



# Dynamique des plages sableuses soumises à l'action des vagues, de la marée et des rechargements artificiels

David MORELLATO

18 décembre 2008

# Content

- 1 Introduction
- 2 Models description
- 3 Model validation on Deltaflume
- 4 Model validation on Pentrez beach
- 5 Influences of waves and tide on a plane sloping beach
- 6 Artificial nourishment study
- 7 Conclusions

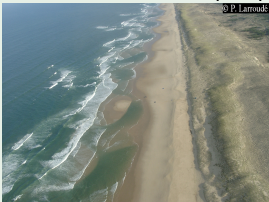
# Content

- 1 Introduction
- 2 Models description
- 3 Model validation on Deltaflume
- 4 Model validation on Pentrez beach
- 5 Influences of waves and tide on a plane sloping beach
- 6 Artificial nourishment study
- 7 Conclusions

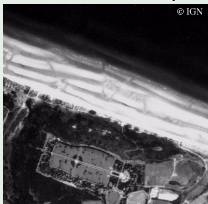
# Examples of bar systems

## 3D Sandbars

Truc Vert beach (FR)



Omaha beach (FR)



## Longshore Sandbars

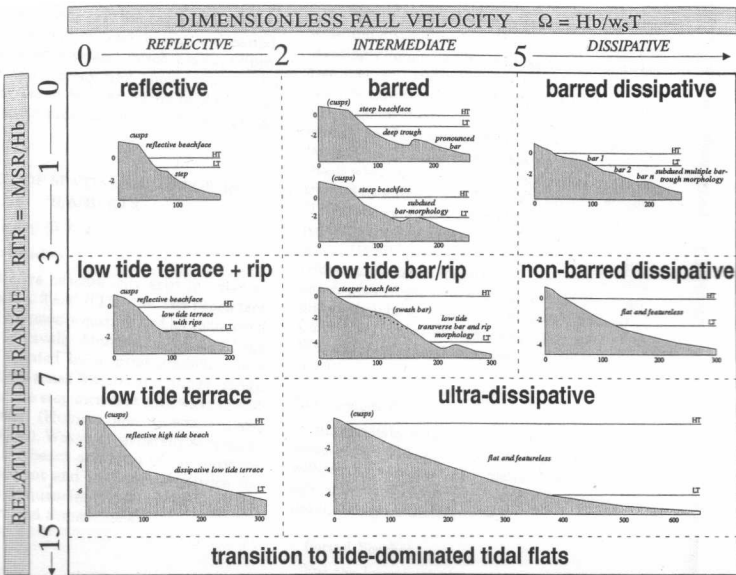
Wessex Coast (UK)



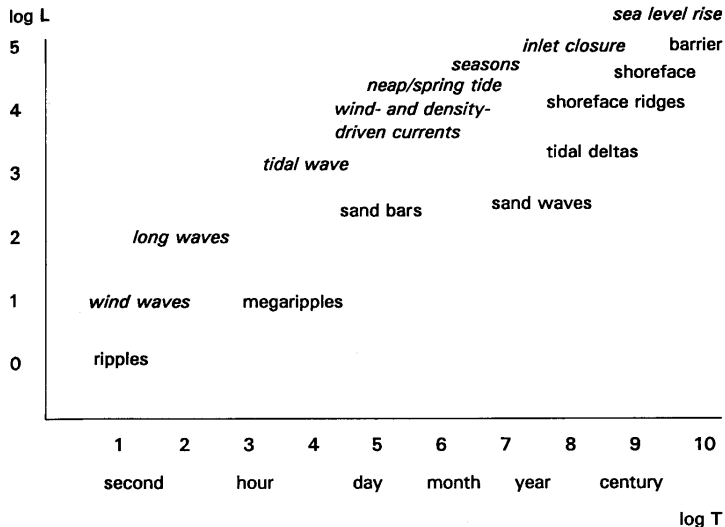
Egmond aan Zee (NL)



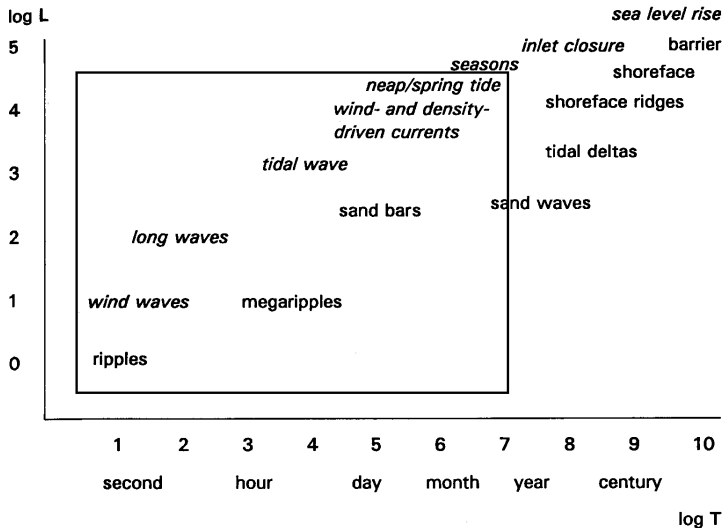
# Masselink and Short (1993) conceptual beach model



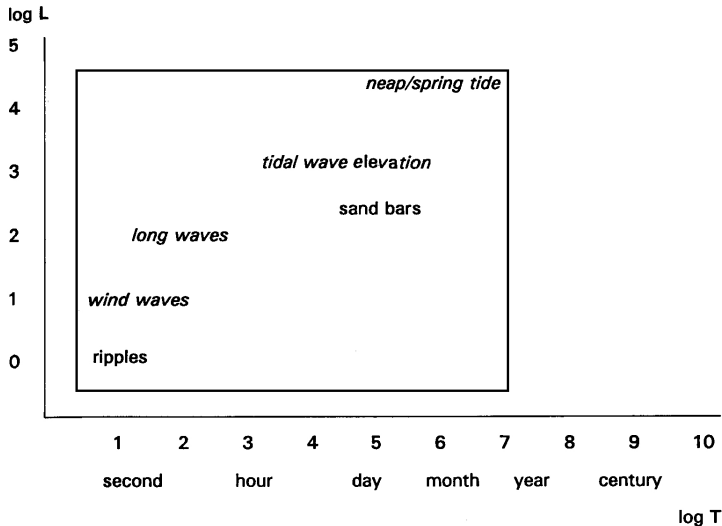
# Time and space scales of the inner-shelf morphodynamic system



# Time and space scales of the inner-shelf morphodynamic system

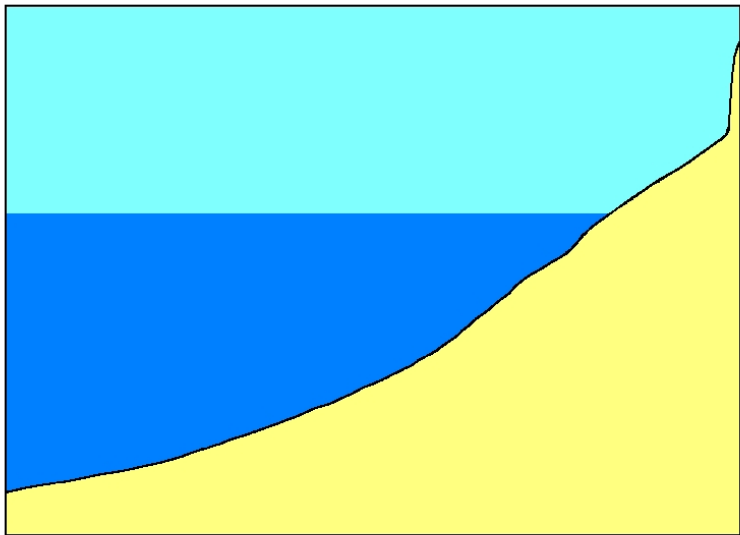


# Time and space scales of the inner-shelf morphodynamic system

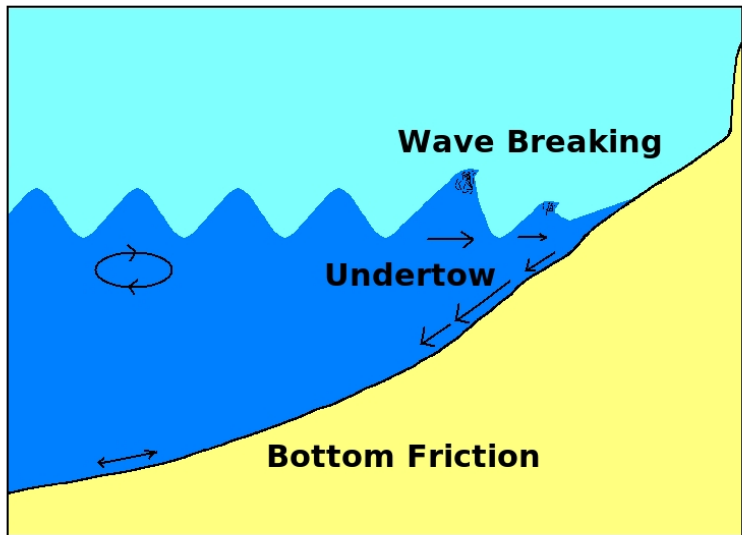




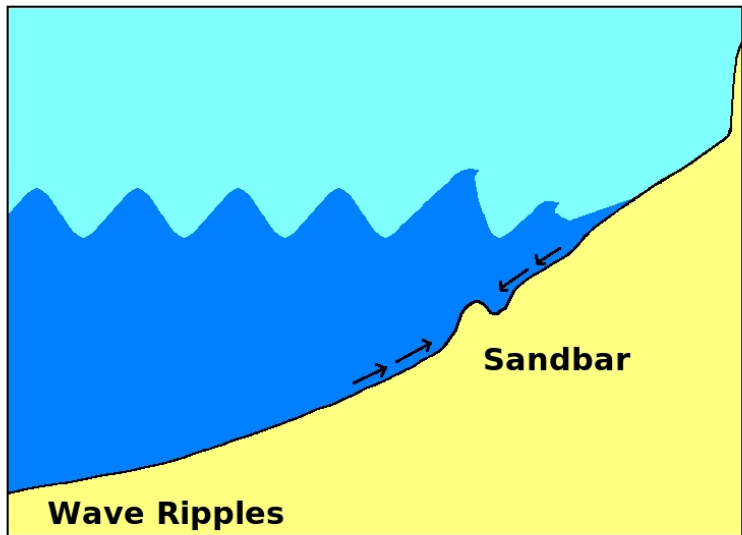
# Cross-shore processes on sandy beaches



# Cross-shore processes on sandy beaches



# Cross-shore processes on sandy beaches



# Topic : dynamic of sandy beaches under waves, tide and artificial nourishments

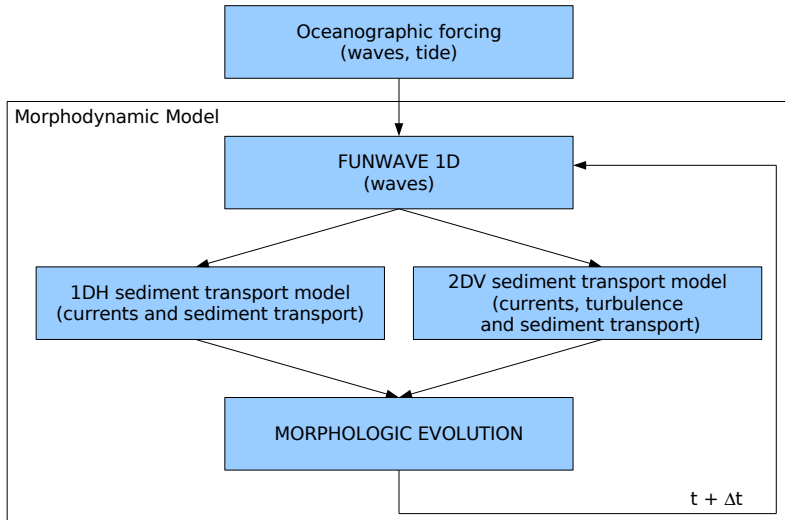
## Questions

- How to model cross-shore processes ?
- What is the fastest-most accurate way to model beach evolutions ?
- What are the effects of waves and tide on beach morphology ?
- What is the best way to nourish a beach ?

# Content

- 1 Introduction
- 2 Models description**
- 3 Model validation on Deltaflume
- 4 Model validation on Pentrez beach
- 5 Influences of waves and tide on a plane sloping beach
- 6 Artificial nourishment study
- 7 Conclusions

# Morphodynamic model



# Wave model

## Wave model FUNWAVE (Kirby *et al.*, 1998)

Based on Wei *et al.* (1995)'s equations :

$$\eta_t + M_x = 0$$

$$u_{\alpha t} + u_{\alpha} u_{\alpha x} + g\eta_x + V = 0$$

$$\begin{aligned}
 M &= (h + \eta) \left[ u_{\alpha} + \left( z_{\alpha} + \frac{1}{2} (h - \eta) \right) (h u_{\alpha})_{xx} \right. \\
 &\quad \left. + \left( \frac{1}{2} z_{\alpha}^2 - \frac{1}{6} (h^2 - h\eta + \eta^2) \right) u_{\alpha xx} \right] \\
 V &= z_{\alpha} \left\{ \frac{1}{2} z_{\alpha} u_{\alpha txx} + (h u_{\alpha t})_{xx} \right\} + \left\{ \frac{1}{2} (z_{\alpha}^2 - \eta^2) u_{\alpha} u_{\alpha xx} + \frac{1}{2} [(h u_{\alpha})_x + \eta u_{\alpha x}]^2 \right\}_x \\
 &\quad + \left\{ (z_{\alpha} - \eta) u_{\alpha} (h u_{\alpha})_{xx} - \eta \left[ \frac{1}{2} \eta u_{\alpha tx} + (h u_{\alpha t})_x \right] \right\}_x
 \end{aligned}$$

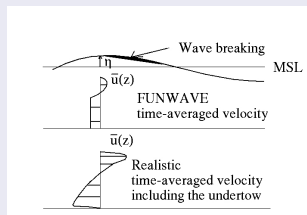
with  $\eta$  the free surface,  $h$  the water depth and  $u_{\alpha}$  the horizontal velocity at  $z_{\alpha} = 0.531h$

$$u_{\text{FUNWAVE}}(z) = u_{\alpha} + \frac{z_{\alpha}^2 - z^2}{2} u_{\alpha xx} + (z_{\alpha} - z) (h u_{\alpha})_{xx}$$

# Wave model

## Wave processes and FUNWAVE (Kirby *et al.*, 1998)

- **Bottom friction**  $F_b = \frac{Kg}{h+\eta} u_\alpha |u_\alpha|$  including **wave-ripples** predictors of Nielsen (1992),
- **Streaming** neglected,
- **Wave breaking** from Kennedy *et al.* (2000) : eddy viscosity of Zelt (1991) and realistic description of the initiation/cessation of wave breaking of Schäffer *et al.* (1993) on free surface slope,
- **Undertow** not well reproduced in  $u_{\text{FUNWAVE}}(z)$ . Needs a correction :
  - 1st option : Post-treatment of Lynett (2006)
  - 2nd option : Turbulence closure vertical model





# 1DH sediment transport model

Bailard's total transport formula (1981) : bedload and suspension

$$q_{1DH}(x) = q_{c0}(x) + q_{c\beta}(x) + q_{s0}(x) + q_{s\beta}(x)$$

$$q_{c0}(x) = \frac{C_f \varepsilon_c}{2g(s-1)\tan\phi} \overline{|u(x, -h, t)|^2} u(x, -h, t)$$

$$q_{c\beta}(x) = -\frac{C_f \varepsilon_c}{2g(s-1)\tan^2\phi} \overline{|u(x, -h, t)|^3} \beta(x)$$

$$q_{s0}(x) = \frac{C_f \varepsilon_s}{2g(s-1)w_f} \overline{|u(x, -h, t)|^3}$$

$$q_{s\beta}(x) = -\frac{C_f \varepsilon_s^2}{2g(s-1)w_f^2} \overline{|u(x, -h, t)|^5} \beta(x)$$

Lynett's model (2006)

$$u_{\text{LYNETT}}(z) = u_{\text{FUNWAVE}}(z) + u_B(z)$$

with

$$u_B(z) = \delta_{\text{breaking switch}} (C_{\text{roller}} - u_{\text{FUNWAVE}}(\eta)) \frac{\exp(k(z-\eta)) - \exp(k(z_B-\eta))}{1 - \exp(k(z_B-\eta))}$$

$$\delta_{\text{breaking switch}} = 0 \text{ ou } 1$$

# 2DV sediment transport model

## Turbulence closure vertical model

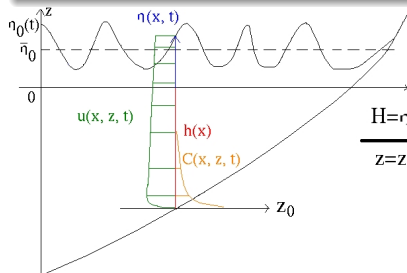
$$\frac{\partial u}{\partial t} - \frac{\sigma}{H} \frac{\partial \eta}{\partial t} \frac{\partial u}{\partial \sigma} = \frac{\partial \bar{u}_0}{\partial t} + \frac{\partial}{\partial \sigma} \left( \nu_t \frac{\partial u}{\partial \sigma} \right) \frac{1}{H^2} - \frac{1}{\rho_w} \frac{\partial \bar{\tau}_{zx}}{\partial z}$$

$$\frac{\partial k}{\partial t} - \frac{\sigma}{H} \frac{\partial \eta}{\partial t} \frac{\partial k}{\partial \sigma} = \frac{1}{H^2} \frac{\partial}{\partial \sigma} \left( \frac{\nu_t}{\sigma_k} \frac{\partial k}{\partial \sigma} \right) + \frac{\nu_t}{H^2} \left( \frac{\partial u}{\partial \sigma} \right)^2 - C_\nu \frac{k^{\frac{3}{2}}}{l} \text{ with } \nu_t = l\sqrt{k}$$

$$\frac{\partial C}{\partial t} - \frac{\sigma}{H} \frac{\partial \eta}{\partial t} \frac{\partial C}{\partial \sigma} = \frac{1}{H} \frac{\partial}{\partial \sigma} [(w_f - w_\sigma) C] + \frac{1}{H^2} \frac{\partial}{\partial \sigma} \left( \varepsilon_{sd} \frac{\partial C}{\partial \sigma} \right) \text{ with } \varepsilon_{sd} = \nu_t$$

$$q_{2DV}(x) = \bar{q}_{su}(x) + \bar{q}_{sw}(x) + \bar{q}_{sl}(x) + \bar{q}_c(x)$$

$$q_{2DV}(x) = \int_{z_0}^H C(z) \bar{u}(z) dz + \int_{z_0}^H C(z) u_w(z, t) dz + \int_{z_0}^H C(z) U_l(z) dz + q_{c0} + q_{cb}$$



$$\sigma = 1 \quad u(1) = u_{\text{FUNWAVE}} + \delta_{\text{breaker}} \gamma \sqrt{gH}$$

$$H = \eta + h - z_0$$

$$\xrightarrow{\quad} z = z_0 + H\sigma$$

$$\sigma = 0$$

$$u(0) = 0$$

$p(0) = w_f C_0$  for sheetflow (Zyserman and Fredsoe, 1984)  
Nielsen's pick-up function (1992) for rippled bed

# Morphologic evolution

## Sediment conservation law

$$\frac{\partial h}{\partial t} = \frac{1}{1-\varepsilon} \frac{\partial q}{\partial x}$$

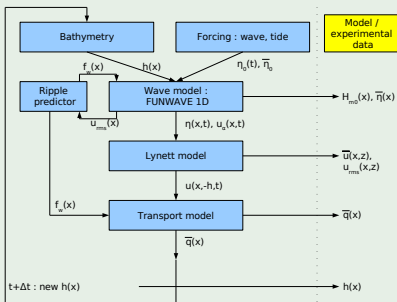
resolved with a modified-Lax scheme (idem Rakha *et al.*, 1997)

## Tide effects

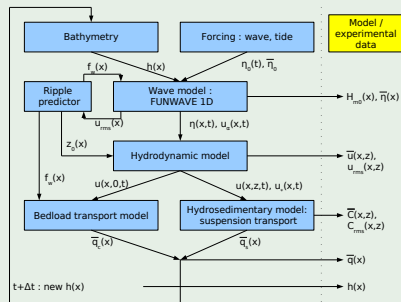
- Water level constant during a morphodynamic step  $\Delta t$  (typically 10 minutes)
- No tidal currents
- Tidal signal :
  - Sinusoidal ( $T_{M2}=12H25mn$ )
  - Spring-to-spring tidal cycle ( $T_{M2}=12H25mn$ ,  $T_{S2}=12H00mn$ )
  - Experimental data

# Two morphodynamic models

## FUNBEACH 1DH



## FUNBEACH 2DV

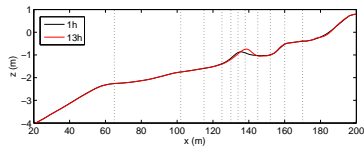
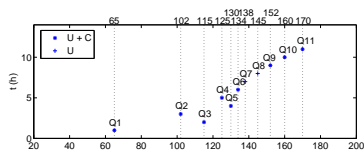
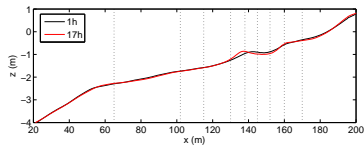
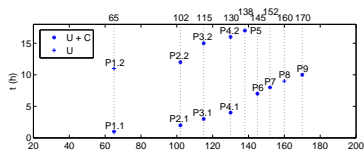


- Large wave tank experiments : Delta flume '93
- Field measurements : Pentrez beach

# Content

- 1 Introduction
- 2 Models description
- 3 Model validation on Deltaflume**
- 4 Model validation on Pentrez beach
- 5 Influences of waves and tide on a plane sloping beach
- 6 Artificial nourishment study
- 7 Conclusions

# Delta Flume '93 data description

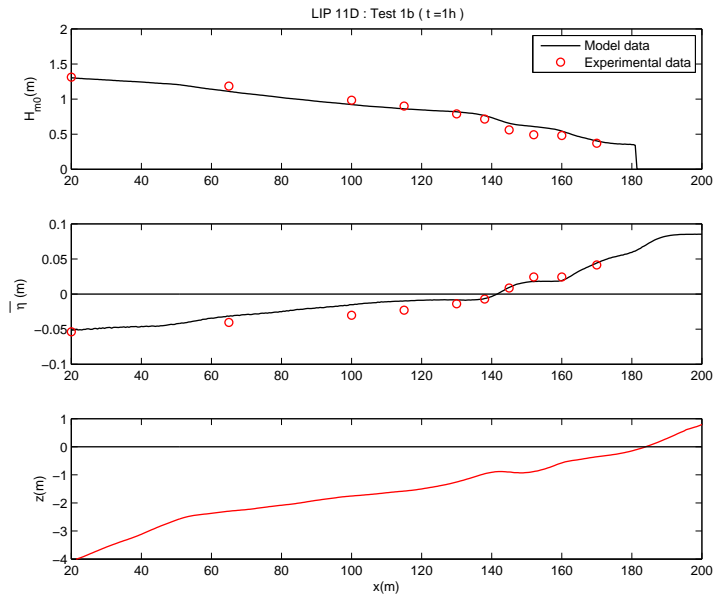


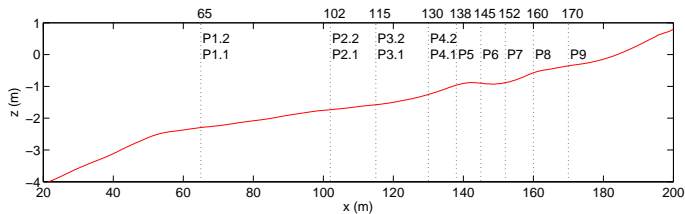
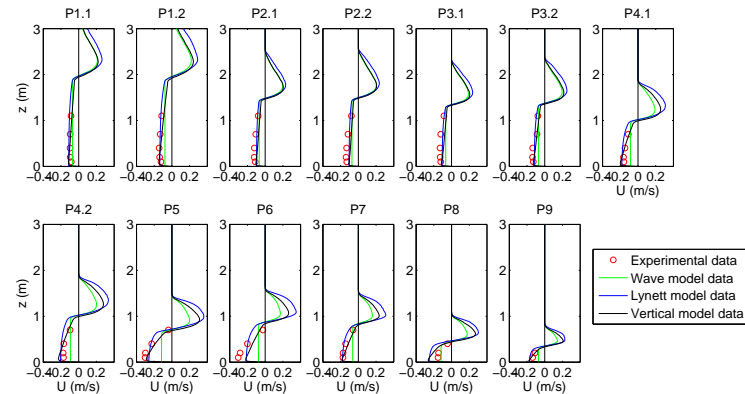
## Test 1b

- $H_{m0} \simeq 1.40$  m,  $T_p \simeq 5$  s
- Duration : 17 H
- Offshore bar migration

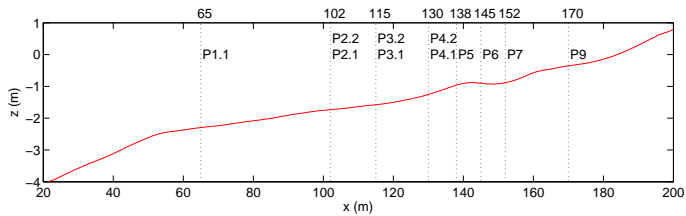
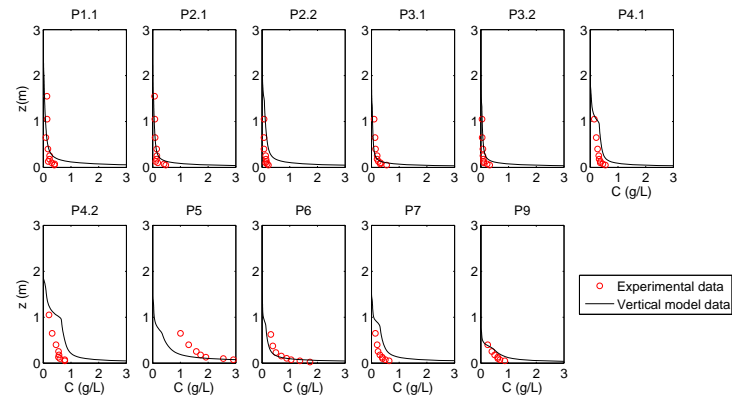
## Test 1c

- $H_{m0} \simeq 0.60$  m,  $T_p \simeq 8$  s
- Duration : 13 H
- Onshore bar migration

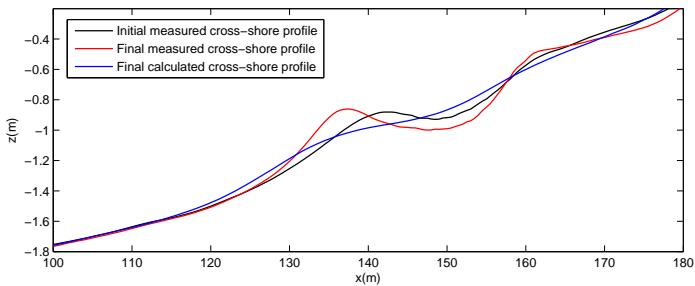
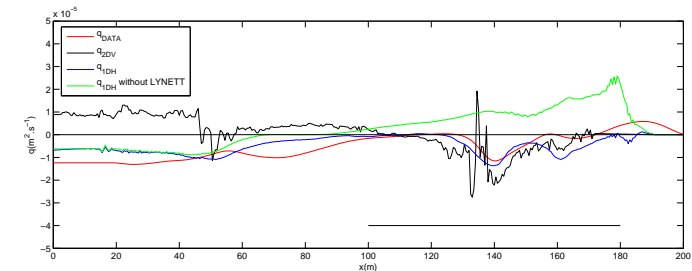
Test 1b :  $H_{m0}$  and  $\bar{\eta}$ 

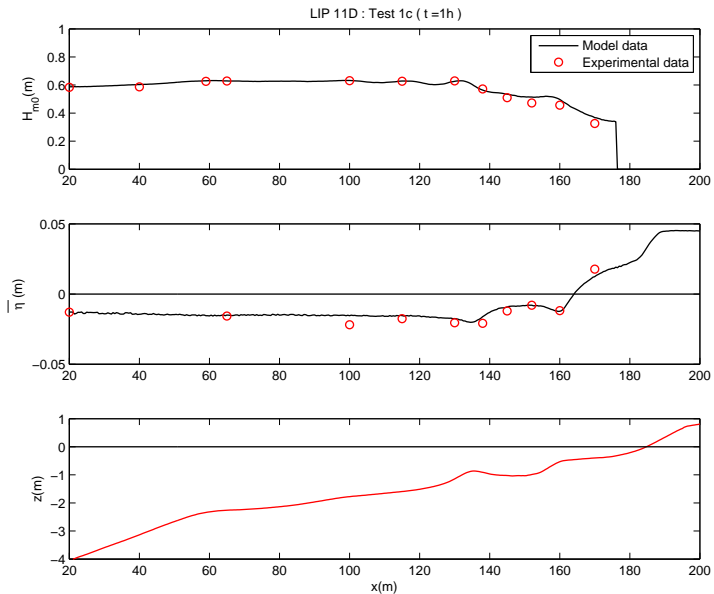
Test 1b :  $\bar{U}$ 

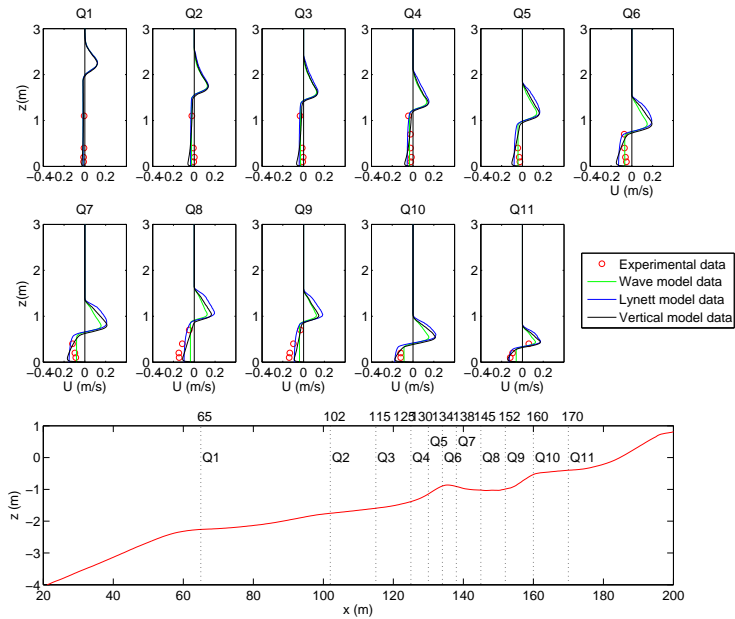


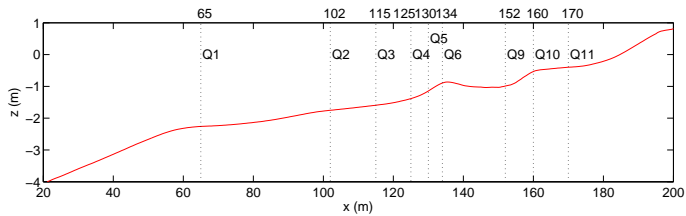
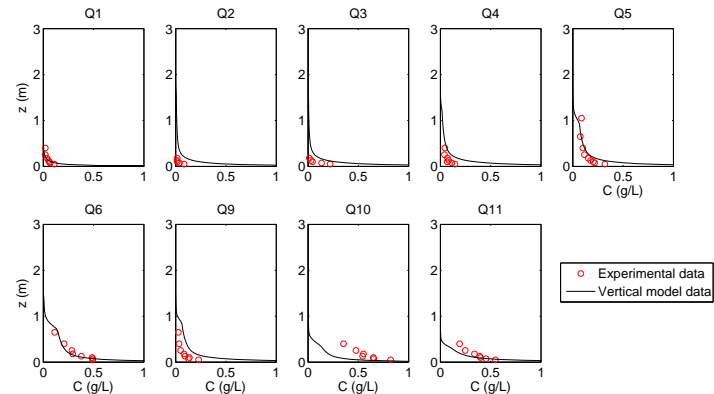
Test 1b :  $\bar{C}$ 

# Test 1b : transport rates (first time step) and cross-shore profile evolution

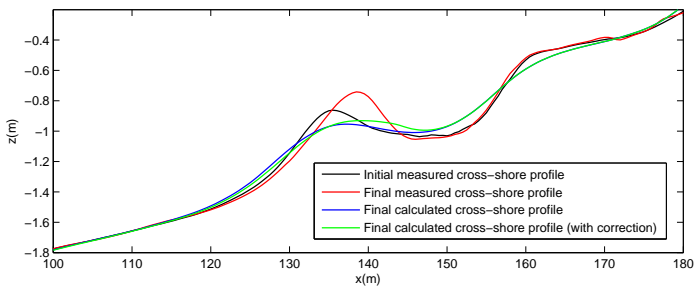
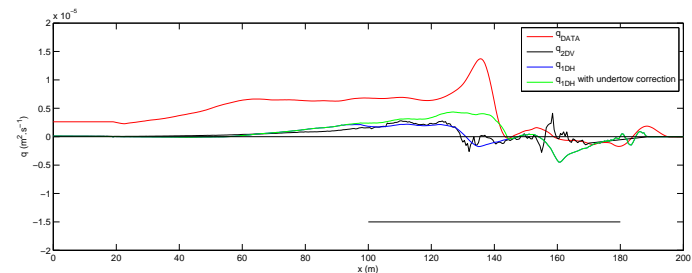


Test 1c :  $H_{m0}$  and  $\bar{\eta}$ 

Test 1c :  $\bar{U}$ 

Test 1c :  $\bar{C}$ 

# Test 1c : transport rates (first time step) and cross-shore profile evolution



# To conclude with Delta Flume experiments :

## Synthesis

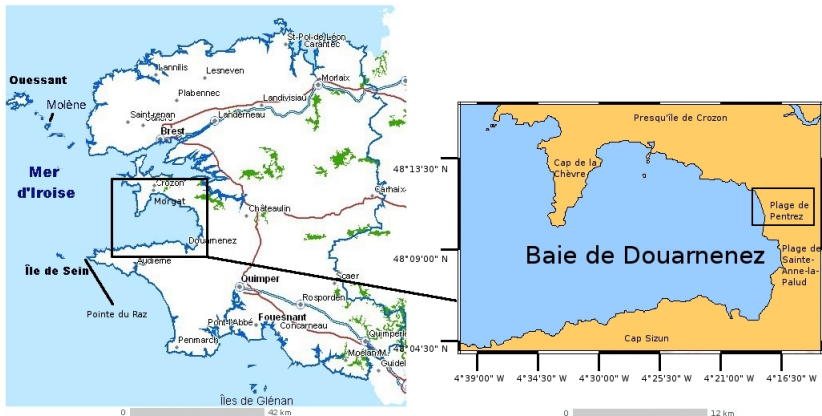
- Good estimation of wave heights, water level, mean velocities and mean concentrations of sediment by FUNBEACH,
- Good estimation of bar movement for test 1b,
- Poor estimation of bar evolutions for test 1c which highlights the interest of estimating correctly the bottom velocities (undertow) to get better morphologic predictions,
- Due to long computational time and numerical instabilities for FUNBEACH 2DV, establishing of a method of computation :
  - Calibration of the 2DV transport model on velocity and concentrations experimental data,
  - Calibration of the 1DH transport model on the 2DV transport model in terms of transport rates,
  - Morphologic evolution calculated with FUNBEACH 1DH.

# Content

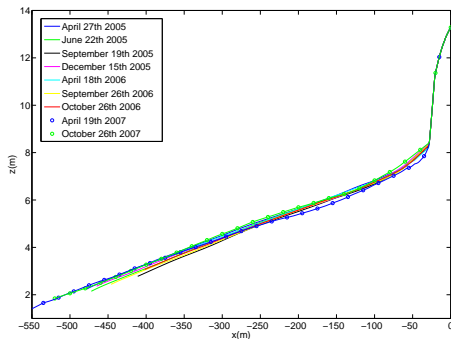
- 1 Introduction
- 2 Models description
- 3 Model validation on Deltaflume
- 4 Model validation on Pentrez beach**
- 5 Influences of waves and tide on a plane sloping beach
- 6 Artificial nourishment study
- 7 Conclusions



# Pentrez beach in the bay of Douarnenez

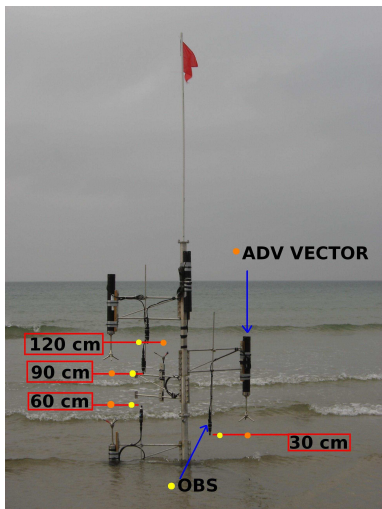


# Pentrez beach and topographic survey



- Macrotidal beach ( $TR > 4m$ ) with weak tidal currents,
- Cross-shore configuration (longshore currents neglected),
- Swell with spilling breakers,
- Weak morphologic evolution (maximum of 40 cm in the intertidal zone during 30 months).

# MII : « Mât Instrumenté en zone Intertidale »



- 3 or 4 Acoustic Doppler Velocimeters VECTOR,
- 3 or 4 OBS turbidimeters.

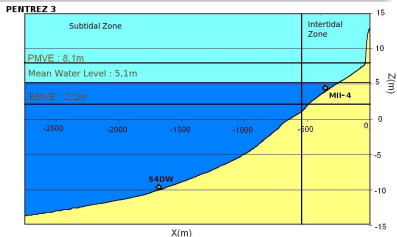
at 30, 60, 90 (and 120 cm)  
over the bottom.

in addition to an offshore  
( $z=-10\text{m}$ ) wave sensor.

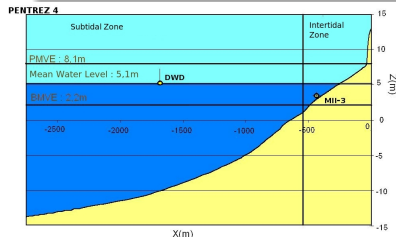
# Pentrez beach Campains

| Campains  | offshore sensor | intertidal sensors | Tidal coefficients |
|-----------|-----------------|--------------------|--------------------|
| PENTREZ#1 | Wave rider      | S4DW velocimeter   | 42 to 62           |
| PENTREZ#2 | Wave rider      | 2 ADV VECTOR       | 86 to 105          |
| PENTREZ#3 | S4DW            | MII#4              | 56 to 74           |
| PENTREZ#4 | Wave rider      | MII#3              | 62 to 96           |

PENTREZ#3 :  
18-20 october 2006



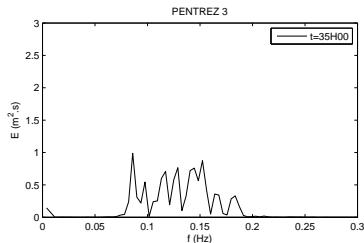
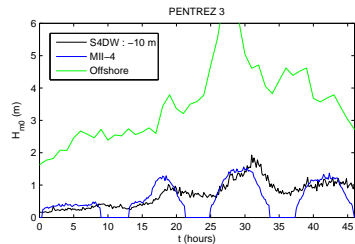
PENTREZ#4 :  
14-16 april 2007



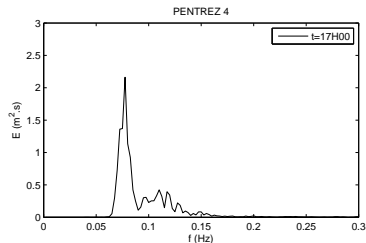
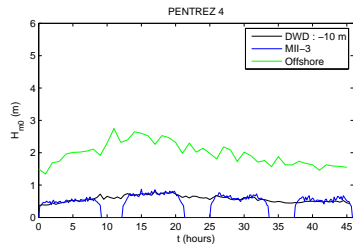
Continuous data acquisition during 46 hours.

# Spectral wave heights and wave spectrum

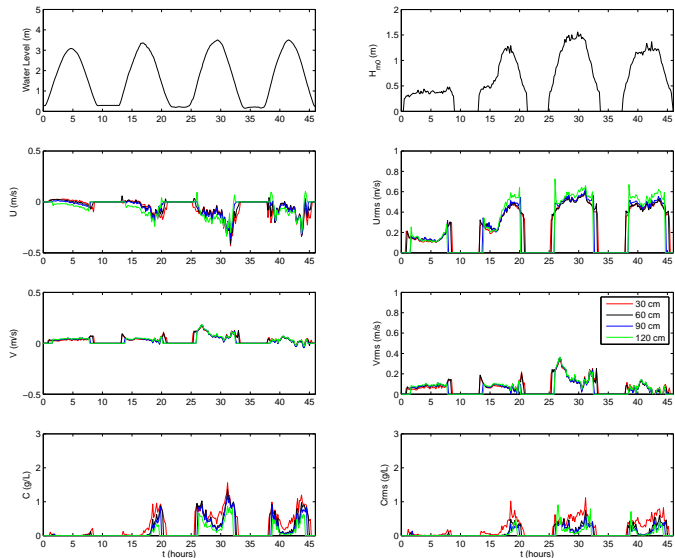
## PENTREZ#3 : Wind Waves



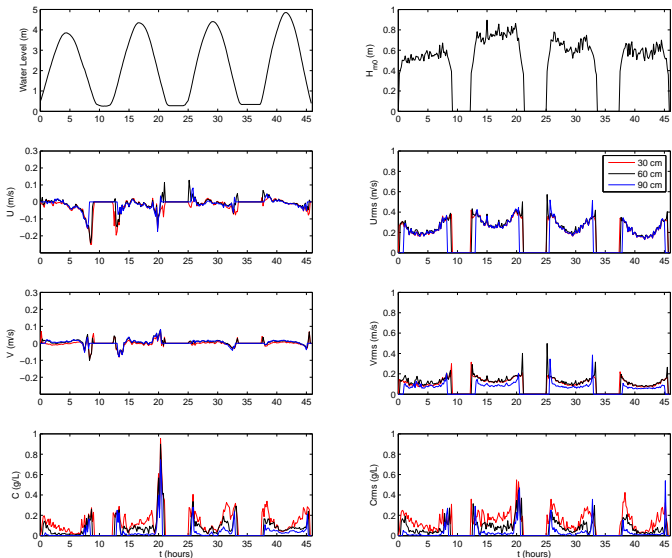
## PENTREZ#4 : Swell



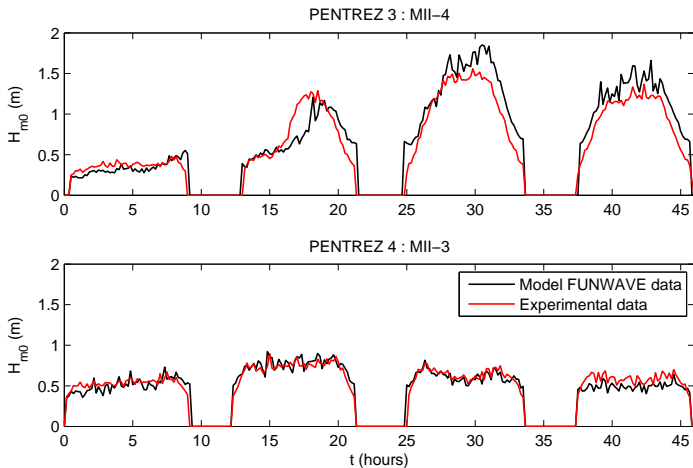
# Experimental data analysis : PENTREZ#3



# Experimental data analysis : PENTREZ#4



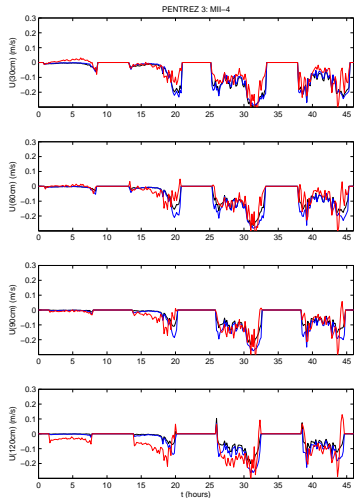
# Experimental vs. FUNWAVE : wave heights



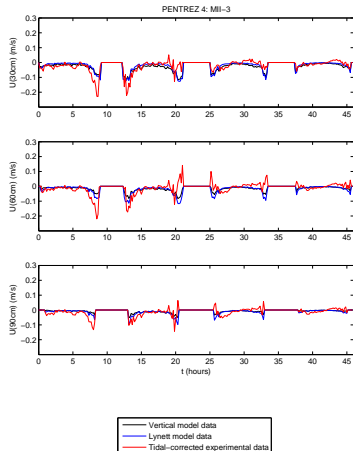


# Experimental vs. models : mean velocities

## PENTREZ#3

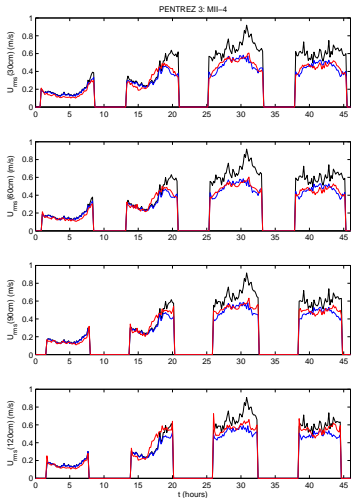


## PENTREZ#4

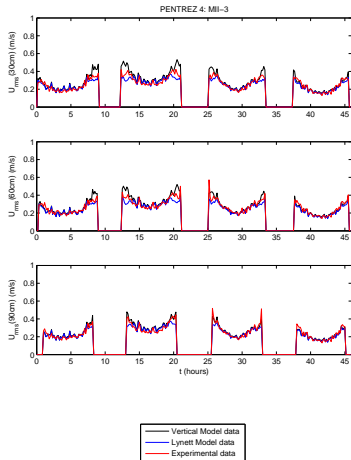


# Experimental vs. models : RMS velocities

## PENTREZ#3

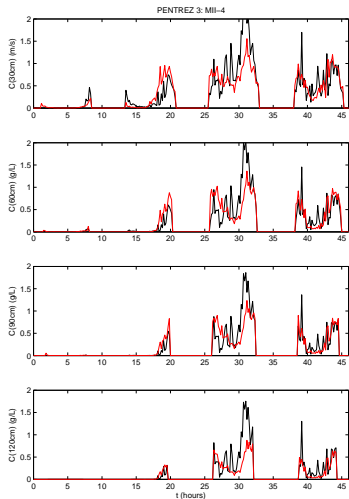


## PENTREZ#4

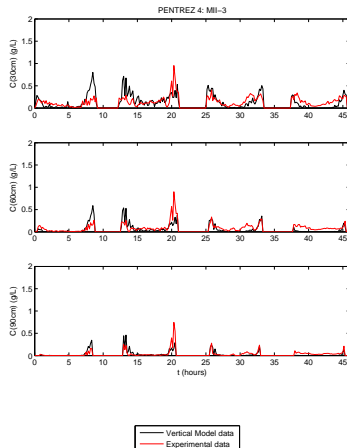


# Experimental vs. 2DV model : mean concentrations

## PENTREZ#3

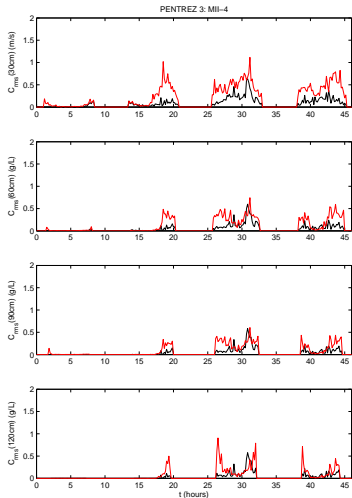


## PENTREZ#4

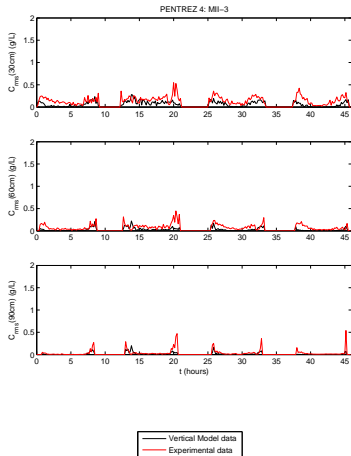


# Experimental vs. 2DV model : RMS concentrations

## PENTREZ#3

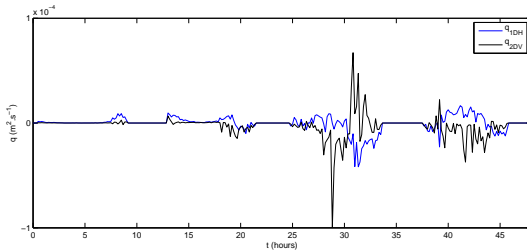


## PENTREZ#4

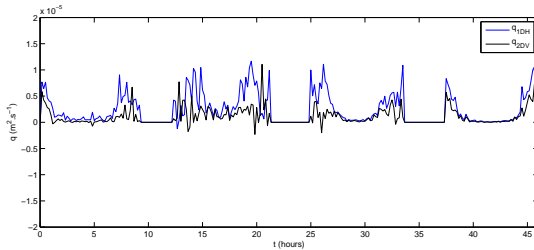


# Predicted transport rates

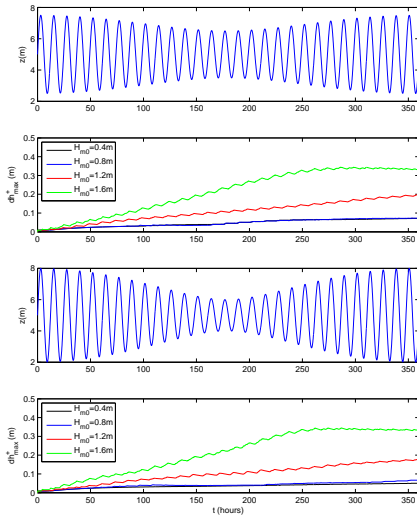
## PENTREZ#3



## PENTREZ#4



# Predicted Spring-to-Spring morphologic evolution on Pentrez beach



## To conclude with Pentrez beach measurements :

### Synthesis

- Good estimation of wave heights by FUNWAVE 1D,
- Good estimation of mean and RMS velocities by FUNBEACH 2DV and FUNBEACH 1DH,
- Good estimation of mean concentration of sediment and worser estimation of RMS concentration of sediment by FUNBEACH 2DV,
- FUNBEACH 2DV predicted transport rates for wind waves in PENTREZ#3 worser than swell in PENTREZ#4,
- FUNBEACH 1DH cheaper in computer time and more stable than FUNBEACH 2DV.

# Content

- 1 Introduction
- 2 Models description
- 3 Model validation on Deltaflume
- 4 Model validation on Pentrez beach
- 5 Influences of waves and tide on a plane sloping beach**
- 6 Artificial nourishment study
- 7 Conclusions



# Numerical study

## Objective

Effects of various parameters on beach morphodynamic with FUNBEACH 1DH :

- Wave height,
- Tide range,
- Wave spectrum,
- Beach slope,
- Grain size.

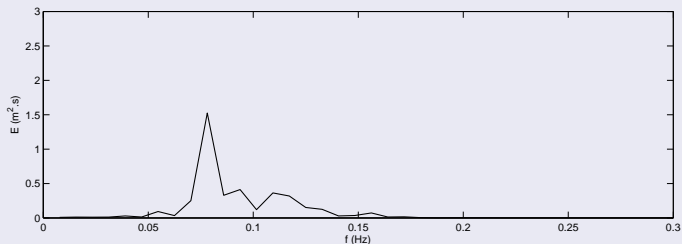
## General conditions of test-cases

- Plane sloping beach,
- 14 tidal cycles of constant wave forcing,
- Constant tide range.

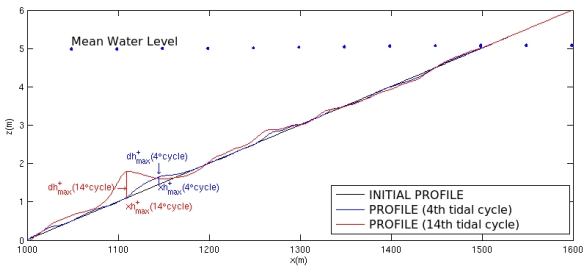
# First test-case : Sensivity of bar formation to Wave Height and Tide Range

## Conditions

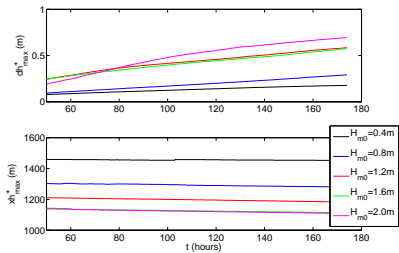
- Wave height : 0.4m, 0.8m, 1.2m, 1.6m and 2 m,
- Tide range : 0m, 1m, 2m, 3m, 4m, 5m and 6m,
- Beach slope :  $\beta_p = 1\%$ ,
- Grain size :  $d_{50} = 0.144\text{mm}$ ,
- Swell conditions :  $T_p = 14.3\text{s}$ ,



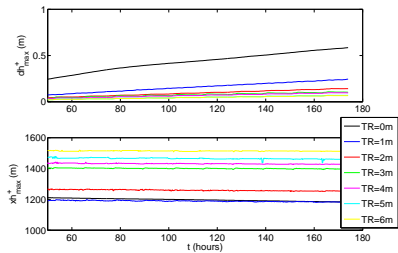
# Bar evolution



$H_{m0}$  variable and TR=0m



$H_{m0}=1.2m$  and TR variable

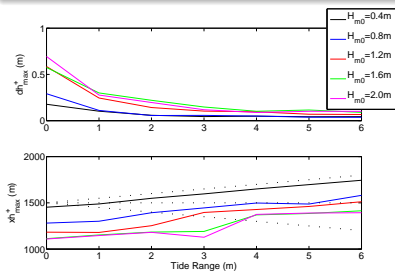


# Morphologic evolution after 14 tidal cycles

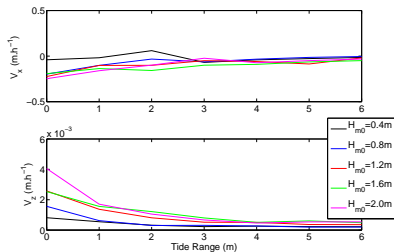
| $H_{m0} / TR$ | 0m         | 1m         | 2m         | 3m | 4m | 5m | 6m |
|---------------|------------|------------|------------|----|----|----|----|
| 0.4m          | BS         | BI         | -          | -  | -  | -  | -  |
| 0.8m          | <b>BS</b>  | BS         | -          | -  | -  | -  | -  |
| 1.2m          | <b>3BS</b> | <b>2BS</b> | BS         | BI | BI | -  | -  |
| 1.6m          | <b>3BS</b> | <b>2BS</b> | <b>BS</b>  | BS | BI | BI | BI |
| 2.0m          | <b>5BS</b> | <b>2BS</b> | <b>2BS</b> | BS | BI | BI | BI |

n BS : n Subtidal Bar ; n BI : n Intertidal Bar ; Bold Form : Big Bar.

## Bar elevation and position



## Bar migration and accretion velocities



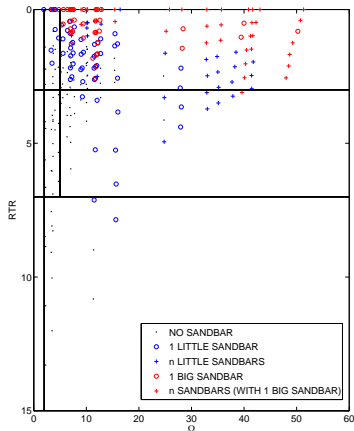
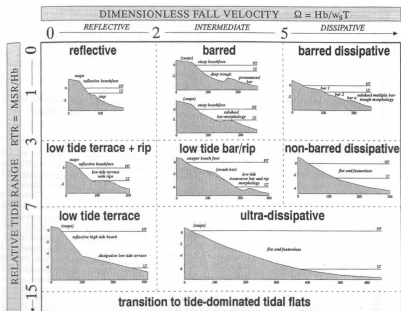
# To conclude with this numerical study :

## Synthesis

- The number, the volume, the distance to coastline and the velocities of bars increase with the wave height.
- This response decreases when :
  - the tide range increases,
  - the wave spectrum width increases,
  - the median grain size increases,
  - the beach slope decreases,
  - the wave period decreases.
- Spring-to-spring tidal cycle : morphology is more influenced by spring tide period.

To conclude with this numerical study :

Masselink and Short (1993) beach model vs. numerical model

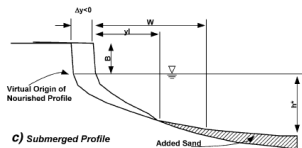
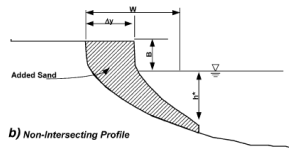
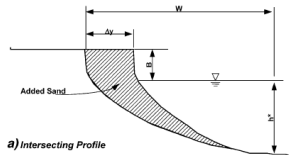


# Content

- 1 Introduction
- 2 Models description
- 3 Model validation on Deltaflume
- 4 Model validation on Pentrez beach
- 5 Influences of waves and tide on a plane sloping beach
- 6 Artificial nourishment study**
- 7 Conclusions

# Beach nourishment with a native sand deposit

Dean's (1998) method  
(equilibrium concept)

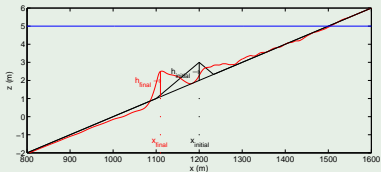


## Questions

- What is the best place to nourish a beach?
- Which profile is the most stable?

## Method

Evolution with FUNBEACH 1DH of an artificial nourishment after 15 days of swell on a plane sloping beach.

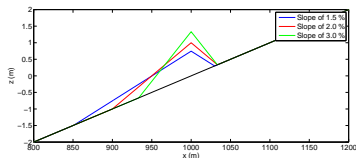
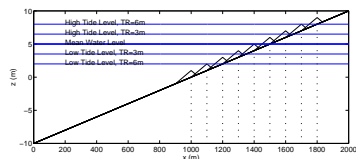
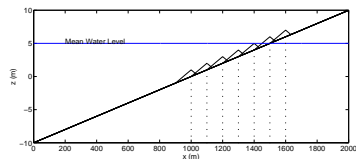




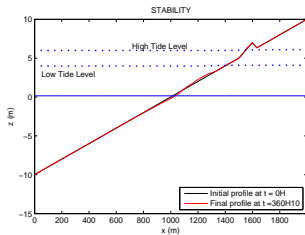
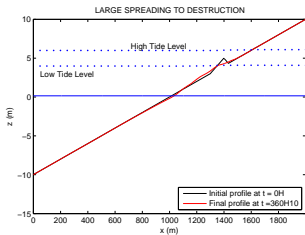
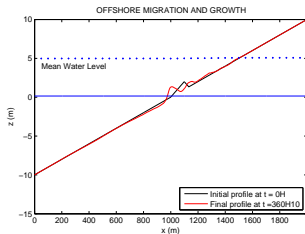
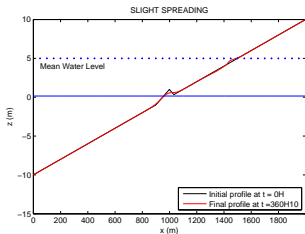
# Numerical study

## Test-cases

- Plane sloping beach ( $\beta=1\%$ ,  $d_{50} = 0.144$ ).
- Artificial nourishment of  $66,7 \text{ m}^3/\text{ml}$ .
- Without tide : 5 wave heights from 0.4m to 2m and 7 positions across the profile from  $z_{MWL}=-5\text{m}$  to  $z_{MWL}= +1\text{m}$ .
- With tide :  $H_{m0}=1.2\text{m}$  with 6 tide ranges from 1m to 6m and 9 positions across the profile from  $z_{MWL}=-5\text{m}$  to  $z_{MWL}= +3\text{m}$ .
- 3 slopes : 1.5%, 2% et 3%.



# Different types of morphologic response



# Synthesis of simulated evolutions

- On microtidal beaches :
  - Before the breaking zone : slight spreading,
  - In the breaking zone : growth,
  - After the breaking zone : large spreading to destruction,
  - Near the shoreline : stability.
- On mesotidal and macrotidal beaches :
  - Before the low-tide breaking zone : slight spreading,
  - In the lower intertidal zone : large spreading to destruction,
  - In the upper intertidal zone : stability.
- Influence of the slope of the artificial nourishment :
  - An artificial nourishment with highest slope moves slowest,
  - The wave height is most reduced with artificial nourishment with highest slope.

# Practical recommendations of beach nourishments

- Bars and berms are the best locations to nourish microtidal beaches,
- The upper intertidal zone is the best location to nourish mesotidal and macrotidal beaches,
- Steep nourishments are recommended.

need to be confirmed by further studies.

# Content

- 1 Introduction
- 2 Models description
- 3 Model validation on Deltaflume
- 4 Model validation on Pentrez beach
- 5 Influences of waves and tide on a plane sloping beach
- 6 Artificial nourishment study
- 7 Conclusions**

# Conclusions

- Development of a new morphodynamic model able to reproduce beach processes :
  - Wave propagation, wave breaker and bottom friction including wave ripples, thanks to FUNWAVE model,
  - Undertow and near-bed velocities, thanks to Lynett (2006) and turbulence closure vertical model,
  - Beach evolution and bar movement.
- Lynett-Bailard approach (1DH) faster and more accurate than the turbulence closure vertical approach (pseudo-2DV).
- Influence of several parameters on beach morphology :
  - The number, the volume, the distance to coastline and the velocities of bars increase with the wave height.
  - This response decreases when the tide range, the wave spectrum width and the median grain size increase, and when the beach slope and the wave period decrease.
- Appropriated locations and forms for beach nourishments have been identified.

# Prospects

- FUNBEACH 1DH and FUNBEACH 2DV + MII to study other field sites,
- Multi-class approach to study grain size evolution of the beach,
- Effective 2DV approach : see Lynett and Liu's (2004) multi-layer model,
- Account for the longshore component : FUNWAVE 2D  $\implies$  FUNBEACH 2DH and FUNBEACH 3D with a potential alternative for long term simulations given by a phase-averaged model like XBEACH (Roelvink *et al.*, 2008).





## Second test-case : Wave spectrum

### Wind waves

| $H_{m0}$ / TR | 0m         | 1m         | 2m | 3m | 4m | 5m | 6m |
|---------------|------------|------------|----|----|----|----|----|
| 0.4m          | <b>BS</b>  | BI         | -  | -  | -  | -  | -  |
| 0.8m          | <b>BS</b>  | 2BS        | -  | -  | -  | -  | -  |
| 1.2m          | <b>3BS</b> | 2BS        | -  | -  | -  | -  | -  |
| 1.6m          | <b>2BS</b> | 2BS        | BS | BS | -  | -  | -  |
| 2.0m          | <b>2BS</b> | <b>2BS</b> | BS | BS | -  | -  | -  |

### Monochromatic wave

| $H_{m0}$ / TR | 0m         | 1m           | 2m           | 3m           | 4m           | 5m           | 6m           |
|---------------|------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 0.4m          | 2BS        | BI           | BI           | BI           | BI           | BI           | BI           |
| 0.8m          | <b>BS</b>  | <b>2BS</b>   | <b>BI BS</b> | <b>BI BS</b> | <b>BI</b>    | <b>BI</b>    | <b>BI</b>    |
| 1.2m          | <b>5BS</b> | <b>BS BI</b> | <b>2BS</b>   | <b>BI BS</b> | <b>BI BS</b> | <b>BI BS</b> | <b>BI BS</b> |
| 1.6m          | <b>3BS</b> | <b>2BS</b>   | <b>2BS</b>   | <b>2BS</b>   | <b>BI BS</b> | <b>BI BS</b> | <b>BI BS</b> |
| 2.0m          | <b>2BS</b> | <b>2BS</b>   | <b>2BS</b>   | <b>3BS</b>   | <b>2BS</b>   | <b>BI BS</b> | <b>BI</b>    |

⇒ **Narrower wave spectrum increases bar dynamics.**

## Third test-case : beach slope

Beach slope  $\beta_p = 0.5\%$

| $H_{m0} / TR$ | 0m         | 1m  | 2m  | 3m | 4m | 5m | 6m |
|---------------|------------|-----|-----|----|----|----|----|
| 0.4m          | -          | -   | -   | -  | -  | -  | -  |
| 0.8m          | <b>BS</b>  | BI  | -   | -  | -  | -  | -  |
| 1.2m          | <b>6BS</b> | BS  | -   | -  | -  | -  | -  |
| 1.6m          | <b>9BS</b> | 3BS | 2BS | -  | -  | -  | -  |
| 2.0m          | <b>4BS</b> | 3BS | -   | -  | -  | -  | -  |

Beach slope  $\beta_p = 2.0\%$

| $H_{m0} / TR$ | 0m        | 1m        | 2m        | 3m        | 4m        | 5m        | 6m        |
|---------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 0.4m          | -         | -         | -         | -         | -         | -         | -         |
| 0.8m          | <b>BS</b> | <b>BS</b> | BS        | -         | -         | -         | -         |
| 1.2m          | <b>BS</b> | <b>BS</b> | <b>BS</b> | BS        | BS        | BS        | BS        |
| 1.6m          | <b>BS</b> | <b>BS</b> | <b>BS</b> | <b>BS</b> | <b>BS</b> | <b>BS</b> | <b>BS</b> |
| 2.0m          | <b>BS</b> | <b>BS</b> | <b>BS</b> | <b>BS</b> | <b>BS</b> | BS        | BI BS     |

⇒ Steeper beach increases bar dynamics.

## Fourth test-case : grain size

Median grain size  $d_{50} = 0.063\text{mm}$

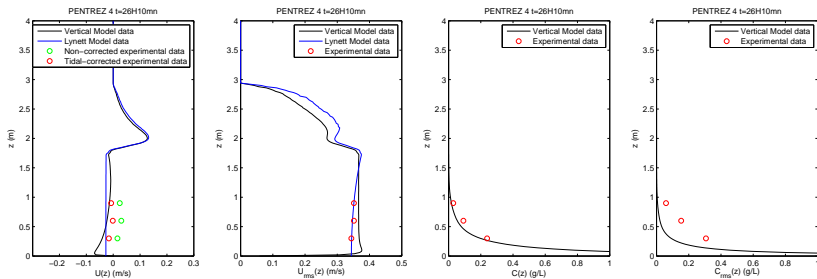
| $H_{m0} / \text{TR}$ | 0m         | 1m            | 2m           | 3m           | 4m           | 5m            | 6m            |
|----------------------|------------|---------------|--------------|--------------|--------------|---------------|---------------|
| 0.4m                 | 2BS        | BI            | BI           | BI           | BI           | BI            | BI            |
| 0.8m                 | <b>4BS</b> | <b>BS</b>     | <b>BS</b>    | BI           | BI           | BI            | BI            |
| 1.2m                 | <b>3BS</b> | <b>BS</b>     | <b>BS</b>    | <b>BS</b> BI | <b>BI</b> BS | <b>BI</b> BS  | BI BS         |
| 1.6m                 | <b>5BS</b> | <b>BS</b> BI  | <b>BS</b> BI | <b>BS</b> BI | <b>BI</b> BS | <b>2BI</b> BS | <b>2BI</b> BS |
| 2.0m                 | <b>3BS</b> | <b>3BS</b> BI | <b>BS</b>    | <b>BS</b> BI | <b>BI</b> BS | <b>2BI</b> BS | <b>2BI</b> BS |

Median grain size  $d_{50} = 0.200\text{mm}$

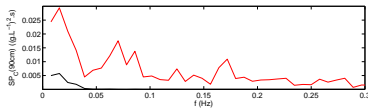
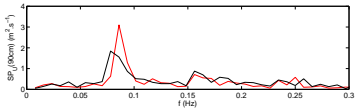
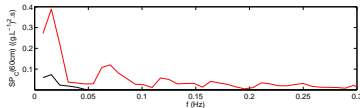
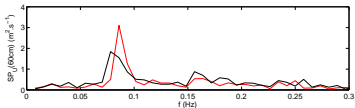
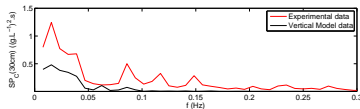
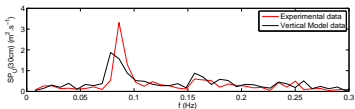
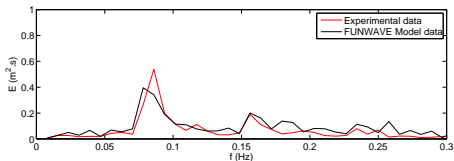
| $H_{m0} / \text{TR}$ | 0m         | 1m  | 2m | 3m | 4m | 5m | 6m |
|----------------------|------------|-----|----|----|----|----|----|
| 0.4m                 | BS         | -   | -  | -  | -  | -  | -  |
| 0.8m                 | BS         | -   | -  | -  | -  | -  | -  |
| 1.2m                 | <b>3BS</b> | BS  | -  | -  | -  | -  | -  |
| 1.6m                 | <b>3BS</b> | BS  | BS | -  | -  | -  | -  |
| 2.0m                 | <b>3BS</b> | 2BS | BS | -  | -  | -  | -  |

⇒ Finer sand beach increases bar dynamics.

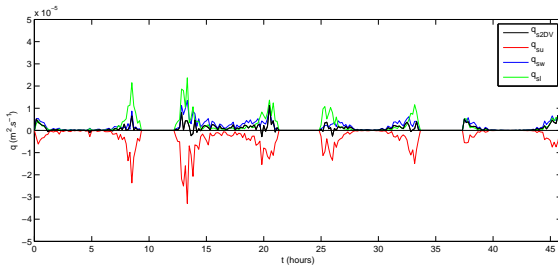
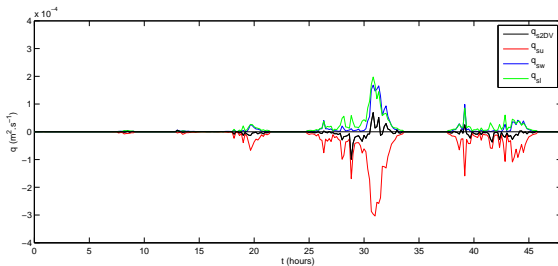
# Vertical profiles example (t=26H10mn PENTREZ#4)



# Wave, Velocity and Sediment concentration spectra (t=26H10mn PENTREZ#4)



# Transport rates components



# Long simulations on a plane sloping beach

