Monitoring Barcelona City Beaches Using Video (Argus) and Laser (LIDAR) Methods.

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Abstract:

This study describes the coastline evolution in Barcelona city beaches (La Barceloneta, Nova Icaria and Bogatell) over a 4-month period during 2002 using video camera (Argus) and laser (LIDAR) techniques. The differential short-term evolution of these beaches is analyzed in response to storms and beach nourishment. In addition, the ability to locate the shoreline using both techniques is compared.

Argus high temporal resolution sampling in conjunction with LIDAR three-dimensional view of the emerged beaches, more spaced in time, appears to be a valuable procedure for monitoring the beaches.

Introduction:

LIDAR (LIght Detection And Ranging) measurements were obtained by the Insitut Cartografic de Catalunya. Two flights were done in 2002 over the coast of Barcelona to demonstrate the possibilities of this technique: on April 17 and July 23.
Argus measurements were obtained from the Coastal Monitoring Station of Barcelona by the Instituto de Ciencias del Mar hourly from April to July 2002.
Since Argus installation in October 2001, a highly energetic period occurred in the region with important storms (November, December 2001, January - March 2002) producing extensive sediment transport and severe erosion problems along Barcelona city beaches. Approximately a week prior to the first flight with LIDAR, a storm with E direction and significant wave height (Hs) of 2.6 m took place in the region (April, 11-12). Moreover the beaches situation changed over the study period, due to a second storm coming from the East (May 7-8), with maximum Hs reaching 3.8 m. Finally, a beach nourishment (110 000 m^3) was carried out in La Barceloneta and Bogatell beaches (June 13 to July 17).

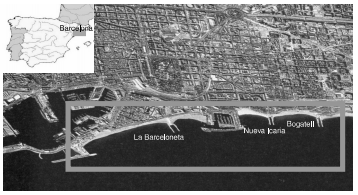

Figure 1. Study region.

Method:

The ARGUS system:

The ARGUS system is an automated video station, with many of the same advantages of satellite remote sensing and with unchanging images geometry. Composed by five cameras and spanning a 180º view of Barcelona beaches, the *Coastal Monitoring Station of Barcelona*, is located atop Mapfre building at approximately 146-m high. Sampling is every daylight hour in a ten minutes register and the images data base is accessible via the Internet (http://www.cmima.csic.es/serveis/argus).

Figure 2. Merged Picture of Barcelona beaches and the Port Olimpic. It corresponds to five images, each of them is the result of averaging out 600 images obtained during a 10 minutes sampling (1 image per second).

LIDAR (LIght Detection And Ranging):

LIDAR can be used in a terrestrial or aerial mode. The airborne LIDAR sensor is an OPtech ALTM 3025 that can operate from an aeroplane or a helicopter.
One of its main applications is coastal cartography, with many advantages over aerial photogrammetry in coastal areas. LIDAR can measure coordinates of 25000 points per second with a precision of around 10 cm in height and sampling densities around 1 point/m^2 are easy to achieve with the system.

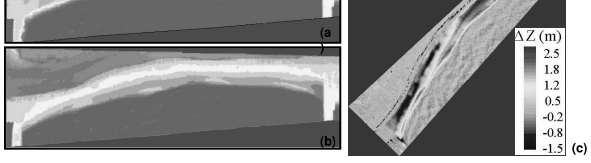

Figure 3. a and **b**: representations in hypsometric tints of the digital terrain models obtained, corresponding to April 17 and July 23, 2002. The grid size of the terrain model generated is 1 metre. **c**: representation of the model of differences. The blue line in the upper part corresponds to the balustrade of the seafront promenade. This was an artefact introduced by the horizontal error of the system (around one metre). Elevation measurement has an RMS accuracy of 20 centimetres.

Results:

The impact of single storm events is derived from Argus images. Extraction of shorelines from video images reveals that the shoreline previous to the May storm (STORM 2) had an eroded position due to the unusually energetic wave pattern. This can explain the fact that the beach erosion was of the same magnitude than during the less energetic storm taken place in April (STORM 1).
The storm occurred in May produced different erosion patterns on each of the studied beaches (Figure 4). Bogatell beach displayed 10 m. of erosion in the northern side and accretion of around 5 m. in the southern part. Nova Icaria did not show significant changes, whilst La Barceloneta was affected by erosion of about 5 m.

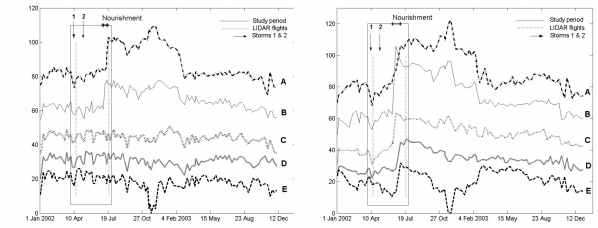

Figure 4. Temporal variations of the shoreline in five sites located in La Barceloneta (right) and Bogatell (left). **A** is close to the Northern extreme and **E** to the Southern one. Distances between sites are of 200 m. in Bogatell and 200-300 m. in La Barceloneta. The ordinate axes is given in meters.

Nourishment (from June 13 to July 5 in Bogatell and from July 5 to 17 in La Barceloneta) can also be appreciated in figure 4. Using Argus images the nourishment effectiveness has been studied by means of shoreline evolution. It has been seen that the replenishment of the beaches evolves, with erosion happening until some stabilization was reached.

Figure 5. Nova Icaria and Bogatell beaches as seen from Argus on July, 7th 2002. The blue line represents the water line several days before nourishment starts.

LIDAR Vs ARGUS SHORELINES

An important point in this study is the comparison of the results obtained using both methodologies. Two different shorelines were derived from LIDAR: the first one using the texture of the DTM to discriminate the sand from the sea. A shadow map was computed from the DTM with a very low illumination source and the shoreline was drawn from this image. The second shoreline was derived from the intensity map of the pulse return. The most similar results to the video observations were obtained using the second method.

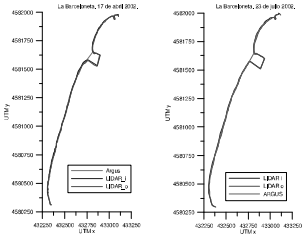

Figure 6. Water lines obtained using LIDAR shadow map (*LIDAR o*), LIDAR intensity map (*LIDAR i*) and Argus in La Barceloneta. *Right:* 17th April 2002. *Left:* 23rd July 2002. Differences between Argus and *LIDAR i* are in a range of ±5 m. on April, 17th and of -3 to 9 m. on July 23rd. Differences with *LIDAR o* are of the same magnitude although *LIDAR o* trend is to overestimate the beach length in every location. It can be seen that the water line estimated using the Argus system, lies between both estimations of LIDAR.

With LIDAR the volumes of sand displaced can be accurately measured from the differences of DTMs. As the sensor cannot take bathymetric measurements, the sand added or removed under water is not taken into account in the calculations. Using this method and the LIDAR-derived shorelines it has been estimated in Bogatell an increase in volume of around 24000 m^3 corresponding to an increase in surface of 12000 m^2. This corresponds to 2 m^3/m of sand necessary to get a shoreline accretion of 1m.

Conclusions:

The study of Barcelona beaches using video images reveals that, despite the fact that they are closed beaches due to man-made structures, they have differential morphological evolution. Argus provides high-resolution information about shoreline changes after storms and beach nourishment.

Argus and LIDAR methods offer similar results for measuring the shoreline position. LIDAR capability to measure 3D characteristics supplies accurate measurement of volume changes in the emerged beach.

Argus and LIDAR are complementary methods in morphodynamic studies. It is suggested to combine both techniques in order to obtain precise information of the beach evolution, persist in Argus continuous sampling, adding 3D information from specific LIDAR surveys.

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. References

- Banco de Datos Oceanográficos de la Dirección General de Puertos y Costas. Modelo WANA de generación de oleaje. Punto 2066051.
- Guillén, J., Chic, O., Ojeda, E., Palanques, A. y Aarnikhoff, S. 2003. Monitorización de las playas de la ciudad de Barcelona utilizando imágenes de vídeo: evolución de la línea de costa en respuesta a temporales y regeneración artificial (2001-2002). VII Jornadas Españolas de Ingeniería de Costas y Puertos, Libro de Resúmenes (Ed. M.-Losada y M. Castillo). 254-256.
- Holman, R.A., Sallenger, A.H., Lippmann, T.C. and Haines, J., 1993. The application of video image processing to the study of nearshore processes. Oceanography, 6(3): 78-85.
- Ruiz A., Kornus W. 'Experiencias y aplicaciones del LIDAR'. V Semana Geomática, 11.2.03 a 14.2.03. Barcelona.