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MAREGOT project experience: Integrated approach to understanding coastal dynamics behaviour

Luca Carpi[1,2], Luigi Mucerino[1,2], Giovanni Besio[3], Nicola Corradi[1], Marco Ferrari[1]

[1] *DISTAV, Department of Earth, Environmental and Life Sciences, University of Genova, Corso Europa 26, 16132, Genova, Italy, luca.carpi@edu.unige.it*
[2] *Geoscape soc. coop, Via Varese 2, 16122, Genova, Italy, info@geoscape.it*
[3] *DICCA, Department of Civil, Chemical and Environmental Engineering, University of Genova, Via Montallegro 1, 16145, Genova, Italy, giovanni.besio@unige.it*

***Abstract* – This paper describes the MAREGOT (MAnagement des Risques de l'Erosion cotière et actions de GOuvernance Transfrontalière) approach to evaluate hydro-mophodinamic behaviuos using different methods on embayed beach in eastern Liguria (Mediterranean NW). Project aimed at the joint prevention and management of the risks arising from coastal erosion in the cooperation area; It is strategic project of 2014 - 2020 INTERREG V Italy - France (Maritime). The research was composed by field surveys, coastal modelling and remote sensing; as a first step, investigation was conducted comparing two topo-batimetric surveys which were made six months apart. At same time coastal video monitoring, composed by two cameras, was used to evaluate principal surface currents; coastal model XBeach was computed to simulate hydrodynamic evolution. In all three applied methods, results came out cross-shore flow close to coastal structures, which could be used by local authorities to define coastal manager plan, evaluating risks related to seaward flows for bathers.**

I. INTRODUCTION

Coastal areas represent one of the most used ecosystems and play a key role in the socio-economic development of most countries [1]. In the last decades, the Mediterranean coastal zones have been heavily affected by an intense anthropization, related to the urban sprawl processes [2]. As well as the traditional activities (e.g. commercial fishing), other new commercial activities gained in importance (e.g. seaside tourism). Coastal settlements are often exposed to storm events [3], and the presence of transitional environments, such as beaches, is a key component for coastal risk prevention [4]. Moreover, about the beaches, it is easy to understand that their extension is an important feature for the development of the seaside tourism industry. For these reasons, a wide and detailed knowledge of coastal dynamics processes is a firm basis for the application of valuable management policies, oriented to the sustainable development of the coastal areas. However, the coastal hydro-morphodynamic studies are often complex, due to the features of the coastal environment themselves. For example, if we consider a beach, its morphodynamic evolution is conditioned by several environmental agents (e.g. waves, currents, sediments, coastal morphology) [5]. Due to that, the field measurements are often problematic to obtain, because measurement instruments are usually developed to detect a single variable. Moreover, also the massive presence of beach users (e.g. in summer season), is a further issue on the conduct of field surveys. In accordance with MAREGOT project approach, in this research study, different investigation methods, integrated among them, were applied to evaluate principal hydro-morphodynamic processes along an embayed beach on the eastern Ligurian coast. The research activity was developed by means of survey instruments (topo-bathymetric surveys, sediment samples), coastal modelling (XBeach 2DH) and remote sensing (coastal video-monitoring). The developed approach allowed a wide and detailed description of the investigated hydro-morphodynamic behaviour, proving to be a useful coastal management tool for local authorities.

II. STUDY AREA

The beach of Levanto (Figure 1) is oriented NNW-SSE and is located within a small bay delimited by two promontories. This beach can be classified as a “embayed beach” [6]. The beach extends linearly for approximately 800 m and it is divided into three sectors (western, central and eastern) by two groynes. It is exposed to south-west storms, which is also the dominant wave direction in this sector of the Liguria region. In the central sector a submerged detached breakwater (almost destroyed) is present ([7][8][9]).

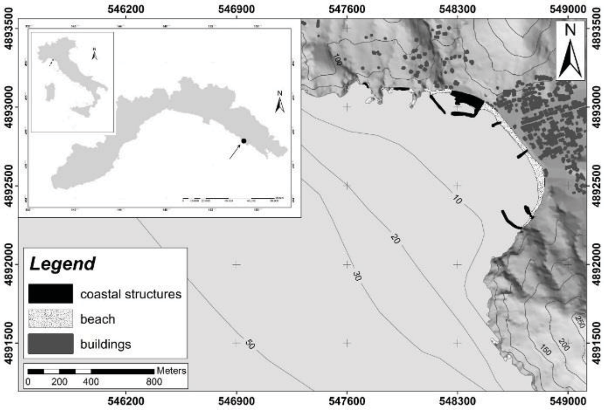

Fig. 1. Levanto beach, La Spezia (Italy), map of study area and its location on the Ligurian coast.

III. MATERIALS AND METHODS

The different investigation methods adopted, and their technical features, are described in the next subsections.

A. Field surveys and sampling

Topographic and bathymetric data were collected in October 2016 and March 2017 along Levanto coastline. Merged beach morphology was surveyed using a Differential Global Position System (DGPS), with a horizontal and vertical accuracy of 0.05 m and 0.10 m respectively. Bathymetric data were collected using a Trimble real time kinematics (RTK) GPS system coupled with a single-beam echo sounder mounted on a small boat. During the beach survey 40 sediment samples was collected using a Van Veen Grab Sampler for the submerged beach, while a hand sampling method was adopted to collected 32 samples on merged beach. Grain size was analysed by dry sifting at ½ phi intervals [10].

All field data collected were imported and analysed in a GIS environment (subsection *B*), compared to the remote sensing data (subsection *C*) or implemented in coastal modelling (subsection *D*). In this way, each possible information was obtained from the collected dataset.

B. GIS elaborations and analysis

Topographic and bathymetric data (subsection *A*) were imported in a GIS environment, where they were interpolated into a regular grid (with resolution of 5 m), producing Digital Terrain Models (DTM). Subsequently, spatial analysis tools were adopted to define the beach morphodynamic behaviour, comparing DTM obtained by two different surveys (October 2016 and March 2017); this method supplies erosion/accretion trend on six months on investigated area. Mean grain size dataset were also analysed in GIS environment to evaluate sediments distribution using Wentworth classification [10].

C. Coastal video-monitoring

The video-monitoring system used is composed by three high resolution cameras (1920×1088 pixels), installed on the promenade at an elevation of 25 m above mean sea level. In this propose, two cameras were used to investigate surface flow features on Levanto beach. Images recorded by camera were geo-rectified using 16 Ground Control Points (GCPs), 8 for each camera, covering dry beach and water surface. The coordinates of the GCPs were acquired using DGPS described in subsection *A*. The video monitoring images were processed using time exposure images (or timex) methods, as suggest by extensive literature of coastal video monitoring ([11] [12] [13]); the analysis was conducted using *Beachkeeper plus* software [14].

D. Coastal modelling

Coastal hydrodynamic processes were simulated using XBeach model. XBeach is an open-source numerical model for coastal morphodynamics that solves coupled two-dimensional depth-averaged equations for short-wave envelope propagation and flow with spectral wave and flow boundary conditions [15]. Computed bed level was made merging bathymetric and topographic surveyed dataset, provided in matrix form. The data obtained by the sediment analysis (subsection *A*) were used to calculate mean grain size (D_{50}) which was adopted in model setup. To optimize the modelling processes, a computational grid characterized by a higher resolution on the surf zone (5 m) and lower resolution in the offshore area (30 m) was implemented.

Offshore wave data were taken from the hindcast database by MeteOcean research group (www.dicca.unige.it/meteocean/hindcast.html).
Validation of the hindcast data resulting by the numerical simulation of the WaveWatchIII and WRF-ARV models [16].

IV. RESULTS

An example of the obtained results was illustrated in this section, to display the integrated approach potentialities.

E. Morphodynamic analysis

The use of a GIS software allowed to obtain a clear field data collected representation. Results of the spatial analysis, applied on the topo-bathymetric data, are depicted in Figure 2. Erosion and sedimentation processes are evident, and the presence of erosion channels in correspondence of central groyne and in the middle of east side of the beach are detected. Moreover, this analysis came out erosion trend close to coastline and deposition process at 3 meters depth; while merged beach is stable, except west side, where erosion/accumulation drift, from east to west, was displayed.

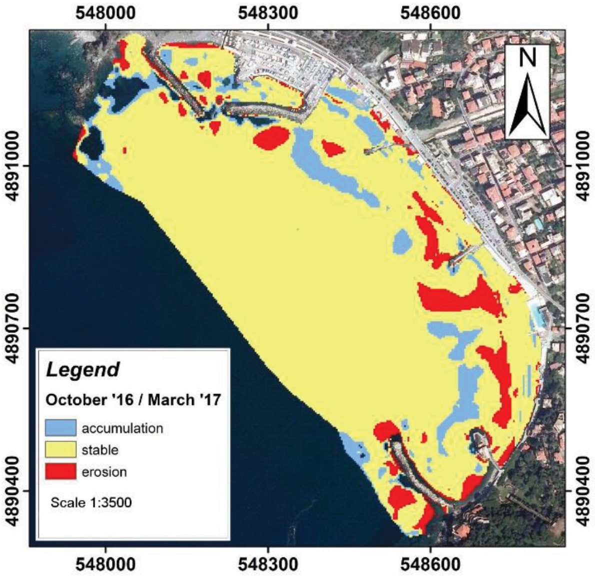

Fig. 2. Map of the morphodynamic trend between October 2016 and March 2017, arrows show erosion channels.

In Figure 3, in accordance with Wentworth classification (Table 1), grain size distribution along the Levanto beach is shown. Results show that coarser sediments are present in the western sector of the merged beach, while, proceeding towards east, sands are predominant. On submerged beach, from 3 meters to 12 meters depth, fine sands are prevalent along Levanto bay.

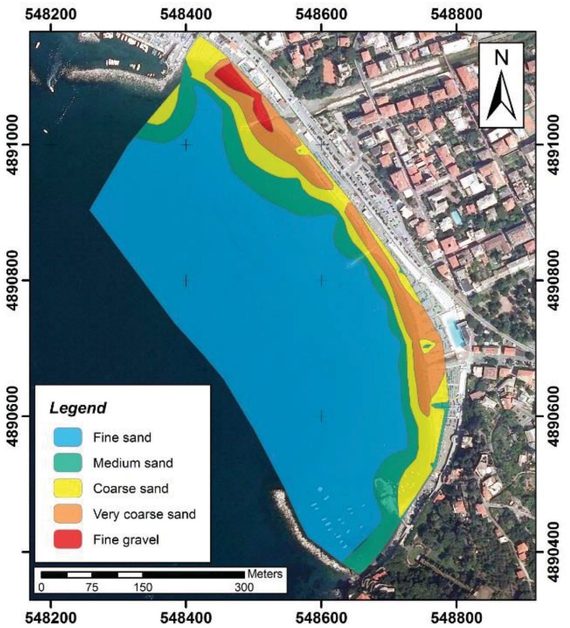

Fig. 3. Map of the grain size distribution along the Levanto beach.

Millimeters (mm)	Wentworth size class
2.00 – 4.00	Fine gravel
2.00 – 1.00	Very coarse sand
1.00 – 0.50	Coarse sand
0.50 – 0.250	Medium sand
0.250 – 0.125	Fine sand

Tab. 1. Wentworth classification; Classes are identified using millimetres range

F. Video-monitoring results

Thanks to the coastal video-monitoring, surface currents were observed over six months of recording from camera. An example is shows in Figure 4, where a suspended sediment plume is develops towards East, starting by the central sector of the beach. In Figure 5, a clear example of a rip current development is depicted. Rip currents are the most recurring observed phenomena in this investigation.

Fig. 4. Suspended sediment plume developed in East direction starting by the central sector of the beach (timex image).

Fig. 5. Rip current development on the Levanto beach. (Top to bottom) snapshot image (rip current in red circle)

and timex image (zoomed).

G. Model results

XBeach 2DH was used to simulate the nearshore hydrodynamics in Levanto Bay. Coastal modelling outputs are depicted in Figure 6. Results came out wave propagation along the beach, showing the coastal structures influence on behaviours of dynamic; diffraction, due to the presence of the tourist port in the west side, produces a cellular circulation nearby beach from east to west. On the other side of the beach, the large headland protects the east area of the bay. In central area, simulated coastal currents direction provides a predominance of cross-shore currents (or rip currents); seaward flows appear particularly relevant close to central groyne and in the middle of the east side faced to camera location.

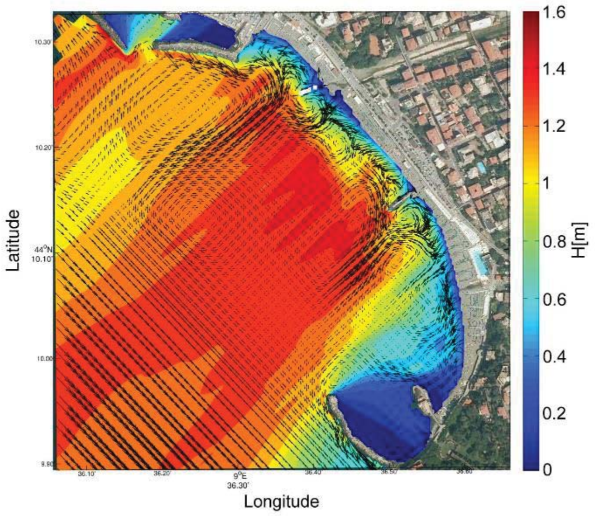

Fig. Coastal hydrodynamics development obtained by the XBeach model application. The predominance of cross-shore phenomena is evident.

V. DISCUSSION

The integrated coastal zone management (ICZM) is a most important practice for the sustainable development of coastal areas ([17] [18]). In this perspective, the use of multidisciplinary investigation approach is a key factor to obtain a reliable description of coastal dynamics. The case study of Levanto, illustrated in this paper, shows how the use of different methodological approaches can be a useful tool to understand the local coastal dynamics.

The field data collection is the first essential starting point. However, the only collected data could be provide an incomplete information on the investigated phenomena. For this reason, the spatial analysis in GIS environment is a very useful tool to increase the data comprehension. For example, in the illustrated case, spatial analysis allowed to define the morphodynamic trend of the Levanto beach. The coastal video-monitoring is characterised by a high data storage capacity. In our case, the video monitoring data supplied a confirm of what was observed through another methodologies. Observed rip currents confirm the predominant cross-shore dynamics (deducted by the GIS analysis). Finally, coastal modelling is a powerful tool for coastal research and coastal management. Models allow to obtain detailed simulations of coastal processes. However, the model reliability can be only evaluated through a validation process which compare the model results with real data. The coastal modelling implementation on the Levanto beach allowed to simulate the local hydro-morphodynamic. Comparing the model results with results obtained by means of others investigation approaches, the predominant of the cross-shore dynamics was confirmed.

VI. CONCLUSIONS

Obtained results show how the integrated methodologies, supplied by MAREGOT project, is a successful approach. It was observed that reliability in physical phenomena description is greater using several investigation methods, because each method can make up for the weak points of others. In the proposed case, it was possible define the hydro-morphodynamics features of the Levanto beach. In detail, Levanto beach was revealed as a beach dominated by the cross-shore dynamics. A future upgrade might be development of a dedicated system for the integrated data management for local authorities.

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