2017 XBEACH X CONFERENCE

Programme

&

Book of Abstracts

Programme

of

XBeach X

Infragravity Wave & Modelling

Conference

Venue:
Deltares, Delft, Netherlands.

Date:
Wednesday, November 1st 2017

The XBeachX Conference
Programme

08:30 – 08:50 Registration and Coffee

Session Chair: Robert McCall

08:50 – 09:00 Welcome
Introduction to the XBeachX Conference
Ap van Dongeren, Deltares

09:00 – 09:25 KEYNOTE: XBEACH: PAST, PRESENT AND FUTURE
Dano Roelvink, IHE Delft & Deltares

09:30 – 9:45 BREACHING OF COASTAL DEFENCES UNDER EXTREME STORM SURGES: RELEVANT HYDRO-GEO-MORPHODYNAMICS & ENVIRONMENTAL CONSEQUENCES
Saber El Sayed, Technische Universität Braunschweig

09:50 – 10:05 EVALUATING STORM EROSION WITH XBEACH ON BEACHES PROTECTED BY SUBMERGED STRUCTURES
Marissa Yates, Saint-Venant Hydraulics Laboratory & Cerema

10:10 – 10:25 UNDERSTANDING THE RESPONSE TO EXTREME EVENTS IN A DELTAIC CURVILINEAR SENSITIVE COAST
Marc Sanuy, Universitat Politècnica de Catalunya

10:30– 11:00 **COFFEE-BREAK**

Session Chair: Gerd Masselink

11:00– 11:15 SIMULATING ACCRETION AND CUSP FORMATION AT NHA TRANG BEACH, VIETNAM
Christopher Daly, Institut Universitaire Europeén de la Mer, Brest

11:20 – 11:35 MORPHODYNAMIC ANALYSIS OF INTERVENTION SCENARIOS AT THE BELGIAN COAST UNDER THE MASTERPLAN 'FLEMISH BAYS'
Gerasimos Kolokythas, Flanders Hydraulics

11:40 – 11:55 USING XBEACH TO TRAIN A BAYESIAN NETWORK FOR COASTAL HAZARD PREDICTIONS AND DISASTER RISK REDUCTION (DRR) EVALUATION. A CASE (RIA FORMOSA).
Haris Plomaritis, U. of Algarve-CIMA

12:00 – 12:15	BAYESIAN NETWORK APPROACH FOR CLIMATE CHANGE AND DRR SCENARIOS' TESTING – PILOT CASES FROM ITALY AND SPAIN *Enrico Duo, U. Ferrara*
12:20 – 12:30	Poster Pitches: Cüneyt Baykal, Hithaishi Hewageegana, Susana Costas, Julien Baills and Tomas FernandezMontblanc.
12:30 – 14:00	**LUNCH ~POSTERS**
	Session Chair: Dano Roelvink
14:00 – 14:25	KEYNOTE: RESEARCH AND DECISION SUPPORT APPLICATIONS OF XBEACH AT THE USGS *Joe Long, U.S. Geological Survey, St. Petersburg*
14:30 – 14:45	OCEAN WAVE SPECTRA FROM PHASE-AVERAGED MODELS AND REMOTE SENSING *Fabrice Ardhuin, Ifremer*
14:50 – 15:05	BREAKING BAR MIGRATION INDUCED BY INFRAGRAVITY WAVES *Hervé Michallet, LEGI, CNRS, Univ. Grenoble-Alpes*
15:10 – 15:25	INTEGRATED MORPHOLOGICAL MODELLING BY COUPLING XBEACH WITH DELFT3D FLEXIBLE MESH *Arjen Luijendijk, Deltares*
15:30 – 16:00	**GROUP PICTURE, COFFEE-BREAK & POSTERS**
	Session Chair: Ap van Dongeren
16:00 – 16:40	Sand Box Demonstration *Matthijs Gawehn and Fedor Baart, Deltares*
16:40 – 16:55	RIP CURRENT GENERATION FROM INTERSECTING WAVES: LABORATORY EXPERIMENTS AND XBEACH MODELLING *Roland Garnier, IH Cantabria*
17:00 – 17:15	ENERGY TRANSFERS AND REFLECTION OF IG WAVES UNDER STORM CONDITIONS *Anouk de Bakker, CNRS-Université de La Rochelle*
17:20 – 17:40	INFRAGRAVITY WAVE FORCING ON A BARRED BEACH: A NUMERICAL STUDY *Diogo Mendes, CERIS, Instituto Superior Técnico, Universidade de Lisboa*
17:40	Closure and refreshments

Venue:
Deltares, Delft, Netherlands.

Date:
Thursday, November 2nd 2017

The XBeachX Conference
Programme

08:30 – 09:00 Registration and Coffee

Session Chair: Joe Long

09:00 – 09:25 KEYNOTE: COASTAL INUNDATION HAZARDS ON FRINGING CORAL REEFS AND ATOLL MOTU OF THE SOUTH PACIFIC
Cyprien Bosserelle, NIWA

09:30 – 9:45 PHYSICAL AND NUMERICAL MODELLING OF LONG WAVES ON A CORAL REEF PLATFORM
Gerd Masselink, U. Plymouth

09:50 – 10:05 XBEACH APPLICATION OF CORAL REEF-LINED COASTS
Ap van Dongeren, Deltares

10:10 – 10:25 WAVE-INDUCED REEF BARRIER CURRENTS, XBEACH SIMULATION VS FIELD MEASUREMENTS
Damien Sous, Université de Toulon

10:30– 11:00 **COFFEE-BREAK**

Session Chair: Annouk de Bakker

11:00– 11:15 NONHYDROSTATIC AND SURFBEAT MODEL PREDICTIONS FOR EXTREME WAVE RUN-UP IN FRINGING REEF ENVIRONMENTS
Christopher H. Lashley, TU Delft & IHE Delft

11:20 – 11:35 BEWARE: BAYESIAN ESTIMATION OF WAVE ATTACK IN REEF ENVIRONMENTS
Stuart G. Pearson, Deltares & TU Delft

11:40 – 11:55 A METAMODEL TO ESTIMATE RUN-UP ALONG CORAL REEF-LINED SHORELINES
Ana Rueda, Universidad de Cantabria

12:00 – 12:15 THE DIFFERENCE IN RUNUP PREDICTIONS BETWEEN XBEACH NON_HYDROSTATIC AND XBEACH SURFBEAT
Anne de Beer, TU Delft & Deltares

12:20 – 12:30 **POSTER PITCHES: Jochem Dekkers, Frédéric Bouchette, Li Wang, Sebastiaan Klaver and Bart-Jan van der Spek.**

12:30 – 14:00 **LUNCH ~POSTERS**

Session Chair: Cyprien Bosserelle

14:00 – 14:25 KEYNOTE: XBEACH-NONHYDROSTATIC: TOWARDS THE DEVELOPMENT OF A PHASE-RESOLVING MORPHODYNAMIC MODEL
Robert McCall, Deltares

14:30 – 14:45 NON-HYDROSTATIC WAVE MODELING OF CORAL REEFS WITH THE ADDITION OF AN IN-CANOPY MODEL
Menno de Ridder, TU Delft & Deltares

14:50 – 15:05 COUPLING XBEACH-G AND LONGSHORE SEDIMENT TRANSPORT TO MODEL STORM RESPONSE UNDER VARYING WAVE DIRECTIONS
Rafael J. Bergillos, University of Granada

15:10 – 15:25 INFRAGRAVITY WAVE MODELLING OVER A STEEP ROCKY BATHYMETRY
Guillaume Dodet, Université de Brest

15:30 – 16:00 **COFFEE-BREAK & POSTERS**

16:00 – 16:45 **FORUM**

16:45 – 17:00 XBEACHX Release
Kees Nederhoff and Ron Thiemann

17:00 **DRINKS**

19:00 – 01:00 **XBEACHX DINNER at RESTAURANT “DE KURK”, Kromstraat 20, Delft**
(Note: only for those who registered, no walk-ons possible)
(Note: the restaurant is in a narrow street/alley, see directions)

PERFORMANCE OF THE XBEACH JAZZ QUARTET

Venue:
Deltares, Delft, Netherlands.

Date:
Friday, November 3rd 2017

The XBeachX Conference
Programme

09:00 – 09:20 Registration and Coffee

Session Chair: Marien Boers

09:20 – 09:45 KEYNOTE: TOWARDS USING XBEACH IN THE DUTCH FORMAL ASSESSMENT OF FLOOD DEFENCES IN 2023
Robert Slomp, Rijkswaterstaat/Public Works Department

09:50 – 10:05 COASTAL SAFETY ASSESSMENT OF THE BELGIAN COAST WITH STATE-OF-THE ART NUMERICAL MODELS
Willem Bodde, Witteveen & Bos

10:10 – 10:25 SEA LEVEL RISE IMPACTS THE NEARSHORE WAVE CLIMATE AND DUNE EROSION
Renske de Winter, University of Utrecht

10:30– 11:00 **COFFEE-BREAK**

Session Chair: Kees Nederhoff

11:00– 11:15 DEFINING TIME-DEPENDENT HYDRAULIC BOUNDARY CONDITIONS FOR THE ANALYSIS OF THE CLIMATE VARIABILITY OF EXTREMES OF COASTAL FLOODING
Fernando J. Mendez, University of Cantabria

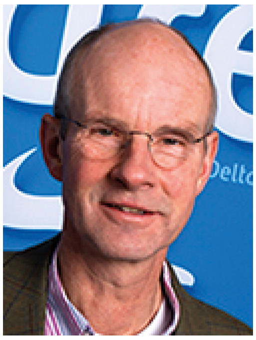
11:20 – 11:35 SHORT-TERM MORPHOLOGY RESPONSE TO STORMS AT A NOURISHED COASTAL AREA IN BELGIUM
Raquel Silva, Flanders Hydraulics Research & Antea Group

11:40 – 11:55 WASHOVER PROCESSES AT THE WADDEN ISLAND OF SCHIERMONNIKOOG, THE NETHERLANDS: FIELD DATA AND XBEACH MODELING
Daan Wesselman, University of Utrecht

12:00 – 12:15 AN ANALYSIS OF THE MORPHODYNAMIC ACCELERATION TECHNIQUE (MORFAC)
Mart Borsboom, Deltares

12:30 – 14:00	**LUNCH**
	Session Chair: Fabrice Ardhuin
14:00 – 14:25	KEYNOTE: MODELLING MORPHODYNAMIC IMPACTS OF STORM CLUSTERS *Harshinie Karunarathna, Swansea University*
14:30 – 14:45	NON-HYDROSTATIC WAVE MODELLING AT WEST BAY HARBOUR, UK *Mark Klein, Royal Haskoning DHV*
14:50 – 15:05	CONTRIBUTION OF IG WAVES TO LOCAL RUNUP AND FLOODING BEACH OF BIARRITZ *Denis Morichon, Univ Pau & Pays de l'Adour*
15:10 – 15:25	INFRAGRAVITY PERIOD OSCILLATIONS IN A CHANNEL HARBOR NEAR A RIVER MOUTH *Florian Bellafont, Univ Pau & Pays de l'Adour*
15:30	**DRINKS**
	END

KEYNOTES



Dano Roelvink has 31 years of experience in coastal engineering and research. He has participated as team member and as project manager in a number of major consultancy projects related to coastal morphology. He has managed the development of the Delft3D model system for two- and three-dimensional simulation of waves, currents, water quality, ecology and morphodynamics, and is still active in the further development of the morphological part of this system. He has been actively involved in the EU-sponsored MaST-G6M and MaST-G8M, SASME, COAST3D, DELOS, MICORE and Risc-Kit research projects on coastal morphodynamics, amongst others as member of the SASME steering group. His field of expertise is in coastal hydrodynamics and morphodynamics modelling, in one, two or three dimensions. In 1993 he obtained a PhD-degree at TU Delft, based on a thesis on the effect of surf beats on coastal profiles. He has published numerous articles on coastal hydraulics and morphodynamics in international journals and conference proceedings, and he has been a part-time Assistant Professor, later Associate Professor at Delft University of Technology from 1990-2005 and presently holds a Professorship there. He has been Delft Hydraulics' principal investigator in the discipline of morphology and is a strong proponent of international scientific cooperation with various parties in order to further the state-of-the-art in morphodynamic modelling and has set up collaborative projects with the US Geological Survey, the US Office of Naval Research and the Army Corps of Engineers. Since working at UNESCO-IHE he has been involved in research and capacity building projects in the US, Australia, China, Vietnam, Indonesia, Brazil, Barbados, Fiji, Ghana, Ivory Coast, Bénin and Bangladesh. He is presently a member of the Programme Committee of the Netherlands Centre for Coastal Research (NCK). In his current position he is head of the Chair Group of Coastal Engineering and Port Development at UNESCO-IHE Institute for Water Education, and Senior Specialist Coastal Morphology at Deltares. His latest work has focused on the development of an open-source model for prediction of storm impacts on sandy coasts, XBeach.

Joseph Long, PhD is a research oceanographer at the U.S. Geological Survey Coastal and Marine Science Center in St. Petersburg, Florida and has over 15 years' experience in studying coastal processes. His research focuses on the role that winds, waves, and circulation have on transforming beaches and dunes over seasonal and long-term time scales and during individual extreme events. He has published numerous papers related to the development and use of numerical models to explain complex hydro- and morphodynamic processes in the coastal region and on using data assimilation methods to enhance predictions of coastal change. Dr. Long also leads a number of applied projects focused on developing model frameworks that can be used for decision support applications. He received a M.S. and Ph.D. in Civil/Ocean Engineering from the Oregon State University, and B.S. from Clarkson University.

Cyprien Bosserelle completed his PhD in 2013 at the University of Western Australia studying the morphodynamics of reef fronted beaches in the Perth area. As part of his PhD he developed a GPU version of XBeach that he continues to manage. His knowledge about the wave climate and wave transformation on reefs led him to work at the Pacific Community in Fiji as a coastal oceanographer. There, he was managing the WACOP research project aimed at improving the baseline knowledge about the wave climate and coastal hazards. In the Last two years, Cyprien has been working on coastal hazard assessments for various islands of the Pacific and developing new tools for coastal inundation forecast. Cyprien has recently moved to New Zealand to continue his work as part of the National Institute for Water and Atmosphere.

Robert McCall received his MSc. with distinction from Delft University of Technology in 2008, where he worked on the development and first-ever application of the XBeach model in a hurricane-induced overwash environment. He has been working at Deltares since 2008 as a coastal engineer and geomorphologist, advising coastal development and flood risk projects, and as a key model developer of the XBeach model. In 2015, Robert completed his PhD research at Plymouth University (UK) and Deltares, where he measured and analysed gravel beach storm processes and developed a process-based storm impact model for gravel coasts (XBeach-G). Robert's areas of expertise are coastal hazards and nearshore, swash and overwash hydrodynamics and morphodynamic processes, with particular focus on extreme storm events and flood risk, as well as numerical model development, analysis and application.

Robert Slomp works for the Ministry of Infrastructure and the Environment in the agency Rijkswaterstaat. Currently I am the technical manager in the project research and development of flood defense assessment tools, WTI2017 now renamed to WBI2017. We hope to include a new phase of Dune research and software development as part of the WBI2023 program.

Harshinie Karunarathna is a personal chair in Coastal and Estuary Engineering at the Zienkiewicz Centre for Computational Engineering, College of Engineering of Swansea University, UK. She obtained her Bachelor of Science in Engineering degree in Civil Engineering from the University of Moratuwa, Sri Lanka and her Master of Science degree in River, Coastal and Estuary Engineering from Imperial College, London. She obtained her PhD in Coastal Engineering from Saitama University, Japan. Her PhD research was focused on computational modelling of infragravity waves in the nearshore zone. She has completed two post-doctoral research fellowships, working on experimental investigations and numerical simulation of rip currents at the Technical University of Denmark and on computational wave modelling at the University of Plymouth, UK. She has over 20 years post-doctoral experience and has extensively worked on coastal hydrodynamic and morphodynamic modelling using Delft3D, XBeach and MIKE models; data-driven methods; and reduced-physics models. Prof. Karunarathna has secured numerous research grants to support her research from the Research Councils UK and other funding bodies, published over 125 peer reviewed research articles, supervised/co-supervised 6 post-doctoral fellows, 12 PhD candidates and numerous MSc students. She received Outstanding Research Performance Award from the University of Moratuwa, Sri Lanka in 2000, was nominated for President's Award for Outstanding Academic Researchers in Sri Lanka in year 2001 and won the JAMSTEC Nakanishi Award from the Federation of Ocean Engineering Societies in Japan for the paper 'Analysis of climate change impacts on seawall reliability' published in Coastal Engineering Journal in 2016.

Book

of

Abstracts

XBEACH PAST, PRESENT AND FUTURE

Dano Roelvink, IHE Delft / Deltares, d.roelvink@un-ihe.org

TOPIC
History of XBeach

XBEACH PAST
There was a time when there was no XBeach, and engineers trying to predict dune erosion limped along using simple rules or models that could not handle any complexity. Surfbeat waves were first seen as the source of all surf one features, and then almost forgotten, until we realized that they were key to understanding what happens in front of and over dunes during storms. The idea of bringing this and other concepts into predictive models of nearshore processes during storms was sold to the US Army Corps of Engineers within the Morphos3D project, after the 2004 hurricane season, and the work started with trying to make some matlab algorithms. This soon got out of hand and Ad Reniers and I started creating more serious matlab code called XBeach. The combination of the surfbeat waves and avalanching turned out to be surprisingly powerful in modelling dune erosion and soon we had enough test cases to show the model to other people. From the start, we went for a completely open source approach, where we shared our codes, including all personal remarks and comments. Matlab soon became too limiting and the first official XBeach product in Fortran90/95 was presented on the Ocean Waves Workshop in the Turtle Beach Resort in Oahu, in 2007. Hard times.

XBeach was consolidated and developed much further in the XBeach room at Delft Hydraulics, with Ap van Dongeren, the boundary conditions guru, Jaap van Thiel de Vries, PhD student who had to prove it was better than DUROS, and Robert McCall, MSc student at the time, to go for the 2D cases. We all just fitted around a big table with Johnny Cash softly playing in the middle. With help from Guus Stelling I made the scheme much more accurate, robust and curvilinear. We got serious help in parallelizing the code rom Willem Vermin of SurfSARA, who also made a heap of improvements to the code structure that made life very easy for developers. Wiz kids like Fedor Baart and Bas Hoonhout did cool things like making library and dll versions, netcdf output, an automated test bed and 'code swarms', showing who was contributing to the code in fascinating animations. Version management was taken up seriously with tortoiseSVN and the clumsy Google Groups forum was moved to the professional oss.deltares.nl site, still accessible as xbeach.org.

Figure 1 Something has gone wrong in the testbed report.

The first real XBeach paper in 2009 was a painful group effort as we tried to go beyond the glossy ad for our model but had to talk science too… but was more than worth it, as it reached a large audience and collected over 600 citations in 8 years. As the user group grew there was a need for stable, well-tested versions. These happened to always come out during special holidays: Easter, Sinterklaas, Groundhog Day, Kingsday. The 'making of' of these versions consisted of the core team sitting in front of a big screen, deciding line for line what to adopt and what not. Of course this was followed by weeks of debugging and testing…

XBEACH PRESENT
The ongoing development was made possible thanks to a series of 'sugar daddies': the Dutch government supported the development and validation for Dutch dune sections that could not be handled with simple empirical methods, through the WTI project. The USGS were early adopters and enthusiastic testers, providing data and occasionally pointing out major problems or flaws; they supported applications from the coast of California (Maarten van Ormondt) to coral reef islands (Ellen Quataert). Two subsequent EU projects, MICORE and RISC-KIT, allowed XBeach to be applied far from home, in a range of different environments. The latest Coastal Engineering special issue on RISC-KIT is full of applications and some further improvements and validations. With Office of Naval Research funding mangrove and saltmarsh vegetation effects were built in by Arnold van Rooijen and the UK EPSRC sponsored the development of XBeach-G by Robert McCall at Plymouth University. As a sign that XBeach is being adopted widely by industry, most major Dutch and Belgian consultants and dredging companies have been collaborating with Deltares in XBeach-JIP, where a range of possible applications are being explored, validated and made ready for practical use.

International collaborations are continuing to thrive, with the USGS on hurricane impacts and coral reefs, with SPC on Pacific islands; with the University of Wester Australia on processes behind reefs, ONR on barrier island impacts, IMDC and Flanders Hydraulics on the Flemish coast and Oregon State University and University of North Carolina on beach-dune coupling, to name but a few.

Regular meetings of the 'XBeach club', an informal gathering called by Marien Boers, serve to exchange ideas and latest developments and to agree on how to get and keep things running smoothly (Joost den Bieman, Kees Nederhoff). Occasionally, a heroic task force is formed to do Herculean things like updating the manual, which presently is uncannily up to date and thanks to Bas Hoonhout looking hip in http://xbeach.readthedocs.io/.

XBEACH FUTURE

According to Niels Bohr, predicting is very difficult, especially if it's about the future. If we just project the past developments onto the future we may have a concept of XBeach like an invasive species rampantly growing in all directions as indicated in this mindmap. Still, we are seeing developments that point in a direction of coupling independent modules and codes through interfaces like BMI, or sharing functionality through the use of libraries and dll's such as the Delft3D morphology module. Going to unstructured grids is not pursued within XBeach; rather, the XBeach functionality has been ported to Delft3D-FM by Johan Reyns and Sander van der Pijl.

Whatever happens, I'm convinced that the XBeach project is alive and kicking and has a community that shows what can happen if you dare to share!

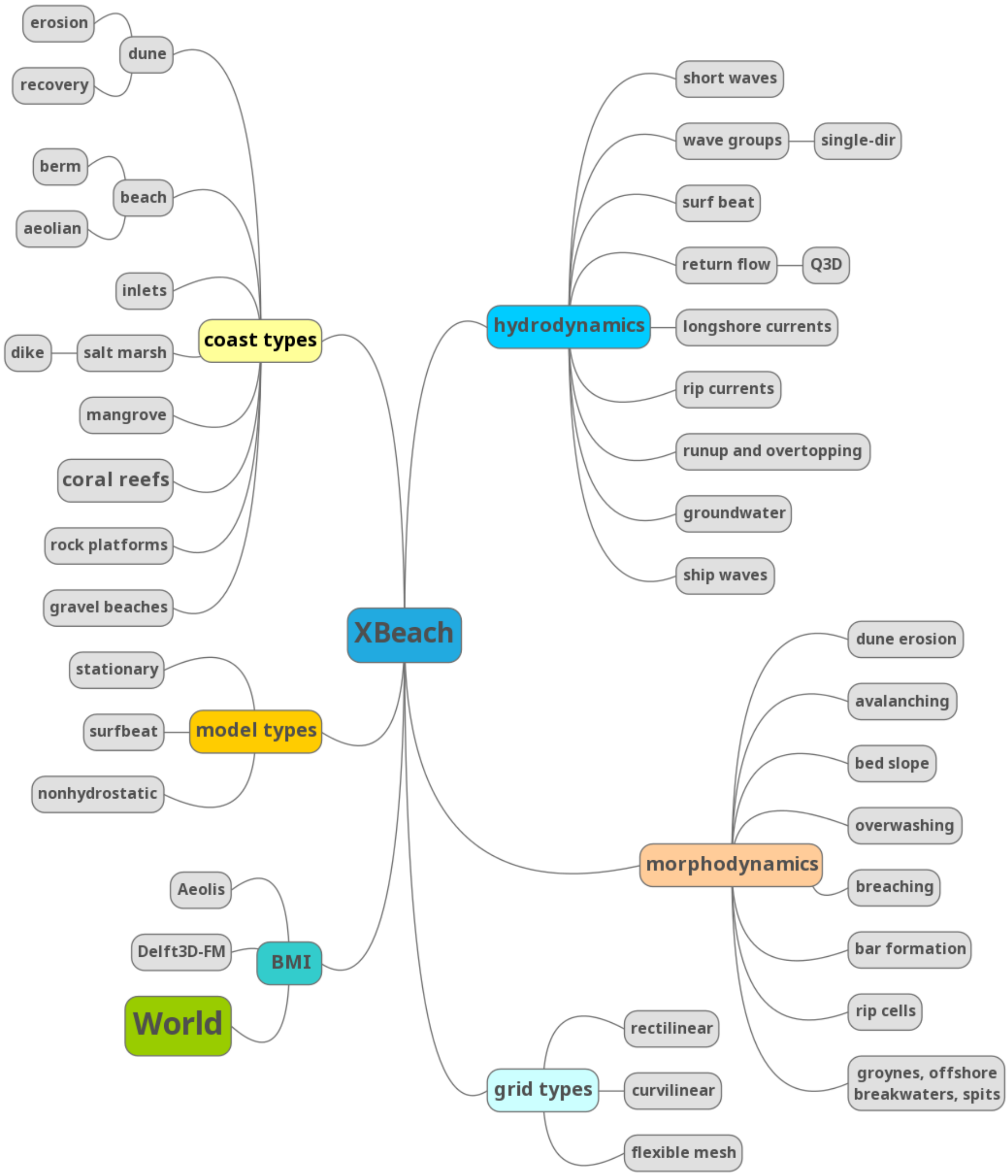


Figure 2 XBeach mindmap

ACKNOWLEDGEMENTS

We'd like to thank our many sponsors, collaborators and friends for keeping the XBeach project alive and kicking, and especially thank Deltares for hosting us along with a great collection of open source software.

BREACHING OF COASTAL DEFENCES UNDER EXTREME STORM SURGES: RELEVANT HYDRO-GEO-MORPHODYNAMICS & ENVIRONMENTAL CONSEQUENCES

Saber M. Elsayed, Leichtweiß-Institut für Wasserbau, LWI, Technische Universität Braunschweig, s-m.elsayed@tu-bs.de
Hocine Oumeraci, Leichtweiß-Institut für Wasserbau, LWI, Technische Universität Braunschweig, h.oumeraci@tu-bs.de

TOPIC
Processes (Hydrodynamics; Morphodynamics; Coastal Inundation; Saltwater Intrusion), Environment (Sandy coasts and shorelines), Numerics (Coupling to other models).

INTRODUCTION
Breaching of coastal barriers (BCB) under extreme storm surges (ESS) represents one of the most important sources of coastal flooding and contamination of coastal freshwater aquifers. In fact, breach-induced inlets work as pathways to marine flooding and subsequent saltwater intrusion (SWI). The lack of research on the possible consequences of ESS on inundation induced by barrier breaching and subsequent SWI into coastal aquifers is certainly due to the high complexity and diversity of the processes/interactions to be considered. Different flow domains are involved starting from the sea where waves propagate toward the coastal barriers (Fig 1), which might result in their overtopping and/or breaching, thus leading to coastal floods behind the barriers and subsequently to SWI due to infiltrating seawater in the hinterland. On the other hand, diverse processes are involved (e.g. coastal hydrodynamics, sediment transport, soil avalanching on barriers' slopes and from breaching wedges, surface runoff of seawater over the hinterland and subsurface flow of infiltrating seawater). In addition, several interactions among these processes exist. The breaching process represents the outcome of complex interactions between hydrodynamics, sediment transport and soil avalanching processes (Elsayed, 2017; Elsayed and Oumeraci, 2016). Moreover, propagation of saltwater over the hinterland and subsequent infiltration into aquifers represent a surface-subsurface interacting transport of a conservative solute (Elsayed and Oumeraci, 2017a). Therefore, the contribution of LWI to XBeach X will focus on the use of XBeach in modelling together the breaching process and induced inundation. Moreover, it will highlight the coupling of XBeach with the SEAWAT model of USGS to assess the environmental consequences of breach-induced SWI. In this context, the hydro-geo-morphodynamic processes associated with BCB will be highlighted and possible improvement of XBeach to successively simulate these processes will be addressed.

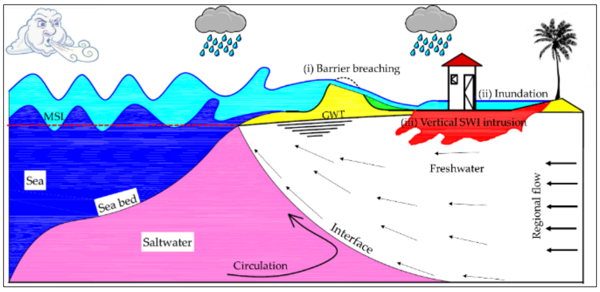


Figure 1: Sea/land boundary during extreme storm surges: the coastal barrier is directly attacked, thus possibly causing barrier breaching, coastal inundation and subsequent vertical SWI.

METHODS
Though XBeach has proven its capability (i) to properly simulate coastal erosion and BCB under extreme events (Elsayed and Oumeraci, 2017b) and (ii) to simulate in combination both breaching process and induced inundation (Elsayed and Oumeraci, 2016), it cannot yet simulate the inundation-induced SWI though it includes a groundwater module. With this in mind, XBeach is coupled with SEAWAT to assess, through simulation, the environmental effects of such vertical SWI. Moreover, essential improvements to extend the scope of XBeach from the surface modelling of the nearshore hydro-morphodynamics and subsequent flooding to the subsurface modelling of SWI is highlighted.

RESULTS
The planned presentation will include the key results of the PhD study of the first author (Elsayed, 2017) that is supervised by the second author, including improvements of XBeach (Elsayed and Oumeraci, 2017b), its use for combined modelling of breaching and subsequent inundation (Elsayed and Oumeraci, 2016) and its coupling with SEAWAT to assess and mitigate the environmental consequences of marine floods (Elsayed and Oumeraci, 2017a).

REFERENCES
Elsayed (2017): Breaching of Coastal Barriers under Extreme Storm Surges and Implications for Groundwater Contamination. PhD dissertation, LWI, TU Braunschweig, Braunschweig, Germany.
Elsayed, Oumeraci (2017a): Modelling and Mitigation of Storm-Induced Saltwater Intrusion: Improvement of the Resilience of Coastal Aquifers Against Marine Floods by Subsurface Drainage. Submitt. to J. Environ. Model. Softw.
Elsayed, Oumeraci (2017b): Effect of beach slope and grain-stabilization on coastal sediment transport: An attempt to overcome the erosion overestimation by XBeach. Coast. Eng. 121, 179-196.
Elsayed, Oumeraci (2016): Combined Modelling of Coastal Barrier Breaching and Induced Flood Propagation Using XBeach. Hydrology 3, 34.

EVALUATING STORM EROSION WITH XBEACH ON BEACHES PROTECTED BY SUBMERGED STRUCTURES

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Marissa Yates, Saint-Venant Hydraulics Laboratory & Cerema, marissa.yates-michelin@cerema.fr
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TOPIC: Morphodynamics (storm-induced erosion), Sandy beach environment with submerged structures

INTRODUCTION

The littoral zone is a complex environment impacted by a variety of processes at a wide range of temporal and spatial scales. Beach stability depends on interactions between these processes including wave forcing, sea levels, sediment availability, human intervention, etc., and future changes in sea level and storm climates will likely strongly affect beach stability worldwide. Engineering solutions such as submerged breakwaters (SBWs) and geotextile tubes are innovative and economical solutions used to preserve the shoreline and the aesthetical and environmental value of the nearshore environment. In a previous study financed by Geocorail, reduced-scale wave flume experiments were conducted to evaluate the efficiency of submerged structures (SSs) in reducing shoreline erosion, and the experiments demonstrated the sensitivity to site-specific characteristics such as the initial profile and the storm characteristics, as well as the type, cross-shore position, and freeboard depth of the SS. The current study aims to use the XBeach model (1DH) to reproduce the observed morphological changes to evaluate its use in conducting sensitivity and design studies to find the optimal structure for a given site.

EXPERIMENTS AND METHOD

The experiments were conducted in a wave flume (36 m long, 0.5 m water depth) at a 1:10 scale using a lightweight PMMA sand (density = 1.19 kg/m³, d_{50} = 0.54 mm) to respect the non-dimensional Rouse and Shields numbers encountered in natural environments with quartz sand of size d_{50} = 0.3 mm. The experimental protocol of Grasso et al. (2009) was followed by establishing a pre-storm equilibrium beach profile and then measuring the morphological changes induced by a storm event. This protocol was repeated with the same pre-storm and storm wave conditions on profiles containing one of four different SS's -- 2 SBWs and 2 geotextile tubes (at different cross-shore positions, with the same freeboard depth) -- to evaluate their efficiency in reducing shoreline erosion. Wave height variations were measured with 14 resistive gauges, and the cross-shore profile was surveyed manually at 50cm intervals along the mobile bed. The XBeach model was calibrated in two phases using the (1) hydrodynamic and (2) morphological measurements converted to full scale (owing to limitations in simulating the reduced-scale particle density), by testing the sensitivity of the results to variations in the model free parameters using the root mean square error (RMSE) and/or Brier Skill Score (BSS) to evaluate the model performance.

RESULTS AND CONCLUSION

The hydrodynamic calibration phase showed the importance of the choice of the wave breaking model and gamma (breaking wave height to water depth ratio), but a series of different tests produced similar errors given the lack of experimental measurements in the zone after wave breaking. The morphodynamic calibration phase presented a stronger challenge for the XBeach model, which was able to reproduce well the observed changes on the upper beach profile (primarily by adapting gamma and the asymmetry parameter 'facAs') but was unable to reproduce the morphological changes near the structures (Figure 1). Finally, if the objective is to analyze only the storm-induced shoreline erosion in the presence of SS's, the XBeach model may be used for preliminary studies. However, a more detailed model of the sediment transport around the structure, including 2DH experiments and simulations, would be necessary to define design criteria and to validate the efficiency of such a structure.

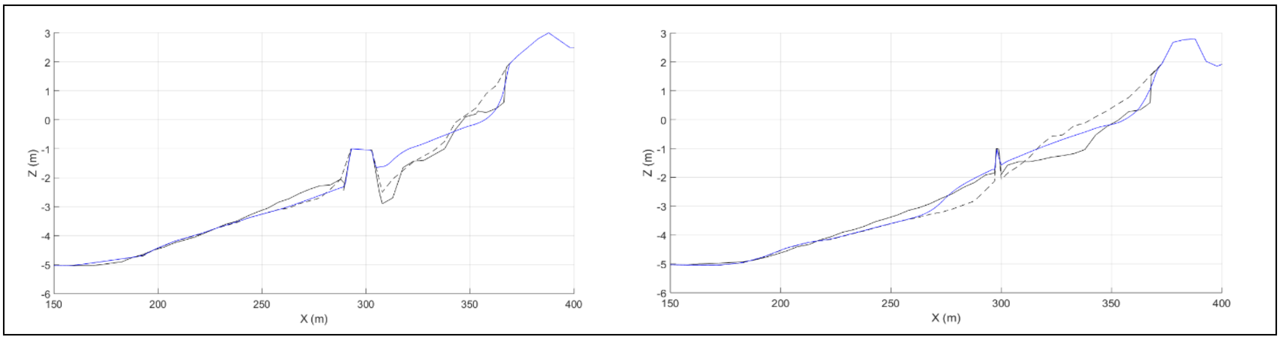

Figure 1 – Comparison of the simulated (blue) and measured (solid black line) beach profiles at the end of the storm, also showing the initial beach profile (dashed black line) for reference, for the (left) small SBW and (right) small geotextile tube.

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UNDERSTANDING THE RESPONSE TO EXTREME EVENTS IN A DELTAIC CURVILINEAR SENSITIVE COAST

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TOPIC
Hydrodynamics and morphodynamics. Sandy coasts and shorelines, Validation and application of the model for inundation and erosion hazard assessments.

INTRODUCTION AND METHODS
Extreme storms hitting the coasts are within the costliest disasters (Bertin et al. 2014). In highly humanized sandy shorelines such as the Catalan coast (NW Mediterranean), these events are likely to induce significant erosion and inundation with the consequent assets destruction (Jimenez et al. 2017). Within this context, the use of morphodynamic models such as XBeach (Roelvink et al. 2009) has become a S-O-A approach to analyze these processes. However, most of existing studies are performed on straight coastlines and gentle slopes, conditions close to the "comfort zone" of the model. However, the effect of very curvilinear shorelines on storm induced hazards and their proper simulation has been seldom covered. In this work, we use XBeach to analyze erosion and inundation and associated damage in a highly curvilinear deltaic sandy coast, the Tordera delta (NW Mediterranean).

To this end, we build a model chain with an external module supplying offshore water level and wave conditions and an internal module consisting of SWAN and XBeach models which propagates conditions towards the coast and simulates coastal erosion and inundation. First, the system was calibrated by using field data gathered during the impact of an extreme storm in the area. Then, the model chain is used to simulate multiple storm conditions under different climate scenarios, such as changing storm wave directions and sea level rise (SLR), and simulating the performance of nature-based risk reduction measures, such as the reconstruction of a submerged spit at the south of the river mouth vs more traditional protection schemes such us dune reconstruction and beach nourishment

RESULTS AND CONCLUSIONS
Results show that the system is able to successfully reproduce the observed response during the St. Esteve event, with a BSS score of 0.651. Erosion and inundation hazards under the impact of extreme storms are very sensitive to changing directions, showing a significant increase as storm direction shifts to the South (Figure 1). Thus, effects of changing direction on inundation are of nearly the same magnitude than the SLR-induced one under the AR5 RCP 8.5 2100 scenario (Church et al. 2013). Finally, the reconstruction of the existing submerged spit reduces the magnitude of storm-induced hazards on the shoreline under current climate scenario, with decreasing efficiency as storms shift to southern directions. To achieve the same level of protection provided by classical coastal protection measures (dune and nourishment), a significant variation of the submerged spit is required, with the additional question on its long-term behavior.

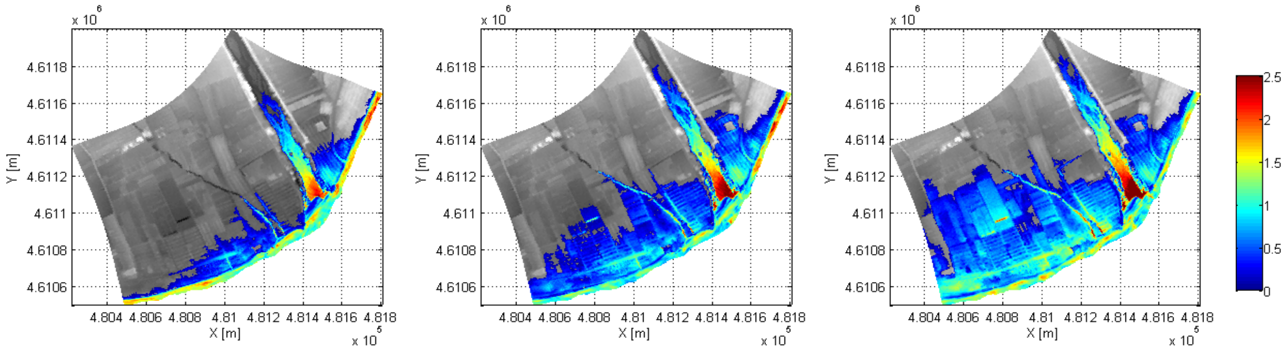

Figure 1. Evolution of the inundation as direction changes from East (left) to South (right).

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SIMULATING ACCRETION AND CUSP FORMATION AT NHA TRANG BEACH, VIETNAM

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TOPIC
Processes (Hydrodynamics; Morphodynamics), Environment (Sandy coasts and shorelines).

INTRODUCTION
Beach accretion occurs due to processes which stimulate and/or regulate onshore sediment transport in the surf and swash zone. In the surf zone, onshore transport is strongly influenced by the non-linear shape of incident short-waves, characterized by asymmetry and skewness (Elgar et al., 2001). Sediment gradually transported from the surf zone toward the base of the swash is lifted to higher elevations via complex swash zone processes: wave-wave interactions and turbulence, superposition of bores and infragravity runup, sheet flow transport, and groundwater infiltration and exfiltration (Bahktyar et al., 2009). Beach accretion is notoriously difficult to simulate in morphodynamic models since many processes have to be accounted for. However, recent work by Daly et al. (2017) has shown that it is possible to do this in XBeach using the non-hydrostatic version to fully resolve wave transformation in the surf and swash zone.

The gradual build-up of sediment on the beach face often results in the formation of rhythmic patterns such as beach cusps. The presence of cusps may depend on local characteristics such as sediment size, beach slope and wave energy (van Gaalen et al., 2011). The formation of beach cusps, with wavelengths between 20-50 m, were observed during a during a field campaign at Nha Trang, Vietnam, in December 2015, where topography across a 1 km length of beach was surveyed daily with high-resolution RTK-GPS and drone photogrammetry. The cusps formed quickly during an accretionary stage lasting for a few days. The aim of the present work is to extend the 1D XBeach model of Daly et al. (2017) to a 2D domain in order to simulate the observed formation of beach cusps at Nha Trang. A validated model will provide insight into processes which initiate cusp formation and that influence their evolution.

PRELIMINARY RESULTS
XBeach simulations were initiated using a long-shore uniform bathymetry, prescribing similar model settings as reported in Daly et al. (2017). These simulations have successfully reproduced beach cusp patterns with wavelengths in the order of 20 m which form after approximately 12 – 24 hours (Figure 1). The position of the cusps are shown to vary with position of the mean water level during the tidal cycle (at Nha Trang, the tide range is approximately 1 m). Further simulations will be carried out to establish how their development may be affected by changes in sediment size. It is expected that finer sediment (with reduced porosity), will require a longer time for the cuspate patterns to develop.

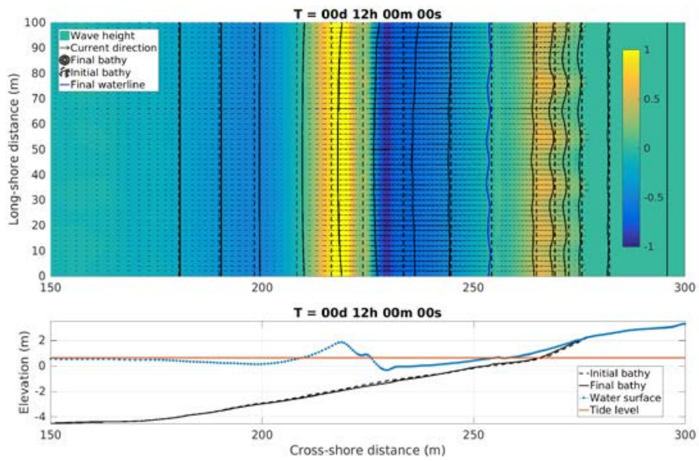

Figure 1 – Simulations showing accretionary cuspate features in the swash zone. Upper panel: plan view of the beach with initial (dashed line) and final (solid line). Contours are spaced at 0.5 m intervals, with 0 m (MSL) shown by the blue line. Color scale shows wave height. Lower panel: Cross-section of the beach showing wave transformation and runup.

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MORPHODYNAMIC ANALYSIS OF INTERVENTION SCENARIOS AT THE BELGIAN COAST UNDER THE MASTERPLAN 'FLEMISH BAYS'

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TOPIC

Processes (Hydrodynamics; Morphodynamics), Environment (Sandy coasts and shorelines; Ports, waterways and ships).

INTRODUCTION

The Masterplan 'Flemish Bays (Vlaamse Baaien)', which was proposed by the Flemish Government on May 2014, outlines the need to develop an integrated vision for the Belgian coast in a long term period, i.e. up to year 2100. One of the Masterplan's goals is to achieve a win-win situation between coastal protection and the improvement of the maritime access to the port of Zeebrugge for inland vessels by creating a sheltered estuarine connection to the Scheldt. Currently only a limited number of certified inland vessels are conditionally, depending on the wave climate, allowed to make use of the trajectory between Zeebrugge and the mouth of the Western Scheldt to connect the port with the inland waterway network. For the protection of this maritime waterway and the coast, the idea of a broad protection belt, which could be made and maintained in a natural and sustainable way, is adopted (Figure 1). However the final arrangement of the protection works is under consideration. In the present study different scenarios of artificial islands layouts and beach nourishment, located at the east side of Zeebrugge, are simulated by use of the morphodynamic module of XBeach software (Roelvink et al., 2009).

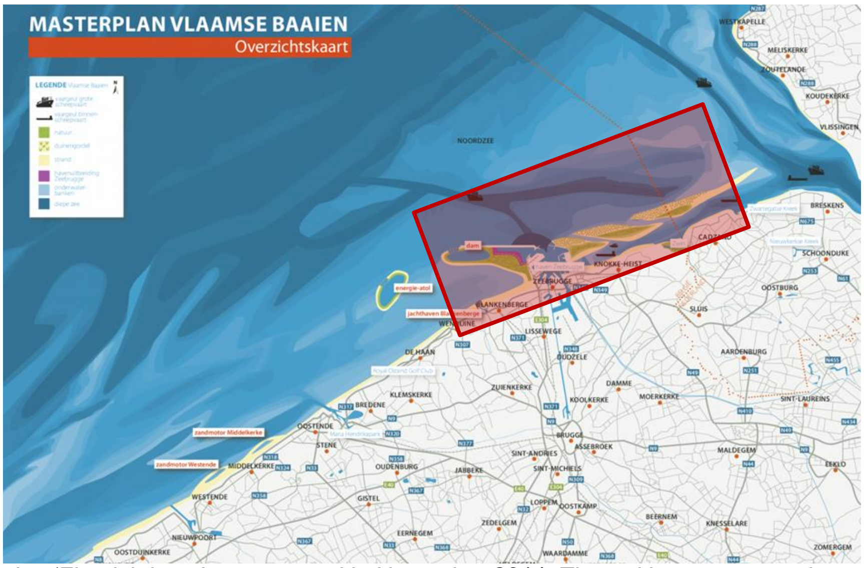

Figure 1: Masterplan 'Flemish bays' as proposed in November 2014. The red box corresponds to the outline of the computational domain.

MODEL SET UP

The simulations are performed on a rectilinear grid, which consists of about 55000 nodes, covering a domain which spans about 8 km west and 18 km east of Zeebrugge harbor in the longshore direction and about 10 km in the cross-shore direction (see Figure 1). The cell sizes range from about 25 m at the area of interest (Knokke-Heist) to about 200 m close to the boundaries. The hydrodynamics are driven by a representative tidal cycle imposed repeatedly at the lateral boundaries and a representative wave forcing imposed at the offshore boundary. The technique of morphological acceleration is applied in order to achieve long-term predictions up to 9 years.

RESULTS

Two of the scenarios foresee nourishment of the Knokke-Heist beach and construction of one detached breakwater close to the eastern breakwater of Zeebrugge and one big island next to it, aligned with the nourished beach. Numerical results show that strong erosion occurs at the west side of the big island, and the eroded material is deposited mainly to the southwest, while very slight sedimentation-erosion patterns appear in front of the beach (at the area of interest). A third scenario foresees the construction of one pilot island at the height of the area between Zoute and Lekkerbek, without any beach nourishment. For this case, strong erosion occurs at the west side of the island, and the eroded material is deposited mainly to the south, while at the east side sedimentation-erosion patterns are less pronounced. It was found that the *wetslp* parameter that defines the initiation of avalanching affects significantly the erosion of the artificial islands.

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USING XBEACH TO TRAIN A BAYESIAN NETWORK FOR COASTAL HAZARD PREDICTIONS AND DISASTER RISK REDUCTION (DRR) EVALUATION. A CASE (RIA FORMOSA).

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TOPIC
Processes (Morphodynamics, storm-induced erosion and overwash), Environment (Sandy coasts barrier islands)

ABSTRACT
Coastal communities are threatened by the impact of severe storms that may cause significant loss or damage of property and life. The main processes causing such impacts are overwash and storm erosion that specifically affect sandy coastlines and nearby coastal communities. Predicted coastal response under present conditions and predicted climate change has been frequently based in the use of numerical models. Furthermore, the effective evaluation of Disaster Risk Reduction (DRR) measures can also be addressed with the same tools. However, detailed morphodynamic models are computationally expensive and not commonly used by coastal managers. The present work applies a probabilistic Bayesian Network (BN) as a surrogate for the numerical simulation (Poelhekke, et al., 2016). The BN is trained following the method proposed by Jäger, et al., (2017) with a large number of XBeach morphodynamic simulations, under a variety of storm conditions and DRR measures and can serve as a front-end platform for visualising, analysing and evaluating combined results of the numerical model.

The BN system was built for a coastal sector of the Ria Formosa barrier island system (South Portugal), within the framework of the EU project Risc-Kit (Resilience-Increasing Strategies for Coasts - toolKIT). The BN starting conditions include variable wave height, water level, wave period and morphology, and as final products it states the degree of impact of overwash and erosion induced hazards for 4 sub-zones of the study area. A total number of 124 Xbeach simulations were used to train the BN. The hazard receptors investigated were houses and infrastructures and the DRR measures evaluated were: beach replenishment and house removal. Results show that for a storm with wave characteristics of 50 years return period and spring tidal conditions; the removal of houses placed at the foredune reduces the overwash and erosion impact by 58% when compared to the present conditions. Beach replenishment, for the same event, reduces the erosion impact by 96% while it has a smaller effect on the overwash impact. The combined effect of the above DRR reduces the storm impact to the study area to a value near zero.

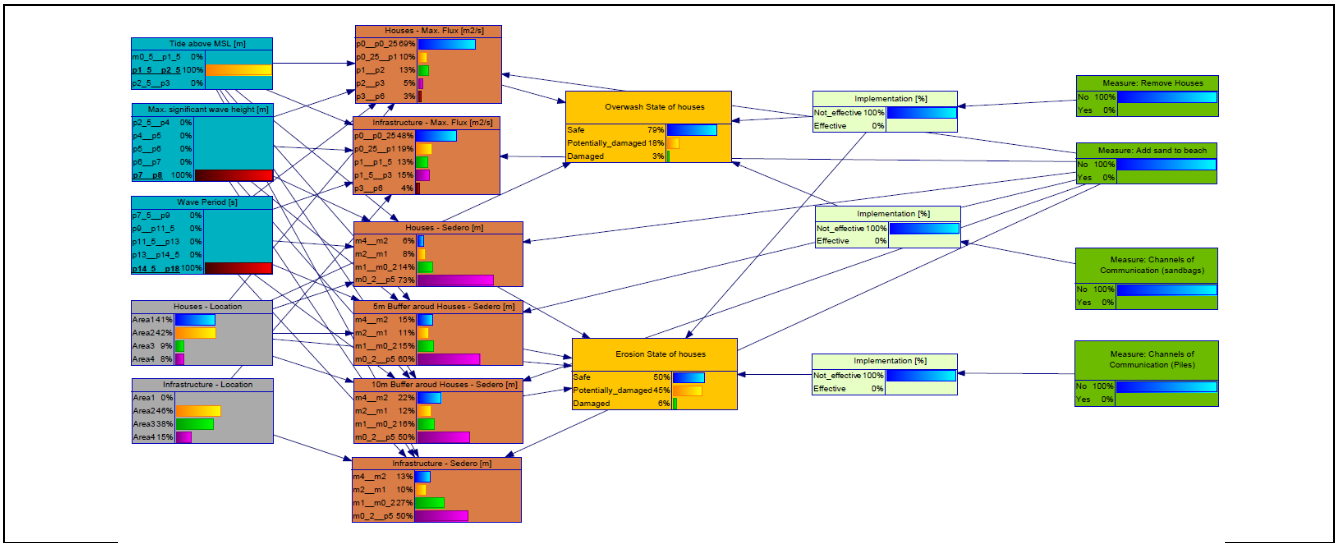

Figure 1 - Bayesian Network Praia de Faro showing a 50 year return period event.

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BAYESIAN NETWORK APPROACH FOR CLIMATE CHANGE AND DRR SCENARIOS' TESTING – PILOT CASES FROM ITALY AND SPAIN

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TOPIC
Hydrodynamics; Morphodynamics; Sandy coasts and shorelines; Numerical methods; Coupling to other models.

ABSTRACT
Recent coastal storm impacts emphasized the need of proper coastal risk assessment to propose adequate risk reduction plans. Coastal managers should be able to predict and compare the effect of Disaster Risk Reduction (DRR) measures under current and future scenarios. The analyses should integrate multi-hazard assessments at the receptor scale and should be as flexible as to be applied at different morphologic and socio-economic settings. The EU Risc-Kit project (www.risckit.eu) provided tools in support to coastal management to be applied at different scales throughout the disaster management cycle (Van Dongeren et al., 2017). In this work, the local scale Hotspot tool (Jäger et al., 2017) was applied at two Mediterranean case studies to test and compare DRR measures under current and future scenarios, considering flooding and erosion hazards. The tool implements the Source-Pathway-Receptor-Consequences (SPRC) concept into a Bayesian Network (BN)(Figure 1). The hazard component is calculated through a process-based model chain. The last step of the chain consists of a 2DH XBeach model providing hydro-morphodynamic results. Hazards are translated into consequences for the exposed receptors through vulnerability relations. Then, results are integrated into the BN linking storm characteristics with expected impacts through conditional probabilities. The approach was repeated for a large number of forcing conditions, in current and future conditions, with and without the implementation of DRR measures affecting hazard, vulnerability or exposure. The BN was used to explore and compare results in an integrated manner. The tool was applied at two urbanized touristic sandy beaches, in Spain (Tordera Delta, Maresme-La Selva) and Italy (Lido degli Estensi-Spina, Comacchio). DRR measures, such as artificial dunes, nourishments, managed retreat and non-structural measures were tested in both current and future conditions. At both case studies: (i) the results of the current conditions appeared to be consistent with the knowledge of the area; (ii) the method was able to provide quantitative information on the variations of the level of risk for receptors under the projected future conditions; (iii) the DRR measures evidenced mainly positive effects in terms of risk reduction, with some exceptions, in both current and future conditions. Strategic alternatives (i.e., single or set of measures) were compared to select optimal combinations of DRR. The main limitations of this study were related to the numerical approximations of the model chain, the adopted vulnerability relations, the design of the measures and the future conditions. Finally, the higher is the number of considered storm conditions, the more complete is the integrated assessment. However, this may lead to a massive effort in terms of computational time. Despite these limitations the scenario comparisons were effective. This work highlighted the advantages of using the Risc-Kit Hotspot tool for DRR testing in current and future conditions. Future applications will be implemented in Scandinavia in the framework of the EU ANYWHERE project (www.anywhere-h2020.eu).

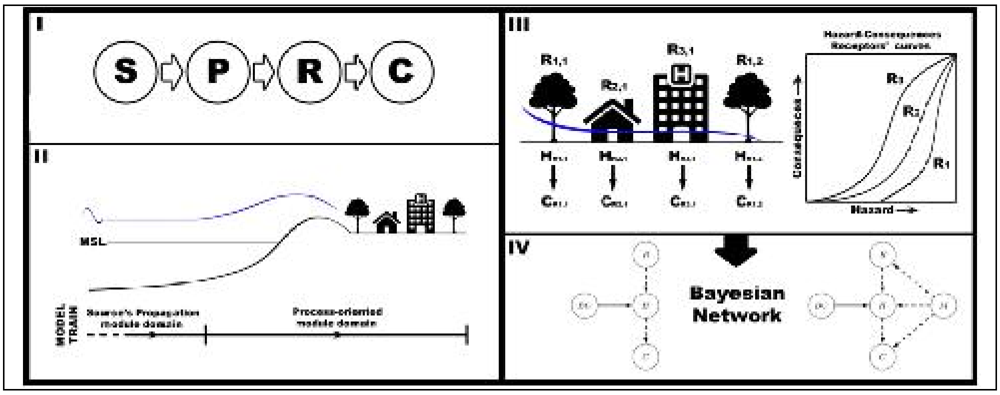

Figure 1- General methodology: (I) The SPRC conceptual framework; (II) the scheme of the model chain; (III) the scheme of hazards, receptors and consequences; (IV) Bayesian Network general scheme (adapted from Sanuy et al., submitted).

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RESEARCH AND DECISION SUPPORT APPLICATIONS OF XBEACH AT THE USGS

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TOPIC(S)
Processes, Environments

MOTIVATION

The vulnerability of beaches and coastal areas to extreme storms is largely dictated by how protective sand dunes, either natural or engineered, respond to elevated levels of surge and wave runup. In addition, the short- and long-term evolution of entire barrier island systems and the coastal ecosystems and infrastructure they support is influenced by the dune erosion and overwash that occurs during these discrete events. The United States Geological Survey (USGS) has a programmatic mission to understand, quantify, and predict the vulnerability of the U.S. coastline and supports other federal partners that manage coastal recreational and wildlife areas and need estimates of the sustainability of potential coastal restoration efforts. In support of these needs, the USGS has been applying and testing the XBeach model in a variety of regions and using results to inform decision-makers and the research community for almost a decade.

APPLICATIONS

Here we focus on summarizing a range of research and decision support applications of XBeach that includes hindcasting the coastal change associated with individual storms to quantify and improve model skill and evaluate the influence of specific boundary conditions (e.g., McCall et al, 2010; Lindemer et al., 2010; Sherwood et al., 2014). Studies focused on the hydrodynamic processes, specifically wave runup, have also been performed as a way to inform future model development by isolating and testing the ability to model infragravity wave runup, a primary driver of coastal erosion (e.g., Stockdon et al., 2014). Other research applications include accounting for physical controls, such as the influence of vegetation and development, which alter erosion processes during large storm events (Passeri et al. 2017). The USGS has also development frameworks to simulate the response of barrier islands, natural and reconstructed, to a range of storms that vary in magnitude and duration to aid in decision support (Mickey et al, 2017). More recently, XBeach has been coupled with historical rates of change and/or other more process-based models like Delft3D to simulate the decadal-scale evolution of barrier islands. These coupled model applications include the impact of multiple storm events and littoral sediment transport processes that can sometimes heal beaches between storm impacts.

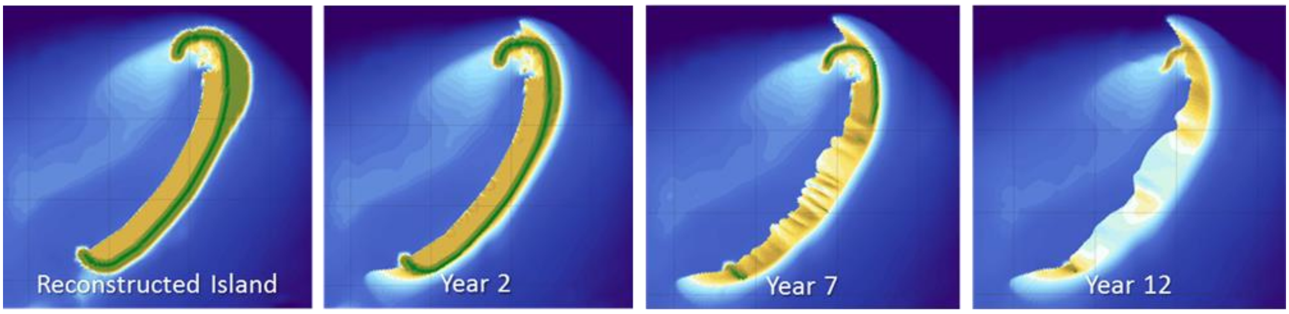

Figure 1 – Simulated evolution of a restored Breton Island, including the cumulative impact of multiple tropical storms.

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OCEAN WAVE SPECTRA FROM PHASE-AVERAGED MODELS AND REMOTE SENSING

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TOPICS: Processes (Hydrodynamics) & Numerics (Boundary conditions & Coupling to other models).

ABSTRACT

Phase-resolved models such as X-BEACH typically define offshore boundary condition from frequency-direction wave spectra, either estimated from buoy data, simple parameters or the output of phase-averaged models such as WAVEWATCH III or SWAN. In this paper we review the ongoing developments in the WAVEWATCH III model that are have extended to lower frequency, covering the infragravity wave range (Ardhuin et al. 2014) and improving on the wind sea and swell properties (Stopa et al. 2016).

Although the parameterization of free IG sources is still very crude, model results suggest that on east coasts, remote swells may be a significant source of IG waves (Rawat et al. 2015). Hence this type of model may be used to provide free IG wave spectra at the open boundary. Conversely, there is certainly much to learn from X-BEACH simulations for improving the parametric source of free IG waves in phase-averaged models. In general the IG response is expected to be linked to the shape of the windsea and swell spectrum, and its interaction with the bathymetry.

The improvement of phase-averaged models in terms of windsea and swell properties, and in particular the spectral width, is not easy given the limited availability of spectral wave measurements. Although satellites cannot provide the time resolution needed to fully monitor coastal areas, they can document typical situations from which the response of spectral shapes and their spatial variability can be investigated. We present the main characteristics of new spectra data sources from Sentinel 1 (radar imagery), Sentinel 2 (Kudryavtsev et al. 2017), CFOSAT (Hauser et al. 2017) and possible future missions such as SKIM (Ardhuin et al. 2017). Their use in the context of wave model validation and calibration will be discussed, in particular in regions influenced by ocean currents. These data will be used in particular to provide a historical record of large swell events across oceanic basins. The "Climate Change Initiative" program of the European Space Agency will in particular fund efforts to produce a consistent database for 2002-2020.

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BREAKING BAR MIGRATION INDUCED BY INFRAGRAVITY WAVES

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TOPIC
Processes (Hydrodynamics; Morphodynamics).

EXPERIMENTAL SET-UP
Experiments have been designed to reproduce beach morphodynamics in a small scale physical model with light-weight sediment (see details in Rocha, 2016). Bichromatic wave packets with associated bound long waves are let to propagate and shape the beach profile. Examples are shown in Figure 1a where C1 is a steady wave packet while C2 has an enhanced infragravity component. The beach profiles exhibit a bar at x=21.8m where the short waves break (Figure 1b). The wave packets are sent successively (C2, then C1, C2, C1), waiting for rest in between. Wave and beach profile variations are highly reproducible.

EVIDENCE OF BREAKING BAR MIGRATION
The short wave heights are identical for the two conditions, while the infragravity wave heights for C2 are about twice that of C1 (Figure 1c). Larger wave skewness and asymmetry (Figure 1d) in the surf zone (x >22.3m) for C1 promote on-shore transport (Figure 1e). The wave non-linearities are similar for the two conditions off-shore and over the bar. Off-shore sediment transport and bar migration are observed for C2. Video and velocity measurements show that the sediment suspension, which is enhanced by the breaking of the largest short waves, is advected by the off-shore directed flow associated to the long wave.

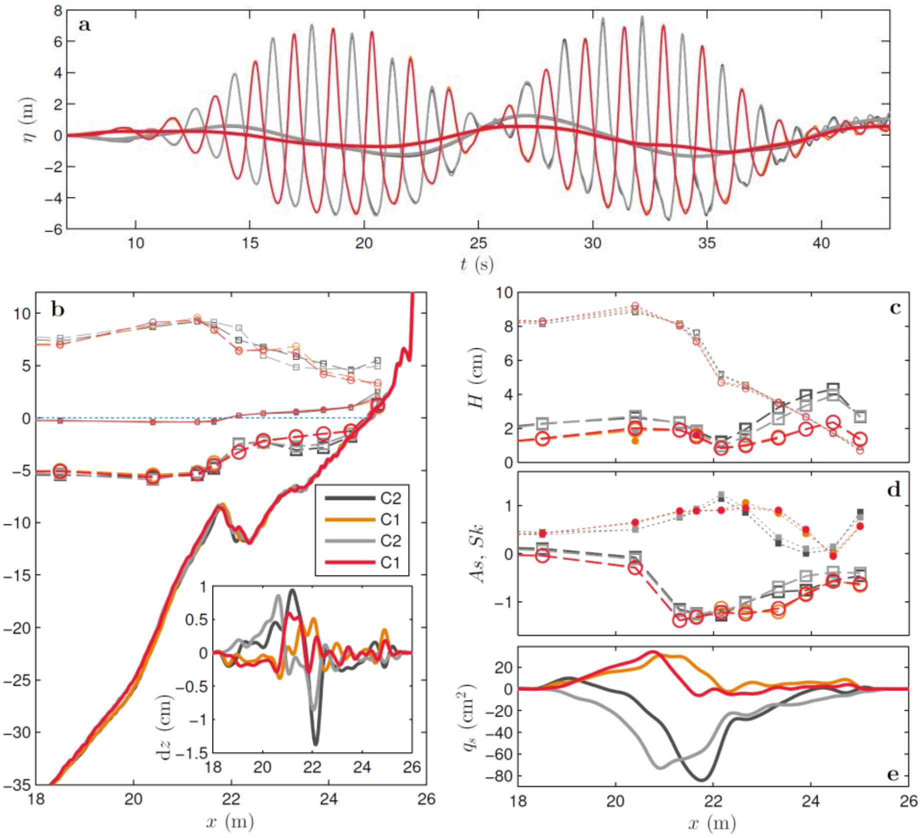

Figure 1 - a: Superimposed time series of the free surface elevation (thin lines) at x =18.5m (x=0 is the wave-maker mean position) for conditions C1 (red) and C2 (grey) with infragravity wave components in thick lines. b: Beach profiles (thick lines) after the successive wave conditions (C2 in black, C1 in orange, C2 in grey and C1 in red), with corresponding maximum (medium symbols), mean (small symbols) and minimum (large symbols) water elevation, the bed variations are plotted in the insert. c: Short wave height (small symbols) and infragravity wave height (large symbols). d: Wave skewness (filled symbols) and wave asymmetry (blank symbols). e: Sediment transport.

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INTEGRATED MORPHOLOGICAL MODELLING BY COUPLING XBEACH WITH DELFT3D FLEXIBLE MESH

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Daniel Caichac, TU Delft

TOPIC
Processes (Morphodynamics), Environment (Sandy coasts); Numerics (Coupling to other models)

MOTIVATION
The most common practice among engineers is to focus on a single spatial and time scale, which means either neglecting certain processes under the assumption that they will average out, or performing detailed simulations for short time-spans in order to optimize the normally limited computational resources. Despite the efforts from several authors, at the moment there is a lack of a clear methodology which would allow incorporating the relevant physical phenomena only when required, hence optimizing the computational effort.

METHODOLOGY
The study investigated the added value of coupling process-based morphodynamic models, regarding the morphological impacts near the beach. For this purpose two models that were originally conceived to resolve different timescales are coupled using BMI; XBeach as a storm model, and the new suite from Deltares, Delft3D-Flexible Mesh (D3D-FM) as a longer-term morphodynamic model. The area selected as study site is Anmok beach, located at the east coast of South Korea. The coastal erosion at this location is not yet well understood (mainly due to human interventions and storms) plus the micro-tidal wave-dominated environment makes this location ideal for this study. The dynamics of Anmok beach is a delicate balance between the stormy and calm periods, where the high energy wave events are the main drivers of local morphology.

RESULTS
A fully coupled morphological simulation was conducted for one year including more than four high-energy wave events (H_s > 4m). Results from the integrated prediction show that the cumulative effect of the storms in one season is larger than observed (see Figure 1). One explanation could be the lack of recovery processes in the simulation. Another interesting finding is that the coupling of independently calibrated models does not necessarily provide better morphodynamic results than the results obtained by running each model separately. Including different processes such as infragravity waves or Eulerian mass transport (which enhances the offshore sediment transport in the surf zone) during highly energetic events tend to generate large supratidal beach erosion. However, the post-storm recovery mechanisms present in long-term morphodynamic models are not sufficient to bring the sediment back to the beach.
Coupling models can play an important role in identifying which processes are missing or are not fully represented by the different modelling packages.

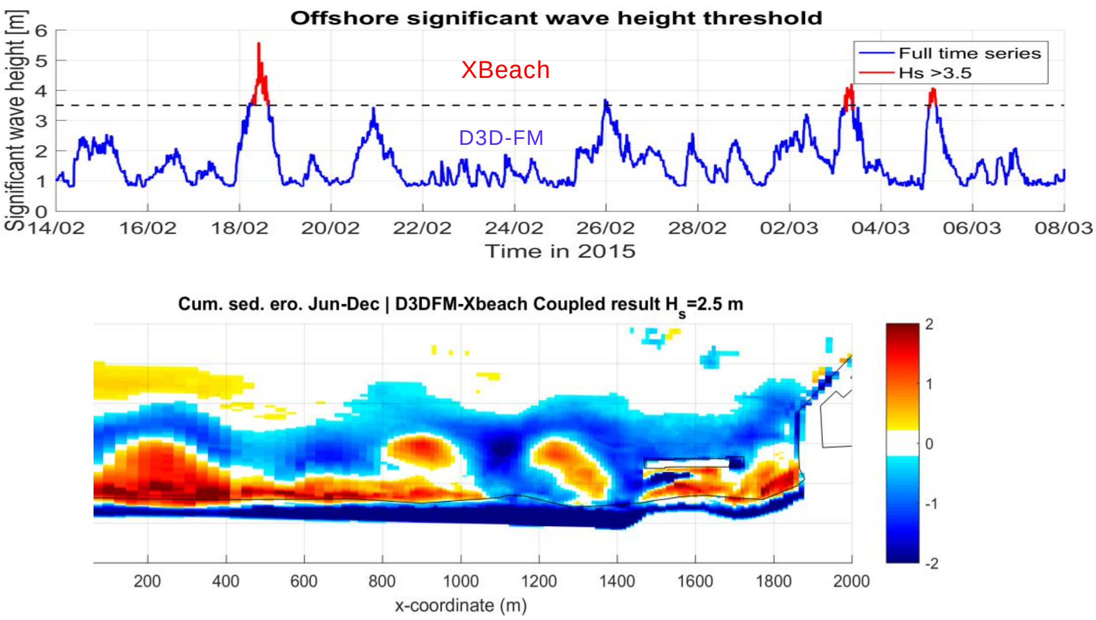

Figure 1 - Time series of alternating XBeach and D3D FM simulations; lower panel shows the resulting integrated bed level changes after 6 months.

RIP CURRENT GENERATION FROM INTERSECTING WAVES: LABORATORY EXPERIMENTS AND XBEACH MODELLING

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TOPIC
(1) Processes: Hydrodynamics (wave transformation, rip currents).
(2) Numerics and validation: Field and lab observations for validation.

INTRODUCTION
The breaking of short-crested waves formed by intersecting wave trains lead to the generation of rip currents (Dalrymple, 1975; Wei, 2017). This hypothesis has been investigated by means of laboratory experiments performed at the Cantabria Coastal and Ocean Basin (CCOB, IHCantabria) during the ANIMO project (Garnier et al., 2014). The objective of this contribution is to reproduce these experiments by using the XBeach non-hydrostatic numerical model (Smit et al., 2010) and to give insight into the generation mechanisms and into the dynamics of rip currents.

LABORATORY EXPERIMENTS
The CCOB measures 25 m in the cross-shore and 32 m in the longshore direction. A concrete plane sloping beach (1:5) was built for the purpose of the experiments. The water depth at the segmented wavemaker was set to 1 m. The 64 waveboards allowed us to generate intersecting wave trains such that a system of three rip currents was obtained for different wave conditions.

XBEACH MODELLING
The XBeach model is applied to the laboratory experiments. The use of the non-hydrostatic mode allows us to resolve the wave field on the timescale of individual waves. The model is validated from comparisons of (1) the wave field obtained from wave gauges deployed along three longshore and two cross-shore transects and (2) the runup obtained from runup wires deployed along the beach (Figure 1a). The XBeach simulations (Figure 1b) will allow us to give a relationship between the rip current dynamics and the offshore wave field.

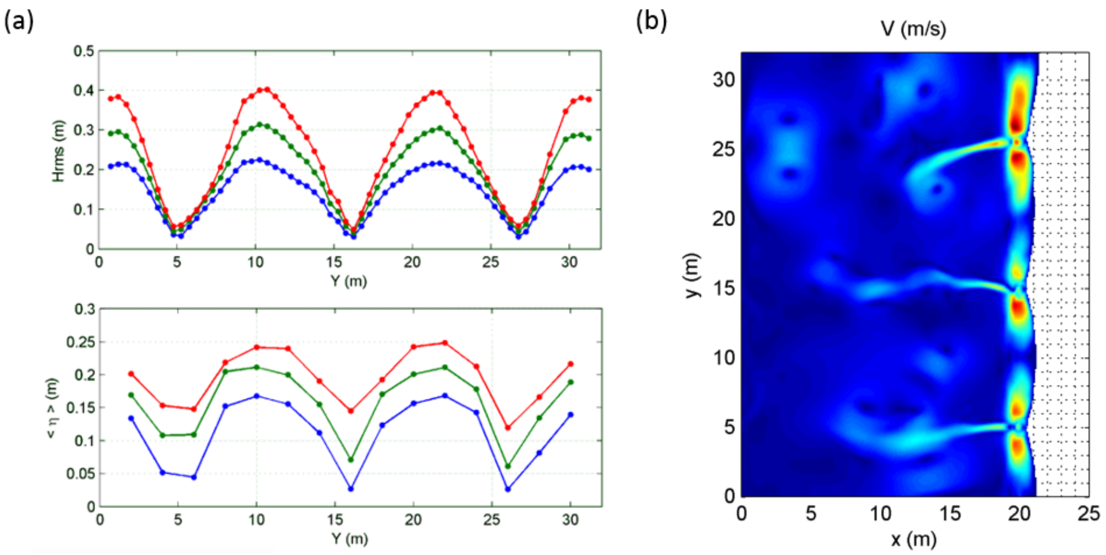

Figure 1 - (a) Wave height measured at the wavemaker (x=0, top) and corresponding mean sea level obtained at the runup wires (bottom) for different wave conditions. (b) Example of mean current magnitude obtained with XBeach.

ACKNOWLEDGEMENTS
This work was supported by the “Ministerio de Economia y Competitividad” under the BIA2014-59643-R grant.

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ENERGY TRANSFERS AND REFLECTION OF IG WAVES UNDER STORM CONDITIONS

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TOPIC Infragravity waves - Hydrodynamics

BACKGROUND
Infragravity (IG) waves (25-250 s in period) can grow to over a meter in height at the shore during storms, and can therefore have a relevant contribution to flooding, sand transport and morphological changes. To unravel how these waves influence the evolution of the coastline, it is necessary to first of all understand their transformation when they propagate towards the coast. Recently obtained measurements during a large storm shed new light on their behavior, in particular on their transformation in shallow water and subsequent reflection at the beach. These field observations are complemented with numerical modeling using XBeach (Roelvink et al. 2009), in order to better understand IG-wave generation and transformation mechanisms but also validate this modelling system under extreme wave conditions.

FIELD CAMPAIGN AND MODEL SETUP
Measurements were obtained at the mild sloping (1:70 - 1:30) beach of St. Trojan, Ile d'Oléron, France, early February 2017 during the storm *Kurt.* Offshore wave heights reached up to 10 m. An ADCP was installed at a water depth of 11 m and indicated that wave height at breaking reached 6 m, with peak wave periods of up to 20s, and incoming IG-wave heights close to 1 m. In the intertidal zone, 9 pressure sensors were installed along a cross-shore transect, at two positions co-located with a velocity meter (either an ADCP or an ADV) and sand concentration sensors (OBSs).
XBeach was implemented over the study area in 2D-mode, using a rectilinear grid starting from a water depth of about 25 m (9km from the shoreline), and with a grid size ranging from 50 m along the open boundary to 5 m in the nearshore. XBeach was forced with time series of hourly directional wave spectra and water levels originating from the regional storm surge model of Bertin et al. (2015).

RESULTS AND CONCLUSIONS
First results demonstrate that IG waves are dominant over short waves in the intertidal zone during the storm, and can reach up to 1.8 m in height. The energy spectra show the presence of both well-defined IG-wave sub- and super harmonics (see Figure 1). Interestingly, while they propagate shoreward, all peaks in the IG-wave band show a displacement towards higher frequencies, during all high tides. As of yet, we have no proper explanation for this behavior, but it might be related to a complex reflection pattern. Their reflection at the shoreline is seen to depend both on frequency as well as on tidal level. Unexpectedly for a dissipative beach, large reflection coefficients were found at the three current meters, with values ranging from 0.5 at low tide to >1 at high tide. This tidal modulation of reflection is explained by the increase in bottom slope from 1:70 in the beach lower part to 1:30 in the beach upper part. This unexpected large reflection of IG waves is explained through IG-wave energy transfers towards very low frequencies (0.002-0.005 Hz), which strongly limit their dissipation by depth-limited breaking in very shallow water. Overall, IG-wave generation and transformation (energy transfers and tidally modulated reflection) are reasonably captured by XBeach. Modeling results are being investigated further in order to better understand the underlying physical mechanisms.

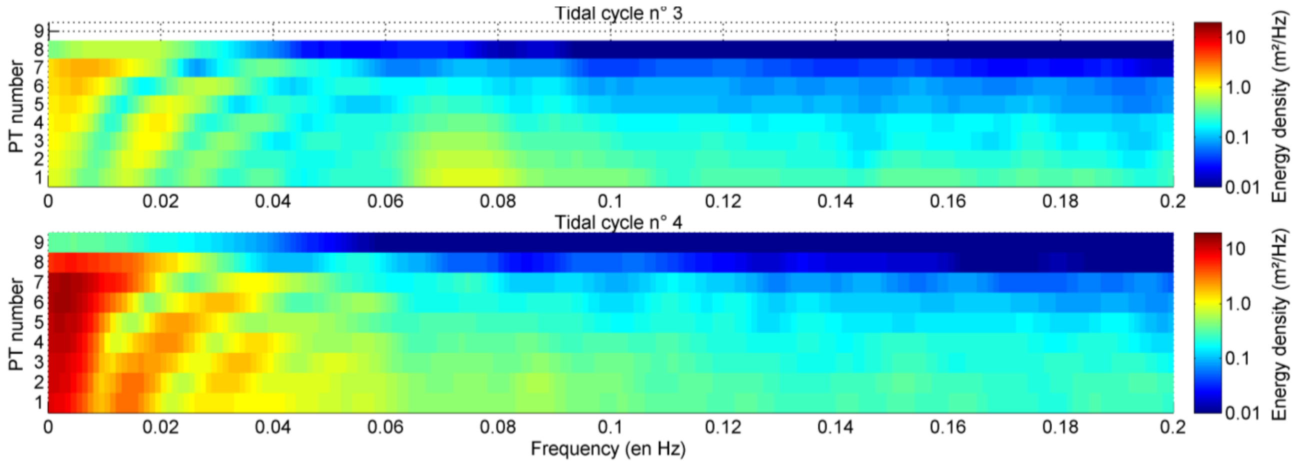

Figure 1 - Measured energy density spectra over the cross-shore transect during four tidal cycles.

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INFRAGRAVITY WAVE FORCING ON A BARRED BEACH: A NUMERICAL STUDY

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PROCESSES (Hydrodynamics)

Infragravity waves (IGW) with typical periods between 25 to 250 s can play an important role in the nearshore zone and particularly during storms (Ciavola and Coco, 2017). The specific effect of a bar on IGW dynamics by specifically comparing an unbarred with a barred beach under same forcing conditions seems to be restricted to Baldock et al. (2004). Our study investigates the IGW dynamics over a dissipative barred beach, thereby extending previous studies.

Numerical simulations were performed with the SWASH model (Zijlema et al., 2011). We considered an unbarred beach with a 1/80 bottom slope and an offshore water depth of 0.85 m (Figure 1d)). The short-wave (SW) forcing was obtained with a JONSWAP type spectrum with a significant wave height of 0.10 m, a peak frequency of 0.4444 Hz and a peak enhancement factor of 20. Similar to Baldock et al. (2004), the bar was added as a linear discontinuity on the unbarred profile with a water depth over the bar crest of 0.25 m and a bar height of 0.10 m (Figure 1d)). Data analysis comprised the cross-shore significant SW and IGW wave heights (Figure 1a) and b)), the cross-correlation coefficient between the radiation stresses and the IGW amplitude (Figure 1c)), the IGW energy flux gradient (Figure 1e)) and the rate of work done by the radiation stresses (Figure 1f)). These last two terms were evaluated following Ruju et al. (2012).

A small SW energy decay occurs near the bar crest induced by partial SW breaking (Figure 1a)). The significant IGW height near the shore is approximately 20% higher for the barred than for the unbarred profile (Figure b)). The phase-lag between the radiation stresses and the IGW amplitude during SW breaking conditions increases on the bar trough when compared to the unbarred beach (Figure c)). The IGW energy flux gradient is positive on the bar trough (Figure e)) which implies that the IGW band is receiving energy. The work done by the radiation stresses is also positive on the bar trough and partially compensates the positive IGW energy flux gradient (Figure f)).

Our numerical simulations indicate that the amount of IGW energy near the shore is higher for the barred than for unbarred profile. The phase-lag between the forcing (radiation stresses) and the IGW amplitude increases at the bar trough probably promoted by the partial SW breaking. Nonlinear energy transfers between the SW and IGW frequencies are occurring at the bar trough. These energy transfers are from the SW towards the IGW frequencies because the positive IGW energy flux gradient is compensated by a positive work done by the radiation stresses. Therefore, the existence of a partial SW breaking at barred beaches seems to control the nonlinear energy transfers between the SW and IGW frequency bands.

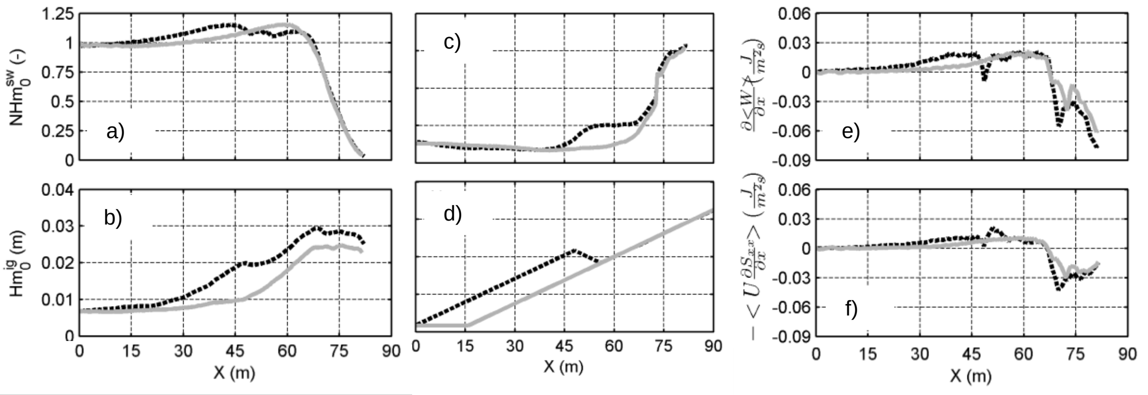

Figure 1 – Normalized significant short-wave height (a)). Significant infragravity wave height (b)). Maximum cross-correlation value between the radiation stresses and the infragravity wave amplitude (c)). Barred and unbarred beach profiles (d)). The infragravity wave energy flux gradient (e)). The work done by the radiation stresses (f)).

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Thursday

COASTAL INUNDATION HAZARDS ON FRINGING CORAL REEFS AND ATOLL MOTU OF THE SOUTH PACIFIC

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TOPIC
Coral Environments

INTRODUCTION
Large swells produced by extra-tropical storms and tropical cyclones can severely affect coastal communities leaving in the South Pacific. The deep water surrounding atoll islands and fringing reefs causes large waves reaches the reef edge after little dissipation and often with very long period (18-22s). When these large swells dissipate on the reef crest of the reef, they cause substantial wave setup on the reef flat and generate large infragravity waves that can exacerbate coastal inundation.

Numerical model XBeach has been previously proved to accurately simulate the water levels, swell waves and infragravity waves on the reef flat and all the way to the shore. Making it the go-to model for evaluating coastal inundation hazards in these environments. However, the extreme conditions that occur during tropical cyclones and the interaction between the mean level of the sea and wave dissipation and model run times makes it difficult to perform statistically robust analysis of the coastal inundation hazard using a process-based modelling.

TROPICAL CYCLONE INUNDATION
This presentation will describe several cases of coastal inundation from Tropical Cyclone (TC). First the Inundation from TC Pam in Vanuatu and Tuvalu will be presented. The Case of Tuvalu for TC Pam is interesting because the TC occurred more than 1,000km from Tuvalu but the swell that was generated cause as much damage as if the cyclone had hit the island group. In Vanuatu Lidar data collected before the TC and photogrammetry data collected after the event shows how the waves flattened several fossil beaches perched on uplifted reef. In February 2016, Tropical Cyclone Winston made landfall in Fiji as a Category 5 tropical cyclone causing severe devastation and inundation on the main islands of Fiji. Post disaster survey has identified runup level as high as 5.6m above the high tide mark as well as a strong variability of runup alongshore (Figure 1). Although complex bathymetry and topography, and local vegetation may explain this alongshore variability, it highlights the challenges of evaluating coastal inundation hazard from such event in complex reef environments.

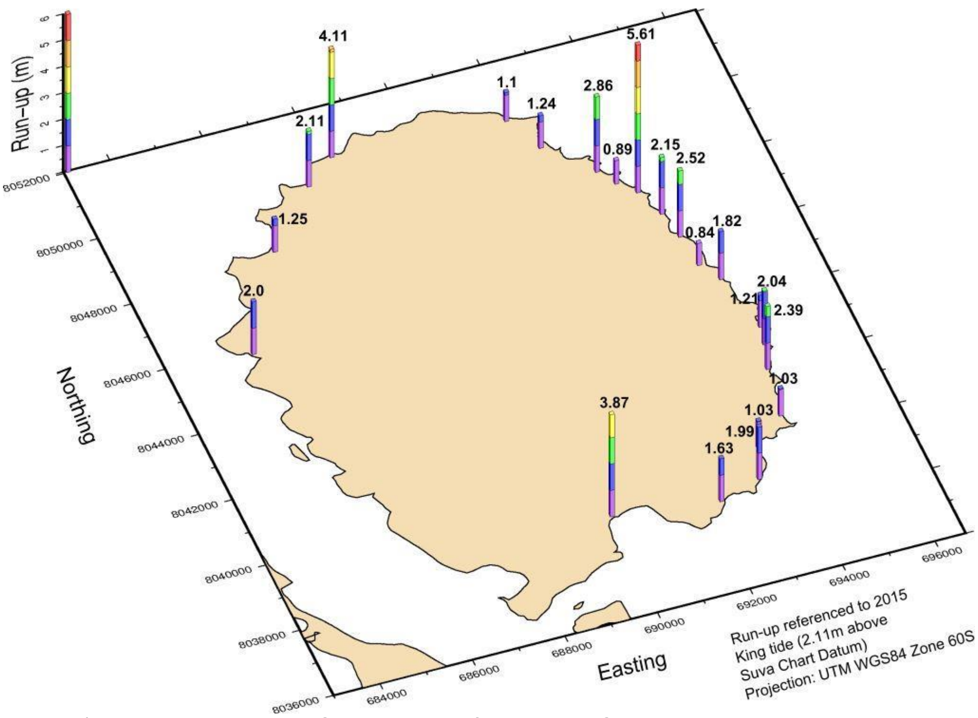

Figure 1 - Maximum runup on Ovalau island after Tropical Cyclone Winston.

INFRAGRAVITY WAVES
The presentation will also describe how wave climate and the geometry of reef flat affect the infragravity waves. In Fiji, The Coral Coast is exposed to the large long period swell produced in the Tasman sea. These swell often occur during fair

weather conditions and cause inundation without warning. Intensive data collection on the Coral Coast has showed that large infragravity waves account for a significant proportion the maximum water level. Similarly, and yet with different characteristics, infragravity wav signal can also be observed in Kiribati, Tuvalu and Vanuatu. Most of the difference is due to a difference in wave climate and shapes of the fringing reef.

COASTAL INUNDATION HAZARDS AND FORECASTING

Finally, the presentation will present a methodology have been used to make the most of the process based modelling XBeach to evaluate the coastal inundation hazards in the South Pacific and produce coastal inundation forecast. The method involves a combination of meta-models and scenario based models. This methodology is being used to produce inundation hazards maps in Vanuatu and to setup an inundation forecast for the Coral Coast of Fiji (Figure 2).

Figure 2 - Inundation map of Maui Bay as produced from by the meta-model

PHYSICAL AND NUMERICAL MODELLING OF LONG WAVES ON A CORAL REEF PLATFORM

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TOPIC
Hydrodynamics, Coral

INTRODUCTION
It is well-established that wave conditions impacting on coral reef islands are controlled by wave transformation processes across the reef platforms, and that these wave transformation processes are in turn strongly modulated by the (tidal) water level. A key characteristic of the hydrodynamics across reef platforms is the transformation of incident wave energy to infragravity wave energy. Here, we present the results of a small-scale lab experiment and Xbeach numerical modelling to investigate the generation and propagation of long waves on coral reef platforms.

METHODOLOGY
A reef platform was constructed out of plywood in the wave flume in the COAST facility at Plymouth University. The model was at the 1:50 scale, and the width of the platform was 8 m (400 m at proto-type) and the water depth in front of the platform was 0.5 m (25 m at proto-type). A coral reef island composed of 0.3 mm sand (1.5 mm at proto-type) was placed on the platform. The configuration of the reef platform and island was chosen the represent the island of Fatato (Figure 1). The reef platform and island were exposed to a range of wave and water-level conditions, and water-level data were collected using 14 wave probes distributed across the reef platform. The exact configuration and forcing conditions were reproduced at the proto-type using XBeach models. The numerical modeling was first validated using the physical modelling results and was then used to study the generation and propagation of long waves across the reef platform for an extended parameter space.

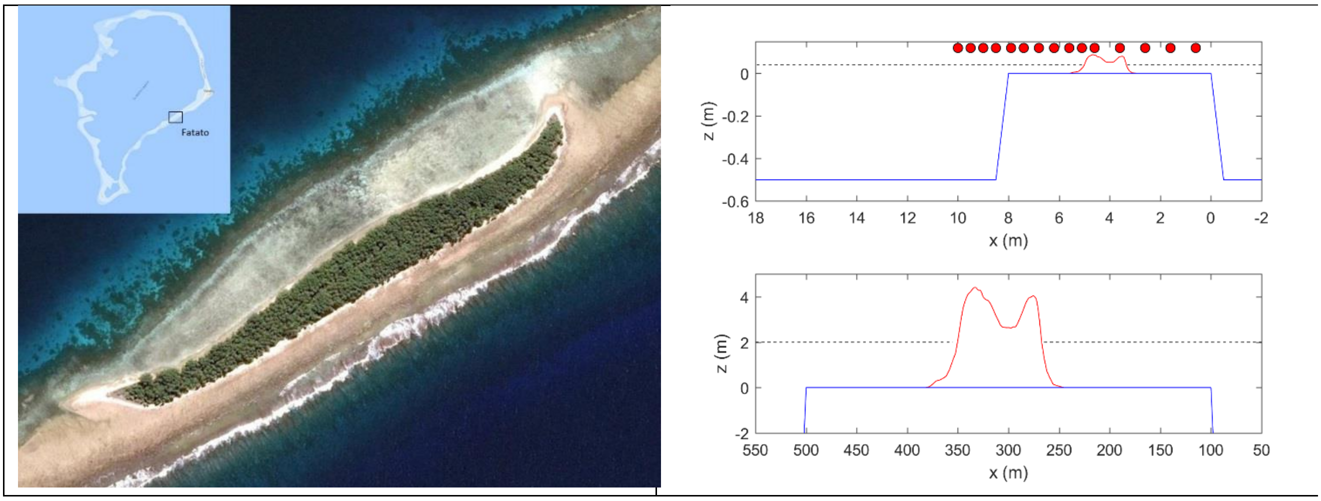

Figure 1 - Left panel shows aerial photograph of Fatato Island on Tuvalu in the Pacific Ocean. Upper-right panel shows cross-section of reef platform and island for the 1:50 scale laboratory experiment. The wave paddle is located at x = 18 m; the wave gauges are indicated by the red circles and the mean high tide level is represented by the horizontal dashed line. Lower-right panel shows zoomed in section of the reef platform and island on the proto-type scale used for the Xbeach numerical modelling. The offshore and onshore boundaries of the model are at x = -1000 m and x = 0 m, respectively, and the water depth away from the reef platform is 25 m.

RESULTS
Both the physical and the XBeach numerical model results indicate that the water motion across the reef platform is dominated by long wave motion. This long wave motion is strongly related to 'offshore' wave groups, but is **not** generated through the release of the bound long wave (BLW). Rather, the long waves propagating across the reef platform represent the remnants of large wave groups breaking onto the fore reef, and the long wave motion can therefore be considered breakpoint-generated. Additionally, a seaward-propagating long wave, exhibiting a negative phase correlation with the incoming wave groups and hence considered the incoming BLW reflected at the fore reef, was also noted in both the physical and numerical modelling results. The long wave motion across the reef platform is progressive without a reef island, but is mainly standing if a reef island is present. Numerical modelling further demonstrated that that the importance of the breakpoint-generated long wave across the reef platform is strongly dependent on the gradient of the fore reef, and that for gentle fore reef gradients (< 0.05) the long wave motion is mainly caused by the release of the incoming BLW.

XBEACH APPLICATION OF CORAL REEF-LINED COASTS

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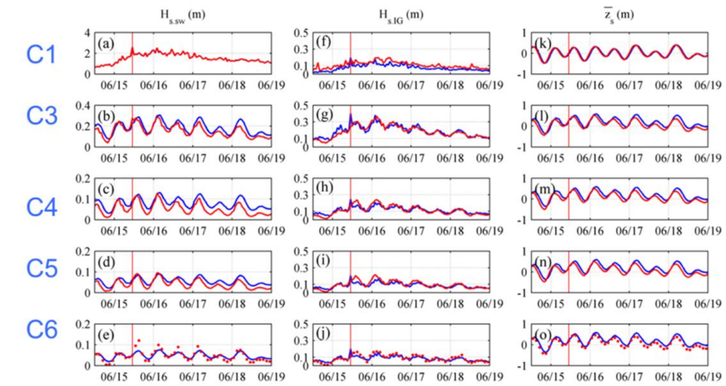
TOPIC
Hydrodynamics; Coral coasts.

INTRODUCTION
Many tropical islands and coasts are lined with coral reefs. These reefs are host to valuable ecosystems that support abundant marine species and provide resources for fisheries and recreation. As a flood defense, reefs protect coastlines from coastal storm damage and flooding by reducing the majority of incident wave energy. However, during storm and large swell conditions, coastal wave-driven flooding and overwash still occur due to high water levels, (infra) gravity waves, and/or low-frequency wave resonance. The wave and flooding effects cause erosion, damage to infrastructure, agricultural crops, and salinization of precious drinking water supplies. These impacts, which are likely to increase due to climate change and ongoing development on the islands, may cause many low-lying tropical islands and coastal areas to become uninhabitable before the end of the century. This paper will describe how XBeach was developed and applied for these types of problems, and what the future holds.

XBEACH APPLICATIONS ON REEFS
The XBeach application on coral reefs started with a question by Dr. Ryan Lowe (U. Western Australia) if the longer-period motions that he observed on reefs could be infragravity waves and if they could be modeled. Sharing data and sharing software, we showed that indeed they were IG waves. In fact, the composite bathymetry of a steep slope and a mild reef platform provided a beautiful case in which the generation of IG waves, and their propagation and decay could be studied.



On the basis of field data obtained at Ningaloo Reef (Aus), Pomeroy et al., (JGR 2012) and Van Dongeren et al., (CE 2013) clarified on IG wave generation through the breakpoint mechanism on fringing reefs.

Figure 1: Short wave heights, IG wave heights and mean water level, observed (red) and measured (blue) on six stations in a transect.

The focus then shifted to wave impact reduction that fringing and atoll coral reefs afford, following an analysis by Ferrario et al. (2014, Nat. Comm) which showed the dramatic wave height reduction effect of reefs. For the case study site of Roi Namur and in cooperation with Dr. Curt Storlazzi of USGS, we demonstrated how changing hydrodynamic forcing, a changing reef geometry and roughness will cause changes in the projected runup using a limited number (50) of XBeach simulations (Quataert et al. ,2015). Challenged by a critical reviewer, we set out to run many more (450,000) permutations of the model and input parameters, producing a Bayesian Network which connects forcing, reef geometry and runup (Pearson et al., submitted and this conference). For the islet of Roi-Namur, different RCP (Representative Concentration Pathways) scenarios were applied to show that wave-driven flooding will start to affect the habitability within several decades. This is much sooner than anticipated based on projections of sea level rise alone (Storlazzi et al., Science Advances, submitted; Van Dongeren et al., 2017 Coastal Dynamics).

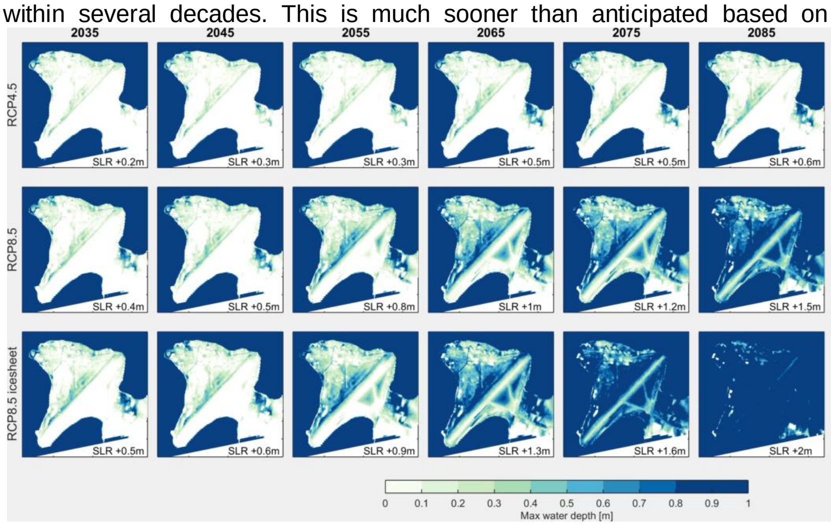


Figure 2: Flooding depth for three RCP scenarios and at six time instances at Roi Namur.

Having validated the model on the above field data and on laboratory data (Lashley et al., submitted and this conference), it was applied on a number of advisory projects on the habitability of small islets such as Tuvalu and Ebeye (Marshall Islands). The presentation will show some of the above results and discuss future research needs.

WAVE-INDUCED REEF BARRIER CURRENTS, XBEACH SIMULATION VS FIELD MEASUREMENTS

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TOPIC
Hydrodynamics; Coral, gravel and rocky coasts and shoreline

INTRODUCTION
Mostly present in intertropical regions, coral reef lagoon systems provide a unique habitat for a wide variety of living organisms and an efficient protection against extreme events such as tsunamis and cyclones. The knowledge of the cross-reef water fluxes and their impact on lagoon dynamics as well as their implementation in coastal circulation models are key issues for the estimation of flushing time and prediction of biological resilience of the complete reef/lagoon system. However, due to the toughness of measuring and analysing hydrodynamics at such a wide range of spatio-temporal scales, the cross-reef effects on the lagoon dynamics remain difficult to analyse and model at the whole lagoon scale.

Xbeach has be shown to accurately represent wave transformation over fringing reefs (Pomeroy et al. 2012), provided that the reef roughness is accounted for. The aim of the present study is to test the ability of Xbeach to simulate the depth-averaged cross-reef currents induced by wave breaking over the reef flat. It is based on previous experimental studies (Chevalier et al. 2015, Locatelli et al. 2017) and new additional field data acquired on the Ouano lagoon (New Caledonia).

THE FIELD EXPERIMENTS
The studied site is the Ouano lagoon, south-west New Caledonia. The field site is a coastal weakly anthropized narrow lagoon, nearly 30 km long, 10 km wide and 10 m deep (see Fig. 1). This reef-lagoon system is a typical “channel” lagoon with strong aspect ratio of horizontal dimensions: the lagoon is much longer than it is wide. Such configuration implies a strong effect of cross-reef fluxes induced by wave breaking on the lagoon dynamics and water renewal time. At high tide, the coral reef barrier is fully submerged, whereas at low tide it can be partly emerged depending on tide and wave conditions as well as large-scale sea level fluctuations. For further description of the Ouano reef-lagoon system and the previous experiments, the reader should refer to Chevalier et al., 2015.
Further experiments have been performed in 2016 in order to improve the spatio-temporal resolution of wave and currents measurements over the reef barrier. Three acoustic Doppler current profilers are used to measure the cross-reef currents The first one, which will be considered here as a reference, is a Nortek Aquadopp profiler located near the inner boundary of the reef barrier. It provides current data over 3 months. The second Aquadopp profiler is deployed at the same cross-shore position, but shifted along the reef in order to identify the possible spatial variations of the cross-reef fluxes. In addition, a high resolution high frequency Nortek Signature profiler is deployed over the reef flat.

THE MODEL
The first step of the XBeach study is to consider a single cross-shore transect, i.e. neglecting the along-reef variations of wave and currents over and around the reef barrier. Regular stationary wave forcing is used, in order to remove the effect of long waves from the current analysis (Locatelli et al. 2017). The numerical bathymetry is interpolated from a series of field surveys performed all along the reef-lagoon system. The model is parameterized with typical values of reef roughness obtained from existing study (Pomero et al. 2012). These values will be compared with the field estimation deduced from log-layer fitting of the velocity profile.
Promising results have been obtained from the first simulations. From moderate to strong wave conditions, XBeach confirms, both qualitatively and quantitatively, the combined effect of wave height and water level over the reef in the cross-reef current. Further work is now engaged to understand the peculiar dynamics observed during extreme wave forcing observed on May, 25 2016 (Hs=6m, Tp=16s).

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NONHYDROSTATIC AND SURFBEAT MODEL PREDICTIONS FOR EXTREME WAVE RUN-UP IN FRINGING REEF ENVIRONMENTS

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TOPIC
Processes: Hydrodynamics (wave transformation, run-up, setup); Environment: Coral coasts and shorelines; Numerics: Lab observations for validation.

INTRODUCTION
The accurate prediction of extreme wave run-up is important for effective coastal engineering and coastal hazard management. While run-up processes on open sandy coasts have been reasonably well-examined, very few studies have focused on understanding and predicting wave run-up at coral reef-fronted coastlines. This research applies the Nonhydrostatic (XB-NH) and Surfbeat (XB-SB) modes of the XBeach numerical model to validate run-up using data from two laboratory fringing-reef profiles (Figure 1), with two objectives: i) to provide insight into the physical processes governing run-up in such environments; and ii) to evaluate the performance of both modes to accurately predict run-up over a wide range of conditions.

METHODS
XBeach was calibrated by optimizing the key wave dissipation parameters (*maxbrsteep* in XB-NH and *alpha* in XB-SB) using the first dataset (Demirbilek et al. 2007); and then applied to the second dataset (Buckley et al. 2015) for validation. XB-NH and XB-SB predictions of extreme wave run-up (R_{max} and $R_{2\%}$) and its components, infragravity- and sea-swell band swash (S_{IG} and S_{SS}) and shoreline setup ($<\eta>$), were compared to observations.

RESULTS AND CONCLUSIONS
XB-NH more accurately simulated wave transformation but under-predicted shoreline setup due to its exclusion of wave-roller dynamics. XB-SB under-predicted sea-swell band swash but overestimated shoreline setup due to an over-prediction of wave heights on the reef flat. Run-up spectra in the swash were dominated by infragravity motions, allowing the short-wave averaged model (XB-SB) to perform comparably well to its more complete, short-wave resolving counterpart (XB-NH). Despite their respective limitations, both modes were able to accurately predict R_{max} and $R_{2\%}$ (Figure 2).

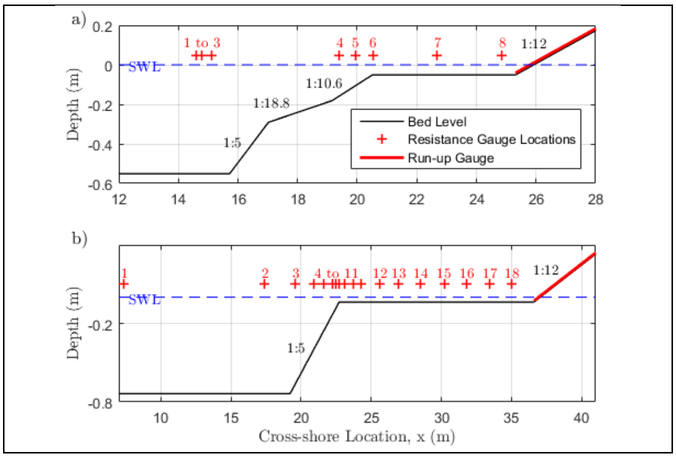

Figure 1 - Profiles of fringing reefs simulated showing instrument locations for a) Demirbilek et al. (2007) and (b) Buckley et al. (2015) experiments.

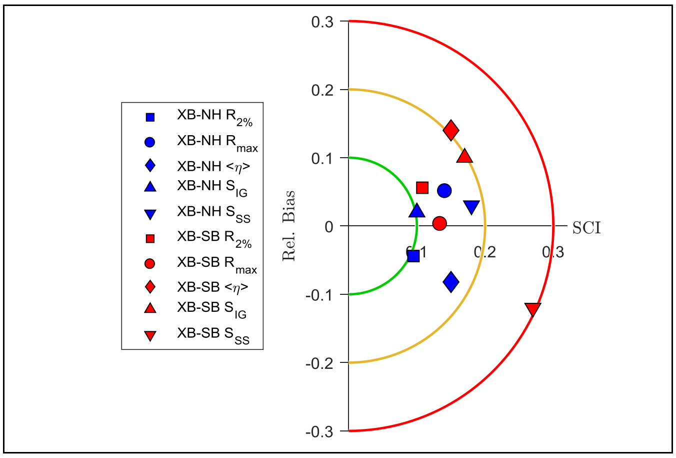

Figure 2 - Target plot showing results of the model validation (Buckley et al. (2015) dataset) with Scatter Index (SCI) and Relative Bias error values for R_{max}, $R_{2\%}$, $<\eta>$, S_{IG} and S_{SS} for both XB-NH and XB-SB model predictions.

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BEWARE: BAYESIAN ESTIMATION OF WAVE ATTACK IN REEF ENVIRONMENTS

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TOPIC
Coral, gravel and rocky coasts and shorelines

ABSTRACT
Reef-fronted tropical coastlines are faced with the threat of wave-induced flooding, a challenge that is expected to worsen under the effects of climate change and sea level rise. However, due to variations in offshore hydrodynamic forcing, vast range of coral reef morphologies, and the complexity of coral reef hydrodynamics, it is challenging to predict wave-induced flooding on these coastlines.

To overcome these challenges, we propose the BEWARE (Bayesian Estimation of Wave Attack in Reef Environments) system (Pearson et al. 2017). In lieu of field measurements of the hydrodynamic response of reef-fronted coasts, we use XBeach Non-Hydrostatic (XBNH) to create a large synthetic database. An idealized 1D reef profile was created in XBNH and varied with 174,372 combinations of offshore hydrodynamic forcing and reef morphology. The results of these simulations were then incorporated in a Bayesian network, a statistical model that uses conditional probabilistic relationships between offshore forcing and reef morphology to estimate runup.

The results suggest that XBNH is capable of reproducing key reef hydrodynamic processes including resonant amplification. BEWARE shows high predictive accuracy for XBNH results, and was tested on a limited number of field cases. A key finding was that water depth on the reef flat, incident wave forcing, and the width of the reef are the most important input parameters for predicting runup. BEWARE can potentially be applied in early flood warning systems or for assessing climate change impacts.

To further validate BEWARE, it was tested using field measurements of runup during Typhoon Meranti at Batanes, Philippines (Tajima et al. 2017). BEWARE showed a tendency to overestimate runup, which may be attributed to the simplifications made in schematizing the model. With additional field measurements such as these, BEWARE's predictive capability can be further validated and improved.

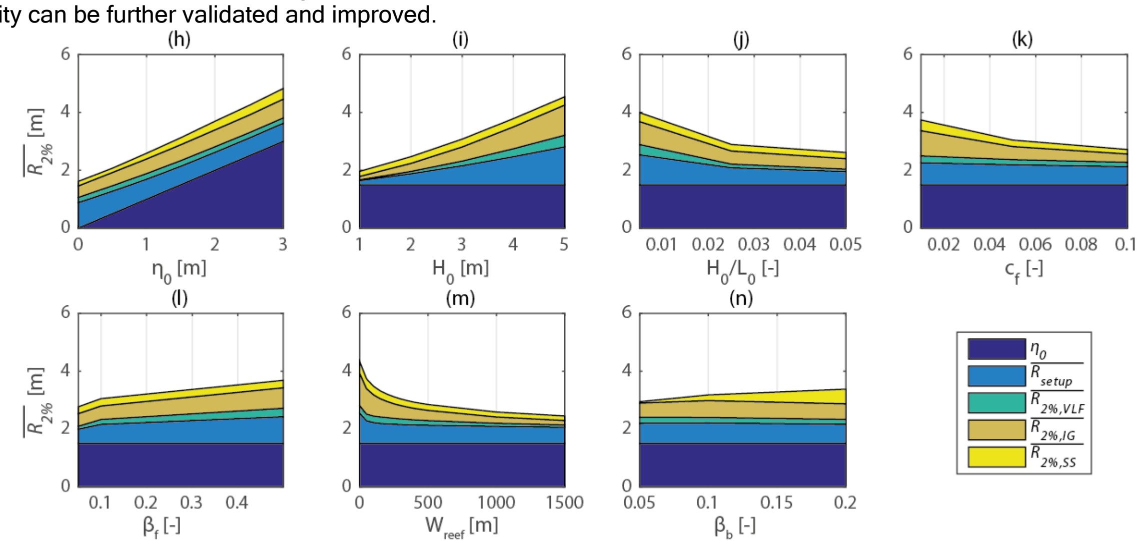

Figure 1 - Variations in modelled runup $R_{2\%}$ as a function of offshore water level (η_0), offshore significant wave height (H_0), offshore deep water wave steepness (H_0/L_0), friction coefficient (c_f), fore reef slope (β_f), reef width (W_{reef}), and beach slope (β_b).

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A METAMODEL TO ESTIMATE RUN-UP ALONG CORAL REEF-LINED SHORELINES

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TOPIC
Hydrodynamics on Coral reef-lined shorelines

ABSTRACT
Wave-induced flooding is a major hazard on low-lying tropical islands (Hoeke et al. 2013), many of which are fringed by coral reefs that act as natural flood defenses (Ferrario et al. 2014). However, coastal flooding still occurs under extreme conditions, causing widespread devastation to people, habitats, and infrastructure (Roeber and Bricker, 2015; Spennemann, 2004). The Sendai Framework for Disaster Risk Reduction adopted by the United Nations (UNISDR, 2015) established the need to be able to predict and mitigate coastal flooding risks using tools such as early-warning systems, (UNISDR, 2015, 18(g)). Such predictions require an improved understanding of the hydrodynamic processes in these environments.
In response to this need, we present a metamodel (model-of-model) of X-Beach Non-Hydrostatic (XB-NH; Smit et al. 2014) simulations and Radial Basis Functions (RBFs) to predict wave run-up under infinity reef and offshore forcing characteristics. Due to the complexity and high dimensionality of the problem, we have assumed an idealized 1D reef profile, characterized by seven primary parameters: offshore water level (η_0), wave height ($H_{s,0}$), and wave steepness ($H_{s,0}/L_0$) as the hydrodynamic inputs, and fore reef slope (β_f), reef flat width (W_{reef}), beach slope (β_b), and coefficient of friction (c_f). XB-NH was chosen to create the synthetic dataset of 43740 simulations (Pearson et al., 2017). To forecast wave run-up for any combination of these parameters, RBFs were chosen as interpolation technique due to its large flexibility (Hussain et al. 2002). Results show the applicability of the metamodel to obtain fast and accurate (RMSE ~ 0.28 m) predictions of wave run-up for any combination of reef characteristic and hydrodynamic inputs, offering a useful tool for risk management and early warning systems.

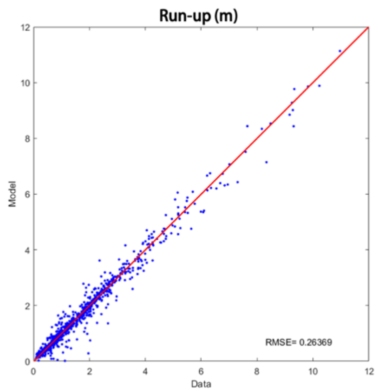

Figure 1. Validation with 1000 random points

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The difference in runup predictions between XBeach Non-hydrostatic and XBeach Surfbeat

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TOPIC
Hydrodynamics, Sandy coasts

INTRODUCTION
Wave runup is generated by energy which remains after wave breaking and travels farther to the coast. It can be seen as a thin wedge of water running up the beach face (Brocchini and Baldock, 2008). Under storm conditions runup is responsible for beach and dune erosion and accurate runup predictions are therefore required (Ruggiero et al., 2001; Stockdon et al., 2005). For runup and its components, the time-mean setup component and the time-varying swash component, empirical parameterizations have been developed in the past, but they cannot be validated for storm conditions due to a lack of data (Stockdon et al., 2005). The data gap can be filled with numerically simulated runup, for example with the XBeach model. Either the phase-averaged XBeach Surfbeat or the phase-resolving XBeach Non-hydrostatic can be used. However, both the significant incident and infragravity swash is underpredicted by XBeach Surfbeat (Palmsten and Splinter, 2016; Stockdon et al., 2014).

VALIDATION OF THE XBEACH MODELS AGAINST SANDYDUCK'97
In order to predict runup under storm conditions with confidence the performance of XBeach under mild energetic conditions should be assessed. Here runup simulated with XBeach Surfbeat and XBeach Non-hydrostatic for the intermediate reflective beach of Duck was compared to measurements of the SandyDuck'97 experiment, where mild offshore conditions were present. A 2DH model was set up using measured bathymetry and forced with measured frequency-directional spectra.

It was shown that the prediction of significant incident and infragravity swash can be improved by using the phase-resolving XBeach Non-hydrostatic model instead of XBeach Surfbeat. XBeach Surfbeat consistently underpredicts incident and infragravity swash. No underprediction in incident swash is seen for XBeach Non-hydrostatic, while infragravity swash is still slightly underestimated. Setup is predicted similarly for both XBeach models. The 2% runup level is also underestimated by XBeach Surfbeat, indicating that the runup components do not compensate for each other in XBeach Surfbeat. The main forcing of runup is the incident and infragravity wave height of which the former is predicted similarly for both XBeach models and the latter is predicted better by XBeach Non-hydrostatic. It can thus be said that on intermediate reflective beaches, where both incident and infragravity waves play a role, the resolving of incident waves is a necessity to predict runup accurately and XBeach Non-hydrostatic should be used instead of XBeach Surfbeat. Here only an intermediate reflective beach and a small range of energetic conditions were included. More type of beaches and storm conditions should be investigated to be able to validate the empirical parameterizations but also to indicate applicability ranges of the two XBeach models.

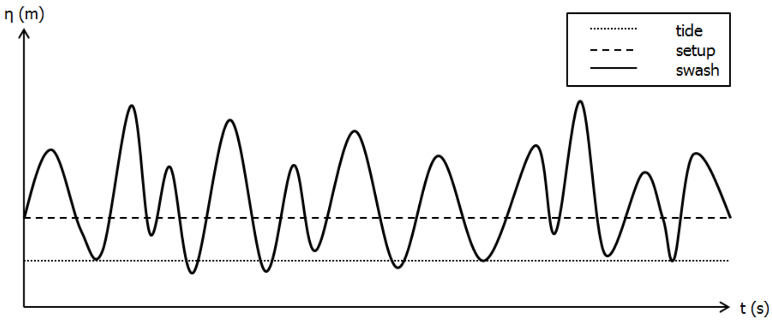

Figure 1 Definition of setup and swash

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XBEACH-NONHYDROSTATIC: TOWARDS THE DEVELOPMENT OF A PHASE-RESOLVING MORPHODYNAMIC MODEL

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ABSTRACT
Since its original development 10 years ago, the XBeach model has used the surf-beat concept to resolve the dominant infragravity wave motions near the coast during storms. This model concept allows infragravity motions to be generated by means of spatial and temporal radiation stress gradients resulting from the computation of the spatially and temporally-varying incident-band wave energy. This approach has proven successful on many dissipative sandy coasts where infragravity waves dominate the inner surf and swash (e.g., Van Dongeren, et al, 2009; Lindemer, et al., 2010; McCall et al., 2010; Dissanayake, et al., 2014; De Vet, et al., 2015; Smallegan, et al., 2016).

A strength of the surf-beat approach is that it combines the explicit computation of intra-wave velocities and surface elevation variation at the infragravity time scale, with a relatively computationally-efficient to solve the wave-averaged properties (wave height, direction, orbital velocity, etc.) of the incident-band waves (Figure 1a). The natural disadvantage of this approach however is that on coarser and more reflective coasts, where the assumption of infragravity wave dominance at the shoreline breaks down, ignoring the contribution of the incident-band waves to the total hydrodynamic signal at the coast can lead to significant errors in the prediction of the storm-driven hydrodynamics and morphodynamics (McCall, 2015).

To overcome the limitations of the surf-beat approach, TU Delft, IHE and Deltares developed the nonhydrostatic extension to the XBeach model (XBeach-nonhydrostatic; Smit, et al., 2010) that allows the explicit computation of intra-wave flow and surface elevation variations of incident-band waves (Figure 1b). The hydrodynamics predicted by the XBeach nonhydrostatic mode have successfully been validated on sandy (De Beer, et al., this conference), coral (Quataert, 2015; Lashley et al., this conference) and gravel (McCall, 2015) beaches. However, the use of the nonhydrostatic mode to simulate morphodynamics on sandy beaches and barriers during storms (e.g., Figure 1c) has been limited due to the lack of validation and understanding of the applicability of the XBeach morphodynamic module under wave-resolved hydrodynamic forcing.

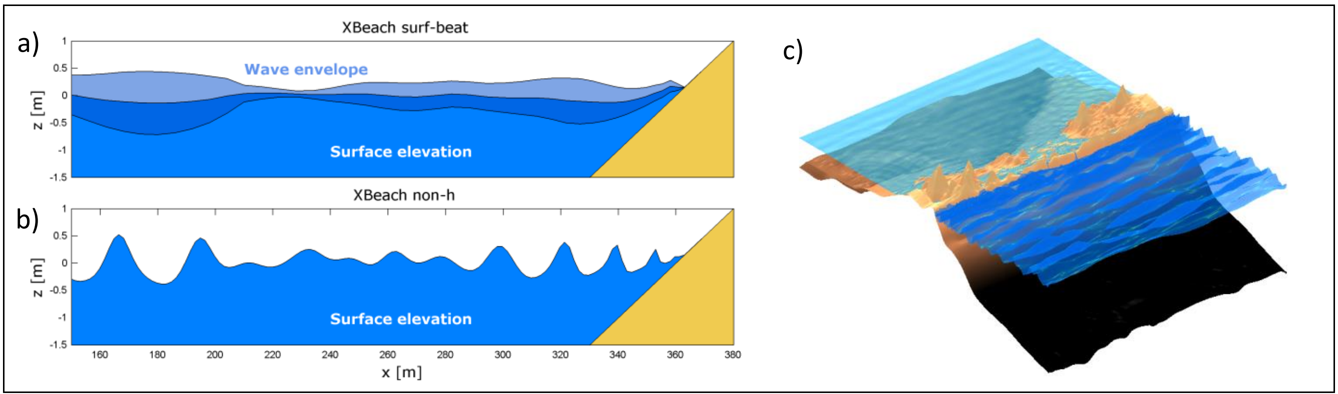

Figure 1. a) Schematic cross-shore profile showing the intra-wave surface elevation (varying at the infragravity wave time scale) and the envelope of the incident-band waves computed in the surf-beat approach; b) intra-wave surface elevation (varying at the incident-band time scale) in the nonhydrostatic approach; c) example of the non-hydrostatic mode applied to compute morphodynamics at Santa Rosa Island during Hurricane Ivan.

In this work we present recent testing and improvements of the XBeach morphodynamics on sandy coasts under wave-resolved hydrodynamic forcing. Through simulation of a series of standard XBeach validation tests, we indicate the applicability of the wave-resolving mode to simulate dune erosion and overwash on dissipative beaches, and indicate the improvements (e.g., Figure 2) and failures of the nonhydrostatic approach relative to the surf-beat approach. We highlight that while inclusion of intra-wave processes improves predictions of nearshore hydrodynamics, this will not result in improved predictions of morphodynamics on coarse-grained beaches without inclusion of additional sediment transport processes. Finally, we discuss current and future uses of the nonhydrostatic mode and directions of future development to improve the skill of morphodynamic predictions on coarse and reflective beaches.

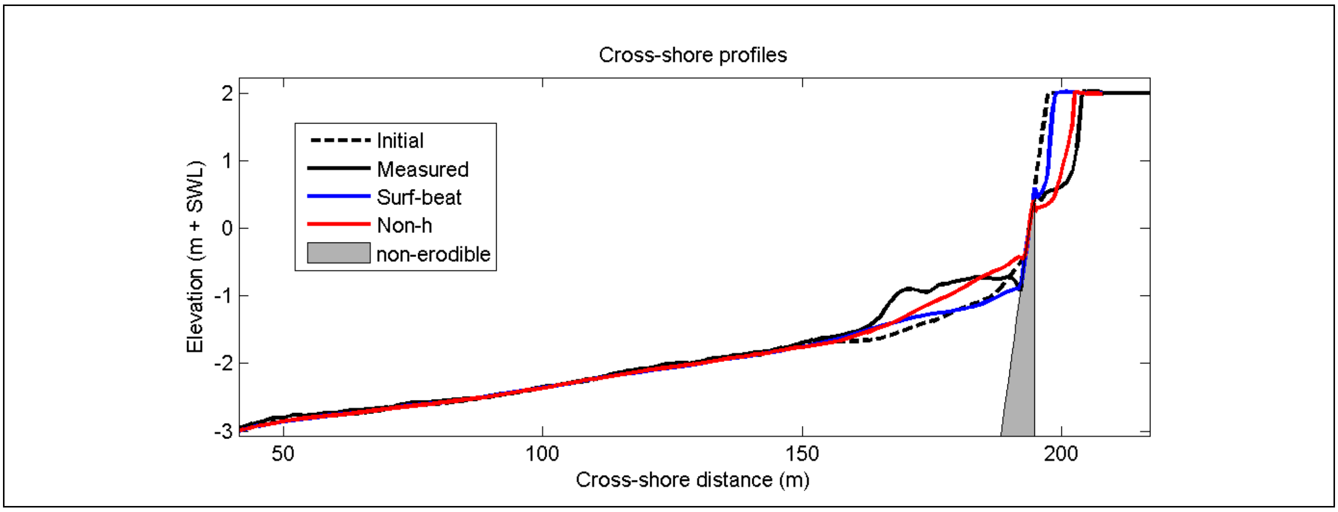

Figure 2. Difference in predicted erosion above a non-erodible dune-foot revetment in the surf-beat (blue) and non-hydrostatic (red) models. Note the increased and more accurate erosion above the revetment predicted by the non-h model and that both models fail to predict a scour hole at the toe of the structure.

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NON-HYDROSTATIC WAVE MODELING OF CORAL REEFS WITH THE ADDITION OF AN IN-CANOPY MODEL

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Processes: Hydrodynamics
Environment: Coral coasts
Numerics: Boundary conditions

The low lying island becomes more vulnerable for inundation due to the rising sea level. As some of this island can be highly populated, a flooding can have a large impact. Thus the need for accurately model the wave propagation for these atoll reefs is becoming more important. The most sophisticated approach is to use a phase-resolving model. Such an approach is preferred when individual waves must be resolved or when non-linear processes are important.
A depth averaged formulation is not suitable due to the large bottom gradients and the relative deep water in front of the reef, To solve this problem the reduced two layer (XBeach-nh+) mode is used. This mode can be used for a relative water depth (kh) up to 5. To accurately force this XBeach-nh+ mode, the boundary condition is adapted. For both layers a boundary signal is generated. Furthermore, the second order effects are included in the boundary signal.
Besides of the hydrodynamics aspects, the coral resistance is also an important process for the wave propagation. It is found that a significant part of the wave energy on the reef flat is dissipated by the coral vegetation. To include this resistance force in the model, a porous in-canopy module is implemented. In most models the induced drag force of the vegetation is based on the depth averaged velocity. However, it is known that the in-canopy velocity will be significant different for oscillating flow (Lowe, 2005). Thus an in-canopy module is implemented to compute the in-canopy velocity from the main flow. Van Rooijen et al. (2016) showed that this approach increased the accuracy for flow through vegetation. An in-canopy module based on porous media theory is used because coral colonies have a 3 dimensional geometry.

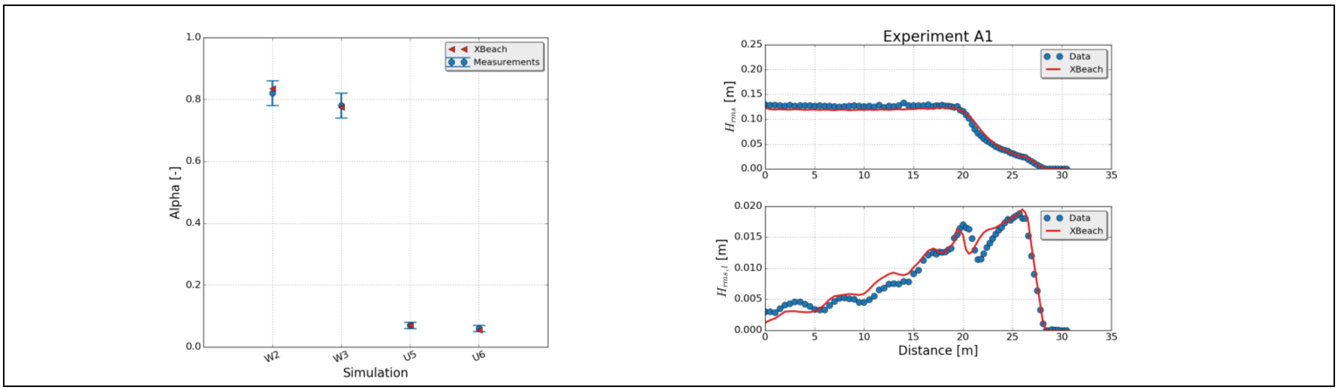

Figure 1: The left panel shows the result of the in-canopy velocity for the four experiments of Lowe (2008). The alpha repents the ratio of the in-canopy velocity over the free stream velocity. The right panel shows the results from the Van Noorloos case (experiment A1). In the upper panel the rms-wave height is shown. The lower panel shows the filtered low-frequency rms-wave height.

To verify the implemented boundary conditions and to check the accuracy of XBeach-nh+ the Van Noorloos (2003) case is simulated. In the right panel of figure 1 the rms-wave height and the filter low frequency rms-wave height is shown. This result shows that XBeach-nh+ is capable in the simulating the low-frequency responds. Both breaking and the standing wave pattern are similar to the data.
To validate the in-canopy velocity, the experiments of Lowe (2008) are simulated with XBeach. Four experiments are simulated with XBeach: Two wave (W2 and W3) and two unidirectional (U5 and U6) experiments. The ratio of the in-canopy velocity over the free stream velocity is compared to the measurements. This result is shown in the left panel of figure 1. This figure shows that XBeach is capable of simulating the in-canopy velocity for both the wave and the current case.

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COUPLING XBEACH-G AND LONGSHORE SEDIMENT TRANSPORT TO MODEL STORM RESPONSE UNDER VARYING WAVE DIRECTIONS

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TOPIC
Processes (Morphodynamics), Environment (Gravel coasts and shorelines), Numerics (Coupling to other models).

INTRODUCTION AND STUDY SITE
Although gravel and mixed sand-gravel (MSG) coasts have received increasing attention during recent years, relatively few numerical models have been applied to and compared with field data for these coastal settings. This work characterizes and models the storm response of a gravel-dominated MSG beach (Playa Granada, southern Spain) forced by varying wave directions through the analysis of field measurements, the application of the XBeach-G model and the proposal of a parametric approach to couple XBeach-G and longshore sediment transport (LST).

METHODOLOGY
Thirteen topographic surveys were performed to monitor beach morphology over a 36-day period with variable wave conditions between January and February 2015. The Delft3D-WAVE model, calibrated for the study site by Bergillos et al. (2016), was used to relate the wave propagation patterns with the coastal dynamics. Delft3D results were also used to obtain the inshore conditions required to apply the XBeach-G model over 2-day periods of low energy, south-westerly (SW) storm and south-easterly (SE) storm conditions. In addition, XBeach-G was combined with the LST equation of Van Rijn (2014) by means of a parametric formulation to consider different cross-shore distributions of LST. All results were compared to the observed response of the upper profile (beach profile above the mean low water spring level). Finally, the approach that best fitted the measured response was used to model extreme SW and SE storms along the deltaic coastline.

RESULTS AND CONCLUSIONS
The observed morphological storm response of the upper profile was clearly related to the difference between the height of the berm and the total run-up (i.e., the free-board). Wave propagation patterns were influenced by the incoming wave directions, generating varying values of total run-up and resulting in different beach responses, with the SW and SE storms eroding and building up the surveyed area, respectively.
The XBeach-G model was capable of reproducing the storm response of the beach under SW waves, with a brier skill score (BSS) higher than 0.95 and a relative bias lower than 0.13. However, the accretionary response of the upper profile under SE storms contrasted with the erosion predicted by the model (BSS<0.14 and bias>1.12). This was influenced by the higher LST gradients under SE storms at the study location compared to those under SW conditions, revealing the necessity to combine XBeach-G with LST.
The coupling of XBeach-G and the LST equation of Van Rijn (2014), through consideration of different cross-shore distributions of LST, improved the model predictions, especially under SE storm conditions. The best fits (BSS>0.96 and BSS>0.88 for the SW and SE storms, respectively) were obtained with a distribution where the peak of the LST volume is located at a distance from the total run-up limit equal to 20% of the length across the profile between this limit and the breaking line (Figure 1), providing insights into the cross-shore distribution of LST on MSG beaches.
Finally, the approach that best fitted the observed beach response was applied to model extreme SW and SE storms along a 6.8-km section of deltaic coastline. Erosional (depositional) changes were obtained along most of the studied stretch of beach for the SW (SE) storm with the coupled model. The depositional response for the SE storm was not predicted by XBeach-G on its own. These results highlight the potential of the approach proposed in this work to extend XBeach-G towards larger longshore scales and to make it more suitable for gravel environments highly influenced by both cross-shore and longshore sediment transport.

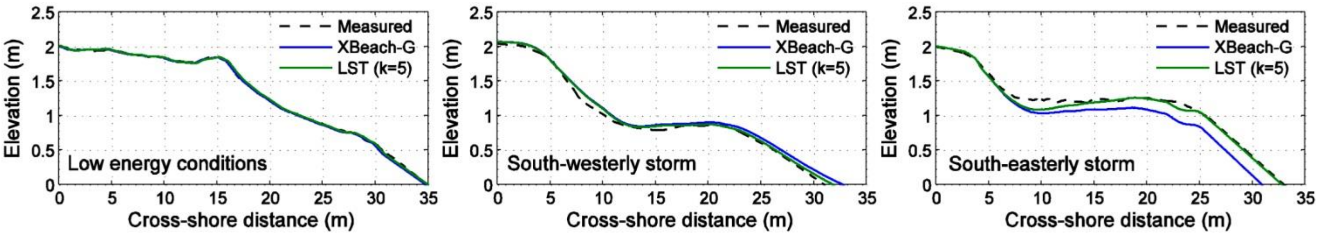

Figure 1 - Initial, final measured and final modelled profiles with XBeach-G and with the coupled model (including LST) under low energy (left panel), south-westerly storm (central panel) and south-easterly storm (right panel) conditions.

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Infragravity wave modelling over a steep rocky bathymetry

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Infragravity waves have been mainly studied on sandy beaches with along-shore uniform and mild-sloping bathymetries (e.g. Ruessink, 1998, Van Dongeren, 2003). Despite some recent studies concerning rocky platforms (Van Dongeren et al., 2017) and coral reef environments (Pomeroy et al. 2012), observations of infragravity waves in steep, non-uniform rocky environments are still very sparse, and the impact of a highly variable bathymetry on the transformation of infragravity waves remains poorly understood. Moreover, the strong depth gradients in both the cross-shore and along-shore directions impose a number of constraints for the implementation of nearshore wave models, originally designed for beach applications. Hence, the skills of such models are often assessed through laboratory or beach applications but rarely for non-uniform rocky environments. In this study, we use hydrodynamic data collected during winter 2013/2014 on Banneg Island, a small uninhabited island located at the north-western tip of the Molène Archipelago (Brittany, France), characterized by steep rocky cliffs on its western part (Figure 1). During winter 2013/2014, several extreme wave events (with Hs up to 9 m) occurred in conjunction with high water levels, causing floods and storm deposits transport across the island (Autret et al., 2016). Such extreme water levels events are believed to be enhanced by the presence of large infragravity waves, known to reach up to 2 m on Banneg's shores (Sheremet et al., 2014). Wave and water elevation data collected by pressure sensors deployed in the intertidal zone is used to calibrate and validate the results of the Xbeach model, implemented with a curvilinear grid to fit the curved-shape of Banneg Island. Several parameters such as the grid resolution, the grid shape, or the degree of smoothing of the bathymetry are tested, and the comparisons with the observations are analyzed in order to discuss the overall model skills, and the impact of the grid characteristics on the model results.

Figure 1 Photograph of the north-western sector of the island.

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Friday

TOWARDS USING XBEACH IN THE DUTCH FORMAL ASSESSMENT OF FLOOD DEFENCES IN 2023

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TOPIC
Processes (Hydrodynamics; Morphodynamics), Environment (Sandy coasts and shorelines);

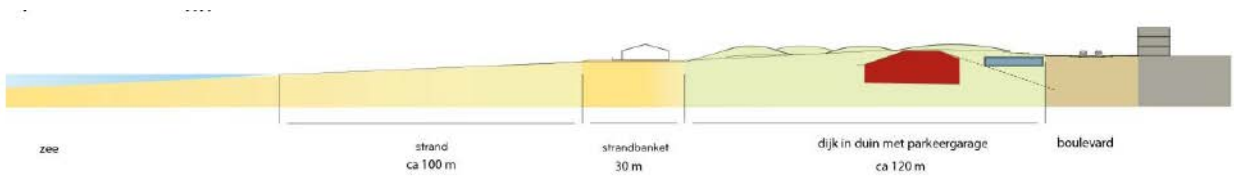
INTRODUCTION
Rijkswaterstaat, an agency of the Ministry of Infrastructure and the Environment in the Netherlands provides models for the assessment and design of flood defences (Slomp, et al. 2016). Currently the standard model for the assessment of Dutch dunes as a flood defence is Duros+ (ENW, 2007). Duros+ is a one dimensional volume balance approach dune erosion model, based on extensive large and small scale flume test performed in the last decades of the 20th century. Duros+ is implemented in the open source morphological software package MorphAn (Lodder and van Geer, 2012). Additional to Duros+, Xbeach 1D and volume calculation tools for coastal management like planning of sand nourishments are also implemented in MorphAn.

The Duros+ model (and its predecessor Duros) has proven to be a robust and quick assessment model for large parts of the Dutch coast. However due to the 1D volume balance approach there are multiple area's in the Netherlands which can not directly be assessed with Duros+. Examples of these areas are:

- Hybrid flood defenses consisting of dunes and levees, eg the flood defenses of the coastal towns of Katwijk (Figure 1) and Noordwijk.
- Strongly curved coastlines where dune erosion processes are likely to be 2 dimensional, e.g. parts of the Zeeland coast and parts of the Wadden islands.
- Relatively low dunes where overtopping and overwash may be an important failure mechanism, e.g. parts of the Wadden Islands and the coastal town of Katwijk.

Generally it is possible to make an assessment of flood risks of these area's but quite elaborated additional engineering and expert judgement is needed. XBeach (1D and 2D) is one of the tools that is being used in these kind of assessment (Deltares, 2011). However also other approaches have been successfully applied (Arcadis, 2012).

TOWARDS XBEACH AS A FORMAL ASSESSMENT MODEL
Rijkswaterstaat sees Xbeach as the most promising model for the future formal assessment of dunes in complex situations. It is therefore the aim to use XBeach 1D or 2D (depending criteria like progress, reliability, performance etc) from 2023 onwards as the formal assessment model for coastal dunes which have a flood defence function. In our presentation we will elaborate on some of the examples mentioned above, give an outline of the requirements Xbeach has meet to be used as the formal assessment tool and outline the foreseen developments in the coming years for which the Ministry of Infrastructure will be partner.



Afbeelding 15 Principedoorsnede Dijk-in-Duin

Figure 1 – Section of coastal flood defence of Katwijk, which incorporates a dune and a levee underneath the dune.

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COASTAL SAFETY ASSESSMENT OF THE BELGIAN COAST WITH STATE-OF-THE-ART NUMERICAL MODELS

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TOPIC

Processes (storm-induced erosion, overtopping, flooding), Environment (sandy coasts and shorelines, coastal safety)

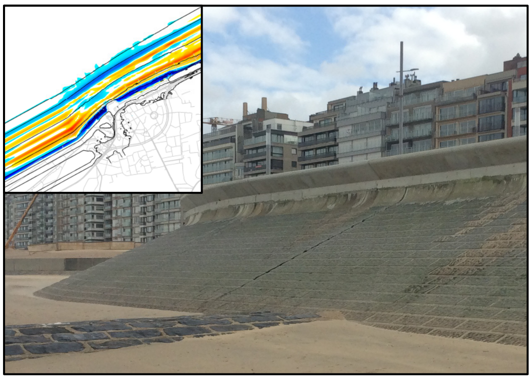
INTRODUCTION

The Belgian coastline stretches about 67 km along the North Sea and is bordered by several coastal cities and harbours. The sea defense consists of dunes, dikes and hybrid structures and should be able to withstand a 1000-year storm. The safety assessment was performed following an innovative approach using state-of-the-art numerical models to compute dune and beach erosion (XBeach 2D) and wave overtopping (SWASH 2D/1D) under storm conditions. Based on the model results the actual safety assessment was performed for all coastal sections.

METHODOLOGY

The methodology for the safety assessment was set up by Flanders Hydraulics for the Flemish government (Coastal Division) (Suzuki et al, 2016). It comprises the combination of two numerical models:

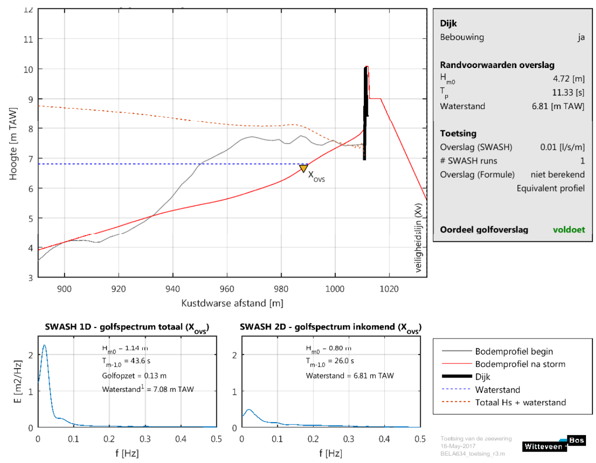
- 2D morphological model XBeach to simulate dune and beach erosion along the entire coastline. 24 model domains were set up based on local hydrodynamic and morphological conditions. The post-storm bathymetry was used for dune safety assessment and as input for overtopping calculations.
- 2D/1D SWASH calculations to simulate overtopping at dikes, low dunes and hybrid structures at the weakest part(s) of each coastal section. A thorough calibration of the wave conditions at the toe of the dike was performed before the final overtopping computations. Results were compared with empirical formulas.



RESULTS

The results of the XBeach models were combined in order to provide an overview of the morphological development of the coastline during the 1000-year storm. Areas where overtopping and/or flooding occurs were identified and the causes for failure were analyzed. Results show that some dune areas do not meet the safety requirements. This study also comprised a sensitivity analysis on model parameters and set-up to come up with the best approach for this model application.

The overtopping computations using SWASH resulted in overtopping rates from 0 to ca. 7.5 l/s/m. For each section, a large number of simulations were performed to account for the sensitivity to wave train (random seed number), small bathymetry variations and numerical instabilities. Overall, the overtopping rates calculated by SWASH and the empirical formulas provide similar results.



SAFETY ASSESSMENT OF THE FUTURE?

Using XBeach 2D for the safety assessment allows better insight in the consequence of alongshore variations on coastal safety than the traditional 1D empirical approach used in The Netherlands. In the results, 2D effects such as alongshore transport of sediment played an important role at several locations. A process-based, 2D approach also allows better identification of processes that lead to failure, providing a better guidance on required mitigation. Notwithstanding, sufficient calibration of model settings is required and simulation times are large, making it unsuitable for quick assessments. The use of SWASH to compute wave overtopping is also an improvement with respect to the previous methodologies, because it allows overtopping computations on cases where the empirical formulas are not applicable (i.e. specific geometries, dike is located in dry area, etc). Significant drawbacks are that a large amount of simulations are necessary, which requires sufficient computational power and SWASH becomes easily unstable. For the application of the methodology for future assessments several aspects should be considered. In this project, guidelines and recommendations were developed for the best practice in using state-of-the-art models for coastal safety assessment.

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SEA LEVEL RISE IMPACTS THE NEARSHORE WAVE CLIMATE AND DUNE EROSION

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INTRODUCTION

Sea level rise is traditionally considered to be the main climate change driver that will affect coastal safety. However, for coastal safety assessments the impacts of a changing wave climate also needs to be taken into account. The deep-water wave climate (height, direction and period) can change because of changes in the atmospheric forcing. The coastal (nearshore) wave climate could additionally change as a result of sea-level-rise-induced larger water depths, implying reduced wave dissipation. Here, we show the impact of sea level rise on the near-shore wave climate and subsequently the impact on dune erosion.

XBEACH VALIDATION

Pre- and post-storm bed level measurements in Egmond after the storm in January 2012 are used to morphologically validate the XBeach model (Fig 1). Hydraulic validation was performed with observations in the autumn prior to this storm. The observed alongshore variation in dune erosion is represented well in the XBeach model simulations.

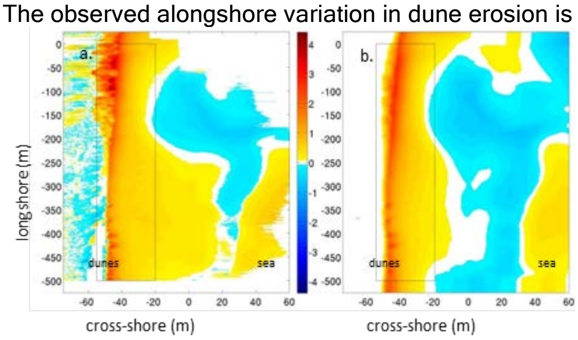

Figure 1.a. Observed bed level changes in Egmond aan Zee after the storm in January 2012. b. Bed level simulations modeled with XBeach. Axis-zero is the location of Argus Tower.

NEAR-SHORE WAVE CLIMATE AND SEA LEVEL RISE

For 3 locations with different steepness, changes in the near-shore short and infragravity wave characteristics are analyzed under different sea level conditions. For all profile slopes, the short waves are higher under the different sea level conditions. Infragravity waves are, however, approximate the same for all sea level conditions.

DUNE EROSION AND SEA LEVEL RISE

For Egmond and Noordwijk, dune erosion volumes are determined using the 1:10,000 year offshore boundary conditions (Egmond, *Noordwijk*: storm surge = +5.5m, *5.8*m, Hs = 9.55m, *8.55*m, Tp = 16.1s, *14.3s*). The offshore surge levels are increased by 0.2m to 3.5m to included sea level rise conditions up to 2200. Model runs show a linear relation between the increase in dune erosion and sea level rise. This relation is site specific, since hydrodynamical boundary conditions vary per site.

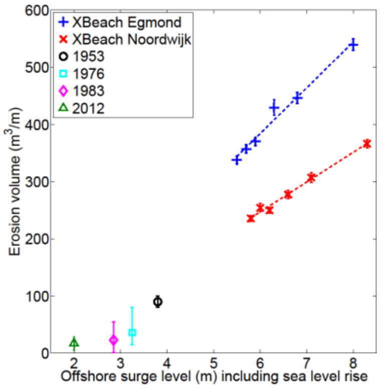

Figure 2. Erosion volume as a function of offshore surge level including sea level rise. The values for surge levels above 5 m are XBeach projections for Egmond (blue) and Noordwijk (red). The vertical bar indicates the ±1 standard deviation. The lines through the model projections are the best-fit linear regression lines. The symbols at lower surge levels (and wave heights) are observations from the Dutch coast (De Winter and Ruessink, 2017)

CONCLUSIONS

The height of near-shore, short waves increases with sea level rise, while the infragravity wave height is independent of sea level rise. The level of attack is dominant for the increased dune erosion. There is a linear relation between sea level rise and erosion. Erosion volumes increase by approximate 25% under 0.8m sea level rise.

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Defining time-dependent hydraulic boundary conditions for the analysis of the climate variability of extremes of coastal flooding

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TOPIC

Numerics (Numerical methods, Boundary conditions, Coupling to other models).

ABSTRACT

The statistical distribution of flooding extents at a particular coastal area is the result of the non-linear interaction of multiple oceanographic, hydrologic, geologic and meteorological forcings (e.g., astronomical tide, monthly mean sea level, large-scale storm surge, dynamic wave set-up, shoreline evolution). Additionally, interannual variability, tropical cyclone activity and trends in storminess and sea-level rise are climate drivers that must be considered. Moreover, the chronology of the hydrodynamic boundary conditions (Antolinez, 2016) plays an important role since a collection of consecutive minor storm events can have more impact than the 100-yr return level event. Therefore, proper modeling of coastal flooding should consider in the definition of the hydraulic boundary conditions both extratropical and tropical cyclones, the sequence of storms, the multivariate nature of the hydrodynamic forcings, and the different time scales of interest (seasonality, interannual and decadal variability).

To address this complex problem, we propose a hybrid approach (see Figure 1) that combines: (a) climate-based statistical downscaling techniques, non-linear data mining, multivariate extreme value models (Rueda 2017) for defining the hydraulic boundary conditions; (b) hydrodynamic models (i.e. SWAN, X-Beach) calibrated with specific field data; and (c) long-term data bases (observational and hindcast) of sea state parameters, astronomical tides and non-tidal residuals. The **time-varying emulator for short- and long-term analysis of coastal flooding** (TESLA-flood) is being applied to four sites within the Pacific basin as part of a National Oceanic and Atmospheric Administration (NOAA) led US Department of Defense (DOD) Strategic Environmental Research and Development Program (SERDP)-funded project to develop techniques for coastal flood vulnerability assessment.

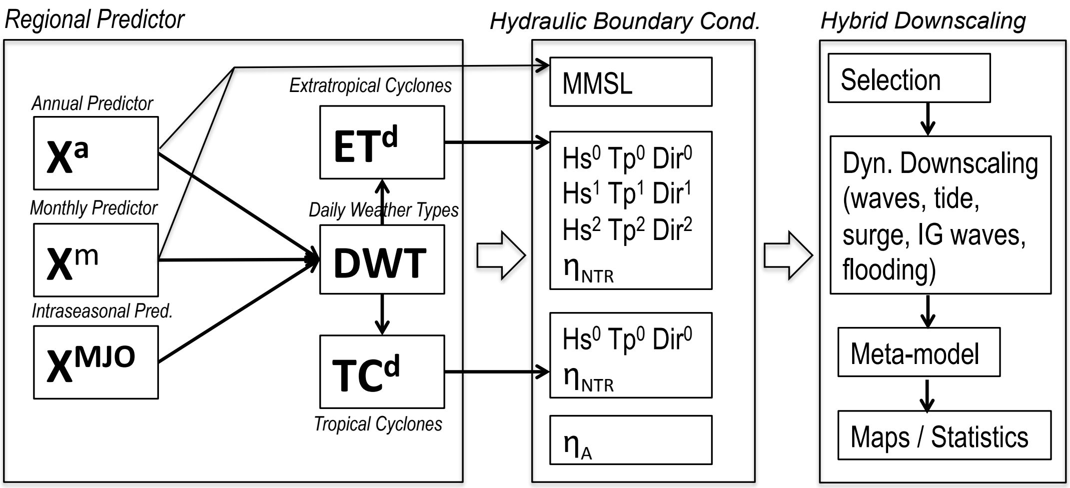

Fig 1. Methodological Framework

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SHORT-TERM MORPHOLOGY RESPONSE TO STORMS AT A NOURISHED COASTAL AREA IN BELGIUM

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TOPIC
Processes and Environment.

INTRODUCTION

Within the framework of the project "Alternative maintenance measures for beach nourishment: monitoring of a pilot site", to optimize the return of investment from beach nourishment actuations, the contribution of underwater nourishment is to be assessed. The assessment is based on an integrated approach, including field measurement campaigns, numerical simulation and the definition and evaluation of a number of morphological indicators. The presentation refers to XBeach model software set-up in the project site and application for discussion of short-term morphological effects. The project site is located west from Ostend harbor, including Raversijde-east and Mariakerke coastal areas. Its morphology is thought to be influenced by the sediment dynamics induced by the harbor and, additionally, by a nearshore sand bar, causing a shoaling at circa 2.5 km from the coastline.

MORPHOLOGICAL SIMULATIONS

The model was set-up in hydrostatic mode, using measured hydrodynamic, sedimentary and morphological conditions. A sensitivity analysis of settings and a calibration were performed in one-dimension. The model behavior and performance was inspected also in quasi-two-dimensional mode. Afterwards, it was set-up in full two-dimensions and applied to simulate and compare the effect of three storm events, occurring between 2013 and 2015. The full two-dimensional mode was required in order to incorporate longshore gradients due to the nearshore bathymetry features.

STORMS CHARACTERIZATION

Three storm events, among the seven identified within the period, from offshore buoys and field campaign measurements, were selected: in December 2013 (Sinterklaas), in October 2014 and in November-December 2015. The more energetic waves were mainly from northwest. The highest significant wave height was observed in 2014. Sinterklaas and the stormy period in 2015 showed the highest average significant wave height, but over a longer period of time in 2015.

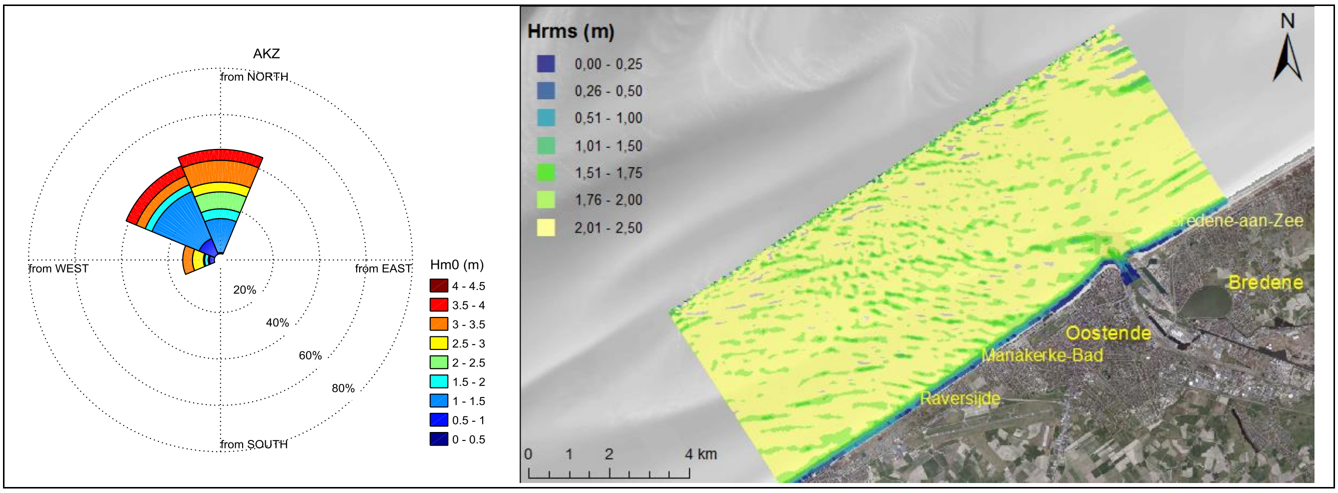

Figure 1 - Significant wave height (Hm0) - direction frequency distribution of observations in Akkaert-Zuid (AKZ) wave buoy, located offshore (left) and root-mean-square wave height (Hrm, m) simulated with XBeach in the peak of Sinterklaas storm (right)

CONCLUSIONS

Because of the long fetches only existing through the north direction, the highest observed waves were from the north and northwest. The relative comparison of the simulated morphological response to the action of the three storm events showed a higher impact of the stormy period of November-December 2015 than of Sinterklaas or October 2014 storms. The impact was higher during Sinterklaas storm than during October 2014 storm, when the highest wave height was registered. The number of high energetic events or their duration might have an higher effect on the morphology than their maximum significant wave height.

Washover processes at the Wadden Island of Schiermonnikoog, the Netherlands: Field data and XBeach modeling

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Maarten van der Vegt, Utrecht University
Renske de Winter, Utrecht University

TOPIC

Wadden Islands in the Netherlands, Germany and Denmark typically contain natural gaps in the dune row, also known as washover openings. These openings are low-lying with heights between 1.6 and 2.3 m above MSL. They are, therefore, regularly inundated during storms, when the water level is high due to tide, storm surge and wave set-up. Potentially, currents and waves can transport sediment through the opening and deposit it more landward. This could be a method to accrete parts of Wadden Islands and to keep up with long-term sea level rise. However, nowadays these washover openings are often closed off by sand-drift dikes, which can be described as artificial dunes. It is considered to re-open the sand drift dikes and to allow inundation events to occur again. The Wadden Island of Schiermonnikoog still partly contains washover openings (Figure 1). We use this island to investigate the dominant hydrodynamic processes during inundation, and how that affects sediment transport and morphology change. During a field campaign at the low-lying and dune-lacking island tail that is inundated several times a year, we measured the hydrodynamics during storms. Furthermore, the model XBeach is first validated against these observations and then used to analyse washover processes in the 1D and 2D mode.

FIELD DATA

The field campaign at the island tail of Schiermonnikoog was performed in the winter of 2014-2015 and contained 11 inundation events. 10 pressure sensors and 2 ADV instruments were used in a cross-shore array to measure water levels, waves and currents. Furthermore, the bed level was measured at the beginning and at the end of the campaign with a dGPS instrument.

XBEACH SIMULATIONS

Firstly, XBeach simulations in 1D mode were executed to validate the model results against the field data. The cross-shore profile was obtained from the field campaign (red array in Figure 1). The grid size gradually changed from 20 to 2 m in shallow water. The water level and wave boundary conditions were taken from water level stations and an offshore wave buoy respectively. Secondly, the 2D mode of XBeach was used to simulate inundation at the location of the washover openings (black arrows in Figure 1). Here, the washover geometry used as input profile was adapted in several ways to investigate the sensitivity on inundation processes of parameters such as the width and height of the opening.

The XBeach hydrodynamics in the 1D mode are in good agreement with the field data, which means that the model is validated successfully. Analyses show that cross-shore currents dominate both the sediment concentration and transport in onshore direction. These currents are largely affected by the pressure gradient across the island from North Sea to Wadden Sea, which is variable during a tidal cycle. Furthermore, although large storms individually contribute more to sediment transport, frequently occurring and milder storms are more important on the long term. From the simulations in 2D mode it can be concluded that the washover opening dimensions are very important for the onshore sediment transport. Openings that are only 30 cm higher lead to two times less transport. The opening width affects the magnitude of the cross-shore currents as well.

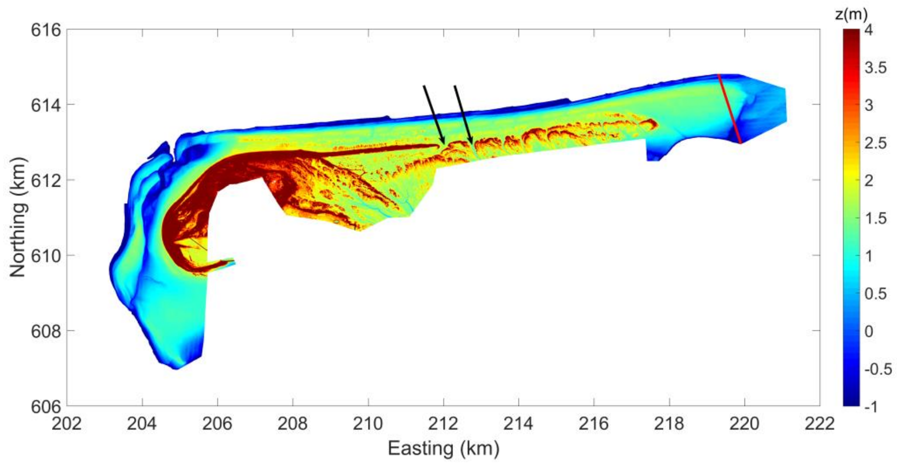

Figure 1: Profile of Schiermonnikoog in 2002, based on coastal lidar data from Rijkswaterstaat. The red line indicates the location of the field campaign. The black arrows show the most updrift washover openings.

AN ANALYSIS OF THE MORPHODYNAMIC ACCELERATION TECHNIQUE (MORFAC)

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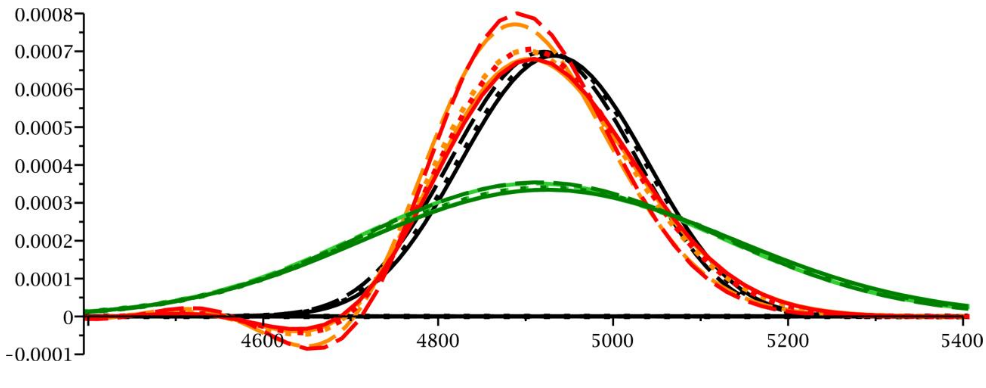
TOPICS
shallow-water flow; bed-level transport; morphology; morphodynamic acceleration; numerical scheme; analysis

ABSTRACT
An important aspect in studying the morphological evolution in rivers and coastal areas is the often large difference in time scale of flow processes and morphological processes. Since the time step of a numerical model is usually dictated by the smallest time scales, i.e., by the flow processes, the much slower morphological processes are often computed with an extremely small time step. As a result, morphodynamic simulations over years to decades (or longer) may take a huge amount of time steps, leading to prohibitively long computational times. One of the methods that have been introduced to remedy this problem is the morphological acceleration technique (Roelvink, 2006). By multiplying the morphodynamic changes by a factor $MF > 1$ (the MorFac), the morphodynamics is accelerated and the morphological time scale is reduced. We have investigated the MorFac technique as implemented in the Delft3D 3D shallow-water solver.

Acceleration of the morphodynamics by means of the MorFac amounts to an artificial, non-physical modification of the model. When applying the MorFac technique, it is therefore essential to know how large MF can be taken in order to keep the deviation from the true physics to an acceptable level. Ranasinghe et al. (2011) have studied this issue by varying the value of MF in a number of 1D numerical experiments using Delft3D, varying other parameters such as Froude number Fr, grid size and time step as well. The limitation of this approach is that errors introduced by $MF > 1$ are mixed with discretization errors.

We present an analysis where the effect of $MF > 1$ and of discretization errors have been separated, using standard techniques like linearization of the equations and Fourier-mode decomposition of the solution. A model problem similar to that in Ranasinghe et al. (2011) has been considered: a 10,000m long 1D channel with a uniform depth of 4m and a sinusoidal bed perturbation at 3200m of 400m long and only 10^{-3}m high, in order to have negligibly small nonlinear effects. Besides the effect of MF, the effects of flow velocity (Fr), viscosity, bed friction, Engelund-Hansen sediment transport formula with Bagnold slope correction, and the Delft3D discretization are included in the analysis.

The figure shows a result obtained for $Fr = 0.2$, when the perturbation reaches position 4900m after 1200 hours. Solid lines, dotted lines, and dashed lines indicate results for respectively MF equal to 30, 100, and 300. Black lines are analytically constructed results of the linear(ized) continuous model, and contain only errors due to $MF > 1$. Computed Delft3D results on a uniform grid of size 20m are indicated by the red lines (central discretization Exner equation selected) and green lines (upwind discretization Exner equation selected). The orange and light green lines are results of the linear(ized) analytical discrete model, confirming that that model is indeed a very accurate representation of Delft3D. The analytical continuous and discrete model have been implemented and investigated in the math software tool Maple.



The conclusion reads that, for the model problem considered, numerical errors are (much) larger than errors due to the MorFac, despite the use of a rather fine grid. Numerical techniques to improve the accuracy of Delft3D are currently being investigated by implementation in the discrete model, prior to full implementation in the Delft3D code.

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MODELLING MORPHODYNAMIC IMPACTS OF STORM CLUSTERS

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INTRODUCTION

Episodic high energy seas generated by storms, hurricanes and tropical cyclones impose huge morphodynamic stresses on beaches over short time scales and trigger rapid morphological changes. The extent of storm-induced beach erosion depends on a range of phenomena. Storms with large wave heights and long durations accompanied by storm surge and high tide have proved to cause excessive damage. However, the occurrence of smaller multiple storms at close intervals have proved to cause erosion levels that may exceed those from a large single storm. Even though beaches erode and become unstable during a storm event, they undergo natural post-storm recovery as a result of onshore sediment transport during calmer wave conditions. However, if time intervals between consecutive storm occurrences are less than the recovery time needed for natural replenishment of the beach then, the next and subsequent storms can potentially trigger a greater damage of the already unstable beach. Thus, sequencing or chronology of storm events and the recovery period in between play an important role on morphodynamics of beaches subjected to frequent storms (Ferreira, 2005; Callaghan et al., 2008; Karunarathna et al., 2014; Dissanayake et al. 2015a). In this paper, we will present the application of XBeach model to investigate morphodynamics response of two very different beaches, Narrabeen Beach, Australia and Sefton Coast, UK to clusters of frequent storms.

STUDY SITES

Narrabeen beach is a meso-tidal, wave-dominated, 3.6 km long embayment facing Tasman Sea, located in New South Wales, Australia (Fig. 1). The beach consists of medium sand and has a relatively steep upper beach and a gentler lower beach in the sub-tidal region (Short, 1984). It is exposed to a highly variable, moderate- to high energy wind wave climate originated from multiple cyclonic sources superimposed on long period, moderate- to high-energy south-easterly swell waves. As a result, the beach experiences frequent storm wave conditions throughout the year. Due to the prevalence of frequent storm wave conditions, Narrabeen Beachs' morphodynamic response is highly variable and extremely rapid (Short & Trenaman, 1992).

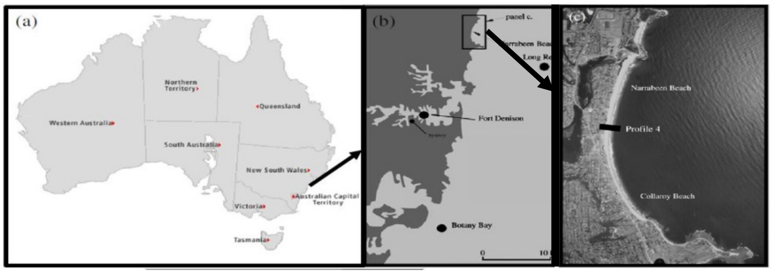

Fig. 1 – (a) and (b) Location map of Narrabeen beach and (c) View of the beach.

Sefton coast is a macro-tidal convex shape beach system located in the Liverpool Bay, UK (Fig. 2). The beach is 36 km long and consists of a large frontal dune system along most of its length. The steep dune face connects with gently sloped inter-tidal region of the beach through a moderately sloped upper beach (Pye and Blott, 2008). Sefton coast is subjected to a seasonal wind wave climate with clear winter-summer variation where fairly frequent storms occur during winters. Summer wave climate is mostly calm. Storm surge at Sefton can exceed 2m (Brown et al., 2010). Most areas of the beach consist of fine sand. A significant erosion of the beach and dune has been observed during historic storm events.

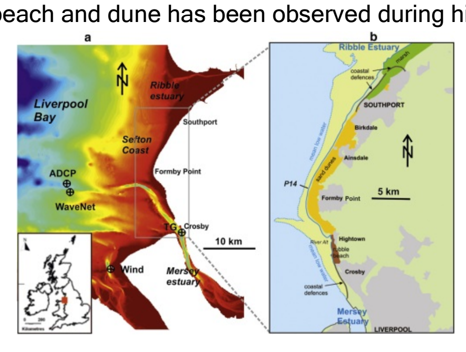

Fig. 2 – (a) Location of Sefton coast (b) Map of Sefton coast.

XBEACH APPLICATION AND RESULTS

XBeach model was applied to both Narrabeen beach and Sefton coast in order to investigate beach response to individual storms and sequences of storms that occur at close intervals. The differences between storm wave climate and erosion/recovery response of the two beaches were carefully considered when applying the model. In both applications, XBeach was calibrated and validated against measured pre- and post-storm beach profiles and for post-storm beach recovery from known historic storm and recovery events.

Fig. 3 shows temporal variation of measured and simulated beach volume between the shoreline and dune crest at Profile 4 of Narrabeen beach from a series of storm events and recovery spells in between storms. The model correctly reproduced both erosion and recovery volumes, when separately calibrated for two contrasting situations. A comparison of measured and simulated cross-shore profiles (not shown) confirms that the model is able to capture storm-induced erosion and recovery above the inter-tidal zone very satisfactorily. The differences between modelled and measured results can be attributed to a number of issues of the model, switching between two models for erosion and recovery simulations and anomalies of measured pre- and post-storm profiles used to determine beach volume. Also, it should be note that here the model was run in 1D mode, which excludes any contributions from longshore transport.

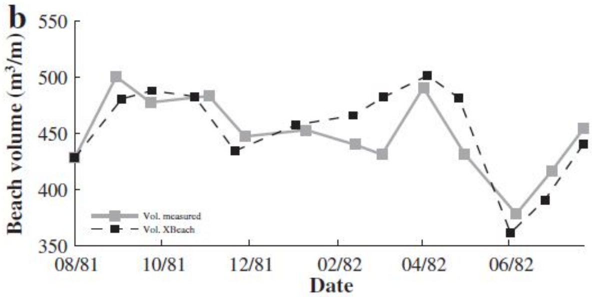

Fig. 3 – Comparison of measured and simulated beach volume between the shoreline and dune crest at Profile 4 of Narrabeen beach, from a sequence of storms and recovery spells (Pender and Karunarathna, 2013).

In Fig. 4, simulation of cross shore beach profile change during six closely spaced storms of various intensities occurred during winter 2013/14 at the cross section P14 of Sefton coast (Fig. 2) can be seen. In this, the profile change modelled with and without beach recovery in between storm events is compared. It is seen here that storms occurring in clusters with little time interval for beach recovery in between can exacerbate beach erosion.

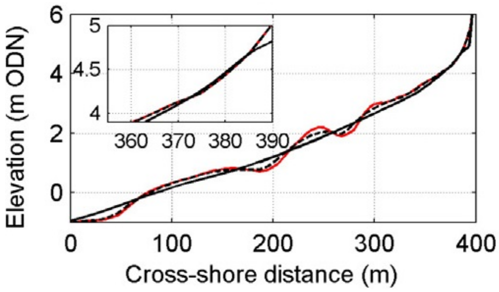

Fig. 4 – Final predicted P14 profile at Sefton coast after six closely spaced storms occurred in winter 2013/14, modelled with (black dash line) and without (black solid line) beach recovery. Pre-storm profile is given by the red solid line.

The talk will expand on the findings of the application of XBeach to investigate impacts of storm clustering on Narrabeen beach and Sefton coast. The model's ability to capture the morphodynamics, site specific nature of the problem and future research needs will be highlighted.

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NON-HYDROSTATIC WAVE MODELLING AT WEST BAY HARBOUR, UK

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TOPIC
Processes: Hydrodynamics. Environment: Ports, waterways and ships

INTRODUCTION
Wave climates in ports significantly determine the efficiency of port operations. Therefore, accurate prediction of hydrodynamics is regarded as indispensable, which is often done by means of numerical modeling. This study is part of the Joint Industry Project XBeach in which the goal is to explore and extend the application limits of XBeach as a hydrodynamic and morphological model. The goal of this paper is to determine the application limits of XBeach for the purpose of modeling hydrodynamics in ports for the one-layer non-hydrostatic (NH) and the reduced two-layer non-hydrostatic model (NH+) and compare those to the default surfbeat (SB) mode. The field case at West Bay, England (Figure 1 – left panel) is considered where waves in the port are measured with a step gauge in the lee of the breakwater. With the various models a 24 hour storm event in January 2015 is modelled. At the peak of the storm the significant wave height measured at an offshore wave buoy was 3.15 m and the peak wave period reached a value of 10.0 s.

MODEL SCHEMATISTATION
XBeach (Roelvink et al., 2009) is an open-source storm impact model that can be run in sea/swell wave phase-averaged (surfbeat) or phase-resolving mode (non-hydrostatic). The NH model is theoretically able to predict all relevant wave hydrodynamics in ports because short and long wave processes are fully resolved, but with higher computational demand as compared to the surfbeat model. Moreover, a new mode of the non-hydrostatic model has recently been developed, namely a reduced two-layer non-hydrostatic (NH+) model. The reduced two-layer model is an adaptation of the original XBeach non-hydrostatic code which, together with other minor changes, improves the dispersive characteristics of the model. The application range for the phase-averaged mode like SB is smaller, because short waves are averaged and no phase-information is considered; a process like diffraction of short waves is therefore not accounted for. Another limitation of all three models is that wave reflection cannot be controlled. Instead all boundaries are fully reflective.

RESULTS
Comparisons between modeling results with default settings and field measurements (Figure 1 – right panel) have shown so far the significant wave height – and also wave period - of the high-frequency part of the spectrum f > 0.04 Hz in the port basin are only properly simulated by NH and NH+ mode as anticipated, though both NH and NH+ result in an underestimation of the high-frequency wave height. Regarding the long waves (f ≤ 0.04 Hz), SB and NH are able to reproduce low-frequency wave heights, and wave periods as well, whilst NH+ yields at present a significant over prediction of the low-frequency wave height. The presented results are work in progress; more simulations are being conducted aiming to further improve the performance of all three models especially the long wave height of the NH+ model.

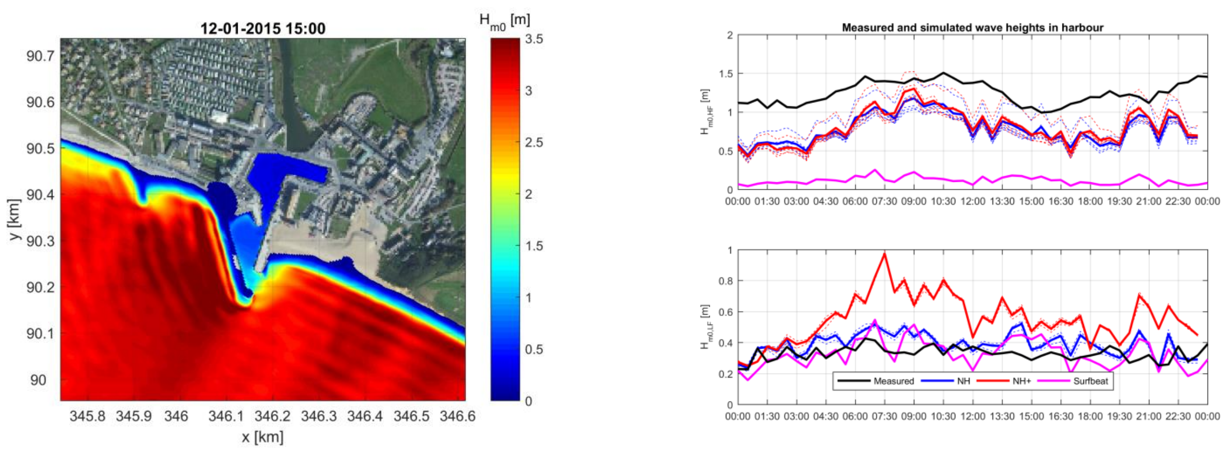

Figure 1 – Left panel: XBeach wave field of West Bay. Right panel: time series of short and long waves.

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CONTRIBUTION OF IG WAVES TO LOCAL RUNUP AND FLOODING BEACH OF BIARRITZ

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TOPIC
Processes (runup, flooding), Environment (Engineered sandy pocket beach), Numerics and validation (Video measurements for model comparisons)

OBJECTIVE & STUDY SITE
Structurally-engineered beaches located at coastlines, which are exposed to energetic wave regimes, are frequently put at risk by large swells and storm surges. By utilizing numerical models, our study aims to identify the relevant processes responsible for wave runup and flooding on structurally-engineered beaches for an efficient assessment of flood hazards. While numerical models are commonly used for flood mapping along natural beaches, less is known when interactions between waves and coastal structures become important. The Grande Plage of Biarritz (GBP) has been chosen as a study site in the framework of the MAREA project (INTERREG POCTEFA), which focuses on the development of new strategies for risk assessment along the Basque coast. The GBP is a 1.2-km-long sandy embayed beach surrounded by two outcrops and backed by a seawall. This tourist destination is located in the southeast corner of the Bay of Biscay, a coastal area famous for surfing but also for its storm intensity. During the winter of 2013-2014, the beach was heavily battered by a series of storms associated with large open-ocean swells. The site experienced great damages to buildings and infrastructure.

METHODOLOGY
During the winter 2017, a video station was installed in a building facing the GBP. This station, based on the KOSTA system, recorded images for 14 min each quarter hour during daylight with an acquisition frequency of 1 Hz. Timestack images for wave run-up measurements were also recorded at two locations along the beach. At low tide, topographic surveys of the corresponding beach profiles were carried out with a RTK DGPS. The cross-shore resolution of the timestack images was 0.1 m. This leads to run-up statistics derived from time series of high frequency water-level elevations. The corresponding 2% exceedance probability, R2%, was calculated from the cumulative probability density function of run-up elevation. Furthermore, frequency spectra of the water-level time series were computed to quantify the respective contributions of infragravity ($f<0.03$Hz) and gravity waves ($f>0.03$Hz) to the swash zone regime. In our study, two numerical models are tested, namely XBeach and BOSZ. The hydrostatic version of the Xbeach model allows forcing of the shallow water equation at the wave group scale. The phase-resolving Boussinesq-type model BOSZ (Roeber et al., 2012) computes the hydrodynamics at the wave scale; therefore the generation of infragravity waves is explicitly solved. SWAN simulations provide wave spectra for offshore wave forcing of both models.

RESULTS
The two models are first used to simulate a moderate storm event that occurred at the end of March 2017 (Hs = 3m, Tp = 16s). During this storm, no overtopping of the seawall was recorded. First, the role of infragravity (IG) and gravity swash energy is determined based on the analysis of frequency-spectra of the water-level time series. It reveals a dominant contribution of IG band energy during low tide and of gravity band energy during high tide. The differences between the measurements and the two models are analyzed both in terms of R2% estimation and energy contribution of IG and gravity bands to the total swash height. A more energetic storm scenario corresponding to the Kurt storm from February 2017 (Hs=7m, Tp=16s) is also considered. This storm was selected as an example of coastal flooding configuration at GPB. Unfortunately, the video system was not fully operational at that time. However, recorded snapshot images provide data for qualitative comparisons. Models are then used to investigate the main processes controlling flooding on the study site. Differences between the two models are discussed by focusing on their respective description of the interaction between waves and seawall.

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INFRAGRAVITY PERIOD OSCILLATIONS IN A CHANNEL HARBOR NEAR A RIVER MOUTH

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TOPIC
Processes: Hydrodynamics (wave transformation).
Environment: Ports, waterways and ships (interaction with structures).
Numerics and validation: Field observations for validation.

INTRODUCTION

Harbor entrances are usually designed for protection against wind and swell waves with periods between 5 s and 20 s. However, many harbors experience problem associated with oscillations and horizontal currents resulting from locally-generated infragravity waves (IG) with periods as long as 300 s (Rabinovich, 2009). This study aims to investigate the mechanisms for the generation and transformation of particular IG-waves and their effects on the hydrodynamic processes in Port of Bayonne, located in SW France, during storm conditions.

STUDY SITE

Port of Bayonne is a channel harbor situated near the river mouth of the Adour. Two breakwaters protect the harbor's entrance from swell waves but long-period oscillations have repeatedly caused snapping of mooring lines of ships berthed near a local steel factory. in addition, these oscillations have led to damage in an adjacent small boat harbor.

METHODOLOGY

A field campaign was carried out during a storm event (Kurt) that occurred around February 03, 2017. Wave conditions, measured offshore by a directional wave buoy moored in 50 m water depth , were typical of a one-year return-period storm (Hs = 5 m and Tp = 16 s). Three pressure sensors, each with a sampling frequency of 1 Hz, were installed at critical locations near the harbor entrance and further upstream. The water elevation near the river mouth was also measured with a tide gauge, operated by SHOM, that recorded the water level at one-minute intervals. A spectral analysis of the measured water level time series was performed to study the energy distribution in the different frequency bands as well as their spatial and temporal evolution. In addition, the storm event was computed with the Boussinesq model, BOSZ (Roeber, 2012), to supplement the measured data and to help understand the governing processes of the IG-waves in Port of Bayonne.

RESULTS

The analysis of the data from pressure sensors shows that the energy in the short-wave frequency band was very low, with a reduction factor of 85% compared to the offshore wave energy. This demonstrates the efficiency of the breakwaters to protect the harbor against incoming swell and sea waves. In contrast, a large amount of energy was found in the IG frequency band, with a significant wave height reaching a maximum value of 0.7 m. The computed waveforms from BOSZ agree well with the measurements and show that the local nearshore bathymetry, including a large man-made deposit of dredged material, focuses wave energy towards the harbor entrance where energetic wave breaking occurs. The breaking process favors the generation of IG waves near the harbor entrance. Contrary to enclosed harbor basins, the configuration of Port of Bayonne allows for free propagation of these long waves over several kilometers affecting upstream locations along the river far away from the source of IG-wave generation.

CONCLUSION

We explain complex mechanisms for the generation and propagation of IG waves in a channel harbor. The effect of a meso-tidal environment on these processes is also discussed. The findings have important implications on risk assessment for harbor operations and mariners' safety. Furthermore, it is suspected that IG waves can contribute to flooding upstream of the river mouth.

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Posters

APPLICATION OF XBEACH IN A BEACH NOURISHMENT AND RESTORATION PROJECT, A CASE STUDY: ALANYA-TURKLER, TURKEY

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TOPIC
Processes (Morphodynamics), Environment (Sandy coasts and shorelines)

INTRODUCTION
This study presents the details of numerical modelling works of a beach nourishment and restoration project in Turkler district of Alanya town, Antalya province, Mediterranean coast of Turkey, with a special focus on the application of the numerical model XBeach (Roelvink et al., 2010) in the assessment of the performance of the nourished beach profiles. The study area beach is approximately 15 m in width and 500 m in length, with the Kargı Stream at the east boundary and a shore-normal 60 m long groin at the west boundary (Figure 1-a). The shoreline is reported to be retreated approximately 80 m in last 40 years mostly due to uncontrolled sand mining and gravel extraction at the stream mouth. Against this severe erosion problem, the beach has been subjected to several attempts of protection and restoration in the past. As a result of these attempts, there exists two additional shore-normal groins of approximately 60 m long and 120 m apart from each other and two submerged offshore breakwaters of 100 m long, which are partly damaged and removed. The existing hard structures have succeeded partly to slow down the erosion at the west and middle parts of the beach in the expenses of loss in scenic beauty and comfort in recreational use of the beach and sea. At the east part, stream mouth, the erosion is more significant, where some scour and damage are observed at the seawalls here.

METHODOLOGY
In the study, wave climate of the study area has been hindcasted with a parametric numerical wave model W61, developed by Middle East Technical University-Ocean Engineering Research Center (METU-OERC), based on the ECMWF (European Center of Medium-range Weather Forecasting) wind data given for the years 1983-2013. Following the wave hindcasting and statistics, various alternative coastal defence systems have been investigated using a one-line numerical model, CSI developed by METU-OERC. As for the beach nourishment to be applied, various profiles with different grain sizes of nourishment material and with or without the other measures (geotextile tubes, offshore breakwaters) have been studied with the XBeach (Figure 1-b). Performances of the nourishment profiles have been assessed by the recessions and volume of eroded material at the end of a storm event with 10 hours per year exceedance probability compared to the initial nourishment volume.

CONCLUSIONS
Two alternative protection plans, in both of which the existing groins at the west and middle parts of the beach are removed and the eastern groin next to pier is shortened, have been proposed. One alternative is composed of submerged geotextile tubes only and the other alternative is a combination of 2 emerged offshore breakwaters and geotextile tubes. The results of the XBeach numerical simulations have shown that the efficiency of the nourishment increases as the grain size increase or the slope close to shoreline gets milder or when the nourishment is applied with a structural measure like submerged geotextile tubes or offshore breakwaters as a result of wave dissipation due to transmission and diffraction.

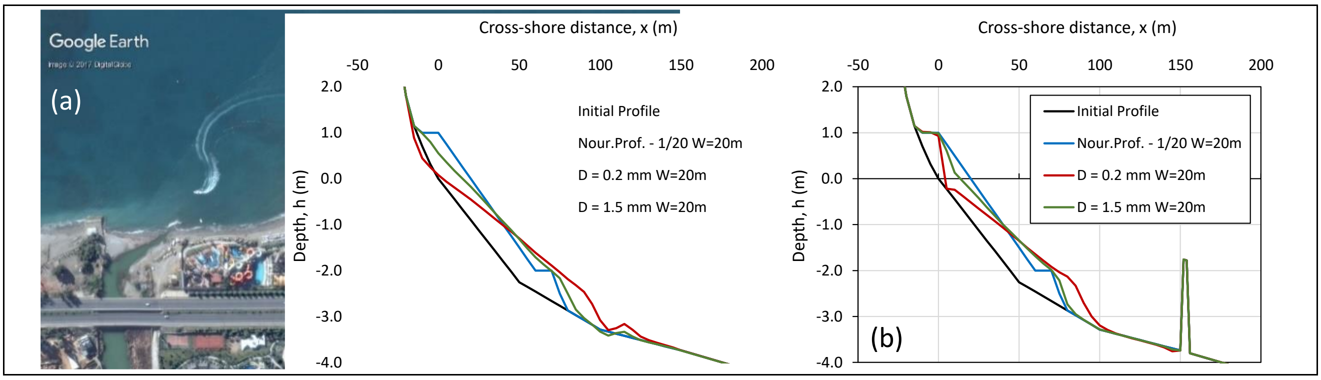

Figure 1 - (a) Study area (Google Earth, 2017). (b) Comparison of pre- and post-storm beach profiles for the beach nourishment profile with 1/20 slope, berm width W = 20 m and a submerged geotextile tube at water depth of 3.7 m, for D50=0.2 mm and D50=1.5 mm.

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WAVE TRANSFORMATION THROUGH MANGROVE COASTS
A MODEL STUDY WITH XBEACH-SURFBEAT

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Wave transformation, Vegetated coasts

INTRODUCTION

Coastal defense mechanisms are an integral part in the safety of infrastructure and communities residing on coastlines around the globe. In long temporal and spatial scales, traditional “hard structures” for coastal defense can become infeasible. Incorporation of soft engineering methods for coastal defense can then be a viable solution.

Vegetation belts along the coasts can be identified as a prominent soft engineering application. Previous studies (field studies, physical and numerical model studies) have been done to identify the protection offered by coastal vegetation. This study focuses on identifying mangrove vegetation interactions under hazardous wave conditions.

METHDOLOGY

The investigations are carried out using the numerical modeling scheme, XBeach-Surfbeat. A 1D grid is used in the model. The grid geometry (grid resolution and grid truncation) was set by performing a sensitivity analysis to ensure the model run times are acceptable without compromising the accuracy of the results. Observation points are used at key locations to acquire output results.

In the model, the waves are propagated from deep water to the shallow water mangrove coasts. The wave data (wave height, wave period, storm surge level) were acquired from the ERA-Interim data base for a 100-year return period (hazardous wave events) for locations where mangroves are present. The wave conditions at the boundary are applied using a JONSWAP spectrum. The mangrove vegetation characteristics (height, diameter, density) were extracted from Jansen (2016). Since mangroves are found within the intertidal range of the coast, the mangrove forest widths used in the model was taken to be a function of the profile slope and the tidal range. The sea bed slopes were also varied in the model runs.

A unique set of 576 model runs were created by varying the hydrodynamic and the profile slope input parameters. These input conditions were then imposed on three different mangrove densities (dense mangrove, medium dense mangrove and sparse mangrove) and a base case of no mangrove coast.

The hydrodynamic-mangrove interactions are analyzed from the perspective of coastal hazard mitigation by mangrove vegetation. The study focuses on wave attenuation, setup variation and runup reduction offered by mangrove vegetation.

RESULTS AND CONCLUSIONS

Wave induced setup variation across the mangrove vegetation can be explained using the forces acting on the water column. The direction of the forces (onshore directed, offshore directed) governs the increase/decrease of the setup. Denser mangroves dissipate short wave energy rapidly at the front of the vegetation increasing the wave setup. Due to the reduced wave energy, the vegetation force acting on the water column in a dense vegetation will be smaller leading to a lower reduction in wave setup. Hence, an increased wave setup was observed in denser vegetation model cases whereas a reduced wave setup was observed for sparse vegetation

The degree of wave attenuation by vegetation mainly was dependent upon the wave height. Higher wave heights induced more wave attenuation. The water depth at the vegetation was also found to be important. Deeper water depths enabled the waves to propagate more within the vegetation (reduced attenuation). Denser vegetation was more capable of attenuating wave energy compared to sparser vegetation. Furthermore, long wave energy band showed lower attenuation rates compared to short waves which resulted in a larger composition of low frequency wave energy towards the end of the vegetation.

Wave runup was calculated on a constant slope at the end of the vegetation using empirical equations proposed by Van Gent (2001) using the wave spectrum at the end of the vegetation width. Denser vegetation showed the largest reduction in runup and the runup attenuation level reduced with the decreasing vegetation density. The wave runup reduction can be attributed to the attenuation of wave energy by the vegetation.

It can be concluded that mangrove vegetation can substantially mitigate the effects of coastal hazards by waves (wave energy, wave induced flooding) faced in the hinterland. However, the level of mitigation depends on several factors. The most important factors are, vegetation density, mangrove forest width, wave height and water level. Denser mangrove vegetation and wider forests increase the wave attenuation while deeper water depths in mangrove forests reduce the attenuation capacity.

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INTRODUCING AEOLIAN DRIVEN PROCESSES AND ECOMORPHOLOGY TO BUILD AND RECOVER DUNES

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TOPIC
Environment (Sandy coasts, dunes and shorelines)
Numerics and validation (Coupling to other models)

ABSTRACT
XBeach has proven to successfully erode dunes under the impact of storms. However, a step forward is needed in order to allow the recuperation of this vulnerable part of the coastal system to more accurately reproduce the long-term evolution of sandy coasts.

Here we present a rather simple approach that could function as an additional module to XBeach in order to reproduce the response of the dune driven by local winds. The latter are able to transfer sand sourced within the dune system and from the adjacent beach. The Duna module is a process-based morphodynamic model that includes a wind model component based on (Kroy et al., 2002), a sediment transport component based on (Bagnold, 1936) and (Sauermann et al., 2001), a vegetation growth approach loosely based on (Durán and Herrmann, 2006), as well as the effect of factors limiting sediment transport such as grain size, vegetation and moisture. The model is flexible enough to allow incorporation of further components and factors interfering with the transport of sand by wind in coastal dunes.

The performance of the model is being tested at the Ria Formosa barrier islands, namely at Ancão peninsula whose mean grain-size varies between 0.38 and 1 mm. Available high resolution DTMs derived from Lidar and Drone flights are used to estimate recent topographical changes, while local winds provide needed boundary conditions to analyze the sensitivity of the model. An example of a realistic development of a foredune over a 3-year period is shown in figure 1.

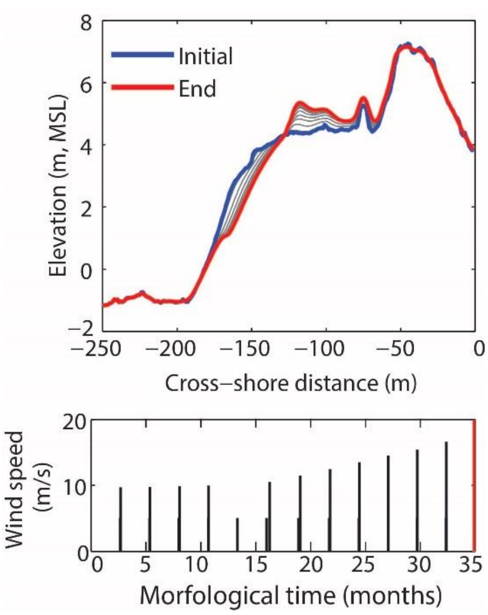

Figure 1 -Duna output after a three years simulation

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ESTIMATION OF DUNE VULNERABILITY ON THE DIFFERENT EXPOSED COASTLINES OF ILE DE RÉ

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TOPIC
Morphodynamics: Storm-induced erosion / Numerics: Field observations for validation

INTRODUCTION
This work aims to assess dune vulnerability as coastal protections on Ile de Ré, located on the west coast of France. Beach/dune systems works as a natural barrier against coastal flooding and are often impacted by storm-induced erosion. Since Ile de Ré is a low-lying island mainly composed of land and villages located below extreme water levels, stakeholders drew attention to the persistent dune retreat. In order to improve knowledge on dune assault during extreme storm event, yearly topographic surveys were carried out over the 20 km (235 cross-profiles) sandy beaches between 2013 and 2016. The 2013/2014 winter wave conditions have severely impacted the Ile de Ré coastline. Masselink *et al.,* 2015 have demonstrated that this winter was the most energetic event recorder over the European Atlantic coast since at least 1948. On Ile de Ré, the storm Hercules which occurred on the 6-7th of January 2014 was the most impacting event with erosions of about 5 to 10 m (Figure 1-b). The peak wave period reached 22 seconds with a wave height around 12 meters during a spring tide.

XBEACH MODEL
Modelling work was undertaken to improve knowledge of the main processes responsible of such erosions and secondly to propose solutions to decrease impacts on dune faces during severe storms. The XBeach model (Roelvink *et al.,* 2009) was used to simulate hydrodynamic and morphodynamic processes.
The wave forcing at the model boundaries was determined from offshore measurements and propagated using the Swan model (Booij et al., 1999). In this study, the XBeach model is firstly used in a 1D domain to simulate the cross-shore evolution on several beach expositions. Calibration of the model was done with available topographic data according to different parameters and phenomena (dune vegetation, wave breaking parameter, sand diameter size, foreshore bathymetry, critical slopes for dry and wet points, morphological factor, etc.). Results gave good correlations with the storm induced erosion observed in the topographic measurements as shown by the Figure 1-a.
XBeach model is also used in a 2D domain to take into account the alongshore topographic non-uniformities comparing to the 1D model.

DUNE VULNERABILITY ANALYSIS
Once the model was calibrated, different extreme conditions has been simulated to evaluate the risk of dune erosion and dune breaches. A final map gives a classification of these different hazards for each section of homogeneous dunes. Finally, investigations on solutions to decrease dune vulnerability will be proposed as perspectives.

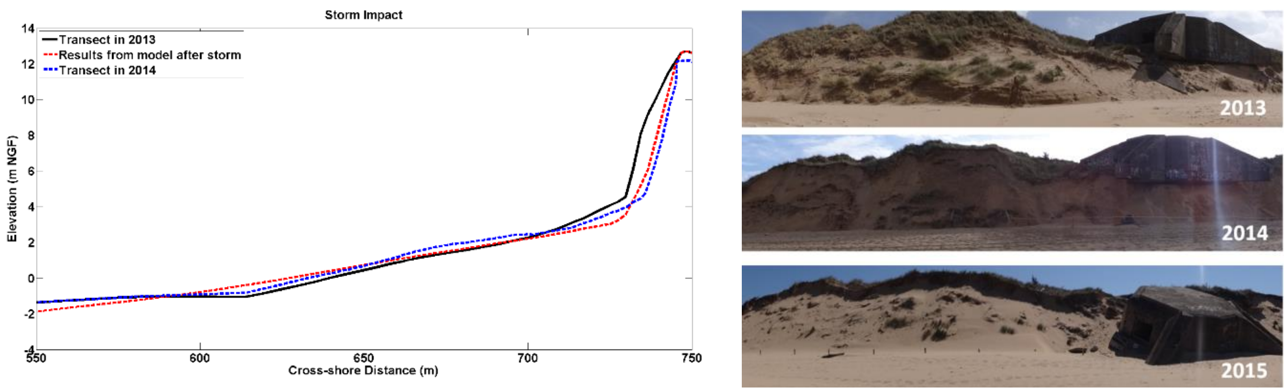

Figure 1 - a) Example of result from the Xbeach model at the cross-profile 8 at St Clément des Baleines. / b) Morphodynamic evolution at the cross-profile 14 of the beach of St Clément des Baleines. Significant dune face retreat and blockhaus fall.

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TESTING GREEN DRR SOLUTIONS BY DUNE RECONSTRUCTION AT A RAPIDLY ERODING COAST IN THE ADRIATIC SEA

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TOPIC
Hydrodynamics; Morphodynamics, Sandy coasts and shorelines; Vegetated coasts and shorelines

ABSTRACT

In the current scenario of climate change and increased sea-level the occurrence of high water level storms threatens coastal landscapes that lye at a low elevation. Naturally coastal dunes provide the so-called first line of defence. At eroding coastlines their reconstruction offers the opportunity to build dynamic coastal defences, in opposition to more static approaches like sea-walls. In order to properly design a revegetated dune, modeling must be undertaken to identify the optimal dune height and width able to withstand the effect of an exceptional storm. The primary role of the plants is to modify the velocity profile above them: this implies to introduce in the model credible values of the drag coefficient that also reflect the spatial distribution of the different plant species and the density of stems per unit area.

Numerical tests of the effectiveness of dune reconstruction and revegetation as a Disaster Risk Reduction (DRR) measure were undertaken on the Bellocchiocoastline, south of Porto Garibaldi, in the northern Adriatic sea coast of Emilia-Romagna. The work was developed as a part of the EU FP7-RISC-KIT project, which elected the site as the pilot case study after selection of a number of highly exposed hotspots (Armaroli and Duo, 2017). A detailed digital elevation model was producedmerginga topographic Lidarfor the emerged area, a nearshore bathymetric Lidar up to -4.5 m water depth and a multibeam bathymetric survey for the offshore up to - 10 m. The storm selected to test the efficiency of the natured-based DRR occurred on 5-6 of February 2015, with a maximum offshore significant wave height of 4.66 m and a peak of 1.2 m of water level above MSL. These conditions approximately correspond to a return period of 50 years. The two-dimensional domain extends 3000 m alongshore and 3600 m cross-shore. The resolution of the ranges from 18m alongshore and 21m cross-shore at the offshore open boundary at (10 depth) to 1m cross-shore and 8m alongshore in the area where the dune is located. The reconstructed dune was built mimicking the current dune but enlarging it and increasing its crest, according to literature knowledge of comparable dune systems in the region. The vegetation was introduced according to spatial distribution of local species assuming either the current stem density or doubling it. Two indicators were chosen to assess performance, respectively the Maximum Water Volume (MWV) and the sediment volume variation (SVV).

The results outline a reduction of inundation with the reconstructed dune (Fig. 1a), which is still breached and overtopped at some points. If the vegetation is reconstructed on the dune there is considerable decrease of inundation (Fig. 1b). Minimum changes are observed between normal and high density of vegetation for the reduction of MWV (Fig. 1c). The high-density vegetation set-up provides instead the most efficient solution for SVV reduction. Further tests will be undertaken at a number of European sites in the context of the EU H2020-ANYWHERE Project, encompassing also different vegetation taxonomy and distribution.

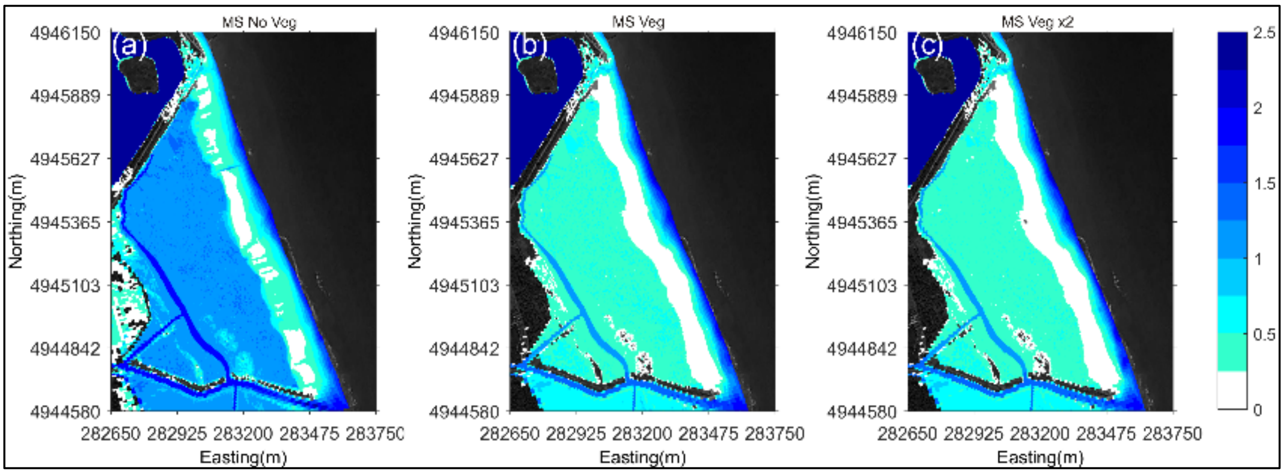

Figure 1-Maps of the maximum inundation depth (m) for the storm of 5 February 2015for different DRR measures: (a) dune reconstruction; (b) vegetated and reconstructed dune; (c) reconstructed dunewith a two-fold vegetation density increase.

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EXPERIMENTAL STUDY ON UNDULAR BORE DEVELOPMENT OVER A FRINGING REEF

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INTRODUCTION
Several studies have reported the development of undular bores over fringing coral reefs (e.g, Gallagher, 1976) but the importance of this phenomenon for reef hydrodynamics has never been studied. Yet, the transformation of a long wave (e.g., swell or infragravity wave) into an undular bore leads to significant modifications of the wave field. The formation of undulations is for example associated to a significant increase of the leading bore height. Moreover, if the undulations have enough time to develop (i.e. if the reef flat is wide enough), the initial long wave will ultimately split into a series of solitons. All this is likely to affect wave run-up. As reef-fronted coastlines are particularly vulnerable to flooding, a good understanding of long wave transformation over the reef flat, including their possible transformation into undular bores, is crucial. In this study, we investigate undular bore development over reef-type profiles based on a series of laboratory experiments. More specifically, we aim to characterize the conditions under which undular bores develop, and analyse how their development affect the hydrodynamics at the toe of the reef-lined beach and the resulting wave run-up.

METHODOLOGY
The experiments analysed in this study were conducted in the 40 m-long wave flume of the Water laboratory at Delft University of Technology (Dekkers, 2017). The bathymetry consisted of a 1:10 fore-reef slope, followed by a 20m long shallow reef flat fronting a 1:5 beach. Surface elevation and horizontal velocity were measured at 17 locations along the fringing reef profile, and run-up was measured on the beach. Both regular and bichromatic wave conditions were run during this experiment. Because we hypothesized that both swell waves and infragravity waves can evolve into undular bores over the reef flat, we considered a relatively large range of regular wave conditions, ranging from typical pacific swell conditions ($T_{prototype}$=20s; $H_{prototype}$=1.6m) to relatively long infragravity waves ($T_{prototype}$=90s; $H_{prototype}$ =0.8m).

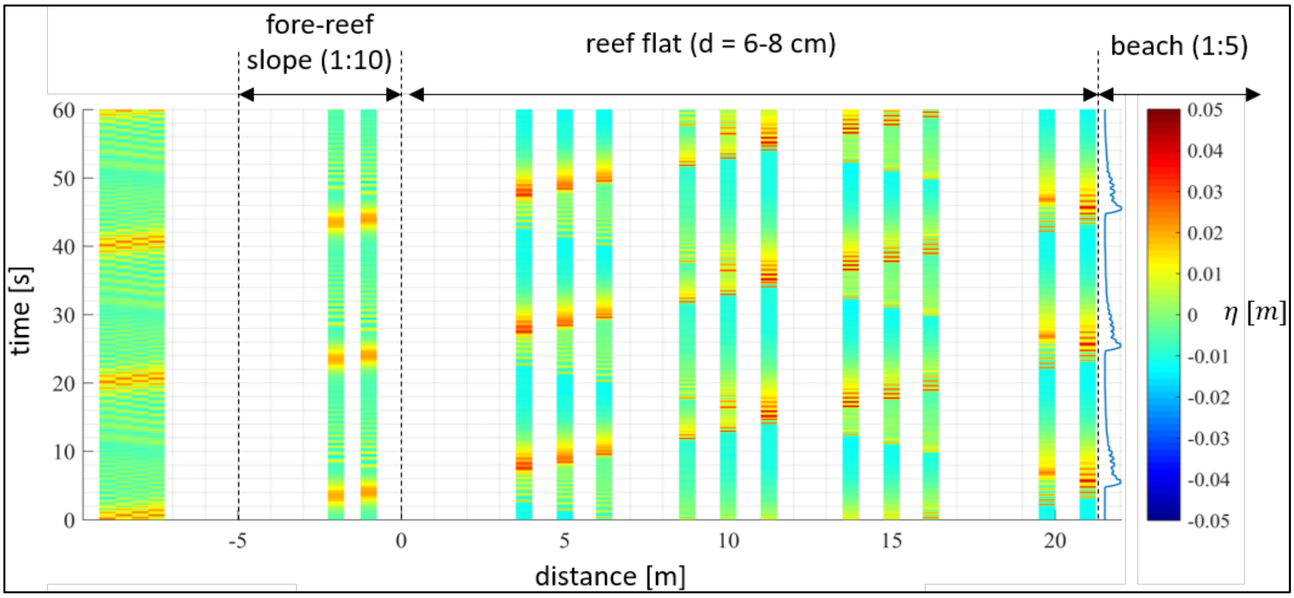

Figure 1 - Space-time diagram of the surface elevation for a long wave of period T=20s and height H=2cm (scale factor: 20) propagating across the laboratory fringing reef. The blue line shows the run-up time-series.

PRELIMINARY RESULTS
Undular bores were observed on the reef flat for all regular wave cases considered. Figure 1 shows wave transformation at different locations for a wave case chosen to mimic a relatively long infragravity wave ($T_{prototype}$ = 90s; $H_{prototype}$ = 0.4m). In this case, the incoming long wave starts developing undulations at the mid reef (x≈8m). At the toe of the beach, the individual undulations are well-developed. At the beach, the undulations are mostly dissipated, and only the underlying long wave is reflected. Interestingly, this reflected wave also develops into an undular bore while propagating seaward on the reef flat.

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NEARSHORE BAR DYNAMICS
XBEACH VS NEARSHORE OPTIMAL THEORY

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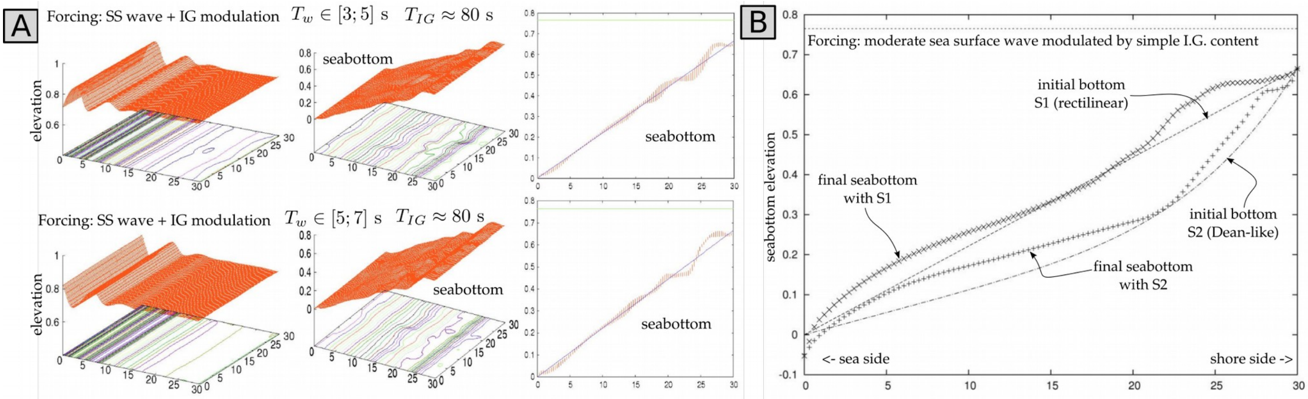
TOPIC
(1) Processes / Morphodynamics (2) Numerics/ Numerical Methods

INTRODUCTION
It is well known that the instantaneous dynamics of near-shore sand bars are partly controlled by the incoming wave spectrum, the morphodynamic inheritance and the features (location of nodes, amplitude, length, period) of the infra-gravity signal. Reciprocally, changes in the location, size and shape of near-shore sand bars can control wave/wave interactions which in their turn alter the content of the wave spectrum. Regarding numerical modelling, most of the existing approaches (including the one developed for Xbeach) are based on the following strategy: 1) define a wave forcing, 2) compute radiation stresses or similar features, calculate subsequent sediment transport, and changes in the sea bottom including sand bars, 3) loop taking into account the morphological changes. We have considered recently an alternative approach named Near-shore Hydro-morphodynamic Optimal Theory (NHOT), which is a full breakdown point of view. In this presentation, we benchmark NHOT comparing it with Xbeach under various conditions for which Xbeach provide robust results. We discuss the pros and cons of NHOT.

NEARSHORE HYDRO-MORPHODYNAMIC OPTIMAL THEORY
NHOT arose with the design of solid coastal defense structures by shape optimization methods (Mohammadi & Bouchette, 2014), and is being now extended in order to model the dynamics of any near-shore system combining waves and sand (Bouharguane et al, 2010). The basics of such a method are the following: the near-shore system state is defined through a functional J representative of the energy of the system in some way. This J embeds the core physics of the problem. Then the paradigm is to say that the system will evolve so that the energy J tends to minimize globally. Insofar as J embeds the correct physics to be explored, the method does not require complex modelling.

RESULTS
Promisingly, NHOT generates complex combination of near-shore sand bars from scratch forced by various wave spectra. We explore the effects of the coupling between narrow wave spectra and a very simple infra-gravity content on morphodynamics. It is shown that gravity waves foster basic sand bars and that even a simple infra-gravity content strongly grow and stabilize them (Figure 1). We compare the various existing theories relative to bar dynamics with NHOT predictions and we discuss them. According to NHOT, a very simple infra-gravity content is enough to nucleate nearshore bars from a linear or smoothly recurved profile. Such simulations are being compared with the same performed with Xbeach.



Examples of sand bar nucleation and growth with NHOT. (A) From an initial linear profile, waves superimposed with a simple infra-gravity signal create and grow various sand bars. (B) Different sand bars are obtained with a similar forcing when different initial bottom profile are used. NHOT is natively a 3D model.

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AN ASSESSMENT TOOL FOR MITIGATION MEASURES AGAINST COASTAL SEDIMENTATION/EROSION–A CASE STUDY FROM THE BELGIAN COAST

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TOPIC
Morphodynamics; Ports, waterways and ships

ABSTRACT
Along the Belgian Coast, the harbour of Blankenberge experiences strong sedimentation in its entrance channel requiring frequent dredging, while the area around Wenduine encounters structural erosion and the nourishment in this area is subjected to a limited lifecycle. Following an integral view proposed in the Masterplan Vlaamse Baaien, these two issues are considered as a whole, and a XBeach model including both locations is developed to investigate effects of different mitigation measures.
This model is imposed with a reduced time series representative of the annual wind-wave climate and a representative tide, which were derived from previous studies (Zimmermann et al., 2012; Wang et al., 2014) and had been successfully applied to simulate the morphological change in scale of 1 to 10 years. In combination with a constant morphological acceleration factor, one-year sedimentation/erosion is simulated by the model. Through a quantitative comparison with a compilation of topographic and bathymetric surveys from 2014 to 2015, a good agreement could be found between the measurement data and the modelled results (Figure 1). The validated model is further used to investigate the different mitigation measures, and their effects on the whole system are assessed.

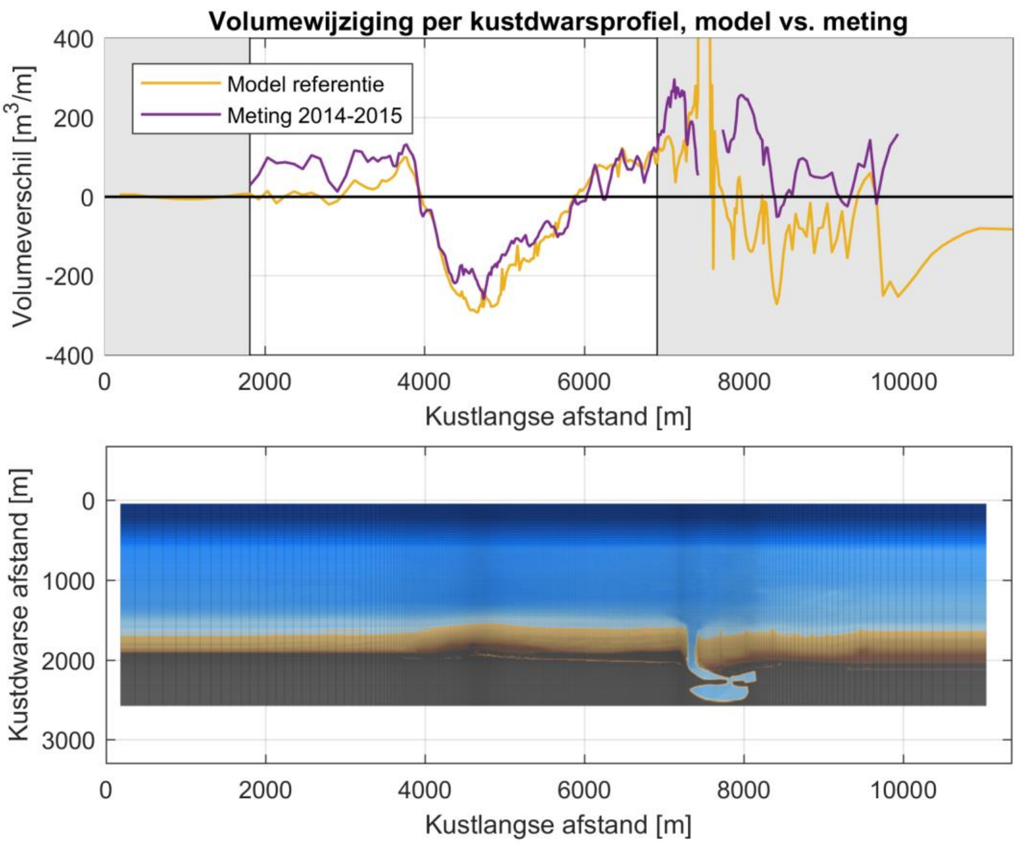

Figure 1 -Modelled and observed sedimentation/Erosion of cross-shore profiles over the area of interest

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Modelling the hydrodynamic effects of excavation pits on fringing reefs with XBeach non-hydrostatic+

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TOPICS: hydrodynamics, fringing reefs & excavation pits, XBeach non-hydrostatic+

INTRODUCTION

Many tropical island states are characterized by having small and densely populated areas on low lying reef structures, such as atolls and fringing reefs. The global impact of climate change is and will continue to be most present in these tropical countries, as some of these nations face the likely possibility of losing their territory due to coastal erosion and sea level rise due to climate change (UN-Habitat, 2015), as well have an increased effect on stresses on freshwater supplies. Currently, in order to cope with construction material demand, such as aggregates and other rocky sediments, a number of these pacific islands have resorted to a seemingly cost efficient source of material. The reef flat, which consists of petrified and consolidated dead coral, is excavated up to a depth of several metres, covering areas which are often similarly sized to football fields.

The fringing reefs are of great importance to these islands, as they play key roles in a number of processes related to ecology, hydrodynamics and sediment dynamics. An alteration of the reef structure, such as reef excavating, is likely to influence these processes. At the moment, a number of studies have been performed that studied the effects of reef excavating on ecology (Brown & Dunne, 1988), hydrodynamics (Ford et al., 2013; Yao et al., 2016) and sediment dynamics (Xue, 2001). However, it has been recommended to further study the broad effects that these excavations have (Ford et al., 2013; Yao et al., 2016).

AIM

As part of an MSc thesis, the following research is being carried out, which aims to further increase the understanding of the effects that reef excavating has on the hydrodynamic processes of fringing reefs, as well as to make an assessment of coastal hazards related to overtopping due to the presence of an excavation pit. The study consists of three main parts: firstly a study which validates the use of XBeach non-hydrostatic+ using near-shore measurements, secondly a conceptual study that uses schematic 1D and 2D XBeach models that are used to assess the hydrodynamic processes and possible coastal hazards, and finally a case study at Tuvalu, which aims to validate the findings of the conceptual study and implement these in a real life situation.

MODEL SCHEMATIZATION & RESULTS

The XBeach module that is used in this research is XBeach non-hydrostatic+ (XB nonh+). The non-hydrostatic mode of XBeach (XB nonh) uses non-linear shallow water equations, including a non-hydrostatic pressure, which is turned off during wave breaking. The non-hydrostatic+ mode introduces an extra computational layer, which further increases the applicability of the model on steep slopes, such as reefs and is also able to model near vertical walls, such as excavation pits. A comparison between outputs of a 1D model of a fringing reef with XB nonh+ and XB nonh is given in Figure 1 (left). An initial provisional result show that the presence of a pit leads to an increase in high-frequency (HF, 0.01-0.4 Hz) wave energy and a decrease in infra-gravity (IG, 0.001-0.01 Hz) wave energy reaching the shoreline. Also, as can be seen in Figure 1 (right), these effects become increasingly present for wider pits compared to narrow pits.

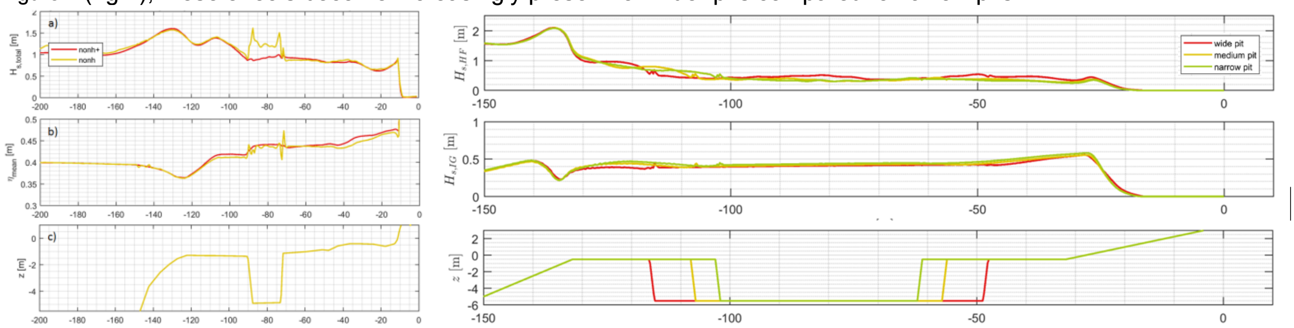

Figure 1. Comparison of wave heights (a) and water levels (b) on a reef (c) using XB nonh+ (red) and XB nonh (yellow) (left). Comparison of wave height and water level transformations for reefs with excavation pits of different cross-shore widths (right).

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COMPARISON BETWEEN XBEACH AND FINEL MORPHO-DYNAMIC MODELLING OF A SANDBAR BREAKWATER

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TOPIC
Morphodynamics, Sandy coasts, dunes and shorelines, Ports

INTRODUCTION

Dangote Petroleum Refinery and Petrochemicals Free Zone Enterprise (DPRP) and Dangote Oil Refining Company (DORC) are setting up a green field refinery, polypropylene plant and fertilizer plant planned at 30 nautical miles east of Lagos, Nigeria. A Jetty with a RoRo facility needs to be developed for unloading of the project cargo meant for the proposed fertilizer plant and the other industries. The design of the approach channel, turning basin and breakwater structure protecting the RoRo Jetty facility included the concept of a Sandbar Breakwater. Following the Building with Nature® concept, a Sandbar Breakwater uses the dynamics of nature and stability of the breakwater will only increase over time.

The Nigerian coast is a typical swell coast: a straight steep sandy coast dominated by a very uniformly directed swell inducing an almost constant (nett and gross) sediment transport of 650.000 to 900.000 m^3 directed to the east. The Sandbar breakwater concept is based on these characteristics. Natural accretion west of the breakwater prevents the necessity of hard construction materials as they lose their function over time. A stable Sandbar, oriented to the equilibrium coastline orientation, acts as a breakwater and ensures sufficient protection of the harbour basin. A relative small groyne at the tip of the Sandbar Breakwater prevents bypassing of sediment and thus keeps the Sandbar in place. Over time, natural sediment import increases the stability of the Sandbar breakwater.

The morphological development of the Sandbar breakwater has been assessed using both FINEL and XBeach. The performance of both models has been compared to assess the applicability of the XBeach model to simulate (longshore dominated) long term morphological developments of sandy coasts dominated by swell and with limited tidal influence.

MODELLING APPROACH

Nearshore wave conditions have been obtained by use of a large scale SWAN model and calibrated against local measurements. These conditions have been used for both models to generate representative seasonal (morphological) wave climate, resulting in a set of a limited number of wave conditions. The FINEL model has been (online) coupled with the SWAN model, while in XBeach the built-in stationary wave solver has been used. Both models have been calibrated based on the annual sediment transport rates. Validation of the models has been performed using satellite images showing the morphological development after construction of small groynes in the same area.

RESULTS AND CONCLUSIONS

To minimize capital costs the initial (construct) Sandbar volume is minimized. Computations with a simulation period of at least 2 years are used to assess the morphological development and thus assess the stability and safety of the Sandbar breakwater. Morphological development simulated with both models are very comparable. The results of XBeach show a more gentle shore face development, although the position of MSL and -5+MSL contours are in both models almost identical. Xbeach shows slightly more accretion at the western side, which could be related to the fact that FINEL has shown some bypassing of sediment along the groyne tip, while in XBeach no bypassing has occurred.
It can be concluded that the XBeach model is a suitable model to simulate longterm longshore morpho-dynamic processes at the swell dominated sandy coast of Lekki.