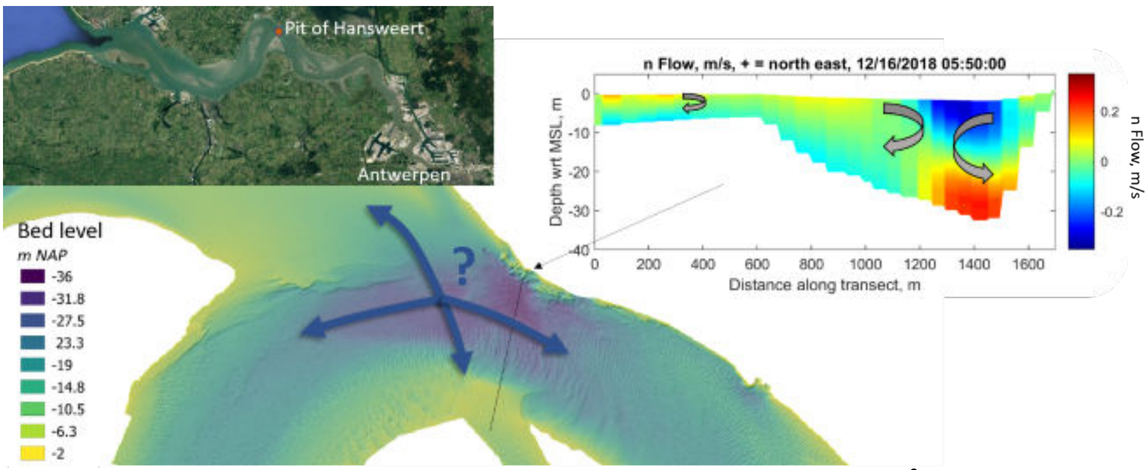

Figure 1 Bed level around the Pit of Hansweert, a pilot location in which 3 Mm^3 sediment is disposed for testing a new disposal strategy. Inset 1: overview Western Scheldt (Source: Google Earth). Inset 2: flow in n-direction.

Tidal sand waves and benthic organisms: observations and modelling of bio-physical interactions

J.H. Damveld[1]*, P.C. Roos[1], B.W. Borsje[1], S.J.M.H. Hulscher[1],
[1] University of Twente, j.h.damveld@utwente.nl

Introduction

The sandy seabed of shallow coastal shelf seas (e.g. North Sea) displays fascinating morphological features of various dimensions. At the same time, the seabed also harbours a rich ecosystem. It is well established that benthic community composition is related to various abiotic variables, such as sediment grain size and bed shear stress. However, less is known about how macrobenthic species relate to morphological bed patterns, and in particular to tidal sand waves. Increasing pressure from offshore human activities makes it necessary to further study the drivers of benthic community distributions over sand waves. Moreover, a greater understanding of the effects of benthic organisms on hydrodynamics and sediment transport processes over sand waves may improve morphological model predictions. In this contribution, we will present a combination of field observations and process-based modelling techniques that are used to determine and understand the effects of the feedbacks between benthic organisms and sand waves.

Methods

First, camera transects were carried out in a sand wave field off the coast of Texel and the footage was analysed to determine crest/trough differences in benthic assemblages. Second, a linear stability analysis (LSA) was performed to study the two-way coupled feedbacks between organisms and small-amplitude sand waves. Third, the numerical model Delft3D was applied to study these two-way coupled feedbacks for finite-amplitude sand waves, in particular for the tube-building worm *L. conchilega.*

Results

The camera footage revealed that organisms living on top of the seabed and within (using seabed holes as a proxy) are significantly more present in the troughs of sand waves, compared to the crests (see Figure 1). These observations generally agree with the results from the two process-based models. In the LSA it was shown that biomass maxima tend to concentrate in the region around the trough and lee side slope of sand waves, whereas the Delft3D model related the highest patch densities of worms to the sand wave troughs. Furthermore, regarding sand wave morphology, the LSA demonstrated that a local disturbance (either to the bed or to the biomass) may trigger the combined growth of sand waves and spatially varying biomass patterns. Moreover, the model results revealed that the autonomous growth of organisms significantly influences the growth rate of sand waves. The Delft3D model showed that small biogenic mounds, created by the tube-building worms, induce (and accelerate) the growth of sand waves with a similar spatial scale as the biogenic mounds itself (tens of meters wide). Initially this leads to shorter sand waves than they would be in an abiotic environment. However, near equilibrium the wavelengths tend towards their abiotic counterparts again, suggesting that the equilibrium sand wave stage is mainly determined by morphological processes alone.

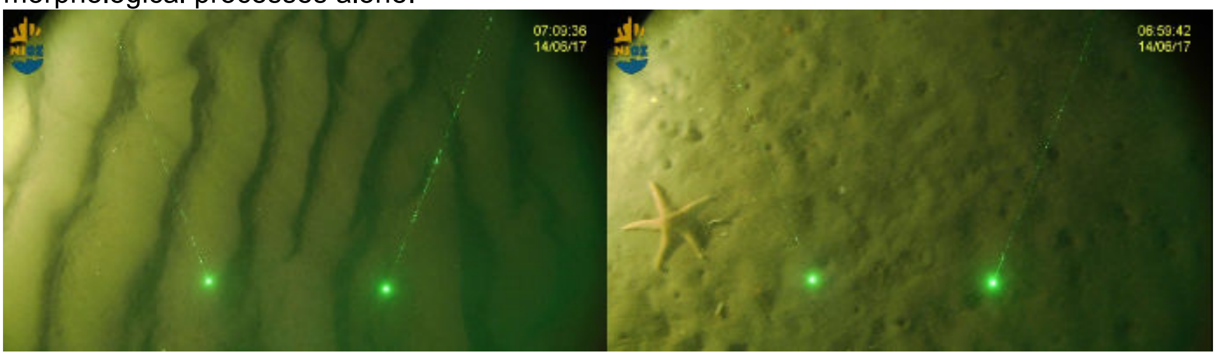

Figure 1 Crest (left) and trough (right) of a sand wave off the coast of Texel, showing clear differences in environment.

Vegetation-driven creek complexity promotes efficient sediment delivery in salt marshes

L. Cornacchia[1]*, R. C. van de Vijsel[1,2], D. van der Wal[1,3], T. Ysebaert[1,4,5], J. van de Koppel[1,2]
[1] Royal Netherlands Institute for Sea Research, Department Estuarine and Delta Systems, and Utrecht University, Yerseke, loreta.cornacchia@nioz.nl, roeland.van.de.vijsel@nioz.nl, daphne.van.der.wal@nioz.nl, tom.ysebaert@nioz.nl, johan.van.de.koppel@nioz.nl
[2] University of Groningen, Groningen Institute for Evolutionary Life Sciences
[3] Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente
[4] Ecosystem Management Research Group, University of Antwerp
[5] Wageningen Marine Research, Wageningen University & Research, Yerseke, Netherlands

Introduction

The adaptability of tidal marshes to sea-level rise relies on the efficient delivery of sediment within the marsh, allowing them to accrete vertically. Crucial for this delivery is the presence of a creek network that mediates the exchange of water and sediments between the sea and the marsh interior.

To what extent plants and their characteristics affect creek formation and influence sediment delivery by concentrating the tidal flow into the creeks, remains unclear. In this study we investigate whether sediment delivery is directly controlled by plant characteristics or indirectly mediated by the effect of vegetation on creek network complexity.

Methods

Here we use an idealized numerical model that couples the dynamics of water flow, vegetation, morphology and sediment transport, to describe the effect of vegetation outside the creeks on sediment transport and deposition onto the marsh platform. We compared different vegetation types, with contrasting effects on above-ground friction and below-ground sediment stabilization. Then, we quantified the resulting intertidal drainage structure and sediment deposition patterns to separate the direct effect of plant characteristics on sediment deposition from their indirect effect via creek geometry.

Results

We found that creek network complexity, rather than plant characteristics, determines the efficiency of sediment delivery in the marsh. While different plant characteristics do not directly affect sediment delivery, they do so indirectly by leading to the formation of simple (linear) or complex (highly branched) creek systems. Once a certain creek network is formed through plant-flow interactions, its planform geometry determines both the amount of sediment deposited and the transport distance in the marsh. Overall, this suggests a more efficient sediment delivery with increasing drainage pattern complexity (see figure below). Our results point out the need to preserve spatial complexity in salt marshes to ensure the resilience of these valuable coastal ecosystems.

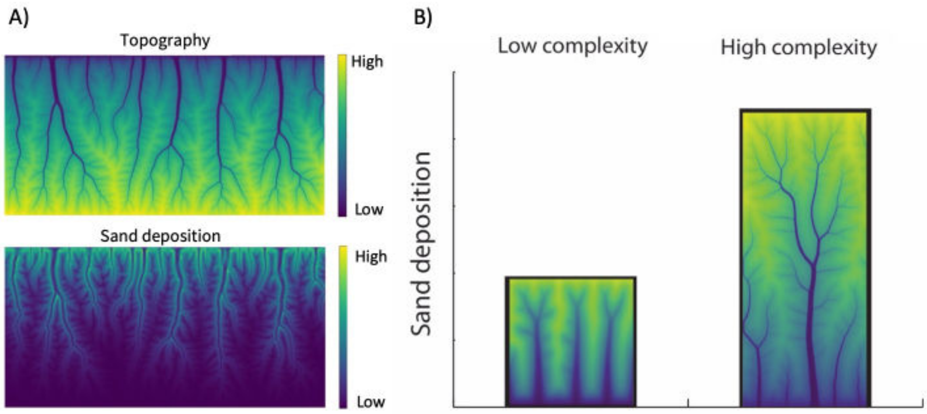

Figure 1 A) Top view on simulated drainage topography and sand deposition patterns. Outflow occurs through the upper boundary; the other boundaries are closed. B) Difference in total sand deposition between low-complexity and high-complexity creek networks.

Modelling wave damping by flexible salt marsh vegetation

T.J. van Veelen[1]*, H. Karunarathna[1], D.E. Reeve[1]
[1] Zienkiewicz Centre for Computational Engineering, Swansea university, United Kingdom
* t.j.van-veelen.922560@swansea.ac.uk,

Introduction

Nature based coastal defences in the form of vegetated foreshores are increasingly preferred over traditional hard defences. Salt marshes are a common vegetated foreshore in temperate climate zones. Their vegetation dampens incoming waves to reduce the load on coastal vegetation structures. However, salt marshes exhibit a wide variety of species, ranging from rigid shrubs to flexible grasses. These interact differently with waves and provides a different level of protection. This is often included in numerical model through the calibration of a drag coefficient. This is not suitable for planned nature-based defences or when vegetation conditions are subject to change. Here, we provide a new modelling approach that links wave damping directly wave and vegetation properties, including plant flexibility.

Methods

Based on combined experimental investigations of wave heights, orbital velocities and plant motion in the Swansea University Coastal Engineering Laboratory, we have developed a physics-based model that includes the effect of plant motion on wave damping. The modelled wave height is directly linked to wave and vegetation properties, including flexibility. Our model is validated for five vegetation species that differ in flexural rigidity under a wide range of wave conditions. We combined the validated model with Delft3D to study wave damping by salt marshes in the Taf estuary under five vegetation conditions.

Results

The salt marshes in the Taf estuary contribute significantly to coastal protection. Wave heights reduce by up to 75% in the first 100 metres. The impact of vegetation flexibility can be significant and strongly relates to the local conditions. It will be shown how vegetation flexibility can be introduced in numerical models, such that model predictions of wave height are less dependent on local calibration.

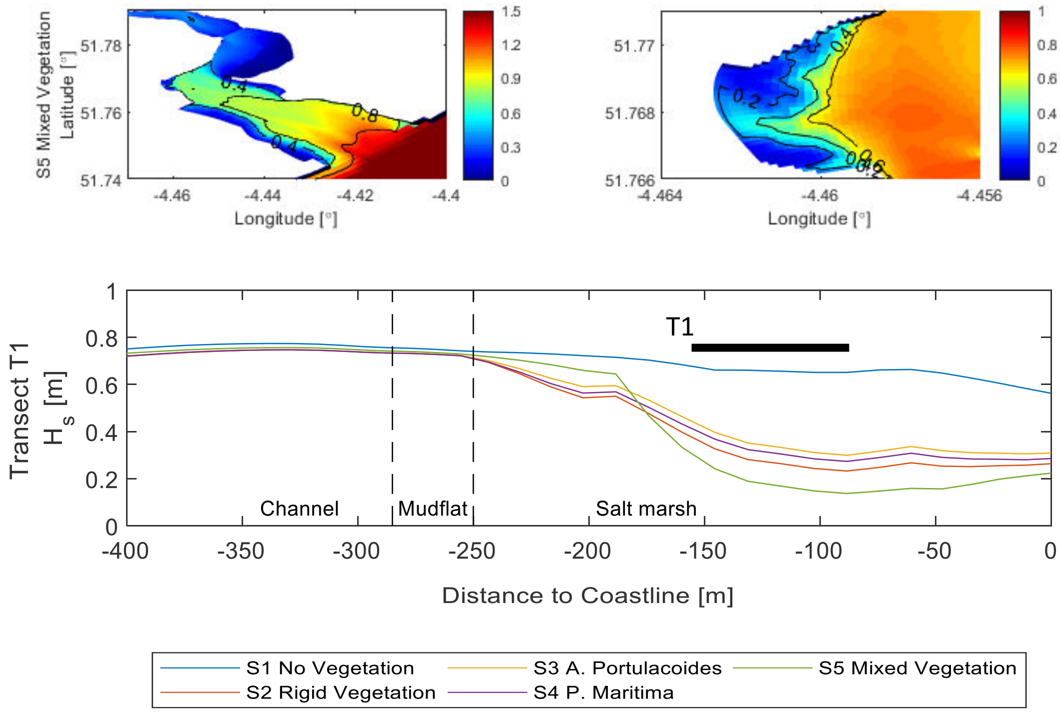

Figure 1 Modelled wave damping under a mixed vegetation scenario (top) and for five scenarios on selected transect T1.

A large-scale field experiment on salt marsh construction

M. Hendriks[1,6], P. Dankers[2], J. Cleveringa[3], L. Sittoni[4,8], P. Willemsen[4,5,6,7], K. Elschot[1], M. van Puijenbroek[1], M.J. Baptist[1]

[1] Wageningen Marine Research, Den Helder, Netherlands. martin.baptist@wur.nl
[2] Royal HaskoningDHV, Nijmegen, Netherlands
[3] Arcadis, Zwolle, Netherlands
[4] Deltares, Delft, Netherlands
[5] Royal Netherlands Institute for Sea Research, Yerseke, Netherlands
[6] Utrecht University, Utrecht, Netherlands
[7] University of Twente, Enschede, Netherlands
[8] EcoShape, Dordrecht, Netherlands

Introduction

Salt marshes provide important natural habitats, mitigate effects of subsidence and sea level rise and help in coastal defence. Commissioned by the municipality of Delfzijl, the EcoShape consortium obtained the opportunity to carry out a large-scale field experiment on salt marsh construction as part of their Living Lab for MUD.

Methods

Land-water boundaries at the port of Delfzijl consist of rock protected dikes. In 2018 the bed level was raised with sand obtained from capital dredging in the estuary and a rockfill dam was built to provide shelter. The new bed height for the projected salt marshes was set around Mean High Water level from 1.65 m to 1.05 m in a gradient of 1:140. In the 15 ha salt marsh site we created test plots delineated with brushwood groynes, Fig. 1. Three plots to the west differ in shape but all have a surface area of 2.3 ha. They differ with respect to the percentage of clay and silt particles that were mixed through the top 1 m of the sandy bed resulting in 5, 20 and 50% silt. Three plots to the south have equal shapes, slopes and sizes. These plots are 1.8 ha (216 x 85 m) in size and have two openings in the groynes. They also differ in clay and silt percentage and in half of each of these plots pieces of glasswort plants (*Salicornia procumbens*) were seeded. A total of 13,500 glasswort plants were manually collected and cut into about 100 pieces each. The 1,350,000 plant pieces were mixed with sawdust and put in freshwater to germinate. In May 2019 in each of the 9,000 m2 test plots the pieces were seeded with a density of 50 m^{-2}.

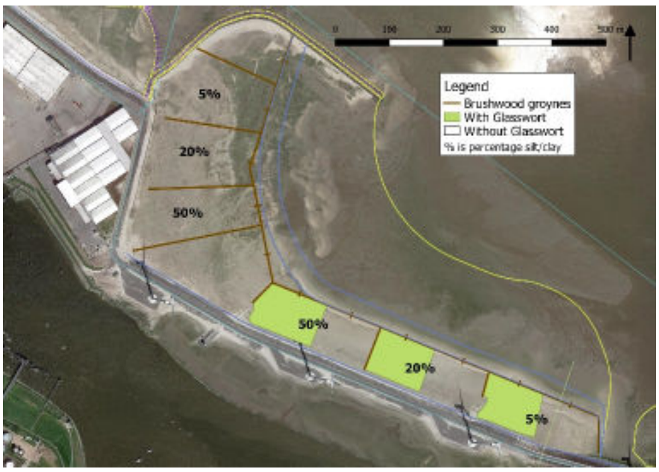

Figure 1 Aerial view of the Marconi test plots.

Monitoring

A two year monitoring programme in 2019 and 2020 will determine sedimentation-erosion rates, development of drainage channels, bed height, flooding frequency, and density & condition of the glasswort seedlings. The biogeomorphodynamic developments will be analysed with respect to heights, slopes, silt percentages, and vegetation cover. Instruments include a.o. LiDAR drone, RTK-DGPS, Sedimentation-Erosion Bars, and Acoustic Surface Elevation Dynamics (ASED) sensors. The presentation will elucidate preliminary results of the ongoing research.

Acknowledgments

This work was supported by the Dutch Waddenfonds. Cash and in-kind co-funding was received from the consortium partners of EcoShape. Abstract writing and presenting is supported by the Wageningen UR Knowledge Base programme KB-36-003-009.

Predicting the survival of coral reefs

G.G. Hendrickx[1,2*], J.T. Dijkstra[2], P.M.J. Herman[1,2], A.P. Luijendijk[1,2], J.D. Pietrzak[1]
[1] Civil Engineering, TU Delft, [2] Deltares, [*] gghendrickx@gmail.com

Introduction

The increasing pressure on Earth's ecosystems due to climate change becomes more and more evident. These pressures are especially visible at coral reefs. Therefore, a good understanding of the biophysical mechanisms controlling these ecosystems is needed, so that accurate predictions of their survival can be made. Such an understanding is also needed to develop efficient recovery and protection programs vital to the maintenance of these ecosystems.

Methods

Because the research on marine ecosystems is relatively young – in comparison with terrestrial ecosystems – and the phenomenon of coral bleaching is yet to be fully understood, there is no comprehensive framework in which the complex interactions between corals and their environment are combined. In this study, a biophysical model is developed in which four environmental factors are included in a feedback loop with the coral's biology: (1) light; (2) hydrodynamics; (3) temperature; and (4) acidity. Literature from multiple disciplines is combined to find the interdependencies between the corals and their environment. These relations include coral growth, coral bleaching, storm damage, and recruitment/recolonization of corals. For the connection with the hydrodynamics, a coupling is made between the biological model developed here and Delft3D-FM.

Results

The composed biophysical model is a big leap forward in understanding the world of coral reefs, as it is the first construction of a model framework including four environmental factors in which the hydrodynamics are included in the feedback loop. Furthermore, it creates the ability to assess recovery and protection programs based on the four aforementioned environmental factors; e.g. the susceptibility of coral bleaching can be reduced by increasing the attenuation of light through the water column (see Fig. 1). Because more environmental factors have a role to play in the coral dynamics, the framework is constructed such that these can be added relatively easily.

Lastly, the model gives insight in the key factors determining the coral survivability. Moreover, focal points are highlighted identifying to which the limited resources and time should be granted.

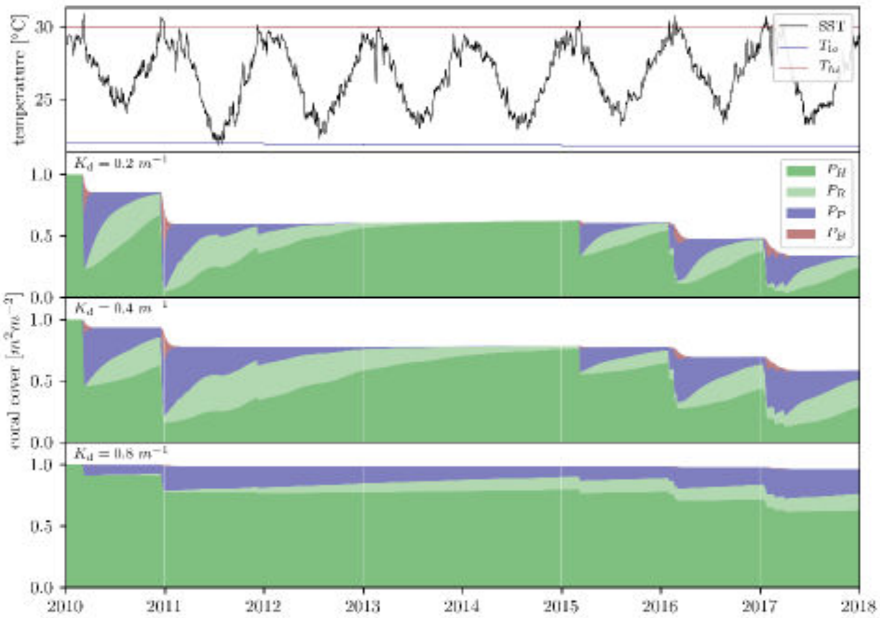

Figure 1 The effects of the light-attenuation coefficient on the bleaching of corals. Top panel shows the SST time-series and the bottom three panels show the population dynamics in which P_H is the healthy population; P_R the recovering population; P_P the pale population; and P_B the bleached population. The white color is the dead population that died due to bleaching. Population covers are given as percentage cover. In the upper left corner of these panels, the light-attenuation coefficient is given.

Drone-based ‘Structure-from-Motion’ (SfM) photogrammetry analysis of mangrove dynamics in the prograding delta in Porong, Indonesia.

S.M. Besselly[1,2,5]*, M. van der Wegen[1,3], D. Roelvink[1,2,3], U. Grueters[4], J. Reyns[1,3],J. Dijkstra[3],.
[1] IHE Delft Institute for Water Education, [2]Delft University of Technology, [3] Deltares, [4]Institute of Plant Ecology, Justus-Liebig-University of Giessen, Germany, [5]Water Resources Engineering Department, Universitas Brawijaya, Indonesia. s.besellyputra@un-ihe.org, s.m.beselly@tudelft.nl

Introduction

The LUSI [acronym of **LU**mpur (mud) and **SI**doarjo (the regency name)] mudflow is reported to be the “largest mud eruption in the world”. On 29 May 2006, the boiling mud erupted at a peak flow rate of up to 180,000m^3/day. Sixty thousand people were forced to evacuate, and 7km^2 of residential area was submerged with mud. LUSI is still actively erupting mud material, gas, water, clasts and oil albeit at a reduced rate. Indonesian government built 10m tall embankments to hold the continuous mudflow and regulate the diversion to the Porong River. These mudflow diversion operations profoundly influenced the estuarine morphology. The delta is rapidly prograding along with the development of mangrove belts. With no end of the mudflow in sight, its influence to delta formation and mangrove ecosystem dynamics urges research on the expected delta progradation and mangrove belt expansion.

Methods

Datasets are required to validate a coupled mangrove dynamics (mesoFON) and Delft3D-FM model. A field campaign in November 2019 is combined with 12 years of observations in Porong Delta, Indonesia. During the field campaign, a bathymetry survey, sediment and water quality samples were analysed. Six sediment traps were also installed perpendicular and parallel to the channel to observe the sedimentation rate on the edge of mangrove forests. One of the key processes of our numerical model is the inclusion of mangrove dynamics. However, the vegetation dynamic model requires mangrove biophysical properties, which mostly relied on traditional forest inventory observation methods. In this research, we used structure-from-motion (SfM) photogrammetry to generate a high-resolution spatial canopy height model (CHM) for the mangroves. This approach is used to determine the structural characteristics of mangrove stands and is validated with ground-truthing. Based on the resulted CHM, the structural information of mangroves (e.g. height and above ground biomass) can be retrieved by using the rLIDAR package in R.

Results

We observed that, in over 12 years, the LUSI-based sediments generated a new delta with a total area of approximately 1.75 km^2 compared to 0.05 km^2 before the eruption. Sediment trap dry volume measurement shows an average increase rate sedimentation of 17cm^3/day. The regional climate conditions and added nutrient flux to the new delta have likely provided a suitable environment to promote the development of mangrove species, such as Avicennia spp., Rhizophora spp., and Sonneratia spp. Analysis of photogrammetry data shows that drone-based observations of the mangrove canopy height are a useful tool to provide data of mangroves characteristics as input to and validation of vegetation dynamics. We used consumer drone DJI Mavic Pro with 75% front overlap, 70% side overlap and 60m flight altitude. The achieved DEM resolution is 5.2cm/pixel.

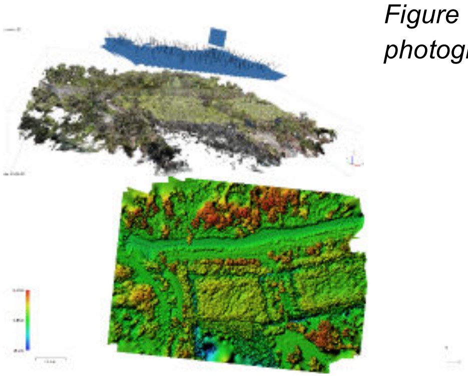

Figure 1 Example of drone imageries processed with SfM photogrammetry. Top: Mangroves dense point cloud. Bottom: SfM

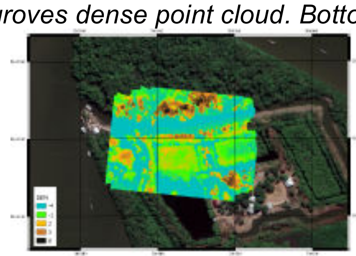

Figure 2 Example of georeferenced DEM overlay to satellite image.

The effect of building geometry on aeolian deposition patterns: a field experiment

D.W. Poppema[1]*, K.M. Wijnberg[1], J.P.M. Mulder[1] and S.J.M.H. Hulscher[1]
[1] University of Twente, d.w.poppema@utwente.nl, k.m.wijnberg@utwente.nl, mulkust@xs4all.nl, s.j.m.h.hulscher@utwente.nl

Introduction

Worldwide, beaches are popular for recreation. As a result, people have built (holiday) houses, restaurants and other buildings at the land-sea interface. These buildings affect the wind field and wind-driven sand transport in their surroundings, thereby shaping the development of the beach-dune system. Currently, society is facing a growing demand for buildings on the beach, but at the same time it lacks knowledge on the effect these buildings have. Therefore, we aim to understand the effect of buildings on the beach-dune interface. In this contribution, we present the results of a field experiment that, as a first step, documents the effect of building geometry on the size of aeolian deposition patterns around buildings in an open sandflat setting.

Methods

During the experiment, cuboid scale models of buildings were placed on the beach at the Sand Motor. The scale models varied in size, where length, width and height ranged between 0.3 and 2 m. The length and width of the deposition patterns around the scale models were measured after 1 day using structure-from-motion photogrammetry. Photos, taken from a height of approximately 5 metres, were computationally combined into an orthophoto (distortion-free top view) and elevation map. In addition, wind speed and direction were measured, as well as the height of the saltation layer by a vertical array of Wenglor sensors. In total, over 4 days, 31 scale models have been tested.

Results

The experiment showed different types of deposition and erosion patterns that can be found around buildings at the beach (see Poppema et al., 2019). The width and length of deposition patterns depended strongly on scale model width (*w*), and to a lesser degree on scale model height (*h*). Scale model length had little effect. Especially the combined effect of $R_W = w^{0.67}h^{0.33}$ showed a strong correlation. From aerodynamic theory, the effects of scale model width and height on flow structures are expected to be of similar strength. However, sediment transport is present in a layer close to the bed and hence scales mainly with scale model width. The deposition is the result of an interplay between sediment transport and flow structures, which explains the strong effect of scale model width and the weaker effect of scale model height.

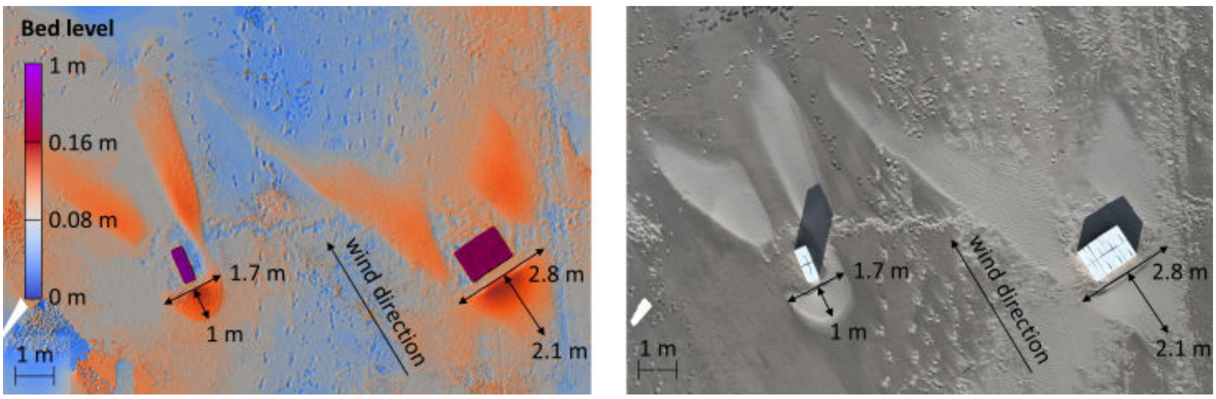

Figure 1 A DEM (left) and orthophoto (right) of de deposition around two scale models that vary in width

References

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Are the Dutch dunes keeping up with sea level rise?

C.O. van IJzendoorn[1]*, S. de Vries, C. Hallin[1 2]
[1] TU Delft, c.o.vanijzendoorn@tudelft.nl, s.devries@tudelft.nl, c.e.hallin@tudelft.nl
[2] Lund University

Introduction

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

Methods

In this study, the extensive JarKus database is used. The dataset contains 200-250 m spaced profiles that have been measured yearly since 1965. In all transects the locations of important geometric features are identified. This allows for quantification and analysis of the development of the coastal profile. Figure 1 shows an example of the dune crest and dune foot in a coastal profile.

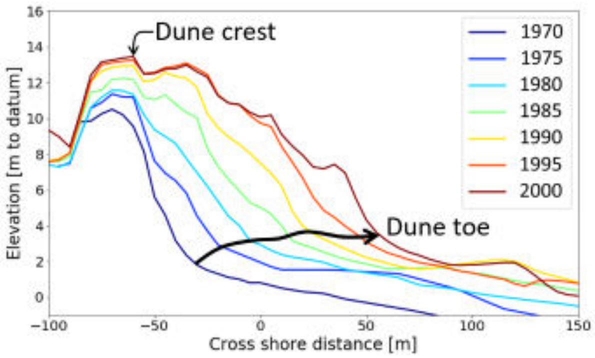

Figure 1 The definition of important geometric features in a coastal profile from the Jarkus dataset.

Results and discussion

The analysis of the Jarkus dataset results in the identification of several long term trends. It is found that when averaging the total dataset, the dune foot elevation increases linearly by 6 mm per year (Figure 2). The dune foot also moves ±1.5 m seaward per year. However, this trend is not linear and shows a clear break around 1990, which could be related to increased nourishments. Additionally, it is found that the dune crest elevation along the Dutch coast increases 4 cm per year (Figure 2). A vertical translation of the coastal profile with sea level rise can be expected based on traditional concepts (e.g. by Bruun). However, the derived dune foot and crest positions show a much larger rise than expected based on sea level rise only (Figure 3). Governing processes for this averaged behaviour remain unclear. A more detailed analysis of specific locations (e.g. nourished areas) might unravel specific governing processes.

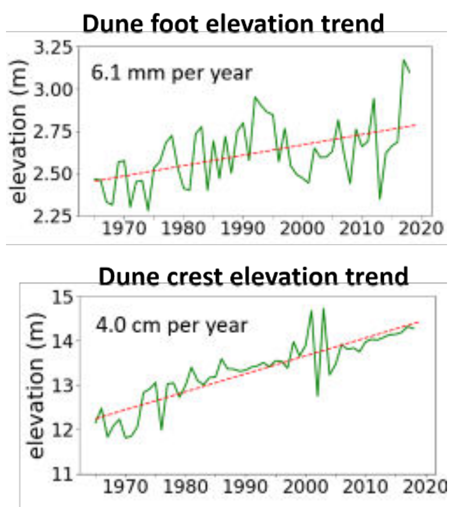

Figure 2 Dune foot and crest elevation through time

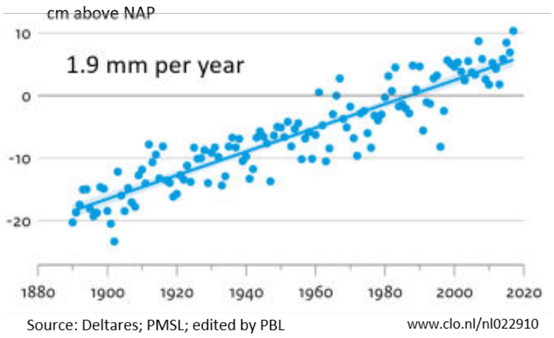

Figure 3 Sea level along the Dutch coast

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The impact of roughness elements on sediment fluxes in coastal dunes and dune valleys: solving the puzzle for Spanjaards Duin

J.J. Oude Vrielink[1,2]*, M.A. Eleveld[2], B. van der Valk[2], B. van Westen[2], G. Hendriksen[2], S. IJff[2], F. van der Meulen[3], R.C. de Zeeuw[4], M.R. van Eerden[5], K. Borst[5], F. Galiforni-Silva[1], K.M. Wijnberg[1]

[1] University of Twente, [2] Deltares, [3] Van de Meulen Consultancy,[4] Shore Monitoring & Research, [5] Rijkswaterstaat
Corresponding author: j.j.oudevrielink@student.utwente.nl

Introduction

In 2009 a new dune area called Spanjaards Duin was constructed in front of the Delfland Coast. Spanjaards Duin was created as a compensation measure for the expected increase in nitrogen deposition from the expansion of the Rotterdam harbour (Maasvlakte 2). The predefined compensation goal is to reach 6 ha of moist dune slack vegetation and 10 ha of dry grey dune in 2033. This is pursued by creating favourable abiotic conditions for natural vegetation establishment (van der Meulen et al., 2014). Sediment fluxes affect establishment and growth of vegetation and shape the dune landscape. Therefore, there is need to know how sediment fluxes behave in Spanjaards Duin.

Methodology

Over the past decade, the morphological development has been monitored with LiDAR sensors (on UAV and airplane). Timeseries of elevation profiles were extracted to study cross-dune morphological development with and without beach houses, and also effects of the planting of marram grass on the foredune. The impact of marram grass on sediment fluxes across the foredune is currently modelled using a numerical aeolian sediment transport model, AeoLiS (Hoonhout & de Vries, 2016). Sediment fluxes within the dune valley were studied by analysing sediment accretion rates in a series of artificial reed bundle fields. Finally, erosion of artificial blowouts was studied by creating a conceptual model focusing on wind steering by morphology.

Results

The presence of beach houses reduced deposition rates on the stoss side of the foredune, most likely due to sediment transport blocking by the houses, whereas morphological impact on the valley located directly behind the foredune seems minor (fig 1). The planting of vegetation resulted in pronounced development of the foredune in terms of height. In the dune valley sediment was deposited within the reed bundle fields, with highest accumulation rates in the field that is most exposed to wind blowing through the valley. Preliminary results show that erosion patterns within blowouts can be predicted from the wind climate.

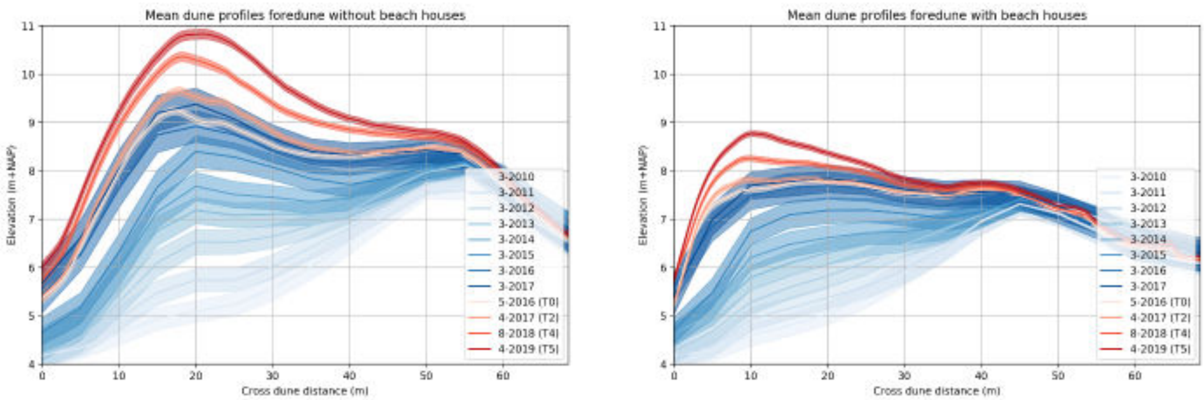

Figure 1 Mean dune profile development for (left) a foredune area without and (right) a foredune with beach houses in front on the beach. North Sea on the left side of the figures.

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Abstracts Poster Presentations Thursday

(in order of numbering in the program)

Lateral flow and sediment transport due to groynes' effects in a channel-shoal system

Zaiyang Zhou[1], Jianzhong Ge,[2]*, Bas van Maren[1,3], Yu Kuai[1], Pingxing Ding[2], Zheng Bing Wang[1,3]
[1] TU Delft, z.zhou-5@tudelft.nl
[2] ECNU, jzge@sklec.ecnu.edu.cn
[3]Deltares, Zheng.Wang@deltares.nl

Introduction

Lateral transport of sediment profoundly contributes to sediment distribution in a tidal channel-shoal system. This research focuses on sediment transport patterns, especially on lateral transport in the North Passage of the Changjiang Estuary. By means of in-situ observation and a validated numerical model, firstly, two sediment transport patterns during low and high water slacks are given. Slack-water dynamics are emphasized in this paper. Momentum balance analysis explains dynamic reasons for lateral sediment transport during high water slacks, stratification and bed level change explain the effect of this lateral transport on sediment accumulation. Secondly, longitudinal oscillation of high-concentration suspended sediment is clearly showed. Calculation of residual sediment flux points out main mechanisms for longitudinal sediment trapping in this system. Particularly, a comparison numerical case is set up, in which one groyne is removed, to further investigate the impact of the groyne-induced lateral flow during low water slacks on sediment transport.

Methods

In this research, we deployed a tripod system between the deep channel and the north shoal in the North Passage. Besides, a high-resolution unstructured-grid Finite-Volume Community Ocean Model (FVCOM) which includes hydrodynamics and sediment dynamics is also applied.

Results

This figure explains the retention effect of groynes on saline water (red part) during ebb tide. Due to this effect, salinity-induced density flow would occur during low water slacks, forming a lateral flow in this channel-shoal system. Except for discussion on lateral flow, we also quantify the effect of groynes on lateral sediment transport. Residual sediment flux would be significantly impacted if one groyne is removed in the numerical simulation. Another important pattern is sediment accumulation on the south shoal during high water slacks.

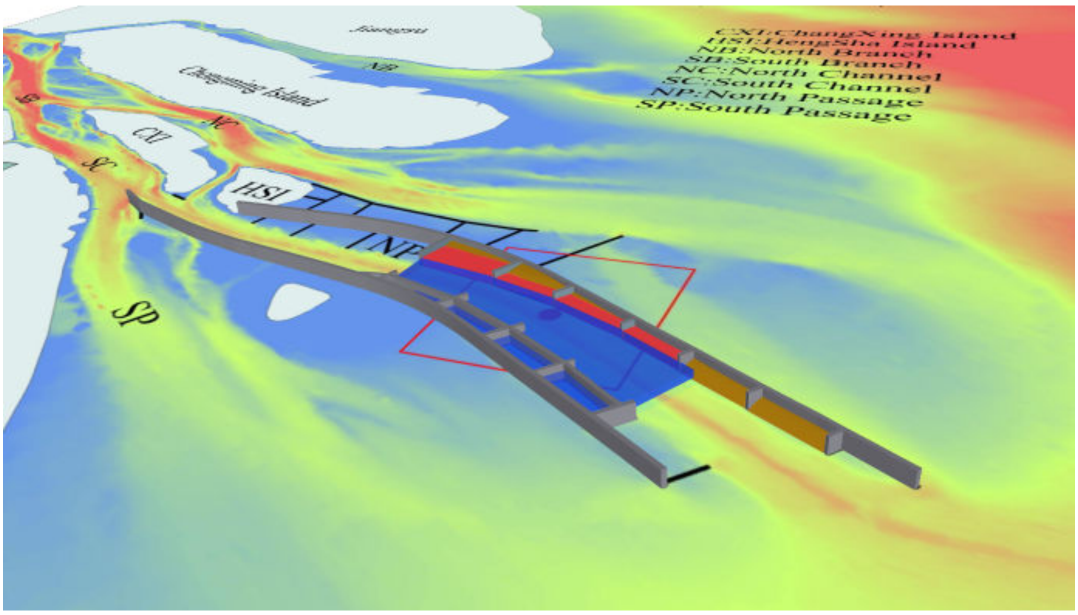

Figure 1 Sketch map of the North Passage in the Yangtze Estuary.

Salt intrusion in the Rhine Meuse Delta: Estuarine circulation or tidal dispersion?

W.M. Kranenburg[1]*, T. van der Kaaij[1], M. Tiessen[1], Y. Friocourt[2], M. Blaas[2]
[1] Deltares, wouter.kranenburg@deltares.nl; [2] Rijkswaterstaat

Introduction

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

Methods

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

Results

From analysis of the salt flux contributions it was found that in the Rotterdam Waterway, the estuarine circulation related salt flux dominates over the tide related contribution most of the time, whereas tide related fluxes dominate further upriver in the New Meuse. However, during surge events the contribution of the estuarine circulation reduces strongly, also in the Rotterdam Waterway. At these times, salt transport into the Rhine Meuse Delta is mainly produced by a reversal of the net, tide-averaged flow. These results imply that measures aiming to reduce salt intrusion by enhancing vertical mixing in the Rotterdam Waterway can be expected to be effective mitigation measures most of the time. However, they will probably not help against salt intrusion during surge events, which might be the more critical conditions.

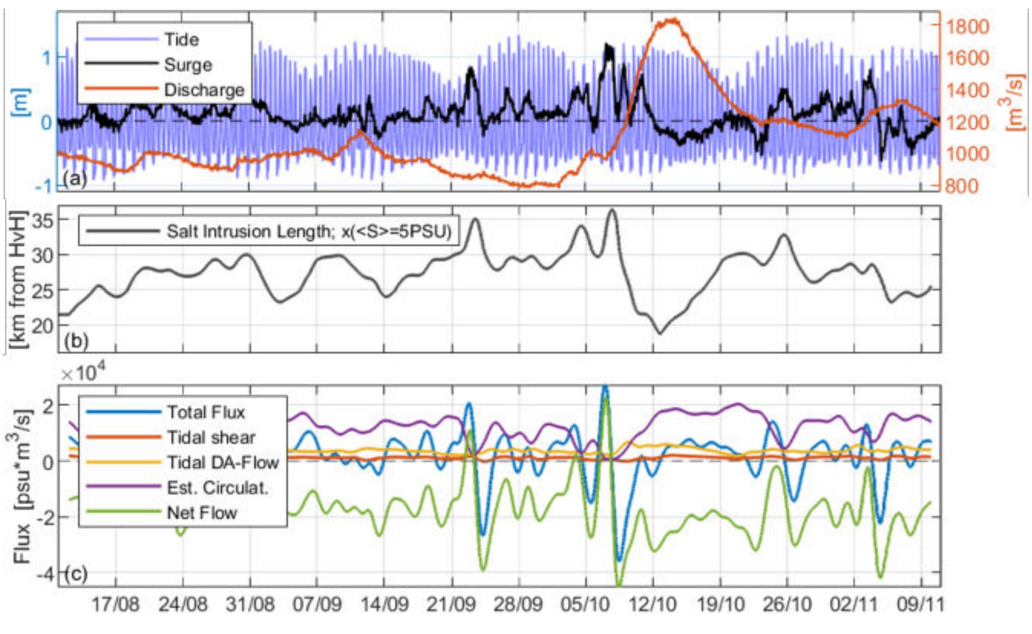

Figure 1 a) Forcing of the system; b) Salt intrusion into the system; c) Total tide-averaged salt flux (positive is inward) and contributions of the individual salt flux components, for location Maassluis (Rotterdam Waterway).

Understanding sand-mud interaction and its large-scale impact on tidal basins

A. Colina Alonso[1,2]*, D.S. van Maren[1,2], Z.B. Wang[1,2], P.M.J. Herman[1,2]
[1] Delft University of Technology, [2] Deltares
*A.ColinaAlonso@tudelft.nl

Bed sediments in estuaries and tidal basins are often composed of both sand and mud. Sand-mud interaction can significantly influence the sediment dynamics and the long-term morphodynamic evolution of a system. However, their dynamics are still often investigated separately (or one fraction is even ignored), partly because of lack of knowledge on this interaction.

Analysis of field data shows that the mud content in intertidal areas of two different systems (Wadden Sea and Western Scheldt, the Netherlands) is bimodal: bed sediments tend to either have a very low or a relatively high mud content, with little variation in between (e.g. see Figure 1). Besides, the large-scale distribution of the mud content seems to be constant on a decadal time-scale, despite local morphological changes. This suggests that the mud content has two stable equilibrium states, and an unstable state in between (Herman et al., 2018). In this research we investigate physical mechanisms related to sand-mud interaction responsible for this bimodality by means of long-term numerical simulations with a schematised Delft3D model.

The first mechanism is based on the theory of van Ledden (2003), stating that there are two regimes within sand-mud mixtures (cohesive and non-cohesive). In the cohesive regime, mud influences the erodibility of the bed, such that muddy beds become muddier. Model results show that this mechanism indeed induces a bimodal distribution of the mud content. Besides, it leads to more abrupt transitions between the sandy and the muddy areas, which are also observed in the field. Moreover, the results show that sand-mud interaction also has an impact on the morphological evolution of the basin.

Another mechanism that can lead to bimodality relates the hydraulic roughness of the bed to the mud content in the top layer (following Soulsby & Clarke, 2005). Larger sand grains generate more near-bed turbulence than mud particles, such that the hydraulic roughness of mud beds is lower than that of sandy beds. Therefore, the bed shear stress is lower and sediment preferentially deposits on muddy beds.

This research brings us a step closer to an understanding of the mechanisms that determine sand-mud patterns. The coming years we will explore this further to unravel the stability of the two modes, the boundary conditions that determine their state and the thresholds that – when exceeded – would lead to regime shifts in the sediment bed composition.

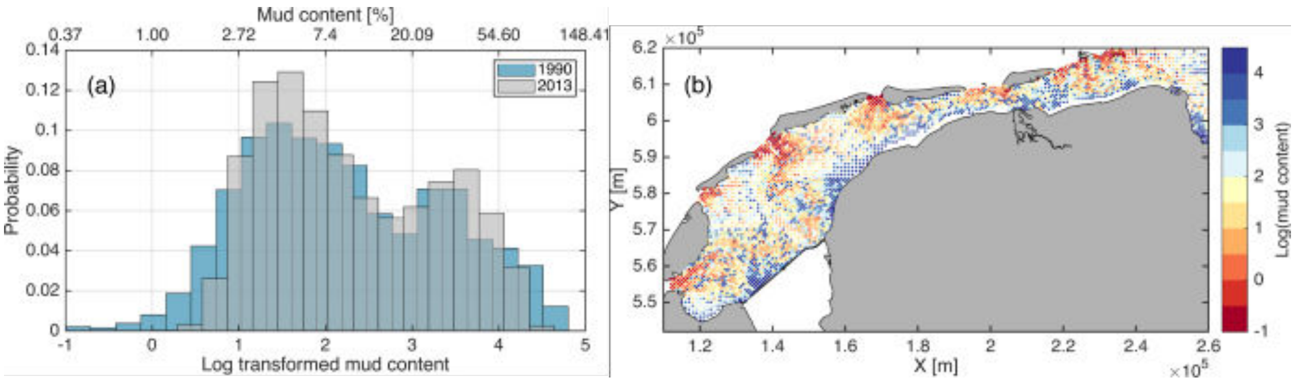

Figure 1 a) The statistical distribution of the mud content in the Wadden Sea and b) its spatial distribution

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High resolution echo sounder data from water surface to sea bed

M. Daugharty[1]*, S. Kamminga[1], H. Huitema[1], J. Van Heesen[1], S. Nylund [1], J. Brinkkemper[2]
[1]Nortek Group BV, maeve.daugharty@nortekgroup.com, sicco.kamminga@nortekgroup.com, herman.huitema@nortekgroup.com, jos.vanheesen@nortekgroup.com, sven.nylund@nortekgroup.com
[2]WaterProof Marine Consultancy & Services BV, Joost.Brinkkemper@WaterProofbv.nl

Introduction

Quantifying marine sediment and biomass in the water column informs environmental management of estuarine and coastal ocean systems. Echograms provide a non-contact means of tracking geomorphic and biological features in the water column over vast spatial and temporal domains. When coupled with current velocity data, flux rates and trajectories can be estimated. Pairing Acoustic Doppler Current Profiler (ADPC) and echo sounder technology, however, has historically yielded echograms with low resolution, limited dynamic range, and data gaps near the sea bed because of competing requirements for velocity output. Nortek's Signature1000 VM ADPC was designed to address these limitations via a fifth, single-beam echo sounder that occupies dedicated pings within the velocity data stream.

Methods

To test the success of this technology, Nortek teamed with WaterProof BV, who deployed a vessel-mounted Signature1000 in conjunction with water sampling in a tidal channel in the Fall, 2019 in the Wadden Sea, the Netherlands. The sampled region is characterized by tidal currents, dredging activities, mud flats, ferry transport, and shallow waters, making for a dynamic regime. Measurements were conducted during 13 hours to cover a full tidal cycle on four separate days in four different locations. Water samples were taken each half hour at three different water depths and analyzed for mud and sand content.

Pulse compressed and non-pulse compressed echo sounder modes were deployed with 5 cm cells and 2 Hz sample rates. Echo sounder backscatter was corrected for losses, the altimeter-derived sea bed delineation was filtered, and backscatter reflections under the bed were suppressed.

Results

Figure 1 displays an example of the high resolution echo sounder relative volume backscatter. The echogram reveals coherent patterns with variability in the vertical and horizontal domains down to the bed. Higher intensity near the sea bed suggests a greater suspended sediment concentration deeper in the water column, consistent with observed sediment samples. This has significant implications for sediment flux computations and associated dredging operations, sand nourishment activities, scour and erosion studies, and ecological restoration efforts. If used with a bottom-mounted Signature1000, which captures fine resolution to the surface, a complete picture of the water column can be obtained for the first time.

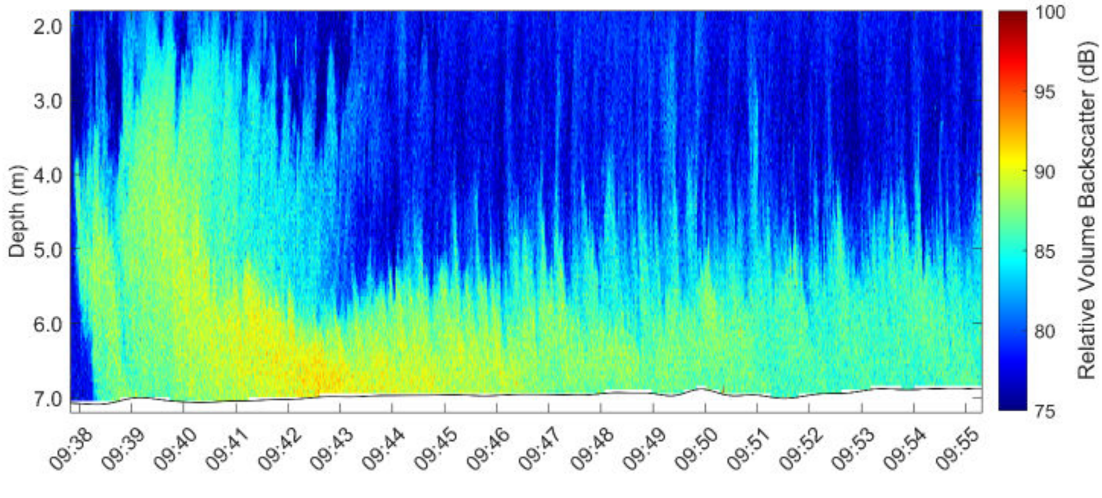

Figure 1 Non-pulse compressed echogram from a vessel-mounted Signature1000 with 5 cm pixels that extend down to the sea bed at a depth of approximately 7 m.

Influence of wind on estuarine circulation and sub-tidal salinity distribution

P.B. Donkers[1]*, Y.M. Dijkstra[1], H. M. Schuttelaars[1]
[1] TU Delft, p.b.donkers@student.tudelft.nl

Introduction

The salinity structure and water circulation in estuaries is the result of various interacting physical transport mechanisms, related to river flow, gravitational circulation and diffusion fluxes. Wind at the water surface results in an additional forcing that has been shown to affect both the estuarine circulation and salinity structure (MacCready et al., 2009). Although wind induced effects have been studied extensively using complex numerical models, a clear understanding of the resulting transport in terms of physical mechanism is still lacking. This presentation aims at obtaining such an understanding concerning the resulting salinity and circulation patterns.

Methods

To systematically analyse the influence of wind stresses on the estuarine circulation and salinity distributions, two existing models have been extended to include wind stresses. The first is a popular analytical model by MacCready (2004) based on vertically averaged salinity profiles. The second model (Dijkstra, 2020), is a semi-analytical model that allows for varying vertical salinity profiles, fully incorporating vertical advection and horizontal diffusion, which have been (partially) neglected in the first model.

Results

Using the extended MacCready model, it is found that for weak down-estuary wind stresses, no unique salinity profile can be identified, while for other wind speeds the salinity profile is unique. Using the extended Dijkstra model, which allows for additional processes, the results of the extended MacCready model can be reproduced for parameter values resulting in a unique salinity distribution, while a unique solution is found for weak down-estuary winds. As an example, using the extended model it is shown that up-stream winds can fundamentally change the salinity and velocity structures in estuaries. The typical direction of circulation, with downstream flow at the surface and upstream flow at the bottom, can be reversed by strong enough surface winds. These two modes of circulation can be present in the same estuary, even if all relevant parameters such as depth and wind speed remain constant over the length of the estuary (Figure 1). In this presentation, the salinity structure and the associated transport balances will be discussed for estuaries ranging from well mixed to a two-layer system.

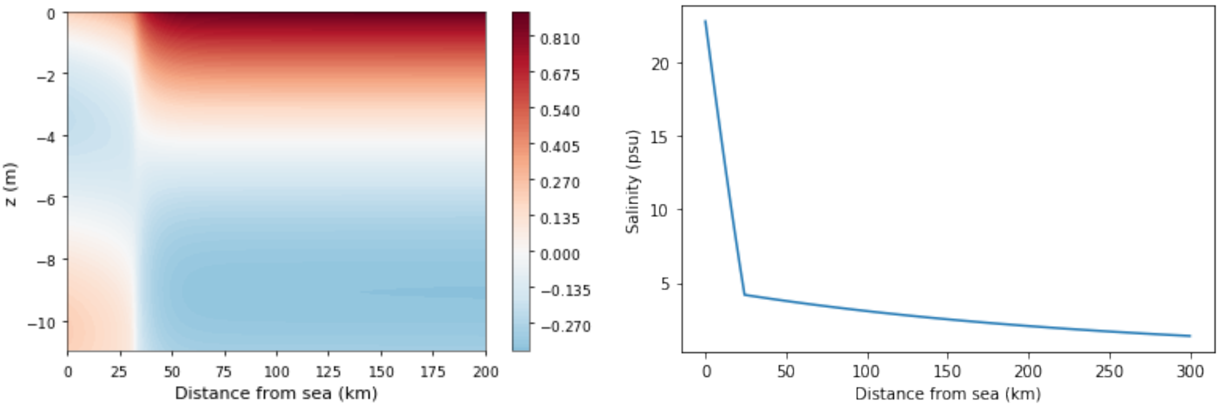

Figure 1 Horizontal water velocity (m/s) (left) and vertically averaged salinity (right) for weak up-stream wind.

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Morphodynamic equilibria and linear stability in tidal estuaries: Influence of Coriolis and planform geometry

H.M. Schuttelaars[1], T. Boelens[2], T. De Mulder[2], X. Deng[1] and Tian Qi[2]
[1] Delft Institute of Applied Mathematics, Delft University of Technology, The Netherlands.
H.M.Schuttelaars@tudelft.nl, X.Deng@tudelft.nl
[2] Hydraulics Laboratory, Civil Engineering, Faculty of Engineering and Architecture, Ghent University, Belgium. Thomas.Boelens@ugent.be, TomFO.DeMulder@ugent.be, Tian.Qi@UGent.be

Introduction

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

Methods

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

Results

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

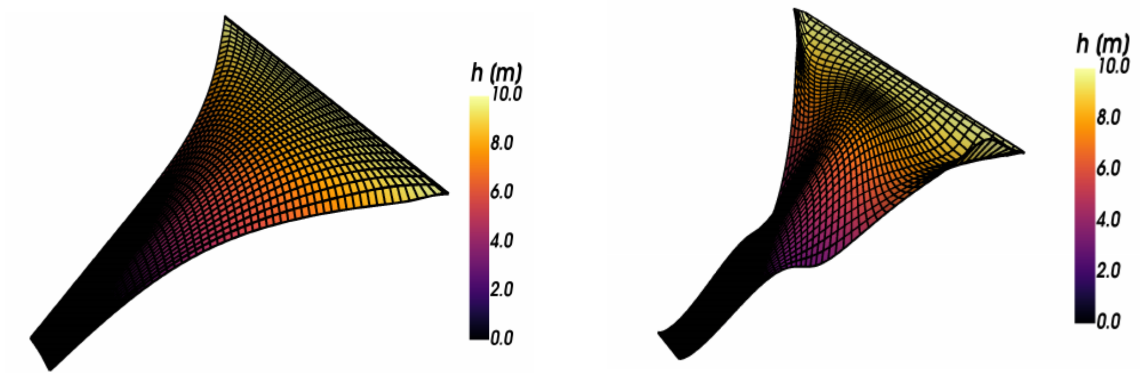

Figure 1 Two examples of morphodynamic equilibrium in single inlet systems

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

Impact of local cross-sectional area reduction by tidal barrage placement on estuarine hydro- and morphodynamics

D.J.K. Schuurman[1]*, M. van der Vegt[1], J.R.F.W. Leuven[2]
[1] Utrecht University, d.j.k.schuurman@students.uu.nl, m.vandervegt@uu.nl
[2] Royal HaskoningDHV, jasper.leuven@rhdhv.com [3] Wageningen University & Research, jasper.leuven@wur.nl

Introduction

Estuaries are morphological dynamic features, positioned on the edge between river and sea. The morphodynamic evolution is the result of continuous interaction between the available sediment and the nonlinear tidal propagation giving rise to residual sediment transport patterns. There is an increased need for renewable energy and tidal energy generation in estuaries might be a viable option. Although tidal energy has big advantages over solar and wind energy (reliability), investments fall behind because full exploitation of the tidal resource is hindered by the limited amount of knowledge on impacts of tidal barrages on estuarine morphodynamics. This study aims to investigate the impacts of a tidal barrage on estuarine scale morphologic evolution. A tidal barrage will locally reduce the cross-sectional area and can reduce the effective basin length. This will impact the flow velocities, tidal prism, and force the system out of morphodynamic equilibrium.

Results

First, a 2DH Delft3D morphodynamic model with an idealized estuary geometry was used to model the morphodynamic response of the estuary to cross-sectional area reduction, as a consequence of tidal barrage implementation. To keep things simple, the effects of waves are neglected and river inflow on the landward end of the estuary was kept constant. Results show strong channel deepening near the barrage, but relatively static patterns of channels and shoals further away. Morphological response near the barrage is initially strong but quickly slows down over time, while morphological response further away from the barrage occurs later and is less prominent as it takes time for morphological change to translate over distance. Sensitivity runs in which we tested the location of the barrage show that the closer to the mouth, the larger the immediate measurable response in channel depth.

Next, a 1D hydrodynamic model was used to solve basic shallow water equations for tidal wave propagation through channels and its result on water level amplitude, flow velocity amplitude and tidal asymmetry. Using that model, we studied the effect of the tidal barrage on tidal range, tidal prism and tidal asymmetry for a wide range of forcing conditions and for different positions of the barrage in the estuary. For an estuary of the modelled size and depth, the tide shows a decrease in ebb-dominance over distance compared to the control run without barrage placement. More results of that analysis will be presented during the NCK days.

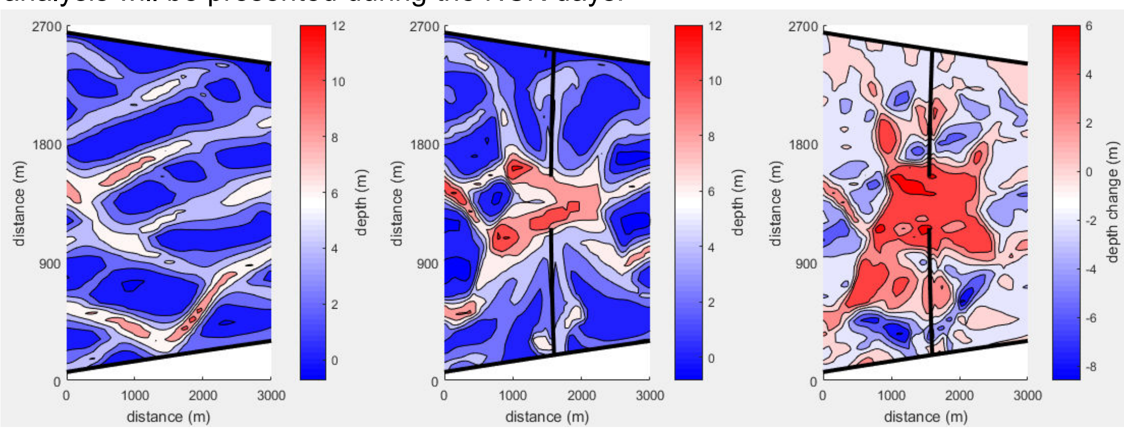

Figure 1 Bathymetry of Delft3D model runs without cross-sectional area reduction (left), and with (middle), and map showing the difference between the two with erosion in red and deposition in blue (right), duration=30 years

Building and raising land: mud and vegetation effects in infilling estuaries

S.A.H. Weisscher[1]*, M.G. Kleinhans[1]
[1] Utrecht University, s.a.h.weisscher@uu.nl, m.g.kleinhans@uu.nl

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. We think that mud and vegetation play a crucial part in this process by elevating bars and confining flow and aim to unravel experimentally how these factors affect the filling of estuaries.

Methods

Experiments were conducted in the 20x3m tilting flume the Metronome that simulated net infilling estuaries from an initially long rectangular basin with barrier islands (Fig. 1). 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 (flood asymmetry; M2+M4) such that sediment was net imported. We ran three experiments: one control with sand, a second with sand and mud and a third with sand, mud and vegetation. Mud was simulated as crushed walnut shell, and sprouts of three vegetation species with different colonising strategies simulated natural vegetation.

We modelled shallow flow in the experiments using the numerical model Nays2D. This modelling approach was validated for scaled river and estuary experiments (Weisscher et al., in prep.) and produces spatiotemporally continuous data of better overall quality than in-situ measurements. Nays2D takes as input a DEM and the corresponding boundary conditions (i.e., tilting parameters, hydraulic roughness, river discharge, grain size) and produces maps of water depth, flow velocity, residual flow and sediment mobility on the resolution of the DEM.

Results

Mud and vegetation mainly settled on intertidal flats and the fluvial bayhead delta. Consequently, bar mobility was strongly reduced, and preservation potential increased in the landward direction. The estuary was narrowed by vegetation colonisation and land formation on large side and mid-channel bars (right column in Fig. 1), which contributed to stronger flood flows that transported sediment further into the basin. The net filling from the landward side caused the tidal prism to drop over the course of the experiments, especially when mud and vegetation were included.

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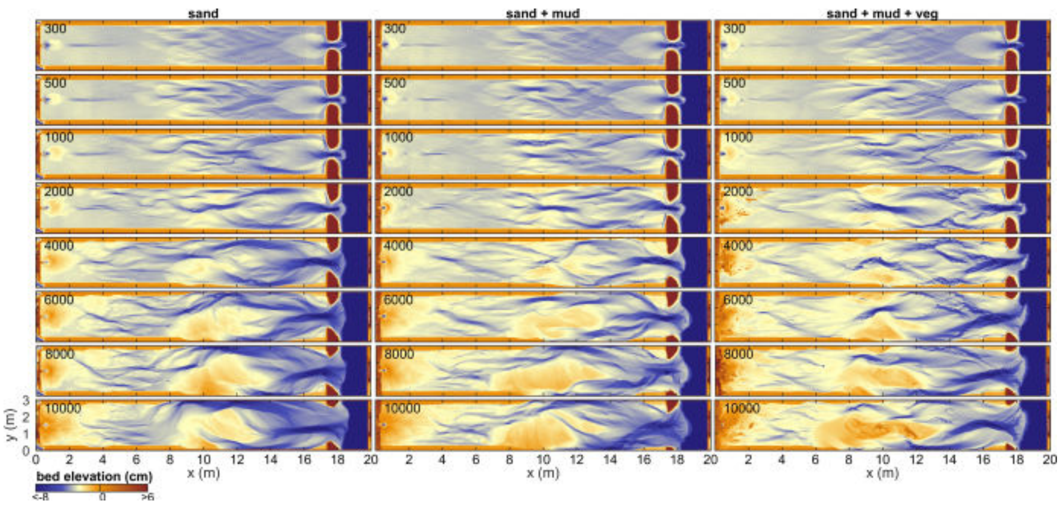


Figure 1 Morphological development of three net infilling estuaries with the number of tidal cycles in the upper left corner for each DEM.

Modelling consequences of artificial structures on salt marsh dynamics in the Wadden Sea

R.W.A. Siemes[1,2], R.J. Daggenvoorde[2], B.W. Borsje[1], S.J.M.H. Hulscher[1]
[1] University of Twente, rutgersiemes09@gmail.com, b.w.borsje@utwente.nl, s.j.m.h.hulscher@utwente.nl
[2] HKV, r.daggenvoorde@hkv.nl

Introduction

Salt marshes are more and more recognised as resilient and sustainable supplements to traditional coastal flood protection structures. Nevertheless, many salt marshes face severe erosion. There is a general consensus that creating an area which is sheltered from high energetic conditions improves the potential for salt marsh growth. However, little proof is provided on the explicit influence of artificial structures to promote salt marsh growth. We investigated how engineering solutions can be used to steer the morphological development of salt marshes.

Methods

A morphological model (Delft3D Flexible Mesh) was applied which enables the analysis of various artificial structures. A small salt marsh in the Wadden Sea was modelled. This marsh has seen heavy erosion (retreat rate of 0.9m/year) since maintenance of its sedimentation field and groyne were halted. In the model, we simulate daily and storm conditions which occurred during the month of October 2017.

Results

The simulated hydrodynamics were validated with measured data. This showed that the model performed well in simulating these hydrodynamics conditions. Key processes relevant for the morphological development of salt marshes are captured and several simulated morphological patterns are observed and identified in literature.

Table 1. An overview of the artificial structure configurations implemented in the model simulation.

Name	Description
Short	A groyne of 2.5m high, 300 m long and perpendicular to the coast
Long	A groyne of 2.5m high, 900 m long and perpendicular to the coast
Combi Long	Combination of the long groyne and a proposed sedimentation field
Combi Short	Combination of the short groyne and a traditional sedimentation field

The calibrated model showed that salt marsh development can be stimulated by artificial structures. The impact of four configurations of artificial structures (Table 1) were analysed. Results hereof are displayed in Figure 1 and show that the artificial structures reduce erosion on the marsh front and tidal flat. Furthermore, most structures are able to increase net accretion on the tidal flat, demonstrating their potential for stimulating salt marsh growth. In addition, results showed that the marsh accretes during storm events. This indicates that salt marshes may provide a resilient supplement to hard structures to improve coastal safety in the face of increasing storminess. However, the artificial structures do reduce accretion on the marsh during the storms.

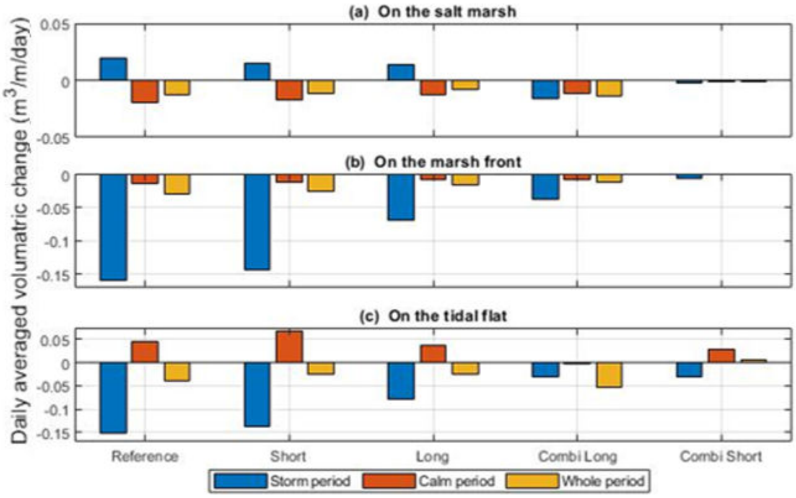


Figure 1 Simulated daily and length averaged volumetric change (a) on the salt marsh, (b) on the salt marsh front and (c) on the tidal flat. The storm period contains the storms of 4-5 October 2017 and 27-28 October 2017. The calm period is from 8 to 21 October. The whole period is the whole month of October 2017.

Regime shift in sediment concentrations in the Loire estuary

R.J.A. de Goede[1,2]*, Y.M. Dijkstra[1], B.C. van Prooijen[1], Z.B. Wang[1,2]
[1] Delft University of Technology,[2] Deltares
* roeldegoede@outlook.com

Introduction

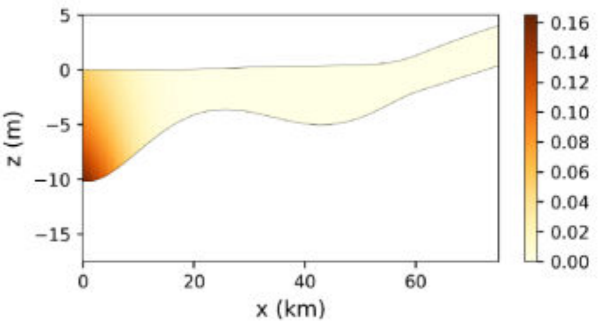
A study of five European estuaries by Winterwerp and Wang (2013) showed that tidal ranges increased significantly along with the ongoing narrowing and deepening of these estuaries. In addition to an increase in tidal range, a dramatic increase in suspended sediment concentrations has been observed in the Ems (Germany) and Loire (France) estuaries, often referred to as a regime shift towards hyperturbid state. While it is generally accepted that the increase in tidal range is a consequence of deepening and narrowing, it is not generally true that deepening and narrowing leads to a dramatic increase in sediment concentrations. Whether deepening is a potential cause for the high sediment concentrations observed in the Loire, is still unclear.

Methods

Although very little observations have been reported over the 20th century, literature clearly shows that sediment concentrations increased drastically over the years. The scarcity of data not only applied for the sediment concentrations over the years but also for bathymetry and hydrodynamics, resulting in uncertainty about the historical states of the estuary. To cope with the large range of uncertainty and variability in the reported observations and model parameters, an idealised model called iFlow has been used. The strength of the iFlow model for this research was twofold. Firstly, iFlow allowed to identify the essential physical processes driving the estuarine sediment dynamics. Secondly, iFlow is computationally efficient, allowing to perform extensive sensitivity studies. In this way, we could determine which processes play a role in the current state of the Loire estuary and how they are affected by deepening. Furthermore, by mapping the effects of the uncertainty on the different physical processes, robust conclusions could be drawn about the effects of deepening, despite the given uncertainty in the input and simplifications of the iFlow model.

Results

The effects of deepening on the physical processes has been assessed by only varying the depth in the model. Deepening generally resulted in enhanced sediment import or decreased sediment export. Hence, the transport capacity in the Loire became much more favourable for the import of sediment. In order to determine the robustness of these findings, an extensive sensitivity study was performed of 14.157 simulations (1287 conditions for 11 bottom profiles over time) to capture the influence of uncertainties in multiple input parameters. For the bottom profile representing the bathymetry in the year 1900, none of the conditions resulted in a hyperturbid state, whereas independent of the conditions, the likelihood to find a hyperturbid state always increased for increasing depth. From this we can conclude, that the observed regime shift towards high sediment concentrations would not have happened without the deepening of the Loire estuary.



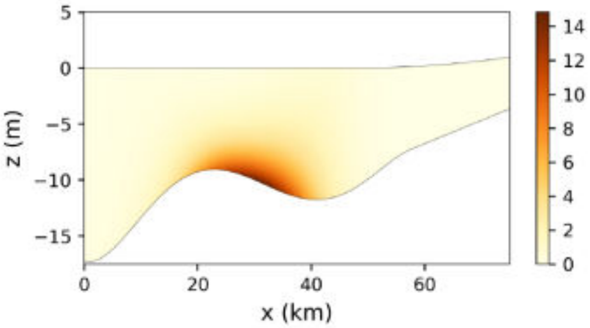


Figure 1 Modelled tidally averaged suspended sediment concentrations in (kg/m^3) along the Loire estuary (x=0 is the mouth) for bottom profiles representing the bathymetries around the years 1900 (a) and 2010 (b). The drastic increase in sediment concentrations is found by only increasing the depth, keeping all other model parameters constant.

Morphological development of the Bollen van de Ooster: A potential hazard for Goeree-Overflakkee?

M.Q.T. Groenewegen[1,2,3]*, S. de Vries[1], A. Colina Alonso[1,2], R. Abraimi[3], P.K. Tonnon[2], S.G.J. Aarninkhof[1],
[1] Delft University of Technology, [2] Deltares, [3] Waterschap Hollandse Delta
* mauritsgroenewegen@hotmail.com

Introduction

The Bollen van de Ooster, a sand bar in the outer delta of the Grevelingen, is separated from the coast of Goeree-Overflakkee by a relatively deep channel, called the Schaar. Since the closure of the Grevelingen in 1971, the Bollen van de Ooster has evolved into an intertidal alongshore parallel shoal of approximately eight kilometers length. Migration of its eastern edge along the coast during the past years led to an erosion trend at the coastline of Goeree-Overflakkee that is measured to be up to 27 m/year. This potentially threatens the local hard sea defence, the Flaauwe Werk. Uncertainty about this behaviour raises questions about the necessity to take measures. In this particular research we aim to provide a better understanding in the changes that have occurred, bring more certainty about the future and therefore contribute to informed decision-making.

Methods & Results

A data analysis of vaklodingen and JarKus, numerical modelling with a 2DH Delft3D model and a case study were applied. The data analysis revealed a periodic arrival of shoals at the coastline since the closure of the Grevelingen until the mid-nineties. Thereafter the Schaar reached a depth of approximately 12 meter. Since 2003, a continuous decrease in depth and flow surface can be observed. The morphological development shows many similarities with two other cases: the recent attachment of the Noorderhaaks at the coast of Texel and the attachment of the Bornrif at Ameland.

Modelling results show that significant flow velocities arise in the channel for a limited time duration during low tide when the Bollen van de Ooster is emerged. This is the result of tide-driven flow along the coast. Simulation of waves showed the small influence of the wave angle on the wave-induced flow velocities near the channel. Waves coming from the north are refracted considerable due to the extension of the Haringvliet outer delta. The result is a large net longshore sediment transport rate at the seaward side of the Bollen van de Ooster. This could explain the pace of the migration in eastern direction. Moreover these sediments are a source for the channel, contributing to the decreasing channel dimensions. Lastly it was found that wind forcing is able to affect the flow velocity in the channel and during more energetic conditions even reverse the flow direction.

Conclusion

Based on these findings we concluded that waves are the dominant forcing mechanism in shaping the morphology. The attachment of the Bollen van de Ooster is expected to occur in the near future. Attachment implies the disappearance of the eroding currents. The duration at which this attachment can be expected could not be deduced from this study. The erosion of the coastline will continue as long as the channel is present. Based on the width of the dune row and the presence of beach groynes the potential threat of the morphological development for the primary flood defences seems minor.

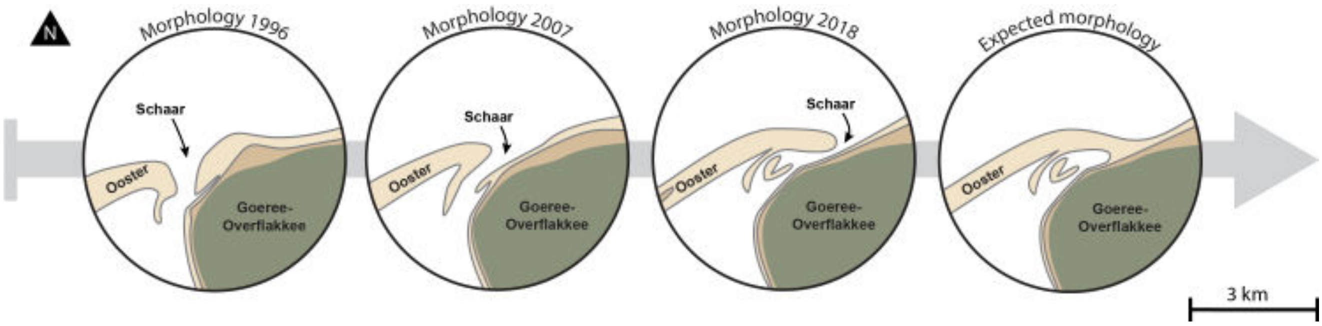


Figure 1 Schematization of morphological evolution of the Bollen van de Ooster near Goeree-Overflakkee and the expected future morphological development.

Hydrodynamic modelling of wave overtopping flow over grass-covered dikes

V.M. van Bergeijk[1]*, J.J. Warmink[1], S.J.M.H. Hulscher[1]

[1] University of Twente, v.m.vanbergeijk@utwente.nl, j.j.warmink@utwente.nl, s.j.m.h.hulsher@utwente.nl

Introduction

High waves during storms can overtop the dike and erode the grass cover resulting in dike failure. Erosion of the cover occurs when the hydraulic load of the overtopping wave exceeds the dike cover strength. High hydraulic loads are caused by three processes: 1) turbulence, 2) high wave front velocities and 3) wave impact at geometric changes in the cross-dike profile. Existing models are only capable of describing the hydraulic load caused by one of these processes. However, a model that accounts for all three processes is required to understand how the hydraulic load varies along the dike profile (Van Bergeijk et al., 2019).

Methods

In this study, a numerical 2DV model is built using the open-source software OpenFOAM® to simulate the flow of an individual overtopping wave over a grass-covered crest and landward slope. Two data sets of overtopping tests on grass-covered dikes in the Netherlands are used to calibrate and validate the model. The model is validated using measured flow velocities and layer thicknesses as function of time. The pressure and stresses are computed in the numerical model to show how the forces on the cover vary along the dike profile and vary over time.

Results and outlook

Figure 1 shows the stresses along the dike profile with a crest width of 2 m and a slope steepness of 1:3. The shear stress τ_s is highest at the wave front (x =21 m) and decreases over the tail of the wave. This behaviour is similar to the flow velocity and layer thickness, which are also maximum at the wave front.

However, the normal stress is maximum halfway the slope (x =12 m) and is 1/3 of the normal stress at the wave front. Both stresses show the largest variation around their maximum. Next, an in-depth analysis will be performed to study which of the three processes lead to this variation in stresses along the profile. Better understanding of the hydraulic force along the dike profile is required to develop an erosion model that is able to predict failure by all three processes instead of a separate erosion model for each process. In this way, the weakest point along the dike profile can be found to improve the assessment and the design of grass-covered dikes.

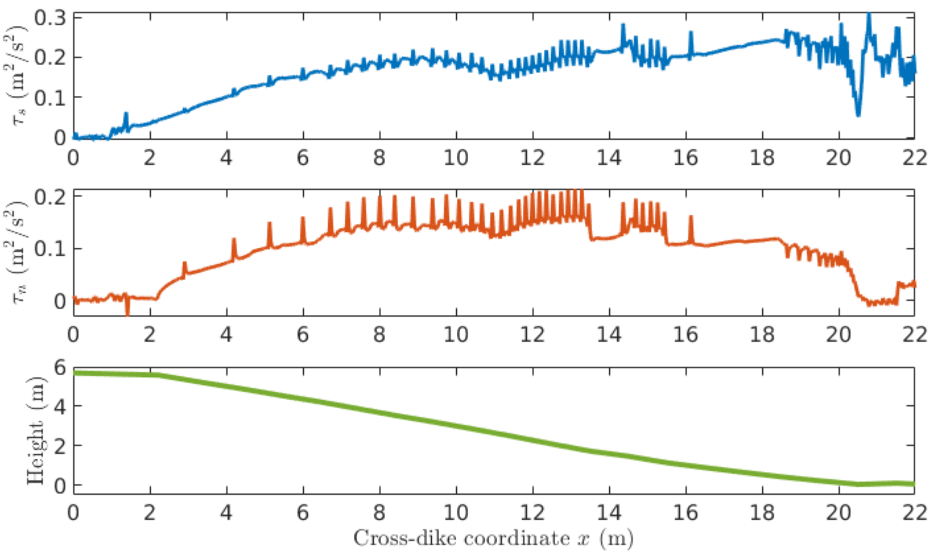


Figure 1 The shear stress τ_s and tnormal stress τ_n along the dike profile after 5 seconds of overtopping for an overtopping volume of 2500 l.

Acknowledgements

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On the importance of net sediment transport capacity to Dutch Coastal Management

Q.J. Lodder[1, 2], Z.B. Wang[2,3], G.Ramaekers[1]
[1] Rijkswaterstaat, Quirijn.Lodder@rws.nl, Gemma.Ramaekers@rws.nl
[2] Delft University of Technology, Faculty of Civil Engineering and Geosciences,
[3] Deltares, zheng.wang@deltares.nl

Introduction

Research on sediment transport in relation to coastal management along the Dutch coast has often focused on diffusion of sediments from nourishment locations. Often the research question bowls down to "how quickly do nourishments diffuse and need to be reinstalled?" or "can we optimize the nourishment strategy by reducing diffusion times". However, for the long-term morphological development of our coast limitations to the net sediment transport capacity might be a more important factor then diffusion times. In our poster presentation we will give examples of the importance of net sediment transport capacity limitation to coastal management.

Example: net sediment transport limitation at the Wadden Sea

Our research has shown that the net sediment transport capacity is a key driver for the development of the Wadden Sea (e.g. Wang, et al., 2018). The morphological development of the Western part of the Wadden Sea is already partly determined by the net sediment transport capacity of the tidal inlets (e.g. Marsdiep). Our analyses show that, under accelerated sea level rise, the net sediment transport capacity also becomes the critical factor determining the large scale development of other parts of the Wadden Sea (Lodder, et al., 2019). On centennial time scales it is likely that the net sediment transport capacity determines the morphological future of the Wadden Sea.

Example: diffusion of the Sand Motor

The Sand Motor was installed at the Delfland coast in 2011. Multiple authors have published on many aspects of the Sand Motor (e.g. Luijendijk & van Oudenhoven, EDS, 2019). One of the conclusions is that the Sand Motors diffusion is confined to a couple of kilometres to the north and south. The diffusion is as expected limited by the net sediment transport capacity. This highlights the challenges for long-term coastal management where nourishments are used to supply the coastline with the sediments it need to adapt to sea level rise. As a result of the limits to the net sediment transport capacity a distributed nourishment strategy is likely needed.

Example: stability of the multiple channel system of the Western Scheldt

At the Western Scheldt large scale dredging is needed for safe navigation to the Antwerp harbour. The dredged material is being placed at disposal sites in one of the two channels. The natural redistribution of the placed sediments is a net sediment transport limited process. Which might result in long-term instability of the two-channel system. Conservation of the two-channel system is an important objective of the management of this system. The net sediment transport capacity therefore has a direct influence on management of the estuary.

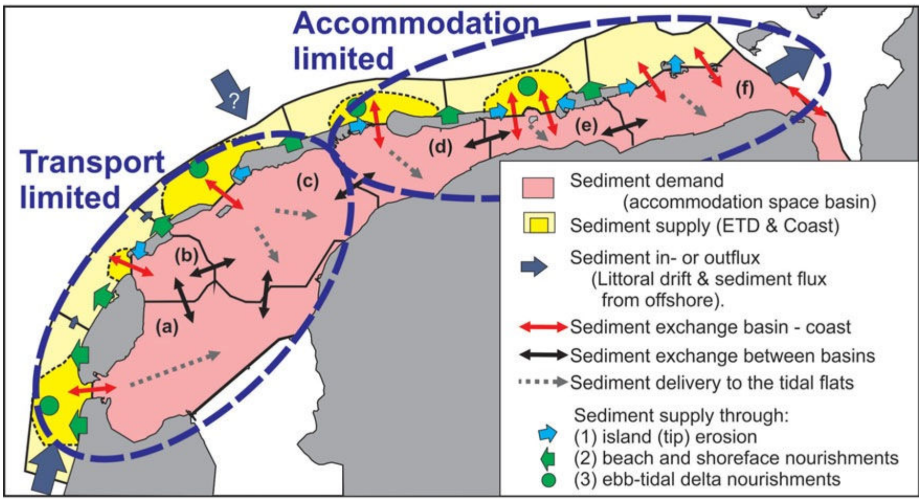

Figure 1 Schematic overview of transport limited and accommodation limited parts of the Wadden Sea (Wang et al., 2018)

Influences of nutrient availability and precipitation on the growth of dune-building grasses

A. Lynch[1*], M. Riksen[1], S.E.A.T.M. van der Zee[1], J. Limpens[1]
[1] WUR, aaron.lynch@wur.nl, michel.riksen@wur.nl, sjoerd.vanderzee@wur.nl, juul.limpens@wur.nl

Introduction

With rising sea levels and changing weather patterns, dynamic dune coastlines may alter. For many reasons such as coastal safety, fresh drinking water supply, and tourism, we need to know how such changes will affect our dunes. In the joint WUR-TUDelft project DuneForce, we aim to create a modelling framework to predict coastal dune evolution on decadal time scales. Coastal dunes owe their existence to the interactions between sediment supply and dune-building grasses, which trap and bind the otherwise mobile sediment. Changes in rainfall patterns and availability of nutrients may alter the way in which these grasses grow, subsequently affecting dune dynamics. To this end we have initiated a large scale field experiment to study the effects of increased rainfall and nutrient availability on the establishment and growth of *Elytrigia juncea* and *Ammophila arenaria*, the dominant dune-building grasses in the Netherlands.

Methods

Running from March 2020 through till September 2021, the experiment covers 2.7 hectares of a typical Dutch beach and foredune landscape near Meijendel, South Holland. Here we will subject exiting stands of healthy *Elytrigia* and *Ammophila* on the embryo- and foredunes to a factorial combination of five levels of rainfall and two levels of nutrient treatments. Through monthly watering we replicate volumes of annual precipitation with return periods of up to 100 years, and with fertiliser additions we simulate increased nutrient availability as a result of mineralisation and atmospheric nitrogen deposition. In March 2021 we will add rhizome fragments to the treatment plots to investigate the effects of rainfall and nutrients on grass establishment, which initiates the formation of dunes. Responses of grass structure, composition and density will be measured, as well as the effects on local topography and soil properties.

Application

After completion in September 2021, we will translate the topographic and vegetation responses observed in the field into model parameters to allow simulation of spatial and temporal variability across dune landscapes.

Figure 1 Cross-section of the Meijendel study site, with Elytrigia*-covered embryo dunes (left) and* Ammophila*-covered foredune (centre).*

Plant-sediment-human interactions along anthropogenic sandy shores

S.J. van Rosmalen[1], J. Limpens[1], M.J.P.M. Riksen[1]
[1] WUR, sasja.vanrosmalen@wur.nl, juul.limpens@wur.nl, michel.riksen@wur.nl

Along the Dutch coastline, nature-based solutions (NBS), in the form of sediment nourishment and natural dynamics, have been implemented on a structural basis since 1990 to maintain and improve flood safety and spatial quality. However, it is only recently that these multifunctional NBS interventions have reached such a magnitude that they instantly, and significantly change the original coastal landscape (such as the Sand Motor and Hondsbossche Duinen). These NBS-modified coastal landscapes, trigger interaction with people using these new landscapes. Although interaction, such as recreation, is intended, it can have unforeseen and unintended side-effects. The challenge is to find ways for social and natural systems to co-exist, co-develop and create synergies. Though, questions about how the social and natural systems interact in the NBS-modified coastal landscapes and if these interactions strengthen or weaken the primary functions of the NBS remain.

Within the ReAshore project, WUR, UT and HZ have teamed up to understand emerging development of multi-functional NBS after its implementation.With this knowledge we will develop guidelines aimed at minimizing the risk of unexpected failure in the functioning of the NBS intervention and to optimize the balance between multi-functional use and required maintenance.

WUR is responsible for assessing the effect of human activities and dune design on vegetation dynamics and associated topographic development in NBS-modified coastal landscapes. More specifically, WUR research will focus on three aspects. 1) The effect of human activities on vegetation, 2) the effect of vegetation on human activities, and 3) the effect of human activities on sediment dynamics. This will be assessed by means of field experiments and field observations at the Sand Motor and Hondsbossche Duinen. This will include the characterisation of sediment parameters such as soil moisture and soil organic matter, surface roughness, vegetation and topography development, and land- and UAV-based observations. The collected and synthesised data will be used to create guidelines for management and maintenance of multifunctional NBS for the sandy Dutch coastal systems.

Figure 1 Anthropogenic shore created by nature-based solutions at Hondsbossche Duinen.

Living on the edge
Quantifying physical dynamics controlling mangrove fringe dynamics

M. Gelderland[1]*, E.M. Horstman[1], P.W.J.M. Willemsen[1,2,3], D.A. Friess[4], J.B. Alemu[4], E.S. Yando[4], K.M. Wijnberg[1]
[1] University of Twente, M.Gelderland@student.utwente.nl; [2] NIOZ Royal Netherlands Institute for Sea Research and University of Utrecht; [3] Deltares; [4] National University of Singapore

Introduction
Mangrove forests are well known as coastal ecosystem defences. Mangrove trees have a significant role in these systems as they attenuate hydrodynamic forces and contribute to the reduction of coastal erosion, (Horstman et al., 2014). However, a mechanistic understanding of the feedbacks of hydro- and morphodynamic stresses on mangrove seedling survival is lacking for the period after establishment (Balke et al., 2011). These feedbacks are key for the development and resilience of mangroves, particularly in an urban area where stressors such as limited accommodation space and reduced sediment supply are prevalent. In this work we address the effects of waves and tidal currents, including fluctuations therein over a seasonal timescale, on the morphodynamics and their combined impact on mangrove seedling development.

Methods
Our study site is a narrow mangrove fringe (~30 m wide) in front of a stop bank in the Sungei Buloh Wetland Reserve (northern coast of Singapore). Along a cross-shore transect, we deployed two frames with Echologgers, to monitor high-resolution surface elevation changes, wave gauges and current meters. The monitoring period comprised a three month period. Seedling numbers, heights, diameters and leave counts are monitored for 10 plots of 1 m^2 for the same period. Furthermore, sediment properties and representative vegetation tree data is collected.

Preliminary results
Preliminary results show a decreasing number of mangrove seedlings within the monitored plots. The average diameter, height and number of leaves show a more stable result, but slightly increase as the largest seedlings survive. The number of pneumatophores (i.e. aboveground pencil roots) varies increases from $O(10^1)$ at the stop bank to $O(10^2)$ at the front of the forest. Tidal inundation of the study site exceeds 2 m during spring tides, but reduces to less than 0.5 m during neap tides. Observed significant wave heights are relatively low $O(10^{-1})$ m due to the small fetch in the narrow straits fronting the study site. Across this narrow fringe, waves are attenuated for approximately 13% per 10 meter. Observed bed level changes show very limited erosion and deposition rates of $O(10^{-2})$ m. This is in line with the limited wave activity and dense near-bed root cover. Preliminary results indicate that the decrease in seedling numbers is related with an increase of the wave energy. This and other stresses will be further quantified to identify potential correlations in the temporal changes of seedling survival, hydro- and morphodynamics.

Figure 1 Avicennia seedlings establishing in the mangroves fringing the north shore of Singapore.

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Horstman, E. M. et al. (2014). Wave attenuation in mangroves: A quantitative approach to field observations. *Coastal Engineering*, *94*, 47–62.

Modelling of interactions between bioturbation and mud distribution reveals effects on large-scale estuarine morphology

M.Z.M Brückner[1]*, C.S. Schwarz[1], A. W. Baar[2] & M.G. Kleinhans[1]
[1] Dep. Physical Geography, Utrecht University, m.z.m.bruckner@uu.nl
[2] Energy and Environment Institute, University of Hull

Introduction

Macrobenthic species that live within or on top of estuarine sediments can destabilize local mud deposits through their bioturbating activities. Resulting enhanced sediment availability will affect redistribution of fines and hence large-scale morphological change. However, various species are expected to affect this feedback differently, leading to distinct morphological features that determine the functioning and management of estuaries.

Methods

To quantify this biological control on the morphological development of estuaries, we numerically model two contrasting bioturbating species present in NW-Europe by means of our novel literature-based eco-morphodynamic model. We couple dynamic macrobenthic growth of two generic bioturbators, loosely based on *A. marina* and *C. volutator*, with an idealized hydro-morphodynamic domain parameterized in Delft3D that includes sand and mud. Species 1 is characterized by low abundance in mud and low bioturbation potential while Species 2 prefers large mud fractions and has a high bioturbation potential. Monthly coupling between the bioturbation model and Delft3D leads to emerging dynamic patterns of both bioturbators and mud deposition.

Results

We find significant effects of both bioturbators on local mud accumulation and bed elevation change, leading to a large-scale reduction in deposited mud and gently sloped intertidal floodplains in the confined part of the estuary. In turn, the species-dependent reduction of mud content redefines their habitat and leads to constricted species abundances. Our results show that species-specific macrobenthic bioturbation determines large-scale morphological change through mud redistribution. This suggests that macrobenthic species have subtly changed estuarine morphology through space and time, depending on their distribution and composition.

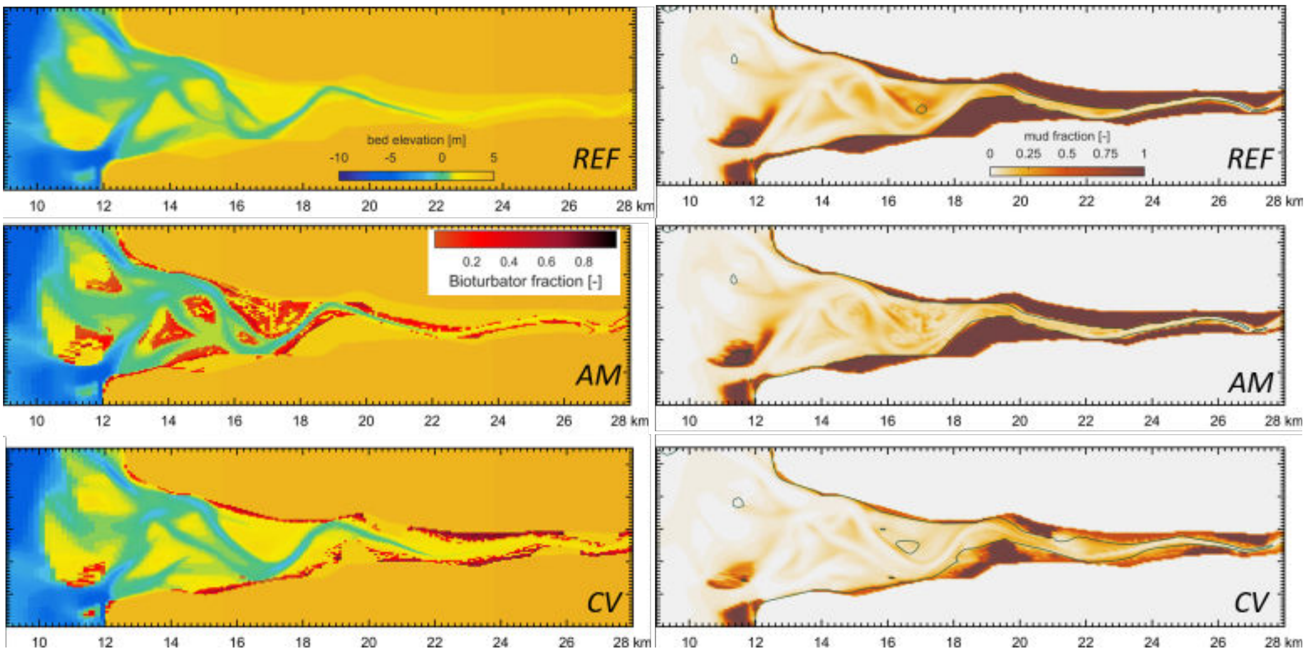

Figure 1 Bioturbator abundance (A) and related mud distribution (B) for two contrasting bioturbating species. Species 1 is abundant in the more dynamic parts of the estuary while species 2 mainly survives at the edges of the estuary. A reduction in mud fraction induced by species 2 leads to a less mud at the shores and a wider central part of the estuary.

Building virtual estuarine ecosystems

J. van de Koppel,[1], R. van de Vijsel[1], L. Cornacchia[1], R. Bidarra[2], and T.J. Bouma[1]
[1] NIOZ, Johan.van.de.Koppel@nioz.nl, Roeland.van.de.Vijsel@nioz.nl,
Loreta.Cornacchia@nioz.nl, Tjeerd.Bouma@nioz.nl
[2] TUDelft, R.Bidarra@tudelft.nl

Introduction

Virtual ecosystems combine fast mathematical models that integrate ecology, hydrodynamics and geomorphology with interactive 3D environments. They can provide a promising tool for managers, policymakers and the general audience to interact with scientific results, and gain insight and impressions of forecasted ecosystems. To create an interactive system, models are needed that can provide the speed and scale needed for the detailed predictions on which visualization can be based. Moreover, new techniques are needed that can provide the details required to provide a believable depiction of a natural system.

Approach

By using models that nest natural patterns at different scales (e.g., sand ripples, ecological patterns) a realistic depiction of modeled landscapes can be generated. I will demonstrate how self-organization models can be used within the context of virtual ecosystems to quickly build representations of natural ecosystems. These representations can then be used to evaluate whether outcome of restoration measures or “building-with-nature” programs will appeal to policy makers and the general audience, and assess whether it is likely to agree to their expectations of the outcome of restoration programs.

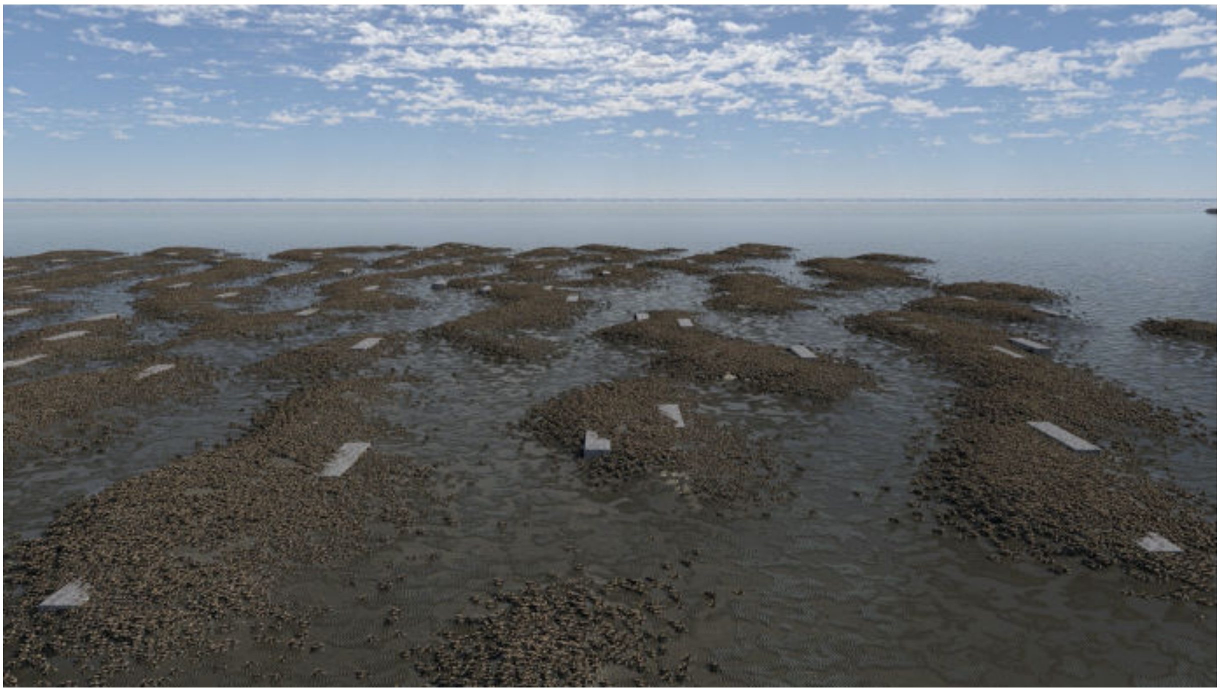

Figure 1 A 3D depiction of a mussel restoration project with the mussel patterns generated by a self-organization model. Note the nesting of patterns to generate this scene.

Mangrove seedling survival in fluid mud and sand

F.F. van Rees[1]*, B.K. van wesenbeeck[1],C.E.J. van Bijsterveldt[2], T.J. Bouma[2]
[1] Deltares, Floris.vanrees@Deltares.nl, Bregje.vanWesenbeeck@deltares.nl
[2] NIOZ, Celine.van.bijsterveldt@nioz.nl, Tjeerd.Bouma@nioz.nl

Introduction

Mangrove restoration successes are very much determined by the physical/environmental conditions of the hydrodynamic system. At the coast of Demak, Java, Indonesia, seedlings in fluid mud die in their first year and full recruitment fails. Unable to link this to research-based causes (e.g. seedlings unable to grow at unsuitable depth, duration and frequency of tidal flooding), this study aims to elaborate on the link between soil strength and seedling anchorage, which has not been studied before.

Methods

Hydrodynamic forces and critical erosion were mimicked by manually dislodging Avicennia ssp. and R. mucronata from the field. The findings were compared with the measured hydrodynamic forces in the field. In addition, a field experiment was conducted in mesocosm in a sheltered environment, so that soil water content could be altered and its effect on dislodgement force could be measured.

Results

Avicennia ssp. stabilizes itself significantly faster with longer stem lengths than R. mucronate in sand and fluid mud, respectively. Seedlings with longer stems have longer, thicker and more roots than seedlings with shorter stems. Surprisingly, wave forces are two orders of magnitude lower than dislodgement forces. Dislodgment of seedlings appeared to be linked to critical erosion. Yet, more erosion was needed to dislodge seedlings (of any species) from sand, compared with dislodging seedlings from fluid mud. Dislodgement by erosion from fluid mud is physically possible. Yet, mortality of seedlings of mangroves remains not fully understood. Possibly unsuccessful recruitments have a biological cause as well.

Figure 1 Sheltered experimental set-up in the field.

Identifying sediment transport mechanisms from grain size-shape distributions: application to an active coastal dune system (Kennemerduinen, the Netherlands)

J.A. van Hateren[1], U. van Buuren[1], S.M. Arens[2], R.T. van Balen[1,3], M.A. Prins[1]
[1] Vrije Universiteit Amsterdam, m.a.prins@vu.nl
[2] Bureau for Beach and Dune Research
[3] TNO-Geological Survey of the Netherlands

Introduction

The way in which sediment is transported (creep, saltation, suspension), is traditionally interpreted from grain size distribution characteristics. However, the grain size range associated with transitions from one transport mode to the other is highly variable because it depends on the amount of transport energy available. In this study we present a novel methodology for determination of the sediment transport mode based on grain size and shape data from dynamic image analysis (DIA).

Methods & approach

The DIA data are integrated into grain size-shape distributions (Fig. 1) and primary components are determined using end-member modelling. In real-world datasets, primary components can be interpreted in terms of different transport mechanisms and/or sediment sources. The new method is tested on surface and sand trap sediment samples from an active aeolian system in the Dutch coastal dunes (National Park 'Kennemerland'). Aeolian transport processes and geomorphology of these type of systems are well known and can therefore be linked to the spatial distribution of end members to assess the physical significance of the method's output.

Results & conclusions

The grain size-shape distributions of the dune dataset are unmixed into three primary components. The spatial distribution of these components is constrained by geomorphology and reflects the three dominant aeolian transport processes known to occur along a beach-dune transect: bedload on the beach and in notches that were dug by man through the shore-parallel foredune ridge, modified saltation on the windward and leeward slope of the intact foredune, and suspension in the vegetated hinterland. The three transport modes are characterised by distinctly different trends in grain shape with grain size: with increasing size, bedload shows a constant grain regularity, modified saltation a minor decrease in grain regularity and suspension a strong decrease in grain regularity. These trends, or in other words, the shape of the grain size-shape distributions, can be used to determine the transport mode responsible for a sediment deposit. Results of the method are therefore less ambiguous than those of 'traditional' grain-size distribution end-member modelling, especially if multiple transport modes occur or if primary components overlap in terms of grain size but differ in grain shape.

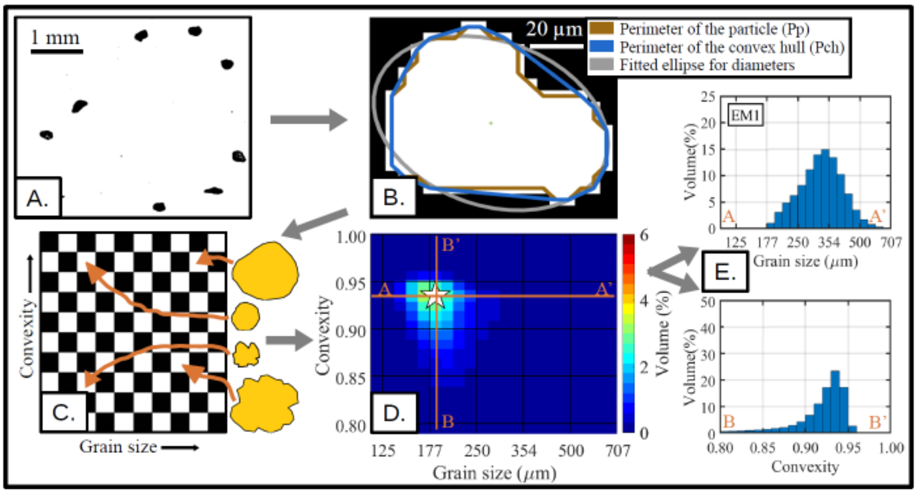

Figure 1 (A) Binary image of sediment grains. (B) Computation of particle characteristics. (C) Assignment of grains to size-shape classes. (D) Grain size-shape distribution (SSD). Star marker designates the mode of the distribution. (E) Grain size (upper panel) and grain shape (lower panel) cross-sections through the SSD along respectively A-A' and B-B'.

Scan Experiment 2020

S. Vos[1], M. Kuschnerus[1], C.van IJzendoorn[1], V. di Biase[1] and R. Breedveld[1]
[1] TU Delft: Email: S.E.Vos@tudelft.nl, M.Kuschnerus@tudelft.nl, C.O.vanIJzendoorn@tudelft.nl, V.diBiase@tudelft.nl, r.breedveld89@gmail.com

Abstract
Building with nature solutions are increasingly seen as a suitable approach to maintain our coasts with the expected climate change. However these kind of solutions show more natural variations and it is therefore important for the protection of the coasts that these variations are well understood and can be modelled accurately. Erosive processes are reasonably well understood but restorative processes are less well known.
Within the framework of two TU Delft projects (CoastScan and DuneForce) the Scan Experiment 2020 (Scanex2020) is organized in February and March 2020 at the beach in Noordwijk (The Netherlands). With various national and international partners the field work is performed to increase our understanding of the restorative processes on sandy coasts. The main objective of the fieldwork is, to obtain more insight into the hydrodynamic, aeolian and morphological processes, which contribute to shore-ward sand transport and the possibilities of different instruments to measure parts of these dynamics. Specific questions are:

- To what extent does short term intertidal sediment exchange govern the long term aeolian sediment transport and dune development?
- To what extend do buildings block shore-ward sand transport?
- To what extent can different measurement systems like for example laser scanning, satellite data, and specialist in-situ samplers measure the evolution of sea/beach/dune properties (i.e. wave height, surface moisture and roughness, sand grain distribution and aeolian transport)?

A multitude of experiments are set up for a duration of two months, to collect data and obtain more knowledge about the various questions.

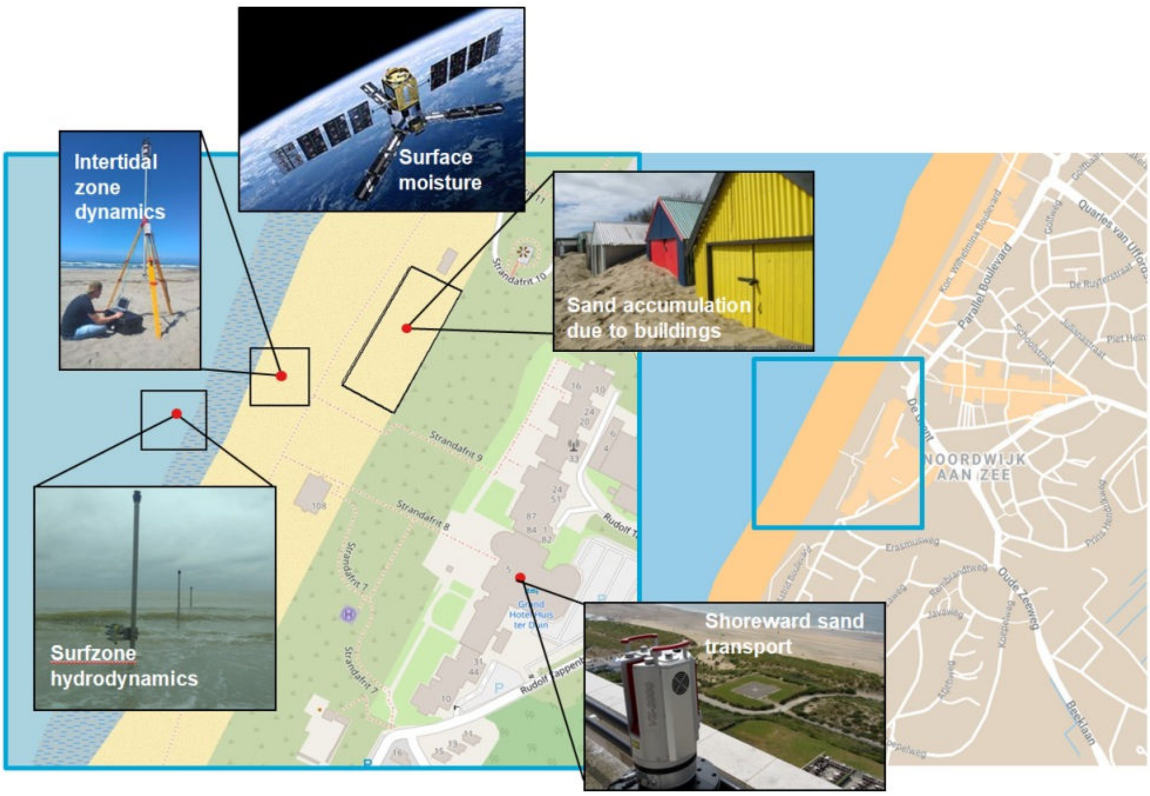

Figure 1 Overview of the Scanex 2020 set-up indicating the different measurements techniques around the beach and dunes near Hotel Huis ter Duin in Noordwijk, NL.

Spatio-temporal aeolian sand dispersal patterns in a coastal dune system, the Kennemerduinen (the Netherlands)

Unze van Buuren[1], Bas Arens[2], Maarten Prins[1]
[1]Vrije Universiteit Amsterdam, u.van.buuren@vu.nl
[2]Arens Bureau for Beach and Dune Research

Introduction

In the National Park Zuid Kennemerland, near the town of IJmuiden, five notches have been dug in the foredune ridge to reactivate and promote aeolian transport of $CaCO_3$-rich beach sand towards the dune system. This project is executed to increase coastal safety and protect the rare (Natura2000 protected) coastal dune biodiversity. Since the start of this project (2013-present) sand transported in suspension has been trapped and collected every two weeks in sandtraps custom made by Arens Bureau for Beach and Dune Research. In this research we investigate spatial and temporal aeolian sediment dispersal patterns of one of those years (2017).

Materials and Methods

The sandtraps (n=15) are distributed in four coast-parallel north-south transects (A to D, 1 km in a N-S and 1.2 km in an E-W direction). The traps are about 80 cm in height and are places 1.5 meter above the surface with the opening pointed to the dominant south-west wind direction. Large holes in the backside of the trap, covered with a fine-grained mesh, allow wind to go through but sand particles >106 µm to drop in a collection bag at the bottom of the trap. Samples (n=213) are analysed by dynamic image analysis, which provides grain size and shape distribution data, and thermo gravimetric analysis which determines the carbonate content. The grain shape parameter used here is the aspect ratio, defined as the ratio of the minimal to the maximal Feret diameter of a grain.

Results and conclusions

The sand flux recorded in the sand traps show large spatial and temporal changes. For instance, trap A1, located on the foredune, has an average flux of 75 gr/2weeks, a maximum of 537 gr/2w and a minimum of 0.9 gr/2w. While C3, ~700 m downwind of A1, has an average flux of 17 gr/2w, a maximum of 187 gr/2w and a minimum of 0.1 gr/2w. The total weight of trapped sediment is 1578 gr/yr for A1 and 359 gr/yr for C3. These results illustrate the effects of downwind and inter-annual weather changes.

The grain-size distributions show the existence of two subpopulations: a coarse population with a modal size of ~350 µm, with a relatively low aspect ratio, and a fine population with a mode at ~210 µm, with a relatively high aspect ratio. Down-wind changes in composition are reflected by a reduction of the proportional contribution of the coarse population (size sorting: down-wind fining) and a decrease of the aspect ratio of especially the coarse population (shape sorting: down-wind increase of proportion of platy/elongated grains).

The carbonate content of suspended load sediment has an average of 7.8 wt%, a maximum of 10.2 wt% and a minimum of 5.7 wt% varying on a spatial and temporal scale. Beach sediments (source) and dune sediments in the subsurface underneath the traps show a significantly lower carbonate content. These results clearly show the positive effects of the reactivation of the dune system considering that all the sandtraps are enriched in carbonate.

Modelling airflow patterns around beach houses using computational fluid dynamics

P. Pourteimouri[1]*, G.H.P Campmans[1], K.M. Wijnberg[1] , S.J.M.H Hulscher[1]
[1] University of Twente, Water Engineering and Management
* p.pourteimouri@utwente.nl

Introduction

Coastal zones have always attracted a large number of people because of the resources and the recreations that they provide. This highly increasing population living along the coastline, increases the demands for construction of restaurants, beach houses and pavilions at the beach-dune interface. These structures block the wind flow and change the airflow patterns which in turn alter the sediment transport pathways and influence the aeolian sand dunes. Figure 1 schematically shows the mean flow field around a cubic building which contains recirculation zones on the top, front and sides of the structure and in the downstream cavity region.

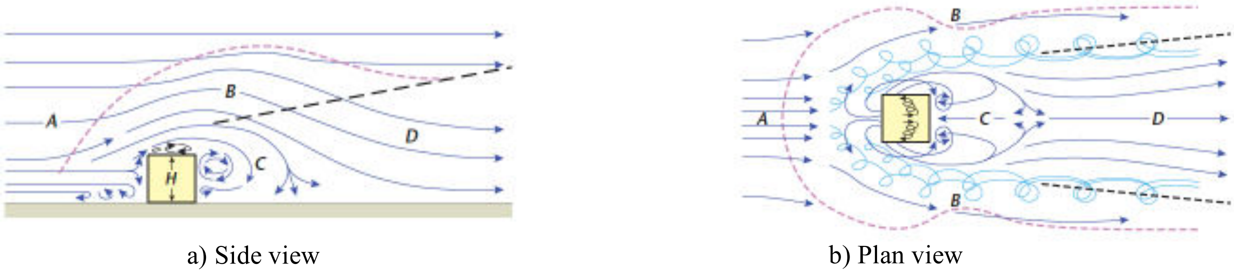

Figure 1 Airflow around an isolated cubic building a) side view, and b) plan view near ground level. A, B, C and D show the incident wind direction, displacement zone, cavity and the wake, respectively. [Oke et al., 2017]

The significant impacts that the buildings' characteristics and their positioning at beaches can have on wind flow patterns and - consequently on aeolian sediment transport - are not fully understood. In this study, we focus on an isolated cubic building and the investigation of the airflow patterns around it.

Modelling flow around buildings

An open-source CFD solver, OpenFOAM, was used to solve the Reynolds-averaged Navier-Stokes equations (RANS). The commonly used $k-\varepsilon$ turbulence closure model was used to simulate turbulent flow structures that are formed around the building. The logarithmic profile was implemented for the inlet wind velocity and the no-slip boundary condition was used for the bottom of the computational domain and the walls of the building. The reference velocity of 6 m/s at the reference height of 10 m was used. The surface roughness height was considered uniform and equal to 0.03 m. Figure 2 shows the three-dimensional model predictions for the wind velocity distribution around an isolated cubic building which is 2 meters in high, length and width.

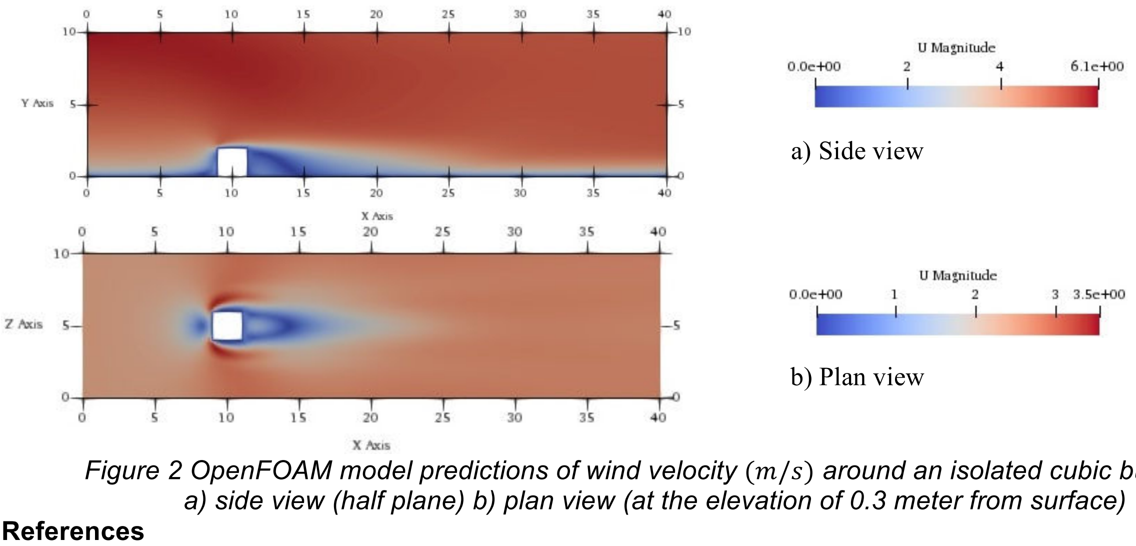

Figure 2 OpenFOAM model predictions of wind velocity (m/s) around an isolated cubic building. a) side view (half plane) b) plan view (at the elevation of 0.3 meter from surface)

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The impact of storms, wind and vegetation recovery on washover development on Rottumeroog, studied using high-resolution satellite imagery

Y. Huberts[1], M. van der Vegt[1]
[1] Utrecht University, y.huberts@students.uu.nl, m.vandervegt@uu.nl

Introduction

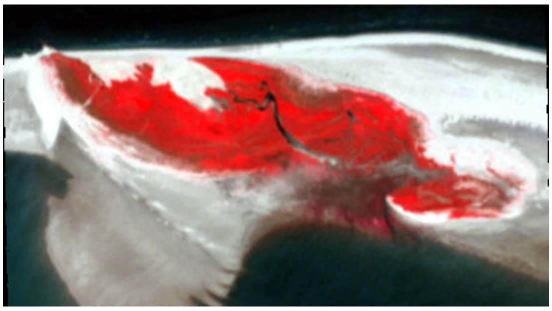
Washovers are naturally occurring, low-lying features on barrier islands. They occasionally experience overwash, which drives morphological change, while at other moments in time aeolian transport is dominant. The vertical accretion rates of washovers can be very high and allow barrier islands to grow with sea-level rise in a natural way. Along the Dutch coast most washovers have been closed off by sand drift dikes, thereby blocking the transport of sediment to the barrier island. Reactivation of washovers is being considered, but questions remain on how effective these measures are and how washovers will develop in time due to storms and aeolian transport. Models (like Xbeach) have been developed that can predict the morphological evolution of washovers during storms, but these need to be validated against field cases. Rottumeroog is one of the most natural barrier islands in the Netherlands and is no longer maintained by nourishments. Recently, a washover has developed and presents an ideal field case to study in detail how washovers develop.

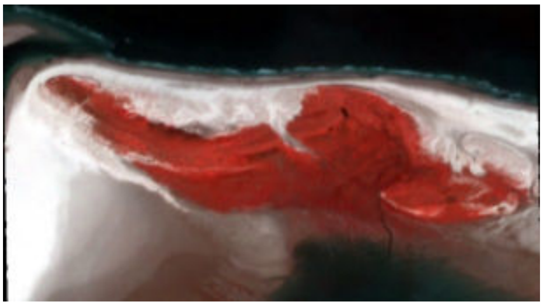
Methods

Using PlanetScope and RapidEye imagery with a spatial resolution of 3 to 5 metres and weekly to monthly intervals, and by using existing LiDAR images, we investigated the seasonal and long-term evolution of a washover on Rottumeroog for the period 2009 to 2019. The satellite imagery was classified into three classes: vegetation, sand and water and it was studied how the different classes developed in time. Changes were related to storm and wind events.

Results

It was found that the washover formed between October 2011 and May 2012. At first, the washover width was relatively small (Figure 1), which likely reduced the storm activity. When dunes were eroded in 2014 and the width of the washover opening increased, the washover rapidly expanded to the south and west, until it reached higher areas beyond which the washover could not expand. The expansion of the washover was coupled with a southward migration of the island (roll-over; Figure 2) as the beach was eroded and sediment from the beach was deposited in the washover. The washover showed strong seasonal patterns in vegetation growth as a result of storms mainly occurring between October to April and the growth cycle of the plants. After the storm season, vegetation starts to grow in the washover as conditions become more favourable. When floods occur in late autumn, vegetated areas change to sandy areas and conditions become unfavourable for vegetation growth. When the washover was still sheltered by the dune rows, conditions were more favourable for vegetation growth than when after these dunes were eroded in 2014. Vegetation regrowth was high again (~70% ±10% of the washover area) from 2016 onwards, which is likely because of an increase in elevation as a result of overwash and related reduced storm activity. Aeolian transport was common in spring but not in other seasons, as vegetation reduces the fetch in summer and the sand is too wet in winter because of the frequent overwash. Our results nicely demonstrate the seasonal and yearly patterns in washover development and can be used to validate models that have been developed.





Left: Figure 1 A false colour (NIR-Red-Green) satellite image of Rottumeroog in May 2012.
Right: Figure 2 A false colour (NIR-Red-Green) satellite image of Rottumeroog in April 2019.

Estimating aeolian sand transport along the Belgian coast

E. Kragiopoulou[1], A. Pieterse[1]*, B. Verheyen[1], A. Bolle[1]
[1] IMDC nv, Antwerp, Belgium. *aline.pieterse@imdc.be

Introduction

Coastal protection programs are now turning more and more towards 'building with nature' solutions, rather than engineering defences, which are often costly and unsustainable in the long run. Also in the context of the 'Complex Project Kustvisie', a project that aims at defining a long term vision for the Belgian coastal protection strategy, several soft, sandy coastal defence measures are being considered. This makes it imperative to gain more insight in the potential evolution of these sandy measures. Aeolian transport plays an important role in the evolution of sandy coasts, especially in dune areas. Approximately half of the Belgian coast consists of sandy beaches combined with dunes (Figure 1). Wind-driven transport is crucial for the natural growth and recovery of dunes between storms and is an important mechanism for a natural, dynamic coastal protection. On the other hand, in areas with towns and dikes, aeolian transport can have a negative economic impact due to the deposition of sand on roads (Strypsteen *et al.*, 2017). Understanding aeolian transport processes in coastal areas, and estimating yearly aeolian transport quantities along the Belgian coast is thus essential.

Approach

To support the design of sandy coastal defence strategies, the use of modelling aeolian processes at the Belgian coast was explored. Aeolian sand transport was estimated using Duna, a 1D profile model (Roelvink and Costas, 2019), which can be applied either as a stand-alone model, or as a module combined with XBeach. Duna is a process-based morphodynamic model that considers wind, sediment, vegetation, and various other components. The wind model combines effects of topography on the distribution of wind shear stress, of wind direction and sheltering, and of vegetation and moisture. The sediment transport model in Duna is based on a Bagnold model, and includes armouring effects. In addition, vegetation cover and height, grain size, slope, and moisture content are taken into account.

Results

Duna was applied to representative profiles of the current situation at the Belgian coast, as well as profiles including potential future nourishment measures. In addition, the numerical modelling results were compared to results from field measurements at the Belgian coast. The highest aeolian transport rates were found for wind directions perpendicular to the coast. In cases where vegetation was present on the high beach, a decrease in wind speed due to the presence of vegetation was clearly visible. In several cases, the aeolian sediment transport peaked at the dune foot, where the slope of the profile sharply increased (Figure 1). Initial estimates of yearly aeolian sediment transport rates were on the same order of magnitude as those previously found in campaigns along the Dutch and Belgian coast.

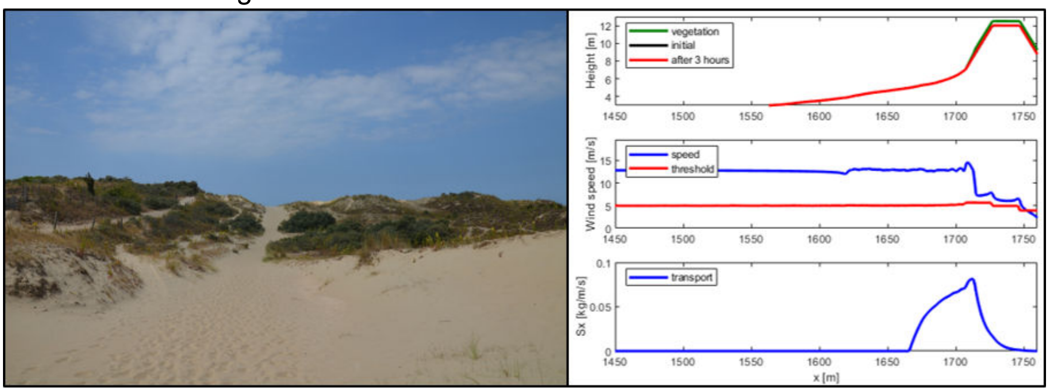


Figure 1 (left) Dune area at De Panne in the west of the Belgian coast. (right) Model simulation for a 3h wind event, with profile (top), wind speed (middle), and aeolian sand transport (bottom).

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Strypsteen G., Montreuil A.-L. & Rauwoens P. (2017). Aeolian sand transport at the belgian coast: Field campaigns and first results. Coastal Dynamics 2017, Helsingør, Denmark.

Abstracts Oral Presentations Friday

(in order of presentation)

Sand redistribution mechanisms of shoreface nourishments: data, models and processes

B.J.A. Huisman[1], D.J.R. Walstra[1], M. Radermacher[2], M.A. de Schipper[3], B.G. Ruessink[4]
[1] Deltares, Bas.Huisman@deltares.nl, Dirkjan.Walstra@deltares.nl
[2] H-Max, max@h-max.nl
[3] Delft University of Technology, M.A.deSchipper@tudelft.nl
[4] Utrecht University, B.G.Ruessink@uu.nl

Introduction

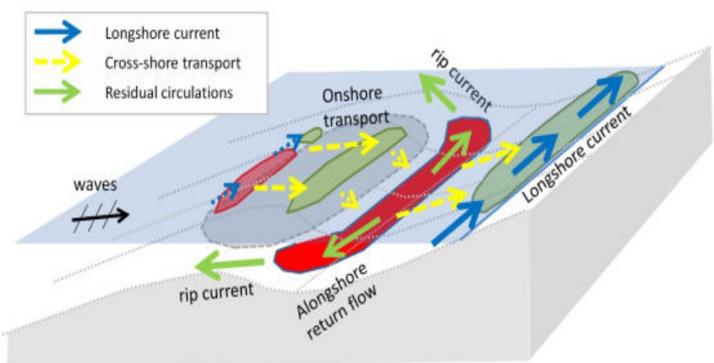
About 300 kilometers of the sandy Dutch coast is maintained with regular sand nourishments to counteract natural erosion trends, ongoing sea level rise and storm erosion. Large elongated sand nourishments at the seaward side of the sub-tidal bar (i.e. between MSL-4m and MSL-8m; referred to as a ‘shoreface nourishment’) are the most commonly applied maintenance measures at the Dutch coast. However, the knowledge of their behaviour and underlying driving processes is lacking. In view of sustainable future coastal maintenance, it is very relevant to know where the sand is going to.

Methods

The study uses bathymetric data of 19 shoreface nourishments located at alongshore uniform sections of the Dutch coast (Huisman et al., 2019). Volumetric changes in alongshore and cross-shore sub-regions were used to identify the reshaping. These data were also used to validate an efficient method for predicting the erosion of shoreface nourishments using Xbeach. The model is used to explain the relative contribution of processes rather than act as a prediction model for other nourishments, the good representation of erosion rates (R^2 of 0.9) gives confidence in the representation of the considered field cases with a shoreface nourishment.

Results

The considered shoreface nourishments provide a long-term (3 to ~30 years) cross-shore supply of sediment to the beach, but with small impact on the local shoreline shape. Most erosion of the nourishment takes place during energetic wave conditions (H_{m0}≥3 m) as milder waves are propagated over the nourishment without breaking. Data shows that considerable cross-shore profile change takes place at a shoreface nourishment. Typically, the crest is moving landward, while the crest height remains at about 4 meter water depth. Some accretion can be seen at the shoreline, and a deepening of the trough of up to 2 meter directly landward of the shoreface nourishment. Cross-shore transport contributed 60 to 85% of the losses from the initial nourishment region for the considered cases. This transport was driven partly by water-level setup driven currents (e.g., rip currents) and increased velocity asymmetry of the waves due to the geometrical change at the shoreface nourishment.



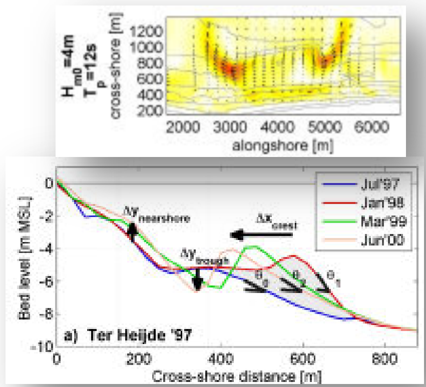


Figure 1 Overview of relevant processes for the redistribution of shoreface nourishments (left panel), an illustration of computed impact of shore-normal storm waves (top-right panel) and an illustration of the measured cross-shore reshaping of a shoreface nourishment at Ter Heijde (lower-right panel).

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Modelling of annual sand transports at the Dutch lower shoreface

Bart Grasmeijer[1]*, Bas Huisman[1], Arjen Luijendijk[1], Reinier Schrijvershof[1], Jebbe van der Werf[1], Firmijn Zijl[1], Harry de Loof[2], Wout de Vries[2]
[1] Deltares, bart.grasmeijer@deltares.nl
[2] Rijkswaterstaat

Introduction

Dutch coastal policy aims for a safe, economically strong and attractive coast. This is achieved by maintaining the part of the coast that support these functions; the coastal foundation. The coastal foundation is maintained by means of sand nourishments.

Up to now, it has been assumed that net transports across the coastal foundation's offshore boundary at the 20 m depth contour are negligibly small. In the framework of the Coastal Genesis 2.0 program we investigate sand transports across this boundary and across other depth contours at the lower shoreface. The purpose of this paper is to provide knowledge for a well-founded choice of the seaward boundary of the coastal foundation. The lower shoreface is the zone where the mixed action of shoreface currents (tide-, wind- and density gradient driven) and shoaling and refracting waves is predominant. Transport rates are relatively small and hence the bed levels in the lower shoreface undergo relatively slow changes.

Methods

We developed an efficient approach to compute the annual sand transport rates at the Dutch lower shoreface. It is based on the 3D Dutch Continental Shelf Model with Flexible Mesh (3D DCSM-FM), a wave transformation tool and a 1DV sand transport module. Waves and currents were decoupled to save computational time, ignoring wave-current-interaction. The effect of Stokes drift and return flow were included.

Results

The wave transformation tool was found to be an appropriate tool to derive wave parameters at the lower shoreface, indicated by a good and equal performance of the tool over the depth range studied. Comparisons against measurements at Ameland, Terschelling and Noordwijk showed that the approach is suitable to correctly model hydrodynamics during normal wind and wave conditions, yielding transport values that are comparable to calculations based on measurements. Wind- or wave-driven residual flows under high energetic conditions were underestimated.

Although cross-shore transports are sensitive to the definition of the coast angle, computations showed predominantly onshore directed transports for the coastal stretch from Westkapelle to about 10 km south of Callantsoog and along the Wadden islands. The transports tend to be offshore directed at the inlets between Callantsoog and Texel (Marsdiep) and between Vlieland and Terschelling (Vliestroom). The onshore directed transport component was generally larger for smaller water depths closer to the shore, except near the inlets.

Computations show decreasing annual mean alongshore transports from Westkapelle to Scheveningen, increasing from Scheveningen to the inlet between Callantsoog and Texel (Marsdiep) and decreasing again towards Schiermonnikoog at the NAP-20 contour. Alongshore transports at the NAP-15 m contour were on average 10% smaller than at the NAP-20 m contour.

Intertidal beach morphodynamics of the tide-dominated Belgian coast

E. Brand[1]*, A.-L. Montreuil[1], M. Chen[1]
[1]VUB, evelien.brand@vub.be, anne-lise.montreuil@vub.be, margaret.chen@vub.be

Introduction

The intertidal zone is a very dynamic area subject to waves, tide, and wind and topographic changes can be large over a short period of time. For macro-tidal coasts (tidal range >4 m), it remains unclear what specific hydrodynamic conditions lead to topographic changes. This is mainly due to a scarcity of reliable field data of sediment transport and beach topography. This study investigates the intertidal beach morphodynamics based on extensive field measurements resulting in a conceptual model of hydrodynamic forcing and topographic response. Two study sites are examined along the Belgian coast: a multi-barred beach (Groenendijk) and a beach with a featureless intertidal zone (Mariakerke).

Methods and results

During six fortnight measuring campaigns, three at each study site, the hydrodynamics and sediment transport were continuously measured at the low water line. Topographic profiles were measured every day at low tide. It is found that the intertidal beach grows when waves are small (wave steepness < 0.010), whereas it erodes when waves are large (> 0.025). For medium wave steepness (0.010-0.025) this is opposite, which is attributed to a sudden rise in sediment supply. This rise is likely related to waves breaking over the sandbanks in front of the coast and at beaches southwest of the study sites. The relationship between wave steepness and intertidal beach volume is heavily distorted by spring-neap variations in tidal current direction though. Strong alongshore currents transport sediment away from the beach during spring tide which enhances erosion. In contrast, currents are cross-shore and wave-dominated during neap tide. The impact of variations in tidal current direction on the intertidal beach topography is in the same order of magnitude as wave impact. The effect of variations in sediment supply is subordinate to the impact of waves and tide. The main mode of sediment transport in the intertidal zone is in suspension. Currents reach a maximum at approximately 1.5 m above the bed resulting in a peak in sediment transport. The mean sediment transport is onshore by tidal currents during calm conditions, while it is offshore by undertow during energetic wave conditions (wave height > 0.6 m or wave steepness > 0.025). Oscillatory transport is always onshore because of wave asymmetry but is subordinate to the mean transport.

Conclusions

It is concluded from this study that waves are not necessarily the dominant forcing factor on macro-tidal beaches. Tidal currents can be equally important and can contribute significantly to the transport of sediment. Besides waves and tidal currents, variations in sediment supply influence the changes in the intertidal beach topography. A conceptual model is provided to illustrate the relationship between hydrodynamic forcing and topographic response.

Figure 1 Measuring frame on the intertidal beach with equipment to measure wave height, flow velocity, suspended sediment concentrations, and grain size.

Morphological development of sandy beaches in low-energy, non-tidal environments

A.M. Ton[1]*, V. Vuik[1,2], S.G.J. Aarninkhof[1]
[1]*TU Delft, a.m.ton@tudelft.nl, [2] HKV, v.vuik@hkv.nl, [1]s.g.j.aarninkhof@tudelft.nl

Introduction

The morphodynamics of sandy foreshores or beaches in lakes, classified as low-energy, non-tidal environments, have not been studied as extensively as open coasts. Low-energy or sheltered beaches are expected to undergo little transformation, therefore little research focusses on this type of shores (Nordstrom & Jackson, 2012). The goal of this research is to analyse the morphology and hydrodynamic steering of sandy non-tidal, low-energy beaches and its development over time.

Methods

Four unique study sites in the Markermeer give us the opportunity to study low-energy, non-tidal sandy beaches. The morphology of the Pilot Houtribdijk (a pilot study into dike reinforcement by sandy foreshores at the Houtribdijk) and three study sites at the Marker Wadden look very similar to results from laboratory studies with constant waves on an initially plane slope. With these lab experiments, Hallermeier (1980) validated his definition of depth of closure (DoC). We analysed the analogy between the laboratory study and our field sites and the meaning of DoC on low-energy beaches. Moreover, the morphological development is quantified by studying volumes in three vertical zones (figure) over time and linking changes to hydrodynamics (figure).

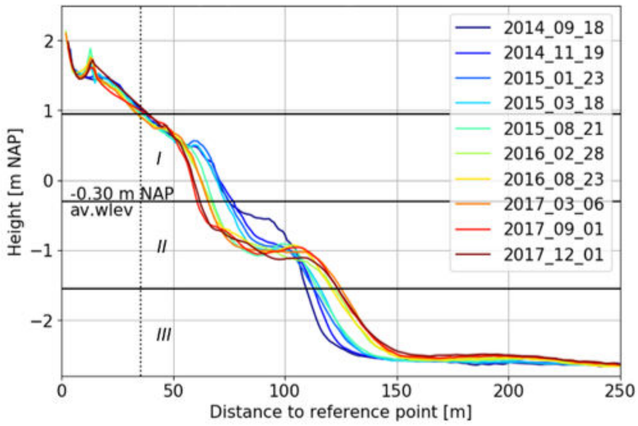

Figure 1 Morphological development Pilot Houtribdijk; I: beach face, II: platform, III: offshore zone

Results and Conclusions

Literature research shows that low-energy sandy beaches generally have a narrow beach face and a low gradient terrace or platform (Nordstrom & Jackson, 2012), which we also see at the four study sites. The platform at Pilot Houtribdijk (figure 1) develops at the depth where wave-induced sediment transport is close to zero, the DoC (figure). The volume in the beach face (zone I) decreases over time for all sites, while the platform (zone II) and the offshore zone (zone III) grow. Sediment transport is mostly cross-shore and the morphological development is erosion-driven. These new findings will facilitate evidence-based design of future nature-based solutions to ensure safety against flooding in non-tidal, low-energy environments.

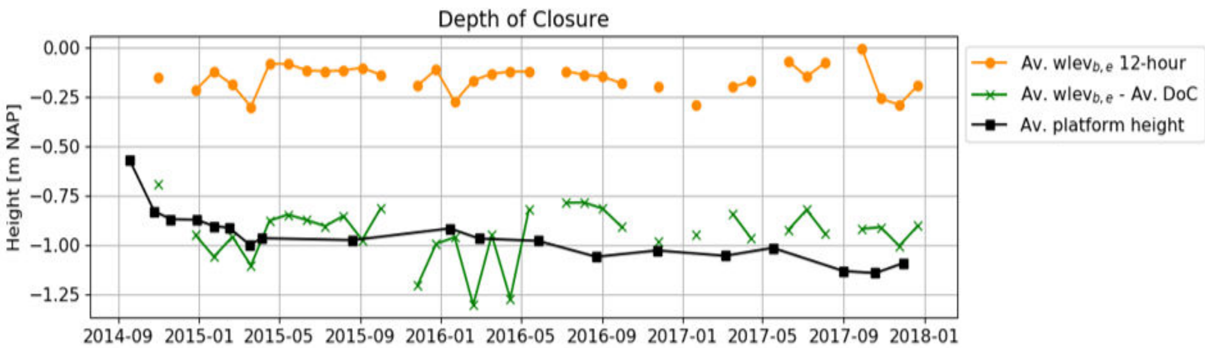

Figure 2 Average (av.) depth of closure w.r.t. average water level before and after storm compared to platform height

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A depth-resolving model for intraswash hydrodynamics and sediment transport

J.W.M. Kranenborg[1]*, G.H.P. Campmans[1], N.G. Jacobsen[2], J.J. Van der Werf[1,2], A.J.H.M. Reniers[3], S.J.M.H Hulscher[1]
[1] University of Twente, j.w.m.kranenborg@utwente.nl, g.h.p.campmans@utwente.nl, s.j.m.h.hulscher@utwente.nl
[2] Deltares, niels.jacobsen@deltares.nl, jebbe.vanderwerf@deltares.nl
[3] Delft University of Technology, a.j.h.m.reniers@tudelft.nl

Introduction

Numerical studies of sediment transport and morphodynamics in the swash zone generally use numerical models based on the depth-averaged shallow water equations. However, such models still have difficulty predicting the sediment transport (and subsequently morphodynamics) in the swash (see e.g. Ruffini et al., 2020). Depth-resolving models, such as models solving the Reynolds-Averaged-Navier-Stokes (RANS) equations have previously shown to accurately simulate swash hydrodynamics and also sediment transport in the surf zone (Jacobsen et al., 2014). However, applications of a RANS model capable of simulating sediment transport in the swash are limited. In this study, we present preliminary results from our RANS model on sediment transport in the swash.

Methods

The 2DV model is developed in OpenFOAM and is based on the model by Jacobsen et al., (2014). This model computes bed load and suspended load separately, where suspended load is computed using an advection-diffusion equation. We use the experiments of Young et al., (2010) to compare our model with. The experiments featured a 1:15 sloped beach made of fine sand (D_{50} = 0.2 mm) on which a swash event was produced by a solitary wave with a height of 60 cm.

Results and outlook

Figure 1 shows a snapshot during the uprush in one of the simulations. Our model is able to produce the large sediment fluxes and sediment plumes associated with the vortices produced by a breaking wave. Also, near the bed a layer of high sediment concentration is visible. We are currently working on the validation of these results. In the future, we aim to use the knowledge obtained from this depth-resolving model to improve sediment transport formulations for depth-averaged models.

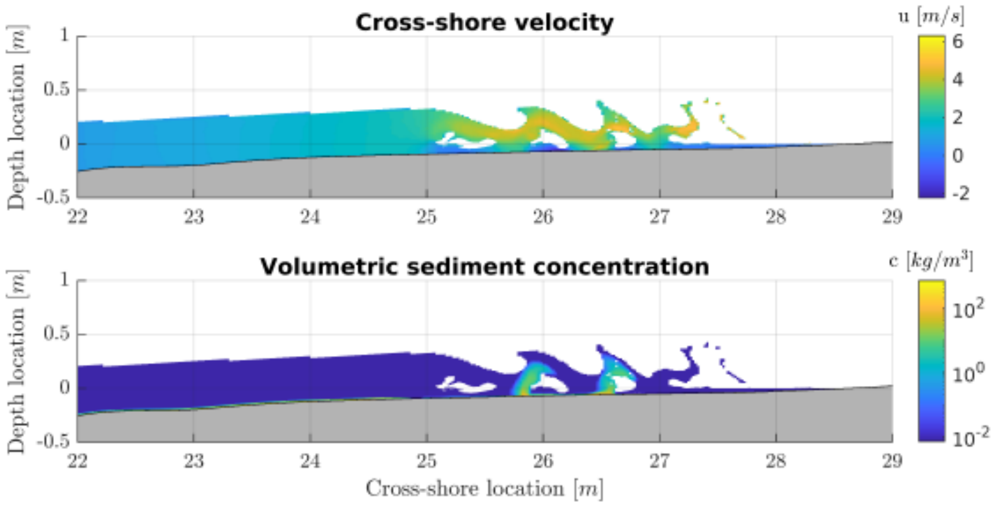

Figure 1 Modelled cross-shore velocity (positive = onshore) and volumetric sediment concentration in a swash bore during uprush. The white gaps show the air entrained from the breaking process.

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Nearshore bar dynamics of a nourished coast with respect to a neighboring natural coast (Egmond aan Zee)

S.M. Haverkate* and T.D. Price
Utrecht University,Sebastiaanhaverkate@hotmail.com, T.D.Price@uu.nl

Introduction

To combat ongoing coastal erosion, in 1990 the Dutch government decided to maintain the volume of sand in the coastal zone by means of nourishments. Nourishments have previously been found to reduce natural dynamics by, among other things, halting autonomous net offshore sandbar migration. Shoreface nourishments, where sand is deposited against the seaward-most sandbar, increase the volume of the outer bar and affect the dynamics of the more landward-located sandbars. Although this is thought to lead to onshore bar migration and a corresponding onshore sediment flux, the process through which shoreface nourishments lead to onshore sediment transport remains largely unknown. The aim of this research is to determine the effect of the long-term nourishing of sand on sandbar characteristics and dynamics, and the corresponding sediment fluxes.

Methods

This study focusses on an 11-km stretch of coast, around the town of Egmond aan Zee, the Netherlands. Approximately the northern half of this study area was regularly nourished after 1990, whereas the southern half remains unnourished to date (Figure 1). This allows for a direct comparison between the two adjacent areas in the period before and after the nourishment policy was implemented. To do so, we used 50 years (1963-2013) of cross-shore profiles (JARKUS data) that were measured yearly with an alongshore spacing of 250 m in the study area. To isolate the bars from the profiles, we developed methods to determine a range of geometric properties, including mean slope in the active bar zone, the landward and seaward bar edge, the center of mass, and the volume of each bar.

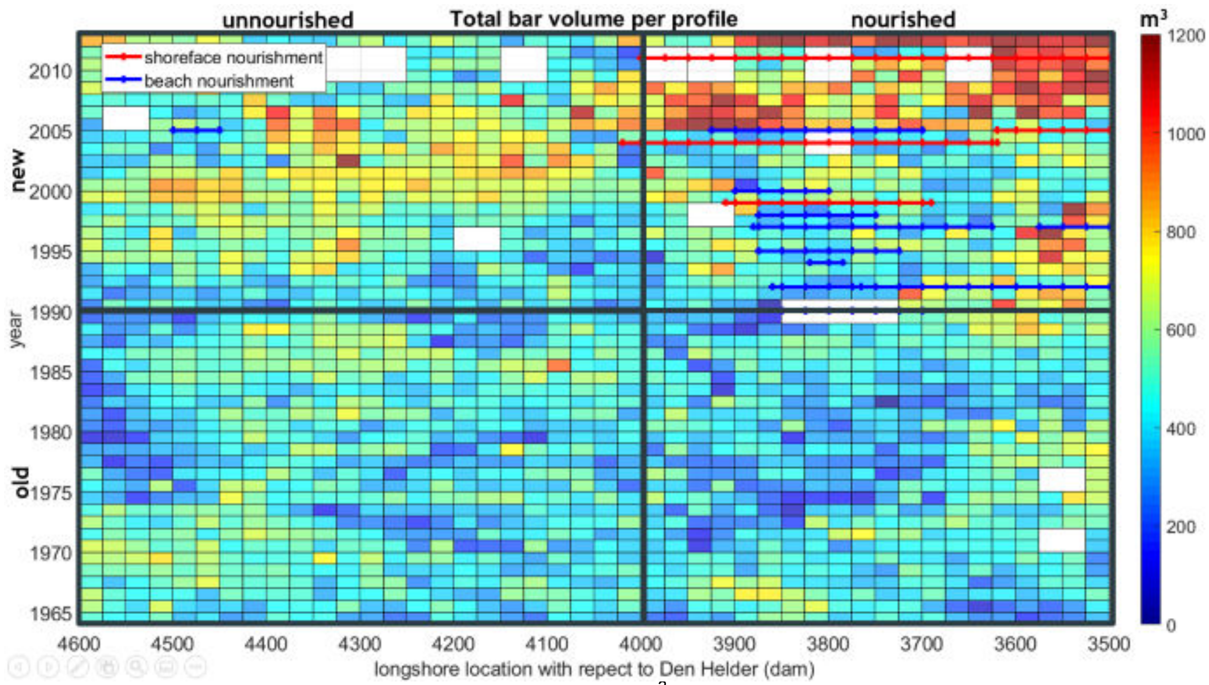

Figure 1Timestacks of total bar volume (colors indicate m^3/ longshore m) per transect (x-axis; left-right corresponds to south-north) between the years (y-axis; from bottom to top).

Results

A total number of 6796 bars were found in the transects and made it possible to investigate the role of sand nourishments on sandbar dynamics. As illustrated in Figure 1, the total bar volume increased both in the nourished and the unnourished sections after 1990. Moreover, in the last 8 years, the bars in the nourished section obtained the largest total volumes of the entire dataset.

Morphodynamic modelling of barrier island response to hurricane forcing

M. van der Lugt[1]*, E. Quataert[1], M. van Ormondt[1], A. van Dongeren[1],
[1] Deltares, Marlies.vanderlugt@deltares.nl, Ellen.Quataert@deltares.nl, Maarten.vanOrmondt@deltares.nl, Ap.vanDongeren@deltares.nl

Introduction

The accurate prediction of barrier island response to hurricane forcing is challenging because of the complex interaction of hydro- and morphodynamic processes, such as dune face erosion by wave attack, formation of breaches by wave overwash and inundation, and erosion of channels by return flow from the bay to the ocean. We investigate the sensitivities of barrier island response to Atlantic hurricanes Sandy, Matthew and Florence with a process-based model.

Methods

High-resolution 2D XBeach models were driven with optimally constrained initial and forcing conditions. High-resolution LIDAR topography obtained before and after hurricane Sandy, Matthew and Florence by the USGS provided initial conditions and validation data. Hydrodynamic boundary conditions were generated with a regional D-Flow FM–SWAN computation which was forced with astronomical tides and COAMPS-TC "best track" wind fields. The XBeach models were initialized with spatially varying roughness derived from a supervised conditional-random-field classification of land cover. The model was supplemented with a dynamic roughness module recognizing that, under extreme conditions, vegetation can be washed away or buried by sediment.

Results

The XBeach models showed good agreement with observed erosion volumes and observed crest level lowering. Prescription of spatially varying initial roughness maps and consideration of reduction throughout the storm improved the model skill. This model skill was furthermore sensitive to small variations in offshore wave boundary conditions and storm surge height (all cases), and to back-bay water levels in case an ebb-surge regime prevailed in the tail of the storm. Therefore, forecasts of barrier island impact should be made using an ensemble approach which takes the inherent uncertainty in forcing conditions into account, rather than relying on a single deterministic run.

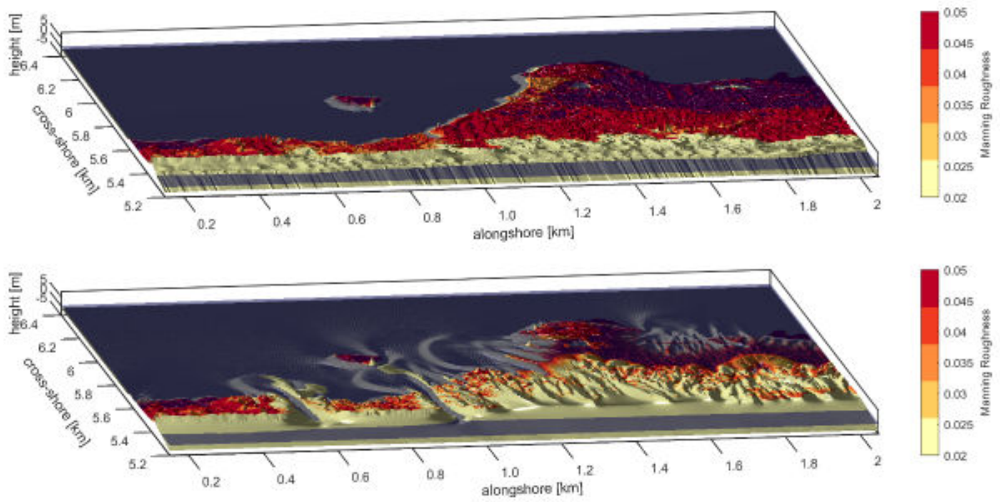

Figure 1 Pre- (top) and modeled post- (bottom) storm barrier island topography for Wilderness Breach – Fire Island (NY-USA) for hurricane Sandy. Color indicates bottom roughness as Manning values. MHW-level in blue for reference.

Reference

van der Lugt, M. A., Quataert, E., van Dongeren, A., van Ormondt, M., & Sherwood, C. R. (2019). Morphodynamic modeling of the response of two barrier islands to Atlantic hurricane forcing. Estuarine, Coastal and Shelf Science, 229, 106404.

Global and regional sea-level projections

A.B.A. Slangen[1]*
[1] NIOZ, aimee.slangen@nioz.nl

Introduction

Sea-level change is the result of changes in many different components of the climate system: the ocean, the land, the atmosphere and the cryosphere. Studying sea-level change and its consequences for coastal systems and communities therefore requires a complete and integrative view of the climate system on a range of spatial and temporal scales.

Projections

In my presentation, I will introduce the different processes that contribute to sea-level change and show how we can use models to project future sea-level changes. We will have a look at recent sea-level projections worldwide, from SROCC, before zooming in at the Dutch coast, and specifically in the Wadden Sea. I will also discuss examples of sea-level change impacts at the coast, such as the change in sea-level extremes.

Developments

There are different ways in which sea-level projections will be evolving in the coming years. For instance, there will be new climate model runs becoming available within the CMIP6 framework. Ice sheet models are developed and compared in the ISMIP6 framework. In addition, high-resolution models of sea-level rise might give a more detailed view of changes along the coast. Some of these developments will already be considered in the forthcoming IPCC AR6 report.

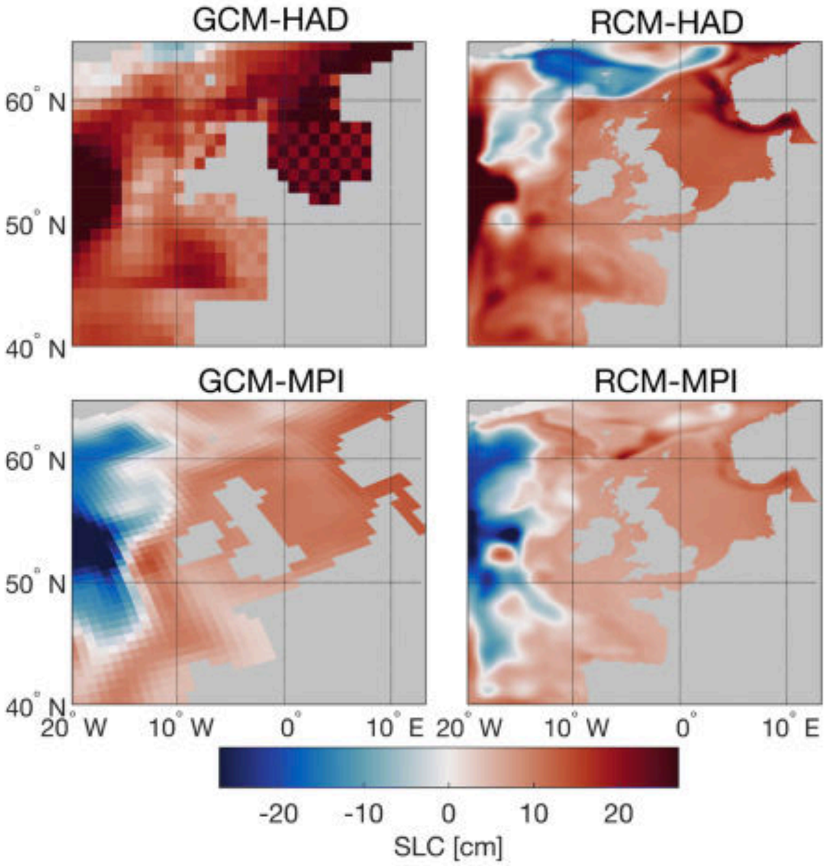

Figure 1 Sea-level change for the RCP8.5 scenario (1980-2005 average vs 2074-2099 average, cm), in 2 global climate models, HadGEM2-ES and MPI-ESM-LR (left) and downscaled with the AMM7 regional ocean model (right). Adapted from Hermans et al., 2020.

Coral restoration for coastal hazard risk reduction

F.E. Roelvink[1]*, A.R. van Dongeren[1] , C.D. Storlazzi[2], S.G. Pearson[1,3]
[1] Deltares, Floortje.Roelvink@deltares.nl, Ap.vanDongeren@deltares.nl
[2] U.S. Geological Survey, cstorlazzi@usgs.gov
[3] Delft University of Technology, S.G.Pearson@tudelft.

Introduction

Coral reefs are crucial for the protection of tropical coastal communities from wave-driven flooding and coastal erosion, while also providing other vital ecosystem services. Key to the shoreline protection service of coral reefs is the efficient wave dissipation by wave breaking and friction. At the reef crest, the high-frequency incident sea-swell (SS, 5 - 25 s periods) wave height rapidly decays by wave breaking. The oscillation of the short-wave breakpoint over time generates low-frequency (LF, 25-1000 s) motions that propagate across the reef flat, where friction reduces the low-frequency wave energy. However, coral reef degradation, sea-level rise and the possible storm intensification increase flooding and erosion hazards on low-lying tropical coastlines. The nature-based solution of coral restoration is proposed to satisfy the need for increased coastal resilience. The large spatial scales of coral reefs and often limited funding necessitate an efficient approach in designing and restoring coral reefs for the purpose of coastal hazard risk reduction.

Methods

Here we address the effects and efficiency of coral restoration through numerical modelling of theoretical reef restorations on characteristic coral reef profiles. Using the k-means method, 30,000 reef profiles across the USA were clustered into four distinct profile types representing 70% of all surveyed reefs: (1) typical fringing reef profile; (2) convex profile; (3) straight sloping fore reef profile; and (4) three-slope profile with a steep nearshore slope, followed by a relatively horizontal shelf, and an offshore fore reef slope. To investigate the potential of coral reef restoration to reduce flooding, the XBeach model was used to compute wave transformation over the reef types and the subsequent flooding of coastlines by adding theoretical coral reef restorations, represented using increased reef height and hydrodynamic roughness at set locations on the profiles.

Results

Restoration potential is distinctly different among varying profile shapes. The reef flat on fringing and convex reefs acts as a natural wave attenuator, reducing the flood risk reduction effect of potential restorations. The straight and three-slope profile are relatively vulnerable to coastal flooding, but also responsive to reef restoration measures. Average wave runup reductions of appr. 30% occur for the three-slope profile due to the effective reflection at restorations on the horizontal shelf. For the straight, sloping fore reef profile, runup reductions of up to 10% are observed, whereas runup reduction across the typical fringing and convex reef reaches 5-10%, much smaller than reduction across straight reefs when measured in absolute terms. For the typical fringing and convex profile, the restoration location significantly affects the reduction potential, as restorations near the breakpoint can strongly increase the setup across the reef flat. The results provide insight into which restoration locations have the greatest runup reduction potential. By allocating ever-limited funds to well-designed coral restorations, vulnerable coastal areas may receive much-needed support for combating the effects of climate change.

Figure 1 Restored Acropora's colonies at Hatamin Island, Indonesia. Source: Coral Guardian

Investigating the long-term morphological evolution of intertidal shoals and SLR impact

H. Elmilady[1,2,3*], M. van der Wegen [1,2], D. Roelvink [1,2,3], and A. van der Spek [2]
[1] IHE Delft, h.elmilady@un-ihe.org, m.vanderwegen@un-ihe.org
[2] Deltares, Dano.Roelvink@deltares.nl, Ad.vanderSpek@deltares.nl [3] TU Delft

Abstract

Intertidal shoals are key components of the estuarine environment. Ensuring their sustainability requires understanding the potential morphological impact of sea-level rise (SLR) on such systems. In contrast to mudflats, sandy shoals have drawn limited attention in research. Inspired by the channel-shoal systems in the Western Scheldt Estuary and Wadden Sea, our work investigates the mechanisms that drive the long-term morphological evolution of sandy shoals.

We apply a high resolution (35 × 65 m) process-based model (Delft3D) to simulate the evolution of a sandy channel-shoal system in a schematized rectangular (20 × 2.5 km) tidal basin. An initially mildly sloping submerged bathymetry is subjected to constant (M_2) semidiurnal tidal forcing along with small wind-generated waves (10-20 cm) modeled by SWAN.

Initial bed-level perturbations trigger a positive morphodynamic feedback between the currents and morphology leading to the emergence of large scale channel-shoal patterns (Figure 1). Shoal formation is driven by tidal currents while wind-waves play an important role when shoals become shallow and intertidal. The added wave-induced shear stress enhances sediment resuspension and redistribution over the shoal along with limiting the shoal elevation. Over a long time-scale (centuries), the residual sediment transport starts diminishing towards a relatively steady morphological state maintained by a balance between sediment supply, wave action, and tidal forcing.

SLR triggers sediment import from the seaward boundary. Shoals accrete due to the drop of wave-induced shear stresses associated with the increased water depth. Highest accretion occurs at the shoal edges and gradually decreases towards central locations. Waves help redistribute the sediment supplied from the channel over the shoal. However, accretion rates are less than the SLR rate leading to intertidal area loss and increased shoal inundation. Incorporating mud fractions accelerates the response to SLR resulting in faster accretion and muddier shoals.

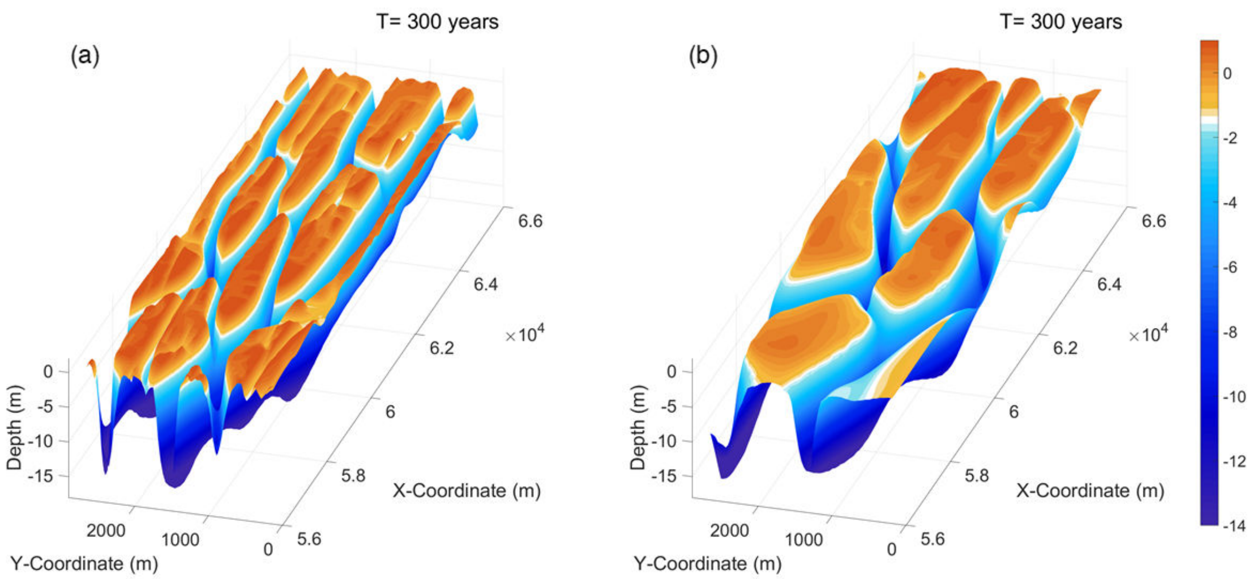

Figure 1 The modelled bathymetry (a) Flow only, and (b) Flow and Waves after 300 years for a section of the model domain. The white band represents the border between intertidal and subtidal areas.

The sensitivity of a dike-marsh system to sea-level rise—A model-based exploration

R.J.C. Marijnissen[1]*, M. Kok[2,3], C. Kroeze[1], J.M. van Loon-Steensma[1,2]
[1] Wageningen University and Research, richard.marijnissen@wur.nl, carolien.kroeze@wur.nl, jantsje.vanloon@wur.nl
[2] Delft University of Technology, Matthijs.Kok@tudelft.nl
[3] HKV

Introduction

Integrating natural components in flood defence infrastructure can add resilience to sea-level rise. Natural foreshores can keep pace with sea-level rise by accumulating sediment and attenuate waves before reaching the adjacent flood defences. In this study we address how natural foreshores affect the future need for dike heightening.

Methods

A simplified model of vertical marsh accretion was combined with a wave model and a probabilistic evaluation of dike failure by overtopping. The sensitivity of a marsh-dike system was evaluated in relation to a combination of processes: (1) sea-level rise, (2) changes in sediment concentration, (3) a retreat of the marsh edge, and (4) compaction of the marsh.

Results

Results indicate that foreshore processes considerably affect the need for dike heightening in the future. At a low sea-level rise rate, the marshes can accrete such that dike heightening is partially mitigated. But with sea-level rise accelerating, a threshold is reached where dike heightening needs to compensate for the loss of marshes, and for increasing water levels. The level of the threshold depends mostly on the delivery of sediment and degree of compaction on the marsh; with sufficient width of the marsh, lateral erosion only has a minor effect. The study shows how processes and practices that hamper or enhance marsh development today exacerbate or alleviate the challenge of flood protection posed by accelerated sea-level rise.

Reference

Marijnissen, R.; Kok, M.; Kroeze, C.; van Loon-Steensma, J. The Sensitivity of a Dike-Marsh System to Sea-Level Rise—A Model-Based Exploration. *J. Mar. Sci. Eng.* **2020**, *8*, 42; https://doi.org/10.3390/jmse8010042

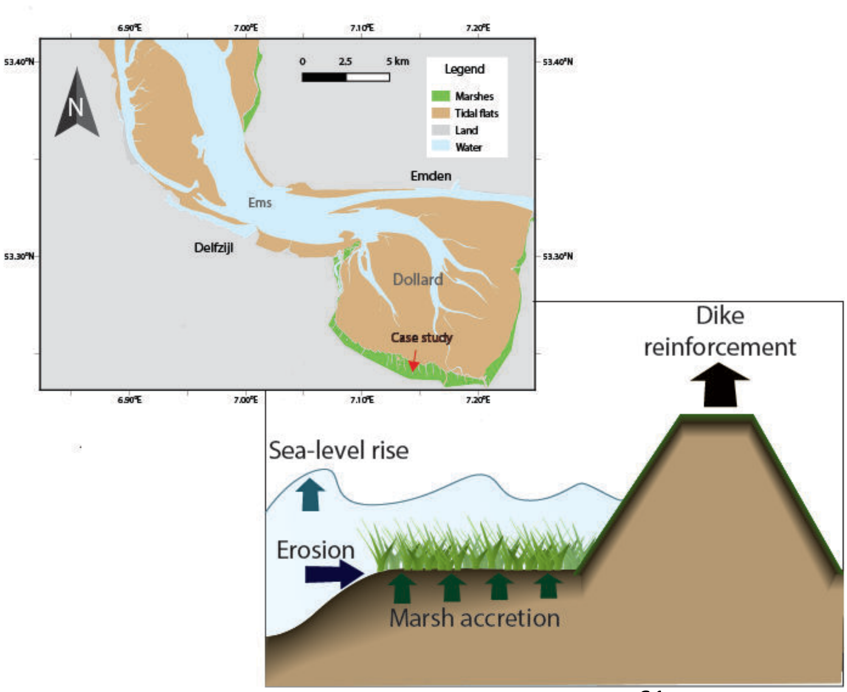

Figure 1 Location of the Dollard dikes and the outside processes affecting their safety

Estimation of Global Synthetic Tropical Cyclone Hazard Probabilities using the STORM dataset

Nadia Bloemendaal[1], Ivan D. Haigh[2], Hans de Moel[1], Sanne Muis[1,3], and Jeroen C.J.H. Aerts[1]

1. Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, nadia.bloemendaal@vu.nl, hans.de.moel@vu.nl, sanne.muis@vu.nl, jeroen.aerts@vu.nl
2. School of Ocean and Earth Science, National Oceanography Centre, University of Southampton, i.d.haigh@soton.ac.uk
3. Deltares, sanne.muis@deltares.nl

Introduction

Tropical cyclones (TCs), also referred to as hurricanes or typhoons, are amongst the deadliest and costliest natural disasters, affecting people, economies and the environment in coastal areas around the globe when they make landfall. In 2017, Hurricanes Harvey, Irma and Maria entered the top-5 costliest Atlantic hurricanes ever recorded, with combined losses estimated at $220 billion. Therefore, to minimize future loss of life and property and to aid risk mitigation efforts, it is crucial to perform accurate TC risk assessments in low-lying coastal regions. Calculating TC risk at a global scale, however, has proven to be difficult, given the limited temporal and spatial information on landfalling TCs around much of the global coastline.

Methods

In this research, we present a novel approach to calculate TC risk under present and future climate conditions on a global scale, using the newly developed Synthetic Tropical cyclOne geneRation Model (STORM). For this, we extract 38 years of historical data from the International Best-Track Archive for Climate Stewardship (IBTrACS). This dataset is used as input for the STORM algorithm to statistically extend this dataset from 38 years to 10,000 years of TC activity. The resulting STORM dataset is then used to estimate global-scale wind speeds at various return periods, at 10 km resolution.

Results

Validation shows that the STORM dataset preserves the TC statistics as found on the original IBTrACS dataset. The return period dataset can then be used to assess the low probabilities of extreme events all around the globe. Moreover, we demonstrate the application of this dataset for TC risk modeling on small islands in e.g. the Caribbean or in the South Pacific Ocean.

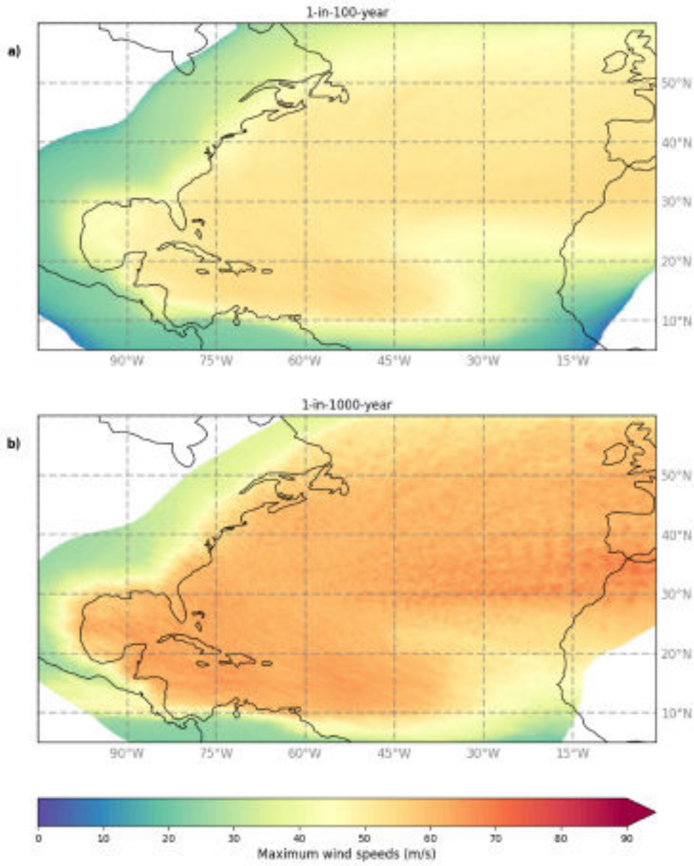

Figure 1 Wind speed return periods in the North Atlantic basin. Here shown are the 1-in-100 year (a) and the 1-in-1000 year maximum wind speeds.

For which sea-level-rise rate will barrier islands drown?

J.H. Nienhuis
Utrecht University, Utrecht, NL, j.h.nienhuis@uu.nl

Introduction

Barrier islands such as the Wadden Islands can drown or migrate landward in response to sea level rise, depending on their ability to move sediment to the back barrier. The potential magnitude of this landward sediment flux over decadal to centennial time scales, however, is 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 (Fig. 1a) (Nienhuis & Lorenzo-Trueba, 2019a, 2019b). The BRIE model integrates existing overwash and shoreface formulations with alongshore sediment transport, inlet stability (de Swart & Zimmerman, 2009), inlet migration, and flood-tidal delta deposition. 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 flood-tidal delta deposition can be a significant component of the long-term landward sediment flux keeping barrier islands above sea-level. For highly developed barrier islands such as the Wadden Islands (Fig. 1b) where protection against storms limits overwash deposition, tidal inlets might be crucial to provide a platform for long-term island transgression.

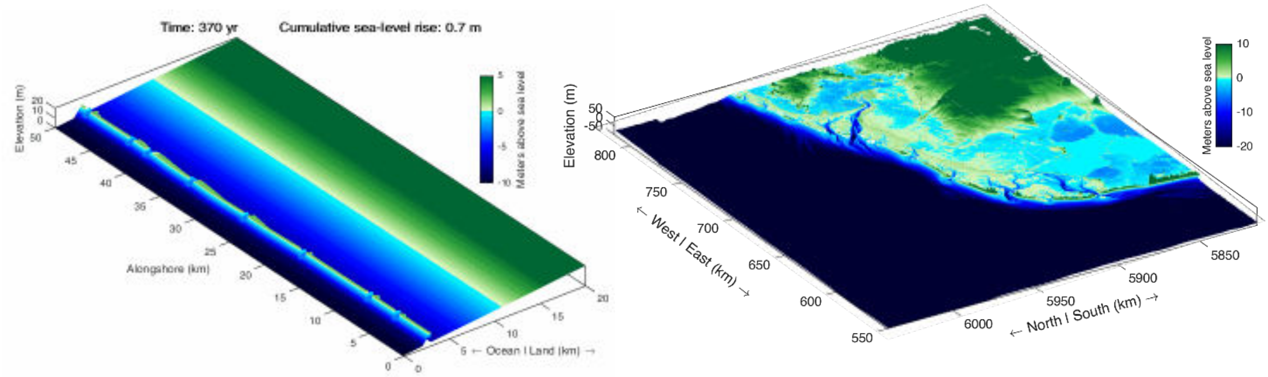

Figure 1 (a) BRIE model of barrier island transgression, (b) Wadden Islands along the Dutch and German coast.

References

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Abstracts Poster Presentations Friday

(in order of numbering in the program)

Modelling shelf morphodynamics and shoreline change using a two-coupled model system

A. Nnafie[1]*, H.E. Swart[1], A. Falqués[2], D. Calvete[2]
[1] Institute for Marine and Atmospheric research Utrecht (Utrecht University), a.nnafie@uu.nl,
[2] Universitat Politècnica de Catalunya, Barcelona, albert.falques@upc.edu.

Introduction

Tidal sand ridges are large-scale bottom features that occur on sandy continental shelves with strong tidal currents, such as that of the southern North Sea (Figure 1a). These ridges have longshore spacings of several kilometres, heights of tens of meters, they evolve on centennial time scales and their crests are cyclonically rotated with respect to the direction of the dominant tidal currents. Tidal sand ridges are important for ecology by providing diverse habitats for fish and invertebrate communities (van Dijk et al., 2012; Atalah et al., 2013) and for coastal stability by dissipating wave energy during storms (Spencer et al., 2015). Many studies have focused on the formation and long-term evolution of these bottom features (see review by de Swart and Yuan, 2018), but little is known about their effects on the shoreline evolution. As these ridges affect the wave transformation and thus the alongshore sediment transport, it is expected that these ridges have a profound impact on the evolution of the shoreline. Conversely, changes in the shoreline will induce bathymetric changes that will affect the ridges. The objective of this study is to investigate the coupled dynamics of tidal sand ridges and shoreline undulations at decadal and centennial time scales.

Methods

Simulations are carried out by utilizing a continental shelf numerical model (Delft3D-SWAN; Nnafie et al., 2020, subm.), which is coupled to a shoreline evolution model (Q2D-morfo). The latter model is a nonlinear morphodynamic model for large-scale shoreline dynamics (Arriaga et al., 2017). The simulations, which start from an initially longshore uniform and cross-shore sloping bottom, are run for a period of 500 years.

Results

Model results show that undulations occur in the shoreline that have an alongshore scale similar to the alongshore scale of the tidal sand ridges (Figure 1b).

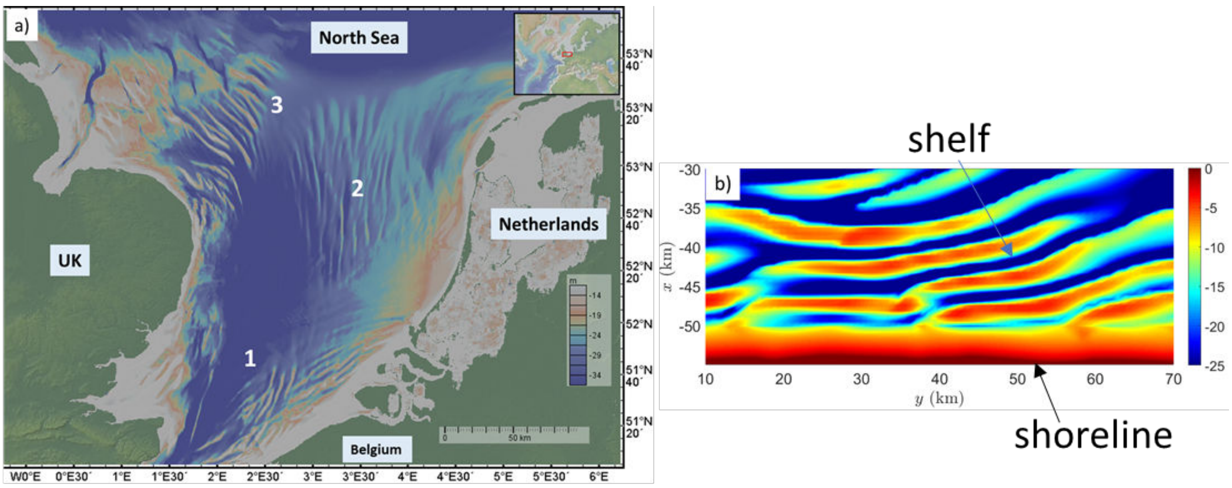

Figure 1 a) Bathymetric map of observed fields of tidal sand ridges (1, 2 and 3) in the North Sea. b) Simulated bed level after 500 years of morphodynamic evolution.

References

References available upon request.

XBeach modelling of Maasvlakte 2 coastal morphology aimed at predicting long term impact of on-the-beach wind turbines

Ype Attema[1]*, Bas van Leeuwen[1]
[1] Svašek Hydraulics, attema@svasek.nl, leeuwen@svasek.nl

Introduction

Rijkswaterstaat is planning to construct wind turbines on the soft (and the hard) sea defense of Maasvlakte 2. This will aid the organization in becoming climate neutral by 2030. Rijkswaterstaat has asked Svašek to explore the morphological implications of wind turbines on the beach and in the surf zone. One of the concerns is the effect of such hard objects on the sustainability of the sandy sea defense.

Applying XBeach on year-round conditions

XBeach has been applied to simulate two years of morphological development. A curvilinear grid is used with cells measuring 5x35 m (cross- x longshore) in the area of interest. The model has been set-up via an automated succession of stationary (for mild conditions, $H_{m0} \leq 1.50$m) and surfbeat (for more significant waves, $H_{m0} > 1.50$m) simulations. These simulations constitute a 15 part representative wave climate. Each simulation has its own morphological acceleration factor (ranging from 1.38 to more than 50) and is defined via a fixed amount of hydrodynamic time per simulation (25 hours).

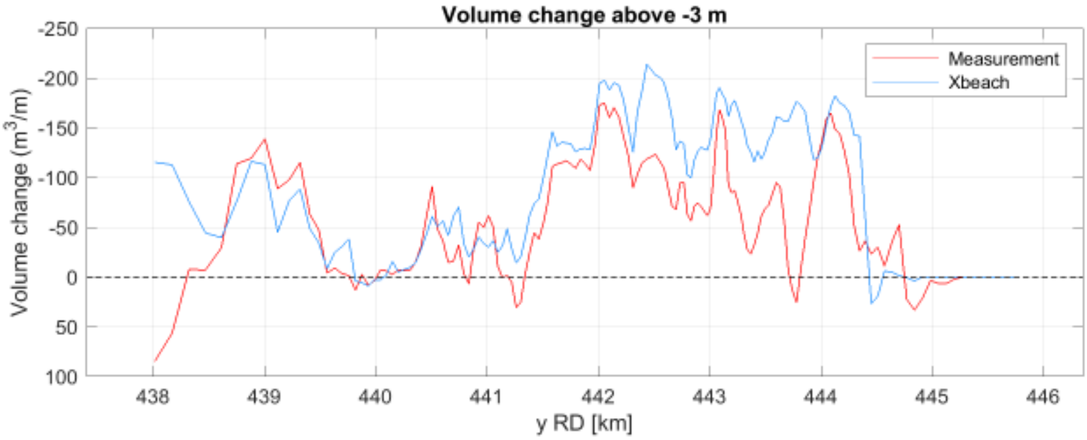

Figure 1 Calibration result against 2017-2018 measured coastal development.

The model has been calibrated against 2017 and 2018 surveys (without nourishment) commissioned by the Maasvlakte 2 project organisation (PUMA). Overall calibration of the model (factor of 0.3) and the cross-shore calibration factor (facua = 0.10) proved most important. The calibration result is given in Figure 1. Please note that the complex southern end of Maasvlakte 2 (y-RD<438.5 km) and its interaction with the Haringvliet entrance is not incorporated in the model. Overall the simulated development matches the measured development very well.

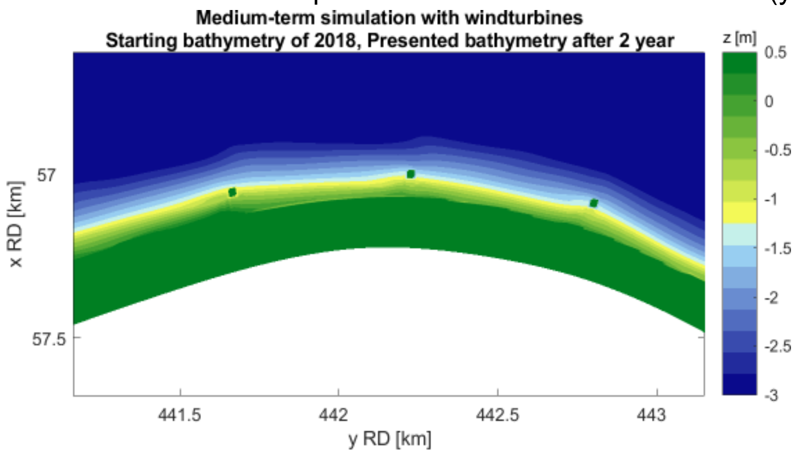

Figure 2 Simulation with wind turbines, final bed lay out.

Application: wind turbines in and above the surf zone

The model has been applied to a situation with ten circular objects (diameter 20 m) in and above the surfzone. Local grid refinements have been applied around the wind turbine location. Final results in Figure 2 show the clear development of salients and local protection of the coast.

The effects of bedform roughness on hydrodynamics and sediment transport in Delft3D

L.B. Brakenhoff[1]*, R.A. Schrijvershof[2], B.T. Grasmeijer[2], J.J. van der Werf[2,3], B.G. Ruessink[1], M. van der Vegt[1]
[1] Utrecht University, l.b.brakenhoff@uu.nl
[2] Deltares
[3]University of Twente

Introduction

To contribute to solving scientific and practical questions, numerical morphodynamic models like Delft3D are often used to predict the hydrodynamics, sediment transport processes and morphological development of coastal systems. In such models, many of the processes are parameterized based on a variety of assumptions. One of the parameterized variables is the bedform-related hydraulic roughness k_s, which is often assumed to be related to the ripple height. This roughness affects the magnitude and vertical structure of the flow and, consequently, the magnitude of the sediment transport. Yet, their sensitivity to k_s is not well understood.

Methods

The aim of this study is to determine the effect of the hydraulic roughness caused by small-scale ripples (length ≈ 10 cm, height ≈ 1.5 cm) on hydrodynamics and sediment transport computed with a high-resolution, fully-coupled Delft3D model forced by waves, tides, wind, and atmospheric pressure. The Van Rijn (2007) sand transport formula is used. The study site is the wave-current dominated Ameland ebb-tidal delta. In 2017, a six-week field campaign was executed here, in which bedform heights and lengths as well as hydrodynamics were measured. The model was run for the duration of the field campaign with ten bedform roughness scenarios, in which the roughness was either coupled to the hydrodynamics, or was set to a constant and spatially uniform value. The default scenario comprised the Delft3D predicted spatio-temporally varying roughness scaled to best match the measured hydrodynamics. We compared the predicted ripple heights hydrodynamics and sediment transport magnitudes and directions of all other scenarios to the default scenario.

Results

First results indicate that the predicted ripple heights in the default scenario are quite similar to the measured ripple heights, although the predicted heights are much more variable through time. The simulations show that k_s affects the depth-averaged current velocity by several cms/sec (Fig. 1). This in turn affects the predicted sediment transport magnitude and direction. In more detail, the cumulative alongshore suspended load transport magnitude can increase with more than 50% when a constant roughness (0.015 m, based on the observations) is used instead of the default variable roughness.

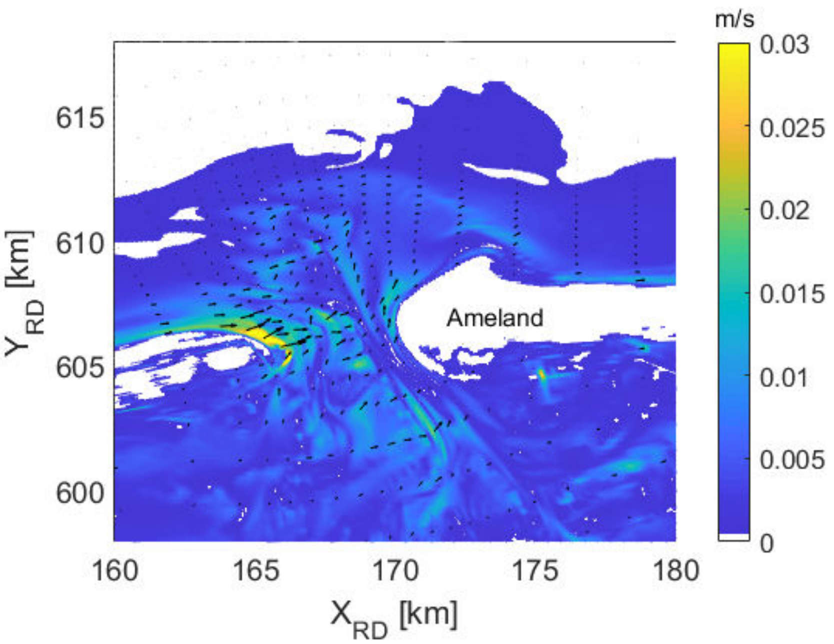

Figure 1 Root-mean-square difference in current velocity between the default scenario and a scenario with constant ripple height of 1.5 cm. Colours are magnitude difference; arrows are magnitude and direction difference.

Design optimization of a multifunctional floating breakwater

J. van der Zanden[1], F. Spaargaren[1], W. Otto[1], B. Walles[2], T. Ysebaert[2]
[1] MARIN, j.v.d.zanden@marin.nl, f.spaargaren@marin.nl, w.otto@marin.nl
[2] Wageningen Marine Research, brenda.walles@wur.nl, tom.ysebaert@wur.nl

Background

The attenuation of waves is essential to secure maritime operations and to protect coastal regions against erosion. Wave-attenuating breakwaters, which can be either fixed or floating, attenuate incident wave energy by means of wave reflection and/or wave dissipation through friction and wave breaking. Compared to fixed breakwaters, advantages of floating breakwaters include their applicability in more challenging environments (deep water, poor foundation), their reduced environmental impacts (minimum interference with water circulation and fish migration, minimum bottom disturbance, minimum visual intrusion), and their flexibility (can relatively easily be re-arranged) [1]. The added value of a floating breakwater can be increased when it supports additional functions such as food production or a new ecological habitat.

Objective

The aim of the present project is to develop a novel multifunctional floating breakwater. Cost-efficiency will be realised by optimizing the floater and mooring system such that the design has optimum attenuation characteristics for minimum mooring loads. The concept should aim for synergy between its primary objective (wave attenuation) and other economic (e.g., food production) or ecological objectives (i.e., positive environmental impact). Although the new design should be applicable at varying locations, the shallow lake Grevelingen (SW Netherlands) is used as a case study throughout the project.

Methods

The breakwater design will be optimized through Computational Fluid Dynamics (CFD) simulations in COMFLOW [2], focusing firstly on the optimization of the floater and at later stage on the mooring lay-out. As a starting point, it is anticipated that the wave attenuation is improved when breaking of incident waves is promoted. Therefore, the initial shape of the floater is a parabolic shaped floating beach that promotes wave shoaling and breaking (see Figure 1). The concept may be developed into a bird refuge or a shellfish reef; these and other potential side-functions will be further developed in parallel to the design optimization. The final design will be validated through physical wave basin tests.

Results

Results of the CFD simulations will be presented at the conference.

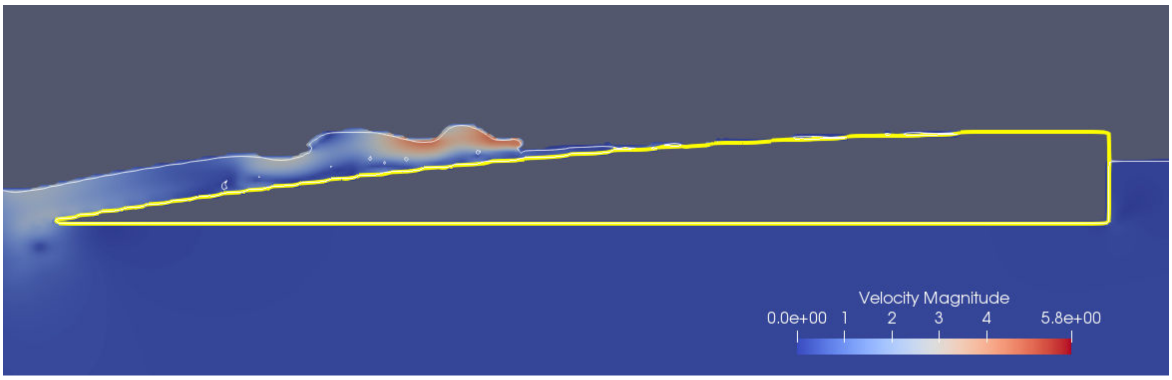

Figure 1 COMFLOW simulation of waves breaking over a parabolic floating reef.

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Sediment Connectivity: a Framework for Analyzing Coastal Sediment Transport Pathways

S.G. Pearson[1,2]*, B.C. van Prooijen[1], E. Elias[2], Z.B. Wang[1,2]
[1] Delft University of Technology, s.g.pearson@tudelft.nl, b.c.vanprooijen@tudelft.nl, z.b.wang@tudelft.nl
[2] Deltares, edwin.elias@deltares.nl

Introduction

Sediment connectivity is a framework for describing networks of sediment transport pathways in coastal environments. It provides a systematic means of quantifying complex systems, taking advantage of conceptual developments in graph theory and analysis tools developed in other fields (e.g. neurology, ecology, hillslope geomorphology). Applying this approach to coastal systems using model results and measurements lets us to identify key pathways and connections at multiple space and time scales.

Methods

We used a tide-only Delft3D sediment transport model as a basis for determining the connectivity of Ameland ebb-tidal delta in the Netherlands. First, we defined geomorphic cells within the system based on bathymetry and functional characteristics. The sediment flux between these units was tabulated into an adjacency matrix (Figure 1a), representing sediment travelling from a particular source to a given receptor. This matrix can then be represented as a network diagram (Figure 1b) where the system has been schematized as a series of nodes (geomorphic cells) and the links (fluxes) between them. Once schematized this way, we can measure the connectivity and emergent patterns of the network using statistical metrics including network density, modularity, and centrality.

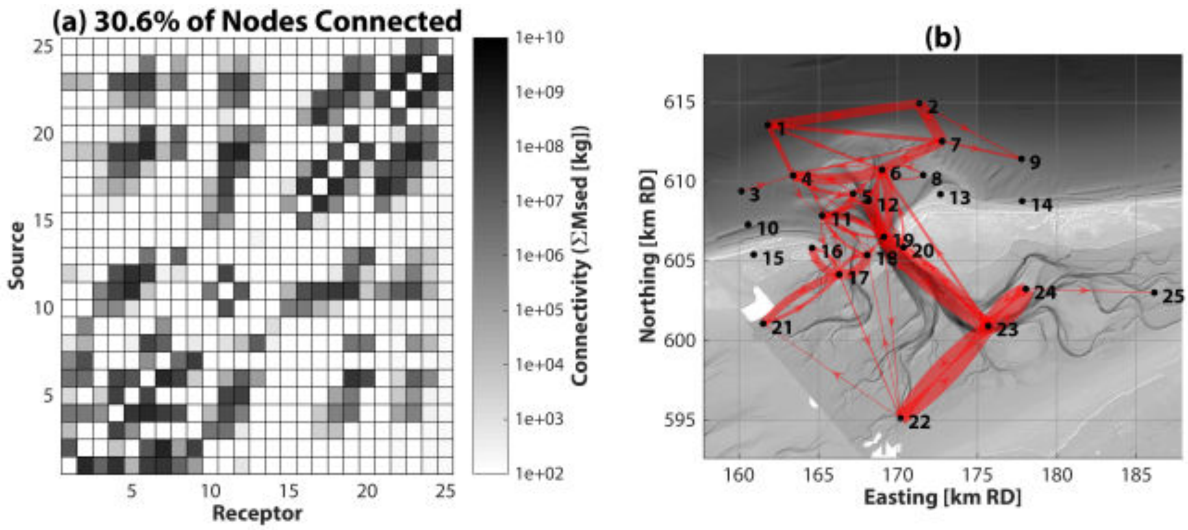


Figure 1 Connectivity of the Ameland Inlet system, based on tide-only Delft3D numerical simulations. (a) An adjacency matrix can be derived from model output and quantifies the fluxes of sediment between geomorphic cells in a coastal system. Asymmetry in this matrix indicates net sediment transport, and self-self interactions (main diagonal) are not considered. (b) A network diagram visualizes sediment connectivity of Ameland ebb-tidal delta. The centre of each geomorphic cell is indicated as a numbered node, and the top 5% strongest sediment pathways between them are indicated by red lines. Line thickness qualitatively indicates the magnitude of sediment transport between two nodes, and arrows indicate direction.

Results

Ameland Inlet is most strongly connected between its major channels and ebb tidal delta. Connectivity is greater for finer than coarser sediment, and there is a tendency towards increased connectivity at longer time scales. With this approach we can quantify sediment bypassing pathways around the inlet and classify the domain into distinct sediment-sharing modules. Connectivity is a valuable tool for analysing sediment pathways in coastal environments, and the wealth of existing tools for its analysis make it accessible for researchers and practitioners alike.

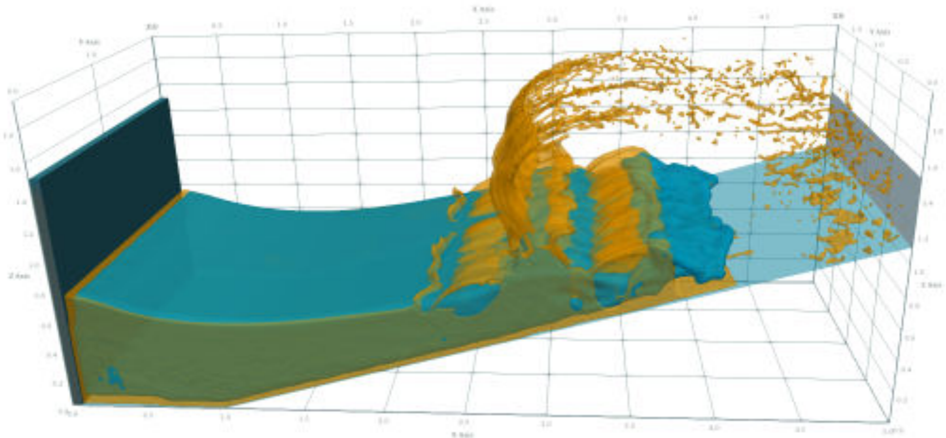
Meshfree simulations of wave breaking on the foreshore

Giordano Lipari*[1], Santosh Ilamparuthi[1], Kees Vuik[1]
[1] Delft University of Technology, g.lipari@tudelft.nl, s.ilamparuthi@tudelft.nl, c.vuik@tudelft.nl

The dynamics in the surf zone features rapid and intricate flow manifestations difficult to simulate in fine temporal and spatial detail. When solving the equations of fluid flow numerically, however, the nodes where flow variables are stored and solved for are not bound in and of themselves to a mesh/grid/raster/lattice. Unlike finite-difference, finite-volume and similar mesh-based methods, in *meshfree modelling* the fluid particles follow the laws of motion free of 'topological constraints' and can then realistically represent the three-dimensional swirling motions and fragmented surfaces too.

Down more than four decades of research *Smoothed Particle Hydrodynamics (SPH)* has been used purposefully in many areas of application (for a review: Monaghan 2012) including coastal and ocean engineering (for example: Altomare *et al* at NCK 2014, Altomare *et al* 2019). SPH simulations are computationally intensive, for the entire fluid domain must be filled with closely-spaced particles and explicit integration constrains the time steps. On the bright side, however, hardware acceleration by graphic processing units (GPUs) enables fast compute times and large problem sizes efficiently.

In line with the policy of the Delft University of Technology to produce *FAIR research output* ('fair' for findable, accessible, interoperable, reusable), high-resolution simulations have been archived by the 4TU Centre for Research Data in a DOI-tagged data set retrievable under a CC-BY 4.0 license. The example is the idealised case '3D Wavemaker' of the solver DualSPHysics 4.4. An oscillating piston creates a sequence of plunging waves interacting with the backrush on a slope. Increasing resolution lets finer flow structures appear (Meringolo et al 2019), and the bulk flow features rapid impacts, stirring, jets and splashes – see below and the YouTube playlist at www.bit.ly/sph_tube.



Three-dimensional interaction of breaking waves and backrush produced by an idealised wave maker. Overlay of the flow at the same instant resolved by SPH with 400k (blue shades) and 27M (yellow shades) elements

Informed access to special features of SPH is stimulated and facilitated. The data archived can be inspected with the open-source tool for data analysis and visualisation ParaView. The insights can be contrasted with practical and fundamental knowledge, measurements, and other simulations. For example, the nonlinear dynamics may invite the analysis of recurring flow events, average properties, convergence metrics. The sensitivity to physical and numerical parameters can be evaluated. Finally, the archive contains the information needed for reproducing the data, if so wished: pre-computed, highly-resolved results may also help users evaluate the loss of information incurred at the resolutions afforded with the compute devices available; or serve as 'hot-start' files for refined investigations.

Extensive monitoring campaign at sandy lake beaches of Houtribdijk and Marker Wadden

Rikke van der Grinten[1], Anne Ton[2], Jan-Willem Mol[3], Rinse Wilmink[3]
[1] Nortek BV, rikke.van.der.grinten@nortekgroup.com, [2] TU Delft, a.m.ton@tudelft.nl
[3] Rijkswaterstaat, janwillem.mol@rws.nl, rinse.wilmink@rws.nl

Introduction

The present Houtribdijk reinforcement project foresees in an innovative measure to guarantee safety against flooding. For the first time ever, a sandy nourishment is applied to ensure large-scale stability of a levee in a non-tidal, inland lake environment. To gain detailed insight in the key hydrodynamic and morphological processes, a dedicated monitoring program is carried out at the foreshores of the Houtribdijk and sandy beaches of the Marker Wadden. This program is developed and executed by Rijkswaterstaat in collaboration with TU Delft and supported by Nortek products and services.

Start of long-term monitoring campaign

Rijkswaterstaat deployed six permanent measurement stations in the vicinity of the levee. Additionally, six smaller stations are temporarily deployed and moved around between areas of interest. Rijkswaterstaat deployed all measurement stations in February 2019 and is responsible for preventive and corrective maintenance. The project will run continuously for at least two years, while measuring during several heavy storms. A real-time data set from each station is produced.

Instruments and data

The extensive data set contains measurements of five types of sensors. In total 22 sensors are allocated at the measurement stations: 6 ADVs, 2 HR ADCPs, 6 regular ADCPs, 6 step gauges, 2 water quality probes and 6 altimeters. These sensors produce a total of 300 MB raw data per day!
The challenging job to send the data and post process the data is executed by Nortek (data transfer), and HKV and Tauw (post-processing and data management). This wealth of information is further analyzed by Anne Ton, PhD candidate at TU Delft.

First results

From initial analysis of ADV results, interesting differences between hydrodynamics on both sides of the Houtribdijk become clear. On the Markermeer side, water level and wave height are positively correlated for southeasterly and southwesterly winds. On the IJsselmeer side, these are positively correlated for northwesterly and northeasterly winds. Both imply that wind driven set-up coincides with increasing wave height. For southerly winds, a wind-driven set down is found on the IJsselmeer side.

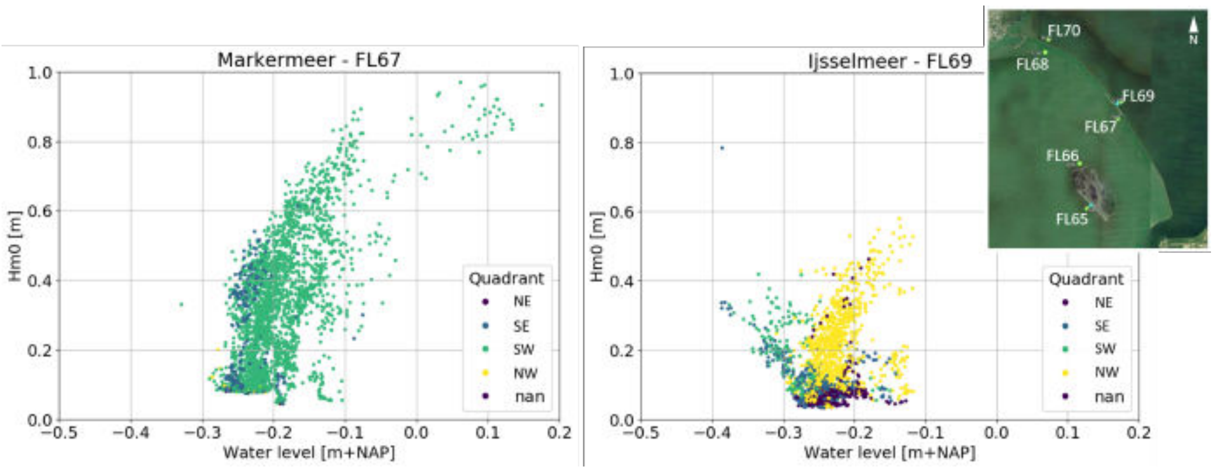


Figure 1 Correlation water level and wave height from ADV measurements

This monitoring campaign will facilitate evidence-based insights into the hydro- and morphodynamics of non-tidal, sandy environments, that will help ensure safety of the Houtribdijk and similar nature-based solutions.

Large observed grain size variability around the Sand Engine

A. Ionescu [1], M.A.de Schipper[1]*, J. Storms[1]
[1] TUDelft, A.Ionescu-2@student.tudelft.nl, M.A.deSchipper@TUDelft.nl, J.E.A.Storms@tudelft.nl

Sediment characteristics are key controls on sediment pickup, settling and advection. However, the majority of coastal beach evolution forecasts are made by assuming homogeneity in sediment type in a coastal cell. Yet, this bed composition may vary in both space and time and these spatiotemporal patterns are poorly known and understood. In this study, we examine the characteristics of the bed level sediments along the 17 km Delfland coast from sediment sampling data. The study area stretches from Hoek van Holland to the Scheveningen harbour, with the Sand Engine in its centre.

Methods

In total 96 samples were collected from the beach along two different elevations; in the intertidal zone at 0.2 m above NAP (NAP ≈ mean sea level) and on the supratidal beach at 1.7 m above NAP. These samples were analysed to obtain the grain size distributions. From these distributions, the D50 values and fraction of shells (taken as the weight percentage of the fraction larger than 2 mm) were mapped and compared with several hypotheses on grain size controls.

Results

Observations show a median particle diameter D50 of 0.465 mm (σ = 0.221 mm) at the 0.2 m elevation when averaged for the entire. Higher up the beach the grain size is finer, with 0.281 mm (σ = 0.067 mm) on average at the 1.7 m NAP level. Grain size increases slightly from south to north with particularly large grain size and shell fractions near (southern end of the) Sand Engine. These values do not show any correlation with the local beach slope or sedimentary/erosional trends of the profile.

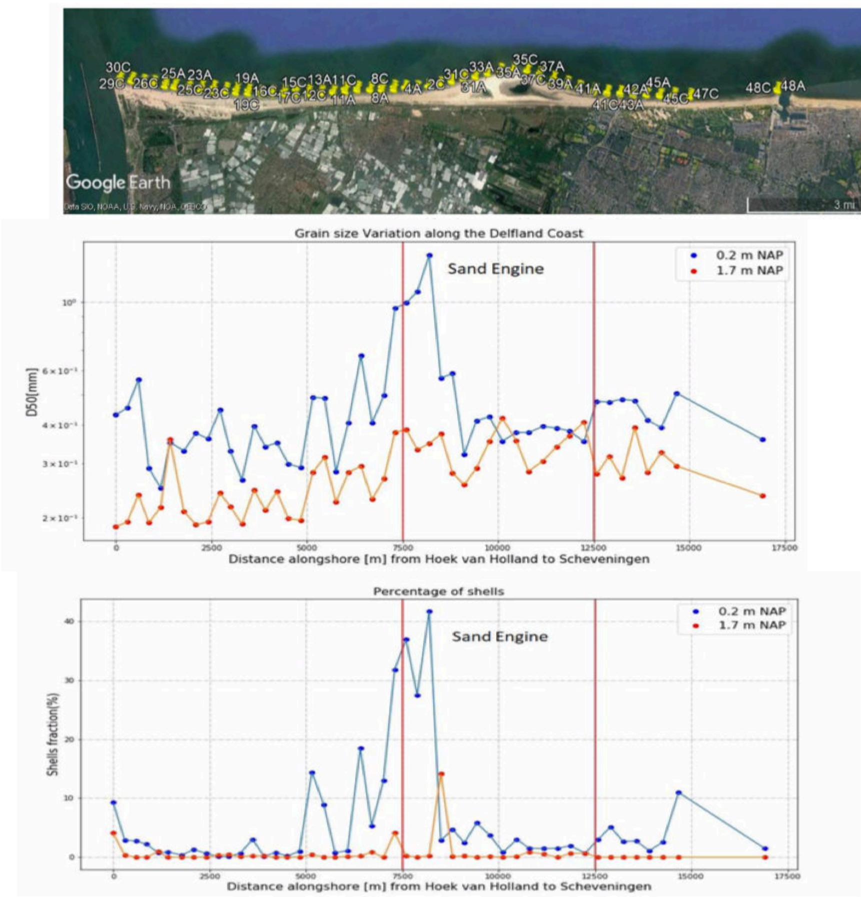


Figure 1 Spatial patterns in bed material along the Delfland coast. (Top) Sampling locations, (middle) median grain size at different levels, (bottom) shell fraction percentage. Source top panel: Google Earth.

Modeling tidal sand wave dynamics in response to dredging interventions

G.H.P.Campmans[1]*, P.C. Roos[1], S.J.M.H. Hulscher[1]
[1]University of Twente, g.h.p.campmans@utwente.nl

Introduction

Tidal sand waves are large scale bed forms observed in many tidally dominates sandy shallow seas, such as the North Sea. They often interfere with offshore human activities, such as navigation, because they are dynamic, are frequently surveyed and dredged. For both, surveying frequencies and dredging strategies, knowledge on sand wave recovery is required.

Methods

To describe sand wave dynamics we use the nonlinear sand wave model by Campmans et al. (2018). First, an equilibrium sand wave profile is obtained on a short domain allowing for a single sand wave in a horizontally periodic domain. Then, to investigate the sand wave response to dredging, this equilibrium sand wave profile is modified to represent sand extraction or redistribution. We look at two types of dredging: 1) topping, were the sand volume above a certain height is removed and 2) swiping, where the 'topped' sand is moved to the sand wave trough such that sand is being conserved. For various dredged volumes of sand the response of a single dredging intervention is investigated. Next to isolated in time dredging interventions, recurring dredging interventions are investigated. Sand waves are being dredged when their crest elevation exceeds a critical height, for instance determined for navigation purposes. Finally, the we look at dredging the highest sand wave in a sand wave field in a longer periodic domain.

Results

Using this model we find that the recovery time of sand waves to equilibrium depend increases with the dredged volume and is longer for swiping compared to topping. When recurrent dredging of the swiping type is applied the times in between consecutive dredging events is not constant. The time between the first two dredging events is the shortest and the time between later dredging events increases towards an equilibrium. The reason for this is that next to sand wave height, the shape of the sand wave matters for its recovery.

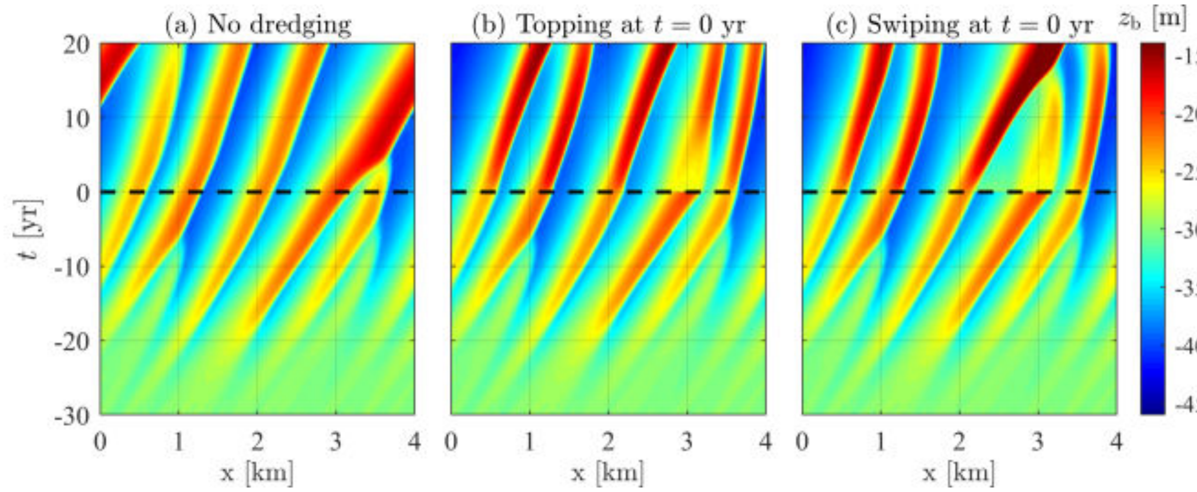


Figure 1 dredging the highest crest in a quasi-equilibrium sand wave field: (a) the undisturbed sand wave field (b) the topping of the highest sand wave crest and (c) swiping the topped sand volume to the trough to the left. This figure is adapted after Campmans et al. (subm.).

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Tendering and measurement innovation in integral monitoring of extremely shallow water embankments and bed level classification: Monitoring sandy reinforcement Houtribdijk

R.C. de Zeeuw[1]*, L. Veltman[1], R.J.A. Wilmink[2], B. Dierikx[3]
[1] Shore Monitoring & Research, roeland@shoremonitoring.nl, [2] Rijkswaterstaat WVL, rinse.wilmink@rws.nl,
[3] Rijkswaterstaat CIV, ben.dierikx@rws.nl

Introduction

Rijkswaterstaat (RWS) reinforced the Houtribdijk from Enkhuizen to Trintelhaven by means of a sandy foreshore and beach against the existing flanks of the dike. The IJsselmeer side was only nourished with sand, without further hard structures whereas on the Markermeer side (more exposed) alongshore breakwaters were constructed in front of the sandy foreshore and on both lateral boundaries. This unprecedented approach of levee reinforcement in a lake environment on this scale called for extensive monitoring and research into the long-term behaviour of the newly constructed sandy shores. Therefore, RWS launched an innovative tender, challenging the market to think of new ways to obtain integral, highly detailed and spatially covering measurements of topography and bathymetry against the strictest Hydrographic Requirements (NL Norm A), in extremely shallow water (0.5 – 2m), potentially simultaneously serving ecological monitoring goals.

Methods

Shore Monitoring & Research designed a monitoring strategy including UAV Lidar & photogrammetry for topographic and ecology monitoring, 360 degree aerial videos for virtual presence on the reinforcement from within the office and, application of a ground-breaking new hydrographic measurement technique for shallow water rendering swaths of up to 10 times the water depth: PingDSP-3DSS, winning the tender for the monitoring campaign. As part of the acceptance proofing, RWS and Shore jointly tested the proposed equipment to gain confidence in the performance of the system in the challenging environment of the Marker- and Ijsselmeer shores. All requirements set by RWS where readily met with the system.

Results

With this new technique and Shore's experience in integral monitoring of challenging shallow embankments, spatially covering bathymetry is obtained in water depths up to 0.5m (Figure 1, left), simultaneously rendering data to classify stones and different types of bottom material in the area based on intensity (Figure 1, right). The measuring technique has large potential for academic research covering the full spatial scale of morphological features.

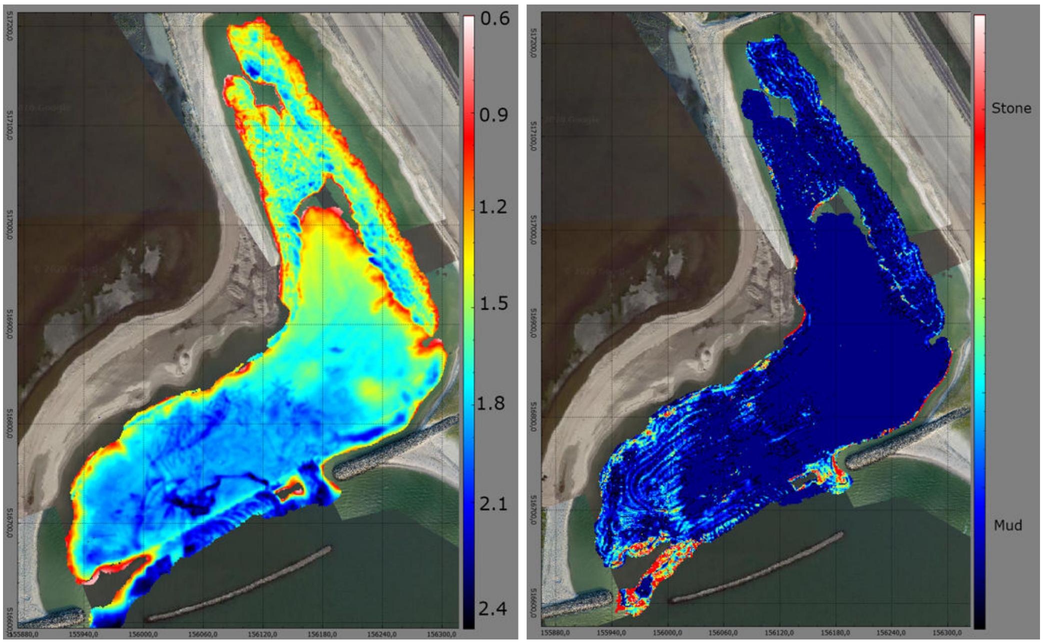

Figure 1 Left: Bottom level elevation expressed in relation to local water depth (m). Right: Bottom material type.

The EURECCA project:
How will waves and tides spread the sand mixture of the Prins Hendrikzanddijk?

T.D. Price[1]*, M.A. De Schipper[2], J. Hopkins[2], S.G.J. Aarninkhof[2], B.G. Ruessink[1]
[1] Utrecht University, {T.D.Price, B.G.Ruessink}@uu.nl
[2] Delft University of Technology, {M.A.deSchipper, J.A.Hopkins, S.G.J.Aarninkhof}@tudelft.nl

Introduction

Placing sandy beaches in front of dunes to prevent future flooding under rising sea levels has been done for over three decades now along the Dutch coast. In recent years this approach has started to be used to improve weak flood defences, such as dikes and dams, in regions that are not necessarily wave-dominated. These so-called sandy retrofits replace traditional reinforcements of concrete, stones or asphalt. The Prins Hendrikzanddijk, on the landward side of the Dutch barrier island Texel, is a recent example of such a sandy retrofit. So far, our understanding of the behaviour of artificially placed sediment has primarily focussed on beaches predominantly forced by waves. Moreover, a single grain size is often assumed when studying the transport of the added sediment. This greatly hampers the prediction of coastal safety and the design of mixed-sand (i.e. various grain sizes) retrofits in mixed wave-current environments, such as around barrier islands or near river entrances.

With our recently awarded NWO-OTP project we aim to provide the quantitative knowledge and tools needed for the design and evaluation of Effective Upgrades and REtrofits for Coastal Climate Adaptation (EURECCA). More specifically, with EURECCA we aim to unravel *when* and *where* the mixed sand of a nourishment will disperse given mixed wave-current forcing conditions. Key scientific challenges are to describe (1) the evolution of the cross-shore profile of the sandy bed level in response to calm and storm periods and (2) the planform evolution and impact of different sediment sizes on this evolution.

Approach

To address above challenges, we will undertake dedicated large field campaigns at the recently completed (2019) Prins Hendrikzanddijk (Figure 1) in combination with state-of-the-art process-based model simulations. With short- and long-term field campaigns and monitoring data we will determine the threshold forcing conditions that mobilize sediment of different grainsizes. Numerical models (XBeach and Delft3D) will be applied to generalize these findings, and to propose new parameterizations in forecast and design tools.

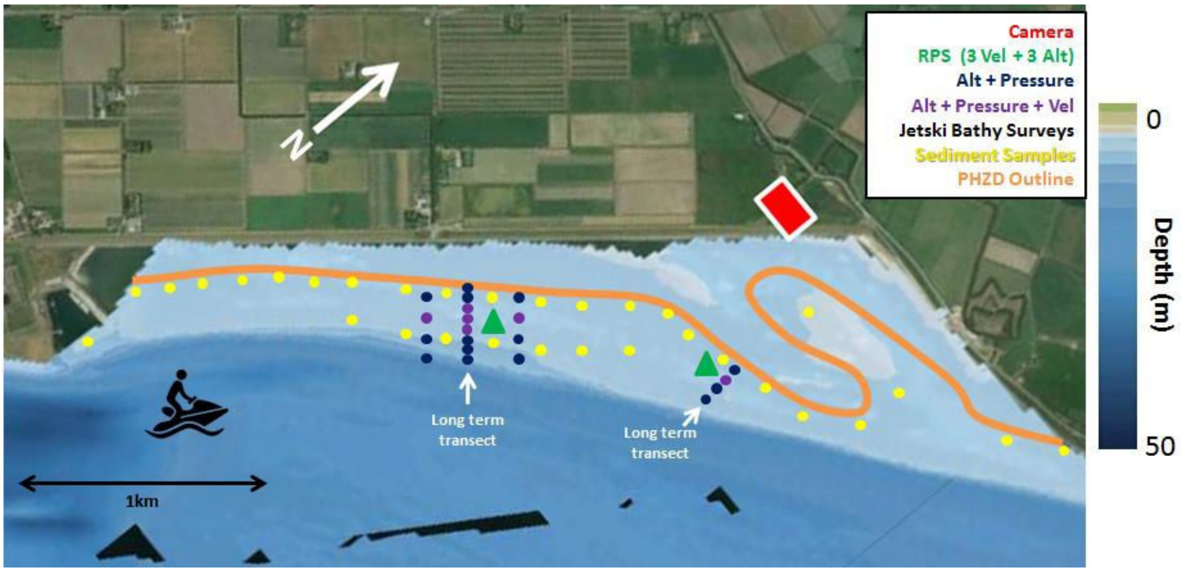

Figure 1 Schematic of planned field observations, including arrays of hydrodynamic sensors for short (monthly) and long (yearly) deployment (dark blue for pressure and depth, purple for pressure, depth, and velocity), a ripple scanner mounted on a frame with pressure and velocity sensors to capture bathymetric change (dark green). The orange line denotes the location of the seaward extent of the Prins Hendrikzanddijk.

Growing dunes, eroding shoreface

L. Roest[1]*, P. Rauwoens[1]
[1] KU Leuven, bart.roest@kuleuven.be

Introduction

The Belgian coast is a 65 km long sandy shore, separating the North Sea from the low-lying hinterland.
Bathymetry of the Belgian part of the North Sea is characterised by the Flemish Banks; shallow areas separated by deep tidal channels. The nearshore sand banks are, veering obliquely from the shoreline for roughly 20 km and up to 5 km offshore.
Flemish coastal defences are formed by alternating stretches of natural dunes and man-made sea dikes, protecting the hinterland from flooding. These structures are required to meet the safety standards which were recently revised in the *Masterplan Coastal Safety* (Afdeling Kust, 2011). Currently, the *Complex Project Coastal Vision* aims for further improvements towards 2100. To assess coastal safety, annual topographical and bathymetrical surveys are performed. These measurements reach from the dunes or sea dike up to 1500 m offshore, covering the entire coast. With measurements starting already in the 1970's, the Belgian coast is amongst the best monitored in the world.

Methods

Existing raw survey data were processed to a set of common cross-shore oriented transects, an approach similar to Dutch JarKus data (Roest, 2017). Annual data were available for 1997-2019. Further, a toolbox is under development to pre- and post-process arbitrary coastal survey data. This allows for derivation long-term statistics and profile parameters on otherwise heterogeneous data. While such research was performed on coastal volumes for the Belgian coast, it was never performed on other parameters.

Results

Previous research has shown that on decadal time-scales, the Belgian nearshore zone has gained sediment by both Natural feeding and artificial sand nourishment at a rate of 10^6 m^3/y (Houthuys and Roest, 2019). Furthermore, Strypsteen et al (2019) concluded that the natural dunes grow linearly in time, at an average rate of 6 m^3/m/y. This dune growth actually exceeds the rate of sea level rise, indicating coastal resilience. Contrastingly, shoreface and seabed are mostly erosive. Exceptions are only found in several well-known accretion zones, such as: *Zeebrugge* and the *Broersbank*. Nearshore erosion is mainly found in the tidal channels confined between the Flemish banks and the coastline. The *Groote Reede* channel between *Oostende* and *Blankenberge* is deepening at a rate of approximately 25 mm/year. Along this tidal channel, the transition from the sloping shoreface towards the flat seabed is migrating onshore, manifesting itself as erosion up to 100 mm/y. The combined effect of growing dunes and an erosive shoreface leads to steepening of the coastal profile. If this trend persists, it may affect the overall stability of the coast.

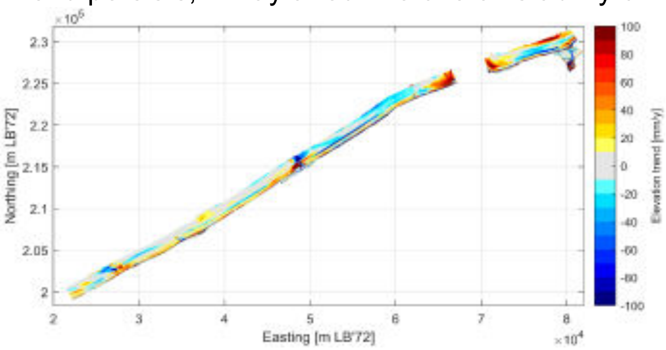

Figure 1 Linear trend (1997-2019) of bed elevation in the Belgian coastal monitoring area.

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Ebb-shoal dynamics and its influence on the adjacent beach-dune system in Texel (NL)

F. Galiforni-Silva[1]*, K.M. Wijnberg[1], S. J. M. H. Hulscher[1]
[1] University of Twente, f.galifornisilva@utwente.nl, k.m.wijnberg@utwente.nl, s.j.m.h.hulscher@utwente.nl

Introduction

In tidal inlets, one of the leading sand input processes to a coastline stretch happens in the form of shoal attachment (Gaudiano and Kana, 2001). The process is characterized by an accumulation of sand that detaches from the ebb-tidal delta and moves towards the coastline, leading to several changes in the neighbouring beach-dune system. Recent insights from Texel (NL) show that a vast ebb-tidal shoal is attaching the coast (Elias and van der Spek, 2017). Such attachment will lead to currently unknown changes in the adjacent beach-dune system. The objective of this study is to evaluate potential scenarios of beach-dune development due to shoal attachment.

Methods

We used a combination of bathymetric (since 1991) and LiDAR (since 1997) datasets available for the area to understand the past behaviour of both the beach-dune system and the shoal. We tracked shoal displacement through both elevation and volume changes. For the beach-dune system, we tracked shoreline variability, dunefoot and dune volume evolution based on 47 cross-shore profiles along the southwest coast of Texel extracted from the LiDAR data.

Results and Discussion

Results show two sand shoals with distinct behaviour and potential consequence for the coastline (Figure 1). The northern tip (1) moves landward and pushes the channel towards the coast, leading to increased erosion of the beach (2). The second one (3) presents higher elevation changes and moves northeast. For (3), the channel is not forcing any coastline erosion. Channel migration and nourishments control shoreline movement and dunefoot. Dune volume presents an accretive trend, with higher accretion in the southern zone and sparse erosive years in the erosion hotspot. Based on data insights and previous studies, we hypothesize that the attachment of the shoal will lead to an increase in beach width and a consequent seaward movement of the dunefoot, but not necessarily an increase in accretion rates of dune volume (Galiforni-Silva et. al., 2019). Considering a channel-induced erosion, monitoring the next shoal cycle will potentially give us the buffering capacity of a shoal-induced shoreline and the necessity of any adjustment in current management practices.

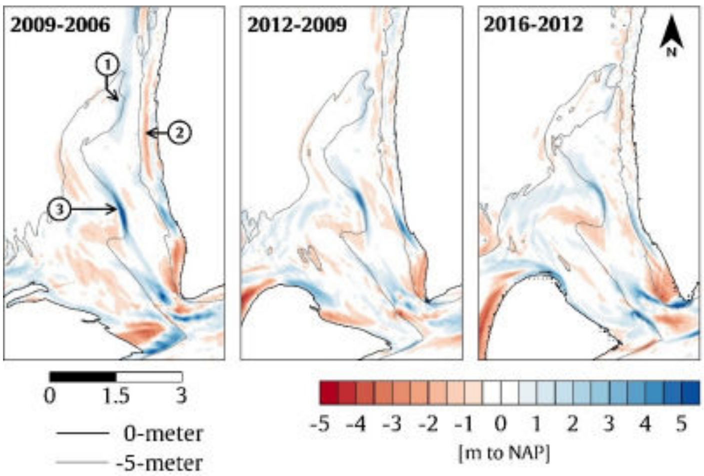

Figure 1 Bathymetric difference maps highlighting three main erosion/accretion characteristics. Isobaths based on 2009, 2012 and 2016 surveys, respectively.

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Role of salt marsh vegetation in sedimentation and modelled wave attenuation (the Slufter, Texel)

B.M. Baaij*, J. Kooijman, J.M. van Loon-Steensma, J. Limpens
Wageningen University & Research
*bmbaaij@kliksafe.nl

Introduction

Salt marshes provide important ecosystem services, such as coastal protection against flooding and erosion by stimulating sedimentation and attenuating wave energy. However, salt marsh functioning is threatened worldwide by human influences and climate change. Salt marshes are expected to drown with sea level rise when they cannot migrate inland or when they cannot gain elevation with similar or higher rates than the relative sea level rise. Although it is known that salt marsh vegetation contributes to sedimentation and wave attenuation, little is known about differences between vegetation types and the (relative) contribution of vegetation characteristics.

Methods

We investigated the role of vegetation presence, type and characteristics in sedimentation, sediment grain size and wave attenuation by a combined field and modelling study on a salt marsh in nature reserve the Slufter on the barrier island Texel, the Netherlands (Figure 1). Vegetation presence was manipulated and vegetation characteristics (total cover, vegetation height, stem height, stem diameter, branching level, stem density and biomass), sedimentation and the sediment grain size distribution were measured in four vegetation types *(Salicornia*, *Spartina*, *Atriplex* and *Limonium* type) in the field. Stem height, stem diameter and stem density were used as input for the XBeach model to explore their (relative) effects on wave attenuation.

Results

We found a strong positive effect of vegetation presence on sedimentation and wave attenuation. Sedimentation was highest for the *Salicornia* type and lowest for the *Limonium* type. Modelled wave attenuation was strongest for the *Spartina* type and weakest for the *Salicornia* type. Sedimentation increased with stem height and branching level, while sediment grain size was not significantly influenced by any vegetation characteristic. Modelled wave attenuation increased with stem height, stem diameter and stem density and was most sensitive to low stem densities. Understanding the role of vegetation presence, type and characteristics in sedimentation and wave attenuation will be valuable in the prediction of salt marsh accretion and the implementation of salt marshes in nature-based flood defences.

Figure 1 Aerial view of study area the Slufter on barrier island Texel, the Netherlands. The salt marsh is situated in between two dikes and connected to the North Sea by a channel. Source: Bing Satellite.

Identifying sediment transport mechanisms from grain size-shape distributions: application to a secondary tidal inlet system (de Slufter, Texel, the Netherlands)

M.A. Prins[1], Y. Cuijpers[1], J.A. van Hateren[1], J.B.W. Stuut[1,2], S.R. Troelstra[1]
[1] Vrije Universiteit Amsterdam, m.a.prins@vu.nl
[2] NIOZ

Introduction

The way in which sediment is transported (creep, saltation, suspension), is traditionally interpreted from grain size distribution characteristics. However, the grain size range associated with transitions from one transport mode to the other is highly variable because it depends on the amount of transport energy available. In this study we present a second application of a novel methodology for determination of sediment transport modes based on end-member modelling of grain size and shape data from dynamic image analysis (see contribution by van Hateren et al).

Methods and approach

The grain size-shape distribution of surface sediment samples (Fig. 1) from an active secondary tidal inlet system along the Dutch coast – the Slufter nature reserve on the island of Texel – are decomposed into a series of primary components by end-member modelling (Fig. 2, upper panel). The spatial distribution of these components (Fig. 2, lower panel) is controlled by the dominant transporting media (water, wind), geomorphology and vegetation cover and reflects the main processes of sediment transport in this mixed aeolian-tidal sedimentary system: wave- and tidal-current-dominated transport of 'coarse' sand on the beach and in the main inlet channel, aeolian transport of 'fine' sand in the coastal dunes, and tidal-current transport of 'fine' sands and 'very fine' mud in the vegetated salt marsh.

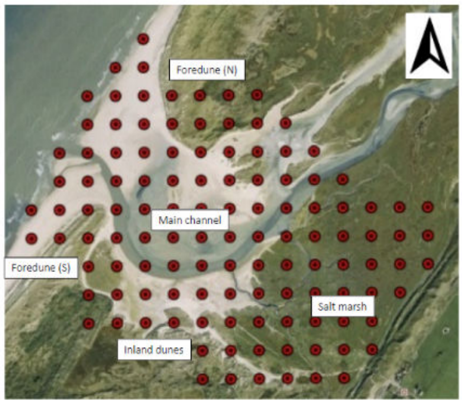


Figure 1 Sample grid across the Slufter nature reserve.

Results & conclusions

The different transport modes and transporting media are characterised by different grain size-shape distributions. Bedload transport by water is characterised by coarse sand and a constant grain regularity with increasing size (EM1, EM2). Bedload transport by wind is also characterised by a constant grain regularity with increasing size, but the distribution is finer-grained (EM2, EM3). Suspension transport of sand in the main channel by water is characterised by a strong decrease in grain regularity with increasing size (EM4). Suspension transport of silts by water shows a strong decrease in grain regularity with increasing size (EM5). The grain size-shape distributions can thus be used to determine the transport mode and potentially also the transporting medium for a sedimentary deposit.

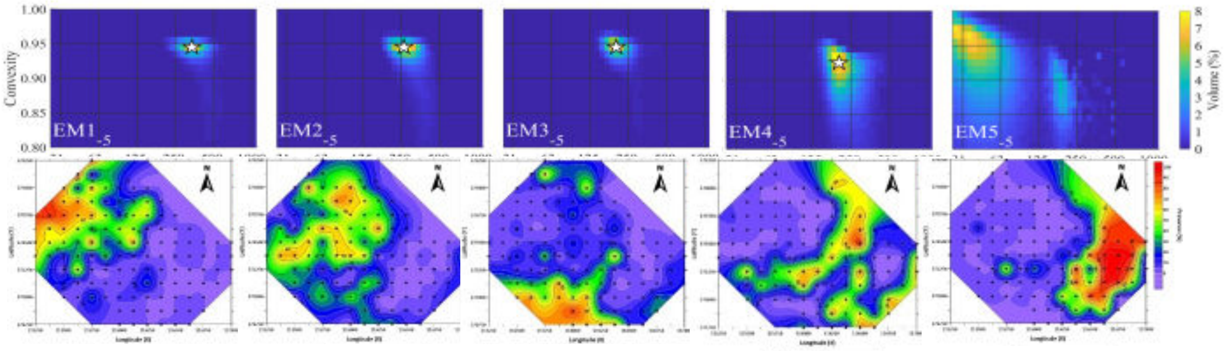


Figure 2 Modelled end-member grain size-shape distributions (upper graphs) and their spatial distribution across the Slufter nature reserve (lower graphs).

Slufter Texel – combined search for change indicators

P. Goessen[1] *, J. Van Loon[2], M.A. Prins[3]
[1] HHNK, p.goessen@hhnk.nl
[2]WUR, jantsje.vanloon@wur.nl,
[3]Vrije Universiteit Amsterdam, m.a.prins@vu.nl

Introduction

Nature reserve 'the Slufter' is a salt or brackish dune valley at the North Sea coast of Wadden island Texel. It is a sandy salt-marsh area, which inundates regularly during high tides and storm surges. It is appointed as Natura2000 area. The natural widening of the channel mouth is managed by water board HHNK to prevent potential erosion of the landward located sand dike. However, new insights in the working of the Slufter system give reason to reconsider the management of the estuary mouth and its surroundings Modelling of the processes indicates that wave reduction is less related to the width of the mouth. Ceasing dredging interventions to give more space to natural processes is therefore possible. Such changes in management of the inlet may affect the biodiversity values of the Slufter nature reserve. In strong collaboration with Staatsbosbeheer, and staff and students from VU Amsterdam, UvA, Wageningen University, Delft University, Utrecht University, and Hogeschool Van Hall-Larenstein the water board collects and analyses sedimentological, hydrological and ecological data. In these analyses we seek to understand the natural processes and to recognize indicators for change. Insight in short-term change may help to foresee long-term development under climate change. We exchange insights and knowledge with our colleagues of Zwin in Belgium.

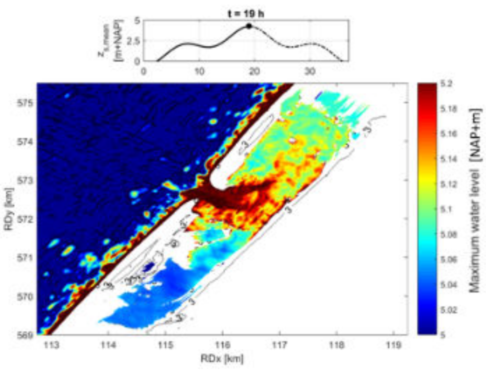
Methods

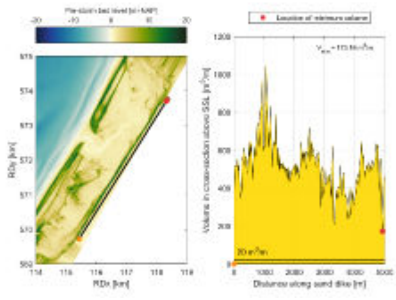
We started to collect data in 2014, and intend to proceed at least until 2024, but expect to extend until 2030. To gain insight in water safety we used Jarkus data and drone data to model the area with Xbeach and explored the impact of a shift of the mouth to a northern location and simulated several scenarios for bed level and sea level rise. Concerning sedimentology, surface samples were taken in a broad grid in 2013 and a tighter grid near the mouth in the following years. Several types of sedimentological analyses have been performed on those samples: (1) laser-diffraction particle size analysis → grain-size distribution, (2) dynamic image analysis → size-shape distribution, (3) thermo-gravimetric analysis → organic matter and carbonate content. (See also poster presentation by Prins et al). We monitored the vegetation and explored wave damping with Xbeach 1D (see presentation by Baaij et al). To gain insight in salinity, we used Dualem and monitored wells for analysing salt water intrusion to the polder.

Results

Water safety: Analyses of modelling for safety assessment give reassuring results, even with sea level rise of 2 m.

Sedimentation: see poster presentation by Prins et al
Vegetation: see presentation by Baaij et al.
Salinity: no extra inlet of salt is to be expected when the location of the mouth changes.





Creating a global database with return periods of extreme sea levels caused by tropical and extratropical cyclones

J.C.M. Dullaart[1], S. Muis[1,2], N. Bloemendaal[1], J.C.J.H. Aerts[1,2]
[1] Institute for Environmental Studies (IVM), VU Amsterdam, job.dullaart@vu.nl
[2] Deltares, Delft, The Netherlands

Introduction

Storm surges are driven by low air pressure and strong winds in tropical (TC) and extratropical cyclones (ETC). Coastal flooding is often caused by this type of extreme weather with large socio-economic impacts in densely populated and low-lying coastal areas. Recent examples of coastal disasters include typhoon Hagibis that made landfall in Japan, Hurricane Dorian which devastated the northwestern Bahamas, and extratropical cyclone Xaver that affected northern Europe. Each of these storms generated dangerous storm surges, reaching 6m in some parts of the Bahamas during Hurricane Dorian with approximately 100 fatalities as a result. Economic losses are estimated at 10 billion U.S. Dollars for both typhoon Hagibis and hurricane Dorian.

To inform flood risk management and develop effective adaptation strategies it is important to have accurate information on return periods of extreme sea levels. To date, there exists no global database with return periods of extreme sea levels that fully includes TCs. Global databases of extreme sea levels are typically based on historical climate simulations covering multiple decades. While this is sufficient for ETCs, TCs will be underestimated in such databases. This because TCs have generally low probabilities and affect only a small stretch of coastline, compared to ETCs. A climate reanalysis covering multiple decades includes too few TCs to perform an extreme value analysis. To resolve this, previous studies at local scale have used synthetic TC tracks generated by a statistical model to estimate the probabilities of extreme sea levels.

Methods

The aim of this research is to develop a global database of extreme sea levels that include both ETCs and TCs. For ETCs, we force the hydrodynamic Global Tide and Surge Model (GTSM) with ERA5 10-meter wind speed and air pressure data to calculate the return periods of extreme sea levels based on the period 1979-2017. Since ERA5 includes all storms, we filter out extreme sea levels caused by TCs. Preliminary results show that GTSM forced with ERA5 atmospheric data performs well for ETCs. For TCs, we force GTSM with synthetic TC tracks that correspond to 10.000 year of TC statistics. The synthetic tracks of TCs are obtained from the STORM model (Bloemendaal et al., in review) based on the International Best Track Archive for Climate Stewardship (IBTrACS) TC database. With STORM it is possible to statistically extend the ~38-year observed dataset to a 10.000-year synthetic dataset. The synthetic dataset preserves the climatological statistics as found in the original dataset. Finally, we will merge the TC and ETC related return periods to create a global extreme sea level database.

Results

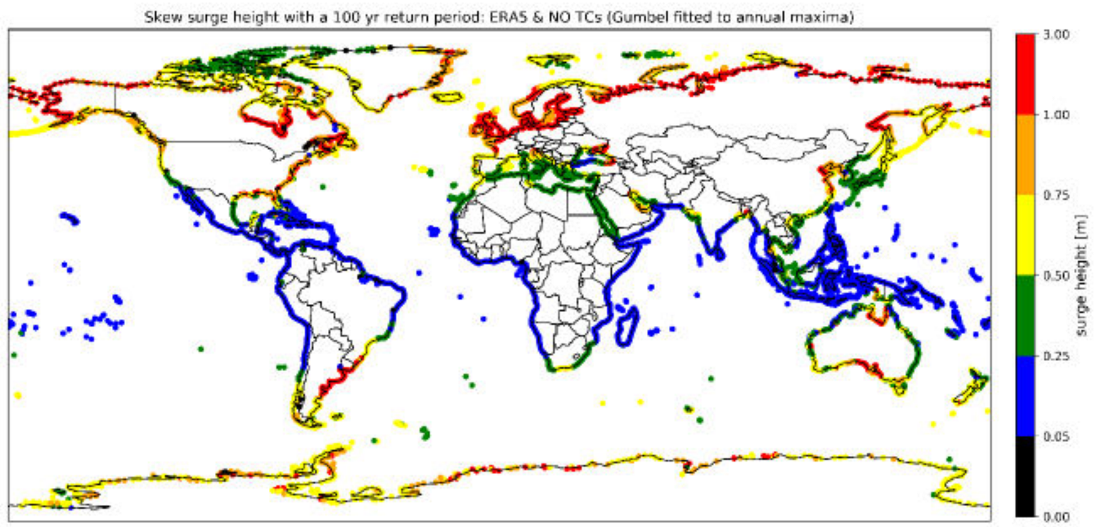


Figure 1 Skew surge heights with a 100 year return period, excluding TC induced extremes

Evaluating reforms of the National Flood Insurance Program by integrating human behavior in a coastal flood risk analysis

L.T. de Ruig[1,*], T. Haer[1], H. de Moel[1], P. Orton[2], W.J.W. Botzen[1,3,4], J.C.J.H. Aerts[1]
[1] Institute for Environmental Studies (IVM), VU University Amsterdam, [*]Lars.de.Ruig@vu.nl
[2] Davidson laboratory, Stevens Institute of Technology
[3] Risk Management and Decision Processes Center, The Wharton School
[4] Utrecht University School of Economics, Utrecht University

Introduction

Flood insurance is one of the main ways to cope with flood risk as a household in the U.S. Since 1968 the National Flood Insurance Program (NFIP) provides government-guaranteed flood insurance to homeowners and businesses in the United States, holding over 5 million policies-in-force and covering $1.2 trillion in assets by 2015 (FEMA, 2019). However, with major insurance claims after Hurricane Katrina and other catastrophic flood events since 2005, the NFIP was driven into debt, up to $30.4 billion in 2017 (Miller et al., 2019). In November 2017 the 21st Century Flood Reform Act was passed by the House of Representatives, to reauthorize the NFIP until 2022 and introduces several reform changes, including opening the market for private insurers and re-insuring coverage. However, the NFIP unsuccessfully tried to reform the program in 2012 but had to revert the changes in 2014 due to large affordability issues and political stress (Michel-Kerjan et al., 2014). It is therefore essential to include human dynamics and decision making in the assessment and evaluation of potential reforms.

Methods

We simulate individual homeowner decisions in an Agent-Based model coupled with a coastal flood risk model to evaluate 4 proposed reform changes: (1) full mandatory policies in high risk flood zones, (2) voluntary risk-based premiums, (3) risk-based premiums with a premium discount for implementing risk reduction measures, and (4) an accessible loan structure to fund risk-reduction measures. Homeowners behave boundedly rational according to a (discounted) subjective expected utility allowing them to invest in floodproof measures, or take (or cancel) insurance. The model is applied to a case-study of Jamaica Bay, NY (see fig. 1).

Findings

Our results show that risk-based premiums improve insurance penetration rates and affordability of insurance compared to the baseline NFIP scenario. A premium discount for disaster risk reduction does incentivize more homeowners to invest in dry-floodproof measures but does not seem to increase overall affordability. An accessible loan structure with a 4% interest and length of 20 years improves the uptake and affordability of dry-floodproof measures significantly.

Figure 1 the NFIP 100-year flood extent for Jamaica Bay, NY.

Can the Demak mangrove-mud coast keep up with relative sea level rise?

B.P. Smits[1], D.S. Van Maren[1,2], B.K. Van Wesenbeeck[1,2]
[1] Deltares, Marine & Coastal Systems, Bob.Smits@deltares.nl
[2] TU Delft, Faculty of Civil Engineering and Geosciences

Introduction

The coastal zone of Demak district (Central Java, Indonesia) is suffering from severe erosion due to the replacement of mangrove forests with fish and shrimp ponds, embankment of rivers and land subsidence (up to 13 cm per year; caused by ground water extraction). To stop erosion, enhance accretion and restore the mangrove ecosystem, permeable bamboo structures are placed in the intertidal zone. These structures are designed to attenuate waves and create still water conditions suitable for sediment accretion. This study uses a process-based numerical model to assess the effectiveness of the implemented permeable structures under various scenarios of sea level rise and land subsidence.

Methods

A Delft3D Flexible Mesh model is used to simulate the morphodynamic development of the coastal zone under various scenarios. An existing model setup is improved and utilized to compare the 10-year autonomous development of the coast under various sea level rise and subsidence scenarios, for conditions with and without the implementation of permeable structures.

Results

The model results show that without permeable structures, most of the Demak coastal zone will erode and drown for all investigated scenarios of relative sea level rise. Implementing permeable structures enhances trapping of sediments, thereby increasing the bed level behind the structures. Most sediment is trapped behind these structures for the most extreme scenarios of relative sea level rise. The bed level behind the permeable structures will keep up with relative sea level rise until some threshold has been exceeded (Figure 1). From that point onwards the permeable structures can no longer trap sufficient sediment to keep up with relative sea level rise, resulting in partial drowning of the coast. This is mainly due to the large rate of land subsidence, which is responsible for 90% of the rate of relative sea level rise. Hence, small rates of subsidence and sea level rise already cause loss of coastal areas if no measures are implemented. However, although measures (such as permeable structures) can help in mitigating the effects of relative sea level rise, on the long run and with high rates of relative sea level rise, this effect does not persist.

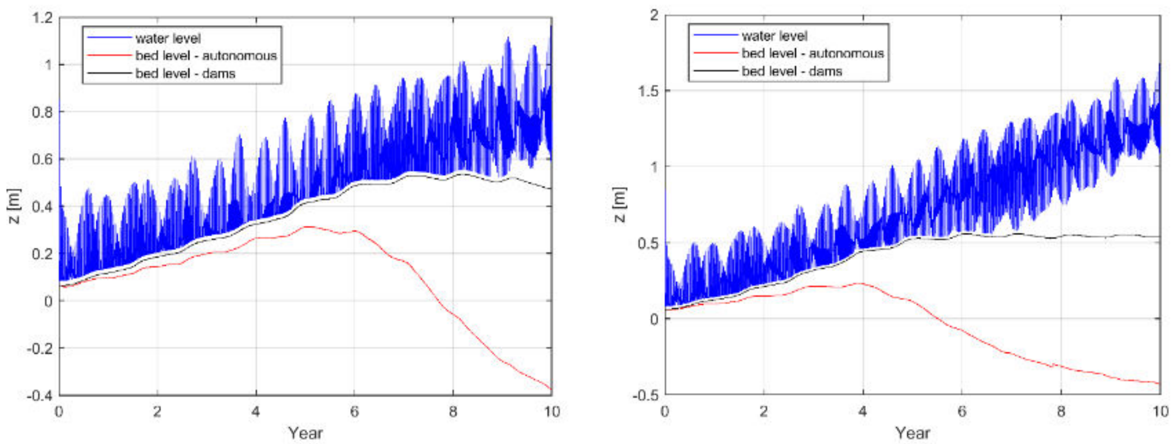


Figure 1 Bed level development over time throughout the model simulation for different scenarios at observation points behind one of the permeable structures. The blue line indicates the tidal water level including relative sea level rise (on hydrodynamic timescale), the red line indicates the autonomous bed level development and the black line the bed level with permeable structures. Subpanels show the best-case scenario with rSLR of 8.2 cm/year (left) and worst-case scenario with rSLR of 13.6 cm/year (right).

The effect of the slope angle on the failure of the grass revetment due to wave impact

M. Peters[1,2], V.M. van Bergeijk[1], J.A. van Zuylen[2], J.J. Warmink[1], S.J.M.H. Hulscher[1]
[1] University of Twente, Martijn.Peters@sweco.nl, v.m.vanbergeijk@utwente.nl, j.j.warmink@utwente.nl, s.j.m.h.hulscher@utwente.nl
[2] Sweco Nederland B.V., Jos.vanZuylen@sweco.nl

Introduction

Parts of the Netherlands are protected against floods from the sea by a variety of dikes. At the Dollard in the Netherlands, a green dike was constructed. A green dike is a dike with a grass cover on the entire slope and such a dike does not contain a hard revetment to deal with the incoming waves (Figure). The assessment of the strength of the grass revetment against wave impact is captured in the “Wettelijk Beoordelingsinstrumentarium” (WBI). However, it is uncertain under which storm circumstances the seaside grass revetment fails, because the slope angle is not included in the safety assessment (WBI). The objective of this research is to determine the effect of the slope angle on the duration until failure of the revetment due to wave impact, also termed resistance-duration.

Methods

Results of historic experiments were gathered from literature and they were used to establish the relation between the slope angle and the resistance-duration of the seaward grass cover. The results of the experiments with different slope angles are compared with the WBI and the Wave Impact Pressure Erosion (WIPE) model. Additionally, the effect of the slope angle on failure probability in the case of the green dike at the Dollard was quantified.

Results

From the data analysis of the executed experiments, a linear negative correlation between slope angle and resistance-duration was found. This means that a grass revetment on a slope of 1:6 has twice the resistance-duration compared to a revetment on a slope of 1:3 with similar wave conditions. When this relation is applied for the Dollard case, we found a return period of a storm that results in failure of once in 90 years for a slope of 1:7. According to the detailed assessment of the WBI, that does not take the slope angle into account, a return period of less than 10 years is predicted. Thus, the slope angle substantially reduces the failure probability for the grass revetment in case of a gentle seaside slope. Including the slope angle in the safety assessment gives a more accurate strength estimation of a wide green dike. This is a first step towards a realisation of a dike that meets the safety requirements while it contributes to the ecological value of the environment.

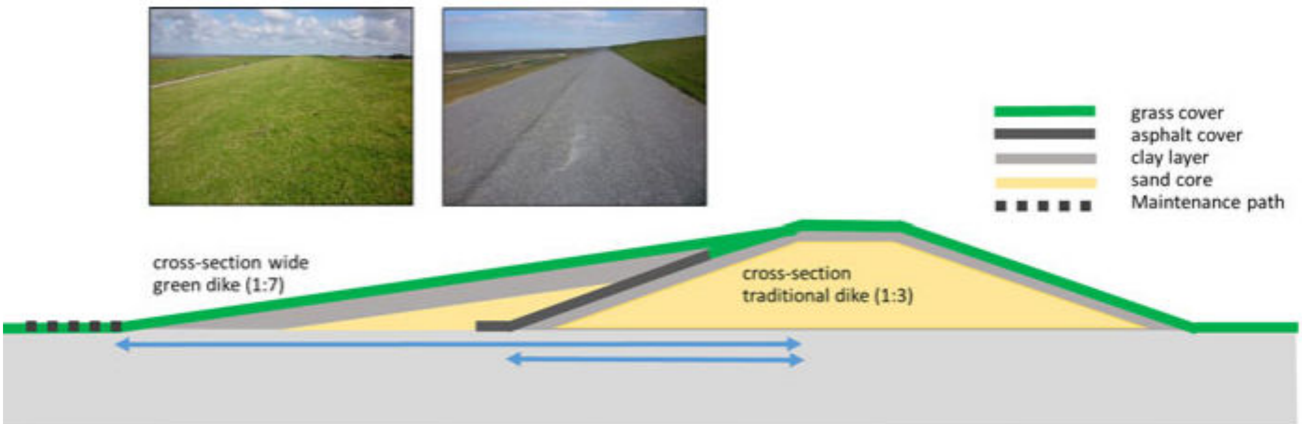


Figure 1 Cross section of a traditional dike and a wide green dike. Source: Van Loon-Steensma and Vellinga (2019)

Reference

Van Loon-Steensma, J. and Vellinga, P. (2019). How “wide green dikes" were reintroduced in the Netherlands: a case study of the uptake of an innovative measure in long-term strategic delta planning. Journal of Environmental Planning and Management.

Multi-stability due to biogeomorphic feedbacks: implications for saltmarsh restoration

R.C. van de Vijsel[1*], J. van Belzen[1], T.J. Bouma[1], D. van der Wal[1], M. Rietkerk[2], J. van de Koppel[1]

[1] NIOZ Royal Netherlands Institute for Sea Research, Department Estuarine and Delta Systems, and Utrecht University, roeland.van.de.vijsel@nioz.nl, jim.van.belzen@nioz.nl, tjeerd.bouma@nioz.nl, daphne.van.der.wal@nioz.nl, johan.van.de.koppel@nioz.nl

[2] Copernicus Institute, Department of Environmental Sciences, Utrecht University, m.g.rietkerk@uu.nl

Introduction

In view of anticipated sea level rise and anthropogenic pressures on coastal areas, saltmarsh restoration efforts through managed coastal realignment (reintroduction of the tide into formerly embanked areas) are undertaken worldwide. Yet, restoration success differs strongly between realigned sites. Whereas in some de-embanked areas, vegetation establishment, drainage channel development and sediment consolidation occur rapidly, other areas remain in an unvegetated and topographically flat state with poorly consolidated sediments for a long time. What explains these large differences? We hypothesize that these are distinct stable states of the intertidal system, induced by biogeomorphic feedbacks between vegetation growth, sediment stabilization and channel formation. Combining lab and modelling efforts, we explore this theory and its consequences for tidal marsh restoration.

Methods

In lab experiments, we found empirical support for the hypothesized feedbacks. Biostabilisers (algae, plants) locally increase the pre-existing, “abiotic” sediment cohesion. This stimulates net sedimentation and hence the build-up of micro-topography. Elevated topography improves biotic growth conditions, which closes the positive feedback loop. We implemented these feedbacks in a spatial, idealized numerical model, combining biotic, sedimentary and hydrodynamic processes, to simulate the formation of vegetation-induced tidal channel networks. We then performed bifurcation analyses on the model, to test if and when these feedbacks lead to the development of separate (multi-stable) landscape states.

Results

Model simulations imply that, when abiotic sediment cohesion is high, vegetated and channelized landscapes self-organize from the biogeomorphic feedbacks (Figure 1). However, vegetation density and topographic relief decrease with decreasing abiotic cohesion. This trend is strongly nonlinear, i.e. at very low cohesion the system drastically changes to become completely unchanneled and unvegetated. We further explored under which conditions these critical state shifts occur, how long it takes for a bare and flat landscape to become vegetated and channelized, and if such recovery can occur at all. These findings may help in interpreting observations of the development of realigned coastal areas and might provide indications as to which measures could be taken to accelerate tidal marsh recovery.

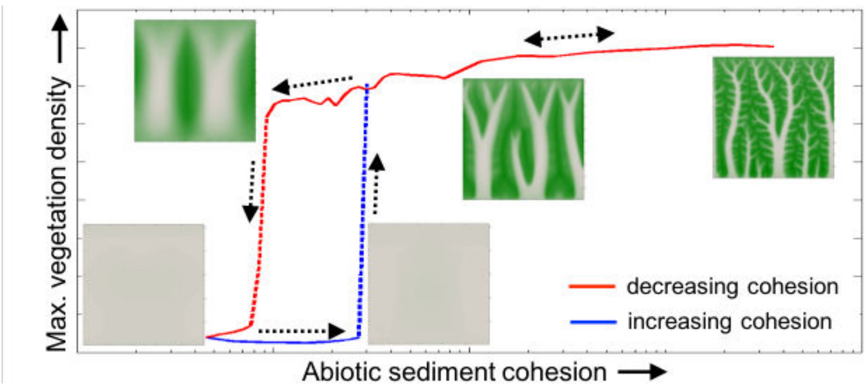


Figure 1 Bifurcation analysis of modelled channel networks (shown: vegetation density) as a function of abiotic sediment cohesion. Decreasing resp. increasing the cohesiveness yields different development routes.

How do tidal divides affect the morphological evolution of tidal inlets?

K.R.G. Reef[1], P.C. Roos[1], H.M. Schuttelaars[2], S.J.M.H. Hulscher[1]
[1] University of Twente, Marine and Fluvial Systems. K.R.G.Reef@utwente.nl.
[2] Delft University of Technology. Department of Applied Mathematical Analysis.

Introduction

Barrier coasts such as the Wadden Sea are important coastal systems that are characterized by a chain of tidal inlets and barrier islands. These systems are highly dynamic, and their long-term (i.e. centurial) morphological evolution is affected by complex interactions between various elements, such as the backbarrier basin and the tidal inlets.

Tidal divides have been identified as important features for the stability of double inlet systems (van de Kreeke et al. 2008), while also allowing residual transport to pass over them (Duran-Matute et al. 2014). Despite these findings, the role of topographic highs (such as tidal divides) on the equilibrium cross-section and spacing of multiple tidal inlets is not yet fully understood. To study that is the aim of this work.

Methods

To achieve our aim, we use an idealized barrier coast model that can simulate the long-term (i.e. centurial) evolution of multiple tidal inlets towards an equilibrium state (Roos et al. 2013). The morphological model for the evolution of the tidal inlets is based on the stability concept of Escoffier (1940) and is coupled with an idealized hydrodynamic model that is forced by a tidal wave on the outer sea and computes the co-oscillation in the tidal inlets and backbarrier basin. As a methodological novelty we extend the model to allow arbitrary bathymetries in the backbarrier basin. We performed ensemble simulation in which we systematically vary the number of bathymetric features by varying the number of valleys and topographic highs.

Results

Our results show that the location of tidal inlets that remain open is strongly affected by variations in bathymetry, with most inlets remaining open in the deeper parts of the basin. Also shown by our results is that the equilibrium number of open inlets is hardly affected by the number of topographic highs in the basin. This implies that the number of open inlets is a system characteristic rather than the effect of local depressions in bathymetry. Furthermore, we identify a competition between bathymetric features and the distance between inlets; the outcome of which determines the equilibrium location of open inlets.

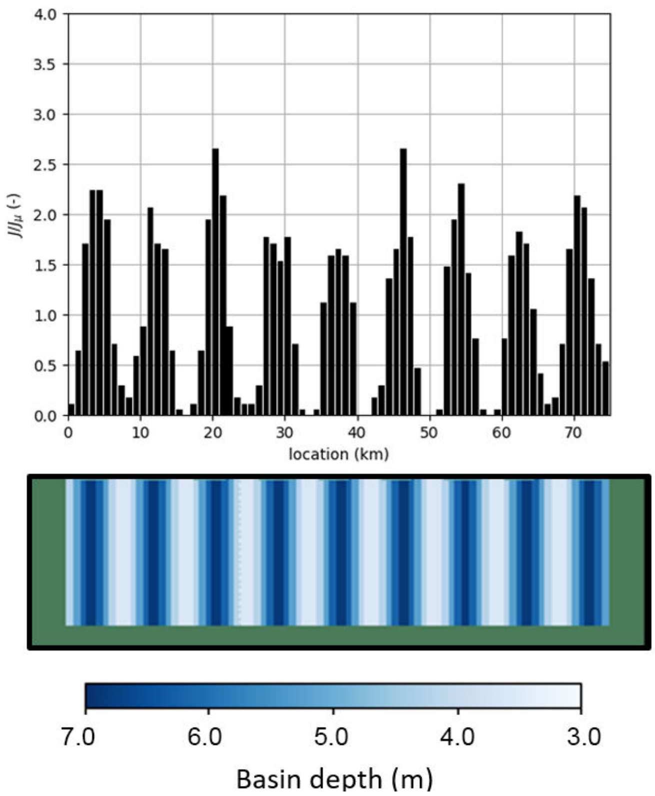


Figure 1 Results of an ensemble (n=249) simulations. Top: histogram with the ratio of open inlets J over the mean J_{mean} per km barrier coast. Bottom: backbarrier bathymetry.

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Effective monitoring campaigns

F.R. Kok*, J.Mol
Rijkswaterstaat, Frank.kok@rws.nl, janwillem.mol@rws.nl

Introduction

Rijkswaterstaat has a long tradition of monitoring and measuring physical, biological and chemical parameters. This long and short term information is used to define policy measures for the integrated water management of Rijkswaterstaat: dry feet, sufficient clean water and reliable and useful information.

Field campaigns

Along the Dutch coast, extensive field campaigns are organized to acquire hydro-, morpho- and ecological data that are needed for the development of system knowledge and fine-tuning of prediction models. Most campaigns are in cooperation with knowledge institutes and universities. By utilising each other's strengths good results are guaranteed. A number of cooperative projects will be presented.

Strength

The availability of well-equipped vessels and auxiliary monitoring platforms make it possible to organize and participate in field campaigns. Rijkswaterstaat is investing in people and resources for optimizing the data management of project related data sets. Our objective is to stay a reliable partner in the joint monitoring campaigns. The presentation includes procedures for setting up effective joint campaigns.

Figure 1 Survey Vessel Scheurrak equipped with ADCP, MBES, SBES, ABS, CTD, OBS, LISST and pump systems.

Coordination of coastal management and policymaking

Mr Pär Persson, The County Administrative Board (CAB) of Sweden/Skåne

Focusing on coastal management and representing the EU project LIFE Coast Adapt, of which the CAB is a beneficiary as well as Lund University, the Skåne Local Association of Municipalities, the municipalities of Ystad, Lomma and Helsingborg, and the regional public authority of southern Sweden, Region Skåne.

“Coordination of coastal management and policymaking” is the subject of action C1, LIFE Coast Adapt (page 2). Three objectives will be conducted.

- Guideline for ecosystem based / nature based solutions to protect the coast
- Policy for errands (legals)
- A map showing where different measures can fit along the coast of Scania

Below you find a short description of identified questions for each objective.

Guideline
Baseline material is important for planning measures. What kind of documents are important to have when planning measures?

Measures

- What measures are relevant at each location?
- Is there a link between the baseline information and the measure chosen?
- Measures other than the chosen ones relevant based on existing documents?
- Accountability and socio-economic factors a role in the choice of measures?

Legals and implementation

- Are the legal processes an obstacle to take appropriate measures? In that case, which measures and what is the obstacle?
- Are there financial barriers to implementing appropriate measures? In that case, what measures are the most difficult to finance?
- Time perspective affect the implementation, what measures are relevant in different time perspectives? What opportunities and difficulties exist for legal, economic, social and ecological time perspectives?

Producing Maps
Maps produced in the project will be products of how best practice of scientific knowledge interact with legal processes and other implementation perspectives. Maps containing of different GIS layers also have to be presented in a way that addresses the recipient.

How relative is relative sealevel change?

R.Hoogland[1*]
[1] Rijkswaterstaat, Rena.Hoogland@rws.nl

Introduction

Relative sea level rise is the rise in sea level relative to a reference plane, which is connected to a fixed point in the subsurface. The relative sea level rise is the sum of the actual sea level rise, due to the increase in and expansion of sea water resulting from temperature rise, and the movement of the reference plane.

Since 1891 the NAP (Normal Amsterdam Level) has been the national reference plane in the Netherlands. Mainly due to land subsidence this reference plane is not stable and has to be remeasured periodically. The last national campaign resulted in the 2005 NAP adjustment.

Rijkswaterstaat has been measuring the water levels along the coast for over decades and compared them to this reference level. The relative sea level rise based on water level measurements over the period 1890 to 2017 shows a constant rise of 18.6 ± 1.2 cm per century. Baart et al. estimated that subsidence is responsible for approximately 4.5 cm of the relative sea level rise that has occurred this last century. The absolute rise in sea level is therefore estimated at 18.6 - 4.5 = 14.1 cm per century (Baart et al., 2018).

Figure 1 Tidal station Hoek van Holland and example of NAP reference bolt in measurement station

Discussion

In the method of sea level rise calculation, described in Dilling et al. in 2010, the time series of water levels are corrected for the 2005 NAP adjustment. They state that the reference height has not been corrected before 2005. Due to archive work it has become clear that the reference height has been altered several times before.

Assuming that water levels historically have been accurately measured in relation to NAP, it is probably better to report the sea level rise in respect to this national reference plane instead of the currently used methods.

Reference

Baart et al., 2018, Zeespiegelmonitor
Dilling et al., 2010, definitie-zeespiegelstijging-voor-bepaling-suppletiebehoefte

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:
P.O. Box 177
2600 MH Delft
Boussinesqweg 1
2629 HV Delft
Tel +31 6 1560 9774
secretary@nck-web.org
www.nck-web.org

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Historical context

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

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

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

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

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

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

The NCK partners

TNO
Geological Survey of the Netherlands

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

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

Representatives
NCK Board of Supervisors: 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

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

UNIVERSITY
OF TWENTE.

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

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

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

Utrecht University
Institute for Marine and Atmospheric Research Utrecht IMAU

Universiteit Utrecht

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

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

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

Wageningen Marine Research

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

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

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