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Küstenmorphologische Modellierung am LWI – Ein Überblick

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1. Einführung zur Modellierung der Küstenmorphologie

Modellierung der Küstenmorphologie

Models are never exact but obviously often useful.
I never expected our physical models to recreate all of
physical reality

In Feynman's "The Character of Physical law"



Modellierung der Küstenmorphologie

Ziele

Bewertung der morphologischen Veränderungen an der Küste unter Einfluss von Wellen und Strömungen



Anwendungen

- **Vorhersage der Erosion von Stränden, Dünens und Nehrungen**
- Verständnis der **Erosionsprozesse an Bauwerken**
- Einfluss auf die **Küstenmorphologie** durch Häfen, Lahnungen, etc.

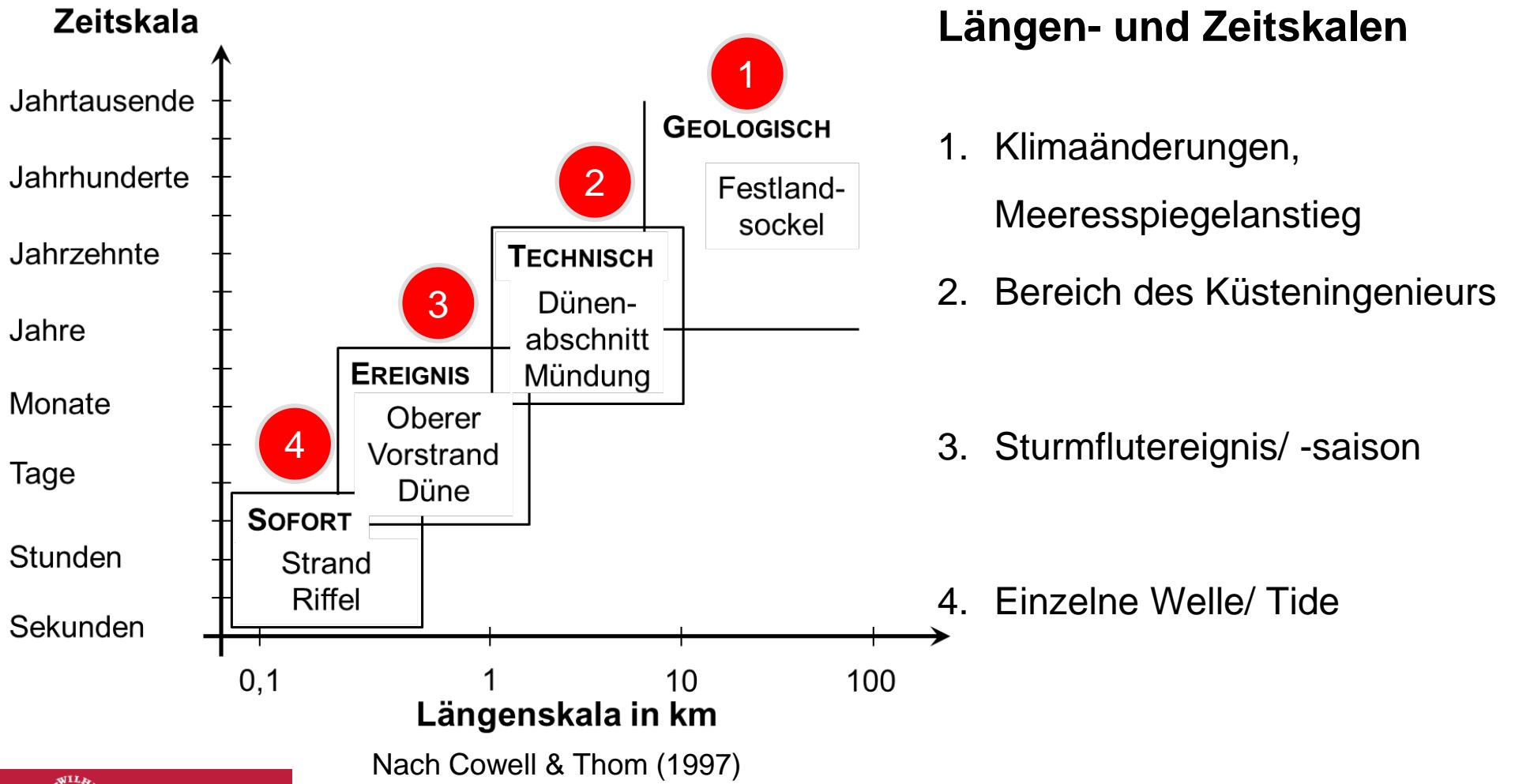


Modellierungsansatz

in Abhängigkeit der Prozesse und des Skalenproblems

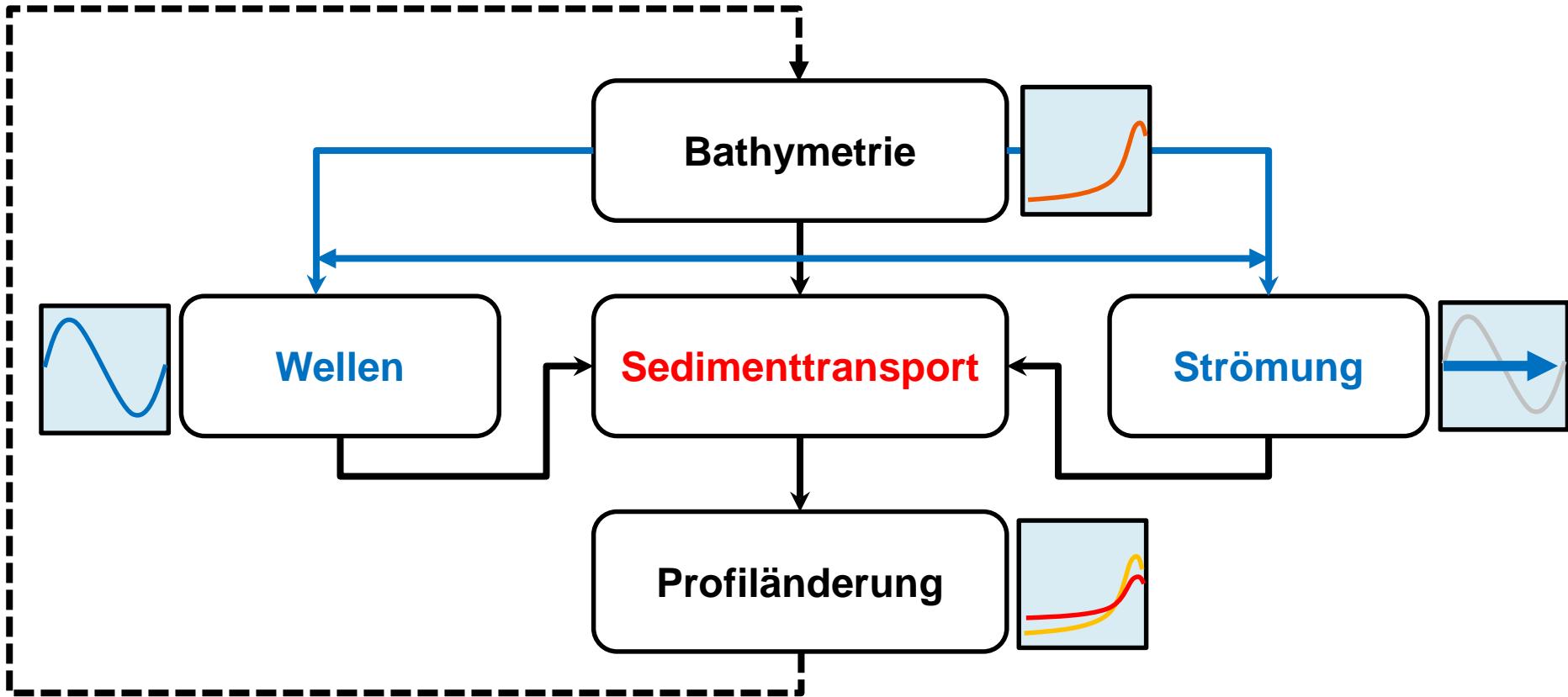


Räumliche und zeitliche Skalen der Küstenmorphologie



Aufbau der küstenmorphologischen Modelle

Interaktion zwischen hydraulischen Einwirkungen und Umlagerungsprozessen

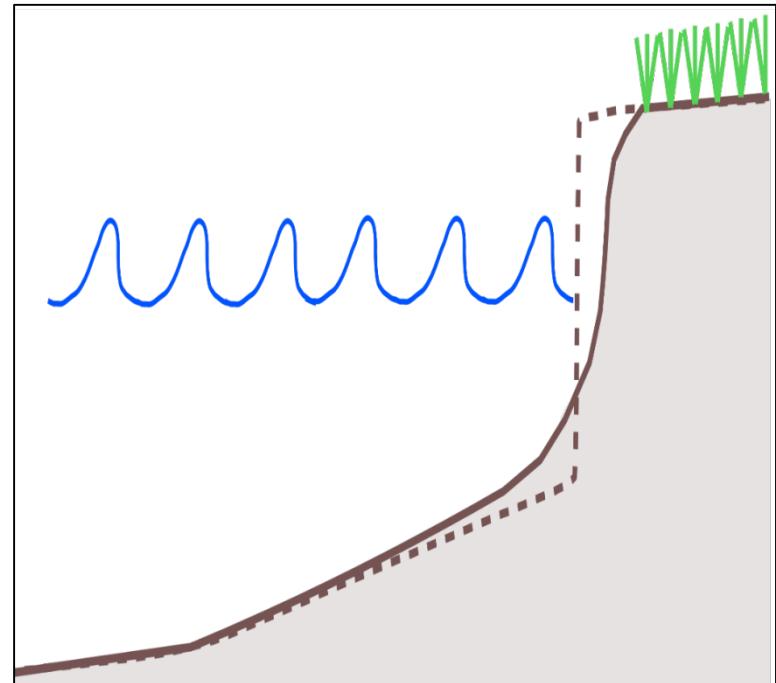


Nach Roelvink & Reniers (2012)

2. Wave-induced Salt Marsh Edge Erosion

Wave-induced Salt Marsh Edge Erosion

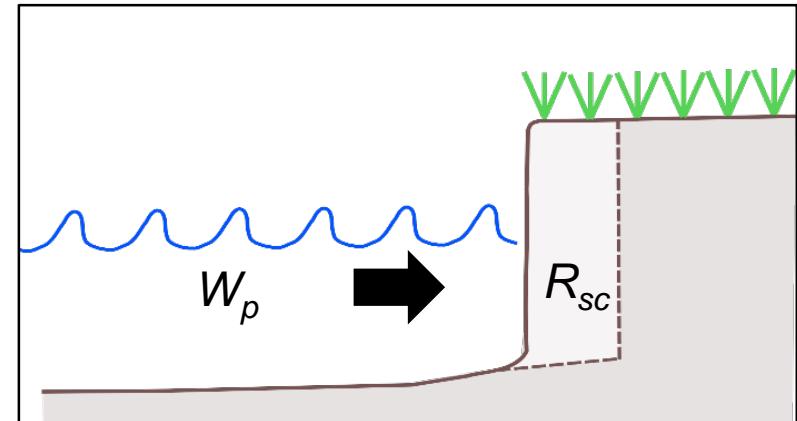
M. Bendoni



Problem Statement: Knowledge Gaps

Vertical Evolution (widely studied)

- Hydrodynamics, morphodynamics
- Vegetation
- Stable/unstable state analyses



Lateral retreat (poorly studied)

- $R_{sc} = f(W_p)$ → Lack of yearly and monthly relations
- Numerical models (decades) → No detailed models for smaller scale
- Cantilever mass failure model → Effect on bank retreat: not yet investigated
- Description of toppling failure → No mathematical model available

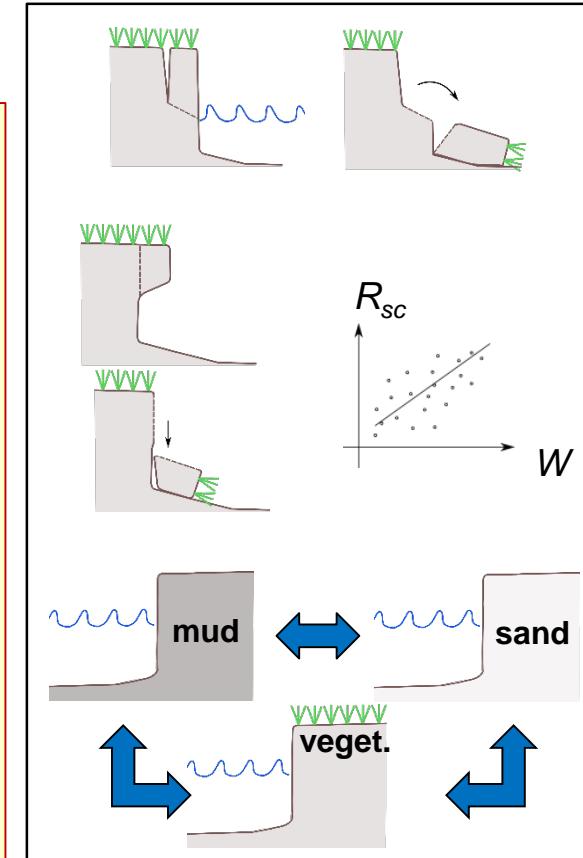
Objectives

Overall objective: improvement of the knowledge of the processes associated with salt marsh lateral erosion (including mass failures) by wind-induced waves

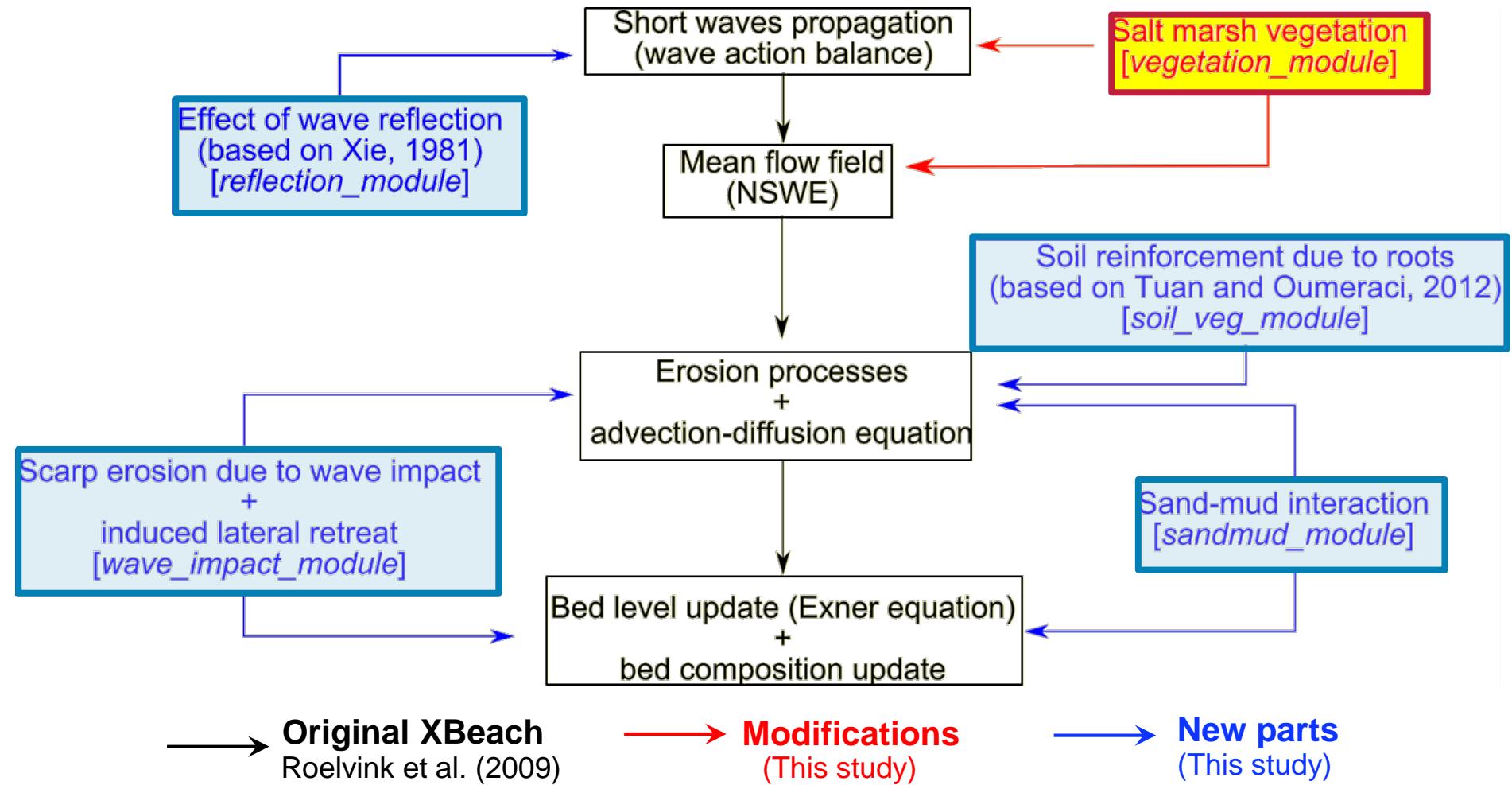


Specific objectives:

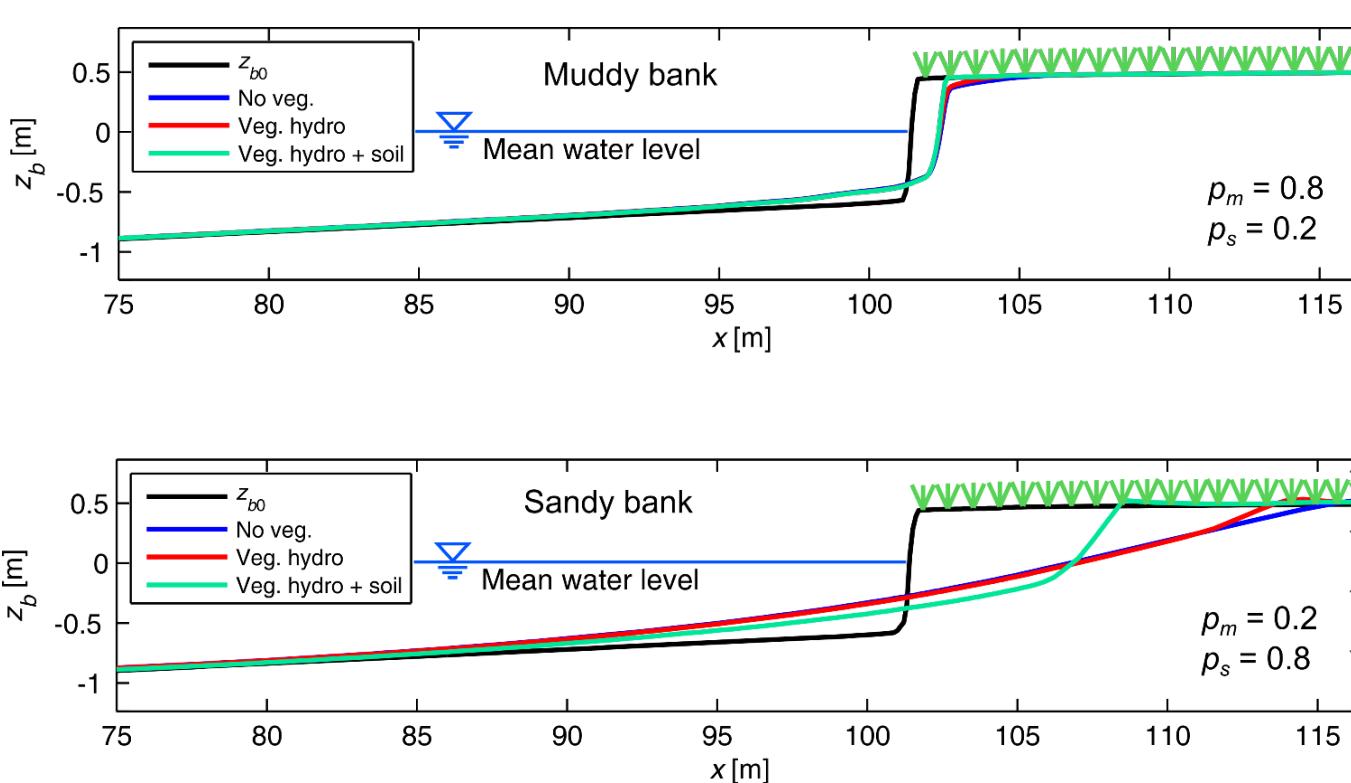
- i) Analysis and interpretation of laboratory experiments:
 - modelling of mass failure of toppling type.
- ii) Field measurement campaign in the Lagoon of Venice:
 - relation $R_{sc} = f(W_p)$ at monthly time scale;
 - cantilever failure mechanism on cumulative bank retreat (incl. vegetation).
- iii) 1D hydro-morphodynamic numerical model:
 - relevant processes involved in bank lateral retreat;
 - sensitivity analysis of bank erosion to main parameters (soil composition, vegetation).



Overview of XBeach with Extensions/Modifications



Results of Extended XBeach: Effect of Vegetation and Soil



a_h	= 0.28 m
b_v	= 1 cm
N	= 500 unit/m ²
H_{rms}	= 0.28 m
T	= 2.5 s
T_{tide}	= 12 hours
Δh_{tide}	\approx 1.1 m
$d_{50,mud}$	= 0.06 mm
$d_{50,sand}$	= 0.2 mm
$p_{m,cr}$	= 0.3
mor_{fac}	= 10
T_{run}	= 5 days

Effect of vegetation is stronger for lower mud fractions

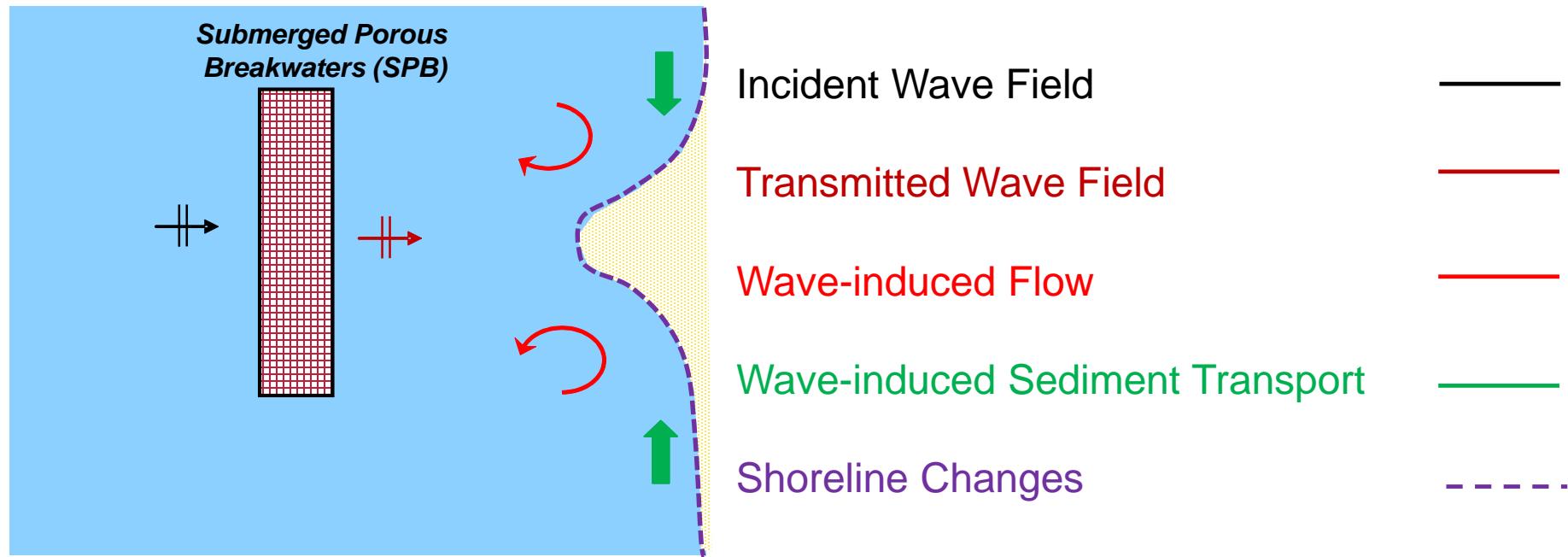
Decreasing mud fraction the bank results in a more dissipative profile

3. Effect of Structure Porosity and Submergence on Coastal Morphology



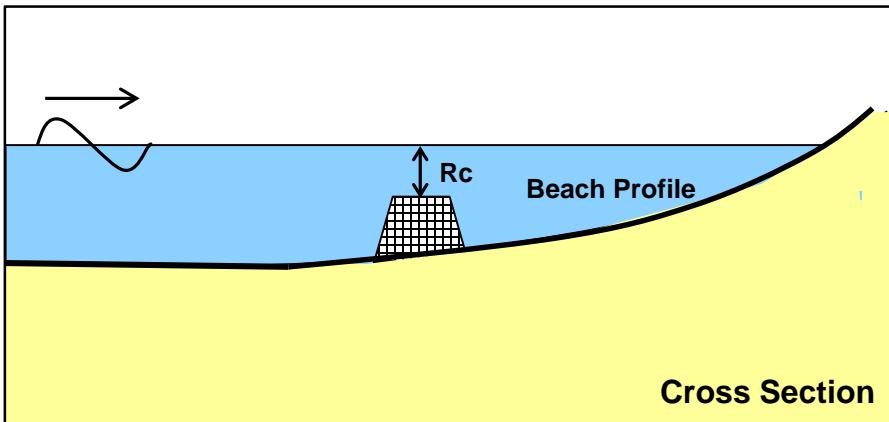
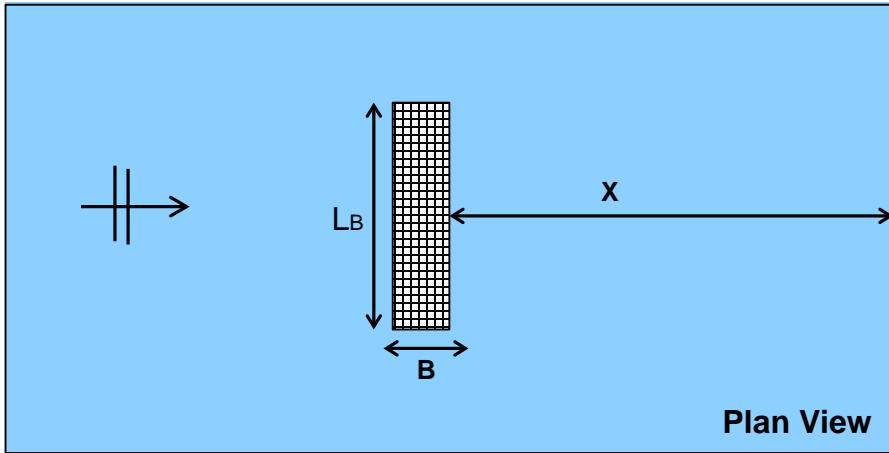
Effect of Structure Porosity and Submergence on Coastal Morphology

S.M. Mojabi



Problem Statement – Knowledge Gaps

Overview of the knowledge gaps



Effect on Shoreline	Current Knowledge
Distance x to shoreline	investigated
Breakwater Length L_B	investigated
Breakwater Width B	investigated
Breakwater Submergence R_c	poorly investigated
Breakwater Porosity n	not yet investigated

X: Distance from Shoreline
L_B: Length of Breakwater
B: Breakwater Width
R_c: Breakwater Submergence
n: Breakwater Porosity

Objectives

Overall objective: improve the understanding of the hydrodynamic and morphodynamic processes governing the effects of submerged porous breakwaters (SPB) on coastal morphology.



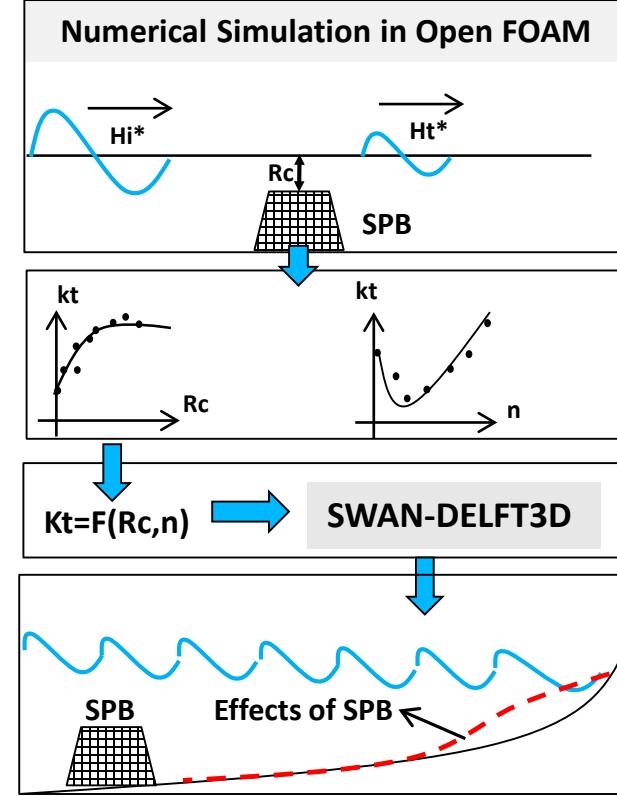
Specific objectives:

- i) Developing a formula for wave transmission coeff. Kt as a function of submergence Rc and porosity n , Parameter study using OpenFOAM: $Kt = f(Rc, n)$.
- ii) Implementing the new formula $Kt = f(Rc, n)$ in SWAN-DELFT3D
- iii) Validating modified SWAN-DELFT3D to calculate coastal morphological changes induced by SPB
- iv) Perform numerical parameter study using validated modified SWAN-DELFT3D
- v) Develop simple design formulae based on the analysis of the data obtained from the numerical study

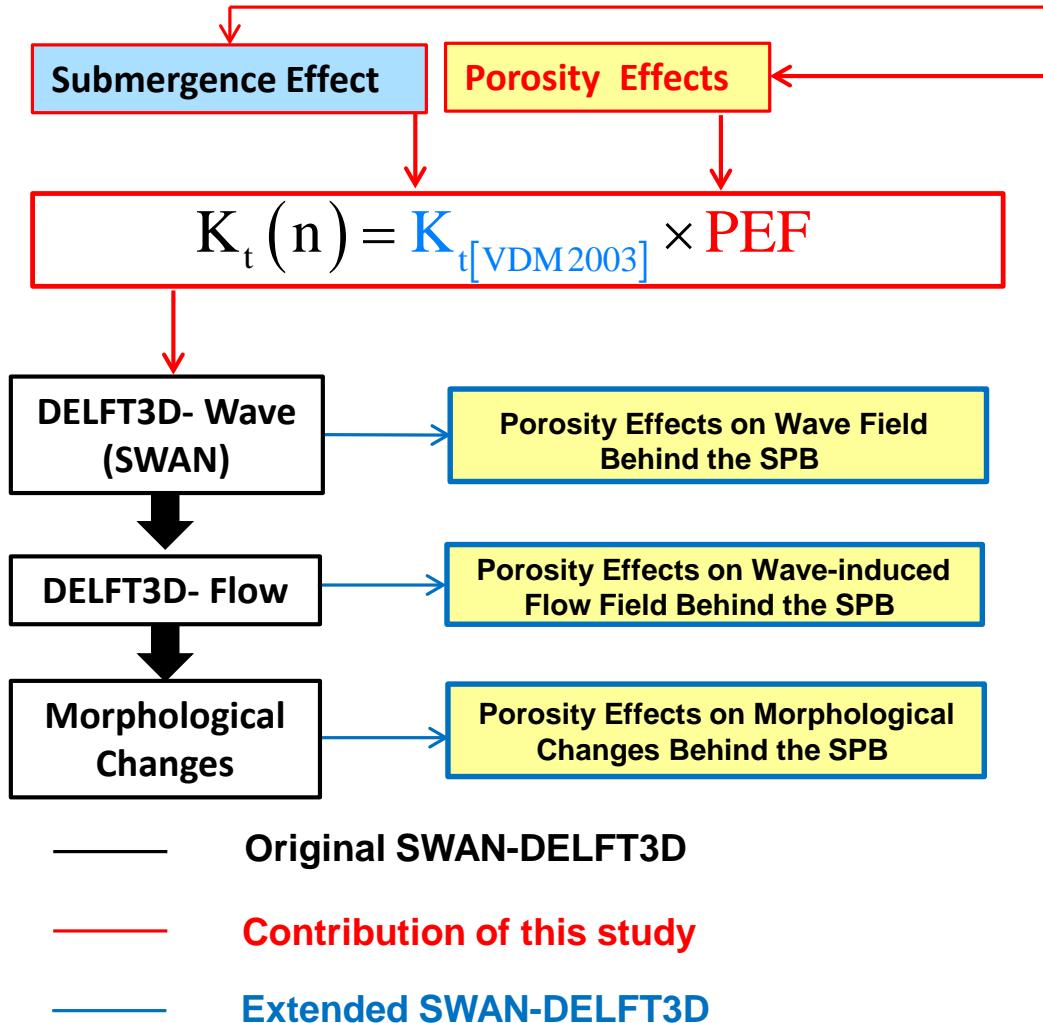
$$Kt = Ht / Hi$$

Ht: Transmitted wave Height

Hi: Incident wave Height



Extension of SWAN-DELFT3D Application



Transmission Coefficient of Submerged Porous Breakwaters

$$K_{t[VDM\,2003]} = f(H, B, R_c, \xi)$$

Van der Meer et al (2003)

$$\text{PEF} = f(\text{H}, \text{Rc}, n)$$

$$0 \leq \frac{R_c}{H} \leq 1.1 \quad 0 \leq n \leq 0.6 \quad 0.3 \leq kB \leq 1.4$$

Rc: submergence

B: Crest Width

n: Porosity

k: wave Number

H:wave Height

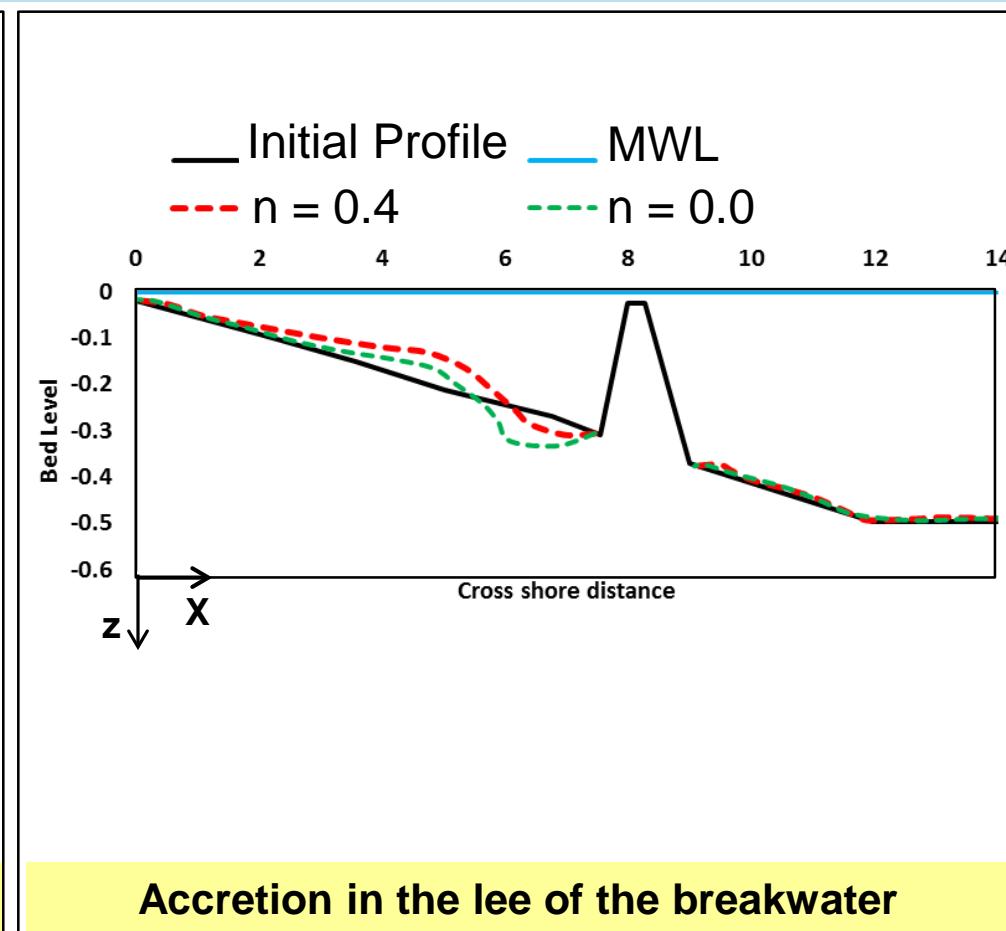
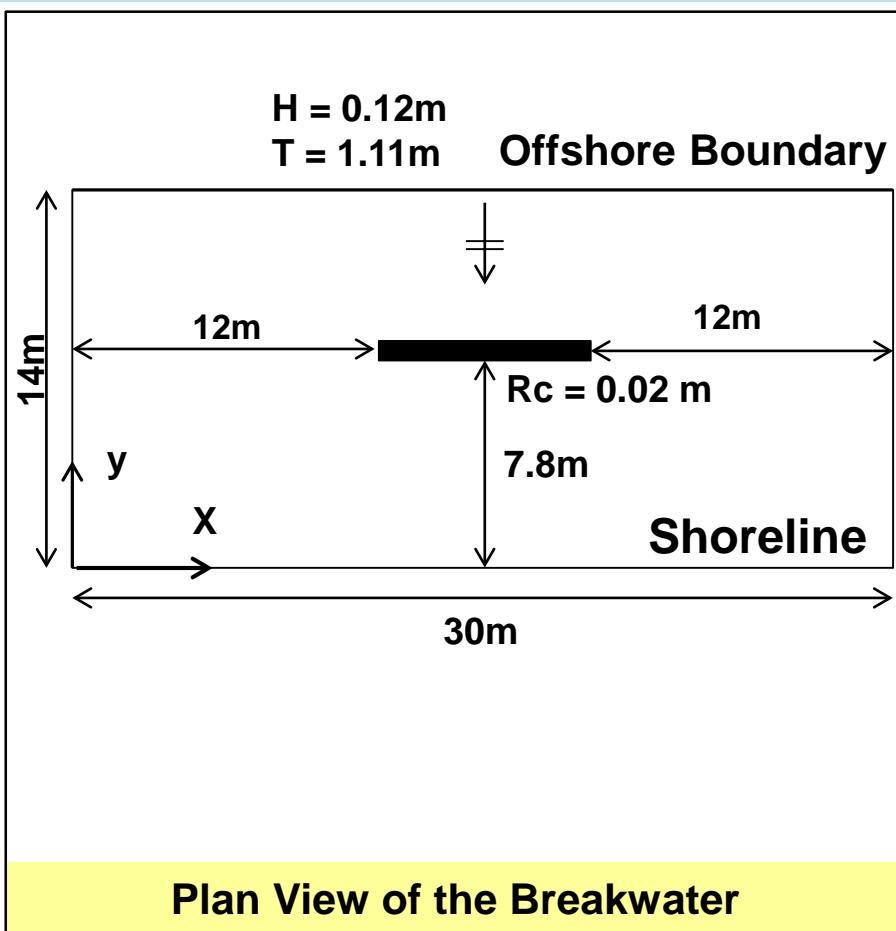
ξ : Surf Similarity Parameter

Kt(n): Transmission Coefficient of SPB

PEF: Porosity Effect Factor



Preliminary Results - A Sample Simulation



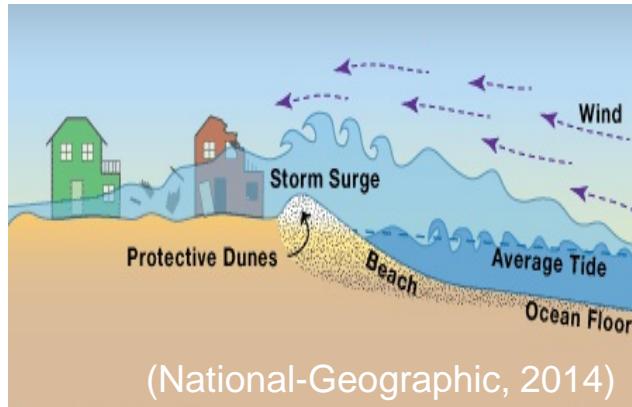
4. Breaching of Coastal Barriers under Extreme Storm Surges and Implications for Groundwater Contamination



Breaching of Coastal Barriers under Extreme Storm Surges and Implications for Groundwater Contamination

S.M. Elsayed

a) Extreme storm surge



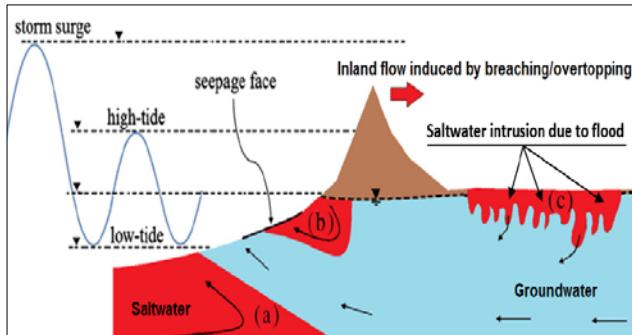
(National-Geographic, 2014)



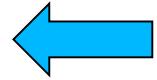
(De vet, 2014)

b) Coastal barrier breaching

d) Aquifers contamination



After Yang et al., (2013)



(Wu, 2011)

c) Coastal flooding

Problem Statement – Knowledge Gaps

Problem: Current breaching models (e.g. XBeach) overestimate erosion volume

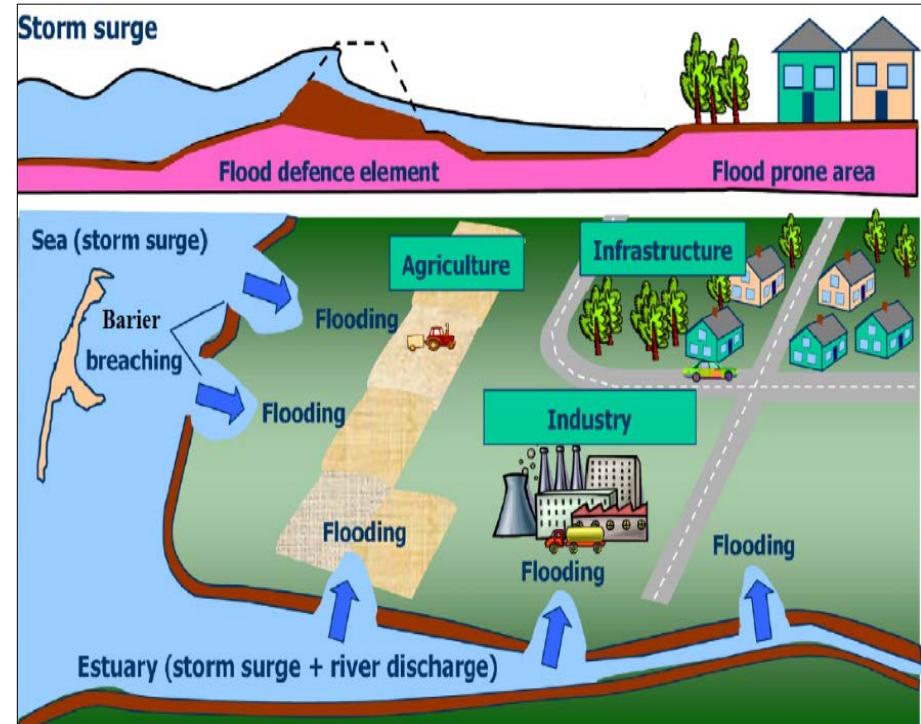
- ❑ Effects of Particles Interaction on Critical Shields Parameter:

Critical shear stress calculated based on Shields curve is underestimated

- particles interlocking
- biological stabilization
- ▶ no mathematical model available

- ❑ Effect of Wave Skewness and Asymmetry on Sediment Transport
- ▶ need to improve the exiting model

- ❑ Coupling Breaching, Flood and Infiltration Models



Oumeraci et al. (2015)

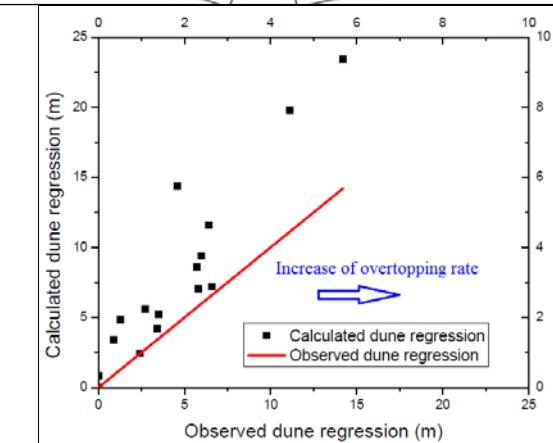
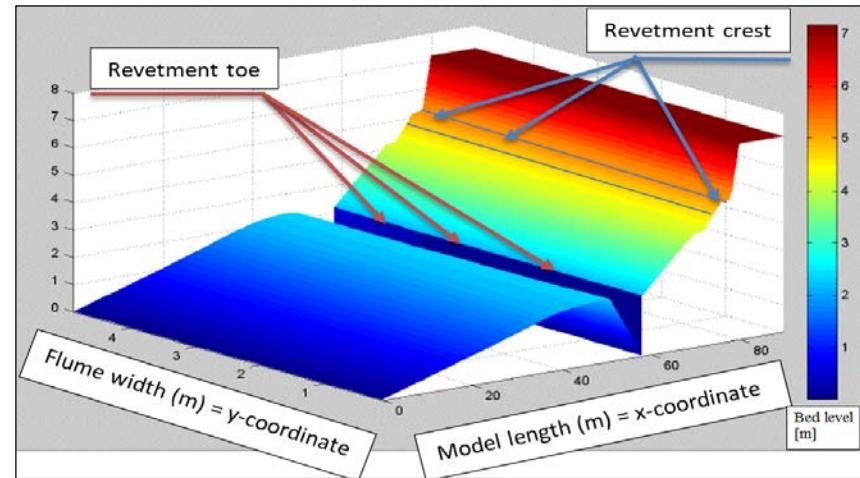
Objectives

Overall objective: improvement of the knowledge of the processes associated with breaching and inundation of dune systems including saltwater intrusion

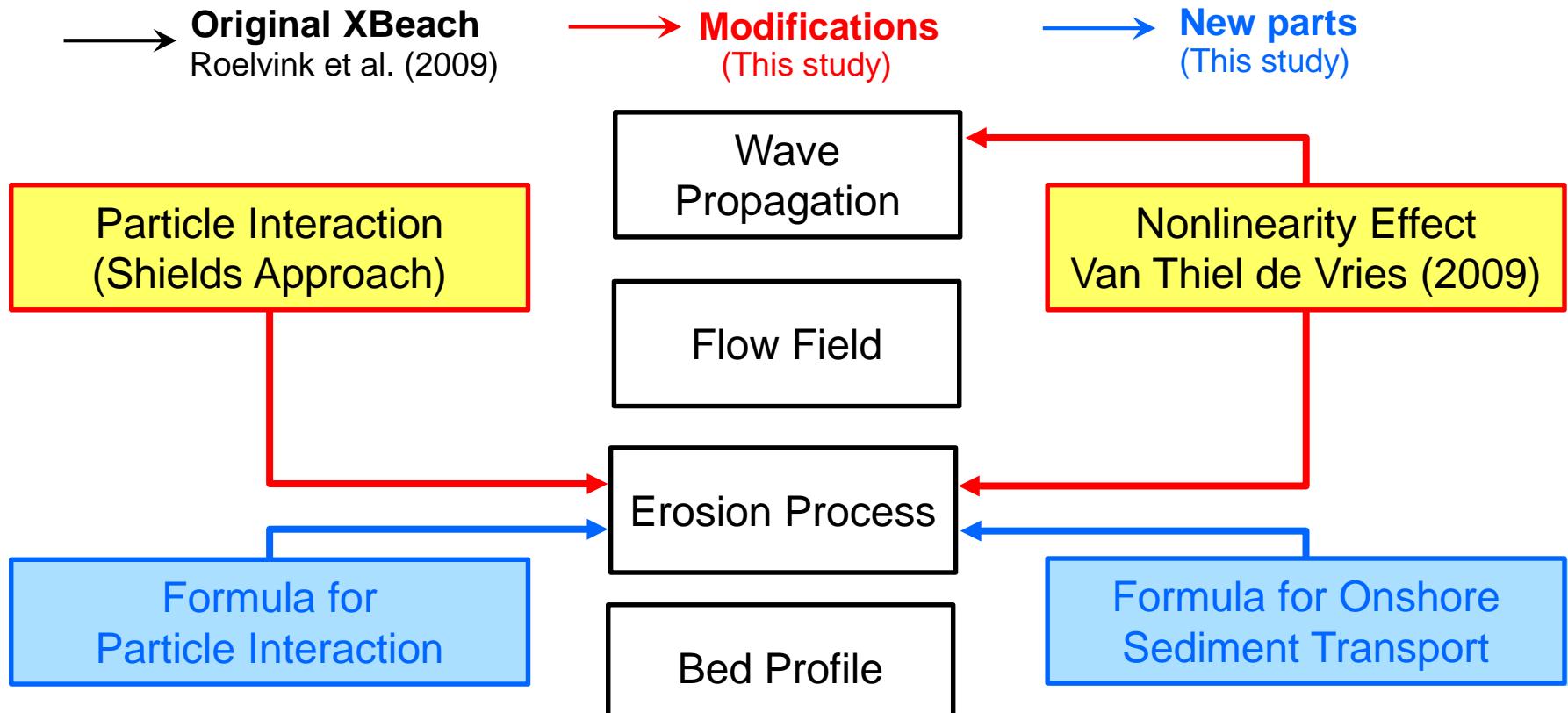


Specific objectives:

- i) Assess XBeach performance based on reanalysis of GWK-tests (Wangerooge dune erosion) and further available data
- ii) Improve/extend and validate XBeach to simulate both breaching and inundation
- iii) Coupling Breaching/inundation model with infiltration model to simulate saltwater intrusion
- iv) Validation of overall model and application for selected site



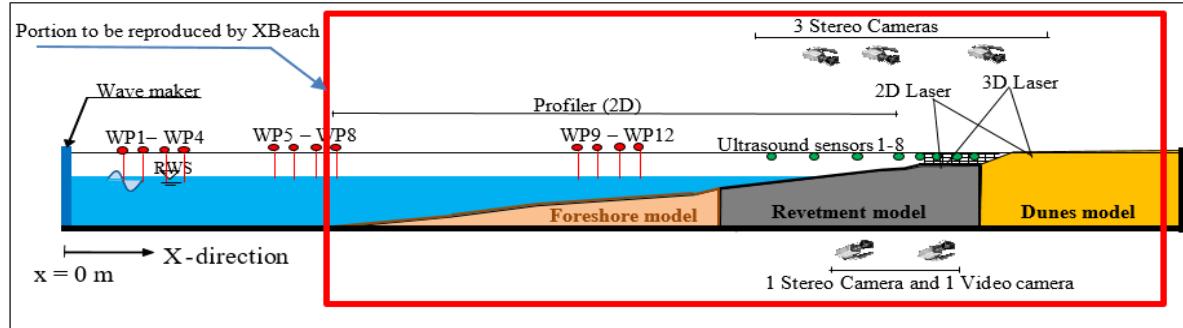
Original XBeach and Extensions/ Modifications (Overview)



The extensions are:

- Implementing/Validating XBeach for coastal inundation
- Coupling XBeach as a breaching/ inundation model coupled with an infiltration model to describe salt water intrusion in groundwater induced by flooding.

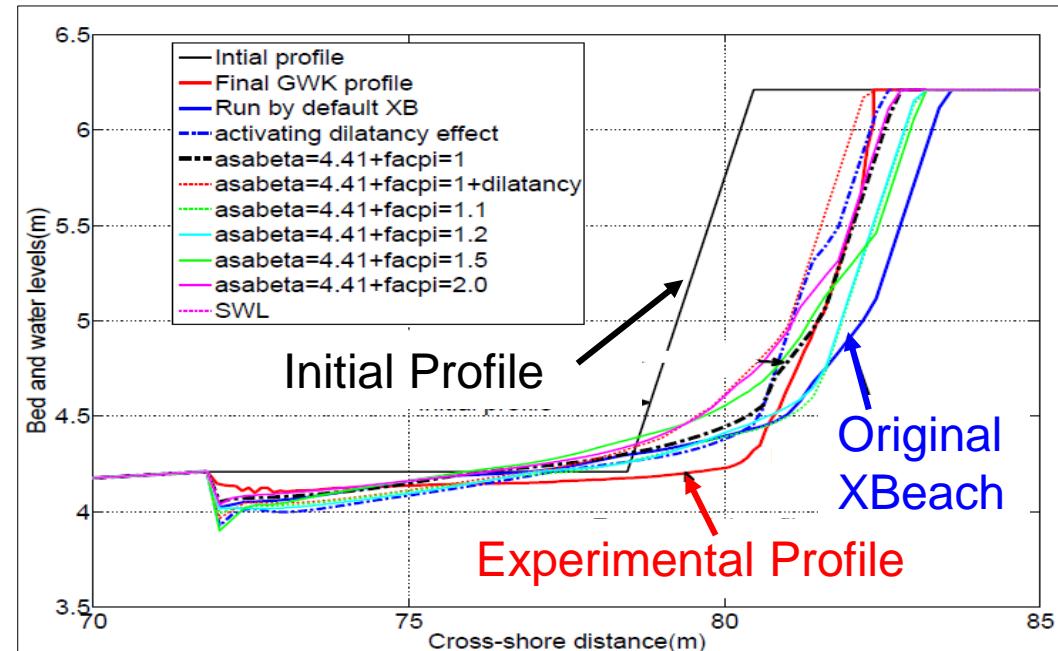
Results of Extended XBeach Model: (GWK Tests)



Oumeraci et al. (2014)

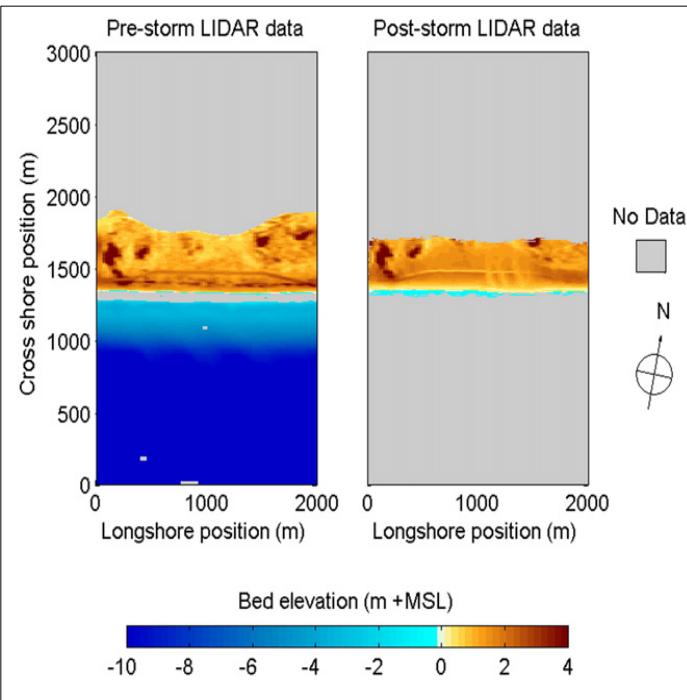


Oumeraci et al. (2014)

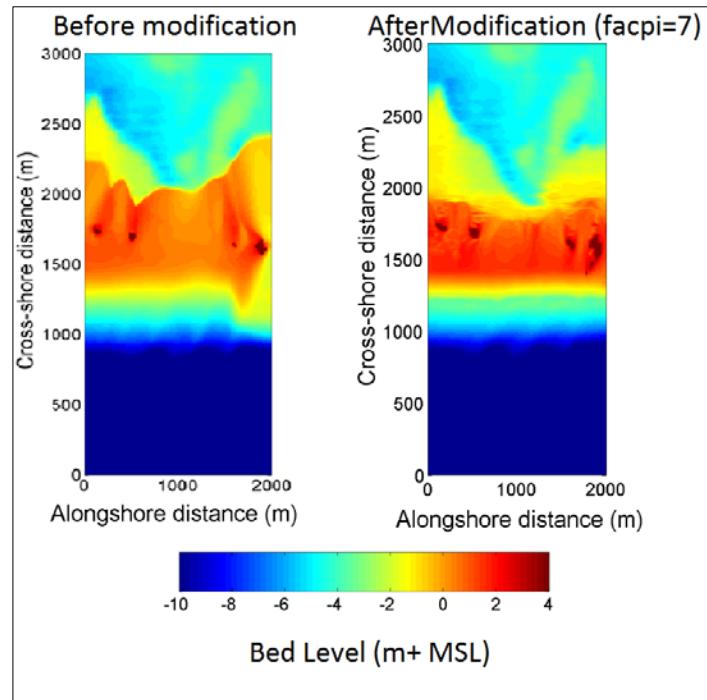


Beach slope steepness affects sediment transport

Results of Extended XBeach Model: (Santa Rosa Island)



Measured Data
McCall et al (2010)



Numerical Data
Current study



Soil compaction has a significant influence on particle interaction and therefore sediment transport and coastal erosion

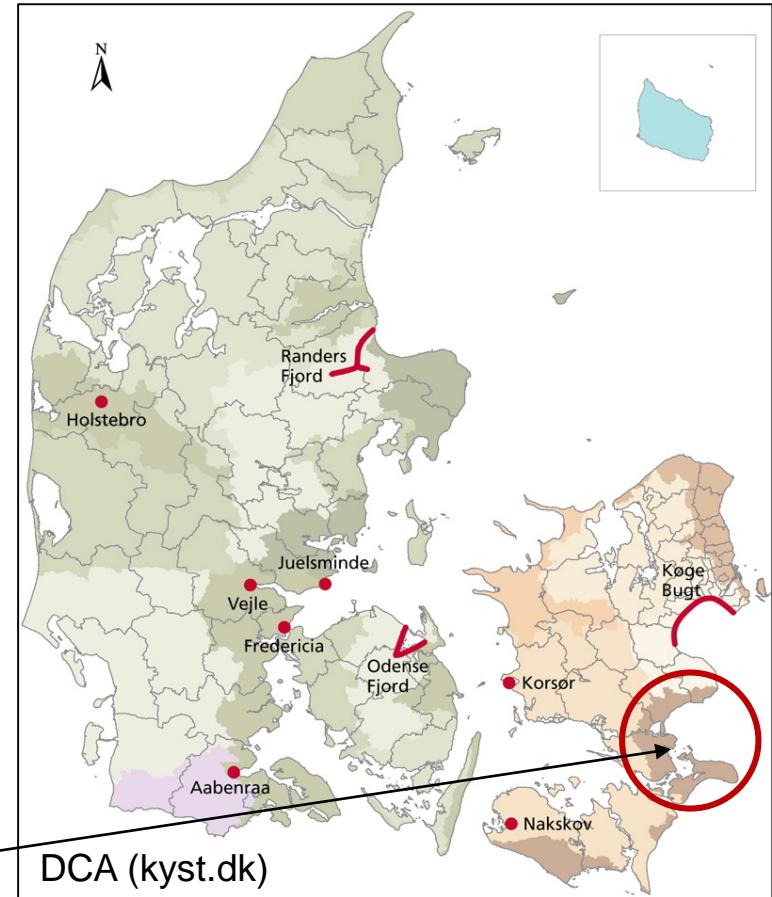
5. Application of XBeach for the Flood Directive in Denmark



Application of XBeach for the Flood Directive in Denmark

D. Schürenkamp

- Hazard and Risk Maps for the 2nd Step of the European Flood Directive in Denmark
- Application and adaptation of existing tools (from XtremRisk, Oumeraci et al. 2015) to flood prone areas in Denmark (DCA)



A. Kortenhaus, T. Piontkowitz, M. Skov, M. Earnshaw, D. Schürenkamp, H. Oumeraci

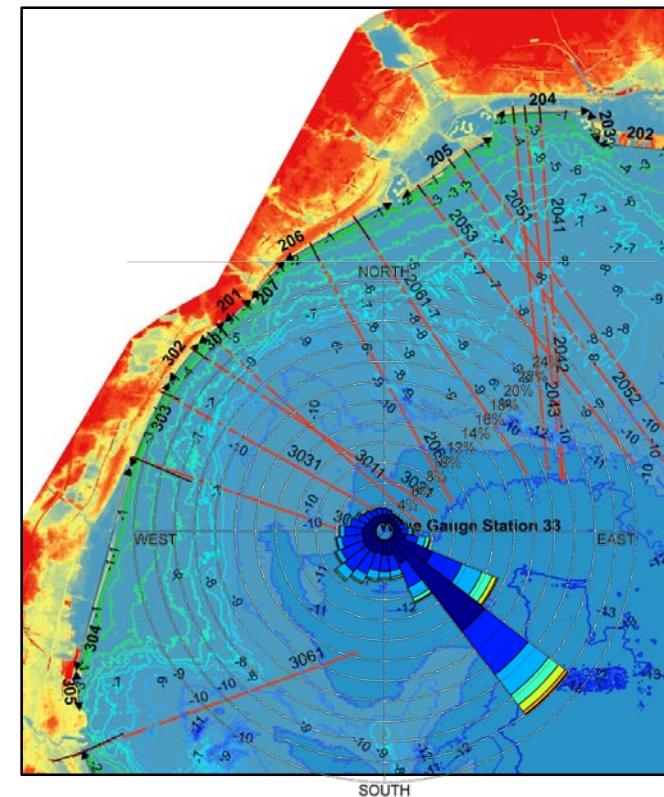
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Objectives

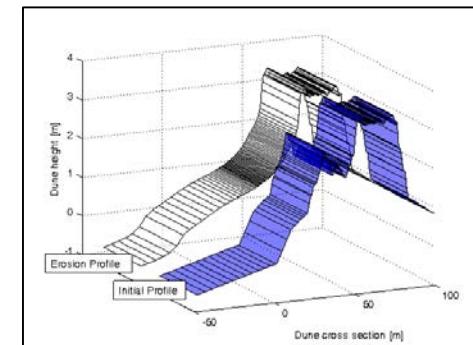
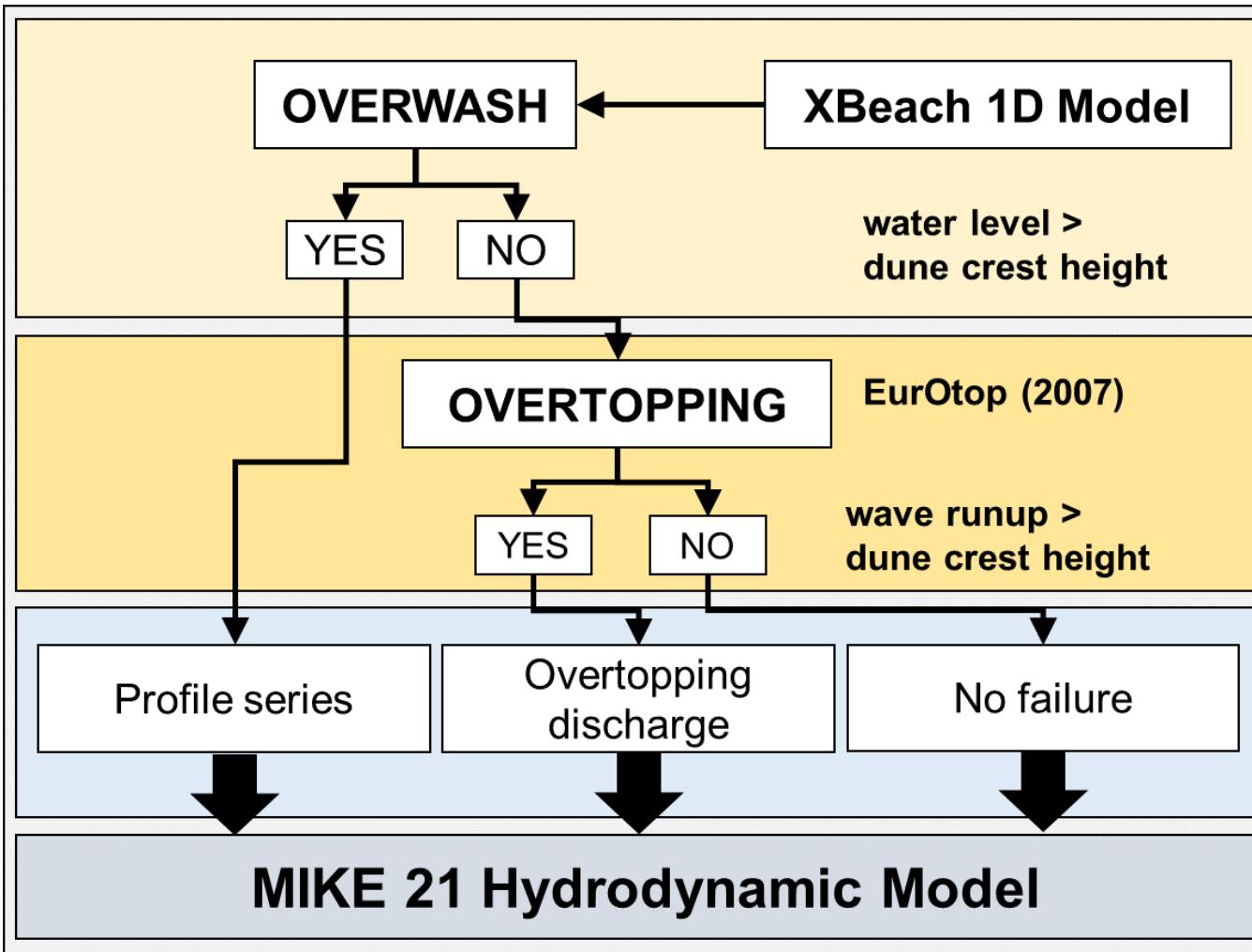
Overall objective: preparation of risk maps for the coastal region Køge, Denmark

Specific objectives:

- i) Assessment of coastal protection structures
 - ii) Design of wave and sea level scenarios
 - iii) Modelling of beach and dune erosion/failure
 - iv) Determination of wave overtopping rates
 - v) Coupling breaching and inundation models
 - vi) Determination of water level/velocity in flood area



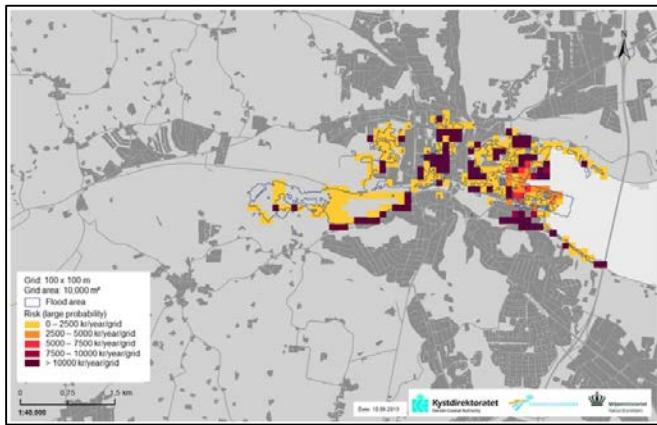
Methodology



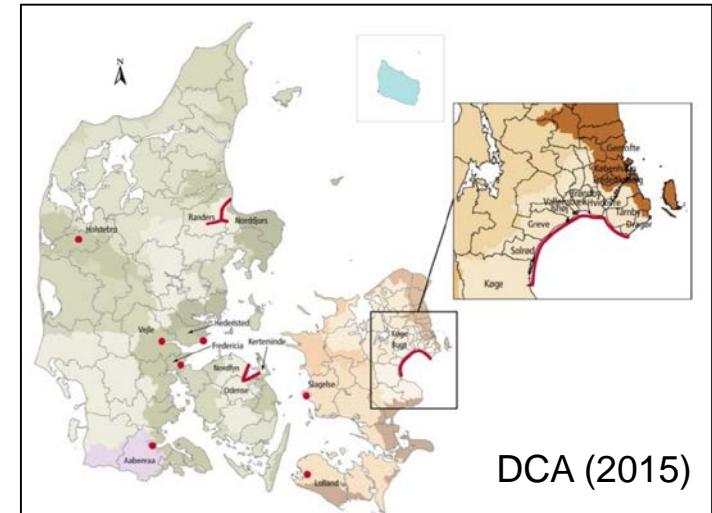
Results

Numerical Modelling with XBeach and MIKE21

- Dune profiles
- Wave runup and wave overtopping rates
- Inundation area including water level and velocity
- Hazard and risk maps



Kortenhaus & Oumeraci (2014)



6. Zusammenfassung und Ausblick

Modellierung der Morphodynamik

- Vielseitigkeit durch Modellkopplung
- Vorsicht bei der Auswahl des geeigneten Modells

Erfahrungen aus der Modellierung (XBeach, Delft3D)

- Große Unsicherheiten der Ergebnisse durch Vereinfachungen und Vernachlässigung einiger Prozesse
- Trotzdem sehr hilfreich für Vergleichsanalysen und Parameterstudien
- Schneller Transfer neuer Forschungsergebnisse in die Praxis durch Implementierung in Open Source Modellen



Vielen Dank!



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