Session 5: Numerical cross-shore models

Session 5: Modèles morphodynamiques numériques

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Synopsis

5.1 Introduction

5.2 The SBEACH model

5.3 The Leont'yev model

5.4 Application with Guide User Interface (GUI)

5.1 Introduction: Model structure

They compute at different locartions of the cross-shore profile simulating beach evolution in each time step

They contain the following modules

- **Hydrodynamic module**
- **Sediment dynamic module**
- **Morphological module**

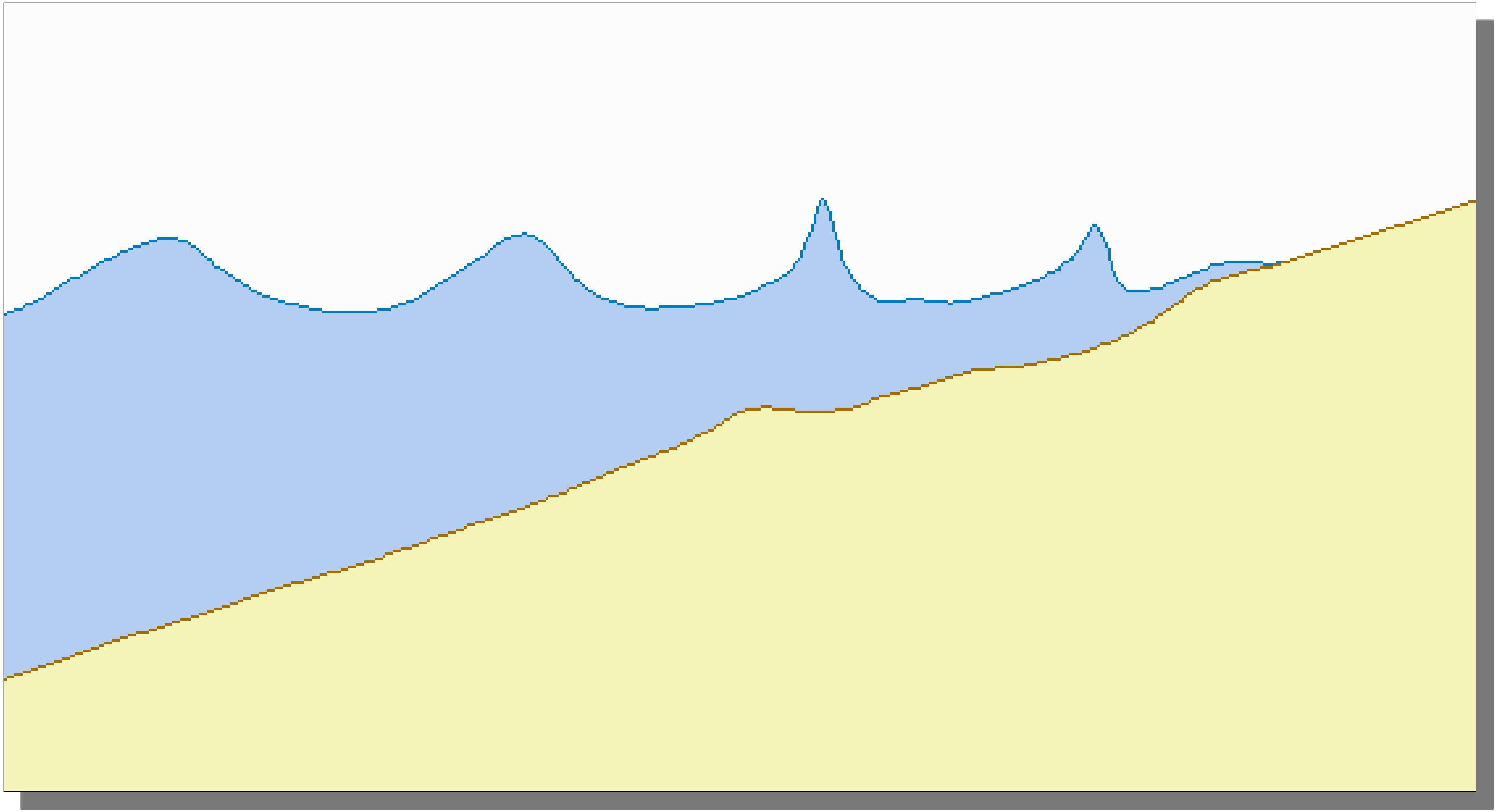


Fig. 5.1 Beach evolution result from a cross-shore (1-D) Boussinesq model (Monioudi, 2013)

5.1 Introduction: Hydrodynamic module

Input data: Bathymetry, open sea wave conditions, and seabed sediments (for estimation of bed friction)

They compute: The cross-shore evolution of the wave height and orbital velocities as well as mean wave-induced currents

They use: The classic momentum and energy equations

Types of models: (1-D), (2-DV), (2-DH), (Quasi-3-D models) και (3-D)

5.1 Introduction: Sediment dynamic module

Input data: The hydrodynamic model output and the sediment distribution

They compute: Sediment transport rate at each time step

Types of sediment transport: Bedload and suspended sediment load

5.1 Introduction: Morphological module

Input data: Sediment transport q_t

They compute: Morphological evolution of the cross-shore profile through the solving of the sediment continuity equation. In many cases, normalization of the profile is used (when bed slope > a threshold value)

Output: New morphology, which is used as input into the hydrodynamic module at the next time-step

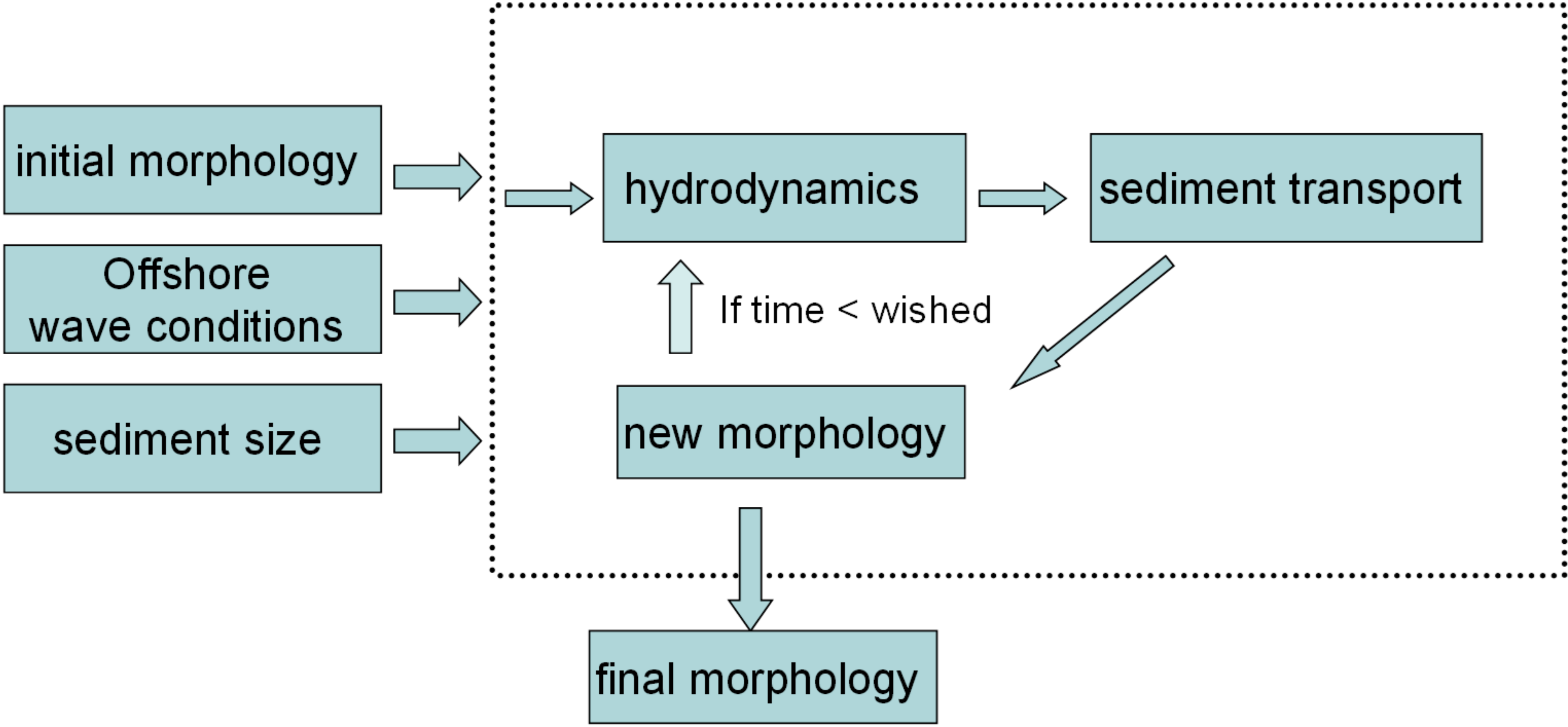


Fig. 5.2 Numerical model flow diagram

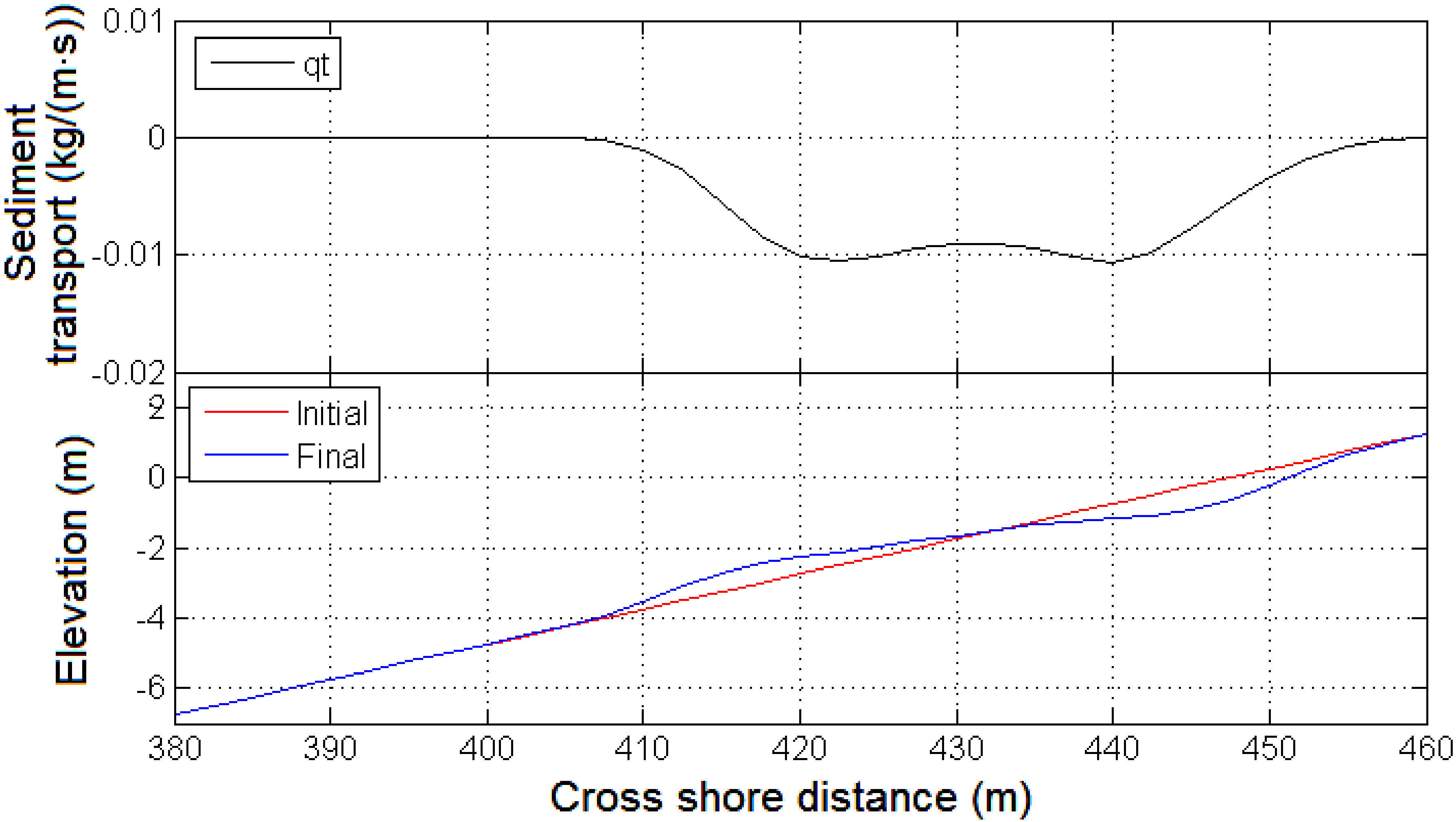


Fig. 5.3 Results from (a) Sediment dynamic module and (b) morphological module for the upper part of the beach profile. The x axis origin is offshore 450 m from the coastline.

5.2 The SBEACH model

Hydrodynamic module

$$\frac{dE_F}{dx} = -\frac{k_w}{h}\left(E_F - E_{Fs}\right)$$

Sediment transport module

$$q = \mathrm{K}_s\left(D_e - D_{eq} + \frac{\varepsilon}{\mathrm{K}_s}\frac{dh}{dx}\right)$$

k_w: empirical wave decay coefficient

E_F: wave energy flux

E_{Fs}: 'stable' wave energy flux

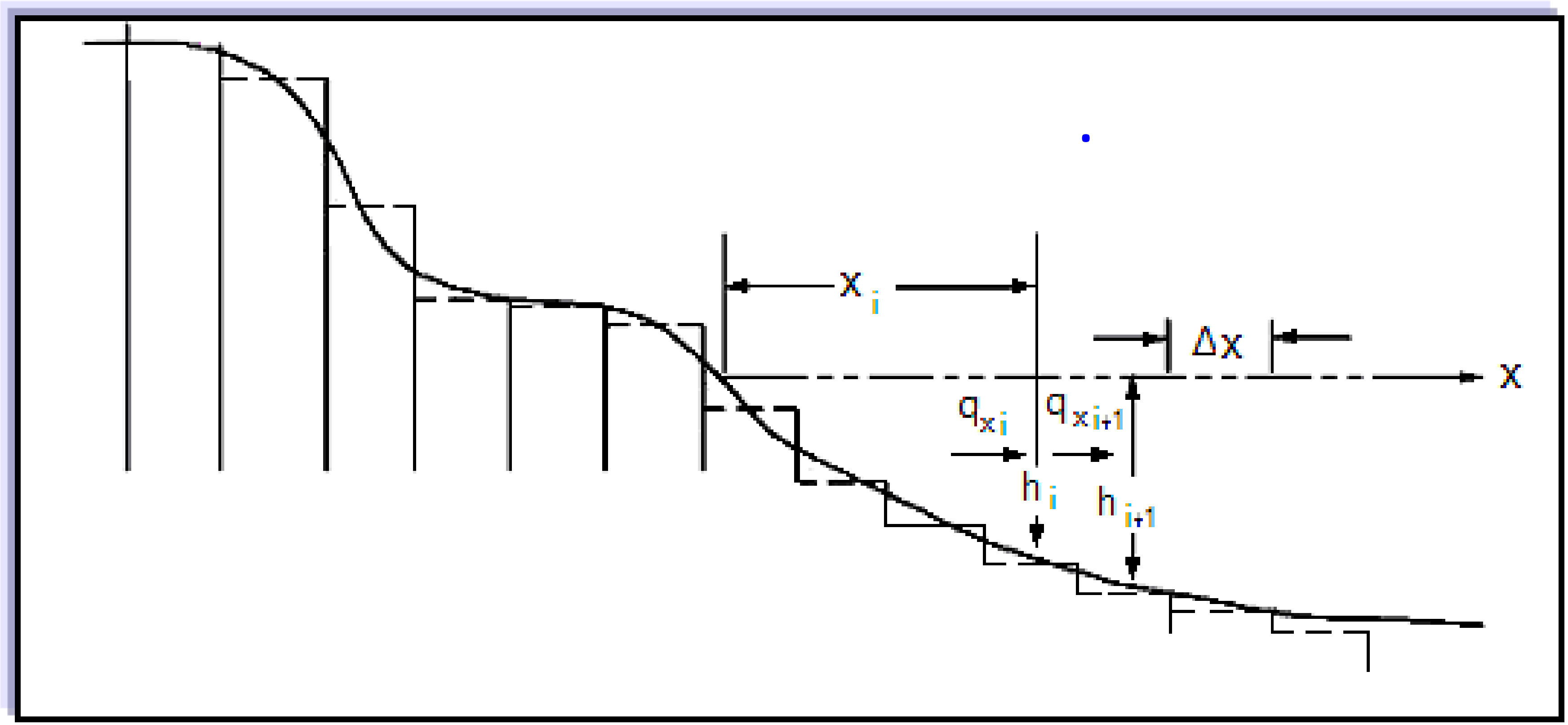
K_s: empirical sediment transport rate coefficient

D_e: Wave energy dissipation per unit volume,

D_{eq}: Wave energy dissipation (equilibrium) per unit volume

ε: transport rate coefficient for the slope-dependent term

5.2 The SBEACH model: Morphological module



Fig, 5.4 SBEACH model operates within a finite differences scheme and a 'stair – step' beach profile discretisation. Water depth h changes are defined by the horizontal gradient of sediment transport q (after CEM, 2008)

5.3 The Leont'yev model: Hydrodynamic module

It is based on the energetics approach of Battjes and Janssen (1978), i.e. on the assumption that cross-shore changes in wave energy flow in each profile location equal wave energy losses due to bottom fiction

$$\frac{\partial\left(\overline{E_w} \cdot c_g \cdot \cos\varphi\right)}{\partial x} = -D_e$$

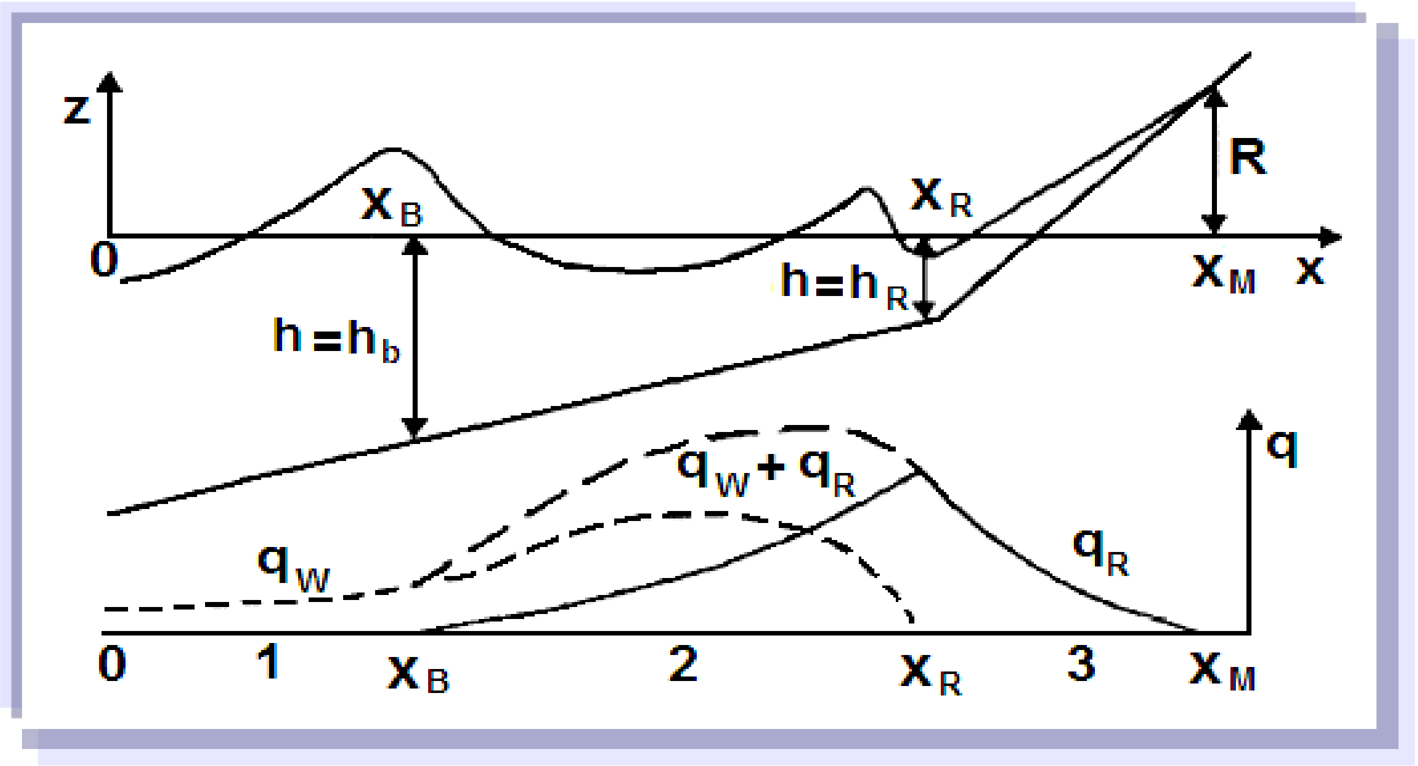
φ: wave angle

E_w: wave energy

c_g: wave group celerity and

D_e: wave energy dissipation

5.3 The Leont' yev model: Sediment transport module



The beach profile is divided into zones, with sediment transport varying along the profile as (Leont'yev 1996):

Wave refraction zone: $q_R = 0$ και $q = q_W$

Surf zone: $q = q_W + q_R$

Swash zone: $q_W = 0$ και $q = q_R$

5.3 The Leont' yev model: Sediment transport module

Sediment transport rate due to wave-current interaction q_W, in the surf zone

Bedload/suspended sediment load

$$q_W = \frac{\varepsilon_b}{2\tan\phi} f_w \rho \left(\overline{\tilde{u}^3} \cos\varphi + 3\overline{\tilde{u}^2} U_d \right) + \varepsilon_s \left(F_e + B_e \right) \left(\frac{w_s}{U_d} - \frac{\partial d}{\partial x} \right)^{-1}$$

f_w: friction factor

w_s: sediment settling velocity

φ: angle of approach

ε_s: effectiveness coefficient

F_e , B_e: energy losses due to bed friction and turbulence, respectively

5.3 The Leont' yev model: Sediment transport module

Sediment transport in the swash zone

$$q_R = \hat{q}_R \left(\frac{1 - x / x_m}{1 - x_R / x_m} \right)^{3/2} \quad x_R \le x \le x_m$$

$$q_R = \hat{q}_R \exp\left(c_3 \left(x - x_R \right) / H_o \right) \quad x \le x_R$$

$\hat{q}_R$: **maximum sediment transport**

c_3= **0.2-0.3**

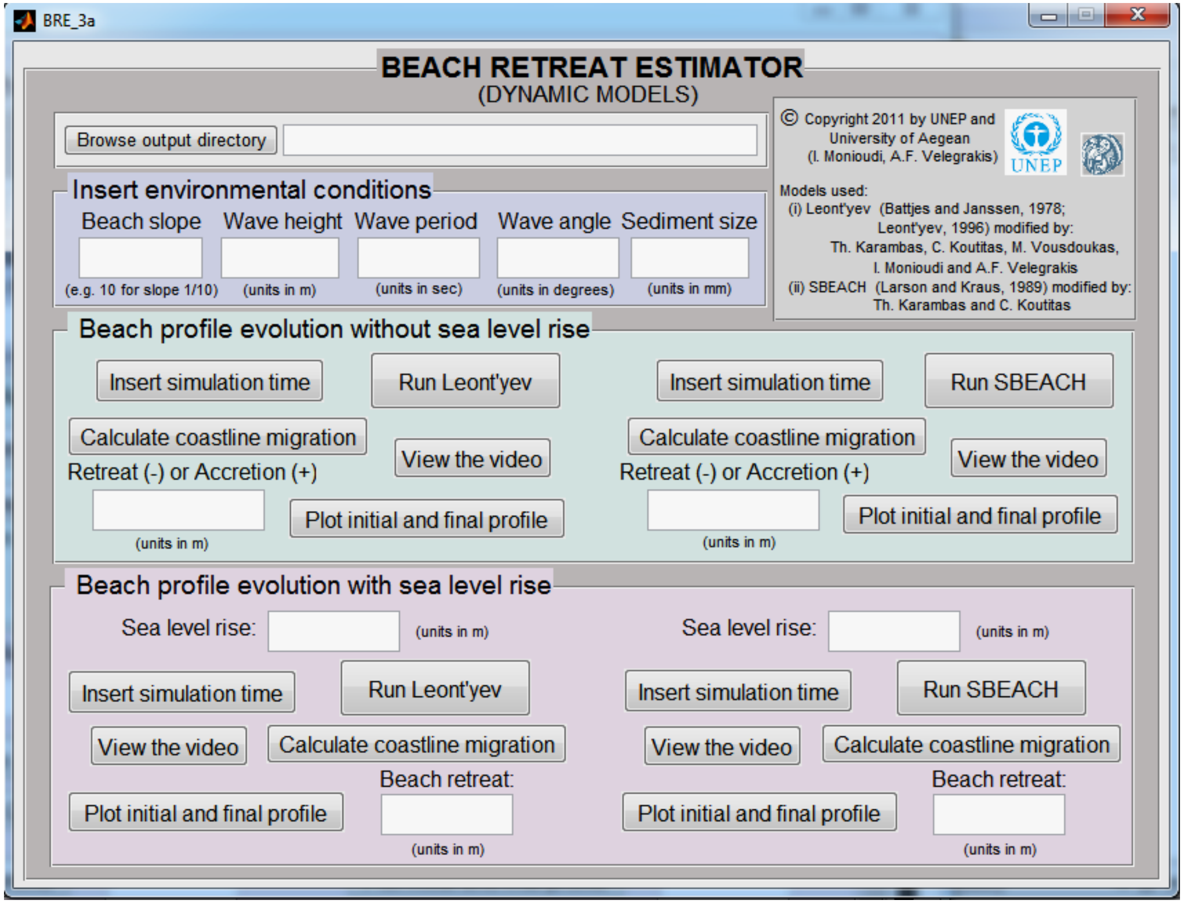
H_0 : **offshore wave height**

5.3 The Leont' yev model: Morphological module

Beach morphological change is defined by the sediment continuity equation

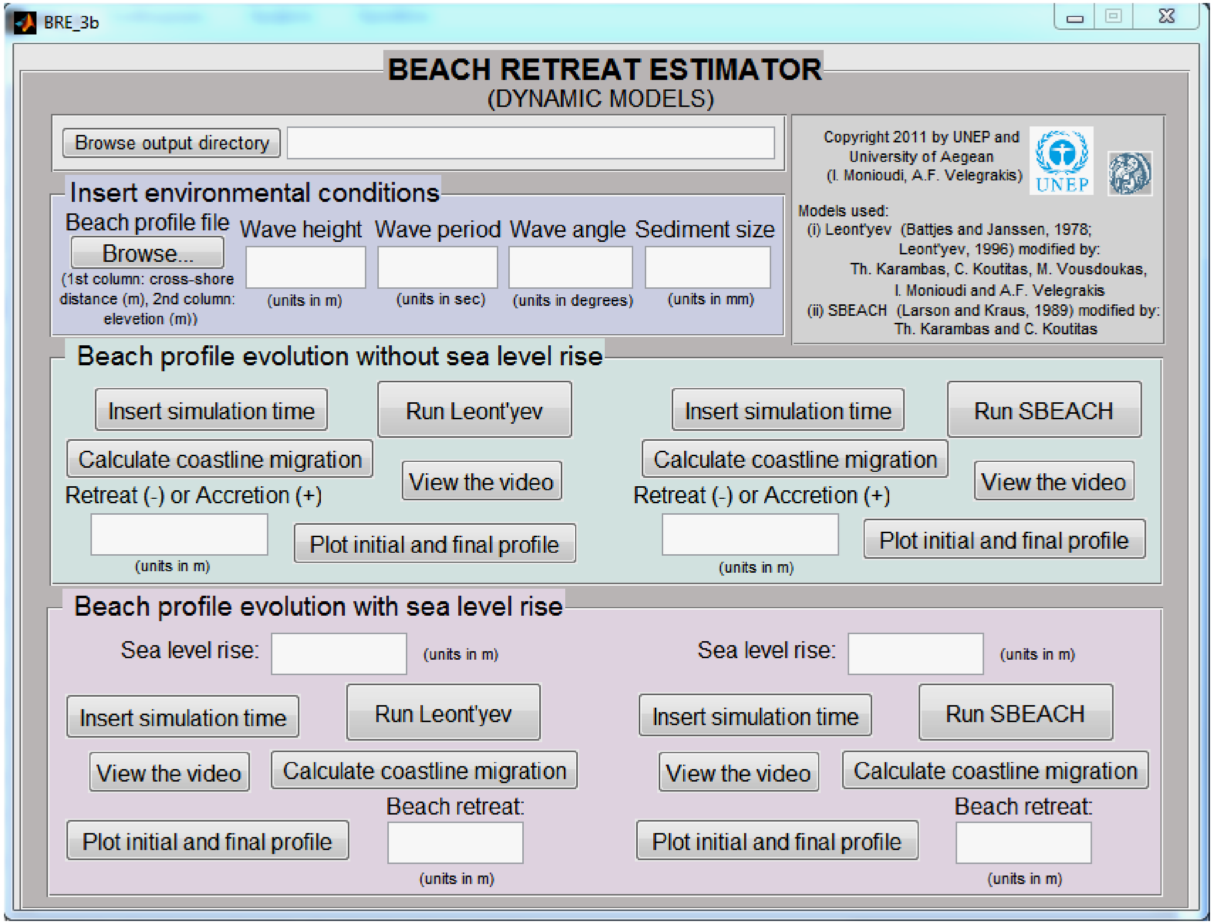
Sediment porosity is also considered

5.4 Application with Guide User Interface (GUI) (user set sea bed slope-linear profiles)



For the output files see accompanying manual

5.4 Application with Guide User Interface (GUI) (natural profiles from file)



For the output files see accompanying manual