

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 locations of the cross-shore profile
simulating beach evolution in each time step

They contain the following modules

- Hydrodynamic module
- Sediment dynamic module
- Morphological module

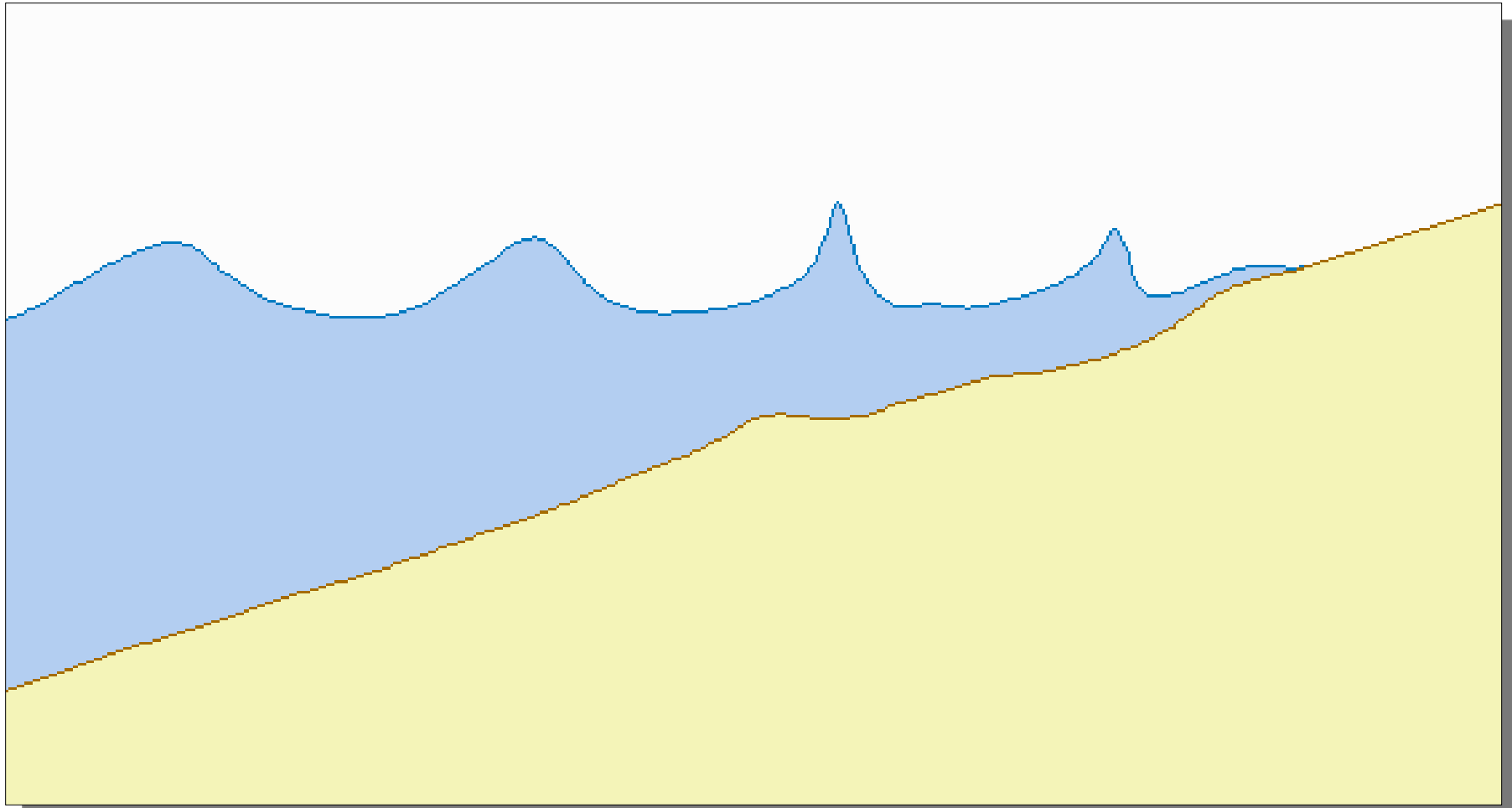


Fig. 5.1 Beach evolution result from a cross-shore (1-D) Boussinesq model (Monioudi, 2013)

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

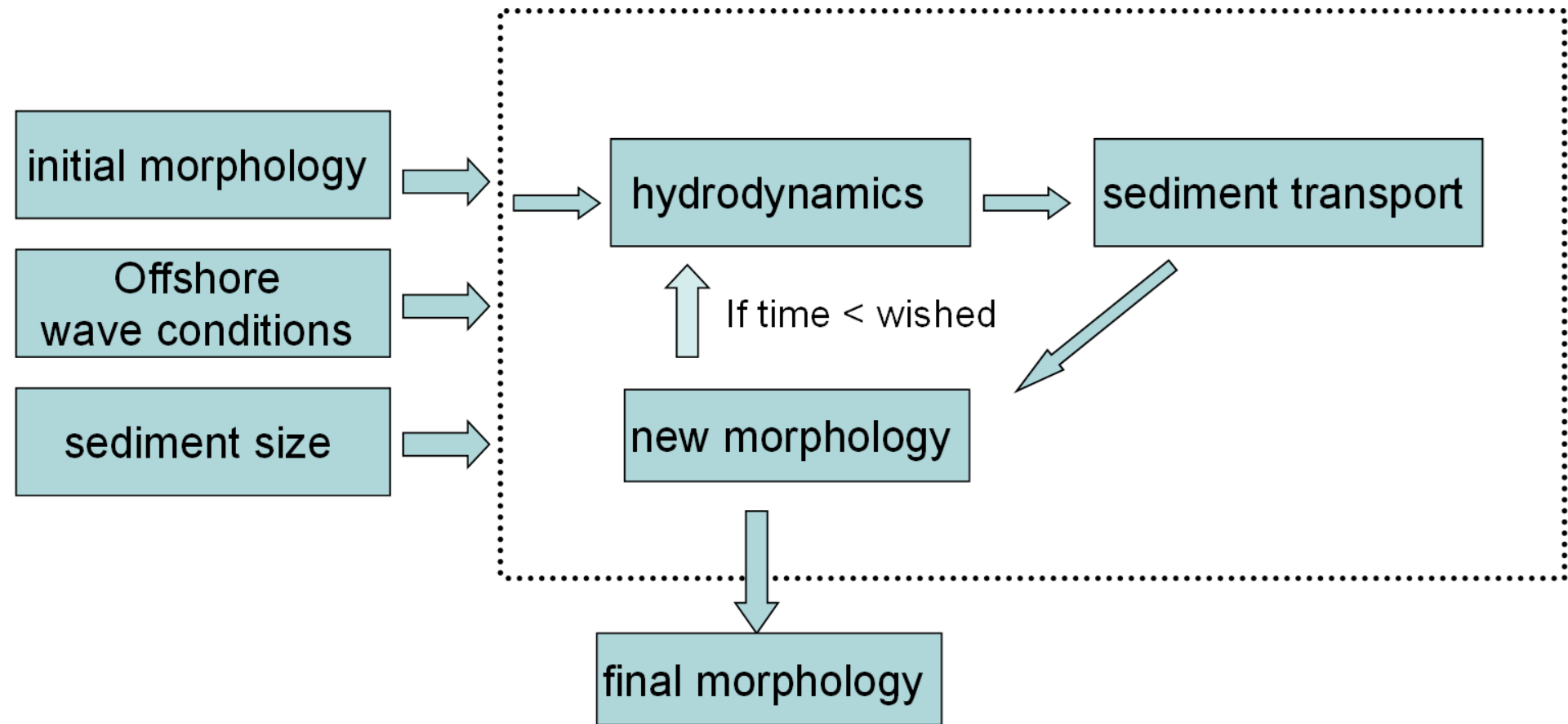


Fig. 5.2 Numerical model flow diagram

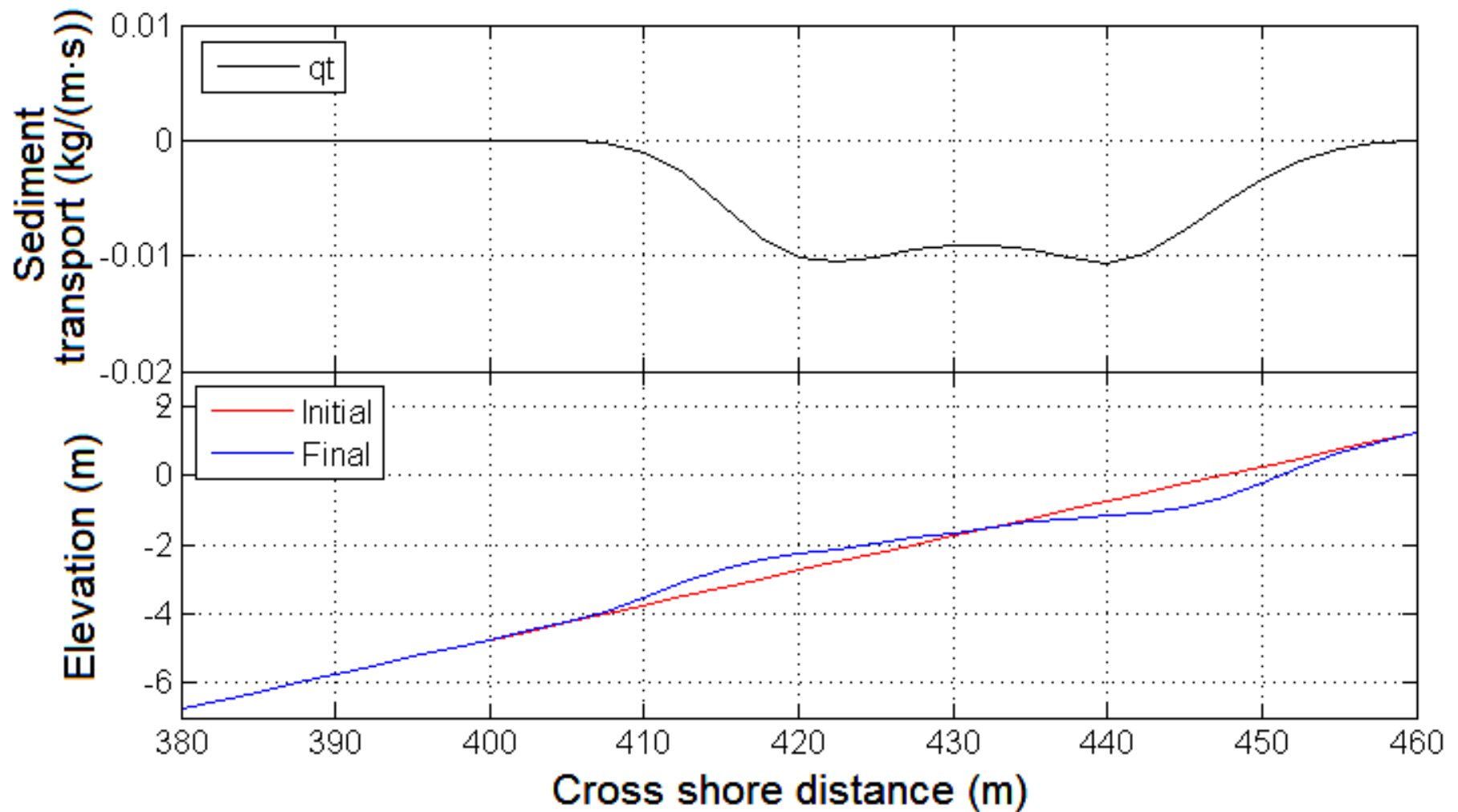


Fig. 5.3 Results from (a) Sediment dynamic module and (b) morphological module for the upper part of the beach profile. The x axis origin is offshore 450 m from the coastline.

5.2 The SBEACH model

Hydrodynamic

module

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

Sediment transport module

$$q = K_s (D_e - D_{eq} + \frac{\varepsilon}{K_s} \frac{dh}{dx})$$

k_w : empirical wave decay coefficient

E_F : wave energy flux

E_{Fs} : 'stable' wave energy flux

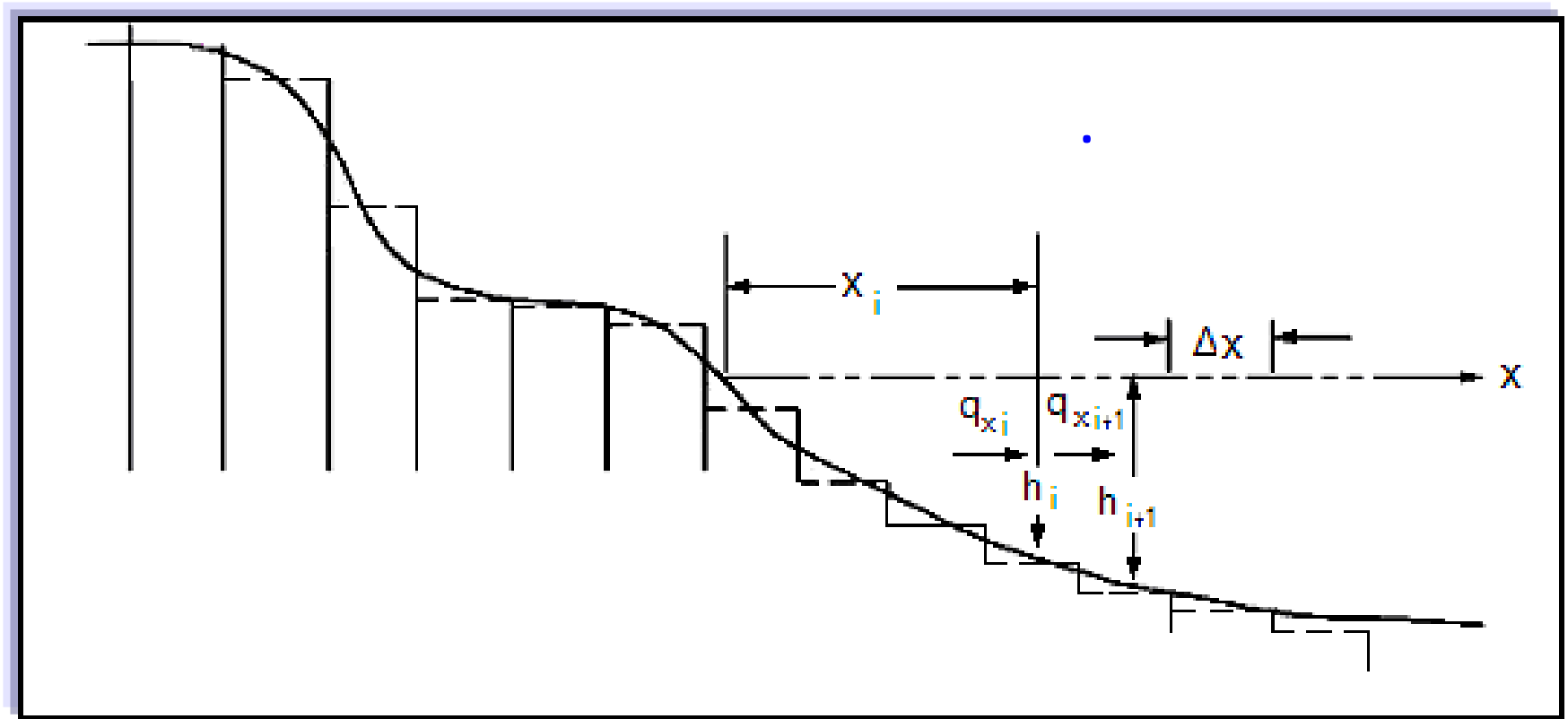
K_s : empirical sediment transport rate coefficient

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 friction

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

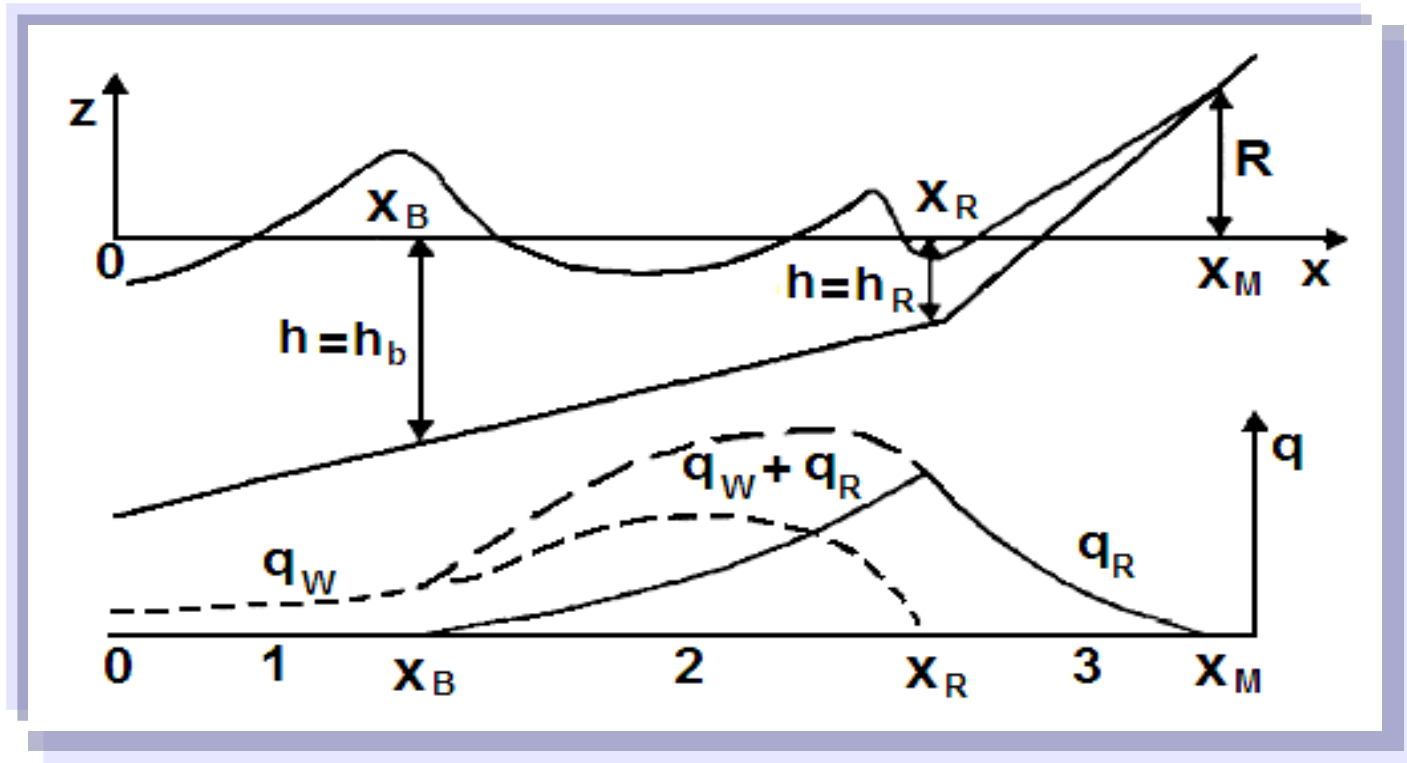
φ : wave angle

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: $q_R = 0$ and $q = q_W$

Surf zone: $q = q_W + q_R$

Swash zone: $q_W = 0$ and $q = q_R$

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

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

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

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

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

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

$c_3 = 0.2-0.3$

H_o : 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)

BEACH RETREAT ESTIMATOR
(DYNAMIC MODELS)

Browse output directory

Insert environmental conditions

Beach slope Wave height Wave period Wave angle Sediment size

(e.g. 10 for slope 1/10) (units in m) (units in sec) (units in degrees) (units in mm)

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Models used:
(i) Leont'yev (Battjes and Janssen, 1978; Leont'yev, 1996) modified by: Th. Karambas, C. Koutitas, M. Voudoukas, I. Monioudi and A.F. Velegrakis
(ii) SBEACH (Larson and Kraus, 1989) modified by: Th. Karambas and C. Koutitas

Beach profile evolution without sea level rise

Insert simulation time Run Leont'yev Insert simulation time Run SBEACH

Calculate coastline migration View the video Calculate coastline migration View the video

Retreat (-) or Accretion (+) Plot initial and final profile Retreat (-) or Accretion (+) Plot initial and final profile

(units in m) (units in m)

Beach profile evolution with sea level rise

Sea level rise: (units in m) Sea level rise: (units in m)

Insert simulation time Run Leont'yev Insert simulation time Run SBEACH

View the video Calculate coastline migration View the video Calculate coastline migration

Beach retreat: Beach retreat:

Plot initial and final profile Plot initial and final profile

(units in m) (units in m)

For the output files see accompanying manual

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

BEACH RETREAT ESTIMATOR
(DYNAMIC MODELS)

Browse output directory:

Insert environmental conditions

Beach profile file: Wave height: Wave period: Wave angle: Sediment size:
(1st column: cross-shore distance (m), 2nd column: elevation (m)) (units in m) (units in sec) (units in degrees) (units in mm)

Beach profile evolution without sea level rise

Insert simulation time: Run Leont'yev Calculate coastline migration: View the video: Retreat (-) or Accretion (+): Plot initial and final profile: (units in m)

Beach profile evolution with sea level rise

Sea level rise: (units in m) Sea level rise: (units in m)

Insert simulation time: Run Leont'yev View the video: Calculate coastline migration: Beach retreat: Plot initial and final profile: (units in m)

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