Long-term Monitoring, Research and Analysis of Bangladesh Coastal Zone

Sustainable Polders Adapted to Coastal Dynamics

Capacity building component

Dano Roelvink

IHE Delft Institute for Water Education

Deltares

Contents

- Brief overview of project short project overview.pptx
- Introduction to coastal education and research at IHE Delft
- Modalities of capacity building for BWDB within project
  - Training programmes in Delft
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  - On-the-job training in Dhaka

Research and education on Coastal Systems & Engineering and Port Development

MSc and PhD programmes at IHE Delft

Dano Roelvink and Trang Minh Duong

IHE Delft Institute for Water Education

IHE Delft Institute for Water Education

www.un-ihe.org



IHE Delft Institute for Water Education is the largest international graduate education institute in the field of water. The institute confers fully accredited MSc degrees and promotes PhDs.

Since 1957 the Institute has provided graduate education to more than 15,000 water professionals from over 162 countries, the vast majority from the developing world.

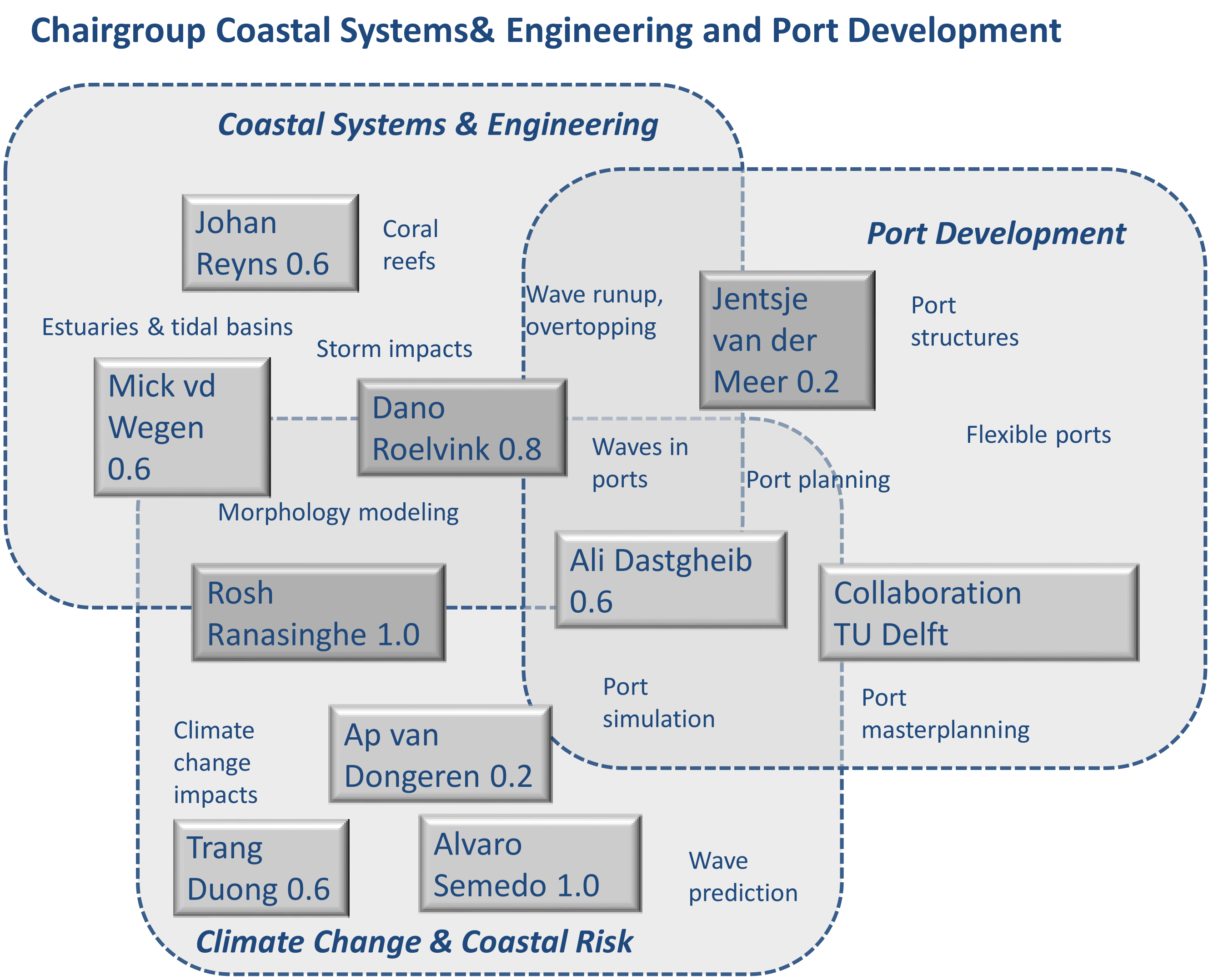
152 PhD fellows are currently enrolled in water-related research. The Institute carries out numerous research and capacity development projects throughout the world.

Core activities

The core activities of IHE Delft are:

Education	Research & Innovation	Institutional Strengthening
IHE Delft offers a wide range of flexible, high quality, specialized educational programmes to respond to the needs of diverse clients from the water sector. These include MSc and PhD programmes, along with online and short courses.	With over 129 academic staff, 152 PhD fellows and 15 post-docs active in water-related, problem-focused and solution oriented research on development issues, IHE Delft has a vibrant multicultural and multidisciplinary research atmosphere.	IHE Delft strives to strengthen the programmes of universities and research institutes as well as the knowledge and capacity base of ministries and other water sector organizations.

Coastal Systems & Engneering and Port Development



CSEPD Staff

Ali Dastgheib
Senior Lecturer in Port Development

Trang Duong
Postdoc Researcher

Aysun Köroglu - Dogan
Postdoc Researcher

Jentsje van der Meer
Professor of Coastal Structures and Ports

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Senior Lecturer in Coastal Oceanography

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Head of the WSE Department

Johan Reyns
Lecturer/Researcher in Coastal Morphodynamics

Dano Roelvink
Professor of Coastal Engineering and Port Development

Mick van der Wegen
Associate Professor of Estuarine Dynamics

IHE DELFT

CSEPD PhD fellows

Jakia Akter

PhD fellow

Uwe Sachelle Ntame Best

PhD fellow

Gerard Dam

PhD candidate

Hesham Elmilady

PhD fellow

Seyedabdolhossein Mehvar

PhD fellow

Hieu Ngo

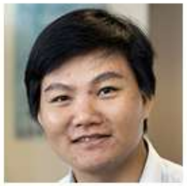
PhD fellow

Duoc Nguyen

PhD fellow

Bamunawala Rajapaksha Mudiyanselage

PhD fellow



Vo Quoc Thanh

PhD fellow

Jeewa Thotapitiya Arachchillage

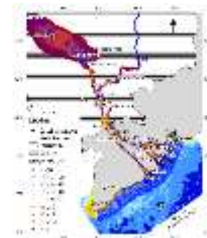
PhD fellow

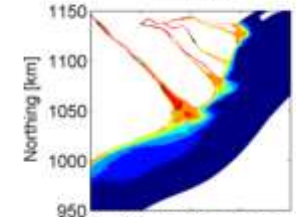
Liqin Zuo

PhD fellow

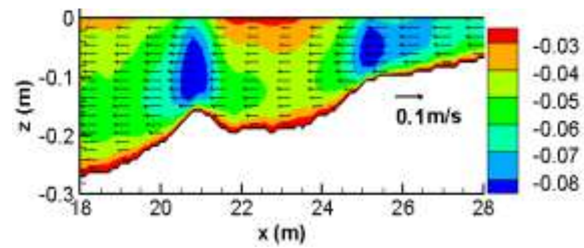
PhD study examples

Impact of sea level rise and human interference on sediment dynamics in the Mekong Delta

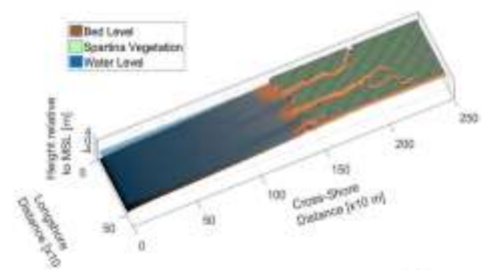




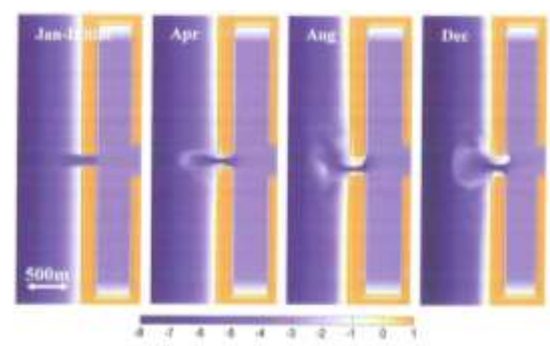
Development and validation of a three-dimensional wave-current interaction formulation



Advancing adaptation measures for fringing mangrove-mudflat coastlines under climate change impacts



Climate Change impacts on the stability of small tidal inlets



Coastal Engineering and Port Development MSc programme (18 months)

Introduction to Water Science and Engineering

Hydraulics and Hydrology

- **Introduction to Coastal Science and Engineering**
- **Port Planning and Infrastructure Design**
- **Coastal systems**
- **Design of Coastal Structures and Breakwaters**
- **Process Based Coastal Modelling**
- **Climate Change Impacts and Adaptation in Deltas**
- **Geotechnics and Dredging Seminar**

European Field Trip and Field Work

Group work

- **MSc Thesis Preparatory Courses**
- **6 Month MSc Thesis Work**

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CSEPD projects

The problem

Hoi An,
Vietnam

The problem

Coastal road near Keta, Ghana

The problem

Gonzagville,
Côte d'Ivoire

Semarang coast, 2002

Semarang coast, 2008

Semarang coast, 2013

Bangladesh – bank erosion

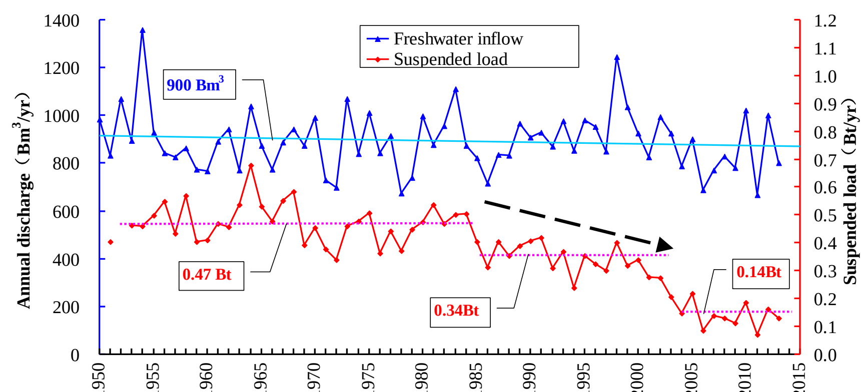
Jamuna

Polder 29

The Causes

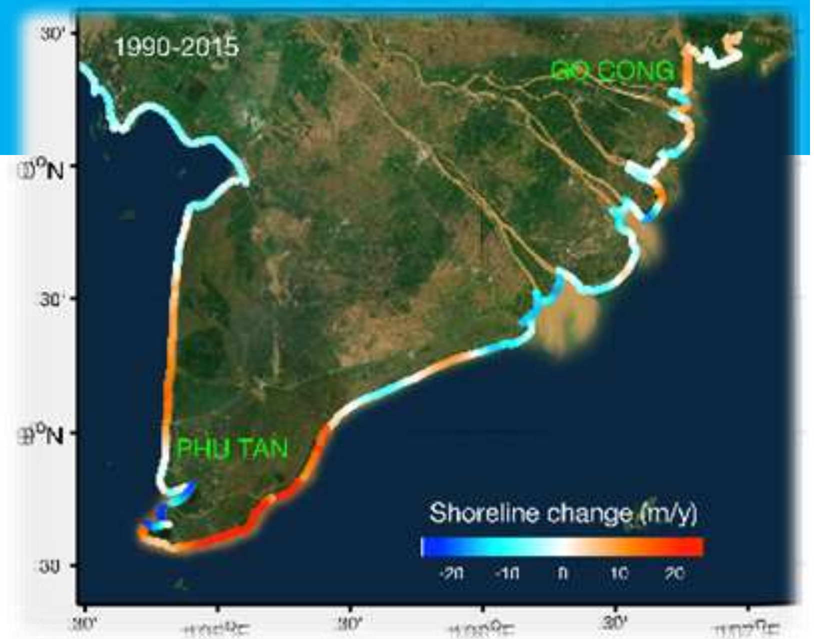
- **sand and gravel used for construction**
  =
  total sediment discharge of all rivers worldwide
  (UNEP, Peduzzi et al.,2014)

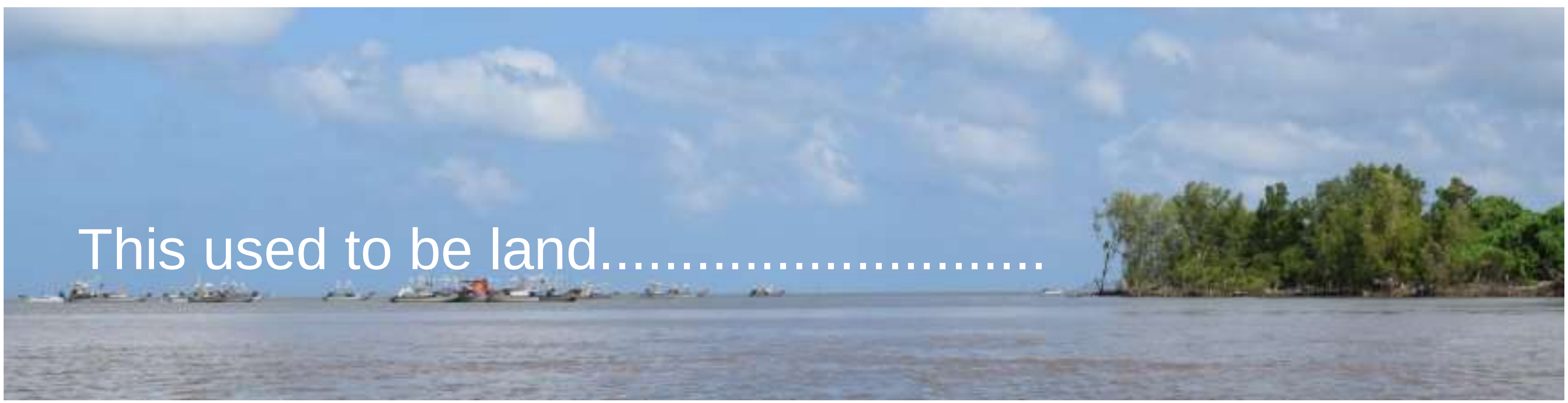
- **total sediment discharge of all rivers worldwide is reduced dramatically**
  (e.g. Syvitsky and Kettner, 2011)



The problem

- **Huge loss of mangrove belts**
- **Example Camau península, Vietnam: tens of m/year of erosion**





The Causes

- **Filling up of accomodation space requires increasing sediment volumes**

- **Degradation of mangrove and coral coasts leads to additional sediment losses**

The Causes

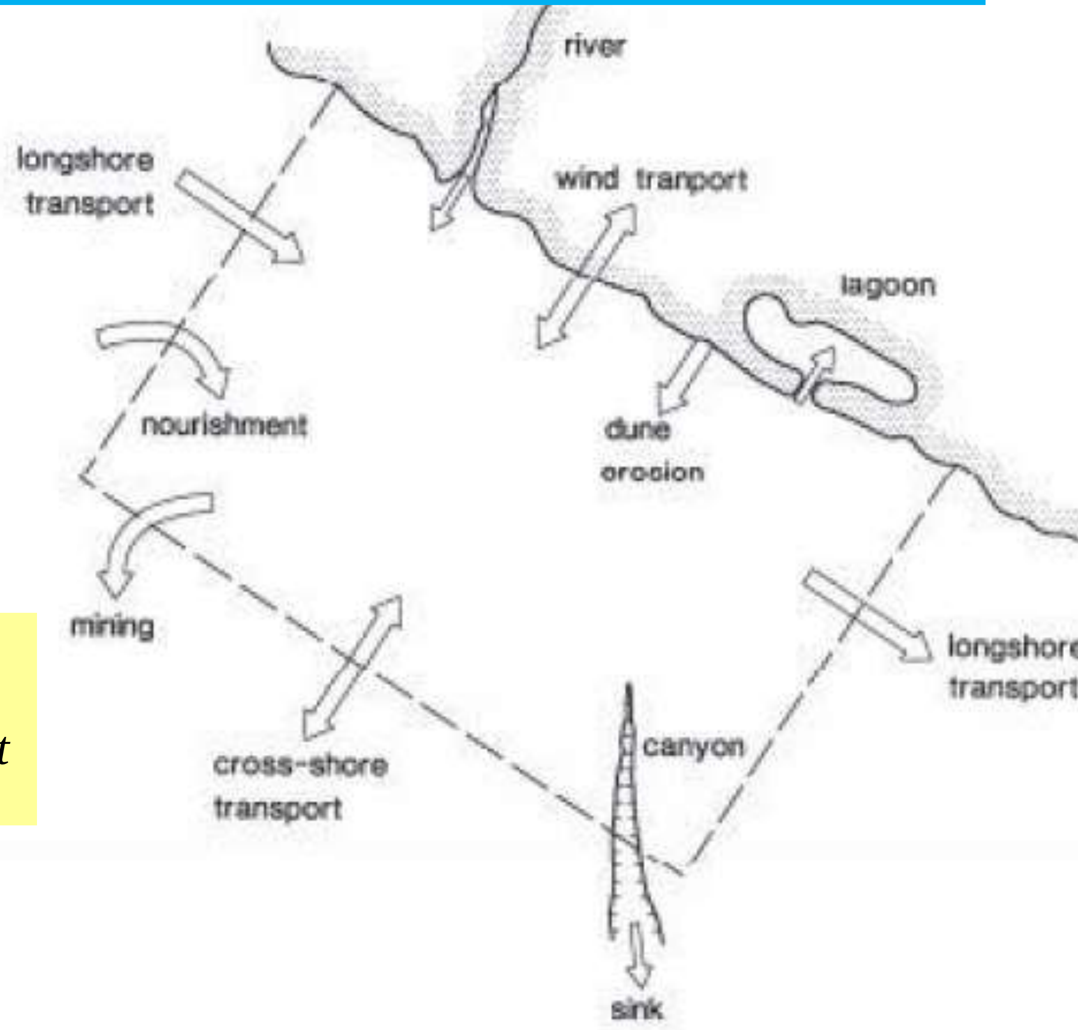
- **Concentration of outflows and dredging disposal leads to big losses offshore**

- **Blocking of longshore sediment transport, leading to local imbalances**

Sediment budget

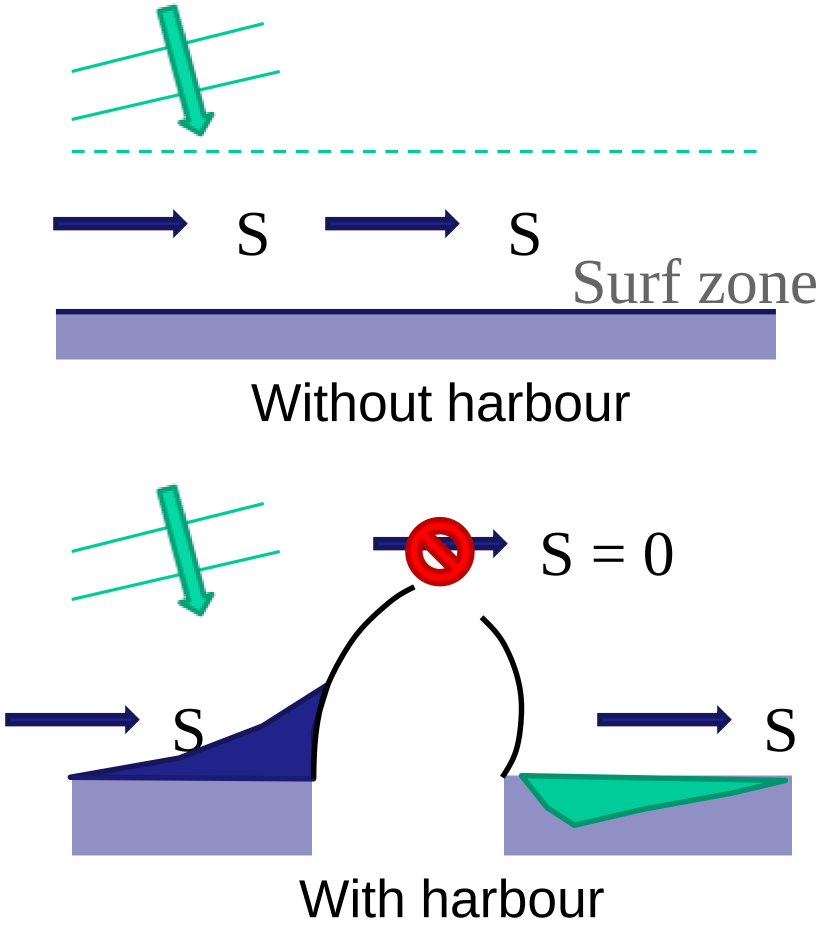
- **Root of all erosion problems**
- **True zero-sum game**
- **Save Our Sediments!**

$$\frac{\partial V}{\partial t} = \sum S_{in} - \sum S_{out}$$



Coastal sediment budget (www.simplecoast.com).

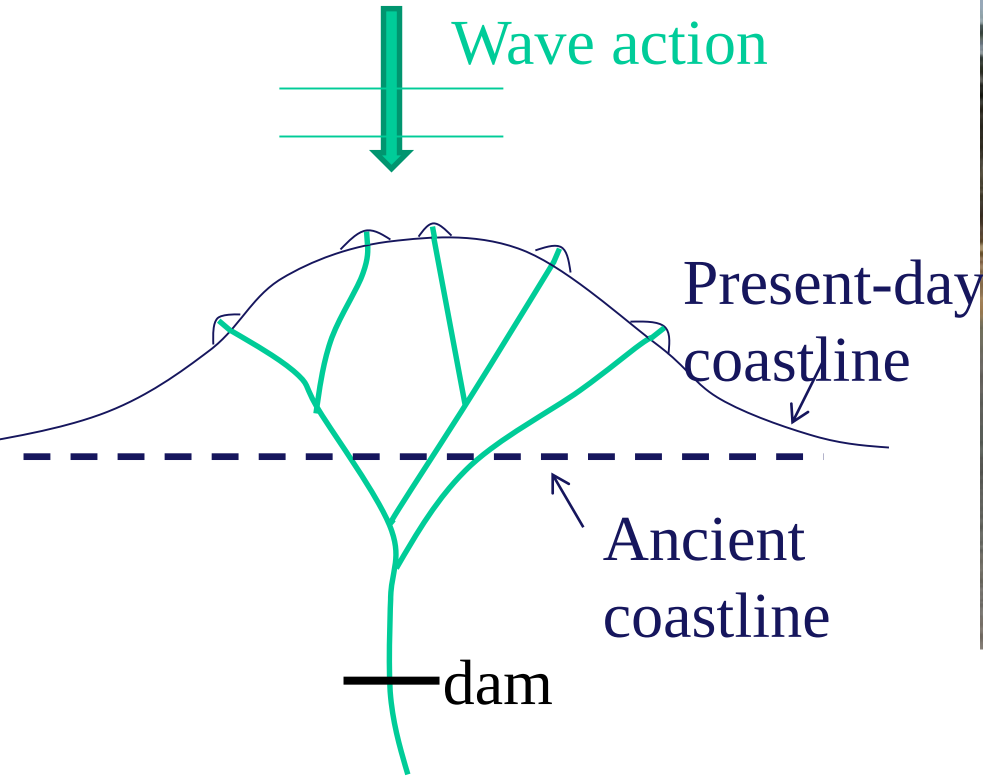
Accretion / erosion near harbour



Per year: S m^3

Accretion after n years: n S m^3

Erosion after n years: n S m^3



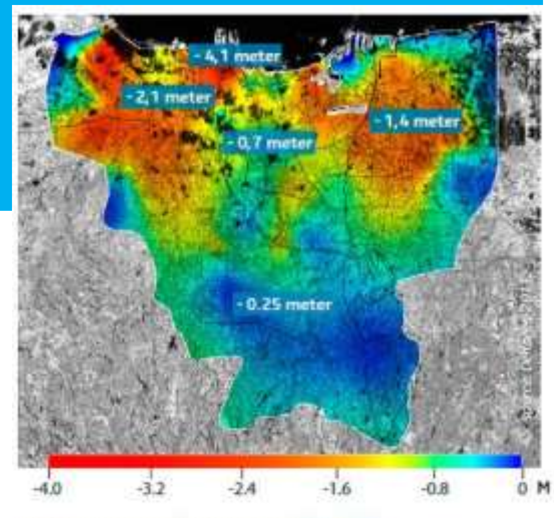
Near Volta delta

- **Dam blocks sediment supply to the delta**
- **Delta lobes are eroded by wave action**
- **Longshore transport away from the delta mouth, depending on wave climate**

Subsidence

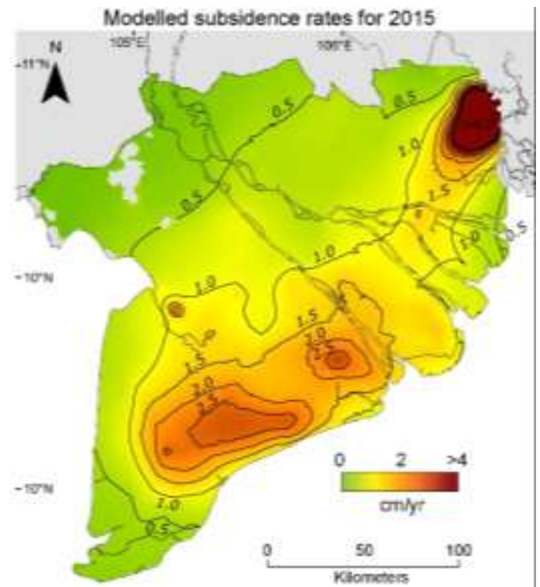
- **Land subsidence due to groundwater extraction often trumps SLR**
- **Has devastating effects on shoreline erosion, frequency of flooding**
- **Could be stopped, see example Venice**

Jakarta

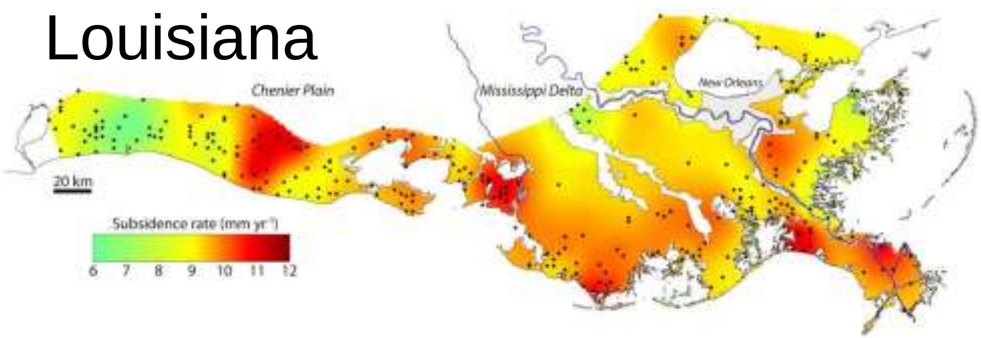


Land subsidence in Jakarta in period 1974-2010

Mekong Delta



Louisiana



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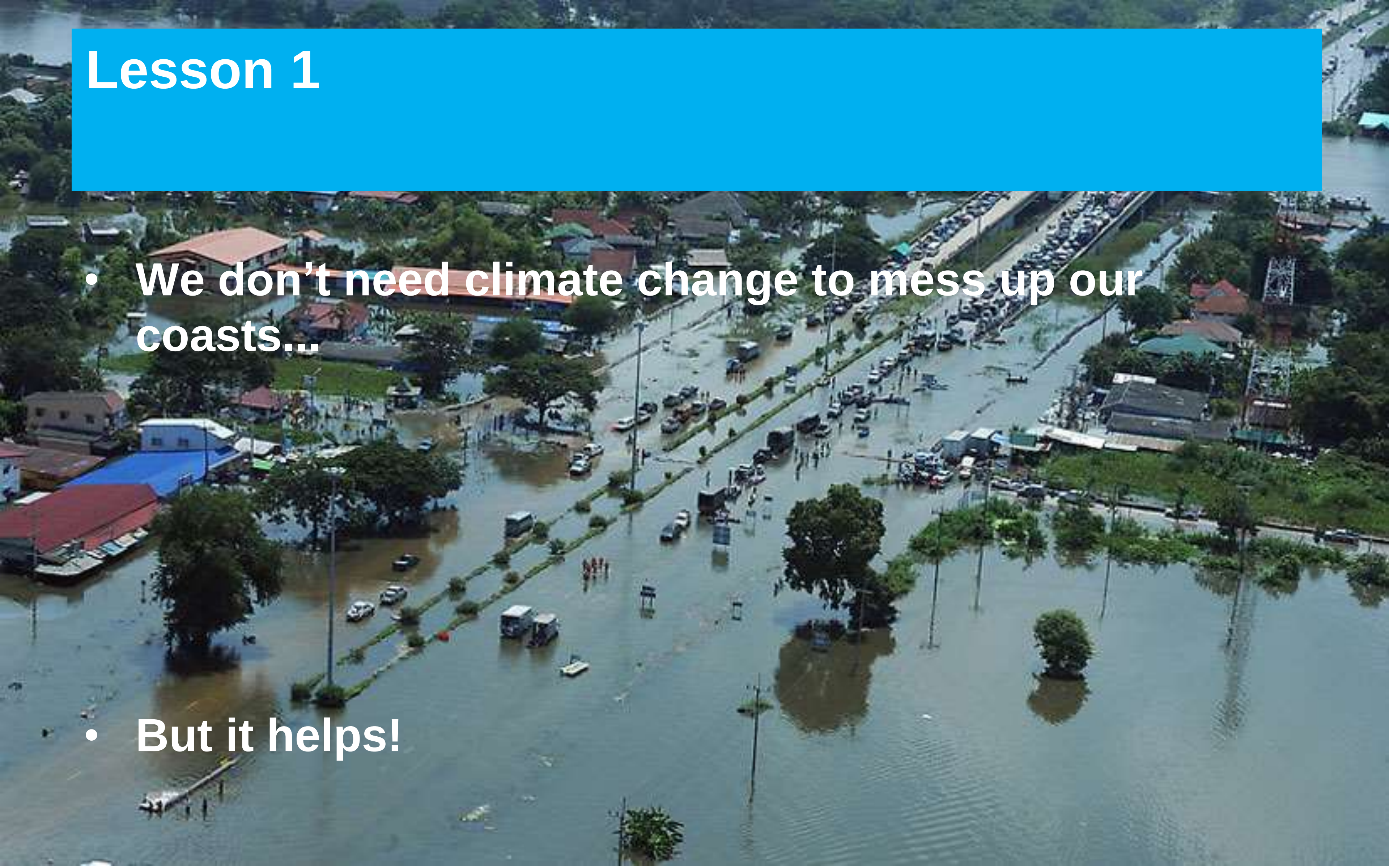


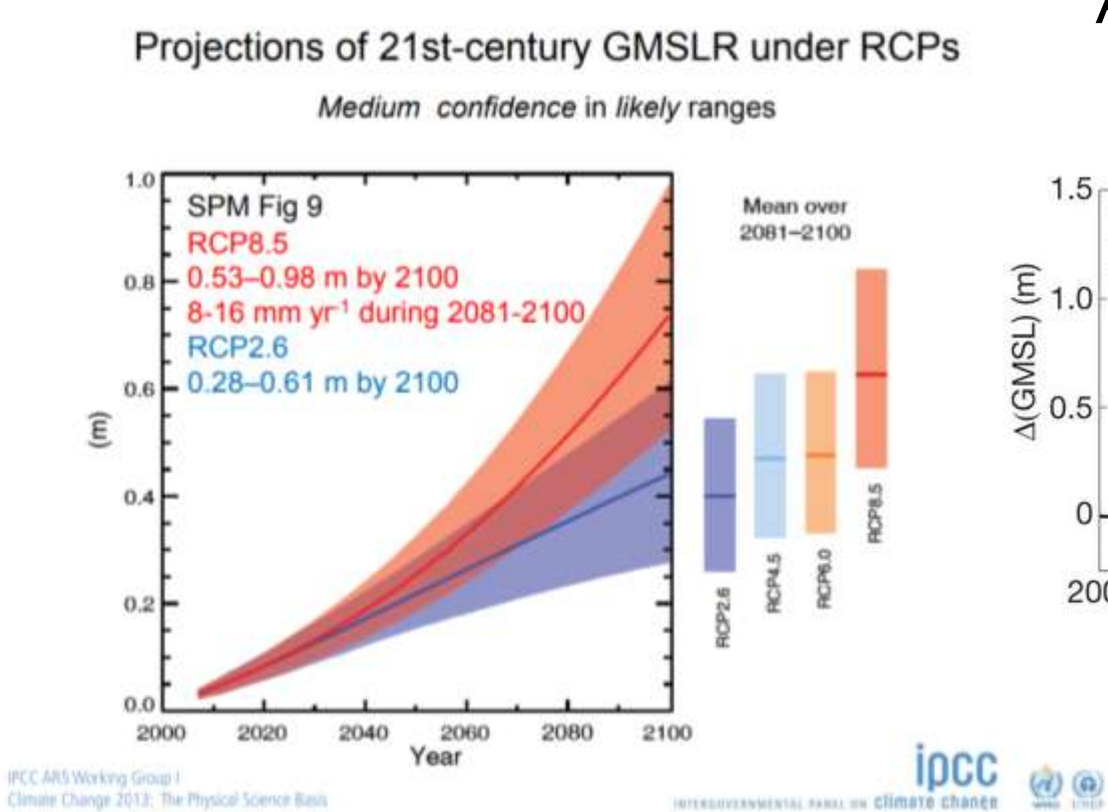
Lesson 1

- We don’t need climate change to mess up our coasts...

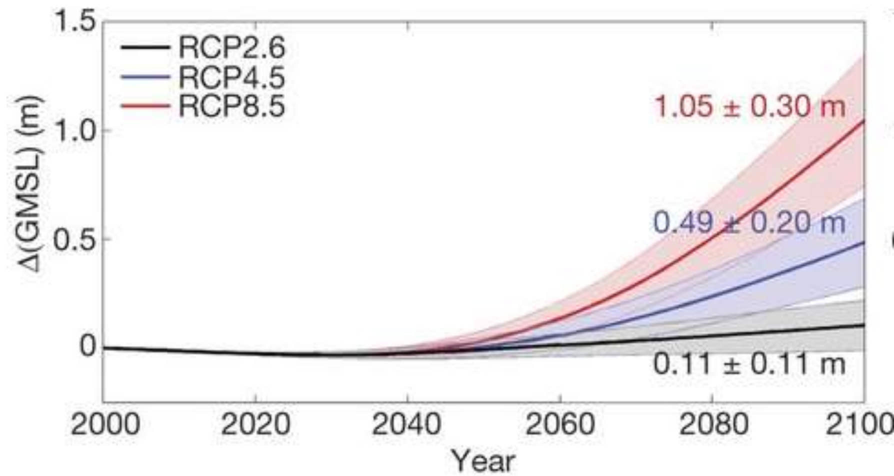
- But it helps!

Scenarios of Sea Level Rise

IPCC AR5



Additional effect of Antarctic 'calving'



DeConto & Pollard, Nature 2016

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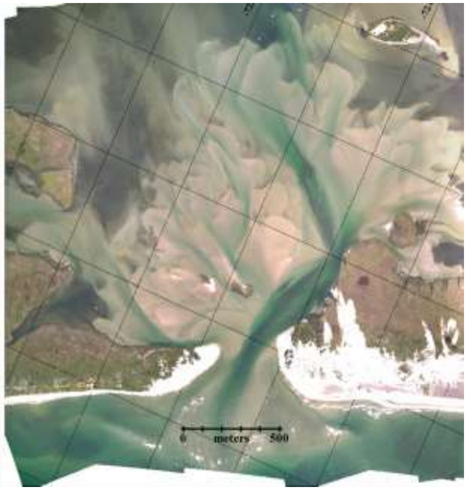
Examples of ongoing research at IHE Delft & Deltares

Example: development of Wilderness Breach after Hurricane Sandy

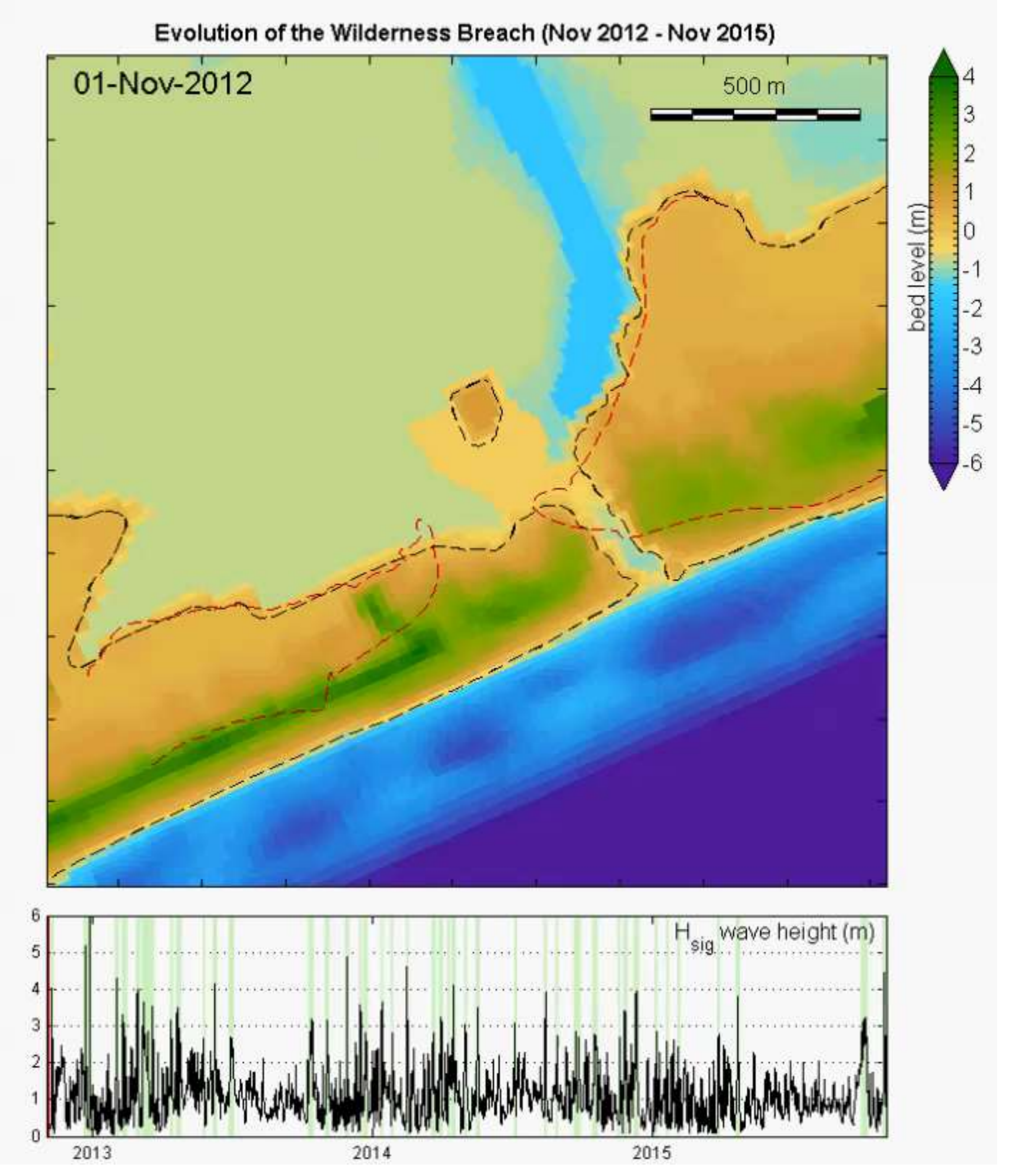
- Breach during Hurricane Sandy
- May affect Long Island flood levels
- PhD Maarten van Ormondt (Deltares/IHE funded by USGS)
- Competing effects of tides wind, waves, infragravity waves



Wilderness Breach

- **Will this happen more frequently?**
- **Can we predict what will happen next?**

- **3 year hindcast**
- **Dashed lines indicate measured shoreline**



Maintaining the coastline

- ‘Soft’ options
  - Nourishments
    - Nearshore
    - Beach

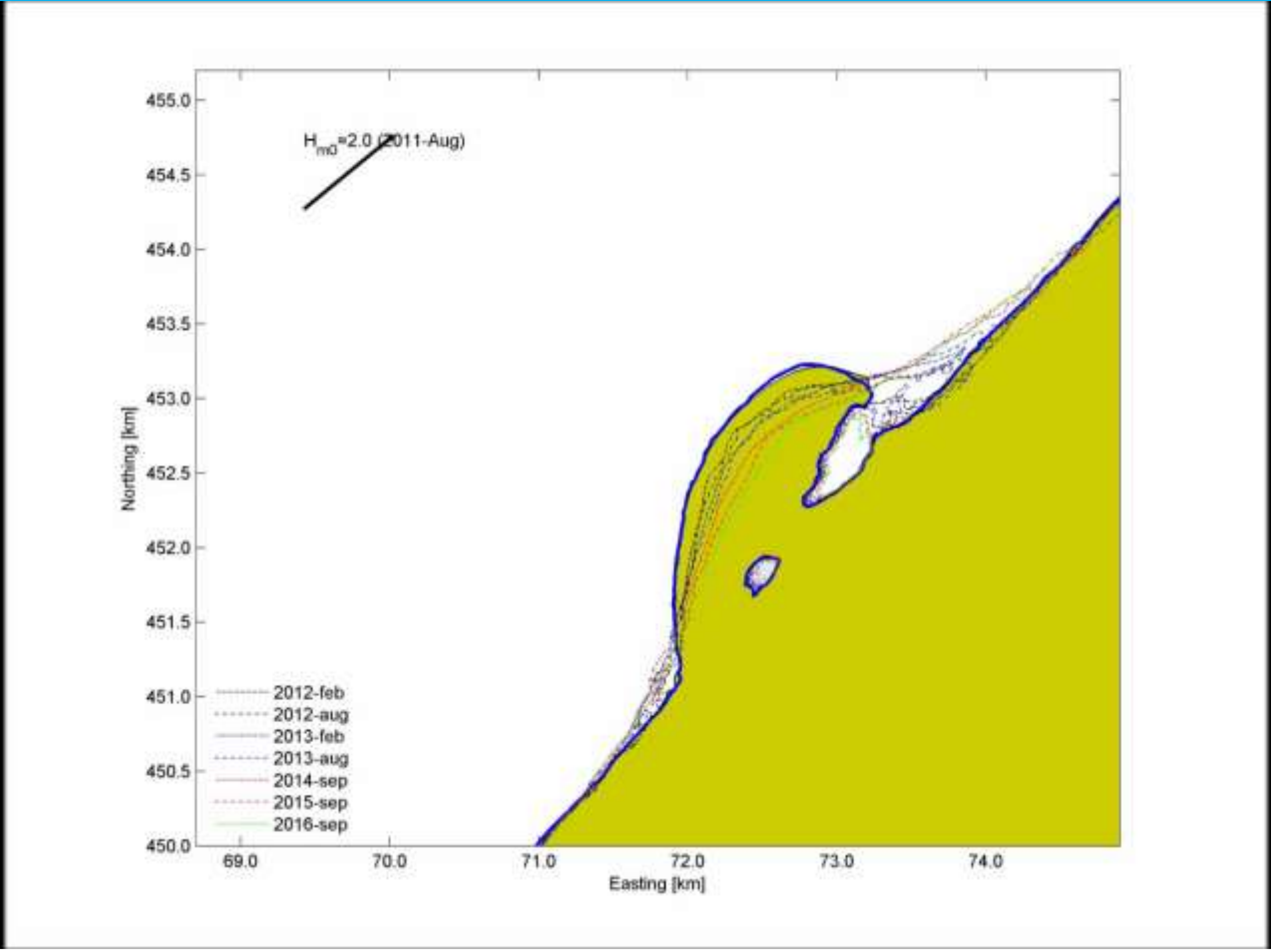
  - Directly address the sediment deficit
  - After disturbance beaches return to natural state
  - Needs to be repeated regularly
  - Latest trend: ‘mega-nourishments’

  - Price per m^3 drops dramatically for larger nourishments!

A well-nourished coast

Innovative mega nourishment

Sandmotor modelled with ShorelineS



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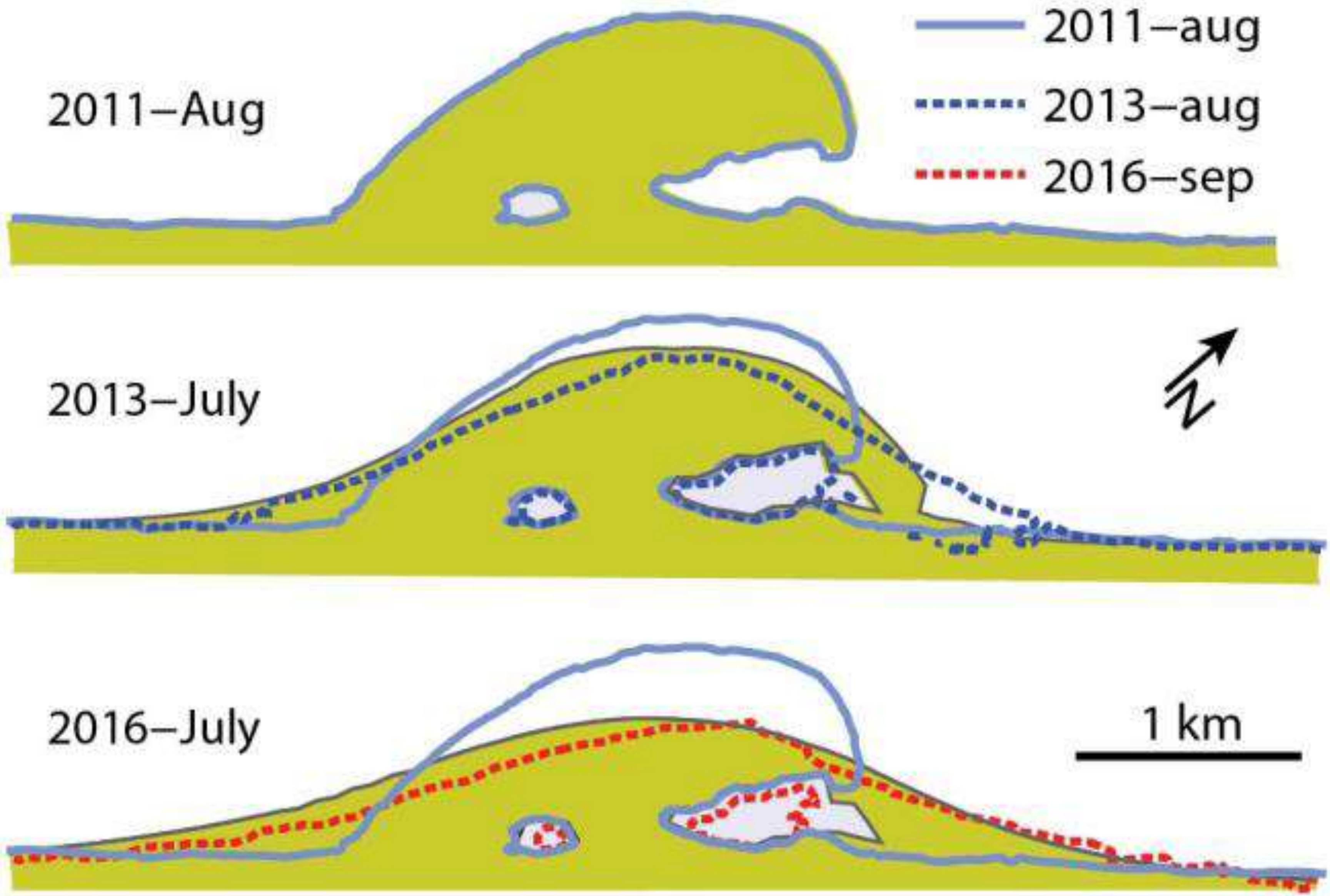

2011–aug
2013–aug
2016–sep
2011–Aug
2013–July
2016–July
1 km

Saving our shores?

- The Netherlands has shown that an erosive trend can be reversed by systematic nourishments
- It requires ‘thinking big’ – a couple of cubic metres does not help
- Hard solutions rarely solve the problem and change shorelines into concrete
- Retreating can be a sensible adaptation if no sand is available

- Need a long-term strategy and commitment to managing risks of flooding and coastal erosion
- Useful tools and information at risckit.eu

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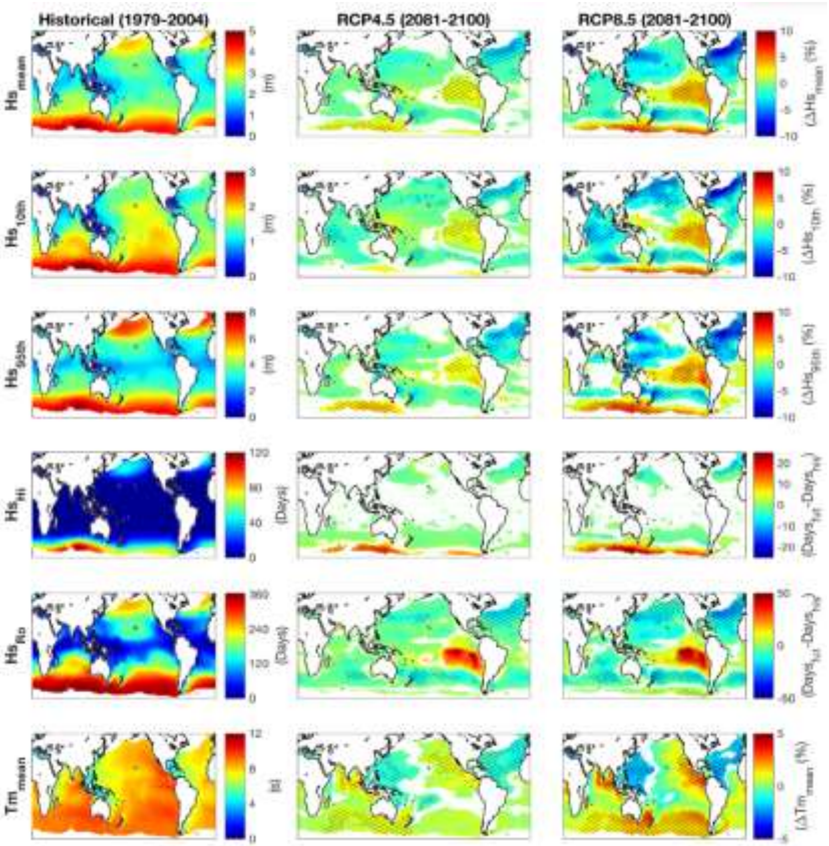
Impact of climate change on future wave climate

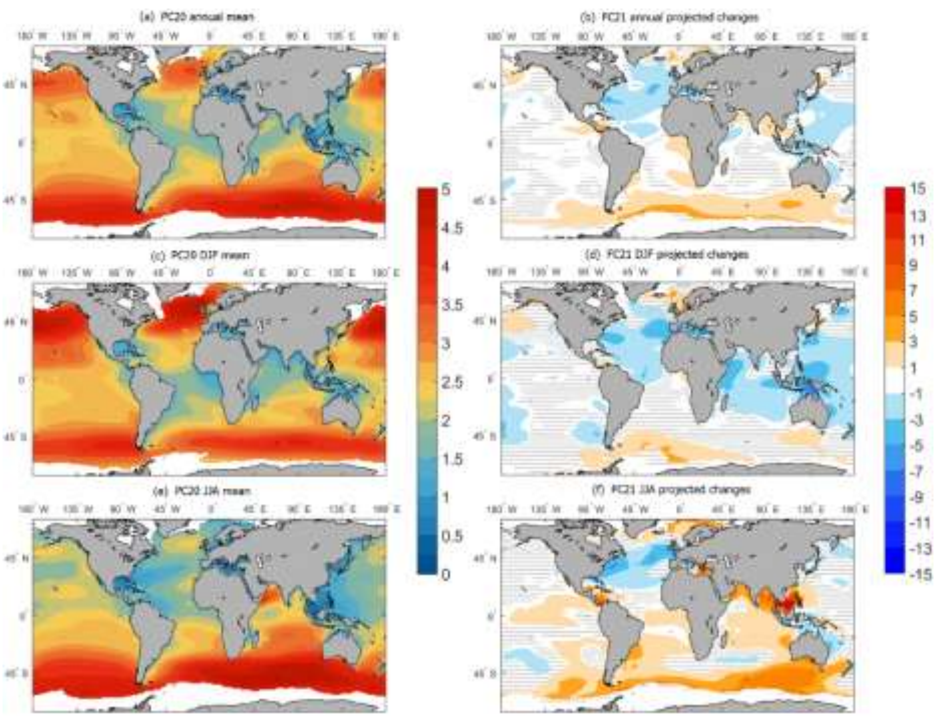


- **Climate change is expected to influence future wave climate**
- **Potential consequences in coastal erosion, along shore sediment transport and natural beach nourishment.**
- **In the recent years most wave climate projections have been done under the COWCLIP (COordinated Wave CLimate Projections) project, where IHE Delft has a significant role.**

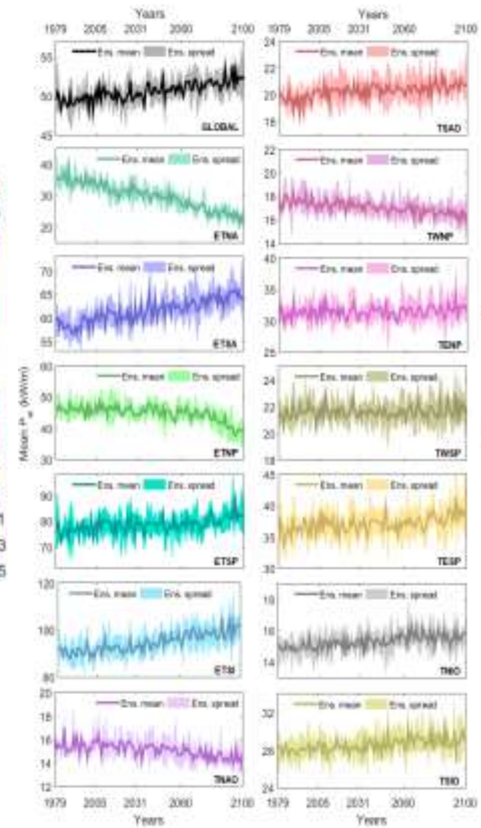
Wave climate projections for the period 2081-2100 for the RCP4.5 and RCP8.5, compared with the historical period (1979-2004). (Mori et al. and COWCLIP team, 2018 – to be submitted).

Impact of climate change on future wave climate

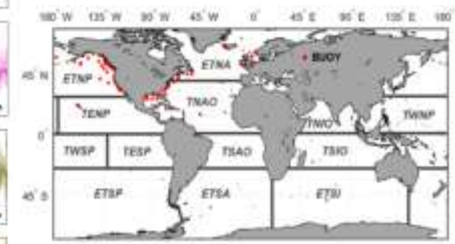
COWCLIP Ocean Wave Climate



Significant wave height projected changes for mid 21st century (2031-2060) in %
(Lemos and Semedo et al. 2018 – under review).



Time series of the ensemble annual mean wave energy flux (kW/m) from 1979 to 2100, globally and along selected areas.
(Lemos and Semedo et al. 2018 – under review)



(Lemos and Semedo et al. 2018 – under review)

Climate change impacts and coastal risk

Overarching objective:

to generate **new fundamental scientific knowledge** and formulate **theoretical and modelling concepts** which will enable the development of **innovative CC driven coastal risk assessment methods**

Research lines:

- Climate change impacts on coasts: The Physics
- Development of efficient modelling methods to simulate CC driven coastal hazards
- Quantitative coastal risk assessment

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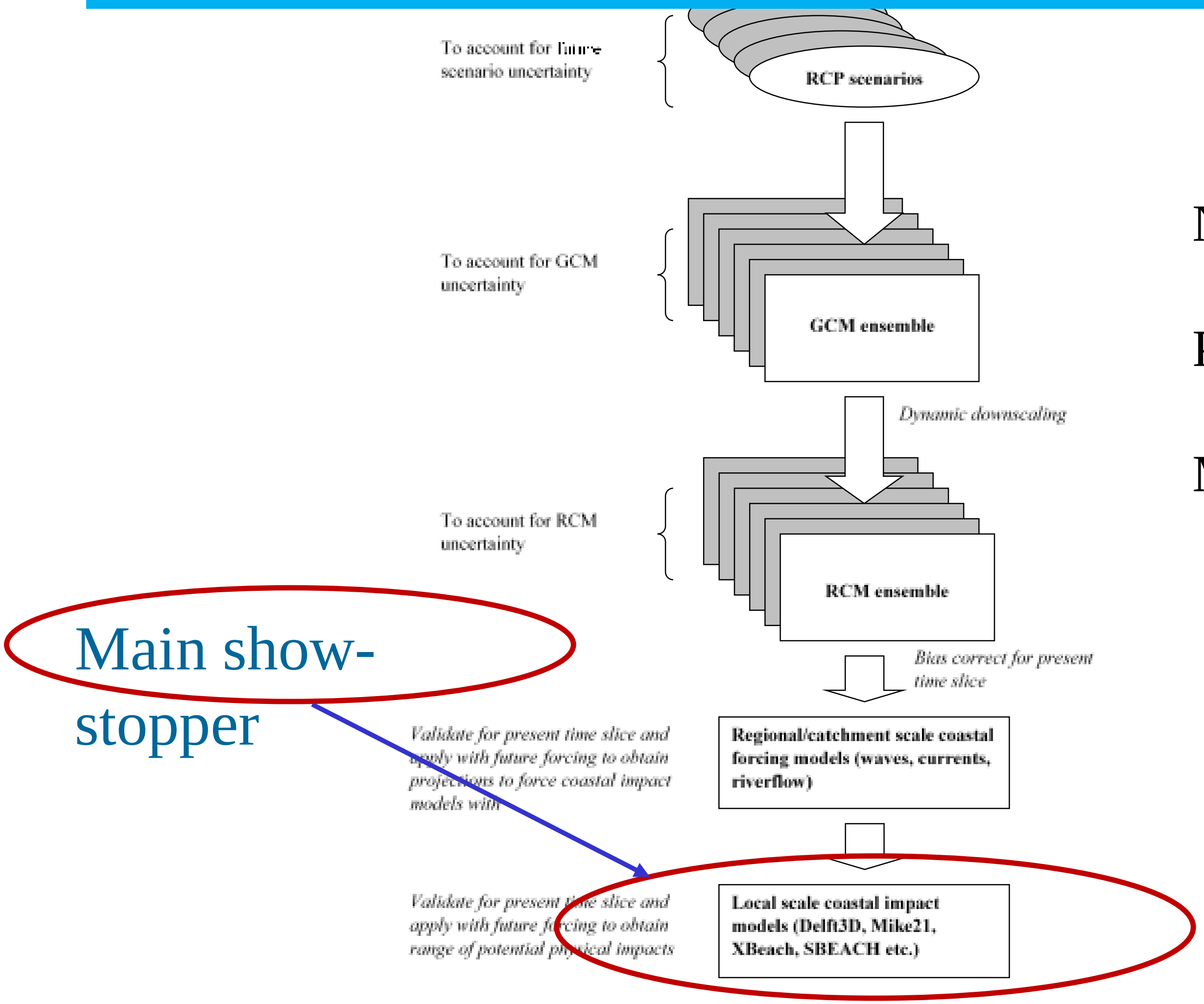
Potential climate change effects on coasts
after Ranasinghe, 2016

Potential impact	Process time scale*	Main drivers
Change in severity and/or intensity of episodic coastal inundation	Episodic	Sea level rise, intensity and/or frequency of storms, storm surge
Change in episodic storm erosion of beaches, dunes and mangroves	Episodic	Intensity and/or frequency of storms, storm surge, storm wave characteristics
More/less frequent episodic formation and closure of small tidal inlets	Episodic	Storm surge, intensity/frequency of extreme riverflow events, storm wave characteristics
Sustained erosion/accretion due to re-alignment of embayed beaches	Medium-term	Mean offshore wave direction
Permanent inundation of low lying land and increased flood height	Long-term	Sea level rise
Chronic coastline recession	Long-term	Sea level rise, riverflow, fluvial sand supply, mean offshore wave conditions

Ranasinghe, 2016. Climate change impacts on sandy coasts: A Review. Earth Science Reviews.

CC impact quantification at regional/local scale



Need to quantify uncertainty

Probabilistic estimates

Multiple simulations

Ranasinghe, 2016. Climate change impacts on sandy coasts: A Review. Earth Science Reviews.

Reduced complexity modelling of CC driven coastal hazards

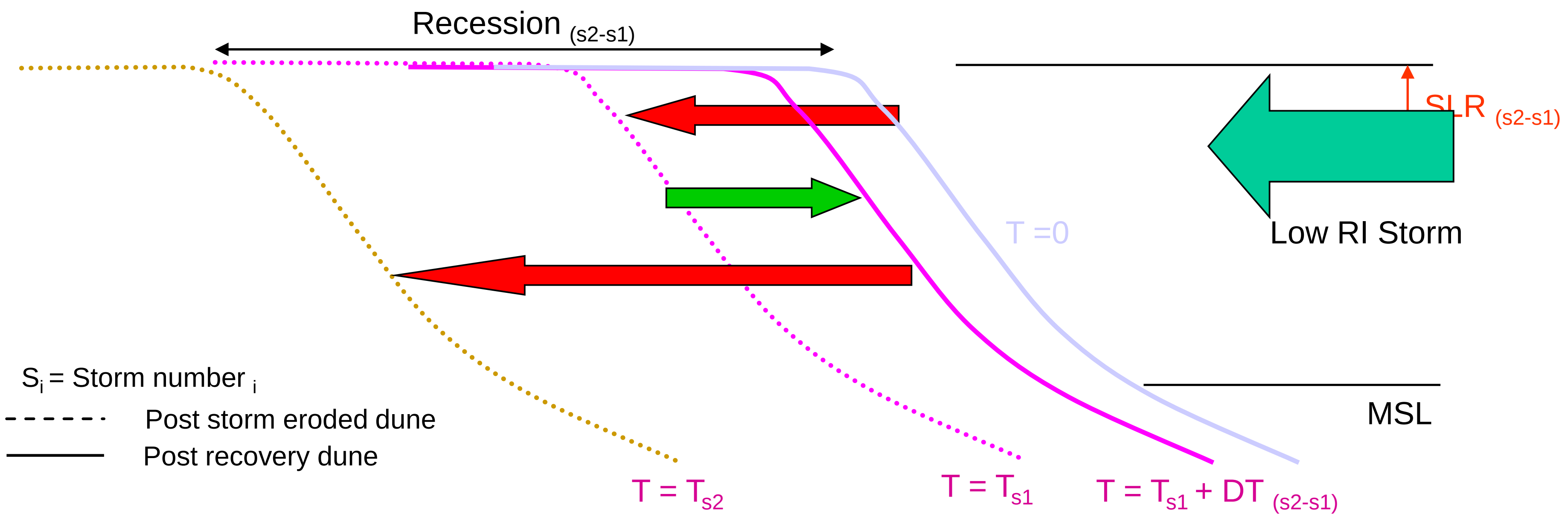
To facilitate the large number of simulations (500-1000) required for fully probabilistic hazard estimations to support risk informed decision making

Physics based reduced complexity models

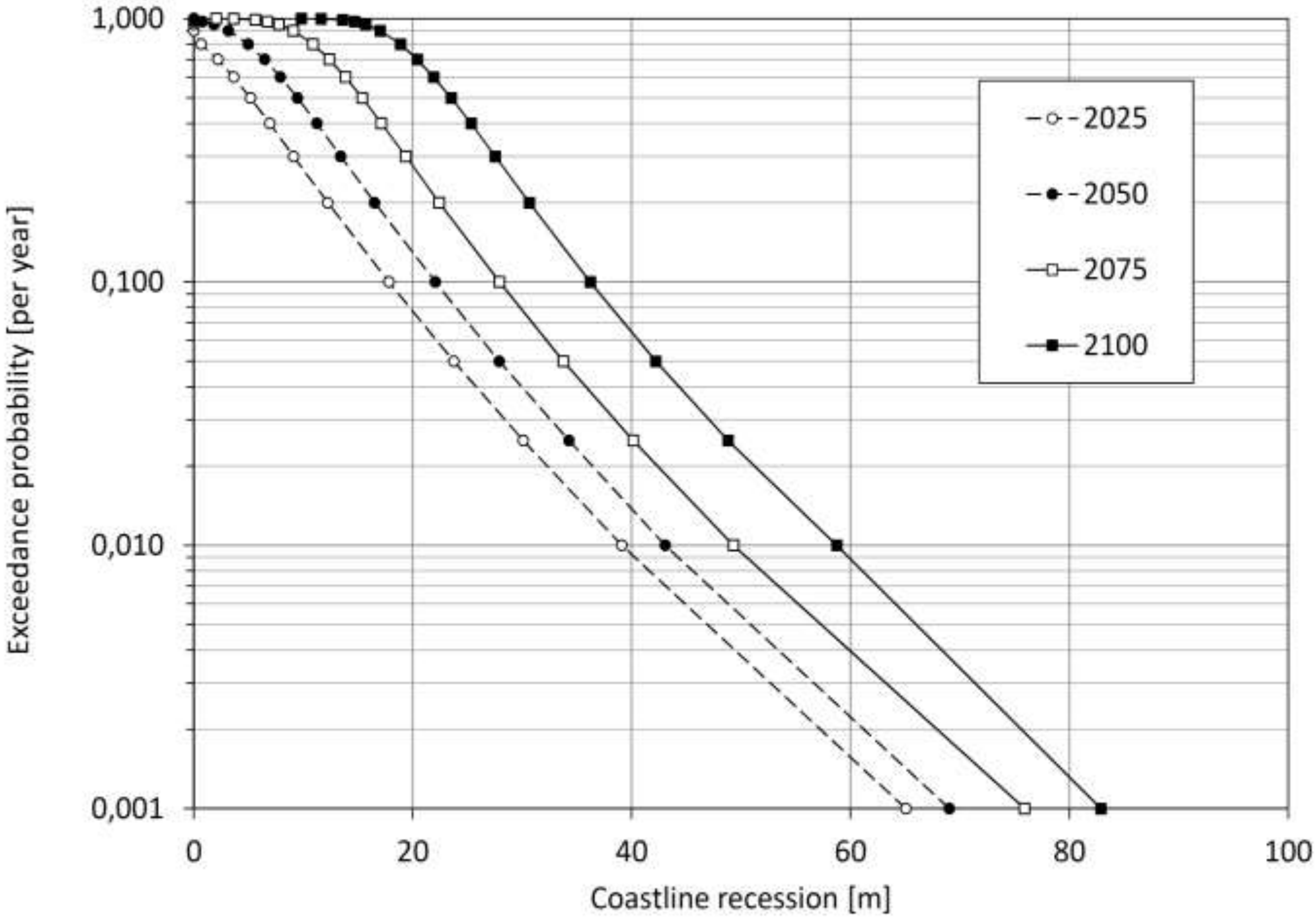
- Simplified descriptions of key system physics
- Fully explicit governing equations

Probabilistic Coastline Recession (PCR) model

- Data based synthetic storm time series from a Montecarlo model (Callaghan et al., 2008); IPCC SLR curve; analytical dune erosion model (Larson et al, 2004)
- Continue simulation for 100 yrs and save most landward dune position for each year



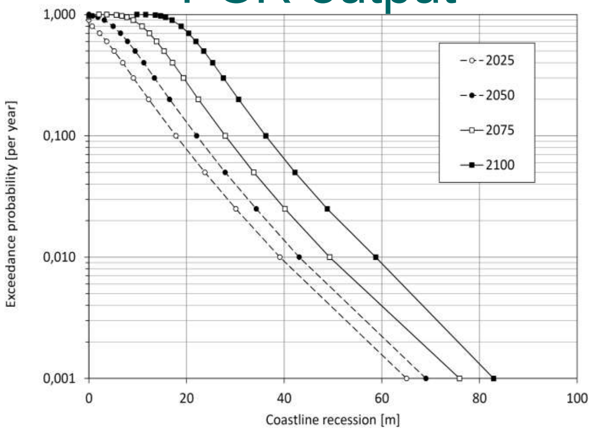
PCR model output for Narrabeen beach, Australia

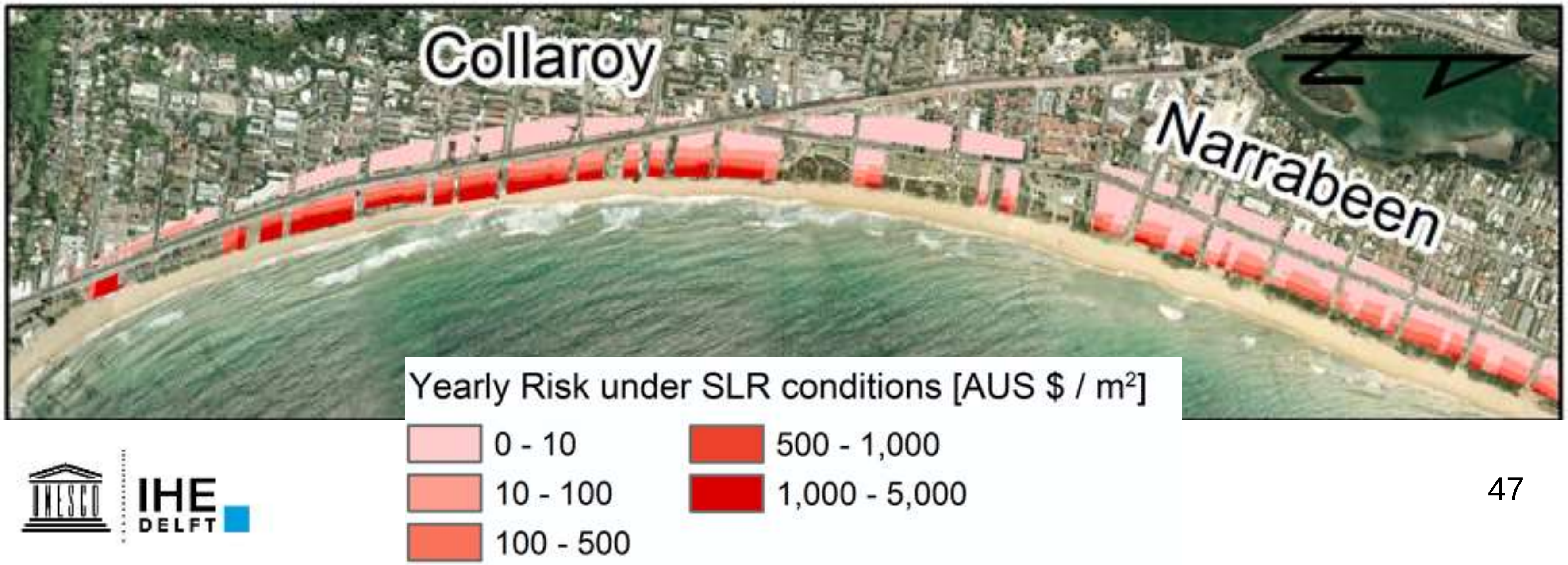


Total simulation time < 10 minutes

From Hazard to Risk

~~PCR output~~





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Satellite image derived global coastline change

www.nature.com/scientificreports

SCIENTIFIC REPORTS

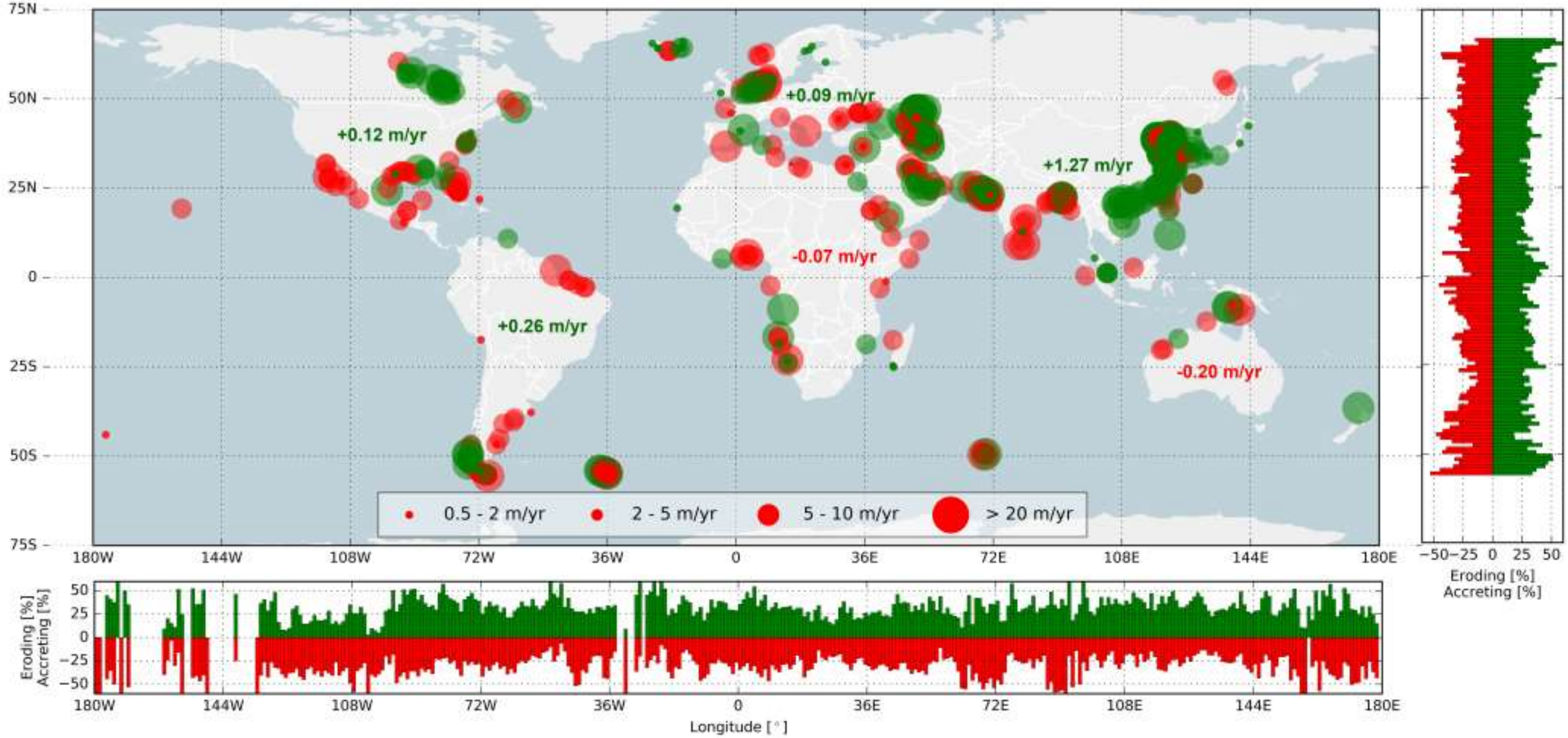
OPEN

The State of the World's Beaches

Arjen Luijendijk[1,2], Gerben Hagenaars[2], Roshanka Ranasinghe[3,4,2], Fedor Baart[2], Gennadii Donchyts[1,2] & Stefan Aarninkhof[1]

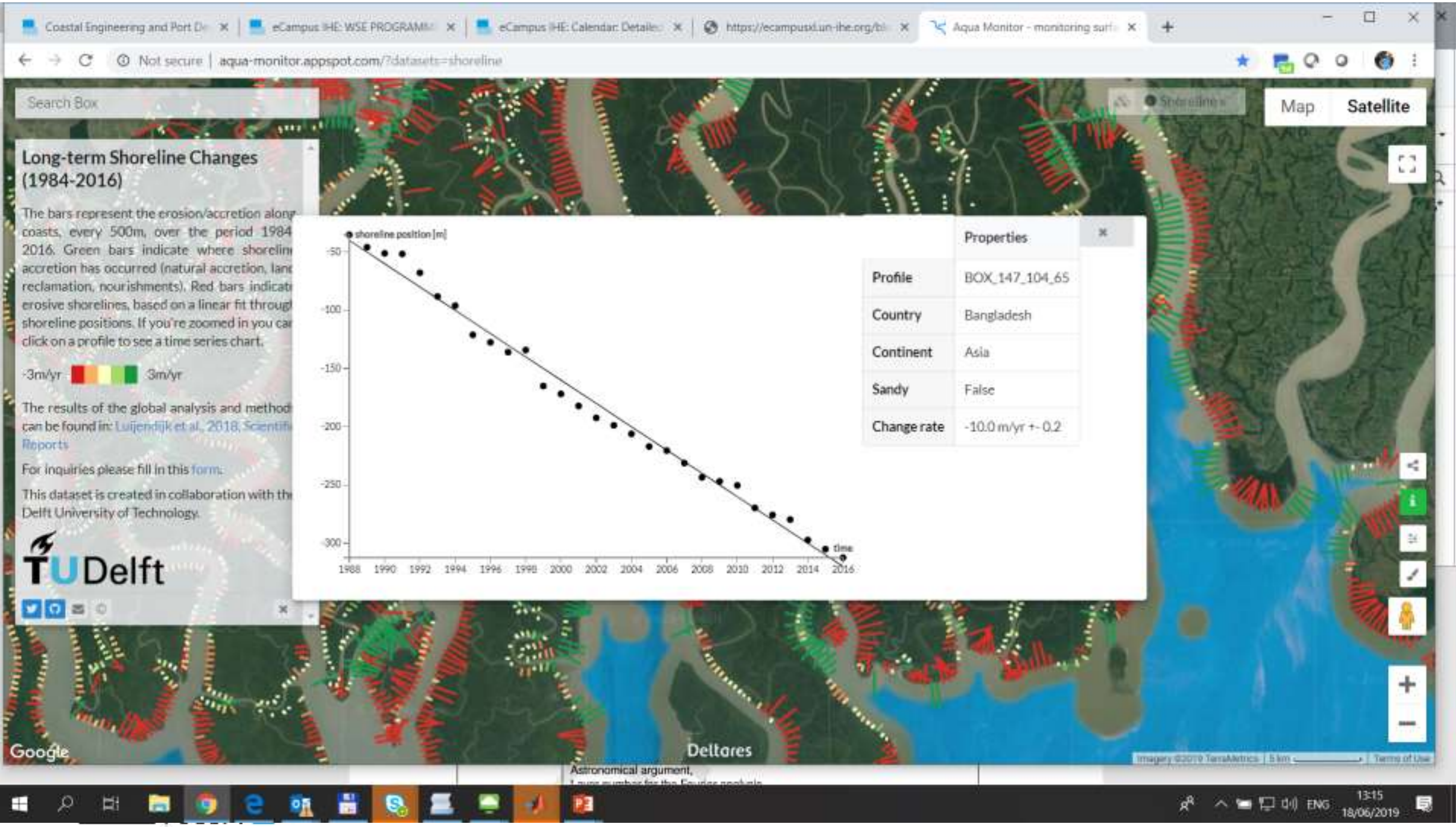
Automated, objective analysis of 35 years of global LANDSAT images

Global hotspots of beach erosion and accretion



Red (green) circles indicate erosion (accretion) for four shoreline dynamic classifications (see legend). The bar plots to the right and at the bottom present the relative occurrence of eroding (accreting) sandy shorelines per degree latitude and longitude, respectively. The numbers presented in the main plot represent the average change rate for all sandy shorelines per continent.

Application of Shoreline Monitor to Bangladesh



Prof. Jentsje van der Meer PhD, MSc

- Professor Coastal Structures and Ports at IHE Delft … struction of Be…
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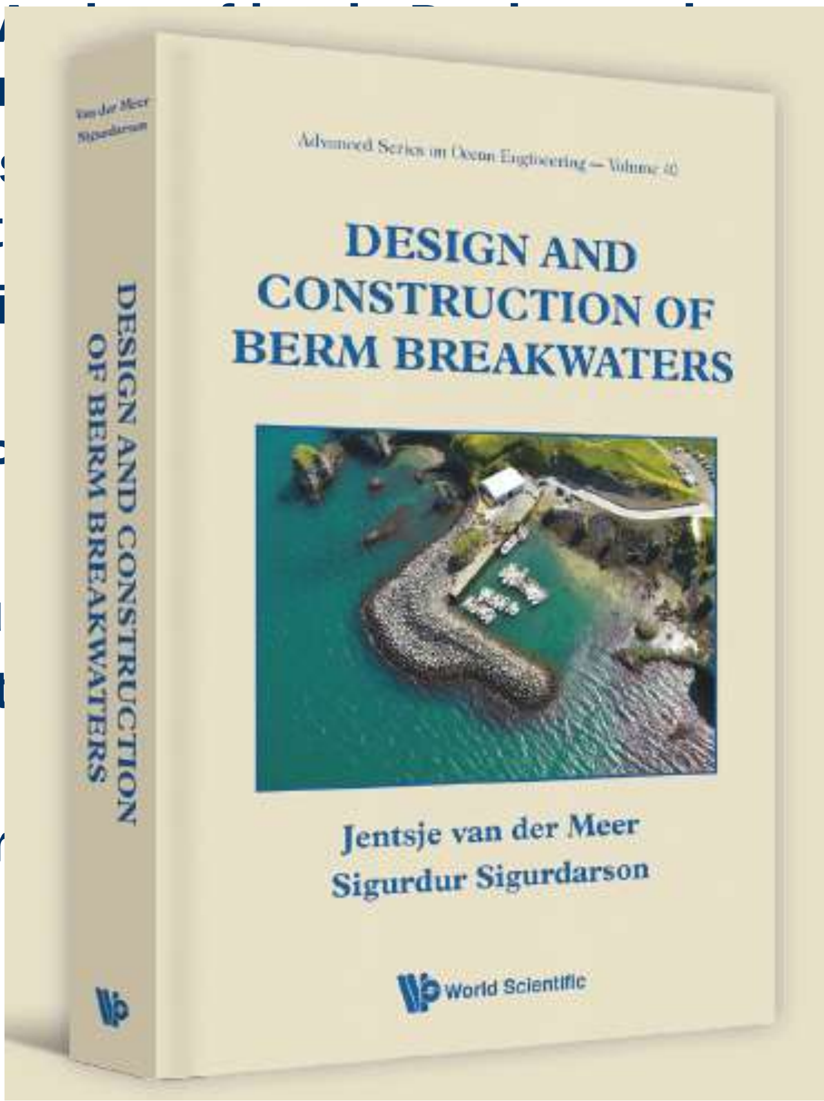

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Stability of coastal structures and breakwaters

- **Appraisal, design and testing of breakwaters and coastal structures;**
- **Work on rubble mound structures included in all manuals all over the world (Van der Meer formula);**

Wave overtopping

- **Editor and co-author of EurOtop (2016) – Manual for wave overtopping.**

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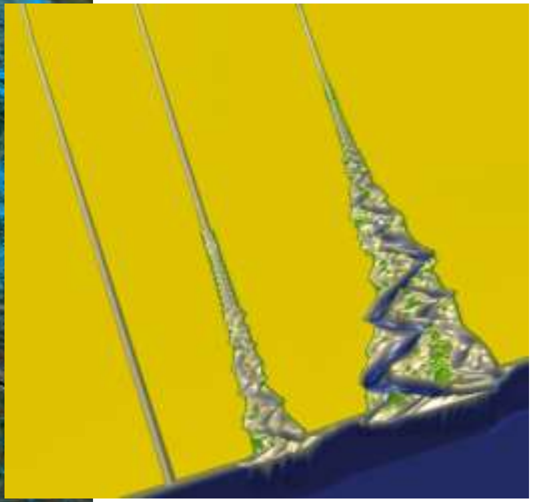
Hydraulic simulators

- **Inventor of:**
  - **Wave overtopping simulator**
  - **Wave run-up simulator**
  - **Wave impact simulator**
- **Development of guideline for strength of grass covers on dikes against wave overtopping**

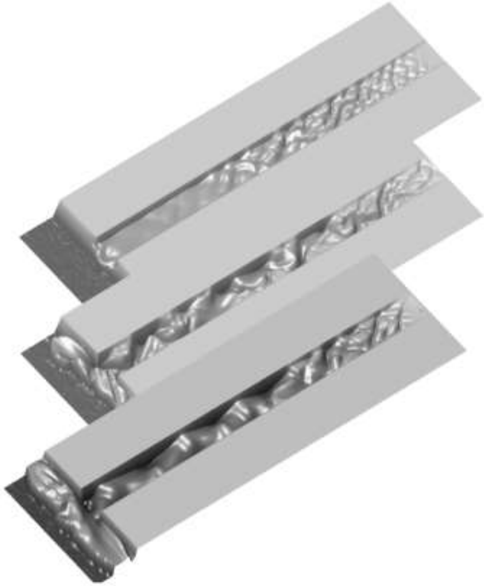
Estuarine dynamics under sea level rise
Associate Professor Mick van der Wegen

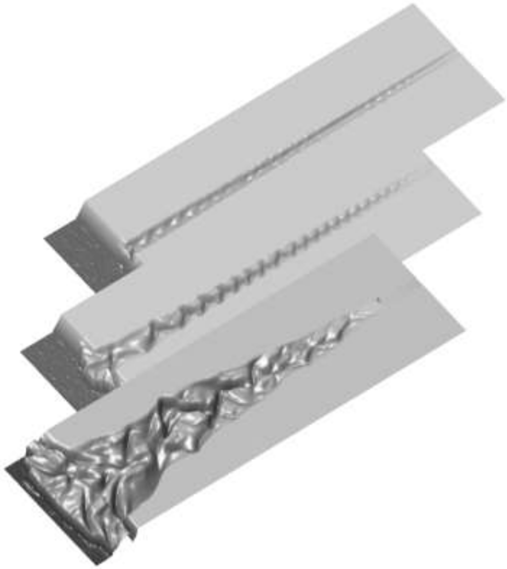
Researcher ID C-6787-2009
ORCID 0000-0002-5227-2679
Scopus Author ID 23981695100

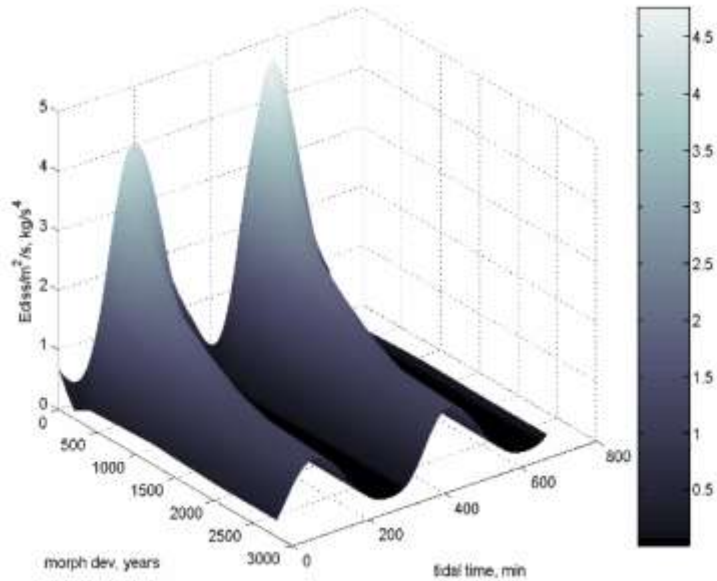


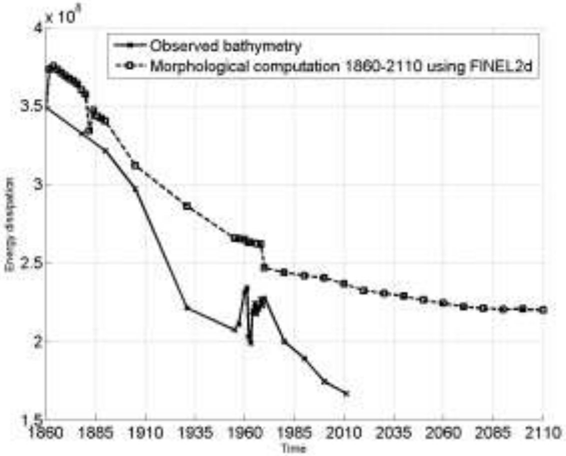
Deltares USGS science for a changing world TU Delft

Modeling long-term morphodynamics in tidal basins





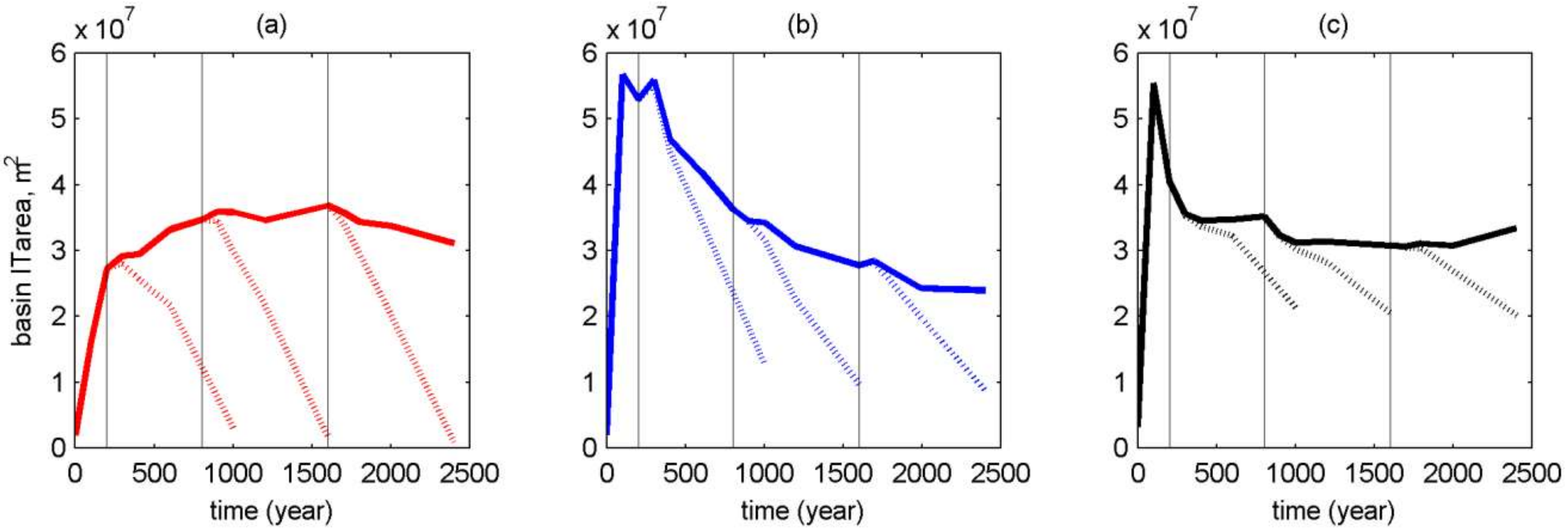




Morphodynamic activity in tidal basins decays on centennial time scale

Van der Wegen, M., Z. B. Wang, H. H. G. Savenije, and J. A. Roelvink (2008), *Long-term morphodynamic evolution and energy dissipation in a coastal plain, tidal embayment*, J. Geophys. Res., 113, F03001, doi:10.1029/2007JF000898

Intertidal area disappears under SLR (dotted line)



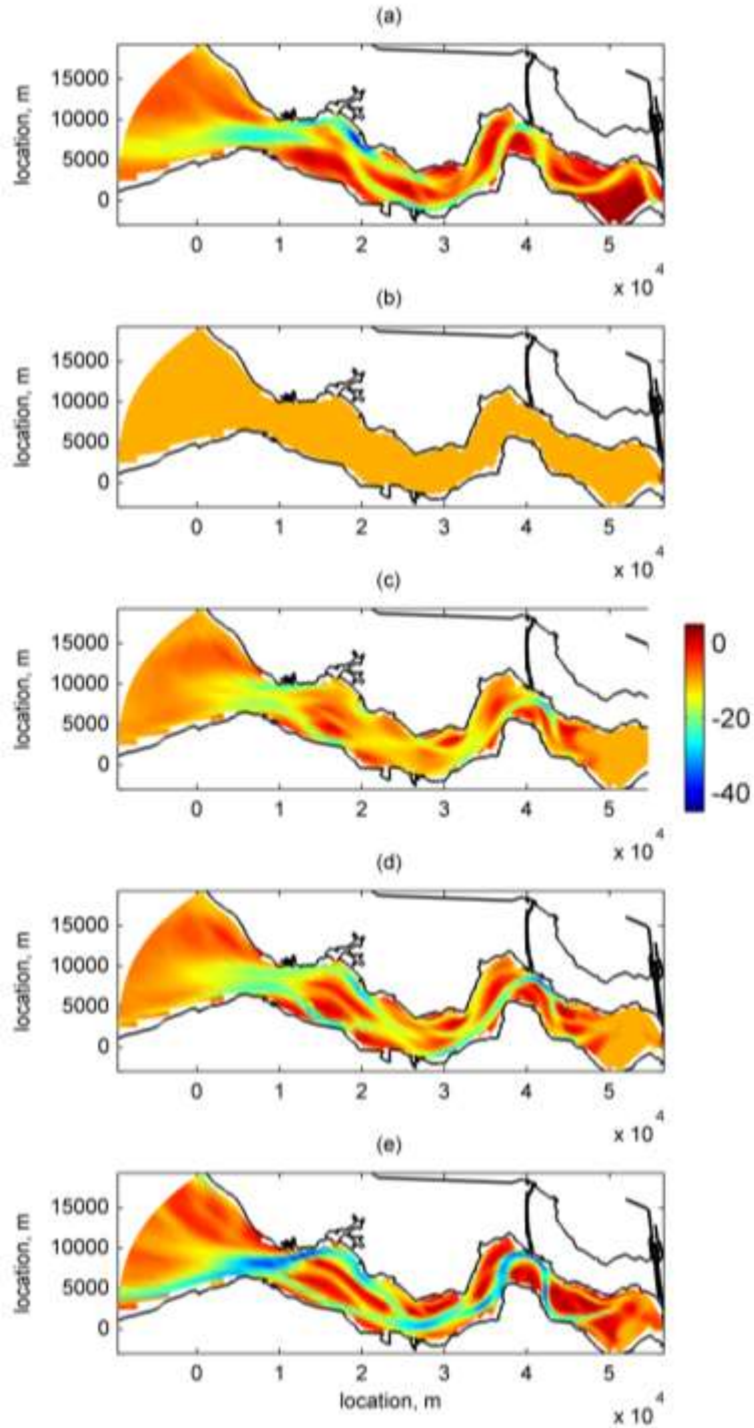
Tidal difference

0.85 m

1.75m

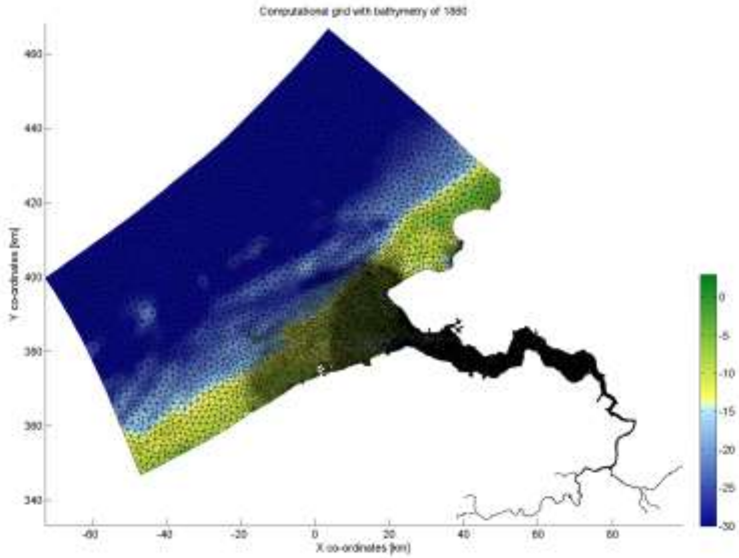
3.5m

van der Wegen, M. (2013). Numerical modeling of the impact of sea level rise on tidal basin morphodynamics. *Journal of Geophysical Research: Earth Surface*, *118*(2), 447-460.

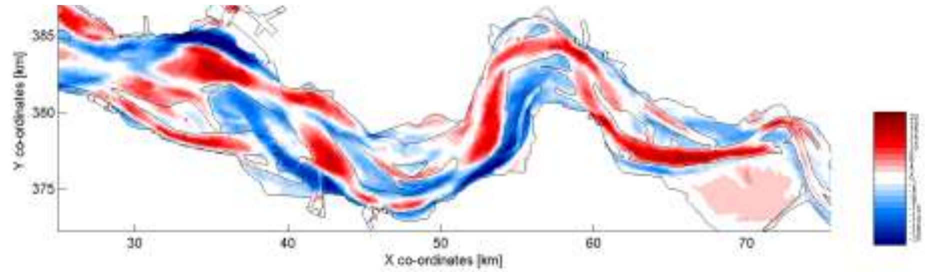


Estuaries' planform determines allocation of shoals and channels

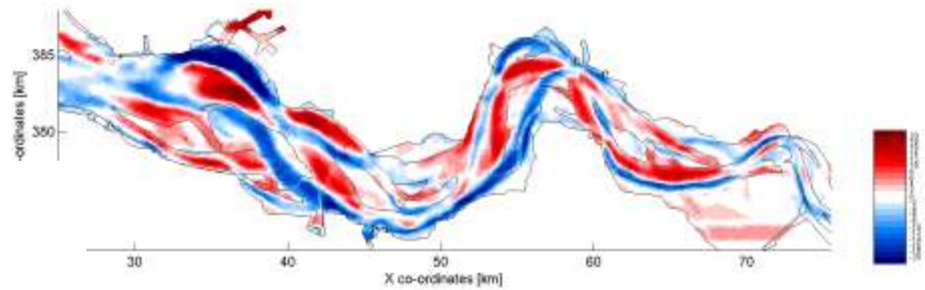
Van der Wegen, M., B. E. Jaffe, and J. A. Roelvink, *Process-based, morphodynamic hindcast of decadal deposition patterns in San Pablo Bay, California, 1856–1887*, J. Geophys. Res., 116, F02008, doi:10.1029/2009JF001614



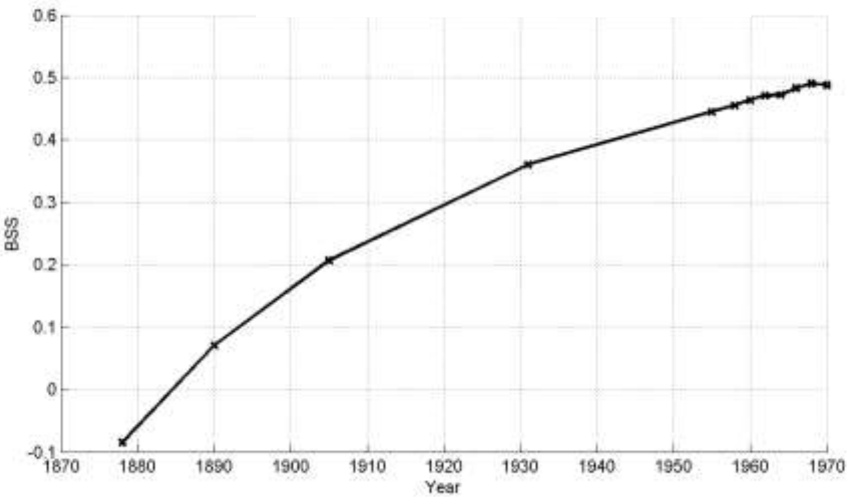
Modeled erosion/sedimentation patterns 1860-1970



Measured erosion/sedimentation patterns 1860-1970



Brier Skill Score



Estuarine bathymetry is predictable on long timescales when model skill increases

G. Dam, M. van der Wegen, R. J. Labeur, D. Roelvink, *Modeling centuries of estuarine morphodynamics in the Western Scheldt estuary*, 43:8, 3839–3847, doi 10.1002/2015GL066725

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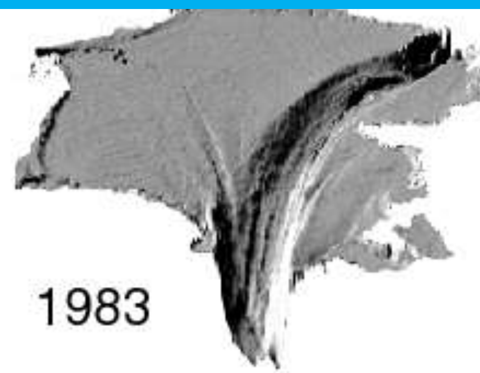
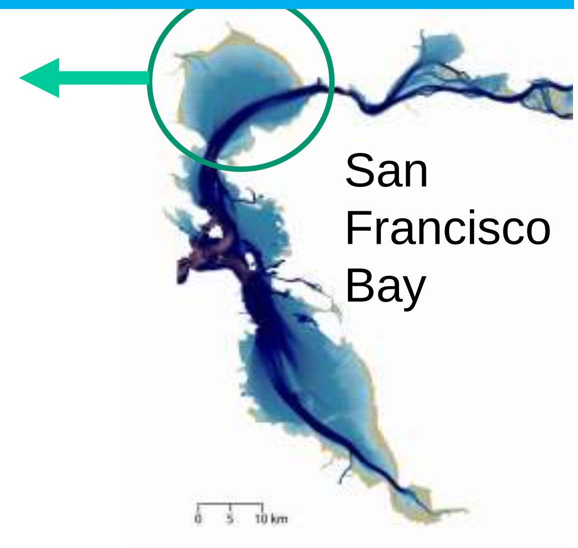
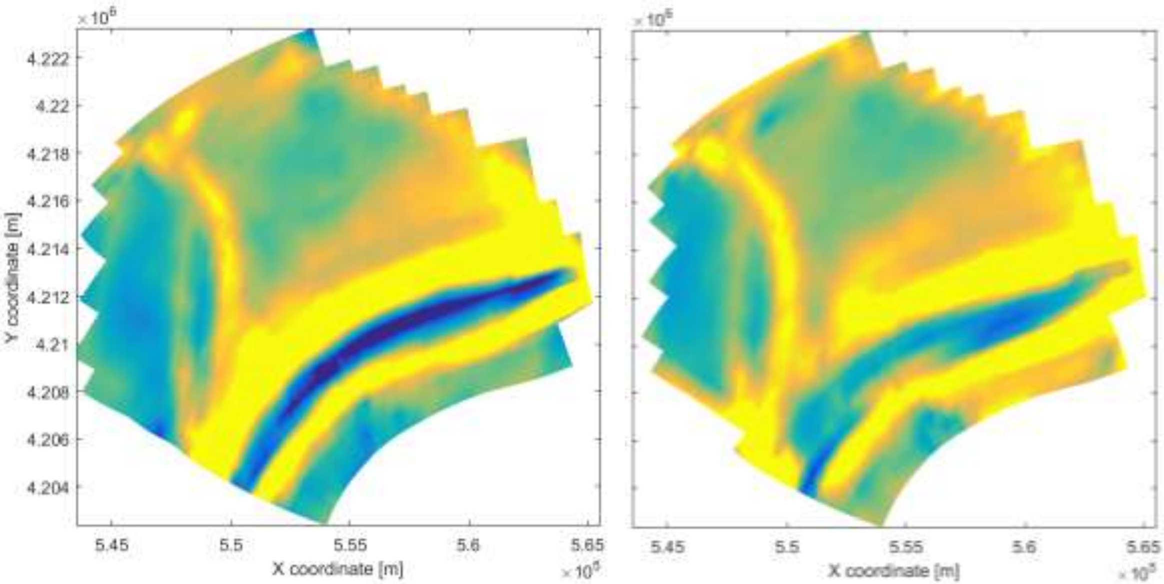
Model reproduces observed channel narrowing in San Pablo Bay







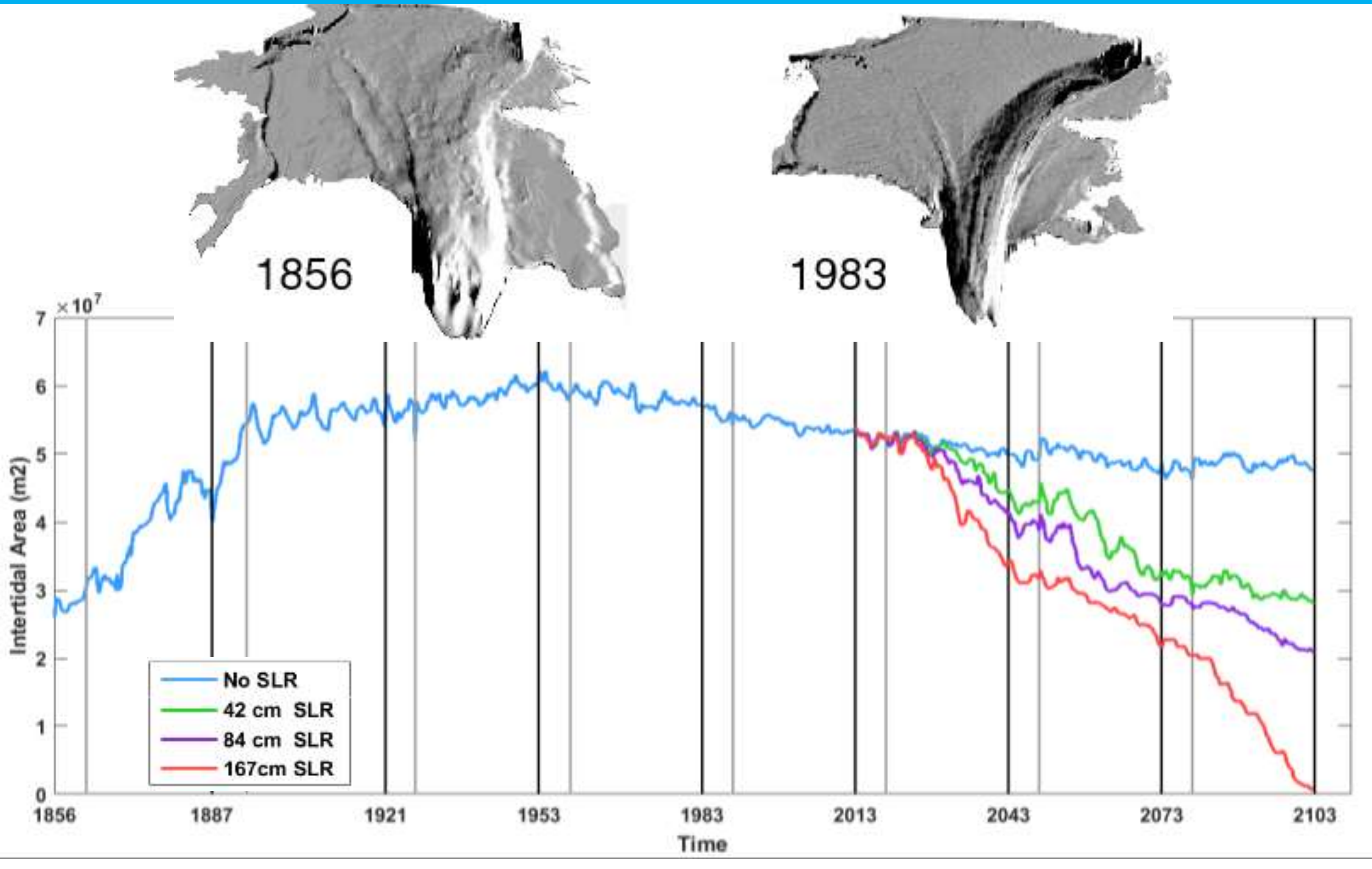
Erosion sedimentation patterns 1856-1983

Observed Modeled

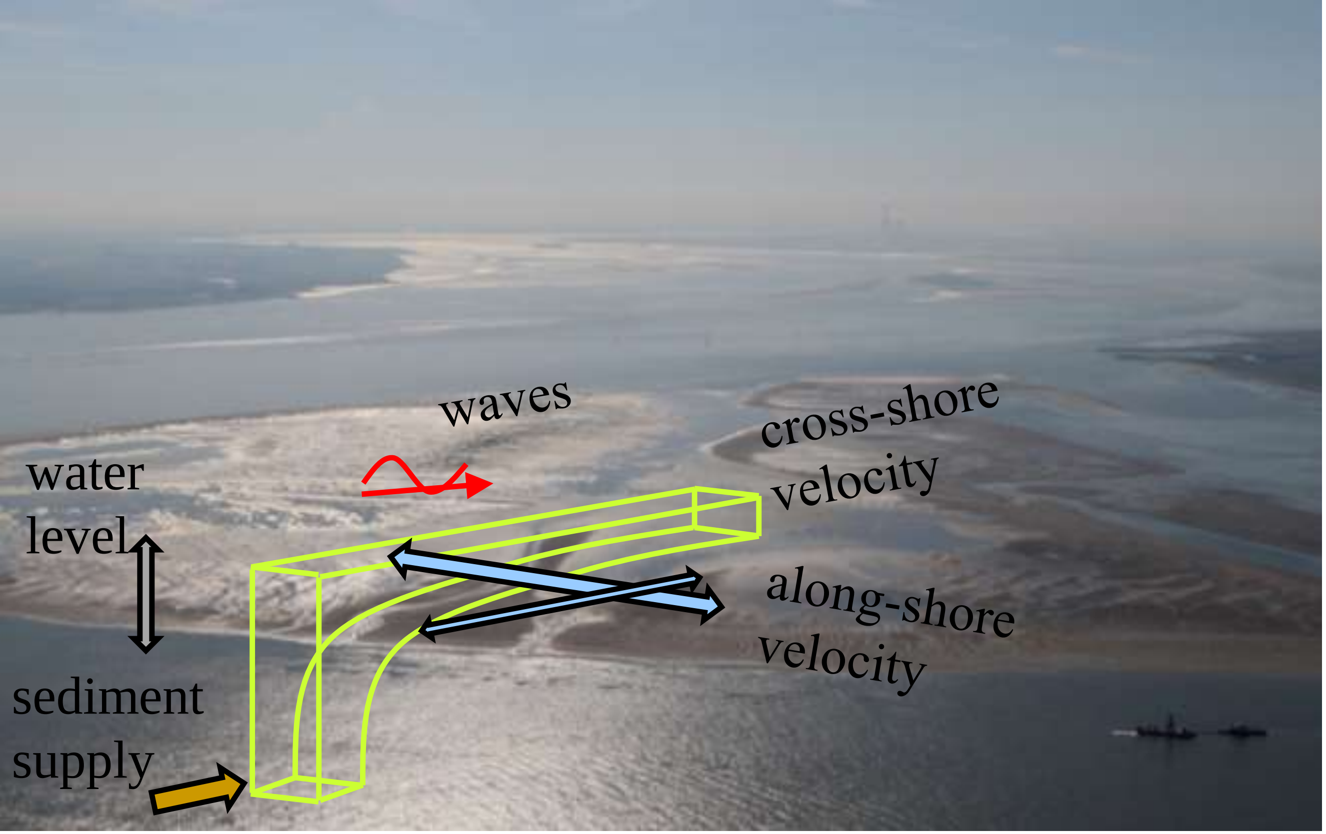
Van der Wegen, M., Jaffe, B. E., & Roelvink, J. A. (2011). Process-based, morphodynamic hindcast of decadal deposition patterns in San Pablo Bay, California, 1856–1887. *Journal of Geophysical Research: Earth Surface*, *116*(F2).

Van der Wegen, M., & Jaffe, B. E. (2013). Towards a probabilistic assessment of process-based, morphodynamic models. *Coastal Engineering*, *75*, 52-63.

San Pablo Bay intertidal area disappears under sea level rise

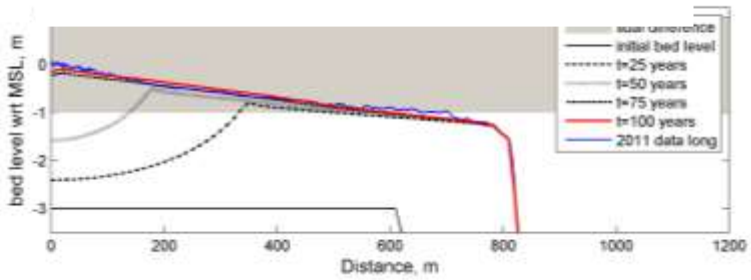


El Milady, Van der Wegen, Roelvink and Jaffe, submitted



Van der Wegen, M., Jaffe, B., Foxgrover, A., & Roelvink, D. (2017). Mudflat Morphodynamics and the Impact of Sea Level Rise in South San Francisco Bay. *Estuaries and Coasts*, *40*(1), 37-49.

1D model reproduces intertidal area that disappears under sea level rise



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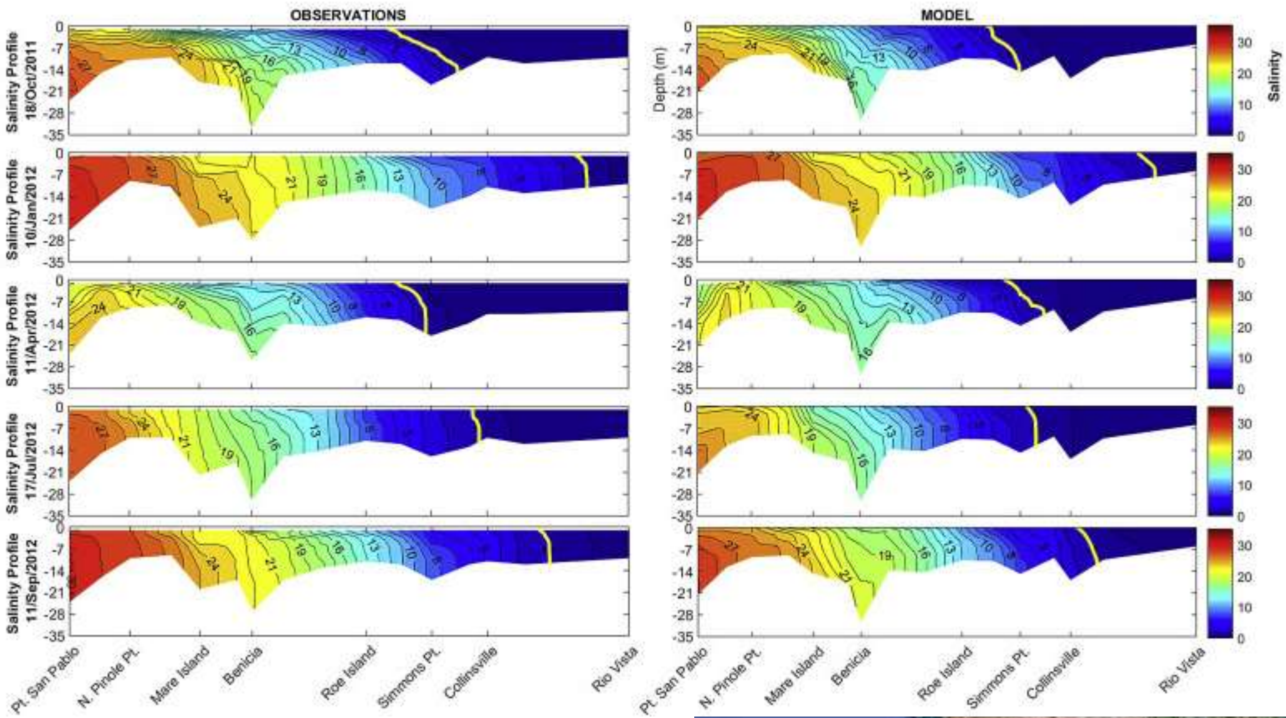
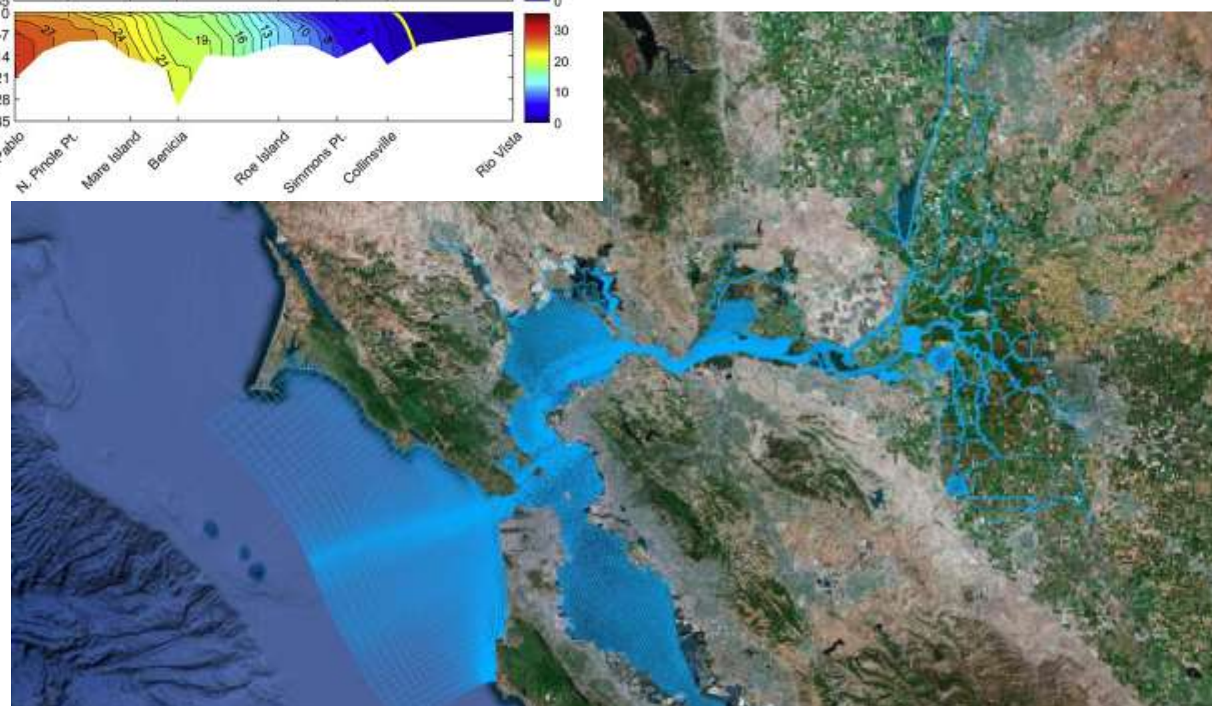
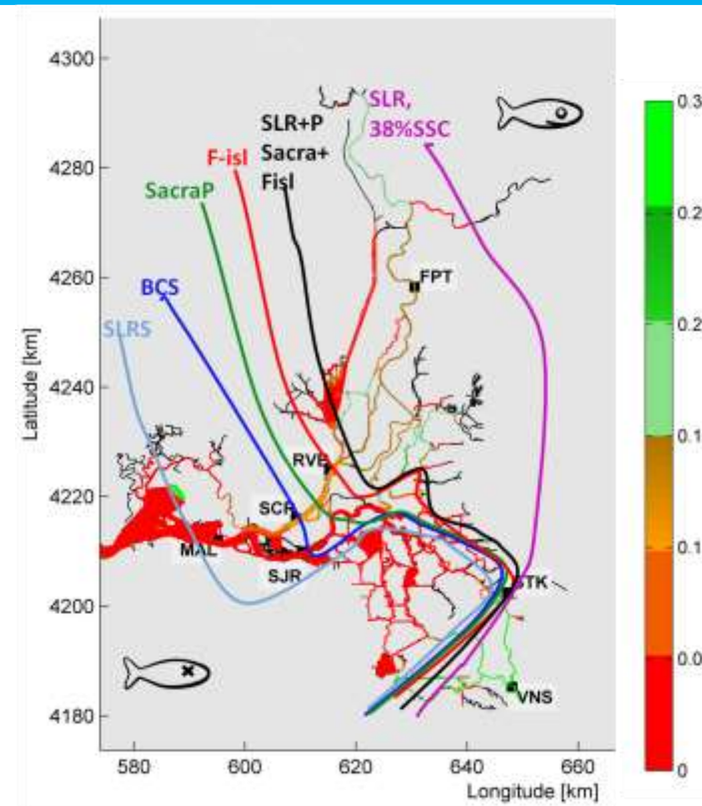
3D model (Delft3D Flexible Mesh) predicts salt intrusion, temperature and turbidity levels under sea level rise scenarios





Martyr-Koller, R. C., Kernkamp, H. W. J., van Dam, A., van der Wegen, M., Lucas, L. V., Knowles, N., ... & Fregoso, T. A. (2017). Application of an unstructured 3D finite volume numerical model to flows and salinity dynamics in the San Francisco Bay-Delta. *Estuarine, Coastal and Shelf Science*, *192*, 86-107.

3D hydrodynamic model translates into ecological indicators



Achete, F., Van der Wegen, M., Roelvink, J. A., & Jaffe, B. (2017). How can climate change and engineered water conveyance affect sediment dynamics in the San Francisco Bay-Delta system?. *climatic change*, *142*(3-4), 375-389.

Johan Reyns, MSc

- Modeling the morphodynamics of complex swell-dominated coastlines, including coral reefs
- Development, validation and application of Delft3D-FM
- Surfbeat, infragravity waves, morphodynamics
- In collaboration with Deltares

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Ria Formosa flexible mesh

Rita Carrasco, UAlgarve


x 10^6
4.098
4.096
4.094
4.092
4.09
5.95
6
x 10^5
0.8
0.6
0.4
0.2
0
Veloc

Proposed setup of capacity building

- Current idea is to have 2 groups of 6-7 persons do a 3-month training in Delft
  - Highly flexible in course content
  - Possibility of dedicated modules and excursions
  - Preferably around time of main specialization modules (Dec-June)
- 2 MSc programmes
  - 18 months total
  - with 6 month research period
  - Of which 4 months in Dhaka
- Study tours overseas (Netherlands, Denmark) for senior staff

Overview of available modules at IHE Delft

Module 3 – Dec/Jan

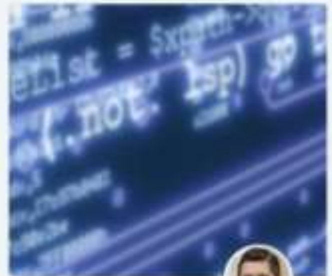
2018/2020-WSE/CEPD/03/s: Introduction to Coastal Science and Engineering

WSE PROGRAMME 2018/2020

201819T03_M3348

2018/2020-WSE/HERBD/03/s: River Basin Development and Environmental Impact Assessment

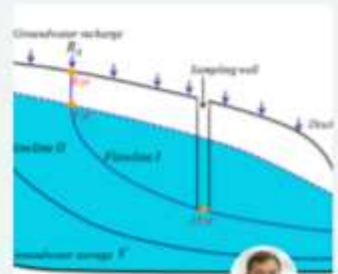
WSE PROGRAMME 2018/2020



2018/2020-WSE/HI/03/s:Information technology and software engineering

WSE PROGRAMME 2018/2020

201819T03_M3337



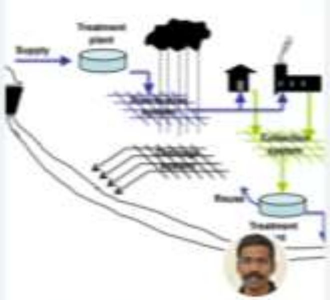
2018/2020-WSE/HWR/03/s: Hydrogeology

WSE PROGRAMME 2018/2020

201819T03_M2166

2018/2020-WSE/LWDFS/03/s: Principles and practices of land and water development

WSE PROGRAMME 2018/2020



2018/2020-WSE/SUWM/03: Urban System Analysis, Planning and Management: An Introduction

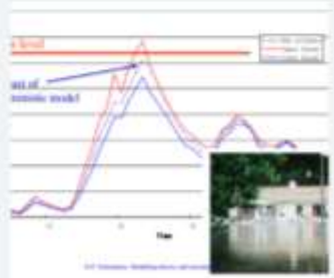
Module 4 - January

2018/2020-WSE/CEPD/04/s: Port planning and infrastructure design

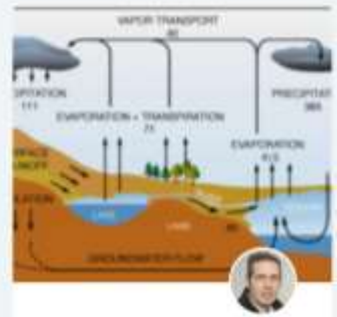
WSE PROGRAMME 2018/2020

2018/2020-WSE/HERBD/04/s: Data Collection and Analysis and Design

WSE PROGRAMME 2018/2020



2018/2020-WSE/HI/04/s: Modelling Theory and Computational Hydraulics

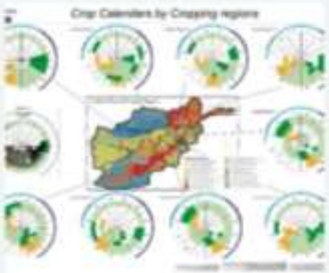


2018/2020-WSE/HWR/04/s: Surface Hydrology

WSE PROGRAMME 2018/2020

2018/2020-WSE/LWDFS/04/s: Design aspects of irrigation and drainage

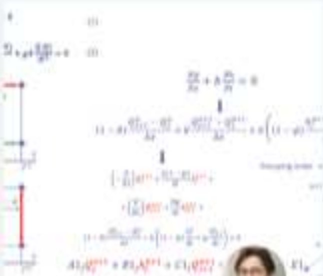
Module 5 - February



2018/2020-WSE/HERBD/05/s: Hydraulics and Remote Sensing for River Basin Development

2018/2020-WSE/CEPD/05/s: Coastal systems

WSE PROGRAMME 2018/2020



2018/2020-WSE/HI/05/s: Modelling and Information Systems Development

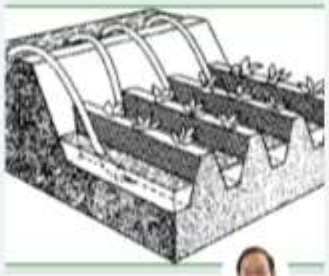
WSE PROGRAMME 2018/2020

201819T05_M3340

2018/2020-WSE/HWR/05/s: Water Quality

WSE PROGRAMME 2018/2020

201819T05_M3425



2018/2020-WSE/LWDFS/05/s: Irrigation and drainage design

WSE PROGRAMME 2018/2020

201819T05_M3447

2018/2020-WSE/Special/05: Online course on Urban System Analysis, Planning and Management: Developing Skills and Attitudes

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Module 6 - March

2018/2020-WSE/CEPD/06/s: Design of Breakwaters and Dikes

WSE PROGRAMME 2018/2020

201819T06_M3369

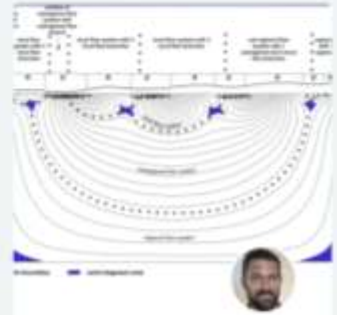
2018/2020-WSE/HERBD/06/s: River Morphodynamics

WSE PROGRAMME 2018/2020

201819T06_M2730

2018/2020-WSE/HI/06/s: Computational Intelligence and Operational water management

WSE PROGRAMME 2018/2020



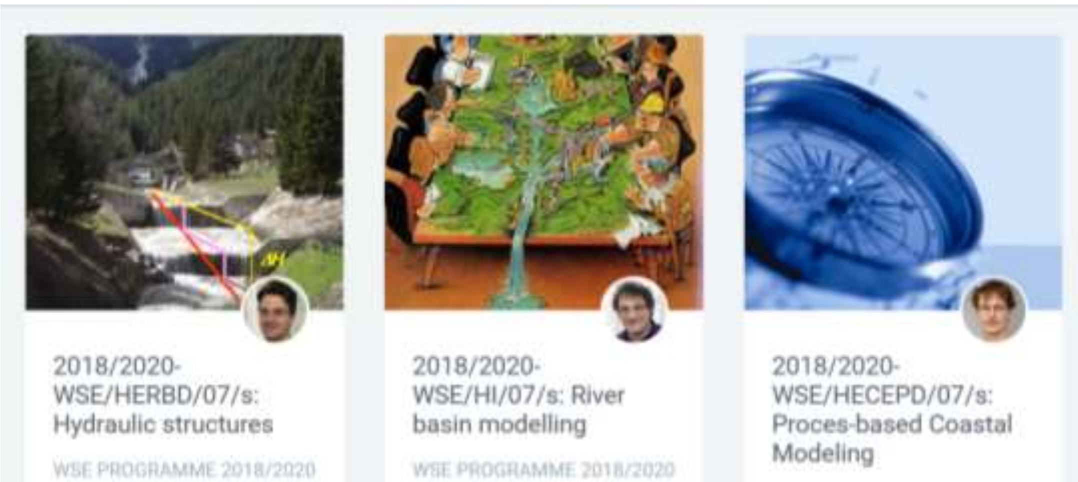
2018/2020-WSE/HWR/06/e: Tracer hydrology and flow systems analysis

WSE PROGRAMME 2018/2020

201819T06_M1903

2018/2020-WSE/LWDFS/06/e: Management of Irrigation and Drainage Systems

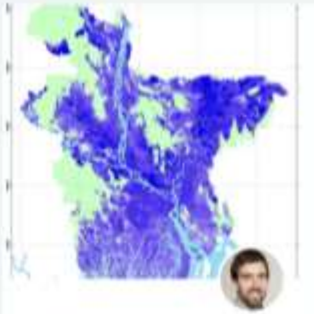
Module 7 - April



Module 8 - May

2018/2020-WSE/HECEPD/08B/e: Climate change impacts and adaptation in deltas

WSE PROGRAMME 2018/2020

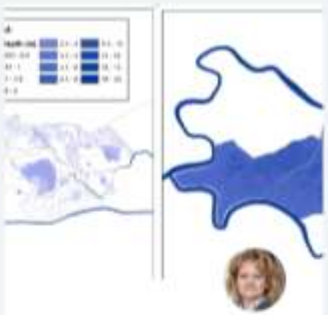


2018/2020-WSE/HERBD/08A/e: Planning and delivery of flood resilience

WSE PROGRAMME 2018/2020

2018/2020-WSE/HERBD/08B/e/UniKL: Dams and hydropower

WSE PROGRAMME 2018/2020

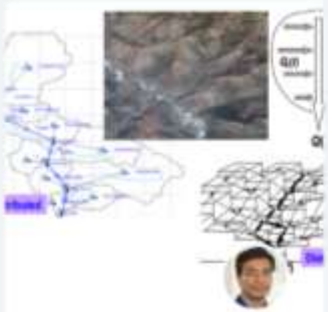


2018/2020-WSE/HI/08A/e: River Flood Analysis and Modelling

WSE PROGRAMME 2018/2020

2018/2020-WSE/HI/08B/e: Urban flood management and disaster risk mitigation

WSE PROGRAMME 2018/2020



2018/2020-WSE/HWR/08/e: Integrated hydrological and river modelling

WSE PROGRAMME 2018/2020

2018/2020-WSE/HWR/08B/e/Groundwatch: Groundwater in adaptation to global change impacts

2018/2020-WSE/LWDFS/08/s: Food security, health and environment

WSE PROGRAMME 2018/2020

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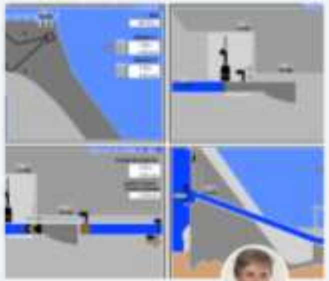
Module 10- June

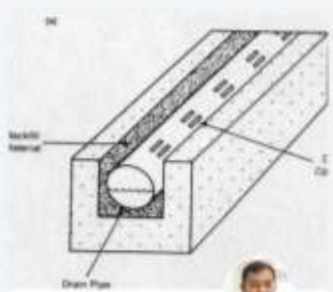
2018/2020-WSE/HECEPD/10/e: Geotechnical engineering and dredging



2018/2020-WSE/HERBD/10/e: Drought Management and Reservoir Operations

2018/2020-WSE/HI/10A/e: Flood risk management

WSE PROGRAMME 2018/2020



2018/2020-WSE/HWR/10B/e: Applied groundwater modelling

WSE PROGRAMME 2018/2020

201819T10_M3353

2018/2020-WSE/LWDFS/10/e: Innovative water systems for agriculture

WSE PROGRAMME 2018/2020

201819T10_M3448

Inventory and discussion

- Background of potential participants
- Main interests and availability 2020/2021
- MSc candidates 2019-2021

- Discussion: opinion on a possible Dredging and Morphology Forecasting Centre, along the lines of the Flood Forecasting and Warning Centre
  - Institutionalize the know-how from the project
  - Be able to follow, model and anticipate bank erosion and unwanted siltation

- Send email to d.Roelvink@un-ihe.org
  - CV
  - Topics of interest
  - Interest in MSc programme?
  - Availability 2020, 2021