Sediment exchanges from the shoreline to the lower shoreface inferred from morphological changes (Llobregat Delta, Western Mediterranean)

Intercambio de sedimentos desde la línea de costa al infralitoral inferidos a partir de cambios morfológicos (Delta del Llobregat, Mediterráneo Occidental)

J. Guillén[1], G. Simarro[1], R. Durán[1], F. Ribas[2], R. L. de Swart[2] and D. Calvete[2].
1 Institut de Ciències del Mar-CSIC. Passeig. Maritim de la Barceloneta, 37, 0803 Barcelona, Spain. jorge@icm.csic.es, simarro@icm.csic.es, rduran@icm.csic.es.
2 Department of Physics, Universitat Politecnica de Catalunya (UPC), Jordi Girona, 1-3, 08034, Barcelona, Spain. francesca.ribas@upc.edu, rinse.de.swart@upc.edu, daniel.calvete@upc.edu..

Resumen: *Se realizaron 14 campañas topo-batimétricas desde la playa emergida hasta los 15 m de profundidad, a lo largo de 1 km en la playa de Castelldefels (Delta del Llobregat, Barcelona) durante el periodo 2011-2020. Se analizan las variaciones morfológicas que tienen lugar, los cambios volumétricos y sus posibles implicaciones en los intercambios sedimentarios en el perfil litoral. Los principales cambios morfológicos están causados por los desplazamientos transversales de las barras de arena, generalmente hacia tierra durante condiciones de buen tiempo y hacia mayor profundidad durante las tormentas más fuertes. Los cambios volumétricos sugieren que el retroceso de la línea de costa durante la última década aporta sedimento a la parte superior de la playa sumergida, mientras que los eventos más extremos producen una transferencia de sedimento hacia la plataforma continental, que podrían ser parcialmente irrecuperables para la dinámica litoral. El balance sedimentario resultante es negativo.*
Palabras clave: *perfil litoral, batimetría, dinámica de barras, cambios volumétricos.*

Abstract: *Fourteen topo-bathymetric surveys that stretch from the emerged beach to 15 m water depth were carried out along 1 km of Castelldefels beach (Llobregat Delta, Barcelona) during the period 2011-2020. Morphological variations on the shoreface are studied, volumetric changes are estimated and implications on sedimentary exchanges in the littoral profile are inferred. The main morphological changes are caused by cross-shore displacements of the nearshore bars, usually onshore during fair-weather conditions and offshore during stronger storms. Volumetric changes suggest that shoreline retreat during the last decade provides sediment to the upper shoreface, while more extreme events produce a prevailing offshore transfer of sediment from the upper to the lower shoreface, causing this sediment to partially loses its ability to reincorporate into beach dynamics. The resulting sediment budget is negative.*
Keywords: *beach profile, bathymetry, bar dynamics, volumetric changes.*

1. Introduction and study area

Forecasting long-term coastal evolution requires an accurate assessment of the sediment budget, including net sediment losses/gains in the littoral profile, which is still largely unknown. While sediment transport can be triggered by a large number of mechanisms, morphological changes along the coast show the produced net result and their study can be used to infer the dominant transport processes. Topo-bathymetric surveys repeated over decades allow estimating volumetric changes across the profile, understanding the key mechanisms behind their dynamics and improving future coastal adaptation strategies.

In this work, we study the morphological variations that take place at the shoreface of Castelldefels beach (Llobregat Delta, Barcelona, western Mediterranean) during a decade, estimate the volumetric changes and infer the implications for sedimentary exchanges in the littoral profile. It is a microtidal (< 0.2 m) beach, dominated by wave action with a median sand grain size around 0.3 mm in the swash zone. The shoreline is straight, oriented E-W, and show small gradients along the higher shoreface at spatial scales larger than 200 m, and allow the investigation to focus on cross-shore processes. A key component in the morphodynamics of Castelldefels beach is the dynamics of sand bars. These dynamics were analyzed in detail by de Swart et al. (2021), showing a rapid offshore migration of the bars during storm conditions and a slower onshore migration during fair weather, post-storms conditions.

2.- Methods

The study is based on 14 topo-bathymetric campaigns from the emerged beach to 15 m depth, carried out with a single-beam echosounder along 1 km of coastline during the period 2011-2020 (Fig. 1). The profiles perpendicular to the shoreline are equidistant 25 and 50 m in the central and extreme part of the study area, respectively, and overlap with the profiles of the emerged beach and shallow zone made with traditional topographic methods. The topo-bathymetric data were projected to previously defined original profiles, interpolated (1 m cross-shore), outliers were removed and the final profile was smoothed. Finally, a vertical correction was applied assuming no changes in the profile deeper than 10 m and comparing each profile to the reference profile (using the June 2017 survey as reference). To contextualize the morphological data, wave data from the Barcelona buoy (Puertos del Estado) were used. It should be noted that the largest storms ever recorded in the area occurred during the study period, in January 2017 and 2020, with maximum significant heights exceeding 5 and 7 m respectively.

3.- Results and discussion

The evolution of the topo-bathymetric profiles shows a shoreline retreat of about 35 m during the study period (Fig. 1). The coastal profile has a mean slope of 0.012 between the shoreline and 10 m water depth and is characterized by the presence of 2-3 bars. The outer bar is typically located at 150-200 m from the shoreline and moves offshore to 400 and 600 m during the extreme storms occurred in January 2017 and January 2020 respectively. Post-storm conditions favor slow onshore migration of shallower bars and partial replenishment of the trough. Depth changes across the profile measured as standard deviation (SD) show a maximum variability between the shoreline and 3 m depth (associated with increased bar dynamics) and a progressive decrease offshore to 11 m depth, where SD is of the same magnitude as expected instrumental errors (SD= 0.05 m).

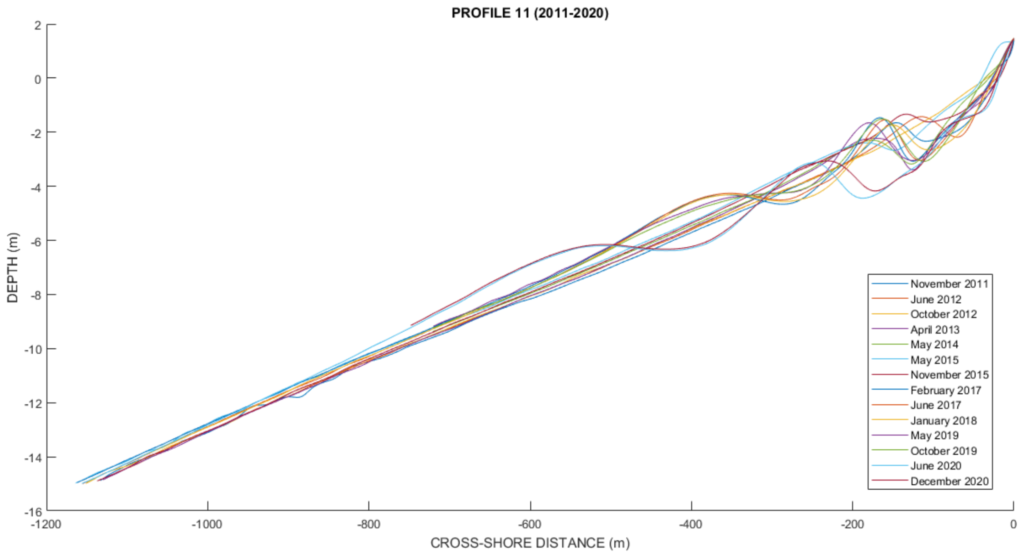

Figure 1. Example of coastal profile evolution

Net volumetric changes across the profile display a high variability associated with the preferential location of bars and troughs, with a negative balance in the shallowest zone (0-400 m) and positive in the deepest one (Fig. 2). Temporal volumetric changes in the profile show the differential behavior (often opposite) between the proximal and distal sectors of the profile, especially during the two extreme storms (Fig. 2). In both storms there are volume losses in the proximal sector due to offshore displacement of the bar and gains in the distal sector due to sediment accumulation in the newly developed bar. In January 2017 the volume changes in the entire profile are moderate (-88 m^2 m), while they are significant in January 2020 (-189 m^2 m), suggesting a transfer of sediment towards the lower shoreface (deeper than 10 m). The resulting volume difference during the study period is about -130 m^2 m (mostly related to the extreme storm of January 2020), with net losses of almost 300 m^2 m in the shallowest zone and net gains of about 170 m^2 m in the deepest profile.

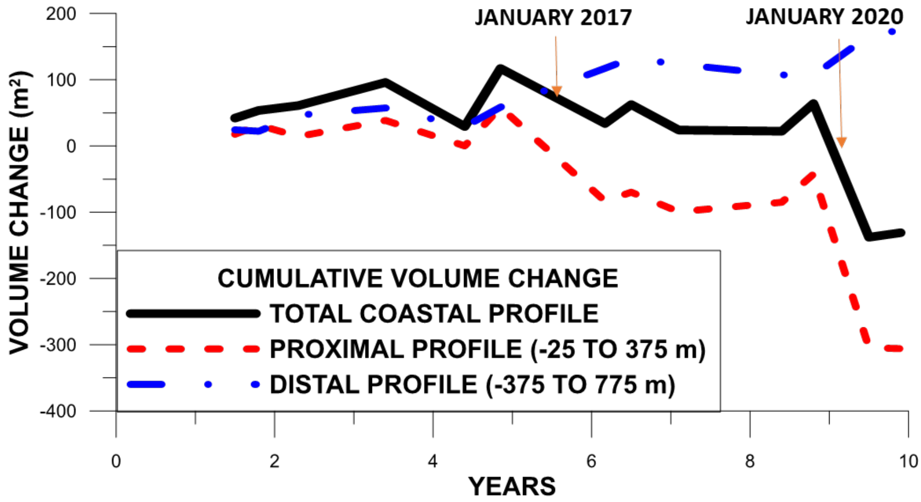

Figure 2. Alongshore averaged cumulative volume change between campaigns

Assuming no significant longshore gradients in the study area, these changes could be explained primarily by cross-shore gradients. Shoreline erosion implies sediment input to the upper shoreface. Although the total volume change on the emerged beach has not been calculated, a reasonable limit for such a flat beach would be less than 35 m^2 m for the observed net shoreline retreat of 35 m. This amount is small compared with the volume of sediment change observed in the subaqueous profile: the development of new bars during both extreme storms implies a sediment accumulation of +80 and +128 m^2 m and sediment losses due to erosion of the former outer bars are about -105 and -140 m^2 m. Therefore, sediment transferred from the shallow profile to deeper zones and accumulated as sand bars plays a relevant role in the sediment budget. In addition, extreme storms as that in January 2020 transport sediment from the upper to the lower shoreface in such large depths that this sediment might not be reincorporated into the beach dynamics during fair weather conditions.

Acknowledgements

This work has been carried out in the framework of the MOCCA research project (RTI2018-093941-B-C3) funded by the Spanish Ministry of Science, Innovation and Universities – National Research Agency.

References

de Swart, R., Ribas, F., Simarro, G., Guillén, J. and Calvete, D. 2021. The role of bathymetry and directional wave conditions on observed crescentic bar dynamics. *Earth surface processes and landforms*. Vol. 46, Issue15, 46: 3252–3270.