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Abstract

In the present work, the changes of cross-shore profile and the coastline of a sandy beach in Pieria, Greece, are studied by using topographic profiles, sediment analysis and a numerical simulation model. The work is motivated by the considerable erosion problems caused to an extended portion of the coast north of the studied area due to the construction of a craft shelter, and its scope is two-fold: to help in understanding the dynamics of the beach based on results of the field work and to proceed a step further, studying the responses of this beach by numerical simulation, utilizing the topographic and sediment field data and measured wave data. The study of the cross-shore profiles, as well as the sediment analysis of the samples obtained along the profiles, revealed the morphological features of the coast under study and provided information concerning the dynamic zones in each profile. The sediment grain size reduces from south to north, following the direction of the long-shore currents generated in the area. The results of the numerical simulation concerning the coastline evolution are found to be in agreement with the qualitative estimations and visual observations of existing coastal changes to the broader area.

Keywords: Sediment transport; Sediment analysis; Numerical simulation; LITPACK; Cross-shore profile; Coastline evolution.

Introduction

Wave-dominated shore and shoreline evolution both due to natural and human-induced causes or factors can vary over a wide range of different temporal and/or spatial scales (STIVE *et al.*, 2002). The complexity and the interplay between these causes or factors limits our capability to understand and especially to predict the above variability, although there are a number of works – evolving field work, analysis of measurements or/and numerical simulation/prediction – towards this direction. As a systematic field and analysis work, we mention that of LEE *et al.* (1998), who used sediment budget analysis to examine the medium-scale (years to a decade) variability of a beach/near shore profile at Duck, North Carolina, from 1981 to 1991, based on biweekly profile data.

Characteristic works on modelling of littoral changes are those of HEDEGAARD *et al.* (1992), where six different models for short-term coastal profile modelling were inter-compared and tested against measured profile evolutions from a large wave flume, VAN RIJN *et al.* (2003), where deterministic and probabilistic profile models were compared with hydrodynamic and morphodynamic data of laboratory and field experiments on the time scale of storms and seasons, BAYRAM *et al.* (2001), where the skill of six formulas – commonly employed ones in engineering studies – developed for calculating the longshore sediment transport rate was evaluated by means of field measurements, as well as those of SCHOONEES & THERON (1995) and SZMYTKIEWICZ *et al.* (2000), mentioned below.

In the present work, the morphology, morphodynamic characteristics and estimated cross-shore and shoreline changes of a sandy beach at Pieria, Greece, are studied with the aim of topographic profiles, sediment analysis and a simulation model. Recent works concerning the coastal area and littoral zone around the Aisonas river are those of SOTIROPOULOS (2003) and CHATZIOPOULOS (2003). The presented one is focused on the coasts of the settlement Skala Katerinis in South Pieria, an area extending north of the estuary of the Aisonas river to south of the port (fishing shelter) of Paralia Katerinis (Figure 1). The coastal zone in question consists of a long (tens of kms), alluvial, sandy beach with a broad on-shore part, stretching almost straight with a NNE–SSE orientation. The beach terrain is fairly smooth with small bottom gradients.

During the last years, a rapid tourist growth took place in the above area. This resulted in infrastructure works in the coastal zone, such as hotels, restaurants, recreation and commercial centers etc., and a small port on the coast of Paralia Katerinis. The construction of the port disturbed the sediment budget of

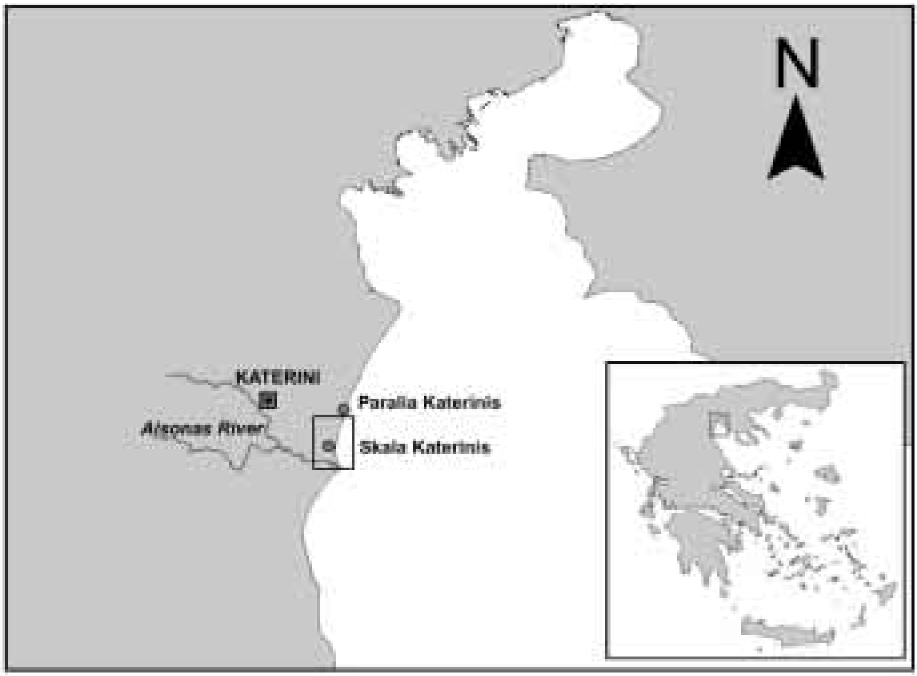


Fig. 1: Map of the studied area.

the coast. More specifically, accumulation of sand was observed in the region south of the port, while the south-to-north longshore sediment transport caused severe erosion and a gradual retreat of the coastline north of the port. As an action to protect the beach and the buildings from erosion, groins from stone, north of the port and vertical to the shoreline, were constructed. These groins suspended the beach erosion locally, temporarily turning away the imminent threat to the buildings in the area, which are located behind the groins. However, the problem was not solved and the erosion started to appear north of the last (northern) groin. Up to now the technical interventions in the area have not solved the erosion problems. Problems of a similar nature have also been reported and studied by POULOS & CHRONIS (2001) in another coastal area of Greece in Kato Achaia, NW Peloponnese: the construction of a port and the extraction of deposits from the local river significantly changed the pattern of sediment transport inducing dramatic changes in coastline configuration, while coastal engineering measures, such as modification of port-breakwaters and construction of groins have had only a minimal contribution to beach recovery.

The continuous monitoring of coastal zones such as the afore-mentioned ones is compulsory and the need for integrated and scientifically-documented studies, as a necessary tool for supporting a unified management policy for the coastal zone, based on the principles of sustainable development, becomes obvious.

Materials and Methods

Measurements

a. Beach topography and sediment

In the area of study, beach profiling was carried out (June 2002) in order to produce the characteristic profiles and their morphodynamic features. The position where the five profiles OA-I – OA-V, used in this work, cut the shoreline is shown in the aerial photo in Figure 2. The survey of the morphological formations at various points of the beach was carried out by using two scaled rods and a tape measure (the so-called 'Emery' method, see for example (KOMAR, 1998)). The profiling started from the boundary of the on-shore part of the beach (defined by dunes and the rural road) and ended at a distance of about 50m off the shoreline.

The bathymetric data of the profile OA-II, collected in the context of field work in June 2002 (including the use of a portable fathometer on a boat), refer to an on-shore distance of 15m (maximum height: 0.82m) and an underwater distance of 382m (maximum depth: 6 m) from the shoreline.

In the sequel, sampling and analysis of the samples of the surface sediments was carried out in order to identify the grain-size classification and to find the percentage of contribution of each grain-size in the sedimentary composition of the littoral zone. More specifically, nine samples were obtained along the cross-shore profiles OA-I – OA-V. The on-shore samples were taken at distances of 2.4m, 6m and 14m from the shoreline, while the underwater samples were taken at distances of 4m, 12m, 22m, 30m and 50m from the shoreline, as can be seen in Figure 3.

b. Wave data

The wave data input to the numerical model was obtained from the buoy of 'POSEIDON network' – developed and maintained by HCMR – located in the sea area off-shore Katerini (40° 14' 96", 22o 42' 96", water depth: 54.5m). The time step of the wave data was three hours. The maximum significant wave height and mean zero up-crossing period as obtained from the measurements were H_{max}= 2.79m and T_{max}=5.36sec, respectively, the waves coming from an easterly direction. It has to be noted here that the use of the real wave climate through measurements in the setup of the numerical model is a considerable

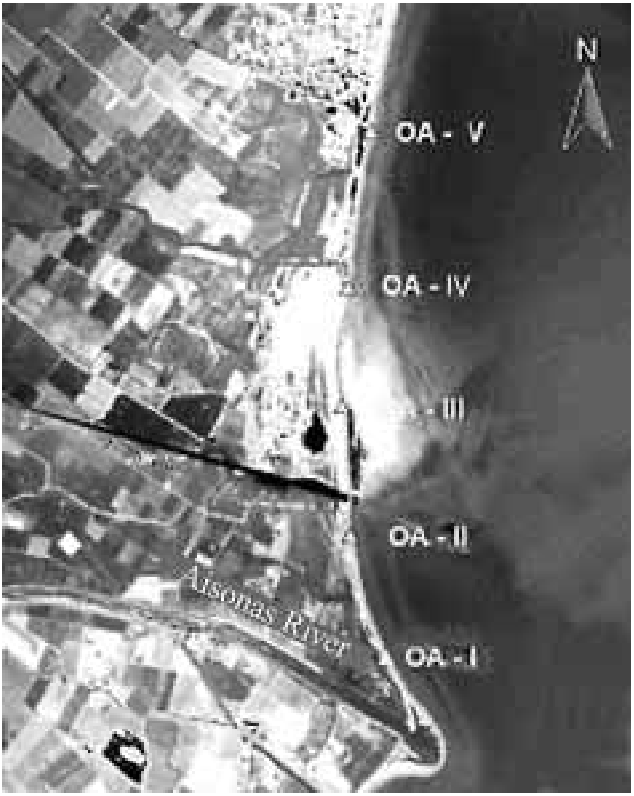


Fig. 2: Aerial photograph of the studied area. The positions of the five profiles OA-I, ... , OA-V used in this work are marked in the picture.

advantage for the present study, rendering the results of the simulation more reliable.

Numerical simulation

A significant part of the present work refers to the simulation and prediction of the morphology of the area, using the software package LITPACK – Version 2.7, developed by the Danish Hydraulic Institute (DHI). LITPACK models the littoral transport of non-cohesive sediment under the action of waves and currents. Indicative works concerning the scientific background of the software (modelling of littoral drift, turbulent boundary layer, distribution of suspended sediment, bed concentration of sediment) have been published by DEIGAARD *et al.* (1986a, 1986b), FREDSOE (1984), FREDSOE *et al.* (1985) and ZYSERMAN & FREDSOE (1994). More references can be found in the software manuals (DHI, 1998). Previous works using LITPACK with satisfactory results are that of SCHOONEES & THERON (1995), where 10 cross-shore sediment transport/morphological models were used to model beach profile changes in order to determine coastal set-back lines, behavior of beach fill and beach profile variations adjacent to coastal structures, and the more recent one of SZMYTKIEWICZ *et al.* (2000), where computations of shoreline evolution were made using four models and their results were compared versus measurements and inter-compared.

In this work, two of the five modules of the package were directly used: (i) LITPROF (DHI, 1998a), which describes the cross-shore

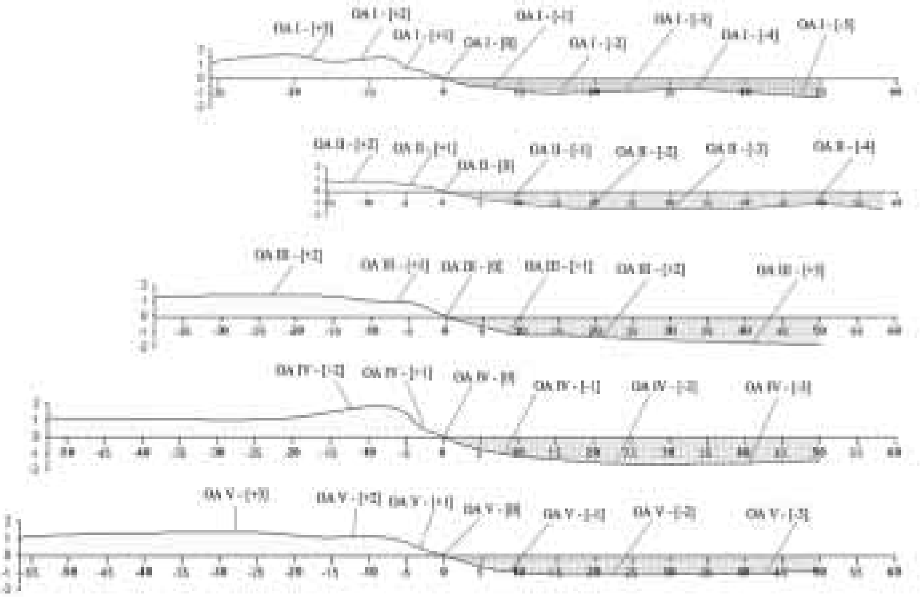


Fig. 3: The five topographic profiles of the studied area, OA-I, ..., OA-V, produced on the basis of measurements collected during the field work in 24-26 June 2002. The positions of the sediment sampling, for which results are presented in Figures 4a-4e, are shown in the profiles.

profile changes, based on a time-series of wave events. The model is based on a one-line theory, according to which it is assumed that the long-shore gradients do not exist, i.e. the depth contours are always parallel to the coast. Thus, the morphology of the coast is solely described by the cross-shore profile bathymetry. LITPROF, being a time-domain model, includes the effects of changing morphology on the wave climate and transport regime. This enables a detailed simulation of profile development towards a new equilibrium for a time-varying incident wave field. (ii) LITLINE (DHI, 1998b) calculates the long-shore coastline position based on input of the wave climate as a time-series. The model is, with minor modifications, based on a one-line theory, in which the cross-shore profile is assumed to remain unchanged during erosion/accretion. Thus, the coastal morphology is solely described by the coastline position (cross-shore direction) and the coastal profile at a given long-shore position. The sediment transport can be calculated for varying profiles in the long-shore direction, and basically four types of coastal structures (groins, jetties, off-shore breakwaters, revetments) can be taken into account together with sources and sinks of sediment.

Results and Discussion

Beach morphology

In general, the morphology of the studied beach – based on the five profiles taken along the beach (Fig. 3) – is formed by two main climatic regimes, a relatively calm one during summer, and a much more intensive one during winter. In the backshore, berms are observed. The first one is formed by low-height and low-intensity waves, while the second one consists of high and intense waves appearing during winter.

The underwater section of the profiles presents a relatively regular bottom terrain, the greater slope being developed within the first meters off the shoreline. Next, the bottom slope decreases up to the point that the bar formation starts. The bar extends from about 50m to about 60m off the shoreline. Profile OA-I is an exception: the bar starts to appear at a distance of 25m and expands up to the 40m off the shoreline. The water depth at both sides of the bottom of the bar is about 1.5m, while the bar height is about 0.5m. The appearance of the bar is an indication of the location of the breaking zone of the waves. Gatherings of mostly coarse-grain sediment at the on-shore side of the bar were observed as a result of wave breaking and induced longshore transport.

The backshore starts from the beach face, where the slope is the maximum within the first meters from the shoreline and up to a point that the first berm appears. Next, the slope decreases up to the point that the second berm appears – which is the highest of the beach and the point up to which the dynamic swash zone is extended. Beyond that point and up to the on-shore boundary of the beach, gradients present small values (in some places even negative). In this last section of the beach, the zone of 'wind processes', one can observe the formation of dunes (e.g. clearly shown in profile OA-I).

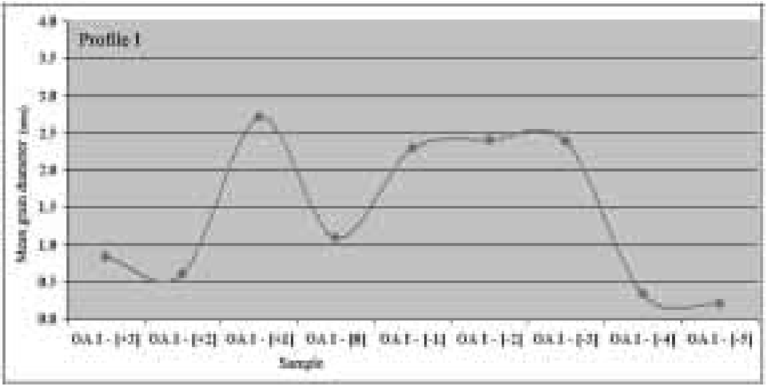
Sediment analysis

The analysis of the sediment samples obtained along the profiles OA-I – OA-V, in addition to the above discussed beach morphology, can lead to conclusions concerning the arrangement and distribution of sediment on the littoral zone under study. The beach consists of sediment grain sizes varying from the category of very fine sand to the category of pebbles. In general, the mean grain diameter of the samples decreases from south to north. This can be explained by observing the diagrams in Figure 7. It can be seen that the south winds and waves prevailing during the year are of low intensity, thus the induced long-shore currents do not have the required energy to transport the coarser sediment for long distances from the main sediment source, the river Aisonas. The river discharges and related rates, the mechanism of deposition and the local sediment formations are subjects beyond the scope of the presented work.

In the diagrams of Figures 4a-e, the mean grain diameter (up) and its standard deviation, i.e. the sorting coefficient (down), is presented for the 9 samples obtained along the cross-shore profiles OA-I – OA-V, respectively, using the [+] symbol for the on-shore samples, the [0] symbol for the shoreline and the [-] symbol for the underwater samples. These diagrams provide information concerning the physical processes that take place in the littoral zone. In general, in the underwater part of the profiles, a good sorting is observed for samples of sediment collected offshore the bottom of the bar, while a poor to very poor sorting is observed in the surf zone, where the decline of wave energy takes place. We must also keep in mind that in the surf zone the wave-induced long-shore currents act, transferring the river discharges from south to north. In the backshore, the sediment sorting is very good in most of the cases, indicating their arrangement by the wave, as well as the moving of the fine-grain sediment towards the zone of dunes by the wind mechanisms. Regarding the grain size of the backshore of the studied profiles, it was found (after the statistical process) that its mean diameter is of the order of 0.2mm to 0.5mm, classifying the corresponding sediment in the category of fine and medium sand.

Numerical simulation results

An integrated work concerning the modelling of a physical system consists normally of (i) defining and limiting the subject of interest, (ii) collecting data, (iii) setting up the model, (iv) calibrating and verifying the model, which includes tuning of the model parameters in order to reproduce



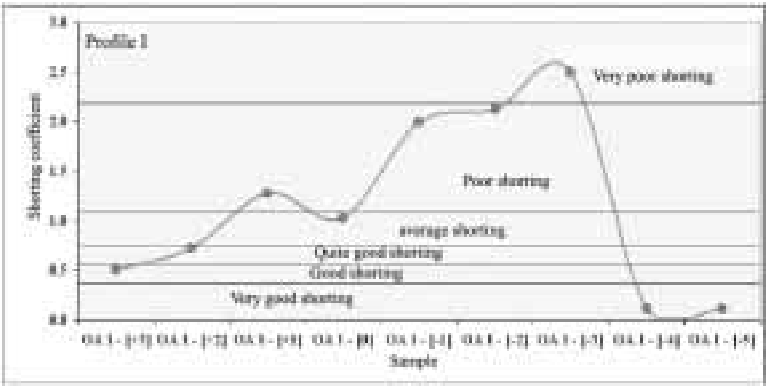


Fig. 4a: Diagrams presenting the mean grain diameter and the shorting coefficient for the nine samples obtained along the cross-shore profile OA-I. The sampling positions OA I - [+3], ..., OA I - [-5] are shown in Fig. 3.

known/measured conditions for a particular situation, running one or more simulations for which measurements are available without changing any tuning parameters and checking the results, (v) running the production simulation, and (vi) presenting results. In the present framework, all the above steps except (iv) were followed. Calibrating and verifying the model was not possible due to the lack of a sufficient number of measurements in the studied area.

a. Profile response

The profile OA-II (Fig. 3) was selected for studying the profile response of the sandy beach in Pieria. The main reasons are that profile OA-II is located north and far enough from the Aisonas estuary, resulting in a minor influence due to the river discharges. Furthermore, the number of measured values of height – in the on-shore part of the profile (including dunes) – and depth – in its underwater part (including the bar which determines the breaking of waves) – are satisfactory for the modelling of the bathymetry changes of the profile. The response of profile OA-II was simulated during a storm (15 hours long) that took place in December 2002, from 1/12/2002, 18:00UTC, to 2/12/2002, 09:00UTC. The bathymetry of the profile was given to the model with a step of 1m.

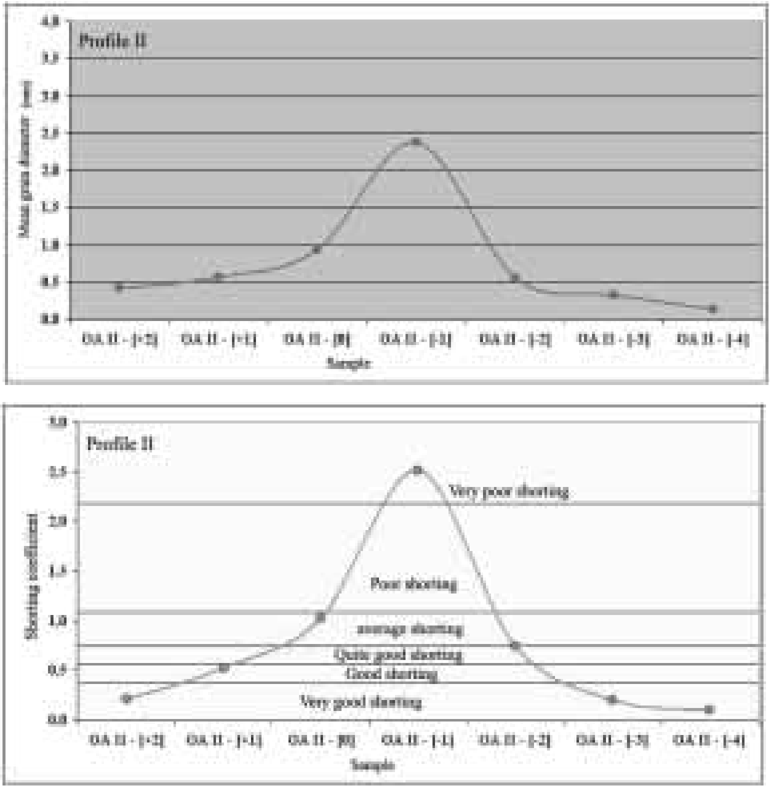


Fig. 4b: Same as Fig. 4a for cross-shore profile OA-II.

In Figures 5a-5d, the initial profile and the profiles obtained from the numerical model (LITPROF) simulation are presented after 3, 9 and 15 hours of simulation. Negative values in y-axis (depth in m) correspond to the underwater part of the profile and the x-axis represents distance (in m) from the deepest part (6m) of the profile. In these figures the bathymetry changes are also plotted around the line of 0m depth, indicating accretion when positive and erosion when negative. Based on the figures, the profile changes can be considered in four areas, starting from the deep water to the shoreline. From about 20m to 100m (area A) an accretion of sediment is gradually observed, resulting in a bar-type formation at the end of the simulation. In this area the maximum accretion is estimated as 0.5m at about 4.6m depth. From about 175m to 320m (area B) slight erosion is observed with a maximum of 0.15m. In the next area C (from 325m to 370m), which actually constitutes the larger part of the surf zone, a more perceptible erosion is observed with its maximum at the bottom of the bar from the on-shore side (about 0.30m), resulting in reduction of the bar size. Lastly, in the swash zone (area D) the simulated erosion with a maximum of about 0.40m causes a retreat of the shoreline of about 2.3m. The aforementioned simulation results for areas B, C and D could be explained as follows: as the waves start to feel the bottom in area B they cause a slight erosion, which becomes more intense in the surf zone (area C), where the breaking of the waves, accompanied by high-turbulence phenomena,

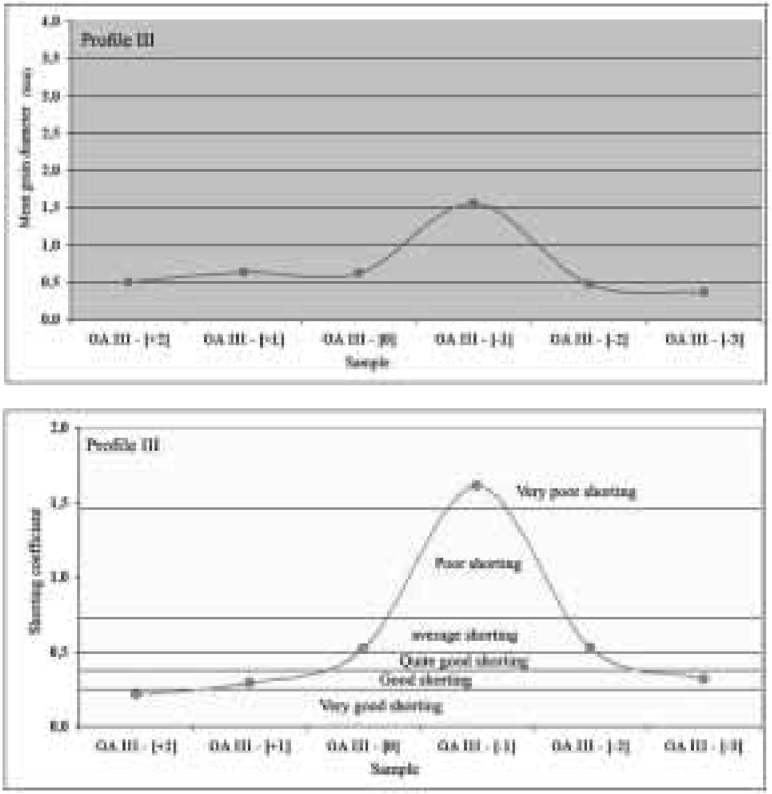


Fig. 4c: Same as Fig. 4a for cross-shore profile OA-III.

takes place, while the swash-up and -down procedure results in a retreat of the shoreline. All the above sediment of the eroded profile seems to be transferred to the area A. A possible explanation for this is the generation of strong rip currents that move the suspended sediment from the areas B, C and D and deposit it in the deeper water area A.

b. Coastline evolution

The module LITLINE of LITPACK was used to simulate the evolution of the coastline of the studied area, about 2km long, for two cases: (1) without coastal structures and (2) with the effect of one coastal structure (groin). The extent of the coastline is determined by the profiles OA-II and OA-V (Fig. 2), while profile OA-I was not used because a coastline extending from profile OA-I to profile OA-V would exceed the model limitations of a quasi-uniform beach and possibly result in inaccurate calculations.

According to the topography of the area, the winds affecting the long-shore sediment transport are the southern and south-eastern. The simulation was carried out for a time period of about 15 months: from 9/9/2001, 00:00UTC, to 31/12/2002, 21:00UTC. The bathymetry of the profiles OA-II – OA-V was given to the model with 1m resolution, while the coastline was defined by 401 equally-distant points.

Case 1: Coastline evolution without structures

The numerical simulation for the coastline evolution in the case of the unobstructed coastline resulted in negligible variations of its morphology with respect to the initial one,

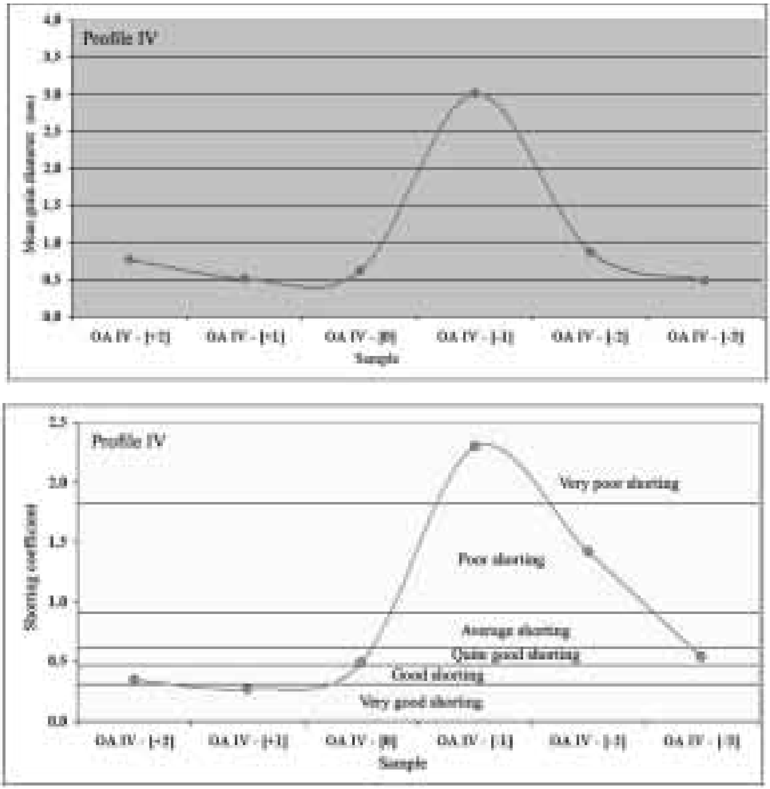


Fig. 4d: Same as Fig. 4a for cross-shore profile OA-IV.

independently from the wave conditions prevailing in the studied area. This result indicates that all the interacting physical mechanisms which determine the morphology of the studied beach are in a state of dynamical equilibrium, thus conserving a morphologically stable coastline.

Case 2: Coastline evolution with a coastal structure

The rationale of the setup for the second case was the following: As mentioned in the Introduction, after the construction of a craft shelter (small port) north of the area studied in this work (in the settlement Paralia Katerinis; Fig. 1), the severe erosion and retreat of the coastline was faced with the construction of a series of groins north of the shelter, gradually shifting the problem after the last northern groin. The beach studied in our work has the same orientation, similar sediment composition and of course, it is exposed to the same wind and wave regime with the adjacent beach, where the aforementioned human interventions took place. Thus, simply introducing to the studied coastline one coastal structure, such as a groin, we expect to obtain numerical simulation results that will reveal and verify the sensitivity of the broader area to human intervention – essentially, the blocking of the long-shore sediment transport due to a structure – avoiding to represent a complex of structures similar to the existing one in Paralia Katerinis. In this connection, a groin of 60m length and 5m width, perpendicular to the coastline orientation and 1150m south of the profile OA-V, was added on the initial coastline.

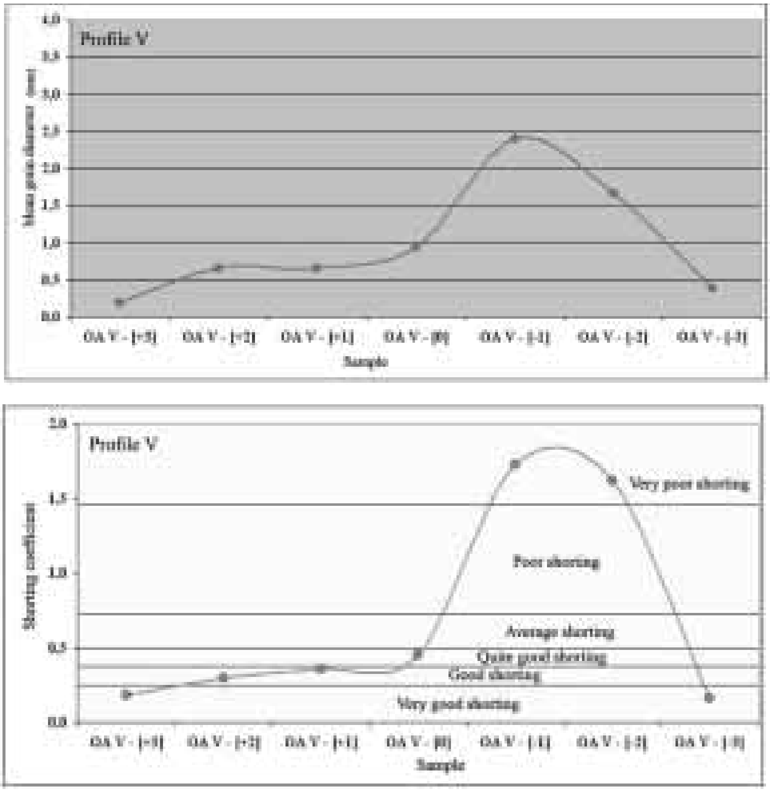


Fig. 4e: Same as Fig. 4a for cross-shore profile OA-V.

The results of the numerical simulation are presented in Figures 6a-d. In Figure 6a the initial coastline (on 9/9/2001) and the coastline as obtained on 30/12/2001, 31/03/2002, 30/06/2002, 29/09/2002 and 29/12/2002 are presented, while the corresponding variations of the coastline (accretion or erosion) with respect to the initial one are shown in Fig. 6b. In Fig. 6a the horizontal axis represents the baseline, i.e. a straight line behind the coastline parallel to the orientation of the beach, and the vertical axis represents the distance from the baseline to a coastline point. In the sequel the coastline changes observed in Figures 6a-b will be explained in relation to the wind and wave regime during the simulation and in connection with the results in the Figures 6c-d.

During the first three months of the simulation N-NW winds and waves prevail in the studied area, while the S-SE waves, affecting the long-shore sediment transport, are of low duration and intensity. At the end of November and during December 2001, the N-NW winds decrease while the S-SE winds increase in frequency and intensity. As a result, the accretion south of the groin and the erosion north of the groin, become more and more severe. More specifically, on 30/12/2001 the accretion starts from the range of 550 (110×5) m and extends up to the tip of the groin. Right north of the groin the retreat of the coastline exceeds 32m and extends up to the range of 855m, while a deposit of sediment is observed after this range with maximum accretion of 1.2m. As can be seen in Figure 6c, the high values of the integrated drift south of the groin

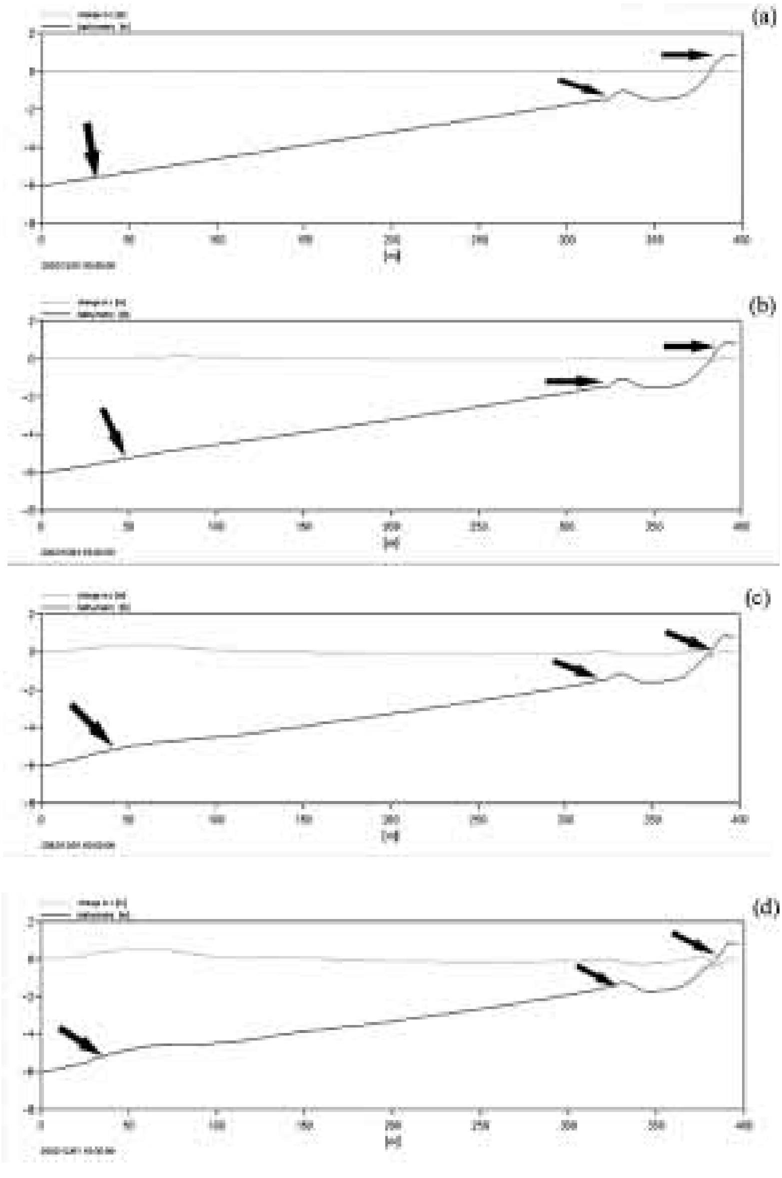


Fig. 5: Changes of the bathymetry of cross-shore profile II as simulated by LITPROF (LITPACK), caused by the 15-hour storm of 1st December 2002. The time interval between the figures is 3 hours. The positions of significant changes are shown by the three arrows.

due to the storm decrease abruptly before the groin, and increase again north of the groin. The drift reaches its maximum at the point where erosion turns into accretion and gradually decreases again until the north end of the studied coastline due to the deposit of sediment along the north part of the coastline. The accumulated sediment volume in m^3/m, shown in Figure 6d, follows the pattern of erosion/accretion in Figure 6b, as expected.

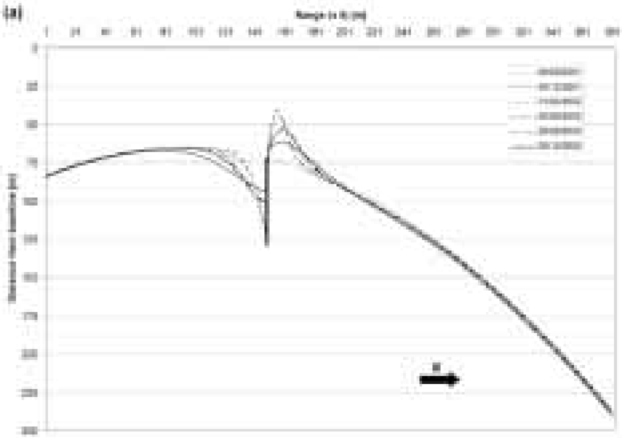


Fig. 6a: Coastline as simulated by LITLINE (LITPACK) for the Case 2 (with the presence of a groin) on 9/9/2001 (initial coastline), 30/12/2001, 31/3/2002, 30/6/2002, 29/9/2002 and 29/12/2002.

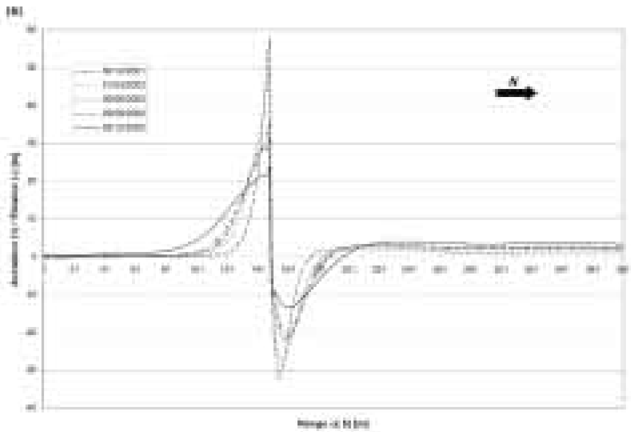


Fig. 6b: Accretion/erosion as simulated by the numerical model for the Case 2 and the dates mentioned in Fig. 6a.

During the next three months (January, February, March 2002), the accretion and erosion procedures around the position of the groin continue to take place with slower rates, as can be seen from the curves of 31/03/2002 in Figures 6, since N-NW winds prevail again (Fig. 7). Focusing on Figure 6c, we observe that the curve of the integrated drift decreases with milder gradient before the groin, indicating the change in shape of the area of accumulated sediment, which is shown in Figure 6b or Figure 6d. Also, the maximum drift north of the groin has shifted about 50m north, which is in accordance with the shift of the erosion-to-accretion turning point observed in Figure 6b or Figure 6d.

In the spring as well as the summer period, the procedures of accretion and erosion continue to evolve with much slower rates, as can be seen more clearly from Figure 6c. However, the constantly increasing concentration of sediment south of the

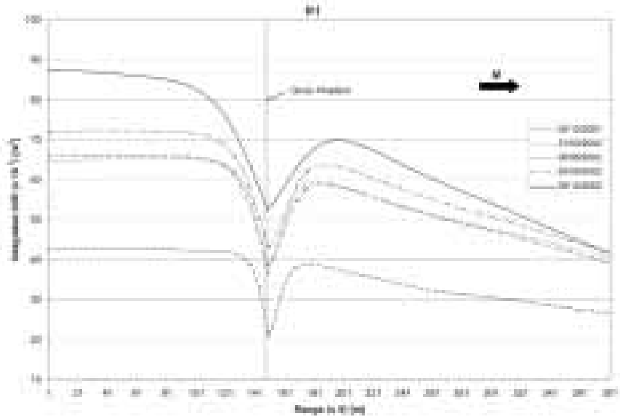


Fig. 6c: Integrated drift along the studied coastline as simulated by LITLINE (LITPACK) for the Case 2 and the dates mentioned in Figure 6a.

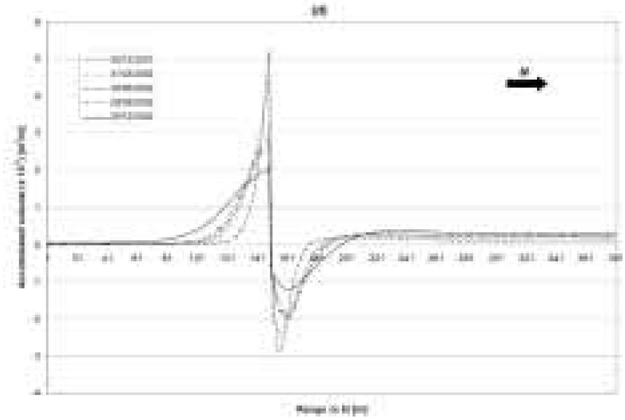


Fig. 6d: Accumulated sediment volume along the studied coastline as simulated by the numerical model for the Case 2 and the dates mentioned in Figure 6a.

structure results in the sediment passing over the groin. Thus, the most significant change of the coastline is a partial recovering of the strongly eroded section of the coastline 50m north of the groin, which resulted in a retreat of about 21.5m on 29/09/2002 (Fig. 6b).

Lastly, the storm of December 2002 with waves of significant wave height 2.5-2.7m, coming from east-to-southeast directions, caused the transference of a part of the accumulated sediment south of the groin more southerly, due to the diffraction of waves from the south side of the groin. This increased drift to the south can be clearly seen in Figure 6c. The same wave action also results in an increased recovery of the most eroded part of the coastline by taking sediment from the section of the beach around the erosion-to-accretion turning point about 200m north of the groin. Thus, the coastline takes the final

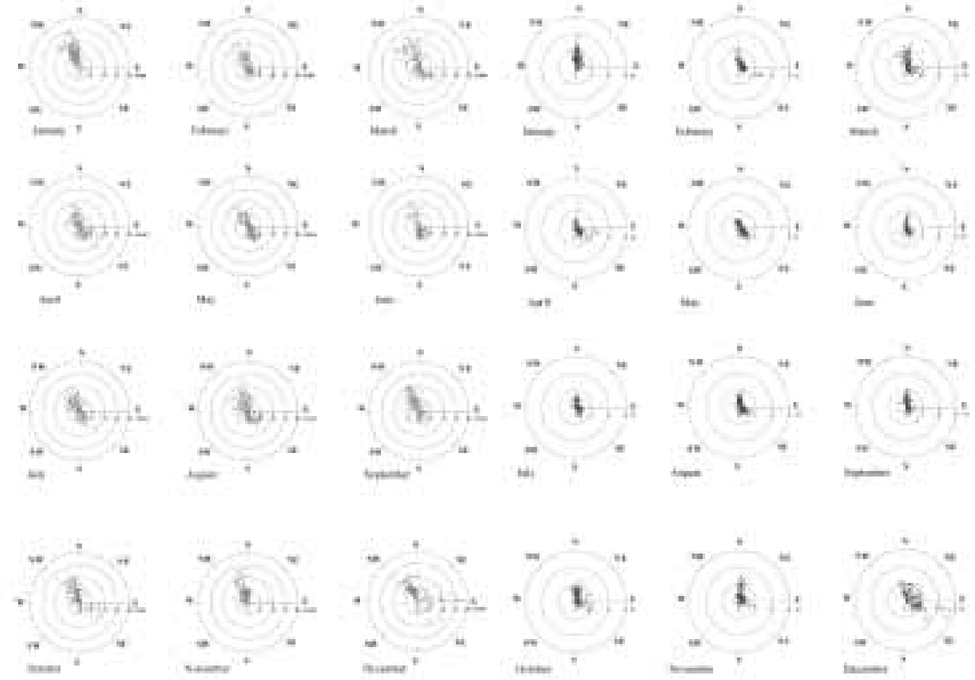


Fig. 7: Polar scatter diagrams concerning the wind speed (in m/sec) and the significant wave height (in m), as obtained from the buoy of the POSEIDON network, offshore Katerini, for each month of the year 2002. (Wind speed: left, significant wave height: right).

form of the 29/12/2002 curve (Fig. 6a) at the end of simulation with maximum accretion of about 24m and accumulated sediment volume of about 3.5×10^4 m^3 south of the groin, while the maximum retreat north of the groin is 13.5m with corresponding eroded sediment volume 1.61×10^4 m^3, as can be estimated from the diagrams in Figure 6b and Figure 6d.

By means of the model implementation, it is illustrated that the structure (groin) blocks the physical long-shore drift of the sandy sediment, which, according to the prevailing wind-wave regime at the area, is from south to north. The simulated maximum erosion of the beach north of the groin, exceeded 32m (Fig. 6b) and is an indication of the magnitude and the consequences of disturbance of the dynamic equilibrium in the area, which can be of crucial importance in cases such as the presented one, since the wider area under study is inhabited and many activities depend on the health of its coastal environment.

Conclusions

In the present work, a section of a sandy beach of Pieria, Greece, was studied with the use of in-situ measurements and topographic profiles, laboratory sediment analysis and the software package LITPACK, which simulates the sediment transport under the action of waves and currents.

The beach morphology was described and connected to the action of the prevailing winds and waves during a year. The grain sediment analysis carried out in five profiles of the beach resulted in a good to very good sorting of sediment in the backshore and offshore the bottom of the bar, while it showed a poor to very poor sorting in the surf zone. The analysis of the samples also showed that the mean grain diameter of the sediment, the size of which varies from very fine sand to pebbles, decreases from south (river Aisonas) to north.

The numerical simulation of the changes for the selected profile OA-II after a 15-hour storm with a maximum significant wave height of about 2.8m, resulted in erosion in the surf and swash zone (with a maximum of 0.3m and 0.4m respectively), about 2.3m retreat of the shoreline and deposit of the sediment at the area of 4.5-5.5 m depth (maximum accretion of 0.5m).

The implementation of the numerical model for the evolution of the unobstructed studied coastline – carried out with the fine time-step interval of 3 hours and a total duration of simulation of 16 months – resulted, at the end of simulation, in a coastline extremely close to the initial one with negligible variations even during the storm. In contrast, the addition of a coastal structure (groin) vertically to the orientation of the coastline caused considerable changes to its morphology, blocking the long-shore sediment transport with corresponding intensive phenomena of erosion and accretion. Representatively, the accretion at the south side of the groin reached the tip of the 60m groin during storms, passed over the groin and reached 24m – corresponding to accumulated sediment volume of about 3.5×104 m^3 – at the end of the simulation. At the north side of the groin the coastline retreat reached the 32m during storms and resulted in 13.5m, corresponding to accumulated sediment volume of about -1.61×10^4 m^3 at the end of the simulation, while from 250m north of the groin up to the end of the studied coastline an accretion of 3.5m in-the-mean with corresponding accumulated sediment volume of about 2.85×10^4 m^3 was estimated at the end of the simulation. The above results concerning coastline accretion and retreat are in agreement with qualitative estimations and visual observations of existing coastal changes in the broader area and they encourage to proceed further to the verification of the model.

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