Session 2: Analysis of cross-shore beach profiles

Session 2: Analyse de donnés topographiques-Profils de plages

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Synopsis

2.1 Beach morphology

2.2. Beach dynamics – spatio-temporal variability

2.3 Beach profile analysis – Empirical Orthogonal functions (EOFs)

2.4. Application with Guide User Interface(GUI)

2.1 Beach morphology

Beaches comprise two constituent parts (‘dry’ and ‘wet’ beach)

The sediments of both parts form the beach sediment reservoir and can move from one part to the other under the wave forcing.

<u>The major morphological features of the beach are</u>

<u>Dry beach (onshore beach):</u>

- Berm (with or without berm scarp)
- Backshore Presence of dunes usually controlled by the beach aerodynamics

<u>‘Wet’ (submarine) beach</u>

- Longshore bar
- Longshore trough

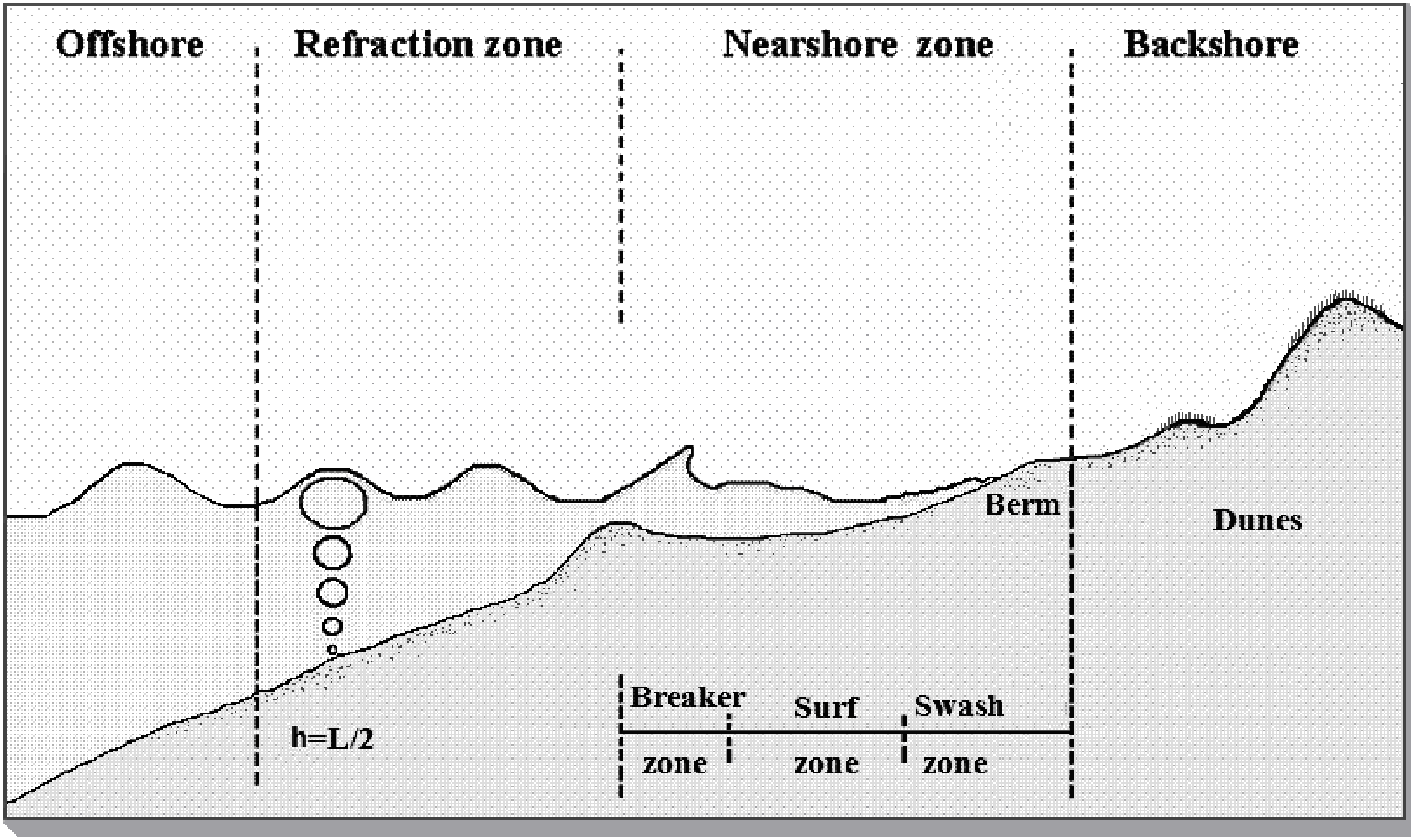


Fig. 2.1 The beach profile: Morphological features and wave zones (Open University, 1997).

‘Dry’ beach

Σχήμα 2.2 (a) Berm with berm scarp (S. California) at the beginning of September. The presence of the berm scarp indicates erosion by the first high waves at the end of summer (SEPM, 1996) (b) Vegetated sand dunes at the backshorw of a N. Zealand beach (SEPM, 1996).

‘Wet beach’

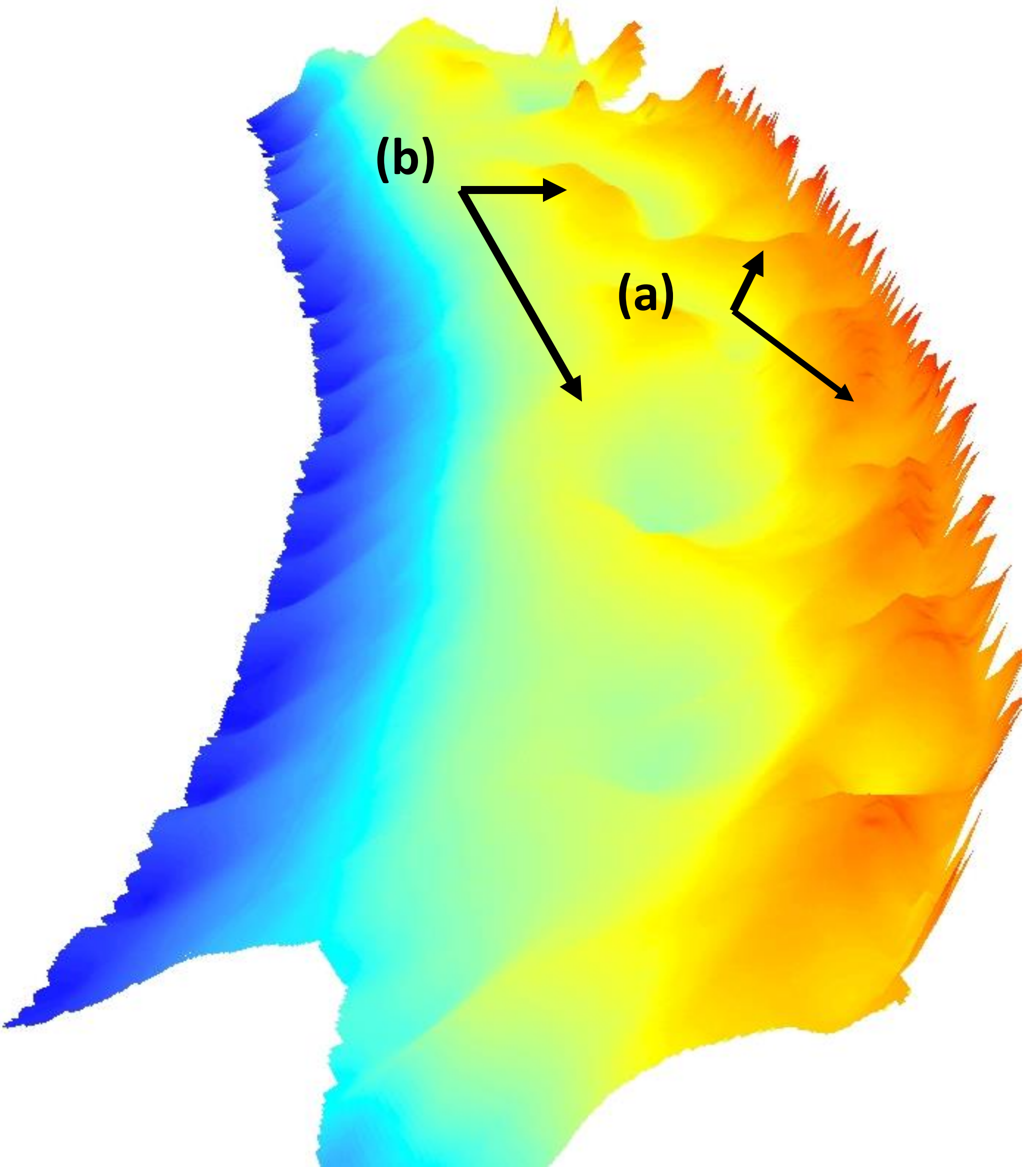


Fig. 2.3 Nearshore bathymetry showing the different morphological features of the wet beach Eresos beach, Lesbos, E. Mediterrannean (Nasras et al., 2014). Key: (a) inshore submarine bars; (b) second line of submarine bars

Beach morphological features

Beaches and their morphological features are very dynamic.

Berms are mostly built under low/moderate waves with their position and height (*Bh*) depending on the wave run up the height of breaking waves *Hb* the wave period *T* (Sunamura, 1989). Well-developed berms are mostly observed on coarse sediment beaches (Komar, 1998).

Submarine bars (longshore, oblique or crescentic) and*troughs* are built mostly during high wave conditions, during which sediments from the onshore beach are transported offshore. The position, size and water depth of the submarine bars depend on the height and position of the breaking waves (Sunamura, 1989; Komar, 1998)

The closure depth

Cross-shore morphological changes of the wet beach decrease in the offshore direction, with the changes becoming insignificant at a distance (and a corresponding water depth) from the shoreline called '*the closure depth*'; beyond this water depth there are no significant water depth changes due to beach sediment transport.

Closure depth is considered to be the offshore margin of the beach sediment reservoir; sediments transported offshore of the closure depth can not return to the beach

If time series of cross-shore beach profiles are available, then the *closure depth* can be estimated on their collective plot as the area where the temporal morphological changes become insignificant i.e. smaller than the measurement error.

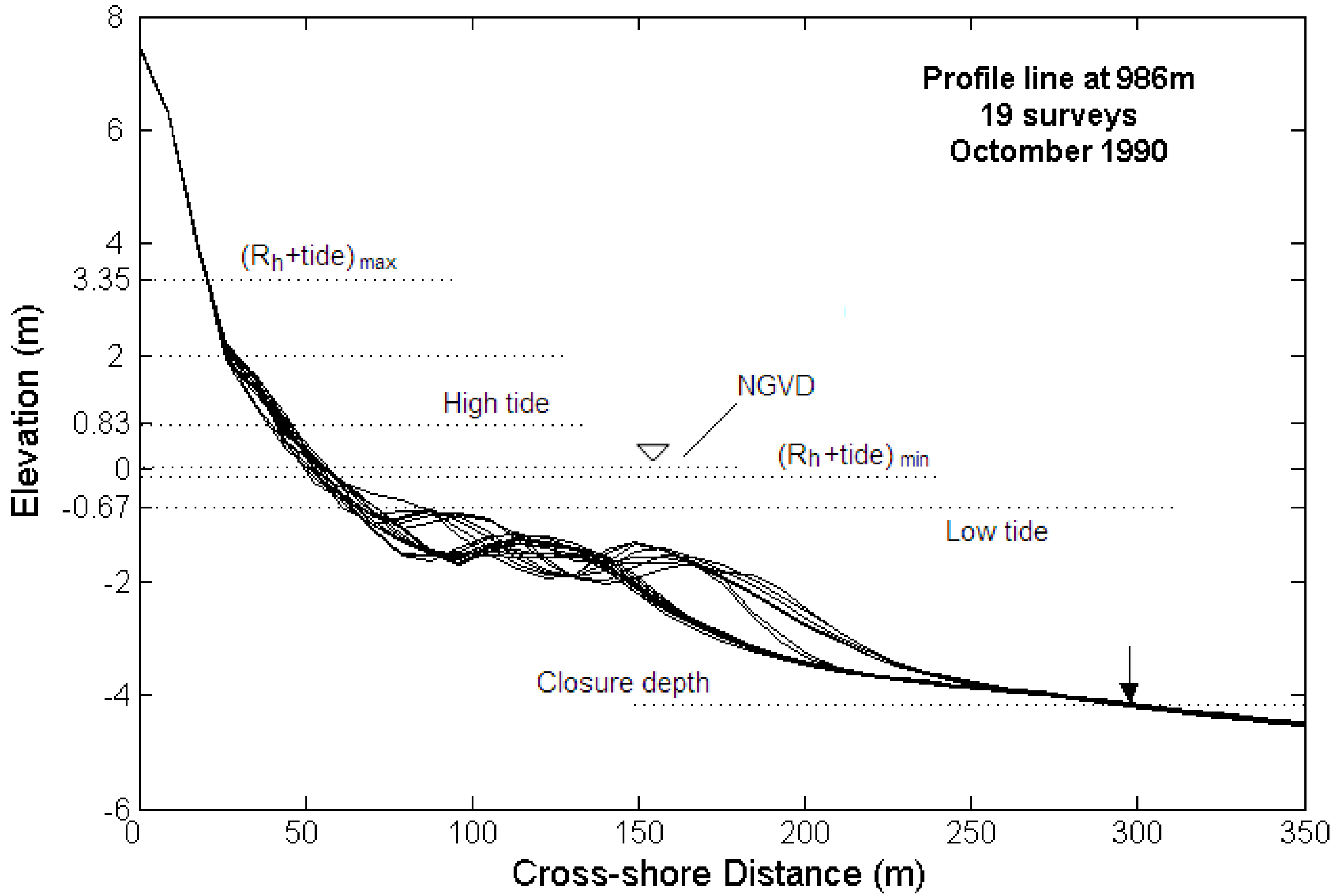


Fig. 2.4 Time series of cross-shore beach profiles (Experiment Delilah) from the US Army Corps of Engineering facility at Duck (Carolina, USA). The Low and High tide levels, the maximum ((Rh+tide)max) and minimum ((Rh+tide)min) wave run-ups are shown. The position of the closure depths is marked by the black arrow.

2.2. Beach dynamics – spatio-temporal variability

Beaches are spatio-temporally dynamic

Different sections of the same beach can have different cross-shore profiles due to the longshore changes in nearshore wave characteristics (e.g. Height and directions)

The are also significant changes in time. The same cross-shore profile can be very temporally variable (see Fig. 2.4)

Beach morphological changes

Changes of the general form of the coastline (scales of some km/decades): related to significant changes in the beach sediment supply, the sea level and the wave climate.

Seasonal changes reflecting the differential seasonal hydrodynamics: mostly associated with berm -submarine bar sediment exchanges. A ‘winter’ and a ‘summer’ beach profile can be identified.

Morphological changes occurring in hours/days usually during extreme events. In such conditions, major morphological changes can take place along the full beach width (onshore and offshore); sediments may even be transported beyond the *closure depth* being lost from the beach sediment reservoir.

Winter and summer profile

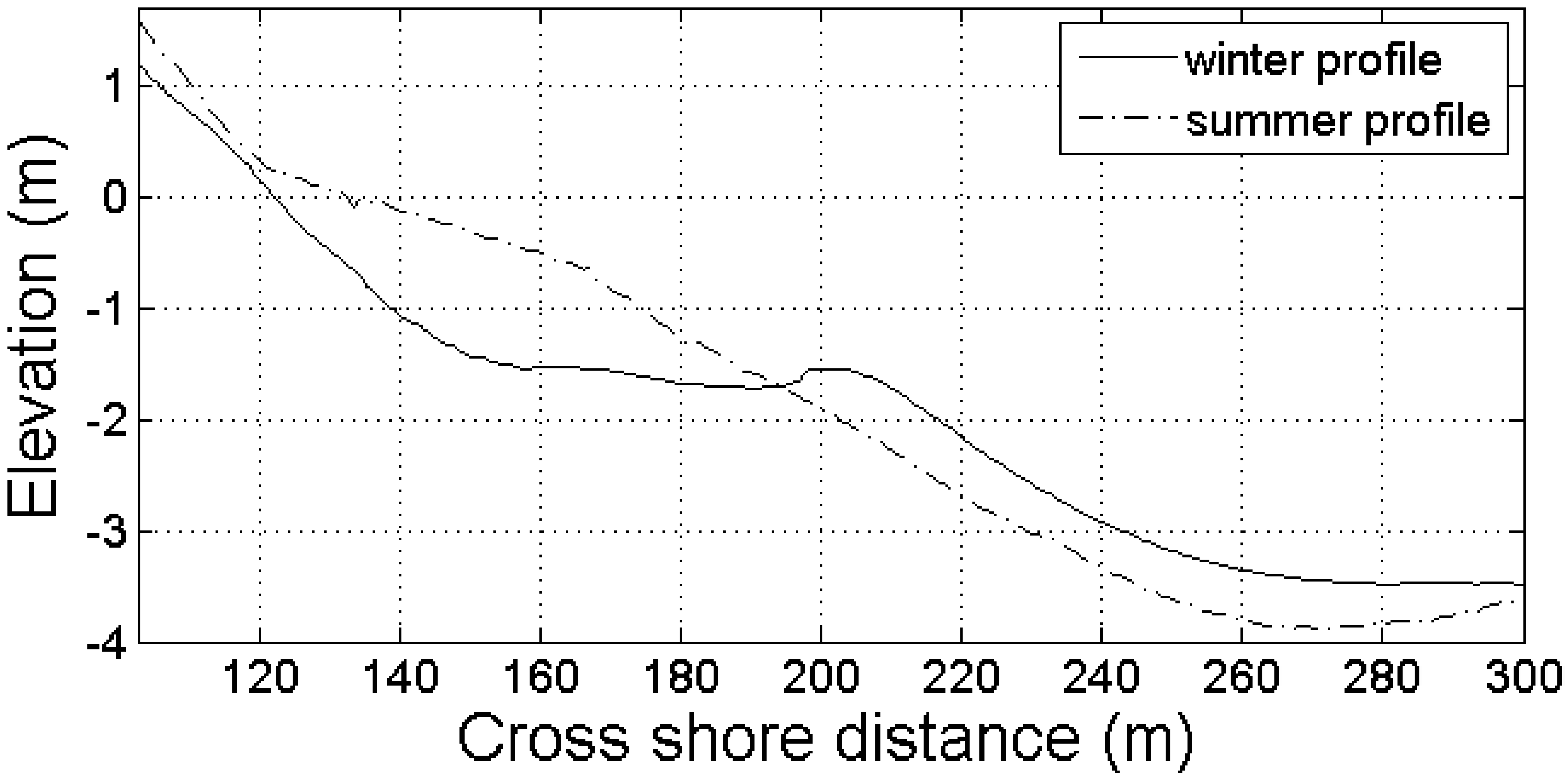


Fig. 2.5 Summer (28th July) and winter (16th December) beach profiles observed during the SandyDuck Experiment (US Army Corps of Engineers data base. The higher-steepness and more energetic winter waves erode the berm and transported its sediments to the submarine bar

2.3 Beach profile analysis – Empirical Orthogonal functions (EOFs)

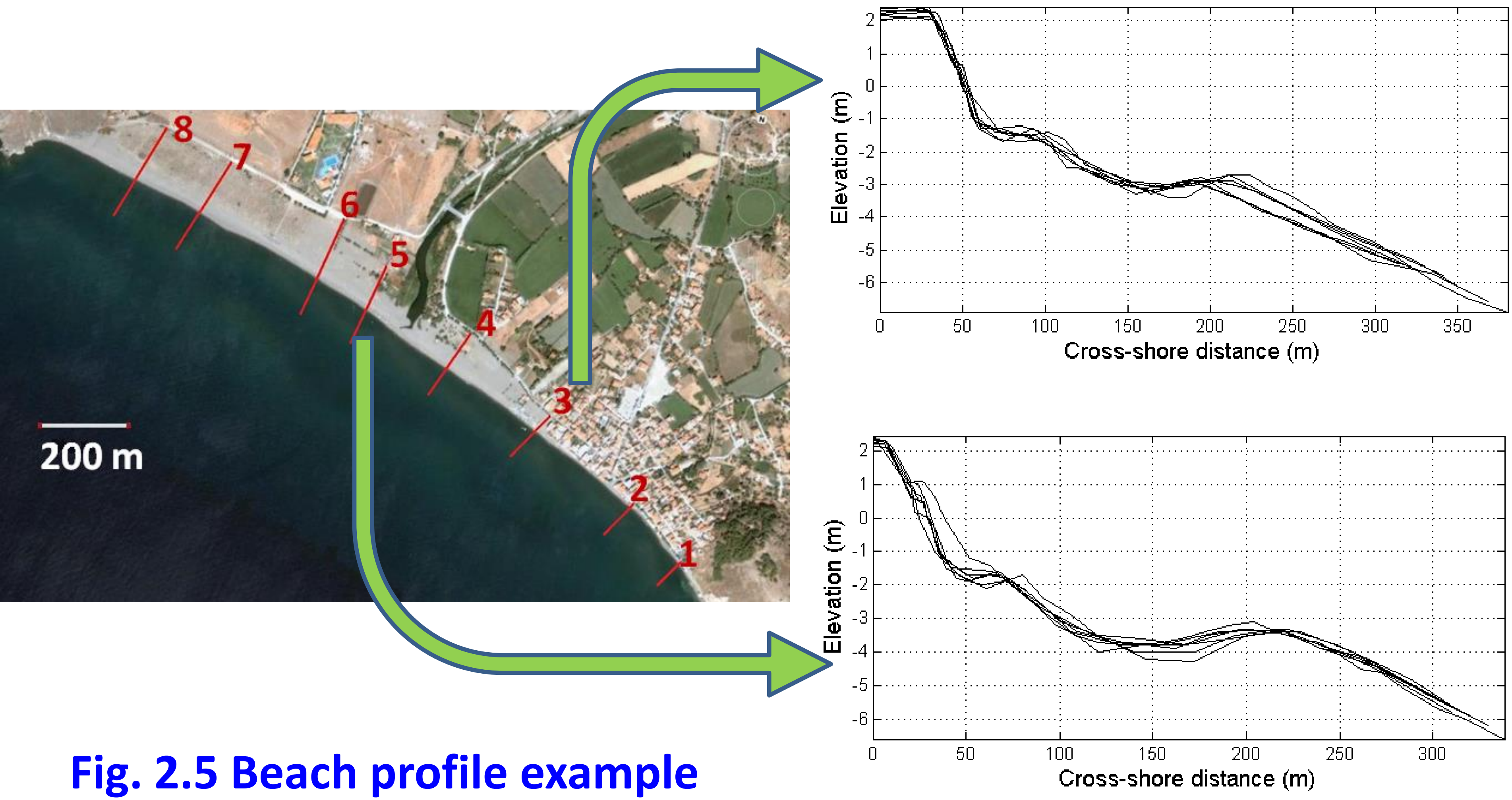


Fig. 2.5 Beach profile example (Eresos.Lesbos, E. Mediterranean

Why needed?

Beach morphology controls (and is controlled by) the beach hydrodynamic and sediment dynamic processes. Therefore, its description is particularly important for the study of beach hydrodynamics and sediment transport

Beach cross-shore profile is dynamic and its instanteous observation may not be representative

There is a need for the description of a ‘mean profile’ which represents the balance between the short- and medium-term morphological changes

What is the result of the approach

It isolates the data spatial and temporal dependence, giving a smaller number of variables which, however, contain maximum information

It provides objective trends and decreases data ‘noise’

It assists in the interpretation of the spatial and temporal variability of the cross-shore profiles .

The data

For each station for which there is a time series of profiles:

Bed elevations at *ns* different locations of the profile and *nt* different times.

For the time *tj* at a location *xi* the elevation is η ανύψωση είναι

$$z_{t_j,x_i}$$

where (j=1,2,…n_t and I = 1,2 ….n_s)

$$\begin{array}{c} t_1 \\ t_2 \\ \cdots\cdots \\ t_{n_t} \end{array} \Rightarrow H_t = \begin{bmatrix} z_{t_1,x_1} & z_{t_1,x_2} & \cdots\cdots\cdots & z_{t_1,x_{n_s}} \\ z_{t_2,x_1} & z_{t_2,x_2} & \cdots\cdots\cdots & z_{t_2,x_{n_s}} \\ \cdots\cdot & \cdots\cdot & \cdots\cdots\cdots & \cdots\cdot \\ z_{t_{n_t},x_1} & z_{t_{n_t},x_2} & \cdots\cdots\cdots & z_{t_{n_t},x_{n_s}} \end{bmatrix}$$

The analysis

From matrix *Ht*, the following square matrices *At* και *Bt are estimated* :

$$A_t = \frac{1}{n_s n_t}(H_t^T H_t) \qquad\qquad B_t = \frac{1}{n_s n_t}(H_t H_t^T)$$

where *Ht*^{T} is the the transpose of *Ht*

They are estimated: $$A_t e_i = \lambda_i e_i$$

***ns* eigenvalues and eigenfunctions of matrix *At,* where *ei* (*i = 1, 2, ..., ns*) are the temporal eigenfunctions**

nt* eigenvalues and eigenfunctions of matrix *Bt

$$B_t c_j = \lambda_j c_j$$

Where c*j* (*j = 1, 2, ..., nt*) are the temporal eigenfunctions

What do they mean

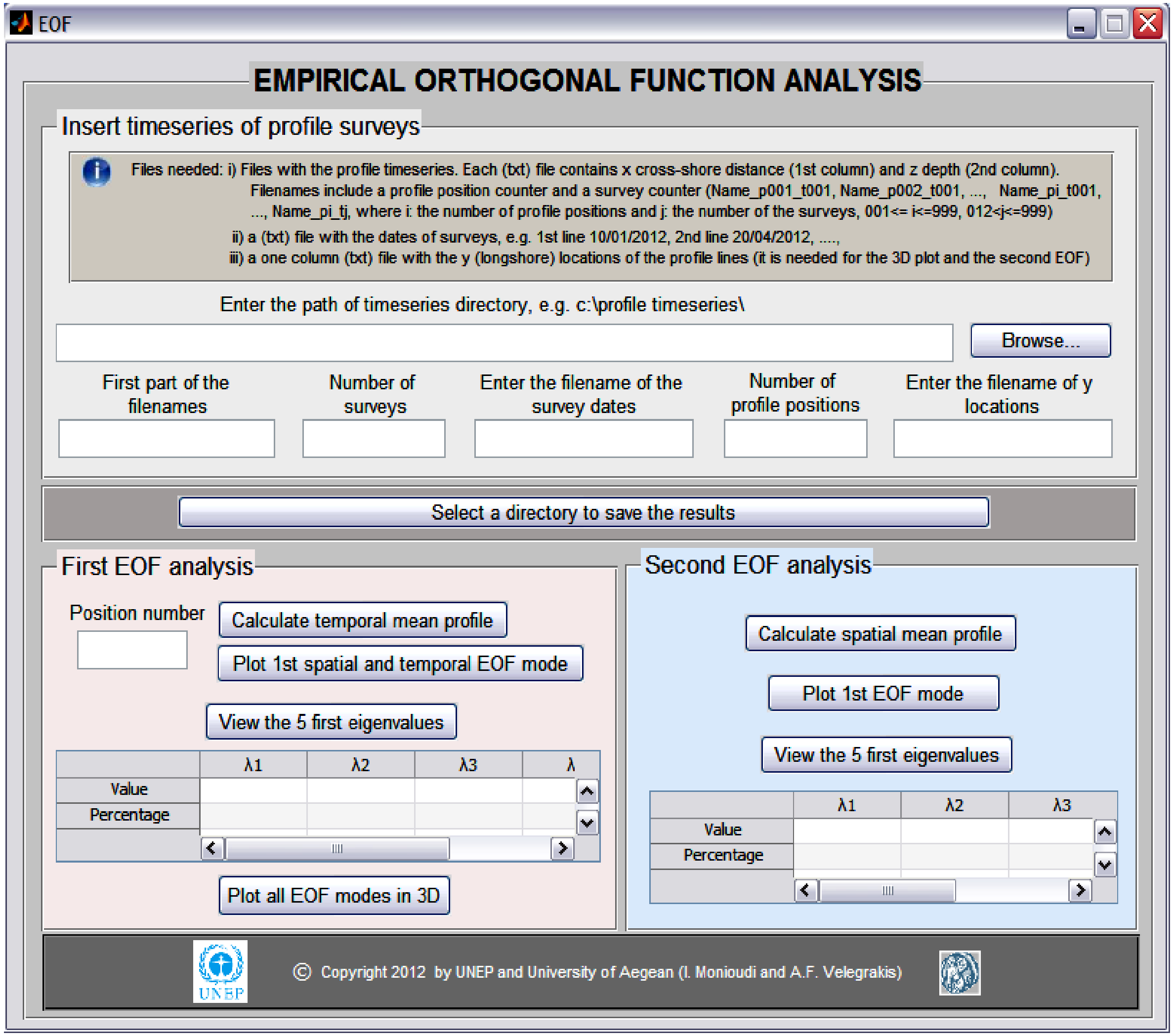
It has been suggested (e.g. Aubrey, 1979) that the 3 spatial eigenfunctions corresponding to the 3 highest eigenvalues can contain almost all the beach profile variability.

- **The first spatial eigenfunction (e1) may describe the 'mean' beach profile during the monitoring time**
- **The second (e2) may provide information on the preferred locations of the berms and submarine bars**
- **The third (e3) may be related to the low tide terrace.**

The 3 fisrt temporal eigenfunction (corresponding to the 3 highest eigenvalues) mayalso provide information:

- **The first (c1) on the presence of general erosion/deposition trends**
- **The second (c2) on the seasonal sediment transport processes;**
- **The third (c3) on the high morphological variability**

2.4. Application with Guide User Interface (GUI)



2.4. Application with Guide User Interface (GUI)

<u>Necessary data</u>

Time series of profiles as *txt files conatining one column with the cross-shore distance (m) and one column with the bed elevation for one station and one observation time*

The filenames

Name_p001_t001, Name_p002_t001, ..., Name_pi_t001, ..., Name_pi_tj,

Where i: the totla number of locations and j: the totla number of time observation 001<= i<=999, 012<j<=999

A *txt* file with the the dates of the beach cross-shore observations

A txt file with the coordinates of the stations along the beach