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UNESCO-IHE Institute for Water Education

NWO Netherlands Organisation for Scientific Research

NCK-Days 2014

Preparedness

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This publication was prepared by:

Mohd Shahrizal Ab Razak
Leo Sembiring
Mick van der Wegen

UNESCO-IHE Delft, March 2014

Cover photo: Aerial photograph of inlet at Grand Lahou, Cote d'Ivoire (courtesy of Dano Roelvink)

Preface

Dear NCK colleagues and guests,

Welcome on behalf of the UNESCO-IHE Institute for Water Education

This year, the NCK-days 2014 is held at the UNESCO-IHE Institute for Water Education in Delft. The NCK days aim to offer young coastal researchers and practitioners the opportunity to highlight and promote their works by oral and poster presentations during a two-day event. This year, we received 74 abstracts from numerous research institutes and universities including the Netherlands and Belgium. All abstracts are included in this book of abstracts as well. Besides, the NCK days offer an excellent opportunity for networking and initiation of joint research efforts. Guest lecturers offer keynote lectures on relevant, present day themes and a field trip (3rd day) offers an opportunity for exposure to the coastal system. The theme of this years' NCK-days 2014 is Preparedness.

Coastal communities all over the world are facing increasing threats and challenges due to the combination of population pressure and climate change. They need to take adequate action to deal with these threats and challenges, but do they indeed? The coastal (research) community puts major efforts in coastal preparedness on timescales ranging from storm events to relative sea level rise rates. But are we aware of all threats and do we oversee all possible scenarios and consequences? What is the level of coastal preparedness required and what knowledge and research efforts do we need to optimize coastal preparedness? Can we export our knowledge and know-how on this topic or are our solutions only useful in our own context?

We hope that you will enjoy these NCK days and that oral presentations, posters, the excursion, and all occasions for informal contacts during this event may reinforce the collaboration within the NCK-community and the productivity of Dutch coastal research.

Mick van der Wegen
Mohd Shahrizal Ab Razak
Leo Sembiring
Dano Roelvink
Martine Roebroeks-Nahon
Jolien Mans-Donkers
Ewout Heeringa

UNESCO-IHE, Delft, March 2014

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About UNESCO-IHE and NCK

UNESCO-IHE 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 partners in the Netherlands. Since 1957 the Institute has provided graduate education to more than 14,500 water professionals from over 160 countries, the vast majority from the developing world. Numerous research and capacity development projects are carried out throughout the world. The Institute offers a unique combination of applied, scientific and participatory research in water engineering combined with natural sciences and management sciences. Since its establishment the Institute has played an instrumental role in developing the capacities of water sector organizations in the South, not least by strengthening the efforts of other universities and research centres to increase the knowledge and skills of professionals working in the water sector. UNESCO-IHE carries out educational, research and capacity development activities that complement and reinforce each other in the broad fields of water engineering, water management, environment, sanitation, and governance.

The Netherlands Centre for Coastal Research (NCK) has been founded in 1992 and was initiated by the coastal research groups of Delft University of Technology, Utrecht University, Deltares (formerly WL | Delft Hydraulics) and Rijkswaterstaat RIKZ. Early 1996, the University of Twente and the Geological Survey of The Netherlands joined NCK, 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 (2004) and Wageningen IMARES(2008).

The NCK aims :

1. to increase the quality of the coastal research in the Netherlands by enhancing cooperation between the various research streams and to guarantee the continuity of coastal research in the Netherlands by exchange of expertise, methods and theories between the participating institutes;
2. to maintain fundamental coastal research in The Netherlands at a sufficient high level and to enhance the exchange of knowledge to the applied research community;
3. to reinforce coastal research and education capacities at Dutch universities; and
4. to strengthen the position of Dutch coastal research in a United Europe and beyond.

Keynote Speakers

Devin is the Groundwater Specialist for the Water Science Field Team–West of the USGS, for whom he has worked for 36 years. His principal research interests are in aquifer mechanics related to subsidence accompanying subsurface fluid extraction. He is the author/co-author of more than 70 articles in peer reviewed journals, USGS publications, conference proceedings, book chapters, and encyclopedias. Devin is Chair of the UNESCO Working Group on Land Subsidence, a member of the Board of Directors of the U.S. National Chapter of the International Association of Hydrogeologists (IAH), Vice-Chair of the American Society of Civil Engineers (ASCE) Subcommittee on Land Subsidence, Managed Aquifer Recharge Committee, and an Associate Editor, Hydrogeology Journal. He earned M.S. degrees from Indiana University (Environmental Sciences) and the University of Illinois (Civil Engineering).

"Global Subsidence Hazards Accompanying Development of Water and Land Resources" addresses increasing global subsidence hazards and damages related to 1) flooding, 2) structurally compromised built infrastructure, 3) ecosystem degradation, and 4) groundwater depletion. Historic and recently identified subsidence caused by three principal anthropogenic drivers—groundwater extraction, drainage of organic soils, and accelerated karstification are presented. The roles of sediment starvation and eustasy are discussed in terms of exacerbating subsidence contributions to relative sea-level rise in coastal areas.

Devin will give a presentation on the topic entitled "***Global Subsidence Hazards Accompanying Development of Water and Land Resources***" during the mini-symposium.

Jandirk Hoekstra (b.1953) landscape architect, senior consultant, studied lands architecture at the Agricultural College in Wageningen and composition at the Rotter Conservatory. He was active in the cultural sector as a booker for a theatre for modern m and cultural debate, at the Department for Urban Development Rotterdam intendant/ambassador and from 1993 to 1999 as senior advisor of urban developmen Heidema Advies/Arcadis. From 1999 until the present he is co-director of H+ Landschapsarchitecten and senior advisor/supervisor for various projects.

He was the director of the Structuurplan Arnhem 2010, as well as the structural plans for the cities of Utrecht, Enschede, Apeldoorn, Dordrecht, Groningen and Almere. He acted on the common ground of content and process as process-director for the Strategic Vision Arnhem 2015, area development urban triangle Leiden-Haarlem-Amsterdam, structural vision Bergen op Zoom-Roosendaal, and finally as supervisor for site plans such as Polder Riverzone Vlaardingen, Businesspark Arnhem (KEMA area) and the Almere Coast area. In cooperation with Maxwan, Urban design winner of the design competition for 'Kommunarka', a city development plan for a large urban quarter south west of Moscow. He was the leader of the design team for a masterplan for the green heart of the Multifunctional Administrative City in South Korea (competition). Recently Jandirk Hoekstra operated as intendant for the Province Overijssel in the role of director of the design studio for regional spatial quality issues. In 2009 and 2010 he coordinated a studio that elaborated a future vision on a safe (climate proof) and ecologically vital Delta of the rivers Rhine, Maas en Scheldt in the south western part of the Netherlands. Since the beginning of 2011 he is the director of the Studio for Coastal Quality that generates visions and perspectives for the Dutch Coast that combine safety and quality. Since March 2012 he was appointed Provincial Advisor for Spatial Quality for the Province of Noord-Holland.

Jandirk Hoekstra will give a presentation on the topic entitled "***Potential and limitations of sediment management for sustainable development of coastal landscapes; a spatial planners view***" during the mini-symposium.

Dr. Jan P. M. Mulder graduated in Physical Geography and wrote a PhD-thesis on Forest Hydrology. He has been employed as hydrologist for two years at TNO, and has over 28 years of research experience in Coastal Morphology and Coastal Management working at Rijkswaterstaat and since 2008, at Deltares. In the framework of the Netherlands Centre of Coastal Research-NCK, since 2004, he has been a part time assistant professor at Twente University. He is author / co-author of over 60 papers in peer reviewed journals, conference proceedings and book chapters, and has contributed to several policy documents. He has been involved in various projects integrating field observations and empirical- and numerical modeling, and physical, ecological and governance disciplines.

Dominant aspect of his work has been the translation of research results into policy- and management concepts. Following his credo No Sediments, No Netherlands, in his contribution Jan Mulder will reflect on the background, implementation and challenges of sediment management for sustainable development, not only of the Netherlands, but also of delta areas worldwide.

Jan Mulder will give a presentation on the topic entitled "***Background, implementation and challenges of sediment management in the Netherlands***" during the mini-symposium.

Programme NCK-Days 2014

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17.00-19.00	**Ice-breaker at UNESCO-IHE**

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SATURDAY, MARCH 29, 2014 **Fieldtrip to Maasvlakte 2 : geological and engineering landscapes**	
10.00	**Departure bus from UNESCO-IHE**
11.00-12.00	**Futureland at Maasvlakte 2**
12.00-15.00	**Tour and stops :** Visit revetment works, beaches, nature compensation areas. hard and soft protection works Lunch is included.
16.00	**Back in Delft**
Organisation	Bert van der Valk, Deltares Mick van der Wegen, UNESCO-IHE/Deltares Karoune Nipius, Boskalis, manager onderhoud MV-2 <vervanger>, Havenbedrijf Rotterdam, afdeling morfologie

Abstracts

of the NCK-Days 2014

Morphodynamic investigation of embayed beaches through the impact of structural headlands

Mohd Shahrizal Ab Razak, UNESCO-IHE , s.abrazak@unesco-ihe.org
Ali Dastgheib, UNESCO -IHE, a.dastgheib@unesco-ihe.org
Dano Roelvink, UNESCO -IHE, d.roelvink@unesco-ihe.org

Headlands and engineering structures like groynes will impact the beach and surf zone through their influence on wave refraction and attenuation, thus limiting the development of longshore currents, rips, and rip feeder currents. The study presents the morphodynamic investigation of embayed beaches through the impact of structural headlands.

An XBeach model was successfully applied to predict the surf zone current pattern and to predict morphological features of three different embayment scales for low-moderate-high wave energy events. An embayment scaling parameter (δ') was used to identify the generation of rip currents that were produced by the XBeach model.

The formation of central rip currents in embayed beaches is linked to the presence of a sand bar, while topographical headland rips developed adjacent to the headland boundary are caused by the geological control of the headland structure itself. The effect of moderate and high waves has resulted to a decreased number of central rips in a longer embayment thus limiting the beach circulation to the cellular type. This type of rips could provide an initial insight into the offshore transport of sand from the coast. Whether wave breaking occurs outside or inside the embayment determines the initiation of large scale rip currents, megarips (see Figure 1). Several factors that lead to the generation of megarip currents in literature should be taken into account as a guideline for morphodynamic studies in a high energy embayed coast. In all cases presented in this study, the characteristics of surf zone current circulation complies with the description of the theoretical embayment scaling parameter (δ') (Short and Masselink, 1999 and Castelle and Coco, 2012). Further establishment of this parameter is needed to properly describe the surf zone current circulation in embayed beach systems.

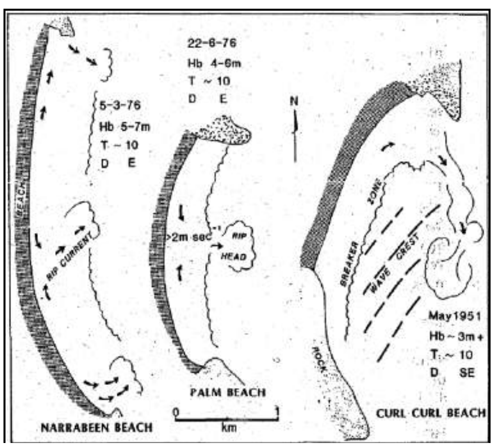


Figure 1. Large central rip circulations in the middle of three large embayments in Sydney region (Short, 1985).

2D Process-Based Model for Assessment of Suspended Sediment Budget

Fernanda Achete UNESCO-IHE, f.achete.@unesco-ihe.org
Mick van der Wegen, UNESCO-IHE, m.vanderwegen@unesco-ihe.org
Dano Roelvink, UNESCO-IHE, d.roelvink@unesco-ihe.org

Starting from a worldwide perspective, rivers transport water and sediments to estuaries and the oceans. Sediment dynamics will differ depending on hydrodynamic conditions varying over different locations and over time. Suspended sediment concentration (SSC) is a key variable determining estuarine health. In many estuaries most of the sediment is fine and transported in suspension. In this context, the goal of this work is to provide a detailed analysis of sediment budget in the Sacramento-San Joaquin Delta (SSD) area by means of 2D, process-based, numerical model. We selected the SSD area as a case study, since the area has been well monitored so that detailed model validation can take place.

We model SSC by coupling the process-based model DFlow-FM, which calculates 1 year (2011) of hydrodynamics, with the water quality model Delft-WAQ, which calculates the SSC levels with Krone-Parteniades formulation. The SSC level results were then compared to in situ data, in order to calibrate the model. From the calibrated stations we calculate sediment budget for different Delta regions.

Since the detailed description of the sediment path, it is possible further understand and describe sediment budget in Delta sub-regions (north, central and south). Overall the Delta traps two thirds of all inflow sediment. However, different parts of the Delta present different trap efficiency. Model results show that Northern Delta (the least efficient) traps ~23%; central/eastern Delta traps 32%, central/western 65%, and the most efficient is the southern Delta region trapping 67% of the sediment. The highest trapping efficient regions correspond to islands inundated through levee breaching.

We could reproduce the sediment budgets and seasonal variation for the area, including small creeks. We then prove that process-based model can be a useful tool for calculating budgets in complex systems. This tool can be further applied to hind- as well as forecast changes in the system budget and sediment concentration variability.

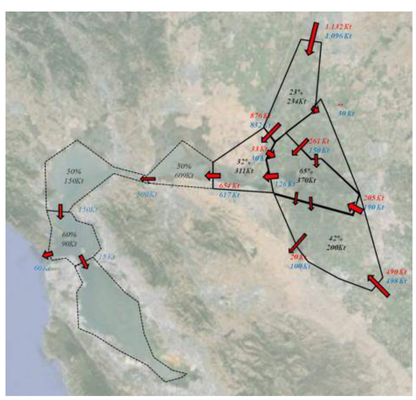


Figure 1. Budget map. Arrows represent sediment fluxes (red data and blue model) and the areas sediment budget.

Division of water at a bifurcation in a tidal network, a process-based analysis with a simple model

Niels C. Alebregtse, Utrecht University, IMAU, n.c.alebregtse@uu.nl
H. E. de Swart, Utrecht University, IMAU, h.e.deswart@uu.nl

Many estuaries around the world consist of a network of branching channels. Examples are the Yangtze Estuary (China) and the Berau Delta (Indonesia). To understand and manage such complex systems, knowledge is required on their hydrological characteristics. Two of such characteristics, tidal propagation and net volume discharge, are the subjects of research in this contribution. Specifically, how tidal propagation through a bifurcating estuary influences discharge division between different branches. In a previous study by Buschman et al. (2010), a numerical model was used to investigate discharge division in an idealized estuary. They found that an asymmetric division of river discharge, caused by different depths in the downstream branches, becomes less pronounced under influence of tides. They attributed this decreased asymmetry to a net circulation resulting from Stokes transport. In the channel with a larger depth, the tidal wave attains a more travelling character, thereby enhancing the Stokes transport. This drives a net circulation from the deeper to the shallower channel, counteracting the enhanced river discharge through the deeper channel. We expand on these results by employing a 2DV analytical model to the same idealized system. This allows not only identifying the effect of river discharge and Stokes transport, but also of other non-linear terms in the shallow water equations, such as advection terms. Results show that each non-linear term effects the discharge division between the different branches.

Figure 1 shows the net volume discharge through a branching estuary for a case with tides (left panel) and without tides (right panel). The channel depicted by the green line is 10 meters deep, while the remainder of the system is 5 m deep. In the left panel, the dashed-dotted line accounts for all non-linear terms in the shallow water equations, except for Stokes transport. This has a slightly more asymmetric discharge division then the river only. Adding Stokes transport (solid line, left panel) finally results in the more symmetrical distribution of net volume discharge as observed by Buschman et al. (2010). This approach thus adds additional insight in how the net volume discharge is set-up in a branching estuary under the influence of tides.

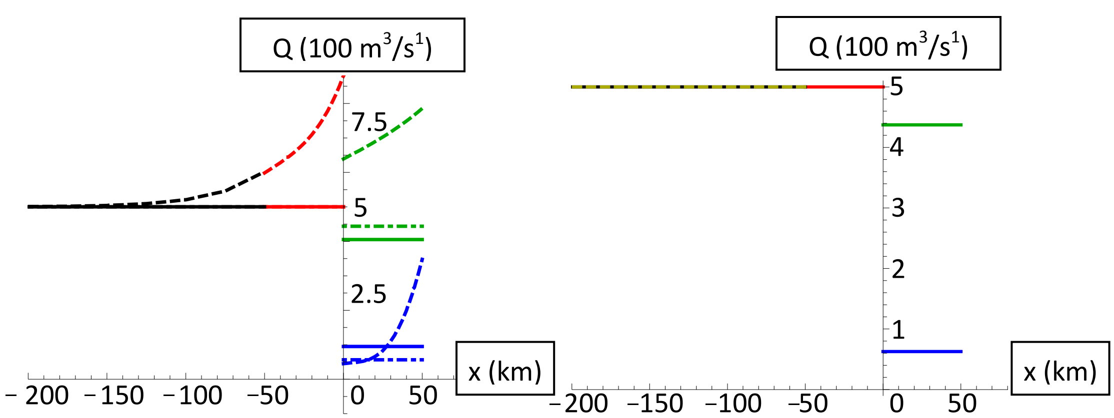


Figure 1. Discharge distribution between a channel of 10 m (green line) and 5 m depth (blue line). The rest of the domain is also 5 m deep. The left panel includes tides, with the solid line showing discharge division with all processes included, while the dashed-dotted line omits the Stokes transport. The right panel shows results for river discharge only.

Characterization of wave loading by numerical modeling: case study of the harbours of Zeebrugge and Blankenberge

Corrado Altomare, Flanders Hydraulics Research, corrado.altomare@mow.vlaanderen.be
Tomohiro Suzuki, Flanders Hydraulics Research, tomohiro.suzuki@mow.vlaanderen.be
Alejandro J.C. Crespo, Vigo University, alexbexe@uvigo.es

The increasing storminess of the last decades, as dramatically remarked by the most recent events in the Northern Sea (e.g. Xaver storm in December 2013), is compelling many Countries in Europe, like Belgium, to review their coastal hazards concepts in order to upgrade the existing coastal defenses with the general intent of guaranteeing reasonable standards for human safety in extreme storm conditions. The Belgian coastline is one of the zones most exposed to wave attack and flooding, since it is a low lying area and because of its high touristic and recreational value. The Flemish Coastal Safety Masterplan was approved in 2011 to tackle these problems through the construction of new coastal defenses or the renovation of the existing structures.

For this reason, the wave action on the new defenses has to be properly characterized, in order to prevent their failure, but the classical approaches (i.e. theoretical formulae) cannot be applied in most of the cases where the particular geometries or hydraulics conditions require extra analysis. Hence numerical modelling can represent an alternative technique, cheap solution and useful tool to analyze the interaction between sea waves and coastal structures that otherwise requests physical experimental campaigns that often are real time consuming and not fully affordable.

The present work describes the validation and application of a mesh-less numerical model for wave loading assessment on coastal structures to face real-life problems from the Belgian coast. The so-called DualSPHysics model has been applied to assess wave loading on the new topping structures and storm return walls conceived for the harbors of Zeebrugge and Blankenberge. DualSPHysics is based on the lagrangian Smoothed Particle Hydrodynamics method and implements a GPU technology (Graphic Unit Interface) that reduces drastically the computational time, making the model less resource-demanding.

DualSPHysics has been applied to different cross sections of the aforementioned harbors and the wave forces due to the predicted maximum waves have been calculated (example in Fig. 1). In some case, when possible, the results have been compared with theoretical solutions, proving the good performance of the analysis. The results underline the capability of the model to reproduce the wave action on coastal structures especially when no formulations from literature can be applied.

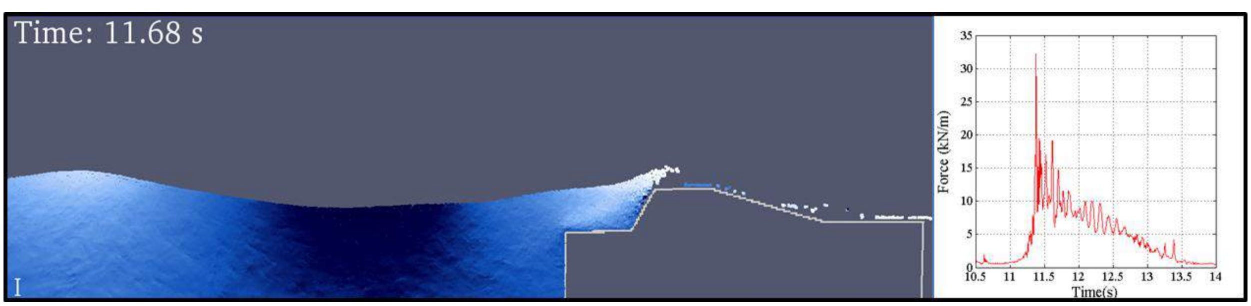


Figure 1. Sketch of numerical modelling and example of the measured force signal

Spatial variability in aeolian sediment transport on a wide beach

Ate Poortinga, Wageningen University, ate.poortinga@wur.nl
Joep Keijsers, Wageningen University, joep.keijsers@wur.nl
Michel Riksen, Wageningen University, Michel.Riksen@wur.nl
Saskia Visser, Wageningen University, saskia.visser@wur.nl

Coastal dunes are the primary defence structure against the destructive forces of the sea in the Netherlands. Aeolian processes are important for this defence as they contribute to dune accretion and thus the safety of the hinterland. However, insights into the dynamics of how small scale aeolian processes contribute to large scale dune development are required for interpretation of the evaluation of these management approaches. In this study, we analyse the horizontal and vertical variability of aeolian sediment transport at one of the beaches of Ameland.

Aeolian transport fluxes, meteorological conditions and groundwater levels were measured on a beach section of the barrier island of Ameland. The meteorological station was installed directly at the beach. Sediment fluxes were measured with 37 customized MWAC catchers placed in a regular grid. The meteorological station was installed in the centre of the grid. Six groundwater tubes were evenly distributed over the beach (cross-shore).

In a three month period, sixteen different aeolian events were measured. Surface moisture, controlled by groundwater was found to have an important effect on the vertical as well as the horizontal sediment flux. Groundwater levels were largely dominated by beach inundation, influencing the groundwater table up to two weeks. Variability in the vertical distribution was large between events compared to variability within events. Sediment transport rates were high at the foreshore and low at the dune foot, but also large variation at small distances was found.

Sediment transport dynamics are dependent on local conditions such as beach dimensions and orientation, meteorological and surface characteristics. It was found that moderate events are capable of transporting large amounts of sediment.

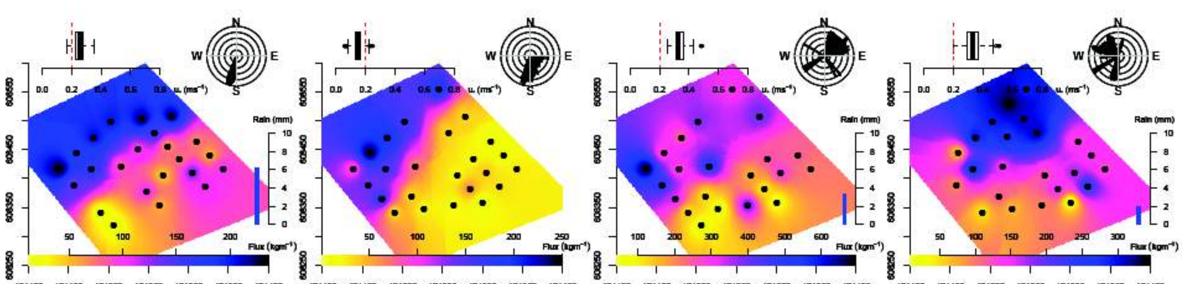


Figure. Sediment fluxes and meteorological conditions for events 13 - 16.

Bispectral evolution over a laboratory beach

Anouk de Bakker, Marion Tissier, Gerben Ruessink, Universiteit Utrecht, a.t.m.debakker@uu.nl
Pieter Smit, TU Delft, p.b.smit@tudelft.nl
Tom Herbers, Naval Postgraduate School, thherber@nps.edu

When waves travel to shore, their shape transforms from sinusoidal into skewed and in shallow water into asymmetric. Non-linear interactions between waves are essential for this shape transformation. At the same time, other wave-wave interactions cause the growth and, potentially, decline of longer-period infragravity motions. Here we use a high-resolution laboratory data set to study triad interactions including infragravity waves. Identifying the coupling, and subsequent energy transfers between sea-swell (HF) and infragravity (LF) frequencies, will help to pinpoint the so far poorly understood infragravity-dissipation mechanism.

The laboratory data experiments were obtained as part of the GLOBEX project, where a high-resolution data set was collected on a low-sloping (1:80) fixed beach. In total 190 (43) positions measured water level (flow-velocity) at a sampling frequency of 128 Hz, for various wave conditions. Here we focus on a narrow-banded swell condition (H_s = 0.1 m, T_p = 2.25 s) and make use of bispectral analysis to study triad interactions. We separate the bispectrum into four parts representative of the frequencies involved (see Figure 1). Zone I where only LF are involved, zone II where interactions between two LF and one HF are shown, zone III where two HF and one LF frequency interact and lastly zone IV, where only HF interactions occur.

Offshore, peak-peak interactions transfer energy to twice the peak frequency and to infragravity frequencies (see Figure 1a). While shoaling, energy transfers strengthen and interactions between the peak-multiples form. The spectral peak shifts to slightly lower frequencies by HF-LF-HF interactions. Just into the surf zone LF-LF-LF interactions develop (see Figure 1b), which close to shore dominate the bispectrum (see Figure 1c). The biphase shows that both sea-swell and infragravity waves are about -90° close to shore, resembling sawtooth shaped waves.

No energy transfer of LF back to HF is observed. In contrast, the asymmetric shape of the infragravity wave and the dominance of LF-LF-LF interactions close to shore seem to indicate that infragravity-wave breaking is the dominant infragravity energy dissipation mechanism.

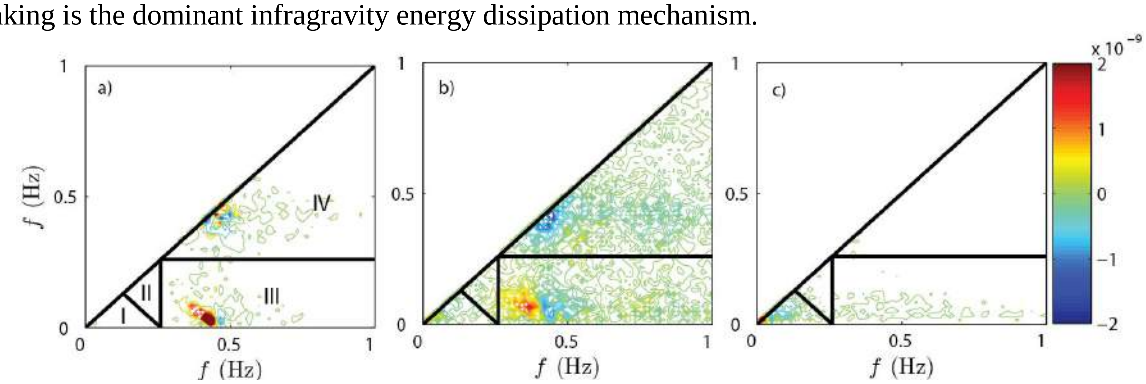


Figure 1. Imaginary part of the bispectrum for incoming waves at (a) x = 26.8 m, (b) x = 74.1 m and (c), x = 79.2 m. The edge of the surf zone is at 62 m and the shoreline is at 84.6 m. Frequencies < 0.26 Hz are infragravity frequencies.

Experiments and modeling of salt marsh erosion due to wind waves

Michele Bendoni, mbendoni@dicea.unifi.it
Simona Francalanci, simona.francalanci@dicea.unifi.it
Lorenzo Cappietti, cappietti@dicea.unifi.it
Luca Solari, luca.solari@dicea.unifi.it

Edge erosion of salt marshes due to surface waves and tide is one of the mechanisms that models marsh boundaries, leading to the loss of marsh areas worldwide (Marani et al, 2011). An experimental activity was conducted in order to investigate the main processes responsible for marsh lateral retreat.

Two physical models of a portion of a marsh bank were built inside a wave flume, with material collected in the lagoon of Venice. The models, being different for the presence of halophytic vegetation, were subjected to tidal excursion and random waves reproduced according to field data. Another set of experiments was carried out to estimate wave impact on bank surface and wave pressure transmission inside it.

During experiments bank profile and bathymetry were collected at different times to characterize the morphodynamic evolution of the system. Through video recordings main processes responsible for bank retreat were identified: mass failures for sliding and toppling occurred at the beginning of the experiments followed by surface and mass erosion. Most observed failures were of toppling type, that is the overturning of blocks, triggered by tension cracks, induced by wave forcing. The presence of vegetation lead to a delay in mass failures due the effect of roots, even if total eroded volume for the two models differed slightly at the end of the experiments (Francalanci et al., 2013).

Based on experimental observation, a novel model for the description of toppling failures was developed and tested against experimental results. The model is able to simulate the incipient failure of cohesive blocks observed during the experiments. Furthermore it reveals the most critical conditions for bank stability in presence of tension crack and the crucial role of the dynamic effect of waves in promoting failure.

An idealized meteorological-hydrodynamic model for exploring extreme storm surge statistics in the North Sea in an alternative way

Niels-Jasper van den Berg, Royal HaskoningDHV, niels-jasper.van.den.berg@rhdhv.com
Mathijs van Ledden, Royal HaskoningDHV/TU Delft, mathijs.van.ledden@rhdhv.com
Wiebe de Jong, Royal HaskoningDHV, wiebe.de.jong@rhdhv.com
Pieter Roos, University of Twente, p.c.roos@utwente.nl
Suzanne Hulscher, University of Twente, s.j.m.h.hulscher@utwente.nl

Storm surges are a threat for low lying areas near coasts. Insight in and quantification of extreme storm surge events are essential for the design of coastal protection systems. Time series of surge levels, used for statistical extrapolation to define extreme surge levels with a 10,000 year return period, is only 150 years. This results in large uncertainty in the extreme values. In addition, the currently used approach results in lack of insight into the coupling between the storm and the storm surge. Little is known about the duration and course of extreme surges.

This study focuses on the properties of storms causing extreme surges at Hoek van Holland, The Netherlands. This alternative method is based on a joint probability model of the storm characteristics at the North Sea, in which surges are modeled with an idealized coupled meteorological-hydrodynamical model. Six storm characteristics are used to define each storm. Using historical data, probability density distributions have been derived for these parameters. The model output is the water level at Hoek van Holland, as a function of time. The model has been applied to define extreme surge levels using Monte Carlo Analysis, see Figure 1. The computed surge level (including tide) with a statistical return period of 10,000 years is 5.4 m, 5.6 m and 6.1m (based on three different datasets), compared to 5.10 m according to the hydraulic boundary conditions determined by the Dutch government. The output also indicates that the average duration of computed surges with a return period of 10,000 year is roughly two hours longer than the storm duration currently adopted.

In conclusion, a strongly idealized meteorological-hydrodynamic model reasonably matches the observed wind speeds and surge levels for individual storms at the North Sea. Using Monte Carlo Analysis, the estimates of extreme surge levels are similar to the statistically extrapolated values. It is recommended to further explore this alternative method by using more realistic numerical models for hydrodynamic behavior (e.g. 2DH or 3D modeling).

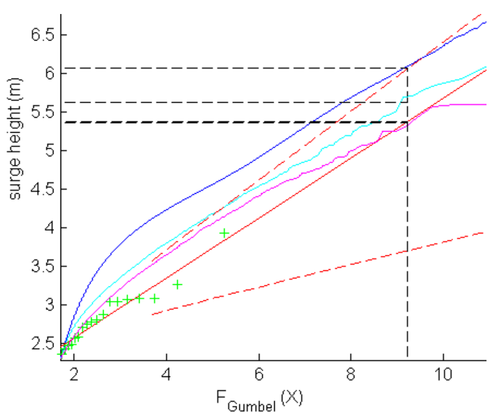


Figure 1: Gumbel plot of $1{\cdot}10^{-4}$ year^{-1} surges (at vertical dashed line). Surge levels based on model output are denoted in blue. Results of improved datasets are shown in cyan and magenta. Results based on extrapolation of measurements (green plusses). The solid red line shows the currently adopted probability of exceedance curve, the 95% probability interval is shown by red dashed lines.

Sediment transport in a fringing reef environment

Willem P. Bodde, Witteveen+Bos (formerly: Deltares/TU Delft), w.bodde@witteveenbos.nl
Ap R. van Dongeren, Deltares, ap.vandongeren@deltares.nl
Andrew W.M. Pomeroy, University of Western Australia, andrew.pomeroy@uwa.edu.au
Jaap S.M. van Thiel de Vries, Boskalis/TU Delft, j.s.m.vanthieldevries@tudelft.nl
Ryan J. Lowe, University of Western Australia, ryan.lowe@uwa.edu.au

Coral reefs are valuable natural structures important for ecology, coastal protection, and the economy (fishing, tourism). Coral reefs are classified as barrier reefs, atolls or fringing reefs. The latter ones stretch along a coast and often have a steep fore slope, a rough coral reef flat and a sandy lagoon with a beach at their lee side. Little knowledge exists on sediment transport in these environments. However, it is increasingly important to understand the hydrodynamics and morphodynamics in reef environments to be able to predict the impact of sea level rise and coastal development. To improve the understanding of sediment transport the objective of the current work is to analyse measurements obtained in the Deltares Scheldt Flume and to hindcast the experiments (Figure 1) using the numerical model XBeach.

The water depth and bed roughness were shown to have influence on processes such as short wave breaking, infragravity (IG) wave generation, IG wave transformation, reef flat seiching, wave-induced setup and wave reflection. The measurements showed that long waves dominate the short waves in the lagoon. The flow velocities in the cases with a rough bed were lower than those in the smooth cases as a result of the bed friction.

It was found that the specific hydrodynamics of a fringing reef environment are reflected in the sediment transport and suspension and in the bed profile development. Significant bed level changes were found in the flat lagoon and the beach area. The effect of bed friction on long waves and of long waves themselves on sediment transport was shown, e.g. by analysing long wave contributions to the third order velocity moments on the reef flat. The long waves are an important factor in sediment transport and bed profile development especially close to the beach. The effect of the roughness elements was observed, mainly in the shape of a swash bar, which is more pronounced for the smooth than for the rough cases. This shows that the dominance of long waves in a fringing reef lagoon indeed results in different sediment dynamics than for example on a regular sandy beach.

The XBeach modelling reproduced the short wave height, long wave height, flow velocity and reef flat seiching rather well. The suspension and transport of sediment was not predicted correctly by the model. Further research is recommended to increase the ability of XBeach to model these processes.

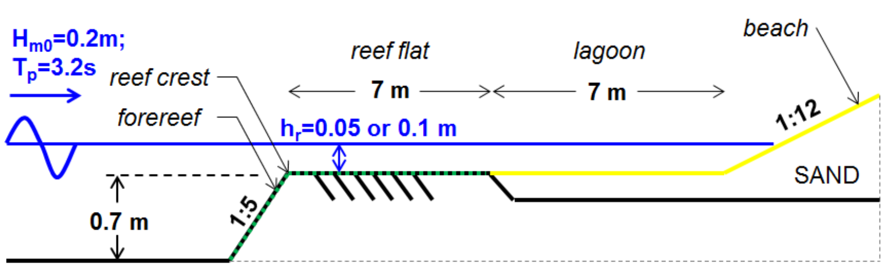


Figure 1. Overview of experimental setup and hydrodynamics conditions.

Numerical modelling of the geologically reconstructed Oer-IJ estuary

Bas Bodewes, Maarten G. Kleinhans and Maarten van der Vegt
Universiteit Utrecht, Faculteit Geowetenschappen (correspondence m.g.kleinhans@uu.nl)
Peter Vos, Deltares, Mick van der Wegen, Deltares and UNESCO-IHE

The Oer-IJ estuary near Castricum was active between 2500 BC and 200 BC. Geological reconstruction resulted in paleogeographical maps and in hypotheses explaining its development and closure. The shape of the estuary was convergent, but with an uncharacteristic northward S-shaped bend of the entire estuary, which was perhaps caused by a washover-like initiation through a spit-like northward migrating barrier that closed off a lake fed by freshwater. Bars were suggested to have partially filled the lower estuary. The estuary was connected with the Hollandse Vecht river and the Almere lake, which must have provided freshwater but little bed sediment. The reconstruction showed that a period of activity between 650 and 200 BC coincided with activity of the Vecht river, and closure coincided with the opening of the Vlie inlet connecting Almere and Waddensea to form the Zuiderzee. Our objectives are to test these hypotheses, in particular the effect of freshwater inflow on estuary opening and closure.

We systematically tested the hypotheses by scenario modeling in Delft3D in 2D mode with a 45 km long curvilinear grid based on the geologically reconstructed intertidal area of 500 BC. Tidal water level was prescribed on the sea boundary offshore based on present components M2, M4 and O1. On the upstream river inflow boundary either a static discharge ranging between 0-500 m^3/s was specified or a sudden or gradual decline. To test the possible topographic forcing on bar pattern we also ran straightened and idealized grids.

All model runs show similar trends in channel and bar pattern along the estuary. Increased river discharge has primary an effect on bed level elevation in the middle estuary. The bended estuary reduces tidal range rapidly in particular when combined with high discharges and forces channels to form in the inner bend.

We conclude that the effect of river discharge on tidal inflow and on estuary filling is significant even when fluvial discharge is only a fraction of the tidal discharge. The bended estuary perhaps reflects part of the tidal energy but this is yet unclear. Most importantly, the interaction between the modelling and reconstruction activities revealed where both model and reconstruction are robust and where either have shortcomings.

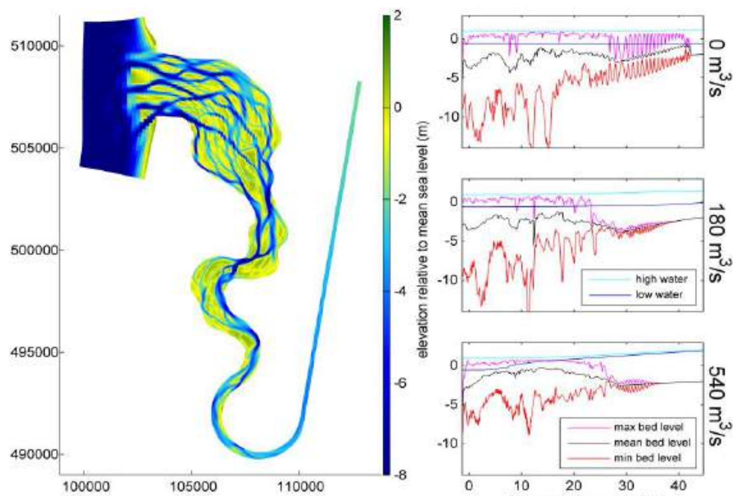


Figure 1. Final bed level elevation of default scenario (left) andlong-profiles of water- and bed levels for a range of discharges (right).

New error metrics for morphodynamic models

Judith Bosboom, Delft University of Technology, j.bosboom@tudelft.nl
Ad Reniers, Rosenstiel School of Marine & Atmospheric Science, areniers@rsmas.miami.edu

The accuracy of morphological predictions is generally measured by an overall point-wise metric, such as the root-mean-squared difference between pairs of predicted and observed bed levels (RMSE). Unfortunately, point-wise accuracy metrics tend to favour featureless predictions over predictions whose features are (slightly) misplaced. From the perspective of a coastal morphologist, this may lead to wrong decisions as to which of two predictions is better. In order to overcome this inherent limitation of point-wise metrics, we propose a new diagnostic tool for 2-D morphological predictions, which explicitly takes (dis)agreement in spatial patterns into account.

Our approach is to formulate errors based on a smooth displacement field between predictions and observations that minimizes the point-wise error. The optimal deformation of the predictions is found by employing an image warping method (Fig. 1). Two new error metrics are formulated: 1) a mean location error that is determined as a weighted mean distance between morphological fields and 2) a combined, single-number metric that takes both location and intensity errors into account.

We illustrate the advantages of this approach using a variety of morphological fields, generated with Delft3D, for an idealized case of a tidal inlet developing from an initially very schematized geometry. It is shown that, as opposed to the RMSE, the new error metrics lead to a ranking of predictions that is consistent with visual inspection by experts.

From the above, which is based on Bosboom and Reniers (2014), we conclude that the quantification of model performance by the new diagnostic tool better reflects the qualitative judgement of experts than traditional point-wise metrics do. We are currently extending the method, such that it can also be used to 1) guide further model development and to 2) facilitate data assimilation.

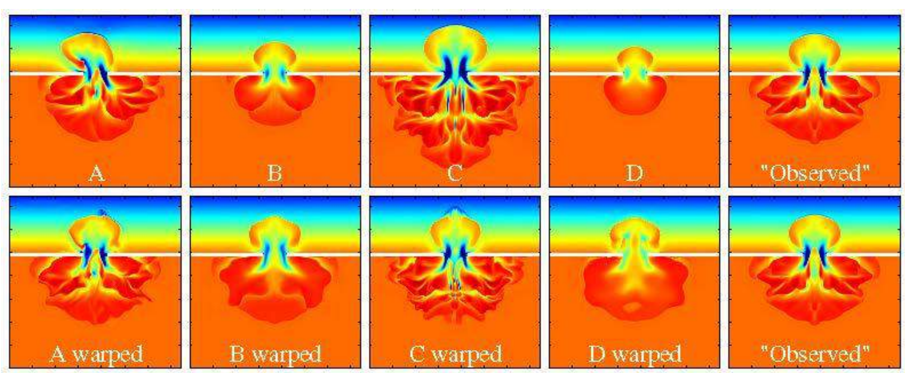


Figure 1. Observations (right), predictions (top) and deformed predictions (bottom).

Influence of liquefaction on scour around offshore monopile foundations

Ferdinand van den Brink, Universiteit Twente & TU Delft, f.vandenbrink@student.utwente.nl
Prof. dr. ir. Wim Uijttewaal, TU Delft, w.s.j.uijttewaal@tudelft.nl
Dr.ir. Pieter Roos, Universiteit Twente, p.c.roos@utwente.nl
Prof. dr. Suzanne Hulscher, s.j.m.h.hulscher@ctw.utwente.nl

Scour hole formation around offshore monopile foundations is a threat for the structure's stability. Large uncertainty leads to conservatism in design codes and hence to high construction costs. Under the same hydrodynamic loading as for scour hole formation the soil can liquefy due to structural vibrations or waves. The aim of this study is to investigate the effect of liquefaction from vibrations of offshore monopile foundations on scour by performing scaled flume experiments, where liquefaction is induced by a monotonic excess pore water pressure (EPWP) gradient.

Liquefaction is known to be caused by EPWP build up under cyclic loading and normally last for limited time, because the built up pore water pressure drains off to the bed surface. Therefore, monotonic EPWP is introduced at the bottom of a pile, which is placed in a flume filled with fine sand. During the experiments a current is used to induce scour, while the EPWP is used as independent variable.

In the experiments the EPWP gradient is observed to take some time to bring the sediment into liquefaction. First the soil is lifted, but as soon as the vertical resistance of the sand is lost a current brakes trough. Subsequently, the flow concentrates in one feeder and sediment is transported as if it is in suspension. When this occurs depends on the magnitude of the EPWP. During the scour experiments this resulted in a sudden collapse of the scour hole. The scour depth decreased and a new balance arises between slope sliding and erosion due to the horseshoe and lea-wake vortices.

It is concluded that under liquefaction the equilibrium scour depth decreases for a larger negative excess pore water pressure gradient. Furthermore, the angle of repose is decreased. The equalising effect of liquefaction on the scour hole is also expected in field situations, but the degree is unknown. The potential gain of the decreased scour depth to the structure's stability is limited, since the liquefied area may not be expected to provide any contribution to the stability of the structure.

Figure 1. Initiation of scour hole formation during experiment

Transport of turbulence in the surf zone of a field scale laboratory beach

Joost Brinkkemper,Utrecht University, j.a.brinkkemper@uu.nl
Gerben Ruessink, Utrecht University, b.g.ruessink@uu.nl

Plunging breakers are characterized by their overturning wave crests and plunging jets, injecting large amounts of turbulence in the water column. The turbulence organizes itself in vortices, which can stir sediment from the bed and keep it in suspension. Suspended sediments are then transported within the vortices by wave-induced currents and mean currents. The direction of the transport by wave-induced currents depends on the phase coupling with turbulence events. As a first step in better understanding sand transport processes, we here examine turbulence characteristics, in particularly, turbulence transport under plunging waves.

In the summer of 2012, BARDEX II was carried out in the Delta flume, the Netherlands. The experimental set-up consisted of a 4.5m high and 75m wide sandy barrier, with a beach slope of 1:15. A variety of instruments were deployed throughout the flume. This study focuses on the data from a surf zone rig that contained instruments to measure wave height, flow velocities including turbulence, sediment concentrations and ripple characteristics. For the estimation of wave breaking location, three ARGUS style cameras were deployed. The test programme included a wide range of wave conditions, with the fraction of breaking waves at the rig varying from 0 to 0.45.

The turbulence intensities in the shoaling zone are highest close to the bed and decrease towards the water surface. Turbulence events close to the bed are phase-coupled with the short wave orbital motion; the peak in turbulence is present after the passing of the wave crest while the orbital velocity is still in the onshore direction. This results in onshore transport of turbulence close to the bed. When more waves are breaking, turbulence intensities increase throughout the water column, indicating a large degree of vertical mixing. Turbulence events are phase-coupled with orbital motions throughout the water column, with most turbulence present beneath the front of the waves. Turbulence events are now also modulated on an infragravity time scale, because most plunging breakers are present in the infragravity troughs. Offshore directed turbulence transport by infragravity waves and undertow exceeds that by short-waves beneath breaking waves, resulting in a net offshore transport of turbulence. Future work will focus on the role of breaking-induced turbulence on sand transport magnitude and direction.

Figure 1. Plunging breaker at the location of the turbulence rig.

Using UAVs for coastal research: first results from the SCOPE field experiment (Destin, Fl.)

Ronald Brouwer, TU Delft, Section of Coastal Engineering, r.l.brouwer@tudelft.nl
Matthieu de Schipper, TU Delft, Section of Coastal Engineering, m.a.deschipper@tudelft.nl
Ad Reniers, University of Miami, RSMAS, a.j.h.m.reniers@gmail.com
Jamie MacMahan, Navy Postgraduate School, Monterey, jhmacmah@nps.edu
Patrick Rynne, University of Miami, RSMAS, patrickrynne@gmail.com
Fiona Graham, University of Miami, RSMAS, fiona@waterlust.org

Unmanned Aerial Vehicles (UAVs) are relatively small, remotely operated aircraft, becoming increasingly popular as environmental surveying platforms. One of the main reasons for their increasing popularity is their potential to provide imagery at a large spatial and temporal resolution. An example of where this capability is needed is the surfzone, where dominant processes typically have timescales on the order of seconds to minutes. The aim of this study is to investigate the usability of UAVs to study coastal dynamics. In particular, we present first results from the Surfzone Coastal Oil Pathways Experiment (SCOPE; 1-21 Dec. 2013, Destin, Fl.), where we have deployed UAVs to monitor dye releases in a rip-channeled beach.

Figure 1 shows the post processing of the RAW images captured with a GoPro Hero 3+ camera, resulting in a georectified image (lower left panel). To show the potential of the UAV-based images, we also present a time exposure of 100 images taken every 2 seconds (lower right panel). This image shows that due to the constantly changing camera angle while the UAV is hovering, a picture can be constructed of approximately 1 km in alongshore and 500 m in cross-shore direction. Moreover, the image shows the average location of wave-breaking, which gives an indication of the underlying bathymetry. Estimating advection and dispersion of the dye cloud from consecutive aerial images is currently under investigation. These preliminary results show great potential for UAVs to study coastal dynamics.

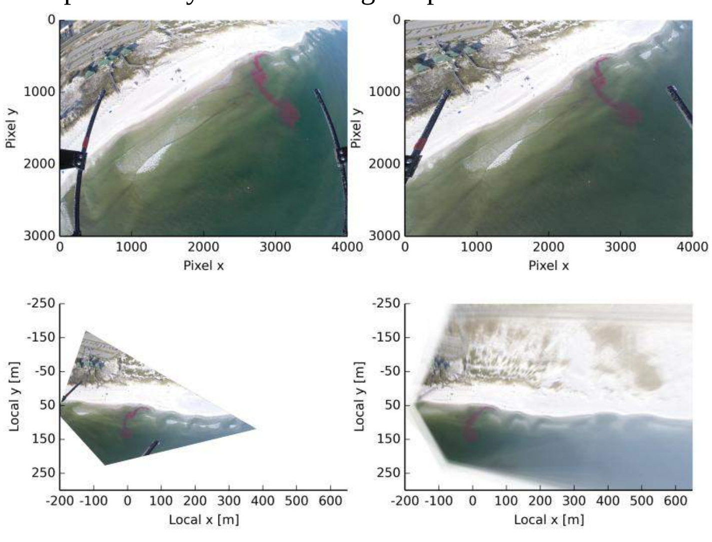


Figure 1. From UAV-based RAW image to geo-rectified time exposure of a dye release in a rip current system. RAW GoPro image (upper left panel), fish-eye removal (upper right panel), georectified image (lower left panel), and time exposure of 100 images (lower right panel). These images were made possible in part by a grant from BP/The Gulf of Mexico Research Initiative and ERC - Advanced Grant 291206: NEMO.

Resonance properties of a closed rotating rectangular basin subject to periodic wind forcing

Wenlong Chen,University of Twente, w.chen-3@utwente.nl
Pieter C. Roos, University of Twente, p.c.roos@utwente.nl
Henk M. Schuttelaars, TU Delft, h.m.schuttelaars@tudelft.nl
Suzanne J.M.H. Hulscher, University of Twente, s.j.m.h.hulscher@utwente.nl

Coastal basins subject to wind forcing often exhibit strong oscillations, leading to a set-up at the coast, which in turn may threaten coastal safety. This is particularly so when the combined properties of the wind field and the basin geometry trigger resonance. The goal of this study is to systematically analyze the influence of spatial variations in the wind field, rotation and basin dimensions on these resonance properties.

To achieve this goal, we have developed an idealized process-based model for closed rectangular basins of uniform depth. The model is forced by imposing a time-periodic wind stress, which can be viewed as a truly periodic event (e.g., a diurnal breeze) or as one of the Fourier modes in the spectrum of a single storm event. We account for spatial variations in the wind field by allowing a linear variation of wind amplitude and phase in the along-wind direction (creating a nonzero divergence) and cross-wind direction (creating a nonzero curl). An essential model feature is that the vertical structure of the flow is resolved in a fully analytical way, and that the horizontal structure is solved by means of a so-called collocation method, using a truncated superposition of analytically obtained channel modes.

The model results (example in Fig.1), supported by an approximate analytical solution for weak rotation, allow us to identify various resonant frequencies and to link them to the spatial structure of the wind field. In particular, some of the resonant modes exist for a spatially uniform wind field, whereas others typically arise from the divergent part and the curl-part of the wind field. Our analysis further shows how cross-wind basin dimensions affect resonance properties. The main effect of friction is a damping of the amplification. Finally, for a spatially uniform wind, the symmetry properties of the system allow for a convergence test, which reveals second order convergence in the truncation number of the collocation method. The results obtained here will be used in a follow-up study, carried out with a Finite Element Model, allowing for more realistic geometry (closed and semi-enclosed basins, possibly including elements such as large-sand pits and artificial islands), wind and pressure fields.

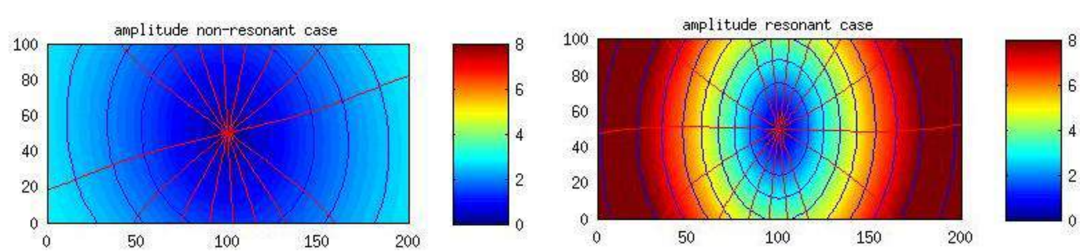


Figure 1. Wind-driven set-up is studied in a closed rectangular basin, of horizontal dimensions 200 km × 100 km, and uniform depth 10 m. Wind is spatially uniform, parallel to the along-basin direction, and time-periodic. Two different frequencies are considered: one well away from resonance (left) and one close to one of the resonant frequencies (right). Colours indicate the surface elevation amplitude, whereas the blue and red lines are the co-amplitude and co-phase lines, respectively.

Ripples in the Scheldt

Jelmer Cleveringa, ARCADIS, jelmer.cleveringa@arcadis.nl
Maarten G. Kleinhans Universiteit Utrecht, m.g.kleinhans@uu.nl
Marcel Taal, Deltares, marcel.taal@deltares.nl

The ecological and morphological qualities of the Scheldt estuary are under close consideration. A key indicator for the ecological quality of tidal flats is the mobility of the sediment, because stable beds provide more suitable habitats for sediment dwellers than flats that are constantly reworked. The aim of the research is to increase our understanding of the dynamics of the sediment bed and relate these dynamics to hydromorphological developments in the Scheldt estuary.

Rijkswaterstaat fabricates geomorphological maps of the inter-tidal and supra-tidal areas, based on (false-colour) aerial photographs. Geomorphic map units consist of mega ripple fields, flats, marsh and pioneer vegetation (not comprehensive). An important subdivision of the maps is in low energetic environments with limited bed mobility and high energetic environments with extensive bed mobility. The surface areas of the map units in the high-energetic environments from the maps of 1996 to 2012 have been determined and trends have been calculated.

The surface area of mega-ripple fields in the inter-tidal realm of the Western Scheldt shows a decrease from 1996 to 2012, with an average of 42 ha/y. Around 1100 ha of mega-ripple fields remain in 2012. Deviations up to 200 ha from the trend are observed. Older geomorphological maps and aerial photographs show even more extensive mega-ripple fields. The decline of the mega-ripple fields appears to be a long-term development in the Western Scheldt.

The decline of the mega-ripple fields occurs concurrently with the reduction of ebb- and flood chutes entering and cross cutting tidal flats. The presence of mega-ripple fields and ebb- and flood chutes coincides and the simultaneous decline may be coupled. Both developments are likely related to structural changes in tidal flow in the estuary and on and over tidal flats. Better grip on the processes that control the formation of ebb- and flood chutes and mega-ripple fields is vital for the management of the estuary.

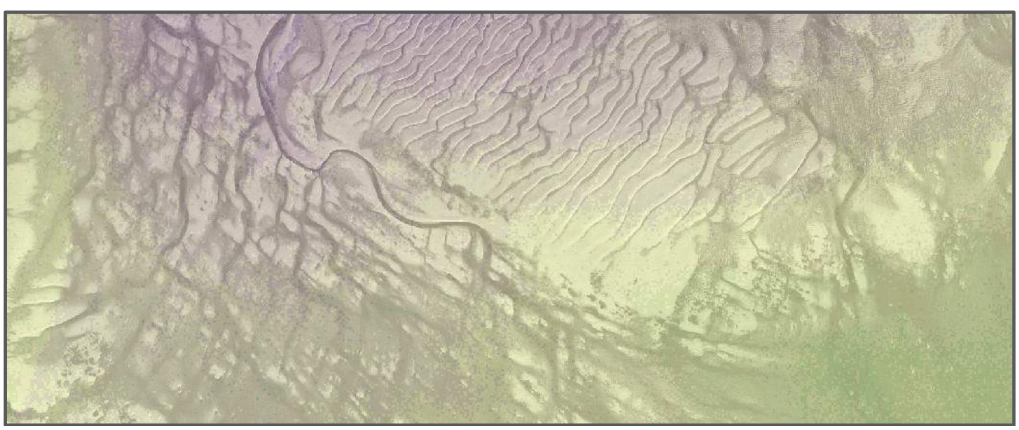


Figure 1. Intricate patterns of ripples and drainage channels on the Hooge platen West (2012 Combined Lidar – Rijkswaterstaat- and aerial photo Provincie Zeeland)

Tiny is mighty, right?
Do microphytobenthos structure intertidal ecosystems?

Tisja Daggers, NIOZ, tisja.daggers@nioz.nl
Peter Herman, NIOZ, peter.herman@nioz.nl
Jacco Kromkamp, NIOZ,jacco.kromkamp@nioz.nl
Tjeerd Bouma, NIOZ,tjeerd.bouma@nioz.nl
Daphne van der Wal, NIOZ,daphne.vanderwal@nioz.nl

Microphytobenthos are tiny algae living in and on the sediment in marine and freshwater ecosystems. In tidal shallow waters, microphytobenthos provide food to an important part of the macrobenthos, that are subsequently consumed by crustaceans, birds and fish. Therefore, they are crucial in the estuarine and coastal food web. We expect that microphytobenthos largely structure these higher trophic levels.

Spatial patterns of microphytobenthos on tidal flats and their food web interactions have mainly been studied on small scales and were limited by the availability of in situ measurements. We aim to develop a predictive model for macrobenthos based on remotely sensed information of microphytobenthos and sediment type.

We will develop a method to retrieve benthic diatom biomass from remotely sensed information and develop a model to predict diatom primary production and macrobenthos abundance on a basin scale from satellite remote sensing. We will test the generality of our model by applying it to three contrasting tidal basins in the Netherlands (the Oosterschelde, Westerschelde and the Wadden Sea). In addition, we will explore possibilities to apply the model to the Sand Engine.

The project has just started, which means the poster will be a presentation of plans and hopefully provide food for discussion, inspiration and perhaps collaboration.

Long-term morphodynamic behaviour of the Western Scheldt explained: chaotic or self-organizing?

Gerard Dam, UNESCO-IHE/Svasek Hydraulics, dam@svasek.nl
Mick van der Wegen, UNESCO-IHE/Deltares , m.vanderwegen@unesco-ihe.org
Dano Roelvink, UNESCO-IHE/Deltares/TU-Delft, d.roelvink@unesco-ihe.org

In this study we aim to examine the long-term morphological change of the Scheldt estuary in the southwest of the Netherlands. Since long, the general view on long-term, process-based morphodynamic modelling has been that model results worsen for longer runs. A unique series of bathymetric maps since 1860 is available, which makes a comparison of model results and measurements possible over a 110 year hindcast period.

We hindcast the Western Scheldt from 1860-1970, using the process-based FINEL2d model, which is based on the finite element method. Contrary to common perception the model shows good results for the erosion and sedimentation pattern with an increasing model skill over time. A Brier-skill score of 0.5 (good) at the end of the computation is obtained.

The question is how it is possible that a fairly straightforward morphological model produces good results over a timescale of 100 years. To answer this question we examined the hypothesis that an estuary strives towards minimum energy dissipation. The results are that both the model and real bathymetries show less energy dissipation (figure 1a) and less morphodynamic activity over time (Figure 1b). This is a clear indication that the estuary is moving towards equilibrium conditions in a self-organising manner and that the system is not chaotic. These equilibrium conditions and self-organising make that the long-term morphology can be predicted using a straightforward 2DH morphodynamic model. Furthermore the results are positively influenced by the geometry, non-erodible layers and the well predictable tidal forcing.

Conclusion is that process-based models are well suited to predict long-term morphology in confined basins such as the Western Scheldt, because of the self-organisation and equilibrium conditions.

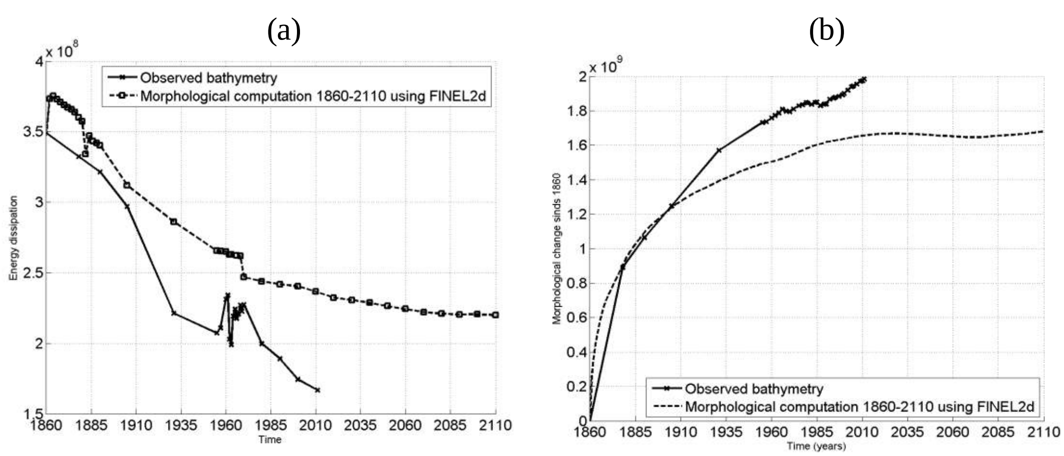


Figure 1. (a): Energy dissipation over time (b): Morphological activity over time

Overtopping reduction for a sloping dyke at Blankenberge harbour, Belgium

Sebastian Dan, Flanders Hydraulics Research, Belgium, sebastian.dan@mow.vlaanderen.be
Corrado Altomare, Flanders Hydraulics Research, corrado.altomare@mow.vlaanderen.be
Tomohiro Suzuki, Flanders Hydraulics Research, tomohiro.suzuki@mow.vlaanderen.be

The Belgian littoral is still vulnerable to the extreme storms such as the one with the return period of 1000 years. To face the coastal hazards, a Coastal Safety Masterplan was adopted aiming to improve the coastal defences against extreme storm events. The harbour of Blankenberge represents one of the weakest areas along the entire Belgian coast: waves can penetrate and produce significant overtopping on the slopping dyke in the south-western part of the harbour. The wave conditions at the dyke toe are: angle of 70-80° respect to the structure normal, significant height 2.5 – 5.0 m and peak period of 12 s.

In the literature there are validated formulas to calculate the overtopping discharge for sloping dykes under the attack of oblique waves and also for the presence of storm return wall. However, the formulas were not designed for the combined effect of the wave obliqueness and the storm return wall position and height. To investigate these combined effects a 3D physical model was designed and built at FHR. The scale of the experiment is 1:50 and the built structure consists of a part replicating the harbour quay with a 1:2.5 slope at the front side and overtopping collecting boxes at the backside. On top of the structure a storm return wall (0.02/0.04 m, in model scale dimensions) is placed at different positions with respect to the front edge of the quay. The water level is varying few centimetres with respect to the quay level, while the waves have Hs=0.030-0.045 m and Tp=1.7s. The wave angle used for simulations ranges between 45 and 80° with respect to the normal. The water surface elevation and incident wave characteristics are measured by resistive wave gauges placed in front and at the toe of the structure (Fig. 1).

The results confirm the abrupt decrease of the overtopping with the increase of the wave angle as mentioned in the literature. The presence of the storm return wall at the crest of the sloping dyke is reducing significantly the overtopping, but the storm return wall is very efficient in preventing overtopping when its position is shifted few meters inland from the dyke's crest. It can also be noticed that the height has less influence than position of the storm return wall for preventing the overtopping. The combined effect of the high wave obliqueness and the inland position of the storm return wall led to almost no overtopping even for the larger waves which normally can occur in the Blankenberge harbour.

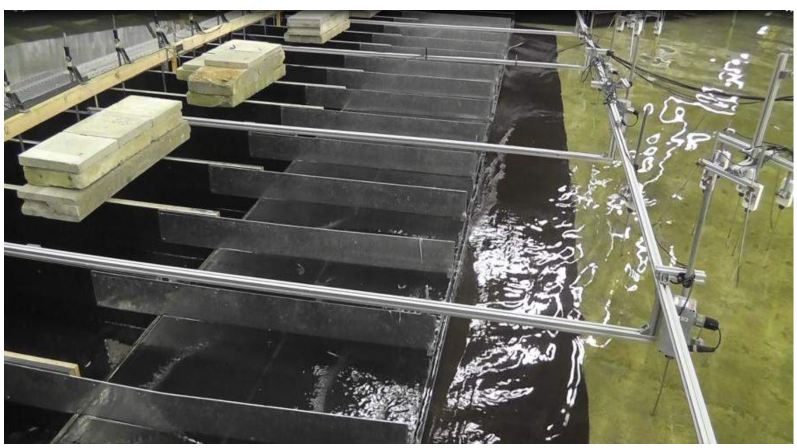


Figure 1. The physical model used to estimate the overtopping discharge at Blankenberge harbour.

Effect of mussel hummocks on flow patterns and food availability

Jasper Donker, Maarten van der Vegt and Piet Hoekstra
Universiteit Utrecht, Faculteit Geowetenschappen , j.j.a.donker@uu.nl

Intertidal mussel beds are a key species in the ecosystem of the Dutch Wadden Sea. They accumulate and stabilize sediments and therefore create possibilities for coastal protection. While some mussel beds remain uniform and flat others form hummocks. Here, we investigate the influence of hummocks on hydrodynamics and food availability and evaluate the benefits for hummock creation in current-dominated intertidal mussel beds.

Elevation data of mussel beds in the Dutch Wadden Sea suggest that flat mussel beds are observed in wave-dominated conditions whereas mussel beds with increasing hummock height seem to be located in current-dominated conditions. A four week field campaign revealed that hummocks (height 0.4 m) significantly influence the tidal flow pattern. At low water the flow velocity between hummocks is large and weak over the hummock. At moderate water levels flow over the hummocks becomes larger than flow between hummocks. At high water levels the velocity difference between flow over and along hummock appears to be small.

Flow over idealized hummock geometry was simulated by applying the SWASH model. The model was forced by observed water levels and flow velocities. Results confirm the two flow regimes observed in the field. Model results are sensitive to length, width and height of the hummock and to the roughness of the mussels.

The modelled flows were used as input to simulate the presence and supply of food near the bottom by solving an advection-diffusion equation. Uptake of algae by mussels is explicitly taken into account. The results demonstrate that when flow is accelerated over the hummock the mussels have better access to food. When flow is larger around the hummock less food is available.
We conclude that both field data and model results suggest that hummocks improve survival chances of mussels in current-dominated environments, while in wave-dominated situations it is more beneficial for mussel beds to develop a flat bed and reduce the amount of relief.

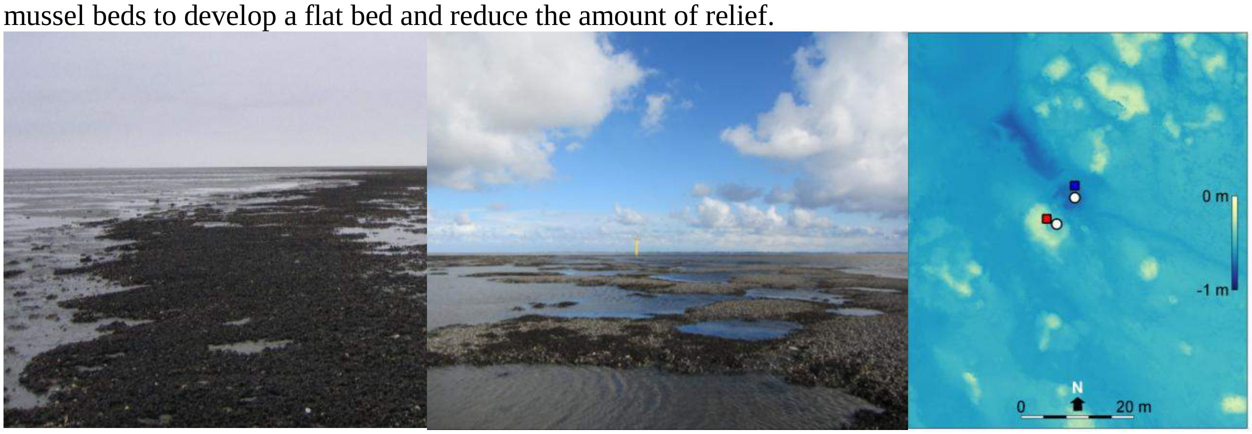


Figure 1. Left panel shows low relief mussel bed, middle one a hummock type. Right panel shows bathymetry and position of equipment at mussel bed where field data was obtained.

Estimating aeolian sand supply from the intertidal beach using video imagery

Leonardo Duarte, WEM Universiteit Twente, l.a.duartecampos@utwente.nl
Kathelijne Wijnberg, WEM Universiteit Twente, k.m.wijnberg@utwente.nl
Elisa Reim, WEM Universiteit Twente, elisa.reim@gmail.com
Suzanne Hulscher, WEM Universiteit Twente, s.j.m.h.hulscher@utwente.nl

Coastal dunes help to reduce the vulnerability to flooding during storm surge events. In between these eroding storm surge events, the dunes are naturally supplied with sand from the beach by aeolian sediment transport. Assessing the longer term (decades) flood defense functionality of dunes requires insight the decadal scale morphodynamics of coastal dunes.

The exchange of sand between the nearshore zone and the beach-dune system occurs through both hydrodynamic and aeolian processes. Supply of sand from land to sea occurs mostly during storm surge erosion. Regarding the supply of sand from the sea to the land (accretion process), the intertidal beach is a crucial zone, because this is the area where sediments that are deposited by marine processes can be picked by wind to become part of the beach-dune system of the coast. The state of the intertidal beach is strongly tied to the nearshore morphodynamics, for instance through the development of ridge and runnel topography or rhythmic bars and beach topography. Therefore, to know the long term evolution of the the coastal dunes, we need to understand also the interaction between nearshore bars and the beach-dune system.

As a first step, we explored how well annual onshore sediment supply by wind from the intertidal zone can be calculated using existing transport formula and existing monitoring data for Egmond Beach (Netherlands). As a novel approach we included Argus video imagery in our analysis to assess the occurrence of aeolian transport.

First results show that for 2009, the volume of sand transported from the intertidal beach was calculated to be 6.9 [$m^3m^{-1}y^{-1}$] (Reim, Master Thesis University of Twente, 2013). This value is the right order of magnitude when compared to the long-term observed dune volume increase in this area. The most aeolian sediment transport occurrences in 2009 were observed while wind was blowing obliquely to the beach to almost alongshore, which means wind directions from South-West (Figure 1). These results are promising and therefore will be expanded to other years.

Figure 1. (a) Visible aeolian sand transport October 2013 (b) Amount of aeolian sand transport according to wind directions during 2009

Climate Change and Inlet Entrance Conditions

Trang Duong, UNESCO-IHE, t.duong@unesco-ihe.org
Roshanka Ranasinghe, UNESCO-IHE/ TU Delft Univ/ Deltares, r.ranasinghe@unesco-ihe.org
Arjen Luijendijk, Deltares/ TU Delft Univ, arjen.luijendijk@deltares.nl
Dirk-Jan Walstra, Deltares/ TU Delft Univ, dirkjan.walstra@deltares.nl
Dano Roelvink, UNESCO-IHE/ Deltares, d.roelvink@unesco-ihe.org

Tidal inlets are of great societal importance as they are often associated with harbours, industry, tourism, recreation, etc. Tidal inlets are also the most morphologically dynamic regions in the coastal zone and are of great scientific interest. Their behaviour is governed by the delicate balance of oceanic processes such as tides, waves, mean sea level (MSL), and fluvial/estuarine processes such as riverflow and heat fluxes (Ranasinghe et al., 2013). All of these processes can be significantly affected by climate change (CC) processes, which may result in negative physical impacts such as inlet closure/relocation, creation of new inlets, erosion of the coast adjacent to the inlet, permanent or frequent inundation of low lying areas on estuary/lagoon margins, eutrophication and toxic algal blooms etc. Although CC impacts on some large tidal inlets (e.g. Wadden Sea inlets) have received some attention recently, potential CC impacts on small tidal inlets (STIs) remain virtually unknown to date. STIs are defined herein as those with inlet channels less than 500m wide, connected to relatively shallow (average depth < 10m) estuaries/lagoons with surface areas less than 50 km^2. This study attempts to investigate the potential range of CC impacts on the stability of STIs via the application of a sophisticated process based morphodynamic model (Delft3D) to strategically selected schematised inlet morphologies and forcing conditions.

A series of schematised inlet/forcing conditions were developed such that the following main inlet morphodynamic characteristics were represented: Type1: Permanently open, locationally stable; Type 2: Permanently open, alongshore migrating; Type 3: Seasonally/Intermittently open, locationally stable. The initial bathymetries for all schematised cases consist of a rectangular estuary/lagoon of constant depth connected to the ocean via a straight, constant depth channel. Riverflow was introduced into the estuary/lagoon. The schematised system dimensions were chosen such that they loosely represent a real-life system in all above 3 system categories. Type 1 is represented by Negombo lagoon, Sri Lanka; Type 2 by Kalu river, Sri Lanka, and Type 3 by Maha Oya river, Sri Lanka. For each inlet type, a series of Delft3D simulations were undertaken to validate for the present condition using the initial bathymetry and forced with schematised tidal, wave and riverflow forcing representing contemporary conditions at the study areas. Then, a series of CC perturbed simulations (CC set) representing potential future changes in MSL (i.e. SLR), riverflow and wave characteristics were undertaken for each system category. The CC scenarios encapsulate all possible combinations of the CC driven variations in forcing. In SLR scenario simulations, the basin infilling due to SLR induced accommodation space effect was also taken into account.

Results show that CC driven variations in system forcing are likely have a profound impact on inlet stability and also show that a process based coastal morphodynamic model (eg. Delft3D) is suitable for investigating potential CC impacts at small tidal inlets.

Temporal variability of the residual transport in the Dutch Wadden Sea

Matias Duran-Matute, NIOZ, m.duran.matute@tue.nl
Theo Gerkema, NIOZ, theo.gerkema@nioz.nl
Gerben de Boer, Deltares, gerben.deboer@deltares.nl
Janine Nauw, NIOZ, janine.nauw@nioz.nl
Ulf Grawe, IOW, ulf.graewe@io-warnemuende.de

The Dutch Wadden Sea presents a estuarine dynamics that is highly variable in space and time, with a complex bathymetry, tides, wind surges, and fresh-water flows. The variability extends not only to quantities like tidal prism but also to the net transports and residual flows.

The aim of this research is to describe, quantify, and interpret the temporal variability of the residual transport in the western Dutch Wadden Sea, i.e. through the tidal inlets and across the Terschelling watershed. We study both the total water transport and the pathways for the fresh water discharged at the Den Oever and Kornwerderzand sluices located in the Afsluitdijk.

We have set up state-of-the-art three-dimensional baroclinic numerical simulations for the years 2009-2011 using the General Estuarine Transport Model (GETM) with a 200m horizontal resolution and 30 vertical layers. The simulations include the most realistic available bathymetry, atmospheric forcing, boundary conditions, and fresh-water discharge. In addition, we use Eulerian passive tracers to follow the fresh water from the sluices at the Afsluitdijk.

The simulations show that tides are responsible for the general pattern of residual transport through the inlets and across the Terschelling watershed, but that the wind imposes a large variability. In fact, wind renders the residual transport across the watershed more important than previously thought. The system presents inherent preferential directions meaning that only wind blowing in such directions is an efficient driver of residual transport. Of large importance are south-westerly storms which invert the typical residual circulation and can strongly diminish the flushing time of fresh water. It is then not only the average residual transport which is important for the state and evolution the Dutch Wadden Sea but also strong episodic events.

The significance of this finding goes beyond the fate of the fresh water alone; it shows that transects with relatively small tidal prisms, like the Terschelling watershed, can be disproportionally important for the net exchange of water and any of its constituents (sediment, pollutants, etc.).

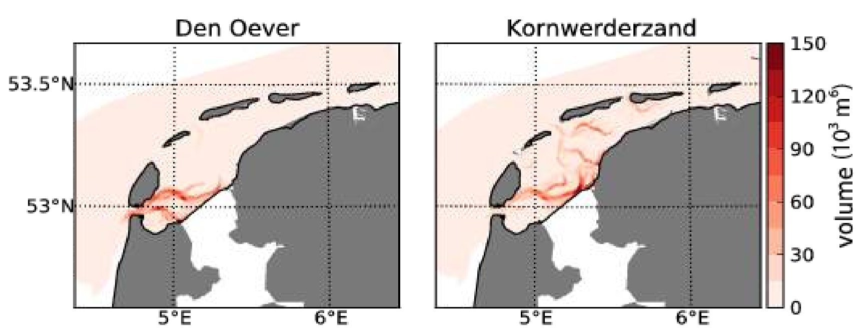


Figure. Average volume of fresh water from the sluices at Den Oever (left) and Kornwerderzand (right) during the month of April 2009.

Analysis of river tides with a case in the Yangtze River estuary, China

Leicheng Guo, l.guo@unesco-ihe.org
Mick van der Wegen, m.vanderwegen@unesco-ihe.org
Dano Roelvink, d.roelvink@unesco-ihe.org
Qing He, qinghe@sklec.ecnu.edu.cn

The tide in an estuary is usually altered by highly varying river discharge, so that the tidal oscillations display strong non-stationary behavior. Traditional harmonic analysis or Fourier analysis are valid based on an assumption that the tide is steady, thus they are only applicable for a small data window during which the river discharge is minor or is uniform. To analyze longer time series river tide signals, e.g. one-year's tide influenced by seasonally varying river discharges, we apply continuous wavelet transformation (Jay and Flinchem, 1997; Torrence and Compo, 1998) to decompose the tidal signals into diurnal, semi-diurnal, quarter-diurnal tidal species. We further use a schematized 1D numerical model to explore river-tide interactions systematically by imposing constant and also time varying river discharges.

Our analysis show that there are both supra- and sub-frequency tides generated internally inside the estuary. The supra-frequency tides generate profound tidal asymmetry while the sub-frequency tides induce significant sub-tidal water level variations in fortnightly, monthly even semi-annual cycles. For instance, the mean water level at neap tide is found lower than that at spring tide owing to the generation of fortnight MSf tide (Figure 1). Furthermore, it was found that, with continuously increasing river discharges, the astronomical tides are increasingly damped and the internally generated overtides and compound tides are modulated non-linearly (Guo et al., 2014). These information on the river tide benefits our understanding of tidal prediction, navigation and associated estuarine morphology.

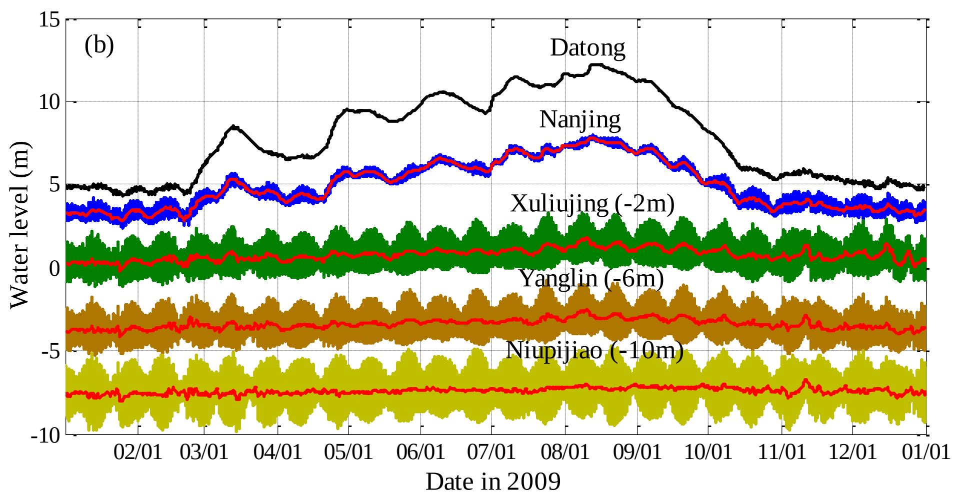


Figure 1. Tidal Water levels at Datong, Nanjing, Xuliujing, Yanglin, Niupijiao in 2009 in the YRE. The red lines indicate the daily mean water levels.

Wave dissipation in mangroves: parameterization of the drag coefficient based on field data

J.M. Hendriks, Twente University, J.M.Hendriks@student.utwente.nl
E.M. Horstman, Twente University, E.M.Horstman@utwente.nl
C.M. Dohmen-Janssen, Twente University, C.M.Dohmen-Janssen@utwente.nl
T. Suzuki, TUDelft/Flanders Hydraulic Research, Tomohiro.Suzuki@mow.vlaanderen.be
D.S. van Maren, TUDelft/Deltares, Bas.vanMaren@deltares.nl

Mangrove forests dwell in relatively sheltered intertidal areas in the tropics and subtropics. Over the past decades, the interest in mangrove forests has increased because of their unique ecosystem services, one of the most important ones being the attenuation of incident waves, thereby protecting the shoreline. Several theoretical and field studies have been performed in the past, studying this wave damping. The most recent numerical model, developed by Suzuki et al. (2011), simulates wave attenuation in mangroves accurately but still requires calibration of a drag coefficient. The aim of this research is to derive a parameterization for this drag coefficient that is based on both wave properties and vegetation characteristics observed in the field.

We used field observations from two different cross-shore transects with a large variation in vegetation density and wave characteristics (Horstman et al., 2012). With the SWAN vegetation module we reconstructed the drag coefficients corresponding to the wave attenuation observed in the field data. A multi-variable regression analysis on these drag coefficients, combined with knowledge from literature, resulted in an accurate parameterization of the drag coefficient.

The multi variable analysis lead to an adaptation of the Keulegan-Carpenter number, including a vegetation length scale as developed by Mazda et al. (1997) instead of the vegetation diameter. This length scale includes the density and frontal surface of the vegetation. This adapted Keulegan-Carpenter number correlates well with the drag coefficient. The obtained parameterization of the drag coefficient allows for the calculation of the drag coefficient from observed wave and vegetation characteristics. This eliminates the need for the calibration of the SWAN vegetation module in the drag coefficient, thus reducing the demand for field data while improving the predictive capacity of the model.

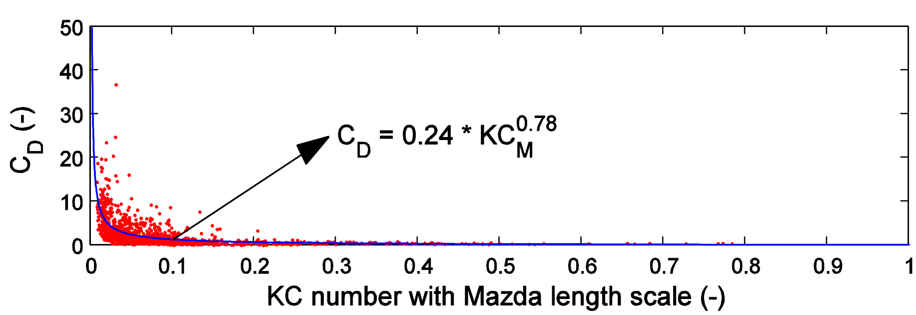


Figure 1. Drag coefficients vs. adapted Keulegan-Carpenter numbers.

Mega Perturbation Experiment 2014 (MegaPex2014)

Martijn Henriquez, TU Delft, m.henriquez@tudelft.nl
On behalf of all participants of MegaPex2014

Since the realisation of the Sand Engine in 2012, the coastal stretch between Hoek van Holland and Scheveningen is subject to continuous and periodic monitoring. In the coming fall, from 15 September to 26 October, the monitoring will be extended with a field campaign that includes in-situ measurement with high temporal and spatial resolution. The campaign is organized by the TU Delft, NatureCoast and, among others, includes international scientists. This presentation presents the intended instrumental setup together with the scientific scope.

The measurements will be conducted at the Sand Engine and can be divided into groups targeting the lower, middle and upper shoreface. Two frames and two moorings will be placed on the lower and middle shoreface measuring the stratification by the Rhine river plume. Closer to shore, bed frames on the -6 m and -8 m NAP will measure the flow velocity profiles and sediment concentration profiles above the bed. Measurements are continued with a cross-shore array of three jetted poles across the surf zone and 2 frames across the intertidal zone. The purpose of the array is to deduct cross and alongshore transport rates during mild and stormy conditions. An alongshore array of pressure sensors in the intertidal zone will investigate infra-gravity waves.

The intertidal zone, beach and dunes are subject to multidisciplinary measurements in the fields of Aeolian transport, hydrology and vegetation. Supply-limited sediment transport from the waterline to the dunes will be measured together with local soil moisture and hydro meteo data. Fresh groundwater will be monitored using wells and the seepage in the intertidal zone with conductivity-temperature-depth meters. Drones will map vegetation.

The campaign provides a solid base for integration of various disciplines that come together in the coastal zone. Now is the opportunity for (inter)-national scientist to provide input and participate.

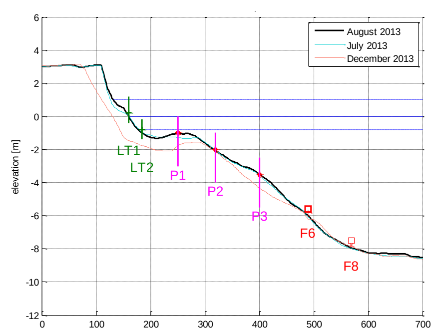


Figure 1. Left: Photo of Sand Engine (from www.zandmotor.nl). Right: Cross shore transect at the tip of the Sand Engine. F for middle shoreface frames. P for surfzone instrument locations. LT for intertidal frames.

Modelling and Monitoring of Meso-Scale Supply-limited Aeolian Transport

Bas Hoonhout, Delft University of Technology, bas.hoonhout@deltares.nl
Sierd de Vries, Delft University of Technology, sierd.devries@tudelft.nl

Traditional Aeolian transport formulae predict the equilibrium transport rate based on wind speed or wind shear velocity. In coastal environments these formulae tend to overestimate the actual transport considerably. The significant lower transport rates measured are accredited to a limited supply of sediment. The objective of this research is to derive meso-scale variations in transport rate due to supply-limiting conditions that vary on different spatio-temporal scales.

In literature spatial variations in supply are often aggregated using the notion of critical fetch. The critical fetch is the distance needed to reach an equilibrium transport rate from a point with zero transport (e.g. the waterline). Given the equilibrium transport rate and uniform supply conditions, the critical fetch is a proxy for space-averaged, aggregated supply. However, in coastal environments supply conditions are rarely uniform. For example supply conditions in the intertidal area are much different from the dry beach. Also critical fetch can often not be measured in the field, because fetches are limited. It is therefore a hypothetical parameter. We argue that the notion of critical fetch is an oversimplification of the complex variations in supply found in coastal environments and propose an alternative method for aggregating supply-limitations and modelling Aeolian transport.

We have been developing such an alternative method to incorporate the influence of supply, omitting the notion of critical fetch. We actually compute the instantaneous supply based on dedicated models for different supply limiters, like soil moisture and sediment sorting. Subsequently we use this instantaneous supply and a simple advection model to compute the development of the saltation cascade over a given beach profile (Figure 1). Using this model setup we relate time series for tide, rainfall and solar radiation to maximum transport rates.

The model provides multivariate transport time series that can be fed to a probabilistic model, e.g. a dynamic Bayesian model, for aggregation. Moreover, our approach closely resembles our long-term monitoring campaign along the Delflandse Kust where we monitor surface moisture, grain size sorting, fetch, transport rates and meteorological factors continuously and in high resolution for a year now. These data will enable us to calibrate and validate the model at a variety of scales.

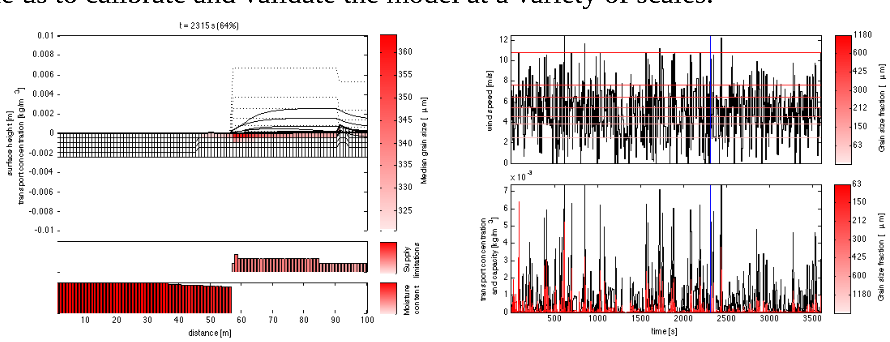


Figure 1. Model output. Instantaneous supply, supply-limitations and transport concentrations (left). Wind speed, threshold velocities and space averaged transport (right).

Tidal-scale flow routing and sediment deposition in mangroves; a combined observational-numerical approach

Erik Horstman, University of Twente, e.m.horstman@utwente.nl
Marjolein Dohmen-Janssen, University of Twente, c.m.dohmen-janssen@utwente.nl
Tjeerd Bouma, NIOZ, tjeerd.bouma@nioz.nl
Suzanne Hulscher, University of Twente, s.j.m.h.hulscher@utwente.nl

Short-term bio-physical interactions in coastal mangroves contribute to coastal stabilization and coastal safety. Spatial explicit observations (or simulations) of sediment deposition rates in mangroves related to gradients in elevation and vegetation and to tidal-scale hydrodynamics are unprecedented. We studied the tidal-scale bio-physical interactions in coastal mangroves by (i) unravelling contributing processes through numerical modelling based on field observations and (ii) simulating system behaviour for conditions beyond the observed field settings.

This study is based on observations obtained in an elevated mangrove forest dissected by tidal creeks, fringing an estuary at the Thai Andaman coast. A process-based 3D numerical model was set-up in Delft3D, explicitly accounting for vegetation induced drag and turbulence. The 3D model and a depth-averaged (2DH) version thereof were calibrated and validated successfully with the observed flow routing and sediment deposition patterns. The 2DH model proved to be an efficient and accurate tool for computing the tidal-scale dynamics at the study site.

According to field data and numerical simulations, the creeks are a major pathway for tidal inflow during the lower tides, while the sheltered interior of the forest is an effective sediment sink during the higher tides. A sensitivity analysis of the initial system response to instantaneous environmental change shows that the studied mangrove system is rather stable: deposition rates are quite independent of the vegetation density, while counteracting adjustments of the topography and relative elevation. Sediment trapping rapidly reduces with diminishing sediment inputs and a loss of mangrove area, e.g. due to river damming or conversion to aquaculture. Deeper inundations of the mangroves would enhance flow routing through the forest while deposition rates diminish when vegetation densities decrease simultaneously. These results stress the sensitivity of mangroves' sediment trapping capacity to environmental change.

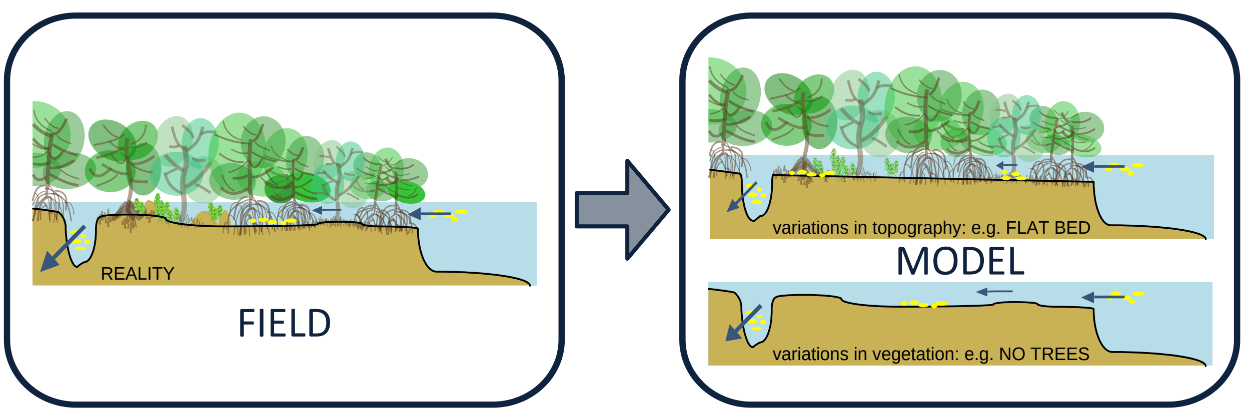


Figure 1. A combined observational-numerical approach to tidal-scale mangrove dynamics.

Near-bed SPM composition in SPM hot spot offshore Egmond, NL: tidal and seasonal variations

Carola M. van der Hout, Rob Witbaard, Gerard Duineveld, Lennart Groot,Magda Bergman, NIOZM. Rozemeijer, IMARES

Continuous measurements over a period of almost two years (2011-2012) of SPM and Chlorophyll concentrations show a marked seasonal variation in the average concentrations of SPM and chlorophyll. Measurements were done with an autonomous measurement platform (lander) at an 11 meter deep site at 2 km offshore of Egmond. With 4 vertically aligned sensors within 2 meters from the seabed an extremely steep concentration gradient is found in this near-bed water layer. At a height of about 1 meter above the bottom a discontinuity in SPM suggests that material moves as a "blanket" over the sea floor. Average concentrations near the seabed are 190 mg/l, while higher up the water column at 2 m from the seabed the average concentration has reduced to 65 mg/l. Waves lead to an increase in the background levels of SPM. The effect of increased wave heights on the maximum SPM concentrations is less straightforward than for the minimum concentrations. The data suggest that already at wave heights of 1-2 meter most of the material which can be resuspended actually is in suspension.

The chlorophyll rich fraction of the SPM shows a more homogenous distribution over the depth than SPM concentration. It is observed that the chlorophyll rich fraction behaves differently from the overall SPM, as over a tidal cycle the ratio of chlorophyll and SPM varies significantly – especially during the spring bloom. There seem to be 2 of more different fractions with different settling properties. Measurements of grain sizes with a LISST100 show large fluctuations over a tidal cycle in the volume of ‘particles’ with sizes larger than 200 mu, while the volume of particles < 63 mu remains more or less constant in time. The difference in settling and resuspension behavior of the chlorophyll rich fraction when compared to the total SPM has a large consequence for the quality (Chl-a/SPM) of the material which can be used as food source by benthic filter feeders.

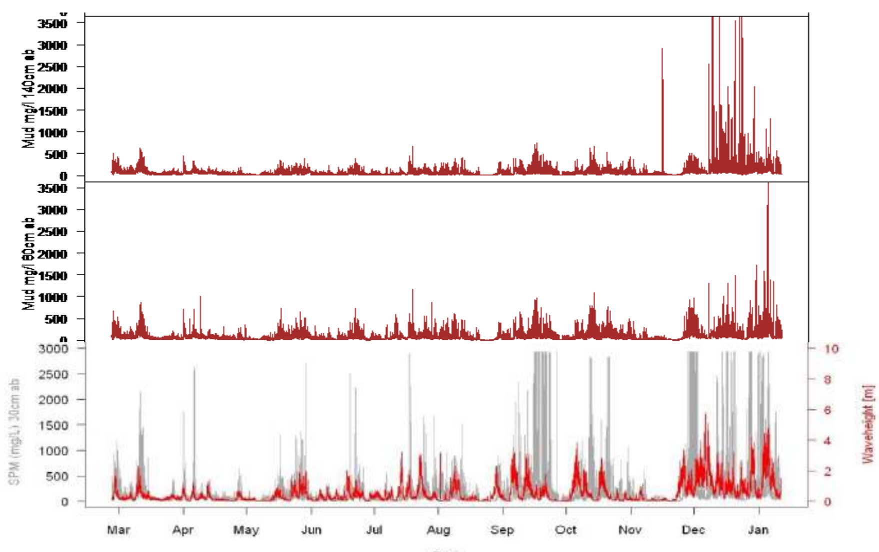


Figure 1. Concentrations of SPM in mg/l at 30 cm (grey lines), 80 cm and 140 cm above the seabed and wave height (lower panel; red lines) in 2011.

Wave dissipation by vegetation in combined current-wave flow

Zhan Hu, TU Delft, zhan.hu@tudelft.nl
Tomohiro Suzuki, Flanders Hydraulics Research, t.suzuki.delft@gmail.com

Coastal wetlands such as salt marshes and mangroves provide valuable ecosystem services including coastal protections. Many studies have assessed the influence of plant traits and wave conditions on wave dissipation by vegetation (WDV), whereas the effect of tide currents is often ignored. To our knowledge, only two studies have investigated the variation of wave dissipation with the presence of following currents (currents velocity is in the same direction as wave propagation) (Li and Yan, 2007; Paul et al., 2012). However, based on independent experiments, they have drawn contradictive conclusions whether steady currents increase or decrease wave attenuation. This inconsistency could be caused by the different velocity ratio (α) tested in the two studies, which is defined as the ratio of imposed current velocities to the amplitudes of horizontal wave orbital velocity. Therefore, systematic tests over a wide range of α are needed to identify the effect of following currents on WDV.

Experiments with plant mimics were conducted in a wave flume of Fluid Mechanics Laboratory at Delft University of Technology. The wave flume is 40 m long and 0.8 m wide (schematized in Fig. 1a). Wave generator with active wave absorption system is placed at one side of the flume (left in Fig. 1a). Mimic canopies were constructed by wooden sticks and the density of the canopies is 62, 139 and 556 stems/m^2 respectively. Imposed currents were in the same direction as the wave propagation. Wave dissipation by the mimic canopy was measured in various wave conditions with steady current velocity equals to 0, 0.05, 0.15, 0.20 and 0.30 m/s.

Our study shows that when α is small, following currents generally reduce the WDV (i.e. $\Delta H_{cw}/\Delta H_{pw}<1$) owing to the reduction of both drag coefficient and the magnitude of period-averaged velocity. However, when α is sufficiently high, currents can also promote the WDV (i.e. $\Delta H_{cw}/\Delta H_{pw}>1$, see Fig. 2) due to the current-wave interaction effect. In conclusion, the effect of current on WDV is not monotonic but varies with α. The two previous studies investigated WDV with different ranges of α, which caused the seeming inconsistency. A simple analytical model has been proposed to understand such mechanism (Fig. 2). Our finding suggests that the flooding high tide during storm events (when α is small) could be a critical scenario for coastal protection schemes that utilize coastal wetlands to attenuate wave energy.

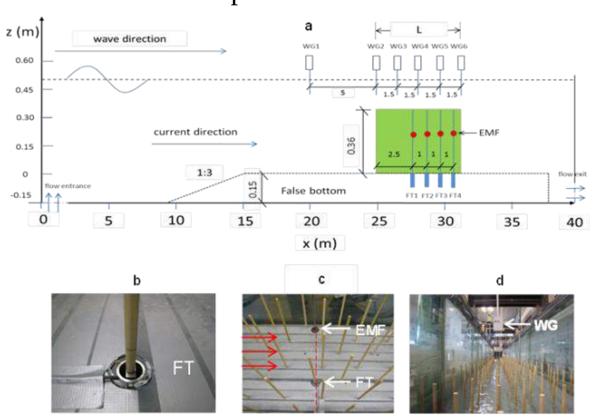


Figure 1. Flume experiment setup

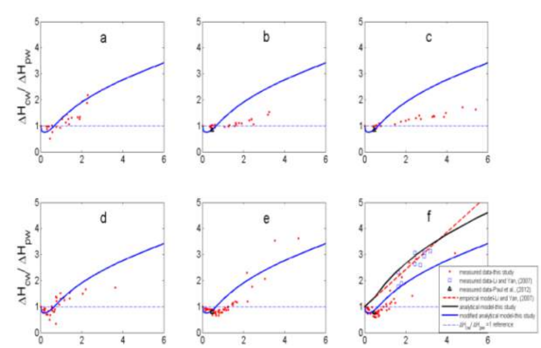


Figure 2. Ratio of wave dissipation in current-wave condition to pure wave condition varies with velocity ratio (α)

Occurrence of beach states at the Sand Motor

B.J.A. Huisman MSc, TU Delft / Deltares, bas.huisman@deltares.nl
M. Radermacher MSc, TU Delft, m.radermacher@tudelft.nl
Y.C. Tan, TU Delft, y.c.tan@student.tudelft.nl

The coast is a very dynamic area which changes shape continuously. As a result of hydrodynamic forcing and local coastline characteristics, coasts develop certain profile shapes and 3D bathymetric features (referred to as beach states (Wright and Short, 1984)) such as various types of rip-bar systems. The beach state of a coast has a considerable impact on the nearshore currents and consequently also on sediment transport. Furthermore, these beach states are responsible for residual circulations that drive dangerous rip-currents. For this reason it is important to understand when these rip-bar systems occur and how pronounced they are. A very nice opportunity for studying these beach states is the Sand Motor (i.e. Nourishment of 21.5 million cubic meters of sand) since it shows beach states that are non-typical for the Dutch coast.

The occurrence of beach states at the Sand Motor has been studied from bathymetrical survey data, consisting of 21 consecutive surveys spanning the 2¼ years since construction of the Sand Motor. A visual classification of the beach states was performed as well as automated approaches to classify the beach states. Furthermore, the inter-relation between environmental conditions and the occurrence of the beach states is investigated. This is under consideration now. The main findings from the study are that:

(i) Three dominant beach states are observed at the Sand Motor (LBT) eTBR and RBB (Price and Ruessink (2011))

(ii)The beach states can be classified on the basis of bathymetrical survey data by computing the alongshore bed level variance (σ alongshore) for the deep and shallow part of the profile (see Figure 1 to 3).

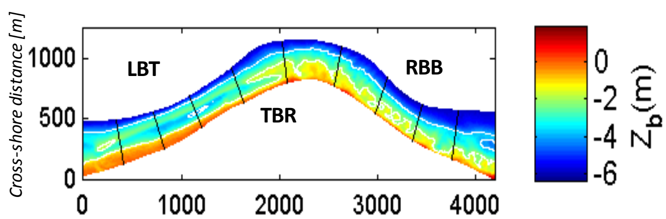


Figure 1. Nearshore bathymetry of the Sand Motor at 26 of August 2013.

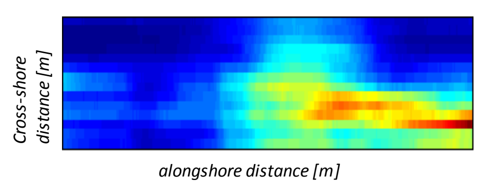


Figure 2. Alongshore variance in the bed level ($\sigma_{alongshore}$)

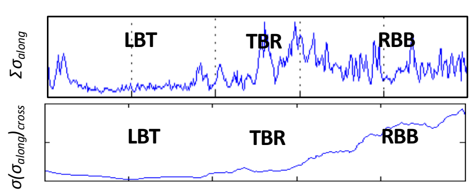


Figure 3. Cross-shore sum of the alongshore bed level variance (top) and cross-shore variance of alongshore bed level variance (bottom)

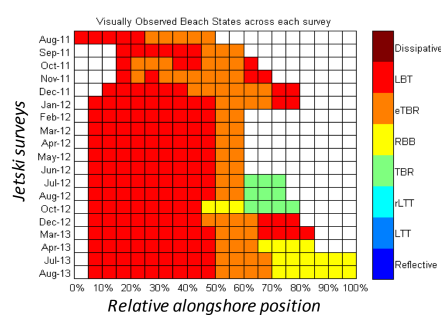


Figure 4. Visual classification of beach states at the Sand Motor

Vegetated foreshores as coastal protection strategy: Coping with uncertainties and implementation

Bas Jonkman, TuDelft, s.n.jonkman@tudelft.nl
Bas Borsje, UTwente, Deltares, b.w.borsje@utwente.nl
Tjeerd Bouma, NIOZ-Yerseke, tjeerd.bouma@nioz.nl
Mindert de Vries, Deltares,mindert.devries@deltares.nl
Jos Timmermans, TuDelft, j.s.timmermans@tudelft.nl
Vincent Vuik, TuDelft, HKV, v.vuik@hkv.nl

Promising Building with Nature solutions for flood protection, such as vegetated foreshores, inherently have a dynamic nature. Therefore there is a relatively large degree of uncertainty with respect to their contribution to flood protection. This hampers innovation and the implementation of vegetated foreshores in flood risk management worldwide. We aim to develop new methods to assess how, and how much vegetated foreshores can contribute to flood risk reduction. The project will lead to a better understanding of (uncertainties in) the functioning and stability of these ecosystems and the development of novel governance arrangements. This requires integration of knowledge from ecology, biogeomorphology, hydraulic engineering, and governance.

By field observations on several sites and flume measurements we will analyse fundamental ecological and physical processes for various types of wetland vegetations. The knowledge obtained will be applied in one implementation case study for a location in the Netherlands where dike reinforcement is needed in the future. This case study integrates fundamental knowledge from all the disciplines. It is used to design governance and implementation arrangements, and to demonstrate how vegetated foreshores can contribute to flood risk reduction.

The project will provide the knowledge, methods and tools (e.g. a maptable) required for the design and implementation of vegetated foreshores as a safe, ecologically desirable, and cost effective alternative in flood management. In the presentation, we present a multidisciplinary research agenda how to address the uncertainties hampering application, how to develop probabilistic tools and how to derive at suitable governance arrangements.

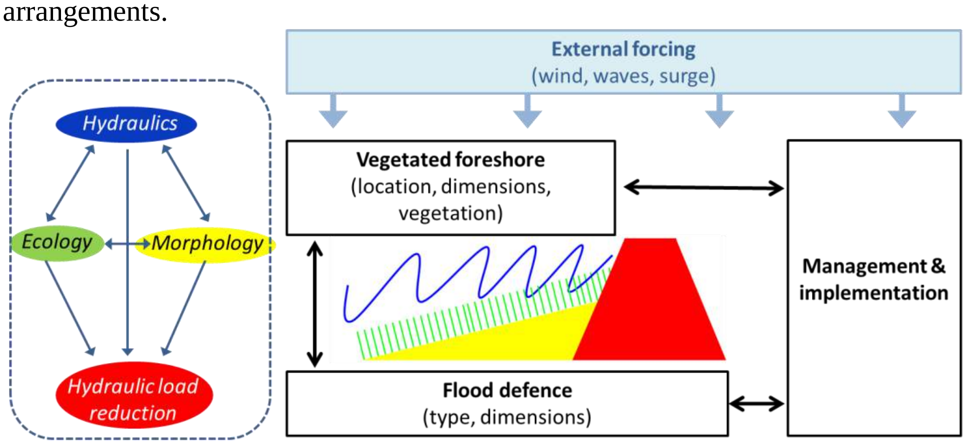


Figure 1. Schematic representation of the role of vegetated foreshores in flood risk management.

Effects of tidal currents, surge levels, wind and waves on the longshore sediment transport along the Sand Motor

Aline Kaji, Witteveen+Bos (former TUDelft), A.Kaji@witteveenbos.nl
Arjen Luijendijk, Deltares/TUDelft, Arjen.Luijendijk@deltares.nl
Jaap van Thiel de Vries, Boskalis (former TUDelft), J.S.M.vanThieldeVries@tudelft.nl
Matthieu de Schipper, TUDelft, M.A.deSchipper@tudelft.nl
Marcel Stive, TUDelft, M.J.F.Stive@tudelft.nl

The Sand Motor is the pilot project of a 'mega-nourishment' built in 2011 at the Delfland coast. Several studies are undergoing in order to understand the behaviour and impacts of such innovative solution for coastal erosion problems. A good comprehension of the different aspects of the sediment transport in the area is important for improving predictions of the future development of the Sand Motor. The objective of this study is to investigate the influence of different types of forcing on the longshore sediment transport magnitudes and patterns along the Sand Motor using a process-based model. The use of numerical simulations enables the independent assessment of the different processes influencing the sediment dynamics. A calibrated depth-averaged model of the Sand Motor was used in order to compute the initial sediment transport rates along the area. Forcing conditions were systematically varied in order to assess the contributions of tidal currents, surge levels, wind and waves on the longshore sediment transport at various transects at the Sand Motor.

Forcing by wind and tides alone results in negligible transport. In case waves above 2 m are applied, wind and horizontal tides become an important role in enhancing the sediment transport. From the total transport at the head of the Sand Motor about 8% is due to a high surge level, 19% due to wind-driven currents, 18% due to tidal currents and 55% due to waves (Fig. 1). For example, storm surges enhance the sediment transport in the area due to less dissipation on the bars. Due to the geometry of the Sand Motor the relative contributions of the different forcing vary alongshore. The peninsula induces contraction and intensification of the tidal flow, inducing high transport rates at the head of the Sand Motor, while the adjacent coastline experience lower transport, and consequently deposition of sediments. More detailed analyses will be presented.

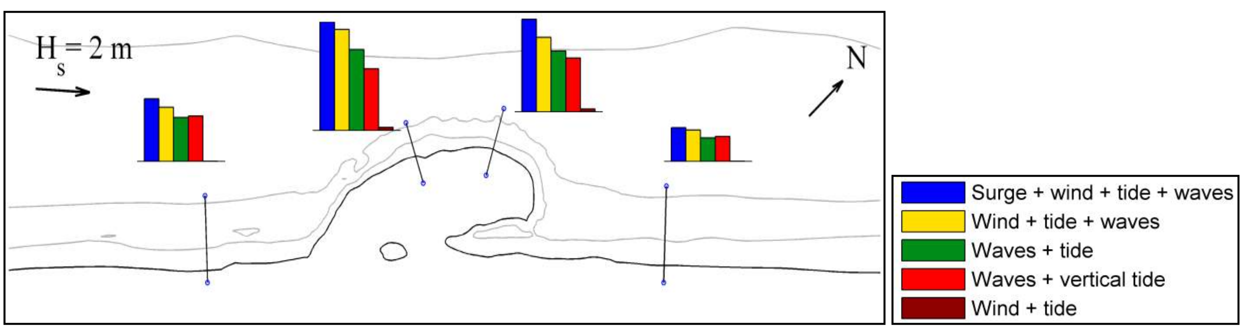


Figure 1. Longshore sediment transport through cross-shore transects for a typical wave condition (H_s = 2 m, T_p = 6.4 s and direction = 225º).

Vegetation and sedimentation profiles across foredunes

Joep Keijsers, Wageningen Unviversity, joep.keijsers@wur.nl
Alma de Groot, Imares, alma.degroot@wur.nl
Michel Riksen, Wageningen University, michel.riksen@wur.nl

Coastal dunes form a natural flood defense. The strength of this defense and the response to dune erosion is influenced by the size and shape of the foredunes. This study investigates how dune morphology changes as a result of interactions between vegetation and aeolian transport. Such knowledge is critical for understanding the morphological development and thus changes in the safety level of dunes.

Cross-shore profiles of vegetation and sedimentation were determined for a number of foredune sections (n=25) on the barrier island of Ameland, The Netherlands. Vegetation profiles were derived from a series of air photos, taken between 2003 and 2011. Supervised classification was performed to distinguish vegetated pixels from bare sand pixels (Figure 1a). Classifications were validated with field measurements. Sedimentation patterns were calculated from yearly elevation profiles (JARKUS dataset), taking the average of 2 larger time windows to reduce the effect of measurement uncertainties.

Generally, sedimentation increases from beach to the dune foot and a maximum halfway the seaward slope. Sedimentation then decreases rapidly further inland. The maximum occurs within the first 15 m of vegetation (Figure 1b). The pattern of sedimentation is mostly determined by the seaward edge of vegetation. Factors such as patchiness or average cover were not found to strongly influence the sedimentation profile.

The combination of elevation and vegetation data presented here provide an excellent basis for studying bio-geomorphological interactions on a foredune. The results imply that when position of the lower limit of vegetation is known, sedimentation along the dune profile can be predicted. Combined with dune erosion models, such predictions can form the basis for simulations of dune development, providing a possibility to examine effects of rising sea level and changing climate on the safety function of the coastal dunes.

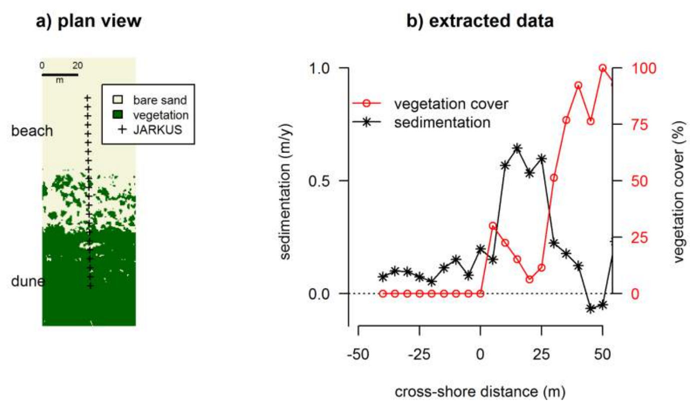


Figure 1. (a) Plan view of vegetation cover and (b) profiles of vegetation cover and sedimentation across the foredune.

The Vici project "Turning the tide": dynamics of channels and shoals in estuaries with sands and mud

Maarten G. Kleinhans, Universiteit Utrecht, Faculteit Geowetenschappen
m.g.kleinhans@uu.nl

Tidal systems such as the Ems and Scheldt estuaries and the Wadden Sea have perpetually changing channels and shoals of sand and mud, sculpted by ebb and flood currents. Shoals that dry and flood daily due to the tides are ecologically valuable habitats, whilst main tidal channels have a multi-billion Euro impact as shipping fairways that provide access to harbours and urban areas. Unfortunately, our present current models fail to adequately predict natural dynamics and the effects of human interference, making optimisation of management for the combined functions precarious.

In the coming five years I will conduct my Vici project (NWO-STW) to generate understanding of natural dynamics and response to human interference of channels and shoals in estuaries, and subsequently produce improved forecasting tools. The working hypotheses are that the natural dynamics are caused by 1) sudden collapses of steep shoal and channel margins and 2) sand transport processes on gentler slopes. These shoal break-down processes are balanced by shoal build-up with 3) a layer-cake of sand and mud. Together processes 1-3 govern the response to human interference.

I will build a large, worldwide unique, tidal facility to systematically create dynamic estuaries and apply dredging scenarios. The novel principle, periodic tilting of the entire flume, successfully reproduced dynamic channel-shoal systems (for pilots see Kleinhans et al., this conference). Numerical models presently ignore channel-shoal margin collapses and inadequately predict gentle slope processes and mud settling, for which novel submodels will be developed and implemented in collaboration with Deltares. The effects on large-scale dynamics of channels and shoals will be explored. Dredging and dumping scenarios will be run that optimise cost and benefit habitat surface area and quality. Tidal bar dimensions and stratification will be analysed to benefit the petroleum industry.

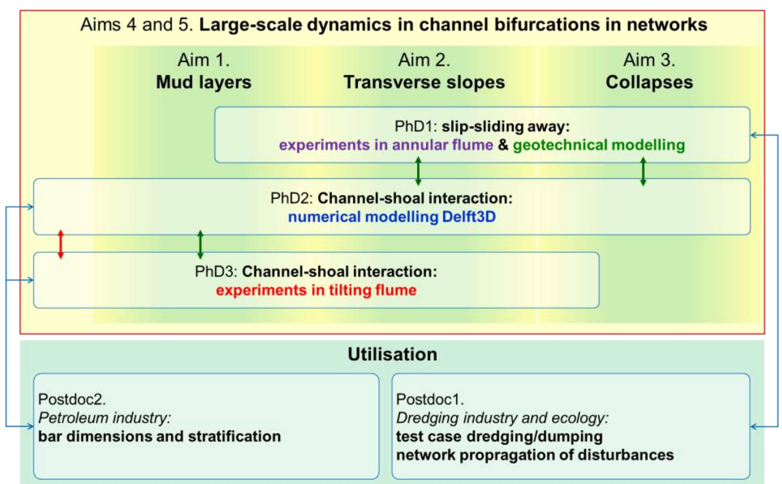


Figure. Project setup.

Turning the tide:
large-scale equilibrium and local morphodynamics in experimental estuaries

Maarten G. Kleinhans, Lisanne Braat, Jasper Leuven and Maarten van der Vegt
Universiteit Utrecht, Faculteit Geowetenschappen, m.g.kleinhans@uu.nl

The effect of river inflow on equilibrium morphology and dynamics of estuaries is poorly understood. At present, models fail to predict natural dynamics and are sensitive to constitutive parameters. Tidal experiments in a tilting flume on the other hand successfully formed equilibrium tidal systems with large-scale dimensions and sustained dynamics of small-scale bars and channels. Here we report preliminary experiments on estuaries with and without river inflow from an initial situation of a small channel in a barely emergent body of low density sediment.

We experimented systematically with the amount of river discharge, the tidal tilting amplitude that sets the tidal current velocity, and the initial level of the bed. Typical river discharge was 0.01-0.1 L/s and tilting amplitude 3-9 mm with tilting flume of 3.5 m length. Initial channel depth was 10 mm and width 5 cm.

We found that estuary width and inlet area are strongly dependent on the tidal amplitude and on the river inflow. For larger tidal amplitude the channel enlarged and bars and bends formed. In small tidal amplitudes with river inflow the inlet often closed despite absence of waves. Equilibrium dimensions were only attained when the entire system dropped below the threshold for sediment motion because of the weak cohesionless banks that allowed continued erosion. For future experiments we hypothesise that estuaries would tend to fill when sediment influx from the river is supplied, and would tend to remain more ebb-dominated when waves are applied to the ebb delta.

Figure 1. Experimental estuaries without (left) and with river inflow (right). QR: movie of a short tidal basin in large-scale equilibrium with sustained bar and channel dynamics.

Sand transport under irregular waves

Wouter Kranenburg, University of Twente, w.m.kranenburg@utwente.nl
Jan Ribberink, University of Twente, j.s.ribberink@utwente.nl
Jebbe van der Werf, Sander Helmendach

Within morphodynamic models, wave-induced sand transport is generally predicted using transport formulas. These formulas, mainly based on experimental results obtained for regular waves / oscillatory flow, are then coupled to a regular wave representing the natural, irregular wave conditions, e.g. through the significant wave height and peak period. In this study, we investigate the differences between transport by regular and irregular waves and examine whether the aforementioned approach is appropriate.

We investigate this with a detailed process-based numerical model validated before for boundary layer velocities and transport of fine and medium sized sand under regular waves (Kranenburg, 2012, 2013). Firstly, we simulate a number of experiments on transport of fine and medium sand by irregular waves to check the model for this situation as well. Next, we run tests with representative regular waves, where the latter has similar energy, but also reflects the non-linear shapes of the irregular waves (i.e. comparable velocity skewness). To explain the differences, we study the sediment flux distribution over time and vertical, and determine the (1) individual wave, (2) wave group and (3) current related contributions to the total flux. We isolate the contributing processes by doing this both for realistic waves and for less complex oscillatory flows.

Our results reveal large differences in sand transport between irregular and representative regular conditions. For fine sand in oscillatory flow this even concerns a reverse in transport direction (figure 2: d_{50} = 0.15mm). In our talk/poster, we explain how this relates to differences in phase-lag behavior and discuss the implications hereof for the 'representative wave approach' in morphodynamic modeling.

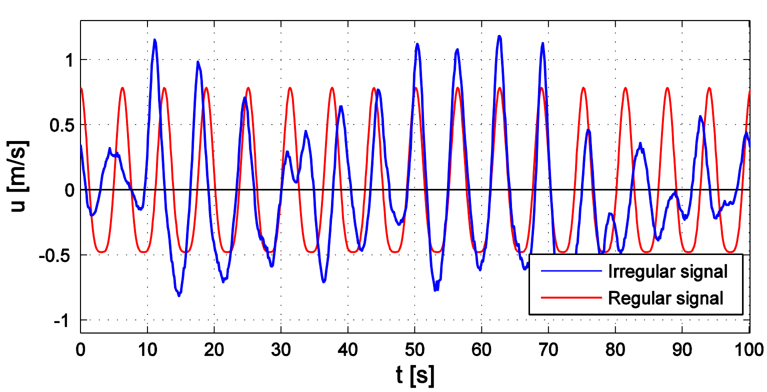


Figure 1. Irregular (blue) and representative regular velocity signal (identical peak period, u_{rms} and $<u(t)^3>$)

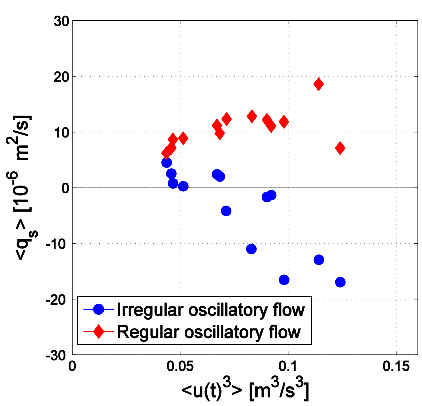


Figure 2. Transport rates for irregular (blue) and repre-sentative regular conditions

The SINBAD project: Sand Transport under Irregular and Breaking Waves

J.S. Ribberink (PI),W.M. Kranenburg, J. van der Zanden, J.J. van der Werf

Numerical morphodynamic modeling systems used in coastal engineering practice consist of coupled models for waves, currents, sediment transport and bed level change. The sediment transport is usually calculated through a *practical* sand transport formula for bed-load or near-bed total-load, in which the sand transport is empirically related to the local flow and sediment conditions. Well-founded practical models are based on a combination of measurements of net sand transport rates and understanding of the key fundamental processes, captured in the model in a parameterized way. However, existing sand transport models are mainly based laboratory experiments involving *regular*, *non-breaking* waves almost exclusively. In many cases of practical interest in coastal engineering waves are irregular and breaking. This raises the question: what key processes associated with wave irregularity and wave breaking need to be included in a practical sand transport model for the model to be applicable for these conditions as well? The SINBAD research project has two main aims: (1) to improve understanding of the near-bed hydrodynamics and sand transport processes occurring under real-scale irregular non-breaking and regular breaking wave conditions and (2) to develop a new practical model for predicting sand transport under waves, accounting for wave irregularity and wave breaking in a way that is well founded on experimental data and understanding of the fundamental processes.

The research is built upon a combination of fixed and mobile bed laboratory experiments and detailed numerical modeling. The key novel aspect of the research is the focus on *real-scale* flows and wave conditions. At present, experiments are running in the oscillatory flow tunnel in Aberdeen (irregular waves) and the large scale wave flume in Barcelona (both irregular non-breaking and regular breaking waves).

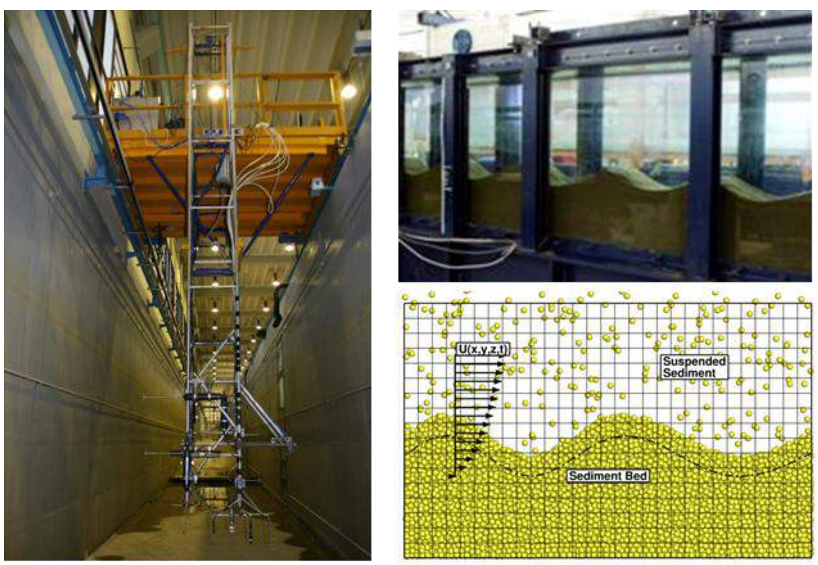


Figure 1. Left: Barcelona wave flume; Upper right: Aberdeen Oscillatory Flow Tunnel; Lower right: illustration two-phase numerical model.

Exploring our marine geological resources in the fifth dimension: About 3D voxels, 4D impact models and uncertainty

Vera Van Lancker, Dries Van den Eynde, Royal Belgian Institute of Natural Sciences
Operational Directorate Natural Environment, vera.vanlancker@mumm.ac.be, dries.vandeneynde@mumm.ac.be
Lies De Mol, Federal Public Service Economy, SMEs, Self-Employed and Energy
Continental Shelf Service, lies.demol@fgov.economie.be
Guy De Tré, Ghent University, Database, Document and Content Management, guy.detre@telin.ugent.be
Denise Maljers, Jan Stafleu, Sytze van Heteren, ***TNO*** *– Geological Survey of the Netherlands,*
denise.maljers@tno.nl, jan.stafleu@tno.nl, sytze.vanheteren@tno.nl
Tine Missiaen, Ghent University, Renard Centre of Marine Geology, tine.missiaen@ugent.be

Mineral and geological resources can be considered to be non-renewable on time scales relevant for decision makers. Once exhausted by humans, they are not replenished rapidly enough by nature, meaning that truly sustainable management of these invaluable and sought-after resources is not possible. Comprehensive knowledge on the distribution, composition and dynamics of geological resources therefore is critical for developing long-term strategies for resource use. For the Belgian and southern Dutch parts of the North Sea, such strategies will be worked out in the project TILES (Belgian Science Policy, 2014-2017). Particularly, TILES has the ambition of:

(1) Developing a decision support system (DSS) for resource use. This DSS contains tools that link 3D geological models, knowledge and concepts, providing information on present-day resource quantities and distribution, to numerical models of extraction-related environmental impact through time. Together they quantify natural and man-made boundary conditions and changes to define exploitation thresholds that safeguard sustainability on a multi-decadal time scale.
(2) Providing long-term adaptive management strategies that have generic value and can be used for all non-hydrocarbon geological resources in the marine environment.
(3) Proposing legally binding measures to optimize and maximize long-term exploitation of aggregate resources within sustainable environmental limits. These proposed measures feed into policy and associated monitoring plans that are periodically evaluated and adapted (e.g. EU Marine Spatial Planning and EU Marine Strategy Framework Directive).

Extensive analyses of data- and interpolation-related uncertainties, and of the propagation of these uncertainties in data products such as maps and GIS layers, form the backbone of the DSS. This is a necessary step in producing data products with confidence limits, and critical to detecting ‘true’ seabed changes in environmental monitoring. Using a dedicated subsurface viewer, a suite of data products will be viewable online. They can be extracted on demand from an underlying voxel (3D pixel) model. Each voxel will be assigned with values for geological, environmental and decision-related parameters, including uncertainty. The flexible 3D interaction and querying, enabled by TILES, will be invaluable for professionals, but also for the public at large and for students in particular. It will herald a new age in assessing cross-border impacts of marine exploitation activities.

What changes the Sand Motor?

Arjen Luijendijk, Delft University of Technology, A.P.Luijendijk@tudelft.nl
Bas Huisman, Delft University of Technology, B.J.A.Huisman@tudelft.nl

The Sand Motor has changed considerably after completion in August 2011. Tides, currents, wind, waves, and storms have altered the bathymetry and topography of this mega-nourishment. The objective of this paper is to spatially link the morphological development of the Sand Motor to the environmental forcing conditions and governing processes by applying process-based numerical modeling.

For the Sand Motor it is hypothesised that stirring and wave driven transport dominate the overall alongshore redistribution of the sediment, but the impact of tidal currents and wind-driven currents may be of importance for specific regions of the Sand Motor. Tidal currents are, for example, expected to be of relevance for the morphological evolution of the exposed seaward part of the Sand Motor and the inland basin. Furthermore, there may be a distinction between regions of the Sand Motor which are influenced predominantly by daily conditions (e.g. sheltered areas North and South of the Sand Motor) and areas that experience a mixed impact of daily and extreme wave conditions (e.g. at the more exposed seaward part of the Sand Motor). In addition, the impact of forcing conditions on morphological evolution can also change over time as a result of reshaping of the Sand Motor.

For this study, the process-based model Delft3D is applied to hindcast the first year of morphological development of the Sand Motor. A comprehensive monitoring programme was setup for the Sand Motor to investigate its behaviour, as its scale and shape are incomparable to other nourishments on the Holland coast. In the first year, monthly bathymetric surveys have been conducted, as well as current and wave measurements. This data has been used to validate and calibrate the model in order to obtain acceptable model performance.

Relationships have been derived between cumulative wave energy during storm events and erosion volume at the Sand Motor. Analysis of the simulations has led to new insights in optimal wave schematisations for the first years of morphological development of such a sandy coastal development.

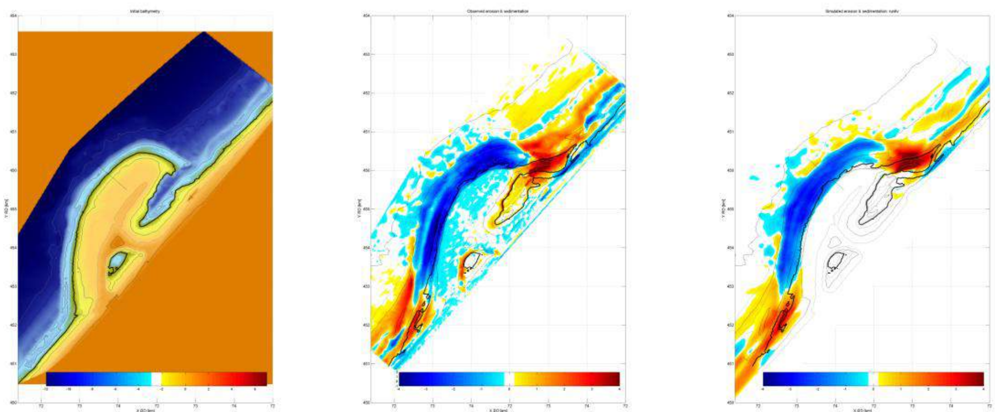


Figure 1 Erosion and sedimentation patterns (observed vs. computed)

Persisting Imbalance of Intertidal Flats due to Postive Feedback

Cynthia Maan, TU Delft, d.c.maan@tudelft.nl

Under constant environmental conditions, intertidal flats come close to an equilibrium state in which the time averaged erosion and deposition fluxes are balanced and the bed level is steady. Even flats that prograde in a self-similar way with a rate of several hundred meters per year are close to such a static equilibrium state, in that the net sedimentation is much smaller than the gross fluxes of deposition and erosion. A completely static equilibrium state, however, is often not reached. With a 1D cross-shore model, we have studied the response of intertidal flats, backed by land, to a constant sediment concentration at their seawards boundary.

At a short time-scale the initial imbalance between the in- and outward flux of sediment is largely reduced by an adjustment of the profile slope and shape. Once the profile shape is steady, however, a small imbalance persists and the profile progrades horizontally. The persisting imbalance can be explained by a positive feedback between the upper-tidal flat morphology and the cross-shore tidal current over the lower flat. Via this mechanism, the slopes and concentration gradients over the flat are continuously `restored', before a static equilibrium can be reached (see figure 2a). In the presence of wind waves it depends on the sediment supply from deeper waters whether deposition on the upper tidal flat is balanced by wave erosion only or whether the tidal current plays an additional role. The first situation implies a static profile with a steep slope towards the salt marsh under influence of a local positive feedback on the upper intertidal flat (Fagherazzi et al., 2006, see also figure 1b). The second situation implies a prograding coastline (figure 1a).Understanding these feedback mechanism is a first step in determining the conditions for which intertidal flats prograde and for which stationary flats are found and in predicting the consequences of engineering works for the status of the intertidal flats.

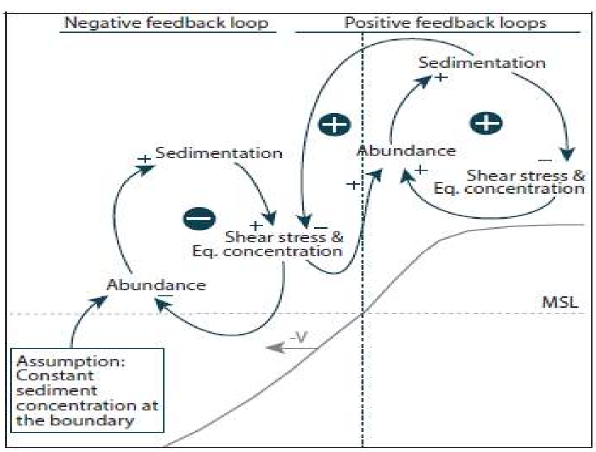


Figure 1a. Feedback mechanisms on a 'tidal dominated' flat. An abundant concentration at the boundary will induce sedimentation over the flat. On the lower flat, this would increase the local shear stress (via a decrease of the slope towards MSL (Friedrichs and Aubrey, 1996)), favouring equilibrium. Sedimentation on the higher tidal flat, however will reduce the tidal shear stresses over the middle and lower tidal flat; accretion on the higher flat will induce accretion over the rest of the flat. This is an ongoing process in which the slopes and concentration gradients are continuesly 'restored' before a morphodynamic equilibrium could be reached (i.e. a stationary equilibrium will not establish).

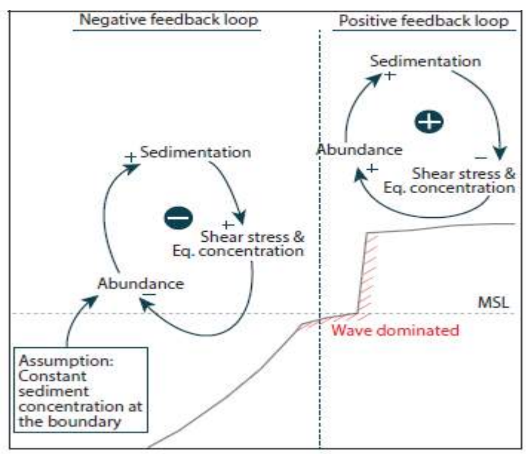


Figure 1b. Feedback mechanisms on a "wave dominated" flat, i.e. with a ´stable wave regime' on the middle flat. In this situation the evolution of the upper and lower flat are not coupled as in figure 2a and a stationary equilibrium with a steep slope on the upper flat develops.

Increasing Coastal Flooding Preparedness in the UK: towards the development of a storm impact tool for gravel beaches

Robert McCall, Deltares and Plymouth University, robert.mccall@deltares.nl
Gerd Masselink, Plymouth University, gerd.masselink@plymouth.ac.uk
Timothy Poate, Plymouth University, timothy.poate@plymouth.ac.uk
Dano Roelvink, UNESCO-IHE and Deltares, d.roelvink@unesco-ihe.org
Pieter van Geer, Deltares, pieter.vangeer@deltares.nl

Gravel beaches in the UK are common forms of coastal defence in the UK. Despite their societal importance and mounting costs of replenishment schemes, relatively little research has been directed towards understanding the response of gravel beaches to storms. As a result, coastal managers in the UK have very limited guidance when predicting the potential of flooding on gravel coasts, and in evaluating coastal defence plans.

In order to address this shortfall, Plymouth University is developing a process-based storm-impact model for gravel coasts, in collaboration with Dutch and UK partners, based on the existing open-source XBeach model for sandy coasts. To this end, the standard XBeach model has been modified to include a groundwater-interaction module and phase-resolving wave module. Modelled storm-hydrodynamics and hydrology have been extensively validated using field data collected during the NUPSIG project (Figure 1, left panel). The model is currently undergoing development and validation of gravel morphodynamics (Figure 1, centre panel).

In order to assist coastal managers in coastal flooding risk assessment, the model has been applied to investigate the validity of current empirical storm impact models in the UK. Results of this investigation, which we will present, show a great underestimation over runup and overwash probabilities in the current empirical models in several historical coastal flooding events. By contrast, the process-based XBeach model shows considerable improvement over the empirical model predictions. We also intend to show a sneak-preview of the user-friendly Graphical User Interface (GUI; Figure 1, right panel) being developed for the XBeach model for end-users in the UK.

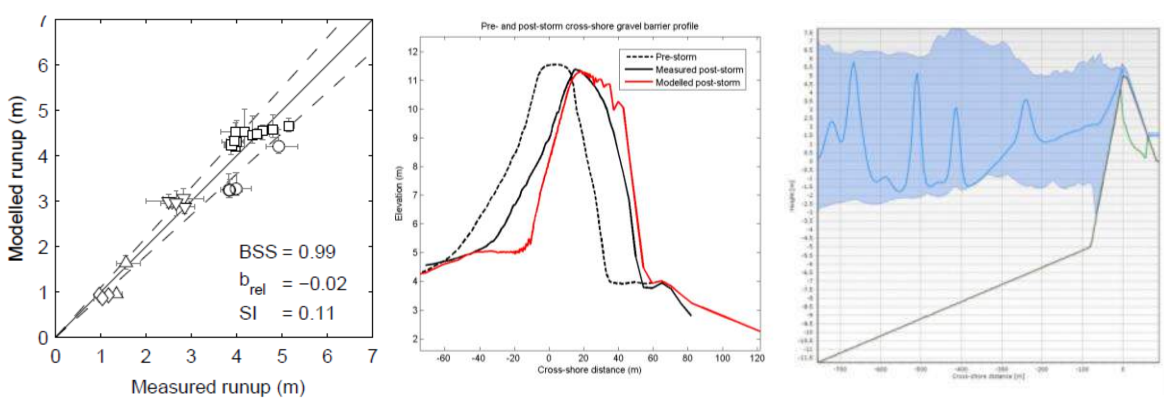


Figure 1. Validation of modelled runup levels (left) and modelled barrier roll-over (centre); and example of end-user model GUI (right)

Modelling of the formation of coral cays on platform reefs

Jan Jaap Meijer[a,b], *janjaapmeijer@gmail.com*, *Ap van Dongeren*[a], *Ap.vanDongeren@deltares.nl*
Huib de Swart[b], *H.E.deSwart@uu.nl*, *Maarten van der Vegt*[b], *M.vanderVegt@uu.nl*
a).Deltares, b).Utrecht University

In tropical seas, many platform reefs are found with nearly elliptical or circular shapes submerged just below MSL. Coral cays/ islands form on top of these reefs possibly as a result of wave refraction and wave-generated currents. Due to climate change and human interventions these diverse, but vulnerable ecosystems are under threat of disappearing.

In a previous study, Mandlier and Kench (2012) used a ray tracing model to simulate the process of waves refracting into energy convergence zones (ECZ), where sediment may accumulate and cays may form. In this contribution the advanced numerical wave, flow and sediment transport model (XBeach, Roelvink et al. (2009) with an application on coral reefs in Van Dongeren et al., 2013) is applied. Its advantage is that it includes not only wave refraction, but also processes such as wave breaking, bottom friction and advection of sediment by wave-generated flow, all of which were not considered by Mandlier and Kench (2012). Thus, the results obtained from a more complete model may improve our understanding of potential future scenarios of the formation and position of these cays. This will lead to a better preparedness to take measures to mitigate climate change effects.

Model simulations are performed for cases of low and high wave heights and of low and high water levels. In the case of low wave heights, the numerical model indeed reproduces the ECZs as predicted by Mandlier and Kench (2012) for most cases, but the wave-generated flow is not strong enough to mobilise the coarse sediment. On elliptical platforms a secondary low energy convergence zone as predicted by Mandlier and Kench (2012) is not reproduced. The absence of the secondary ECZ on the elliptical platform is most likely due to the absence of diffraction in the model. When the wave height is increased most of the energy dissipates close to the reef-edge, such that only a fraction of the remaining energy flux convergences. However in contrast to low wave heights it does transport sediment to the ECZ. The wave-generated flow that induces sediment transport is the result of the divergence in radiation stress by wave breaking, the wave-induced water level gradient and bed friction. During high tidal levels the set-up is small, but significant during MSL and low tidal levels. For high tidal levels and MSL the spatial erosion and sedimentation patterns are relative similar, but the intensity is larger during high tide. The conditions during low tidal levels are complex in the surf zone and need further study.

Figure 1 Hoskyn Islands, Bunker Group on the Great Barrier Reef, From: Bob Charlton (Lonely Planet Photographer)

The STRAINS Experiment: an overview

Saulo Meirelles, Delft University of Technology, s.meirellesnunesdarocha@tudelft.nl
Alexander Horner-Devine, University of Washington, arhd@u.washington.edu
Martijn Henriquez, Delft University of Technology, M.Henriquez@tudelft.nl
Julie Pietrzak, Delft University of Technology, J.D.Pietrzak@tudelft.nl
Alejandro J. Souza , National Oceanography Center ajso@noc.ac.uk

The STRAINS (STRAtification Impacts on Nearshore Sediment transport) experiment involved the deployment of two moorings and 3 instrumented frames along a transect off the Sand Engine's tip from February 11 2013 to March 07 2013. The experiment combines several projects. Two of these are science projects; the NEMO project (Nearshore Monitoring and Modelling) looking at inter-scale coastal behaviour of this coastal stretch; and the STW project (Sustainable ROFI's) that investigates the effect of Regions Of Freshwater Influence (ROFI's) on sediment transport. The other project is the MOS2 project between the Port of Rotterdam and Deltares that studies the impacts of the expansion of the Rotterdam harbour.

The STRAINS experiment was located ~10 km to the North of the mouth of the Rotterdam Waterway and was influenced by the Rhine ROFI, a tidally dominated river plume that extends along the Dutch coast. The Rhine ROFI plays a key role in the hydrodynamic circulation patterns along much of the coast and over the entire water column. The periodic stratification of the Rhine ROFI has been observed to affect the transport of the fine material and may also influence the coarser fraction. The overall objective of the experiment was to understand the role of the Rhine River plume on the regional sediment transport.

Moorings were deployed at two sites in 12 m and 18 m water depths, corresponding to 2 km and 6.5 km from the shoreline, respectively. Salinity, temperature, pressure and suspended sediment concentration (SSC) were measured at both sites using a combination of CTD (Conductivity-Temperature-Depth) and OBS (Optical BackScatter) instruments. Velocity was measured with a 600 kHz ADCP at each site. Wave statistics were measured with a Waverider buoy located 1 km to the southwest of the 12 m site. Moreover, an instrumented bed-frame (coined the 'NEMO Lander') was deployed on this same depth contour. Current profiles were measured with a downward-looking Aquadopp-HR that was mounted ~50 cm above the bed. Also, current profiles throughout the water column were recorded from an up-looking Aquadopp alternately with wave measurements. Near-bottom flow was also continuously measured using an ADV (Vectors).

The first results suggest that the plume dynamics played a key role on the cross-shore sediment exchange which showed differences between fines and sands.

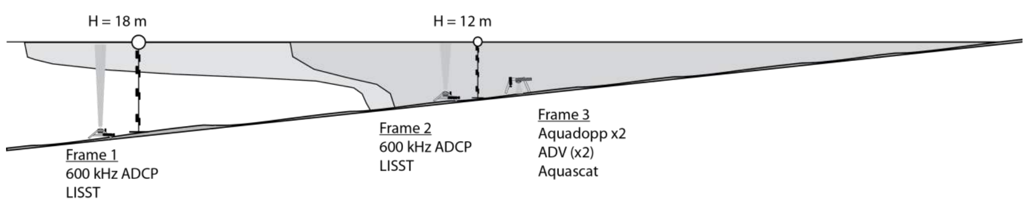


Figure 1 Sites and deployment configuration.

Middle shoreface sand transport under the influence of a river plume: a field observation

Saulo Meirelles, Delft University of Technology, s.meirellesnunesdarocha@tudelft.nl
Martijn Henriquez, Delft University of Technology, M.Henriquez@tudelft.nl
Alexander Horner-Devine, University of Washington, arhd@u.washington.edu
Julie Pietrzak, Delft University of Technology, J.D.Pietrzak@tudelft.nl
Alejandro J. Souza , National Oceanography Center ajso@noc.ac.uk

This paper presents field observations on the middle shoreface at the south-Holland coast. The observations are part of the STRAINS Experiment (STRAtification Impacts on Nearshore Sediment transport). The experiment was located ~10 km to the North of the mouth of the Rotterdam Waterway and was influenced by the Rhine ROFI (de Boer et al., 2006), a tidally dominated river plume that extends along the Dutch coast. The periodic stratification of the Rhine ROFI has been observed to affect the transport of the fine material (Simpson et al., 1993, Joordens et al., 2001) and may also influence the coarser fraction. The present study aims to elucidate the qualitative contribution of the net sand transport during the field observations.

An instrumented bed-frame (coined the 'NEMO Lander') was deployed in February 2013. The Lander was at a nominal depth of -12 m NAP. The NEMO Lander measured currents and waves during approximately 21 days. Current profiles were measured with a downward-looking Aquadopp-HR that was mounted ~50 cm above the bed. Current profiles throughout the water column were recorded from an up-looking Aquadopp alternately with wave measurements. Near-bottom flow was also continuously measured using an ADV (Vectors) at 8 Hz. Density were estimated from Conductivity-Temperature-Depth (CTDs) sensors mounted in a mooring deployed in the vicinity of the NEMO Lander location. Backscatter signal was corrected to a qualitative analysis of the sand concentration.

In general, the oceanographic conditions during the measurement favoured a net alongshore sand transport in the southward direction and the cross-shore net transport shoreward. Waves played a key role on the resultant of the transport direction. Stratification re-enforced the onshore direction. An inversion of the cross-shore net transport was observed. This could be attributed to pulses of fresh water related to the release of bulges of fresh water out of the Rhine ROFI. Figure 1 depicts a summary of the main findings.

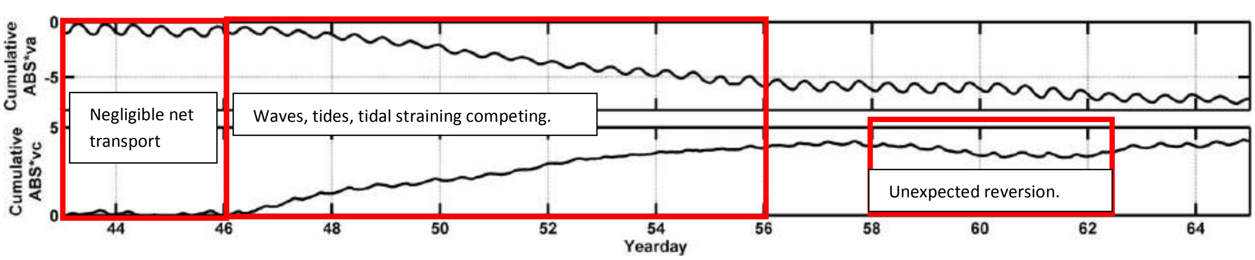


Figure 1 Net sand transport over the 21 days of measurement. Upper panel: alongshore net transport (negative gradient means southward). Lower panel: cross-shore net transport (negative gradient means offshore).

Bubble momentum plume as a mechanism for an early breakdown of the seasonal stratification in the northern North Sea

Janine Nauw, NIOZ, Texel, the Netherlands, Janine.Nauw@nioz.nl
Peter Linke, HZG-GEOMAR, Kiel, Germany. plinke@geomar.de
Ira Leifer, University of California, Santa Barbara, ira.s.leifer@gmail.com

The presence of a seasonal thermocline likely plays a key role in restraining methane released from a seabed source in the deeper water column, thereby inhibiting exchange to the atmosphere. The bubble plume itself, however, generates an upward motion of fluid, e.g. upwelling and may thereby be partially responsible for an early breakdown of the seasonal thermocline. Measurements at site 22/4b, located at (57˚55'N, 1˚38'E) in the UK Central North Sea, 200 km east of the Scottish mainland, where gas is still being released since a blow out in 1990, have been used to identify the generation of the seasonal thermocline, the depth of the upper mixed layer and its breakdown in autumn. Data derived from two landers, containing an Acoustic Doppler Current Profiler (ADCP) and a Conductivity Temperature Depth (CTD) sensor, were used to determine the mixed layer depth (MLD) and the breakdown of the thermocline. Mixing of upper layer fluid into the lower layer has been inferred from large amplitude variations in the near-bottom temperature observations. The ADCPs estimate velocities profiles in four beam directions using Doppler shifted frequency from acoustic pings sent out and received by four different transducers in a specific configuration. Besides that, the intensity of the backscattered sound per transducer is also recorded. Bubbles from the nearby plume contaminate the signal during part of the tidal cycle, but in bubble free periods, the MLD can be estimated using the acoustic backscatter signal as local maxima. Results show that the thermocline broke down between mid-October and early November, several weeks earlier than the breakdown of the thermocline in nearby/comparable areas, likely induced by bubble-induced downwelling at the site. The early breakdown of the thermocline was accompanied by multiple occurrence of a strong jetlike structure, associated with the seasonal tidal mixing front.

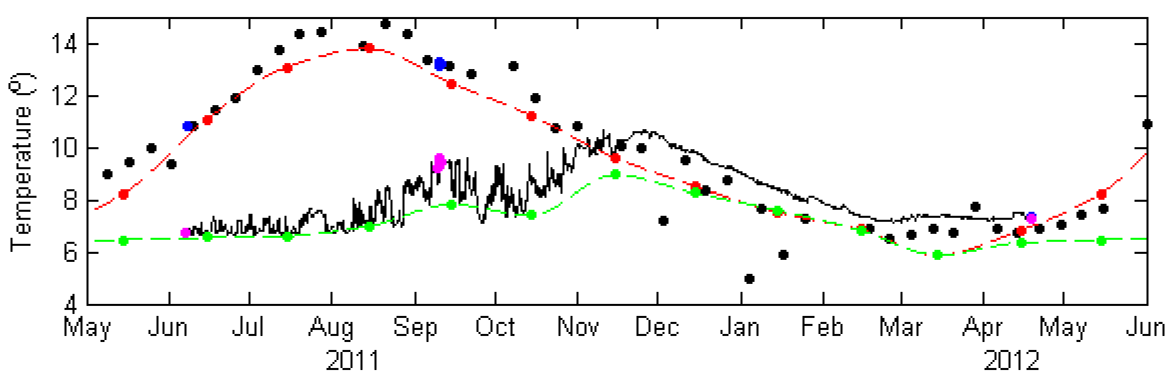


Figure 1 Time-series of the temperature (oC) on the lander (black drawn), TLB. Black dots represent the Sea Surface Temperatures (SST) at the location of the lander based on the 8 day composites of the MODIS Level 3 SST maps, TMS. Blue (magenta) dots represent surface (bottom) temperatures derived from CTD casts, TCTD. Red (green) dots connected with dashed lines are the climatological values for the temperature at the surface, TCS (near the bottom, TCM) at the location of the lander derived from the climatological values (Berx and Hughes, 2009).

Estimates of exposure times in the Wadden Sea with contrasting models

Janine Nauw, Netherlands Institute for Sea Research, janine.nauw@nioz.nl
Katja Philippart, Netherlands Institute for Sea Research, katja.philippart@nioz.nl
Matias Duran-Matute, Eindhoven University of Technology, m.duran.matute@gmail.com
Theo Gerkema, Netherlands Institute for Sea Research, theo.gerkema@nioz.nl

The vertical tide in the Wadden Sea causes an alternate flooding and drying of the intertidal flats, the duration of which is also affected by wind surges. To answer questions, such as the potential foraging time of waders, it is important to have spatio-temporal data of these exposure times.

In this study, we have compared two methods to determine the exposure times of tidal flats in the Dutch Wadden Sea. The first method is based on a triangulation of the sea level elevations measured at the tidal gauges surrounding the Dutch Wadden Sea following Rappoldt (in prep); in the second method model simulations with the General Estuarine Transport Model (GETM) are used (Duran-Matute, 2014). Both methods have their advantages and short-comings. The triangulation method uses *in-situ* measurements and therefore incorporates the effect of storm surges in a direct way.

Figure 1. SAR image of 2009-04-30,06:08 UTC

However, the method ignores the fact that the tidal wave experiences a phase difference across a tidal water shed and therefore between subsequent basins. The model output on the other hand carefully determines the propagation of the wave through the Wadden Sea and takes the phase difference into account. However, caveats arise from the way “drying” of tidal flats are taken into account, e.g. “dry” in GETM mean “below a certain threshold value”. Besides that, numerical modelling is quite expensive in terms of computational effort.

First results show that there is quite some correspondence between the methods for the western Dutch Wadden Sea, where tidal gauges are well-covered and density of intertidal flats is low. But distinct differences are found between the methods for the much shallower eastern Dutch Wadden Sea, where tidal gauge measurements are quite distant and intersected by one or more watersheds.
Verifications of the results will be done using a third set of data, such as Synthetic Aperture Radar (SAR) images as shown in Figure indicating the exposed and flooded areas in the Balgzand area and in the Eierlandse gat.

NatureCoast: an interdisciplinary approach to understanding sandy coasts

Timothy Price, VU University Amsterdam, t.d.price@vu.nl
Arjen Luijendijk, Delft University of Technology, A.P.Luijendijk@tudelft.nl
Vera Vikolainen, University of Twente, v.vikolainen@utwente.nl
Jaap van Thiel de Vries, Boskalis, j.v.thiel.de.vries@boskalis.com
Marcel Stive, Delft University of Technology, M.J.F.Stive@tudelft.nl

Sandy coasts are highly dynamic environments, governed by interactions of various physical, biological and societal processes. Waves, currents and wind, for example, are important environmental drivers for coastal morphodynamics. At the same time, these drivers affect ecological processes, with possible feedbacks to groundwater levels, nutrient dynamics and dune morphology. Besides these natural dynamics that constitute the coastal ecosystem, humans may influence this system, driven by the benefits they wish to obtain from the system and the societal dynamics involved. A common intervention in coastal systems is the nourishment of sand, of which the Sand Motor on the Delfland coast, The Netherlands, is an example with an unprecedented volume of 21.5 Mm^3. Our aim is to improve our predictive understanding of this type of sandy nourishment as an ecosystem, in order to apply it elsewhere.

With our research programme NatureCoast we have seized the opportunity to gather strategically important interdisciplinary knowledge from the Sand Motor, which forms a unique full-scale experiment. The programme includes 12 PhD projects, in which the key morphological, hydrological, geochemical, ecological and societal processes that govern the evolution and acceptability of this type of nourishments are studied (Figure 1). The innovative aspect of our approach lies in the integration of these research projects through interdisciplinary research questions. At the same time, we incorporate the wishes of public and private parties. These include the benefits they wish to exploit from the coastal system, such as protection against flooding by the dunes; so-called ecosystem services. In our work, we show that the concept of ecosystem services is useful to bridge the gap between the various research disciplines and parties involved.

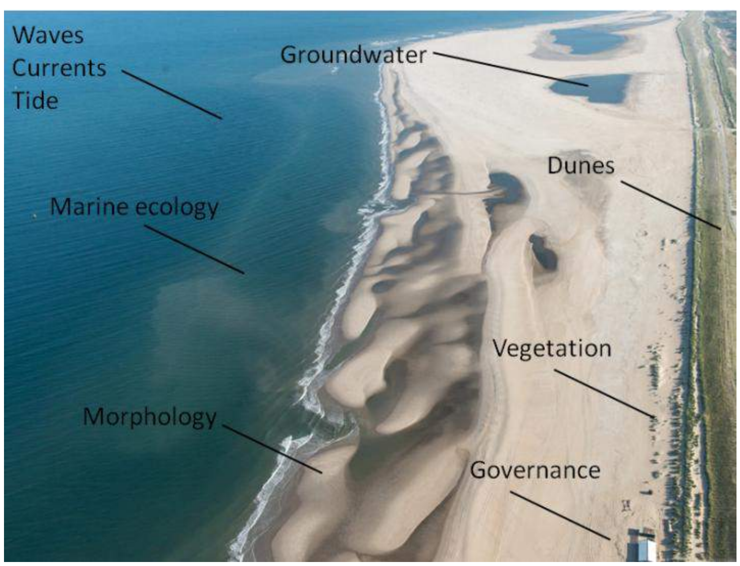


Figure 1. Different research disciplines at the Sand Motor

Swimmer Safety around Mega-Nourishments

Max Radermacher, Delft University of Technology, m.radermacher@tudelft.nl
Jaap van Thiel de Vries, Delft University of Technology, j.s.m.vanthieldevries@tudelft.nl
Marcel Stive, Delft University of Technology, m.j.f.stive@tudelft.nl

The Sand Motor (Stive et al., 2013) is an unprecedented large-scale sand nourishment, intended to counteract erosion along the Delfland coastal cell in the Netherlands. One of the main questions regarding this mega-nourishment is its impact on hydrodynamics and swimmer safety, which is studied in this PhD-research. The presence of such a large-scale perturbation can invoke several hazardous hydrodynamic processes, like tidal flow separation (Wengrove et al., 2013) and enhanced formation of rip currents (Smit, 2009).

Predictive insight in hazardous hydrodynamics can be obtained with operational models that can assist lifeguards in controlling risk levels during their daily operations.. However, providing these hydrodynamic models with up-to-date bathymetry is a necessity for sensible predictions, given the dynamic character of the nearshore morphology and its feedback to the hydrodynamics. To this end, bathymetries based on Argus imagery obtained by applying the cBathy-algorithm (Plant et al., 2008; Holman et al., 2013), have been imposed to the hydrodynamic model. The feasibility of this approach has been evaluated by comparing to model simulations with a groundtruth bathymetry.

It is found that although errors in the estimated bed levels are rather large, deviations in simulated currents are limited. Largest deviations reside around the shoreline, where cBathy based bathymetries are strongly biased from in-situ observations. Expanding remotely sensed bathymetries with shoreline mapping techniques (e.g. Aarninkhof et al., 2003; Uunk et al., 2010) will yield a big improvement and is currently investigated.

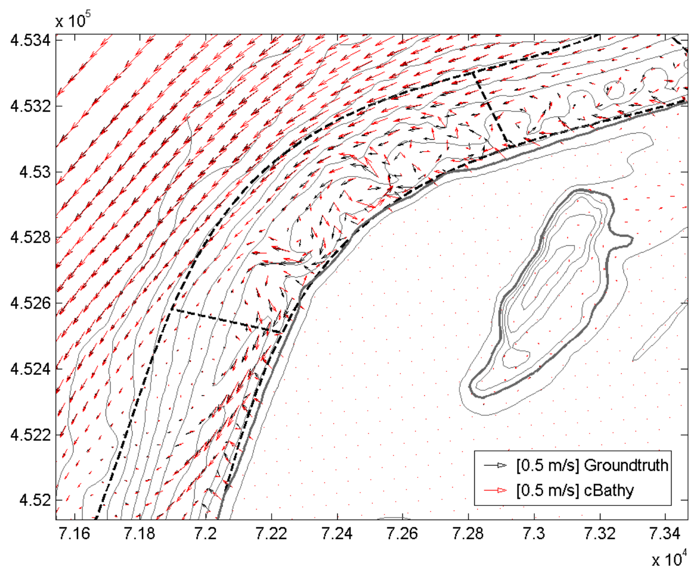


Figure 1. Comparison of nearshore currents at the tip of the Sand Motor computed on a groundtruth bathymetry (black arrows) and a bathymetry inferred from Argus imagery (red arrows) during low tide.

Breakdown of stratification and the distribution of SPM in the Rhine ROFI
Analysing two parallel transects

S. Rijnsburger[1,3,4], C. van der Hout[2], O. van Tongeren[3], W. Borst[3], B.C. van Prooijen[1], G. de Boer[4], J. Pietrzak[1]
1) Delft University of Technology; 2) NIOZ; 3) Port of Rotterdam; 4) Deltares
SRijnsburger@gmail.com

The Rhine River and the Meuse River discharge into the North Sea, forming the Rhine Region of Fresh Water Influence (ROFI) in front of the Dutch coast. A complex hydrodynamic system is generated, where strong tides interact with wind, waves and stratification. This complicates the distribution and dynamics of fine sediments. Proper understanding of the system is required to evaluate the effects of human interferences, like the dredging for Maasvlakte 2. In previous years more insight is gained into the interaction between the tide and the stratification by numerical modelling (de Boer et al., 2008). Furthermore, various measurement campaigns are carried out to determine the effect of dredging activities for Maasvlakte 2.

This study aims at unravelling the physical processes responsible for the dynamics in the Rhine ROFI by analysing a unique in-situ dataset. In October 2011 the Port of Rotterdam Authority and NIOZ sailed simultaneously on two parallel cross-shore transects, one near Egmond and one near Wijk aan Zee. The measurements took thirteen hours, both transects were sailed eight times. Salinity, temperature, SPM and velocities were collected. The dataset covers information over depth, time, cross- and alongshore direction, allowing analysis in four dimensions. The contribution of alongshore advection and straining is investigated with a simplified form of the three-dimensional Potential Energy Anomaly Equation (de Boer et al., 2008), influenced by wind, waves and tide.

Distinct differences between the two measured transects are found for the salinity distribution. The data indicate stronger stratification at the northern transect. This can be explained by the thinner fresh water plume more northwards. Therefore at the northern transect denser water is pushed onshore. The Potential Energy Anomaly analysis showed the relevance of alongshore advection for the onset and breakdown of stratification. Alongshore advection and wind seems to have a significant contribution to stratification.

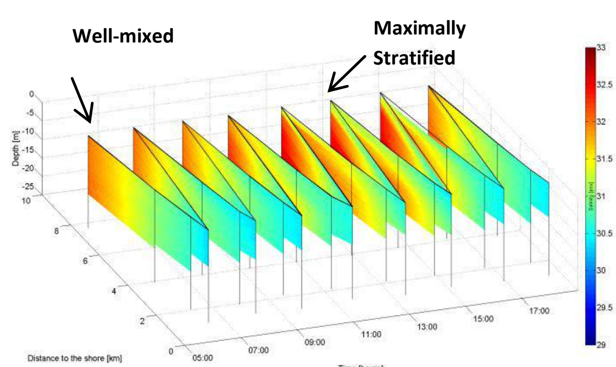


Figure. Salinity distribution during the measurements (northern transect). The figure shows the onset and breakdown of stratification in time. The Dark blue has a value of 29 PSU and red has a PSU of 33.

Figure. The two measured transects at the North Holland coast

Recent experiences with non-hydrostatic modelling of infragravity waves

Dirk Rijnsdorp, Delft University of Technology, d.p.rijnsdorp@tudelft.nl
Pieter Smit, Delft University of Technology, p.b.smit@tudelft.nl
Gerben Ruessink, Utrecht University, b.g.ruessink@uu.nl
Marcel Zijlema, Delft University of Technology, m.zijlema@tudelft.nl

Infragravity waves are surface gravity waves with periods ranging 25 to 200s which are found to be relevant for various topics that are of interest to coastal and harbour engineers. Therefore, it is important to be able to predict the infragravity wave conditions at an arbitrary nearshore location. Traditionally, numerical models based on a phase-averaged approach are used to simulate the nearshore evolution of infragravity waves (e.g. van Dongeren et al., 2013). Alternatively, phase resolving models based on Bousinessq-type equations or a non-hydrostatic approach can be used. Phase resolving models pursue to resolve all relevant scales and processes, but are computationally demanding compared to the more approximate phase-averaged approach, and have not been widely used to study the nearshore evolution of infragravity waves.

Here, we present an overview of recent experiences with simulating the nearshore evolution of infragravity waves using the non-hydrostatic wave model SWASH (Zijlema et al., 2011). Various wave conditions have been considered, including a laboratory experiment of bichromatic waves (Noorloos, 2003) and random waves (Boers, 1996), and field measurements of short-crested waves (Ruessink et al., 2001). The results of the model comparison against the laboratory measurements were previously published in Rijnsdorp et al. (2014).

In general, the model predicted and measured bulk wave parameters are in good agreement, which demonstrates that SWASH is capable of simulating the nearshore transformation of infragravity waves. An example of the comparison is depicted in Figure 1.

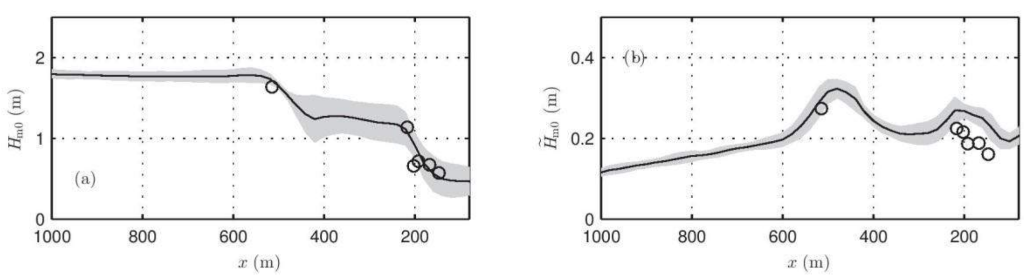


Figure 1. Example of the cross-shore variation of the short-wave height (panel a), and infragravity wave height (panel b), for the field experiment of Ruessink et al. (2001). The markers indicate the measured values, the solid lines the predicted alongshore mean values, and the gray shade the alongshore variability of the predicted parameter.

SMARTSEA: Safe navigation by optimizing sea bed monitoring and waterway maintenance using fundamental knowledge of sea bed dynamics

P.C. Roos, University of Twente, p.c.roos@utwente.nl
A.A. Verhagen, TU Delft, a.a.verhagen@tudelft.nl
T.A.G.P. van Dijk, Deltares & University of Twente, t.a.g.p.vandijk@utwente.nl
S.J.M.H. Hulscher, University of Twente, s.j.m.h.hulscher@utwente.nl
R.F. Hanssen, TU Delft, r.f.hanssen@tudelft.nl
L.L. Dorst, Netherlands Hydrographic Service ll.dorst@mindef.nl,
N.A. Kinneging, Rijkswaterstaat, niels.kinneging@rws.nl
R. Bijker, ACRB, romke.bijker@acrb.nl

Safe navigation in the North Sea calls for accurate nautical charts and adequate maintenance of the waterways to the ports of e.g. Amsterdam and Rotterdam. However, the North Sea is a shallow sea with a highly dynamic seabed, mostly caused by the behavior of bed forms known as tidal sandwaves. Hence, smart surveying and maintenance policies are required. A risk-based approach is the step forward for the responsible authorities. However, setting up such policies is unfeasible unless we gain more knowledge on (i) sandwave dynamics, (ii) waterway morphodynamics and (iii) the combined interpretation of such knowledge and bathymetric data. This is the goal of SMARTSEA, a multidisciplinary project with three subprojects P1, P2 and P3. Subproject P1 aims to improve our understanding of sandwave equilibrium heights and shapes, by modeling the influence of storm events and wind waves on sandwave dynamics. This will be done by means of complex morphodynamic modeling, supported by bathymetric data. By developing new data analysis techniques, P2 investigates the feedback among waterways, the associated maintenance operations and the surrounding marine environment (including megaripples). Combined with modeling results (also from P1), we will develop a tool that helps to optimize maintenance strategies. In P3, a geodetic algorithm will be developed for a risk-based survey policy. Next to the innovations of each subproject, the project overall's innovation lies in the fact that we make a big step towards a probabilistic approach in bathymetric surveying, waterway maintenance and, hence, in safe navigation. A user group has been formed representing Rijkswaterstaat, Netherlands Hydrographic Service, Deltares, engineering consultancy firms and the Flemish Hydrographic Service. A workshop will be held to disseminate the project's results to a wider scientific, governmental and engineering community. In addition to applications on the Netherlands Continental Shelf (also including risk analysis for marine spatial planning), successful utilization will also provide opportunities abroad.

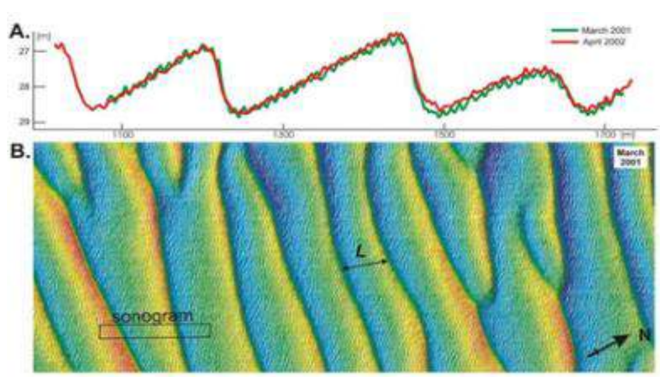


Figure 1. Sandwave field in the North Sea. Top: migrating profiles; bottom: plan view (Van Dijk & Kleinhans 2005).

Aeolus meets *Poseidon*: wind-blown transport on wave-dominated beaches A Vici project

Gerben Ruessink, Utrecht University, b.g.ruessink@uu.nl

Coastal dunes are vital to protection of the hinterland against marine flooding. Storm-wave processes have therefore been studied intensively, resulting in well-developed dune-erosion models for use in scientific and applied studies. In contrast to erosional processes, dunes may grow by aeolian (wind-blown) transport. This natural replenishment of the eroded sand ensures coastal safety by allowing dunes to grow vertically with sea-level rise and is crucial to the dunes' high biodiversity. Our understanding of meso-scale (seasons-years) beach sand supply to the dunes is largely qualitative and conceptual. This prevents us from answering scientific and applied questions on beach-dune interaction and quantifying coastal evolution (i.e., storm impact and aeolian recovery) under natural and human-induced changes in wave and wind conditions. The overarching aim of the recently awarded NWO-STW Vici project "Aeolus meets Poseidon" is to develop a robust, efficient and accurate predictive model, applicable in both scientific and applied studies, of annual sand supply to dunes.

The moisture content of the beach surface is particularly influential in aeolian-process dynamics. Its high temporal and spatial variability lies at the core of complex process interactions, geomorphic feedback and scale issues that defy accurate prediction of aeolian sand supply to the dunes. Through integrated data-modelling research, three PhD projects aim to unravel this complexity. **PhD1** will focus on quantifying and modelling the temporal and spatial variability in moisture content. **PhD2** will study aeolian bedforms, called sand strips (Figure 1), which arise through moisture – transport feedback. As very visual manifestations of aeolian transport, sand strips may hold crucial clues regarding which wind events control meso-scale sand supply. **PhD3** will explore the actual magnitude of aeolian transport, including its windward growth and its dependence on factors such as turbulence in the wind field and beach characteristics. A 5-year (0.8 fte) **postdoc** will transform the detailed research findings into an aggregated meso-scale sand supply model and apply it, in close co-operation with end users, in a dune-revival (Wandelande Duinen) and coastal-safety (Hondsbossche and Pettermer Zeewering) project. The Vici project will start in late-summer or early-autumn 2014.

Figure 1. A 15-year long data set of semi-hourly Argus images of Egmond beach, often displaying aeolian bedforms termed sand strips (lower left of image), forms the key data set for PhD2.

How to measure morphologic evolution near a mega-nourishment? Inter-comparison of four survey techniques

Jantien Rutten, Utrecht University, j.rutten@uu.nl
Gerben Ruessink, Utrecht University, b.g.ruessink@uu.nl

During the last decades our understanding of processes driving bed level changes and the resulting morphologic evolution in the nearshore zone has improved tremendously because of an ever-increasing availability of data combined with numerical modelling. At the same, human measures are increasing in scale, implying a need for surveys that span a spatially extensive area (~ a few km^2) and that are performed regularly (~ daily to monthly) for a long (~ years) time. An example of such an extensive study area is the Sand Motor mega nourishment.Due to the nourishment design the Sand Motor shows a high variety in morphology, active on small and large spatial and temporal scales. Large wave-formed morphologic features, such as a spit and sandbars, evolve on the time scales of days to years. Also non-marine wind formed features develop such as embryonic dunes near the old dune foot. Thus next to the difficulty of the wide study area of the Sand motor, the high variety in morphology on different timescales strongly complicates monitoring. Therefore, the aim is to combine smartly three different remote sensing techniques with a traditional technique and evaluate their applicability to monitor morphologic evolution in a rapidly changing environment. We consider traditional echo-sounding measurements as in-situ. The remote sensing techniques we use are optical imaging with the Argus video system, microwave imaging by X-band radar, and mobile terrestrial laser scanning (MTLS).

We will compare the four techniques by studying (1) digital terrain models and their temporal evolution and (2) the aggregated parameters sandbar crest and shoreline position. Preliminary results indicate that the depth inversion algorithm, cBathy, with default settings provides reliable bathymetric maps during low energetic conditions. In shallow water cBathy overpredicts water depth (~0.1m). This might be solved by correcting for non-linearity in wave celerity.

Argus derived sandbar position depends strongly on the tidal level, with a 30m cross-shore shift for 1m decline in water level. When accounting for this shift, the Argus sandbar positions follow the in-situ position closely.

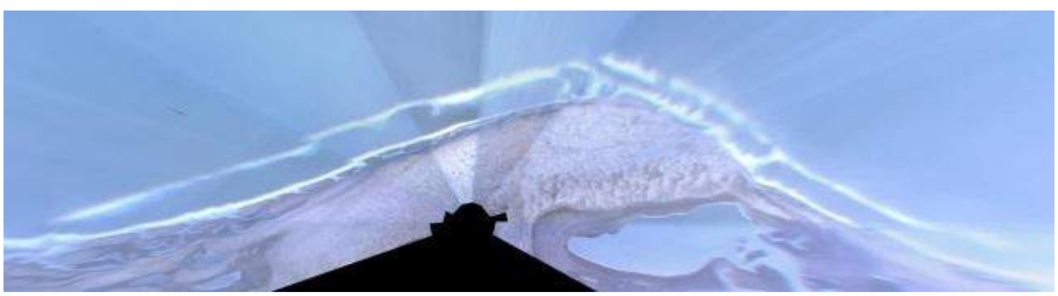


Figure 1. Argus plan view 10min time-exposure image of the Sand Motor at 31 Oct 2013.

Suspended particulate matter transport in the Dutch Wadden Sea: results from numerical simulations.

Maximiliano Sassi, NIOZ, Royal Netherlands Institute for Sea Research, Texel, Netherlands
Matias Duran-Matute, NIOZ, Royal Netherlands Institute for Sea Research, Texel, Netherlands
Gerben de Boer, Deltares, Delft, Netherlands
Ulf Grawë, IOW, Leibniz Institute for Baltic Sea Research, Warnemünde, Germany
Theo Gerkema, NIOZ, Royal Netherlands Institute for Sea Research, Texel, Netherlands
Thijs van Kessel, Deltares, Delft, Netherlands
Katherine Cronin, Deltares, Delft, Netherlands

The Dutch Wadden Sea (DWS) is a semi enclosed basin connected to the North Sea by a series of tidal inlets and composed mainly of tidal flats and sea gullies. The DWS is of high ecological importance and it is a dynamic area subject to regional relative sea level rise. For intertidal areas to continue to serve as feeding ground for migratory birds, a net import of sediment is required. Observations of sediment transport are crucial but provide only scarce information in space and time. To estimate the net influx of suspended sediment into the DWS, realistic high resolution three dimensional numerical simulations of hydrodynamics and suspended sediment transport have been carried out using the General Estuarine Transport Model (GETM).

Hydrodynamic simulations with GETM show residual circulation in the DWS is mainly governed by the tides, the fresh water discharge from several sluices and wind variability. It is expected that the transport of suspended particulate matter (SPM) is governed by the same factors, too, in combination with sediment sink and source terms. For validation of the hydrodynamics, the results were compared against tidal gauges, temperature and salinity at a fixed station, and the volumetric flux rate through the Marsdiep inlet obtained from an acoustic Doppler current profiler (ADCP) attached to a ferry.

SPM transport is modeled for several sediment classes spanning from mud to coarse sand. Each class is defined by the critical shear stress and the settling velocity. Results show a clear net import of SPM through the Marsdiep inlet, which is in agreement with preliminary ferry-based observations of SPM. First estimates of the total sediment fluxes through the Marsdiep and Vlie inlets are presented together with an analysis on their variability and sensitivity to the external forcing. Of particular importance is the net export of SPM during storms and the role of storms on sub-tidal variability.

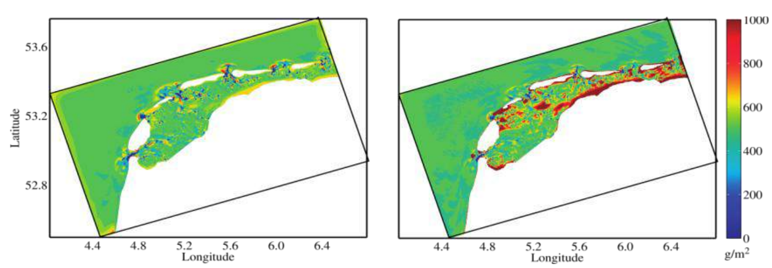


Figure. Sedimentation maps in the DWS as obtained from the numerical simulations. Left: sediment class with settling velocity of 1 mm/s. Right: sediment class with settling velocity of 2 mm/s.

Application of nearshore bathymetry from video for rip current predictions on The Dutch Coast

Leo Sembiring, Ap van Dongeren, Gundula Winter, Maarten van Ormondt,
Christophe Briere, Dano Roelvink,
l.sembiring@unesco-ihe.org

In this work we present an approach to simulate and predict the occurrence of topographically-controlled rip currents by making use of process based models in combination with video-derived bathymetries. For the Dutch Coast, a model system named CoSMoS has been built (Van Ormondt et al., 2012), where predictions of waves and water levels are provided on the surf zone scale model domain. To this end, having an accurate and up to date bathymetry is necessary for the CoSMoS to provide accurate predictions in the nearshore zone. Here, the nearshore bathymetry will be obtained using video techniques: Beach Wizard (BW, Van Dongeren et al., 2008) and CBathy (CB, Holman et al., 2013). Surveyed bathymetry obtained using jet ski will used for validation of the methods. For the nearshore model, XBeach is used. The model is validated using measurement of Lagrangian mean flow data, obtained using floating drifter deployment mounted by GPS device (Winter et.al, 2012). Furthermore, to assess the applicability of video-derived bathymetry for the purpose of rip current predictions, the nearshore model will be simulated using video-derived bathymetry and the result will be compared with those based on the jetski survey simulation. Bathymetry estimates from Beach Wizard and CBathy show a good agreement with jet ski data. Features like sandbars are well produced, as well as bar-channel features near the shoreline.

When the bathymetry from Beach Wizard is used in the XBeach nearshore model, results show the high potential use of such bathymetry when forecasting rip currents, as the results show fairly good agreement with results from reference model (using jet ski bathymetry), in terms of maximum offshore-directed velocity. Moreover, in forecast mode, the flows obtained from the model still resemble adequately the presence of rip currents as they are in hindcast results using reference model. This shows that the model and video-derived bathymetries from video are potential tools to be used for rip current predictions for the Dutch Coast.

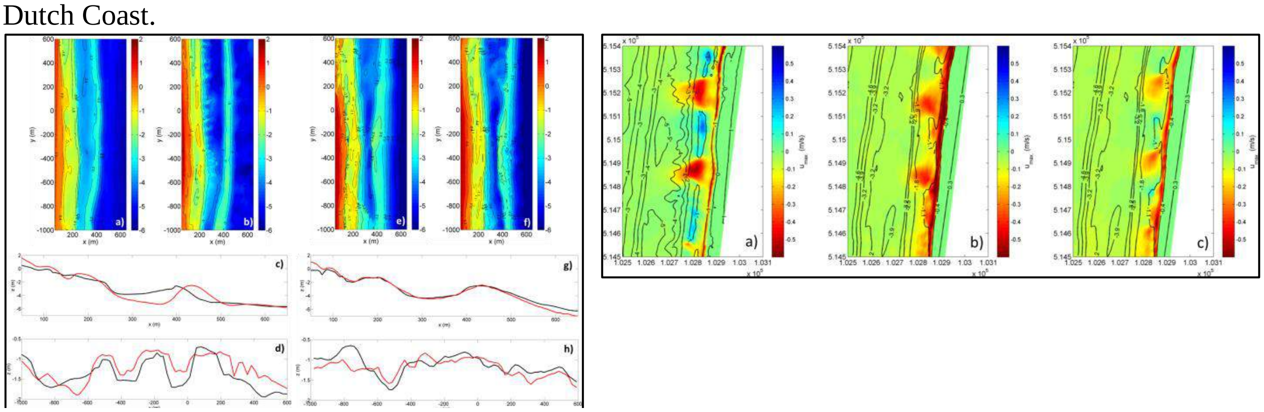


Figure 1. Left: Bathymetry estimate from video compared with jet ski survey. a) BW estimate, b) jet ski bathymetry; e) CB result, f) jet ski bathymetry; c) and g): cross shore transect red line is jet ski bathy and black line is estimate; d) and h) alongshore inner bar-crest transect (~x = 180 m). Right: Maximum cross shore component velocity for three different model set up, a): reference model, b): using BW bathymetry, c): using BW bathymetry and wave boundary from CoSMoS forecast.

Directional spreading effect on wave transformation and wave overtopping in a shallow foreshore

Tomohiro Suzuki, Flanders Hydraulics Research, tomohiro.suzuki@mow.vlaanderen.be
Corrado Altomare, Flanders Hydraulics Research, corrado.altomare@mow.vlaanderen.be
Toon Verwaest, Flanders Hydraulics Research, toon.verwaest@mow.vlaanderen.be
Marcel Zijlema, Delft University of Technology, m.zijlema@tudelft.nl

For the actual designs for coastal defenses such as construction of storm walls and implementation of beach nourishment, an appropriate estimation of wave boundary condition is necessary. The wave boundary conditions are typically estimated at toe of dike using numerical models (e.g. SWAN). However these approaches do not always represent wave transformation in the field, especially in shallow foreshores where low-frequency waves would be generated due to wave breaking and wave-wave interaction. These processes are key issues to understand for the appropriate estimation of wave overtopping.

In general, more low-frequency energy is generated when directional spreading is small and the generated low-frequency waves give more flux landwards. For example, Guza and Feddersen (2012) shows that the directional spreading effect influences wave run-up significantly. It indicates that the directional spreading effect would influence wave overtopping discharge as well.

In this study, the influence of the directional spreading on the wave transformation in shallow foreshore and wave overtopping over a dike are investigated by the SWASH model (Zijlema et al., 2011), which shows a good representation of wave transformation in a shallow foreshore and wave overtopping over the dike (Suzuki et al., 2011;2012). The SWASH model is based on the non-linear shallow water equations with a non-hydrostatic pressure model developed at the Delft University of Technology. The computational time is not demanding due to the depth averaged assumption and the parallel computation capability.

The result of the wave overtopping discharge estimated by the SWASH model shows that the wave overtopping discharge reduces significantly by changing the directional spreading.

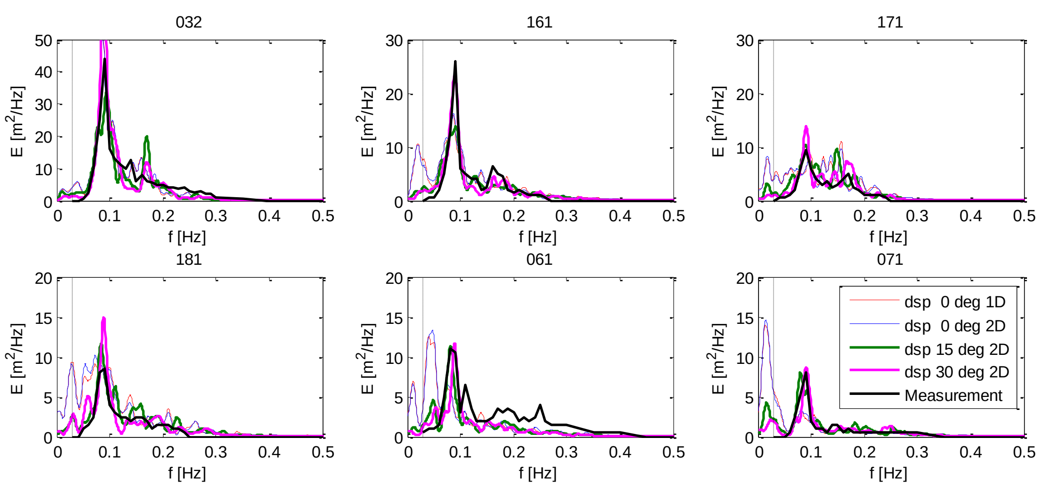


Figure. Wave spectrum estimated by SWASH using different directional spreading

The depth dependent short-term variability in transport along a fine sediment plume in the Southern North Sea

Meinard Tiessen, Janine Nauw & Theo Gerkema
NIOZ Royal Netherlands Institute for Sea Research (meinard.tiessen@nioz.nl)

Research over the past decade has revealed the seasonal changes to a fine sediment plume that extends across the Southern Bight of the North Sea. This was mainly based on satellite imagery, and therefore lacked the depth dependent sediment dynamics. As part of the FOKUZ project at the NIOZ, we conducted a scientific cruise to study the sediment dynamics over depth across the Southern Bight. Preliminary findings suggest a significant net transport at the boundary between different water masses. Additionally, also a strong impact of short-term weather conditions was observed.

The East Anglia plume is a fine sediment plume that mainly occurs during autumn and winter. Sediment from this plume originates from river inflow, cliff erosion along the eastern shores of the UK and re-suspension from the seabed. This plume has recently been studied extensively via satellite images, showing strong seasonal and monthly changes in the intensity and the geographic distribution [Eleveld et al. 2008; Pietrzak et al. 2011]. Field studies concerning the East Anglia plume generally only contained measurements at a coarse temporal interval and over a wide area [Dyer and Moffat. 1998].

From March 6th until March 15th 2013 a scientific cruise was conducted to measure the short-term (over a tidal cycle) morpho- and hydrodynamic variability, using continuous ADCP measurements as well as CTD casts. Measurements were conducted along two transects spanning the East Anglia plume (Fig. 1). A patchy plume was observed under calm conditions prior to the cruise (Fig. 1): Preliminary findings along Transect 1 also showed low near-bed sediment concentrations at the boundary between English Channel and Central North Sea water (Fig. 2 *left*). Subsequent stormy conditions resulted in a rapid increase in sediment concentrations over the entire water column, along with a change in net transport direction of the sediment. Along transect 2, a contrast between satellite imagery and field measurements existed, as stratification reduced the near-surface sediment concentration (Fig. 2 *right*).

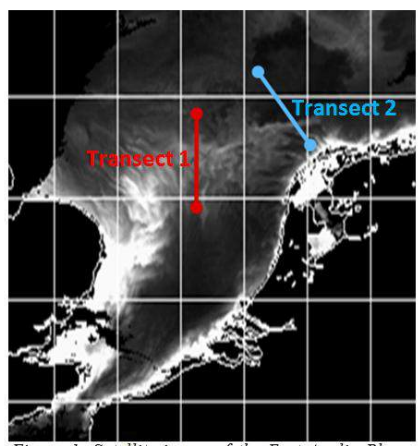


Figure 1: Satellite image of the East Anglia Plume (in white), provided by Marieke Eleveld, IVM, Free University of Amsterdam. Superimposed are the two transects studied during the FOKUZ cruise.

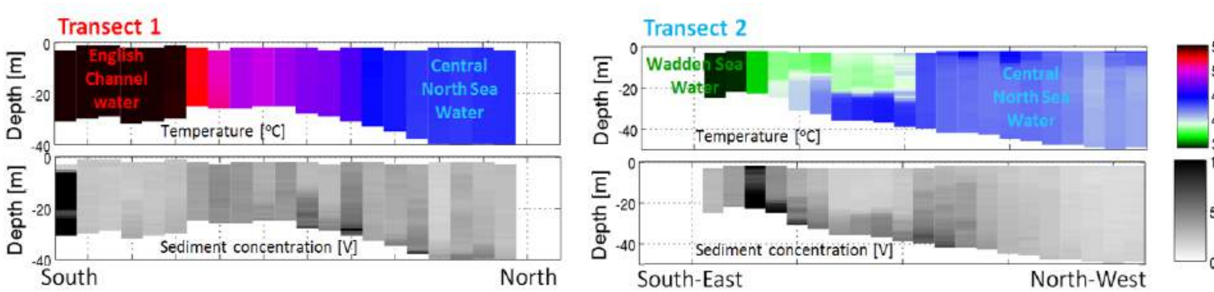


Figure 2: Hydro and morphodynamic conditions along both transects. The distribution for Transect 1 (left) shows the that the highest sediment concentrations (bottom) can be found on the boundary between the English Channel water and the Central North Sea water masses (top). For Transect 2 (right), the East Anglia Plume (bottom) coincides with the transition between colder Wadden Sea water and the Central North Sea water masses (top), with the sediment plume continuing below the thermocline.

The impact of inter-annual changes to hydrodynamic conditions on the drift and settlement success of plaice eggs and larvae

Meinard Tiessen, Theo Gerkema, Piet Ruardij & Henk van der Veer
NIOZ Royal Netherlands Institute for Sea Research (meinard.tiessen@nioz.nl)

The life cycle of European plaice (*Pleuronectes platessa*) consists of various life stages: Spawning in the middle of the North Sea and in the English Channel, pelagic egg and larval stages and a juvenile stage bound to shallow water nursery grounds (such as the Wadden Sea). Spawning grounds are connected to juvenile nursery areas via (semi-)passive drift governed by residual currents. Field data from the Balgzand nursery area have shown a strong variability in the number of plaice juveniles settling there over the years [Van der Veer et al., 2009]. Inter-annual variability in current patterns and water temperatures are expected to be strongly linked to the settlement success.

Here, we investigated this using a coupled numerical model: GETM produced hydrodynamic data (Fig. 1a) that was fed into a particle tracking routine (GITM), that computed the trajectories for a million particles (representing pelagic plaice) (Fig. 1b) for each of the years 1994 - 2005. Focus was on the physical processes, while biological contributions such as behaviour (vertical migration) and mortality were excluded from the simulations.

Results showed a strong inter-annual variability in the drift direction, drift duration and settlement success of the particles settling in (for instance) the Western Wadden Sea (Fig. 2c, 2d). These results can be ascribed to changes in the dominant wind direction and water temperature (Fig. 2a, 2b) [Tiessen et al., 2013].

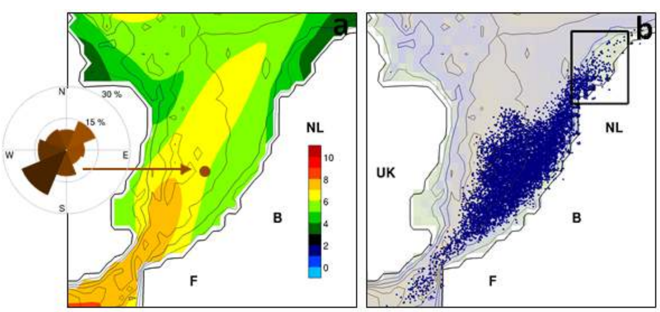


Figure 1: Input and output of numerical model simulating the drift and development of plaice eggs and larvae. (a) Surface temperature for February (2001); inset shows wind direction and intensity at the brown dot. (b) Origin of particles settling in the Western Wadden Sea (depicted as the black box).

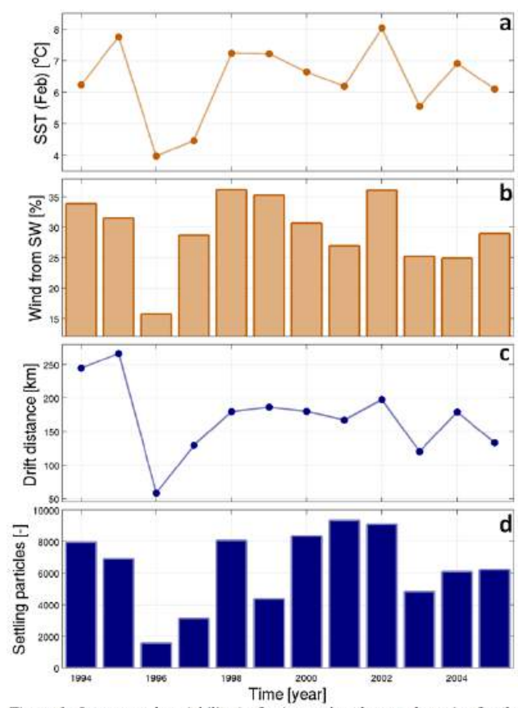


Figure 2: Inter-annual variability in forcing and settlement dynamics for the Western Wadden Sea. (a) SST at the Southern Bight station for February. (b) Wind intensity from the SW, as percentage of the total. (c) Mean drift distance for settling particles. (d) Number of settling particles per year.

Individual wave celerity in the surf zone

Marion Tissier, Universiteit Utrecht, m.f.s.tissier@uu.nl
Gerben Ruessink, Universiteit Utrecht, b.g.ruessink@uu.nl

In the last decade, remote-sensing based methods have become increasingly popular to monitor coastal evolution. These methods often rely on the estimation of wave celerity from video-images, which is used as a proxy to retrieve water-depth. The efficiency of these methods depends on the accuracy of the parameterization of celerity. However, if wave celerity is relatively well-understood before breaking, it is still not the case in the surf zone. In particular, significant discrepancies between celerity predictors and measurements still remain in the most inner part of surf zone. In such shallow water, (long) infragravity waves are often energetic and can significantly affect short-wave dynamics. The associated modulations in water depth and velocity are expected to induce local changes in short-wave celerity, but have not been investigated in previous studies.

In this study, we investigate the effects of infragravity waves on short-wave celerity. This work is based on the analysis of two complementary small-scale laboratory datasets, investigating short- and long-wave propagation over beaches of constant slope. Individual wave celerity is calculated based on a simple crest-tracking method. The intra-wave variability of celerity is then related to the transformation of the underlying long waves.

Figure 1a shows the cross-shore evolution of individual wave celerity for a representative case. The divergence of celerity starts in the breaker zone, where some waves persistently travel faster than others. This is related to the increase of water level (and velocity) induced by the infragravity waves (Fig. 1b,c). These differences of celerity ultimately leads to bore-bore capturing processes. Estimates of celerity accounting for infragravity-wave induced variations of water level and velocity outperform classical linear estimates based on the mean water depth. In general, our results suggest that the effects of infragravity waves should be accounted for to obtain reliable predictions in the inner surf zone.

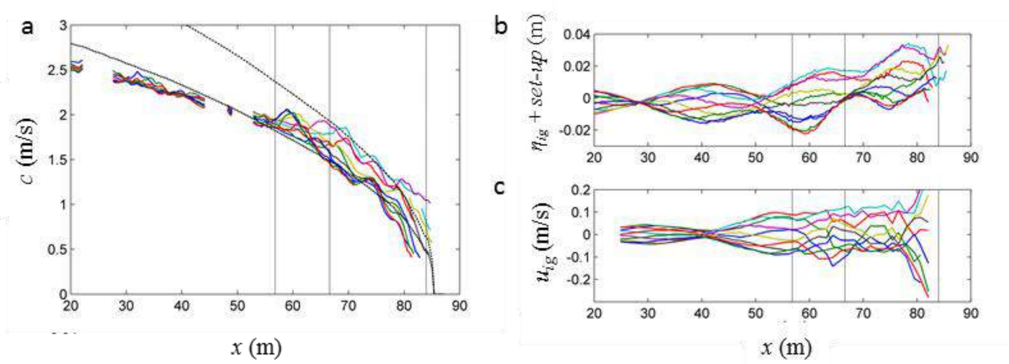


Figure 1. (a) Cross-shore evolution of individual wave celerity for 10 consecutive waves (one wave group); (b) and (c): local variations of water level and velocity induced by the infragravity waves; Each coloured line represents the evolution of the variable for a given wave. The three vertical lines indicate, from left to right, the outer breakpoint, the inner breakpoint and the start of the swash zone.

Improving wave-driven cross-shore sand transport modelling in Delft3D using the new SANTOSS transport formula

Roelof Veen, University of Twente, r.veen-1@student.utwente.nl
Jebbe van der Werf, Deltares, jebbe.vanderwerf@deltares.nl
Jan Ribberink, University of Twente, J.S.Ribberink@utwente.nl
Joep van der Zanden, University of Twente, j.vanderzanden@utwente.nl

Morphological modelling systems like Delft3D are used to understand coastal morphodynamic and predict erosion and sedimentation. These models are important tools for coastal managers, for example for harbor design and nourishments. This study aims to assess and improve the way Delft3D models wave-driven cross-shore sand transport by implementing and testing the recently developed SANTOSS (Van der A et al., 2013) near bed transport model.

For implementation, the SANTOSS model is extended so it could be applied to coastal conditions. The first addition was to determine sand transport in current dominant flow. The second addition was adding a method to determine the wave velocity and acceleration skewness. The third was applying a longitudinal slope effect to the critical shear stress for the calculation of sand transport on slopes. The near bed transport of the SANTOSS model in Delft3D is combined with the current related suspended sediment transport of Van Rijn (2007).

The Delft3D assessment was done by modelling an erosive and accretive case of the LIP experiments (Roelvink and Reniers, 1995). The results of the near bed transport modelled with the new SANTOSS model are promising for the accretive case as the new model preforms better than the current state-of-the-art Van Rijn (2007) transport model (Figure 1). For the erosive case, the SANTOSS model preforms better than Van Rijn (2007) offshore but worse onshore of the breaker bar.

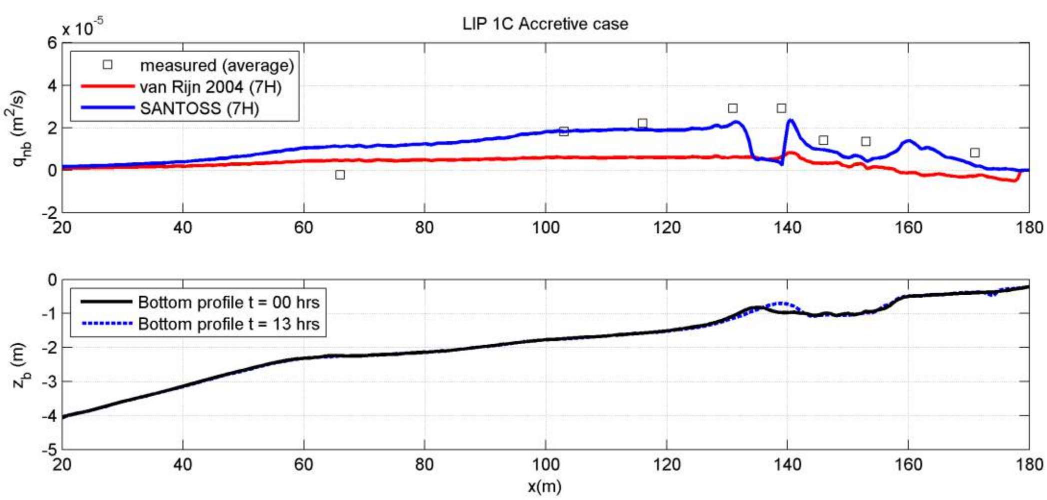


Figure 1. Bottom profile and near bed transport for the accretive beach conditions.

Discharge distribution and salt water intrusion in the Rhine-Meuse river delta network

Nynke Vellinga, Utrecht University and Wageningen University, n.e.vellinga@uu.nl
Maarten van der Vegt, Utrecht University, m.vandervegt@uu.nl
Ton Hoitink, Wageningen University, ton.hoitink@wur.nl

Tidal river networks form complex environments in which both river and tidal processes play an important role in determining the hydrodynamics. Some research has been conducted on single-junction tidal rivers, but for tidal networks the available research is limited. This paper aims to take a first step in the understanding of the development of hydrodynamics of tidal river networks by analysing flow velocity data in the Rhine-Meuse tidal network in the western Netherlands. This network is a heavily engineered system in which both hydrodynamics and morphology are in large part determined by anthropogenic influences.

13-hour measurements of flow and salinity have been conducted at twelve different tidal junctions, at an exceptional low-flow event, thereby providing good insight in flow and salinity processes under relatively high tidal influence.
When analysing the data throughout the tidal river network, three main features are seen in flow patterns:

- At seaward stations, a two-layered flow pattern is seen as a result of density gradients. Moving upstream, the vertical layering disappears
- Upstream junctions display higher degrees of horizontal flow differentiation than downstream junctions. The shift from vertically to horizontally differentiated flow is gradual.
- In general tidal effects decrease when moving upstream, but local effects and differences between branches are important in determining the precise flow pattern

A preliminary analysis of the salinity measurements and salinity fluxes at the most seaward junctions shows that the contribution of the salt water flux to the total water flux quickly decreases moving upstream, although the exact distribution of salt water depends on the stage of the tide and local effects.
Future research will focus on the on the role of salinity and density-driven gradients on flow and discharge distributions on tidal junctions, combined with three-dimensional modelling of the area in order to further understand the underlying processes.

Morphological and ecological effects of multiphase large nourishment at the coast of Ameland, The Netherlands

Tommer Vermaas (tommer.vermaas@deltares.nl), Harriëtte Holzhauer, Edwin Elias (Deltares), Rena Hoogland, Petra Damsma, (Rijkswaterstaat)

Since 1990 the Dutch coastline is maintained by nourishments on the shoreface and beach. Typically, shoreface nourishments have a volume of 400-450 m^3/m and are reapplied frequently (in 3 to 5 year intervals). On the coast of Ameland between 2010 and 2011 a much larger nourishment of 600 m^3/m was applied. Due to contract agreements the nourishment was executed in multiple phases and spread over several years. This larger nourishment with flexible nourishment scheme is supposably more cost efficient. In this research we analysed the morphological and ecological response of this innovative nourishment.

The morphologic response is analysed using two-yearly bathymetrical measurements performed by Rijkswaterstaat. From this data, sedimentation-erosion maps, cross-shore profiles and volume calculations are determined. For the ecology a six year study program has been set up. In the first three years (2010-2012) three areas have been monitored: the direct impact area of the nourishment, the area directly next to the nourishment (Fig. 1, yellow areas) and a reference area on Schiermonnikoog. At each area samples along transects have been taken at morphological entities (e.g. troughs and crests of bars). Sediment characteristics and fauna were analysed.

The nourishment shows a similar morphological response as the previously applied regular nourishments in this area. Like regular nourishments, it reacted instantaneously by forming into new (multiple) breaker bars. All breaker bars extended in eastward direction. Changes in sediment volume indicate an eastward transport of the nourished sediment. The volume changes after the nourishment are in the same order as the long term changes, -0.5 million m^3/year. The nourishment is therefore expected to yield a longer lifespan than regular nourishments. The benthic recolonisation of the nourished areas corresponds with the time frame in which a phase of the nourishment is performed. The benthic community is affected in the surrounding area of the nourishment, up to a distance of 1.5 km in eastward direction and cross shore just offshore the nourished area. After the nourishment opportunistic species appear quickly, but the benthic community was not recovered completely in 2012. With the results of the monitoring campaign conducted in 2013 we hope to obtain a more final picture of the benthic recovery in his area.

In the final two years of the ecological study program the focus is more on the variability in benthic communities during a year in respect to new nourishment.

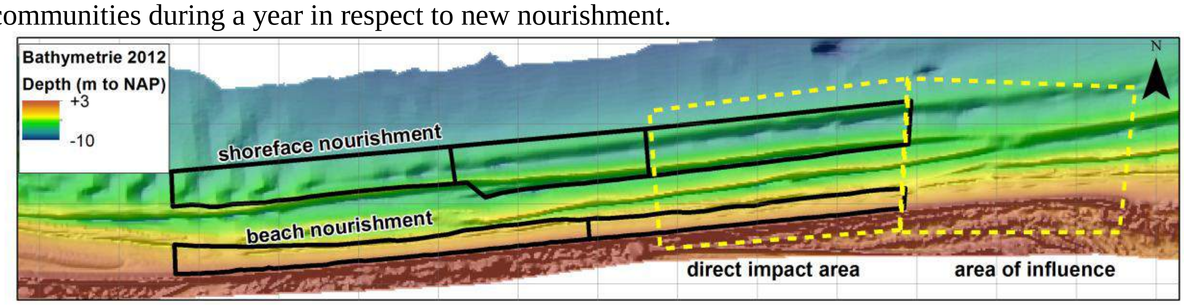


Figure 1. Morphology of 2012 with the locations of nourishments with phases (black) and ecological study areas (yellow)

Short-term morphological evolution around the Eierlandse Dam

Pieter Visser, Deltares, pieter.visser@deltares.nl
Arjen Luijendijk, Deltares, arjen.luijendijk@deltares.nl

After decades of coastal erosion in the north-west area of the Island of Texel, the shore-normal 'Eierlandse Dam' was built in 1995. The dam, situated in the outer delta of the Eierlandse Gat tidal inlet, resulted in a remarkable short-term morphological development of the adjacent coast. Four years following completion of the dam, large sedimentation rates were measured on both sides of the dam. On the updrift (south) side, sedimentation was predicted as a result of the blocked alongshore sediment transport. However, on the downdrift (north) side of the dam, no sedimentation was predicted. Today, almost two decades later, it remains unclear which processes contributed to the sediment accumulation on the north side of the dam. The increased functionalities and capabilities of the present-day modelling software enable a re-evaluation of the morphological processes around the dam in particular, and gain insights in the complex short-term morphodynamics in this area.

To capture the driving mechanism(s) of the net sediment transport towards the northern area of the Eierlandse dam, the state-of-the-art process-based computational model Delft3D is applied. To investigate the influence of various conditions and processes on the morphological development around the dam, simulations are performed with various boundary conditions, model processes and formulations.

After calibration and validation of the model, one-year morphological predictions show large similarities with the observed bed level development at both sides of the dam. The ebb tidal currents seem responsible for the large amounts of sedimentation at the north side of the dam, predominantly during spring tides when flow velocities and tidal excursion increase. The ebb tidal channel 'Robbengat' is located along the northern tip of the Island of Texel and curves from the inlet around the Eierlandse dam. The Robbengat channel has been eroding by strong ebb tidal currents since 1985. The eroded sediments of the channel are transported by the flow towards the outer delta. Before the channel curves, the flow is partly deflected towards the northern area of the Eierlandse dam. The flow enters a shallow area and decelerates, resulting in deposition of sediment.

This conclusion rejects the conclusions drawn by previous studies regarding the same area, where complex hydrodynamics such as eddy forming and spiral flow in the channel bend were drawn as possible causes of the sedimentation.

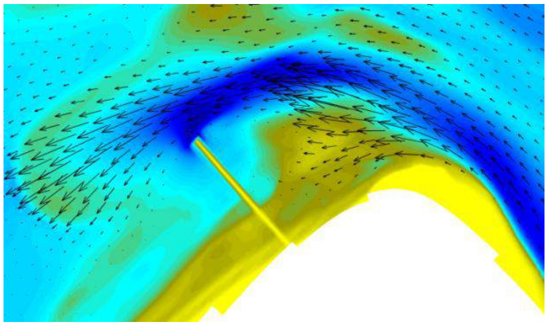



Figure. Left: Areal view of the Coast of Eierland (From: https://beeldbank.rws.nl);Right: Sediment transport pattern as a result of ebb-currents, predicted by Delft3D

A Multiple Grid Approach for Accurate and Efficient Morphodynamic Simulations

Nicolette D. Volp, N.D.Volp@tudelft.nl, Bram C. van Prooijen, B.C.vanProoijen@tudelft.nl
Julie D. Pietrzak, J.D.Pietrzak@tudelft.nl,Guus S. Stelling, G.S.Stelling@tudelft.nl

The simulation of the morphological evolution of coasts and tidal areas faces many challenges. One of those is how to deal with the gap between the short time scales related to the hydrodynamics and the much longer time scales related to the morphological response. The computational cost for morphodynamic simulations is largely determined by the cost of the hydrodynamic part. The computational cost increases significantly when increasing the resolution to improve the accuracy of the model. Thanks to new measurement techniques like LIDAR, such high resolution bathymetry data is available. However, the strong increase in computational cost is a limiting factor in the application of this data. To increase the accuracy, without increasing the computational cost, a multiple grid approach is proposed here.

The multiple grid approach uses three different grids. The hydrodynamics are simulated with the subgrid-based model which is described in Volp et al. (2013). Computations are made on a coarse grid, accounting for high resolution bathymetry and roughness data on a subgrid. The model automatically accounts for wetting and drying on subgrid level. The model provides accurate results even for very coarse computational grid cells. The computational cost of the hydrodynamic part can be reduced with more than a factor 10 with a minimum loss in accuracy.

The morphodynamic computations are made on the *morphodynamic* grid, that can be as fine as the high resolution subgrid. A physics-based interpolation method is introduced to determine the water levels and velocities on the higher resolution grid. The development of a dune is shown in Figure 1 for a traditional model. Such models are not capable of resolving the proper development for these coarse resolution grids. Figure 2 shows the same dune only simulated using the multiple grid approach. Even for these coarse resolution grids, accurate results are obtained. Although the accuracy of the results is increased significantly by modelling the morphodynamics on a much higher resolution, the computational cost is only slightly affected.

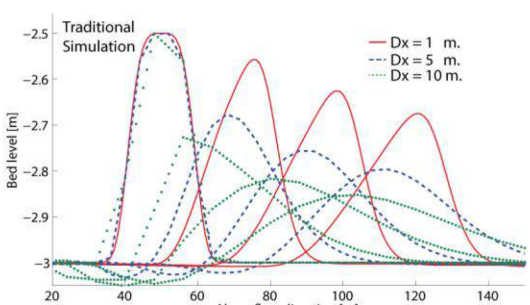


Figure 1. The propagation of a hump with a traditional single grid for various grid resolutions.

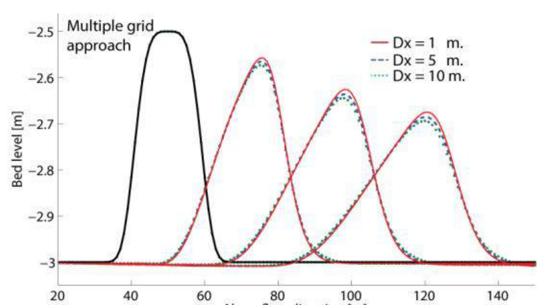


Figure 2. The propagation of a hump using the multiple grid approach. The indicated grid size refers to the coarse grid resolutions. The subgrid resolution is 1m.

Intra-tidal variability of the vertical current structure in the western Dutch Wadden Sea

Jurre de Vries, Herman Ridderinkhof and Hendrik van Aken, NIOZ Royal Netherlands Institute for Sea Research,
jurre.de.vries@nioz.nl

Residual currents are a crucial component in the estuarine dynamics, determining the transport pathways of fish larvae, plankton, nutrients, pollutants and total suspended matter. *Jay and Musiak* [1996] were the first to suggest that intra-tidal variations in the vertical current structure might be important in determining the residual circulation patterns. Other studies [e.g. *Stacey et al.*, 2001; *Burchard and Hetland*, 2010] have supported this hypothesis. Recently, lateral processes have been shown to influence the vertical current structure of alongstream velocity and hence the residual circulation [e.g. *Lerczak and Geyer*, 2004; *Burchard and Schuttelaars*, 2012]. Therefore to better understand the residual circulation patterns in the western Dutch Wadden Sea, it is first crucial to understand the processes that determine the vertical current structure. The aim of this study is to understand the processes that determine the vertical current structure in the Marsdiep basin.

Long-term velocity measurements are presented which were collected during three different seasons at one single location in an estuarine basin, the Marsdiep. These data are used to investigate the processes that determine the variability of the vertical current structure, in combination with simplified model runs using the one-dimensional water column model GOTM (http://www.gotm.net/).

The two main findings of this study are that the complex bathymetry at the study site seems to produce an intra-tidal asymmetry in near-bed velocities and secondly that cross-stream processes strongly modify the current structure during late flood. Near-bed velocity and the bed roughness are greater during ebb than during flood. The GOTM simulations suggest that vertical mixing during ebb is sufficient to destroy vertical stratification generated by classical tidal straining. The cross-stream current during late flood generate vertical stratification and drive an early reversal of the flood current near the surface.

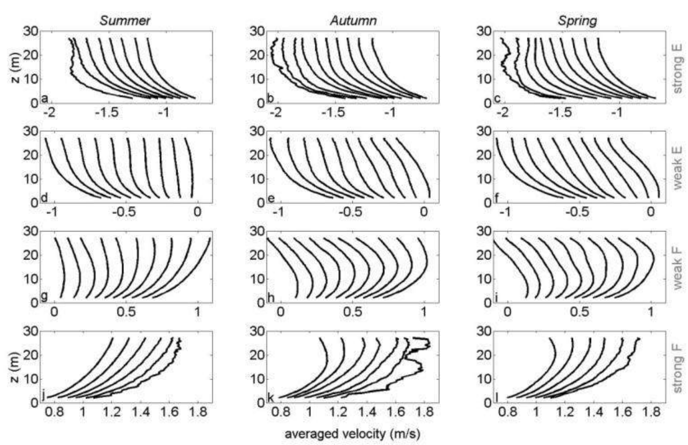


Figure. Example of the variability in vertical current structure.

Early results of high resolution topographic measurements in the Zandmotor/Nemo domain.

Sierd de Vries, TUDelft , Sierd.devries@tudelft.nl
Matthieu de Schipper, TUDelft,, M.A.deSchipper@tudelft.nl
Martijn Henriquez, TUDelft, M.Henriquez@tudelft.nl

This paper presents early results of a study on the sediment budget on the Delfand coast including the Zandmotor/Nemo domain. During 1 year we have collected (630!) morphological transects using Jetski and ATV along an 18 km alongshore domain (see the left panel of the Figure). The morphological data covers beach and foreshore. These data are collected bi-monthly and allows for a detailed study on sediment budgets. Both the spatial and temporal scale of these measurements are unprecedented.

At this stage we have made a budget calculation for each of the profiles. The middle panel of the Figure 1 shows changes in sediment volume (ΔV) at each of the measured locations during a period of one year. The effects of the zandmotor are clearly visible where at the tip of the zandmotor at (109 km) there is significant erosion and at the sides of the zandmotor there is significant accretion.

Using an Exner equation an estimation can be made of the aggregated alongshore transport (Q):

$$Q(x,t) = -\int \frac{dV(x,t)}{dt} dx$$

The right panel of the Figure 1 shows the estimated aggregated alongshore sediment transport when the transport at the south boundary (at 117 km alongshore) is assumed 0. It is shown that significant gradients in aggregated alongshore transport exist in de zandmotor area.

Data is available from a total of 8 bi-monthly surveys to date. Using this data we aim to gain new knowledge on transport gradients and the sediment budget for this coastal section.

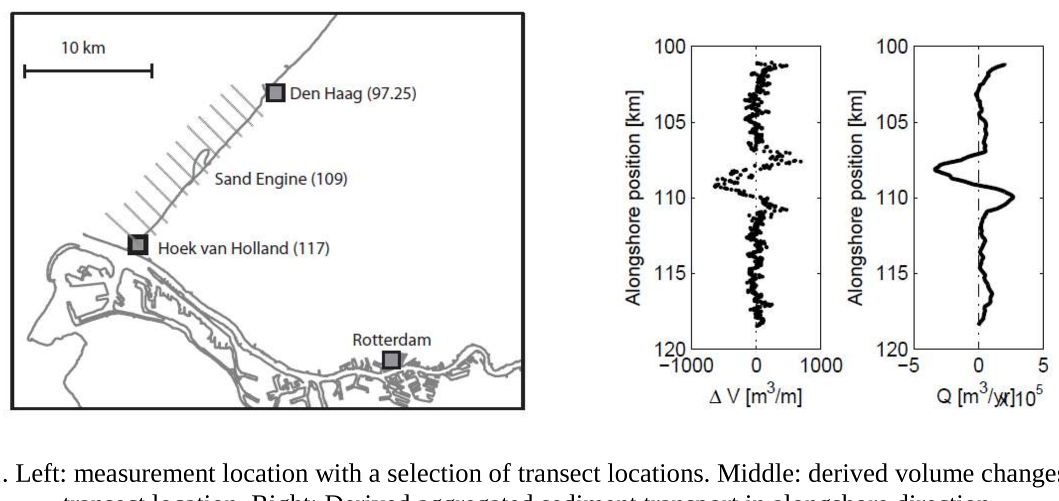


Figure 1. Left: measurement location with a selection of transect locations. Middle: derived volume changes at each transect location. Right: Derived aggregated sediment transport in alongshore direction.

An innovative way to track aeolian sediment transport patterns by using Argus video system.

Lianne van der Weerd, Universiteit Twente, a.j.vanderweerd@utwente.nl
Kathelijne Wijnberg, Universiteit Twente, k.m.wijnberg@utwente.nl
Suzanne Hulscher, Universiteit Twente, s.j.m.h.hulscher@utwente.nl

Coastal dunes are important for coastal safety. To maintain this natural means of coastal protection on the longer term, it is important to have predictive insight in the aeolian transport processes that naturally supply the dunes with sand from the beach. At present, such insights are insufficient. A first step forward is to better observe and quantify the actually occurring spatio-temporal variability in aeolian transport across beaches. In this study, we investigate how automatically collected video imagery can be used to track aeolian sediment transport patterns over a nourished beach surface.

The study site is the 'Sand Motor' mega nourishment (21 Mm^3 of sand) at the Dutch coast. An Argus video system, consisting of 8 cameras mounted on a 40 meter high tower in the middle of the Sand Motor, collects snapshot and time-exposure images every 30 minutes. These images show aeolian sediment transport patterns, such as streamers and aeolian bed forms (Figure 1a).

Preliminary results show that the movement of sand patches and aeolian bed forms can be tracked across consecutive images (Figure 1b). Not only can the images be used to obtain qualitative information – movement or not – but it also seems feasible to measure their migration speed and direction during aeolian transport events.

Gained knowledge about aeolian sediment transport patterns is expected to lead to improved insight in the contribution of intermittent aeolian processes to longer term sand supply towards the dunes. Next research steps will be to verify remote sensing results with ground truth data and to apply the methodology of tracking aeolian sediment transport patterns to several storms.

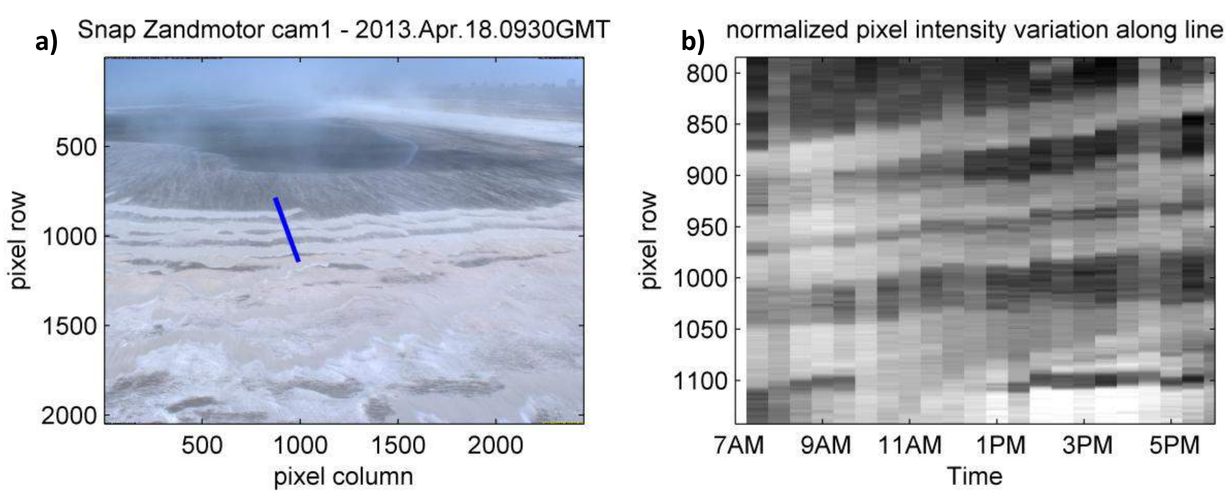


Figure 1. Tracking aeolian sediment transport patterns using video images. a) Snapshot image of Sand Motor. Blue line indicates pixel array over which the bedforms are tracked. b) pixel time stack showing (grayscale) pixel intensity in time over the pixel array. Light areas show dry sand bodies.

Co-designing Coasts using natural Channel-shoal dynamics (CoCoChannel)

Kathelijne Wijnberg[1](k.m.wijnberg@utwente.nl), Jan Mulder[1,4], Mick van der Wegen[2], Jill Slinger[3], Suzanne Hulscher[1], Dano Roelvink[2], Alma de Groot[5],Ali Dastgheib[3], Roshanka Ranasinghe[2], Edwin Elias[4], Petra Goessen[6], Quirijn Lodder[7]
[1]University of Twente, [2]UNESCO-IHE, [3]Delft University of Technology, [4]Deltares, [5]IMARES-Wageningen UR, [6]Hoogheemraadschap Noorderkwartier, [7]Rijkswaterstaat

Recently, the CoCoChannel project was granted funding by NWO-ALW under the *Building with Nature* call, as part of the collaboration between NWO and Top consortium Knowledge and Innovation Delta technology (Topsector Water).

This project aims at developing the knowledge required for the co-design of Building-with-Nature (BwN) type interventions in barrier island - inlet systems. 'Co-design' stands for a collaborative design approach, in which the eventual design of a BwN solution is the product of the network of scientists, engineers and stakeholders, and its social dynamics. Therefore, this project not only aims at increasing the knowledge on the dynamics of inlet systems and the adjacent coast, but also on the role of natural systems understanding in the process of co-designing BwN solutions with stakeholders.

Three subprojects have been defined that link through nested scale aspects in the geoscience part of the problem, and through cross- and trans-disciplinary aspects in the co-design part of the study (Figure 1). These three subprojects are:

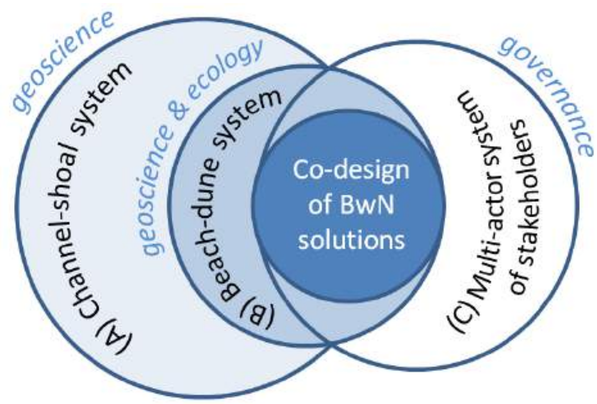
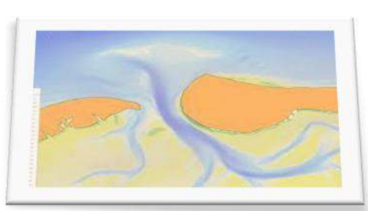


Figure 1. Graphic representation of the set-up of the CoCoChannel project.

A - Morphodynamics of channel-shoal patterns on an ebbtidal delta (project leader Unesco-IHE)
B - Linking Building-with-Nature type interventions in channel-shoal systems to sub-aerial impacts on the beach-dune system (project leader University of Twente)
C - Co-designing nature-based interventions in Coastal Systems (project leader TUDelft)

The project involves 3 PhD positions in total, and the foreseen starting date is mid-2014.



Morphological development of the Ameland inlet/Boschplaat in the Dutch Wadden Sea

Pim Willemsen, University of Twente, p.w.j.m.willemsen@student.utwente.nl
Tommer Vermaas, Deltares, tommer.vermaas@deltares.nl
Suzanne J. M. H. Hulscher, University of Twente, s.j.m.h.hulscher@utwente.nl

The eastern tip of the Island Terschelling (Boschplaat) has been eroding significantly over the last decades. The loss of valuable nature (such as Cupido's Polder) has raised the question whether this erosion will continue in the future. Historical data show a cyclic development of the morphology of the Ameland inlet and the adjacent island tips (having a period of 50 to 60 years). As part of this cycle the Boschplaat grows seaward and retreats (Israël, 1998).

In this research we aim to acquire more insight in the morphological state of the Boschplaat. Are we still in the eroding part of the cycle and how long will this last? We aim to answer this question by analysing and interpreting the morphological development of the Ameland inlet. Five different methods to determine changes in the sediment budget of coherent morphological units are developed.

The five methods of sediment budget analysis include the analysis of: aggregated grids, differences in surface determined by height intervals, polygons, the development of morphological units including sediment budgets, allocation and deformation and a combination of the previous methods. The penultimate method uses contour lines to determine (non-arbitrary) the morphological units, which can be followed through time. The last method uses positive and negative sediment budgets to automatically create coherent areas.

Using the new methods, the tidal channels in the inlet have been characterized separately, based on reference contour lines. The channel next to the Boschplaat (the Boschgat) shows a north-westward movement from 1971 to 1989, however it shows a slight south-eastward movement since 1999 (Fig. 1). The volume of this channel fluctuates, and is not showing a decrease. The channel situated in the east (the Borndiep) shows a westward movement in the most recent years and a decrease in volume.

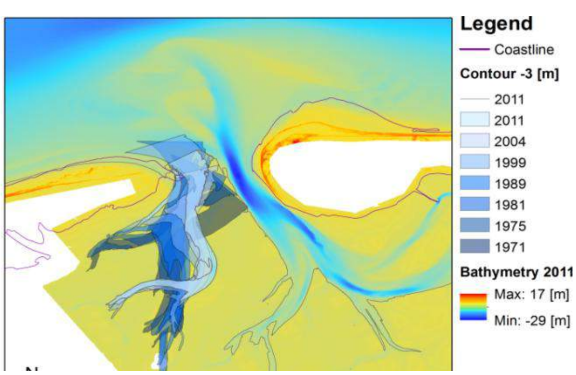


Figure 1. Development of Boschgat, Ameland inlet (development of morphological units)

The decrease in volume of the Borndiep and the relative stable volume of the Boschgat give the indication that the cyclic behaviour as described by Israël (1998) is not yet continuing. However, the direction in which the two channels are migrating might indicate that the system will change into a one-channel inlet. This is an indication of the continuation of the cyclic behaviour, in contradiction to the volume development of the channels.

The effect of climate change on dune erosion in the Netherlands

Renske de Winter, Utrecht University and KNMI, r.c.dewinter@uu.nl
Gerben Ruessink, Utrecht University, b.g.ruessink@uu.nl

Large parts of the Netherlands are protected against marine flooding by wind-blown dunes. These dunes are occasionally eroded by a combination of high storm waves and a severe water (surge) level. It is expected that, due to climate change, mean sea level will rise, which increases the overall surge level. Modeling of future North-Sea wave climates has also indicated that the angle of storm-wave incidence θ (with respect to shore normal) may change this century. Here, we discuss the effect of sea level rise (SLR) and wave angle on dune erosion, leaving, as projected, offshore wave heights and periods unaltered.

In our analysis, we used the dune erosion model XBeach as calibrated for a dune-erosion event that took place at Egmond aan Zee in January 2012. Representative cross-shore profiles of Egmond and of Noordwijk were used to set-up two area models with alongshore-uniform bathymetry. Based on the KNMI'14 and IPPC AR5 sea level estimates, we ran XBeach with SLR varying from 0 (current situation) to 150 cm, all with the current design (1:10.000) wave conditions for Egmond and Noordwijk, respectively, and θ = 0°. For SLR = 0, 40 and 80 cm we also ran simulations with θ = 11.25, 22.5 and 33.75°.

The predicted erosion volume under the current design conditions are about 335 m^3/m and 235 m^3/m at Egmond and Noordwijk (Figure 1: left panel), respectively, which is about the same as can be deduced from earlier large-scale laboratory experiments. Moreover, we found a linear relation between the surge level and erosion volumes at both sites. An increase in θ also resulted in an increase in erosion volume (Figure 1: right panel). Note that an increase in erosion volume from θ = 0° to 22.5° is equivalent to an about 40 cm rise in sea level.

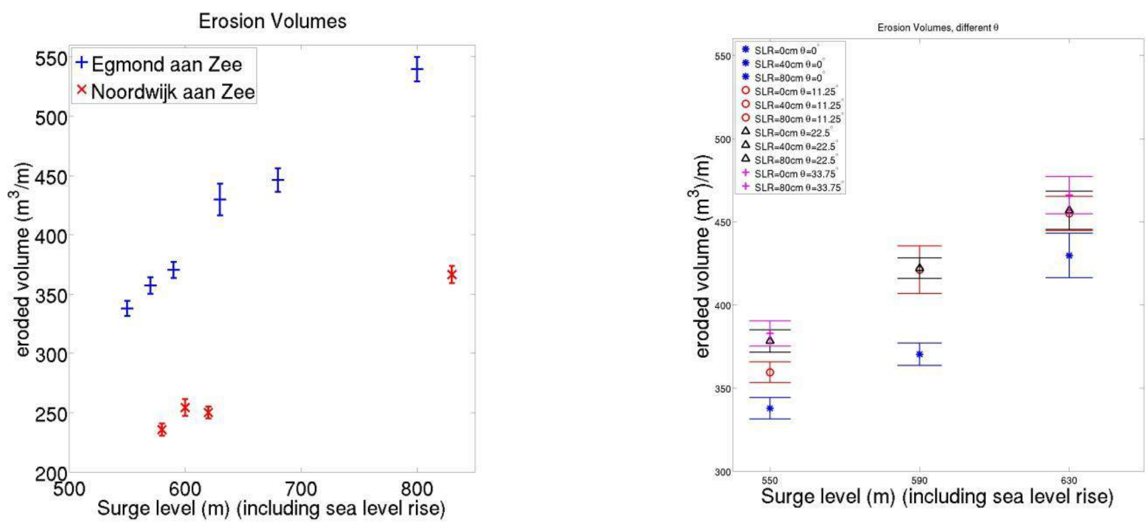


Figure 1. Left panel: Erosion volume versus surge level, including SLR, at Egmond and Noordwijk. (right panel) Erosion volume versus surge level, including SLR, for θ = 0°, 11.25°, 22.5° and 33.75° at Egmond. Error bars in both panels are indicative of alongshore variation in predicted erosion volume.

SPM versus *Ensis directus* in the Dutch coastal zone

R. Witbaard, rob.witbaard@nioz.nl
G.C.A. Duineveld, gerard.duineveld@nioz.nl
M.J.N. Bergman, magda.bergman@nioz.nl

There is concern about the effects of increased amounts of suspended mud due to coastal maintenance works along the Dutch coast. This zone is inhabited by a dense population of *Ensis directus* which has become ecologically important as food for fish and birds. Potentially growth and production of this species is retarded because of high amounts of mud. At the same time *E. directus* might influence mud dynamics and transport processes. With field measurements we tried to unravel this interaction.

From 2010 to 2012 a measurement platform (lander) was deployed at 10m depth off the coast of Egmond to measure transport of mud in the near-coastal zone and to study interactions between environmental conditions, mud and *E. directus*. Attention focused on behavior, growth and burial of mud by this species. Hereto we performed *in situ* experiments on silt burial and valve gape.

The data collected during the deployments of the measurement platform showed a negative effect of elevated SPM levels on the valve gape of *E. directus.* Maximum valve gape decreases with higher SPM levels. Although this suggests that their filtration rate is reduced the growth and production of this population is not different from populations elsewhere (Wadden Sea, German Bight). Our observations on silt burial suggest that in quiet weather conditions *E. directus* facilitates the burial of mud into the sediment. Observations on fecal pellets and literature data on pseudo-faeces production suggest that the dense *Ensis* population along the Dutch coast significantly influence the dynamics and transport of suspended matter (SPM).

Our results show that it is unlikely that growth and production of *E. directus* in the coastal zone is retarded because of maintenance works. Highest densities are found where SPM levels are highest and observations suggest that *Ensis* might influence near bottom mud dynamics and transport.

Figure. Fecal pellets of *Ensis directus* modify dynamics and transport of SPM in the Dutch coastal zone. (Detail of pellets, inset; *Ensis* shell end amid of pellets)

Sand transport process measurements around an evolving breaker bar

Joep van der Zanden, University of Twente, j.vanderzanden@utwente.nl
Jan S. Ribberink, University of Twente, j.s.ribberink@utwente.nl

Sand transport formulations form a main component of morphodynamic models, and are therefore essential tools for coastal engineers. Although various sand transport models are available, they all encounter difficulties when it comes to sand transport in the near-shore region and in particular the breaking zone. The cause of this is that the sand transport processes induced by wave breaking are not yet understood in sufficient detail. With a recently finished new series of measurements in a large-scale wave-flume, using innovative instruments to obtain accurate data, we hope to improve our understanding of the wave-breaking effects on sand transport. The obtained dataset includes both process measurements and net transport rates (profile evolution) and can hence also be used for validation of morphodynamic models.

The experiments were conducted in the large CIEM wave flume at UPC, Barcelona, from October 2013 to January 2014. Main instruments were deployed from a measuring frame that was horizontally and vertically mobile, and included a Vectrino Profiler and an Acoustic Concentration and Velocity Profiler (ACVP) for near-bed sediment fluxes, and an Acoustic Backscatter Sensor for concentration profiles higher in the vertical (Figure 1, left). Moreover, two CCM tanks for sheet-flow measurements were buried below the bed and an additional two ACVP's were deployed from the wall. We used regular waves (H=0.85 m, T=4 s) that were breaking on a horizontal test section, consisting of medium-grained sand, and we measured at various locations around the evolving breaker bar (Figure 1, right).

First results show the formation of a large breaker bar and breaker trough at the beginning of the test section. Further examination revealed that this evolution could be explained by sand coming from both the offshore and onshore direction. Likely explanations are that prior to breaking, velocities are strongly acceleration-skewed which drives an onshore sand transport. After breaking, the transport in the surf-zone is offshore-directed due to a strong undertow.

During next weeks, we will continue analyzing the new dataset and focus more on the other instruments. In particular, we will study the near-bed sediment transport processes with a particular interest in the expected wave-related suspension fluxes resulting from wave breaking.

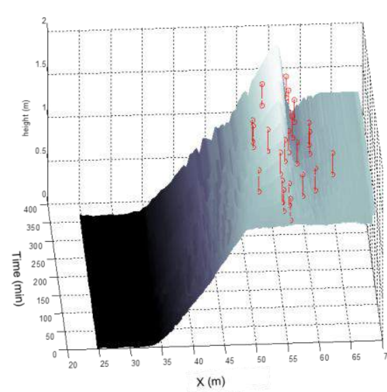


Figure 1. Left: instrumental set-up on mobile measuring frame;
Right: profile evolution and measuring positions (red bars).

Modelling of sediment sorting in space and time for the Sand Motor

J. van der Zwaag, Deltares / TU Delft, jelle.vanderzwaag@deltares.nl
Ir. B.J.A. Huisman, Deltares / TU Delft, bas.huisman@deltares.nl

The sediment composition of the sea bed is of relevance for various coastal properties such as bed forms, beach slopes and marine ecology. Furthermore it may significantly influence the morphological evolution of the coast. The sediment sorting processes at natural beaches are, however, difficult to distinguish since there can be a both a large temporal variability in bed composition as well as considerable spatial heterogeneity resulting from geological history. Often encountered problems are the lack of knowledge concerning the initial bed composition and the low spatial and temporal sampling for most field surveys. The latter is generally insufficient to analyse the sorting processes at natural beaches with some certainty. For this reason a perfect case study is provided by the Sand Motor, since it is monitored extensively and provides a rather uniform initial bed composition (250 to 350 µm sand).

A combination of field surveys and numerical modelling (with Delft3D) of the bed composition is used to assess longer term sorting processes at the Sand Motor. Surveys from before, during and after construction (i.e. October 2010, June 2011, October 2012 and February 2013) revealed longer term large scale sorting (Sirks, 2013). Although additional measurements were carried out in October 2013 and February 2014 (see Figure 1), time and spatial scales of the sorting processes are not yet well known. For this purpose the Delft3D model (with multiple fractions) was used to hindcast the observed composition evolution of the Sand Motor. The aim of the model is to assess the relevance of specific hydrodynamic events on the sorting processes and the corresponding morphological impact on the Sand Motor. For single storm events the 2Dh model is extended to 3D, to be able to account for undertow processes.

Preliminary results show that storm events cause rapid coarsening of the swash zone, while forcing finer sediments both offshore and towards less energetic areas (e.g. north and south of the Sand Motor). Onshore transport of fine sands is observed directly after these events. This is in line with the observations from the surveys (Sirks, 2013).

Based on the findings it can be concluded that sediment sorting processes may take place on short time scales (e.g. days), depending on the severity of the hydrodynamic conditions. Furthermore, storm events dominate the sediment sorting processes, which can lead to large spatial gradients in sediment diameter. The hindcast with Delft3D matched well with the observed bed composition of the surveys, although an accurate initial bed composition is necessary for good results.

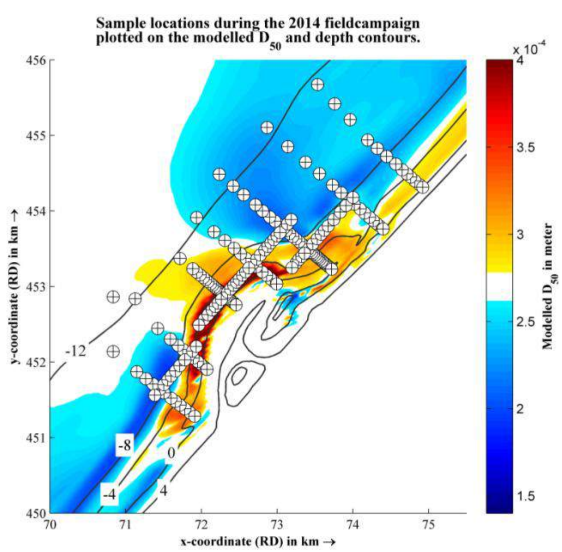


Figure 1. The sample points of the 2014 field campaign are partially based on a Delft3D model, to determine where interesting phenomena (e.g. large gradients) occur.