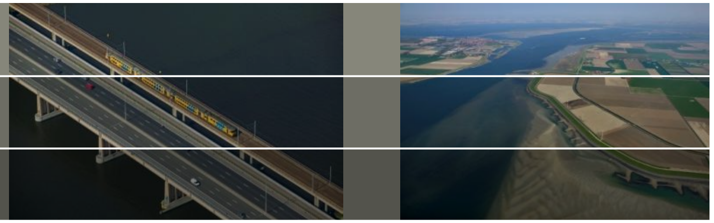


Delft Software Days 2012: XBeach Course

Dano Roelvink
Ap van Dongeren
Jaap van Thiel de Vries
Arnold van Rooijen

UNESCO-IHE
Institute For Water Education

Deltares

XBeach

XBeach: motivation

2004 Hurricane season hit Florida coast 4 times

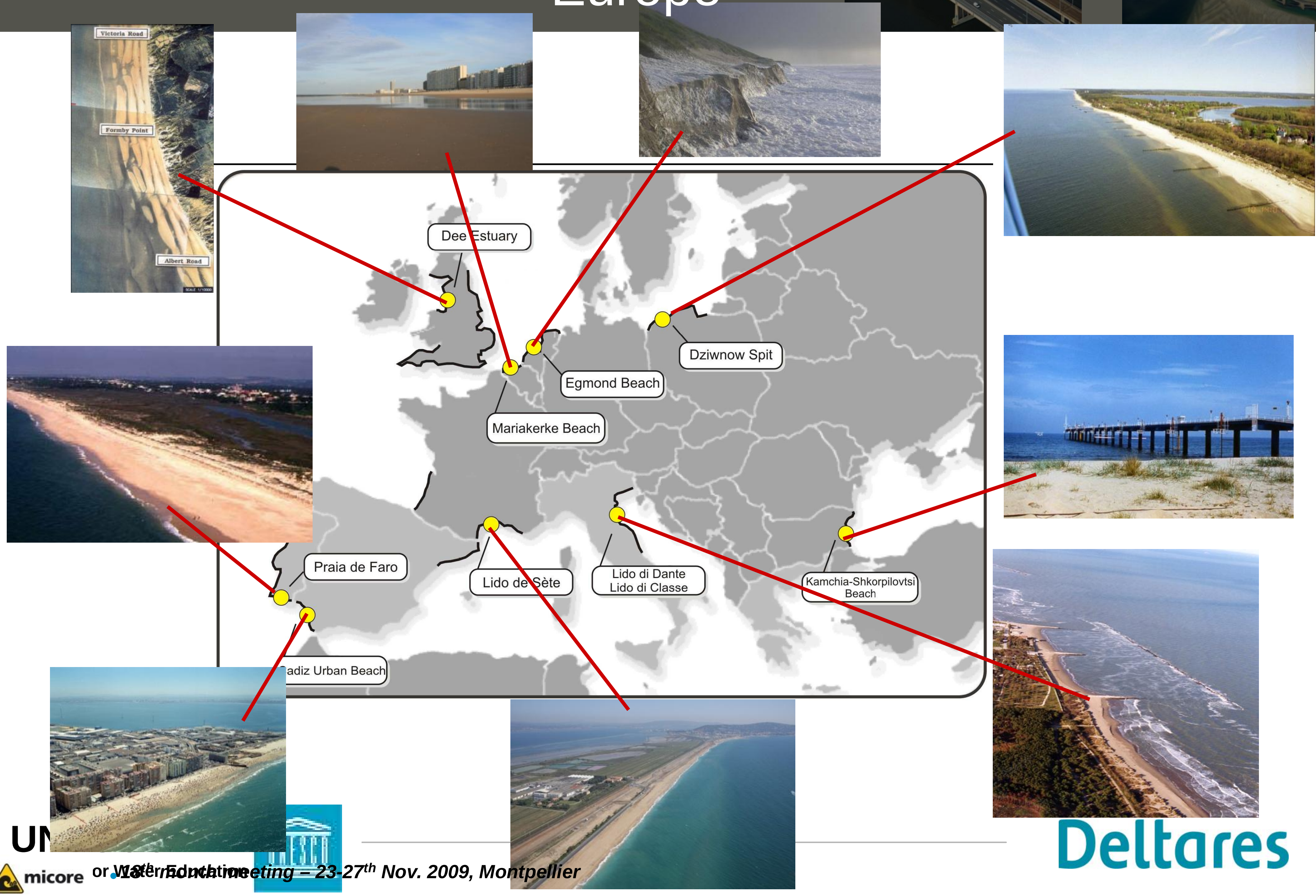
Congress awarded multi-million project MORPHOS3D to develop new physics-based model system to assess hurricane impacts

Scope: wind-surge-waves-nearshore processes-impacts

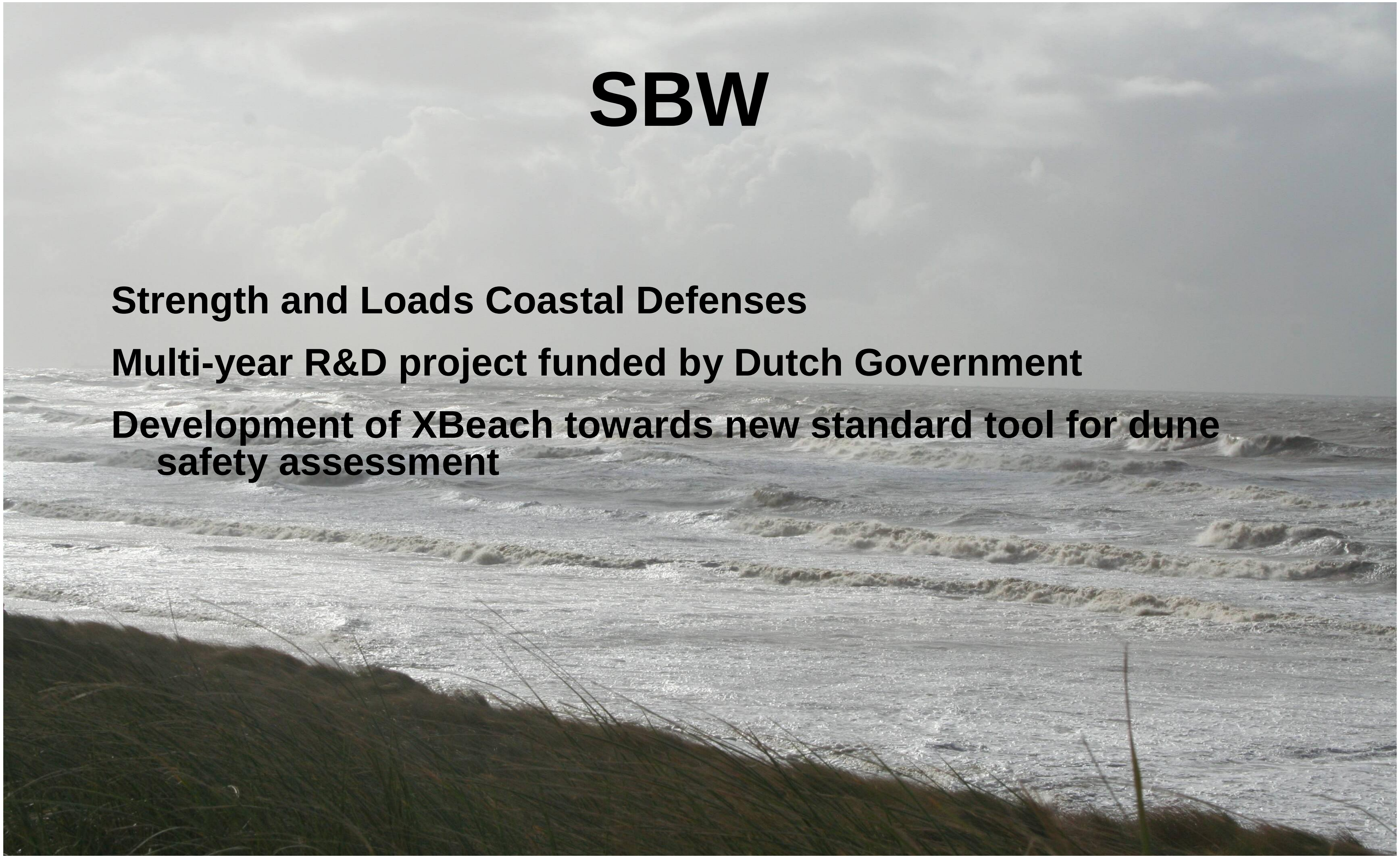
Play ‘what-if?’ games around Corps of Engineers projects

- **Figure 1 Pre- and post hurricane Ivan, Perdido Key, Florida (source: USGS)**

MICORE.EU Field measurement sites in Europe



SBW



Strength and Loads Coastal Defenses

Multi-year R&D project funded by Dutch Government

Development of XBeach towards new standard tool for dune safety assessment

Open Source

- Removes hurdles
- Invites collaboration
- What you can do:
  - > Find and report problems
  - > Provide data sets for validation
  - > Add or improve code
  - > Test in new environments
  - > Help each other through forum
- What we can do
  - > Support in many ways
  - > Create new releases
  - > Run automated testbed

Program

9:15 **THEORY I:** Introduction to XBeach in which we discuss model philosophy, model formulations and some standard applications. r1

10:00 **HANDS ON I:** Dune erosion and overwash:

Dune erosion at Delfland, Netherlands (1D)

Overwash at Santa Rosa Island , USA (2D)

12:00 **LUNCH**

13:00 **THEORY II:** Advanced functionality including application of hard structures, drifters, output options, matlab toolbox, ground water flow.

14:00 **HANDS ON II:**

Introduction to coral reef modeling with XBeach.

Selection from modeling cases (Coral reef, Boscombe beach, own)

Theory Intermezzos : on demand

17:00 **CLOSURE**

r1 Check met jaap
rooijen; 26-11-2012

THEORY I: Introduction to XBeach

A nearshore morphology model for dune erosion and overwash under storm conditions

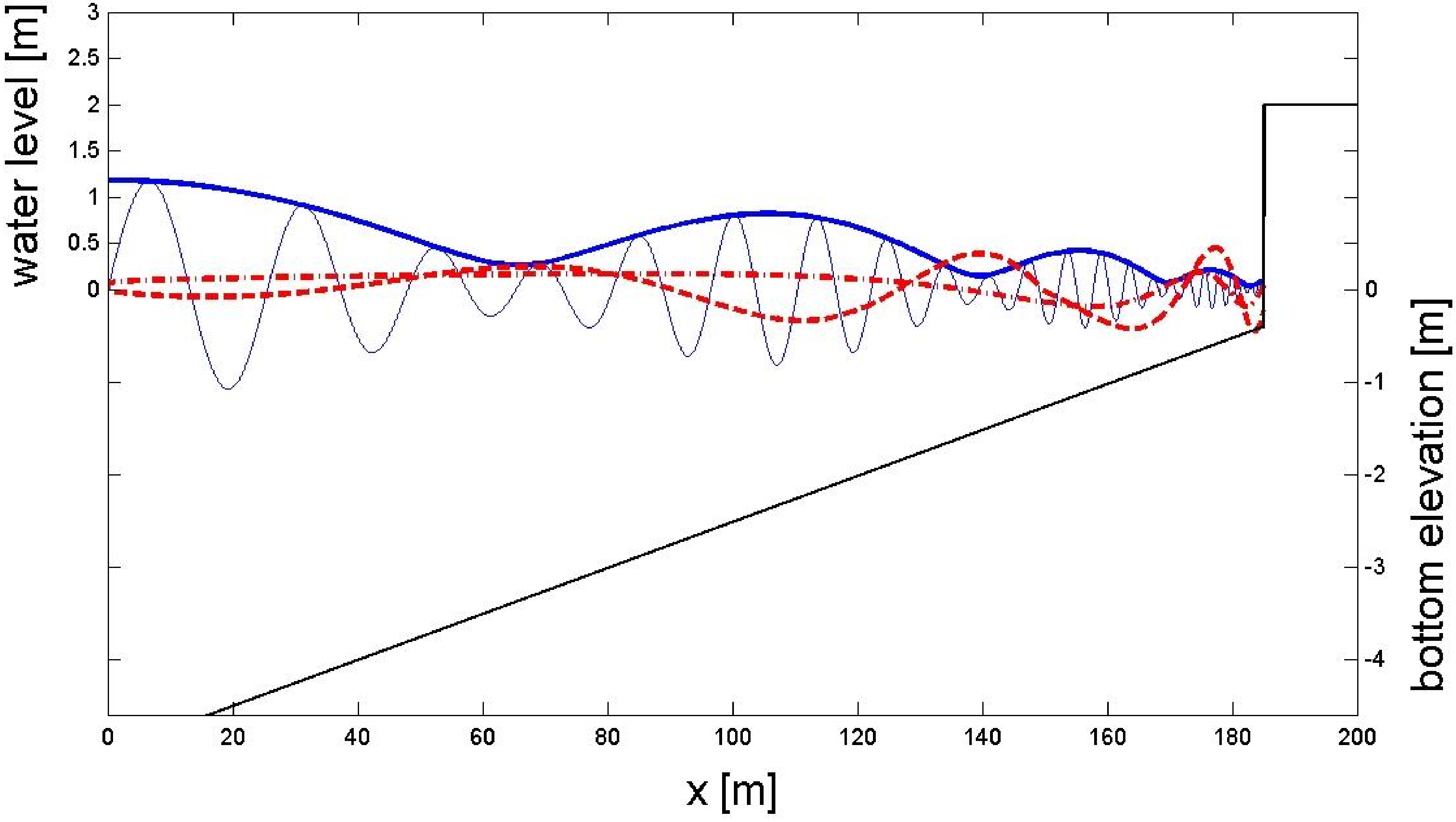
Dano Roelvink, Ap van Dongeren, Ad Reniers,
Jaap van Thiel de Vries, Robert McCall, Bas Hoonhout, Fedor Baart

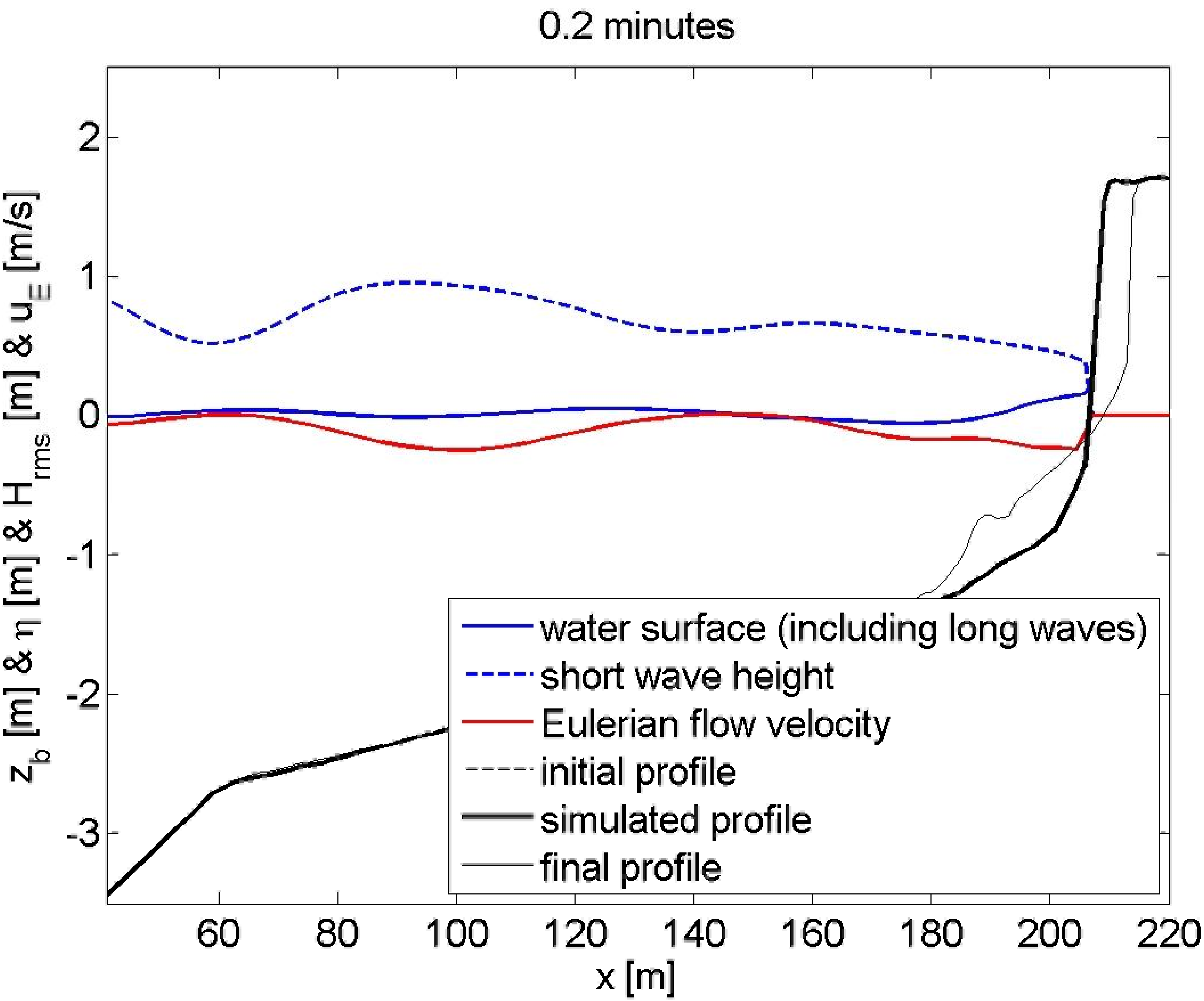
Contents

- Model philosophy and model description
- Examples
- Online XBeach Community
- Running XBeach

Model Philosophy

Near shore hydrodynamics and morphodynamics during storm conditions are dominated by time scales associated with wave groups and longer.




0.2 minutes
z_b [m] & η [m] & H_{rms} [m] & u_E [m/s]
x [m]
2
1
0
-1
-2
-3
60
80
100
120
140
160
180
200
220
water surface (including long waves)
short wave height
Eulerian flow velocity
initial profile
simulated profile
final profile

Model Description: Surf Beat model

Long waves

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}-\nu_h\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)=-\frac{\tau_{bx}}{\rho h}-g\frac{\partial \eta}{\partial x}+\frac{F_x}{\rho h}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+\nu_h\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)=-\frac{\tau_{by}}{\rho h}-g\frac{\partial \eta}{\partial y}+\frac{F_y}{\rho h}$$

$$\frac{\partial z_s}{\partial t}+\frac{\partial hu}{\partial x}+\frac{\partial hv}{\partial y}=0$$

Short waves

And

Rollers

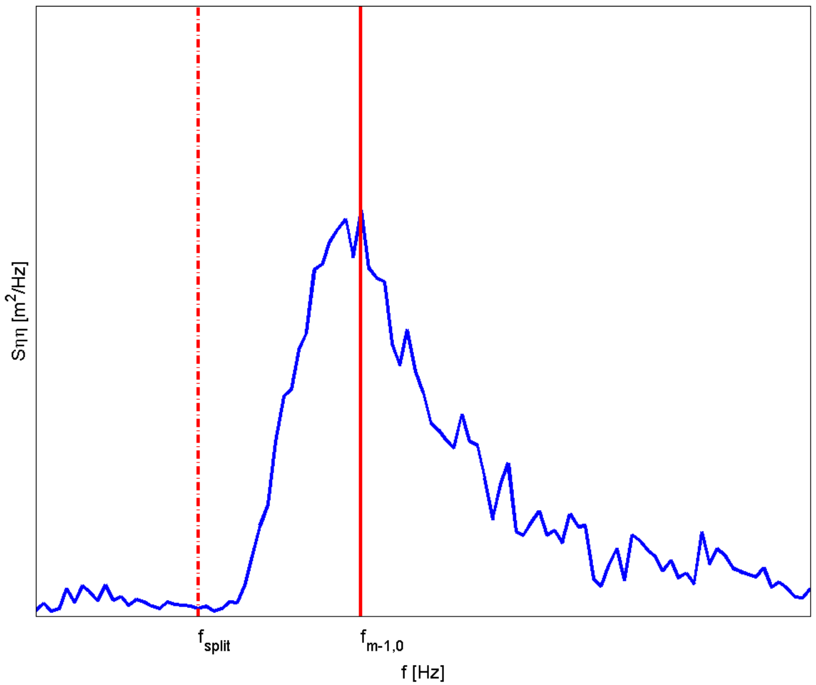
$$\frac{\partial A}{\partial t}+\frac{\partial c_x A}{\partial x}+\frac{\partial c_y A}{\partial y}+\frac{\partial c_\theta A}{\partial \theta}=-\frac{D_w}{\sigma}$$

$$\frac{\partial S_r}{\partial t}+\frac{\partial c_x S_r}{\partial x}+\frac{\partial c_y S_r}{\partial y}+\frac{\partial c_\theta S_r}{\partial \theta}=-D_r+D_w$$

$$F_x=-\left(\frac{\partial S_{xx}}{\partial x}+\frac{\partial S_{xy}}{\partial y}\right)$$

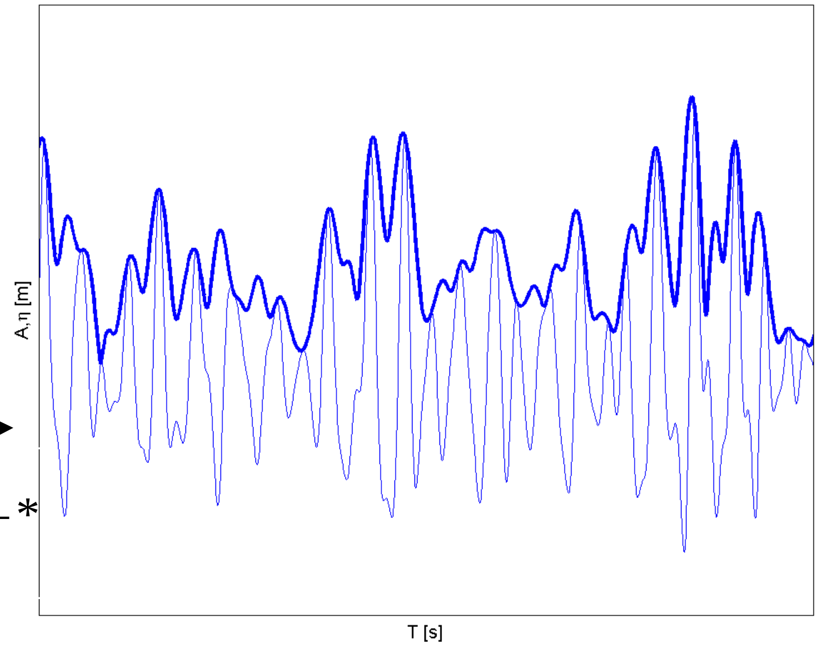
$$F_y=-\left(\frac{\partial S_{xy}}{\partial x}+\frac{\partial S_{yy}}{\partial y}\right)$$

Surf Beat: Boundary Conditions



$$E_w(x,t) = \frac{1}{2}\rho g \,|\, A_{low}(x,t)\,|^2$$

Hilbert Transform



$$\eta(x,t) = \sum_{j=N_{split}+1}^{N} \hat{\eta}_j e^{i(\sigma_j t - k_{x,j} x + \phi_j)} + *$$

$$\eta(x,t) = \sum_{j=1}^{N_{split}} \hat{\eta}_j e^{i(\sigma_j t - k_{x,j} x + \phi_j)} + *$$

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Model Description: Sediment transport

$$\underbrace{\frac{\partial hC}{\partial t}+\overbrace{\frac{\partial hCu^E}{\partial x}+\frac{\partial hCv^E}{\partial y}+\frac{\partial}{\partial x}\left[D_h h\frac{\partial C}{\partial x}\right]}^{=S_x}+\frac{\partial}{\partial y}\left[D_h h\frac{\partial C}{\partial y}\right]}_{}=\frac{hC_{eq}-hC}{T_s}$$

(Bracket above: $\frac{\partial hCu^E}{\partial x} + \ldots + \frac{\partial}{\partial x}\left[D_h h\frac{\partial C}{\partial x}\right]$ $= S_x$; bracket below: $\frac{\partial hCv^E}{\partial y} + \ldots + \frac{\partial}{\partial y}\left[D_h h\frac{\partial C}{\partial y}\right]$ $= S_y$)

- Depth-integrated advection-diffusion equation
- Equilibrium sediment concentration determined by extended Van Rijn 2008 formulation or Soulsby-Van Rijn formulation
- Sediment advection velocity includes seaward return flow
- T_s is adaptation time scale:

Model Description: Bed Update

- ***Sediment transport gradients**:*

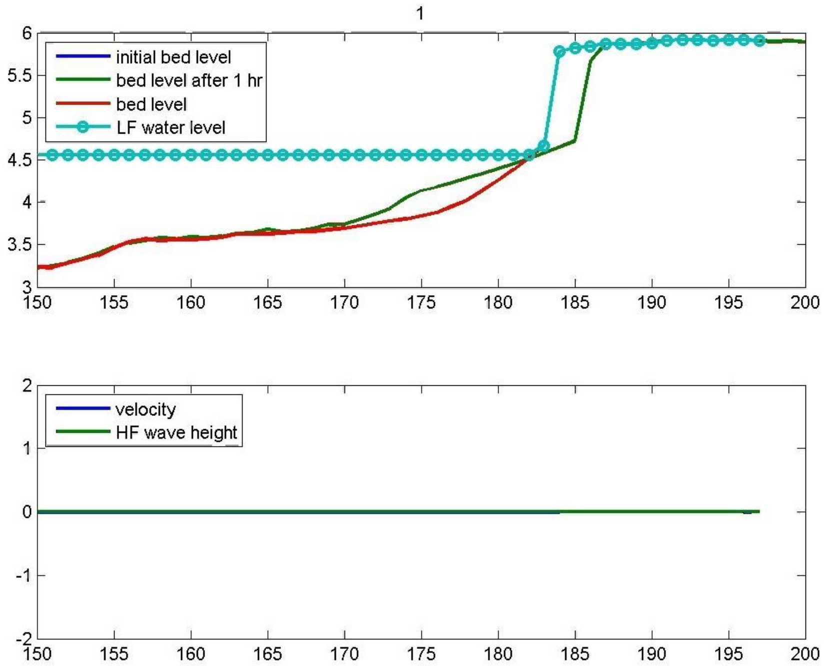
$$(1-\varepsilon)\frac{\partial z_b}{\partial t} + f_{mor}\left(\frac{\partial S_x}{\partial x} + \frac{\partial S_y}{\partial y}\right) = 0$$

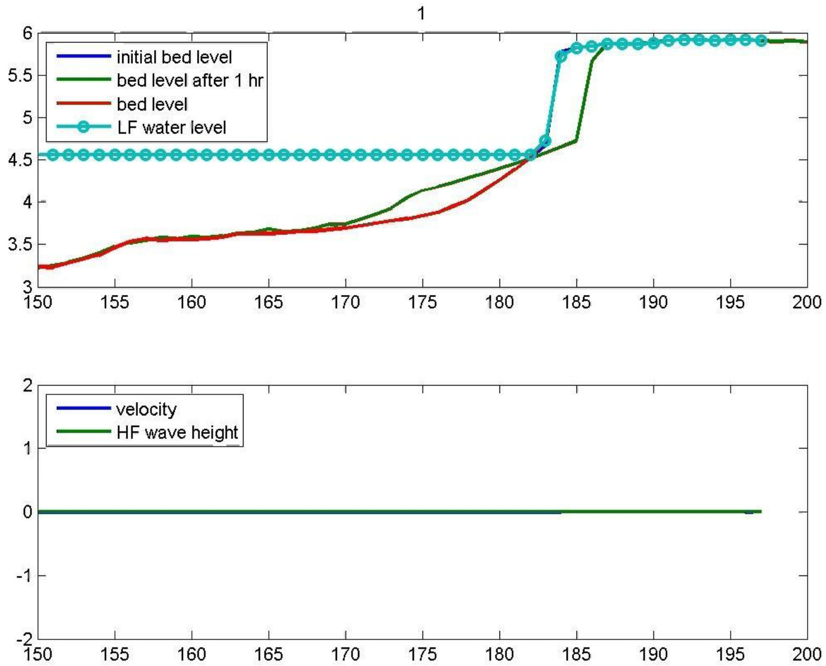
- ***Avalanching** (to simulate interaction with dry dune):*

$$\frac{\partial z_b}{\partial x} > m_{cr} \quad \text{or} \quad \frac{\partial z_b}{\partial y} > m_{cr}$$

- *Different critical slopes (mcr) for dry and wet points*
- *Default values are above water (~ 1.0) and below water (~ 0.10-0.3)*
- *Avalanching is carried out in both x- and y- direction*

Avalanching

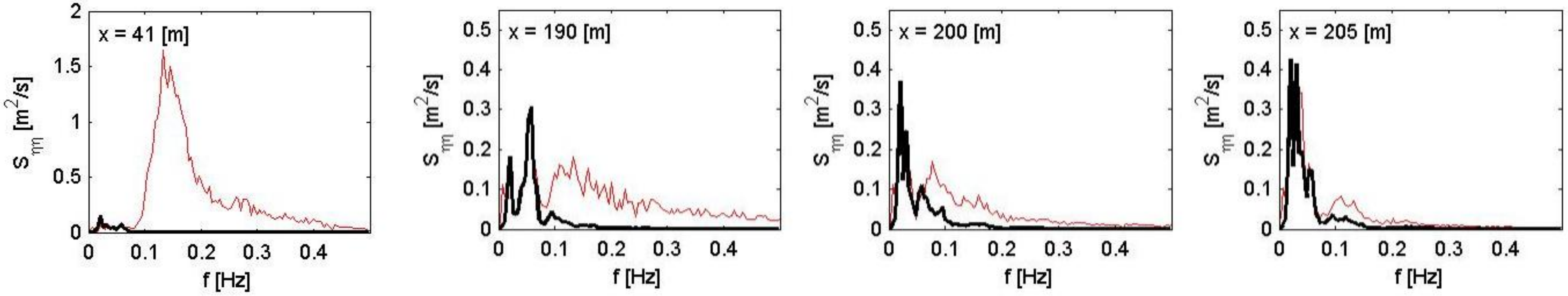




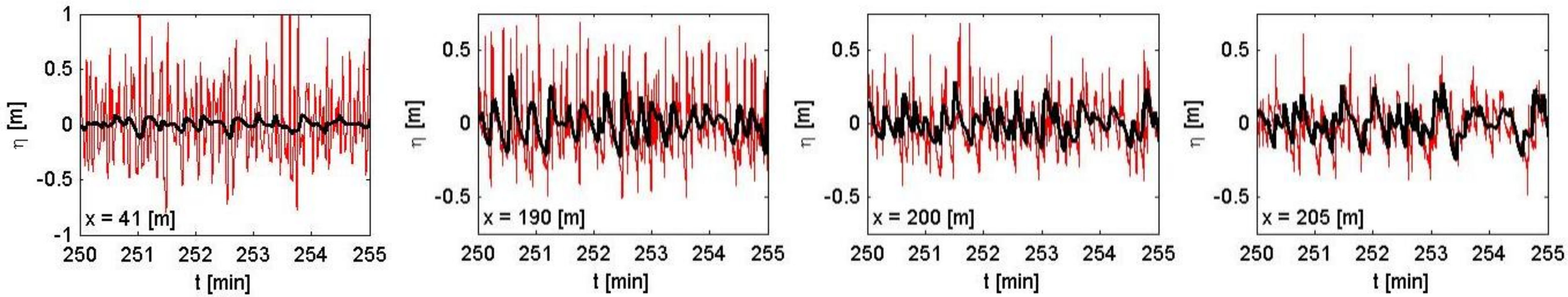
Dune erosion case: Deltaflume test

Dune erosion case: Deltaflume test

Wave spectra



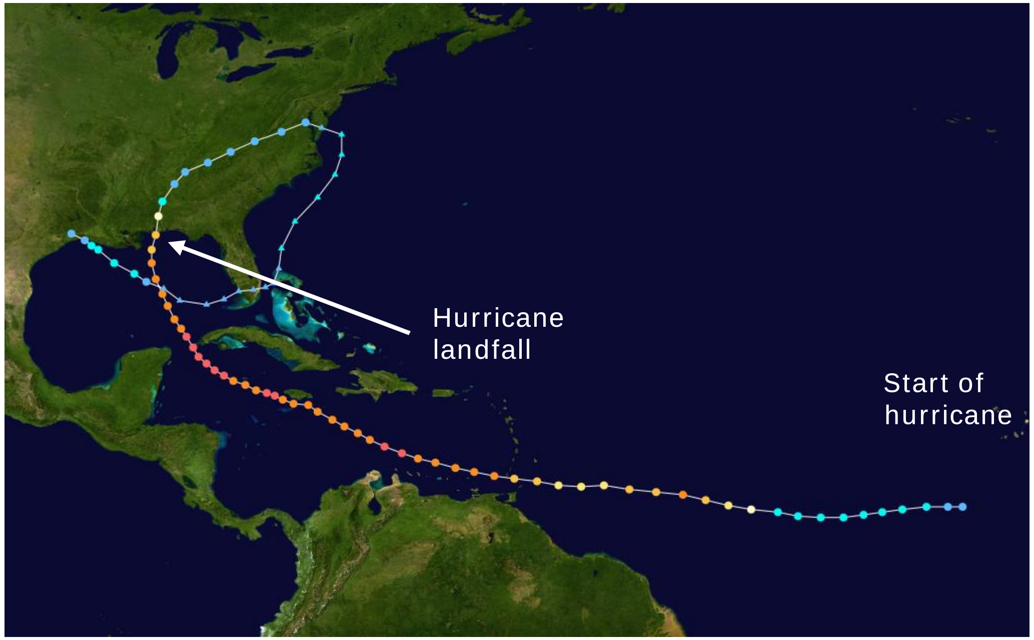
Water surface elevation time series



Dune erosion case: Deltaflume test

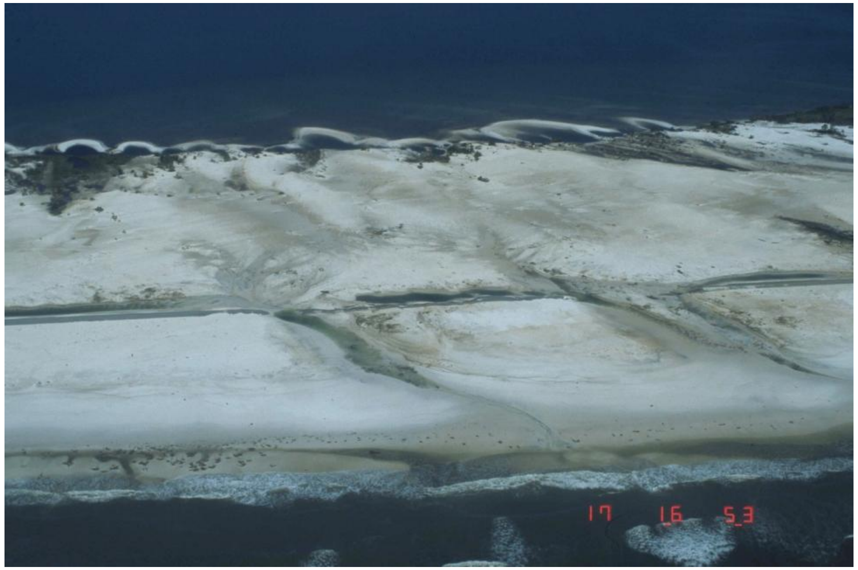
Overwash case: Santa Rosa Island

Hurricane Ivan: 16 September 2004



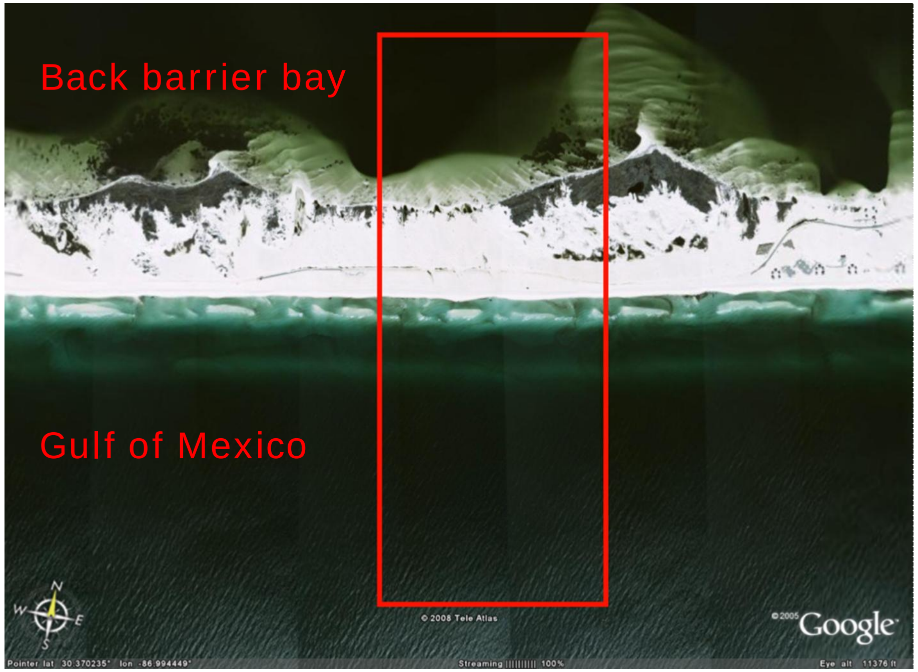
Overwash case: Santa Rosa Island

Pre- and post-storm Santa Rosa Island

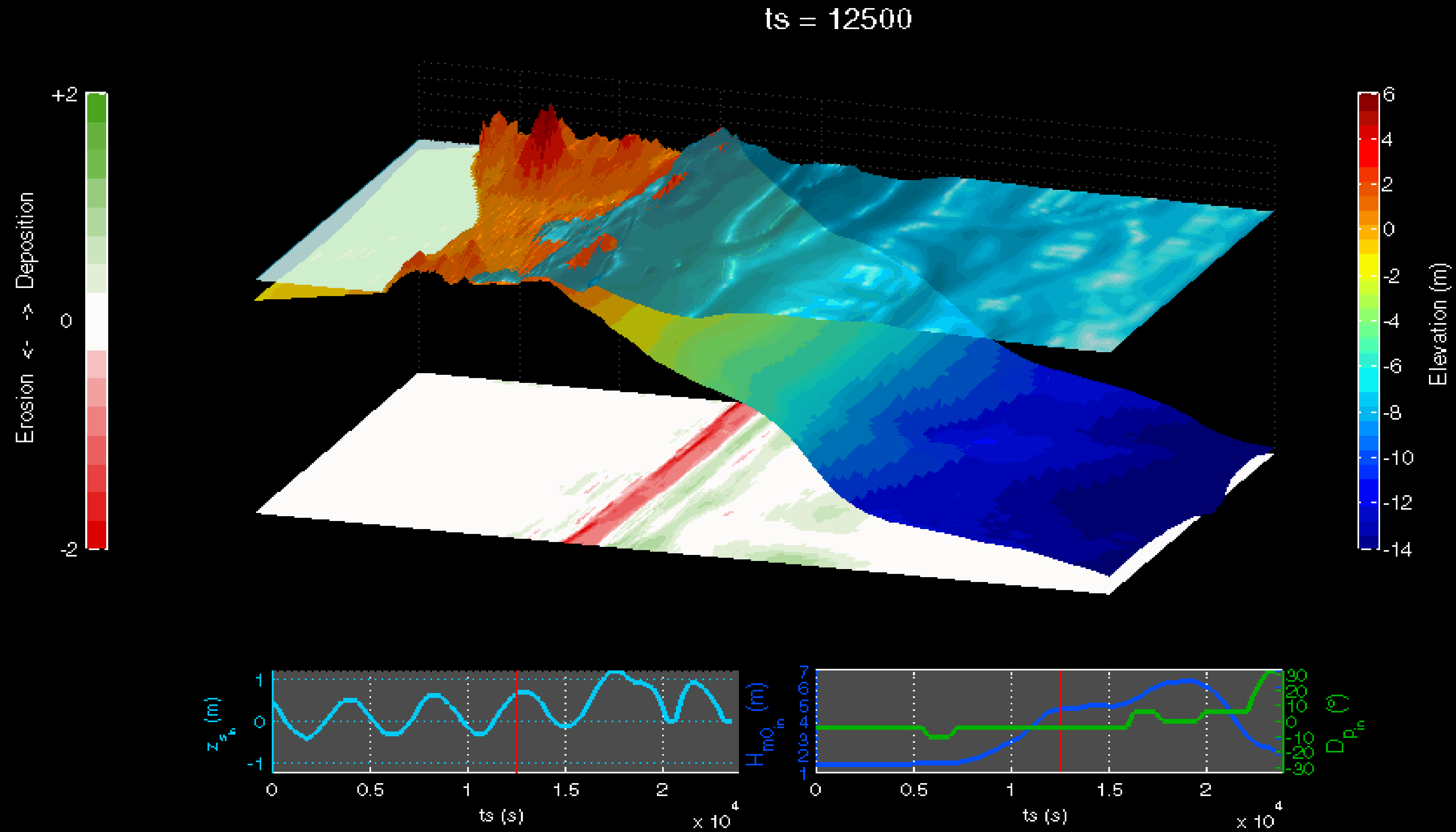


Overwash case: Santa Rosa Island

- Domain:
  - 3 km cross-shore
  - 1 km longshore
- Simulation period 41 hours
- Surge level extracted from Delft2D numerical model
  - Maximum surge 1.2m +NAVD
- Wave conditions extracted from SWAN model
  - Maximum significant wave height 6.5m
  - Peak wave period 20s



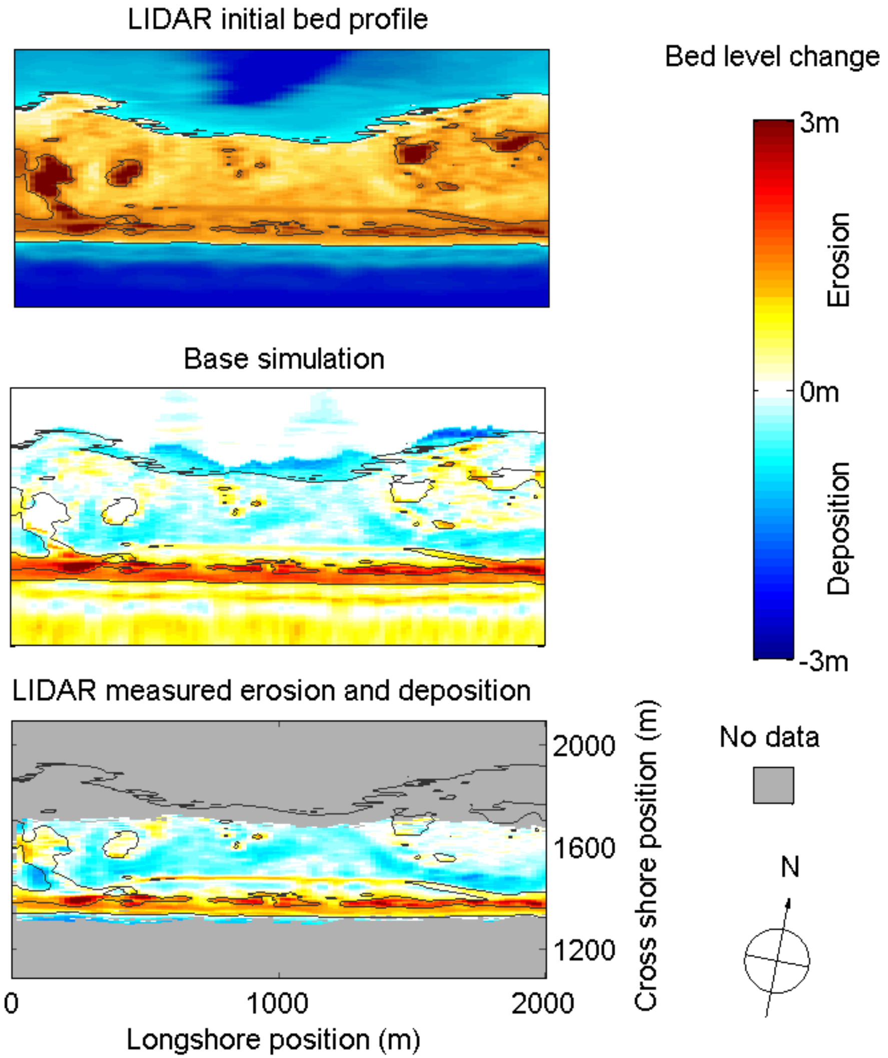
Overwash case: Santa Rosa Island



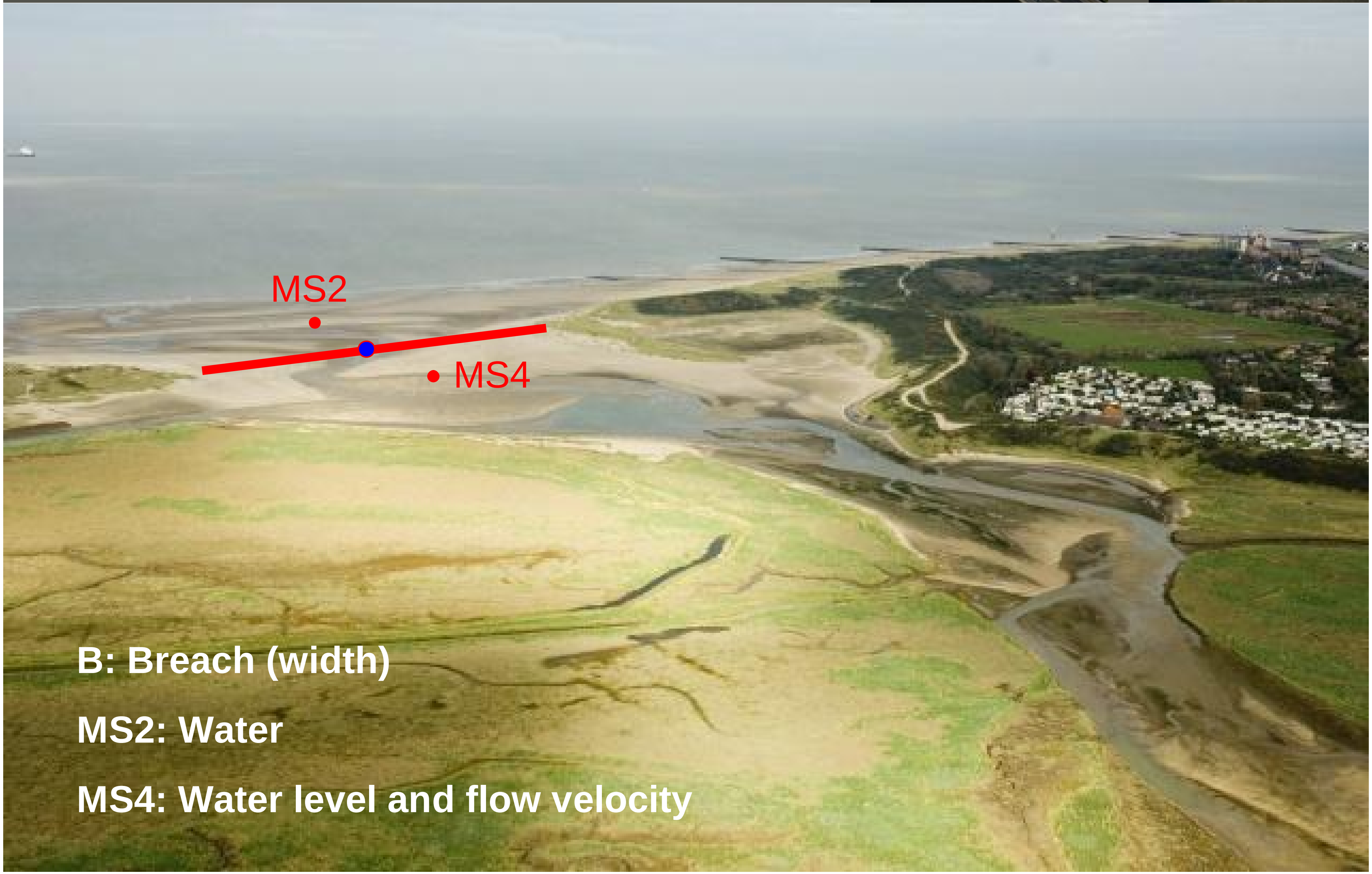
Overwash case: Santa Rosa Island

Similar erosion and deposition patterns:

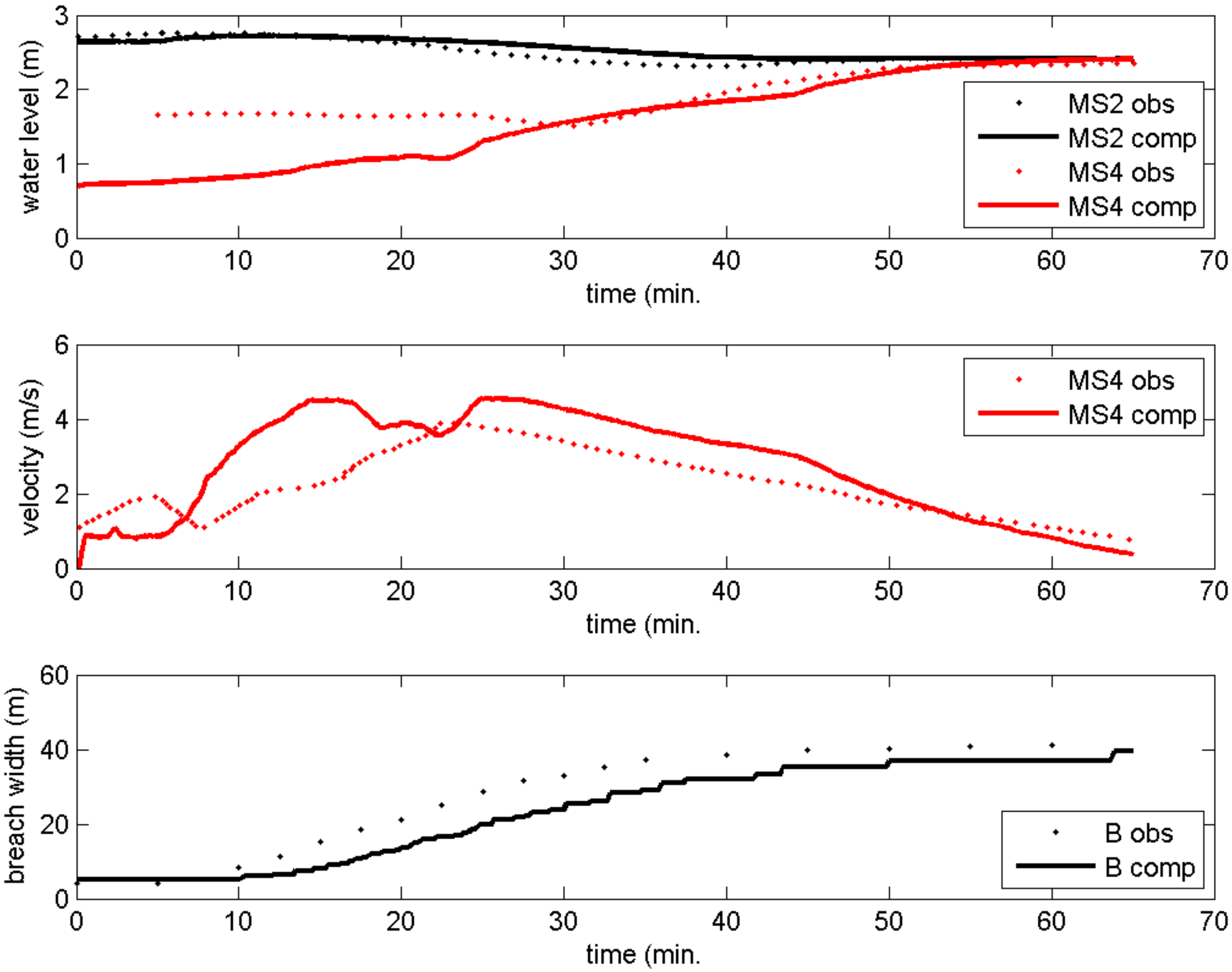
- erosion of dune face
- deposition on island



Breaching Case: Zwin



Breaching Case: Zwin



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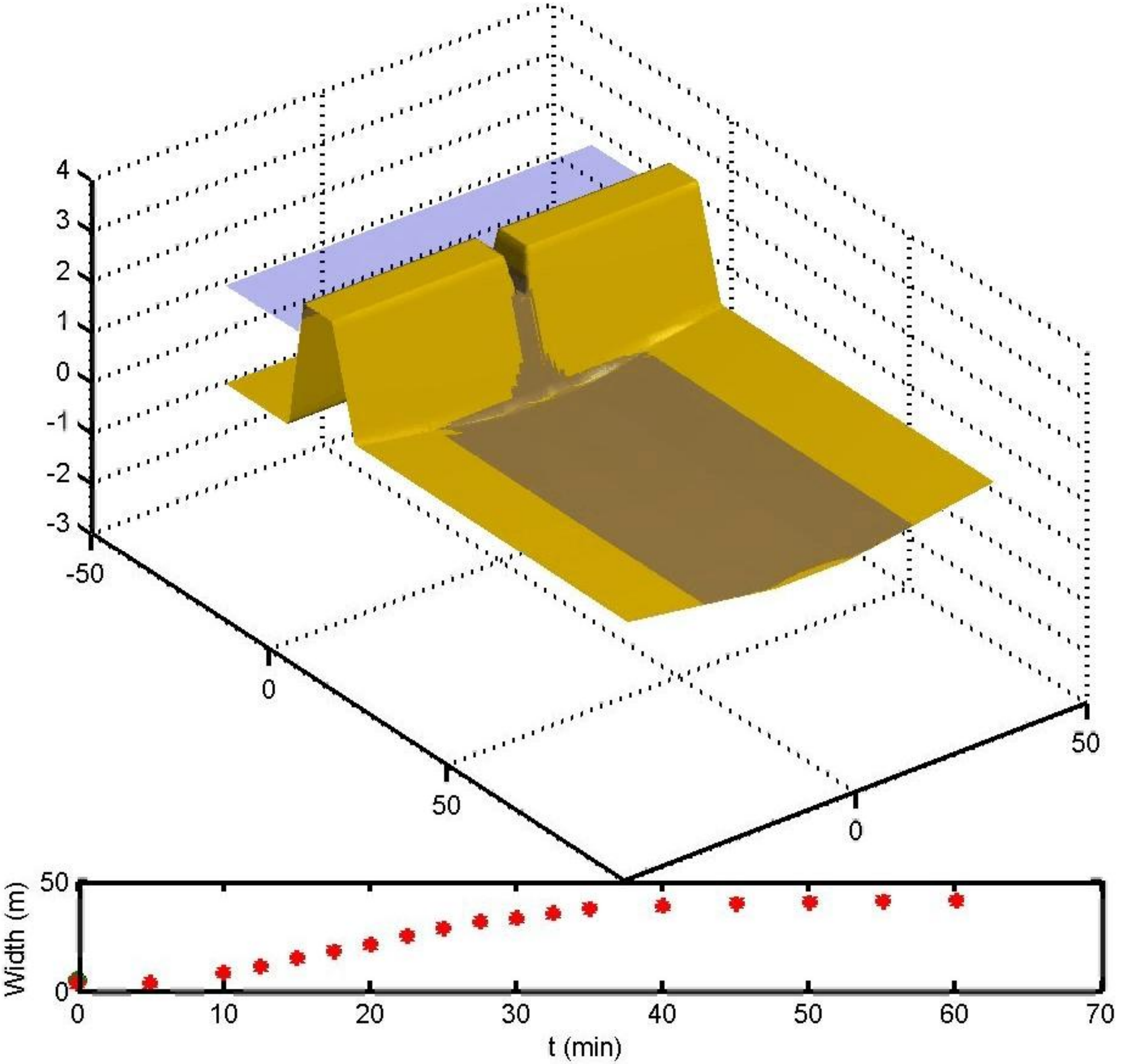
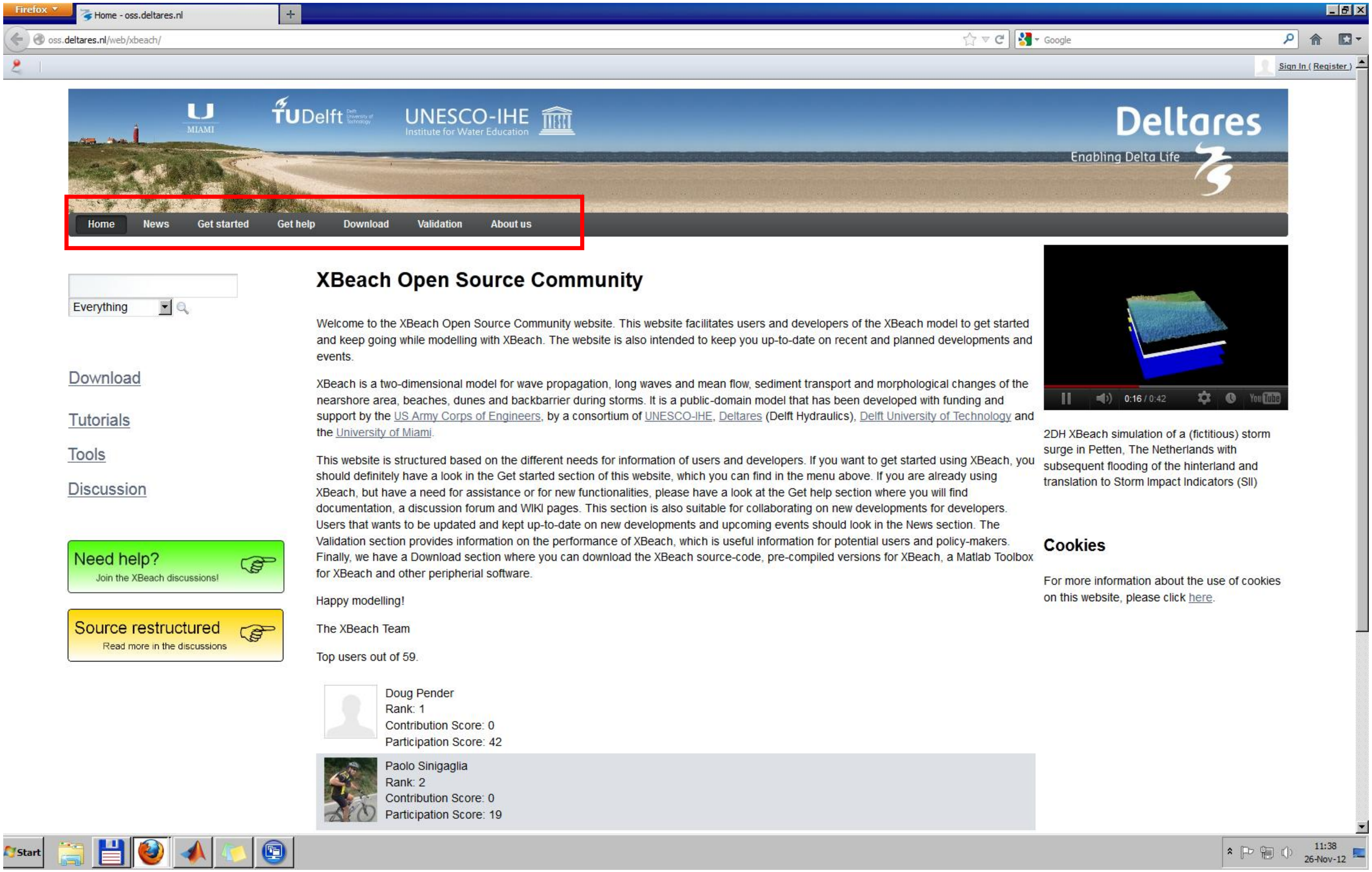
Breaching Case: Zwin



XBeach.org (accessible via oss.deltares.nl)



Home - oss.deltares.nl

oss.deltares.nl/web/xbeach/

Sign In (Register)

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Enabling Delta Life

Home | News | Get started | Get help | Download | Validation | About us

Everything

Download

Tutorials

Tools

Discussion

Need help?
Join the XBeach discussions!

Source restructured
Read more in the discussions

XBeach Open Source Community

Welcome to the XBeach Open Source Community website. This website facilitates users and developers of the XBeach model to get started and keep going while modelling with XBeach. The website is also intended to keep you up-to-date on recent and planned developments and events.

XBeach is a two-dimensional model for wave propagation, long waves and mean flow, sediment transport and morphological changes of the nearshore area, beaches, dunes and backbarrier during storms. It is a public-domain model that has been developed with funding and support by the US Army Corps of Engineers, by a consortium of UNESCO-IHE, Deltares (Delft Hydraulics), Delft University of Technology and the University of Miami.

This website is structured based on the different needs for information of users and developers. If you want to get started using XBeach, you should definitely have a look in the Get started section of this website, which you can find in the menu above. If you are already using XBeach, but have a need for assistance or for new functionalities, please have a look at the Get help section where you will find documentation, a discussion forum and WIKI pages. This section is also suitable for collaborating on new developments for developers. Users that wants to be updated and kept up-to-date on new developments and upcoming events should look in the News section. The Validation section provides information on the performance of XBeach, which is useful information for potential users and policy-makers. Finally, we have a Download section where you can download the XBeach source-code, pre-compiled versions for XBeach, a Matlab Toolbox for XBeach and other peripherial software.

Happy modelling!

The XBeach Team

Top users out of 59.

Doug Pender
Rank: 1
Contribution Score: 0
Participation Score: 42

Paolo Sinigaglia
Rank: 2
Contribution Score: 0
Participation Score: 19

2DH XBeach simulation of a (fictitious) storm surge in Petten, The Netherlands with subsequent flooding of the hinterland and translation to Storm Impact Indicators (SII)

Cookies

For more information about the use of cookies on this website, please click here.

Running XBeach:

- Simulation folder where you collect the following files:
- XBeach executable
- Params.txt file
- Depth file

- Additional Files:
  - Grid file(s): In case you work with non-equidistant grids
  - Wave input files: This can be a list of (irregular) wave conditions
  - Waterlevel input files: In case you want to apply varying tide and surge conditions
  - Files related to additional functionality: i.e. to specify structure, ground water flow, tracers, river discharge.

Running XBEACH: Tips and Tricks

Setting up a Grid:

- Grid resolution should be sufficient to describe long wave
- Vary grid resolution based on Courant condition
- Near water line, grid resolution based on expected morphological changes

Define Depths:

- Offshore boundary at sufficiently deep water for realistic long wave boundary conditions (n < 0.8)
- Uniform coast (three cells) near lateral boundaries and offshore boundary

Settings:

- Use defaults as much as possible (especially when you start)

REMARK: Tricks for robuust model set-up are implemented in Toolbox

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Enabling Delta Life

HANDS ON I: Dune erosion and overwash

Dune erosion at Delfland, Netherlands (1D)

Overwash at Santa Rosa Island, USA (2D)

Getting Started (1)

- All will receive hardcopy assignments and a USB stick that contains model software, documentation and software.
- When you brought your own PC:
  - Copy all data to a local folder on your laptop and wait for further instructions.
- Otherwise have fun with our Deltares laptops

Deltares

Enabling Delta Life

THEORY II: Advanced functionality

Dano Roelvink, Ap van Dongeren, Ad Reniers,

Jaap van Thiel de Vries, Robert McCall, Bas Hoonhout, Fedor Baart

Contents

r2

- Hard Layers
- Sediment Transport Options
- Output Options
- Drifters
- Curvi Linear Grids
- Matlab Toolbox

r2 dit kan weg?
rooijen; 26-11-2012

Hard layers

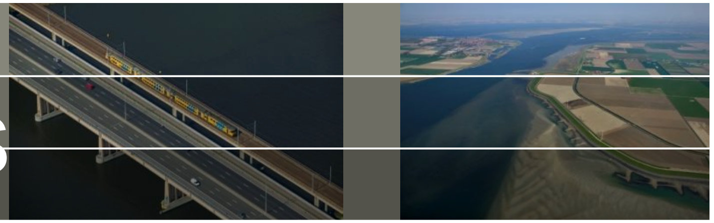
• Hard structures substantially affect the morphodynamic evolution during a storm in both cross-shore and longshore direction


Hondsbosche en Pettemer sea defense


Coral reef Australia: Great Barrier Reef


oostende sea defense

Hard Layers



Implementation:

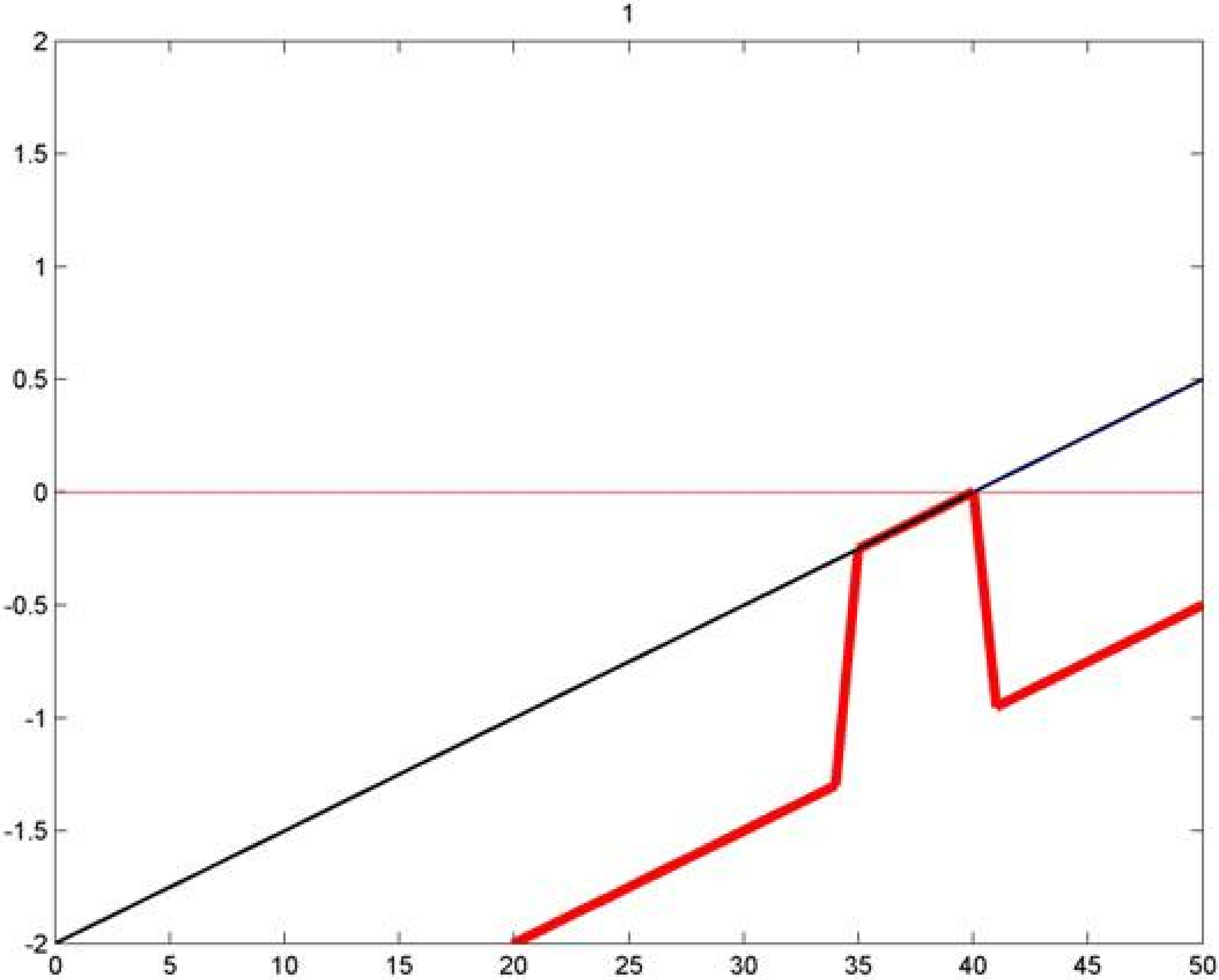
- You specify the sediment thickness on top of a hard layer.
- In case the sediment thickness on top of the layer becomes sufficiently small the sediment source term is limited:

$$\frac{\partial hC}{\partial t}+\frac{\partial hCu^{E}}{\partial x}+\frac{\partial hCv^{E}}{\partial y}+\frac{\partial}{\partial x}\left[D_h h\frac{\partial C}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_h h\frac{\partial C}{\partial y}\right]=\min\left(S_{\max},\frac{hC_{eq}-hC}{T_s}\right)$$

- In which $S_{\max}=(1-p)\frac{dz_{remain}}{dt}$

Hard Layers

- To setup a model with a hard layer two additional keywords need to be specified in params.txt:
  - struct: struct =1 in case of a hardlayer and struct = 0 (default) in the abscence of hardlayer.
  - ne_layer: ne_layer is a filename that contains the thickness of the sediment layer on top of the hardlayer.



1
2
1.5
1
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-1
-1.5
-2
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5
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25
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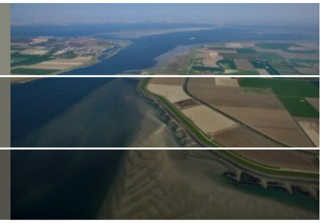
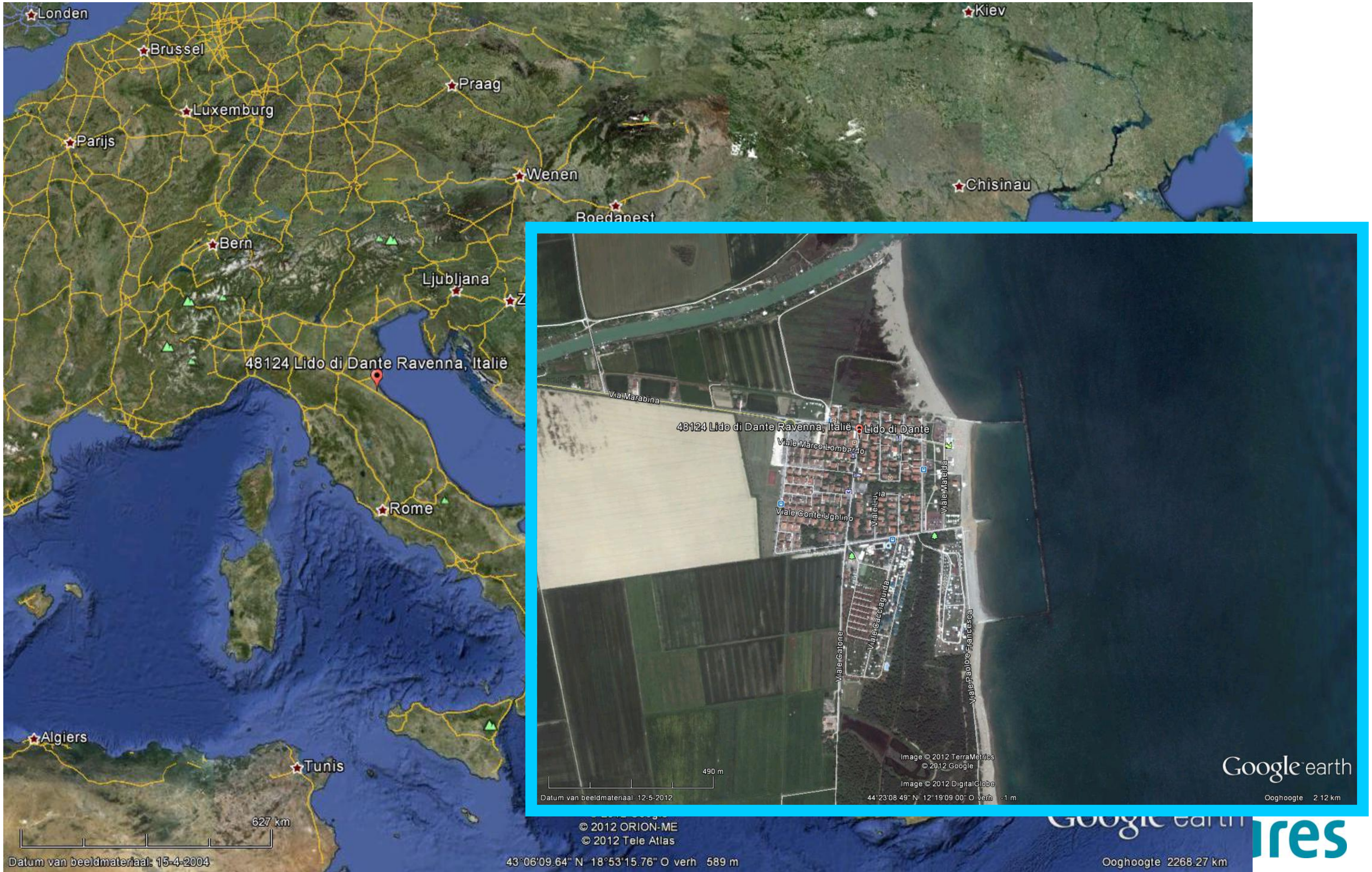
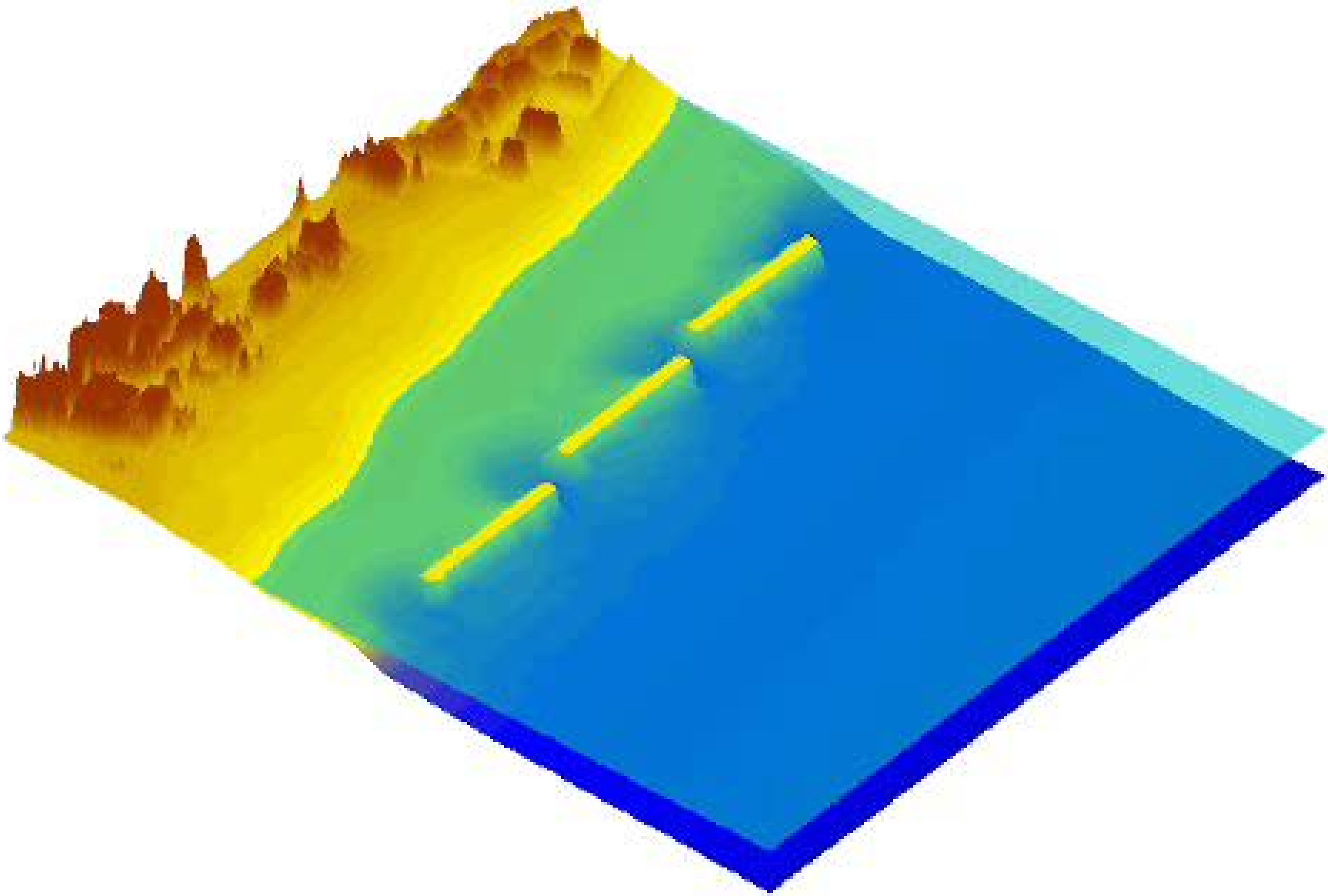
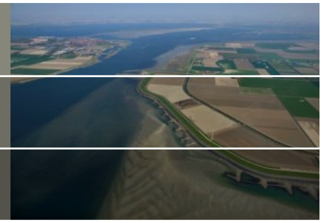
45
50

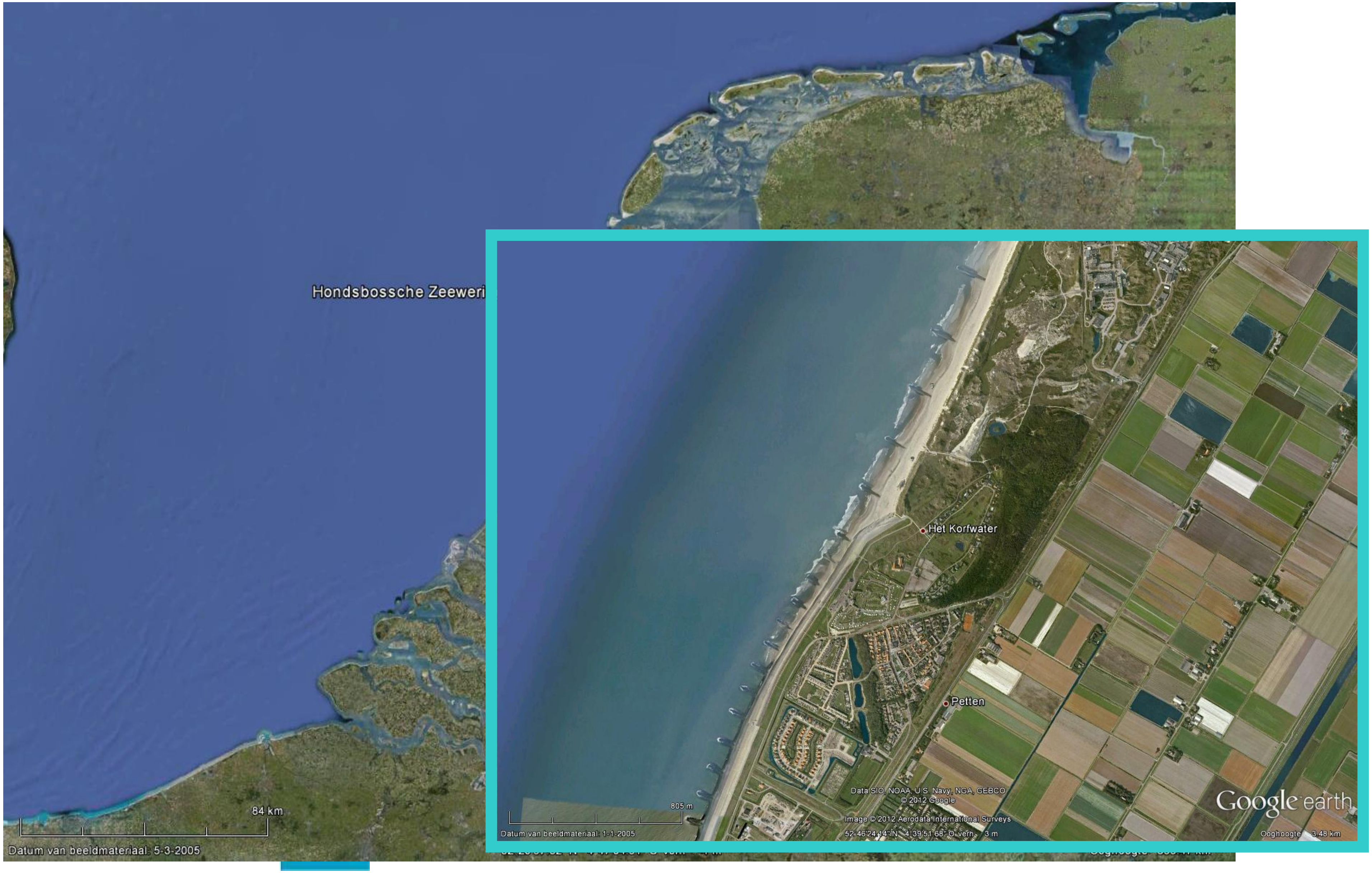




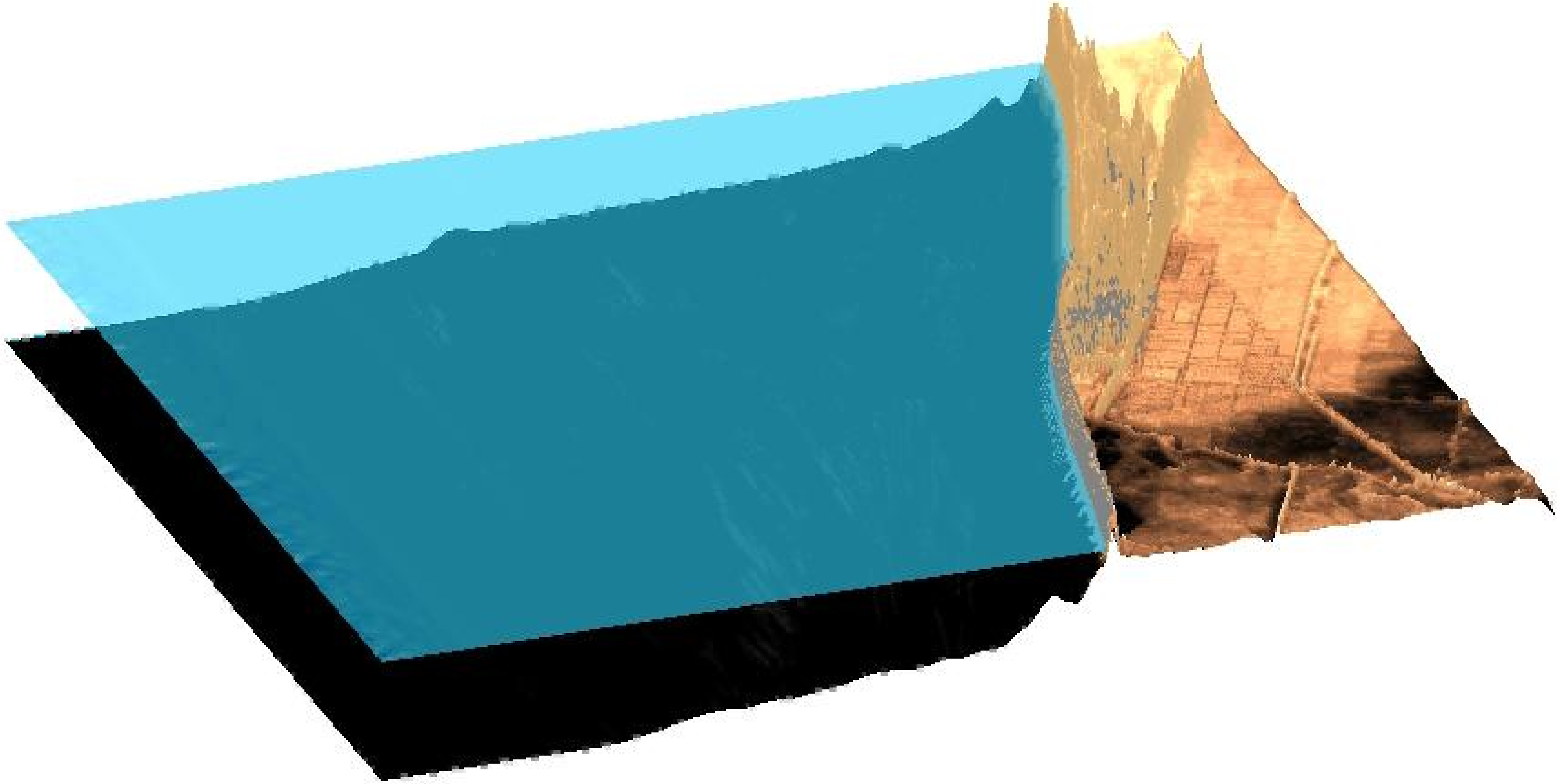
Londen
Brussel
Praag
Luxemburg
Parijs
Wenen
Boedapest
Kiev
Chisinau
Bern
Ljubljana
48124 Lido di Dante Ravenna, Italië
Rome
Algiers
Tunis
627 km
Datum van beeldmateriaal: 15-4-2004
© 2012 ORION-ME
© 2012 Tele Atlas
43°06'09.64" N 18°53'15.76" O verh 589 m
Ooghoogte 2268.27 km
Via Marabina
48124 Lido di Dante Ravenna, Italië
Lido di Dante
Viale Marco Lombardo
Viale Conte Ugolino
Viale Matelda
Viale Catone
Viale Paolo e Francesca
490 m
Image © 2012 TerraMetrics
© 2012 Google
Image © 2012 DigitalGlobe
Datum van beeldmateriaal: 12-5-2012
44°23'08.49" N 12°19'09.00" O verh 1 m
Google earth
Ooghoogte 2.12 km

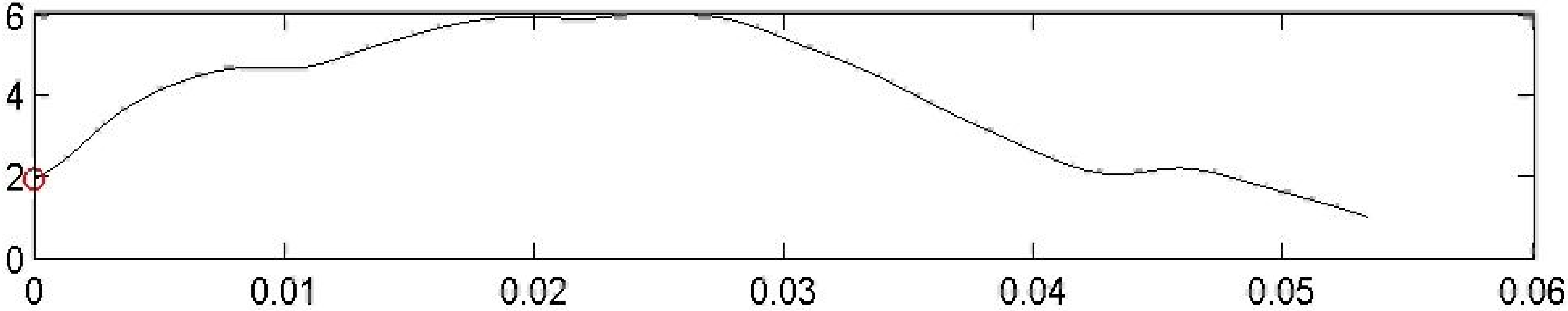






Hondsbossche Zeeweri
84 km
Datum van beeldmateriaal: 5-3-2005
Het Korfwater
Petten
805 m
Datum van beeldmateriaal: 1-1-2005
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Google
Image © 2012 Aerodata International Surveys
Google earth





6
4
2
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0
0.01
0.02
0.03
0.04
0.05
0.06

Sediment Transport Options:

- Sediment transports in XBeach are solved for with an advection diffusion equation (as we saw in the introduction):

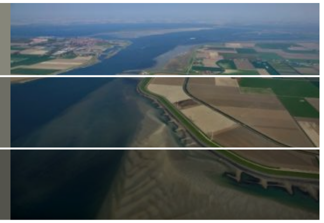
$$\frac{\partial hC}{\partial t}+\frac{\partial hCu_{rep}}{\partial x}+\frac{\partial hCv_{rep}}{\partial y}+\frac{\partial}{\partial x}\left[D_h h\frac{\partial C}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_h h\frac{\partial C}{\partial y}\right]=\min\left(S_{\max},\frac{hC_{eq}-hC}{T_s}\right)$$

- The sediment source in this equation can be computed with two (equilibrium) transport formulations:
  - Soulsby van Rijn (1997)
  - Van Rijn (2007)
  - (Reniers et al. 2012, accepted)

- Both transport formulations are extended with the effect of wave breaking induced turbulence and limiters for super critical flow

- The sediment advection speed can be corrected to account for onshore sediment transport due to skewed and assymetric waves

Van Rijn 2007:



- Transport formulation reads (see papers Journal of Hydraulic Engineering for details):

$$c_{eq} = \frac{A_{sb}}{h}\left(\sqrt{u^2 + 0.64U_w^2} - u_{cr}\right)^{1.5} + \frac{A_{ss}}{h}\left(\sqrt{u^2 + 0.64U_w^2} - u_{cr}\right)^{2.4}$$

- To this formulation two modifications were made:

1 $$U_w = \sqrt{U_w^2 + 1.45k_b}$$

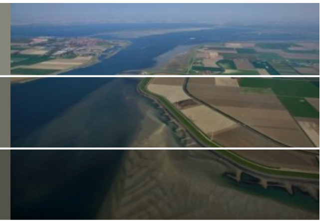
$$k_b = \frac{\overline{k_s}}{\exp(h/L_{mix}) - 1}$$

Wave averaged turbulence

$$k_b = \frac{\overline{k_s}\,T/T_{bore}}{\exp(h/L_{mix}) - 1}$$

Bore averaged turbulence

2 $$\min\left(\sqrt{u^2 + 0.64U_w^2}, \gamma_{s\max}\frac{gD_{50}}{c_f}\frac{\rho_s - \rho}{\rho}\right)$$

Onshore transport:

- The sediment advection speed can be corrected for the effect of onshore transport due to skewed and assymetric short waves:

$$u_{rep} = V_W \cos\theta_m + u^E$$
$$v_{rep} = V_W \sin\theta_m + v^E$$

- In which the sediment advection velocities due to wave skewness and asymmetry are estimated as

$$V_{W,Sk} = \gamma_{sk} \frac{\int_0^T u(t)^2 u(t)dt}{\int_0^T u(t)^2 dt} = \gamma_{sk} S_k u_{rms}$$

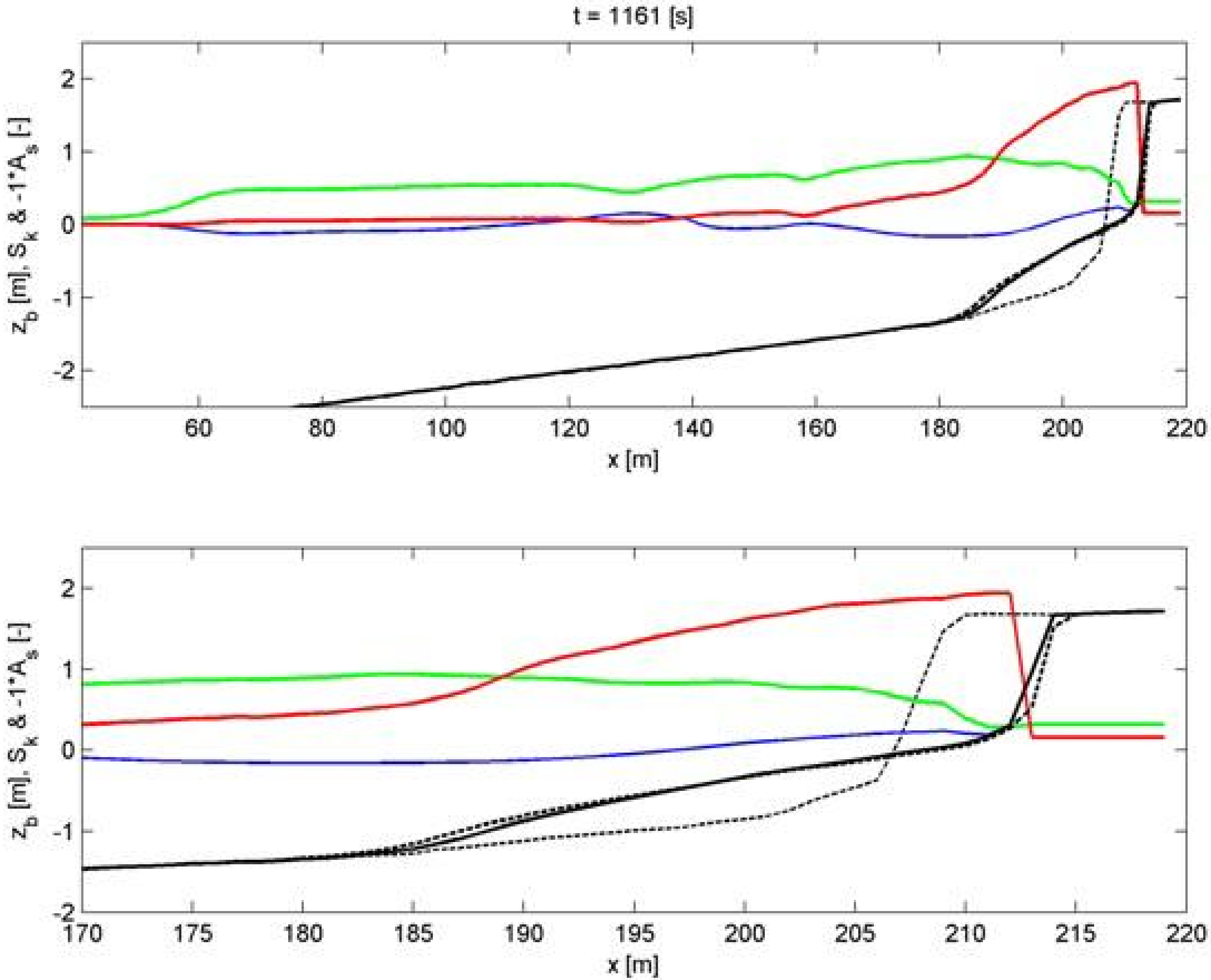
$$V_{W,As} = \gamma_{as} \frac{\int_0^T \left(a(t)/\omega\right)^2 u(t)dt}{\int_0^T \left(a(t)/\omega\right)^2 dt} \approx -\gamma_{as} A_s u_{rms}$$

$$V_W = V_{W,Sk} + V_{W,As} = u_{rms}\left(\gamma_{sk} S_k - \gamma_{as} A_s\right)$$

- The skewness (Sk) and assymetry (As) can be computed with two expressions (Ruessink and Van Rijn or Rienecker and Fenton)

Onshore transport:

- To setup a model with onshore sediment transport due to short waves the following keywords need to be set in params.txt:
  - facsk: Skewness related factor (default facsk = 0.1, range allowed [-1,1], remark that negative values will enhance offshore transport).
  - facas: Assymetry related factor (default facas = 0.1, range allowed [-1,1], remark that negative values will enhance offshore transport).
  - waveform: Specifies the method to compute Skewness and Assymetry (default waveform = vanthiel (based on Rienecker Fenton))
- To setup a model that takes into account wave breaking induced turbulence on sediment suspensions you need to set:
  - turb: Default turb = bore averaged (waveform is automatically set to vanthiel)


t = 1161 [s]
z_b [m], S_k & -1*A_s [-]
x [m]
z_b [m], S_k & -1*A_s [-]
x [m]


Output Options

- All global variables can be outputed (see XBeach trunk spaceparams.tmpl for the full overview)
- We support two output formats:
  - Binary (*.dat file for each output variable)
  - NetCDF (one output file xboutput.nc that contains all output)
- And four output types:
  - Global output: Instantaneous output fields at time interval tintg
  - Point output: Instantaneous output at user specified locations (npoints) at time interval tintp
  - Runup gauge: Instantaneous runup levels at user specified locations (nrugauge) at time interval tintp
  - Mean output: Mean, Min, Max and Variance output fields over all computational time steps at time interval tintm

Global Output

To setup a model with Global Output the following keywords need to be specified in params.txt:

- outputformat: netcdf or fortran
- ncfilename: <filename> (default xboutput.nc)
- tstart: Start time of output (morphological time)
- tintg: Time interval for global output
- nglobalvar: Number of global output variables (as specified by user)
- Example:

```
tstart      = 0
tintg       = 120

nglobalvar    = 3
zs
u
v
```

Point Output

To setup a model with Point Output the following keywords need to be specified in params.txt:

- tintp: Time interval for point output
- npoints: Number of output point locations
- npointvar: Number of point output variables
- example

```
tstart      = 0
tintp       = 1

npoints     = 2
0 100
1000 100

npointvar   = 3
zs
u
v
```

Mean Output

To setup a model with Mean Output the following keywords need to be specified in params.txt:

- tintm: Interval time of mean,var,max,min output
- nmeanvar: Number of mean,min,max,var output variables
- example

```
tintm       = 3600

nmeanvar    = 3
zs
u
v
```

Drifters

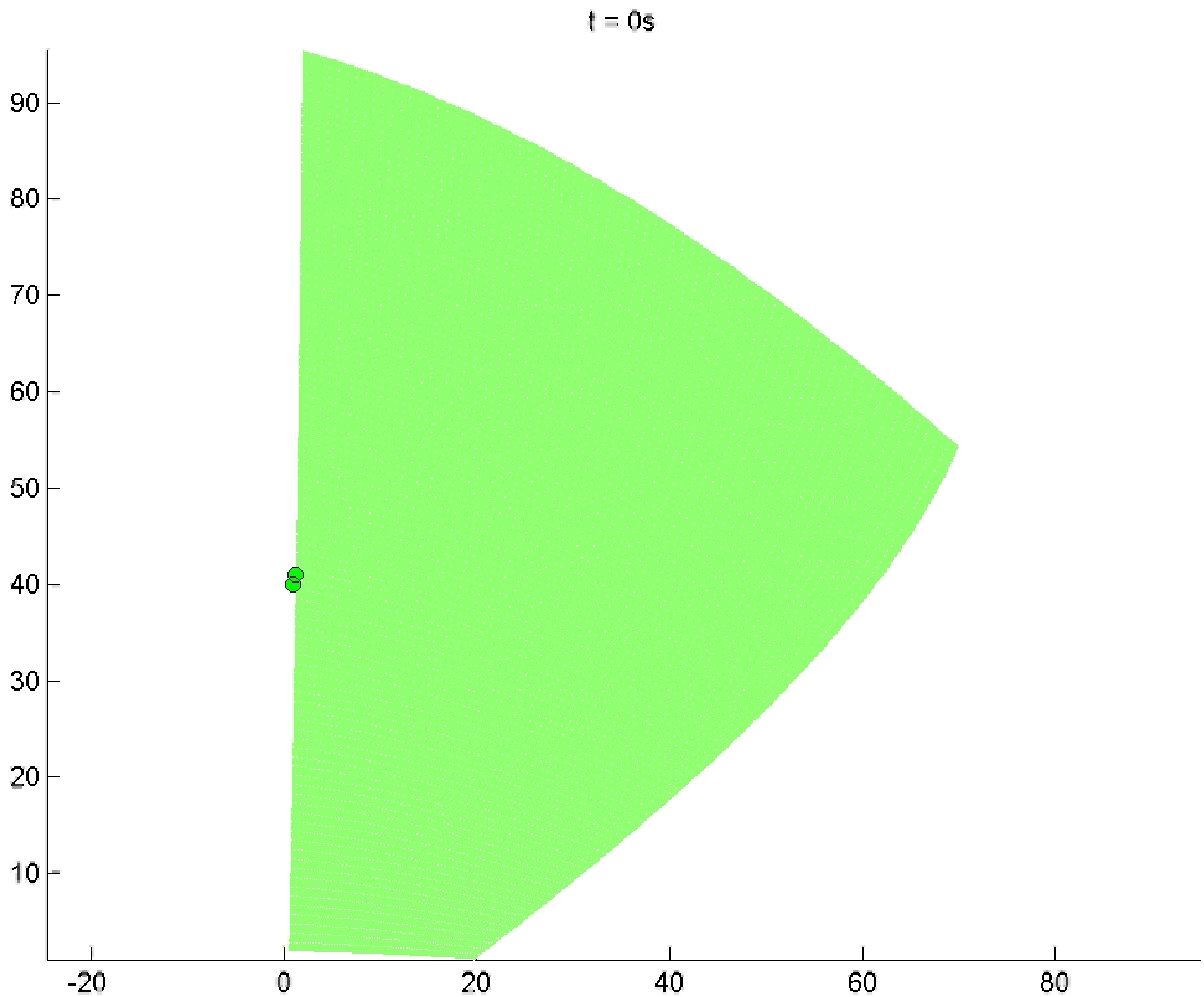
- Drifters are passive objects that move with the lagrangean speed. They are released at specified points and time and retrieved at given times.
- Integration is carried out each timestep based on the nearest uu and vv velocities.
- The routine is MPI compliant
- For curvilinear grids the time-integration is carried out in the (i,j) space, rather than the physical space. This is much easier and removes the need to find the cell where the drifter is at each timestep.
- The propagation speeds in (i,j) space are uu/dsu and vv/dnv respectively.

Using Drifters

- To setup a model with drifters the following keywords need to be specified in params.txt:
  - drifterfile = <filename>

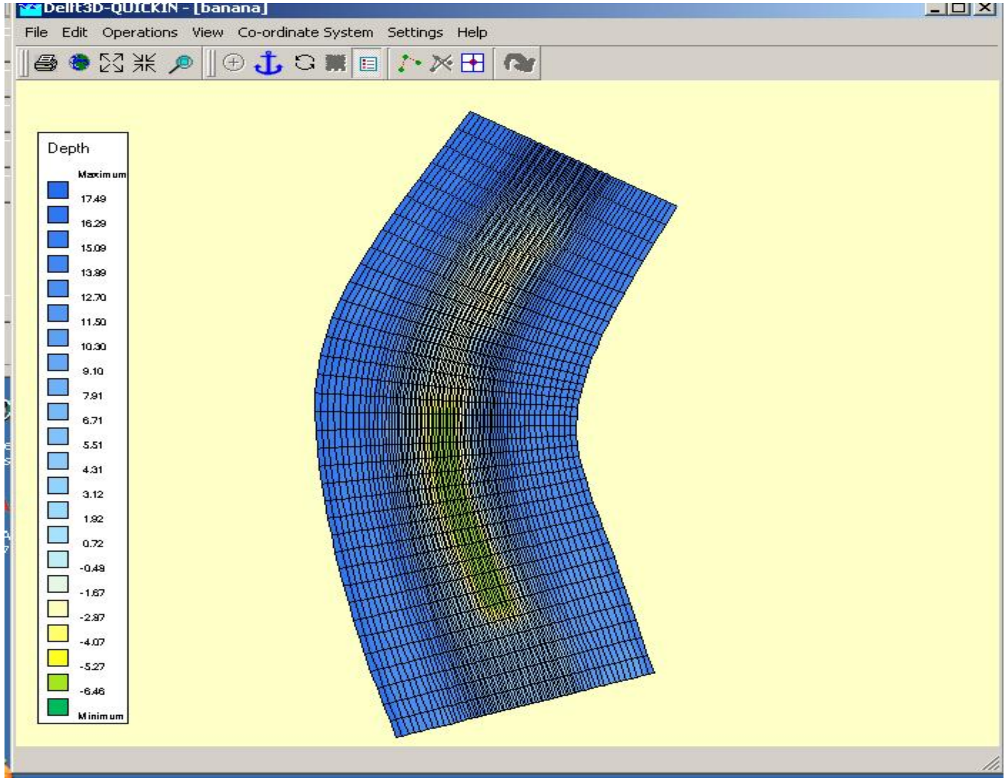
- The file <filename> should contain a number of records where each describes a drifter deployment by x position (m), y position (m), time of release (s) and time of retrieval (s)

- Results (x,y,time) are written to files drifternnn.dat. At the moment this option works only for outputformat=fortran


t = 0s
90
80
70
60
50
40
30
20
10
-20
0
20
40
60
80

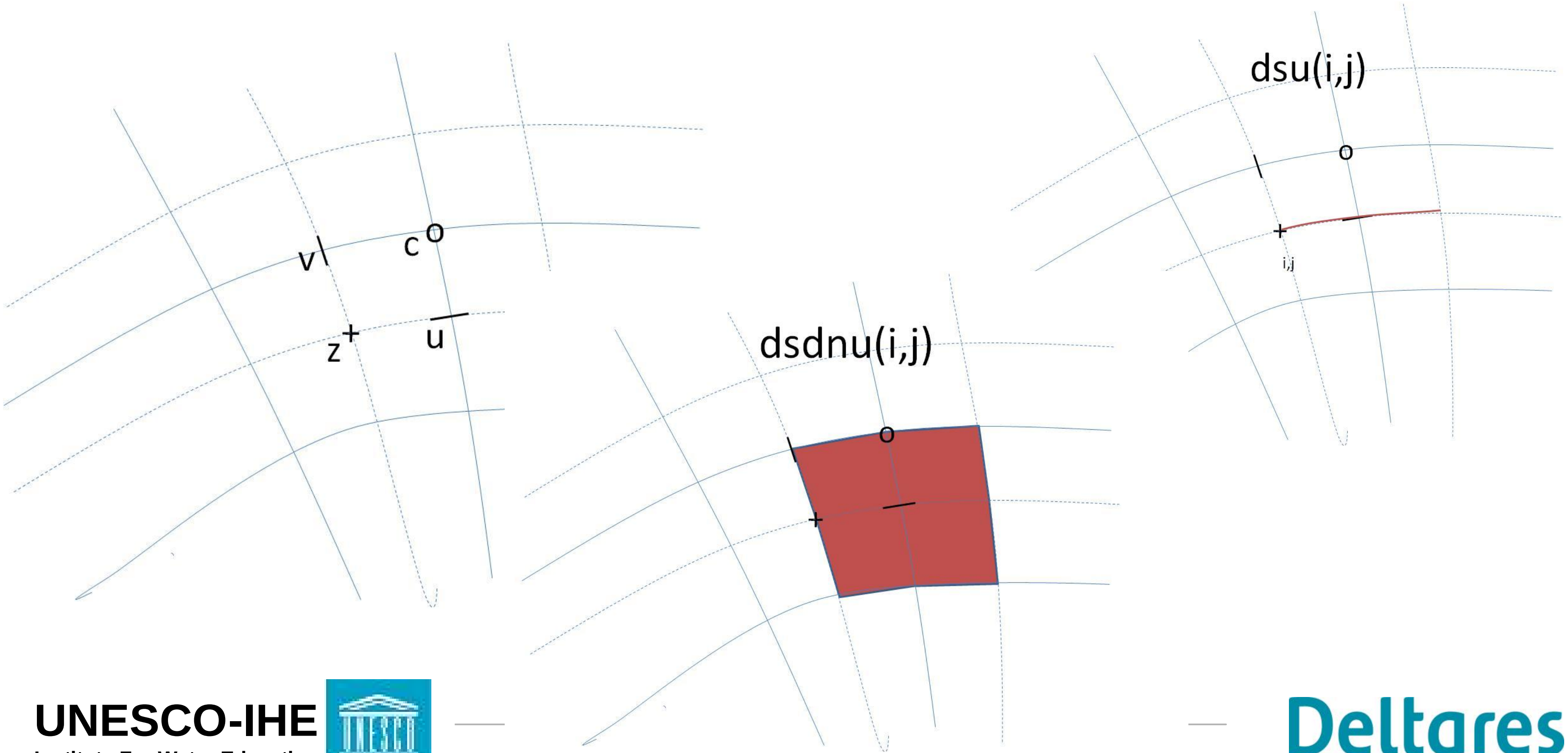
Curvilinear grids

- For even slightly curved coasts a curvilinear grid allows good cross-shore grid resolution at much fewer grid points
- Longshore gradients in transport can be resolved more smoothly
- Islands can be represented efficiently



Implementation

- Finite volume approach
- Guaranteed conservation of mass, momentum, wave action
- For details see “curvilinear grid properties.ppt”



Using curvilinear grids

- Specify x and y values of curvilinear grid in usual way using

  gridform =xbeach

  xfile = <xgrid file>

  yfile = <ygrid file>

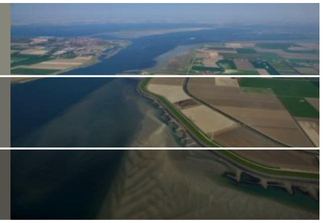
  depfile = <depth file>

- Use Delft3D grid and depth files

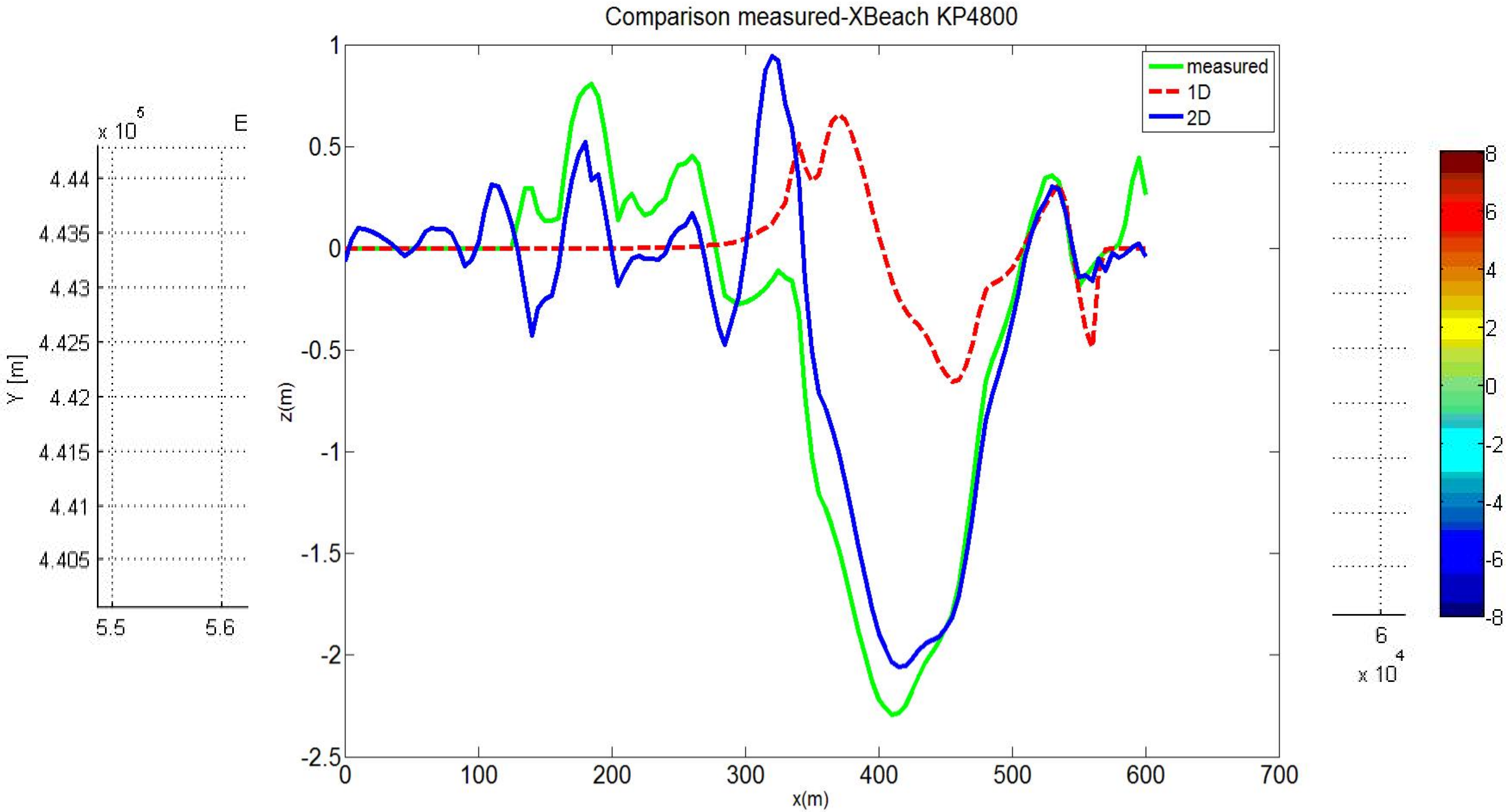
  gridform = delft3d

  xyfile = <grid file created by RGFGRID>

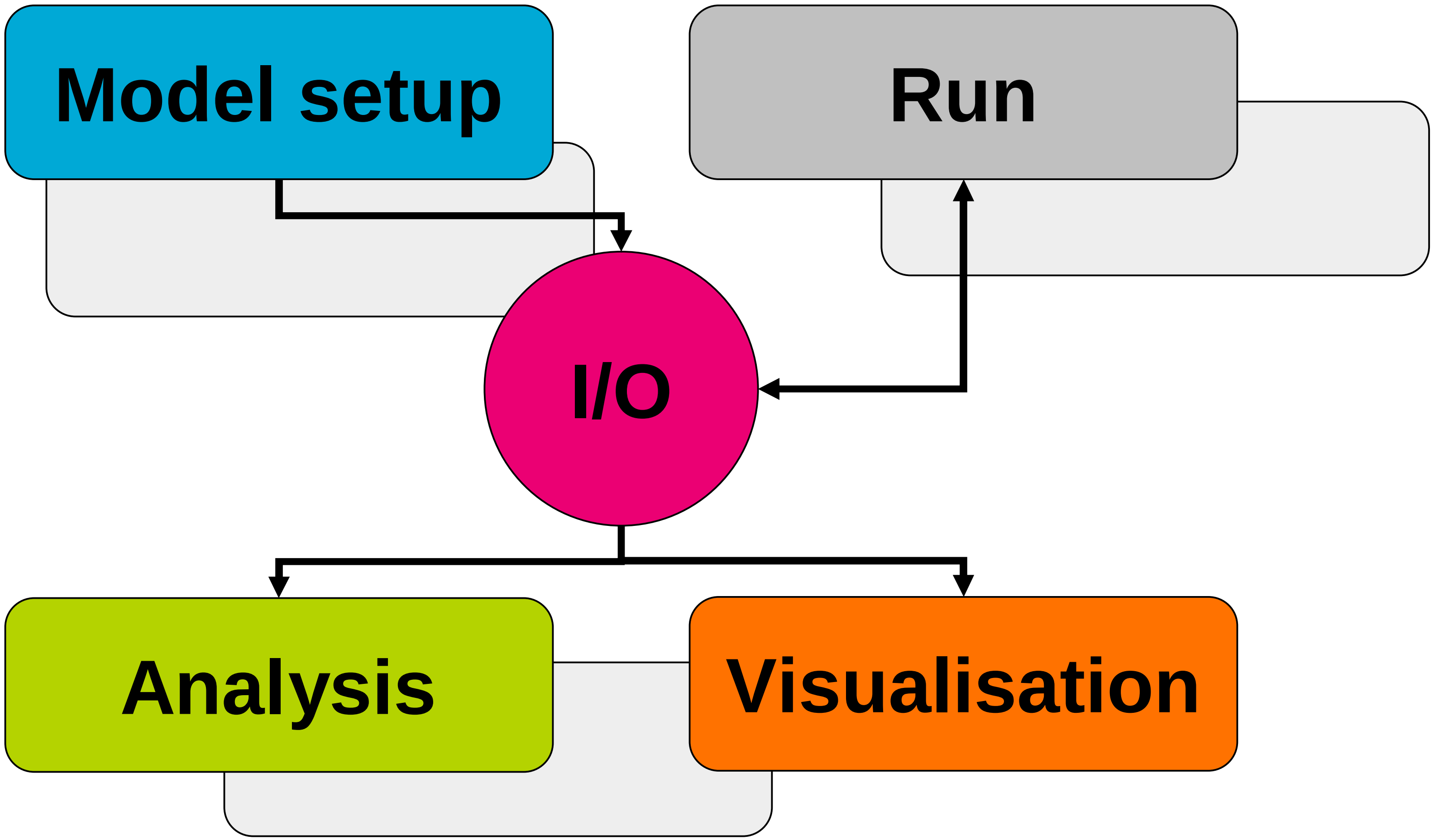
  depfile = <depth file created by QUICKIN>



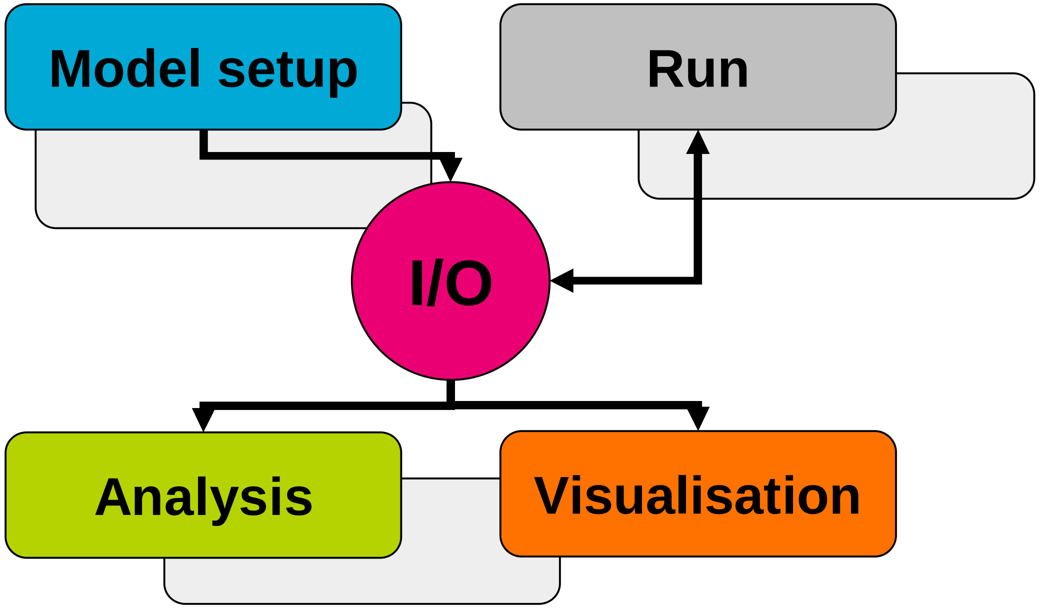
Example Maasvlakte-II



Matlab Toolbox for XBeach



Complementary with Delft3D tools



QuickIn

QuickPlot

RGFGrid

https://svn.oss.deltares.nl/repos/openearthtools

OpenEarth Product Suite - Op

publicwiki.deltares.nl/display/OET/OpenEarth+Product+Suite

Dashboard › OpenEarth › OpenEarth › OpenEarth Product Suite

OpenEarth Product Suite

3 Added by Gerben de Boer, last edited by Wiebe de Boer on 29-10-2011 (view change)

OpenEarth.nl - OpenEarth.eu: Home | Join | Data | Models | Tools | Produ... | Tutori... | ...arch | ...us

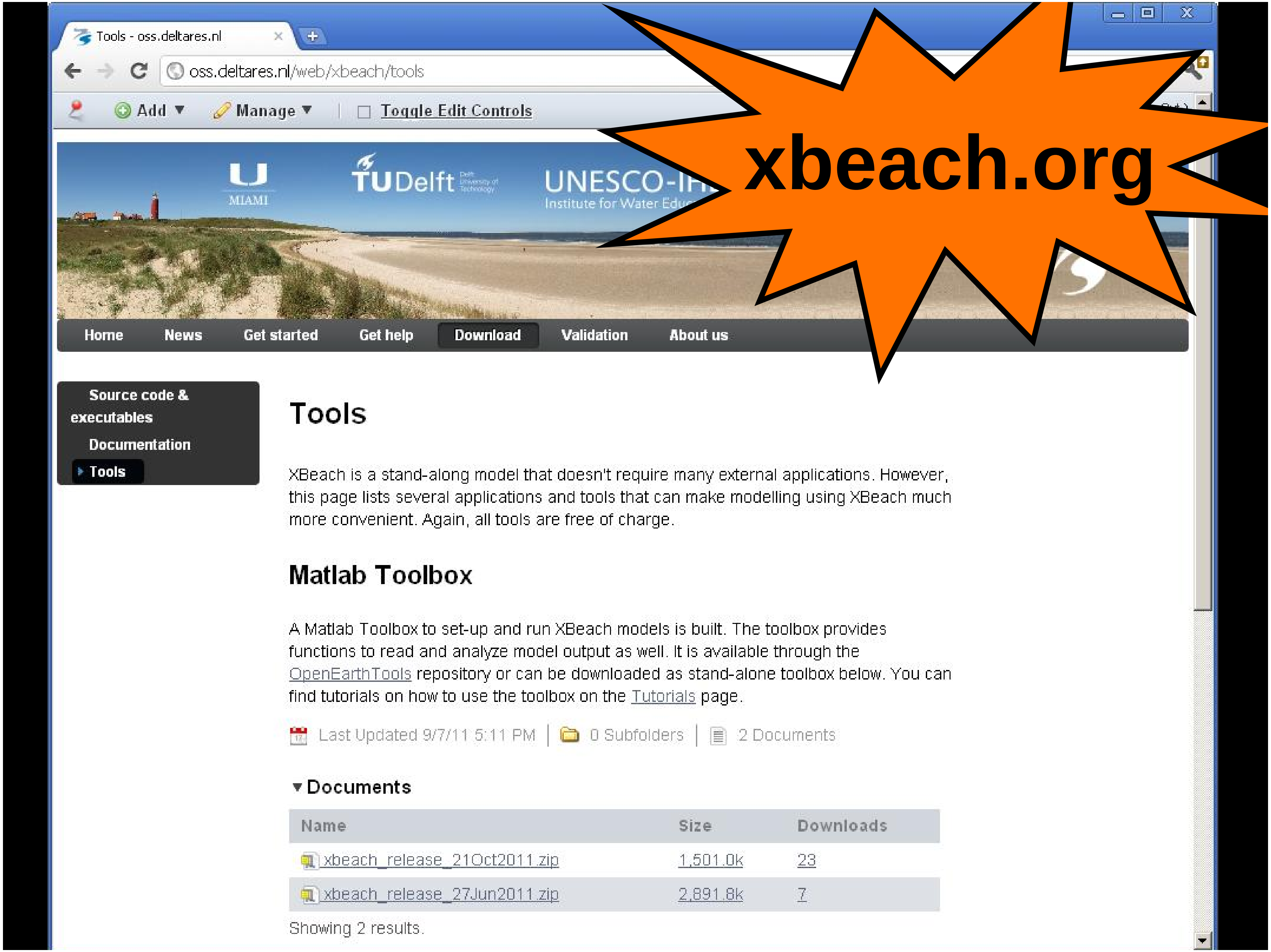
This page disseminates OpenEarth products. The installers are easy-installable software packages, including the necessary program files, documentation, etc. The toolboxes are collections of routines (Matlab, Python, etc) from the OpenEarth repository. In order to get access to the entire collection of OpenEarth tools, you are invited to join the OpenEarth community (click here for more information).

Programs

Name	Description
Delft Dashboard	An information system developed by Deltares aimed at facilitating the use of data and (expert) knowledge in coastal problems. It does so by supporting modellers as much as possible in the efforts needed to set up new models and manage and use existing ones enabling researchers to quickly try out innovative approaches by advanced prototyping

Toolboxes

Name	Description
Google Plot	Google Earth toolbox (coming soon, now only as beta in OpenEarthTools)
SWAN	Tools to process SWAN files (coming soon, now only as beta in OpenEarthTools)
Coordinate conversion	A matlab toolbox to convert coordinates between numerous of coordinates systems.
XBeach	XBeach toolbox to read and write XBeach files, setup entire models and visualise or analyse XBeach results
Probabilistic Toolbox	Generic toolbox for probabilistic computations


xbeach.org
Tools - oss.deltares.nl
oss.deltares.nl/web/xbeach/tools
Add
Manage
Toggle Edit Controls
MIAMI
TUDelft
UNESCO-IH
Institute for Water Edu
Home
News
Get started
Get help
Download
Validation
About us
Source code & executables
Documentation
Tools
Tools
XBeach is a stand-along model that doesn't require many external applications. However, this page lists several applications and tools that can make modelling using XBeach much more convenient. Again, all tools are free of charge.
Matlab Toolbox
A Matlab Toolbox to set-up and run XBeach models is built. The toolbox provides functions to read and analyze model output as well. It is available through the OpenEarthTools repository or can be downloaded as stand-alone toolbox below. You can find tutorials on how to use the toolbox on the Tutorials page.
Last Updated 9/7/11 5:11 PM
0 Subfolders
2 Documents
Documents
Name
Size
Downloads
xbeach_release_21Oct2011.zip
1,501.0k
23
xbeach_release_27Jun2011.zip
2,891.8k
7
Showing 2 results.

Other Developments

Physics:

- Short wave runup on and erosion above structures / revetments
- Aeolean Transport model (xDune)
- Gravel functionality (tomorrow):
  - Groundwater flow
  - Multiple sediment fractions
  - Non-hydrostatisc solver

Usability:

- MPI (mpich2 openMPI)
- Supporting Linux and Windows platforms
- For developers that want to build their own executable:
  - Make environment: VS2008, Automake
  - Compilers: Intel Fortran 11, G Fortran

HANDS ON II:

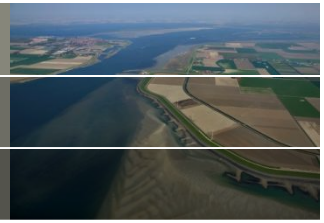
Basic XB cases: Yanchep perched beach & Santander Spit

OR

ADVANCED CASE (Boscombe Beach)

OR

YOUR OWN XBEACH CASE



THEORY III: Modelling Infragravity Waves and Currents Across a Fringing Coral Reef

Ap Van Dongeren, Ryan Lowe, Andrew Pomeroy, Duong Minh Trang, Dano Roelvink, Graham Symonds and Roshanka Ranasinghe

Deltares, Delft, The Netherlands
University of Western Australia, Crawley WA, Australia,
Unesco-IHE, Delft, The Netherlands,
CSIRO, Floreat, Australia.

UNESCO-IHE
Institute For Water Education

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Introduction

Coral reef systems are

- present along large parts of tropical coastlines
- protect the coast from storm impacts
- form habitat for great number of species

Waves and wave-induced currents are important to reef systems, drive

- Sediment transports
- nutrient dynamics,
- Uptake by benthic communities

Studied since Darwin (1842) but recent field studies show dominance of infragravity wave motions over the reef: little studied in detail.

Research questions

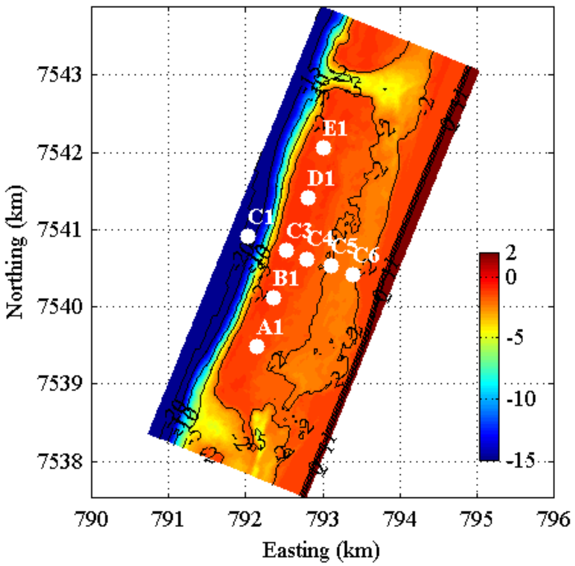
Can we predict IG motion with XBeach (derived for mildly-sloping beaches) on a coral reef?

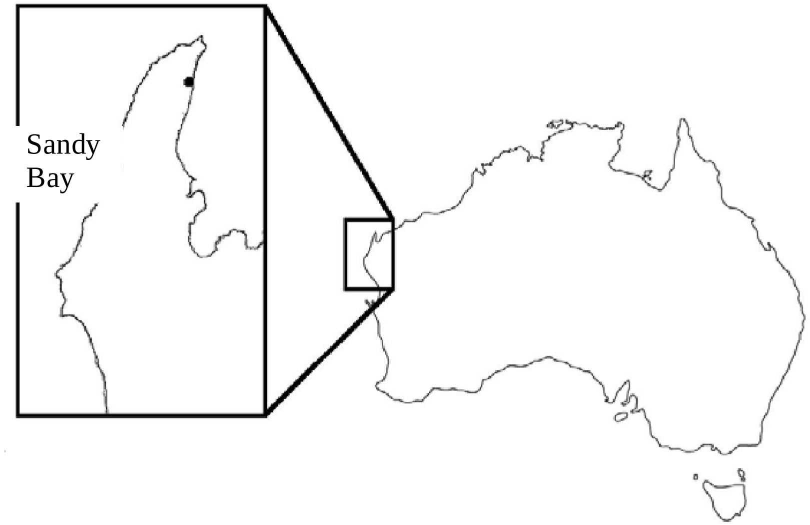
What is the IG generation and dissipation mechanism on reefs?

How important are IG waves and where?

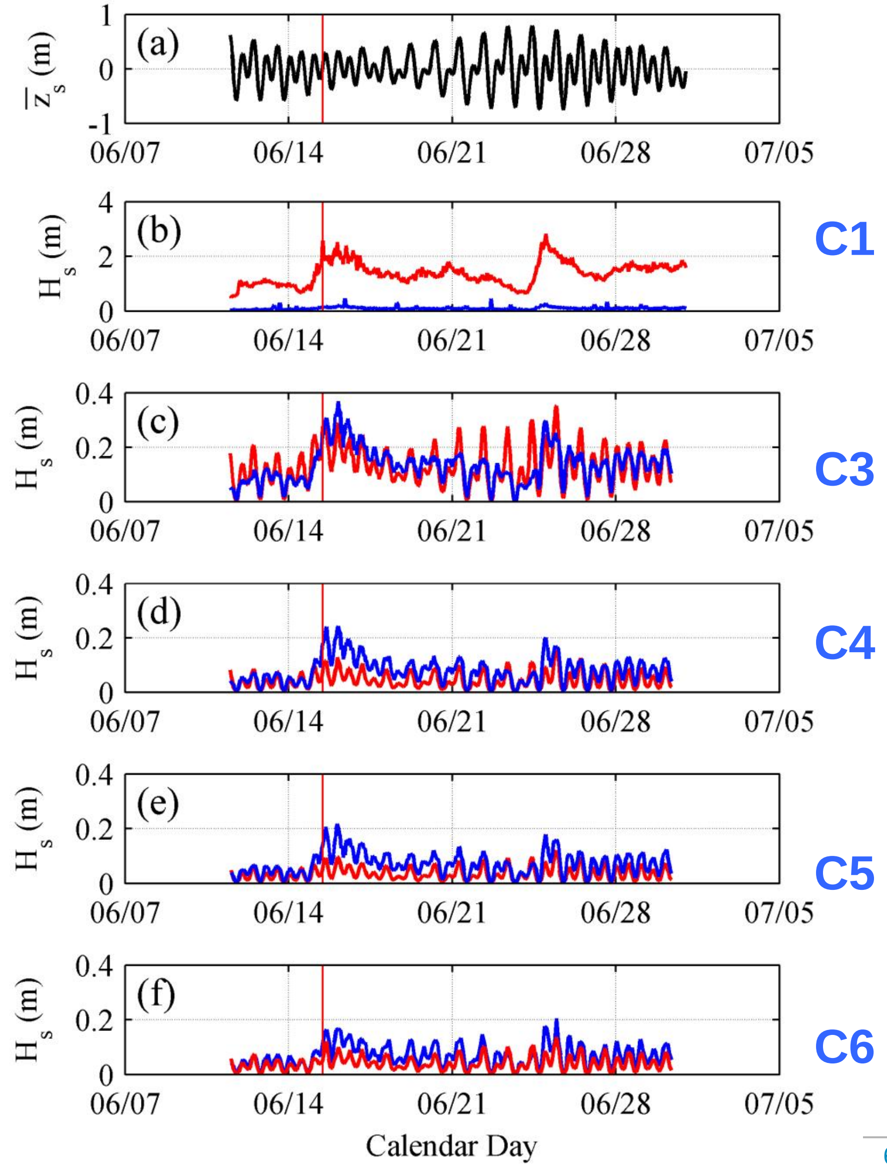
Ningaloo Reef Observations

- Ningaloo Reef extends 250 km along the North-West Cape of Australia
- Hundred individual reef-lagoon-channel circulation systems with gaps (channels) occurring in the reef every few kilometers.
- Swells from the South-West (roaring 40's).
- Field data by Ryan Lowe (U. of Western Australia) in 2009

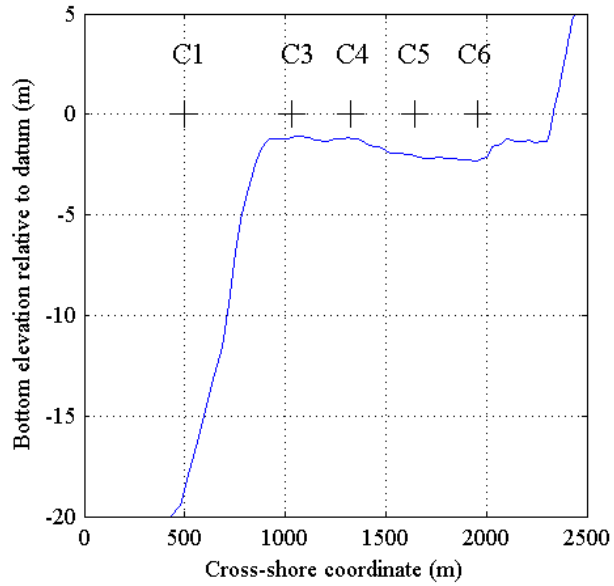




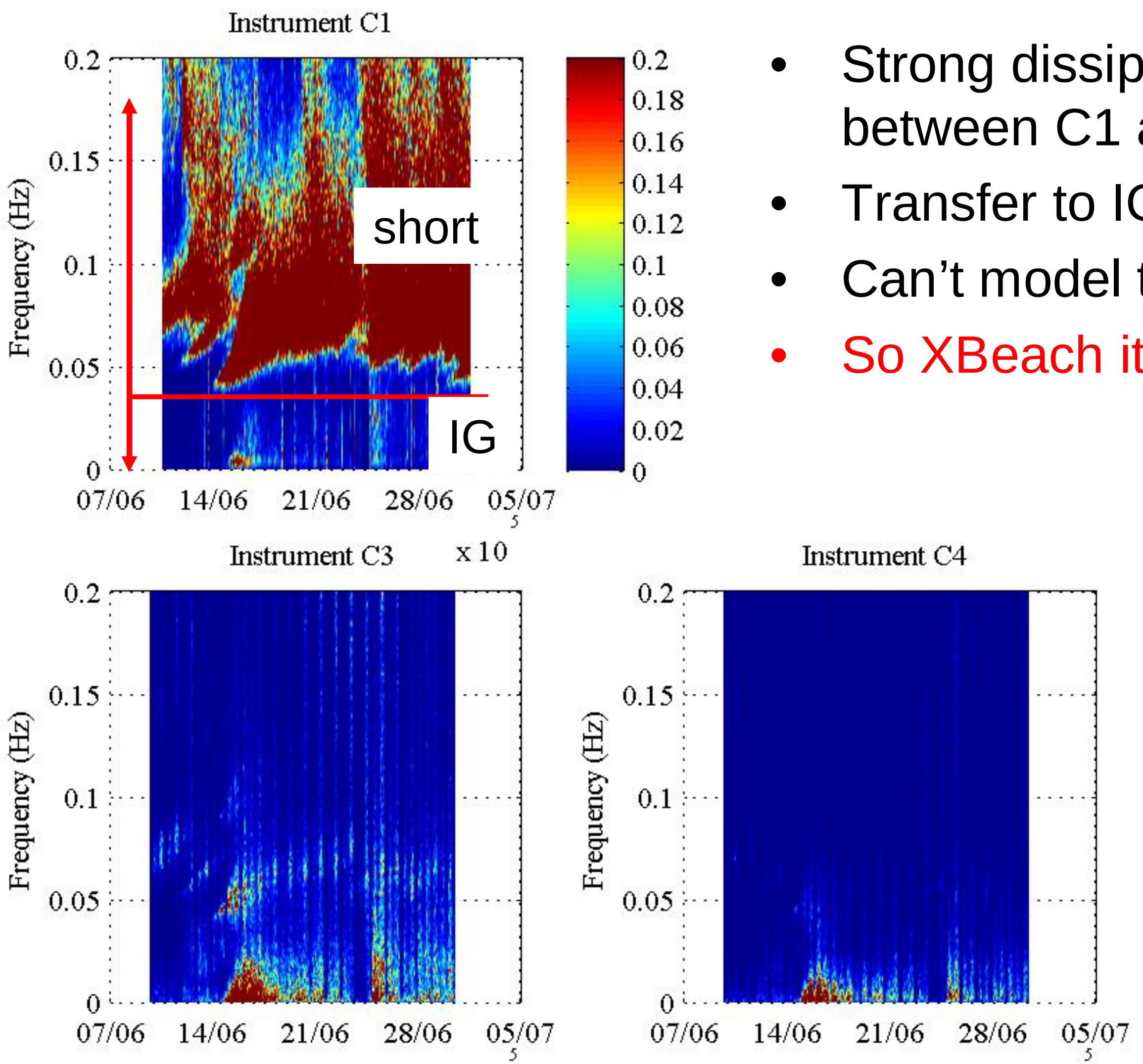
Short wave and IG wave heights



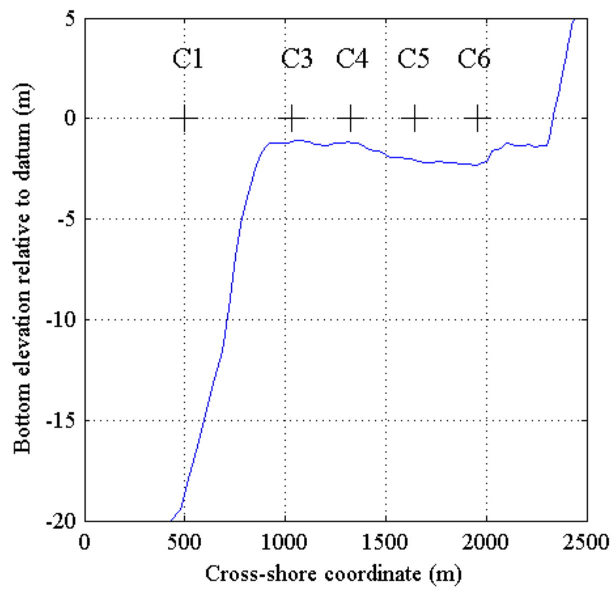
- Low frequency IG signal dominant in the lagoon
- Short waves decay
- Clear tidal signature of IG and short waves



Observations of spectra



- Strong dissipation of short waves between C1 and C3
- Transfer to IG wave frequencies
- Can't model this with SWAN!
- So XBeach it is



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Modification of equations

Wave action equation including bottom friction dissipation

$$D_f = \frac{2}{3}\rho\pi f_w \left(\frac{\pi H}{T_{rep} \sinh kh} \right)^3$$

With free parameter f_w

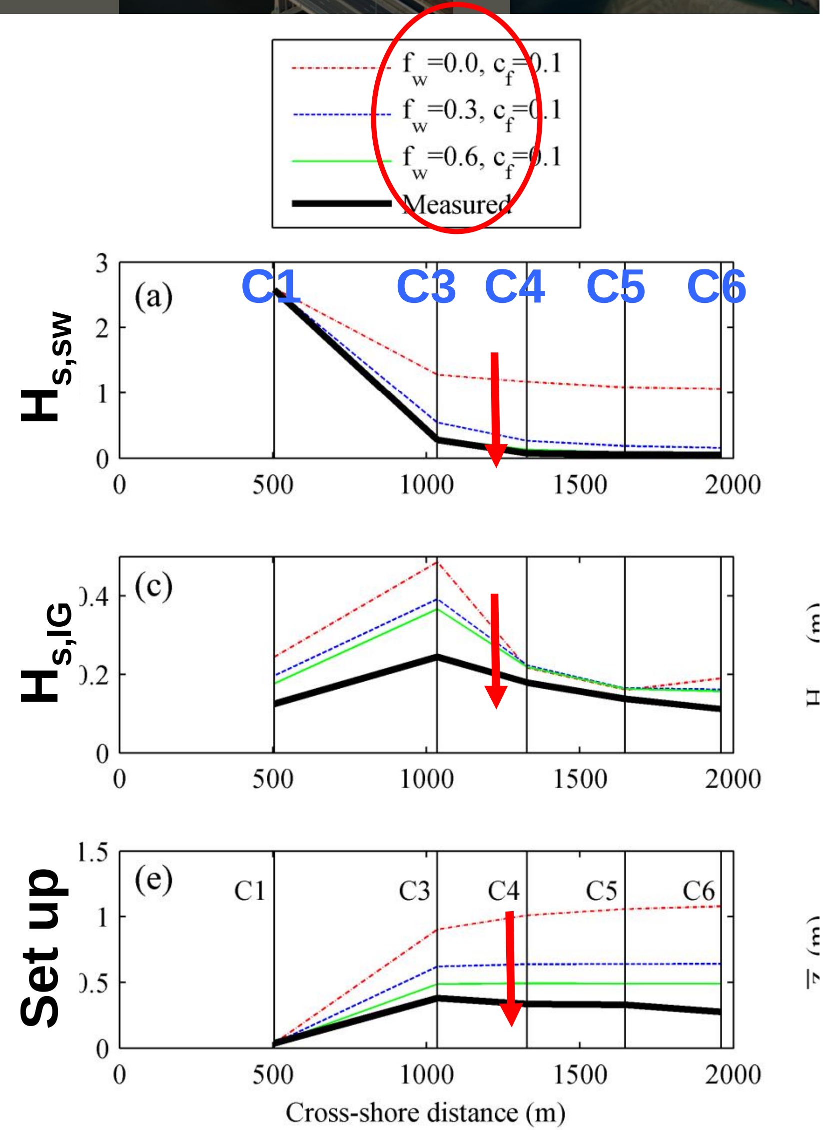
We use default settings, except calibration of short wave friction f_w and unsteady current (IG) friction c_f.

1D Calibration of short wave friction f

Large value of the friction parameter explains sharp decay of short waves

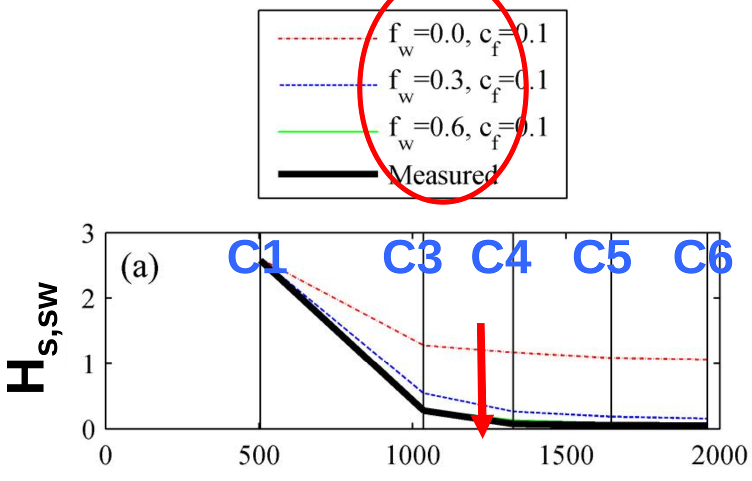
Friction suppresses IG wave generation

Lowers water levels

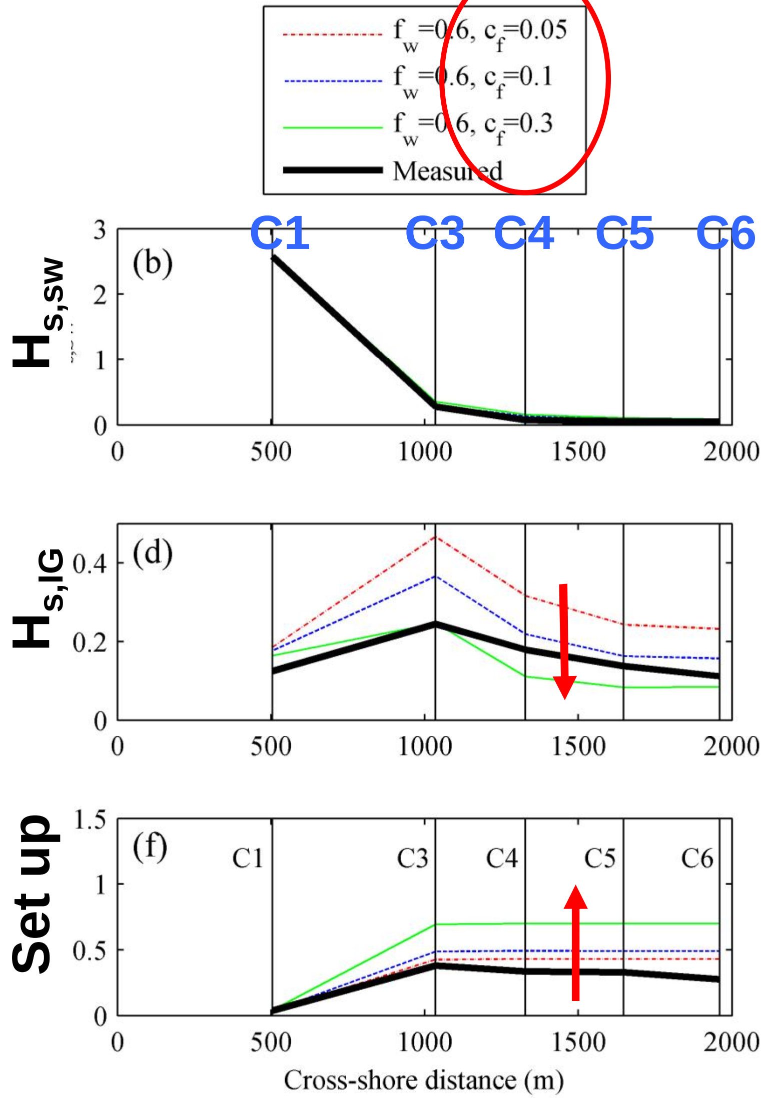


1D Calibration of short wave friction f

Large value of the friction parameter explains sharp decay of short waves



1D Calibration of unsteady current



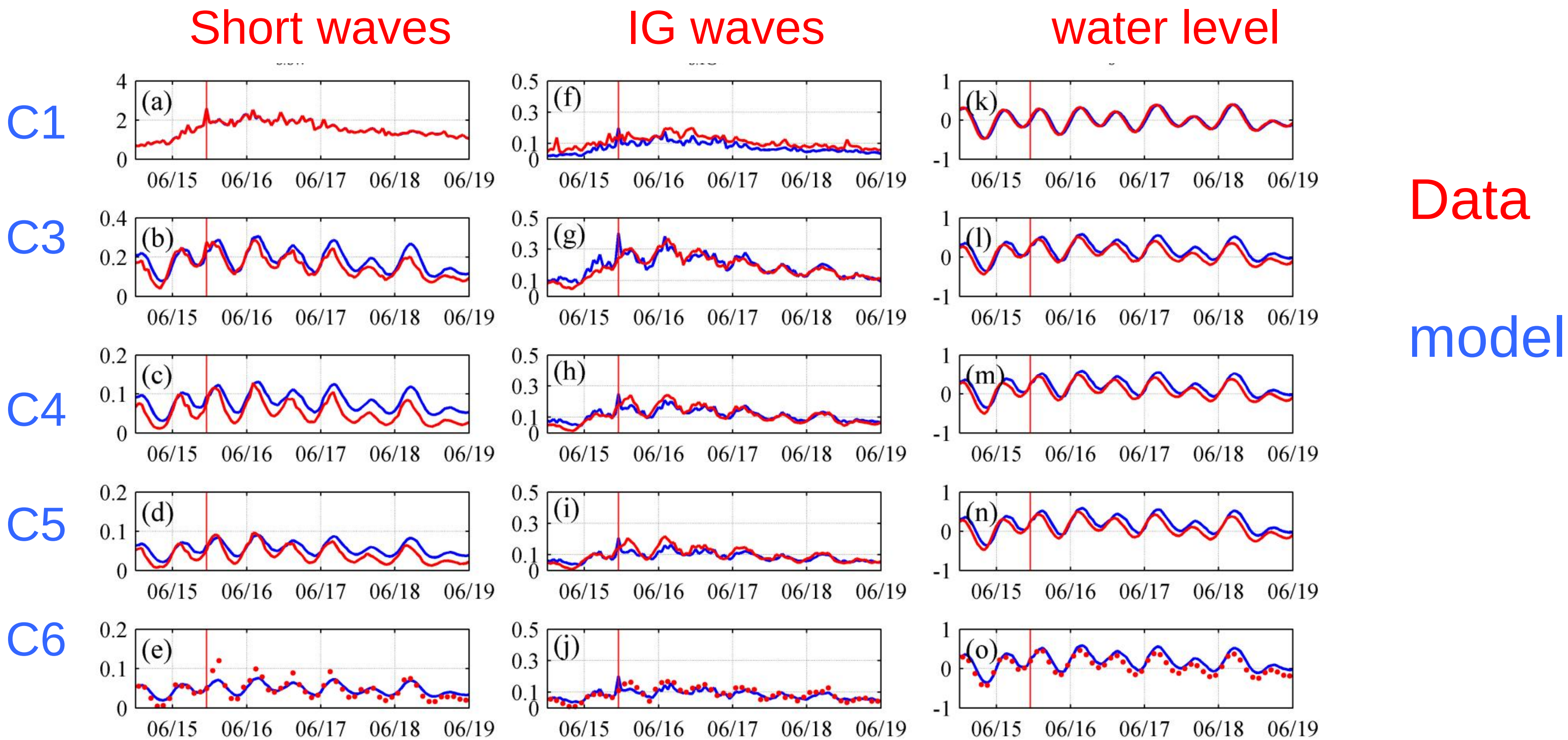
c_f has no effect on short wave transformation

Increase in c_f, reduction in IG wave height

BUT increases set up

Cross-shore distance (m)

Results for storm duration 1D



Short waves slightly overpredicted

Water levels slightly overpredicted

Short waves and Infragravity wave displays tidal signature

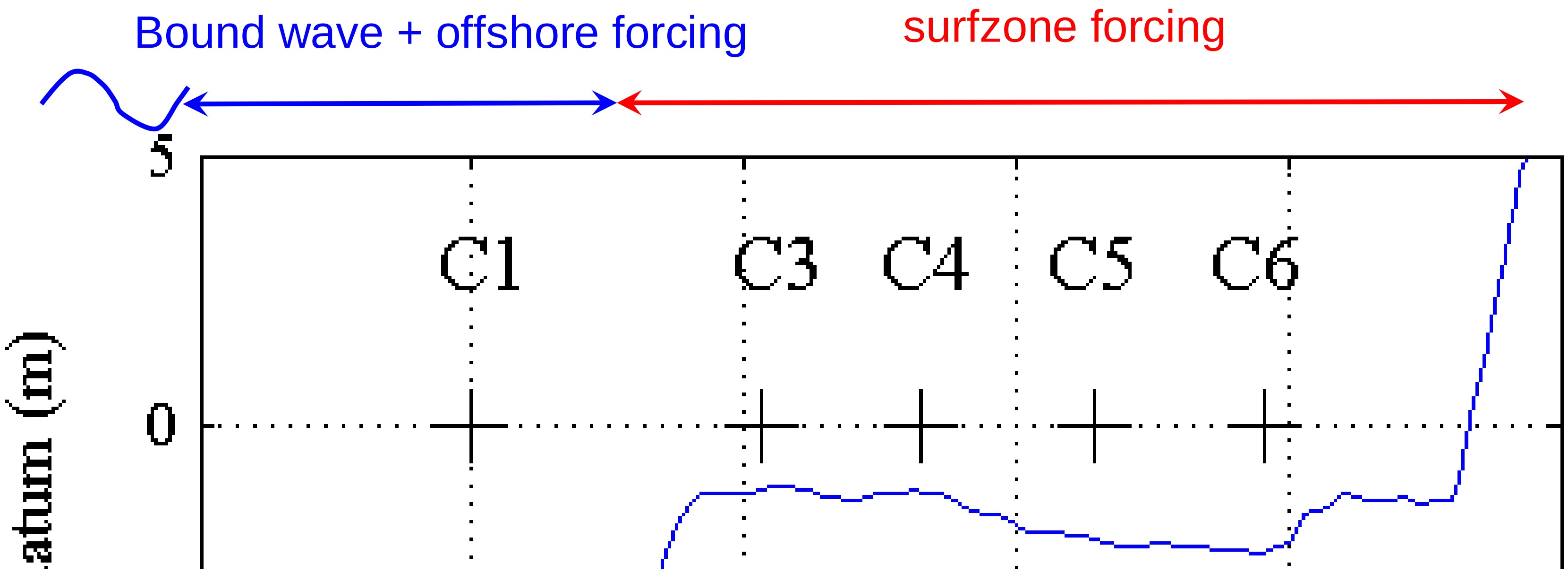
Generation of IG waves on reefs

Two alternative mechanisms:

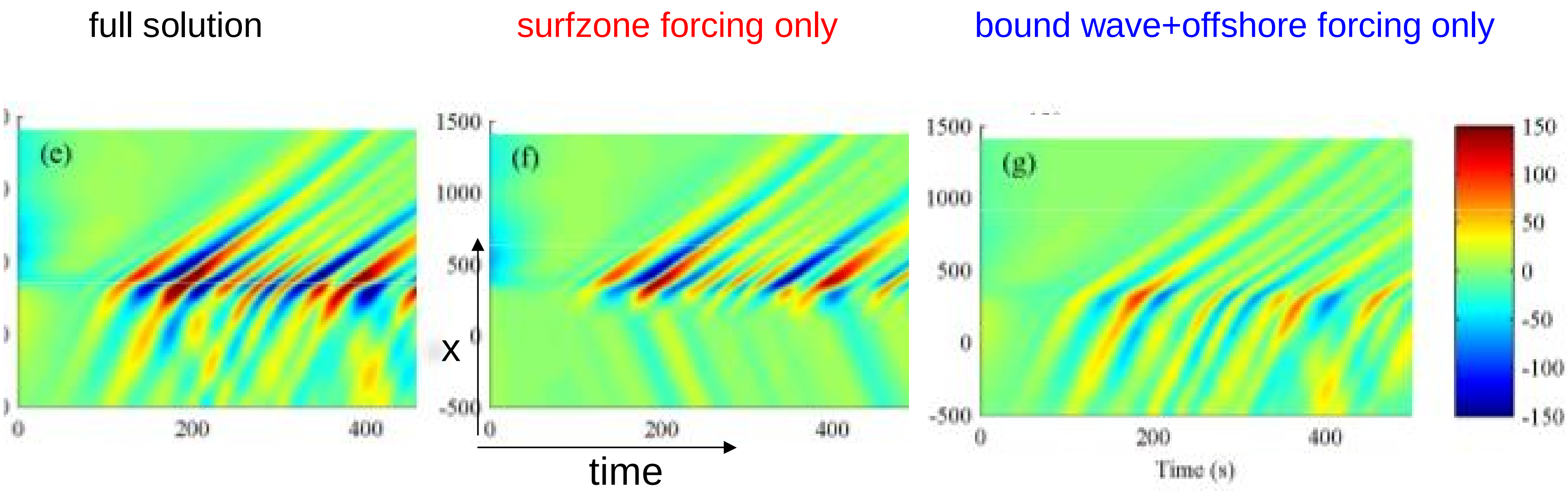
- Bound wave shoaling (Longuet-Higgins and Stewart, 1960/62): dominant on relatively mild slopes (Battjes et al., 2004)
- Breakpoint forcing by oscillating breakpoint (Symonds et al, 1984): dominant on relatively steep slopes.

The reef slope is steep (χ=0.16), so we hypothesize bp forcing

Test with forcing turned on and off in offshore and lagoon



Generation of IG waves – in parts



IG wave signal variance on the reef explained for 70% by breakpoint (surfzone) generation

Dissipation of IG waves on reefs

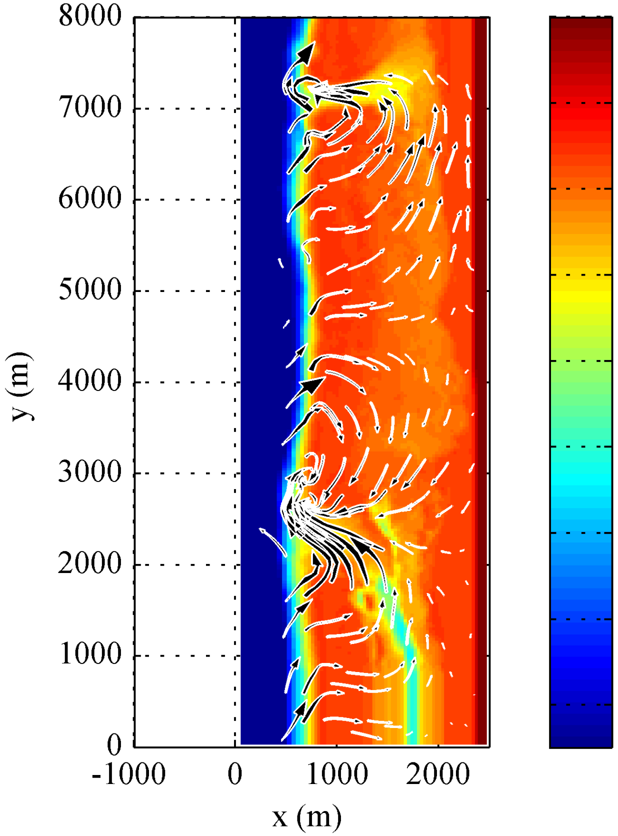
Which mechanism dissipates IG waves?

Three options:

- Nonlinear interactions with the groups (Thompson et al, 2006)
  - Not here, no wave groups in the lagoon
- IG wave breaking (Van Dongeren et al., 2007)
  - Not here, waves do not steepen up
- Bottom friction dissipation (Henderson and Bowen, 2002)
  - Corals much rougher than sandy beaches

And: can we explain the tidal signature?

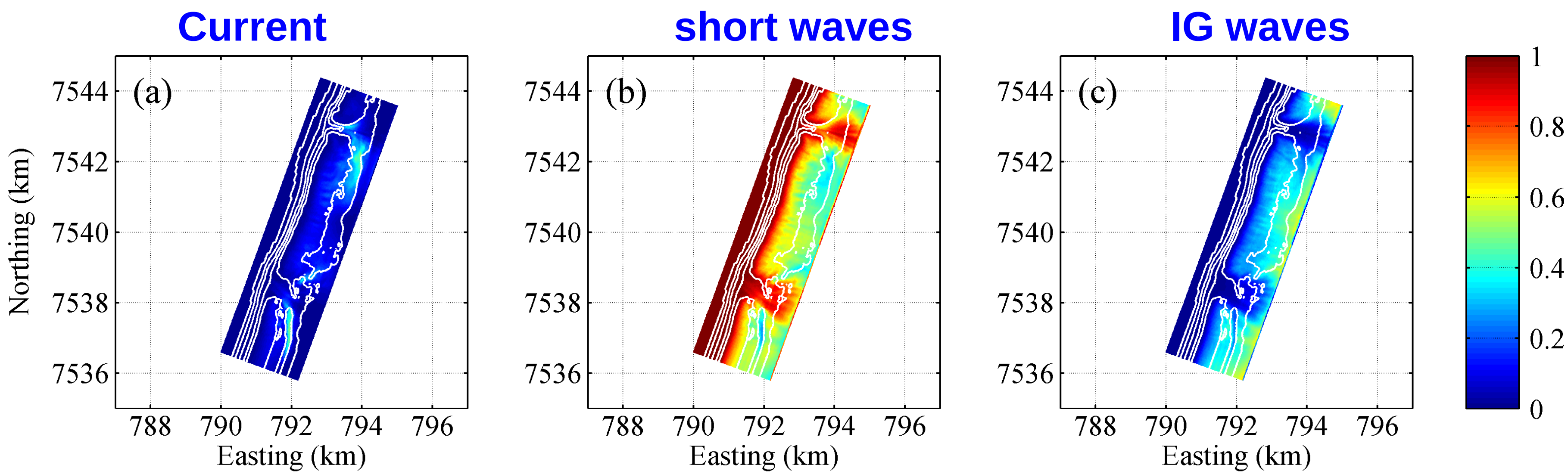
Now to 2D



Note: need recalibration, not discussed here today.

Where are IG waves important?

Contribution to shear stress by different processes



Mean (current) flow – consistently 20 % except in key channel locations (40%)

Short waves – important offshore, on reef crest and in channels (80-100%)

IG waves – important in lagoon (40%) and near shoreline (60%)

Conclusions

- Model results for short and IG wave heights compare well to data for the duration of a swell event.
- IG waves are predominantly dissipated by friction
- IG waves cause 40-60% of shear stresses on the reef top and near the shoreline
- IG waves are important on reefs and we can model them in 2D!

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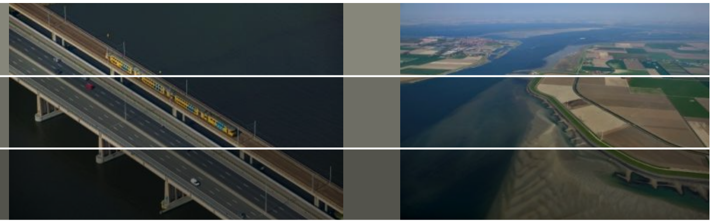
Enabling Delta Life

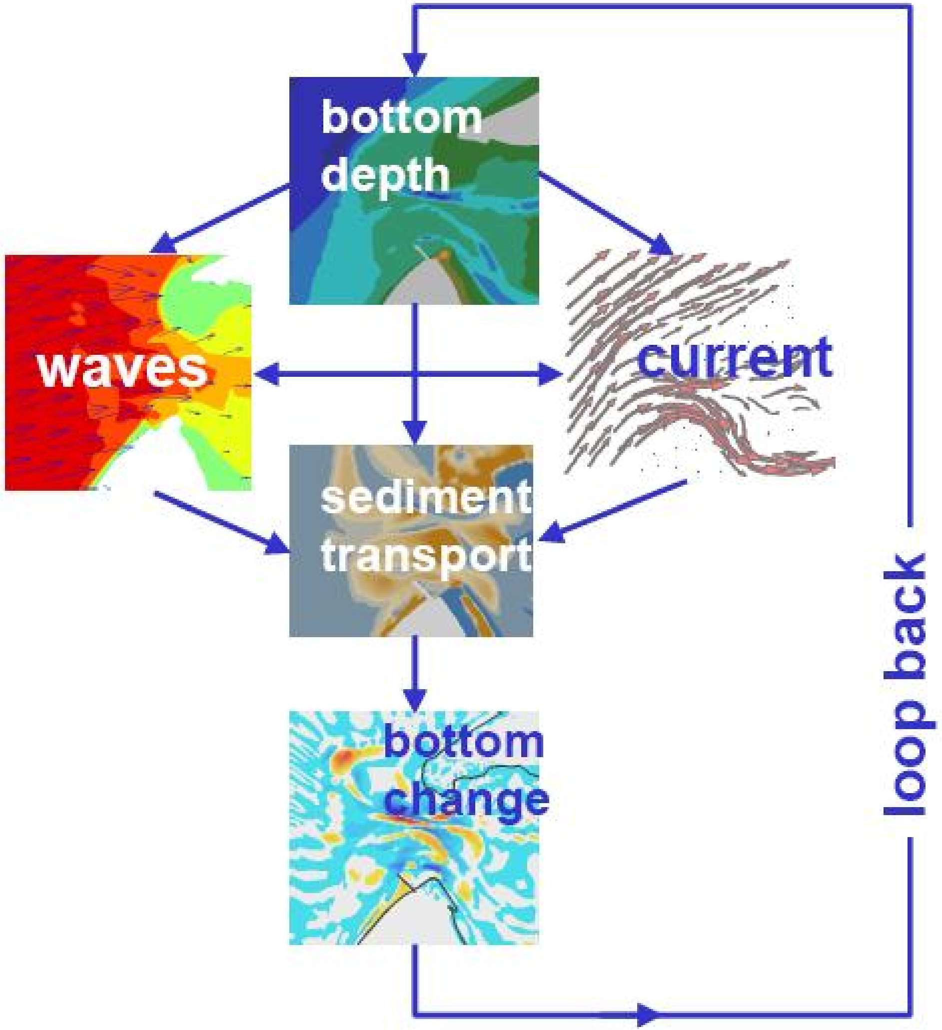
THEORY INTERMEZZO:
On long term stationary simulations



Time scales	1 m- 1 km	10 m – 10 km	100 m – 100 km
1 year – 1000 years	Climate change impact on profile behaviour	Evolution of tidal inlets, including climate change impacts	Evolution of tidal basins Large-scale coastline evolution
1 day – 10 years	Cyclic bar behaviour Effect of shoreface nourishments Evolution of beach states Effects of small-scale coastal structures	Impact of harbour extensions, land reclamations Mega nourishments	Longshore spreading of nourishments Coastal realignment in response to wave climate variability (El Niño, La Niña)
1 hour – 10 days	Dune erosion (1D) Reset events Dune erosion, overwashing and breaching (2D)		

Space scales

Morphodynamic loop



- Bottom changes are fed back into bathymetry after each time step
- Bottom changes are multiplied by morphological factor MORFAC
- Difference between hydrodynamic time scale and morphodynamic timescale

Morfac options

- We can either:
  - > Specify morphological time and adjust hydrodynamic time, or
  - > Specify hydrodynamic time and adjust morphological time
- In the first option (morfacopt=1):
  - > All input times are divided by morfac
  - > Time series of boundary conditions are shortened
  - > Tidal dynamics may be distorted
  - > Time series of wave energy may get too short
- In the second option (morfacopt=0):
  - > Hydrodynamic time series are untouched
  - > Tidal dynamics are preserved
  - > Effects of changes within tidal cycle are exaggerated

Morfacopt

Options for using morfac:

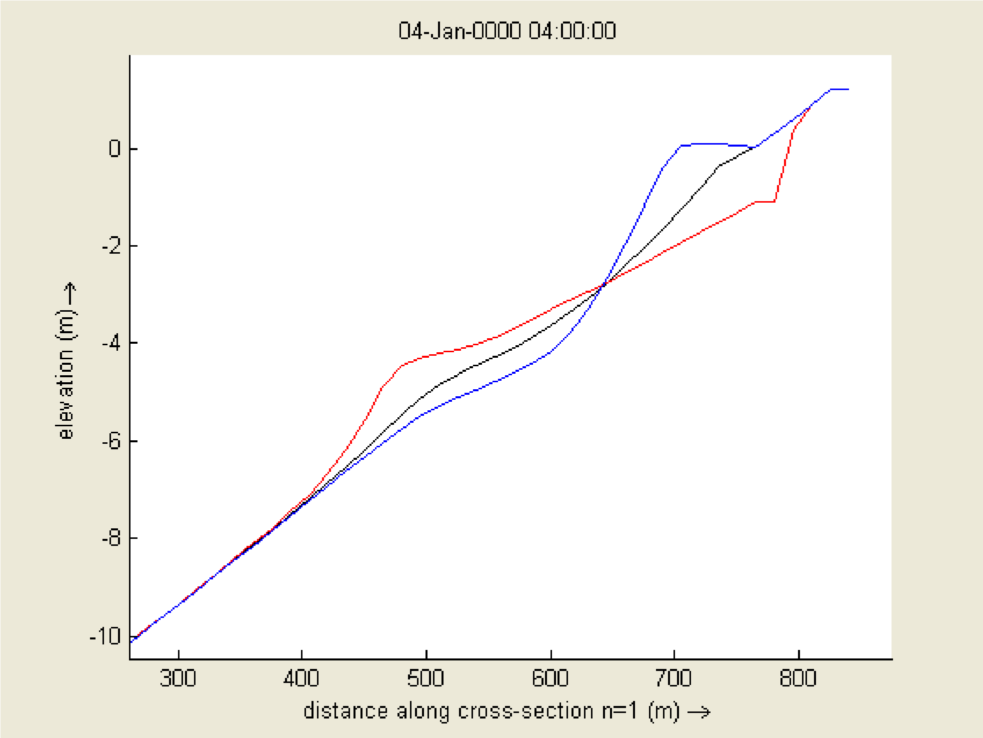
Morfacopt=0	Morfacopt=1 (default)
Times are specified as hydrodynamic times	Times are specified as morphological times All times divided by Morfac
Hydrodynamics of tidal cycle are not disturbed	Tidal variation is accelerated

Differences in approach / Considerations

- Need to calibrate longer-term profile behavior
- More attention to onshore processes
  - > Facua or facsk, facas
- During moderate conditions, infragravity waves much less important
- **Stationary approach** possible if infragravity waves can be neglected
- Higher morphological factor for moderate conditions

Example profile evolution

- River outflow case turned into 1D model of straight beach, to calibrate profile behaviour
- Facua (=facsk=facas)= 0.0, 0.2,0.4
- Which is which?
- More subtle calibration is possible using separate values for facas and facsk
- facas effects shoreline
- facsk effects surfzone



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Stationary wave solver

- First, the wave and roller balances are iterated per longshore line until no change; screen output tells how many iterations

Short waves And Rollers

$$\frac{\partial A}{\partial t}+\frac{\partial c_x A}{\partial x}+\frac{\partial c_y A}{\partial y}+\frac{\partial c_\theta A}{\partial \theta}=-\frac{D_w}{\sigma}$$

$$\frac{\partial S_r}{\partial t}+\frac{\partial c_x S_r}{\partial x}+\frac{\partial c_y S_r}{\partial y}+\frac{\partial c_\theta S_r}{\partial \theta}=-D_r+D_w$$

- Then wave and roller forces are computed

$$F_x=-\left(\frac{\partial S_{xx}}{\partial x}+\frac{\partial S_{xy}}{\partial y}\right)$$

$$F_y=-\left(\frac{\partial S_{xy}}{\partial x}+\frac{\partial S_{yy}}{\partial y}\right)$$

- NO WAVE GROUP FORCING
- Stationary run repeated every *wavint* seconds

Running stationary waves

- Instat = stat or stat_table
- Break = 2
  - > Baldock formulations meant for wave-averaged simulations, other formulations meant for simulations varying on wave group scale
- Hrms =
  - > Watch out: Hrms not Hm0
- Trep =
  - > Representative period = Tp
- Dir0 =
  - > Mean wave angle (nautical convention)
- Wavint = <interval of repeating wave simulation (s)>
  - > Note: take into account morfac!

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HANDS ON IV:

Long term stationary case with a river discharge

Dano Roelvink and Jaap van Thiel de Vries

River Outflow

- Classical case from De Vriend et al, 1993
- River discharging into straight coast with oblique waves
- Initial channel turning due to longshore current
- Illustrates use of discharges, stationary wave solver

Discharges

- disch_loc_file = discharge_locations.txt
- disch_timeseries_file = discharge_timeseries.txt

- Contents discharge_locations.txt:
  - 840 820 840 890 (x1 (m) y1 (m) x2 (m) y2 (m))

- Contents discharge_timeseries.txt
  - 0 150 time (s) discharge (m3/s)
  - 1000000 150 time (s) discharge (m3/s)

  - Note: positive discharge means INTO model area

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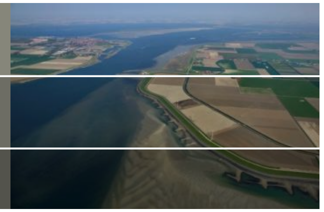
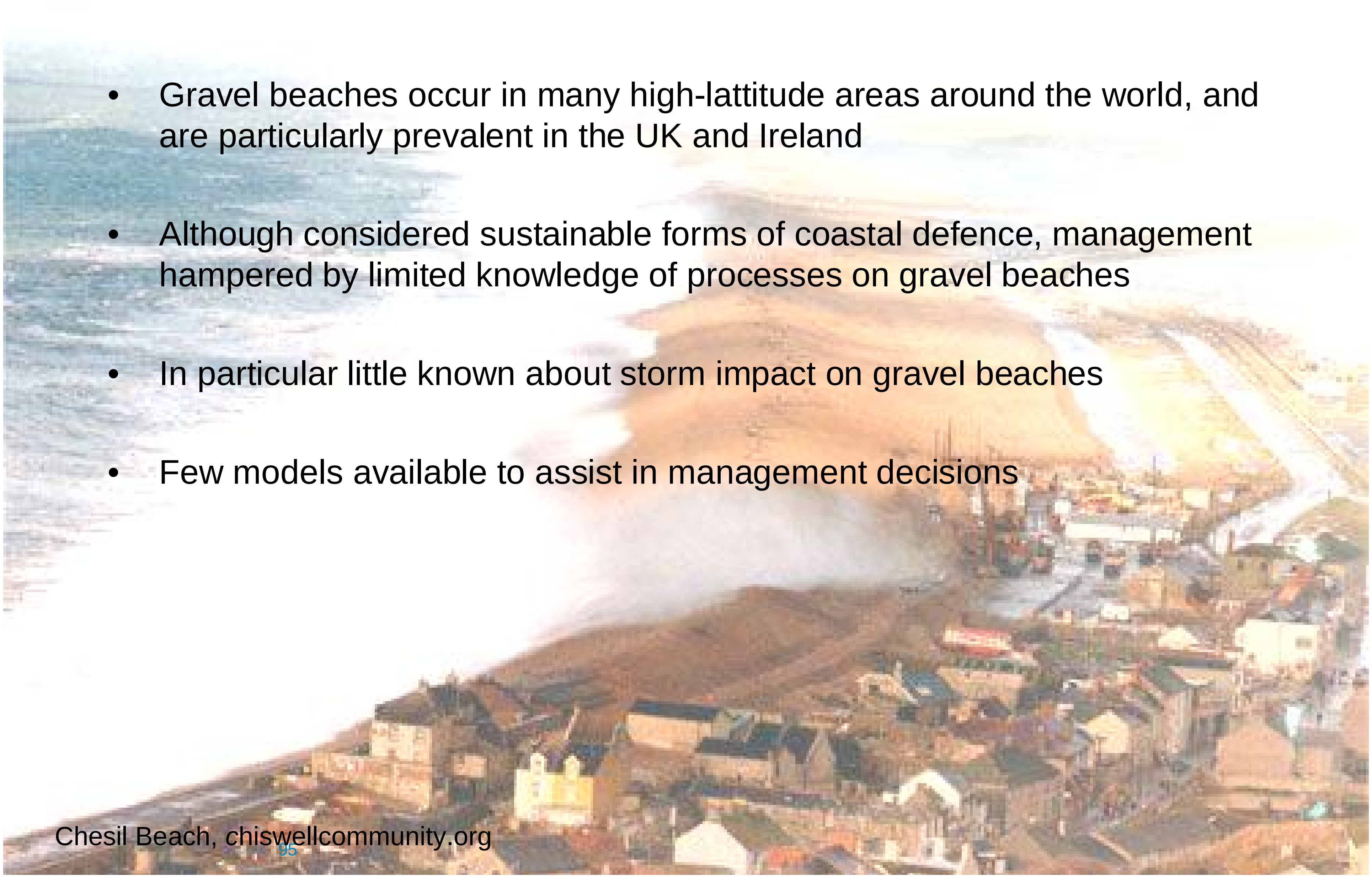
THEORY INTERMEZZO:

Storm impact on gravel beaches

Introduction

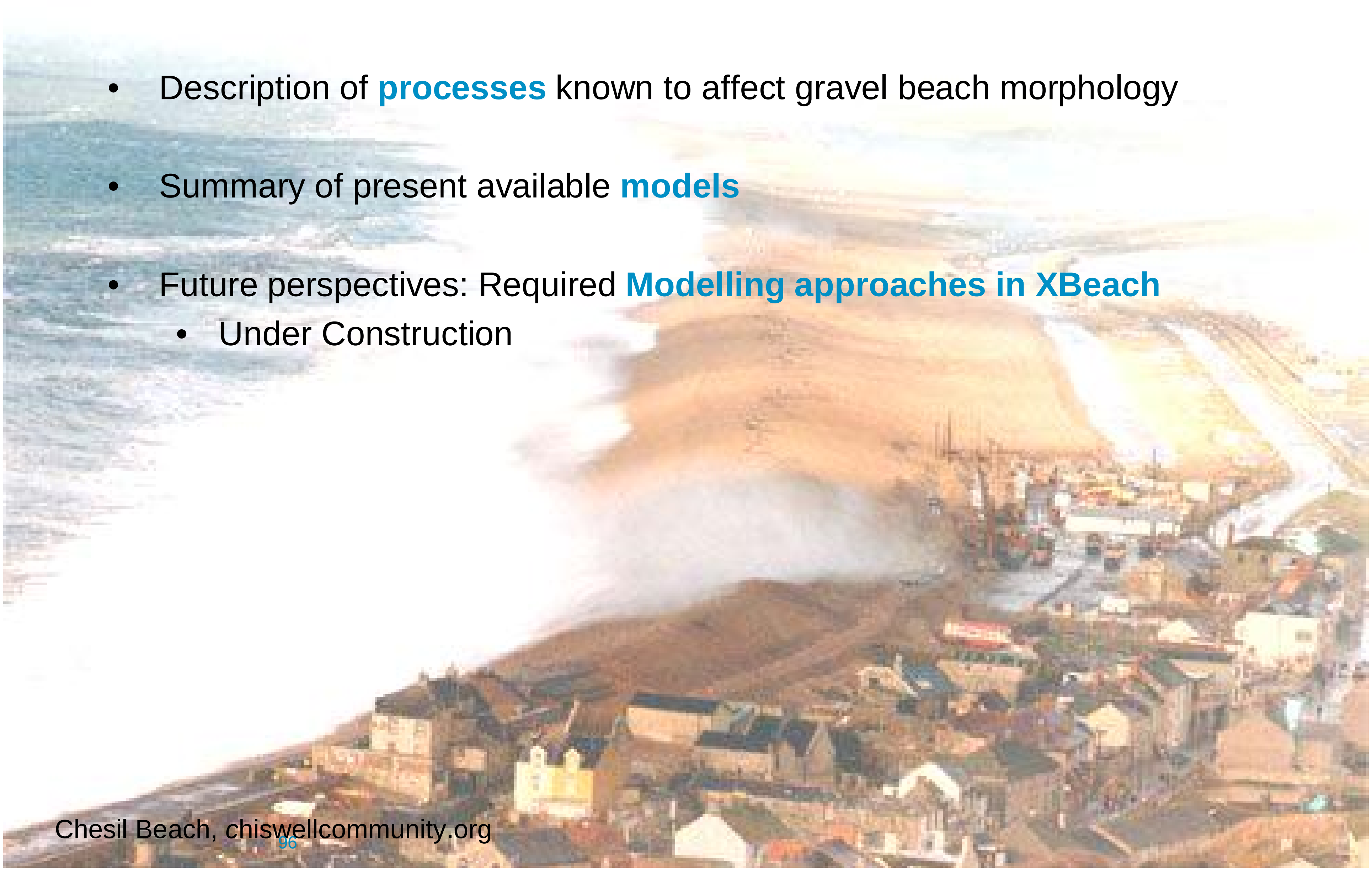
- Gravel beaches occur in many high-lattitude areas around the world, and are particularly prevalent in the UK and Ireland
- Although considered sustainable forms of coastal defence, management hampered by limited knowledge of processes on gravel beaches
- In particular little known about storm impact on gravel beaches
- Few models available to assist in management decisions



Chesil Beach, chiswellcommunity.org

Content

- Description of **processes** known to affect gravel beach morphology
- Summary of present available **models**
- Future perspectives: Required **Modelling approaches in XBeach**
  - Under Construction

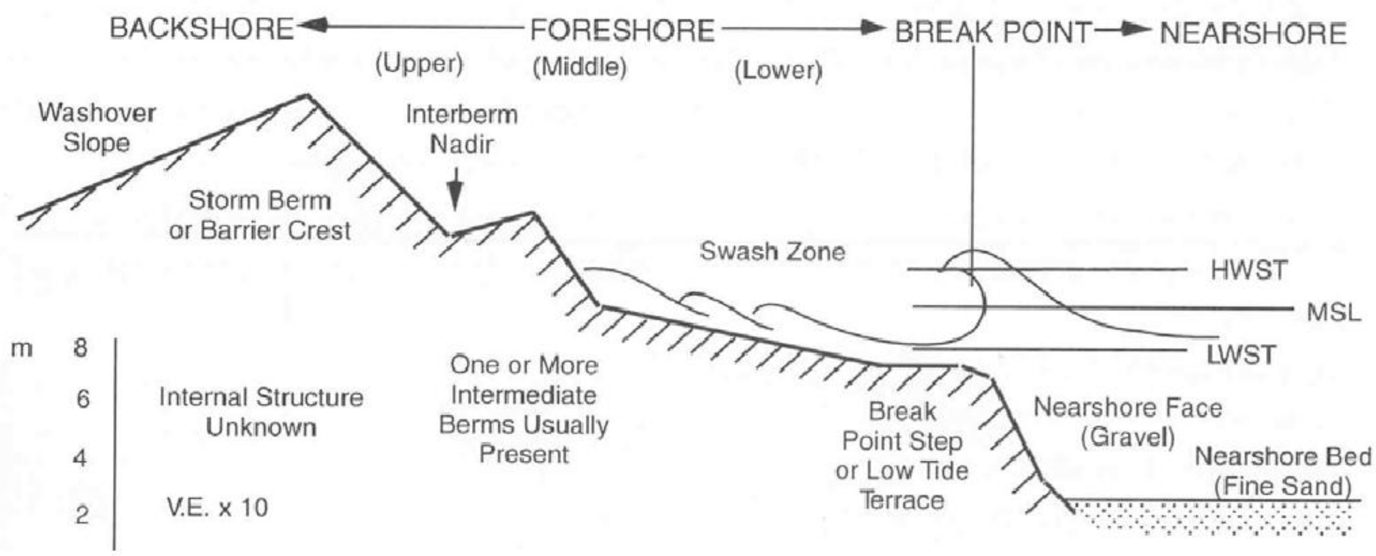


Chesil Beach, chiswellcommunity.org

Processes: beach profile

Gravel beach characteristics

- Steep step at bottom of profile
- Steep reflective foreshore
- One or more high water berms
- Cross-shore varying sedimentology



From: Single and Hemmingsen, 2001

Processes: waves

Gravel beaches are generally steep and reflective, with wave breaking occuring very close to the shore:

- Large amounts of energy in the swash zone, where the majority of gravel beach morphology takes place

- Sudden dissipation of energy at the shore results in highly turbulent environment

- Mechanisms for the generation of infragravity waves are limited, so the incident band is dominant near the shore

Processes: groundwater

Gravel beaches are relatively permeable compared to sand beaches. In general this permeability adds to the strength of the coastal system:

• Infiltration of water during the swash cycle leads to net onshore transport of gravel

• Groundwater levels affect the amount of infiltration: low groundwater level enhances onshore transport

• Infiltration leads to sediment sorting: coarse (flat) sediments are left at the edge of runup where there is not sufficient flow to return them to sea

Processes: sediment transport

Sediment transport on gravel beaches is concentrated in a narrow surf zone and the swash zone:

• Critical thresholds for transport are almost always exceeded by waves due to very strong energy dissipation at the shore

• Sediment transport is dominated by sheet flow and bed load transport

• Saltation of individual clasts takes place under energetic conditions

• Because of large variations in the size of sediment on gravel beaches, armouring, sheltering and exposure of sediments can play an important role

Processes: morphology

The morphology of gravel beaches differs from that of sandy coasts:

• Gravel beaches respond quickly to changes in hydrodynamic forcing (minutes) and tend to morph over the tidal cycle

• Development of a steep step-like feature in the subtidal beach profile causes wave breaking

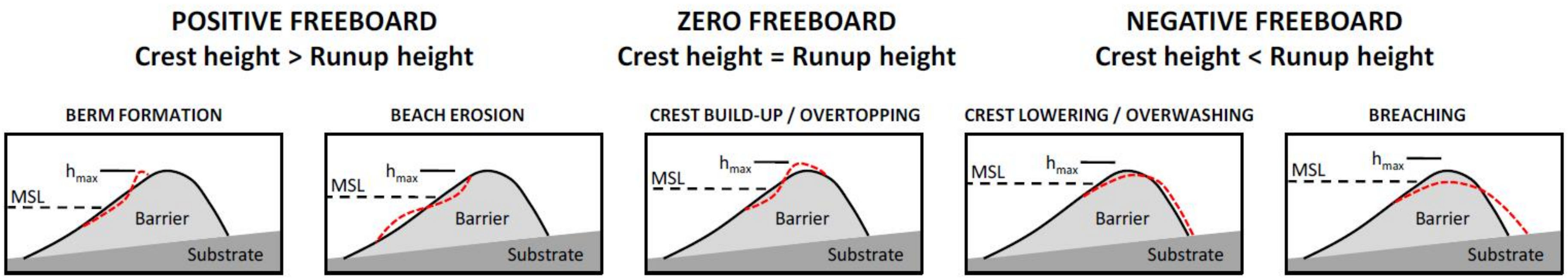
• Under typical accretive conditions, waves and infiltration combine to generate a berm at the upper limit of runup, thereby steepening the beach

• Reflective gravel beaches often develop 3D cusp and horn features that strongly influence local swash hydrodynamics

Processes: storm morphology

Storm impact on gravel coasts can be described by the morphology of the beach / barrier in order of increasing severity:

- Berm formation
- Beach erosion
- Overtopping and crest build up
- Overwashing and crest lowering / roll back
- Breaching and barrier destruction

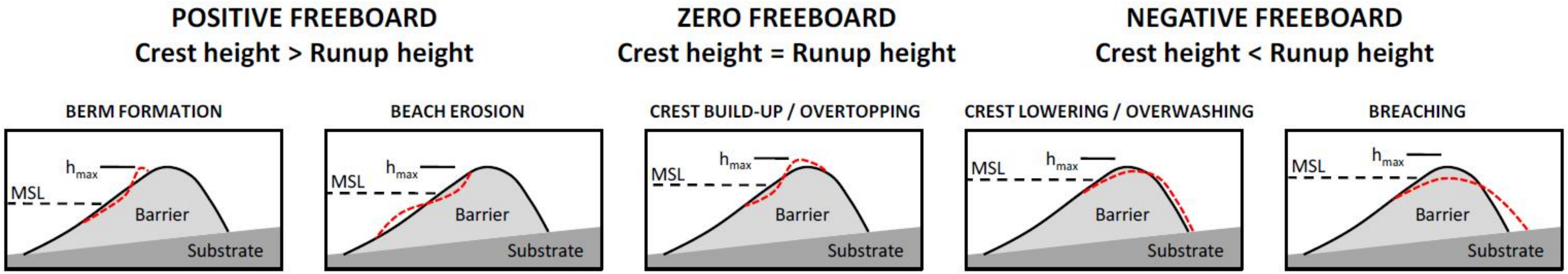


Processes: storm morphology

Conditions for, and thresholds between, morphological stages are not fully understood:

- Berm formation is *thought* to be caused by low steepness waves
- Beach erosion is *thought* to be caused by high steepness waves
- Beach permeability and grain size affect transition

However, in field cases long period swell conditions and bi-modal conditions seem to cause greater erosion than short period wind waves.

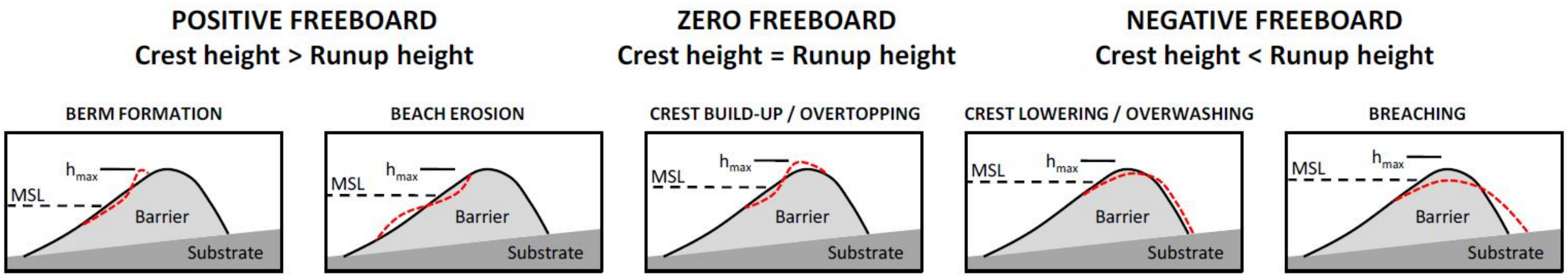


Processes: storm morphology

Conditions for, and thresholds between, morphological stages are not fully understood:

- Overtopping and crest build-up occurs when runup reaches crest
- Overwashing and breaching usually only occurs when the surge level is extreme, not under wave forcing alone

However, breaching may occur if the barrier is narrow and waves have sufficient time to erode the beach and crest




Models

Unlike sandy coasts, relatively few models exist to aid coastal managers in gravel coasts. In general, models are limited to local site knowledge and simple parametric models:

- Local site knowledge

  Commonly used where long records of coastline change exist

- Parametric / empirical models

  Used for scenario-testing, forecasting

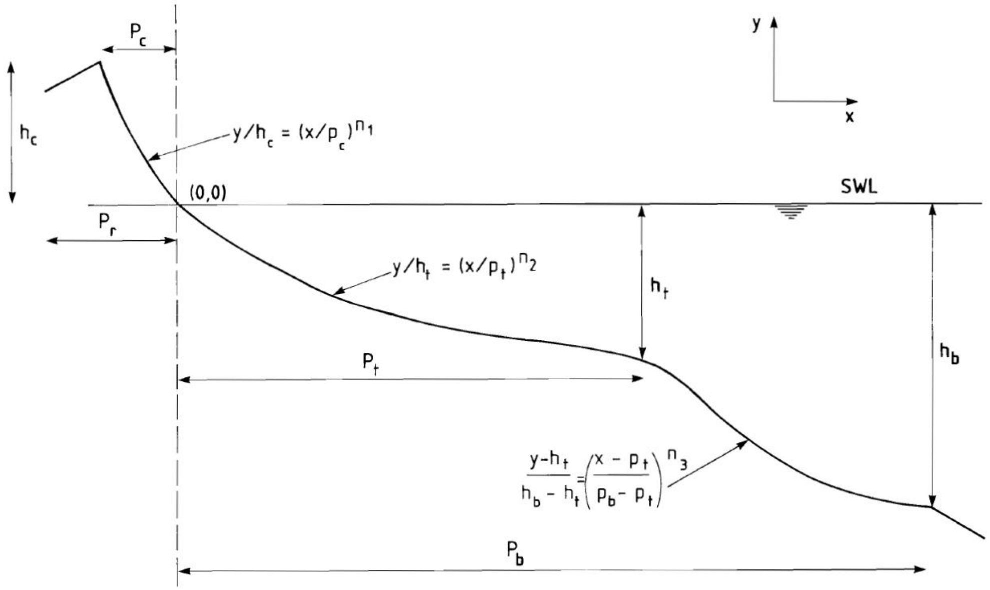
- Process-based models

  In developmental stage, not yet used in practical applications

Models: parametric

Two parametric models are used frequently in the UK to determine gravel coast storm impact:

- SHINGLE (Powell, 1990)
  - Profile shape description model based on scaled physical model experiments



From: Powell (1990)

Models: parametric

Two parametric models are used frequently in the UK to determine gravel coast storm impact:

•SHINGLE (Powell, 1990)

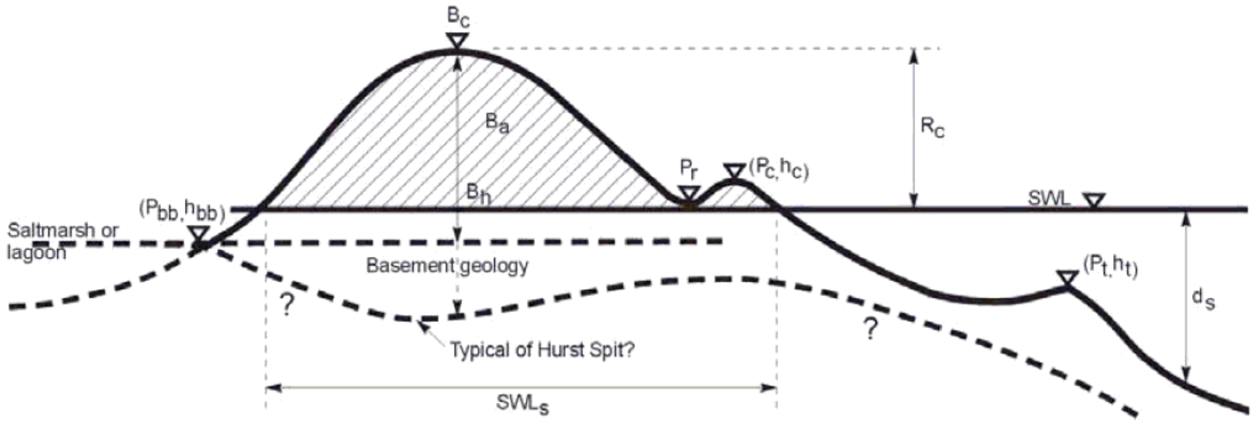
- Profile shape description model based on scaled physical model experiments
- Advange: fast; commonly-used; well validated within range of applicability
- Disadvantage: does not perform well for long period waves, or coarse sediment; does not account for overtopping/overwash; no longshore transport

Models: parametric

Two parametric models are used frequently in the UK to determine gravel coast storm impact:

• Barrier Inertia Model (Bradbury, 1990)

- Relates barrier overwash threshold to incident wave steepness, relative freeboard and barrier width



From: Bradbury (1998)

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Models: parametric

Two parametric models are used frequently in the UK to determine gravel coast storm impact:

•Barrier Inertia Model (Bradbury, 1990)

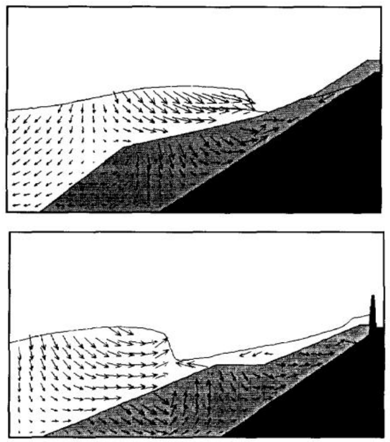
- Relates barrier overwash threshold to incident wave steepness, relative freeboard and barrier width
- Advange: fast; only model with field validation for overwash on gravel barriers
- Disadvantage: range of validity limited due to lack of data; underprediction of overwash due to bi-modal wave conditions; does not incoporate grain size or permeability; no longshore component

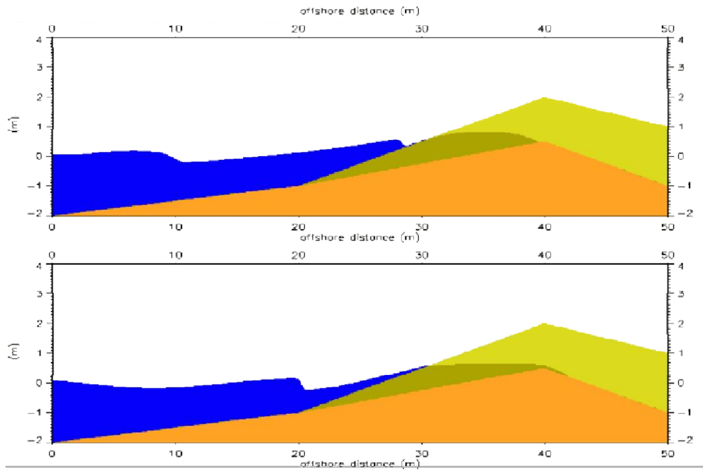
Models: process-based

Development of process-based models for gravel beaches has been limited compared to sandy beaches:

•SKYLLA (Van Gent, 1995), OTTP-1D (Clarke et al, 2004)

- Models initially developed to simulate hydrodynamics round rubble mound structures
- Solve nearshore and groundwater dynamics in 2DV (SKYLLA) or 1D (OTTP) using NLSW equations for surface water and groundwater





Right from: Van Gent (1995)
Left from: DEFRA (2008)

Models: process-based

Development of process-based models for gravel beaches has been limited compared to sandy beaches:

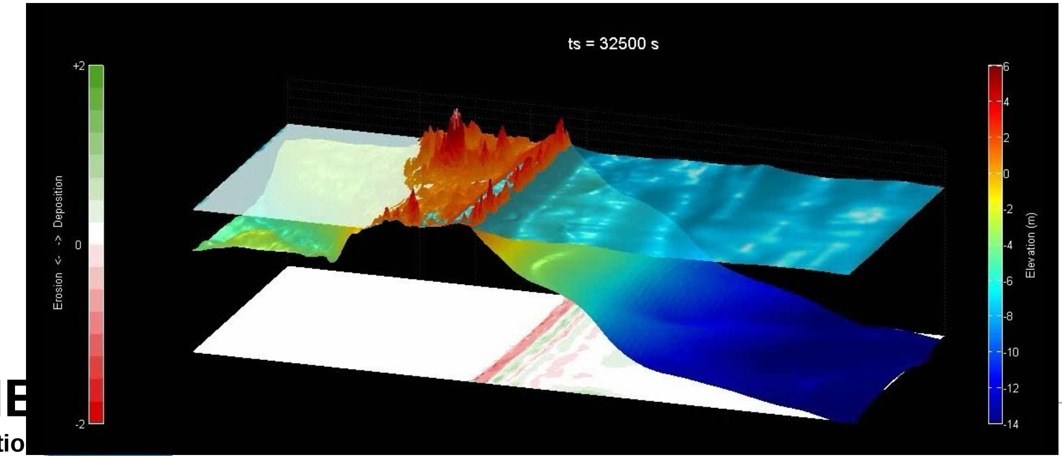
- SKYLLA (Van Gent, 1995), OTTP-1D (Clarke et al, 2004)
  - Models initially developed to simulate hydrodynamics round rubble mound structures
  - Solve nearshore and groundwater dynamics in 2D (SKYLLA) or 1D (OTTP) using NLSW equations for surface water and groundwater
  - Advantage: accurate simulation of hydrodynamics in complex environments; inclusion of groundwater interaction
  - Disadvantage: No, or very limited (SKYLLA), morphological component; can only compute shallow water dynamics; no longshore component; computational effort.

Models: process-based

Current development of process-based storm impact model for gravel / MSG beaches:

• XBeach (Roelvink et al, 2009)

- Models initially developed to simulate storm impact on sandy coasts
- Solve hydrodynamics and morphodynamics in 1D or 2DH using wave action balance, NLSE and advection and diffusion of sediment transport
- Model validated in multiple studies from NL, UK, Europe and USA with physical model experiments and field data



Models: process-based

Current development of process-based storm impact model for gravel / MSG beaches:

- Development of XBeach for gravel (ongoing)
    - Incorporation of groundwater interaction (McCall et al, 2012)
    - Phase-resolving incident band wave dynamics using simplified SWASH model (Zijlema et al, 2011; Smit et al, 2010)

    - Sediment transport and morphology: under development

Models: process-based

Application of XBeach on gravel beaches:

•McCall et al (2012)

- Validation of overwash hydrodynamics (phase-resolved waves) and groundwater dynamics using data from BARDEX physical model experiment (Williams et al, 2012a)

•Williams et al (2012b)

- Initial attempt at simulating overwash morphology (phase-resolved waves) for BARDEX experiment. Reasonable agreement with measured profiles
- Application of XBeach to define overwash criterium on field case (Slapton Sands). Results showed underprediction of overwash because incident band was not phase-resolved

Models: process-based

Application of XBeach on gravel beaches:

- Jamal et al (2010,2012)
  - Application of XBeach (no phase-resolved waves) to gravel beach berm development
  - Initial berm development with incorporation of infiltration in the swash zone
  - Reasonable berm development with strong calibration of sediment transport factors in the swash zone
  - Calibrated model showed promising results in berm morphology over tidal cycle

XBeach model strategies

Model objectives:

- Full morphodynamic development of gravel beach during storm

  Not yet available: under development in cooperation with Plymouth University (NUPSIG project)

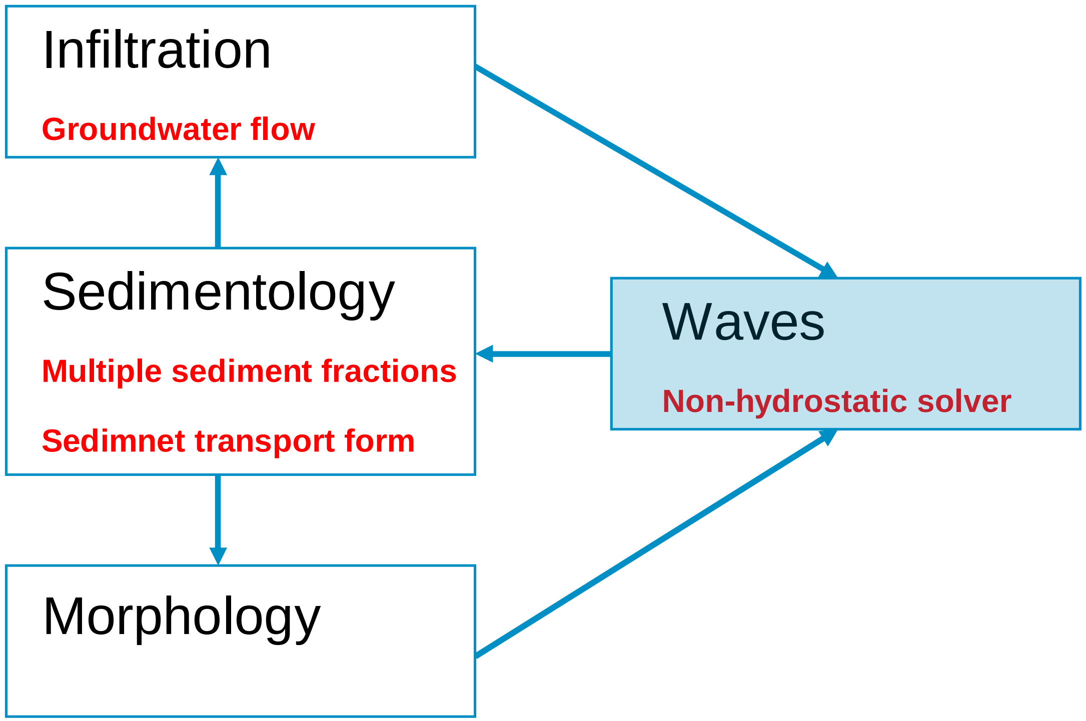
- Morphodynamic development of fine MSG beach during storm

  Beach behaves similar to sandy beach and may be possible to simulate using current XBeach model with added processes (groundwater, multiple sediments)

- Analysis of expected wave runup and estimates of overwash thresholds

  May be possible using well calibrated XBeach model with phase-resolved waves and groundwater model

Process-based model approach



Non-hydrostatic model (1)

- Is the incident band important in the swash?
  - Usually the case on gravel beaches, but may not be important on MSG beaches with shallow foreshore

- Can nearshore runup be parameterised (runup on rock structure)?
  - Usually not the case on gravel beaches

- Are nearshore wave conditions available?
  - COSMOS output point

↓

Non-hydrostatic wave solver

Non-hydrostatic model (2)

Waves model input (described in draft nonhydrostatic report):

- Use XBeach nonhydrostatic model
  - *parameter 'nonh' turns on nonhydrostatic pressure correction*
- Wave boundary conditions for nonhydrostatic model
  - *parameter 'wbcversion = 3' uses the most advanced wave boundary condition generation scheme*
  - *parameter 'nonhspectrum = 1' sets XBeach to generate individual random waves from a spectrum*
  - *parameter 'instat' sets the type of spectrum file to be read (parameterised, SWAN, or 2D variance density table)*
  - *parameter 'front = nonh_1d' sets the offshore boundary condition to (1D) absorbing/generating for nonhydrostatic wave simulations*
  - *other parameters can be the same as described in the XBeach manual*

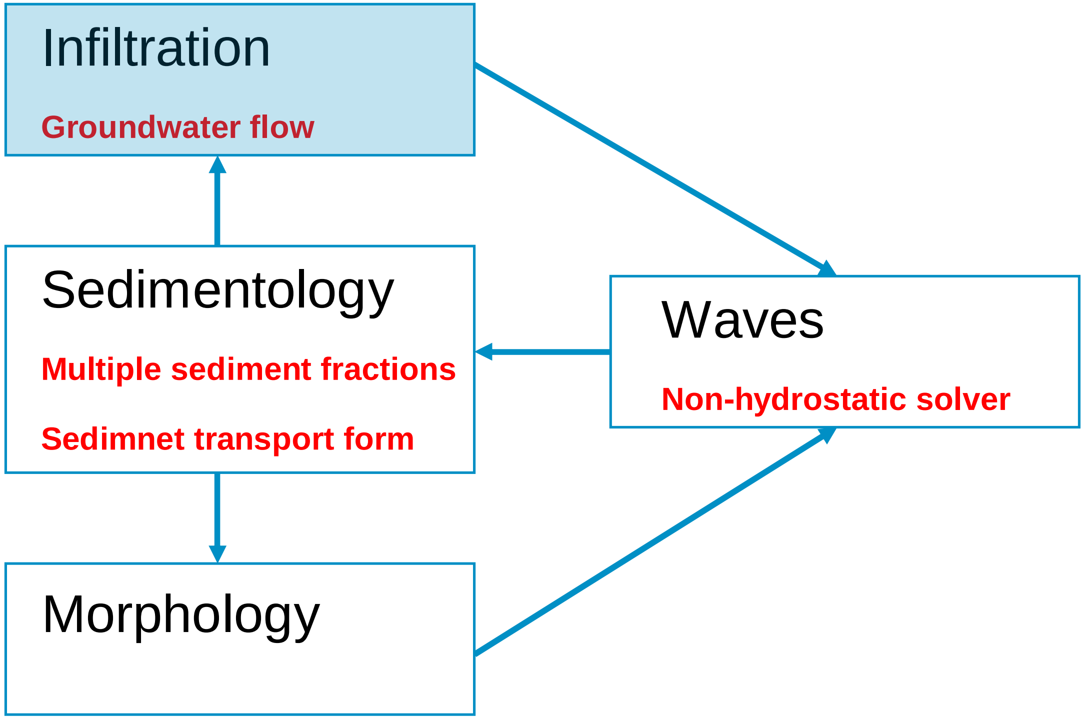
Non-hydrostatic model (3)

Waves model input (described in draft nonhydrostatic report):

•Numerical parameters

- *parameter ‘solver=2’ uses a fast nonhydrostatic pressure solver that can only be used in 1D simulations, else use slower ‘solver=1’*
- *set parameter ‘Topt’ to the dominant wave period in your simulation*

Process-based model approach



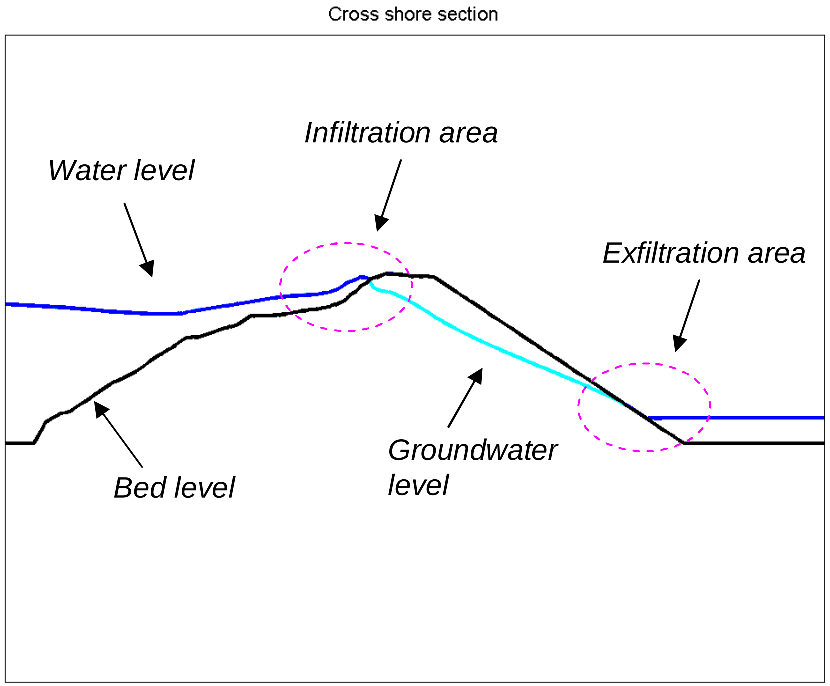
Groundwater flow (1)

Consideration of important processes:

- Infiltration and groundwater dynamics
    - Infiltration typically becomes important when K>0.01m/s (e.g. Masselink and Li, 2001) ~ grain size 1.5mm
    - Influence of hydraulic conductivity on overwash/runup large on gravel beaches, so correct estimate of K essential
    - On MSG beaches hydraulic conductivity may be orders of magnitude lower than expected from surface gravel sample
    - Groundwater levels and seepage point may vary in time (tidal and seasonal scales) to affect infiltration rates in the swash

Groundwater flow (2)

- ***Physics:***
  - ***Groundwater volume seperate from surface water, connected only by infiltration-exfiltration***
  - ***Horizontal groundwater flow solved by Darcy flow equation, driven by horizontal pressure gradients***
  - ***Infiltration: Surface water driven to groundwater by vertical pressure gradient***
  - ***Exfiltration: Groundwater level exceeds bed level***



Groundwater flow (3)

- ***Physics:***
  - ***Darcy flow***

$$u_{gw} = -k_x \frac{dp_{gw}}{dx} \qquad p_{gw} = f\left(\eta_{gw}, zs, d_{wetlayer}\right)$$

$$v_{gw} = -k_y \frac{dp_{gw}}{dy}$$

$$por\frac{d\eta_{gw}}{dt} + \frac{du_{gw}h_{ugw}}{dx} + \frac{dv_{gw}h_{vgw}}{dy} = w$$

  - ***Infiltration (w positive, volume expressed in terms of surface water, no pores)***

$$w = -k_z\left(\frac{dp}{dz} + 1\right) \qquad \text{minimum dz is } \mathrm{d}_{\mathrm{wetlayer}}$$

  - ***Exfiltration (w negative)***

$$w = \frac{\left(\eta_{gw} - z_b\right)}{dt} por \qquad \text{if} \quad \eta_{gw} \geq z_b$$

Groundwater flow (4)

Groundwater model input (section 5.15 in manual):

- Use XBeach groundwater model

  parameter 'gwflow' turns on groundwater

  Default = 0, *range* = [0,1]
- Hydraulic conductivity

  parameter 'kx' (and 'ky','kz' if conductivity varies per direction)
  Default = 1E-4m/s, *range* = [1E-6,1E-2]
- Bottom of the aquifer

  'aquiferbot', 'aquiferbotfile' specify single value or field of the level of the bottom of the aquifer

  Default = 3m below lowest point in model
- Initial conditions

  'gw0', 'gw0file' specify single value or field of the initial groundwater level

  Default = 0m

Groundwater flow (5)

Groundwater model input (section 5.15 in manual):

• Numerical parameters

'dwetlayer' sets thickness of interaction layer between surface water and groundwater. Should be ~20cm for stability, less is low conductivity

'gwdelay' sets time delay on transmission of pressure from surface water to groundwater. Should be small ~0.2s

• Boundary conditions for groundwater level are taken to be the same as the imposed tide, or constant at the back if no tide is given.

Groundwater flow (6)

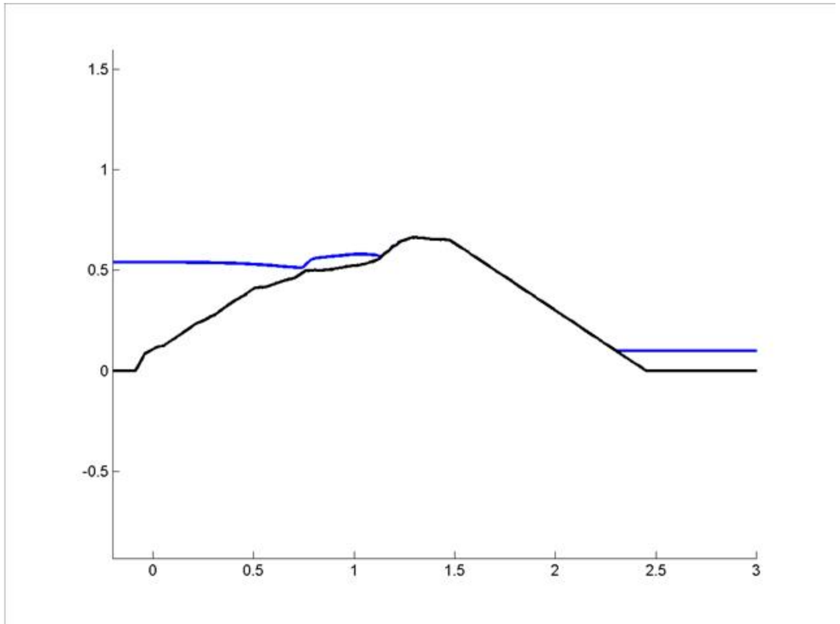
Output variables:

• Groundwater pressure head (m)	: gwhead
• Groundwater level (m)	: gwlevel
• Height (thickness) of aquifer (m)	: gwheight
• Bottom of aquifer (m)	: gwbottom
• Horizontal groundwater velocities (m/s)	: gwu, gwv
• Vertical infiltration and exfiltration (m/s)	: gww

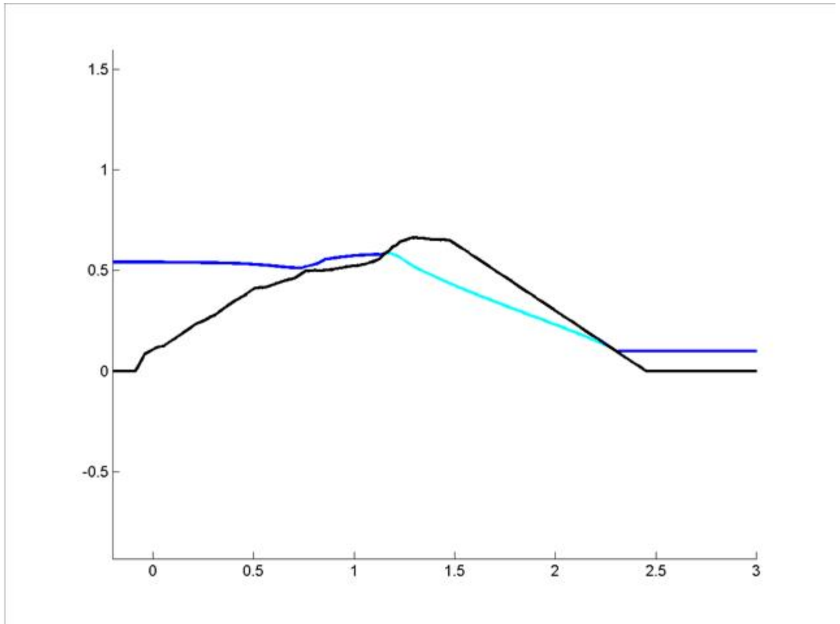
Groundwater flow (7)

Example simulation of gravel beach during BARDEX experiment

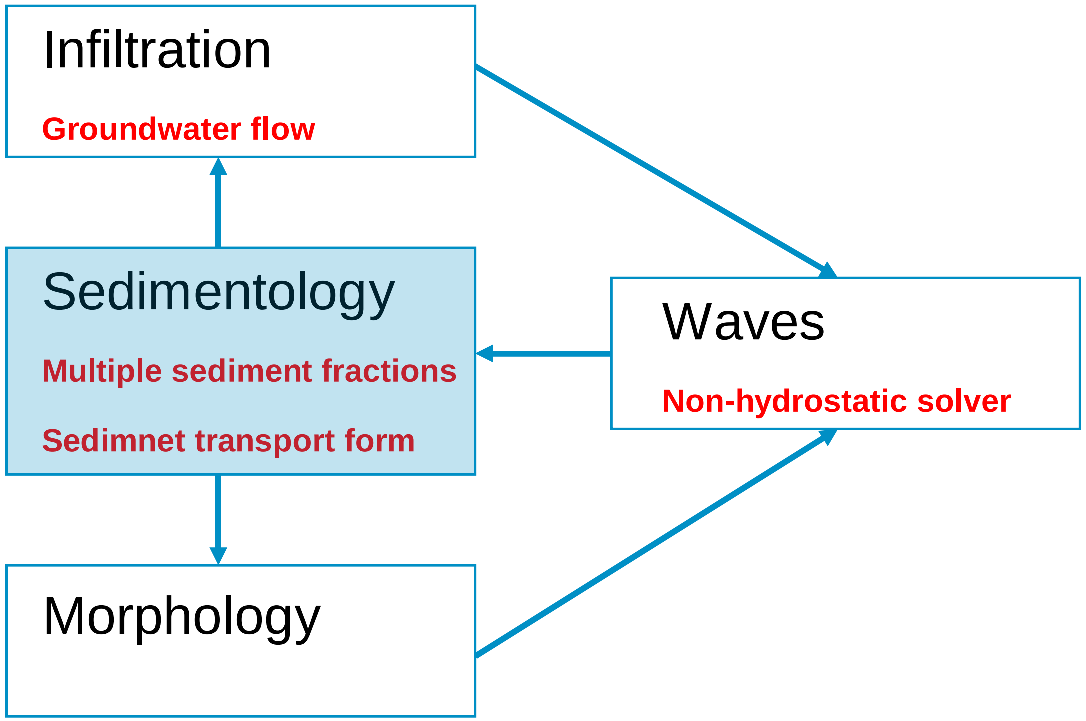
No groundwater



Groundwater flow



Process-based model approach



Multiple sediment fractions (1)

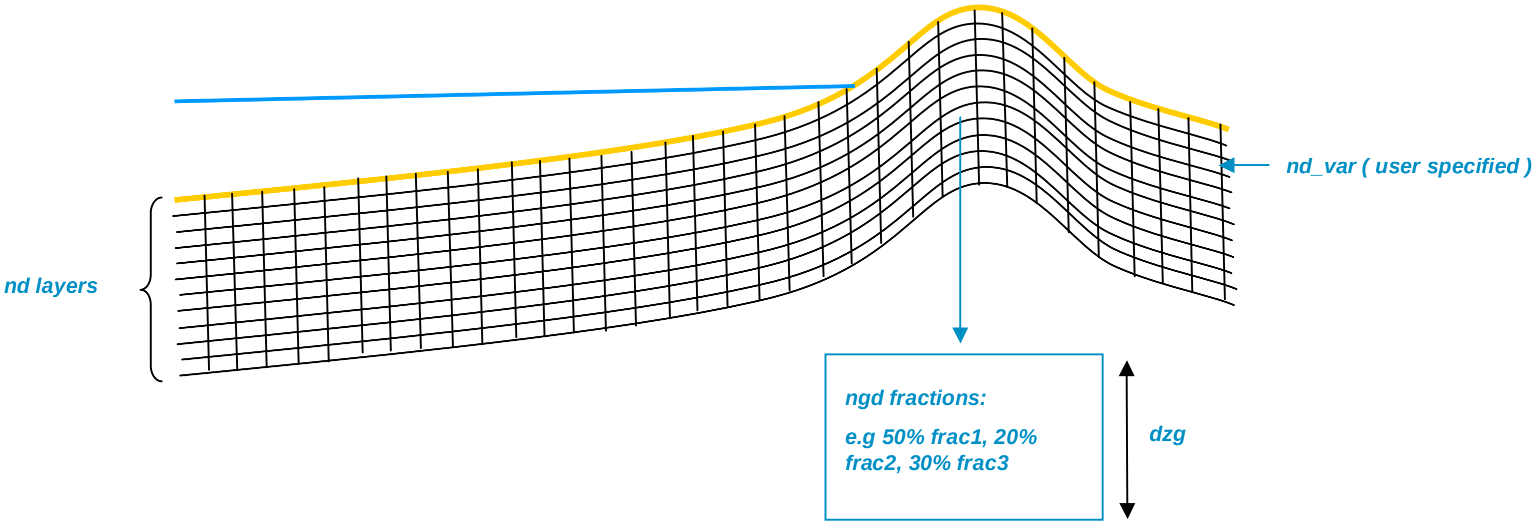
Multiple sediment fractions input (section 5.13 in manual):

• Do differences in sediment size have an important effect on the storm dynamics at the study site?

• Typically composite MSG beaches (sand and gravel separated) are more applicable to multiple sediment fraction approach than other MSG and gravel beaches

Multiple sediment fractions (2)

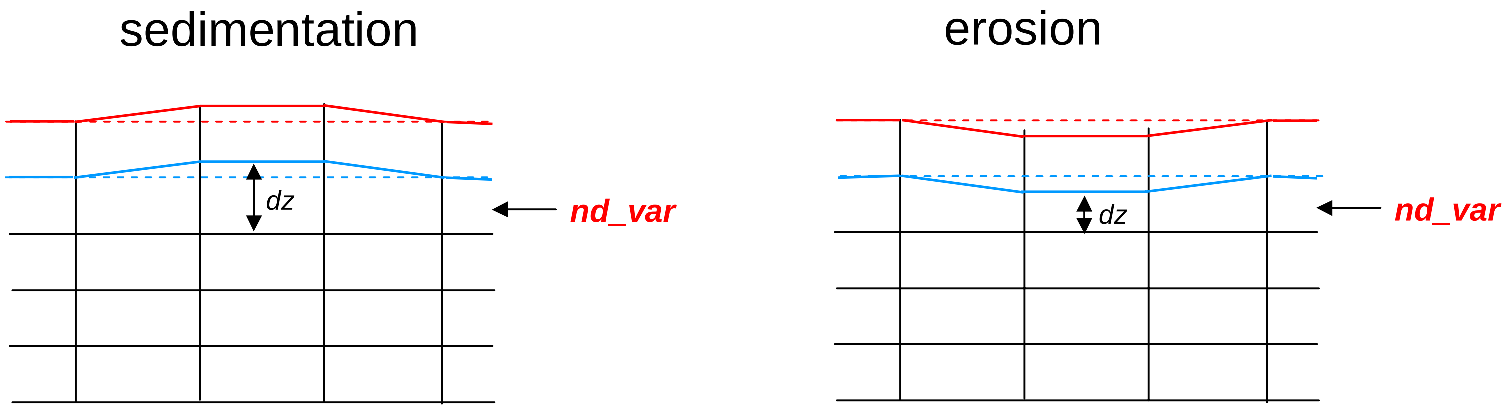
1. Modeling multiple sediment fractions requires bookkeeping of sediment properties at the bed.
2. Sediment properties at (and in) the bed are stored on a grid with:
   1. nd layers of which one (user defined) layer can vary in thickness (nd_var)
   2. the (initial) layer thickness is dzg
   3. ngd sediment fractions are specified



3. Sediment entrainment per fraction is based on sediment properties in the upper layer (nd=1)

Multiple sediment fractions (3)

4. Bed level changes are applied on the variable layer and are computed per sediment fraction



5. The mass fractions in the variable layer with are updated as:

$$p_{nd\_var,g}^{t+1} = \frac{S_{nd\_var,g}^{t+1}}{\sum_{g=1:ngd} S_{nd\_var,g}^{t+1}} \quad \text{where } S_{nd\_var,g}^{t+1} = S_{nd\_var,g}^{t} + (D-E)\Delta t$$

Multiple sediment fractions (3)

INPUT: The user needs to specify in params.txt:

1. the number of sediment fractions (ngd)
2. the number of layers (nd)
3. the initial thickness of the sediment layers (dzg)
4. the sediment properties (D50, D90) per sediment fraction
5. gdistk.inp which contains the sediment fraction for sediment class k for each grid cell
6. the index of the layer with variable thickness (nd_var)

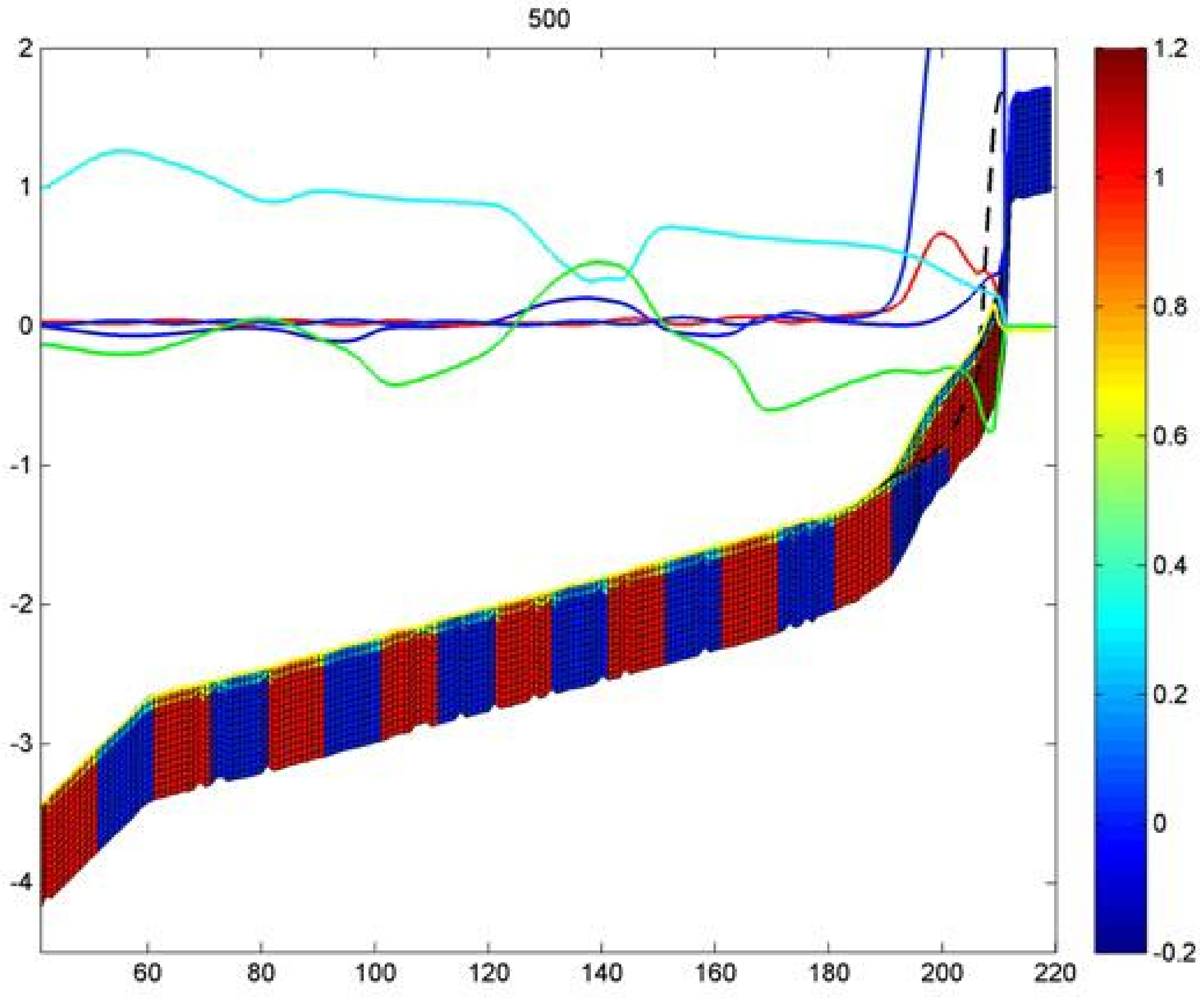
OUTPUT: The following variables can be outputted:

1. sediment concentrations and sediment transports per fraction (ccg, Susg, Subg)
2. the sediment fractions for each grid cell for all sediment classes (pbbed)
3. the thickness of the sediment layer for each grid cell (dzbed)

ASSUMPTIONS: constant porosity, constant density, constant critical slopes, constant morphological factor

Multiple sediment fractions (5)

Example simulation: blue and red sand



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Enabling Delta Life

THEORY INTERMEZZO:

Ship Waves

To be filled in by Dano

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THEORY INTERMEZZO:

Numerical implementation

Numerical Implementation

- explicit time-updating
- automatic time step based on Courant criterion
- first order accuracy → acceptable in combination with explicit scheme (small time steps) and small space steps needed to resolve beach/dune features
- upwind schematizations → chosen because of the many shock-like features in both hydrodynamics and morphodynamics, where this is acceptable without too much damping, as a means to avoid numerical oscillations
- Stelling and Duinmeijer momentum-conserving scheme to propagate “shock” waves (long-wave runup and backwash) on the beach.
- staggered grid

CLOSURE:

Dano Roelvink

Thank You

Don’t hesitate to update us about:

- Experience using XBeach
- Ideas for developments
- Projects you are working on
- Bug issues
- Courses or other assistance
- QA